3rd NATIONAL CONFERENCE on Water, Environment & Society (NCWES - 2016)

6th - 8th June, 2016
Hyderabad, India

Editor : Dr. M.V.S.S Giridhar

Organized by

CENTRE FOR WATER RESOURCES

Institute of Science and Technology

Jawaharlal Nehru Technological University Hyderabad

Kukatpally, Hyderabad - 500 085

3rd National Conference
on
Water, Environment & Society
(NCWES - 2016)
6th - 8th June, 2016
Hyderabad, India.

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JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

Smt. Shailaja Ramaiyer, IAS,
Incharge Vice-Chancellor

Foreword

Water is an essential commodity upon which all life on Earth depends. For most nations, economic development is inextricably linked to the availability and quality of freshwater supplies. Although everyone uses water on a daily basis, we often take this vital commodity for granted - particularly in regions with a natural abundance of water. We forget that, in many regions, the availability of water is a matter of life and death. Water demand already exceeds supply in many parts of the world, and many more areas are expected to experience this imbalance in the near future. Advancements in Science and Technology, consequent industrial development and alarming growth of human population have all contributed to deterioration of environment which calls for urgent action.

Climate change will have significant impacts on water resources around the world because of the close connections between the climate and hydrologic cycle. Due to the expanding human population competition for water is growing such that many of the world's major aquifers are becoming depleted. It is critical that local bodies responsibly manage water resources in all local communities in order to minimize the adverse effects of climate change.

Emphasizing water & environment management as a means to an end rather than an end itself, the proceedings of the conference seeks to explore global water as resource for economic, social & environmental development. In an attempt to address diversities of this complex world, this initiative focuses to balance rural- urban dichotomy, agricultural- industrial needs in wake of technological advances. It recognizes need for inclusive & environmentally sustained growth for shared prosperity and directed accordingly.

There is thus an urgent need to promote Research and Development, educational and training activities in the areas of water and environment by way of organizing seminars, workshops, conferences and training programs to bring about and development more awareness. The 3rd National Conference on "Water, Environment and Society (NCWES-2016)" is an appropriate step in this direction. Keeping this in view, the subject matter of the conference is planned to cover a wide range of topics spreading over eight technical sessions.

I appreciate efforts of the Centre for Water Resources, Institute of Science and Technology, Jawaharlal Nehru Technological University Hyderabad for taking up such a stupendous task. I congratulate the editor and publisher for bringing out the pre-conference proceedings in time.

Shailaja

Smt. Shailaja Ramaiyer, IAS

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HEAD

Preface

Water is for sure the only common and global issue that interests all the living bodies of the world including humans, flora and fauna. Without water, survival is not possible. The two components of water are namely quality and quantity. Some countries have abundant water resources, whereas some others suffer from inadequate water, and even face severe water scarcity problems.

Currently, a portion of accessible global water resources are polluted especially through human-induced activities, and can no longer be used. Another portion of water is lost during transmission due to lack of efficient and proper infrastructure. On the other hand, the wastewater arising from the use of water is an even more significant problem when they are discharged into receiving water bodies. At this critical juncture, harmonizing efficient water use and ensuring safe environments with climate resilience have become need of the hour. The present conference offers broad contribution towards achieving goals of diversification & sustainable development.

It is in this context and backdrop that the Centre for Water Resources, Institute of Science and Technology, JNTUH felt the need to organize 3rd National Conference on Water, Environment and Society (NCWES-2016) to take stock of the current status of applications in water resources development and management.

Researchers, engineers, site managers, regulatory agents, policy makers, Consultants, NGO's, academicians and vendors will all benefit from the opportunity to exchange information on recent research trends and to examine ongoing research programs in the areas of water and environment. Keeping in view the importance and need of the hour, this issue of proceedings is brought out to coincide with the conduct of the national conference. The high value contributions by eminent speakers, Research scholars and participants have been overwhelming and encouraging.

The 3rd National conference NCWES 2016 will focus its attention on various themes in the form of technical sessions such as

1. Hydrological parameter Estimation& modeling
2. Climate change and Environment
3. Urbanisation, Biodiversity and EIA
4. Groundwater Exploration, Development, Recharge, Modeling and Quality
5. Water Quality, Water Treatment, Pollution and Society
6. Water Conservation and Irrigation Management
7. Water Management, Rain fall and Rainwater Harvesting
8. Geospatial Applications in Water Resources

More than 100 delegates and 80 technical papers are being presented in these eight technical sessions. I hope the present conference would serve as a link between technology, policy, practice and decision making in the quest for synergetic solutions for sustainable development of water resources and environment.

It is with this great pleasure; I extend a warm welcome to all the delegates, speakers and participants to NCWES – 2016.

mvssgiridhar

Dr. M.V.S.S Giridhar
- Editor

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JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

Smt. Shailaja Ramaiyer, IAS,
Incharge Vice-Chancellor

MESSAGE

The organizing secretary and the faculty of the "Centre for Water Resources, Institute of Science and Technology, Jawaharlal Nehru Technological University Hyderabad are to be appreciated for organizing 3rd National conference on "*Water, Environment and Society NCWES*", during 6th - 8th June 2016.

Water is the foundation of life. And still today, all around the world, far too many people spend their entire day searching for it. To ensure adequate supply of water for our future generation every individual should feel responsible to effectively conserve, manage, and distribute the water we have. I am sure that this National Conference will be of immense use to all those, who move with high aspirations.

In this context, I hope the conference will bring out important policy decisions and strategies to be adopted to meet pressing demands of this ever changing society.

I congratulate the organizing secretary and committee members of this conference for taking up this topic and wish them all success.

Shailaja

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Dr. N.V. RAMANA RAO
B.E (OU), M.Tech.(IIT), PGDCS (UOH), Ph.D.(UK), Post Doc (UK)
Professor of Civil Engineering &
RECTOR

MESSAGE

The organizing secretary and the faculty of the "Centre for Water Resources, Institute of Science and Technology, Jawaharlal Nehru Technological University Hyderabad are to be appreciated for organizing 3rd National Conference on ***"Water, Environment and Society"*** during 6th - 8th June 2016 which would serve great importance to the field engineers, NGO's, academicians, researchers and students.

Water is the most essential component of life and is vital for sustenance. People use up our planets fresh water faster than it can naturally be replenished so, save water for the Earth, family and community.

I hope all the participants will avail this opportunity by enriching themselves greatly and augment their technical knowledge and skills. A conference on such topic is appropriate to spread the message across all the sections of the society.

I congratulate the organizers, sponsors and other sponsors for their excellent work in conducting such conference and I wish the conference a grand success.

Dr. N.V. Ramana Rao

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MESSAGE

It gives me immense pleasure to note that the "Centre for Water Resources, Institute of Science and Technology, Jawaharlal Nehru Technological University Hyderabad is organizing 3rd National Conference on "***Water, Environment and Society***" during 6th - 8th June 2016.

As citizens of India , we can , in our small way , contribute towards water conservation. Firstly, we can implement rainwater harvesting in all our homes. Also, waste water can be recycled and reused for various purposes. I would like to appreciate Centre for Water Resources for their continuous efforts on creating public awareness about rainwater harvesting structures in JNTUH.

I hope this conference provides a platform for the researchers, engineers, managers, policy makers and the academicians to discuss about the advancements in the field of water resources and environment and bring out new ideas among academic sections and educate every individual in facing this challenge effectively.

On this occasion I wish the program a grand success.

Dr.N.Yadaiah
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BN Bhandari
Ph.D (IIT KGP)
Professor of Elect. & Commn. Engg., &
Director,
Academic & Planning

MESSAGE

I am glad that the "Centre for Water Resources, Institute of Science and Technology, Jawaharlal Nehru Technological University Hyderabad is organizing 3rd National Conference on ***"Water, Environment and Society"*** from 6th to 8th June 2016.

Water is a precious resource to us and to our future generations. Life wouldn't be the same without it. We must all begin to use this resource more carefully and efficiently. Conservation will not only save our water supply, but also save money.

I hope that the outcome of the conference will be very much useful not only to the academic community but also to the field engineers and all others working in the area of water resources engineering and environmental engineering.

I wish the Conference a grand success.

Bnbhandari

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Prof. A. JAYA SHREE, Ph.D.
Professor of Chemistry
DIRECTOR

MESSAGE

I am pleased to note that the Centre for Water Resources, Institute of Science and Technology, Jawaharlal Nehru Technological University Hyderabad is organizing 3rd National Conference on "***Water, Environment and Society - NCWES 2016***" during 6th - 8th June 2016.

First of all I would like to appreciate the efforts put by Centre for Water Resources for adopting Rainwater harvesting practices within JNTUH campus. We understand water is elixir of life. Unfortunately, this resource has been depleting at an alarming rate. It is a matter of great concern. Let us join hands for a better world. My vision is **"TRANSFORM JNTUH- A ZERO DISCHARGE UNIVERSITY"**.

I am positive that the participants will avail this opportunity to enhance their technical knowhow greatly and contribute to the wider utilization of Watershed Management and Impact of Environmental Changes on Water Resources.

I extend my best wishes for the success of the conference.

Dr.A. Jayashree

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HEAD

MESSAGE

I am very glad to note that the "Centre for Water Resources, Institute of Science and Technology, Jawaharlal Nehru Technological University Hyderabad is organizing 3rd National Conference on ***"Water, Environment and Society"*** during 6th - 8th June 2016.

Water is critical for sustainable development, including environmental integrity and the alleviation of poverty and hunger, and is indispensable for human health and well-being. Clean water, the essence of life and a birthright for everyone, must become available to all people now. Over the years rising populations, growing industrialization, and expanding agriculture have pushed up the demand for water. Efforts have been made to collect water by building dams and reservoirs and digging wells; some countries have also tried to recycle and desalinate water. Water conservation has become the need of the day. The idea of ground water recharging by harvesting rainwater is gaining importance in many cities.

The topics covered and sessions are contemporary and experts across the India are likely to bring about interesting discussions during the course of the conference, which will be of great interest to academics, researchers and students of water resources and environment.

We Centre for Water Resources extend our warm welcome to environment and water academicians, practitioners & interested colleagues regardless of discipline and states.

I hope this National conference shall be a great success.

Mvssgiridhar

Dr. M.V.S.S Giridhar

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Acknowledgements

The 3rd National Conference on Water, Environment and Society NCWES-2016 has been made possible with the support of many technical experts, individuals and organizations both in man power and finance. This support is gratefully acknowledged.

I owe a deep sense of gratitude to **Smt. Shailaja Ramaiyer, IAS**, Vice-Chancellor, Jawaharlal Nehru Technological University Hyderabad and Chief patron of the conference for her constant encouragement valuable guidance in organizing the conference in most efficient way.

I am very thankful to Dr.N.V.Ramana Rao, Rector, Jawaharlal Nehru Technological University Hyderabad for his precious support as Patron of this 3rd National Conference.

My sincere and special thanks to Dr.N. Yadaiah, Registrar, Jawaharlal Nehru Technological University Hyderabad as Patron of the conference for his cordial, time to time permissions and support.

I am deeply indebted to Dr.A.Jayashree, Director, IST, JNTUH and Chairman of this conference for her constant support and having taken every responsibility for completing this task through various stages.

My grateful thanks are due to Dr. B. Venkateswara Rao, Dr. K. Ramamohan Reddy and Dr. C. Sarala, Professors of Centre for Water resources for their valuable support throughout the conference.

My sincere thanks to the officials of Technical Education Quality Improvement Program, Phase-II, IST, ISRO, State Bank of Hyderabad and JNTUH University for sponsoring this event. Without their help organization of this conference would not have been possible.

We have been very fortunate enough to be backed by a team of very motivated and dedicated experts of various committees in guiding us throughout the conference very meticulously. My sincere thanks to all the members of the Scientific and Advisory Committee, Technical Committee and Organizing Committee for their sincere advice and help from time to time.

I profusely thank all the Key note speakers, Chair persons and Co-chair persons of various technical sessions of conference have readily responded to our invitation to conduct the proceedings and to address the gathering and for their kind gesture in the conference.

I thank all the students of M.Tech (WET) and research scholars who have assisted in every event of conference.

My thanks are also due to various other Teaching and Non-teaching staff of IST and Engineering Staff of JNTUH who have cooperated on several occasions in organizing this Conference.

I sincerely thank M/s BS Publications for bringing out the souvenir and pre-conference proceedings well in advance.

My sincere thanks to all my students Smt. P. Sowmya, Senior Research Fellow, UGC Project, Ms. P.B.Rakhee Sheel, M.Tech students Sri. Rathod Ravinder and Smt. S. Kalavathy for their continuous day and night support for this conference.

Finally, I thank all the people and organizations who are directly and indirectly involved in organizing the conference, but I could not mention their names due to paucity of space.

I thank one and all.

M.V.S.S. Giridhar

Organising Secretary

Contents

THEME - I

Tillage and Nutrient Management using Energy Estimates for Resource Conservation in Rainfed Condition

M. B. Nagdeve, R. S. Patode, V. V. Gabhane and M. M. Ganvir
All India Coordinated Research Project for Dryland Agriculture,
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra 444 104.

ABSTRACT

The field experiment was conducted at All India Coordinated Research Project for Dryland Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra. For tillage management, three treatments viz. T_1 – Conventional tillage (CT), T_2 – 50% of CT + hand weeding and T_3- 50% of CT+ herbicide with five replications were tested. Each treatment consists of three sub treatments of nutrient management i.e. N_1-recommended dose through inorganic fertilizers, N_2- 50% recommended dose through inorganic and 50% through organic (FYM/Glyricidia) and N_3- recommended dose through organic sources (FYM/Glyricidia). Increase in soil loss was observed to be 74.82% in conventional tillage, T_1 over low tillage with herbicides (T_3). It was also observed that the treatment, T_1 has recorded 85.98% more runoff compared to T_2. It was concluded that the treatment low tillage with hand weeding (T_2) was more effective in soil and water conservation. The effect of tillage management on productivity of sorghum is low as compared to integrated nutrient management. The resource conservation in the treatment, 50% conventional tillage with hand weeding was observed to be 16.42% and in 50% conventional tillage with herbicide treatment it was 31.74% over conventional tillage treatment. The equivalent energy requirement for sorghum crop was observed to be higher in the treatment combination T_1N_1.

Keywords: Resource conservation, tillage, rainfed, runoff.

INTRODUCTION

Soil and water are the two basic resources for any agricultural production system. These cannot be created or produced and therefore their conservation is a national concern. Further, sustainability of our agriculture totally depends on how best we manage and conserve these natural resources. Rainfed agriculture is now emerging as a major opportunity in raising overall agricultural growth. Water is a limiting factor for crop growth and development. The success of dryland farming mainly depends on the evenly distributed rainfall during crop growing period. The root zone soil moisture is utilized for transpiration, when the rainfall becomes insufficient to meet the potential needs to transpiration. This causes depletion in soil moisture storage and a situation which may be designated as agricultural drought. In terms of crop groups, 77% of pulses, 66% of oilseeds and 45% of cereals are grown under rainfed conditions. Therefore, a breakthrough in rainfed agriculture is an imperative for poverty alleviation, livelihood promotion and food security in India (Abrol, 2011). In order to meet the food requirements of the growing population, it is essential to develop strategies for crop, land and water productivity improvement through resource conservation. In this scenario the improved crop productivity in less intensively cropped and land degraded rainfed areas may play vital role. Sorghum in Vidarbha is cultivated in three Agro ecological zones viz. Western Vidarbha zone with 700 – 950 mm rainfall, Central Vidarbha zone with 950 – 1250 mm rainfall and Eastern Vidarbha zone with 1250-1700 mm rainfall. In order to know the effect of different tillage methods on runoff, soil loss, yield and to quantify the energy estimates the experiment was undertaken.

MATERIALS AND METHODS

The site is situated at the latitude of 20^0 42' North and Longitude of 77^0 02' East. The altitude of the place is 307.4m above MSL. The climate of the place is subtropical and characterized by hot dry summer and cool winter. Rains are mostly received from South-West monsoon during June to October. Mean annual rainfall is 824.8mm, which is generally received in 41 days. The soil belongs to Vertic Inceptisols. Inceptisols are developed from basalt and they are very shallow to shallow. Inceptisols show vertic characteristics, whereas, the Vertisols are developed in basaltic alluvium brought out by rivers. These soils are medium to heavy in texture, high in lime content with high base saturation.

Treatments

The experimental layout had been arranged in split plot design with five replications. Main plots and sub plots includes following treatments.

Tillage treatments

T_1 : Conventional Tillage, (CT) Ploughing (after every three years) + Two intercultural operations + Two hand weeding.

T_2 : 50% of CT (one intercultural operation + one hand weeding).

T_3 : 50% of CT (one intercultural operation + pre emergence herbicides).

Nutrient Management Treatments

N_1 : Recommended dose of sorghum through inorganic fertilizers,

N_2 : 50% recommended dose through inorganic and 50% through organic (FYM/Glyricidia) and

N_3 : Recommended dose through organic sources (FYM/Glyricidia).

RESULTS AND DISCUSSIONS

Runoff and Soil Loss

Rainfall, runoff and soil loss as influenced by different treatments observed during 2012 season is given in Table 1. The highest runoff of 4.95 mm was observed in conventional tillage treatment (T_1) and lowest total runoff of 0.69 mm was observed in low tillage with hand weeding treatment (T_2). The runoff of 3.75 mm was observed in low tillage with herbicides treatment (T_3). Percent increase in runoff was observed to be 31.61% in conventional tillage treatment (T_1) over low tillage with herbicides treatment (T_3). The conventional tillage treatment (T_1) has recorded 85.98% more runoff compared to low tillage with hand weeding (T_2). Similar trends were observed in case of total soil loss as observed in case of runoff for different treatments (Table 1). Increase in soil loss was observed to be 74.82% in conventional tillage (T_1) over low tillage with herbicides (T_3) and decrease of 92.79% in low tillage with hand weeding (T_2) over low tillage with herbicide (T_3).

Productivity of sorghum

Pooled analysis of the data 2011-12 and 2012-13 for the yield of sorghum crop was done and the results are presented in Table 2. It was observed that the effect of tillage treatment was non significant on grain and fodder yield of sorghum. However, the nutrient management treatments have shown statistically significant effect on grain and fodder yield of sorghum. In case of grain yield, treatments recommended dose through inorganic (N_1) and 50% recommended dose through organic and inorganic (N_2) are statistically significant over treatment recommended dose through organic (N_3). However treatment N_1 and N_2 are statistically at par with each other. In case of fodder yield, treatment recommended dose through organic (N_3) is statistically significant over treatment 50% recommended dose through organic and inorganic (N_2) and recommended dose through inorganic (N_1). The interaction effect of tillage and nutrient management on fodder yield was statistically significant (Table 3). The treatment combination of low tillage with hand weeding and recommended dose through organic (T_2N_3) was found superior over other combination.

Table 1 Runoff and soil loss for sorghum crop

Date	Rainfall, mm	Runoff, mm			Soil loss, tons ha^{-1}		
		T_1	T_2	T_3	T_1	T_2	T_3
19-08-2012	10.7	0.108	0.035	0.094	-	-	-
31-08-2012	24.8	0.147	0.035	0.400	-	-	-
04-09-2012	50.7	3.90	0.239	2.160	0.949	0.018	0.511
22-09-2012	23.6	0.397	0.056	0.552	-	-	-
03-10-2012	28.9	0.394	0.328	0.552	0.044	0.023	0.057
Total	138.7	4.946	0.693	3.758	0.993	0.041	0.568

Table 2 Pooled data of grain and fodder yield for sorghum as influenced by different treatments

Treatment	Grain yield ($kgha^{-1}$)			Fodder yield ($kgha^{-1}$)		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
A) Tillage						
T_1	3790	2157.26	2973.61	7608	6396.24	7001.92
T_2	3834	2092.35	2962.97	7757	6247.24	7001.90
T_3	3925	2116.83	3020.96	7522	6194.03	6858.25
S. E. (m) $\pm$	93	40.73	105.09	122	85.42	74.43
C. D. at5%	NS	NS	NS	NS	NS	NS
C. V. %	9.40	7.43	19.27	6.21	5.26	5.86
B) Nutrient Management						
N_1	3981	2347.77	3164.63	7299	6364.31	6831.67
N_2	3813	2315.31	3064.34	7671	6098.24	6884.84
N_3	3754	1703.35	2728.57	7916	6374.95	7145.55
S. E. (m) $\pm$	76	60.54	85.47	197	85.86	78.61
C.D. at 5%	NS	176.71	249.47	NS	NS	229.45
C. V. %	7.67	11.04	15.67	9.98	5.29	6.19
C) Interaction						
S.E. (m) ±	132	104.87	148.03	340	148.72	136.15
C.D at 5%	NS	306.10	NS	9.93	434.12	397.42

Table 3 Interaction effect on fodder yield (pooled)

Treatments	N_1	N_2	N_3	Mean
T_1	7007.26	7007.17	6991.33	7001.92
T_2	6624.17	6975.32	7406.22	7001.90
T_3	6863.59	6672.04	7039.13	6858.25
Mean	6831.67	6884.84	7145.55	
S.E. (m) ±	136.15			
C.D at 5%	397.42			

Energy Estimates

1. **Total input energy:** The sum of all equivalent energy required for the growth of sorghum is the total input energy distribution according to its form in various treatments is depicted in Fig.1. The equivalent energy requirement for sorghum crop was observed to be higher in the treatment combination of conventional tillage and recommended dose of inorganic fertilizer (T_1N_1) as compared to treatment combination of conventional tillage and 50% recommended dose through inorganic fertilizers and 50% through organic (FYM/Glyricidia) (T_1N_2) and conventional tillage and recommended dose through organic (FYM/Glyricidia) (T_1N_3).

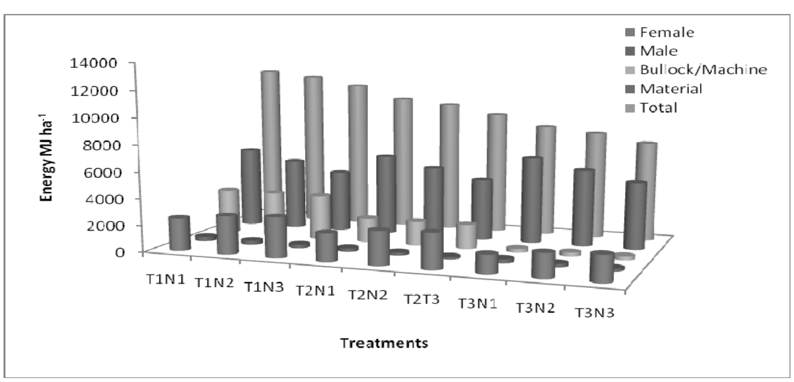

Fig. 1 Input equivalent energy requirement for the different treatments

2. **Total input-output energy:** The equivalent input-output energy is depicted in Fig.2. The equivalent energy requirement for sorghum crop was observed to be higher in the treatment combination of conventional tillage and application of inorganic fertilizer as the energy input through fertilizer is high as compared to organic but the energy required for application of fertilizer is also high. However, the labour requirement is higher for application of organic manures as compared to inorganic fertilizer.

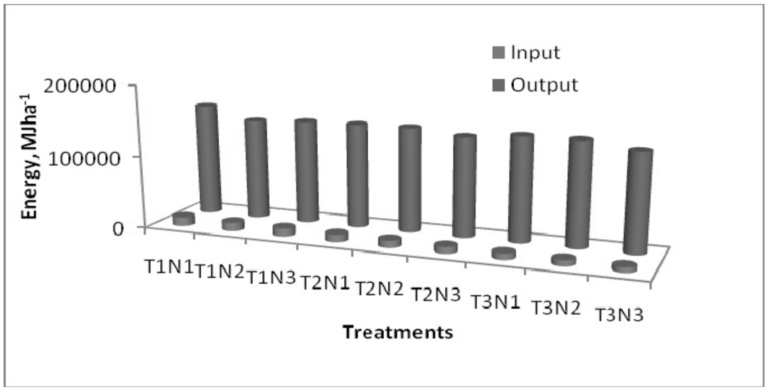

Fig. 2 Input-output energy as influenced by different treatment combinations

Energy use efficiency and rain water use efficiency influenced by different treatments

Energy use efficiency and rain water use efficiency as influenced by different treatments is given in Table 4. In tillage management, energy use efficiency in low tillage with herbicides, T_3 (17.59) was statistically significant over conventional tillage, T_1 (12.33) and low tillage with hand weeding, T_2 (14.41). In nutrient management, energy use efficiency in the treatment recommended dose through organic, N_3 (15.15) was statistically significant over treatment recommended dose through inorganic, N_1 (14.53) however it was at par with half dose through organic and inorganic treatment, N_2 (14.65).

Interaction effect of treatment combination

Interaction effect of tillage and nutrient management on energy use efficiency is given in Table 5. The treatment combination of low tillage with herbicides and recommended dose through organic (T_3N_3) was found superior over other combination.

Resource conservation through tillage operation

The equivalent input energy utilized in different tillage operations including equivalent rainfall energy is given in Table 6. From the table it is observed that, conventional tillage practices (T_1) had required more energy as compared to 50% conventional tillage with hand weeding (T_2) and 50% conventional tillage with herbicide practices (T_3). The resource conservation for 50% conventional tillage with hand weeding treatment was observed to be 16.42% and in 50% conventional tillage with herbicide treatment it was 31.74% over conventional tillage treatment.

Table 4 Energy use efficiency and rain water use efficiency as influenced by different treatments

Treatment	Energy use efficiency	Rain water use efficiency
A) Tillage		
T_1	12.33	4.22
T_2	14.41	4.05
T_3	17.59	4.12
S. E. (m) $\pm$	0.14	-
C. D. at 5%	0.48	-
C. V. %	3.92	-

Contd…

Treatment	Energy use efficiency	Rain water use efficiency
B) Nutrient Management		
N_1	14.53	4.58
N_2	14.65	4.48
N_3	15.15	3.32
S. E. (m) ±	0.17	-
C.D. at 5%	0.51	-
C. V. %	4.64	-
C) Interaction		
S. E. (m) ±	0.30	-
C.D at 5%	NS	-

Table 5 Interaction effect on energy use efficiency

Treatments	N_1	N_2	N_3	Mean
T_1	14.26	14.48	14.25	15.72
T_2	15.36	16.00	17.51	16.08
T_3	17.54	17.77	18.79	16.85
Mean	14.33	16.29	18.03	
S.E. (m) ±	6.84			
C.D at 5%	1.02			

Table 6 Overall equivalent energy required in different tillage operations

Equivalent energy, $MJha^{-1}$	T_1	T_2	T_3
Input energy	35730	29835	24342
Rainfall energy	143.52	144	143
Total energy	35873	29979	24485

CONCLUSION

The treatment low tillage with hand weeding (T_2) is more effective in soil and water conservation than conventional tillage. The effect of tillage management on productivity of sorghum is low as compared to integrated nutrient management. The equivalent energy requirement for sorghum crop was observed to be higher in the treatment combination of conventional tillage and application of inorganic fertilizer. Pooled analysis of the data revealed that the effect of tillage on productivity of sorghum can be minimized through integrated nutrient management. The resource conservation in the treatment, 50% conventional tillage with hand weeding was observed to be 16.42% and in 50% conventional tillage with herbicide treatment it was 31.74% over conventional tillage treatment.

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Runoff and Nutrient Status Monitoring of a CCT Treated Catchment

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ABSTRACT

In this study four catchments has been monitored at the field of AICRP for Dryland Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. Out of which two catchments had been treated with continuous contour trenches and other two are without continuous contour trenches. The catchments consists of Custard Apple (*Annona squamosa*) and Hanumanphal (*Annona cherimola*) plantation. The hydrological monitoring and nutrient status of the catchments was studied and here the results of runoff and nutrient analysis are presented. It was observed that the runoff in the CCT treated catchment was estimated as zero, 2 mm and 6 mm during 2013 to 2015 respectively, compared to corresponding runoff of 43 mm, 44 mm and 52 mm for the untreated catchment. Continuous contour trenches results in 100, 95.45 and 88.46% reduction in runoff leading to moisture conservation which ultimately influences the growth of plantation. In case of nutrient analysis, it was observed that the available N, P, K and organic carbon content in the soils under custard apple plantation in CCT treated catchment was more by 33.38, 14.14, 11.19 and 0.03% over untreated catchment respectively. For Atemoya plantation, the available N, P, K and organic carbon content in the soils of treated catchment was more by 26.08, 12.65, 3.12 and 0.04% over untreated catchment respectively. From this results it can be said that the CCT are useful measures for rainwater conservation and improving the soil fertility of the catchment.

Keywords: CCT, catchment, nutrient, runoff.

INTRODUCTION

Present climate change scenario is inviting an attention towards best management practices that reduces soil erosion, sustains soil fertility and improves water management. This can be achieved by adopting *in-situ* soil and moisture conservation practices along with integrated nutrient supply system for improvement of soil fertility as well as crop productivity on sustained basis. The concept of contour trench is rehydrating the earth by sustainable, small-scale sub-surface water retention technique (Royal Haskoning report, Vietnam 2006). Continuous contour trench system (CCT) system, developed for plantation in non arable lands in low rainfall areas, has been found to be very effective in soil and water conservation. Whenever rainfall-runoff event occurs, runoff begins and flows down from the slopes causing erosion giving not much chance for water to infiltrate down the soil. In such situations CCTs are adopted for reducing runoff and enabling the water to infiltrate down to the ground. Contour trenches break the velocity of runoff. The rainwater percolates through the soil slowly and travels down and benefits the better types of land in the middle and lower sections of the catchments refilled continuous contour trenching (RCCT) method is the solution for watershed management, soil and water conservation (Sadgir *et al.*, 2006). In order to know the effect of continuous contour trenches (CCTs), hydrological research needs to be conducted.

Contour trenches

Contour trenches are used both on hill slopes as well as on degraded and barren waste lands for soil and moisture conservation and afforestation purposes. It can be used in all slopes irrespective of rainfall conditions (i.e., in both high and low rainfall conditions), varying soil types and depths. Trenches can be continuous or interrupted. The interrupted one can be in series or staggered, continuous one is used for moisture conservation in low rainfall areas and require careful layout (Thomas *et al.*, 2010). Intermittent trenches are adopted in high rainfall areas. The trenches are to be constructed strictly on contours irrespective of the category. The size of the trench depends upon the soil's depth. Normally 1,000 sq cm to 2,500 sq cm. in cross section are adopted. The trench may be of 30 cm base and 30 cm top width and square in cross section or it can be trapezoidal with side slopes 1:1. Based on the quantum of rainfall to be retained, it is possible to calculate the size and number of trenches.

Runoff and Soil loss

Due to spatial variability of rainfall, runoff is frequently localized and runoff generated in some parts of the catchment may later re-infiltrate and thus not contribute to runoff at the outlet of the catchment. Runoff may infiltrate in the bottom of valley into a bed of alluvial sediments or overland flow may be lost as infiltration into fractural bedrock channels. In all cases groundwater recharge is augmented. During a rainfall event the water which flows over the ground surface is known as surface runoff. The volume of runoff which fills the CCTs depends upon the factors such as infiltration rate, rainfall intensity, rainfall duration, antecedent soil moisture, soil type, vegetation, slope and catchment size. Pre calibrated devices for measuring runoff are most commonly used because of their high accuracy. Most commonly runoff and soil loss measuring devices are H-type flumes along with stage level recorder and Coshocton wheel samplers.

Study Area

The study was undertaken on the experimental field of AICRP for Dryland Agriculture, Dr. PDKV, Akola in the Vidarbha region of Maharashtra. In this study three types of soils were identified viz. Inceptisol, Entisol and Vertisol. Four micro-catchments were selected for the study out of which two catchments had been treated with continuous contour trenches and other two are without continuous contour trenches. The catchments consists of Custard Apple (*Annona squamosa*) and Hanumanphal (*Annona cherimola*) plantation. The runoff monitoring and nutrient status of the catchments was studied and the results are presented below.

RESULTS

During 2013 the runoff events was occurred and given in Table 1. The runoff causing rainfall was 261.1 mm which had caused surface runoff of 43mm (16.46%) in untreated catchment, T_1 and no surface runoff was observed in the CCT treated catchment, T_2. This indicates that in the CCT treatment catchment the runoff (100%) was recharged in the soil and ultimately reached to the groundwater.

Table 1 Runoff during the season 2013 through treated and untreated catchment

Date	Rainfall, mm	Runoff, mm	
		Untreated catchment (T_1)	CCT treated catchment (T_2)
16-06-2013	23.0	4.48	0.00
23-07-2013	37.0	2.16	0.00
25-07-2013	33.0	6.14	0.00
01-08-2013	69.5	9.00	0.00
03-08-2013	14.4	5.65	0.00
23-09-2013	24.0	10.57	0.00
04-10-2013	60.2	5.00	0.00
Total	261.1	43.00	0.00

During 2014 the runoff events was occurred and given in Table 2. The runoff causing rainfall was 332.8mm which resulted into surface runoff of 44mm (13.22%) in untreated catchment, T_1 and 2mm (0.6%) in the CCT treated catchment, T_2. This means that in the CCT treated catchment the runoff of 99.4% was conserved in the soil and ultimately reached to the groundwater.

Table 2 Runoff during the season 2014 through treated and untreated catchment

Date	Rainfall, Mm	Runoff, mm	
		Untreated catchment (T_1)	CCT treated catchment (T_2)
12-06-2014	18.5	2.00	0.00
11-07-2014	44.4	8.00	0.00
20-07-2014	10.5	1.00	0.40
23-07-2014	136.4	18.0	1.60
24-07-2014	42.0	4.00	0.00
08-09-2014	81.00	11.0	0.00
Total	332.8	44.00	2.00

During the season 2015, total 2 runoff events was occurred and given in Table 3. The runoff causing rainfall was 272.5mm which had caused surface runoff of 52mm (19.08%) in untreated catchment, T_1 and 6mm (2.20%) runoff was observed in the CCT treated catchment, T_2. This indicates that in the CCT treatment catchment the runoff (97.8%) was recharged in the soil.

Table 3 Runoff during the season 2015 through treated and untreated catchment

Date	Rainfall, Mm	Runoff, mm	
		Untreated catchment (T_1)	CCT treated catchment (T_2)
04-08-2015	194.0	33.2	6.0
17-09-2015	78.5	18.8	0.0
Total	272.5	52.0	6.0

Soil fertility

The nutrient parameters were analyzed and based on average estimation the results are presented in Figs. 1 and 2 for soils under Custard apple and Atemoya plantation. The organic carbon content in the soils of treated and control micro-catchments of Custard apple and Atemoya plantation is presented in Fig. 3.

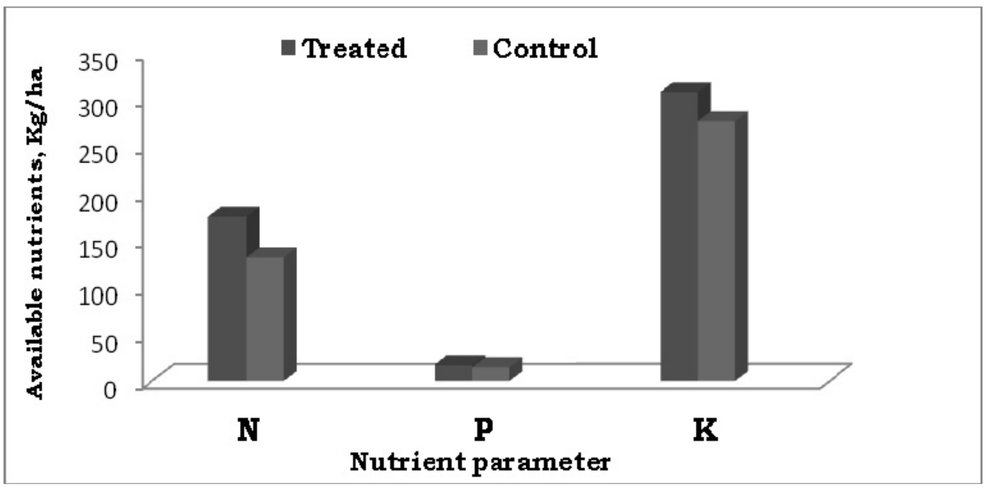

Fig. 1 Nutrient status in Custard apple plantation

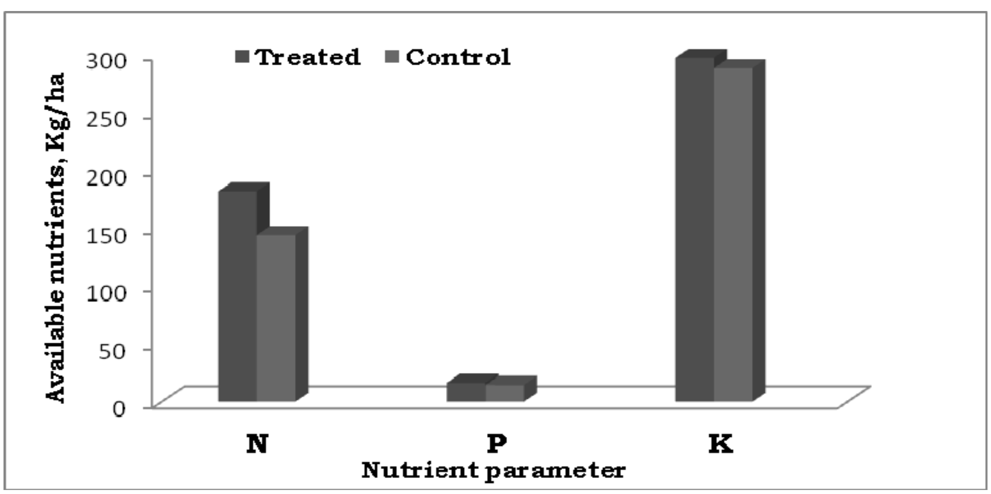

Fig. 2 Nutrient status in Atemoya plantation

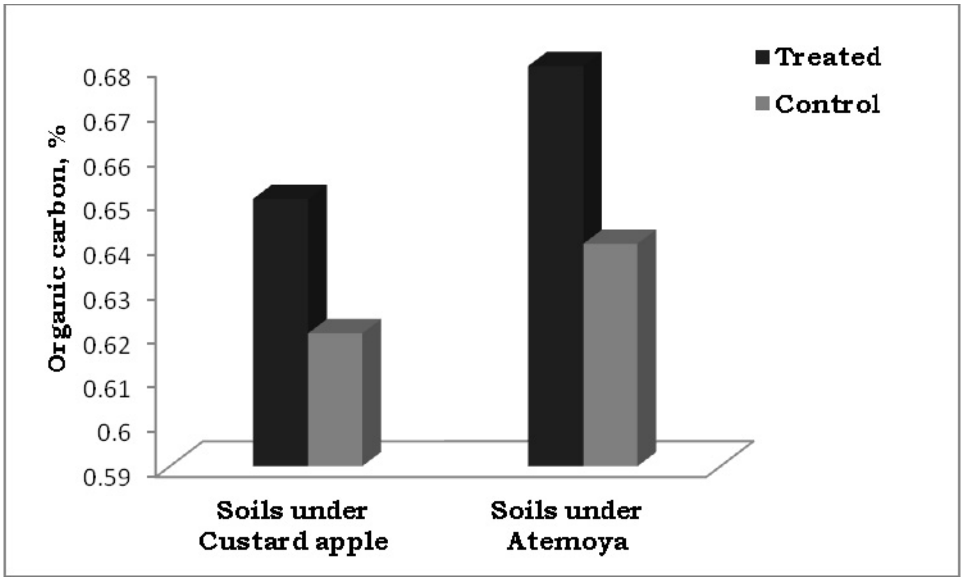

Fig. 3 Organic carbon in soils of Custard apple and Atemoya plantation

It was observed that the available nitrogen (N), phosphorus (P), potassium (K) and organic carbon content in the soils under custard apple plantation in treated micro-catchment was more by 33.38, 14.14, 11.19 and 0.03% over soils of the control micro-catchment respectively. In case of Atemoya plantation, the available nitrogen (N), phosphorus (P), potassium (K) and organic carbon content in the soils of treated micro-catchment was more by 26.08, 12.65, 3.12 and 0.04% over soils of the control micro-catchment respectively. Overall it can be inferred that the CCT helps in improving the soil fertility.

CONCLUSION

The results shows the advantages of CCT in low rainfall areas as a runoff and thereby moisture conservation measure. Moreover, it can be an effective measure for utilising non-arable lands for fruit plantations. Overall the impacts of continuous contour trenches on the hydrology of the catchments are positive. Besides the positive effect on hydrology, increased infiltration and lower runoff lead to lower soil loss rates and a higher sediment deposition rate within the catchment. This ultimately helps in improving groundwater recharge of a catchment.

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Ranking of Plotting Position Formulae in Frequency Analysis of Annual and Seasonal Rainfall

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ABSTRACT

In the frequency analysis of hydrologic data, the frequency of occurrence of the observed distributions is important for the purpose of plotting observed data called the "plotting positions". An acceptable determination of plotting positions has been a debatable question and has generated a great deal of discussion. Many methods for computing plotting positions have been proposed over the years. In the present study, the performance of nine plotting position formulae namely, Hazen, California, Weibull, Beard, Chegodayev, Blom, Gringorten, Cunnance and Adamowski, in estimating magnitudes of annual and seasonal rainfall with higher return periods (or lesser probability of exceedance) at Puducherry in Union Territory of Puducherry, has been assessed using the error statistics such as Mean Square Error (*MSE*), Root Mean Square Error (*RMSE*) and Mean Absolute Error (*MAE*) and Agreement Index (*AI*) . The plotting-position formulae are assigned ranks based on the mentioned error statistics and the Agreement Index.

Keywords:

INTRODUCTION

Rainfall is one of the most important natural resources used as a direct/indirect input for meeting the water requirements of crop and an indirect input in satisfying the water demands of domestic, commercial and industrial activities through surface and subsurface storage. The occurrence and distribution of rainfall vary temporally and spatially. For overall water resources development on a larger time scale of any location/region, it becomes necessary to analyze the historical long-term annual and seasonal rainfall of the location/region. One of the most imperative problem in hydrology deals with inferring the past records of hydrological events in terms of probabilities of occurrence. Probability and frequency analysis of rainfall data facilitate us to determine the expected rainfall with various chances of occurrence.

Probability plotting positions are used for the graphical demonstration of annual maximum hydrologic series and serve as estimates of the probability of exceedance of those series. Probability plots allow a visual assessment of the capability of the fit provided by alternative parametric flood frequency models. They also provide a non-parametric means of forming an estimate of the data's probability distribution by drawing a line by hand and/or programmed means through the plotted points. Because of these striking characteristics, the graphical approach has been preferred by many hydrologists and engineers. It has been commonly used both in hydraulic engineering and water resources research. Probability plotting positions have been discussed by hydrologists and statisticians for many years. In the past about 100 years, a number of plotting-position methods and related numerical methods have been proposed for analysis of extreme values. Reviews on plotting-position formulae have been made by Cunnane (1978), Castillo (1988), Stedinger et. al (1993), Folland and Anderson (2002) and Jordaan (2005). Cunnane (1978) mentioned that a plotting formula should be unbiased and should have the smallest Mean Square Error (MSE) among all estimates.

PLOTTING POSITIONS

Many plotting - position formulae are available, some of the more commonly used ones are given in Table 1 (Singh, V. P, 1994). Adamowski (1981) has shown that all of these formulae can be expressed in the general form

$$P_m = \frac{m-a}{N+b}$$

where *a* and *b* are constants, P_m is the probability of the exceedance of the *m*th observation. *m* is the rank of N ordered observations (in decreasing order) such as $P_{m=1} > P_{m=2} > ...... > P_{m=N}$.

Table 1 More commonly used plotting-position formulae

Plotting-Position method	Formula for probability of exceedance, P_m $P_m = \frac{m-a}{N+b}$	*a*	*b*	Return period, $T = \frac{1}{P_m}$
Hazen (1914)	$\frac{m-0.5}{N}$	0.5	0.0	$\frac{N}{m-0.5}$
California (1923)	$\frac{m}{N}$	1.0	0.0	$\frac{N}{m}$
Weibull (1939)	$\frac{m}{N+1}$	0.0	1.0	$\frac{N+1}{m}$
Beard (1943)	$\frac{m-0.31}{N+0.38}$	0.31	0.38	$\frac{N+0.38}{m-0.31}$
Chegodayev (1955)	$\frac{m-0.3}{N+0.4}$	0.30	0.40	$\frac{N+0.4}{m-0.3}$
Blom (1958)	$\frac{m-0.375}{N+0.25}$	0.375	0.25	$\frac{N+0.25}{m-0.375}$
Gringorten (1963)	$\frac{m-0.44}{N+0.12}$	0.44	0.12	$\frac{N+0.12}{m-0.44}$
Cunnane (1978)	$\frac{m-0.4}{N+0.2}$	0.40	0.20	$\frac{N+0.2}{m-0.4}$
Adamowski (1981)	$\frac{m-0.25}{N+0.5}$	0.25	0.50	$\frac{N+0.5}{m-0.25}$

The most commonly used plotting - position formula in hydrology is the Weibull formula given by

$$P_m = \frac{m}{N+1}$$

where, P_m is the exceedance probability of the *m*th data point (observed value) is the sample arranged in the descending order of magnitudes. The return period of the mth data point, T_m, is the reciprocal of the probability of exceedance, P_m. Using the Weibull formula, the return period is given by

$$T_m = \frac{1}{P_m} = \frac{N+1}{m}$$

METHODOLOGY

Annual rainfall pertaining to the first 30 years (1900 – 1929) of available historical record of 100 years (1900 – 1999) for Puducherry town, Union Territory of Puducherry State, is taken and the data are arranged in decreasing order of magnitude. Each data point is assigned a rank. The data having the highest magnitude is assigned the rank 1 (m = 1) and the data having the lowest magnitude is assigned the rank N ($m = N$ = number of data points in the sample = 30). This arrangement gives an estimate of the exceedance probability, that is, the probability of a value being equal to or greater than the ranked value. A graphical plot of probability of exceedance, P_m, obtained by the particular plotting – position formula, versus the obtained annual rainfall, R, with both variables on logarithmic scale, is made.

The observed values of annual rainfall, R, and their exceedance probabilities, P_m, are related such that observed values of annual rainfall are taken as the y-values and their exceedance probabilities are taken as the x-values. Logarithmic scale is used for both the axes. Linear equation of the form $R = AP_m + B$ is fitted to the plot where R is the annual rainfall with probability of exceedance P_m; A is the slope of the fitted line and B is the y – intercept. The degree of goodness of fit thus obtained is indicated by the R^2 value obtained. The closeness of fit (for any plotting-position method) with the observed values of annual rainfall is examined as follows: The probability of exceedance, P_m, of the observed annual rainfall magnitudes in the 100 years of historical data (1900 – 1999) available is determined by the particular plotting-position method as outlined above. Then, using the linear equation of the form $R = AP_m + B$ fitted considering the first 30 years (1900 – 1929) of data , the annual rainfall magnitudes for different exceedance probabilities obtained with 100 years data are estimated (designated as R_{est}) . Then, the error statistics such as Mean Square Error (MSE), Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) and Agreement Index (AI) which are determined as follows:

$$\mathrm{MSE} = \frac{1}{N}\sum_{i=1}^{N}(R_{est,i} - R_i)^2$$

$$\mathrm{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(R_{est,i} - R_i)^2}$$

$$\mathrm{MAE} = \frac{1}{N}\sum_{i=1}^{N}|R_{est,i} - R_i|$$

$$\mathrm{AI} = \frac{R_{est}}{R}$$

The above exercise is done for all the nine plotting - position methods listed in Table 1. The performance of each of the plotting - position formulae is examined using the error statistics mentioned above. This procedure of evaluation will help in assessing the performance of each plotting-position formula in estimating annual rainfall magnitudes with probability of exceedance less than those obtained with sample data of size N = 30 taken for obtaining the linear fit. Or in other words, this procedure of performance evaluation will help in ranking the different plotting-position methods for estimation of magnitudes of annual rainfall with higher return periods.

The plotting-position formulae are assigned ranks based on the error statistics and the Agreement Index as detailed herein. The method which yields the least *MSE* is assigned the rank “1” and the method that yields the highest *MSE* is assigned the rank “9”. The same criterion is adopted for ranking of methods in terms of *RMSE* and *MAE*. The plotting-position method that yields an AI closest to unity is assigned the rank “1” and the one that yields an *AI* farthest from unity is assigned the last rank (Rank “9”). This logic is applied for minimum *AI*, maximum *AI* and mean *AI*. The method which has the minimum standard deviation of AI is given the best rank (Rank “1’) and the one that has the maximum standard deviation is given the rank “9.

The overall ranking for each method is assigned by computing the mean of the ranking of that method in terms if *MSE*, *RMSE*, *MAE*, minimum *AI*, maximum *AI*, mean *AI* and standard deviation of *AI*. The mean ranking for a plotting-position method is computed as the average of all the rankings assigned to that method in terms of the seven statistics namely, *MSE*, *RMSE*, *MAE*, minimum *AI*, maximum *AI*, mean *AI* and standard deviation of *AI*. The method which yields the minimum mean ranking is assigned an overall ranking “1” and the one which yields the maximum mean ranking is assigned the overall ranking “9”.

The methodology as described above is used for assessing the performance of each plotting-position method mentioned in estimating magnitudes of annual rainfall, North-east monsoon rainfall and South-west monsoon rainfall with different probabilities of exceedance.

FUNDAMENTAL STATISTICS OF HISTORIC RAINFALL DATA

The maximum and minimum annual rainfall of 212.6 cm and 56.6 cm recorded in the years 1997 and 1968 respectively are found to be 68.9% more and 55.8% less than the mean annual rainfall of 125.9 cm. The annual rainfall was more than the mean annual rainfall in 32 years while it was less than the mean annual rainfall in 68 years. The North-east monsoon and the South-west monsoon contribute nearly two-thirds and one-third of the annual rainfall in the study location. The mean proportion of rainfall during North-east and South-west monsoons put together is nearly 90% of the mean annual rainfall while the mean proportion of rainfall during the summer and winter seasons put together is only about 10% of the mean annual rainfall. The coefficient of variation is found to be less than 50% in annual (28.8%), South-west monsoon (38.7%) and North-east monsoon (41.5%) rainfalls while it was more than 100% in winter (135.7%) and summer (116.2%) rainfalls. The skewness of 0.4 for annual rainfall and 0.3 for North-east monsoon rainfall indicate that the distributions of both annual rainfall and North-east monsoon rainfall are approximately symmetric. As per Bulmer (1979), if skewness is between −½ and +½, the distribution is approximately symmetric. The distribution of South-west monsoon rainfall can be considered as moderately skewed. If skewness is between −1 and −½ or between +½ and +1, the distribution is moderately skewed (Bulmer, 1979). As the skewness of both annual rainfall (0.168) and North-east monsoon rainfall (0.320) recorded during the 30-year period from 1900 to 1929 lie between −½ and +½, the distribution is approximately symmetric.

RESULTS AND DISCUSSION

The probability of exceedance of observed annual rainfall in the 30-year period 1900-1929 were obtained by the various plotting-position formulae considered in the study. Table 2 shows the linear equations of the form $R = AP_m + B$ fitted to observed annual rainfall, North-east monsoon rainfall and South-west monsoon rainfall in the 30-year period 1900-1929, with different probability of exceedance, P_m, given by different plotting-position formulae.

Table 2 Linear equations fitted to observed Annual rainfall and Seasonal rainfall in the 30-year period 1900-1929

Plotting-position formula	**Linear equation of the form $R = AP_m + B$ fitted to estimate magnitudes of**		
	Annual rainfall	**North-east monsoon rainfall**	**South-west monsoon rainfall**
Hazen	$R = -1.076P_m + 181.8$	$R = -1.019P_m + 131.8$	$R = -0.386P_m + 54.96$
California	$R = -1.076P_m + 183.6$	$R = -1.019P_m + 133.5$	$R = -0.386P_m + 55.60$
Weibull	$R = -1.112P_m + 183.6$	$R = -1.053P_m + 133.5$	$R = -0.399P_m + 55.60$
Beard	$R = -1.090P_m + 182.5$	$R = -1.032P_m + 132.4$	$R = -0.391P_m + 55.20$
Chegodayev	$R = -1.090P_m + 182.6$	$R = -1.033P_m + 132.5$	$R = -0.391P_m + 55.22$
Blom	$R = -1.085P_m + 182.3$	$R = -1.028P_m + 132.2$	$R = -0.389P_m + 55.12$
Gringorten	$R= -1.080P_m + 182.1$	$R = -1.023P_m + 132.0$	$R = -0.387P_m + 55.04$
Cunnane	$R = -1.083P_m + 182.2$	$R = -1.026P_m + 132.1$	$R = -0.388P_m + 55.09$
Adamowski	$R = -1.094P_m + 182.7$	$R = -1.036P_m + 132.6$	$R = -0.392P_m + 55.28$

From Table 5, it is observed that the multiplication constants, *A*, in all fitted linear equations are negative indicating that higher the probability of exceedance, lesser the magnitude of rainfall (Annual/North-east monsoon/South-west monsoon). The multiplication constant, A, varies in narrow ranges (-1.076 to – 1.112 for annual rainfall; - 1.019 to – 1.053 for North-east monsoon rainfall and – 0.386 to – 0.399 for south-west monsoon rainfall). The rate of decrease in magnitude of rainfall (Annual/ North-east monsoon/South-west monsoon) with probability of exceedance is found to be the smallest for both Hazen and California methods while it is found to the largest for the Weibull method. The r^2 values for the fitted linear equations are found to be same for all the plotting-position formulae at 0.966 for annual rainfall, 0.940 for North-east monsoon rainfall and 0.931 for South-west monsoon rainfall. The high r^2 values obtained for all the methods indicate the goodness of the linear fits obtained in estimation of magnitudes of rainfall with different probability of exceedance.

The probability of exceedance, P_m, of the observed rainfall magnitudes in the 100 years of historical data (1900 – 1999) available was determined for each of the plotting-position formulae mentioned above. Then, using the linear equation of the form $R = AP_m + B$ fitted considering the first 30 years (1900 – 1929) of data, the estimates of rainfall magnitudes with different exceedance probabilities obtained with 100 years data are determined (designated as R_{est}). This exercise was done for all the nine plotting-position formulae and estimates of annual rainfall, north-east monsoon rainfall and South-west monsoon rainfall were obtained. The estimated rainfall magnitudes were compared with the corresponding observed rainfall magnitudes and the error statistics namely, *MSE*, *RMSE*, *MAE* and *AI* were obtained.

The error statistics namely, *MSE*, *RMSE* and *MAE* are found to be consistently the least for Weibull method in estimation of rainfall magnitudes with different probability of exceedence (for Annual Rainfall – 65.5, 8.1 and 5.9; for South-west monsoon rainfall – 15.0, 3.9 an 2.8; North-east monsoon rainfall – 34.7, 5.9 and 4.4), while they are found to be consistently the most for California method (for Annual Rainfall – 78.2, 8.8 and 6.9; for South-west monsoon rainfall – 17.1, 4.1 and 3.2; North-east monsoon rainfall – 44.4, 6.7 and 5.6). The *MSE*, *RMSE* and *MAE* are found to lie in the narrow range 68.3 to 71.3, 8.3 to 8.4 and 6.0 to 6.2 respectively.

The mean *AI* for all methods except the California method is found to lie in narrow ranges (1.028 to 1.031 for annual rainfall; 1.063 to 1.067 for South-west monsoon rainfall and 1.049 to 1.054 for North-east monsoon rainfall). It should be noted that an *AI* of less than unity indicates that the method underestimates the magnitude of rainfall whereas an *AI* of more than unity indicates overestimation of rainfall magnitude.

The overall ranking of methods in estimation of magnitudes of annual rainfall, South-west monsoon rainfall and North-east monsoon rainfall with different probability of exceedence is provided in Table 3.

Table 3 Overall ranking of plotting-position methods in estimation of rainfall magnitudes with different probability of exceedance

Plotting-position	**Overall ranking in estimation of**		
	Annual rainfall	North-east monsoon rainfall	South-west monsoon rainfall
Hazen	7	9	7
California	9	8	9
Weibull	1	1	1
Beard	4	3	2
Chegodayev	2	4	3
Blom	5	5	5
Gringorten	8	7	7
Cunnane	6	6	6
Adamowski	3	2	3

The performance of Weibull method has been consistent that it secures the overall ranking "1" in best estimation of magnitudes of Annual rainfall, South-west monsoon rainfall and North-east monsoon rainfall with different probabilities of exceedance. The Adamowski method secures overall ranking "2" in estimation of Annual rainfall and North-east monsoon rainfall while it secures overall ranking "3" in estimation of South-west monsoon rainfall. The Chegodayev and Beard methods secure overall ranking from "2" to "4" in estimation of Annual, North-east monsoon and South-west monsoon rainfalls. The California method obtained the last overall ranking "9" in estimation of Annual and South-west monsoon rainfalls. Makkonen (2006) compared the return period of the largest value in a sample of 21 annual extreme values as determined by the commonly used plotting-position formulae namely, Weibull, Beard, Gringorten, Hazen, and the numerical method proposed by Harris (1996) and reported that the percentage error in estimation of the event was zero for Weibull method while all the other methods overestimated the return period of the largest annual extreme event, that is, underestimated its risk of occurrence.

Ani Shabri (2002) ranked eight plotting position methods based on their performance in estimating annual maximum flood flows at 31 stations of peninsular Malaysia. The methods were ranked according to values of *RMSE* and *MAE* on a scale 1 to 8 with "1" being the best method. He reported that the Weibull method was the best performing one compared to the other methods considered in his study. Adeboye and Alatise (2007) fitted the normal distribution to the peak flow discharge of two rivers in Nigeria using seven probability plotting positions. They concluded that the Weibull method is suitable for fitting the normal distribution.

CONCLUSION

Based on the assessment of performance of different plotting positions considered in the study in best estimation of magnitudes of annual and seasonal rainfall at Puducherry, in terms of the error statistics and agreement index, it is found that the Weibull method attains the overall ranking "1" followed by Adamowski method.

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Optimal Reservoir Operating Policies using Genetic Algorithm

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ABSTRACT

Application of optimization techniques for determining the optimal operating policy of reservoir is a major issue in water resources planning and management. In reservoir operation, appropriate methodology for deriving reservoir operating rules should be selected and operating rules should then be formulated. Genetic Algorithm is an optimization technique, based on the principle of natural selection, derived from the theory of evolution and is popular for solving optimization problems. In the present study Genetic Algorithm (GA) has been applied to derive the optimal operating policy of Nagarjunasagar reservoir, existing multipurpose reservoir in India. The fitness function of the proposed GA model is minimizing the sum of the squared deviation of monthly irrigation deficits while minimizing the spills from the reservoir. The decision variables are monthly reservoir releases for irrigation, monthly storages and spills of reservoir. The constraints considered for this model are mass balance equation and the bounds for decision variables. Reservoir operating policies are developed for various levels of Inflows in to the reservoir and are presented.

Keywords: Optimization, Genetic algorithm, Nagarjunasagar reservoir.

INTRODUCTION

In spite of the large investments made in dams and reservoirs worldwide, many are still operated on the basis of experience, rules of thumb or static rules established at the time of construction. Thus, there are many areas where even a small improvement in the operating policies can lead to large benefits for many consumers. Major water resources projects are intended to provide a number of water related benefits, directly or indirectly, to the public at large. The incorporation of some of these objectives into the planning, design, and operational phases of a water resources project is necessary to ensure feasibility, justification and social acceptability for the project. Over the past decades, optimization of reservoir systems operation has been a major field of water resource studies. Progress has been achieved due to the improvements in mathematical models, optimization methods and advancements in computer technology and calculating tools.

A reservoir operation problem can be considered as a decision making problem having many constraints. Optimizing reservoir operations incorporate allocation of resources, development of stream flow regulation strategies, operating rules and real-time release decisions in its bodily constitution. A reservoir regulation plan, which is sometimes referred as operating procedure or release policy, is a set of rules quantifying the amount of water to be stored, released or withdrawn from a reservoir or system of reservoirs, under various conditions. This study intended to build an operational model to ease the decisions about the optimal volumes to be stored or released from the reservoirs in question, i.e. the operational decisions. Unlike all investigation methods, system analysis helps in solving the question properly and distinctly setting the objectives and correctly formulating the problem and task. System analysis converts a complicated problem into a simple one and it transforms the problem which is difficult to solve and understand into series of precise tasks with direct method of their solution. On the one hand, system analysis makes it possible to decompose a problem which is too complex for a direct solution into its components for definition and resolution of the specific tasks and on other hand keep them together as a single entity.

To overcome the limitations of Conventional techniques, recently metaheuristic techniques are being used for optimization. By using these techniques, the given problem can be represented more realistically. These also provide ease in handling the nonlinear and non convex relationships of the formulated model. Genetic algorithms (GA), Ant Colony Optimization (ACO) and particle swarm optimization (PSO) are some of the techniques in this category. These evolutionary algorithms search from a population of points, so there is a greater possibility to cover the whole search space and reaching the global optimum.

GENETIC ALGORITHM

Genetic Algorithm is a search and optimization technique based on the principle of natural selection and genetics. This is efficient, adaptive and robust search process, producing near optimal solution. Genetic Algorithms are heuristic techniques for searching over the solution space of a given problem in an attempt to find the best solution or set of solution. The basic elements of natural genetics–reproduction, cross over, mutation are used in the genetic search procedure. Fig.1. shows the flow chart of Genetic Algorithm.

Genetic algorithm differs from conventional optimization techniques in following ways:

- GA's operate with coded versions of the problem parameters rather than parameters themselves.
- Almost all conventional optimization techniques search from a single point but GAs always operate on a whole population of points (strings).
- GA uses fitness function for evaluation rather than derivatives. As a result, they can be applied to any kind of continuous or discrete optimization problem. The key point to be performed here is to identify and specify a meaningful decoding function.

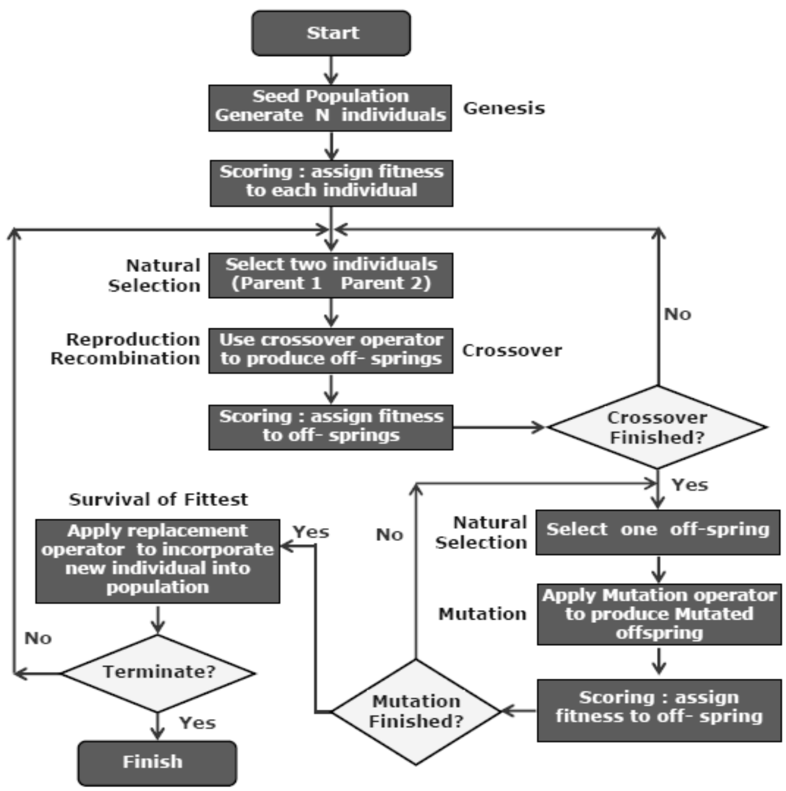

Fig. 1 Flow chart of genetic algorithm

Use of Genetic Algorithm (GA) in determining the optimal reservoir operation policies, is receiving significant attention from water resources engineers. Earlier its potential was explored by Oliver and Loucks (1997) and Wardlaw and Sharif (2000). Many traditional numerical methods are available to facilitate the formation of reservoir operating policies. Yeh et. al (1985) discussed in detail in state of art review on reservoir management and operation models, the usefulness of various models for reservoir operations. Labadie (2004) highlighted in state of art review on optimal operation of multi reservoir system different optimization models suitable for high-dimensional, dynamic, nonlinear and stochastic characteristic of reservoir system. In spite of extensive research in reservoir optimization, researchers are still in search of new optimizing techniques, which can derive more efficient reservoir operating policy for reservoir operation. GA is one such optimizing technique which it is robust and is considered in this study for deriving multipurpose reservoir operating policies.

The GA is based on Darwinian natural selection process that combines the concept of survival of the fittest with natural genetic operators. The working of GA and its application are very well documented by Goldberg and Michaelwiez (1989). One of the advantages of GA is that it identifies alternative near optimal solutions. In the field of water resources for reservoir operation, many applications of GA technique to derive reservoir operating policies have been reported. Oliveira and Loucks (1997) reported that GA can be used to identify effective operation policies. Sharif and Wardlaw (2000) used GA in water resource development and compared it with dynamic programming, they concluded that both results were comparable. Ahmed J. A., et al. (2005) developed a GA model for deriving the optimal operating policy and compared its performance with that of stochastic dynamic programming (SDP) for a multipurpose reservoir. The objective function of both GA and SDP was to minimize the squared deviation of irrigation release. Sensitivity analysis was carried out for mutation and cross over. They found that GA model releases nearer to the required demand and concluded that GA is advantageous over SDP in deriving the optimal operating polices. Janga Reddy M and Nagesh Kumar (2005) developed Multi-objective Evolutionary Algorithm to derive a set of optimal operation policies for a multipurpose reservoir system and concluded that the results obtained using the proposed evolutionary algorithm was able to offer many better alternative policies for the reservoir operation, giving flexibility to choose the best out of them. Jotiprakash V and Ganesan Shanthi (2006) developed a GA model for deriving the optimal operating policy for a multi-purpose reservoir. The objective function was to minimize the squared deviation of monthly irrigation demand deficit along with the deviation in the target storage. Sensitivity analysis was carried out for crosses over and size of population, and they found that GA model releases nearer to the required demand and concluded that GA model is advantageous in deriving optimal operating polices.

MODEL FORMULATION

In the present study, a GA model has been used for deriving optimal reservoir operating policies. The objective of this study is to minimize the squared deviation of monthly irrigation demand deficit along with minimizing the spill from the reservoir. The decision variables are the release for demand from the reservoir, initial storage and spill in each month. The constraints used for this optimization are mass balance equation, reservoir capacity, and the bounds for decision variables.

The ***objective function*** of the proposed GA model is

$$Z = \text{minimize } \sum_{t=1}^{12} (R_t - D_t)^2 + \sum_{t=1}^{12} SP_t \quad (1)$$

where R_t, D_t , SP_t are the release, demand and spill from the reservoir in time period 't',

The above objective function is subject to the following ***constraints***:

Reservoir Storage continuity equation

Water balance of reservoir is governed by reservoir storage continuity equation

$$S_{t+1} = S_t + Q_t - EVP_t - R_t - SP_t \ \forall t \quad (2)$$

where S_t, Q_t and EVP_t are reservoir storage, inflow into reservoir and evaporation from reservoir in time period t

Upper & Lower bounds on releases

Maximum release from the reservoir in each time period is restricted by its target demand in that period and minimum release of at least 50% of the demand is to be given in any time period.

$$0.5\ D_t \le R_t \le D_t \ \forall t \quad (3)$$

Upper & Lower bounds on Reservoir Storage

The storage of the reservoir in any time period S_t should not less than minimum storage and should not exceed its capacity.

$$S_{min} \le S_t \le S_{max} \ \forall t \quad (4)$$

where S_{max}, S_{min} are maximum and minimum storage of reservoir

Carry over year storage

The carry over year storage is taken is the initial storage of the year in order to ensure steady state model.

$$S_{13} = S_1 \tag{5}$$

Non-Negativity Condition

All the decision variables must be non-negative

$$R_t , S_t, SP_t \geq 0 \quad \forall t \tag{6}$$

Study Area

The study area considered in the present study to demonstrate the proposed model is Nagarjuna Sagar Reservoir on the river Krishna in Andhra Pradesh, India (Fig.2). The reservoir is located at latitude 16^0 – 34' N and longitude 79^0 – 19' E with a live storage capacity of 5733 MCM. The maximum and minimum water spread area corresponding to FRL and MDDL are 295 Km^2 and 186 Km^2 respectively. The dam created a water reservoir whose gross storage capacity is 11,560 Million cubic metres (MCM). The dam is 490 feet (150 m) tall from its deepest foundation and 1.6 km long with 26 flood gates which are 42 feet (13 m) wide and 45 feet (14 m) tall. The dam provides irrigation water to the Prakasam, Guntur, Krishna, Khammam, West Godavari and Nalgonda districts along with hydro electricity generation. This project also stabilizes irrigation under Krishna delta system and required water to Krishna delta is released through eight power units with an installed capacity to generate 810 MW of power. The designed discharge capacity of two main canals is 311.3 m^3/s each with provision for increasing the capacity. The length of right canal is 203 Km with an ayacut of 0.4505 M ha. The length of left main canal is 295 Km with an ayacut of 0.3869 M ha. Fig.3 shows the plot of years against reservoir inflow in MCM. The total demand of the reservoir is shown in Table.1. Forty three years of monthly historical inflow data entering into the Nagarjuna Sagar Reservoir is adopted in present study and monthly inflows of 75%, 80%, 85%, 90% probability of exceedence & average inflows are calculated and are shown in Table 2. The mean annual rainfall in the command area varies from 700 to 950 mm. Cropping pattern and basic crop data considered in the present study is shown in Table 3. Mean daily Reference Evapotranspiration and mean monthly rainfall data is obtained IMD stations Rentachintala and Khammam for crops grown under Nagarjuna Sagar right and left canals respectively and presented in Table.4. Fig.4. represents inflows into the reservoir with different probabilities of exceedence.

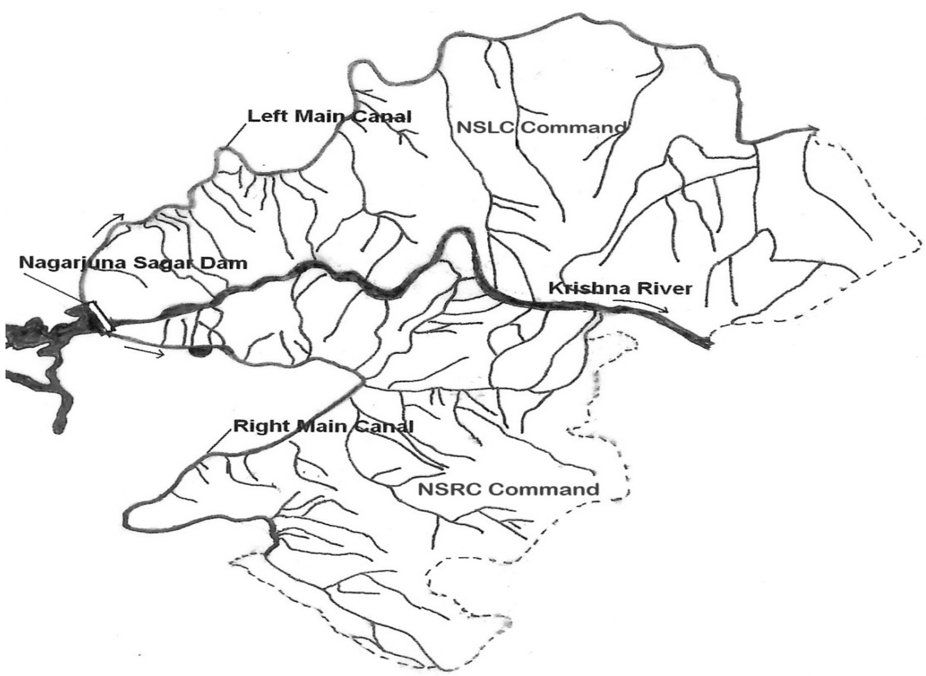

Fig. 2 Schematic representation of nagarjuna sagar project

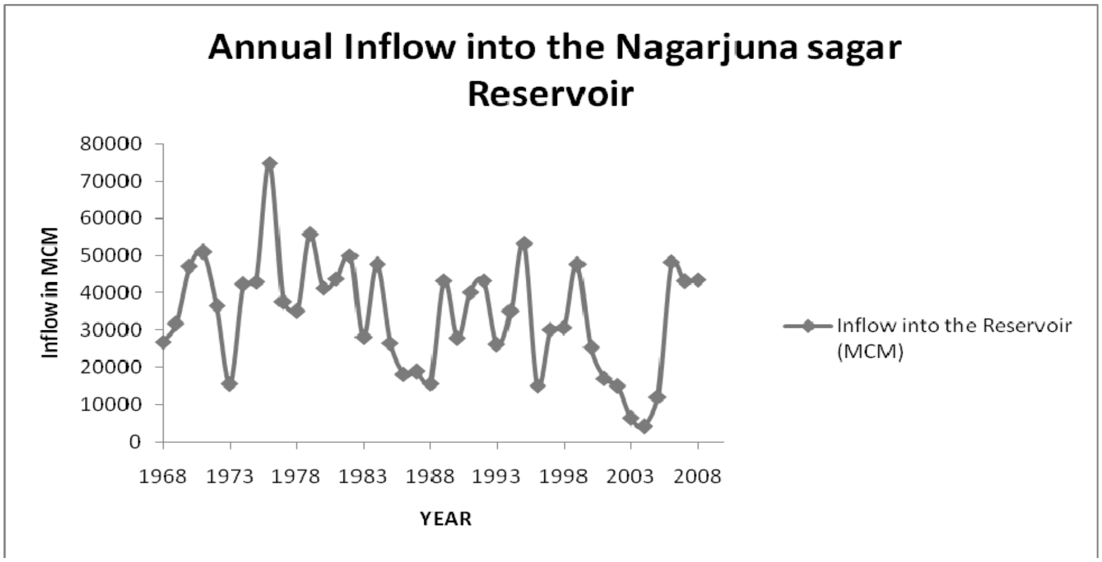

Fig. 3 Annual inflows into the reservoir

Table 1 Monthly demands from reservoir

(All units are in MCM)				
Month	**NSLC Irrigation Demand**	**NSRC Irrigation Demand**	**D/S Power Demand**	**Total Demand**
JUNE	0	0	358.816	358.816
JULY	767.240	707.800	875.994	2351.034
AUGUST	384.200	945.800	1202.679	2532.679
SEPTEMBER	752.300	1355.000	1231.418	3338.718
OCTOBER	572.000	633.800	1075.692	2281.492
NOVEMBER	704.300	709.100	611.866	2025.266
DECEMBER	825.800	895.400	490.470	2211.670
JANUARY	654.700	682.900	496.522	1834.122
FEBRUARY	38.100	271.300	503.348	812.748
MARCH	0.000	0	643.064	643.064
APRIL	0.000	0	490.488	490.488
MAY	0	0	307.874	307.874

Table 2 Statistical analysis of the historical inflows (All units are in MCM)

Month	Average Inflow	Inflow with 75% PE	Inflow with 80 % PE	Inflow with 85 % PE	Inflow with 90 % PE
JUNE	739.67	156.84	150.87	120.15	86.17
JULY	4614.15	1175	652.15	500.25	0
AUGUST	10059.52	3201.52	2860.7	2500.15	1910.5
SEPTEMBER	6919.30	2458.61	2364.5	1720.15	1400
OCTOBER	5854.16	2255.04	2109.86	1750.54	1501.3

Contd…

Month	Average Inflow	Inflow with 75% PE	Inflow with 80 % PE	Inflow with 85 % PE	Inflow with 90 % PE
NOVEMBER	1571.76	888.36	758.8	732.12	580.12
DECEMBER	896.31	614.5	452.7	364.15	314.25
JANUARY	766.79	394.58	348.67	305.55	257.26
FEBRUARY	777.77	292.16	267.44	254.15	214.27
MARCH	773.21	217	201.8	182.56	165.24
APRIL	469.09	174.1	158.4	152.15	120.25
MAY	259.41	88.11	75.37	45.26	18.8

Table 3 Basic data of crops grown under NSRC and NSLC

Crops (Season)	Date of sowing	Crop Coefficients Kc			Area (ha)	Duration of growth stages in fortnights and yield response factors K_y				
		Initial	Mid	End		Initial	Crop Develo p-ment	Flower -ing	Grain formati on	Ripen -ing
NSRC										
Rice1 (K)	16 July	1.050	1.175	0.902	50000	1, 1.07	2, 1.07	1, 2.15	2, 2.15	1, 0.33
Rice2 (K)	1 August	1.050	1.175	0.902	50000	1,1.07	2,1.07	1,2.15	2,2.15	1,0.33
Groundnut K)	1 July	0.831	1.137	0.562	40000	2, 0.20	1, 0.20	1, 0.80	2, 0.60	2, 0.20
Sorghum (K)	16 July	0.835	0.958	0.489	70000	1, 0.20	2, 0.20	1, 0.55	2, 0.45	1, 0.20
Grams (K)	16 July	0.835	1.016	0.559	100000	1, 0.05	2, 0.05	1, 0.40	2, 0.35	1, 0.20
Cotton	16 July	0.814	1.105	0.702	100000	2, 0.20	2, 0.20	3, 0.50	3, 0.50	3, 0.25
Chilli	16 August	0.863	0.967	0.708	40000	2, 0.40	3, 0.40	2, 0.80	2, 0.80	1, 0.40
Groundnut (R)	1 November	0.761	1.152	0.623	40000	2, 0.20	1, 0.20	1, 0.80	2, 0.60	2, 0.20
Sorghum (R)	1 November	0.761	1.002	0.582	15000	1, 0.20	2, 0.20	1, 0.55	2, 0.45	1, 0.20
Grams (R)	1 November	0.761	1.056	0.625	60000	1, 0.05	2, 0.05	1, 0.40	2, 0.35	1, 0.20
NSLC										
Rice1 (K)	1 July	1.050	1.175	0.902	100000	1, 1.07	2, 1.07	1, 2.15	2, 2.15	1, 0.33
Rice2(K)	1Aug	1.050	1.175	0.902	100000	1,1.07	2,1.07	1,2.15	2,2.15	1,0.33
Cotton	16 July	1.010	1.085	0.690	10000	2, 0.20	2, 0.20	3, 0.50	3, 0.50	3, 0.25
Chilli	16 August	0.971	0.960	0.697	10000	2, 0.40	3, 0.40	2, 0.80	2, 0.80	1, 0.40
Groundnut (R)	16 October	0.884	1.133	0.608	40000	2, 0.20	1, 0.20	1, 0.80	2, 0.60	2, 0.20
Sorghum (R)	16 October	0.884	0.975	0.551	80000	1, 0.20	2, 0.20	1, 0.55	2, 0.45	1, 0.20
Grams (R)	16 October	0.884	1.038	0.601	75000	1, 0.05	2, 0.05	1, 0.40	2, 0.35	1, 0.20

Table 4 Reference evapotranspiration, rainfall and reservoir rate of evaporation

Month	IMD Station Khammam		IMD Station Rentachintala		Rate of Evaporation (mm/day)
	ETo (mm/day)	Monthly Rainfall (mm)	ETo (mm/day)	Monthly Rainfall (mm)	
January	3.890	1.6	4.00	0.4	3.0
February	5.142	7.3	4.72	9.3	3.0
March	6.510	10.5	5.62	6.1	5.8
April	6.934	25.5	6.16	9.6	7.6
May	7.472	27.1	6.44	40.8	8.0
June	6.031	126.5	5.67	86.2	6.0
July	4.016	260.1	4.92	115.3	4.8
August	3.881	185.5	4.64	114.6	4.8
September	3.863	164.5	4.34	146.1	4.8
October	3.699	107.1	4.11	123.8	4.2
November	3.547	33.8	3.81	41.1	3.3
December	3.846	3.9	3.70	13.3	3.3

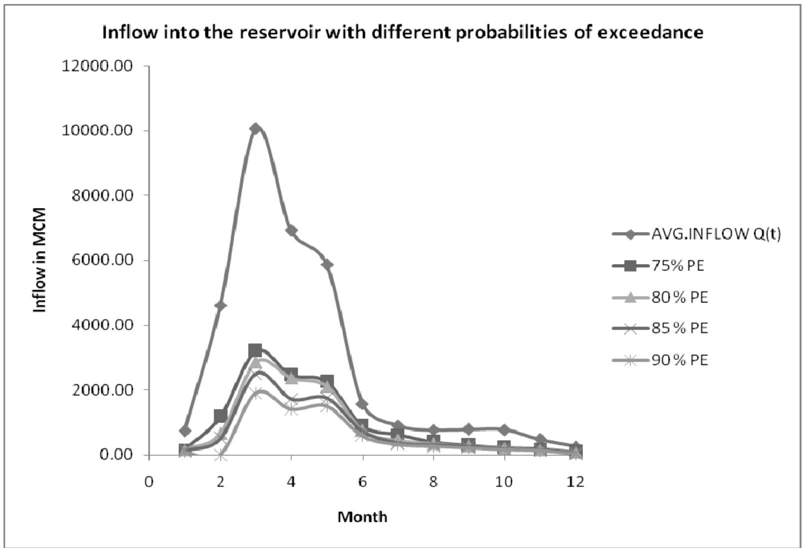

Fig. 5 Monthly demand and optimal releases from GA model.

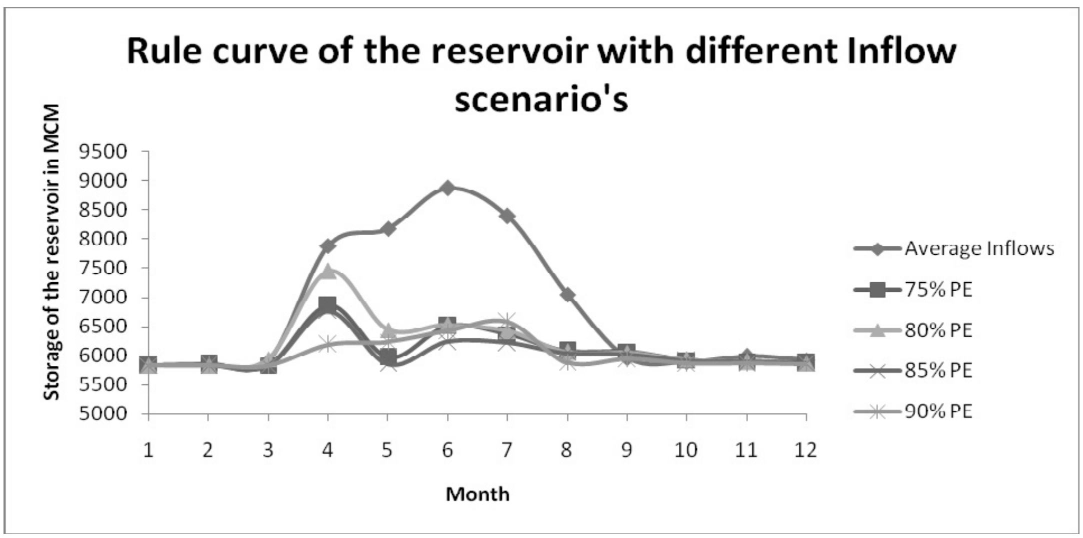

Fig. 6 Rule curve of the Nagarjuna Sagar Reservoir with different inflow scenario's.

CONCLUSIONS

The GA approach is applied to Nagarjuna sagar reservoir system to derive operating policies for the multipurpose reservoir systems with single objective. The sensitivity analysis of GA model applied to this particular reservoir suggests optimal size of population to be used 500 and probability of crossover of 0.75, to find optimal releases for Nagarjuna sagar reservoir. The model releases for different inflow scenarios are presented. Minimum storages are observed in start of monsoon i.e. at the end of water year and maximum storage is observed when the monsoon reaches to its peak. These types of rule curves are expected to be useful in real life implementation of reservoir operation.

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Optimal Steady-State Reservoir Operating Policy by Stochastic Dynamic Programming

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ABSTRACT

Reservoir releases are to be made to meet the demands of all time periods in a year. When the annual available water is not sufficient to meet the annual demands, releases are to be made less than the demands. Amount of river inflow entering into the reservoir is also uncertain and depends on rainfall which is again a random event that cannot be predicted accurately. Optimal release decisions are to be made sequentially for all time periods with uncertain inflows to achieve the objective considering the available limited water and the annual demands. In the present study, an optimal steady-state fortnight reservoir operation model has been developed by Stochastic Dynamic Programming minimizing sum of squared deviations of releases from the corresponding targets. Reservoir storage and inflow into reservoir are considered as state variables of SDP. The model developed is applied to a case study of Nagarjuna Sager Reservoir Project. Fortnight optimal operating policy is obtained for all combinations of 77 storage states and 10 inflow states. Reservoir Releases in each fortnight are obtained by running a simulation model for forty years with the both optimal operating policy derived in the present study and also with standard operating policy. By comparing the releases, it is found that performance of reservoir with optimal operating policy is better than that of with standard operating policy.

INTRODUCTION

Development of agriculture plays a vital role for development of any country like India where most of the population depends on agriculture directly or indirectly. Reservoir operation forms a very important part of planning and management of water resources system. Once a reservoir has been developed, detailed guidelines have to be given to the operator to enable him to take decisions about storing or releasing water. In dry years, when the inflows into the reservoir are low, the reservoir manager has to take a wise release decision for the current period based on current storage state of reservoir, expected inflows and demands of the remaining time periods of the year. It is difficult to take a decision for a reservoir manager under limited water supply unless a reservoir operational policy is provided with him.

Under limited water supply, when deficits are inevitable, these deficits are to be distributed among intra-seasonal periods of a year optimally. Many optimization techniques are being applied in water resources systems analysis and description of these techniques are available in literature (Loucks et.al., 1981). Amount of river inflow entering into the reservoir is uncertain and depends on rainfall which is again a random event that cannot be predicted accurately. Reservoir inflow is treated as stochastic process and is assumed to follow a Markov Chain (Vedula and Mujumdar, 2005). Many researchers developed optimal reservoir operating policies for irrigation in multi-crop environment by stochastic dynamic programming (Vedula and Mujumdar, 1992; Umamahesh and Srinivasulu, 1997).

Best release decisions are to be made sequentially for all time periods with uncertain inflows to achieve the objective considering the available limited water and the annual demands. In case of an irrigation reservoir, the objective may be maximization of crop yield, net benefit from crops, total annual releases or minimization of deficits & spills. Optimal reservoir operation is nothing but obtaining optimal release decisions from the set of feasible decisions in such a way that these release decisions optimize the proposed objective of operation. In the present study, a stochastic dynamic programming model is formulated and applied to a case study of Nagarjuna Sagar Reservoir Project arriving an optimal steady-state reservoir operating policy.

MODEL FORMULATION

The objective of the reservoir operation model is to minimize the annual water supply deficit function. This function is defined as the sum of the squares of the deviations of reservoir release from the corresponding target release for all time intervals of the year. A stochastic dynamic programming (SDP) model is formulated to determine the optimal operation policy of an irrigation reservoir under multi-crop environment. One year is taken as the operating horizon which is especially relevant in monsoon climates where the annual periodicity of reservoir inflows is well pronounced. Optimal release decisions are obtained taking fortnight as intra-seasonal period.

Formulation of Reservoir Operation Model

The optimal releases from the reservoir are related to two state variables, namely the storage state of the reservoir at the beginning of the time period and the expected inflow into the reservoir in time period. Each state variable is discretised into several class intervals. Any value within the range of the class interval can be represented by a single value. Let i, j and k, l represent class intervals of inflows and reservoir storages at the beginning of time periods t and t+1, respectively.

The objective function is given by,

$$\text{Minimize} \sum_{t=1}^{T} \left\{ \left(LT_t - LR_t\right)^2 + \left(RT_t - RR_t\right)^2 + \left(DT_t - DR_t\right)^2 \right\} \tag{1}$$

Where RT_t, LTt are targets and RR_t, LR_t are releases into right and left main canals of reservoir. DT_t and DR_t are the downstream target and release from the reservoir respectively. The solution of the model is obtained by backward recursion, which is initiated from the last time period T. i.e., last fortnight of the year.

Let $f_t^n\left(S_{k,t}, Q_{i,t}\right)$ represent optimum expected value of the objective function. The general recursive equation of the stochastic dynamic programming model can be written as

When t = T-1 to 1,

$$f_t^n\left(S_{k,t}, Q_{i,t}\right) = \text{Min}\left\{ \left(LT_t - LR_{k,i,l,t}\right)^2 + \left(RT_t - RR_{k,i,l,t}\right)^2 + \left(DT_t - DR_{k,i,l,t}\right)^2 + \sum_j P_{i,j}^t f_{t+1}^{n-1}\left(S_{l,t+1}, Q_{j,t+1}\right) \right\}$$

$$\forall\, k,i \tag{2}$$

When t = T,

$$f_T^1\left(S_{k,T}, Q_{i,T}\right) = Min\left\{ \left(LT_T - LR_{k,i,l,T}\right)^2 + \left(RT_T - RR_{k,i,l,T}\right)^2 + \left(DT_T - DR_{k,i,l,T}\right)^2 \right\} \forall\, k, I \tag{3}$$

Where $P_{i,j}^t$ is the transition probability defined as the probability that the inflow in period t+1 is in state j, given that the inflow in period t is in state i.

The reservoir releases $RR_{k,i,l,t}$ and $LR_{k,i,l,t}$ are subject to the following constraints in all time periods, t = 1 to T

(i) The reservoir water balance

Given the initial storage volume $S_{k,t}$, the inflow $Q_{i,t}$, downstream release $DR_{k,i,l,t}$, final storage is determined by the continuity equation.

$$S_{l,t+1} = S_{k,t} + Q_{i,t} - DR_{k,i,l,t} - EVP_{k,i,t} - LR_{k,i,l,t} - RR_{k,i,l,t} \tag{4}$$

(ii) The storage limits of the reservoir S_{max} and S_{min}

$$S_{k,t} + Q_{i,t} - EVP_{k,i,t} - S_{max} < \left(LR_{k,i,l,t} + RR_{k,i,l,t} + DR_{k,i,l,t}\right) < S_{k,t} + Q_{i,t} - EVP_{k,i,t} - S_{min} \tag{5}$$

(iii) Dead storage requirement of reservoir

$$\text{if } S_{k,t} + Q_{i,t} - EVP_{k,i,t} < S_{min,}$$

$$LR_{k,I,l,t} = RR_{k,I,l,t} = DR_{k,i,l,t} = 0 \quad (6)$$

(iv) Release decisions must be less than target releases

$$LR_{k,i,l,t} \leq LT_t \quad (7)$$

$$RR_{k,i,l,t} \leq RT_t \quad (8)$$

$$DR_{k,i,l,t} \leq DT_t \quad (9)$$

The objective function is minimized by backward recursion subjected to the above constraints.

Study Area

The study area considered in the present study to demonstrate the proposed model is the Nagarjuna Sagar Reservoir on the river Krishna in Andhra Pradesh, India (Fig.1). The irrigation project comprises of 124.66 m height masonry dam with two canals taking off from the reservoir on either side. The reservoir is located at latitude 16^0 – 34' N and longitude 79^0 – 19' E. The maximum and minimum water spread area corresponding to Full Reservoir Level (FRL) and Minimum Draw Down Level (MDDL) are 295 Km^2 and 186 Km^2 respectively. This project also stabilizes irrigation under Krishna delta system through d/s releases. The study area is characterized by two distinct seasons: Kharif (rainy) and Rabi (dry). The Kharif season is from July to October and Rabi season is from November to February. The major crops grown are rice, groundnut, sorghum and grams in the Kharif season and groundnut, sorghum and grams in the Rabi season, as well as chilly and cotton as two seasonal crops. Date of sowing and duration of growth stages of crops grown under left canal and right canal are shown in Table 1.

Rainfall data to compute fortnight irrigation requirement is obtained from nearby weather stations Khammam and Rentachintala for crops grown under NSLC and NSRC command areas respectively. Table.2 shows rainfall data, rate of reference evapotranspiration and rate of evaporation from reservoir. Forty years of fortnightly historical inflow data entering into the Nagarjuna Sagar Reservoir is adopted in generating synthetic flows.

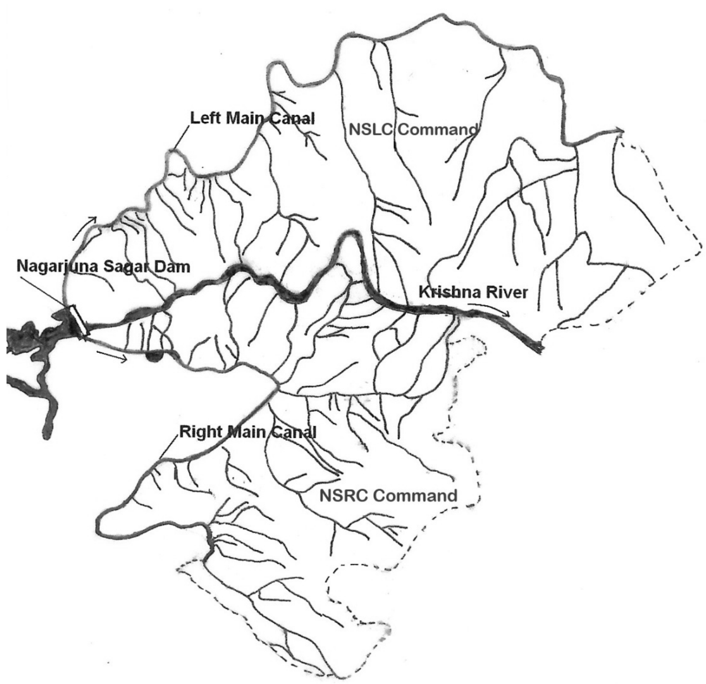


Fig. 1 Schematic Representation of Nagarjuna Sagar Project

Table 1 Basic Data of Crops Grown under NSRC and NSLC

Crop (Season)	Date of sowing	Crop Coefficients Kc			Area (ha)	Duration of growth stages in fortnights and yield response factors K_y				
		Initial	Mid	End		Initial	Crop Develop-ment	Flowering	Grain Form-ation	Ripeni ng
NSRC										
Rice1 (K)	16 July	1.050	1.175	0.902	50000	1, 1.07	2, 1.07	1, 2.15	2, 2.15	1, 0.33
Rice2 (K)	1 August	1.050	1.175	0.902	50000	1,1.07	2,1.07	1,2.15	2,2.15	1,0.33
Groundnut(K)	1 July	0.831	1.137	0.562	40000	2, 0.20	1, 0.20	1, 0.80	2, 0.60	2, 0.20
Sorghum (K)	16 July	0.835	0.958	0.489	70000	1, 0.20	2, 0.20	1, 0.55	2, 0.45	1, 0.20
Grams (K)	16 July	0.835	1.016	0.559	100000	1, 0.05	2, 0.05	1, 0.40	2, 0.35	1, 0.20
Cotton	16 July	0.814	1.105	0.702	100000	2, 0.20	2, 0.20	3, 0.50	3, 0.50	3, 0.25
Chilli	16 August	0.863	0.967	0.708	40000	2, 0.40	3, 0.40	2, 0.80	2, 0.80	1, 0.40
Groundnut (R)	1 November	0.761	1.152	0.623	40000	2, 0.20	1, 0.20	1, 0.80	2, 0.60	2, 0.20
Sorghum (R)	1 November	0.761	1.002	0.582	15000	1, 0.20	2, 0.20	1, 0.55	2, 0.45	1, 0.20
Grams (R)	1 November	0.761	1.056	0.625	60000	1, 0.05	2, 0.05	1, 0.40	2, 0.35	1, 0.20
NSLC										
Rice1 (K)	1 July	1.050	1.175	0.902	100000	1, 1.07	2, 1.07	1, 2.15	2, 2.15	1, 0.33
Rice2(K)	1Aug	1.050	1.175	0.902	100000	1,1.07	2,1.07	1,2.15	2,2.15	1,0.33
Cotton	16 July	1.010	1.085	0.690	10000	2, 0.20	2, 0.20	3, 0.50	3, 0.50	3, 0.25
Chilli	16 August	0.971	0.960	0.697	10000	2, 0.40	3, 0.40	2, 0.80	2, 0.80	1, 0.40
Groundnut (R)	16 October	0.884	1.133	0.608	40000	2, 0.20	1, 0.20	1, 0.80	2, 0.60	2, 0.20
Sorghum (R)	16 October	0.884	0.975	0.551	80000	1, 0.20	2, 0.20	1, 0.55	2, 0.45	1, 0.20
Grams (R)	16 October	0.884	1.038	0.601	75000	1, 0.05	2, 0.05	1, 0.40	2, 0.35	1, 0.20

Table 2 Reference Evapotranspiration, Rainfall and Reservoir Rate of Evaporation

Month	IMD Station Khammam		IMD Station Rentachintala		Rate of Evaporation (mm/day)
	ETo (mm/day)	Monthly Rainfall (mm)	ETo (mm/day)	Monthly Rainfall (mm)	
January	3.890	1.6	4.00	0.4	3.0
February	5.142	7.3	4.72	9.3	3.0
March	6.510	10.5	5.62	6.1	5.8
April	6.934	25.5	6.16	9.6	7.6
May	7.472	27.1	6.44	40.8	8.0
June	6.031	126.5	5.67	86.2	6.0
July	4.016	260.1	4.92	115.3	4.8
August	3.881	185.5	4.64	114.6	4.8
September	3.863	164.5	4.34	146.1	4.8
October	3.699	107.1	4.11	123.8	4.2
November	3.547	33.8	3.81	41.1	3.3
December	3.846	3.9	3.70	13.3	3.3

RESULTS AND DISCUSSION

Estimation of Target Releases

Crop coefficients of all crops grown under NSRP and NSLP are calculated as per the guidelines given in FAO Irrigation and Drainage paper 56 (Allen et. al., 1998). Fortnight evapotranspiration is calculated by multiplying crop coefficient (K_c) with reference evapotranspiration ETo of the corresponding fortnight. Net irrigation requirement is obtained by deducting effective rainfall from the evapotranspiration. Gross Irrigation requirement of each crop in mcm for each time period at head works is determined considering irrigation efficiency. Irrigation efficiency is 56% in Kharif season and 42% in Rabi season.

$$ETM = K_c \, ETo \tag{10}$$

Where K_c = Crop coefficient and ETo = fortnight reference evapotranspiration in mm

$$NIR = ETM - R_e \tag{11}$$

Where NIR is fortnight net irrigation requirement in mm.

$$GIR = \frac{NIR \times A \times 10^{-5}}{\eta} \tag{12}$$

Where A is the area occupied by crop in hectares and η is the efficiency of irrigation. Aggregate reservoir release target for each fortnight is obtained by summing the gross irrigation requirement of all crops existing in that particular fortnight. Downstream target releases are considered to be releases corresponding to 75% probability of exceedence. Table 3. shows the fortnight target releases for right canal, left canal and d/s of reservoir.

Table 3 Target Releases (MCM) of Nagarjuna Sagar Reservoir

Sl. No.	Fortnight	NSRC	NSLC	D/S
1	JUN-II	0.00	0.00	125.41
2	JUL-I	175.67	193.68	215.72
3	JUL-II	351.15	193.68	156.27
4	AUG-I	231.89	3.35	122.02
5	AUG-II	282.06	10.96	152.02
6	SEP-I	173.11	50.88	109.28
7	SEP-II	184.82	55.44	157.12
8	OCT-I	222.95	134.07	60.30
9	OCT-II	163.08	203.42	50.67
10	NOV-I	312.54	305.14	21.80
11	NOV-II	249.88	242.64	79.27
12	DEC-I	301.96	298.57	110.98
13	DEC-II	306.26	297.89	110.13
14	JAN-I	311.61	298.57	114.37
15	JAN-II	260.83	234.56	121.17
16	FEB-I	174.08	54.65	144.10
17	FEB-II	51.10	0.00	163.35
18	MAR-I	0.00	0.00	131.36
19	MAR-II	0.00	0.00	104.46
20	APR-I	0.00	0.00	28.31
21	APR-II	0.00	0.00	0.28
22	MAY-I	0.00	0.00	125.98
23	MAY-II	0.00	0.00	204.12
24	JUN-I	0.00	0.00	324.72

Transition Probability Matrix

Considering the range of inflows for each fortnight from the historical data, the inflows are classified into ten classes. Fortnightly synthetic flows are generated for 600 years using the historical time series of 40 years. Probablility of transition from i^{th} state of inflow of t^{th} period to j^{th} state of inflow of $(t+1)^{th}$ period $P^t_{i,j}$ is prepared for each fortnight.

Reservoir Operation Model

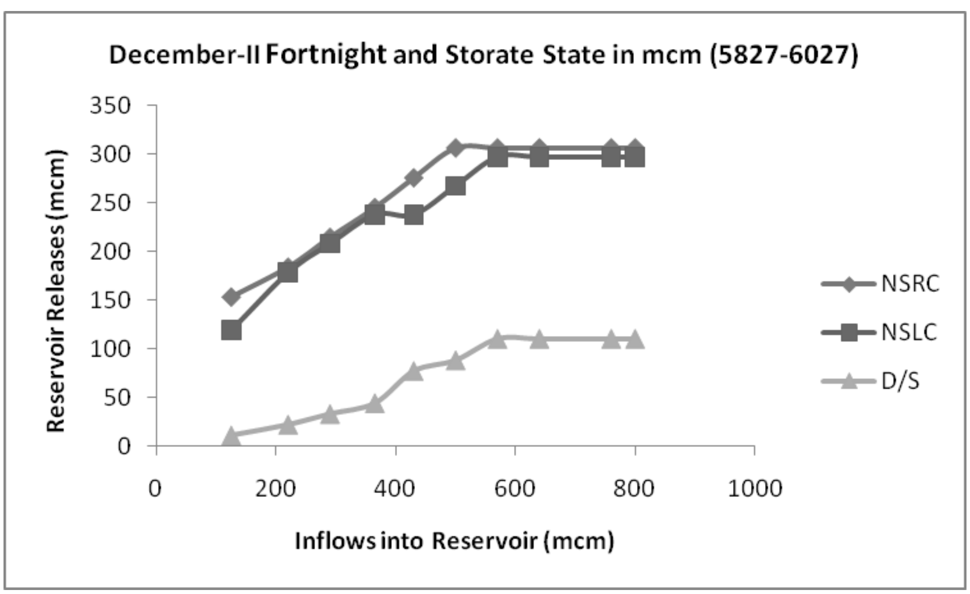
The reservoir operation model defines the releases to be made into left canal and right canal as well as release into d/s of the river. Maximum release is restricted to the target releases. Stochastic dynamic programming is used to obtain the reservoir release policy for any given state of reservoir storage at the beginning of the current fortnight and expected state of inflow into the reservoir in the current time period, minimizing the deficit function. In Stochastic dynamic programming of reservoir operation model, 77 discrete storage states starting from minimum storage of 5827 MCM to maximum storage of 11560 MCM are considered and 11 release decisions are considered starting from 0% to 100% of targets with an increment of 10%. Reservoir evaporation during the current period is estimated as a function of storage at the beginning of the current fortnight and rate of evaporation of that fortnight.

$$EVP(t, k) = \{ A_0 + a [s(k) - s_{min}]\} \text{ x } e(t) \text{ x delta x} 10^{-3} \quad (13)$$

Where EVP is evaporation in the given time period‘t’ in MCM when the storage state is s(k) ; A_0 is the water spread area of reservoir in million sq.km corresponding to storage S_{min} ; a is change in area of reservoir per unit change in storage in excess of S_{min}; delta is number of days in the time period and e(t) is daily rate of evaporation in time period (mm/day).

The model formulated is applied to Nagarjuna Sagar Reservoir and optimal operating policy for finding the releases into NSLC, NSRC and d/s of reservoir for various states of reservoir storage and expected inflow into the reservoir is obtained. A total number of 24x77x10 release decisions for all possible states of storages (77) and expected inflow states (10) for all fortnights (24) of a year are obtained. A typical optimal operating policy obtained for time periods 13 and 15 are shown in Fig.1. and Fig.2. respectively. From the figures, it is observed that releases from reservoir are less than the targets for initial states of storages and initial states of inflows as available water for release is less. For higher storage states and inflow states, releases are equal to the target releases.

A simulation model for reservoir operation is formulated to simulate the reservoir storages, releases, spills and evaporation using optimal operating policy and standard operating policy. The model is run for 38 years of historical inflow data into the reservoir assuming constant cropping pattern and demands and sum of square of deviations of releases from their respective targets are obtained as a measure of performance. Table 4(a) and Table 4(b) shows the simulation results obtained for optimal and standard operating policies respectively for the year 36. Simulation results show that sum of square of deviations of targets from the releases is more in case of standard operating policy when compared to optimal operating policy. From these results it can be concluded that optimal operating policy performs better than standard operating policy and found to be more significant especially at times of water scarcity.



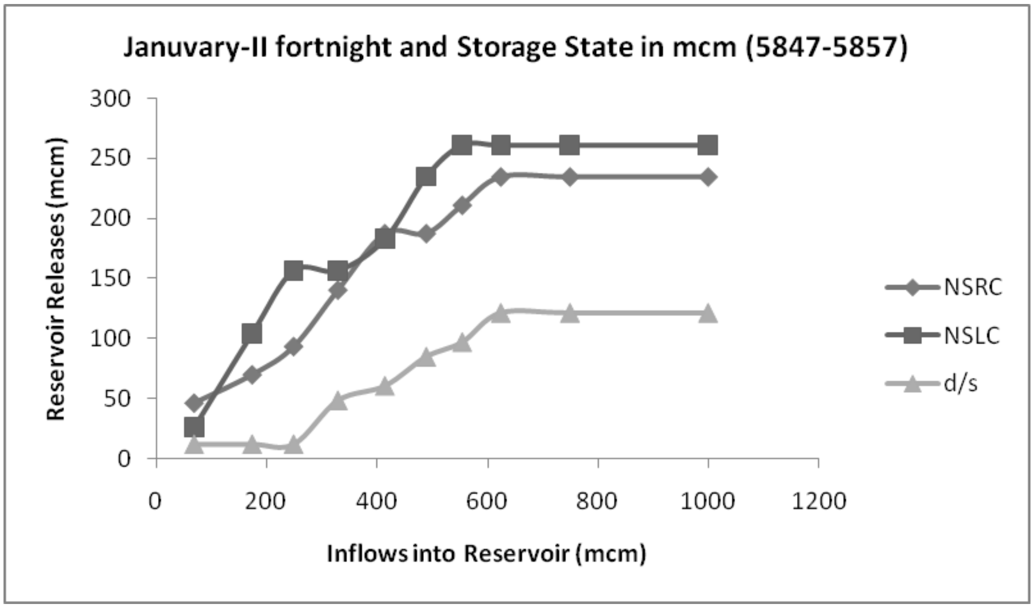


Table 4(a) Simulation results for the year 36 by optimal operating policy

Time	STB	INFLOW	NSRP	NSLP	D/S	EVP	SPILL
1	7793.9	0.0	0.0	0.0	125.4	18.6	0.0
2	7649.9	0.0	175.7	193.7	215.7	14.3	0.0
3	7050.5	0.0	351.2	193.7	156.3	13.4	0.0
4	6336.0	21.0	231.9	3.4	122.0	12.7	0.0
5	5987.1	11.3	282.1	11.0	152.0	12.1	0.0
6	5541.2	174.4	173.1	50.9	109.3	11.7	0.0
7	5370.6	205.9	184.8	55.4	157.1	11.5	0.0
8	5167.6	281.2	178.4	93.8	18.1	9.9	0.0
9	5148.6	10.8	114.2	122.1	0.0	9.8	0.0
10	4913.4	345.7	250.0	213.6	21.8	7.5	0.0
11	4766.2	732.3	249.9	242.6	79.3	7.5	0.0
12	4919.2	672.2	302.0	298.6	88.8	7.6	0.0
13	4894.5	356.2	183.8	148.9	22.0	7.5	0.0
14	4888.5	137.9	93.5	59.7	11.4	6.9	0.0
15	4854.9	131.7	78.2	93.8	0.0	6.8	0.0
16	4807.7	191.4	87.0	10.9	57.6	6.8	0.0
17	4836.7	331.9	51.1	0.0	163.3	6.9	0.0
18	4947.3	0.0	0.0	0.0	0.0	13.3	0.0
19	4933.9	22.1	0.0	0.0	0.0	13.3	0.0
20	4942.7	509.4	0.0	0.0	8.3	18.0	0.0
21	5405.8	23.5	0.0	0.0	0.3	18.5	0.0
22	5410.6	70.5	0.0	0.0	50.4	19.5	0.0
23	5411.2	17.6	0.0	0.0	0.0	19.5	0.0
24	5409.4	0.0	0.0	0.0	0.0	14.6	0.0

sum of square of deviations of releases from targets = 455703.69

Table 4(b) Simulation results for the year 36 by Standard operating policy

Time	STB	INFLOW	NSRP	NSLP	D/S	EVP	SPILL
1	7793.9	0.0	0.0	0.0	125.4	18.6	0.0
2	7649.9	0.0	175.7	193.7	215.7	14.3	0.0
3	7050.5	0.0	351.2	193.7	156.3	13.4	0.0
4	6336.0	21.0	231.9	3.4	122.0	12.7	0.0
5	5987.1	11.3	10 0.7	3.9	54.3	12.3	0.0
6	5827.1	174.4	84.3	24.8	53.2	12.2	0.0
7	5827.0	205.9	90.1	27.0	76.6	12.2	0.0
8	5827.0	281.2	144.5	86.9	39.1	10.7	0.0
9	5827.0	10.8	0.0	0.0	0.0	10.7	0.0
10	5827.0	345.7	164.8	160.9	11.5	8.4	0.0
11	5827.0	732.3	249.9	242.6	79.3	8.5	0.0
12	5979.0	672.2	302.0	298.6	111.0	8.5	0.0
13	5931.2	356.2	193.8	188.5	69.7	8.5	0.0
14	5827.0	137.9	56.0	53.7	20.6	7.6	0.0
15	5827.0	131.7	52.5	47.2	24.4	7.6	0.0
16	5827.0	191.4	85.8	26.9	71.0	7.6	0.0
17	5827.0	331.9	51.1	0.0	163.3	7.6	0.0
18	5936.8	0.0	0.0	0.0	94.9	15.0	0.0
19	5827.0	22.1	0.0	0.0	7.3	14.8	0.0
20	5827.0	509.4	0.0	0.0	28.3	19.9	0.0
21	6288.2	23.5	0.0	0.0	0.3	20.3	0.0
22	6291.1	70.5	0.0	0.0	126.0	21.4	0.0
23	6214.2	17.6	0.0	0.0	204.1	21.0	0.0
24	6006.7	0.0	0.0	0.0	164.1	15.4	0.0

sum of square of deviations of releases from targets = 491247.94

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Reservoir Siltation Studies on Tungabhadra Project in Krishna Basin

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ABSTRACT

The Tungabhadra Project, a multipurpose river valley project on the interstate river Tungabhadra is the life line of both states of undivided Andhra Pradesh and Karnataka. The project was constructed in 1953 with a storage capacity of 133 TMcft to provide irrigation water to 3.5 Lakh hectares in Karnataka and 1.46 Lakh hectares in undivided Andhra Pradesh. The project has a catchment area of 28,180 Sq Km spread in Tungabhadra Upper sub basin of Krishna River basin. The siltation of the reservoir started from the beginning of impounding of water in the year 1953 and of late the issue has drawn the attention of all the stake holders as the cost of removing the silt is equal to the cost of construction of another reservoir of original capacity. Because of loss in storage capacity due to siltation both the states of Karnataka and undivided Andhra Pradesh are not able to utilize the allocated water of 230 TMcft as per **KWDT** (Krishna Water Disputes Tribunal) from the project even though inflows are much more than 230 Tmcft for most of the years. The present paper presents the means and methodology to estimate the sediment yield from the catchment area, the rate of silting and pattern of silting in the reservoir. The study is carried out as a collaborative work with the field engineers of Tungabhadra Project and proves to be a theoretical insight to propose remedial measures for the siltation of the Project. The estimated siltation parameters compare well with the actuals.

Keywords: Tungabhadra Project, siltation, storage capacity, catchment area, rate of silting.

INTRODUCTION

The water resources development in all major river basins of India has been taken up to meet the growing demand for water for various needs of populace. The projects constructed ranged from major facilities to minor facilities on main rivers and tributaries. Some of them were taken up as interstate river valley projects. The issue of reservoir siltation has become quite alarming as the intended objectives of water resources projects are at stake due to decrease in storing capacity of reservoirs due to siltation. The challenge before the engineers and researches is to find innovative solutions to fix the issue. The siltation is the problem common to all the projects, but the solutions are specific to individual cases.

The Tungabhadra project is an interstate multipurpose river valley project of Karnataka and erstwhile combined Andhra Pradesh. The project is in Krishna basin which consists of seven sub basins and the catchment area of the project lies in Tungabhadra Upper sub basin. There are 45 delineated and classified watersheds in the sub basin named as C04TUU01 to C04TUU45, where C stands for water resource region, 04 represents basin code, TUU stands for Tungabhadra Upper sub basin and 01-45 represent watershed no's. (www.india-wris.nrsc.gov.in) The objective of this research paper is to estimate the rate of siltation of Tungabhadra project and sediment yield from the catchment based on the data of nine hydrographic surveys conducted by Tungabhadra Board from 1953 to 2008.

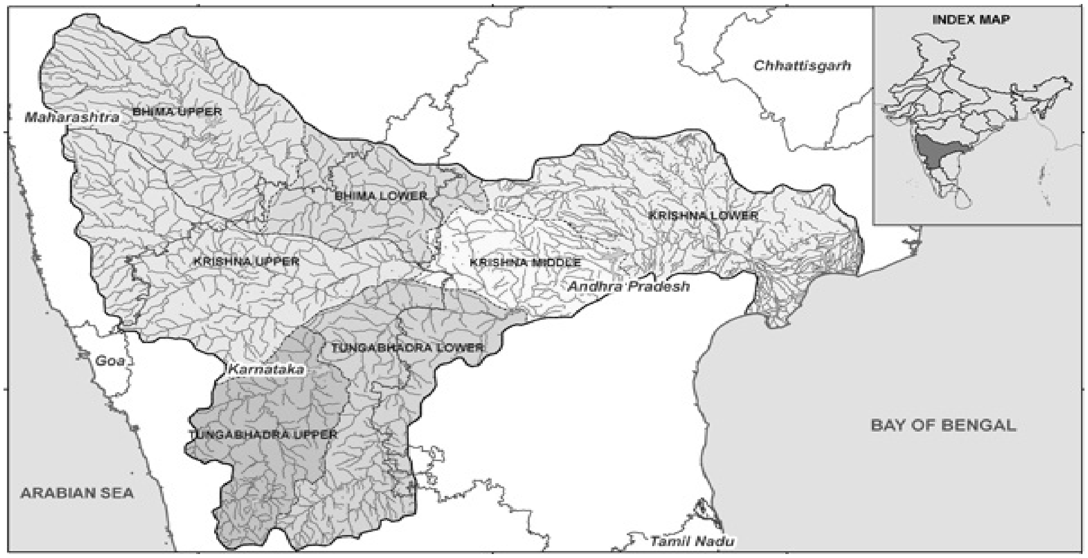

Fig 1 The Krishna river basin with seven sub basins

LITERATURE SURVEY

The research on reservoir siltation has been taking place based on the need to find solutions for the problems of reservoir siltation. The new knowledge and refinement to existing knowledge on reservoir siltation have been reported widely in reputed national and international journals. Though the cases of total loss of storage are not reported, many cases with a loss of around 30% storage capacity due to siltation are well reported (Umesh C. Kothyari 1996). The estimation of rate of siltation using universal soil loss equation, GIS and Remote Sensing is reported for many basins in India (Manoj K Jani & Kothyari 1987). The preventive measures and curative procedures for erosion and reservoir siltation are also reported in general and specific to some projects (H. Mahabaleshwara and H.M Nagabhushan 2014).

Tungabhadra Project

The Tungabhadra project was constructed at Longitude 76º 20’ 10” E and Latitude 15º 15’ 19” N, on the river Tungabhadra at Mallapuram village in Hospet Taluk of Bellary District in Karnataka. Tungabhadra has got its name from two tributaries Tunga and Bhadra which join together to form Tungabhadra river. The two tributaries originate from western ghats and flow towards east. The Tungabhadra river travels 382 Km in Karnataka, forms boundary between Kanrnataka and Andhra Pradesh for 58 Km and finally runs for 91 Km in Andhra Pradesh before joining Krishna River. The project comprises of 1040 m long masonry dam, 546.8 m long composite dam and 152.4 m long earth dam. The project is managed and maintained by Tungabhadra Board. The Krishna Water Disputes Tribunal (KWDT) has awarded allocation of 151.49 Tmct to Karnataka and 78.51 Tmcft to Andhra Pradesh, totaling 230 Tmcft.

The Data collection

The required and relevant data for the present study is collected from Tungabhadra Board, www.india-wris.nrsc.gov.in and other sources to carry out reservoir siltation studies. The inflow data from 1978 to 2008 and Details of Hydrographic Surveys are presented in Table 1 and Table 2.

Table 1 Yearly inflows of tungabhadra reservoir

Year	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**
Inflow	275.41	558.78	291.34	553.10	362.65	369.48	316.25	303.18	217.27	244.06	163.48	252.43	224.06	316.04	372.08	521.61
Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	
Inflow	309.87	540.60	180.91	211.52	339.82	323.18	328.88	322.18	160.08	126.74	117.10	171.15	316.79	296.27	476.02	

Table 2 Details of hydrographic survey on reservoir capacity

Year	1953	1972	1978	1981	1985	1993	2004	2008
Capacity (TMcft)	132.473	121.08	117.695	115.68	111.832	111.5	104.34	100.855

METHODOLOGY

The gross sediment production is the quantity of sediment produced in the catchment area of a basin expressed in Tons/Sqkm/Year. The sediment yield refers to the quantity of sediment reaching a particular point in the stream in the basin. The sediment delivery ratio is the ratio of sediment yield and sediment produced. The trap efficiency of a reservoir refers to the ability of the storage facility to trap the sediment from the incoming sediment carried by the flowing water. The trap efficiency is mainly a function of capacity inflow ratio and the sediment characteristics. The trap efficiency of Tungabhadra reservoir is estimated using the formula $\gamma = 100\left(1 - \frac{1}{1+100X}\right)^{1.5}$ where X is the capacity inflow ratio. The year wise sediment yields at Tungabhadra project are calculated in Table 3 by assuming a specific weight of sediment as 12 KN/m^3 and by taking catchment area as 28180 SqKm.

Table 3 Analysis for determination of reservoir siltation of tungabhadra project

Year	**Reservoir (TMcft) Capacity**	**Average Capacity (TMCft) C**	**Inflow (TMcft) I**	**X=C/I**	**Trap Efficiency %**	**Loss of Volume (TMCft)/ Year**	**Sediment Trapped Tons/SqKm/ Year**	**Sediment Yield Tons/SqKm/ Year**
1977	118.260							
1978	117.695	117.978	275.408	0.428	96.598	0.565	693.715	718.148
1979	117.020	117.358	558.775	0.210	93.261	0.675	828.775	888.665
1980	116.345	116.683	291.341	0.401	96.368	0.675	828.775	860.008
1981	115.680	116.013	553.100	0.210	93.252	0.665	816.497	875.578
1982	114.718	115.199	362.649	0.318	95.457	0.962	1181.158	1237.369
1983	113.756	114.237	369.482	0.309	95.337	0.962	1181.158	1238.923
1984	112.794	113.275	316.253	0.358	95.954	0.962	1181.158	1230.967
1985	111.832	112.313	303.183	0.370	96.083	0.962	1181.158	1229.306
1986	111.791	111.811	217.267	0.515	97.154	0.041	50.954	52.447
1987	111.749	111.770	244.058	0.458	96.812	0.041	50.954	52.632
1988	111.708	111.728	163.482	0.683	97.845	0.041	50.954	52.077
1989	111.666	111.687	252.433	0.442	96.703	0.041	50.954	52.692
1990	111.625	111.645	224.061	0.498	97.063	0.041	50.954	52.496
1991	111.583	111.604	316.036	0.353	95.898	0.041	50.954	53.134
1992	111.542	111.562	372.075	0.300	95.198	0.041	50.954	53.525
1993	111.500	111.521	521.609	0.214	93.373	0.041	50.954	54.571
1994	110.849	111.175	309.868	0.359	95.960	0.651	799.308	832.957
1995	110.198	110.524	540.598	0.204	93.087	0.651	799.308	858.663
1996	109.547	109.873	180.912	0.607	97.580	0.651	799.308	819.130
1997	108.896	109.222	211.524	0.516	97.164	0.651	799.308	822.639
1998	108.245	108.571	339.815	0.319	95.482	0.651	799.308	837.126
1999	107.594	107.920	323.181	0.334	95.670	0.651	799.308	835.480
2000	106.943	107.269	328.877	0.326	95.571	0.651	799.308	836.347

Contd…

Year	Reservoir (TMcft) Capacity	Average Capacity (TMCft) C	Inflow (TMcft) I	X=C/I	Trap Efficiency %	Loss of Volume (TMCft)/ Year	Sediment Trapped Tons/SqKm/ Year	Sediment Yield Tons/SqKm/ Year
2001	106.292	106.618	322.176	0.331	95.633	0.651	799.308	835.810
2002	105.641	105.967	160.082	0.662	97.776	0.651	799.308	817.488
2003	104.990	105.316	126.740	0.831	98.222	0.651	799.308	813.780
2004	104.340	104.665	117.100	0.894	98.345	0.650	798.080	811.511
2005	103.469	103.905	171.150	0.607	97.579	0.871	1069.427	1095.959
2006	102.598	103.034	316.790	0.325	95.559	0.871	1069.427	1119.125
2007	101.727	102.163	296.270	0.345	95.803	0.871	1069.427	1116.282
2008	100.855	101.291	476.020	0.213	93.343	0.872	1070.655	1147.008
Average sediment yield								719.414

RESULTS AND DISCUSSIONS

The analysis carried out in Table 3 in collaboration with the engineers of Tungabhadra Board gives an average sediment yield of 719.414 Tons/SqKm/Year. The sediment production in the catchment area can be calculated if the sediment delivery ratio (SDR) is available for the catchment area. The Tungabhadra Upper sub basin which is the catchment for the project is not yet thoroughly studied to estimate SDR. The extension of this work aims at finding out SDR.

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THEME - II

Solid Waste Leachate Recirculation

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ABSTRACT

Waste is generated due to need and greed of man. Mankind has always utilizing the resources of earth to support them. Solid waste is often called the third pollution. The material which arises from various human activities is normally discarded as useless (or) unwanted at surroundings. The dumped solid wastes gradually decompose when exposed to water and release the bye-products. The process by which soluble materials such as salts, nutrients, pesticide, chemicals, leafy biomass and contaminants dissolves in lower levels of soil by moving is called leachate. Leachate contains a high concentration of organic matter and inorganic ions including heavy metals. One of the most severe threats caused due to leachate is contamination of ground water when it percolates from landfills. This not only contaminates the ground water but also surface water. The main objective of study of this work is to suggest the method of characteristics of re-circulated leachate to avoid ground water contamination and to reduce environmental threat as well as to reduce treatment costs of the landfill.

Keywords: Solid Waste, Water Pollution, Leachate Treatment, Pollution of Ground Water, Case Study, Responsibilities.

INTRODUCTION

Waste is generated due to need and greed of man. Mankind has always utilizing the resources of earth to support them. The living conditions today have surely improved to a great deal due to industrialization and urbanization but only at the cost of environmental degradation. The resources are not only getting depleted, but also getting polluted. One of the environmental degradation & pollution is due to disposing of waste. In early times the needs were less and the resources were plenty as the population was much less and consequently wastes generated was not a significant problem. The relationship between man and nature has vastly changed over time due to the development of human consciousness represented by science, technology, values & culture.

Solid waste is often called the third pollution after air and water pollution is that material which arises from various human activities and which is normally discarded as useless (or) unwanted. It consists of highly heterogeneous mass of discarded material from urban community as well as the more homogenous accumulation of agricultural, industrial and mining waste. It is normal practice to dispose waste along landfills (or) open dump yards which are subjected to infiltration from precipitation. The dumped solid wastes gradually decompose and release the by-products into water moving through it.

Leachate is generated due the decomposition and squeezing of the waste due to its self-weight and by water that has entered into the landfill from external sources mainly due to precipitation (Xu Hai-Lou….et.al 2003). Leachate contains a high concentration of organic matter and inorganic ions, including heavy metals. Leachate from municipal solid waste landfills is a highly concentrated that small amounts of leachate can pollute large amount of groundwater rendering its suitability for use domestic requirements.

METHODOLOGY

The main objective is to study the phenomenon's taking place due to recirculation of leachate by performing various tests and the change in the characteristics of re-circulated leachate is observed by comparing it with non-re-circulated leachate.

The generation of leachate is caused principally by precipitationpercolating through waste deposited in a landfill [1]. When water percolates through the waste, it promotes and assists process of decomposition by bacteria and fungi. These processes in turn release by-products of decomposition and rapidly use up any available oxygen creating an anoxic environment. Once in contact with decomposing solid waste, the percolating water becomes contaminated. Some infiltration will evaporated and transpirated, some may be stored within the landfill, and the balance becomes percolates and flows out of the waste material and it is eventually termed as leachate. Leachate production deals with the creation of contaminated liquid at the base of a landfill [2].

Composition of Leachate

A landfill that receives a mixture of municipal, commercial, and mixed industrial waste may be characterized as a water-based solution of four groups of contaminants;

- Dissolved organic matter (alcohols, acids, aldehydes, short chain sugars etc.),
- Inorganic macro components (common cations and anions including sulfate, chloride, Iron, aluminum, zinc and ammonia),
- Heavy metals (Pb, Ni, Cu, Hg) and Xenobiotic organic compounds such as halogenated organics, (PCBs, dioxins etc.) (MCG RAJAN….et.al. 2010)

The physical appearance of leachate when it emerges from a typical landfill site is a strongly- yellow odor- or orange-coloured cloudy liquid. The smell is acidic and offensive and may be very pervasive because of hydrogen, nitrogen and sulfur rich organic species such as mercaptans.

As leachate first emerges it can be black in colour, anoxic and may be effervescent with dissolved and entrained gases. As it becomes oxygenated it tends to turn brown or yellow because of the presence of Iron salts in solution and in suspension. It also quickly develops a bacterial flora often comprising substantial growths of Sphaerotilus.

Problems with Leachate

One of the most sever threat caused due to leachate is contamination of ground water when it percolates from land fills. Not only the ground water is contaminated but also there is a problem to surface water when it is disposed off (or) when its level rises above in landfills. Leachate streams running directly into the aquatic environment have both an acute and chronic impact on the environment which may be very severe and can severely diminish bio-diversity and greatly reduce populations of sensitive species. Where toxic metals and organics are present this can lead to chronic toxin accumulation in both local and far distant populations. Rivers impacted by leachate are often yellow in appearance and often support severe overgrowths of sewage fungus.

Prevention of Leachate

The risks of leachate generation can be mitigated by properly designed and engineered landfill sites, such as sites that are constructed on geologically impermeable materials or sites that use impermeable liners made of geotextiles or engineered clay. More modern landfills in the developed world have some form of membrane separating the waste from the surrounding ground and in such sites there is often a leachate collection series of pipes laid on the membrane to convey the leachate to a collection or treatment location. Instead of avoiding the merging of leachate with water sources either surface or sub surface sources it better to avoid generation of leachate by preventing infiltration of precipitation (or) implementing other techniques of waste disposal.

Fig. 1 Municipal dump yard where solid waste was collected

REMEADIAL MEASURES FOR LEACHATE CONTROL

The ancient practice in some older landfills was to direct leachate to sewers, but this can cause a number of problems. Toxic metals from leachate passing through the sewage treatment plant concentrate in the sewage sludge making it difficult or dangerous to dispose of to land without incurring a risk to the environment. The sewage treatment works operators are finding that leachates are difficult waste streams to treat because they contain very high ammoniacal nitrogen concentrations, they are usually very acidic, they are often anoxic and, if received in large volumes relative to the incoming sewage flow, the lack of Phosphorus in particular can result in nutrient starvation for the biological communities that perform the sewage treatment processes making leachate a difficult to treat waste stream. However, within aging municipal solid waste landfills this may not be a problem as the pH returns close to neutral after the initial stage of acidogenic leachate.

Now technology has improved and various alternatives has been adopted which will reduces the impact of leachate. One among the various method of leachate management which was more common in uncontained sites was leachate re-circulation in which leachate was collected and re-injected into the waste mass. This process greatly accelerated decomposition and therefore gas production and had the impact of converting some leachate volume into landfill gas and reducing the overall volume of leachate for disposal. However it also tended to increase substantially the concentrations of contaminant materials making it a more difficult waste to treat.

Because of the characteristics of landfill leachate the main goal of leachate control is to prevent uncontrolled dispersion. Leachate should always be collected, treated or contained before it is released into the environment. Leachate recirculation is one of many techniques used to manage leachate from landfills. Leachate recirculation is the process of Reintroducing collected leachate back into the landfill. Benefits of leachate recirculation include improvement of leachate quality, faster stabilization of the landfill, and enhancement of gas production.

METHODS OF LEACHATE RECIRCULATION

During leachate recirculation, the leachate is returned to a lined landfill for re-infiltration into the municipal solid waste. This is considered a method of leachate control because as the leachate continues to flow through the landfill it is treated through biological processes, precipitation, and sorption(Kevin Fellin et. al.1981). This process also benefits the landfill by increasing the moisture content which in turn increases the rate of biological degradation in the landfill, the biological stability of the landfill, and the rate of methane recovery from the landfill. If microbial respiration is increased in landfills there will be decrease in the total volume of leachate generated. The less liquids which enter a landfill means the less leachate leaving the landfill, this in turn means less problems with which as to be deal. Leachate recirculation will not result in nuisance conditions or odors or leachate outbreaks in general. It is expected that leachate would be recycled through the landfill for a period of 3 to 5 years. At the ends of the leachate recycle period, clean water would be added to leach the waste; leaching should be practiced until the leachate produced no longer represents a significant threat to groundwater quality.

Direct application to the waste during disposal-During this process the leachate is added to the incoming solid waste while it is being unloaded, deposited, and compacted. The problems with this method include odor problems, health risks due to exposure, exposure to landfill equipment and machinery, and off-site migration due to drift. This method also requires a leachate storage facility for periods such as high winds, rainfall, and landfill shut downs when the leachate cannot be applied. Spray Irrigation of landfill surface-Here leachate is applied to the landfill surface in the same method that irrigation water is applied to crops. This method is beneficial because it allows the leachate to be applied to a larger portion of the landfill, and because the leachate volume is reduced due to evaporation. However, the disadvantages associated with direct application are associated with this method as well.

Surface application-This is achieved through ponding or spreading the leachate. The ponds are generally formed in landfill areas that have been isolated with soil berms or within excavated sites in the solid waste. The disadvantages of these methods include an increase in the amount of required land area, and monitoring of the ponds to detect seepage, leaks, and breaks that would make it possible for leachate to escape directly or with storm-water runoff. Subsurface application-This is achieved through placing either vertical recharge wells or horizontal drain fields within the solid waste. There is a large amount of excavation and construction required with this method, but the risk of atmospheric exposure is drastically reduced.

Advantages

There are numerous advantages to treating leachate through recirculation and following are the advantages due recirculation of leachate.

It primarily avoids the danger of ground water contamination.

Leachate recirculation is a leachate management method that is relatively simple and inexpensive.

Landfills that use leachate recirculation experience a decrease in the concentration of the leachate compared to landfills without recycle treatment. This reduces the amount of leachate treatment that is needed and therefore costs are also reduced.

The increased moisture content within the solid waste enhances the system conditions for improved biological decomposition of organic matter in the landfill.

The organic matter in the leachate, which requires treatment outside the landfill, receives further treatment each time it is recycled through the landfill. This reduces treatment costs of the landfill.

Leachate recirculation stabilizes the biological system in the landfill and this reduces the environmental threats of the landfill, and reduces the amount of post closure monitoring that is required.

It also provides the opportunity for landfill mining and space reclamation.

Leachate recirculation increases the rate at which the waste decomposes and this increases the rate of methane production. This makes methane recovery for energy much easier [6].

Disadvantages

In spite of various benefits incurring due to recirculation of leachate it also bear various disadvantages and side effects may encountered due to recirculation of leachate and following are the various disadvantages due recirculation of leachate.

Leachate disposal or storage in the landfill can result in leachate Outbreaks, unstable waste mass and unstable slopes, increased potential for ground water contamination and gas migration.

A more significant risk may be the failure or abandonment of the leachate collection system. Such systems are prone to internal failure as landfills suffer large internal movements as waste decomposes unevenly and thus buckles and distorts pipes.

If a leachate collection system fails, leachate levels will slowly build in a site and may even over-top the containing membrane and flow out into the environment(Peter Kjeldsen et. al.1986)

Rising leachate levels can also wet waste masses that have previously been dry triggering off a new way of active decomposition and leachate generation.

Rising of leachate level can re-activates and restart significant gas production and exhibit significant changes in finished ground levels.

Critics point to the risk that it may increase the hydraulic loading on the landfill containment system, and clearly if leachate was allowed to build-up within the landfill to a level above the elevation assumed for the purpose of the design it would either increase the risk of groundwater pollution.

Since landfills are heterogeneous the leachate may find discrete channels to travel through. This makes it difficult to insure that the leachate is reacting with all of the waste and is thoroughly treated

CASE STUDY

Rajam town of Srikakulam is selected to study the characteristics of recirculated leachate resulted from municipal solid waste. The waste is collected from dump yard in Rajam. Solid waste is transported from dump yard to college for the study. The per capita solid waste generation for figures in India is 0.47 kg/day. The quantity of MSW generated based on population of Rajam is 10931.26 kg/day.

Table 1 Sources of municipal solid waste generation in Rajam town.

Domestic waste	Household wastes-kitchen, house cleaning, old papers, packing, crockery wares, furnishing, materials, garden trimming etc.
Commercial wastes	Wastes generated from business premises, shops, offices, markets, departmental stores, organic, inorganic, chemically reactive and hazardous waste.
Institutional wastes	Schools, colleges, hospitals, small hotels and restaurants, markets selling vegetables, fruits etc, community halls, religious places etc.,
Street sweeping	Unconcerned throwing, littering made by pedestrian traffic, vehicular traffic, stray animals, road side leaves, rubbish from drain cleansing debris etc.,
Industrial wastes	Waste from manufacturing trade units.

Municipal solid waste is transformed from Rajam municipal dump yard to laboratory for study. The solid waste is mixed thoroughly and weighed, later the mixed waste is stored in two relatively same PVC pipes i.e., prototype for dump yard as shown in Fig.1.

The pipes are of four inches diameter and one and half meter in length and other details are shown in table below. The pipes are held in vertical position by stands. Initially for collection of leachate water is added to waste in both pipes at regular intervals in same amount and waste is allowed to decompose. The resulted leachate is collected in collecting tubs through holes in dummy which was fixed at lower end of pipes. Coarse aggregate is laid in dummy's to retain suspended solids. The resulted leachate from two pipes is tested separately and leachate from pipe "1" which was re-circulated is stored in other tub and the same is re-circulated in same rate as the other.

Fig. 2 Pipes which are used as prototypes of dump yard

RESULTS AND DISCUSSIONS

The leachate formed due to the decomposition of the solid waste was collected from the experimental setup and tests were conducted. The various properties such pH, conductivity, total dissolved solids, total hardness, calcium hardness, magnesium hardness, bicarbonates, chlorides sulphates, BOD, COD was determined. The results obtained are shown in tables 2. The percentage removal in each recirculation is shown in table 2.

Table 2 Percentage removal of contents of leachate in pipe 1

Sl.no	Parameters	1st recirculation	2nd recirculation	3rd recirculation
1	Total hardness(mg/lt)	17.95	28.2	46.15
2	Calcium hardness(mg/lt)	40	46.66	60
3	Magnesium hardness(mg/lt)	4.16	16.66	37.5

Contd…

4	Sulphates (mg/lt)	66.66	82.2	85.71
5	Total dissolved solids(mg/lt)	34.52	63.27	78.16
6	Alkalinity(mg/lt)	4.42	6.19	55.75
7	Chlorides(mg/lt)	7.14	10.71	28.57
8	C.O.D (mg/lt)	37.5	50	59.56
9	B.O.D(mg/lt)	40.98	55.73	70.88

Graphs were plotted and the variations are shown from Fig 3.

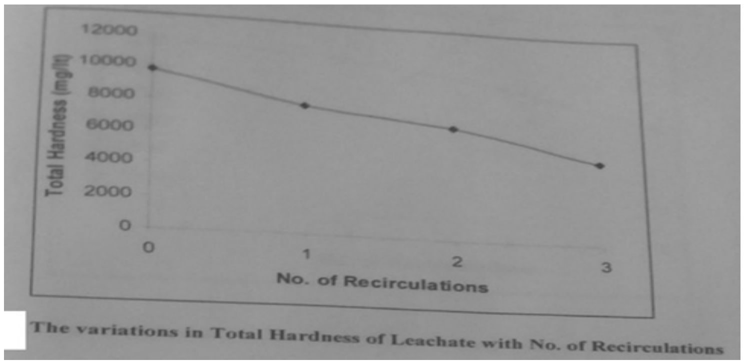

Fig. 3 Shows the decrease in hardness with no. of recirculations

The results shows the variation of Total Hardness of leachate with number of recirculations. It was observed from results that after each recirculation, the amount of total hardness present in leachate (mg/lt) from “pipe 1 starts decreasing. A decreasing trend in total hardness is also observed in “pipe 2”.

During the study period it was observed that a decrease in the magnesium hardness of leachate from pipes 1 and 2 was observed. The variations in magnesium hardness of leachates from both pipes were observed.

A significant decrease in the sulphate content in leachate from both the pipes was observed. The variation in sulphates with number of recirculations were also shown.

There has been little increase in the conductivity of the leachate from pipe 1 after each recirculation. A significant decrease in the conductivity of the leachate from pipe 2 is observed.

From starting of recirculations it was observed that alkalinity of leachates of recirculated and non recirculated pipe starts decreasing and the variation in alkalinity of leachates from pipes 1 and 2 are observed

The chloride content present in leachate of both the pipes starts decreasing after each recirculation. A great decrease in the chloride content present in pipe was observed. The variation in chlorides with number of recirculations was shown in the table

A significant decreasing trend in the C.O.D in leachate of pipe 1 was observed. A much variation in C.O.D in leachate of pipe 2 was not observed.

CONCLUSION

This study showed that the high activity of risks of leachate generation can be mitigated by properly designed and engineered landfill sites, such as sites that are constructed on geologically impermeable materials or sites that use impermeable liners made of geotextiles or engineered clay. Instead of avoiding the merging of leachate with water sources either surface or sub surface sources it better to avoid generation of leachate by preventing infiltration of precipitation (or) implementing other techniques of waste disposal.

To reduces the impact of leachate, recirculation process of Reintroducing collected leachate back into the landfill was adopted. This process greatly accelerated decomposition and therefore gas production and had the impact of converting some leachate volume into landfill gas and reducing the overall volume of leachate for disposal. However it also tended to increase substantially the concentrations of contaminant materials making it a more difficult waste to treat.

Under certain circumstances, leachate recycle is a useful technique for acceleration of refuse decomposition in the laboratory, thus reducing the period of time required to study the effect of an addition to the refuse ecosystem on methane production.

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Influences of Ambient Air Quality on Environment and Agriculture Crop Production

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ABSTRACT

Crop production is highly dependent upon environmental conditions, among them air quality plays a major role. The air pollution could be a major constraint on peri-urban crop yield and its nutritional quality in India. Among many atmospheric pollutants, gaseous pollutants generally cause more damages to plants than do particulates. While the other pollutant, ambient SO_2 may inflict incremental stress on crop production, either alone or together with photochemical oxidants. The reduction of crop yield because of coal fired smoke pollution in the ambient environment is well-documented. SO_2 is the prime pollutant next to O_3 in the atmosphere. High-level concentration of SO_2 has shown yield reduction in several fields in India. Hence, this paper deals the effect of air pollutant SO_2 on crop yield in the neighbourhood of Super Thermal Power Plants in Cuddalore District, Tamil Nadu.

Keywords: Ambient air quality, Environment, Peri-urban, Crop yield Reduction etc.

INTRODUCTION

Crop yield variability is a defining characteristic of agriculture which is strongly influenced by fluctuations in environmental conditions (Adams, R.M., 2000). Studies (Ossai, N.O., 2004) show that the year-to-year in variations in crop yields is normally associated with the effect of these factors. Light, temperature, water and soil are the environmental factors which are greatly influence crop growth and environmental disseminations. These factors helped to decide the suitability of a crop for a particular location, cropping pattern, management practices, and the needs of various inputs. To increase the production of any crop, it is important to understand how these environmental factors affect plant growth and development. The general state of the environment, including air quality, is deteriorating in many cities of the developing countries. World Bank studies in selected cities of developing countries have shown that swelling urban populations and the growth of industrial activities and automative traffic in Asia have caused serious air pollution (World Bank, 2009). In India, high levels of SO_2 can result in localized impact on crops as demonstrated in the vicinity of industrial complex (Agrawal et al., 2006). Keeping in view the information that this review focuses on the trend of emissions and concentrations of SO_2 and the relative responses of morphological parameters for both the seasons from cultivars of rice (Oriza sativa L.) leading to variable yield responses under realistic natural conditions along pollutants gradient.

MATERIALS AND METHODS

Study Area

The study area was chosen around a super thermal power plant called Neyveli Lignite power Corporation (NLC), Neyveli in Cuddalore district of Tamil Nadu. NLC is located in the latitude of 11^{o}28’ and 11^{o}37’ N and longitude of 79^{o}25’ and 79^{o}33’E of river Cauvery Delta region in India. NLC covers an area of about fifty-four square kilometers, much of which is forested. It mines twenty-four million Metric Tonnes Per Annum (MTPA) of lignite, and produces 2,490 MW/year of electricity from three open cast mines. The eleven elevated stacks from this power plant emanate a substantial amount of sulphur dioxide into a tropical boundary layer. (http://www.nlcindia.co.in).

Source Data

Data recorded in Central Applied Research and Development (CARD) Station at Neyveli for the period 1997 to 2007 shows that temperature varied from 18.3^o to 40.4^o C, and relative humidity varied from 24 to 100 %. The average annual rainfall is 1225.5 mm. Mostly south west, south-east and northeasterly wind blows in this region. Micro-meteorological survey was undertaken from January to April 2009. The quick weathering genesis has produced shallow, loam and sandy soil. The sandy soils are poor in organic contents and have low moisture retaining capacity. The pH of soil is slightly alkaline to neutral. In Cuddalore district, however, rice is the main crop cultivation in this region. Rice cultivation has been carried out twice / thrice a year according to the time, place and water availability. At Neyveli region, Kuruvai, Thaladi/ Samba, Sornavari and Navarai Patttam, etc., have been practiced as crop seasons (See Table 1).

Table 1 Rice cropping calendar at neyveli, cuddalore district

<table>
<tr><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th><th>Jan</th><th>Feb</th><th>Mar</th></tr>
<tr><td></td><td colspan="2">Kuruvai</td><td colspan="2">Kuruvai Har./ Samba Estb.</td><td colspan="3">Samba/Thaladi</td><td colspan="2"></td></tr>
<tr><td colspan="4">South-west Monsoon</td><td colspan="2">North-East Monsoon</td><td colspan="2">Winter</td><td colspan="2">Summer</td></tr>
<tr><td colspan="5">Kurvai Raifed/Irrigation water</td><td colspan="5">Rabi Irrigation water</td></tr>
</table>

Experimental Setup

In order to find out the effect of air pollution on rice crop yield, a pilot field study was conducted at selected sites adjacent to the thermal power plant. This study consists of the reconnaissance survey to determine the problems existing in the study area with suitable method. The water quality analysis and analysis of soil characteristics were also carried out to find the suitability of water and soil for irrigation purposes. Ambient air quality monitoring was conducted at various sites in the adjoining area of thermal power plant in Neyveli. Atmospheric dispersion models were validated and their performance also evaluated at Neyveli.

Field Setup

Kammapuram and Mudhanai are the two sites were selected along NE-SW transect in rural locations of the thermal power stations according to the upwind and down wind direction. Kammapuram is situated on the downwind directions with respect to the thermal power stations which are an agricultural area and 10.5 km radials distance from the source complex. Mudhanai is situated on upwind direction about 6.5 km radial distance west to the source complex. Kammapuram is taken as the Uncontrolled Open Field Plot (UOFP) and Mudhanai is taken as the Controlled Open Field Plot (COFP). There is no change in climatic conditions between these two sites. Soil and water sample were collected and tested in the Government of Tamilnadu agricultural soil testing laboratory, Cuddalore.

Rice (Oriza sativa L.) cultivar ADT 36 grown widely as summer crop in Cuddalore district by farmers having small as well as large land holdings was selected as test plants. The ADT 36 is a fine rice crop having a life span of 105 and 110 days. The same variety may be taken for both the seasons to identify whether that the crop is affected/ effected by the ambient air pollutants or not. For the Kuruvai (Rabi) crop season, initially the nursery field was prepared in large pots filled with well manures garden soil prepared by mixing garden soil and farm-yard manure in 3:1 ratio. Sowing was carried out in the last week of June 2008, after 20th day of sowing; seedlings were transplanted to two sites namely Muthanai and Kammapuram on 8th July '08, each pot of 12.5 cm apart in rows by hand. The two sites were kept in a well-watered condition in order to maintain constant soil moisture.

Morphological Analysis

Plant growth and development were monitored throughout the crop period by weekly measurements of plants height and number of tillers, number of live and senescent leaves for both the seasons. A single destructive harvest was performed at crop maturity on 18th October 2008, with the measurements of panicles per plant, grains per plant, and the number of fertile and infertile spikelet per panicle. Grain, straw and root dry weights were determined for each plant. In such a way, a harvest was performed on the last week of January/ first week of February, 2009. The panicle per plant, grains per plant, the number of spikelet per panicle and infertile spikelet per panicle were also measured for the samba crop harvesting. The statistical analyses were carried out on the final harvest data based on mean value for both the seasons.

During the study period air quality monitoring also was carried oud out at all sites by using high volume sampler at ground level for 6 h daily from 8.30 to 21.30 hrs thrice in alternate days. The gaseous pollutant Sulphur dioxide was scrubbed separately in tetrachloromercurate, NaOH (0.1 N) and buffered by KI (0.1 N), respectively. The absorbed solution was analysed calorimetrically for SO_2.

RESULTS AND DISCUSSION

The reconnaissance survey was conducted to determine the problems existing in the study area with questionnaire and also interviewed the progressive farmers. The questionnaire revealed that paddy yield was higher in Rabi season than in Kharif season. The expenditure for the crop cultivation in the Kharif season is more than the Rabi season. Hence, the study believes that there is a relationship between air pollution and paddy yield responses to the Kharif crop season.

The water quality analysis and analysis of soil characteristics were also carried out to find the suitability of water and soil for irrigation purposes. The environmental parameters and chemical analysis of rice field in soil and water (see Tables 2 and 3) were found. As this is only a primary study, the results presented are those of a one-time study. Since the study has been undertaken for water and soil in the same place in all pots hydrologically, they have almost similar normal values and very low amount of nutrient materials. The pH of natural water above the level of 8 is probably due to photosynthetic activity that demands CO_2 as shown by Jayakumar and Karpagam (2005). In this present investigation, this could be the reason for alkaline range in pH in rice field. The chlorine content of rice field water in UOFP showed 5.8 meq/l, which may be due to various factors.

Ambient air quality monitoring was conducted at various sites in the adjoining area of thermal power plants in Neyveli. Atmospheric dispersion models were validated and their performance also evaluated at Neyveli. In order to find out the effect of air pollution on rice crop yield, a pilot field study was conducted at selected sites adjacent to the thermal power plant. Mean monthly average concentration of SO_2 was found more at UOFP than at COFP. During the Rabi crop season the maximum mean monthly average concentration of SO_2 was ranged from 0.996 to 5.20 at Muthanai and from 1.52 to 7.14 at Kammapuram, and during the Kharif crop season the maximum mean monthly average concentration ranged from 0.97 to 6.38 at Muthanai and Kammapuram from 2.402 to 9.52. There is no significant difference during the Rabi season between the COFP and UOFP, except that the maximum SO_2 concentration is found in COFP in alternate months (i.e July and September ‘08’), but in UOFP it is gradually in the increasing order during Rabi season.

Table 2 Soil quality analysis of the study area

Sl. No.	Parameters	Unit	Muthanai (COFP)	Kammapuram (UOFP)
1.	Bulk Density	g/cm^3	1.52	1.56
2.	Porosity	%	46	44
3.	Organic Carbon	%	0.57	0.24
4.	Carbonate (CO_3)	g/kg	0.00	0.00
5.	pH		7.70	8.1
6.	Electrical Conductivity (EC)	Ds/m	0.230	0.260
7.	Texture	Silt Clay SC loam (SL)	SC SL	SL
8.	Exchangeable Potassium	g/kg	0.125	0.0325
9.	Nitrogen	g/kg	0.065	0.035
10.	Phosphorous (P)	g/kg	0.005	0.0015

Table 3 Water quality analysis of the study area

Parameters	Muthanai (COFP)		Kammapuram (UOFP)	
	Rabi	**Kharif**	**Rabi**	**Kharif**
Colour	<5	<5	<5	<5
Odour	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable
Taste	Agreeable	Agreeable	Agreeable	Agreeable
pH	7.39	7.54	7.54	7.7
EC_w	0.7	1.23	1.23	1.06
CO_3	0	0	0	0
HCO_3	2.85	3.08	3.08	4.8
Cl	2.62	10.61	10.61	5.8
SO_4	0.38	0.7	0.7	0.1
Na	3.7	4.38	4.38	4.1
K	0.78	0.87	0.87	0.32
Ca	2.70	4.2	4.2	3.9
Mg	1.85	3.1	3.1	2.3
Fe	0.23	0.21	0.21	0.20
SAR	2.45	2.28	2.28	2.33

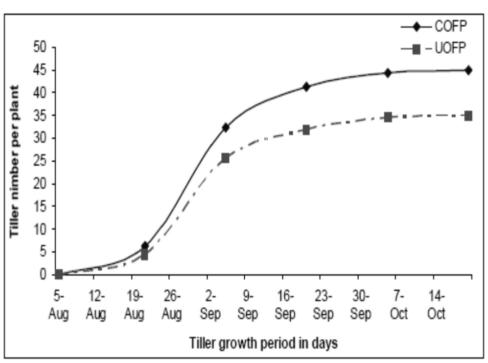
In the present study, SO_2 concentrations were much higher during the Kharif season compared to Rabi season. This suggests that precursors of SO_2 concentrations are abundant at site kammapuram, because it is along the down wind gradient from the source points. The site Muthanai shows minimum level of SO_2 concentration on both the crop seasons Kharif and Rabi, i.e. it lies on the upwind direction of the source points.

Morphological Study

Plants developed in COFP showed increased growth parameters when compared to those grown in UOFP. There was a slightly significant effect of treatment on tiller production in both the sites at COFP and UOFP (See Figure 1 and 2). In both sites; there were no differences in tiller number until early August after this time, no tiller production showed in UOFP but in COFP it continued at same rate through to end of August. Final tiller numbers were significantly reduced by 13.87% in UOFP compared to COFP. There was also an accelerated rate of leaf senescence in UOFP when compared to COFP which became apparent for early august in both sites.

Yield Responses

During the Kharif crop season the final harvested result shows the significant effect of treatment from both sites. Yield has increased in COFP relatively large in amount when compared with the UOFP with total grain weight per plant showing increments of 14.75% in ADT 36. Increments in straw weight were slightly lower than the increments in total grain weight (28.36%) and significant increment in root biomass (17.30%) was also found. A substantial part of the yield reduction was due to reduction in the number of panicles per plant of 19.45% with UOFP, this reflects the reduced level of tillage in UOFP cultivar (see Figures 1 and 2) and, the number of filled grains per panicle was reduced by 4.91%. The reduction of filled grain per panicle was largely due to an increase of sterilities in UOFP. The increased sterilities also affect the straw and root dry weight in UOFP by means of lowering.



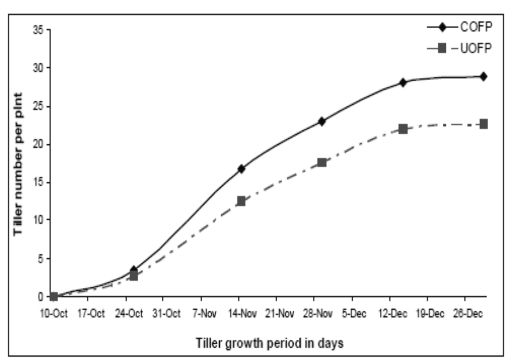


Fig. 1 Tiller developments DAT During Rabi Crop Season

Fig. 2 Tiller Developments DAT During Kharif Crop Season

Yield was comparatively less by 10 – 15% in average (ADT36) at Kammapuram (UOFP) compared to Mudhanai (COFP). However, the yield reduction was not significantly different between the two sites during the Rabi crop season. But in Kharif crop season yield reduction was found 25 – 30% in average at UOFP with COFP. This reduction may be due to the SO_2 concentrations which were relatively high compared to air quality standards in the atmosphere. The sulphur dioxide is one of the most prevalent phototoxic air pollutants and causes substantial damage to the green plants (Khan and Khan, 1991). It is known that SO_2 alters the metabolic processes of plants (Wellburn, 1982; Ziegler, 1992), decreases their photosynthetic activity (White et al, 1974; Black and Unsworth, 1979) and yield (Thomas, 1961). In a similar study on effect of ambient air pollution on wheat and rice in Pakistan a significant yield reduction has been reported in two successive seasons which ranged from 33% to 46% in wheat and from 37% to 51% in rice (Meggs, et al. 1995). These results are very significant in terms of the maintenance of agricultural yields, because there is a continuous extension of power producing units at Neyveli Thermal Power Plant to meet the demand of power supply. Based on our observation in rice crop development, yield response between COFP and UOFP may be due to exposure of SO_2 air pollutant for a longer period in the downwind directions.

CONCLUSION

Crop pilot study was conducted at COFP (Muthanai) and UOFP (Kammapuram) village sites for both the seasons. During the Rabi season, the yield reduction and crop growth reduction was found to be 10 to 15% in UOFP when compared to COFP. Similarly, the yield reduction and crop growth reduction was also found to be 10 to 28% in UOFP with the COFP. This study found reduction in growth and yield of paddy at Kammapuram site 15% to 30% during Kharif season when compared with Rabi season. The air quality monitoring data clearly show that SO_2 is the main air pollutant in the ambient air at the experimental site in the rural agricultural area of Neyveli thermal power plant during the growth period of rice. SO_2 also showed maximum variations during the crop growth period. Highest SO_2 concentration was found at UOFP during Kharif season which coincided with the period of grain setting and filling stage of rice during September and October. Plants grown in COFP showed higher rate of tillering, panicle, spiklet and yield, but lower levels in UOFP. Thus, the present study concludes that air pollution could be a major constraint on rural rice crop yield and its nutritional quality in the vicinity of industrial complex in Neyveli, India.

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Biosorption of Heavy Metals from Aqueous Solutions using Prawn and Egg Shell Wastes

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ABSTRACT

The paper evaluates two different food wastes for the removal of heavy metal ions from wastewater. This paper compares the current methods to explore the utilization techniques for various food wastes such as prawn and egg shells as bio adsorbents which are abundantly and easily available in India for the elimination of heavy metals from wastewater. In this study, the adsorption behaviour of two adsorbents such as Prawn and Egg shell with respect to Cu(II) and Zn(II) ions, has been studied in order to consider its application to the purification of metal finishing wastewater. The batch method was employed and the parameters such as pH, contact time, and initial metal concentration were studied. The influence of the pH of the metal ion solutions on the uptake levels of the metal ions by the different adsorbents used were carried out between pH 4 and pH 11. Adsorption parameters were determined using both Langmuir and Freundlich isotherms, but the experimental data were better fitted to the Freundlich equation than to Langmuir equation. The results showed that Prawn and Egg shells hold potential to remove cationic heavy metal species from industrial wastewater in the order Prawn shell < Egg shell.

Keywords: Prawn shell, Egg shell, Adsorption, Langmuir, Freundlich.

INTRODUCTION

Copper(II) is one of the heavy metals most toxic to the living organisms and it is one of more widespread heavy metal contaminants of the environment. Extensive intake of Cu can cause hemolysis, hepatotoxic and nephro toxic effects, vomiting, cramps, convulsions, or even death (Ozar et al., 2007). The increase levels of copper in environment are posing a serious threat to mankind (Gustavo et al., 2007). It can cause harmful biochemical effects, toxicity and hazardous disease in human beings. Prescribed limit for copper in drinking water is 0.05mg/L as per WHO norms and also 0.05 mg/L as per ISI prescribed limits, 1993(Shrivastava, 2009). Zinc is chemically active and alloys readily with other metals. The excessive intake of zinc may cause toxic effects such as carcinogenesis, mutagenesis and teratogenesis as a result of bioaccumulation (Nriagu, 1980). Zinc is widely used in many industries such as paint, batteries, fertilizers and pesticides, galvanization, pigment, polymer stabilizers, fossil fuel and combustion, electroplating, paper and pulp, pharmaceutical, textile mills, mining industries, etc. these industries are the main source of zinc pollution. The waste generated from these industries directly discharge to the environment and the water is polluted with zinc due to the excessive amount of zinc (Harte et al., 1991).

MATERIALS AND METHODS

In this Section methods for using viable non-conventional low-cost adsorbents like Prawn shell and Egg shell for removal of metals such as Copper (II) and Zinc (II) are discussed.

Adsorbent Materials

Egg shell powder

The Eggshell used in the experiment collected from different hotels located in Chennai city, India. The samples were then washed with distilled water several times to remove dirt particles. The Eggshells were then dried overnight in oven at 40^{o} C. The dried Eggshells were ground into small particles and then finally sieved to fine powder of less than 0.425mm particle size and stored in air tight container for future use.

Prawn shell powder

The shell of Prawn was obtained from an aquaculture farm in Chennai (Tamil Nadu). It was air- dried and powdered in a grinder. The dry biomass was crushed into granules, sieved to different particle sizes, and then preserved in desiccators for use (i.e.PR- Raw). Air- dried and powdered prawn waste was soaked in concentrated H_2SO_4 for 12 hours and washed thoroughly with distilled water till it attained neutral pH and soaked in two percent

$NaHCO_3$ overnight in order to remove any excess acid present. Then the material was washed with distilled water and dried at 110±20° C. The dry biomass was crushed into granules, sieved to different particle sizes, and then preserved in desiccators for use.(i,e.,PR- carbon).

Preparation of Adsorbate Solutions

Metal solutions

Stock solution of 10 mg/l Cu (II) ion is prepared dissolving copper sulphate pentahydrate ($CuSO_4.5H_2O$). To do this 39.28 mg $CuSO_4.5H_2O$ is added in distilled water contained in 1000 ml volumetric flask. Stock solution of 10 mg/l of Zn(II) is prepared by dissolving zinc sulphate heptahydrate ($ZnSO_4.7H_2O$). To do this 43.96 mg of Zinc sulphate heptahydrate solution is added to distilled water contained in 1000 ml volumetric flask. Hydrochloric acid and Sodium hydroxide were used to adjust the solution pH. Distilled water was used throughout the experimental studies.

Batch mode adsorption studies

Batch mode adsorption studies for individual metal compounds were carried out to investigate the effect of different parameters such as adsorbate concentration, adsorbent dose, agitation time and pH. Solution containing adsorbate and adsorbent was taken in 250 mL capacity beakers and agitated at 150 rpm in a mechanical shaker at predetermined time intervals. The adsorbate was decanted and separated from the adsorbent using Whatman No.1 filter paper. To avoid the adsorption of adsorbate on the container walls, the containers were pretreated with the respective adsorbate for 24 hours.

Effect of pH on Cu(II) and Zn(II) Adsorption

The effect of solution pH on adsorption of Cu(II) and Zn(II) was studied by mixing 2.5 g of individual adsorbent with 250 ml of mixed metal solutions having concentration of 3.6mg/L, 4.2 mg/L, of Copper and 3.3 mg/L and 3.7 mg/L of Zinc concentration at different pH value (5 – 8) at room temperature. The pH was adjusted with 1 N NaOH or 1 N HCl solutions and measured by pH meter. Agitation was made at a constant stirring speed of 170 rpm for 180 minutes. The remaining concentration of Cu(II) and Zn(II) after adsorption was measured using AAS. The percentage uptake of Cu(II) and Zn(II) was calculated according to the following equation:

$$\text{Percentage uptake (\%)} = \frac{C_o - C_t}{C_o} \times 100$$

Where, C_o is the initial concentration and C_t is the concentration at time *t*.

Effect of Contact Time On Cu(II) And Zn(II) Adsorption

The effect of solution Contact Time on adsorption of Cu(II) and Zn(II) was studied by mixing 1.25 g of both adsorbents with 250 ml of mixed metal solution having concentration of 4.2 mg/L of Copper and 5mg/L of Zinc concentration at pH value of 6 at room temperature. Agitation was made at a constant stirring speed of 170 rpm. The remaining concentration of Cu(II) and Zn(II) after adsorption was measured at different time intervals of 30, 60 120 and 180 minutes using AAS. The percentage uptake of Cu(II) and Zn(II) was calculated according to the following equation:

$$\text{Percentage uptake (\%)} = \frac{C_o - C_t}{C_o} \times 100$$

Where C_o is the initial concentration and C_t is the concentration at time *t*.

Effect of Adsorption Dose On Cu(II) and Zn(II) Adsorption

The effect of adsorption dose on Cu(II) and Zn(II) adsorption was investigated by different amount of adsorbents 1.5 gm, 2 gm and 2.5 gm in 250 ml of mixed metal solutions having initial concentration of 4.4 mg/l, 7.9 mg/l of Copper and 5 mg/l, 9.2 mg/l of Zinc. Agitation was made at a constant stirring speed of 170 rpm for 120 minutes. The remaining concentration of Cu(II) and Zn(II) after adsorption was measured using atomic adsorption spectrometer (AAS).

RESULTS AND DISCUSSION

Effect of pH on Cu(II) and Zn(II) Adsorption

The pH value of aqueous solution is an important parameter in adsorption process because it affects the surface charge of the adsorbent, the degree of ionization and specification of the adsorbate. The batch equilibrium studied for mixed metal solutions having concentration of 3.6mg/L, 4.2 mg/L, of Copper and 3.3 mg/L, 3.7 mg/L of Zinc concentration at different pH value ranging from 5 to 8 were carried at room temperature. Fig.1and Fig.2 shows that maximum percentage of Cu(II) and Zn(II) adsorption on Egg shell and Prawn shell were observed at pH 6.

Table 1 Effect of pH on the adsorption of Cu(II) and Zn(II) by Eggshells

S.No	Quantity of Egg shell powder(gm)	pH	Initial concentration of Cu(mg/L)	Initial concentration of Zn(mg/L)
			3.6	3.3
			Adsorption Efficiency(%)	
1	2.5	5	97	99
2	2.5	6	99.7	99
3	2.5	7	95.8	96.6
4	2.5	8	97	99

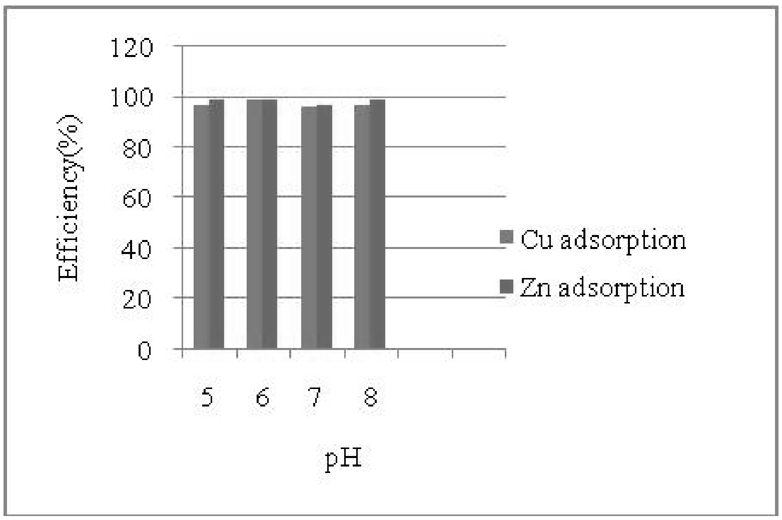

Fig. 1 Effect of pH on the adsorption of Cu(II) and Zn(II) by Egg shells and Prawn shells

Table 2 Effect of pH on the adsorption of Cu(II) and Zn(II) by Prawn shells

S.No	Quantity of Prawn shell powder(gm)	pH	Initial concentration of Cu(mg/L)	Initial concentration of Zn(mg/L)
			4.2	3.7
			Adsorption Efficiency(%)	
1	2.5	5	90	85
2	2.5	6	95.9	91
3	2.5	7	95.9	89
4	2.5	8	93	88

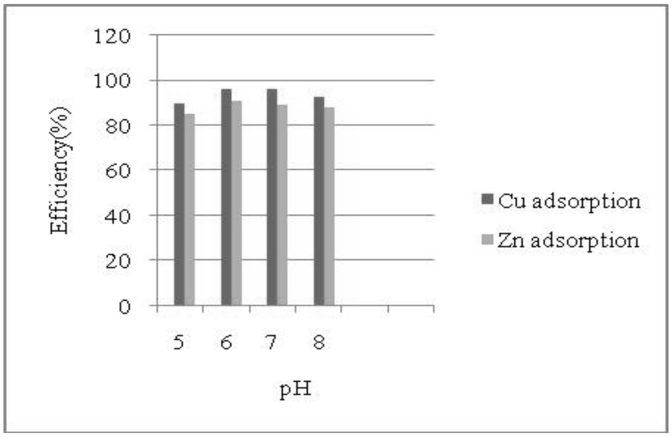

Fig. 2 Effect of pH on the adsorption of Cu(II) and Zn(II) by Prawn shells

Effect of Contact Time on Cu(II) and Zn(II) Adsorption

Contact time plays an important role in adsorption process and the effect of contact time on adsorption capacity has been studied by varying the contact time from 30 to 180 minutes. The Copper and Zinc adsorption percentage at different contact time by Egg shells and Prawn shells is shown in Fig 3.

Results indicated that the Cu(II) adsorption by Egg shell and Prawn shells reached almost 95% and Zn(II) adsorption by Egg shells and Prawn shells reached almost 86% at 2 hours contact time.

Table 3 Effect of contact time on the adsorption of Cu(II) and Zn(II) by Egg shells and Prawn shells

S.No	**Quantity of Egg shell powder(gm)**	**Quantity of Prawn shell powder(gm)**	**Contact Time (min)**	**Initial concentration of Cu(mg/L)**	**Initial concentration of Zn(mg/L)**
				4.2	**5**
				Adsorption Efficiency(%)	
1	1.25	1.25	30	88.9	82
2	1.25		60	92.8	80
3	1.25	1.25	90	95.2	86
4	1.25	1.25	120	95.2	84

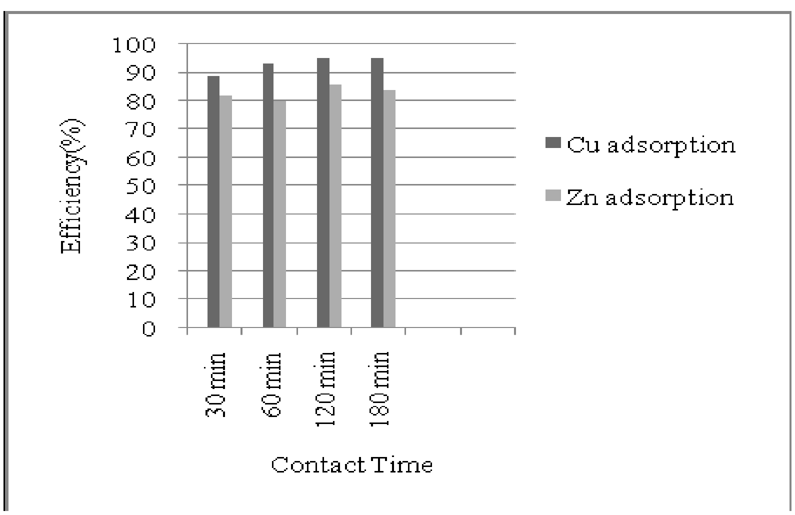

Fig. 3 Effect of contact time on the adsorption of Cu(II) and Zn(II) by Egg shells and Prawn shells

Effect of Adsorption Dose on Cu(II) and Zn(II) Adsorption

The effect of adsorbent dosage was studied by varying the amount of adsorbent from 1.5 gm to 2.5 gm in 250 ml of mixed metal solutions of copper and zinc. After equilibrium the solutions were analyzed for the amount of Cu(II) and Zn(II). The results indicate that adsorption increased with increase in adsorption dosage.

Table 4 Effect of adsorption dose on the adsorption of Cu(II) and Zn(II) by Egg shells and Prawn shells

S.No	Quantity of Egg shell powder(gm)	Quantity of Prawn shell powder(gm)	Initial concentration of Cu(mg/L)	Initial concentration of Zn(mg/L)
			4.4	5
			Adsorption Efficiency(%)	
1	1.5	1.5	95	88
2	2	2	97	90

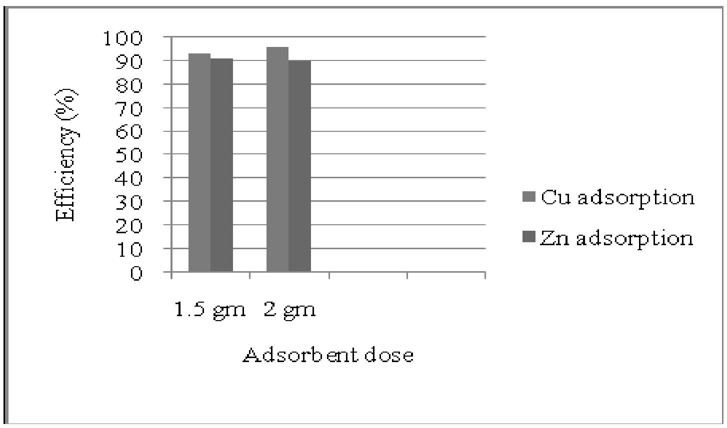

Fig. 4 Effect of adsorption dose on the adsorption of Cu(II) and Zn(II) by Egg shells and Prawn shells

Table 5 Effect of adsorption dose on the adsorption of Cu(II) and Zn(II) by Egg shells and Prawn Shells

S.No	Quantity of Egg shell powder(gm)	Quantity of Prawn shell powder(gm)	Initial concentration of Cu(mg/L)	Initial concentration of Zn(mg/L)
			7.9	9.2
			Adsorption Efficiency(%)	
1	1.5	1.5	93	91
2	2	2	97	93

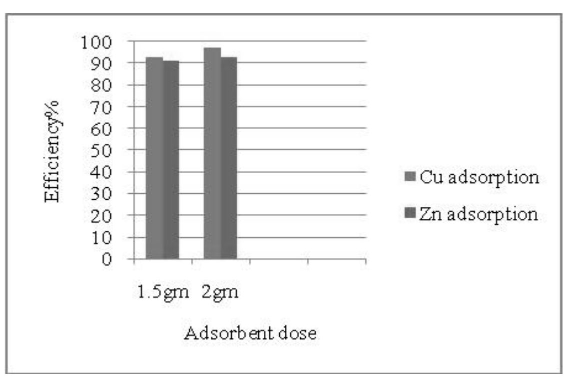

Fig. 5 Effect of adsorption dose on the adsorption of Cu(II) and Zn(II) by Egg shells and Prawn shells

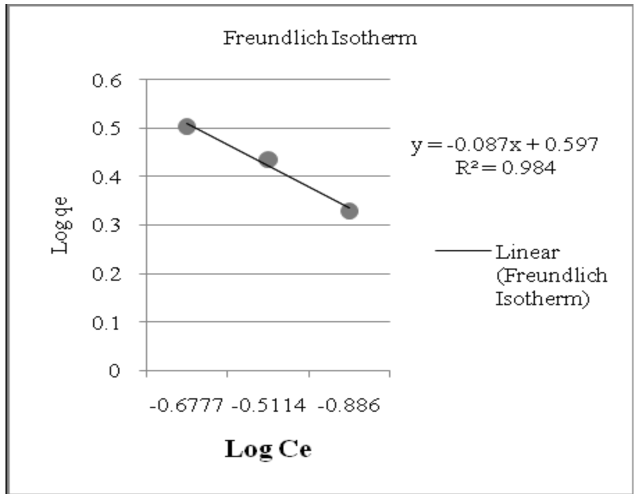

Fig. 6 Freundlich Isotherm shown amount of Cu(II) adsorbed and equilibrium concentration

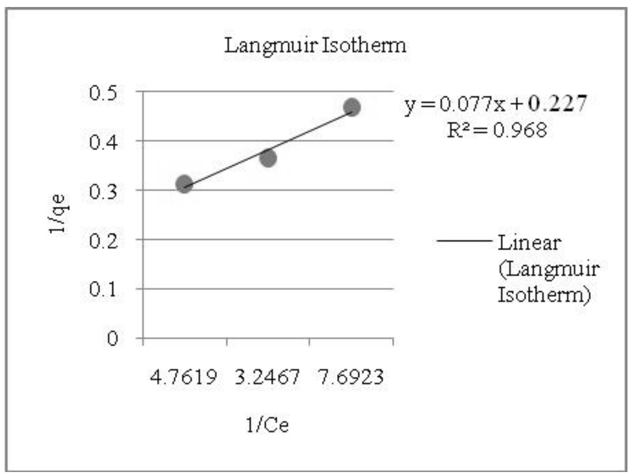

Fig. 7 Langmuir Isotherm shown amount of Cu(II) adsorbed and equilibrium concentration

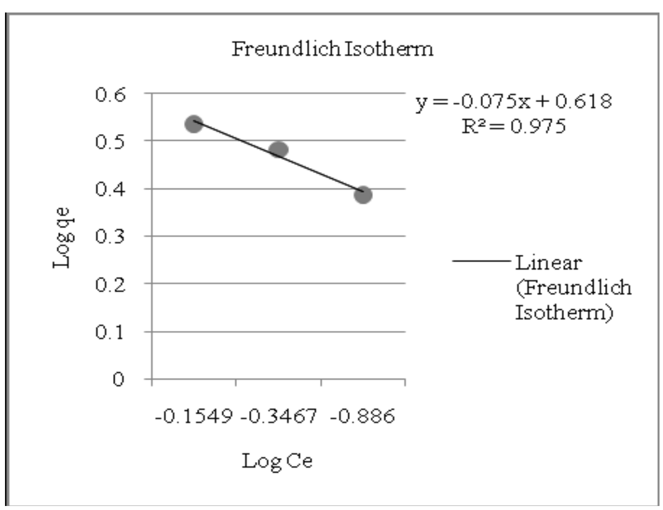

Fig. 8 Freudlich Isotherm shown amount of Zn(II) adsorbed and equilibrium concentration

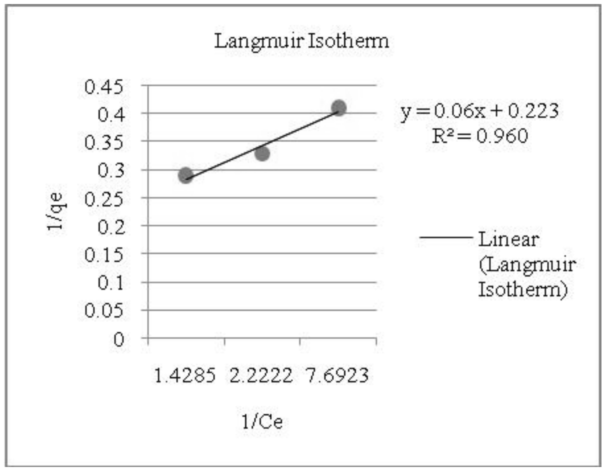

Fig. 9 Langmuir Isotherm shown amount of Zn(II) adsorbed and equilibrium concentration

CONCLUSION

The removal of Cu(II) and Zn(II) from waste water by using Eggshells and Prawn shells has been experimented under several conditions such as at different pH, contact time and adsorption dose. The optimum pH for copper and zinc adsorption was found at pH 6. The optimum contact time was found to be 120 minutes at an agitation speed of 170 rpm. The adsorption data were fitted to different isotherm model equation and the Freundlich model was found to be the best model for both metals i.e. Cu(II) and Zn(II) with R^2 values 0.984, 0.975 respectively. Increase in adsorption dose increased the adsorption of metals. The results showed that Prawn and Egg shells hold potential to remove cationic heavy metal species from industrial wastewater in the order Prawn shell < Egg shell.

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Environmental Pollution by FRP Composites and Plastics - A Study with Image Analysis

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ABSTRACT

One of the recent studies shows that a civilian has to spend about one third of his income to his/her health. The pollution in environment is responsible for most of the human ill health, other than hereditary problems most diseases are due to pollution. It's important to educate the people to keep up the health of individuals. The plastics, pollution from plastics, the burning smoke of plastics is causing lung and respiratory problems to humans. The new generation materials like FRP composites causes still more dangerous problems to human health. The study of photographs gives the conclusions of nature pollutants in house hold garbage.

Keywords: Image analysis, household garbage, FRP composites, human health

INTRODUCTION: PLASTIC AND FRP COMPOSITE POLLUTION

All the towns and cities are filled with plastic garbage, for example every day 40tons of plastic garbage is accumulating; to transfer them to a faraway place is becoming difficult to municipal authorities. These plastics are not degradable, so the garbage accumulates day by day, the places are filled completely. By the way of burning them, the harmful gases are evolving and the garbage is filling in drainage lines, ponds and other places, because of plastics, water is not soaking into the soil. By eating plastics the animal are dying with digestive system failure in them. The dead animals are not completely degraded because of the plastic in their stomach.

STATISTICS

Data of Hyderabad

Every day 40 tones accumulating, to collect them, 193 units are working every day, for recycling of plastics PCB pollution control board is gave permission for 209 units. From these With this, how many working is not known, but only 16 tons are recycled, remaining 26 tons is accumulating, this way every month 800 tons are accumulating in this way, in this not only plastics, cigar ends, water bottles, cool drink bottles, gutka pouches, ice cream, chocolate covers, flexi banners etc are in garbage.

Data of Warangal

per day about 230 tons of garbage comes out. 56 divisions are there, 42 tractors, 7 tippers, 8 dumpfacers,7 mini autos, are working every day, about 1000 thousand litres of disel is used every day. 400 push cots are used to collect the wet and dry garbage, with each cot one male and one female workers are there, each day the collect garbage from 250 to 300 houses., they send garbage to dump yards. Push cots submit garbage to a vehicle also.

Collection Management in Hyderabad

Hyderabad GMC had made report to procure, 800 pull cots, 429autos, 403dumper bins, 101 tractors, 34tppers, are needed, 11 biogas plants are to be prepared, 41 compost sheds are to be constructed, these will be purchased by central public health environment engineering organization under central government of India.\

1. **Chemical concern**

   (a) *Plastics*: The plastics damages human health, if plastics are burnt at 800 deg cen, the gives less harmful gases, but municipal works burn these plastics at less than100 deg cen, the diaxenes and furans are coming out, which are harmful to humans and animals.

   After filling the dump yards every day about 20 tons are being burnt, which is harmful

   (b) Vinyl Flexis: Vinyl fexi banners burning also very dangerous to human, poly vinyl chlorides, synthetic polymers, printing inks do not degrade easily, burning of flexi gives toxins, breathing of toxins is dangerous and causes lung cancers. Some acids also come out and mix in soil. Burning of PVC is still harmful. So PCB is thinking to relocate these recycling units to far way places.

   (c) Medical waste: Hyderabad is city of hospitals, medical waste is also important concern, medical waste includes bio waste, plastic disposals, saline bottles, tonic bottles, bandages, slides, these are harmful to humans.

Burning of garbage in an industrial area

Construction waste

Unsold rose flowers in dump yard

Plastic waste – thrown away glasses

Thrown away POP sheets

Burnt and unburnt FRP composite laminates

Banana leaves in garbage

Burnt glass fibers of FRP composites in soil

Broken Glasses of automobiles in an industrial area

Plastic garbage in open soil

BURNING THE GARBAGE

The garbage will be set fire, then there is no supervision .the burning will be continued to unending state, continuously smoke is evolved, roads are filled with smoke . Sudden uncontrolled fire may erupt. People will be getting lung diseases.Make people responsible to transport the garbage to the dump yards. People should be educated to not use plastics. The wet and dry garbage should separated in the house by people and submitted in the dump yard. From dry garbage separate plastics, glass bottles, should be separated and sold out. From wet garbage, bio gas can be obtained.

PROBLEMS

People are not properly educated, collecting staff do not attend regularly, garbage will be accumulated gives bad smells, spreads entire road, mixes with water, soil and causes pollution. The drainage will be filled with garbage and makes the drainage water will be stopped and causes many problems. The workers are not educated the consequences of accumulated garbage, shortage of man power etc. No co-ordination among the government agencies like municipality, public health and engineering departments. Absenteeism of workers due to many problems. Workers are not given proper tools like broom sticks, hand glosses, hats regularly. Age of worker is also important.

CONCLUSIONS

The images shows the different types of pollution, the plastics and FRP composites are responsible for the dangerous pollutions. Proper education should be given all citizens including municipal staff. The people should be made responsible to keep the garbage in the dump yards. Image analysis can give proper information about the garbage.

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Bi-metal Oxides Composites and their Pollution Scavenging Properties: A Glimpse

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ABSTRACT

Metal oxides nano-materials due to their diversified structural geometrical configuration and electronic modification are prominently dominate in the field of nanotechnology. Unique physical and chemical properties of oxide nanoparticles are mainly based on their little size and a high density of corner or edge surface sites. Particle size of any metal oxides plays a crucial role in determining their chemical and physical relativities. Single metal oxide possesses various oxygen-containing and hydrophilic (hydroxyl, Oxo) groups and, henceforth exhibits strong adsorption efficiency rather than traditional adsorbents. Such adsorption efficacy can be enhanced more executively with calculative incorporation of metal nanoparticles such as iron, aluminum, zinc, cerium, zirconium, gold, silver, chromium, manganese and others.In recent years, different form of bi-metal oxides composites namely Fe-Al, Mg-Al, Ce-Zr, Mg-Fe, Zr-Zn etc. are used as water purification media by utilising their adsorption potentiality. Metal oxides and their composites are explored and being upgraded to enhance their adsorption capability for a vast range of pollutants. The aim of this article is to focus on the usefulness of metal oxides nanocomposites and their pollutant scavenging properties, fluoride in particular.

Keywords: Fluoride, Metal oxides, Nanocomposites, Nanotechnology.

INTRODUCTION

Metal oxides are able to form diversified oxide compounds with unique physical and chemical characters. In general materials with particle size ranging between 1 nm to 100 nm are designated as nanocomposites. Particle size is thought as a crucial factor that effectively influences the basic properties of any chemical compounds. Classically bulk oxides pose very stable systems with well-defined crystallographic structures. Simultaneous decease in particle size directly affects the surface free energy; and stress with decreasing particle size must be considered. Thermodynamic stability associate with size is very important parameter in nanocomposites formation process. It is essential to maintain low surface free energy to ensure mechanical or structural stability of nanoparticles. It was observed that phases with low stability in bulk materials are become very stable in nanostructures (Samsonov et al., 2003; Zang et al., 2005). Synthesis procedures are considered as very important factor in formation of nanocomposites as it influence particle size which in turn causes structural alteration in nanomaterials. With decrease in particle size a strain is generated on the surface of materials that forced too little structural perturbation. These structural phases are very unique features of nanocomposites that generally not appear in bulk materials.

Electronic properties of nanocomposites are also determined by the particle size. Discrete, atom-like electronic states are responsible for generation of confinement effects in nanostructure. Quantum confinement is related to the energy shift of exciting levels and optical band gaps. Madelung field is an in connection with the electronic properties of a bulk surface; this field is generally absent or limited in a nanostructure oxide (Rodríguez and Hrbek 2010)

Chemical ionisation and covalence of metal oxide is directly proportional with particle size. Number of surface active groups is normally increased with development of nano range of metal oxides. Surface properties play a vital role in chemical reactivity of any chemical composites. Solid-liquid interaction mostly confined to the surface and/or sub-surface regions of the adsorbent. Metal oxides in bulk condition pose wide band gaps hence have low reactivity. Change in particle size change the magnitude of band gaps which in turn increase conductivity and chemical reactivity. Furthermore, the presence of under coordinated atoms like corners or edges or O vacancies in an oxide nanoparticle should produce specific geometrical arrangements as well as occupied electronic states located above the valence band of the corresponding bulk material, enhancing in this way the chemical activity of the system. This article entails the adsorptive properties of diverse metal oxides forms and their pollution scavenging properties in general with special emphasis on fluoride.

SYNTHESIS OF NANOSTRUCTURE METAL OXIDES – A CONCISE APPROACH

Morphological versatility of oxide nano-particles is basically depend on corresponding preparation methods; broadly described into two main streams liquid-solid and gas- solid transformation. A number of specific methodologies have been developed in recent years; among them co-precipitation method and sol-gel process are widely accepted. Achievement of nano size and physico-chemical homogeneity of mixed metal oxides is mainly determined by preparation procedure. In general co-precipitation occur by dissolving chloride, nitrate etc. salt precursor in water or in acid then precipitate oxy-hydroxide form with help of a base. Hydrolysis of alcoxides in alcoholic solution to form oxo-hydroxide is the baseline of sol-gel process. Condensation leads to the formation of a network of the metal hydroxide followed by polymerization form a dense porous gel. Proper drying and calcinations of prepared materials ensure fine porous oxide structure. Micro-emulsion technique, Solvothermal method, template methods are also most convenient method for the preparation of nano-materials in case of liquid-solid alteration . In context of gas-liquid transformation, for ultrafine powder synthesis, two methods are very common. They are Chemical Vapour Deposition (CVD) and Pulsed Laser Deposition (PLD). In process, heating of sample and instant evaporation, ionisation, decomposition leads to successive mixing of atoms. Production of uniform, pure, reproducible nanoparticles is the crucial point related with these methodologies. Scientific studies regarding structure and crystallisation of nano-particles reveal that both the features are not directly influenced by conventional nucleation and growth mechanism. Crystallisation proceeds either through single particle or through multiple particles nucleation. Prevalence of one of the mechanism is considered as a function of chemical composition of metal oxide and temperature.

FLUORIDE- ITS OCCURRENCE AND ENVIRONMENTAL IMPACT

'Fluorosis' both dental and skeletal is closely associated with elevated concentration of fluoride in drinking water. 'Second thoughts about fluoride', a published report in Scientific American in 2008, revealed the severity of fluoride poisoning (Fagin, 2008). Beneficial and detrimental effects of fluoride in human health are highly dependable upon its concentration in drinking water and also on the total amount water consumed. Desirable fluoride concentration in drinking water is in the range of 0.5-1.5 mg/L. Recommended fluoride concentration in drinking water is 1.5 mg/L (WHO 1985). Diversified geological, climatological, and topographical pattern influence the occurrence of fluoride in drinking water. The ultimate concentration of fluoride in groundwater largely depends on reaction times with aquifer minerals. High fluoride concentrations generated in groundwater with long residence time in the aquifers, deep aquifer in particular. Shallow aquifers has the chance of infiltration of rainwater, usually have low fluoride. Arid regions are prone to high fluoride concentrations. Here, groundwater flow is slow and the reaction times with rocks are therefore long. The fluoride contents of water may increase during evaporation if solution remains in alkalinity is greater than hardness and calcium content is low. (Alagumuthu et al.,2008; Chakrabarty et al., 2011; Das et al., 2003). Dissolution of evaporative salts deposited in arid zone may be an important source of fluoride. Fluoride increase is less pronounced in humid tropics because of high rainfall inputs and their diluting effect on the groundwater chemical composition (Frencken et al, 1992).

TECHNOLOGIES AVAILABLE FOR FLUORIDE REMOVAL

The Nalgonda technique is the most common defluoridation method used in developing countries like India for the treatment of fluoride rich drinking water. This technique is purely based on a two-step process with a combined use of alum and lime. Adequate quantities of alum, lime, and bleaching powder are added with raw water followed by rapid mixing, flocculation, sedimentation, filtration, and disinfection. Co-precipitation of fluoride with insoluble aluminium hydroxide flocs ensures fluoride removal from water. Addition of bleaching powder ensures disinfection during the process. The entire operation is carried out in "batch reactor", the defluoridation unit for small community (around 200 people) can be completed within 2–3 h (Ayoob et al., 2008).High residual aluminium concentration (2–7 mg/L) and high sulphate ion concentration (above 400 mg/L) in the treated water are the main disadvantage of this technique (Maheshwari et al., 2006).

Different membrane techniques such as reverse osmosis, ion exchange, and electro-dialysis have also been extensively studied for the defluoridation of drinking water. Highly pure grade water is generated by these techniques. The main limitations of these processes are the extensive installation and maintenance cost. Fouling, scaling, membrane degradation are the very common problems associated with membrane techniques.

Electrochemical techniques are mainly avoided due to their high cost both during installation and regular maintenance.

Though membrane separation techniques show successful reduction of fluoride in drinking water, surface adsorption process is widely accepted as defluoridation method in terms of cost, simple in functioning and operation. Different types of conventional and non-conventional adsorbents have established their potentiality for fluoride removal from water. The nature of fluoride adsorption on the surface of various adsorbents can broadly explain in three different steps (fan et al., 2003).

(i) Firstly the external mass transfer- In this step diffusion of fluoride ions from bulk solution to the external surface of the adsorbents takes place.

(ii) Next, the fluoride ions adsorptions on particle surfaces occur.

(iii) Chemical Structure of adsorbents plays a crucial role in this step. Fluoride ions either exchanged with the structural elements of adsorbents or fluoride ions diffused into the internal surface of absorbent materials.

Adsorption efficacy of an adsorbent is depended on some variables such as adsorption potentiality of adsorbent in dilute solution, solution pH, contact time for fluoride removal, regeneration, sludge disposal and loading capacity in presence of other cations and anions. All these parameters finally influence the cost of water treatment. As fluoride contamination in drinking water is a worldwide problem so the prime concern should be development an effective defluoridation technique with minimum cost because most of fluoride contaminated areas are poor communities dominated.

METAL OXIDE NANO-AGGREGATES, AN USEFUL DEFLUORIDATION MEDIUM – AN APPRAISAL

Various forms metal oxides and their composites are being increasingly explored by scientists across the globe to upgrade their adsorption efficiency. In last few decades, strong emphasis has been given to various metal oxide nano-composites, as cost effective adsorbent and extensively prepared and examined in a wide array at lab based conditions to establish their efficacy to act as a fluoride scavenging media. It is experimentally established that multivalent cations like Al, Fe, Zr, Ce, Ti, Mg, Zn etc.((Biswas et al., 2009; Jiao et al., 2002) show strong affinity towards fluoride ion. Adsorption performance of metal oxide nano-aggregates is highly dependable on the porous structure and presence of hydroxyl groups in their structure (Ghosh et al., 2014). To make the composite more cost effective, in most of the reported nano-aggregates iron is selected as base material (Biswas et al., 2009; Biswas et al., 2010; Zhao et al., 2012; Biswas et al., 2007&2008). Natural abundance on earth crust and natural pollution scavenging property of iron raises its acceptance as base element. Metals such as zirconium, cerium, aluminium, tin, lanthanum, magnesium, manganese are experimentally proven to possess strong affinity to form chemical linkage with fluoride (.Ghosh et al., 2014; Chang et al., 2011; Liu et al., 2010; Deng et al., 2011). Integration of these metals into iron accentuates the adsorption efficiency and makes these nanocompsites a promising medium for defluoridation. Characterisation of nano-materiasl is an important aspect and plays significant role in determining the adsorption efficacy and mode of application of nanocomposites in defluoridation.

REMARKS

Pure and safe drinking water is the elixir of life and forms the lifeline of existence. Availability of good quality drinking water is the basic need of all human beings on earth. But millions of people worldwide are deprived of this vital natural resource. Safe water for all can only be assured when access, sustainability, quality and equity are guaranteed. Fluoride contamination (>1.0 mg F L^{-1}) of drinking water is one such problem worldwide that has assumed the face of a burning environmental issue and cast its toll heavily on poor rural population. Development of cost effective, environmental friendly domestic filtration units based on synthetic fixed bed media packed with metal oxide nano-aggregates can serve as long term solution to this problem. Bi-metallic or poly metallic nano-crystallites have recently drawn strong attention for their efficacy as filter medium on domestic scale. The aim of this research is, therefore, to ensure design and development of innovative bed packed filter unit for treatment and supply of fluoride free drinking water to the poor fluoride affected population in India, particularly in West Bengal at an affordable price. The poor villagers of affected areas are now being forced to drink fluoride contaminated water in absence of any other safe source and, in the process, have developed chronic symptoms of fluorosis in their physiological manifestations. Installation of filter medium in domestic scale will help to redress the physiological status of the fluoride affected victims and bring them to the socio-economic mainstream.

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Effect of Cow Dung based Fly Ash Composite on Eco-friendly Bricks and Flower Pots

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ABSTRACT

Conservation and effective utilization of by-products and wastes plays an important role in developing a green and healthy environment. Effective utilization of Fly-ash along with Cow-dung, clay and coconut fibre for the manufacture of flower pots and bricks not only solves the problem of disposal of waste but also paves way for the production of low cost and light weight bricks and flower pots. These materials (Cow-dung, Fly-ash, clay, coconut fibre) were mixed and the strength of the composite material was found for different proportions. Cost analysis is also carried out. Among all the proportions, the composite with 30% fly ash, 30% clay, 1% coconut fibre by weight of cow dung showed an optimized result both in terms of strength and also cost. Bricks are made for different proportions and were tested for compression test and water absorption. The specimen with 30% fly ash, 30% clay and 1 % coconut fibre of the weight of cow dung was found to have better compression strength and lesser water absorption values.

INTRODUCTION

Eco Friendly Bricks: As the population is increasing day by day the need of shelter is also increasing. This marks huge need for construction materials like bricks. Now-a-days we are using conventional clay bricks in most of the places. The making of these clay bricks leads to devastation of many quarries and also results in lot of pollution due to burning of bricks. So there is a need to find alternative materials for making bricks. Fly ash and cow dung are one such material which may become a better substitute to make bricks as they are eco friendly. Unlike clay bricks, there is no need of burning, and hence there is no pollution. This process does not involve any energy consumption.

Cow Dung Composite Flower Pots: In nurseries, conventionally plastic bags are used to grow the plant saplings. There are many disadvantages associated with the plastic bags like not being bio-degradable, having nil porosity, and hence not being eco friendly. Moreover, after germination, the bag has to be torn off to facilitate root growth and in case the bag is not properly the plant gets damaged. So there is a necessity of making earthen pots which is Bio-Degradable so that there is no necessity of plastic bags and saplings can be grown in these pots. Cow dung is a natural fertiliser which is used to improve the growth of plants. Fly ash is a material which improves fertility and productivity of the soil.

MATERIALS USED

Cow Dung: Cow dung was procured from local village at the rate of Rs 1.5 per Kg.

Fly Ash: Class C fly ash was used which was procured at the rate of Rs 2.5 per Kg. Fly ash adds to the strength of the composite on a whole and it also improves soil fertility and productivity.

Clay: Clay was procured from a local village at the rate of Rs 2 per Kg.

Coconut Fibre: Fibre is removed from dry coconuts and is estimated to cost about Rs 2 per Kg.

METHODOLOGY

Cow Dung Composite Flower Pots: Pots of 18cm diameter and 20 cm height were prepared using different proportions of fly ash, raw cow dung, clay and coconut fibre as mentioned in table 1. The specimens were allowed to dry in air for a period of 10 days. Due to the porous nature of the materials used to make these pots, there is a possibility of water leakage from the pots. After drying, basal plant (holy tulasi) was grown in these pots for growth comparison with a plant grown in ordinary clay pot.

Cylindrical Specimens: Cylindrical specimens of 9 cm diameter (D) and 18 cm height (L) with different proportions of fly ash, clay, cow dung, coconut fibre were prepared to find the split tensile strength of the specimen. These specimens were allowed to dry in air for a period of 10 days. Split tensile strength of the cylindrical specimens was found.

Table 1 Different compositions showing the percentage of materials used with respect to weight of cow dung for cylindrical Specimen

Specimen no.	Flyash	Clay	Coconut fibre
1	10%	-	0.5%
2	20%	-	0.75%
3	30%	-	1%
4	-	10%	0.5%
5	-	20%	0.75%
6	-	30%	1%
7	10%	10%	0.5%
8	20%	20%	0.75%
9	30%	30%	1%

Cow Dung Composite Bricks: For the compositions mentioned in below table, bricks were casted and were allowed to dry in air for a period of 6 days and were checked for compression and water absorption. The best proportion both in terms of cost and strength was found.

Table 2 Different compositions showing the percentage of materials used for brick specimen

Specimen No	Composition of specimen
1	10% fly ash,10% clay, 1% fibre of the weight of cow dung
2	20% fly ash,20% clay, 1% fibre of the weight of cow dung.
3	30% fly ash, 30% clay, 1% fibre of the weight of cow dung.
4	30% fly ash, 30% clay of the weight of cow dung without any fibre

TESTS AND RESULTS

Split tensile strength test for cylindrical specimen: Split Tensile Strength = 2P/(ΠDL)

Table 3 Split tensile strength of specimen with cow dung, fly ash & coconut fibre

Specimen no	Flyash	Coconut fibre	Peak load (p) in (KN)	Split tensile strength in (N/mm^2)
1	10%	0.50%	6.5	0.255
2	20%	0.75%	7.6	0.298
3	30%	1.00%	8.9	0.349

Table 4 Split tensile strength of specimen with cow dung, clay & coconut fibre

Specimen no	Clay	Coconut fibre	Peak load (p) in (KN)	Split tensile strength in (N/mm^2)
4	10%	0.50%	4.9	0.192
5	20%	0.75%	5.4	0.212
6	30%	1.00%	5.6	0.220

Table 5 Split tensile strength of specimen with cow dung, fly ash, clay & fibre

Specimen no	Fly ash	Clay	Coconut fibre	Peak load (p) in (KN)	Split tensile strength in (N/mm^2)
7	10%	10%	0.50%	6.2	0.243
8	20%	20%	0.75%	7	0.275
9	30%	30%	1.00%	8.6	0.337

The above expressed percentage is the weight of the material with respect to the weight of the cow dung.

Compression Strength Test For Bricks:

Table 5 Compression test values of bricks

Specimen no	Peak load in KN	Compression strength in N/mm^2
1	11.6	0.7
2	19	1.1
3	25	1.5
4	32	1.9

Water absorption test for bricks:

Table 6 Water absorption values of bricks

Specimen No	Dry weight (W_1) in kg	Wet weight (E_2) in kg	Water absorption in (%) $[(W_2\text{-}W_1)/W_1]*100$
1	1.24	1.59	28.22
2	1.20	1.49	24.16
3	1.15	1.41	22.60
4	1.17	1.39	18.80

RATE ANALYSIS FOR POTS AND BRICKS

Rate Analysis for Pots: it is found that the cost of these pots on an average is around Rs 12, whereas clay and cement pots of same dimensions are being sold at the rate of Rs 40 and Rs 75 respectively.

Rate Analysis for Bricks: It is found that average cost of these bricks is around Rs 3, whereas conventional clay bricks are being sold at a rate of Rs 7.

INFERENCE AND DISCUSSION

Cylindrical specimen: As the amount of fly ash ,clay and coconut fibre is increased in the specimen, the peak load and the split tensile strength of the specimen is also observed to increase. But the value of the split tensile strength is more in the specimen with 30% fly ash and 1 % fibre when compared to all other specimen. From the rate analysis, it is found that specimen with 30% fly ash, 30% clay and 1% coconut fibre has a least cost when compared to the specimen with 30% fly ash and 1% fibre. So in order to find the optimised value, the specimen composite with 30% fly ash, 30% clay and 1% coconut fibre was selected as the ideal one for making the pots since it has got good strength and also low cost.

Growth comparision of plant grown in cow dung composite pot and ordinary clay pot: In order to compare the growth of plants, **Basal plant** (Tulasi) was grown in the cow dung pots made of the above optimised composite and an ordinary clay pot. Samplings were planted at the same time and are exposed to ordinary daily climatic conditions. They were watered daily and were kept under observation for 25 days. It was observed that plant in the cow dung pot had a better growth when compared to the other. It is recommended that the pot made up of cow dung composite, is coated with cement milk on its outer surface so that it acts as water proof and also improves the strength.

Fig. 1 Growth comparison of plants

Compression Strength of Bricks: From the above results it can be inferred that as the amount of replacement of fly ash and clay in the cow dung is increased, the compressive strength of the brick is also increased. There is a significant difference in the compression strength of the specimen with coconut fibre and without coconut fibre. So, the addition of coconut fibre improves the strength of the composite on a whole. The brick with 30% fly ash, 30% clay, 1% coconut fibre of the weight of cow dung has got a better strength when compared to all other specimen.

Water Absorption of Bricks: As per IS 1077 : 1992 , water absorption shall not be more than 20 percent by weight. Specimen 4, i.e. the specimen having 30% fly ash, 30% clay, 1% coconut fibre of the weight of cow dung satisfies above condition. Taking both compression strength and water absorption into consideration, the specimen having 30% fly ash, 30% clay, 1% coconut fibre of the weight of cow dung is found to be a ideal composite for making bricks.

CONCLUSION

Earthen Pots: The pots with 30% fly ash, 30% clay , 1% coconut fibre of the weight of the cow dung has got a better strength and also less cost when compared to other pots.In nurseries and gardens where conventionally plastic bags are being used to grow the saplings, these pots find application because of its eco friendly and bio-degradable nature. Moreover, growing of samplings in these pots improve the growth of the pots as cow dung acts as a natural fertiliser and also helps in getting maximum germination. In educational, industrial and work places, where plants are grown for decorative purposes, these cow dung pots find a major role as it is cheap and eco friendly. Now a day's roof gardening is gaining lot of significance and importance. In these places these pots will be better substitute for clay and cement pots.

Fig. 2 Cow dung pots for roof gardening

Cow dung composite bricks: From all the results, it is found that bricks with 30% fly ash , 30% clay, 1% fibre of the weight of the cow dung has got a strength of nearly 2 MPa and water absorption less than 20%.So these bricks are recommended for constructing Partition walls, Garden walls, Low economy houses, Surface terracing for horticulture estates. Though these bricks have less strength (2MPa) when compared to conventional clay bricks of class 3.5 (3.5MPa), these bricks are of lesser cost, lesser weight and can be used in places where the load subjected to is less. There is a possible employment generation through local manufacturing and sourcing of these cow dung cups and bricks.

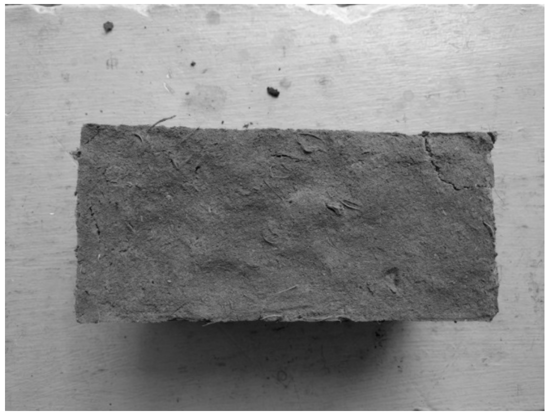

Fig. 3 Cow dung composite bricks

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Water Resources Development under Climate Change Scenario

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ABSTRACT

Water resources can be developed by adopting the concept of catchment management. For this purpose every piece of land should be treated as a micro-catchment and *in-situ* rainwater conservation techniques should be adopted. Strategies of water conservation and management in arable lands should be planned and adopted. On arable cropped lands with very shallow, shallow medium deep and deep soil cover; contour cultivation is recommended to achieve higher crop yield and *in-situ* rainwater and soil conservation. The fields having the slope in one direction at least the sowing and cultivation across the slope needs to be adopted. Development of good perennial vegetation systems on degraded lands is possible with CCT's layout. Adoption of CCT layout at 5-6 m horizontal interval (H.I.) resulted in 97 per cent *in -situ* rainwater conservation. The farm pond technology for rainwater harvesting and its reuse should be adopted by constructing farm ponds / dug-outs at suitable locations. With these techniques the maximum amount of rainwater will be recharged into the ground and ultimately the water resources development is possible.

Keywords: *in-situ*, rainwater, resources.

INTRODUCTION

In India, water is a limiting factor in larger area, particularly in the 80 Mha drylands out of 141 Mha cultivated area in the country. With uneven and low quantum of rainfall, often it is a challenge to dryland farmers to cope up for higher productivity under limited or no irrigated conditions. If adequate water is available, farmers would try to apply higher levels of irrigation whereas crop is lost frequently where water is not reaching. Therefore, we need to understand the crop water requirements in relation to energy and water availability for increasing crop productivity in these drylands. Due to its multiple benefits and the problems created by its excesses, shortages and quality deterioration, water as a resource requires special attention. *In-situ* soil and water practices can be useful for rainwater conservation and may increase the overall soil moisture regimes of the treated area due to this the infiltration of rainwater into the deeper soil layers will increase and ultimately the water availability in crop root regimes will also be more. This will lead to augmentation of water resources in the areas where these practices are being adopted.

MANAGEMENT OF WATER RESOURCES

The National Mission on Water will be mounted to ensure better integrated water resource management. This would lead to water conservation, less wastage of water, equitable distribution of water. The mission will also come out with a framework to improve water efficiency by 20%, through regulatory and pricing mechanisms. It sees the issue of groundwater management and use as important. It is necessary to study the management of surface water as it not only indicates the status of the environment but also has huge economic impacts. Improving water storage capacities and protecting wetlands form an important aspect that will be looked into by this mission. Therefore there is an urgent need to take up the artificial recharge of the rain for which water harvesting and water conservation structures are to be build up in large scale (Sivanappan, 2006).

Strategies of Water Conservation and Management in Arable Lands

A) ***Preventive measures***

Crop management: Early planting, adequate stand, crop rotation, multiple cropping, strip cropping, balanced fertilizer application, use of organic farming and agroforestry.

Water conservation through soil management: Mulch farming, conservation tillage, rough seed bed, contour cultivation, ridge furrow system of planting, formation of tie ridges and soil conservation systems

B) ***Control measures***

a. ***Slope management through***

(i) Terracing

(ii) Contour bunds

b. ***Runoff management through***

(i) Surplus water disposal structures

(ii) Grassed Waterways

(iii) Soil Conservation structures

(iv) Rainwater harvesting

RESULTS AND RECOMMENDATIONS

At the experimental farms of Dr. PDKV, Akola Agriculture University the various research experiments of *in-situ* rainwater conservation had been conducted. Based on the results of some of these experiments, following recommendations has been made. These recommendations are useful for water resources development.

A. *Rainwater management*

1. For reducing runoff and soil loss and increasing crop productivity, vegetative key line of *Vetiver* or *Leucaena* should be developed on contours and cultivation should be done along the vegetative key lines on contour.

   Impact : Uniform moisture distribution due to contour cultivation gave higher productivity in case of test crops i.e. sorghum and cotton to the extent of 15 and 20%, respectively.

2. For obtaining high monetary returns and soil and moisture conservation on slopey field (up to 3% slope), it is recommended to take soybean-chickpea double cropping on 30% area of lower topo-sequence in place of sole cotton under cotton based cropping system in dryland condition.

   Impact : The strip of soybean – chickpea reduced the runoff and soil loss to the extent of 24 and 20 per cent, respectively as compared to cotton under lower toposequence.

B. *In-situ soil and water conservation measures*

The results obtained by adopting the different in-situ soil and water conservation measures are ,

1. On arable cropped lands with very shallow, shallow medium deep and deep soil cover, contour cultivation along vetiver hedge at 1 m VI is recommended to achieve higher crop

   yield and *in-situ* rainwater and soil conservation.

2. The fields having the slope in one direction at least the sowing and cultivation across the slope needs to be adopted.

3. Development of good perennial vegetation systems on degraded lands is possible with CCT 's layout. Adoption of CCT layout at 5 – 6 m horizontal interval (H.I.) resulted in 96 per cent *in -situ* rainwater conservation.

4. In graded bunded field one *Vetiver* line at the center of adjacent graded bunds is developed which helps in reducing runoff and soil loss. The vegetative bund established within three season and there is no need to rehabilitate the graded bund.

   Impact : The *Vetiver* barriers get well established within three seasons and takes care of soil and water conservation and reduces applicability of the graded and hence, the cost of rehabilitation of the graded bunds can be reduced which has to the carried out every year.

5. For *in situ* soil moisture conservation and increased seed cotton yield it is recommended to open furrows after every two rows of cotton at 30 to 35 days after sowing, furrows are to be opened by hoe.

C. *Rainwater Harvesting*

Farm Ponds: Scientific management of water conservation techniques such as water harvesting and moisture conservation can maximize productivity and increase water use efficiency of different agronomical crops. During drought years, supplemental irrigations at critical stages may be essential not only to prevent mortality of crops but also to maintain a required vigor for normal productivity. In Vidarbha region of Maharashtra State and most part of the country, occurrence of high intensity rainfall events may results in floods. In these areas dry spells even within the monsoon periods are not uncommon, resulting in fluctuation in crop production. In these areas it would be wise to harvest the runoff water for supplemental irrigation to different agronomical crops by constructing farm ponds to store and recycle it. Farm ponds hold great promise as a life saving device for rainfed crops in the areas characterized by low and erratic rainfall. The stored pond water can be used as protective irrigation during critical stages of crop growth depending upon the crop water requirement and availability of water.

Types of Farm Pond: The ponds are mainly of two types. One is embankment type and other is dug out type. The embankment type pond is constructed across streams/ravines and big gullies in order to impound certain quantity of runoff water which will otherwise find its way to rivers. The impounded water infiltrated into subsoil and recharges the groundwater table. The excess runoff is collected in dug out farm pond and the stored water can be used as a supplementary irrigation to the crops grown in adjoining areas.

Dimensions of farm ponds for different catchments at AICRPDA centre : Based on the runoff from three catchments, the capacity of the farm pond has been decided at AICRPDA, Akola. Accordingly the location for construction of the farm pond had been chosen and the dimensions were decided and construction of three farm ponds for three different catchments was done and the details are given in Table 1.

Table 1 Dimensions of farm pond

Farm pond no.	Catchment area (ha)	Capacity (cum)	Top dimensions (m x m)	Bottom dimensions (m x m)	Depth (m)	Side slopes
1	3.5	2753	45 x 27	36 x 18	3.0	1.5:1
2	5.0	4265	60 x 30	51 x 21	3.0	1.5:1
3	2.0	370	18 x 11	12 x 5	3.0	1:1

Use of harvested farm pond water

1. 2013-14 (*Rabi*)

During the rabi season 2013-14, the storage was there in the farm pond and the protective irrigations of 50 mm depth were given to chickpea and the recorded yield of chickpea with protective irrigation and without protective irrigation are given in Table 2. The highest yield (717 Kgha^{-1}) was recorded in the treatment irrigation of 50mm depth at flowering stage with sprinkler set from stored pond water (T_2) followed by the treatment irrigation of 50mm depth after sowing with sprinkler set from stored pond water (T_1) and no irrigation treatment (T_3).

Table 2 Yield of chickpea

Treatments	Yield, Kgha^{-1}	Increase in yield over T_3 (%)	RWUE (kg/ha-mm)
T_1(protective irrigation of 50 mm depth on 8.11.2013)	583	18.25	1.17
T_2 (protective irrigation of 50 mm depth on 12.12.2013)	717	45.43	1.43
T_3 (No irrigation)	493	-	0.98

2. 2014-15 (*Kharif*)

During the *kharif* season 2014, the total rainfall received during the crop growing period was 570.0mm. Two major runoff events has been occurred in the season which has resulted in rainwater harvesting in the farm pond. From the stored farm pond water the supplemental irrigation for soybean crop has been given. The recorded yield of soybean with different treatments is given in Table 3. It was observed that the treatment T_2 have recorded better yield as compared to other treatments.

Table 3 Effect of supplemental irrigation through farm pond on yield and its economics

Treatments	Yield (kg/ha)		Increase in yield over T_3 (%)	RWUE (kg/ha-mm)	B:C ratio
	With irrigation	Without Irrigation, T_3			
T_1 (One protective irrigation)	474	422	12.32	0.83	1.03
T_2 (Two protective irrigation)	1021	422	141.94	1.79	2.20

3. 2014-15 (*Rabi*)

During the *rabi* season 2014-15, the stored farm pond water was used for supplemental irrigation to different vegetables by using micro-irrigation systems. The details of vegetables alongwith irrigation system used, yields and water used is given in Table 4. It was observed that in the vegetable crops like lady's finger, cow-pea, ridge gourd, Indian round gourd (demshe), brinjal, spinach and fenngreek (methi) the water use efficiency was in the range of 1.03-4.35 kg/m^3. The total income from these small vegetables plots during the season 2014-15 is Rs. 7575/-. The total income from these vegetables is computed to be Rs. 78,092/ ha.

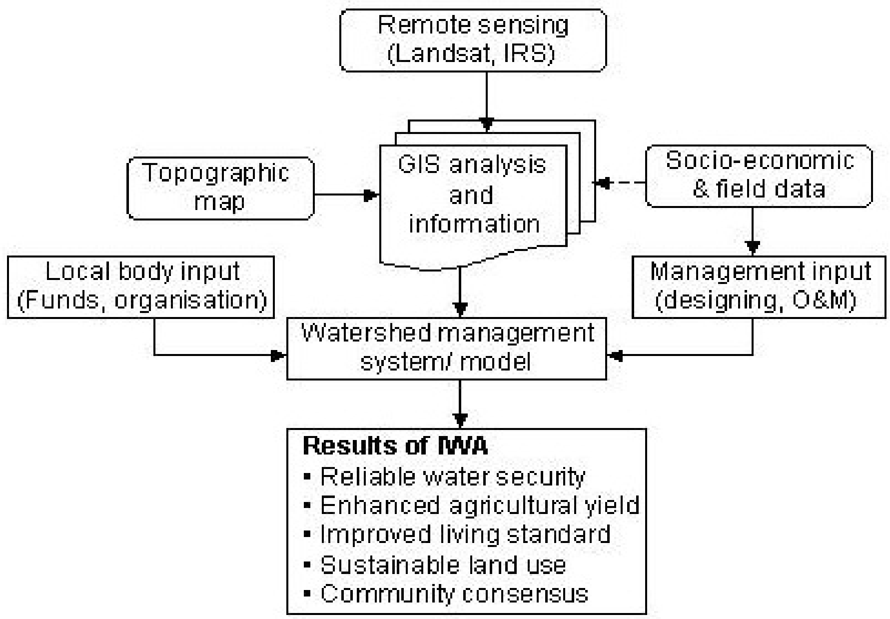
Table 4 Irrigation through micro-irrigation system from farm pond for different vegetable crops

Crop	Irrig. system	Total water applied through MIS (m^3)	Plot Area (m^2)	Yield (Kg/plot)	Computed Yield (Kg/ha)	Net Income (Rs/ha)	B:C ratio	Water use efficiency, Kg/m^3
Lady's Finger	Micro-sprinkler	21.60	280	94.00	3357.0	25638.0	1.94	4.35
Cowpea	Inline drip	7.0	100	15.00	1500.0	10627.0	1.89	2.14
Ridge Gourd	Inline drip	7.0	100	12.75	1275.0	9600.0	1.60	1.82
Indian round gourd (Demshe)	Inline drip	7.0	100	12.50	1250.0	3950.0	1.26	1.78
Brinjal	Micro-sprinkler	13.20	150	57.25	3817.0	15953.0	1.86	4.33
Spinach	Inline drip	14.70	120	27.00	2250.0	8167.0	1.83	1.84
Fenngreek /Methi	Inline drip	12.60	120	13.00	1083.0	4157.0	1.62	1.03

Harvesting of rainwater is of utmost important. Judicious mix of ancient knowledge, modern technology, public and private investment and above all, people's participation will go a long way in reviving and strengthening water harvesting practices throughout the country. Availability and storage of water in reservoirs and lakes depends ultimately on yearly rainfall. Natural conservation of water and efficient use of this natural storage and at the same time making arrangements for additional recharge of groundwater aquifer by one way or other, to replenish the used groundwater becomes our responsibility.

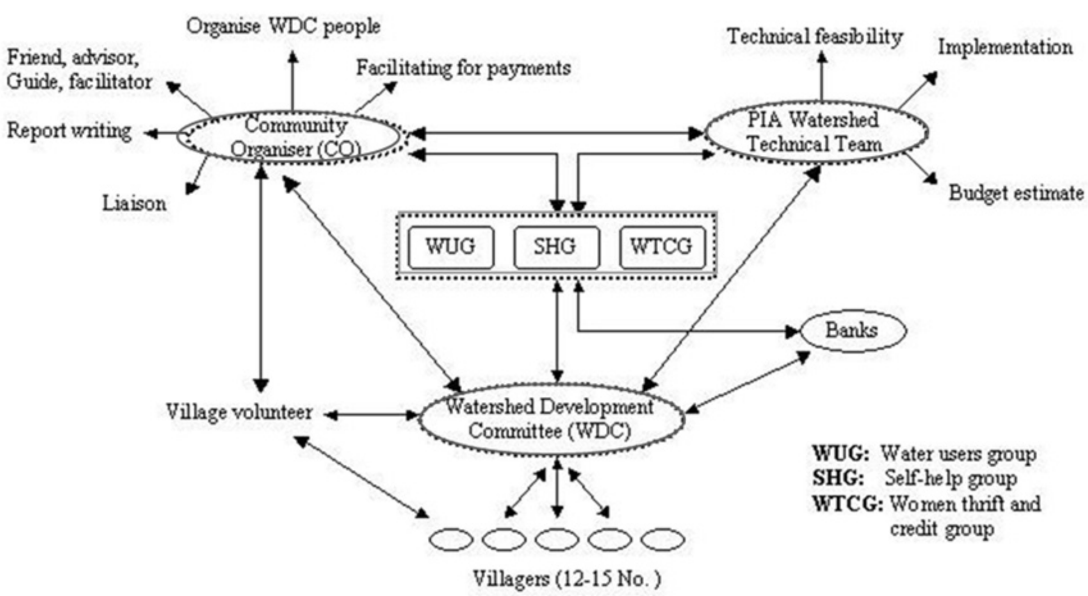
International Water Association – Modeling through Advanced Technologies

The flow chart of IWA through advanced technologies is given below.



Community participation and local capacity building

For peoples participation and integrated watershed management the following flow chart is useful for development of water users association.



CONCLUSION

Climate change will burden irrigation due to precipitation variability. Dryland farmers need techniques, technologies and investments that improve water management efficiency. Technologies and management methods exist to increase irrigation efficiency and reduce problems of soil degradation, but we lack economic incentives to reduce wasteful practices. Tillage method and incorporation of crop residues are other means of increasing the useful water supply for cropping. Increased precipitation and more intense precipitation will likely mean that some areas will need to increase their use of drainage systems to avoid flooding and water-logging of soils.

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Effect of Growth Regulators on Flower Regulation in Mango Var. Pairi

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ABSTRACT

The study was undertaken for three years during 2010-11 to 2012-13 on 15 years old mango trees of Pairi variety at Main Garden, Department of Horticulture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola for induction of regular bahar in mango. The treatments were consisted of Cycocel - 2500, 5000, 7500 ppm, KNO_3 -0.5 %, 1.0 %, 1.5 %, Ethrel- 200 ppm, 300 ppm and Control and replicated trice. Chemicals of different concentrations were sprayed in the first fortnight of October (one month before the fruit bud differentiation). Cycocel -2500 ppm sprayed in the month of October recorded maximum fruit set per cent (2.11 %) and highest yield in terms of number (585.11 numbers) and weight (160.71 kg / tree). While, Minimum number of days required for initiation of flowering (45 days) recorded by KNO_3-0.5 %, longest of flower panicle (46.11 cm) recorded by KNO_3-1.5 % and maximum number of panicle per tree (746.33) recorded by KNo_3-0.5%.

Keywords: Mango, Growth Regulators, Flowering and yield.

INTRODUCTION

Biennial bearing is one of the most burning problems in mango since it renders less remuneration to the growers. Most of the commercial varieties of mango flowers in alternate years and the habit set in only after age of 10-12 years after planting. Early flowering is the demand of the mango growers. Early arrival of the fruits in market fetches good price for mango. With a view to regulate and early fruiting in mango, an experiment was conducted with variety Pairi.

MATERIALS AND METHODS

The study was undertaken for three years during 2010-11 to 2012-13 on 15 years old mango trees of Pairi variety at Main Garden, Department of Horticulture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola for induction of regular bahar in mango. The treatments were consisted of Cycocel - 2500, 5000,7500 ppm, KNO_3 -0.5 %, 1.0 %, 1.5 % , Ethrel- 200 ppm, 300 ppm and Control and replicated trice. Chemicals of different concentrations were sprayed in the first fortnight of October (one month before the fruit bud differentiation). Observations were recorded on days required for flower inintiation, length of flower panicle, number of panicles per tree, Fruit set (%) and number of fruits per tree and average yield per tree in kg.

RESULTS AND DISCUSSION

It is revealed from the pooled data presented in Table 1 that the days required for flower initiation after spraying, length of flower panicle (cm), number of panicle per trees, fruit sets (%), average yield per tree were significantly influenced by different chemical treatments in mango var. Pairi during three seasons of experimentation (2010-11 to 2012-13).

Table 1 Days required for flower initiation after spraying

Treatments	2010-11	2011-12	2012-13	Pooled mean
Cycocel-2500 ppm	102	86	83	90.33
Cycocel-5000 ppm	60	60	57	59.00
Cycocel-7500 ppm	50	47	51	49.33
KNO_3 – 0.5%	48	42	45	45.00
KNO_3 – 1.0 %	54	53	47	51.33
KNO_3 – 1.5 %	117	92	94	101.00
Ethrel – 200 ppm	90	88	87	88.33

Contd…

Treatments	2010-11	2011-12	2012-13	Pooled mean
Ethrel – 300 ppm	70	68	63	67.00
Control	98	114	102	104.66
S.E.(m) $\pm$	5.15	5.10	4.45	3.59
CD at 5%	15.41	15.26	13.32	10.73

The pooled data indicated that the early flowering was noticed in the trees sprayed with KNO_3-0.5 % (45 days) as compared to other treatments except the spraying of Cycocel-7500 ppm (49.33 days) and KNO_3 -1.0 % (51.33 days). While the trees sprayed with water (Control) took maximum days (104.66 days) for initiation of flowers on the trees. Regarding Ethrel, the tree sprayed with 300 ppm bears flower earlier than 200 ppm.

Application of KNO_3 and cycocel known for anti-gibberellins role causes effective translocation of carbohydrates with the positive effect of Cytokinins and auxins in the conversion of vegetative bud to flower bud. Growth retardants had anti-gibberellins effect, which in terms checked vegetative growth and promote early flowering. The vegetative growth have antagonistic effect on flowering, thus duration of flowering may reduce down. These results are in accordance with results of Monselise *et al.* (1966) in lemon, Maiti *et al.* (1971) in mango and Nir *et al.* (1972) in Eureka lemon with application of cycocel.

Table 2 Length of flower panicle (cm)

Treatments	2010-11	2011-12	2012-13	Pooled mean
Cycocel-2500 ppm	31.40	30.20	30.90	30.83
Cycocel-5000 ppm.	29.50	29.80	30.46	29.92
Cycocel-7500 ppm	31.10	30.00	30.32	30.14
KNO_3 – 0.5%	35.00	35.00	35.33	35.11
KNO_3 – 1.0 %	31.00	30.10	30.80	30.63
KNO_3 – 1.5 %	47.00	46.00	45.33	46.11
Ethrel – 200 ppm	36.80	36.60	36.93	36.77
Ethrel – 300 ppm	34.30	32.20	33.26	33.25
Control	28.00	27.30	27.13	27.47
S.E.(m) $\pm$	2.87	1.44	1.32	0.28
CD at 5%	8.57	4.30	3.94	0.85

From the Table 2 it is observed that, the trees sprayed with KNO_3-1.5 % produced the longest flower panicle (46.11cm) which was significantly superior to other treatments. Cycocel 2500 ppm (30.83 cm) and Ethrel 200 ppm (36.77 cm) produced longer panicles as compared to higher concentrations of Cycocel and Ethrel. These results are in accordance with results of Nir *et al.* (1972) observed stimulated vegetative growth with 1000 ppm cycocel in Eureka lemon.

Table 3 Number of panicles per tree

Treatments	2010-11	2011-12	2012-13	Pooled mean
Cycocel-2500 ppm	620	542	530	564.00
Cycocel-5000 ppm.	598	272	260	376.66
Cycocel-7500 ppm	632	425	412	489.66
KNO_3 – 0.5%	831	710	698	746.33
KNO_3 – 1.0 %	830	480	468	592.66
KNO_3 – 1.5 %	853	360	348	520.33
Ethrel – 200 ppm	653	453	441	515.66
Ethrel – 300 ppm	535	248	240	341.00
Control	520	124	110	251.00
S.E.(m) $\pm$	91.45	34.22	31.75	44.63
CD at 5%	--	102.29	94.93	133.41

Gur *et al.* (1976) found increased shoot length of apple tree in spring season with foliar application of potassium nitrate.

The highest numbers of panicles were produced by the trees sprayed with KNo_3-0.5% (746.33) and this treatment was significantly superior to rest of the treatments. The minimum number of panicle per tree was recorded in control. Cycocel concentrations produced little bit lower number of panicles. Similar results were obtained by Rojas and Leal (1994) in mango cv. Haden when sprayed with 6 % KNo_3 significantly increased percentage of flowering shoot, number of mixed panicle and vegetative shoots/auxiliary branch. Leonal and Rodriques (1994) noted that the application of KNo_3 in different combination of 1 and 2 per cent resulted in best seedling growth of citrus species.

Table 4 Fruit sets (%)

Treatments	2010-11	2011-12	2012-13	Pooled mean
Cycocel-2500 ppm	4.17 (2.04)	5.09 (2.25)	4.29 (2.06)	4.51 (2.11)
Cycocel-5000 ppm.	3.94 (1.97)	4.86 (2.20)	4.06 (2.00)	4.28 (2.05)
Cycocel-7500 ppm	4.10 (2.02)	5.02 (2.23)	4.22 (2.05)	4.44 (2.10)
KNO_3 – 0.5%	3.04 (1.74)	3.96 (1.98)	3.16 (1.77)	3.38 (1.83)
KNO_3 – 1.0 %	3.50 (1.86)	4.42 (2.09)	3.62 (1.88)	3.84 (1.94)
KNO_3 – 1.5 %	4.04 (2.00)	4.96 (2.22)	4.16 (2.03)	4.38 (2.08)
Ethrel – 200 ppm	2.19 (1.47)	3.26 (1.79)	2.46 (1.56)	2.63 (1.60)
Ethrel – 300 ppm	2.74 (1.64)	3.66 (1.99)	2.86 (1.68)	3.08 (1.77)
Control	2.00 (1.41)	3.11 (1.75)	2.31 (1.51)	2.47 (1.55)
S.E.(m) $\pm$	0.04	0.04	0.05	0.01
CD at 5%	0.13	0.14	0.16	0.05

(Figures in parenthesis are square root values)

The pooled mean in respect of fruit setting per cent showed that the spraying of Cycocel- 2500 ppm (2.11 %) except Cycocel- 7500 ppm (2.10 %), KNo3-1.5% (2.08) and Cycocel – 5000 ppm (2.05 %) treatments promoted the highest fruit set in mango than other treatments. Growth retardants had anti-gibberellins effect, which in terms checked vegetative growth and promote early flowering. The vegetative growth have antagonistic effect on flowering, thus duration of flowering may reduce down.

These results are in accordance with results obtained by Ahlawat and Daulta (1981) in grape, Daulta *et al.* (1981) and Maiti *et al.* (1971) in mango, Nath and Baruah (2001) in Assam lemon and Nir *et al.* (1972) in Eureka lemon with application of cycocel. During three years of experimentation (2000-01,2001-02 and 2002-03) it was seen that maximum fruit yield (585.11 number and 160.71 kg / tree) was obtained from the trees sprayed with Cycocel-2500 ppm which was significantly superior over the remaining treatments (Table 5 and 6). The minimum fruit yield (85.44 number and 26.84 kg /tree) was observed in control.

Table 5 Average yield per tree (Number)

Treatments	2010-11	2011-12	2012-13	Pooled mean
Cycocel-2500 ppm	563.00	605.33	587.00	585.11
Cycocel-5000 ppm.	492.00	524.33	483.00	499.77
Cycocel-7500 ppm	368.66	391.00	322.66	360.77
KNO_3 – 0.5%	248.00	265.33	252.66	255.33
KNO_3 – 1.0 %	301.66	324.00	298.33	307.99
KNO_3 – 1.5 %	435.00	390.66	402.66	409.44
Ethrel – 200 ppm	143.66	167.00	122.00	144.22
Ethrel – 300 ppm	199.00	121.00	235.33	218.44
Control	91.66	96.00	68.66	85.44
S.E.(m) $\pm$	39.96	42.52	21.07	10.59
CD at 5%	119.44	127.11	63.00	31.67

Table 6 Average yield per tree in weight.(Kg)

Treatments	2010-11	2011-12	2012-13	Pooled mean
Cycocel-2500 ppm	171.71	160.33	150.10	160.71
Cycocel-5000 ppm.	150.06	140.38	125.36	138.60
Cycocel-7500 ppm	114.28	105.13	88.46	102.62
KNO_3 – 0.5%	76.88	77.03	73.33	75.74
KNO_3 – 1.0 %	95.02	92.30	84.96	90.76
KNO_3 – 1.5 %	132.67	107.40	110.66	116.91
Ethrel – 200 ppm	47.41	48.63	35.50	43.84
Ethrel – 300 ppm	64.67	63.86	68.00	65.51
Control	31.16	28.80	20.56	26.84
S.E.(m) $\pm$	12.36	11.23	5.68	3.55
CD at 5%	36.96	33.59	16.99	10.63

The increase in yield might be due to more fruit set, fruit retention and ultimately more number of fruits per tree. These results are corroborated with the results of Mukhopadhyay (1976) in Langra and Baramasi mango and Daulta *et al.* (1981) in Dashehari mango.

CONCLUSION

Overall it can concluded that Cycocel -2500 ppm sprayed in the month of October recorded maximum fruit set per cent (2.11 %) and highest yield in terms of number (585.11 numbers) and weight (160.71 kg / tree). While, Minimum number of days required for initiation of flowering (45 days) recorded by KNO_3-0.5 %, longest of flower panicle (46.11 cm) recorded by KNO_3-1.5 % and maximum number of panicle per tree (746.33) recorded by KNo_3-0.5%.

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Trend and Variability in Evapotranspiration at Akola, Maharashtra

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ABSTACT

Akola is situated at in Vidarbha meteorological sub-division of Maharashtra State, India, with latitude/ longitude 20.7^0 N/77.0^0 E and altitude of 282 m AMSL. District falls in assured rainfall zone, and receives monsoon rains during June to September. The mean maximum and minimum temperatures of the district are 41^O C and 21^O C respectively. Historical weather data (1971-2015) for the study were taken from the Agromet observatory located at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. These records includes pan evaporation, air temperature, relative humidity, wind speed and bright sunshine hours. The weekly value of weather parameters recorded at Agromet observatory for 46 years were used in the study to work out the trend and variability in evapotranspiration at Akola, (MS). Evapotranspiration demands and trends were analyzed for Akola region in western part Vidarbha (Maharashtra) by assessing reference eapotranspiration (ETo), energy balance and aerodynamic components for 46 years (1971-2015). Analysis indicated multiple trends in annual ETo and annual aerodynamic component of ETo. Throughout the study period, a clear decreasing trend was notice with low ETo values. Meddle stage, the ETo started slight increase in trend with 1796 mm ETo it was observed in the year 1996. An energy balance component has shown a negative trend with the reduction in temperature and sunshine hours. Trends in average ETo values indicated a reduction in *kharif* season while the ETo increased in *rabi* season. Present study highlights the necessity to understand ETo of the region before planning and management.

Keywords: Crop reference evapotranspiration (ETo), actual evapotranspiration (ETa), maximum possible evapotranspiration (ETm).

INTRODUCTION

The mean earth temperature has changed by 0.74°C during 1906 – 2005. Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations. During last 50 years, cold days, cold nights and frost have become less frequent, while hot days, hot nights, and heat waves have become more frequent. The frequency of heavy precipitation events has increased over most land areas. Global average sea level rose at an average rate of 1.8 mm per year over 1961 to 2003. This rate was faster over 1993 to 2003, about 3.1 mm per year.

There are a few Indian studies on this theme and they generally confirm similar trend of agricultural decline with climate change. Recent studies done at the Indian Agricultural Research Institute indicate the possibility of loss of 4 – 5 million tons in wheat production in future with every rise of 1^oC temperature throughout the growing period (but no adaptation benefits). It also assumes that irrigation would remain available in future at today's levels. Losses for other crops are still uncertain but they are expected to be relatively smaller, especially for *kharif* crops. Pathogens and insect populations are strongly dependent upon temperature and humidity. Increases in these parameters will change their population dynamics resulting in yield loss.

Agricultural sector is one of the vulnerable sectors influenced by the rise in temperature, rainfall variability and climate change. Climate change is likely to alter crop durations, impact pest populations, hasten mineralization in soils, increase Evapotranspiration (ET) and bring in more uncertainities in crop yields. Demand for irrigation water is more sensitive to agricultural production as climatic variability increased dryness thereby creating more demand of water to fulfil crop growing period (IPCC, 2001). ET is a major component of hydrological cycle and maximum portion of total rainfall falling on land surface is returned to the atmosphere through ET. (Sankaranarayanan *et al.,* 2010).

A common practice for estimating evapotranspiration includes estimation of reference crop evapotranspiration i.e. grass reference evapotranspiration (ET_o), from a standard surface and use of an appropriate empirical crop coefficient which accounts for the difference between the standard surface and crop evapotranspiration (ET_c).

The concept of the ET_o was introduced to study the evaporative demand of the atmosphere independently of soil factors, crop type, crop development and management practices. ET_o values measured or calculated at different locations or in different seasons are comparable as they refer to the evapotranspiration from the same reference surface. The only factors affecting ET_o are climatic parameters. The Food and Agriculture Organization of the United Nations (FAO) Expert Consultation (1990) on revision of FAO methodologies for crop water requirements accepted the following unambiguous definition for the reference surface and evapotranspiration.

Reference crop Evapotranspiration (ETo) was determined at ICRISAT, Patancheru using FAO Penman Montenith equation using data for the period 1975-2009 and analysis showed that annual reference crop Evapotranspiration (ETo) has decreased during the period. Rate of reduction in ETo was about 10% for *kharif* and 14% for *rabi* seasons. Contribution of energy balance to the total ETo has shown negative trend while positive trend was seen for aerodynamic component (Rao and Wani, 2011). In the arid region of China, a study with dataset of 1955-2008 from meteorological stations indicated than ETo has shown a decreasing trend with wind speed as a most sensitive meteorological variable followed by relative humidity, temperature and solar radiation (Huo *et al.,* 2013). The present study is attempts to estimate the ETo and its components and to assess the trend in ETo and climate variability of Akola conditions.

MATERIALS AND METHODS

Akola is situated at in Vidarbha meteorological sub-division of Maharashtra State, India, with latitude/ longitude 20.7^0 N/77.0^0 E and altitude of 282 m AMSL. District falls in assured rainfall zone, and receives monsoon rains during June to September. The mean maximum and minimum temperatures of the district are 41^O C and 21^O C respectively. Historical weather data (1971-2015) for the study were taken from the Agromet observatory located at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. These records include pan evaporation, air temperature, relative humidity, wind speed and bright sunshine hours. The weekly value of weather parameters recorded at Agromet observatory for 46 years (1971-2015) were used in the study to work out the trend and variability in evapotranspiration at Akola, (MS).

Normal monthly climatic parameters at Akola are presented in Table 1. Average annual rainfall is about 788.8 mm with 41 rainy days. About 84 % of the annual rainfall is received during southwest monsoon season (Jun-Sept). Average relative humidity in the morning and evening were observed to be highest in August as it is the rainiest month with a rainfall of 204.8 mm. Maximum number of rainy days are 11 in the months of July. Bright sunshine varies from 3.8 to9.5 hours per day over the year with February –May experience above 9 hours of bright sunshine. July and August experience lowest, about 4 hours of sunshine due to cloud cover in monsoon season.

Daily reference crop ET was computed for 46 years using the FAO Penman-Monteith method (Allen *et al.,* 1998) as followed in CROPWAT model (2009) version 8.0 in which outputs are generated for component wise viz. energy balance and aerodynamic term along with daily ETo. Daily values of ETo and components were converted into monthly, seasonal and annual formats.

RESULTS AND DISCUSSION

ETo showed a decreasing trend throughout the study period as maximum temperature and sunshine hours also decreasing during this period with lowest ETo observed in the 2013 year (Fig. 1). ETo increased in the second period as wind velocity and rainfall also increased during 1997 to 2005 with highest value of 1758.6 mm observed in the 2002 year. Thomas (2000) worked on spatial and temporal characteristics of PET trend over China and reported that the wind speed, relative humidity and maximum temperature are primary factors to be associated with evapotranspiration changes in northwest, central and north-east China. A 10 % increase in temperature and actual vapour pressure coupled with 10 % decrease in net solar radiation could result in a marginal decrease of total ET by 0.30 (Goyal, 2004).

The energy balance component has shown negative trend with values ranging from 1309 to 1037 mm (Fig. 2). It showed a decreasing trend throughout the study period as sunshine hours also decreased continuously during this period. Analysis indicated multiple trends in annual ETo and annual aerodynamic component of ETo. Throughout the study period, a clear decreasing trend was notice with low ETo values. Meddle stage, the ETo started slight increase in trend with 1796 mm ETo it was observed in the year 1996. After 2000, wind velocity and rainfall observed increasing trend up to 2003. Low values of 320.8 mm were observed in the 2006 while high ETo of 755.4 mm observed in year 1976. At Akola, energy balance contributes about 70 % while aerodynamic component by 30

% to the total ETo. Energy and aerodynamic components were observed to be contributing 70 % and 30 % respectively to ETo at ICRISAT, Patancheru (Rao and Wani, 2011). This reported that the energy balance component was the dominating factor than aerodynamic component to ETo.

To evaluate temporal changes in evapotranspiration demands, average ETo of *kharif* (Jun to Sept), *rabi* (Oct to Feb) and summer (March to May) season are computed. Normal values of ETo and its components for *kharif*, *rabi* and summer season along with monthly and annual mean values over the last 46 years are computed and presented in Table 2. Variation of ETo is an extremely important variable to be considered for agriculture purpose. Mean annual ETo observed 1731 mm while 1206 mm and 525 mm for energy balance component and aerodynamic component respectively. When comparing *kharif*, *rabi* and summer season, ETo and aerodynamic components observed minimum in *rabi* season with 507 mm and 122 mm respectively while maximum in summer season with 618 mm and 243 mm respectively. Summer season ETo values observed highest while lowest in winter season among all the season (Rao *et al.,* 2011). In energy balance component, maximum ETo of 446 mm observed in *kharif* season while lowest ETo in summer season with 374 mm. Mean monthly ETo, energy balance component and aerodynamic component found maximum in the month of May having maximum temperature of 42.4 ^{o}C with ETo of 263 mm, 150 mm and 113 mm respectively. Lowest mean monthly ETo, energy balance component and aerodynamic component observed in the month of December with ETo of 82 mm, 64 mm and 18 mm respectively.

CONCLUSIONS

Evapotranspiration demands and trends were analyzed for Akola region in western part Vidarbha (Maharashtra) by assessing reference eapotranspiration (ETo), energy balance and aerodynamic components for 46 years (1971-2015). Analysis indicated multiple trends in annual ETo and annual aerodynamic component of ETo. Throughout the study period, a clear decreasing trend was notice with low ETo values. Meddle stage, the ETo started slight increase in trend with 1796 mm ETo it was observed in the year 1996. Seasonal analysis has shown that ETo has increasing trend during *rabi* season. Mean annual ETo is 1731 mm while 1206 mm for energy balance component and 525 mm for aerodynamic component. Mean monthly ETo, energy balance component and aerodynamic components observed maximum in the month of May while lowest in the month of December. Crop water requirement are more during April to June as ETo is observed to be highest during this period. Trend analysis provides indication on patterns in historical data of evapotranspiration. Monthly ETo variation is very useful for analysis of various water requirement of crops, irrigation plants etc. present study highlights the necessity of ETo trend analysis as it depend on different weather parameters.

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Climate Change and Water Use

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ABSTRACT

Climate change, generally resulting from Global warming, will cause significant impacts on Water Resources. The National Action Plan on Climate Change (NAPCC) in India was released in June 2008; identifying eight core National Missions, including National Water Mission and National Mission for Sustainable Agriculture, which are water-related. The NWM sets a goal of 20% improvement in water use efficiency and NMSA aims to support Climate adaptation in agriculture. The future water scenario suggests an urgent need for a shift to *Conservation* of water on a larger scale and *Use* should be a sub-set of *Conservation,* while *Preservation* has to be ensured on a war footing. Small scale water bodies are likely to be the thrust areas, while mega and medium schemes have to be managed in a better way, duly meeting the adverse impacts of climate change in water sector. Mission Kakateeya and Mission Bhageeratha in Telangana as well as the attempts for restoring Tank Cascade Systems in Andhra Pradesh are typical examples of innovative thrust in water resources sector in recent times. To increase WUE, irrigation sector has to be given top priority, being the bulk user of available water to an extent of 80%, made up of conveyance, distribution and field application efficiencies.

Climate change is the phenomenon of the present times.

Mounting scientific evidence now suggests that large changes in climatic conditions have occurred across the globe over the last millennium and could recur independent of human-induced global warming. Combating climate change is one of the frightening challenges humanity and other living organisms are fraught with.

It is scientifically estimated and predicted that climate change will cause significant changes and impacts on water resources for the mankind. The government, industry and other managers dealing with and concerned about water are required to identify, understand, document and spell out their measurable, achievable and affordable objectives for responding to climate changes and emergency and other plans of action for implementation so as to achieve water-related quantity, quality and timing goals. While adverse climate change affects water availability for use severely, the pattern of water use itself may worsen the situation by environmental degradation.

As an indication of the national concern in the matter, the then Prime Minister, Shri Manmohan Singh released India's First National Action Plan on Climate Change (NAPCC) on 30th June 2008, outlining the existing and future policies and programs addressing climate mitigation and adaptation. The Plan identified eight core National Missions running up to the year 2017 and directed the concerned Ministries to submit detailed implementation plans to the Prime Minister's Council on climate change by December 2008. The Plan also identified measures to promote our development objectives while also yielding Co-benefits for addressing climate change effectively.

The eight National Missions are:

National Solar Mission;

National Mission for Enhanced Energy Efficiency;

National Mission on Sustainable Habitat;

National Water Mission;

National Mission for sustaining the Himalayan Ecosystem;

National Mission for a "Green India";

National Mission for Sustainable Agriculture; and

National Mission on strategic knowledge for climate change.

As regards implementation, the Concerned Ministries with lead responsibility for each of the Missions were directed to develop objectives, implementation strategies, timelines and monitoring and evaluation criteria, to be submitted to the Prime Minister's Council on climate change. The Council was made responsible for periodically reviewing and reporting on each Missions progress. It was proposed to develop appropriate indicators and methodologies to assess both avoided emissions (of green house gases) and adaptation benefits.

Out of the above mentioned 8 Core Missions, National Water Mission (NWM) and National Mission for Sustainable Agriculture (NMSA) are specifically water-related. Under the NWM, the Plan sets a goal of 20% improvement in Water Use Efficiency through pricing and other measures. Under the NMSA, the Plan aims to support climate adaptation in agriculture through the development of climate resilient crops, expansions of weather insurance mechanisms, and agricultural practices.

Climatic change is characterized by global warming resulting from concentration of Green House Gases (GHG) like carbon dioxide (CO2), Carbon Monoxide (CO), Methane (CH4), Nitrous Oxide (N2O), Nitric Oxide (NO2) etc. in the atmosphere on account of indiscriminate use of fossil fuels and burning of forest biomass. This Green House effect, in simple terms, means the heating of the earth and it is a direct consequence of the ravaging of ecological balance. Anthropogenic atmospheric concentration of GHG and the magnitude of climate change are expected to get worse during the coming decades. The results will be higher temperatures, more instability in weather and precipitations, amplification of the extreme climatic events like hurricanes, tornadoes, temperature extremes and droughts, a dramatic loss of biodiversity and sea level rise connected with thermal expansion and ice melting, most of which will affect developing Countries more adversely than developed Countries. As regards water resources, higher temperature and decreased precipitation would lead to decreased water supplies and increased water demands, deterioration in the quality of fresh water bodies, stretching the fragile balance between supply and demand in many regions, apart from the likelihood of increased flooding of low lying areas, intrusion of salt water into estuaries, small islands and coastal aquifers.

It is widely recognized there is a looming water crisis globally. The World Water Vision 2025 developed by Global Water Partnership (GWP) in the year 2000 points out that "the crisis is not about having too little water to satisfy our needs. It is a crisis of managing water so badly that billions of people – and the environment – suffer badly…..We have threatened our water resources with bad institutions, bad governance, bad incentives, and bad allocations of resources. In all this, we have a choice. We can continue with business as usual, and widen and deepen the crisis tomorrow. Or we can launch a movement to move from Vision to Action------------by **making water everybody's business".** The National Water Policy 2002 of India stresses that "Water is a scarce and precious national resource to be planned, developed, conserved and managed as such, and on an integrated and environmentally sound basis, keeping in view the socio-economic aspects and needs of the States". The real question and challenge now is what constitutes an **integrated and environmentally sound basis?**

Analysts are cautioning that India is running out of water. And it has a lot to do with climatic change. The statement seems rather banal, but the fact remains that India's water future seems insecure, at least at the moment. The Country's ground water resources are dwindling at a much faster pace than they are being recharged, naturally or otherwise. And it certainly is an irony for a country that takes pride in the fact that even in an environment of global economic gloom, it is expected to witness a strong GDP growth. Somehow, India's economic might has not helped much on the water front. Our water management record is among the poorest. It does not show any signs of improvement, at least for now. Our past efforts have either fallen woefully short or were carried out in a disconcerted manner.

Doomsayers are warning that some time in the future, wars may erupt over sharing of the fast dwindling water resource. And climate change is going to exacerbate the problems. India is not an exception. Some of the Indian States have been fighting between themselves (legally, of course, so far) over water, in respect of Krishna, Godavari and Kaveri river waters particularly. Internationally, India is involved in various stand-offs with its neighbours over water: with Pakistan over Baglihar dam and Chenab river; with Bangladesh over the Ganga; with Nepal over Kosi & other rivers; and with China over the mighty Brahmaputra.

Climate change is expected to worsen water scarcity in India. The Himalayan glaciers are melting at an alarming rate. These glaciers are the lifeline for a sizeable population in India, Nepal and China. 2 billion people in the basins of Ganga, Brahmaputra, Indus, Mekong, Yellow and Yangtze rivers , which depend on the Himalayan glaciers for their water supply , face acute water shortages ahead. The Ganga alone drains an area of over a million square km with a population of over 407 million; Brahmaputra drains 9,40,000 sq km with a population of over 118 million; and Indus which drains over 1.2 million sq km with about 178 million people. Life will come to a standstill, if, for instance, and God forbid, Ganga goes dry!

India's northern region runs the risk of more floods in the coming years due to changing stream flow patterns in the Himalayan rivers .Researchers have stated that small glaciers in the Himalayas have receded at a relatively faster rate than the larger ones due to global warming. The fear is that the smaller glaciers may even disappear. Even the national capital, New Delhi, is expected to have a tough time ahead and to face more conflicts and pollution in the years to come. Climatic change decreases stream flow and ground water recharge in many parts of the world, but increases it in some other areas. Changes in climatic conditions are also playing havoc with the weather patterns over India. On account of changing monsoon rain patterns, people are already facing severe hardship, as we depend on rains for agriculture, hydropower and drinking water. Several Indian States have seen a fall in agricultural production as rains are below normal to an extent of 40%. On the other hand, some states like Orissa have experienced drought and floods at the same time. Maharashtra is compelled to go in for use of chemicals or polymers in their tanks and reservoirs to prevent / reduce evaporation losses. To-day's situation should make us beware of tomorrow's possibilities with the present trends. Thus, India's water woes are plenty and would very likely grow if concerted efforts are not put forth on a water footing. In the present context and scenario, the National Action Plan on climate Change (NAPCC) with its core National Missions is a modest, but well-meant, beginning, which has to be carried forward seriously by all concerned. Broadly speaking, the water sector situation encompasses three aspects – Preservation (P), Conservation(C) and Use (U). In the past, as per the then prevailing pattern, Preservation was wide-spread, Conservation was restricted and use was minimal (as per the *needs* only). The present situation shows that **P** is practically extinct, Conservation efforts are becoming difficult and Use is widespread in the form of over-use, misuse and abuse. There are eternally conflicting and competing demands on the scarce water resources, which are supposed to be not only *precious* but also *sacred*. The future CUP of water suggests an urgent need for a shift to Conservation (C) of water on a larger scale and USE (U) should be the sub-set of Conservation. Further, Preservation (P) is going to be critical and has to be attempted and ensured on a war footing. Small-scale water bodies like tanks, ponds, springs and streams are likely to be the *thrust areas* of the present generation, while *managing* the present infrastructure of mega and medium schemes in a better way .Mission Kakateeya taken up for restoring 46000 old tanks and Mission Bhageeratha for providing water taps to every household in Telangana, as well as the attempts for restoring the tank cascade systems in Andhra Pradesh are typical examples of innovative thrust in water resources sector in recent times.

Coming to the issue of **Water Use Efficiency** (WUE), which the National Water Mission has to address, it should be understood that Water Use efficiency means accomplishing the given tasks with least application of water. It is assessed basically by comparing with the existing Consumption levels. It can be attained both by *better technology* and by *pricing* especially for commercial use. In the domestic sector, use efficiency can be brought about effecting attitudinal changes. The appropriate slogan can be **Use Less – Use it again.**

In the attempts to increase WUE, irrigation sector has to be given top priority, as it is the bulk user of available water to an extent of 80%. As water released from the storage has to entail several losses before it reaches the crop (root zone, precisely), its quantum has to be considerably in excess of the actual crop water requirement (CWR). The overall efficiency of an irrigation system is measured by the extent of water actually used by the crop out of the water released from the reservoir. This is made up of partial system efficiencies like

(i) Conveyance Efficiency (Ec) which is the ratio of the volume of water delivered to the distribution system to the volume released from the storage (excluding water drawn for non-irrigation uses, if any)

(ii) Distribution Efficiency (Ed) which is the ratio of the volume of water delivered to the fields to the volume delivered at the head of the distribution system (excluding non-irrigation uses if any) and

(iii) Field Application Efficiency (Ea) which is the ratio of the actual volume required by the crop to the volume of water delivered to the field.

The overall efficiency E can thus be expressed as: $E = Ec \times Ed \times Ea$

E can be high if the system losses can be minimized. Conveyance and Distribution losses occur because of seepage and evaporation, leakage from structures, evapo-transpiration through weeds, pilferage of water, operation of escapes, non-use of water by farmers during night resulting in wastage at tail end etc. Losses on field also occur on account of inadequate land leveling and land shaping, deep percolation, overflow over field dykes, evaporation from the field and differences in WUE of different modes of application like border-strip, basin, furrow, flooding, field to field etc.

System losses as above have resulted in low WUE of 30% in India. If WUE can be increased by 20 to 30%, the savings of water can be used for extending irrigation facilities to additional areas. It calls for Better Water Management adopting measures like selective lining of canal systems, provision of adequate control structures, prevention of leakages and pilferages, rotational supplies with obligatory night irrigation, undertaking adequate CAD and OFD works and training of farmers for efficient water application practices.

Pricing is also considered as one of the effective measures for improving WUE. On the one hand, water is a ***social good***. Its use beyond a minimum necessary level converts it to an ***economic good.*** In the domestic sector of water use, the social good in a hot climate and Indian Cultural habits is calculated at 100-150 liters per capita per day (lpcd). On the other hand, beyond this level, it becomes an ***economic good*** even in the domestic sector. In the commercial and industrial sector, the total consumption should be considered as an economic good. Increase in pricing should lead to reduction of wasteful practices. Pricing is a critical and sensitive issue in the Irrigation sector. The general principle advocated is that water rates should be such as to convey the scarcity value of the resource. They should be adequate to cover the annual operation and maintenance charges and part of the capital costs. Efforts should be made to reach this ideal over a period, while ensuring assured and timely supplies of irrigation water. According to the National Water Policy 2002, “There is a need to ensure that the water charges for various uses should be fixed in such a way that they cover at least the O&M charges of providing the service initially and part of the capital costs subsequently. These rates should be linked directly to the quality of service provided. The subsidy on water rates to the disadvantaged and poorer sections of the society should be well targeted and transparent.” Sooner or later, water should be delivered to the users, whether it is for Irrigation, domestic, industry or other purposes, on a volumetric basis and charged accordingly for full cost recovery, duly permitting subsidy to the deserving sections of the society below Poverty line on socio-economic considerations. It is well-established that the water rate structure is a powerful management tool to help rationalize the use of scarce irrigation water resources. The National Mission for Sustainable Agriculture (NMSA) has to address climate adaptation in Agriculture through climate-resilient crops, expansion of weather insurance mechanisms, and agricultural practices. Climatic changes are known to bring about extreme hydrological events, i.e. droughts and floods. The drought mitigation measures in Agriculture can be classified into three main groups:

(i) ***Water supply measures*** intended to increase the available water supply during drought.

(ii) ***Water Demand measures*** intended to decrease the water demand during drought.

(iii) ***Impact minimization*** measures intended to minimize drought impacts occurring in spite of increased water supply and decreased demands.

The supply-oriented measures include maximizing surface water storage, evaporation and evapotranspiration suppression, increasing groundwater use, weather modification, long distance transfer of water etc.

The demand-oriented measures include:

(a) Active demand reduction (b) Reactive demand reduction

These measures are adopted by appeals to consumers to reduce water use, water reuse, restrictions on water use, and economic incentives for reducing water consumption. As part of the reactive demand reduction, the selection of cropping pattern as per water availability will reduce adverse impacts of drought on potential water-consuming crops. The plants suitable for water-scarce areas can be:

(i) with shorter growth period

(ii) high yielding plants requiring no increase in water supply

(iii) plants that can tolerate saline irrigation water

(iv) plants with low transpiration rates

(v) with deep and well branched roots

(vi) Some of the techniques used for reducing water demand in Agriculture are:

(vii) Reducing evapotranspiration

(viii) Adjusting cropping pattern

(ix) Improving irrigation practices

(x) Reduction of seepage and improving Irrigation Efficiency

(xi) Changes in water use pattern

(xii) Conjunctive use of surface and ground water

(xiii) Practice of ***deficit irrigation*** with only marginal reduction in crop yields

(xiv) Raising naturally drought-resistant crops with less water consumptions.

In respect of climate characteristics, Rainfall in an area is important in determining the maximum or minimum grades permissible for field. The amount, intensity and season of rainfall affect the drainage requirements that must be met by a minimum grade for a field. Rainfall characteristics also affect the maximum grade allowable to prevent erosion hazards. Where rainfall intensities exceed 25 mm per hour, longitudinal slope should in no case exceed 1%.

CONCLUSION

Climate change is going to influence water availability and water use severely in the coming years. Water Resource Development and Management, including Hydrology, Design operation and Management of Irrigation and Domestic Water Supply systems are within the purview of Water Manage men Engineers. These Engineers have, therefore, a major role to play in facing the challenges in Water Management now and in future. There is no doubt that they will be able to deliver the goods as required and come out in flying colors.

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THEME - III

Enhancement of Primary Productivity after the Dust storm

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ABSTRACT

A dust storm is a meteorological phenomenon common in arid and semi – arid regions. Atmospheric aerosols play a vital role on the dynamics of climate processes through direct and indirect effects. Using remote sensing data, an anomalous enhancement in the biological productivity of sea was observed in the Arabian sea was attributed to nutrient rich dust particles (transport) from dust storms .We have carried out a study of Dust storm was occur during the 13-14 December 2003 over the Arabian Sea. Using Moderate Resolution Imaging Spectroradiometer (MODIS) Aqua, we have found that the deposition of dust along the passage of major dust storms (aerosol optical depth (AOD) occurring over the Arabian Sea causes chlorophyll blooming (usually 10–20 mg/m3) within a period of 1–2 to up to 3–4 days. Exact nature and cause of chlorophyll bloom in the Arabian Sea, surrounded by one of the world's major sources of dust storms (Africa, Middle East, Iran, and Afghanistan), are very important in understanding the productivity and the biogeochemical cycles of the marine ecosystem. After the dust storm passes over the Arabian sea chlorophyll concentrations and primary Productivity increased, because of the growth of the Phytoplankton's, using nutrients from the dust deposition, CO_2 (inorganic carbon) from both Atmosphere and Ocean, and sunlight to produce organic compounds (carbon) .

Keywords: Dust storm, Chlorophyll concentration, Productivity, MODIS Ocean color data.

INTRODUCTION

Dust storms originating over the world's arid regions contribute a large fraction of aerosols in the atmosphere. Phytoplankton's are autotrophic components of the Plankton community, live in the sunlit layer of the ocean. They are equally significant to life on land due to the production of more than half of Earth's oxygen supply. Like plants on land Phytoplankton has Chlorophyll to capture sunlight and they use Photosynthesis to produce organic compounds (materials). Most Phytoplankton are too small to be individually seen with the unaided eye. However, when present in high numbers, they may be appear as green light (discoloration) of the water due to the presence of Chlorophyll (Green pigment) within these cells.

They consume carbon dioxide (CO_2) and release oxygen. Phytoplankton's growth depends on the availability of CO_2 sunlight, and nutrients. When all these conditions are required sufficiently Phytoplankton's can grow explosively, a phenomenon called the Bloom. Blooms in the ocean may cover 100's of square Km's and are easily visible in the satellite images.

Phytoplankton's are the foundation of the aquatic food web (Figure1), the primary producers, feeding everything from microscopic, animal- like zooplankton to multi-tonn whales. Small fish and invertebrates also graze on the plant-like organisms, and then those smaller animals are eaten by bigger ones.

STUDY AREA

The study area covering the northern part of the Arabian sea is located between latitudes 30°N and 15°N and longitudes 50°E and 75°E bordered by India, Pakistan, Iran, Somalia, Arabian Peninsula, Oman. Productivity is highest in the northern region of the Arabian Sea.

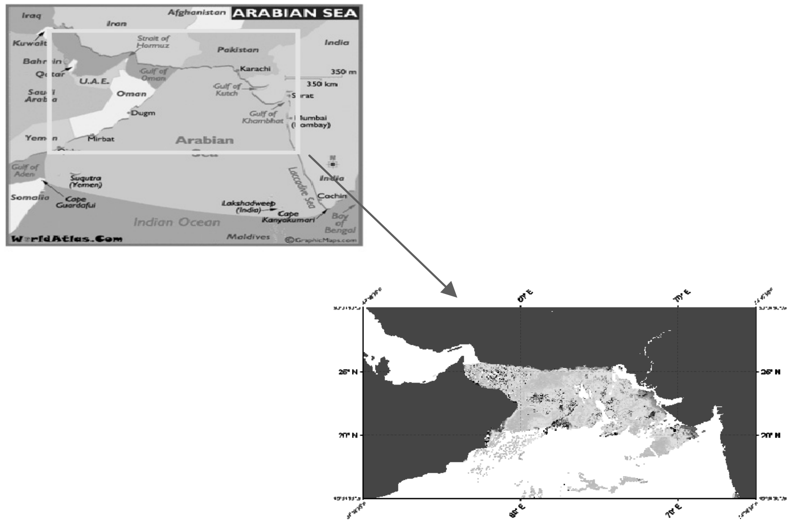


Fig. 1 Map showing the study area of the Arabian Sea.

MATERIALS AND METHODS

Data and Methodology

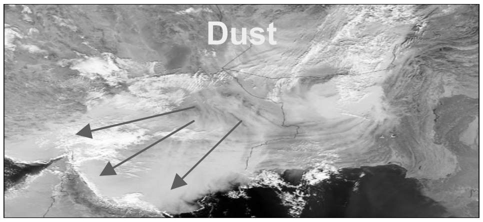
Moderate Resolution Imaging Spectroradiometer (MODIS) Aqua daily data sets (Level – 2 LAC products) of 1.1 km resolution and 8-day composites of Primary Productivity, from ocean color website were taken to study the effect of Dust Storm over the Arabian sea for a selected Dust storm event during December 2003 (13-14 December 2003). MODIS Aqua Level 2 data consists of various derived geophysical parameters at the same resolution as the source Level 1 data, and we have extracted Chlorophyll a concentration (mg/m^3), and Aerosol Optical Thickness (aot_869nm) at 869nm from above data set. And also we used MODIS Terra & Aqua true color images from MODIS website to study the Dust transport across the Arabian Sea.

The VGPM is a "Chlorophyll-based" model that estimates net Primary production from chlorophyll using a temperature-dependent description of chlorophyll-specific photosynthetic efficiency. For the VGPM, net primary production is a function of chlorophyll, available light, and the photosynthetic efficiency.

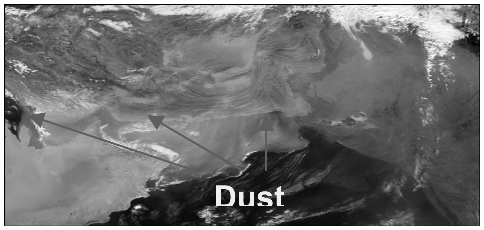
SeaDAS is a comprehensive image analysis package for the processing, display, analysis, and quality control of ocean color data. By using SeaDAS we mosaic the multiple images derived from different passes of same Aqua satellite, to create a single image to study the effect of Dust storm over the Arabian Sea. The present study carried out from 30°N – 15° N Latitude to 50° E – 75° E Longitude across the Arabian Sea. We found that maximum Chlorophyll Concentration was observed after Dust storm and Aerosol Optical Thickness maximum during dusty days (12-14 December 2003).

RESULTS AND DISCUSSIONS

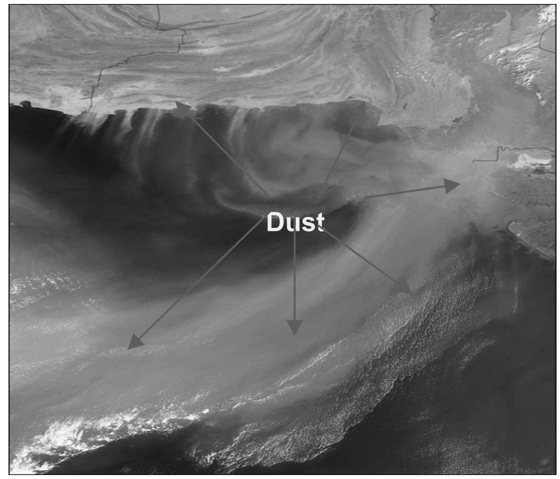
Dust storm was occur 13-14 December (347-348 Julian day) 2003. Figure 2a) showing a massive dust storm on December 12, 2003, almost completely obscured large parts of southwest Asia at the time of this image, which was captured by the MODIS on the Terra satellite. In Figure 2b) showing the Dust storm extending from the Arabian Peninsula (left) eastward over the Persian Gulf and the Gulf of Oman toward the Arabian Sea and parts of southern Afghanistan and much of Pakistan are also covered by airborne dust. Figure 2c) showing the Dust storm blowing along Pakistan southern coast and out over the Arabian Sea on December 14, 2003.



a) 12 December 2003



b) 13 December 2003



c) 14 December 2003

Fig. 2 Shows the transport of Dust from land to Arabian Sea (from 12 -14 December 2003)

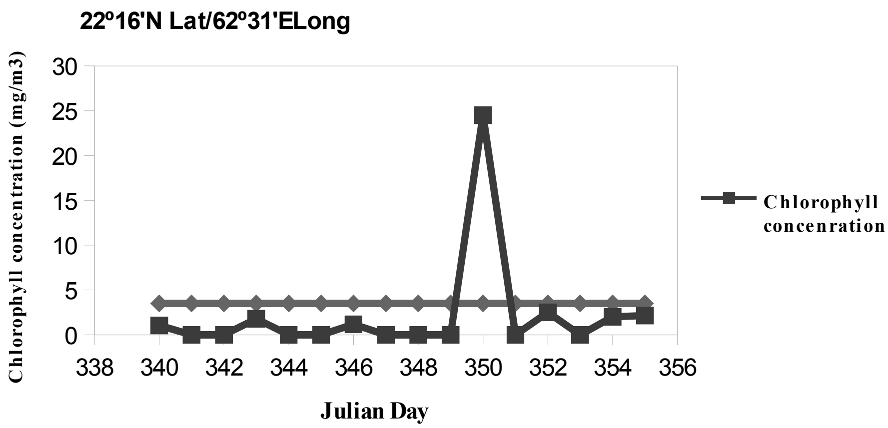


Fig. 3 Showing the Maximum Chlorophyll concentration (mg/m^3)
over the region 22º16'N Lat, 62º31'ELong in the Arabian Sea.

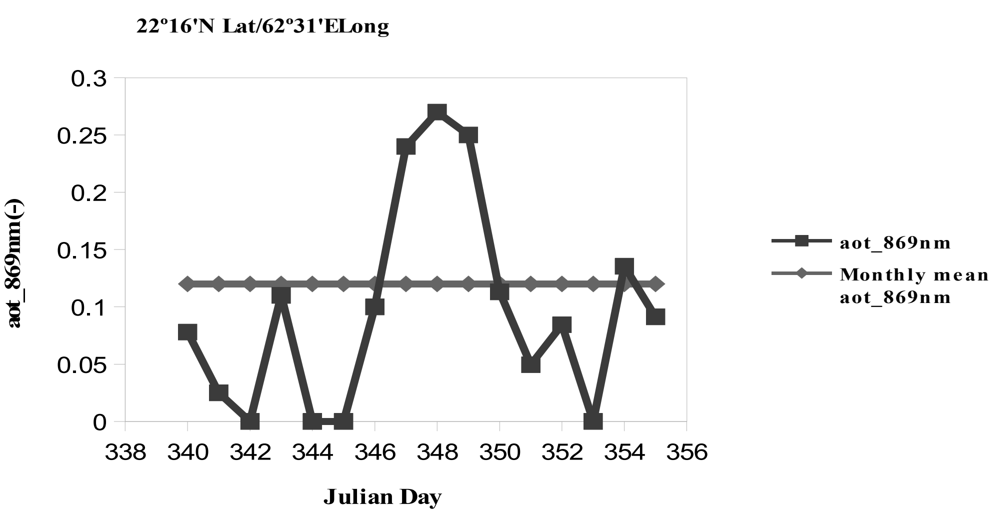


Fig. 4 Shows the Maximum aot (-) values over the region 22º16'N Lat, 62º31'ELong in the Arabian Sea.

By using Sea DAS, after analysis we found that during the Dust event, maximum aot values were found (figure 4). During the dusty days (347-348) the maximum aot value of 0.27 has been found at 22º16'N Lat, 62º31'E Long over the Arabian Sea. After the Dust storm the chlorophyll concentration and Primary Productivity values were increased because of the growth of the Phytoplankton's. Phytoplankton's are the ocean's green machines. These microscopic photosynthetic phytoplankton's contain green pigment called the Chlorophyll a. When the Dust storm passes over the Arabian Sea nutrient rich dust deposited. Phytoplankton's using the nutrients from the dust deposition and carbon dioxide from the atmosphere and ocean to produce organic compounds. The productivity increased because of the growth of the Phytoplankton's.

After Dust storm maximum Chlorophyll concentration 24.5 mg/m^3 (Figure 3) was found at 22º16'N Lat, 62º31'E Long on 16 December 2003 over the Arabian Sea. After Dust storm maximum Primary productivity 3344.122 mgCm^{-2} day^{-1} was found (Figure 5) at 22º16'N Lat, 62º31'E Long over the Arabian Sea. Before Dust storm Primary productivity was lower when compared to After dust storm 1501.5 mgCm^{-2} day^{-1} was found at 22º16'N Lat, 62º31'E Long over the Arabian Sea.

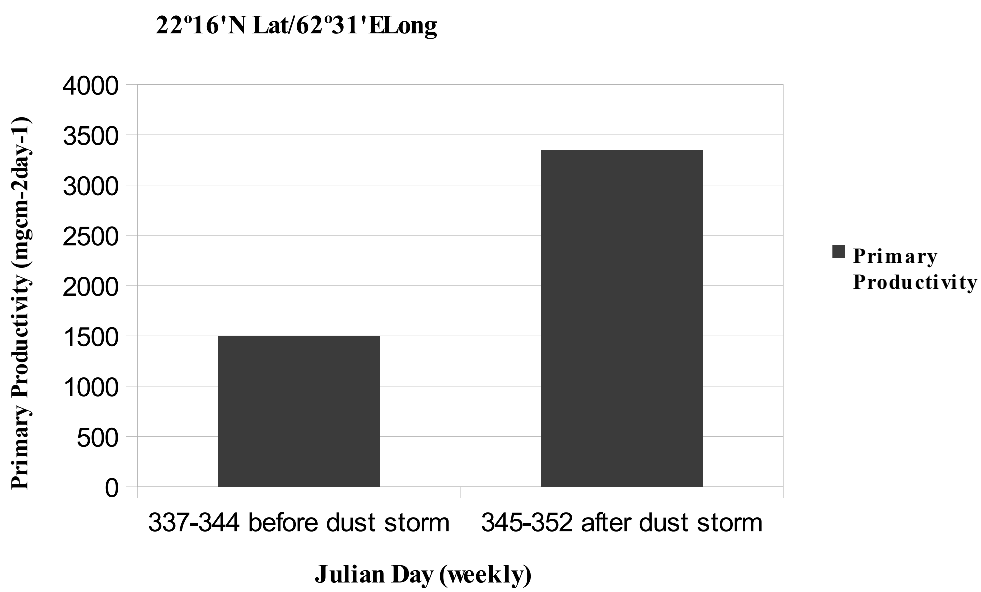
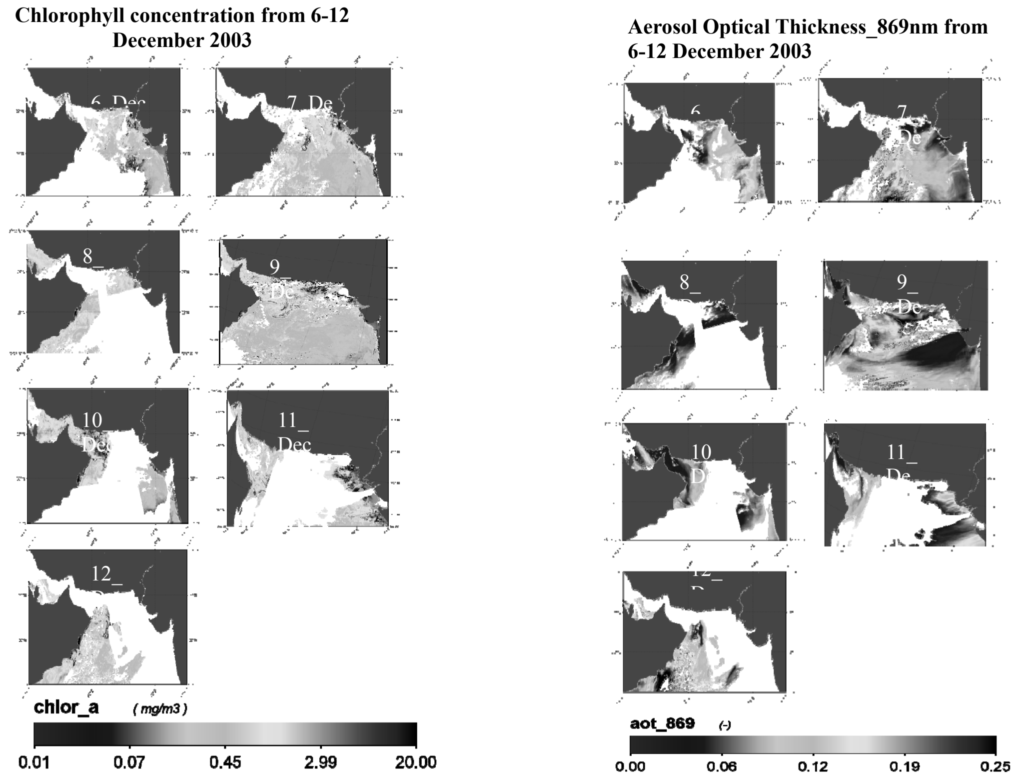


Fig. 5 Shows the Maximum Primary Productivity (mgCm^{-2} day^{-1}) values before and after Dust storm (13-14 December 2003) over the region 22º16'N Lat, 62º31'ELong in the Arabian Sea.

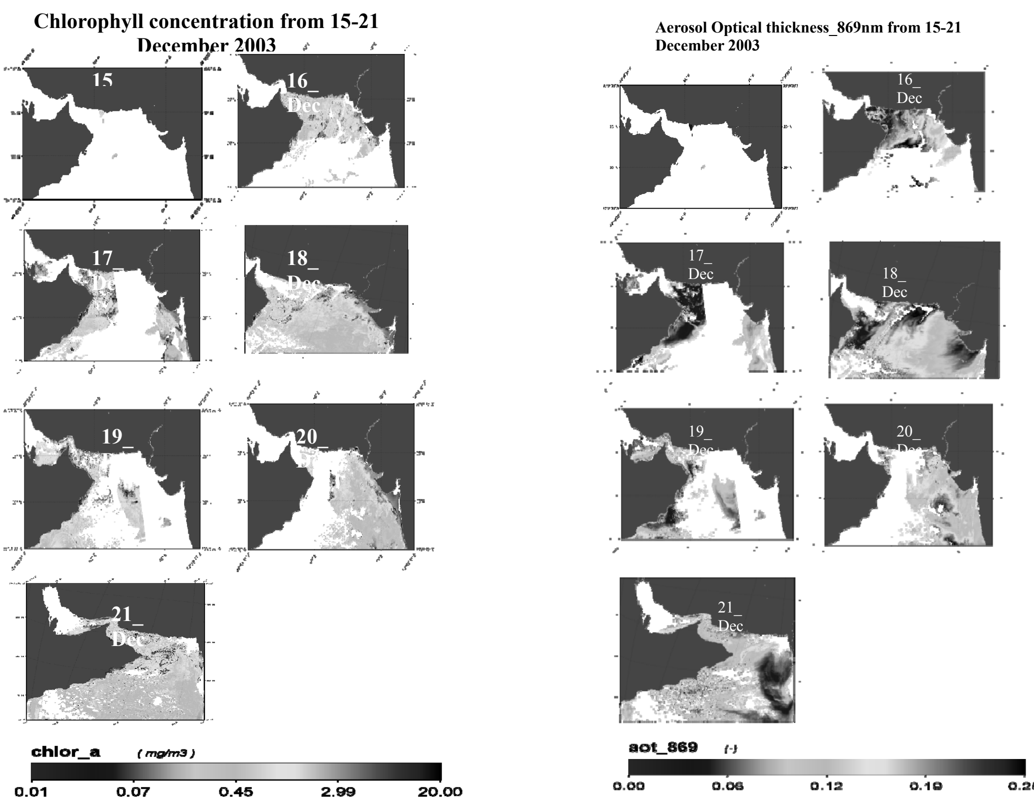
CONCLUSION

Arabian Sea is found to be highly productive region during dust storm. After dust storm chlorophyll concentrations and Primary productivity increased when compared to before dust storm days within a lagtime of 1-3 days over the Arabian Sea. During the dusty days (347-348) the maximum aot value of 0.27 has been found at 22º16'N Lat, 62º31'E Long over the Arabian Sea. After Dust storm maximum Chlorophyll concentration 24.5 mg/m3 was found at 22º16'N Lat, 62º31'E Long on 16 December 2003 over the Arabian Sea. After Dust storm maximum Primary productivity 3344.122 mgCm^{-2} day^{-1} was found at 22º16'N Lat, 62º31'E Long over the Arabian Sea. Before Dust storm Primary productivity was lower when compared to After dust storm 1501.5 mgCm^{-2} day^{-1} was found at 22º16'N Lat, 62º31'E Long over the Arabian Sea. After the dust storm passes over the Arabian sea chlorophyll concentrations and primary Productivity increased, because of the growth of the Phytoplankton's, using nutrients from the dust deposition, CO_2 (inorganic carbon) from both Atmosphere and Ocean, and sunlight to produce organic compounds (carbon) .



(a) (b)

Fig. 6. (a) The daily Chlorophyll concentration (mg/m^3) from 6-12 December 2003 (before Dust storm), b). The daily aot_869nm (unitless) from 6-12 December 2003 (before Dust storm) , derived from MODIS Level-2 Aqua



(a) (b)

Fig. 7 (a) The daily Chlorophyll concentration (mg/m^3) from 16-21 December 2003 (after Dust storm), (b). The daily aot_869nm (unit less) from 16-21 December 2003 (after Dust storm), derived from MODIS Level-2 Aqua

Primary Productivity (mgCm-2day-1)

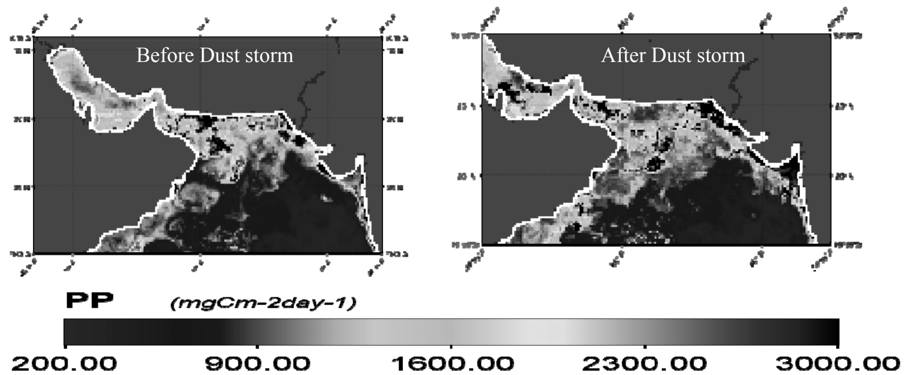


Fig. 8 Eight day Primary Productivity (mgCm^{-2} day^{-1}) from MODIS Aqua.

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The Quantification and Evaluation of Drought Indices: A Case Study on the Ananthapur District

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ABSTRACT

Drought is a complex, natural, slow-onset phenomenon of ecological challenge that effects people more than any other natural hazards by causing serious economic, social and environmental losses in both developing and developed countries. The drought vulnerability can be reduced by drought mitigation measures. The success of Drought mitigation measures depends upon how well drought is quantified and characterised. Drought assessment is a challenging task for drought researchers and professionals. There are many Drought Indices (DIs) that have been developed around the world and are commonly used to quantify drought conditions. It was found that in most cases, DIs are developed for a specific region, and therefore may not be directly applicable to other regions due to inherent complexity of drought phenomena, different hydro-climatic conditions and catchment characteristics. Suitability of some of the existing DIs had been analyzed for different climatic regions around the world. However, no such study had been conducted in Ananthapur region which is the driest inhabited region in the Andhra Pradesh. In the present study, drought is quantified for the Ananthapur district in meteorological, hydrological and remote sensing contexts. The study reveals that 1) Percentage of departure along with percent of normal are suitable drought indices for quantifying drought conditions for the Ananthapur region. 2) It is essential for policy makers to use percentage of departure for drought assessment.

Keywords: Drought, Drought assessment, Ananthapur, Drought indices and Evaluation.

INTRODUCTION

Drought is one of the worst natural hazard to mankind. It is root cause of famines in many parts of the world and more so in our country where agricultural success and prosperity are virtually dependent on the amount and distribution of rainfall. Drought ranked as the first among all natural hazards (Bryant, 1991). Drought is a temporary phenomenon experienced when precipitation falls appreciably below normal and is virtually possible in any rainfall or the temperature regime. Drought is not only confined to arid and semi-arid regions but often visits potentially good rainfall areas. There is no universally applicable and acceptable definition for drought as yet. Numerous attempts to define drought have led to several definitions of the term (Nagarajan, 2003). Unlike other natural hazards like floods, hurricanes and tsunamis that develop quickly and last for short time, drought has a creeping or insidious nature. It evolves and builds up across a vast area over a period of time and its effect lingers for years even after the end of drought (Narasimhan, 2004). This complex nature of drought makes it least understood of all natural hazards.

Drought Indices (DIs) have been most commonly used to assess drought conditions around the world, since they are more functional than raw data in decision making. A drought index is typically a single number value used for indicating severity of drought and it is far more useful than raw data to understand the drought condition over an area. Most of the drought indices are not precise enough in detecting the drought conditions (Bhuyan and Wilhite, 1990). Many drought indices are developed regionally, they cannot be used directly to assess the drought conditions in other regions without prior evaluation (Shishutosh Barua et al., 2011). Therefore it is necessary and useful to consider several indices, examine their sensitivity and accuracy, and evaluate them. The present study was motivated by the fact that no such study has been carried out in the case study area which is driest inhabited region in Andhra Pradesh.

Accordingly the objectives of present study are framed. They are:

1. Quantification of drought in meteorological, Hydrological and Remote sensing contexts.
2. Evaluating the performance, strength, weakness and limitations of drought indices.
3. To determine which type and combinations of drought indices are best.
4. To develop a composite drought index.
5. To determine a return period using risk analysis.

In the present study, Percentage of departure, percent of normal, deciles, Standardised precipitation index (SPI), reconnaissance drought index are selected as meteorological drought indices. Stream flow drought index, surface water supply index and Standardised stream flow index are selected as hydrological drought indices. Normalised difference vegetation index (NDVI) and Normalised difference water index (NDWI) are selected as a remote sensing based drought indices. These drought indices are selected because of their popularity and different approach in characterising the drought. All the drought indices are evaluated using the evaluation criteria (Keyantash and Dracup, 2002). This is the first study conducted in the Ananthapur region to evaluate the suitability of existing drought indices for drought management.

STUDY AREA

The area of investigation in this research study is the Ananthapur district, Andhra Pradesh, India. Ananthapur district lies in between $13^{0}40'$ and $15^{0}15'$ North latitude and 76^{0} $50'$ and 78^{0} $30'$ East longitude. The total geographical area of the Ananthapur district is 19,225 k.m^{2}.The normal rainfall of the district is 553.0 mms. The normal rainfall for the South West Monsoon period is 338.0 mms. The rainfall for North East monsoon period is 156.0 mms.

The normal daily maximum temperature ranges between 31.7 C to 38.9 C. Anantapur's history will reveal that the district has been subjected to severe droughts and famines right from 14 century. The whole district lies within the famine zone, with very scanty rainfall, poor soils and precarious irrigation sources exposing the district to famines.

Fig. 1 Location map of study area

Data Collection

Different data sets were used to fulfill the intended purpose of the project.

Meteorological Data: Data required for this project to compute the drought indices were rainfall and potential evapotranspiration. Monthly mean rainfall data of Ananthapur district for the period 1901 to 2013 was collected from the Indian Meteorological Department (IMD). Climatological data such as potential evapotranspiration was collected from meteorological department (IMD).

Hydrological data: The hydrological data used in this study to compute the drought indices was stream flow data. Monthly stream flow data for the period 1980 to 2012 was collected from hydro observation stations at Singavaram and Tadipatri.

Remote Sensing Data: The remote sensing data used in this study was Landsat 4-5 TM Satellite images. The satellite images spanning from 2006-10 of month September from Landsat-4-5 were obtained from the USGS National Center for Earth Resources Observation and Science (http://glovis.usgs.gov/).

METHODOLOGY

Drought assessment is carried out by using the following indices because of their popularity and different approach in characterising the drought.

Meteorological drought assessment: Meteorological drought assessment was carried out using following drought indices.

Table 1 Meteorological drought indices

PERCENTAGE OF DEPARTURE	PERCENT OF NORMAL	DECILES
$P_d = \frac{p-\bar{p}}{\bar{p}} * 100$	$P_n = \frac{p}{p_{30}} * 100$	$(N+1)\frac{p}{10}$ (INTERPOLATION)
STANDARDISED PRECIPITATION INDEX	RECONNAISSANCE DROUGHT INDEX	
SPI.SL.6.exe (National Climatic Data Centre)	$\alpha_0 = \frac{\sum_{j=1}^{12} P}{\sum_{j=1}^{12} PET_{ij}}$, $y_{i=ln(\alpha_0)}$ RDI=$\frac{y_i - \bar{y}}{\sigma_y}$	

Table 2 Meteorological drought indices

INDEX	NO DROUGHT	MILD DROUGHT	MODERATE DROUGHT	SEVERE DROUGHT	EXTREME DROUGHT
P_d	≥0	0 to -25	-26 to -50	>-50	
P_n	<100	>100			
Deciles	Deciles 5-6 Deciles 7-8 Deciles 8-9	Deciles 1-2 Deciles 3-4			
SPI	>2 to 1	-0.99 to 0.99	-1 to -1.49	-1.5 to -1.99	< -2
RDI	>2 to 1	-0.99 to 0.99	-1 to -1.49	-1.5 to -1.99	< -2

HYDROLOGICAL DROUGHT ASSESSMENT

Hydrological drought assessment was carried out using following drought indices.

Table 3 Hydrological drought indices

INDEX	NON DROUGHT	MILD DROUGHT	MODERATE DROUGHT	SEVERE DROUGHT	Extreme drought
SDI	>0	-1 ≤ SDI <0	-1.5 ≤ SDI <-1	-2≤ SDI ≤-1.5	< -2
SWSI	1.1 to 4.2	-1.9 to 1.0	-2.9 to -2.0	-	-3.0 to -4.2
SSFI	>2 to 0	-1.0 to 0	-1.5 to -1	-1.5 to -2.0	≤ -2.0

Remote sensing based drought assessment

Remote sensing drought assessment is carried out using the following indices.

Normalised Difference Vegetation Index: The Normalized Difference Vegetation Index (NDVI) is a satellite data driven index measures chlorophyll absorption in the red portion of the spectrum relative to reflectance or radiance in the near infrared. NDVI was computed by using the following equation

$$\mathrm{NDVI} = \frac{1}{1} \tag{11}$$

$$\mathrm{NDVI} = \frac{\mathrm{Band}}{\mathrm{Band}} \tag{12}$$

Normalised Difference Water Index: The Normalized Difference Water Index (NDWI) (GAO, 1996) is a satellite-derived index from the Near-Infrared (NIR) and Short Wave Infrared (SWIR) channels. This index is calculated by the equation

$$\mathrm{NDWI} = \frac{\mathrm{N}}{\mathrm{N}} \tag{13}$$

$$\mathrm{NDWI} = \frac{\mathrm{Band\ 5}}{\mathrm{Band\ 5}} \tag{14}$$

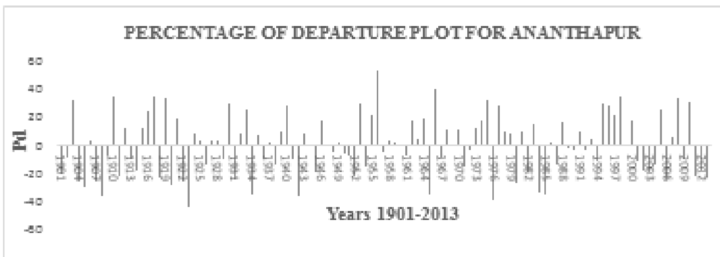

Fig. 2 Time series plot of percentage of departure

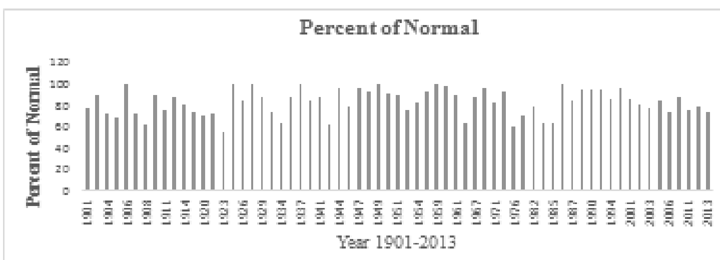

Fig. 3 Time series plot percentage of normal

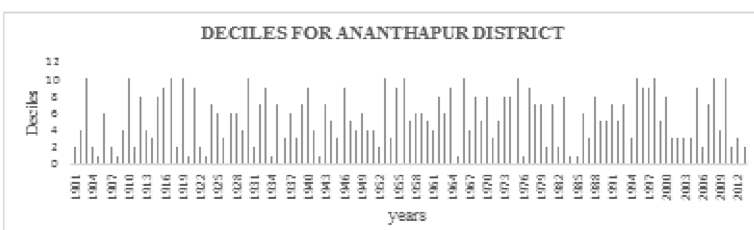

Fig. 4 Time series plot of decles

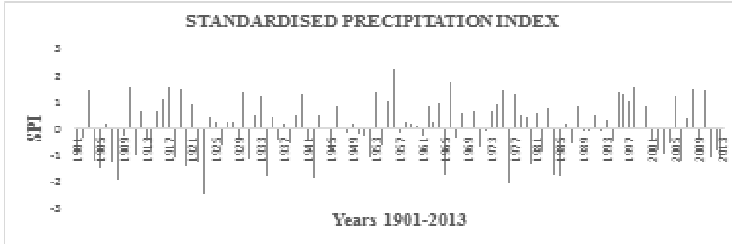

Fig. 5 Time series plot of SPI

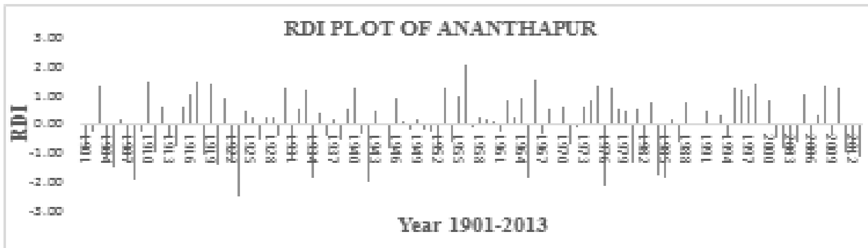

Fig. 6 Time series plot of RDI

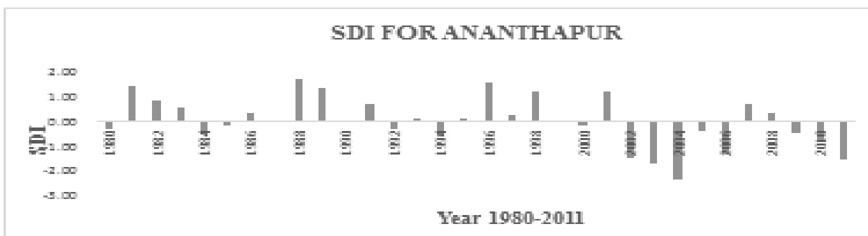

Fig. 7 Time series plot of stream flow drought index

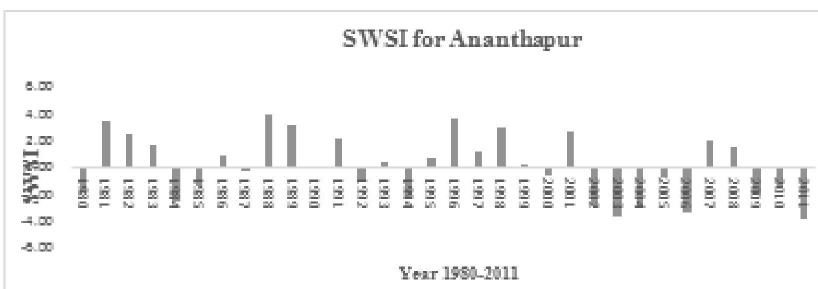

Fig. 8 Time series plot of surface water supply index

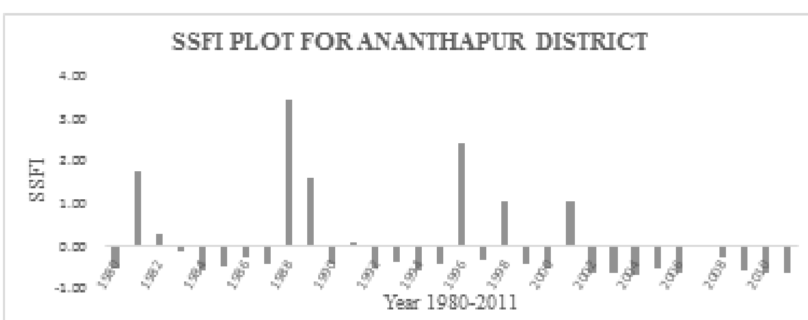

Fig. 9 Time series plot of SSFI

Evaluation criteria

In judging the overall usefulness of the DIs, five decision criteria namely robustness, tractability, sophistication, transparency and extendability are used (Keyantash and Dracup; 2002; Shishutosh Baruva; 2011). A range of raw scores from 1 to 5 (5 being the most desirable) were assigned to each of the five selected decision criteria to evaluate the DIs for the Ananthapur region. Therefore, the maximum possible total weighted score any DI could have is 25.

Table 4 Comparative scores of drought indices based on evaluation criteria

Drought Index	Robustness	Tractability	Transparency	Sophistication	Extendability	Total
Pd	4	5	5	1	5	20
Pn	4	4	5	1	5	19
Deciles	3	4	4	2	5	18
SPI	1	3	2	4	3	13
RDI	1	3	3	5	2	14
SDI	1	4	4	3	4	16
SWSI	1	3	3	5	3	15
SSFI	1	4	4	2	4	15
NDVI	4	5	2	4	1	16
NDWI	4	5	2	4	1	16

CONCLUSIONS

Drought has been occurring in Ananthapur district for the last one century. It is essential to come out with most appropriate techniques to assess drought in a better way and map the mild, moderate and severe droughts. From the present study, the following conclusions are drawn:

1. Quantification of drought for the period 1901 to 2013 reveals that the study area affected by drought continuously.
2. For meteorological data based drought analysis, Percentage of departure, percent of normal and deciles characterised the historical droughts accurately. Standardised precipitation index and reconnaissance drought index shows temperamental characteristics in detecting historical droughts.
3. For hydrological data based drought analysis, SDI, SWSI and SSFI shows high temperamental characteristics in detecting the historical droughts and unstable in nature.
4. Satellite data based drought analysis is the most effective technique for spatial analysis and near real time drought assessment. NDVI and NDWI represented the drought conditions accurately.
5. Overall evaluation of drought indices based on evaluation criteria reveals that Percentage of departure is most suitable drought index in identifying drought conditions. It is stable and has the smooth transitional characteristics. SWSI index is most unsuitable index for characterise the drought for Ananthapur district.
6. It is essential for policy makers to use Percentage of departure index for rainfall based drought assessment, SDI or SSFI for Stream flow based drought assessment and NDVI for remote sensing based drought assessment. However integrated approach using percentage of departure, SDI or SSFI and NDVI is suggested to assess the drought conditions taking place in Ananthapur district.

The present study is able to consider, meteorological, hydrological and agricultural droughts using combination of different methods. However the combination of Percentage of departure, SDI and NDVI are found to be best combinations.

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Design of Four Lane Roads in Urban Areas

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ABSTRACT

The effect transport facilities on land is now widely recognized and many transport planners acknowledge that two are interdependent. but the implications for transport planning are not often fully appreciated. In this paper we look closely at a number of investment criteria used in urban planning to see to what extent they treat all land uses, including transport routes, as a variable. it will be argued that even most sophisticated criteria do not score highly. Road Safety Audit (RSA) is a formal procedure for assessing accident potential and safety performance of new and existing roads. RSA is an efficient, cost effective and proactive approach to improve road safety. It is proved that RSA has the potential to save lives. The RSA was originated in Great Britain and is well developed in countries like UK, USA,Australia, New Zealand, Denmark, Canada, Malaysia and Singapore. It is at varying stages of implementation in developing nations like India, South Africa, Thailand and Bangladesh. RSA appears to be an ideal tool for improving road safety in India, as basic and accurate data on accidents have yet to be collected. The study aims to evaluate Road Safety Audit of a section of four-lane National Highway (NH) and will focus on evaluating the benefits of the proposed actions that have emanated from deficiencies identified through the audit process. After conducting RSA, it is found that trucks are parked on highway which reduces the effective width of carriageway and creating traffic hazards to high speed moving traffics. Unauthorized median openings were found which should be immediately closed. Missing road and median markings to be done and speed signs should match with speed. Access and service lanes are also deficient which requires immediate improvement. The most Vulnerable Road User (VRU) i.e. pedestrians and cyclists facilities near habitation are lacking and needs to be facilitated on priority. Keywords: Road Safety Audit, Safety Analysis, Four-Lane National Highways. Mainly this paper focuses on make the safety in Urban areas and reduce the traffic volume for future generations.

Keywords: Road Safety Audit, Safety Analysis, Four-Lane National Highways and Urban areas.

INTRODUCTION

With the development fast moving population, the fast moving traffic requirements have increased and become a necessity now a days. The speed, safety and comfort have become the main requirements of road users. Everybody wants to reach the destination within the shortest possible time in a comfortable manner and in safe condition. In order to full fill these requirements, Physical features of a road such as pavement width, formation width, right of way, curves etc. And speed of road vehicles play a major role while designing a highway. Roads are considered to be one of the most cost effective and preferred modes of transportation.

Then term highway is used to mean a public road used for travelling and transportation. Engineering is the art of designing constructing and maintaining works. Thus highway engineering means the art of designing, constructing and maintaining public roads. Apart from the design, construction and maintenance of different type of roads, highway engineering also includes the study of the following.

(i) Development planning and location of roads

(ii) Materials required for their constructions

(iii) Highway traffic performance and it's control

(iv) Drainage systems of roads, etc

Materials for Construction

The materials required for construction of highways can be broadly divided into following categories:

1. Aggregates
2. Bituminous Material
3. Cement

The aggregates form nearly 75% - 90% of the volume of a road structure and hence the quality of aggregates plays a great role in the performance and long term economy of the road structure. The aggregates also bare the main stresses occurring in the road and resist wear from surface abrasion.

Types of Road Aggregates

The raw material which is used as road aggregates can be classified in following two categories:

1. Natural aggregates
2. Artificial aggregates

Thus the natural aggregates can be divided into following 3 types:

A. Crushed rock aggregates

B. Gravel

C. Sand

Road Design

General design principles

Roads should be designed to:

- provide safe, short and fast thoroughfare and access to all road users, being motor vehicles, cyclists and pedestrians;
- clearly convey the primary function to road users and encourage appropriate driver behaviour;
- deliver traffic volumes at speeds compatible with function;
- provide convenient location for services;
- provide an opportunity for landscaping;
- allow for parking, where appropriate;
- have due regard to topography, geology, climate, environment and heritage of the site;
- provide low cost of ownership;
- comply with these Standards and relevant AUSTROADS, ACT Code and other State Road Authorities' Guidelines and/or Standards;

The appropriate design criteria for a specific road largely depend on a set of economic indicators, namely costs of construction and operation on one side, and the financial benefits to the community on another. These are strategic parameters that influence a decision to build a road. Economic analysis, in conjunction with the traffic analysis, determine the functional class of the road and the design speed.

Guide to the Geometric Design of Major Urban Roads and *Guide to the Geometric Design of Rural Roads* define road classification. This classification is further refined in the ACT as follows:

- parkways (i.e. urban motorways);
- arterial roads;
- sub-arterial roads;
- collector roads; and
- access streets.

Refer to Chapter 2 Road Planning for further details.

Traffic speed

Traditionally, design speed has been a basic parameter in determining road standards and is a function of the road classification. However, Guide to the Geometric Design of Major Urban Roads and Guide to the Geometric Design of Rural Roads have introduced an operating speed concept. Operating speed in these guidelines is defined as 85th percentile speed of cars when traffic volumes are low. For rural roads, the methodology for the geometric design has moved to the use of "Section Operating Speed" (see *Guide to the Geometric Design of Rural Roads*) . For major urban roads, geometric design for cars is based on the operating speed that is 10km/h higher than the legal speed limit (see *Guide to the Geometric Design of Major Urban Roads*). For local roads, since low standard and low design speed roads tend to return operating speeds higher than the arbitratory speed limits, operating speed is used to assess the need for traffic calming measures in suburban areas in accordance with *Guide to Traffic Engineering Practice, Part*

Unless otherwise sign posted, the following general legal speed limits are in force in the ACT:

- 100km/h on parkways and rural roads;
- 80km/h on all arterial roads and some sub-arterial roads;
- 60km/h on some sub-arterial roads and major collector roads;
- 50km/h on minor collector roads and access streets.

Traditionally, access streets are designed for 40km/h (horizontal alignment) and 60km/h (vertical alignment) design speed. Refer to Chapter 2 Road Planning for further information on the road hierarchy, traffic modelling and vehicular speed. For the purpose of cross referencing with documents that are still based on design speed, operating speed that is determined in accordance with *Guide to the Geometric Design of Major Urban Roads, Guide to the Geometric Design of Rural Roads* and/or *ACTcode*, and design speed shall be considered to be the same.

Sight distance

A minimum stopping sight distance should be provided at all points along the road. Stopping sight distance is a function of vehicle speed, reaction time, eye hight and object hight. The recommended values of the object heights are given in Table 1.

Table 1 Object heights

Object height (m)	**Situation**
0.00	Intersections
0.20	General situations
0.60	Car tail lights
1.05	Entering sight distance

A car driver eye height of 1.05m is used for the geometric design of both urban and rural roads. For commercial vehicles, a driver eye height of 1.8m is used for general geometric design. A driver eye height of 2.5m is used for checking sight distances on sag curves. For the geometric design of major urban roads, a reaction time of 2.0 seconds is to be used. For the geometric design of rural roads, a reaction time of 2.5 seconds is to be used. In situations where the adoption of a reaction time of 2.5 seconds would result in impractical solutions, a reaction time of 2.0 seconds may be considered. Minimum values for stopping sight distance for cars and trucks are given in *Guide to the Geometric Design of Major Urban Roads* and *Guide to the Geometric Design of Rural Roads.*

Overtaking sight distance (OSD), intermediate sight distance (ISD), man oeuvre sight distance (MSD), approach intersection sight distance (ASD), intersection entering sight distance (ESD) and safe intersection sight distance (SISD) are defined and discussed in detail in both *Guide to the Geometric Design of Major Urban Roads* and *Guide to the Geometric Design of Rural Roads.*

In situations where opportunities for the provision of safe sight distance might be limited, it is a good practice to show sight lines on drawings.

Elements of horizontal geometry

General

Horizontal alignment of a road is a basis for definition of strings of characteristic points determined from typical cross section (centerline line, edges of carriageway, edges of road formation, longitudinal drains etc) in a horizontal X-Y plane. The geometry of the road strings is made up of a series of connected curves, straights and spirals. Physics of vehicular movement and the vehicle speed dictate selection of appropriate elements of horizontal alignment. These elements should also be aesthetically pleasing and result in cost effective solutions. Refer to *Guide to the Geometric Design of Major Urban Roads* and *Guide to the Geometric Design of Rural Roads* for further discussion on the movement on a circular path.

Horizontal alignment

Traditionally, the horizontal alignment of a road normally comprises of a series of straights and circular arcs, which may be connected by transition (spiral) curves. Recently, curvilinear horizontal alignment is frequently used in flat terrain in lieu of long straights, especially in the design of major dual carriageway roads. Curvilinear alignments are more aesthetically pleasing and blend better with environment, resulting in less ecological impact and lower construction cost. Principles for the design of a curvilinear alignment are discussed in *Guide to the Geometric Design of Rural Roads. Guide to the Geometric Design of Major Urban Roads* and *Guide to the Geometric Design of Rural Roads* give guidelines for the length of straight as a function of speed.

Straights longer than $20V_d$ expressed as meters should be avoided.

The following are common types of complex horizontal curves:

- **Compound curves.** Compound curves comprise of two or more adjoining curves of different radii in the same direction.
- **Broken back curves.** Broken back curves are horizontal curves in the same direction joined by a straight.
- **Reverse curves.** Reverse curves are adjoining horizontal curves in opposite direction, either back-to-back or connected by a straight or spiral.
- **Transition curves.** Transition curves are normally used to join straights and circular curves. They provide for a comfortable transition between two elements with a different curvature and provide room for transition of cross fall to the full super elevation. The most frequently used form of transition curves is clothed or Euler spiral. Transition curves should be omitted for sections of roads with operating speed not exceeding 60km/h.

Guidelines for use of the above complex horizontal curves in the horizontal alignment design are discussed in *Guide to the Geometric Design of Major Urban Roads* and *Guide to the Geometric Design of Rural Roads* in more detail. Formula for calculation of the radius of horizontal curve is given in both G*uide to the Geometric Design of Major Urban Roads* and *Guide to the Geometric Design of Rural Roads.* Minimum radii of horizontal curves, maximum super elevation and maximum friction demand for a range of operating speeds are tabulated in *Guide to the Geometric Design of Major Urban Roads* and *Guide to the Geometric Design of Rural Roads.* The minimum curve length is required to provide satisfactory appearance and avoid kinks in the horizontal alignment. On curves with radii less than 200m, lane widening is required in order to accommodate standard design vehicle (ie 19m long semi trailer). Where the required lane widening on a curve is greater than 4.6m, cars have a tendency to travel two abreast. Thus, the full pavement should be constructed across the 4.6m width, with the constant line width (normally 3.5m) line-marked around the curve. Small radius curves shall be checked against the sight distance requirements, since the sight distance may be limited by close proximity of lateral obstructions such as cut batters, vegetation, bridge piers and signs. If required, benching shall be provided on the inside of the curve in accordance with *Guide to the Geometric Design of Rural Roads.*

Super elevation

Super elevation is introduced to help vehicles to negotiate circular path by reducing friction demand. Super elevation also provides driver guidance into the curve. In general:

- urban roads with design speeds of up to and including 60km/h shall not be super elevated;
- urban roads with design speeds between 60km/h and 80km/h and rural roads with design speeds up to 60km/h should be super elevated, if super elevation does not encourage speeding;

- urban roads with design speeds in excess of 80km/h and rural roads with design speed in excess of 60km/h shall be super elevated.

Maximum values of super elevation shall be in accordance with Table 2.

Table 2 Maximum values of super elevation as a function of operating speed

Road type	Operating speed (km/h)	Maximum Recommended Super elevation (%)	Absolute maximum Super elevation (%)
Urban	= 60km/h	No super elevation	No super elevation
	= 60km/h	4%	6%
	= 80km/h		
	> 80km/h	5%	7%
Rural	= 60km/h	5%	7%
	> 60km/h	7%	10%

Generally

- The minimum radii of horizontal curves and the absolute maximum values of super elevation should be avoided, especially on urban roads.
- The designer should note that the minimum radius of horizontal curve corresponds with the maximum super elevation adopted for the operating speed. By selecting different values for the super elevation and/or operating speed, the designer has an opportunity to provide driving comfort commensurate with the intended road function.
- All rural roads, regardless of the operating (design) speed should be super elevated.
- Adverse cross fall on urban roads with operating speed above 60km/h are acceptable provided that the requirements of the *Guide to the Geometric Design of Major Urban Roads* are met.
- Change of super elevation on bridges should be avoided.

Guide to the Geometric Design of Major Urban Roads and *Guide to the Geometric Design of Rural Roads* provide further considerations regarding the application of super elevation.

Ideally, a person driving at operating speed should experience the same centripetal acceleration in every curve, including the minimum radius curve. Therefore, every curve on a given section of the road with a constant operating speed should be super elevated so that proportions of centripetal force due to super elevation and side friction are the same as for the minimum radius curve. This indicates that the required super elevation in a particular curve is proportional to maximum super elevation, maximum side friction factor and minimum radius of horizontal curve adopted for the operating speed of the road section.

Super elevation development and length of transition

Super elevation development is the pavement rotation from normal cross fall to the full super elevation required for the particular curve. Full super elevation should be developed at both ends of the circular arc. The adopted position of the axis of the pavement rotation depends on the type of road, typical cross section, terrain, and location of the road and surface drainage requirements. Normally:

- On a two lane two way road the axis of rotation is centerline of the road and both halves of the cross section (including shoulders) are rotated independently.
- On a two lane dual carriageway road the axis of rotation is the median edge of the pavement.

- On three lane dual carriageway road the axis of rotation is between the centre lane and the median lane.
- On interchange ramps the axis of rotation is the pavement edge.

The length of superelevation development is the distance required for the pavement to change its crossfall from normal to superelevated, at the same time providing riding comfort and satisfactory appearance. Thus, two criteria are used to determine this length:

- Rate of rotation; and
- Relative grade, ie the difference between the longitudinal grade of the edge of the carriageway and the longitudinal grade of the axis of rotation.

For circular arcs with transition (spiral) curves, it is a common practice to adopt the length of the superelevation development equal to the length of the transition curve. At reverse curves with common tangent points, zero pavement crossfall is unavoidable at the common point. This should not be coincidental with zero longitudinal grade. Extreme care shall be taken in the vicinity of zero crossfall. The designer is to check drainage and provide adequate longitudinal grade to ensure that water is not ponding on the pavement. The subgrade superelevation shall be treated as shown in the Standard Drawing. Refer to Chapter 1 Storm water for drainage details. Refer to *Guide to the Geometric Design of Major Urban Roads* and *Guide to the Geometric Design of Rural Roads* for detail requirements. Refer to *ACTCode* for the requirements for the design of residential roads.

Elements of vertical geometry

General principles

Vertical alignments are designed with respect to sight distances, which in turn are a function of speed. As an absolute minimum, a safe stopping sight distance must be provided at every point on the vertical alignment.

Typical controls for the vertical geometry, in no specific order, are:

- topology;
- geology;
- existing intersections;
- property accesses and driveways;
- required clearances for structures;
- required clearances for services; and
- pedestrian and cycling requirements.

In addition to checking for the required minimum lateral clearance, overpasses and large trees should be checked for truck sight stopping distance. For this purpose, driver eye height shall be set to 2.5m and the target height to 0.6m (tail lights of the vehicle in front).

Grades

The minimum grade is a function of road drainage. On rural roads, in cuttings and at the superelevation transitions, grades should be adequate for at least table drains or gutters, ie minimum 0.5% to 1.0%. In fill and outside the superelevation transitions, unkerbed roads could have 0% grade providing that table drains have positive gradient.

On all kerbed roads in the ACT, the desirable minimum grade shall be 1.0%. Flatter grades (between 0.5% and 1.0%) may be permitted subject to the designer providing satisfactory evidence that drainage provision and the proposed construction practices are such that no ponding shall occur. Grades flatter that 0.5% may be permitted only in exceptional circumstances (ie widening of existing pavement). The designer shall outline procedures that will ensure that the finished gutter profile and pavement surface are free draining and that the width of flow is within the requirements. Unkerbed roads may be provided as the first stage of kerbed roads. To minimise abortive work and maximise utilisation of the most expensive single road component (the pavement), it is a good practice to adopt grades as required for the kerbed roads. The maximum grade is a function of site conditions, vehicle dynamics, road construction cost and maintenance cost. Depending on the design speed and terrain, maximum grades vary from 3% to 10% and more. The minimum length of grade is governed by appearance. The maximum length of grade, especially steep grade, is governed by the operating speed of a typical loaded truck (uphill) and the risk of brake failure (downhill).

Guide to the Geometric Design of Major Urban Roads, *Guide to the Geometric Design of Rural Roads* and *ACTCode* provide adequate information to adopt the correct maximum grade and the length of grade for the operating conditions of the road.

Vertical curves

Vertical curves are used to provide transition between different grades and increase sight distance across the two grades. The most common form of the vertical curve is a parabola, which is an approximation of circular curve.

Convex vertical curves are referred to as crest or summit curves. Concave vertical curves are commonly known as sag curves.

Three criteria are used to determine the length of a vertical curve:

- sight distance, usually sight stopping distance;
- appearance; and
- comfort, i.e; vertical acceleration.

In case of crest curves, the third (comfort) criterion is met if the sight distance and appearance criteria are met. However, on low speed suburban roads, meeting the appearance criterion may not be possible. In such cases, the length of the vertical curve adopted from the sight distance criterion should be also checked for comfort. In case of sag curves, appearance and comfort are normally the governing criteria. Sight distance is checked for overhead obstructions (if present) and/or for headlight sight distance (for operating speeds above 80km/h). Contrary to the horizontal curves, reverse vertical curves with common tangent points are acceptable.

The designer should check the resulting grade from superimposing superelevation and longitudinal grade for drainage considerations. Some combination of long transitions and steep grades result in sheet flows along the road and slow evacuation of the surface water across the road. Refer to Chapter 1 Stormwater for detail requirements.

Design form

Horizontal and vertical alignments should be in tune with each other. Good three dimensional co-ordination of the horizontal and vertical alignment of a road improves traffic safety and aesthetics. Careful consideration is needed when deciding on the initial position of the alignment. Incorrect selection of the alignment results in high cost of the road. The operating speed in both horizontal and vertical projections should be the same or, as a minimum, of the same order. However, the combination of minimum elements of plan and profile should be avoided, as it is likely to produce an unsatisfactory solution.

Where adopted, minimum sight distances shall be checked three dimensionally.

The designer should remember that the combined road alignment must be safe for all users in all conditions.

Refer to *Guide to the Geometric Design of Major Urban Roads* and *Guide to the Geometric Design of Rural Roads* for further discussion.

Typical cross section

The typical cross section defines the relationships between functional elements of the road. It defines origin points of lines (strings) that will be created in the other two projections (plan and profile).

Selection of elements of a cross section is an iterative process based on road function, safety environmental constraints, aesthetics and available funding. All design elements of the cross section must have proper crossfall to efficiently evacuate surface water away from the road formation. Subsoil (pavement) drainage is discussed in Chapter 6 Road Pavements. The width of a kerbed road is measured from the face of the kerb. Normal lane width is 3.5m. Typical widths and normal crossfall of cross sections of urban roads above and including internal roads are given in *Guide to the Geometric Design of Major Urban Roads*. Typical widths and normal crossfall of cross section of urban road up to and including collector roads are given in *ACT Code*. See Chapter 13 Pedestrian and Cycling Facilities for the provision for on road cycling.

The designer should note that there are some benefits, particularly in narrow access streets, in using one way crossfalls. Overland drainage flows should be checked in roads with one way crossfalls as the overall capacity of the road to transfer flows is significantly reduced over the two way crossfall configuration. Kerbs are normally provided on urban roads with speed limits up to and including 80km/h. Details of the kerbs normally used in the ACT are given in the Standard Drawings. In the areas adjacent to open space where parking is to be discouraged, kerb only or kerb and gutter should be used. Refer to Standard Drawings for typical use of specific kerb types.

Even on unkerbed urban roads, intersections should be kerbed in order to:

- better channel the traffic;
- provide protection for pedestrians and off road cyclists crossing the road; and
- allow protection for the traffic signals and signs.

Careful treatment of on road cycling provisions is required at all intersections, especially in cases when mid block unkerbed roads with on shoulder cycling are approaching kerbed intersections. Refer to Chapter 13 Pedestrian and Cycling Facilities. If construction of a dual carriageway road (usually a 80km/h+ arterial road) is staged, the width of the first stage carriageway shall be 9.0m. During the first stage of operation, a 4.5m wide shared lane shall be provided in each direction. When the road is duplicated, the existing carriageway shall be line-marked with two 3.5m wide traffic lanes and 2.0m wide cycle lane. The minimum width of the second carriageway shall be 9.0m to allow for the same lane configuration. The first stage carriageway should have mountable kerbs on both sides to allow for broken down vehicles to be pushed on the verge. The second carriageway should typically have barrier kerb on the verge side and mountable kerb on the median side. For the widths of median , refer to Guide to the Geometric Design of Major Urban Roads. For landscaping in verges see Chapter 22 Soft Landscaping Design.

For the lighting design requirements and lateral position of light poles refer to Chapter 12 Public Lighting.

Auxiliary lanes

Refer to and *Guide to the Geometric Design of Rural Roads* for further discussion.

Intersections

Types and control

Two major intersection types are grade separated intersections (interchanges) and intersections at grade. Interchanges are not covered specifically in these Standards since they are rare in the ACT. The fundamental design considerations related to intersections at grade are 113inimize113d in this section. Detailed information is provided in *Guide to Traffic Engineering Practice – Part 5 – Intersections at Grade, Guide to Traffic Engineering Practice – Part 6 – Roundabouts, Guide to the Geometric Design of Major Urban Roads* and *Guide to the Geometric Design of Rural Roads.* Refer also to Chapter 2 Road Planning and to Chapter 13 Pedestrian and Cycling Facilities.

Basic geometric intersection forms are:

- three leg intersection ('T' intersection);
- four way intersection (cross intersection); and
- multi leg intersection.

Multi leg intersections should be avoided.

Intersection treatments may be:

- plain;
- flared; and
- minimize, including roundabouts.

Plain intersections are the most common type where continuation of the line marking provides traffic minimize113d. The designer shall design the left turn to satisfy turning requirements for an adopted design vehicle.

Flared intersections have one or more approaches which are widened to accommodate additional turning lanes. Traffic minimized is provided by line marking.

Channelled intersections have physical traffic islands which are used to direct traffic into clearly defined paths, thus minimized undesirable and dangerous movements, and increasing safety and capacity. A roundabout is considered to be a special form of a minimize intersection.

Intersection control may be:

- priority control ("Give way" or "Stop"); and
- minimized.

Refer to Chapter 9 Traffic Control Drawings for details regarding signage, linemarking and traffic signals.

Geometric type, treatment and intersection control on major roads should be miniinimiz using SIDRA. SIDRA minimize is usually not required in suburban design.

Traffic manoeuvres at intersections

Basic types of manoeuvres at intersections are:

- crossing;
- diverging;
- merging; and
- weaving.

Multiple manoeuvres should be avoided as they are confusing and usually lead to capacity and safety problems.

Assuming that all legitimate traffic movements are possible at the intersection, the number of conflict points is calculated as

$$n!$$

where

n = number of incoming legs.

Thus, for a three leg intersection, the number of conflict points is: $3! = 1\times2\times3 = 6$.

For a four leg intersection, the number of conflict points is: $4! = 1\times2\times3\times4 = 24$, and for a five leg intersection: $5! = 1\times2\times3\times4\times5 = 120$.

This clearly indicates why priority controlled 'T' intersections are preferred.

Intersection positioning and spacing

Intersection positioning and spacing is usually governed by road planning and urban planning. Refer to Chapter 2 Road Planning.

Generally, intersections in major roads should be positioned:

- in or near horizontal curves of large radii;
- on the outside of horizontal curves;
- close to the middle of tangent straights;
- in sags;
- away from objects like bridges and underpasses; and
- away from any constraints that might impact on a future capacity upgrade. Intersections should not be positioned:
- in or near horizontal curves of small radii;
- on the inside of horizontal curves;
- in curves with superelevation greater than 3%;
- within the area of superelevation development; and

- on or close to sharp crests.

Similar guidelines should be followed in the design of subdivision intersections.

Intersection layout

Once the geometric intersection form, treatment and type of control have been adopted in accordance with Chapter 2 Road Planning, detail intersection layout shall be designed in accordance with *Guide to Traffic Engineering Practice – Part 5 – Intersections at Grade* and *Guide to Traffic Engineering Practice – Part 6 – Roundabouts* as appropriate. The designers are reminded that the sight distances given in these Guides are calculated for 1.15m eye height and should be recalculated for the 1.05m eye height as per these standards

All turning manoeuvres should be checked for compliances with the swept path of the design vehicle either using standard templates or, preferably, using computer software such as AutoTURN.

Alignments of the incoming legs

The Geometric Design of Major Urban Roads and Guide to the Geometric Design of Rural Roads provide information about acceptable treatments of the alignments of the incoming legs. The incoming alignments should be of the highest possible standard. Major movements should have operating speeds consistent with the adjoining mid block sections. Normally, the grade of the major road should be carried through the intersection unmodified. The exception is an intersection located on a steep grade, where the steep grade needs to be flattened to minimize a risk of overturning of high vehicles when travelling on adverse cross fall. This is especially important at roundabouts.

It is a good practice to locate an intersection on a maximum 3% to 4% grade. If a roundabout is located on a grade steeper than 4%, the designer should demonstrate that the resulting crossfall of the circulating lanes of the roundabout provides sufficient stability for high vehicles.

ROAD SAFETY

Some official estimates indicate that around 30% of crashes relate to the roadside environment. This figure is probably underestimated since the roadside environment figures in many speed related crashes.*)*

Refer to *Guide to the Geometric Design of Major Urban Roads* and *Guide to the Geometric Design of Rural Roads* for detail discussion on the road safety principles and practice. Refer also to Chapter 9 Traffic Control Devices, Chapter 11 Guardrails, Fences and Barriers, Chapter 12 Public Lighting, Chapter 13 Pedestrian and Cycling Facilities and Chapter 22 Soft Landscape Design for further safety requirements.

Currently, there is no policy on road safety audits of new projects in the ACT. The Client should decide on a project to project basis if a formal road safety audit in accordance with *Road Safety Audit* is required, and appoint an independent auditor to conduct the audit.

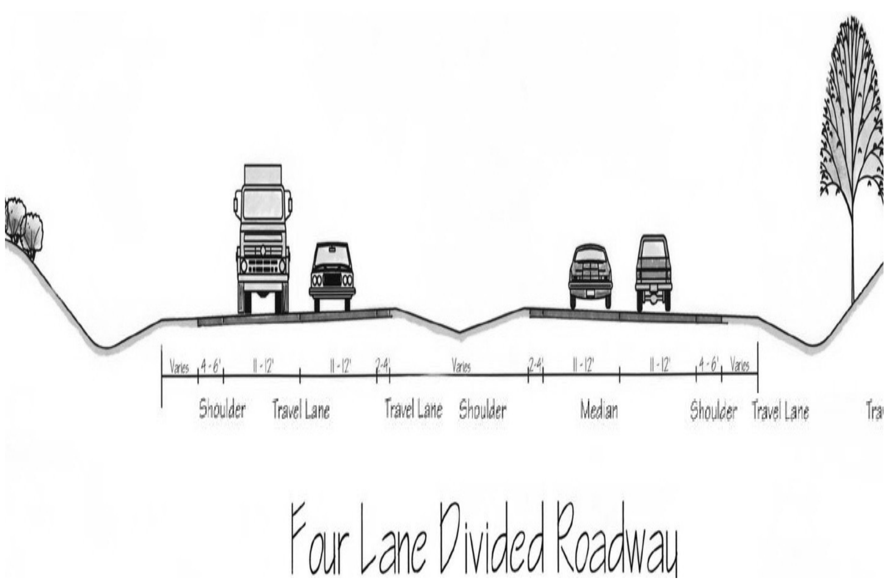

Fig. 1 Four lane divided road way

Tests for road Aggregates:

A. Abrasion Test

B. Crushing test

C. Impact Test

D. Shape Test

E. Soundness Test

F. Specific Gravity & water absorption Test

G. Stripping Value Test

TESTS ON MATERIALS

(a) Aggregates: Aggregate plays an important role in pavement construction. Aggregates influence, to a great extent, the load transfer capability of pavements. Hence it is essential that they should be thoroughly tested before using for construction. Not only that aggregates should be strong and durable, they should also possess proper shape and size to make the pavement act monolithically. Aggregates are tested for strength, toughness, hardness, shape, and water absorption.

In order to decide the suitability of the aggregate for use in pavement construction, following tests are carried out:

1. Crushing test
2. Abrasion test
3. Impact test
4. Soundness test
5. Shape test
6. Specific gravity and water absorption test
7. Bitumen adhesion test

1. **Crushing Test**

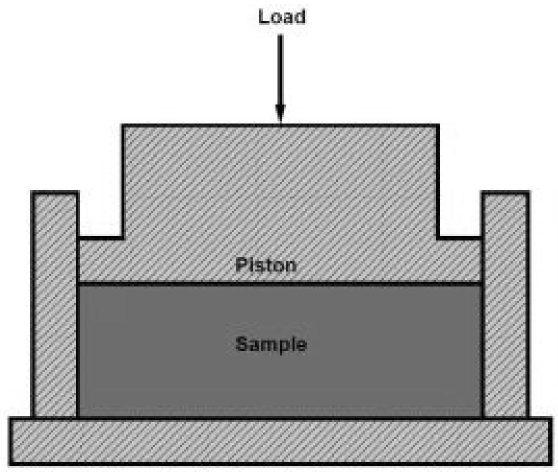

Fig. 2 Crushing test setup

One of the model in which pavement material can fail is by crushing under compressive stress. A test is standardized by **IS: 2386 part-IV** and used to determine the crushing strength of aggregates. The aggregate crushing value provides a relative measure of resistance to crushing under gradually applied crushing load.

The test consists of subjecting the specimen of aggregate in standard mould to a compression test under standard load conditions (See Fig-1). Dry aggregates passing through 12.5 mm sieves and retained 10 mm sieves are filled in a cylindrical measure of 11.5 mm diameter and 18 cm height in three layers. Each layer is tamped 25 times with at standard tamping rod. The test sample is weighed and placed in the test cylinder in three layers each layer being tamped again. The specimen is subjected to a compressive load of 40 tonnes gradually applied at the rate of 4 tonnes per minute. Then crushed aggregates are then sieved through 2.36 mm sieve and weight of passing material (**W2**) is expressed as percentage of the weight of the total sample (**W1**) which is the aggregate crushing value.

Aggregate crushing value = (W1/W2)*100

A value **less than 10** signifies an exceptionally **strong aggregate** while **above 35** would normally be regarded as **weak aggregates**.

2. **Abrasion Test**

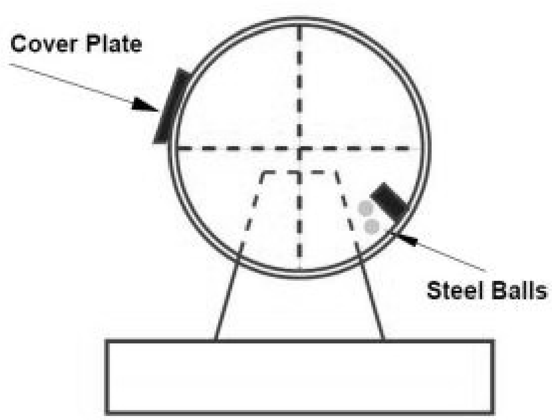

Fig. 3 Los angeles abrasion test setup

Abrasion test is carried out to test the hardness property of aggregates and to decide whether they are suitable for different pavement construction works. Los Angeles abrasion test is a preferred one for carrying out the hardness property and has been standardized in India (**IS: 2386 part-IV**).

The principle of Los Angeles abrasion test is to find the percentage wear due to relative rubbing action between the aggregate and steel balls used as abrasive charge. Los Angeles machine consists of circular drum of internal diameter 700 mm and length 520 mm mounted on horizontal axis enabling it to be rotated (see Fig-2). An abrasive charge consisting of cast iron spherical balls of 48 mm diameters and weight 340-445 g is placed in the cylinder along with the aggregates. The number of the abrasive spheres varies according to the grading of the sample. The quantity of aggregates to be used depends upon the gradation and usually ranges from 5-10 kg. The cylinder is then locked and rotated at the speed of 30-33 rpm for a total of 500 -1000 revolutions depending upon the gradation of aggregates.

After specified revolutions, the material is sieved through 1.7 mm sieve and passed fraction is expressed as percentage total weight of the sample. This value is called Los Angeles abrasion value.

A maximum value of **40 percent** is allowed for **WBM base course** in Indian conditions. For **bituminous concrete**, a maximum value of **35 percent** is specified.

3. **Impact Test**

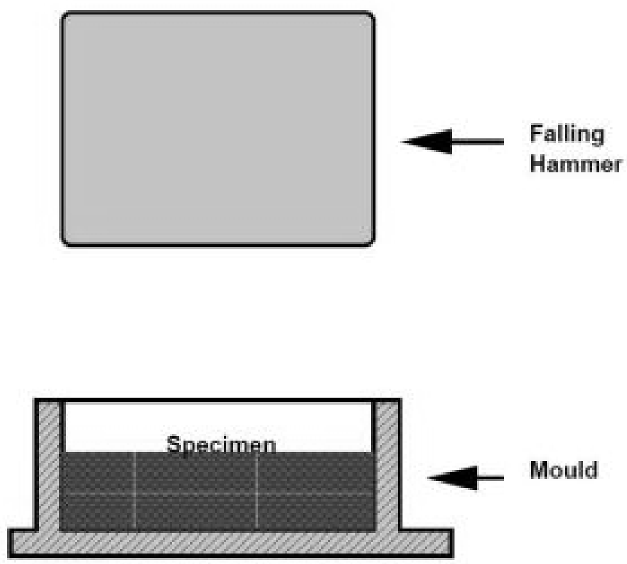

Fig. 3 Impact test setup

The aggregate impact test is carried out to evaluate the resistance to impact of aggregates. Aggregates passing 12.5 mm sieve and retained on 10 mm sieve is filled in a cylindrical steel cup of internal dia 10.2 mm and depth 5 cm which is attached to a metal base of impact testing machine. The material is filled in 3 layers where each layer is tamped for 25 numbers of blows (see Fig-3). Metal hammer of weight 13.5 to 14 Kg is arranged to drop with a free fall of 38.0 cm by vertical guides and the test specimen is subjected to 15 numbers of blows. The crushed aggregate is allowed to pass through 2.36 mm IS sieve. And the impact value is measured as percentage of aggregates passing sieve (**W2**) to the total weight of the sample (**W1**).

Aggregate impact value = (W1/W2)*100

Aggregates to be used **for wearing course**, the impact value **shouldn't exceed 30 percent**. For **bituminous macadam** the **maximum** permissible value is **35 percent**. For **Water bound macadam** base courses the maximum permissible value defined by IRC is **40 percent.**

4. **Soundness test:** Soundness test is intended to study the resistance of aggregates to weathering action, by conducting accelerated weathering test cycles. The Porous aggregates subjected to freezing and thawing is likely to disintegrate prematurely. To ascertain the durability of such aggregates, they are subjected to an accelerated soundness test as specified in **IS: 2386 part-V**.

   Aggregates of specified size are subjected to cycles of alternate wetting in a saturated solution of either sodium sulphate or magnesium sulphate for 16 – 18 hours and then dried in oven at 105 to 110^0C to a constant weight. After **five cycles**, the loss in weight of aggregates is determined by sieving out all undersized particles and weighing.

   The loss in weight should **not exceed 12 percent** when tested with **sodium sulphate** and **18 percent** with **magnesium sulphate** solution.

5. **Shape Tests:** The particle shape of the aggregate mass is determined by the percentage of flaky and elongated particles in it. Aggregates which are flaky or elongated are detrimental to higher workability and stability of mixes.

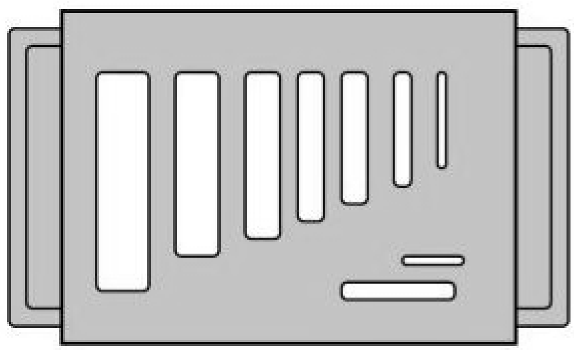

Fig. 4 Flakiness Gauge

The **flakiness index** is defined as the percentage by weight of aggregate particles whose **least dimension is less than 0.6 times their mean size**. Flakiness gauge (see Fig-4) is used for this test. Test procedure had been standardized in India (**IS: 2386 part-I**).

The **elongation index** of an aggregate is defined as the percentage by weight of particles whose **greatest dimension (length) is 1.8 times their mean dimension**. This test is applicable to aggregates larger than 6.3 mm. Elongation gauge (see Fig-5) is used for this test. This test is also specified in (**IS: 2386 Part-I**). However there are no recognized limits for the elongation index.

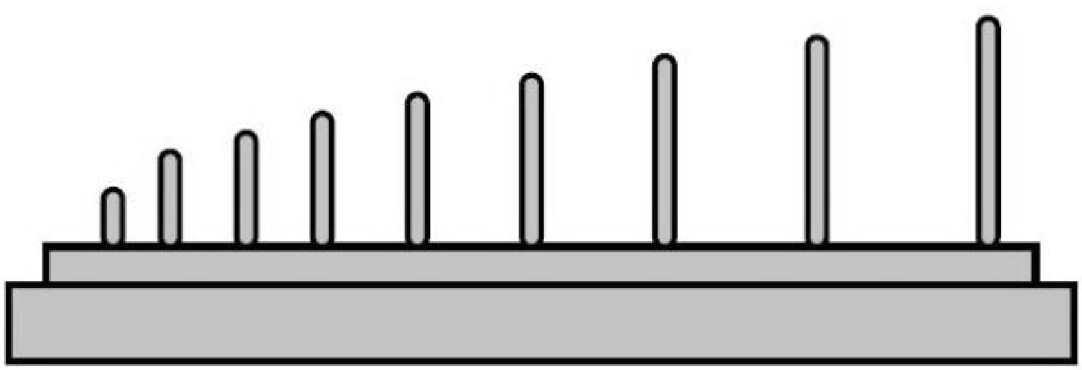

Fig. 5 Elongation Gauge

6. **Specific Gravity and Water Absorption Test:** The specific gravity and water absorption of aggregates are important properties that are required for the design of concrete and bituminous mixes. The specific gravity of a solid is the ratio of its mass to that of an equal volume of distilled water at a specified temperature. Because the aggregates may contain water-permeable voids, so two measures of specific gravity of aggregates are used:

   1. Apparent specific gravity and
   2. Bulk specific gravity.

   Apparent Specific Gravity, G_{app}, is computed on the basis of the net volume of aggregates i.e the volume excluding water-permeable voids. Thus

$$G_{app} = [(M_D/V_N)]/W$$

Where,

M_D is the dry mass of the aggregate,

V_N is the net volume of the aggregates excluding the volume of the absorbed matter,

W is the density of water.

Bulk Specific Gravity, G_{bulk}, is computed on the basis of the total volume of aggregates including water permeable voids. Thus

$$G_{bulk} = [(M_D/V_B)]/W$$

Where,

V_B is the total volume of the aggregates including the volume of absorbed water.

Water Absorption: The difference between the apparent and bulk specific gravities is nothing but the water permeable voids of the aggregates. We can measure the volume of such voids by weighing the aggregates dry and in a **saturated surface dry condition**, with all permeable voids filled with water. The difference of the above two is M_W.

M_W is the weight of dry aggregates minus weight of aggregates saturated surface dry condition. Thus,

Water Absorption = (M_W/M_D)*100

The specific gravity of aggregates normally used in road construction ranges from about 2.5 to 2.9. Water absorption values ranges from 0.1 to about 2.0 percent for aggregates normally used in road surfacing.

List of IS Codes Related to Aggregate Testing

Tests for Aggregates with IS codes

Property of Aggregate	Type of Test	Test Method
Crushing strength	Crushing test	IS : 2386 (part 4)
Hardness	Los Angeles abrasion test	IS : 2386 (Part 5)
Toughness	Aggregate impact test	IS : 2386 (Part 4)
Durability	Soundness test	IS : 2386 (Part 5)
Shape factors	Shape test	IS : 2386 (Part 1)
Specific gravity and porosity	Specific gravity test and water absorption test	IS : 2386 (Part 3)
Adhesion to bitumen	Stripping value of aggregate	IS : 6241-1971

(b) Cement: Fineness

Standard EN 196-6 describes two methods of determining the fineness of cement: Sieving method

Sieving Method

This method serves only to demonstrate the presence of coarse cement particles. This method is primarily suited to checking and controlling production process. The fineness of cement is measured by sieving it on standard sieves. The proportion of cement of which the grain sizes are larger than the specified mesh size is thus determined.

Determination of Setting Time

The setting time is determined by observing the penetration of needle into cement paste of standard consistence until it reaches a specified value. The laboratory shall be maintained at a temperature of 20 ± 2 °C and a relative humidity of not less than 65 %. Standard Consistence Test Cement paste of standard consistence has a specified resistance to penetration by a standard plunger. The water required for such a paste is determined by trial penetrations of pastes with different water contents. Content of water is expressed as percentage by mass of the cement.

Vicat apparatus with the plunger is used for the test. The plunger shall be of non- corrodible metal in the form of a right cylinder of 50 ±1mm effective length and of 10,00 ±0,05 mm diameter. The total mass of moving parts shall be 300 ±1 g. Part of the Vicat apparatus is the mould from hard rubber (of truncated conical form) on the glass base-plate.

(c) Bitumen:

Determining the Ductility Of Bitumen

This test is done to determine the ductility of distillation residue of cutback bitumen, blown type bitumen and other bituminous products as per IS: 1208 – 1978. The principle is : The ductility of a bituminous material is measured by the distance in cm to which it will elongate before breaking when a standard briquette specimen of the material is pulled apart at a specified speed and a specified temperature.

The apparatus required for this test:

(i) Standard mould
(ii) Water bath
(iii) Testing machine
(iv) Thermometer – Range 0 to 44^{o}C, Graduation 0.2^{o}C

Determining Penetration of Bitumen

This test is done to determine the penetration of bitumen as per IS: 1203 – 1978. The principle is that the penetration of a bituminous material is the distance in tenths of a mm, that a standard needle would penetrate vertically, into a sample of the material under standard conditions of temperature, load and time. The apparatus needed to determine the penetration of bitumen is

(i) Penetrometer
(ii) Water bath
(iii) Bath thermometer – Range 0 to 44^{o}C, Graduation 0.2^{o}C

Determining Specific Gravity of Bitumen

This test is done to determine the specific gravity of semi-solid bitumen road tars, creosote and anthracene oil as per IS: 1202 – 1978. The principle is that it is the ratio of mass of a given volume of bitumen to the mass of an equal volume of water, both taken at a recorded/specified temperature.

The apparatus needed to determine specific gravity of bitumen is

(i) Specific gravity bottles of 50ml capacity
(ii) Water bath
(iii) Bath thermometer – Range 0 to 44^{o}C, Graduation 0.2^{o}C

Take the sample (half the volume of the specific gravity bottles).

CONCLUSIONS

Based on the present study of road safety audit for 4 lane national highways the following

Conclusions have been drawn: Due to newly upgraded four lane National Highway-58 between Km 75.000 to Km 130.00, the road standards have been raised suddenly. But other related factors are not brought to this level such as road user behavior, surrounding prevailing conditions etc. The road standards are permitting high speeds, but prevailing traffic conditions are not conducive to such speeds. Earlier the average speed of vehicles was 30-40 Kmph and now 60-70 Kmph where as design speed is 100 Kmph which is very high. From data simulation, it found that Road Markings, Condition of Shoulder, Traffic Volume, Spot Speed, Median Opening and Carriageway condition were main parameters for causing accidents. It was also seen that slow moving traffics were creating traffic hazards for fast moving traffic as it always occupied the innermost lane of highway. Therefore service roads should be provided for the entire length of four lane roads in order to separate slow moving traffic from fast moving traffic. All unauthorized median openings should closed and adequate provisions for crossing local people be made on priority. All undeveloped major and minor intersections must be developed with adequate lighting provisions as quickly as possible since maximum accidents were observed on these locations. Pedestrian guardrail should be provided all along the footpath of service road and at bus stops.

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Input Significance Testing of Parameters Governing Bed Load Transport

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ABSTRACT

The bed load transport has been extensively studied in the past few decades and many bed load equations have been developed which essentially differ from each other in derivation and form. If bed load transport rate can be related to various flow conditions on a general basis, a proper understanding of bed load movement can be ascertained. As the process involved in bed load transport is extremely complex, getting deterministic or analytical form of process phenomena is too difficult. Neural network modeling, which is particularly useful in modeling processes about which adequate knowledge of the physics is limited, is presented as a tool complimentary to modeling bed load transport. The prediction capability of model has been found satisfactory and methodology to use the model is also presented. Bed load transport comprises of different parameters of different nature such as hydraulic, bed character tics, geometric parameters of the channel and the nature of sediment particles. Here it is important to know the influences of these parameters on bed load transport process. Based on the input significant techniques through ANN model, it has been found that hydraulic parameters are influencing more the bed load transport. The most influencing parameter is flow discharge and least is the sediment gradation coefficient. This shows the importance of determining the hydraulic parameters more correctly. The variability of bed load transport with different parameters is also important to have a proper understanding of the bed load transport process. Based on the ANN model, it has been shown in the present work.

Keywords: alluvial channel; bed load transport; bed shear stress; input significance; sensitivity analysis; neural network.

INTRODUTION

Bed load transport in alluvial rivers is the principle link between river hydraulics and river form (Parker 1978; Leopold 1994; Gomez 2006) and is responsible for building and maintaining the channel geometry (Parker 1978; Leopold 1994; Goodwin 2004). Bed load transport provides the major process linkage between the hydraulic and material conditions that govern river-channel morphology and knowledge of bed load movement is required not only to elucidate the causes and consequences of changes in fluvial form but also to make informed management decisions that affect a river's function. Bed load transport can be described as a random phenomenon that is generated by the interaction of turbulent flow structure with the materials of the bed surface (Einstein 1950). This interaction is very complex and as a result, attempts to model this process have largely resulted in limited or qualified success. A number of sediment transport models designed to describe bed load have been formulated e.g. Meyer-Peter & Müller (1948), Bagnold (1966), Einstein (1950), Yalin (1963), Chang et al., (1967). Some of the many other transport models which can be mentioned in this context are: Engelund & Hansen (1967), Ackers-White (1973), Engelund & Fredsøe (1976) and van Rijn (1984). There have been two general approaches towards the concept of bed load transport. The first and most popular approach is through the use of a critical variable such as shear stress, stream power, discharge, or velocity. This approach assumes that there is no bed load transport until the critical variable has been exceeded by the flow conditions and that the bed load transport rate increases in proportion to the increase in the flow condition beyond the critical value. Use of these equations depends on the conditions under which the equations were developed. The second approach, introduced by Hans Einstein in 1942 (Einstein 1950), is based on a probabilistic approach to bed load movement. This approach offered new insight into bed load transport processes. However, the level of complexity made application of this method to natural channels very difficult (Yang, 1996). Bed load transport is an immensely complex process and the expression of the transport process through a deterministic mathematical framework may not be possible in the foreseeable future. In parallel with research into sediment transport has been the emergence of new modeling paradigms such as data mining (DM). This has opened up new opportunities for modeling processes about which the level of available knowledge is too limited to put the relevant information in a mathematical framework. DM is presently being utilized in almost all branches of science as an alternative and complementary to the more traditional physically-based modeling system. Use of artificial neural networks (ANN) remains in the forefront of this complementary modeling practice. ANN modeling has been used in a wide variety of applications. The primary application of ANNs involves the development of predictive models to forecast future values of a particular response variable from a given set of independent variables. Recent studies have provided a variety of methods for quantifying and interpreting the contributions of the variables in the neural networks (Olden and Jackson, 2002; Gevrey et al., 2003; Olden et al., 2004). As said earlier, a proper understanding of the parameters governing bed load is of paramount importance in the planning and design of hydraulic structures in alluvial settings. Thus the methods developed for input significance testing through ANN have been applied in the present work to find out most important parameters governing bed load transport. It is also tried to find out the variability of bed load transport under constant hydraulic and sediment conditions (Hydraulic parameters include depth, flow rate, slope, and hydraulic radius; sediment parameters include size, shape, and grain distribution).

DATA STRUCTURE

Brownlie (1981) has compiled by far one of the most comprehensive documentation of existing flume and field data in this area. Present work is based on the data compiled by Brownlie (1981). It consists of both field and flume type data. Observations having substantial bed load concentration are taken in the analysis. Data source is not cited in the present manuscript, as it is already exist in Brownlie (1981). Variables to characterize the bed load transport are as follows:

- Channel geometry – b (width of the channel), y (flow depth) and BF (bed form of the channel)
- Dynamic properties – Q (Channel discharge), S_f (friction/energy slope), τ_b (bed shear stress) and τ_c (critical shear stress or shields shear stress)
- Sediment properties – d (mean size of sediment), σ (gradation coefficient of the sediment particles) and G_s (specific gravity)
- Fluid properties – ν (viscosity)

So it can be said that bed load transport (C) is a function of all the above parameters or in other words:

$$C = f(b, y, \mathrm{BF}, Q, S_f, \tau_b, \tau_c, d, \sigma, G_s, \nu) \qquad (1)$$

Brownlie (1981) database gives the all value of the different datasets except the value of bed shear stress and critical shear stress. The idea of taking bedform in the analysis of bed load transport is due to the fact the bedform is generally classified based on the increasing order of bed shear stress (Southard and Boguchwal 1990). The observed bedform types are indicative of the transport condition. In the present analysis Equation

(1) shows the dependent and independent quantities or in terms of ANN modeling input and output vectors.

MODELING

Artificial neural networks, coupled with an appropriate learning algorithm, can be used to learn complex relationships from a set of associated input-output vectors. The most versatile learning algorithm for the feed forward layered network is back-propagation (Irie and Miyanki, 1988). Hornik et al. (1989) proved that neural networks have the ability to find any nonlinear relationship between inputs and outputs without having a priori knowledge about the system, provided sufficient hidden nodes and hidden layers are chosen. Here it can be said that according to Hornik et. al. (1989), one hidden layer is a universal approximator of physical process. The major drawback of back-propagation algorithm is that it is affected by local minima. Various other modifications to back-propagation have been proposed and the Levenberg-Marquardt modification (Hagan and Menhaj, 1994) has been found to be a very efficient algorithm in comparison with the others like Conjugate gradient algorithm or Quasi-Newton algorithm. Levenberg-Marquardt works by making the assumption that the underlying function being modeled by the neural network is linear. Entire modeling and analysis has been done by the use of neural network toolbox of MATALB ® software. Determining the number of neurons in the hidden layer is also an important issue. The common strategy of the constructive methods is to start with a small network, train the network until the performance criterion has been reached, add a new neuron and continue until a 'global' performance in terms of error criterion has reached an acceptable level. The final architecture of neural net used in the analysis is 11-14-1 and given in the Figure 1.

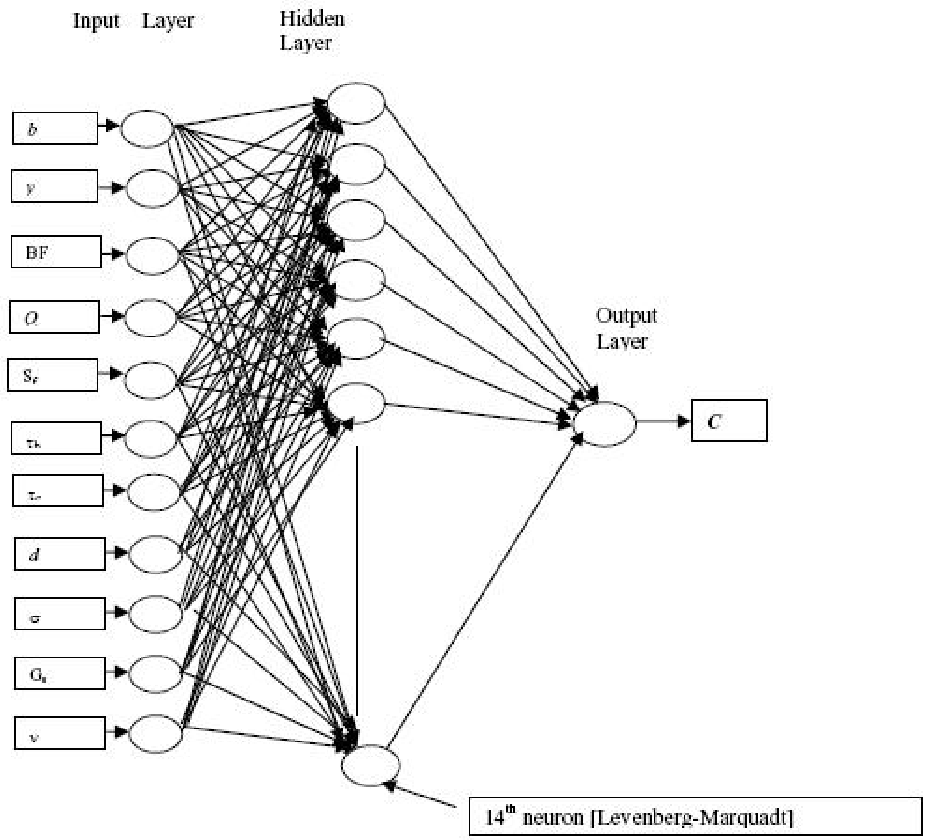

Fig. 1 Neural network architecture

The transfer function used in the hidden layer is tan sigmoid and at the output layer is tan sigmoid. The maximum epochs has been set to 5000. The idea behind choosing sigmoid functions as transfer functions is that it bears a greater resemblance to the biological neurons. In case of sigmoid functions, the output of the neurons varies continuously but not linearly with the input. Results of neural modeling are shown in Figure 2.

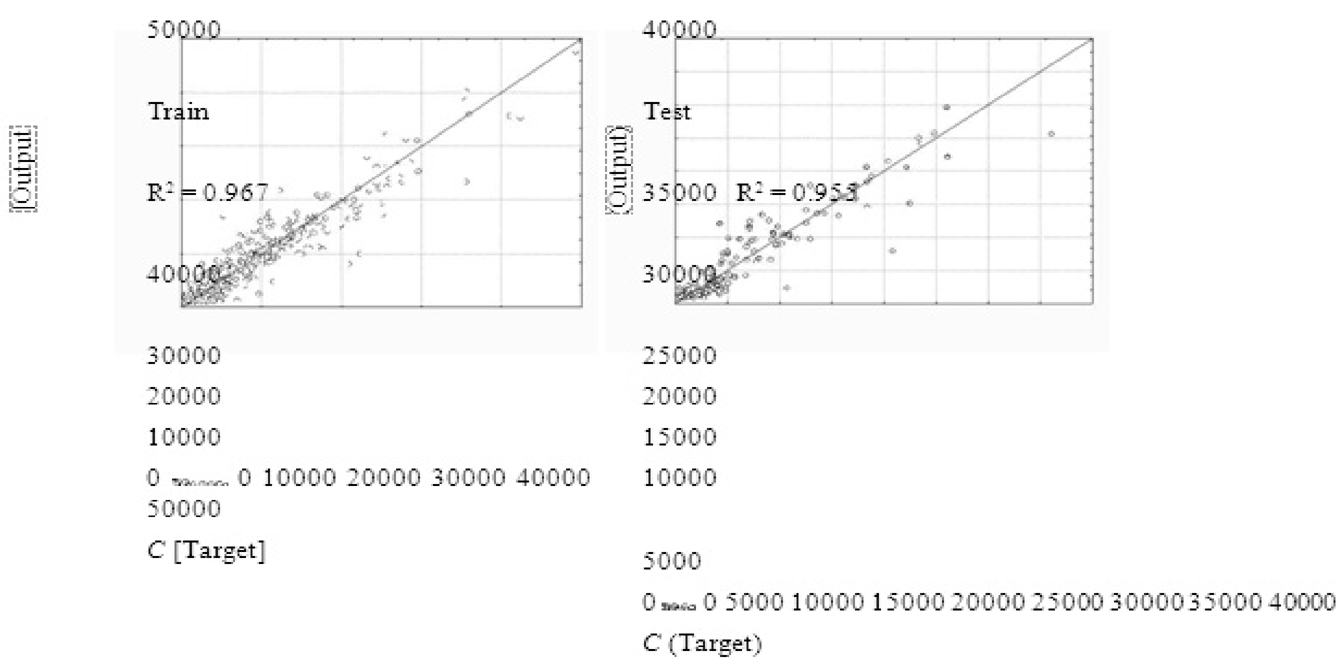

Fig. 2 Results of ANN model (a-Training; b- Testing)

It can be clearly seen from Figure 2 that the linear coefficient of correlation is very high between observed data and values predicted through neural nets and it is 0.967 and 0.955 in training and testing. This shows the learning and generalization performance of the network is good.

INPUT SIGNIFICANCE TESTING

A variety of methods are available for the estimation of the contribution of predictor variables in relationship to the output. For example, Partial Derivative method provides a profile of the output variations for small changes of each input variable and classification of the relative contributions of each variable to the network output. ‘Stepwise’ method is based on the classical stepwise approach that consists of adding or rejecting step by step one input variable and noting the effect on the output results (Gevrey et al., 2003). ‘Profile’ method proposed by Lek et al. (1996) studies each input variable successively when the others are blocked at fixed values. In the neural network, the connection weights between neurons are the linkages between the input and the output of the network, and therefore are the link between the problem and the solution (Olden and Jackson, 2002). Garson algorithm or ‘Weights’ method includes partitioning the connection weights to determine the relative importance of the various inputs. In the present work, two such methods have been implemented to know the importance of the input variables on output.

Connection weights: Calculates the product of the raw input-hidden and hidden-output connection weights between each input neuron and output neuron and sums the products across all hidden neurons (Olden and Jackson, 2002). In the neural network, the connection weights between neurons are the links between the inputs and the outputs, and therefore are the links between the problem and the solution. The relative contributions of the independent variables to the predictive output of the neural network depend primarily on the magnitude and direction of the connection weights. Input variables with larger connection weights represent greater intensities of signal transfer, and therefore are more important in the prediction process compared to variables with smaller weights.

Garson’s algorithm: - Garson (1991) proposed a method for partitioning the neural network connection weights in order to determine the relative importance of each input variable in the network. The methodology for this algorithm is as follows:

(a) For each hidden neuron h, divide the absolute value of the input-hidden layer connection weight by the sum of the absolute value of the input-hidden layer connection weight of all input neurons, i.e.

For h =/1 to nh, For i=/1 to ni,

$$A_{ih} = \frac{|W_{ih}|}{\sum_{i=1}^{ni} |W_{ih}|} \tag{2}$$

(b) For each input neuron i, divide the sum of the A_{ih} for each hidden neuron by the sum for each hidden neuron of the sum for each input neuron of A_{ih}, multiply by 100. The relative importance of all output weights attributable to the given input variable is then obtained.

For i: 1 to ni

$$RI\ (\%)_i = \frac{\sum_{n=1}^{nh} A_{ih}}{\sum_{n=1}^{nh} \sum_{i=1}^{ni} A_{ih}} \times 100 \tag{3}$$

Connection weight and Garson’s algorithm are based on the weight matrices of the neural network.

Calculations of all approaches are tabulated in the Table 1. As it can be seen from the Table 2, as expected dynamic variables are having much more influence on the bed load transport than any other group parameters. In dynamic parameters, flow discharge and flow depth are greater influence on the process. Each bed load transport equation available in the literature has its own validity and range of applicability of its data set (Zhang and McConnachie, 1994; Snakaudan et al., 2006). Calculations shown in the Table 1 indicate that any error in determining flow discharge and flow depth may result in under or over estimation of bed load transport. Table 2 also shows that determining the bed particle size is also important.

Table 1 Input Significance test of the Variables

Variables	Connection Weights	Garson's algorithm	Ranking
Q	3.188	0.169	1
y	3.105	0.165	2
d	2.703	0.144	3
τ_b	2.214	0.118	4
τ_c	2.095	0.111	5
S_f	1.957	0.104	6
BF	1.191	0.063	7
b	0.946	0.050	8
v	0.729	0.039	9
G_s	0.469	0.025	10
σ	0.210	0.011	11

CONCLUSION

Bed-load transport models are often very complex and subject to semi -empirical or empirical equilibrium transport equations that relate sediment fluxes to physical properties such as velocity, depth and characteristic bed-load sediment particle sizes. In this work, ANN model for predicting bed-load transport has been developed using several published flume and field datasets. The main conclusions of the study are listed below:

1. The performance of the ANN model can be said satisfactory if taken into the consideration of variability of the different datasets and nature of the experimental condition.
2. In engineering applications, errors in determining governing parameters affect the accuracy of the prediction of bed load transport. Experimentation has inherent errors which can not be neglected. Present analysis based on the input significant test through ANN model shows that in order to get the accurate prediction of bed load transport, there should be a more accurate determination of hydraulic parameters.

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Solid Waste Management in India – An Overview

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ABSTRACT

Solid Waste Management has become an issue of increasing global concern as urban populations continue to rise; rapid economic development & urbanization have led to an increase in the generation of solid waste. Municipal Solid Waste has being produces since the establishment of man –kind and unavoidable by product. Municipal Solid Waste Management has remained one of the most neglected areas of the municipal systems in India. About 70-80% of generated Municipal Solid Waste is collected & the rest remains unattended on streets or in small open dumps. The lack of infrastructure for collection, transportation, treatment and disposal of solid waste, proper solid waste management planning, insufficient financial resources, technical expertise and public attitude have made the situation exasperating due to which several environmental and health related problems are increasing. The study describes and evaluates the present state of Municipal Solid Waste Management in India.

INTRODUCTION

Rapid Industrialization, population explosion, urbanization and economic growth in India led to the migration of rural people to ciites, a trend of significant increase in municipal solid waste generation has been recorded around the whole country. Solid waste generation is natural phenomenon of human life. Municipal solid waste generation shows a positive correlation with the economic growth of people in terms if kg/capita/day as a consequence of improved life style and social status (Pradeep kumar and Rajender Kumar Kaushal, 2015). The ever rising population, along with rapid urbanization and industrialization directly affects the amount of urban and Municipal Solid Waste generated (Singh and Sharma 2002: Minghua et al. 2009). Presently waste is generated faster than other environmental pollutants, including green house gases (GHGs) (Hoornweg et al. 2013). Being the world's second most populous county the level of urbanization in India, has increases from 27.81% in 2001 to 31.16% in 2011. The ever rising population is putting immense pressure on demand for food, shelter and on other natural resources (Manser and Keeling 1996; Cointreau 2006a, b; Kathiravale and Muhd Yunus 2008).

Municipal solid waste management (MSWM) is one of the most overlooked basic services provided by the Government of India. Generation and characteristics of MSW may vary at the level of country, state, city as well as within different areas of the same city. MSW generation rates range between 0.3 and 0.6 kg/capita/day in Indian cities and annual increase in MSW generation (volume) is estimated as 1.33 % per capita (Pattnaik and Reddy2010). Municipalities, usually responsible for managing MSW in developing countries like India are facing a challenge in providing an effective and dynamic system to the society. They usually fail to attain this due to lack of appropriate collection system, lack of technical expertise and insufficient financial resources (Sujauddin et al. 2008 ;Guerrero et al. 2013). The municipalities use major chunk of their financial resources on MSW collection (primary and secondary) from different locations in municipal areas and very little is left thereafter for its management (Collivignarelli et al. 2004). In develop- ing countries, the cities barely spend 0.5 % of their per capita gross national productivity (GNP) on services for managing MSW (What a waste 1999). Moreover, political, legal, socio-cultural and institutional factors greatly influence MSWM plan.

Generally in India MSW is disposed off in low lying areas or open dumps without necessary precautions. Therefore, MSWM is one of the most challenging environmental issues in Indian megacities. In India the current urban MSW production rate is 109,598 tonnes per day (or 0.34 kg/capita/ day) and is assumed to reach to 376,639 tonnes per day (or 0.7 kg/capita/day) by 2025 (Hoornweg and Bhada-Tada 2012). The survey of 59 Indian cities, conducted by Central Pollution Control Board (CPCB) (through NEERI) has suggested that about 35,401 tonnes per day MSW was generated from 59 cities during 2004–2005. Thereafter, a survey con- ducted by the Central Institute of Plastic Engineering and Technology (CIPET) has reported that about 50,592 tonnes per day MSW was generated during 2010–2011 in the same 59 cities. MSW generation in selected Indian cities during 2004–2005 and 2010–2011.

Municipal solid waste generation in Indian cities (CPCB 2012)

City	Municipal solid waste generation (tones per day)	
	2004–2005[a]	2010–2011[b]
Ahmedabad	1,302	2,300
Bangalore	1,699	3,700
Bhopal	574	350
Bhubaneswar	234	400
Chandigarh	326	264
Chennai	3,036	4,500
Dehradun	131	220
Delhi	5,922	6,800
Guwahati	166	204
Indore	557	720
Jammu	215	300
Kanpur	1,100	1,600
Kolkata	2,653	3,670
Lucknow	475	1,200
Mumbai	5,320	6,500
Patna	511	220
Pune	1,175	1,300
Shillong	45	97
Srinagar	428	550
Varanasi	425	450

a. NEERI, Nagpur (2004–2005)
b. CIPET (2010-2011)

Generation of Solid Waste Global and Indian Scenario

The rapid pace of urbanization (migration of people from rural to urban areas) and growing economy have greatly accelerated the MSW generation rate in developing countries (Hassan 2000; Minghua et al.2009 ; Singh et al. 2011b). Presently, the volume of waste generated from urban centers of the world is around 1,300 million tonnes per year (1.2 kg/capita/day) which is expected to rise to 2,200 million tonnes per year by 2025 (World Bank 2012). The Gross national income (GNI) per capita of a country greatly influences MSW generation rate (What a waste 1999). India, the second most populous country aiming to attain an industrialized nation status by 2020 has experienced rapid urbanization and industrialization during the last few decades (Sharma and Shah 2005). India has a population of over 1.2 billion which accounts for 17.5 % of the world population (http:// censusindia.gov.in). About 31.16 % of the country's population lives in urban areas (Census of India 2011 ; Sudhir and Gururaja 2012). The continuous population expansion as well as migration from rural to urban areas has resulted in rapid boost in waste generation.

In India, although more than 90 % of municipality's total budget is spent on collection of waste, yet collection efficiency is very poor about 70–72 % (Nema2004 ; CPCB 2012).

Composition

The composition and characteristics of MSW is greatly influenced by the economic status, living standards, food habits, rituals, literacy rate, type of energy source, climatic and topographical conditions (Jin et al. 2006). The characteristics of waste in India show great variation in respect to composition and hazardous nature, when compared to western part of the world (Gupta et al. 1998 ; Sharholy et al. 2008). The organic waste contributes as major fraction in all cases. The highest amount of organic waste was reported in Mumbai (62 %), which was followed by Chandigarh (57 %). Besides this, moisture content was also high in all cases (except Ahmedabad) ranging between 41 and 64 %. The CV is very low ranging between 742 and 2,632 kcal/kg and the C/N ratio ranging between 18 and 37.

Physical composition of MSW in Indian cities

City	Organic (%)	Recyclables (%)	Others (%)	Moisture content (%)	C/N ratio	HCV (kcal/kg)
Ahmadabad	41	12	47	32	30	1,180
Bengaluru	52	22	26	55	35	2,386
Bhopal	52	22	26	43	22	1,421
Bhubaneswar	50	13	37	59	21	742
Chandigarh	57	11	32	64	21	1,408
Chennai	41	16	43	47	29	2,594
Delhi	54	16	30	49	35	1,802
Guwhati	54	23	23	61	18	1,519
Indore	49	13	38	31	29	1,437
Kanpur	48	12	40	46	28	1,571
Kolkata	51	11	38	46	32	1,201
Lucknow	47	16	37	60	21	1,557
Mumbai	62	17	21	54	39	1,786
Nagpur	47	16	37	41	26	2,632
Puducherry	50	24	26	54	37	1,846

Source: Status report on municipal solid waste management, CPCB 2004–2005

Health Impacts

Due to continuous increase in solid waste generation, its ever-changing composition, mismanagement and poor public attitude, people are directly exposed to health risks. According to Giusti (2009), there is direct and indirect association of health impacts with each step of the handling, treatment and disposal methods of waste. In developing countries, the poor attitude of waste generators has made the situation exasperating. They commonly throw their wastes on the roads, which is further scattered by rag pickers in search of recyclables, and animals (cows, dogs, pigs, etc.) looking for food. Hence, waste generated by them clog the drains, creating stagnant water condition which is favorable for insects and mosquitoes breeding responsible for malaria, lymphatic filariasis and other diseases, thus posing risks to human health (Castro et al. 2010). However, according to the World Health Organization (WHO 2000, 2007), the evidence that links waste landfills and incinerators to health problem particularly cancer, reproductive outcomes and mortality is inadequate. Nevertheless, this is supported by findings of Ray et al.

(2005, 2009), who has reported the impairment of lung function of landfill workers of Okhla landfill site, Delhi by 62 % as compared to 27 % of the controls which are of the same age, sex and socio-economic conditions. The landfill workers are more susceptible to tissue damage and cardiovascular diseases due to activation of leukocyte and platelets as well as airway inflammation (Ray et al. 2009).

Environmental Impacts

Each and every kind of waste generated needs to be managed in an appropriate manner. In India, the landfill site selection is done on the basis of convenience without prior consideration of environmental impact. The mismanaged and unscientific disposal of waste deteriorates the nearby environment causing severe imply cations on air, soil and water pollution.

Soil

Soil is "a dynamic natural body on the surface of the earth in which plants grow, composed of mineral and organic materials and living forms'' (Brady 1974). Additionally, it also acts as a protecting filtering layer laid over the ground water that mitigates the impact of several harmful pollutants (Venkatesan and Swami- Nathan 2009). The urbanization and industrialization have increased the burden of MSW on land which is adversely affecting soil properties (both biotic and abiotic) and its yield. This situation is very common in cities of developing countries. Rawat et al. (2009), has reported increased concentration of heavy metals (Mn, Zn, Cu, Cd, Ni, Pb and Cr) in soil and road dust samples from Kanpur city, this might be due to the deposition of dust from industries.

Water

Water is the basic element of life, livelihood, food security and sustainable development. On one side the world is facing fresh water scarcity, on the other hand whatever the remaining ground water resources are available, is facing critical stress in quality due to improper urbanization and industrialization. Besides this, inadequate maintenance of distribution system also pollutes drinking water. Nagarajan et al. (2012) has compared different physic-chemical parameters of ground water quality in Erode city, Tamil Nadu, India with Bureau of Indian Standards (BIS) and World Health Organization standards (WHO), and had observed increased concentration of constituents like total dissolved solids (TDS), total hardness (TH), total alkalinity (TA), sodium (Na^+), magnesium (Mg^{2+}),chloride (Cl^-), fluoride (F^-) and nitrate (NO^{3-}) above the upper permissible limit for drinking purpose making the water not potable.

Air

In developing countries MSW is mainly characterized by high density that emulates high degree of biodegradable organic matter and moisture content, which when undergoes anaerobic decomposition in landfills, leading to production of landfill gas. The landfill gas mainly consists of about CH4 and CO 2 together with small amount of volatile organic compounds and other trace gases (Hegde et al. 2003). Being GHGs both CH4and CO2 have global warming potential, which is 25 times higher in CH4 than global warming potential of CO2 with atmospheric residence time of 12 ± 3 years (IPCC 2007).

Waste Management Practices

Incineration

is a thermal waste management process. In incineration combustion of raw or unprocessed waste takes place under controlled condition at 850° C in the presence of air (DEFRA 2007). It takes place in an enclosed structure. The byproducts are carbon dioxide, sulphur dioxide, carbon monoxide, particulate matter, dioxins, furans, water vapor, ash, heat and non-combustible material. The ash produced is termed as incinerator bottom ash (IBA) which contains residual carbon in little amount. Incineration provides maximum volume reduction of waste but employ second last priority in an ISWM approach due to environmental concerns. It is highly an exothermic process, generating heat which could be utilized in the production of steam and electricity. For high level of efficiency, solid waste should have low moisture content (<50 %) and high heating value (5MJ/kg) (Vergara and Tchobanoglous 2012).

However, the potential inimical effect of waste incinerators on human health is always being a matter of concern. Elliott et al. (1996) reported that the people residing in the close vicinity of municipal incinerators are more prone towards liver cancer in Great Britain.

Pyrolysis and Gasification

Both pyrolysis and gasification are endothermic process. In both the processes the end products are gas (termed as syngas), liquid (containing acetic acid, acetone and methanol) and char (containing carbon with inert material)

Composting

Composting is referred as the process of aerobic biological decomposition of organic material under controlled conditions like temperature, humidity and pH. The indigenous microorganisms (thermophile and mesophile) mold organic material to a stabilized product i.e. compost (Hashemimajd et al. 2004). The compost thus produced acts as soil conditioner and can be used in agricultural and horticultural or landscaping applications (Singh et al. 2011a; Neher et al. 2013). The quality of compost from MSW depends on many factors like source and nature of waste, the composting design, maturation length and composting procedures which have been followed during composting (Hargreaves et al. 2008).

Composting of MSW is one of the most promising and cost effective option for MSWM. It was encouraged earlier 1960s by the Government of India (GOI) which was blocked in 4th 5 year plan (1969–1974). In 1974, GOI launched a modified scheme to revive MSW composting once again, particularly in cities with a population greater than 0.3 million. In India, composting of MSW is taking place in large scale as well as at decentralized level. The first large scale composting plant was established in Mumbai which process 500 tonnes/day of MSW by Excel Industries Ltd. Another plant has been operated in Vijayawada which handle 50 tonnes/day. About 9 % of MSW is treated by composting (Kansal 2002 ; Sharholy 2006;Sharholy et al.2008). About 700 tonnes/day of MSW is composted by Kolkata Municipal Corporation (KMC) in collaboration with M/S Eastern Organic Fertilizers (India) Private Limited. The selling price of end MSW compost is 3.50 INR (Chattopadhyay 2003, 2009).

Vermicomposting

Vermicomposting is an eco-friendly, eco-biotechnological and bio-oxidative process which stabilizes organic solid waste into valuable bio-product, i.e. vermicompost. It involves inter-mutual action of earthworms and microorganisms. In addition to the feedstock, the microbial biomass present in the earthworm's gut is also responsible for the biochem- ical decomposition of organic matter. Earthworms act as important mediators which increase accessible surface area to microorganisms, thereby improving enzymatic actions and responsible for alteration of physical status of organic waste directly and chemical status indirectly (Malley et al. 2006; Fornes et al. 2012). Besides this the faecal matter produced by earthworms provides suitable organic substrate to colonize surrounding microbes supporting microbial growth and action (Williams et al. 2006).

As earthworms are considered as the biological indicators of soil health (Ismail 1997) thus they have a major role in solid waste management plus soil management. They decrease the stabilization time of household waste and sewage sludge by vermicomposting and turned them into valuable end product i.e. vermicompost that can be further utilized in agricultural and horticultural practices (Kale et al. 1982;Ismail1993; Edwards and Bohlen 1996 ; Ismail 2005 ; Ansari and Ismail 2008), thus improving the productivity and fertility of soil (Edwards et al. 1995).

Landfilling

Landfill is a vacated land area onto or into which waste is disposed. It is an integral part of any planned MSW management system. They are the final depot of any city's MSW after pertinence of all available management options. Open dumping is the most common, lucid and economical practice implemented in most of the developing countries. In Asia 51% open dumping takes place among all available management practices (World Bank 2012).

A landfill is an area of land onto or into which waste is deposited. The aim is to avoid any contact between the waste and the surrounding environment, particularly the groundwater. Landfills can be classified into three categories, which are:

(i) Open dumps or open landfills, which are the most common in all developing countries, involve the refuse simply being dumped haphazardly into low lying areas of open land.

(ii) Semi-controlled or operated landfills are designated sites where the dumped refuse is compacted and a topsoil cover is provided daily to prevent nuisances. All kinds of municipal, industrial, and clinical hospital wastes are dumped without segregation. This type of landfill is not engineered to manage the leachate discharge or emissions of landfill gases.

(iii) Sanitary landfills are used in developed countries and have facilities for interception and treatment of the leachate using a series of ponds. This type of landfill also has arrangements for the control of gases from waste decomposition (Tchobanoglous et al., 1993).

CONCLUSIONS

1. Waste management involves a large number of different stakeholders, with different fields of interest. They all play a role in shaping the system of a city, but often it is seen only as a responsibility of the local authorities. In the best of the cases, the citizens are considered co-responsible together with the municipality. Detailed understandings on who the stake- holders are and the responsibilities they have in the structure are important steps in order to establish an efficient and effective system. Communication transfer between the different stakeholders is of high importance in order to get a well functioning waste management system in the cities in developing countries.
2. Solid waste management is a multi-dimensional issue. Municipalities in general seek for equipment as a path to find solutions to the diversity of problems they face. This study shows that an effective system is not only based in technological solutions but also environmental, socio cultural, legal, institutional and economic linkages that should be present to enable the overall system to function.
3. Solid waste services have a cost as any other services provided but in general the expenditures are not recovered. Resources are required with the objective of having skilled personnel, equipment, right infrastructure, proper maintenance and operation. The financial support of the central government, the interest of the municipal leaders in waste management issues, the participation of the service users and the proper administration of the funds are essential for a modernized sustainable system
4. Fundamental is to produce reliable data and to create prope r information channels within and between municipalities. Decision makers, responsible for planning and policy making, need to be well informed about the situation of the cities in order to make positive changes, developing integrated waste management strategies adapted to the needs of the citizens considering their ability to pay for the services.
5. The information provided about the factors influencing solid waste management systems is very useful for any individual Or organization interested in planning, changing or implementing a waste management system in a city

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Effect of Different Mulches on Growth, Yield and Quality of Acid Lime

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ABSTRACT

The present investigation "Effect of different mulches on growth, yield and quality of acid lime." was conducted at acid lime garden, College of Horticulture, Dr. PDKV, Akola. The experiment was laid out in Randomized Block Design with eight treatments and four replications during mrig bahar 2013-2014. Results obtained in the present investigation revealed that, polythene mulches and organic mulches had influenced the growth, yield and quality of acid lime fruits. The black polythene mulch showed significantly more length of shoot (14.07 cm), number of new shoots per branch (6.39), leaf area (15.05 cm^2), number of fruits tree-1 (683.62), weight of fruits^{-1} tree (36.09 Kg), yield ha^{-1} (99.96 q), diameter of fruit (3.97 cm), average weight of fruit (52.80 g), average volume of fruit (31.69 cm^3), juice per cent (52.46 %), TSS (8.43^0Brix), ascorbic acid (30.32 mg/100 ml), followed by dry grass mulch. However, minimum fruit drop (85.14 %), peel per cent (17.93 %) and weed count (3) was observed in black polythene mulch followed by dry grass mulch. Among the polythene mulches, black polythene mulch and among the organic mulches, dry grass mulch gave significant increase in all characters.

Keywords: *Acid lime, Mulching, growth, yield and quality.*

INTRODUCTION

Citrus is considered as most important fruit crops, with their wholesome nature, multifold nutritional and medicinal values have made them so important. Its attractive appearance, penetrating aroma of peel and excellent taste, hold a remarkable position in fruit world. Although area wise it stands third in position among all sub-tropical fruit crops, value wise it on a better position. In India, area under citrus plantation is about 865.0 thousand ha with production of 8522.0 thousand MT with productivity 9.85 MT/ha. Among which, the area under acid lime and lemon is 246.0 thousand ha with production 2329 thousand MT with productivity 9.46 MT/ha (Anon., 2012). Acid lime has great value because of its various kind of uses and nutritional as well as medicinal values. It is used in preparing refreshing drinks, preserved products like pickle, syrup, marmalade and squash. Lime peel is also used as cattle feed. Lime juice is used in cosmetic also. 100 gram fruit juice content 80 per cent of water, (26 IU carotene), 20 mg Vit. B_1, 0.1 mg Riboflavin, 63 mg Vitamin C, 1.83 mg iron (Fe), 0.16 mg Copper (Cu), Oxalo-acetic acid 0.30%, malic acid 8.2% and alkaline salt. Therefore, it is an essential for human health (Decuypere's, 2000). Mulching in the basins of the trees had shown some positive effects in this regard and decrease fruit drop, yield and weed intensity around the trees. Many workers had shown that mulching increases soil moisture and also effects soil temperature. High moisture retention was found with dry leaf mulching in Mandarin (Mustaffa, 1988). In lemon, clean cultivation cum mulch contained more moisture (Saha *et al.,* 1974). Mulching also influences fruit set, fruit drop, fruit size and quality. Climatic conditions of this region are more suitable for healthy plantation of acid lime than mandarin and this is main reason for promoting acid lime plantation in this region. In mrig bahar the sporadic rains comes late upto July which effects on the quality of mrig bahar fruits. If we could able to conserve the moisture in the soil by mulching then it will be beneficial for retention of the mrig bahar. But negligible work on mulching was done in Vidarbha region. Therefore, an attempt is made to find out the suitable mulch for better growth, yield and quality of acid lime.

MATERIALS AND METHODS

The present studies was carried out during the year 2012-13. The soil on which acid lime trees were planted was medium, well drained and fertile. The plot was kept free from weed**.** The recommended dose of fertilizer i.e. 50 kg FYM, 600 g N, 300 g P_2O_5 and 300 g K_2O per tree was given. Half dose of nitrogen and full dose of FYM, P_2O_5 and K_2O were applied in the month of May, 2013 at the time of release of stress and remaining half dose of nitrogen 300 g/tree was applied one month after fruit set i.e. at the pea size fruit stage. Observations were recorded on number of new shoots, length of shoot (cm), leaf area (cm^2), number of fruits per plant, fruit yield (kg $tree^{-1}$), fruit yield ha^{-1} (q), fruit drop (%), fruit size, average weight of fruit (g), average volume (cm^3), peel percentage, fruit juice per cent, Total Soluble Solids (^{0}Brix), Acidity percentage estimated value then expressed in terms of per cent acid by adopting the following formula.

$$\text{Acidity (\%)} = \frac{\text{Titre} \times \text{N of NaOH x eq. wt. of acid x vol. made up} \times 100}{\text{Wt. of sample x aliquot taken for estimation} \times 100}$$

Ascorbic acid content in fruit juice (mg/100 ml) Ascorbic acid content was calculated by using following formula.

$$\text{Ascorbic acid} = \frac{\text{Titrate} \times \text{Dye equivalent} \times \text{Volume made up}}{\text{Aliquot taken for estimation} \times \text{weight of sample}} \times 100 \text{ (mg/100 ml)}$$

Soil temperature (°C) was recorded at every fortnight using soil thermometer at 30 cm depth.

Soil moisture (%) was calculated by using following formula.

$$\text{Moisture content (\%)} = \frac{\text{Initial weight - oven dry weight}}{\text{Oven dry weight}} \times 100$$

Weed count in each treatment, 1m X 1m area was marked and weed flora were counted before the mulching and again at the stage of harvesting of fruits.

RESULTS AND DISCUSSION

The plant growth parameters viz., number of new shoot branch^{-1}, length of new shoot, leaf area was significantly maximum in the black polythene mulch followed by dry grass mulch while, minimum number of new shoot branch^{-1}, length of new shoot, leaf area was found in without mulch. (Table 1). Similar results on increase in leaf area with the use of plastic and natural mulches have been reported by Badiyala and Aggarwal, (1981), which was at par with green shed net. No any treatment was at par with black polythene mulch in respect to the growth parameters.

The results are in accordance with the findings of Mohanty *et al.* (2002) found that mulching with polythene sheet as well as organic mulches leads to better vegetative growth in mandarin than control due to better moisture conservation. Increase in new shoots in black polythene mulching might be due to better soil hydrothermal regimes, better moisture conservation and suppression of weeds in the plants mulch by black polythene mulch than other mulches (Badiyala and Aggarwal, 1981; Singh and Asrey, 2005).

Yield and yield attributing characters viz., number of fruits per tree, weight of fruit per tree in kg, yield ha^{-1} in quintal and fruit physical parameters i.e. fruit diameter, average weight of fruit, average volume of fruit were significantly maximum in the black polythene mulch treatment followed by dry grass mulch treatment, while minimum in without mulch which was at par with green shed net. Peel content was found minimum in the black

Table 1 Effect of different mulches on growth and yield

Treatments	Shoot length (cm)	No. of new shoots	Leaf area (cm^2)	Fruits tree^{-1}	Weight of fruits tree^{-1} (Kg)	Yield qha^{-1}
Black polythene mulch	14.07	6.39	15.05	683.62	36.09	99.96
Silver polythene mulch	11.44	5.11	12.44	543.25	26.04	72.13
Bicolour polythene mulch	10.01	4.32	11.01	445.13	19.59	54.26
Green shade net	8.73	3.80	09.56	381.11	15.95	44.18
Dry grass mulch	13.17	5.67	14.17	617.53	31.08	86.09
Wheat straw mulch	11.53	5.12	12.53	534.81	24.28	67.25
Leaf litter mulch	10.14	4.53	11.03	492.63	23.52	65.15
Control (without mulch)	8.43	3.78	09.33	360.7	14.84	41.10
S.E. (m) ±	0.19	0.17	0.21	14.15	0.61	1.69
C.D. at 5 %	0.59	0.50	0.63	42.93	1.86	5.14

polythene mulch followed by dry grass mulch. Whereas, maximum peel content was observed in without mulch which was at par with green shade net. (Table 2)

These results are corroborated with Bajwa *et al*. (1970) in grape vine observed that, black polythene and rice straw were significantly better that control in respect of yield. Dixit and Majumdar (1995) revealed that yield and starch content of potato tubers were highest under black polythene mulch. Patra *et al.* (2004) in guava observed that, the mulching of black polythene resulted in maximum fruit yield followed by straw mulch. Singh *et al.* (2006) in strawberry observed that black polythene mulch is most suitable and resulted into 41% higher fruit yield compared to straw mulch.

Fruit drop was found minimum in black polythene mulch followed by dry grass mulch and highest fruit drop was observed in without mulch which was at par with green shade net. These results are in conformity with the findings of Kumar *et al*. (1999), Mage (1982) and Mishra *et al*. (1984).

Weed count was found minimum in black polythene mulch followed by bicolour polythene mulch which was at par with silver polythene mulch. Whereas, maximum weeds were observed in control treatment which was at par with green shade net. These results are in conformity with the findings of Patel *et al*. (2009) observed that, black plastic mulch registered higher water use efficiency as compare to no mulch and also reduced weed. Patil *et al.* (2013) revealed that, mulching technique helps to avoid weeds and improve soil health. (Table 2)

Table 2 Effect of different mulches on fruit quality, fruit drop and weed count

Treatments	Diameter of fruit (cm)	Av. weight of fruit (g)	Peel (%)	Av. volume of fruit (cm^3)	Fruit drop (%)	Weed count
Black polythene mulch	3.97	52.80	17.93 (4.73)	31.69	85.14 (9.72)	3
Silver polythene mulch	3.61	47.94	19.98 (4.96)	27.40	89.54 (9.96)	5
Bicolour polythene mulch	3.27	44.01	21.89 (5.17)	24.10	93.50 (10.16)	5
Green shade net	3.10	41.87	22.89 (5.28)	22.00	95.75 (10.28)	13
Dry grass mulch	3.80	50.33	18.95 (4.85)	29.54	87.45 (9.85)	9
Wheat straw mulch	3.53	47.41	20.18 (4.99)	26.94	90.62 (10.01)	8
Leaf litter mulch	3.31	47.74	21.27 (5.11)	24.85	92.75 (10.13)	9
Control (without mulch)	3.04	41.15	22.97 (5.29)	21.92	96.43 (10.31)	14
SE (m) ±	0.05	0.68	0.02	0.61	0.02	0.74
CD at 5 %	0.15	2.08	0.06	1.86	0.08	1.17

Fruit quality parameters viz., juice percentage, total soluble solids and ascorbic acid was found maximum in black polythene mulch followed by dry grass mulch treatment while, minimum in without mulch, which was at par with green shed net and the acidity was found non-significant. (Table 3). Similar results were found by Mustaffa (1988) obtained highest T.S.S in sod culture plot of Coorg mandarin followed by digging once a year and dry leaf mulching and highest ascorbic acid content in Coorg mandarin under dry leaf mulching. (Table 3).

Table 3 Effect of different mulches on chemical parameters of acid lime fruits

Treatments	Juice (%)	T.S.S (°Brix)	Acidity (%)	Ascorbic acid (mg/100 ml)
Black polythene mulch	52.46 (46.41)	8.43	7.99 (3.33)	30.32
Silver polythene mulch	48.33 (44.04)	7.68	7.61 (3.26)	28.70
Bicolour polythene mulch	45.87 (42.63)	7.18	7.58 (3.25)	27.61
Green shade net	43.90 (41.49)	6.80	7.40 (3.22)	26.81
Dry grass mulch	50.34 (45.19)	8.06	8.03 (3.33)	29.50
Wheat straw mulch	48.22 (43.98)	7.59	8.07 (3.34)	28.51
Leaf litter mulch	45.90 (42.65)	7.20	7.96 (3.32)	27.72
Control (without mulch)	42.92 (40.93)	6.77	7.23 (3.19)	26.70
SE (m) ±	0.11	0.11	--	0.24
CD at 5 %	0.35	0.33	--	0.73

The maximum soil temperature was observed with black polythene mulch followed by silver polythene mulch which was at par with bicolour polythene mulch. Whereas, minimum soil temperature was observed with control treatment which was at par with green shade net. Gautal *et al.* (1992) observed that, use of plastic mulches helped to increase the production per unit area for all types of crops as polythene mulch films increase the soil temperature (5-7 ^{0}C) facilitating faster germination and better root proliferation in addition to checking weed growth, preserving the soil structure, retaining the soil moisture and increasing the carbon dioxide content around the plants. Mulching reduces evaporation and maintaining slightly higher temperature which could be essentially help in uptake of nutrients.

Table 4 Effect of mulches on soil temperature

Treatments	Soil temperature (^{0}C)									
	Initial	15 June	30 June	15 July	30 July	15 Aug.	30 Aug.	15 Sept.	30 Sept	15 0ct.
Black polythene mulch	41.73	35.47	38.13	36.21	35.98	37.01	37.12	41.17	40.10	36.07
Silver polythene mulch	41.70	33.54	36.25	34.27	34.02	35.12	35.20	39.19	38.18	34.19
Bicolour polythene mulch	41.71	33.48	36.18	34.12	33.96	35.01	35.14	38.75	37.76	33.51
Green shed net	41.72	28.74	32.22	29.96	29.90	30.95	29.50	33.80	33.10	28.52
Dry grass mulch	41.20	31.56	34.28	32.14	32.01	33.12	33.26	36.78	35.80	31.50
Wheat straw mulch	41.70	30.65	34.10	32.01	31.90	33.03	32.96	36.12	35.56	30.97

Treatments	Soil temperature (^0C)									
Leaf litter mulch	41.69	30.71	34.15	31.97	31.87	32.84	31.38	35.86	35.02	30.52
Control (without mulch)	41.30	28.70	32.15	29.89	29.84	30.65	28.76	33.15	32.88	28.04
SE (m) ±	0.59	0.61	0.61	0.58	0.60	0.59	0.61	0.59	0.61	0.59
CD at 5 %	1.81	1.87	1.87	1.76	1.83	1.81	1.87	1.81	1.87	1.86

The maximum soil moisture retention was recorded under polythene mulch followed by the organic mulches. However, no mulching recorded minimum soil moisture in acid lime orchard. Earlier Chakarborty and Sadhu (1994) also reported poor ability of natural mulches to conserve soil moisture than that of polythene mulch. Aiyappa *et al.* (1966) found that soil mulch practice in citrus kept soil cooler and conserved moisture. (Table 5).

Table 5 Effect of mulches on soil moisture (%)

Treatments	Soil moisture (%)									
	Initial	15 June	30 June	15 July	30 July	15 Aug.	30 Aug.	15 Sept.	30 Sept	15 0ct.
Black polythene mulch	15.30	21.68	21.70	23.34	22.27	29.12	23.55	22.09	26.78	22.17
Silver polythene mulch	16.50	21.65	21.03	23.13	24.18	29.08	23.40	22.01	26.71	22.12
Bicolour polythene mulch	16.43	21.38	20.89	22.91	23.97	28.84	23.19	21.91	26.34	21.97
Green shed net	15.93	17.20	16.20	18.30	18.01	24.28	19.01	18.16	22.08	18.03
Dry grass mulch	15.90	19.54	18.90	20.79	22.06	26.84	21.27	20.13	24.45	20.12
Wheat straw mulch	16.23	19.31	18.54	20.63	22.04	26.58	21.08	20.01	24.11	20.01
Leaf litter mulch	15.72	19.02	18.12	20.24	19.98	26.27	20.94	19.97	23.98	19.89
Control (without mulch)	16.40	17.04	16.11	18.09	17.96	24.03	18.84	17.98	21.92	17.90
SE (m) ±	0.34	0.52	0.59	0.61	0.61	0.62	0.59	0.56	0.59	0.60
CD at 5 %	1.05	1.60	1.81	1.86	1.86	1.87	1.81	1.70	1.80	1.82

CONCLUSIONS

On the basis of above findings, the response of different mulches in respect to growth, yield and yield attributing characters and fruit quality of acid lime was found to be promising in black polythene mulch.

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Conductance and Solvation Behaviour of L-Lysine Monohydrofluoride in Aqueous-Acetone and Aqueous Dimethyl Sulphoxide

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ABSTACT

The conductance of L-Lysine monohydrofluoride has been studied in water -acetone and water-acetone mixtures of different compositions in the temperature range 303-313K.The molar conductance data collected at different concentrations of the electrolyte is analyzed using Shedlovsky and Kraus-Bray models. The limiting molar conductance is found to be dependent on the temperature and dielectric constant of the medium. The salvation number computed in each solvent suggest that the solvent solute interactions are independent of the dielectric constant of the medium.

Keywords: Ion-pair association constant, ion-pair dissociation constant, solvation number, L-Lysine monohydrofluoride.

INTRODUCTION

Studies on electrolyte conductance of an electrolyte and the effect of ion – solvation on it in aqueous and partially aqueous media have received considerable attention in recent years as they are important both from fundamental and technological points of view1 -5. The use of non aqueous and partially aqueous solvents has been widely accepted, in place of water due to their wide applicability 6-8 in various fields. It has become a practice to use solvent mixtures, water being one among the solvent mixtures 9-11. The solvent mixtures not only give an idea about ion- solvent and solvent – solvent – interactions but also the preferential salvation of ion.

Literature survey indicates12-22 that the conductance data and the viscosity data of different electrolytes is useful in analyzing the ion solvent interactions and solvation behaviour of the ions. Similar studies on aminoacids are limited. As a part of the broad program on the conductance and solvation studies of different amino acid hydrofluoride in aqueous organic mixtures, the authors studied the conductance behaviour of L-Lysine monohydrofluoride in aqueous DMSO and aqueous acetone at different temperatures. In the present communication the results of there studies are presented.

EXPERIMENTAL

Deionized water was distilled and used. Dimethyl sulphoxide (Merck), acetone (Sd-fine) were used as such. L-Lysine monohydrofluoride (LOBA CHEMIE) was used without further purification. A conductivity bridge (ELICO model -180) equipped with a glass conductivity cell of cell constant 0.9445 cm^{-1} was used to measure the conductance of the solution. Temperature of the reaction mixture was maintained constant using a thermostat (INSREF) with an accuracy of $\pm 05.^{0}$ C . A stock solution of 0.1M L-Lysine monohydrofluoride was prepared in water/ aqueous organic mixture of different compositions (v/v) in the range 0 to 60%organic component. The solute was found to be insoluble above this composition. It was diluted to different concentrations using different volumes of solvent/ solvent mixture and conductance values were measured in the temperature range 300-318k. The solvent / solvent mixtures used in these studies have conductance values in the range (16.0 to 90.0 mho). The conductance of the solvent each composition and at each temperature was subtracted to get the conductance of the solute at each concentration. The molar conductance (Λ) values determined are ate different concentrations analyzed using Kraus-Bray equation[23] (eqn1) and shedlovsky equation[23] (eqn 2)

The least square analysis of the data (Λ) using the above two equations (1,2) is satisfactory with linear correlation coefficient in the range 0.93 - 0.96.

RESULTS AND DISCUSSION

The molar conductance (Λ) was determined from the solvent corrected specific conductance for L-Lysine monohydrofluoride in water, acetone, DMSO and various compositions (v/v) of water– acetone as well as water – DMSO at 300,308,313 and 318K. The values were analysed by Kraus – Bray and shedlovsky models of conductivity to evaluate molar conductance at infinite dilution Λo. Thus obtained values are shown in Table-1.

Table 1 Limiting molar conductance values in mho cm^2 mol^{-1} of L-Lysine mono hydro fluoride in water-acetone & Water- DMSO mixtures

T(K)	0%Acetone		20% Acetone		40%Acetone		60% Acetone	
	1	2	1	2	1	2	1	2
303	74.87	76.21	56.00	56.20	36.19	36.23	23.88	23.76
305	76.56	79.39	61.53	65.74	40.84	40.84	26.02	26.02
89.22	96.67	97.52	67.37	67.37	46.99	46.92	32.38	32.38
313	108.52	107.29	71.78	68.27	64.15	64.13	33.06	33.06
303	74.87	76.21	59.55	54.94	38.21	37.43	20.79	21.23
305	76.56	79.39	61.1	55.06	41.55	41.55	24.43	24.53
308	96.67	97.5	63.73	61.31	51.86	51.26	26.87	26.58
313	108.52	107.29	145.31	152.39	58.81	57.21	29.87	29.87
	(1) Kraus - Bray Model			(2) Shedlovsky Model				

As expected Λo value increased with increase in temperature in all the cases due to increase in thermal energy and mobility of ions. Limiting molar conductance of L-lysine monohydrofluoride in water decreased from 74.87 to 23.88 mho cm^2mol^{-1} on adding acetone to water at 300K. Same trend in the conductance values is observed at each temperature. In aqueous DMSO also, in general similar behavior is observed. On adding the co-solvent (acetone/ DMSO) to water, the dielectric constant decreases solvent –solvent interaction increases. Due to this conductance decreases.

From the slopes of the linear least square analysis using Kraus-Bray and shedlovsky models, the dissociation constant K_C and association constant K_A of the ion pair have been evaluated and presented in Table-2. These values indicate that they do not vary regularly with the temperature. The same trend is observed at all compositions of solvent mixtures of aqueous acetone and aqueous DMSO. Hence it is difficult to predict whether the process is endothermic or exothermic in nature. At any given temperature the association K_A values change randomly with the composition of solvent mixture also.

Table 2 K_A and K_C values of L-Lysine mono hydro fluoride in water-acetone & Water- DMSO mixtures

T(K)	0% Acetone		20%Acetone		40% Acetone		60% Acetone	
	K_A	K_C	K_A	K_C	K_A	K_C	K_A	K_C
303	4.95	0.22	14.24	0.07	13.63	0.08	15.85	0.07
305	6.70	0.15	16.47	0.06	11.33	0.09	10.94	0.1
308	6.98	0.15	12.13	0.08	12.59	0.08	16.19	0.06
313	7.11	0.14	8.78	0.11	26.86	0.04	11.03	0.09

T(K)	0% DMSO		20% DMSO		40% DMSO		60% DMSO	
	K_A	K_C	K_A	K_C	K_A	K_C	K_A	K_C
303	4.95	0.22	16.54	0.06	91.26	0.01	7.00	0.14
305	6.70	0.15	13.31	0.08	87.63	0.01	5.27	0.19
308	6.98	0.15	7.25	0.14	52.82	0.02	4.20	0.23
313	7.11	0.14	57.42	0.02	32.50	0.03	5.45	0.18

The variation in K_A with change in the composition of the solvent indicates the influence of dielectric constant of the medium on the stability of the ion pair. The free energy change accompanied by the ion pair formation (G) is computed using the relation. $G = -RT \ln K_A$ and tabulate in Table-3. These values are all negative and vary between -3.75 and -11.45 k.J. mol^{-1} in both the systems, at all the temperatures studied.

Table 3 Computed values of ΔG ($k.J.mol^{-1}$) for ion pair formation of L-Lysine mono hydro fluoride in water - Acetone and water - DMSO mixtures

T(K)	0% Acetone	20% Acetone	ΔG	40% Acetone	ΔG	60% Acetone	ΔG
303	-3.99	-6.63	-2.64	-6.51	-2.52	-6.89	-2.90
305	-4.87	-7.17	-2.30	-6.21	-1.34	-6.12	-1.25
308	-5.06	-6.50	-1.44	-6.59	-1.53	-7.24	-2.18
318	-5.18	-5.73	-0.55	-8.70	-3.52	-6.34	-1.16
303	-3.99	-6.99	-3.00	-11.26	-7.27	-4.85	-0.86
305	-4.87	-6.63	-1.76	-11.45	-6.58	-4.25	**+0.62**
308	-5.06	-5.15	-0.09	-10.32	-5.26	-3.75	**+1.31**
313	-5.18	-10.71	-5.53	-9.20	-4.02	-4.45	**+0.73**

RESULTS AND DISCUSSION

The molar conductance (Λ) was determined from the solvent corrected[23] specific conductance for L-Lysine monohydrofluoride in water, Acetone, DMSO and various compositions (v/v) of water – Acetone as well as water – DMSO at 303,305,308 and 313K. The values were analysed by Kraus – Bray and shedlovsky models of conductivity to evaluate molar conductance at infinite dilution Λo. Thus obtained values are shown in Table-1.

As expected Λo value increased with increase in temperature in all the cases due to increase in thermal energy and mobility of ions. Limiting molar conductance of L-lysine monohydrochloride in water decreased from 74.87 to 23.88 mho cm^2mol^{-1} on adding DMF to water at 300K. Same trend in the conductance values is observed at each temperature. In aqueous DMSO also, in general similar behavior is observed. On adding the co-solvent (DMF/ DMSO) to water, the dielectric constant decreases solvent –solvent interaction increases. Due to this conductance decreases ion pair formation calculated taking water as referenc0e solvent addition are computed and presented in Table-3. Except in 60% aqueous DMSO. There are all negative system that the ion -pair is more stabilized due to addition of co-solvent to water. The energies of activation of the conducting process obtained from the Arrhenius relationship, ln Λ_0 $\Lambda_0 = A - \frac{E_a}{RT}$ where A is a constant, are tabulated in Table-4. These values appear to be highly dependent on solvent composition. The activation energy is maximum in 40% (v/v) acetone system, where as in case of DMSO -water system it is maximum in 20% (v/v).

Table 4 Energy of activation values Ea($k.J.mol^{-1}$) of L-Lysine mono hydro fluoride in water - Acetone and water - DMSO mixtures

0%Acetone	20% Acetone	40%Acetone	60% Acetone
14.98	8.82	23.69	15.99
0% DMSO	**20% DMSO**	**40% DMSO**	**60% DMSO**
14.98	20.1	18.6	14.76

In solution, the ion pair is solvated and it is stabilized due to solvation. The solvation number (Sn) which is the number of solvent molecules in the solvent around the species is calculated from the effect of dielectric constant ∈ on Λ_0 based on the equation

The solvation number data of the ion thus determined at 27^0C in all the binary solvent systems studied is shown in Table 5. Solvation number at all composition in both solvents is nearly constant, however in acetone the solvation number is slightly higher than in DMSO. This suggests that ion solvent interactions are slightly more in acetone compared to DMSO.

Table 5 Solvation number of L-Lysine mono hydro fluoride in water - Acetone and water - DMSO mixtures at 300K

0% Acetone	**20% Acetone**	**40% Acetone**	**60% Acetone**
1.38	1.49	1.44	1.35
0% DMSO	**20% DMSO**	**40% DMSO**	**60% DMSO**
0.25	0.40	0.41	0.40

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Impact of Urbanisation on Urban Water Bodies in Hyderabad City

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ABSTRACT

Lakes are most important components of global water cycle and are assumed of great significance for emerging water crisis. They act as ground water recharge, water supply, flood control, breeding grounds for fish and other aquatic life. They also provide recreational activities; large open space with greenery in urban areas and maintains eco-system. In cities, they moderate microclimate and provide a soothing effect in warm urban landscapes. Hyderabad is blessed with number of water bodies due to its undulating topography. With increasing in urbanization many lakes have been lost. Some of the lakes have shrunk in size due to encroachment by slums while some are suffering from pollution (domestic and industrial effluents). Because of unplanned construction activities in the catchment area the natural drainage is blocked and there is less percolation of water leading to water logging and flooding problems. There is shear wastage of fresh water which can be consumed but due to lack of proper tapping facility it is getting wasted. If rainwater is not trapped in lakes, ground water recharge does not take place. Hence, water table is depleting causing water crisis. Despite knowing their environmental, social and economic significance, these water bodies are being continuously ignored. Therefore there is need to protect water bodies not only to restore the water body but also integrate it with the surrounding land use. Considering this alarming situation of negligence urban water bodies, this paper intends to step ahead to the conservation of one such urban water bodies in Hyderabad city. The paper will also explore the policies and guidelines for the management of the urban water bodies.

Keywords: lakes, eutrophication, encroachments, silting, flooding, conservation.

INTRODUCTION

Urbanisation is an index of transformation from traditional rural economies to modern industrial one. It is progressive concentration of population in urban unit. It is a long term process (Davis). Urbanisation is taking place at a faster rate in India. Population residing in urban areas in India, according to 1901 census, was 11.4%. This count increased to 28.53% according to 2001 census, and 31.16% as per 2011 census. This phenomenon of rapid urbanization is causing unorganized and unplanned growth in most of the towns and cities (Sarfaraz Ahmad, 2008). The urban lakes are suffering from varying degrees of environmental degradation. The main reasons are increase in population and establishment of industries in the catchment area. The domestic and industrial sewerage from the surrounding areas into the lakes is causing severe pollution In addition to this the deforestation in the catchment areas led to siltation and flow of pesticides into the lakes. The polluted water body causing unhygienic and other health hazards for the lake neighborhood. As a result the quality and quantity of water in the water bodies is getting affected by growing urbanization. Many lakes which provided drinking water earlier no longer serve the same purpose. Hyderabad city is also experiencing rapid urbanization over past five decades. This is mainly due to establishment of many industries and IT sector. This has resulted in development of new housing colonies, commercial and other institutional complexes without matching to infrastructure. Many lakes are occupied by buildings and rest are suffering from pollution (domestic and industrial effluents).

STUDY AREA

Hyderabad is located in Southern India at 17°22" N latitude and 70°22"E longitudes and is in an average of 1734 ft above mean sea level. It is situated on the banks of river Musi. It emerges from Anathagiri hills about 90 km to the west of Hyderabad. Hyderabad city and its environs were dotted with a number of natural water bodies.

Construction of storage reservoirs is an age old practice in India. Hyderabad known as city of lakes. From past many rulers built tanks. They are used as drinking and irrigation purposes. They acted as cushions for absorbing, storing rain water and preventing floods. They are also used for recharging ground water level and supporting a variety of aquatic life.

rulers developed a water management system of interconnected Lakes. The main tanks built by them are Ramappa, pakhala, laknavaram, ghanapuram, Bhayyaram. The vision and legacy is carried by Qutub Shahi rulers and Asaf Jahi rulers hundreds of tanks were built by them which include Hussain Sagar, Mir Alam, Afzal Sagar, Jalpalli, Ma-Sehaba Tank, Talab Katta, Osmansagar and Himayatsagar etc. Hussain sager was built in 1562 first source of drinking water. It acted as drinking water source up to 1930. There was flood in 1908 from Musi destroyed Hyderabad, to protect the city Osmansagar, Himayat Sagar Reservoirs were planned and to supply water to Hyderabad city. But now the water with drawn from these reservoirs is decreasing. Even though there is enough rain fall the reservoirs are not filled this is due to the catchment area is completely occupied by buildings. All the construction activities in the catchment area have blocked the natural drains which led to the lakes. Now we are depending on Krishna water which is 150kms away from the city. Long distance source of water involves more energy consumption, supply is complex, increase in cost of water supply and loss of financial resources.

Population and growth rate of Hyderabad city

Hyderabad city, is the capital of Telangana State has undergone considerable growth in recent decades due to pace of development, rapid urbanization and industrial development and burgeoning population. It is the sixth largest metropolis in India with a population of 6.8 million and third most densely populated city in India with density 3351 persons per sq.km.

Table 1 Shows the population and growth rate of Hyderabad city

Year	Population	Growth rate (%)
1971	1,796,000	---
1981	2,546,000	41.8%
1991	3,059,262	20.9%
2001	3,637,483	31.2%
2011	6,809,970	67.2%

(Source: Census of India)

Like other urban cities in India, Hyderabad has witnessed a rapid increase in population. From 1.7 million in 1971 the city's population touched 6.8 million in 2011. If we see population of Hyderabad there is steep increase population from 2001 to 2011.

Table 2 Land use change in 1975

S. No.	Land use	Area in ha	Percentage of total area
1.	Residential	2694	13.88
2.	Commercial	147	0.76
3.	Industrial	306	1.57
4.	Recreational	771	3.97
5.	Public and semi-public	1016	5.23
6.	Transport and communications	1295	6.67
7.	Vacant	7633	39.32
8.	Agricultural	3462	17.84
9.	Other	2089	10.76
	Total	19411	100

(Source: Development Plan for Hyderabad, 1975)

Table 3 Land use change in 2008

S. No.	Land use	Area in ha	Percentage of total area
1.	Residential	7635	44.24
2.	Commercial	1270	7.36
3.	mixed	749	4.34
4.	Industrial	425	2.46

Table 3 *Contd…*

S. No.	Land use	Area in ha	Percentage of total area
5	Public & semi public	1555	9.01
6.	Parks & playgrounds	1175	6.81
7.	Vacant land, open lands, rocks & hills	273	1.58
8.	River, lake, nalahs, kuntas	1075	6.23
9.	Agriculture & gardens	104	0.6
10.	Transportation & communication	1864	10.8
11.	Defense	834	4.83
12.	Burial grounds	300	1.74
	total	17259	100

(Source: Master Plan of HMDA (MCH Area))

As the city expands in area with more population growth the land use gets changed with the hitherto non-urban areas like forest, agricultural lands, other vegetative areas, water bodies etc., getting replaced by concrete structures and black-topped roads (Strahler, 1975). The Land use pattern indicates the changing pattern of land use over the years. It shows increase in residential, commercial at the expense of vacant and agricultural land.

By thoroughly examining the land use and land cover changes the urban built up areas have grown. The vegetation and vacant land are decreased. All natural resources such as water bodies, rocky barren land and crop land are being transformed as urban settlements

LOSS OF WATER BODIES

Once beautiful and plentiful lakes have become a stinking drain due to rapid unplanned development in Hyderabad. The basic factor that contributes to this is urbanization phenomena which leads to rapid growth of industries which in turn creates employment opportunities so many people migrate from surrounding areas. Due to this there is huge migration which led to increase in population, pressure on land and resulted in formation of slums and encroachments along the water bodies. Added to this the waste water from all these industries is disposed into the lakes without prior treatments and every year over thousands of idols are immersed which are coated with non biodegradable substances which contain heavy metal which led to environmental degradation of many lakes. As a result the lakes in the urban areas are choking to death.

Major problems faced by the lakes in Hyderabad city

The rapid growth of human population, proliferation of buildings, roads and vehicular traffic congestion is Hyderabad has taken a heavy toll on lakes. Further encroachment and illegal waste disposal activities and bad management have threatened the very existence of many of the valuable and productive lakes in the city. As a result the lakes are polluted from two major sources: the point source pollutants and non point source pollutants. Pollution coming from the point source contaminants include excessive nutrients from waste water coming from municipal and domestic effluents; organic and toxic pollution from industrial effluents, sediments and organic matter pollution along with storm water runoff from human settlements spread over areas along the periphery of the lakes and tanks. Degradation of lakes forms another major part of the environmental problem. For example, the silting of lakes on account of increased erosion as a result of expansion of urban areas, deforestation, road construction and such other land disturbances taking place in the drainage basin; diversion of streams and channels feeding the lakes reducing their sizes. Decrease in ground water recharge due to increasing runoff due to paved areas. The water bodies in urban areas are continuously facing degradation due to developmental anthropogenic activities.

Encroachment is another major problem faced by the urban lakes. Encroachment on Hyderabad's water resources has been rampant in the past 15 years. Until about the 1980s, most of the lakes in and around the city were sources of drinking water, and a buffer zone around them used to be seasonal farmland with no construction activity. Rapid and unplanned urbanization blocked the feeder channels to the lakes, which dried up gradually. The exposed lakebeds and buffer zone became a lucrative real estate opportunity for unauthorized construction. Several residential and commercial establishments came up on these lands and sewage from them found their way into what remained of the water bodies.

Encroachments

- Due to the Rapid urbanization there is increase in urban population without corresponding increase in physical infrastructure. Hence as there is increase in population in urban centers there is increase in dry weather flows of domestic sewage. The sewerage network and treatment infrastructure could not cope with the rapid growth of the city and rapid increase in population. As a result urban water bodies are suffering and are used for disposing untreated sewage and solid waste.

Lake pollution by solid waste

Sewage flow into the lake

Another major problem faced by the lakes is industrial pollution. The effluent from the industries is disposed into the lakes without prior treatment. The main reasons might be treatment of industrial wastes is costly and time taking process. So the wastes are disposed directly into the lakes. Which is causing severe pollution and loss in bioesthetic values. 450 year old Hussain sagar which was built by Nizams to meet irrigation needs of old Hyderabad. Later, it was used for drinking water source up to 1930. Over the years the lake is polluted through the entry of untreated sewage and industrial effluents. It has become sewage collection zone of twin cities. Other sources of pollution included dumping of domestic solid waste along the shore line and immersion of large numbers of Ganesh and Durga Idols during festivals containing paints, clay, gypsum and plaster of Paris, flowers and garlands.

LAKE EUTROPHICATION

Eutrophication of lakes means the reduction or depletion of dissolved oxygen in water. It is the major form of lake pollution because it promotes excessive plant growth and decay, favoring certain weedy species over others, and causes severe water quality problems and depletion of dissolved oxygen. This occurs when nutrient enrichment of lakes happens and is mostly from runoff (nitrates and phosphates). This enrichment during hot dry weather can lead to algae blooms and decrease of photosynthesis takes place. Then drying algae then drops BOD levels, this fish kills and results in bad odour.

Eutrophication in Pedda cheruvu, Nacharam

Suggestions/ remedial measures that can be taken to protect water bodies

- Demarcation of lake boundary and shoreline should be fenced properly to protect from encroachments.
- Creating buffer zones around the lake and no construction activity in the buffer zone
- De silting of lakes (removing mud, silt & other plant materials)
- Relocating the industries
- To prevent entering of domestic and industrial effluents entering the lakes
- strictly prohibiting disposal of solid waste in lakes
- creating awareness among people
- Public participation in conservation of lakes
- The inlet and outlet of the Water Body should be identified and monitored at frequent intervals. If there is any obstruction in the inlet and outlet should be removed.
- Catchment area treatment like afforestation, storm water drainage management, silt traps, etc., may be undertaken.
- Measures like cleaning of Water Body involving de-silting (removing mud, silt & other plant materials), de-weeding, aeration, reduction of nutrient.
- Urbanization has to take into account the delineation and protection of catchment areas, feeder channels of lakes and restore them to the extent possible.

CONCLUSION

Hyderabad, due to urbanization has witnessed a profound impact on its inherent features such as landscape, water-bodies, etc. Urbanization involves change of land cover in vast expanse of areas with growing concentration of human population. It is an irreversible process. High population densities in urban landscapes could lead to shortfall of infrastructure and basic amenities.

Many lakes are been lost due to the urbanization and others are suffering from severe pollution and encroachments has resulted in the shrinkage there by reducing water yield and water holding capacity from the catchment. This has resulted in lowering of the water table and many localities are facing from water crisis. Therefore, urban lakes have to be in the focus of urban planning and decision-making processes as these surface water sources, if protected and managed properly, will create tremendous potential to augment the water supply, if not immediately for drinking, but for other non-potable water requirements of ever increasing urban population. On this back ground there is urgent need to protect urban water bodies in the form of lakes and reservoirs to cater to the present days well as for future generations. Hence, there is a need to propose and implement policies and guidelines for development and treat the water-network as a continuous system.

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A Review on the Present Status of Osman Sagar, Hyderabad- Causes and Consequences

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ABSTRACT

Lakes are habitats of great human importance as they provide water for domestic, industrial and agricultural use as well as providing food. In spite of their fundamental importance to humans, freshwater systems have been severely affected by a multitude of anthropogenic disturbances, which have led to serious negative effects on the structure and function of these (lake) ecosystems. The aim of the present study is to review the current status and causes, consequences of one of the most important lake of Hyderabad City viz., Osman Sagar Lake. It was constructed during the reign of the last Nizam of Hyderabad, Osman Ali Khan, on the river Musi between 1912 and 1920 to meet a part of the drinking water needs of the people in the Hyderabad city and to protect the city after the Great Musi Flood of 1908. The length of the total dam is 1920.24 m where the length of the masonry dam is 1036.32 m and the 84 length of the composite dam is 883.92 m ., the permanent storage level of Osmansagar is R.L. 545.59 m with the lowest sluice level of R.L. 535.53 m. The total number of flood gates are 15 (each gate has dimensions of 1.83 m × 3.05 m) with the spill level of R.L.540.72 m. As on records dated February 2016, the Osmansagar has 0.023 TMC against its full capacity of 3.900 TMC. Serving the need for the requirement of water in the twin cities, the Osman Sagar has been facing various environmental degradation which has led to its destruction. The degradation of Osman Sagar is both direct and indirect consequences of humans. Chaotic urbanization, rampant construction, absence of effective management process, lack of proper legislation and awareness, encroachment, escalation of real estate prices, rural urban migration due to poor employment opportunities in agriculture. Though GO 111 stipulates protection of catchment areas of the lake since 1996, trenching and encroachments in and around the lake are going on unabated. However, there has been no water supply from these lakes since December 2015. A situation is not far away when in 1987, the city faced a similar predicament and people were forced to vacate houses due to severe water problem. In June 2012, the water level at Osman Sagar was 1769.8 feet. On October 1, 2012, the level was 1771.8 feet, an increase of a mere 2 feet. But now this year 2016, the level of water cannot be assessed as the water in the lake has been completely dried up. Only a few centimeter of water has been sparsely distributed across the dam of Osman Sagar.

Keywords: Water, Osman Sagar, Musi River, Lake, Ecosystem, Causes and Consequences.

INTRODUCTION

Historically human civilizations are mostly river centric. Agriculture and settlements had their origin on the river floodplains. Irrigation also had its beginning from the rivers. After human settlements started near water sources in areas receiving precipitation only seasonally, construction of reservoirs became necessary to ensure water supply. All uses of lakes other than for drinking water started only later.

Lakes are habitats of great human importance as they provide water for domestic, industrial and agricultural use as well as providing food. In spite of their fundamental importance to humans, freshwater systems have been severely affected by a multitude of anthropogenic disturbances, which have led to serious negative effects on the structure and function of these (lake) ecosystems. Hyderabad, the city of pearls and the historical monuments, is also a home for several lakes most of which are just beautiful bodies of water where people can unwind away from the hustle and stressful day at work. There are around 169 lakes larger than 10 hectares in Hyderabad Metropolitan Area, of which the major ones being the Himayat Sagar, Osman Sagar Lake, Hussain Sagar Lake, Mir Alam Tank, Saroornagar Lake and Patancheruvu Lake, Yousufguda Cheruvu, Yellareddy Cheruvu etc.

One of the most important lake of Hyderabad City is the Osman Sagar. It was created by damming the Musi River in 1920, to provide an additional source of drinking water for Hyderabad and to protect the city after the Great Musi Flood of 1908. It was constructed during the reign of the last Nizam of Hyderabad, Osman Ali Khan, hence its name. The Nizam invited prominent engineer and recipient of Bharat Ratna Mokshagundam

Visvesvarayya to Hyderabad and got long-term plans prepared to check further floods, loss of life and property. Visvesvarayya was assisted by high-ranking official Nawab Ali Nawaj Jung in finalizing the plans and designs.

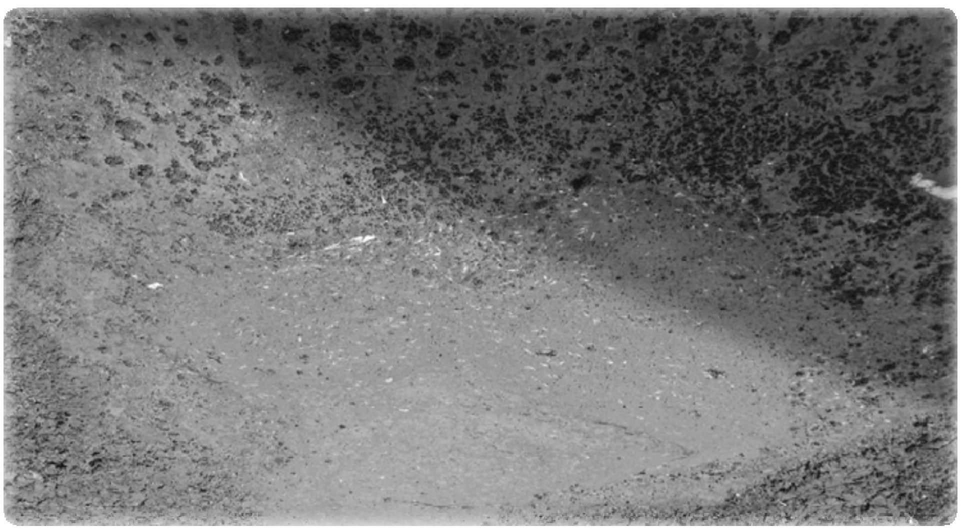
The length of the total dam is 1920.24 m where the length of the masonry dam is 1036.32 m and the 84 length of the composite dam is 883.92 m ., the permanent storage level of Osmansagar is R.L. 545.59 m with the lowest sluice level of R.L. 535.53 m. The total number of flood gates are 15 (each gate has dimensions of 1.83 m ×3.05 m) with the sill level of R.L.540.72 m.

METHODOLOGY

Physical survey of Osman Sagar has been done to check the status of their pollution. Common physical observation of water include Odour, Color, Taste of the water and others like Foam, garbage etc.

Previous Image of Osman sagar - THE HANS INDIA | Oct 28, 2015 , 05:42 AM IST

May 02nd 2016 Pictures of Osman Sagar



RESULTS

Osman Sagar degradation can be the cause of deforestation, overgrazing, intensive agriculture, urbanization and industrial development. Eutrophication, i.e. enrichment with nutrients, can also be another major and most widespread problem. Enrichment occurs due to nutrients entering with the runoff from the catchments. Storm water runoff from urbanized catchments brings a variety of toxic substances besides nutrients and particulate matter. Siltation due to high sediment load in the runoff caused by erosion is also a serious problem in the lake. Being a rural lake much of siltation occurs due to human activities such as agriculture and overgrazing in their close vicinity. Invasive aquatic weeds, particularly exotic species such as water hyacinth, are among other factors responsible for rapid degradation of it. Other factors contributing to the deterioration of Osman Sagar is settlements and tourism.

DISCUSSION

Major Reason for destruction as studied by the local newspaper has been stated as the following, which are – unregulated and fast pace of urbanization, escalation of real estate prices, rural urban migration due to poor employment opportunities in agriculture. Records of this ongoing change are weak and not available in public domain. Other reasons might be the absence of any conscious & focused policy for urban water bodies.

As a major chunk of recharge of ground water - this destruction is a serious threat to drinking water security of the city where surface sources water accounts for less than 50 % of water supply to the city. Destruction of water bodies is at an exponential rate since last 30 years. No comprehensive and systematic study has been done in understanding the status of these valuable water bodies. Historical documents on lakes are in a dilapidated condition and often remain inaccessible. Substantial research gap lies in identifying, mapping and documenting these lakes across time and space has added to the woes of the urban lakes.

CONCLUSION

Serving the need for the requirement of water in the twin cities, the Osman Sagar has been facing various environmental problems which led to its degradation and destruction. If we think the lack of rain is the only reason for the sorry state of Osman Sagar, you are mistaken. Industrialists, landlords, political leaders cutting across parties and the owners of farms abutting the lake have been digging bore wells and trenches within the full tank level obstructing the natural flow of water into the lake. Alarmingly, more than 50 bore wells and hundreds of trenches have been dug all along the feeder channels right up to the mouth of the lake. The feeder canals have been trenched and diverted through several minor canals in the FTL, which blocks water from entering the reservoir, even during monsoon. This is clearly visible in Google maps.

The degradation of Osman Sagar is both direct and indirect consequences of humans. Chaotic urbanization, rampant construction, absence of effective management process, lack of proper legislation and awareness, encroachment, escalation of real estate prices, rural urban migration due to poor employment opportunities in agriculture. Though GO 111 stipulates protection of catchment areas of the lake since 1996, trenching and encroachments in and around the lake are going on unabated. On an average, about 2.81 crore litre per day is supplied from Himayatsagar and Osmansagar lakes to residents in the city. However, there has been no water supply from these lakes since December 2015. A situation is not far away when in 1987, the city faced a similar predicament and people were forced to vacate houses due to severe water problem.

In June 2012, the water level at Osman Sagar was 1769.8 feet. On October 1, 2012, the level was 1771.8 feet, an increase of a mere 2 feet. But now this year 2016, the level of water cannot be assessed as the water in the lake has been completely dried up. Only a few centimeter of water has been sparsely distributed across the dam of Osman Sagar. To prevent the degradation of the lake, measures like Controlling the nutrient inputs from the catchment into the lakes, Removing the nutrients from the lake, In situ measures of lake cleaning such as de-silting, de-weeding, bioremediation, aeration, bio-manipulation, nutrient reduction, Catchment area treatment which may include afforestation, storm water drainage, silt traps etc. Strengthening of the bund, lake fencing, shoreline development, lake front eco-development including public interface, prevention of pollution from non-point sources by providing low cost sanitation.

Conservation and management involving a large array of stakeholders. It requires coordination between different user organizations and stakeholders and a participatory approach to the preparation and implementation of all management action plans. It further requires the support by way of appropriate policies that consider water bodies in an integrated holistic manner. Adequate and appropriate institutional arrangements are required to ensure the implementation of policies and management plans. Decision and policy-makers as well as planners and managers in turn require the knowledge and an understanding of the contemporary science and technology related to the functioning and management of water bodies. Obviously, the need for training and capacity building at all levels cannot be underestimated. Finally, the implementation policies and plans also require support from legal measures.

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THEME – IV

Groundwater Quality and its Suitability for Drinking and Agricultural purpose around Lamapur Area, Nalgonda District, Telangana State, India

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ABSTRACT

Assessment of suitability of groundwater for domestic and agricultural purposes was carried out in Lamapur area, Nalgonda district of Telangana state. Groundwater is the major source for domestic and agricultural activity in the study area. Suitability of groundwater for irrigation purpose was evaluated based on US salinity diagram, which shows that 80% of the total groundwater falls in the zone of high-salinity hazard (C3) and low-sodium hazard (S1) type. The Wilcox diagram shows that most of the groundwater (70%) falls in the category of good to permissible for irrigation purposes. The residual sodium carbonate (RSC) in groundwater is less that 1.25 meq/L and hence, suitable for irrigation. Residual sodium bicarbonate concentration varied from -3.5 to -26.94 meq/L in the study area. All the samples collected from study area found to be satisfactory (<5 meq/L) for irrigation purposes.

Keywords: Water Quality, Drinking purpose, Sodium Absorption Ratio, Residual Sodium Carbonate.

INTRODUCTION

Groundwater is the major source of water for domestic, agricultural and industrial purposes in many countries. India accounts for 2.2% of the global land and 4% of the world water resources and has 16% of the world's population. It is the estimated that approximately one third of the world's population use groundwater for drinking (Nickson, 2005). The increased demand for the water due to agriculture expansion, growing population and urbanization, so water resources management has become very important. The interaction of the natural and anthropogenic factors leads to various water types. According to Hamzaoui-Azaza (2011), the increased knowledge of the geochemical evolution of water quality could lead to effective management of water resources. In India and various parts of the world, numerous studies have been carried out to assess the geochemical characteristics of groundwater (Ahmad and Qadir, 2001; Alexakis, 2011; Aghazadehm, 2010; Jeevanandam, 2006; Laluraj, 2005; Subramani, 2005; Sujatha, 2003). Importance of hydrochemistry of the groundwater had led to a number of detailed studies on the geochemical evolution of groundwater (Garrels, 1967; Paces, 1973; Sarin, 1989). The graphical representation diagrams of US salinity and Wilcox diagrams will help to recognize the various types of hydrogeochemical data in groundwater system. It will helps in evaluation of the suitability of the groundwater for irrigation purposes. The objective of this study is to determine the groundwater quality of Lamapur area and to delineate regions where groundwater is suitable or unsuitable for drinking and irrigation purpose. The study area lying between North latitude from 1640' - 1635' and East longitude 7910' - 7915' is located in the survey of Imfia Topo Sheet No. 56 p12 and experiences semi-arid climate. The study area is covered by Archean granites intruded by dolerite dykes, Quartz reffs, pegmatits and quartz veins.

EXPERIMENTAL

The sampling bottles soaked in 1:1 HCL for 24h were rinsed with distilled water followed by deionized water. At the time of sampling, the bottles were thoroughly rinsed two or three times, using the groundwater to be sampled. The chemical parameters viz. pH and electrical conductivity (EC) were collected in 1000-ml polyethylene bottles from hand pump/bore holes in the study area. The bottles were labeled, tightly packed, transported immediately to the laboratory, and stored at 4˚C for the chemical analyses.

The samples were analyzed for total alkalinity(TA) as $CaCO_3$, total hardness (TH) as $CaCO_3$, calcium (Ca^{2+}),sodium(Na^+), potassium (K^+), bicarbonate (HCO_3), chloride(Cl^-), Sulfate(SO_4), Nitrate(NO_3), and fluoride (F^-), following the standard water quality methods (Table-2).The evaluation of chemical characteristics of groundwater and suitability for drinking, irrigation and industrial purposes have been carried out. Total dissolved solids (TDS) were computed as per Hem (1985, 1991) and Karanth (1987) from EC values multiplied by 0.64 and magnesium (Mg^{2+}) was calculated, using the values of TH and Ca^{2+} .

The flame photometer (Systronics, 130 India), concentrations of sodium (Na^+) and potassium (K^+) in the groundwater were measured. Electrical conductivity (EC) and pH were measured by conductivity meter (Systronics, 304) and digital pH meter (systronics, 802).

RESULTS AND DISCUSSION

Suitability of groundwater quality for drinking purpose was assessed, following the drinking water quality standards of Bureau of Indian standards (BIS, 2003) and (WHO, 2004) to know the implication of health conditions; irrigation needs was judged, using the salinity hazard and sodium hazard with the United states Salinity Laboratory staff USSLS, 1954) diagram, the total salt concentration and percent of sodium in the Wilcox (1995) diagram, the residual sodium carbonate (Eaton, 1950), to assess the adverse impacts on crop-growth was evaluated with respect to the chemical parameters, i.e., pH, TDS, TH, HCO_3, Cl^-, and F^- (Johnson, 1983) to assess the common undesirable effects of incrustation and corrosion. The pH of water is easily measured in the field and must be measured in-situ to achieve accuracy. When groundwater is exposed in to the atmosphere, dissolved CO_2 escapes and the pH rises. The combination of CO_2 with water forms carbonic acid, which affects of the pH in the water. The pH in the groundwater is varied from 7.78 to 8.31 in all the groundwater samples of the study area and is within safe limit.

Pure water contains low electrical conductance of around 0.1µS/cm (Jeff Lewis, 2010). Ionic species dissolved in the water, then increase the conductivity, but conductance measurements cannot be used to estimate ionic concentrations, natural water contain a variety of dissolved species in various amounts. The value of EC is between 494 and 1802 µS/cm .The Ec is a measure of a materials ability to conduct an electric current so that the higher Ec indicates the enrichment of salts in groundwater. The TDS, which indicates total dissolved ions in the water, is between 316 and 1153 mg/L. Based on total dissolved solids, groundwater is classified (Davis and De Wiest 1966) into desirable for drinking (up to 500 mg/L), permissible for drinking (500-1000 mg/L), useful for agriculture purposes (up to 300 mg/L) and unfit for drinking and irrigation (above 3000 mg/L). Accordingly, the quality of groundwater in present study area is classified as desirable for drinking, permissible for drinking for drinking, agricultural purposes and unfit for drinking and irrigation in 30% (samples 2, 4, and 5);) and 10% (sample 1 and 5) of the total water samples respectively. The high TDS, may be due to the influence of the anthropogenic sources, such as domestic sewage, septic tanks, and agriculture activities. 20% groundwater of the study area exceeds the desirable limit of 500 mg/L of TDS . Generally, the higher TDS decreases palatability, and causes gastrointestinal irritation in the consumers. It has also laxative effect, especially upon transits (Subba Rao, 2011). But, the extended intake of water with the higher TDS can cause kidney stones, which are widely reported from different parts of the country (Garg, 2009).

Table 1 Instrumental and volumetric methods used for chemical analysis of groundwater in the adjoining Lamapur area Nalgonda District, Telangana State, India

Chemical parameters	Units	Method, instrument (make)	Reagents	Reference
pH	pH meter	(Systronics) pH 4, 7, and 9.2	(buffer solutions)	APHA (1992)
EC	µS/cm	EC meter (Systronics)	Potassium chloride	APHA (1992)
TDS	mg/L	EC×conversion factor (0.55 to 0.75)		Hem (1991)
TA	mg/L	Volumetric	Hydrochloric acid (HCl) and methyl orange	APHA (1992)
TH	mg/L	Volumetric	Ethylenediaminetetraacetic acid (EDTA),ammonia and eriochrome black-T	APHA (1992)

Contd…

Chemical parameters	Units	Method, instrument (make)	Reagents	Reference
Ca2+	mg/L	Volumetric	EDTA, sodium hydroxide and murexide	APHA (1992)
Mg2 +	mg/L	Calculation		APHA (1992)
Na+	mg/L	Flame photometer	Sodium chloride (NaCl), KCl and calcium carbonate (CaCO3)	APHA (1992)
K+	mg/L	Flame photometer	NaCl, KCl and CaCO3	APHA (1992)
HCO3-	mg/L	Volumetric	Hydrosulfuric acid (H2SO4), phenolphthalein	APHA (1992)
CO32-	mg/L	Volumetric	Hydrosulfuric acid (H2SO4), methyl orange	APHA (1992)
Cl−	mg/L	Argentometric	Silver nitrate, potassium chromate	APHA (1992)

Calcium and Magnesium are the principle ions responsible for total hardness. The observed value of TH in the groundwater is between 285 and 775 mg/L. The TH can be classified as soft, if the TH is less than 75 mg/L; moderately hard, if the TH is varied from 75 to 150 mg/L; hard, if the TH is between 150 and 300 mg/L; and very hard, if the TH is more than 300 mg/L (Sawyer, 2003). According to the classification of TH, approximately 90% of the groundwater comes under the hard category and the remaining 10% of the groundwater fall in the very hard category. Bicarbonate is a major element in human body, which is necessary for digestion. When ingested, for example, with mineral water, it helps buffer lactic acid generated during exercise and also reduces acidity of dietary components. It has a prevention effect on dental cavities (Subba Rao, 2011). The concentration of HCO_3- is observed from 158 to 286 mg/L. The Cl^- plays an important role in balancing level of electrolytes in blood plasma, but higher oncentration can develop hypertension, risk of stroke, left ventricular hypertrophy, osteoporosis, renal stones, and asthma (McCarthy, 2004). The concentration of Cl^- is between 52 and 316 mg/L. 50% of groundwater is within the desirable limit of 250 mg/L (Table-2). This is the second largest ion, after HCO_3- ion. In fact, the Cl^- is derived mainly from the non-lithological source and its solubility is generally high and the groundwater is caused by the influences of poor sanitary conditions, irrigation-return flows and chemical fertilizers.

The concentration of Na^+ is varied from 324 to 483 mg/L than that of the recommended limit of 200 mg/L for safe water and all groundwater samples are within the safe limit. Generally, the concentration of K^+ is less than 10 mg/L in the drinking water. It maintains fluids in balance stage in the body. The K^+ is observed between 38 and 279mg/L, which is below the prescribed limit (Table-2). The Ca2+ is an important element to develop proper bone growth. The concentration of Ca^{2+} is between 146 and 680 mg/L. 50% of groundwater has below the standard limit of 75 mg/L, while that of the concentration of Mg^{2+} is varied from 235.23 to 99.63 mg/L. 50% of groundwater has below the prescribed limit of 30 mg/L (Table-2). Although, Mg^{2+} is an essential ion for functioning of cells in enzyme activation, but at higher concentration, it is considered as laxative agent (Garg, 2009).

Table 2 Criteria for groundwater quality for drinking in the adjoining Lamapur area, Nalgonda District, Telangana State India

Chemical parameter	BIS (2003)	WHO (2004)	Sample numbers exceeding the safe limit	% of samples
pH (units)	6.5–8.5	6.5–8.5 0	0	0
TDS (mg/L)	500	500	2	20
TH (mg/L)	300	300	1	10
Ca2+ (mg/L)	75	75	5	50
Mg2+(mg/L)	30	30	5	20
Na+(mg/L)*	200	200	5	50
K+(mg/L)	–	10	5	50
HCO3-	–	10	5	50
Cl− (mg/L)	250	200	1	10

*Holden (1970).

IRRIGATION WATER QUALITY

Excessive amounts of dissolved ions in irrigation water, which can affect to the plants and agricultural soils as physically and chemically, it will reduce the crop productivity. The physical effects of these ions decrease the osmotic pressure in the plant structural cells, thus preventing water from reaching the branches and leaves, while the chemical effects disrupt plant metabolism (Ravikumar, 2011).

SODIUM ADSORPTION RATIO (SAR)

Wilcox (1955) and US Salinity Laboratory Staff (1954) proposed irrigational specifications for evaluating the suitability of water for irrigation use. There is a significant relationship between sodium adsorption ratio (SAR) values for irrigation water and the extent to which sodium is adsorbed by the soils. If water used for irrigation is high in sodium and low in calcium, the cation exchange complex may become saturated with sodium, which can destroy the soil structure owing to dispersion of clay particles (Singh, 2002). Sodium hazard is a tendency of water to replace adsorbed Ca^{2+} plus Mg^{2+} with Na+, which is expressed in terms of sodium adsorption ratio (SAR). This is a ratio of Na+ ion concentration to square root of half of combination of Ca2+ and Mg2+ ions concentration (Eq. 1).

$$\mathbf{SAR = Na/(\sqrt{(Ca+Mg)/2})} \qquad \mathbf{(1)}$$

Where all the ionic concentrations are expressed in milliequivalents per liter.

The measured value of EC is varied from 494 to 1802 μS/cm the computed value of SAR is between 2.09 and 3.9 with an of the groundwater collected from the study area .The chemical data of the area plotted in the salinity hazard versus sodium hazard diagram designed by the USSLS (1954;).which judges the water quality for irrigation. The values of electrical conductivity and SAR values, plotted on a US Salinity diagram, show that 80% of the total groundwater samples (1, 2, 3, 4 and 5) fall in the zone of C3-S1, indicating high-salinity hazard (C3) and low-sodium hazard (S1), which can be used for irrigation on almost all soil types, with little danger of exchangeable sodium. Approximately 10% of the groundwater samples (6) fall in the zone of C4-S2 indicating poor quality of water for irrigating plants. In the zone of medium salinity hazard C2 and low sodium hazard S1.

PERCENT SODIUM (Na+)

Another expression of sodium hazard is percent sodium ($\%Na^+$). This is a ratio of combination of Na^+ and K^+ ions concentration to combination of Ca^{2+}, Mg^{2+}, Na^+, and K^+ ions concentration, which is multiplied by 100 (Eq. 2).

$$\mathbf{\%Na = (Na+K)/(Ca+Mg+Na+K) * 100} \qquad \mathbf{(2)}$$

Where all ionic concentrations are expressed in milliequivalents per liter.

RESIDUAL SODIUM CARBONATE (RSC)

Carbonate ions (HCO_3^-+CO_3^{2-}) have an effect on water alkality through the precipitation of alkaline earths (Ca^{2+} +Mg^{2+}), thereby increasing the percentage of Na+ (Eaton ,1950). This is more ,when the concentration of carbonates is in excess of the concentration of alkaline earths. The excess carbonates combine with Na+ to form $NaHCO_3$, which affects the soil structure. This is called the Residual Sodium Carbonate (RSC). Therefore, a relation between carbonates concentration and alkaline earths concentration can be used to explain the suitability of water for irrigation. The RSC is computed by subtracting the amount of alkaline from the amount of the carbonates, as shown below (Eq - 3).

$$RSC=[(HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+})] \qquad (3)$$

Where an ionic concentrations are expressed in milli equivalents per liter.

Based on the RSC values, the water can be classified as suitable, if the RSC is less than than1.25 meq/liter; marginally suitable, if the RSC is between 1.25 and 2.50meq/liter; and unsuitable, if the RSC is more than 2.50 meq/liter. The higher RSC leads to increase of absorption of Na+ in soil, which reduces the soil permeability and hence not supporting the plant growth. The value of RSC is between -8.55 and -29.48meq/liter in the present study area (Table-4). It is also observed that approximately 100% of the groundwater samples have the RSC less than 1.25 meq/liter and hence suitable for irrigation.

RESIDUAL SODIUM BICARBONATE (RSBC)

Gupta and Gupta (1987) defined the Residual Sodium Bicarbonate as given in (Eq-4):

$$RSBC= (HCO_3^- - Ca^{2+})$$

Where all the ionic concentrations are expressed in milli equivalents per liter.

The samples of RSBC values varied from -3.5 to-26.94 meq/liter in the study area . All the samples collected from study area also were found to be satisfactory (<5 meq/liter) according to the criteria set by Gupta (1987).

CONCLUSION

The groundwater sources in around Lambapur area, Nalgonda district of T.S. have been evaluated for their chemical composition and suitability for drinking and irrigation purposes .In the study area malignity of groundwater samples are within permissible limits prescribed for drinking water. Wilcox and US Laboratory Salinity Staff diagrams reveal that 80% of the groundwater locations are suitable for irrigation purposes .Based on RSC, RSBC, groundwater is considered suitable for irrigation purposes.

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Source of Heavy Metals in Groundwater of Karaipottanar Sub-Basin, Tamilnadu

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ABSTRACT

The aim of the study is to understand the distribution of heavy metals, their sources, environmental process and health hazards. A total of 44 samples were collected in Karaipottanar sub-basin that covers the Namakkal and part of Tiruchirappalli districts of Tamilnadu. The groundwater samples were analysed for pH, Redox potential (ORP), Electrical conductivity (EC) as well as for heavy metals, like, Fe, Cr, Zn, Cu, Ni, Co, and Mn for the post monsoon season (January, 2015). The order of dominance is as follows: Fe > Zn > Mn > Co > Cu > Ni > Cr. Fe, Ni, and Mn exceed the permissible limit of BIS (2012) in 82%, 73% and 2% of the samples, respectively. They are influenced by pH, and EC of the groundwater in the study area. The spatial distribution of Co, Cr, Cu, and Ni reveal that the host rock, namely, Fissile hornblende biotite gneiss is the source for these heavy metals. Fe in the groundwater is due to charnockite, and Mn and Zn are due to alluvium of the study area. Lithology and anthropogenic activities control the process of heavy metals in groundwater of these regions.

Keywords: Heavy metals, Source, Spatial distribution, Groundwater/drinking water.

INTRODUCTION

Heavy metals are the elements that have atomic weight between 63.54 and 200.59 amu, and specific gravity greater than 4 kg/cm^3 (Kennish 1992). Some of the heavy metals are needed by living organisms and if it exceeds, it leads to harmful effect for life (Berti and Jacobs 1996). The solubility and leaching of the metals in groundwater is mainly controlled by pH (Baker and Walker 1990; McNeil and Warring 1992; Henry 2000). The occurrence of heavy metals in groundwater due to natural processes such as dissolution of elements in soil zone or also due to human induced activities such as mining, fuels, smelting of ores and improper sewage disposal of industrial wastes (Sridhar et al. 2014; Kanagaraj et al. 2014). Agriculture is also a main source of heavy metals due to its intensive use of fertilizers (Kidd et al. 2007; Mico et al. 2006). Investigation of heavy metals gain its importance since minute changes in the concentration above the acceptable limits either due to natural or anthropogenic processes can results in severe environmental problems and subsequent health problems. Hence, the study aims to understand the heavy metals concentration in Karaipottanar sub basin which covers the Namakkal and part of Tiruchirappalli district of Tamilnadu.

STUDY AREA

The study area is Karaipottanar sub-basin (Fig. 1). Its major part is located at Southeast region in Namakkal district and least part in Northwest of Trichy district. The basin lies between 10°56'and 11°23'N latitudes and 78°06'and 78°28'E longitudes and its covers an area of 1116 km^2. The basin has a tributary of Cauvery river, being originated from the Kolli hills and it passes through the Archaean Crystalline granitic gneisses, Fissile hornblende biotite gneiss and Charnockite (Kolli hill) with pockets of lateritic bauxite and recent alluvial deposits occurring along the river courses and Colluvium at the foot hills (John et al. 2005) (Fig. 2). The aquifer system in the basin is constituted by weathered and fractured crystalline rocks and Colluvial deposits. The geomorphology of this region comprises of alluvial plains, structural hills, residual hills, valley fills, pediments and undulating plain. The area comes under tropical climate and predominantly receives northeast monsoon than southwest monsoon and its rainfall varies from 640 mm to 880 mm (CGWB 2008).

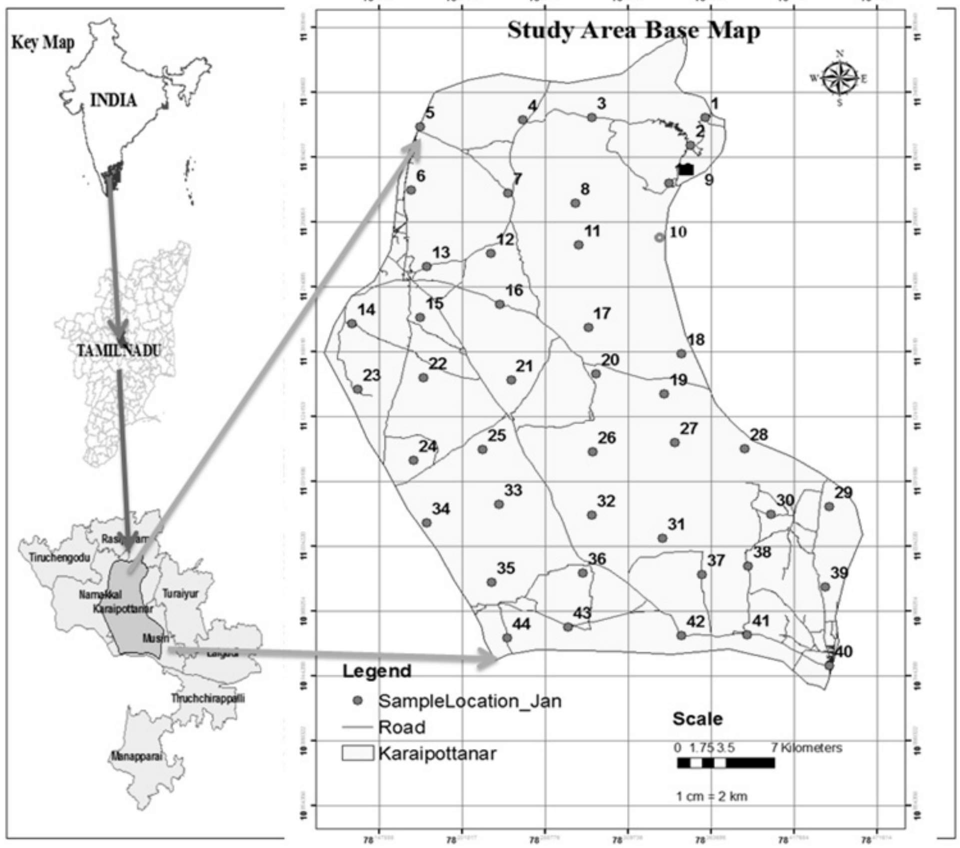


Fig. 1 Study area with sampling locations

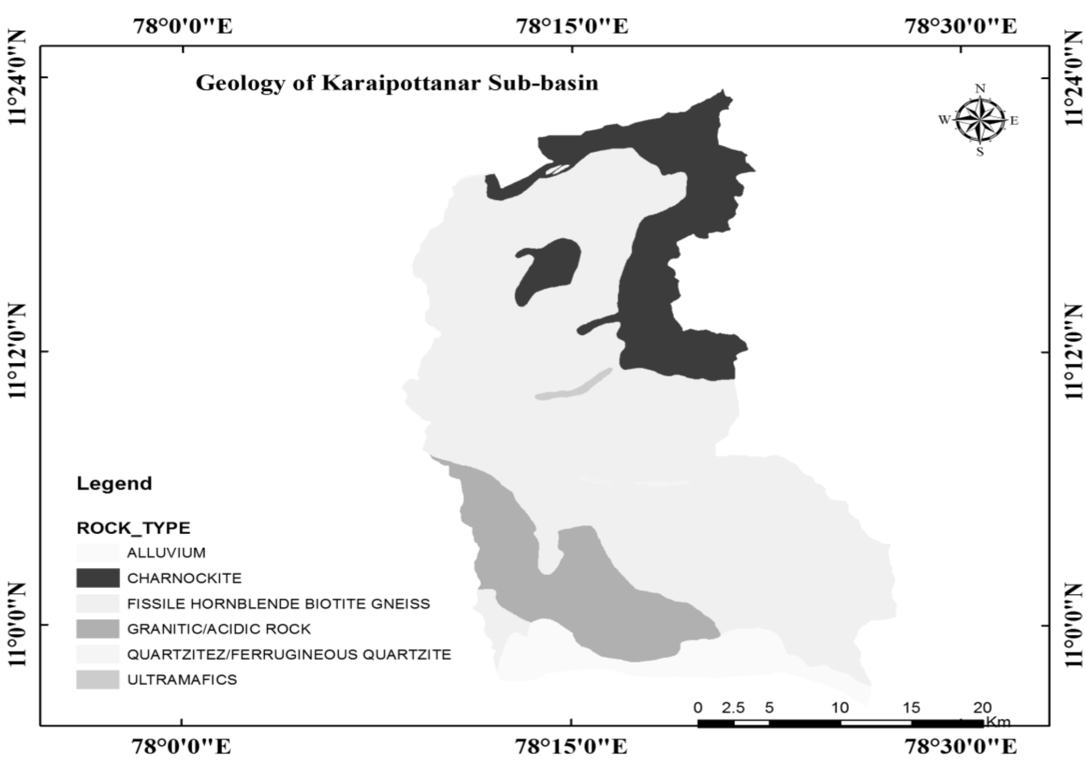


Fig. 2 Geology map of study area

MATERIALS AND METHODS

Totally, forty-four samples were collected from the phreatic aquifer during January 2015. pH, ORP (Redox potential) and electrical conductivity were analysed in the field. Polyethylene bottles were properly cleaned with 1 N of HCl and groundwater samples are acidified with 1 N of Nitric acid. Trace elements such as Fe, Cr, Zn, Cu, Ni, Co and Mn are analyzed using Atomic Absorption Spectrometry (AAS). The obtained results are compared with Bureau of Indian Standard (BIS 2012) for determining the quality of groundwater for drinking purpose. Box and Whisker plots are drawn to reveal the order of dominance of heavy metals. Distribution of each trace elements are shown as spatial distribution diagram using Arc GIS Software. Relation between pH and heavy metals as well as ORP and heavy metals are being discussed. Correlation matrix helps to know about the significant correlation of these heavy metals in the study area.

RESULTS AND DISCUSSION

pH of groundwater in the study area exhibits slightly acidic to slightly alkaline nature which ranges from 6.06 to 7.84 with an average of 7.19 (Table 1). The lowest pH values are observed in hilly region. EC values show wide variation from 47 to 11,770 µS/cm, with an average of 2906 µS/cm. The lowest EC values are observed in Kolli hill. Highest value is observed in sample number forty-four, where high anthropogenic activities have been observed. ORP (Redox Potential) ranges from 30 to 132 mV, which reveals that all location reflects the oxidizing processes in the study area.

Table 1 Minimum, maximum and average values for different parameters in groundwater

Parameters	Minimum	Maximum	Average
pH	6.06	7.84	7.21
EC (µS/cm)	46.70	11770.00	2769.55
ORP (mV)	30.00	132.00	71.16
Fe (mg/L)	0.022	13.910	1.264
Cr (mg/L)	0.001	0.055	0.023
Zn (mg/L)	0.004	1.172	0.136
Cu (mg/L)	0.012	0.168	0.091
Ni (mg/L)	0.003	0.090	0.035
Co (mg/L)	0.006	0.279	0.095
Mn (mg/L)	0.003	0.826	0.123

Table 2 Comparison of heavy metal with BIS standards (2012)

Elements	Min.	Max.	Avg.	BIS Limit		Below required Limit	Required to permissible Limit	Above permissible Limit
				Required Limit	Permissible Limit			
Fe (mg/L)	0.022	13.910	1.264	0.30	-	8	-	36
Cr (mg/L)	0.001	0.055	0.023	0.05	-	41	-	1
Zn (mg/L)	0.004	1.172	0.136	5.00	15	44	-	-
Cu (mg/L)	0.012	0.168	0.091	0.05	1.5	4	40	-
Ni (mg/L)	0.003	0.090	0.035	0.02	-	12	-	32
Co (mg/L)	0.006	0.279	0.095	No recommended value in BIS				
Mn (mg/L)	0.003	0.826	0.123	0.10	0.3	21	22	1

TRACE METALS

Concentration of heavy metals in the study area, are controlled by various rocks in the study area and also by various anthropogenic processes like, agricultural and industrial activities. According to Box and Whisker Plot (Fig. 3) the heavy metals concentration in study area are in the order of Fe > Zn > Mn > Co > Cu > Ni > Cr.

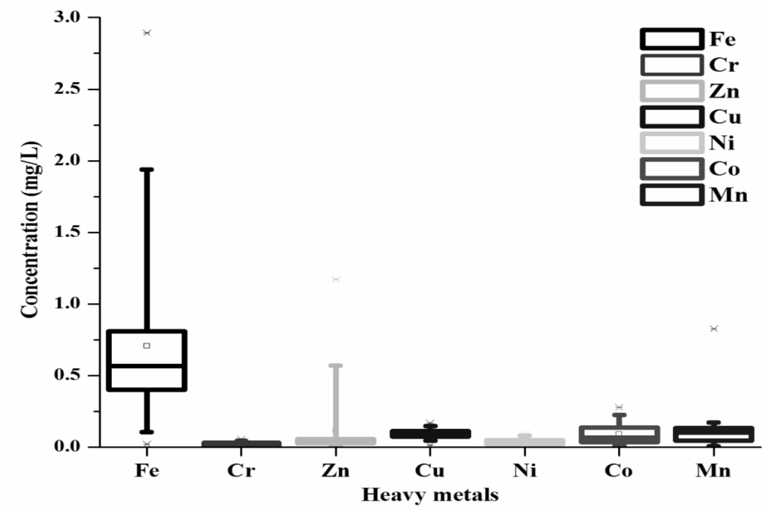


Fig. 3 Box and Whisker plot for heavy metals concentration

Iron (Fe mg/L)

82 % of samples exceed the permissible limit of iron in drinking water. Concentration of Fe in groundwater ranges from 0.022 to 13.910 mg/l with an average of 1.264 mg/l. The source of iron is due to rock-water interaction with Fe bearing rock and corrosion of house hold pipes in low pH of groundwater (Mondal et al. 2010). As per BIS guideline, above 0.3 mg/l give staining effects on laundry and sanitary and with additional concentration also lead to chronic intoxication (Huang Bin et al. 2015). Fe considered as pro-oxidative element which lead to affect spermatogenesis, sperm motility, and fertilization when present excess amount in human body (Kasperczyk Aleksandra et al. 2015). The higher concentration of Fe is observed in north east part due to rock-water interaction (Fig. 4) and as the host rock in this region is charnockite, it is inferred that the source of Fe in groundwater of the study area is charnockite.

Chromium (Cr mg/L)

Concentration of Cr in the study area varies from 0.001 to 0.055 mg/l with an average of 0.023 mg/l. Only one sample exceeds the permissible limit. Generally, chromium in groundwater is due to agrochemical activities (Mortvedt et al. 1995), electro-plating processes and painting pigments (Campos et al. 2005). Cr is highly distributed in southern and central part of the study area (Fig. 5).

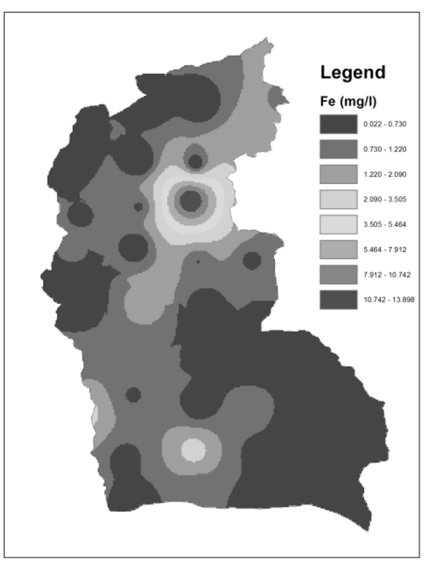


Fig. 4 Spatial distribution of Fe in groundwater of Karaipottanar sub-basin.

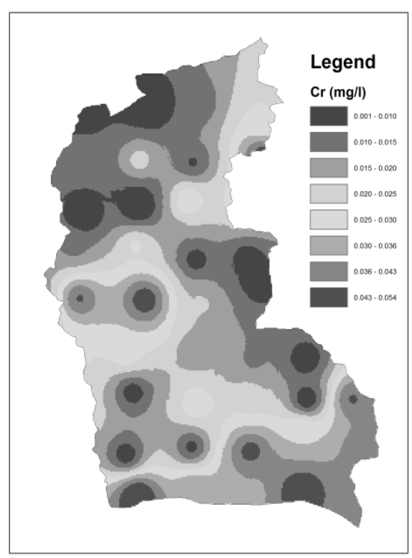


Fig. 5 Spatial distribution of Cr in groundwater of Karaipottanar sub-basin.

Zinc (Zn mg/L)

Zn concentrations ranges from 0.004 to 1.172 mg/l, with an average of 0.136 mg/l. All the samples are within the required limit of 5 mg/l (BIS 2012). Zinc is one of the important elements for nucleic acid metabolism and brain tubulin growth and photosporylation but Zn deficiency causes impaired DNA, RNA and protein synthesis during brain development (Khan Taqveem Ali et al. 2004) and gives abnormality of birth for pregnant women (ASTR 2005).There is no elevated concentration of Zn in study area (Fig. 6). As the southwest part consist of alluvium and the value of Zn is being recorded higher, it is observed that the rock-water interaction and the host, namely alluvium is responsible for Zn concentration in the groundwater sample.

Copper (Cu mg/L)

Cu concentration ranges from 0.012 mg/l to 0.168 mg/l, with an average of 0.091 mg/l. Copper is also an essential trace elements for human. It helps to binding of bacteriotoxins and increase the activity of antibiotics (Khan Taqveem Ali et al. 2004), and also help to maintain bone metabolism effectively (Dermience Michael et al. 2015). Sources of copper in the study area are copper-based fungicides and fertilizers (Mirlean et al. 2009) and also derived from feldspar, muscovite and biotite from sources rock (Mondal et al. 2010). Cu is within the permissible limit in all the samples (Fig. 7). Cu being leached from the host rock, namely, Fissile hornblende biotite gneiss and dissolved in the groundwater of the study area.

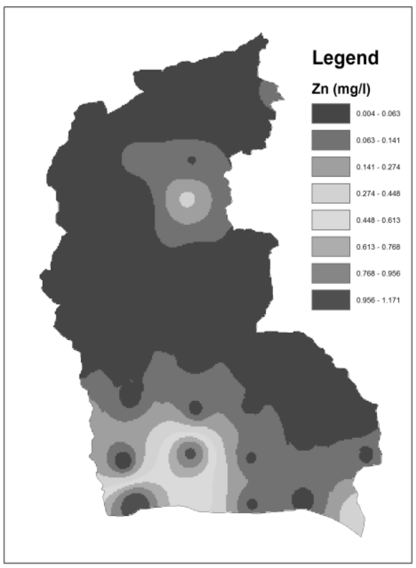


Fig. 6 Spatial distribution of Zn in groundwater of Karaipottanar sub-basin.

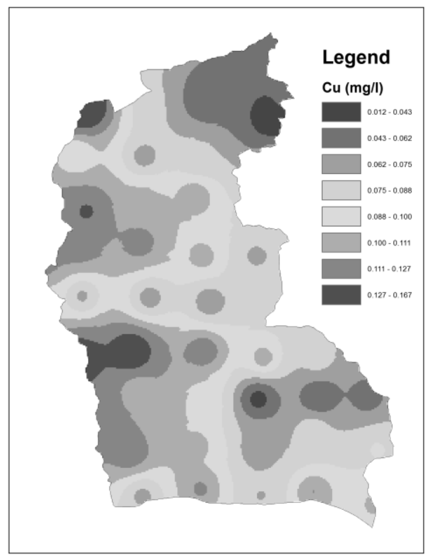


Fig. 7 Spatial distribution of Cu in groundwater of Karaipottanar sub-basin.

Nickel (Ni mg/L)

Nickel concentration in groundwater shows that 73% samples have exceeded its permissible limit of 0.02 mg/l and it ranges from 0.003 to 0.090 mg/l, with average of 0.035 mg/l. Nickel is essential for human nutrition, but the elevated concentration of nickel may give allergy contact dermatitis effects for human and life-long consumption of higher concentration may give carcinogenic effects. Higher concentration of Ni is seen in almost all over the study area especially, in the northeast and southeast region (Fig. 8), where Fissile hornblende biotite gneiss is being found as host rock.

Cobalt (Co mg/L)

The spatial distribution of Co is shown in Fig. 9. Cobalt concentration varies from 0.006 to 0.279 mg/l with an average of 0.095 mg/l. Generally, Ni and Co shows similar geochemical behaviors in groundwater and they are co-precipitated with iron oxide, and especially with manganese at ferromagnesian igneous-rock minerals (Hem 1985). But, here both elements show wide variation in their concentrations at different sample location in the study area, which indicate that both the elements were not from same sources and anthropogenic activities are responsible for such variation. The concentration of cobalt may derive from cobalt containing fertilizers and industrial activities, apart from the rock-water interaction where Fissile hornblende gneiss is being found.

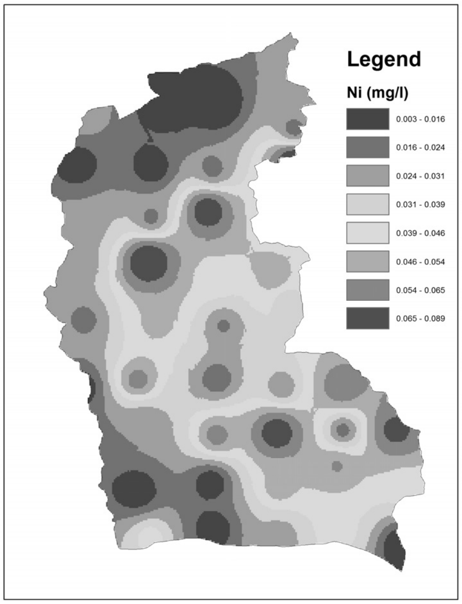


Fig. 8 Spatial distribution of Ni in groundwater of Karaipottanar sub-basin.

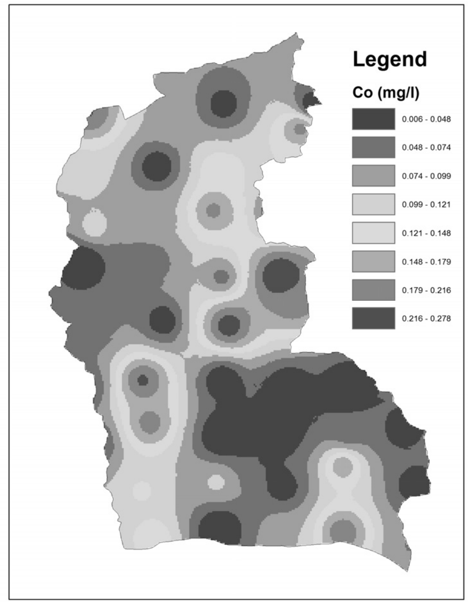


Fig. 9 Spatial distribution of Co in groundwater of Karaipottanar sub-basin.

Manganese (Mn mg/L)

Manganese concentration in groundwater has almost in safer condition. Its value varies from 0.003 to 0.826 mg/l, with an average of 0.123 mg/l. Most of the samples in study area are within the permissible limit except one location where industrial waste water containing manganese discharges its effluent into Cauvery river. Spatial distribution (Fig. 10) shows that the southwest part of the study area has higher concentration.

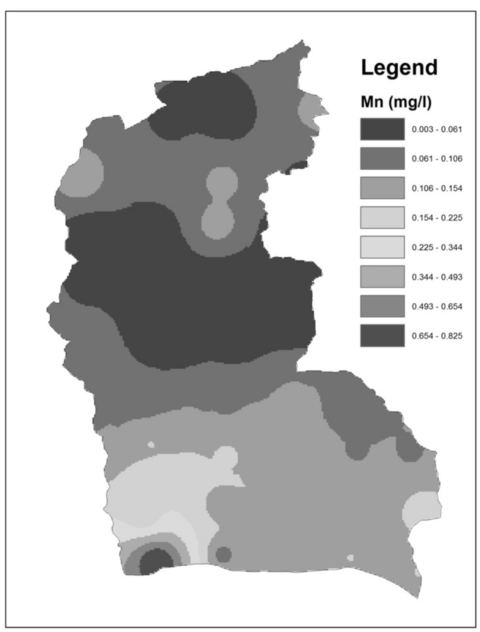
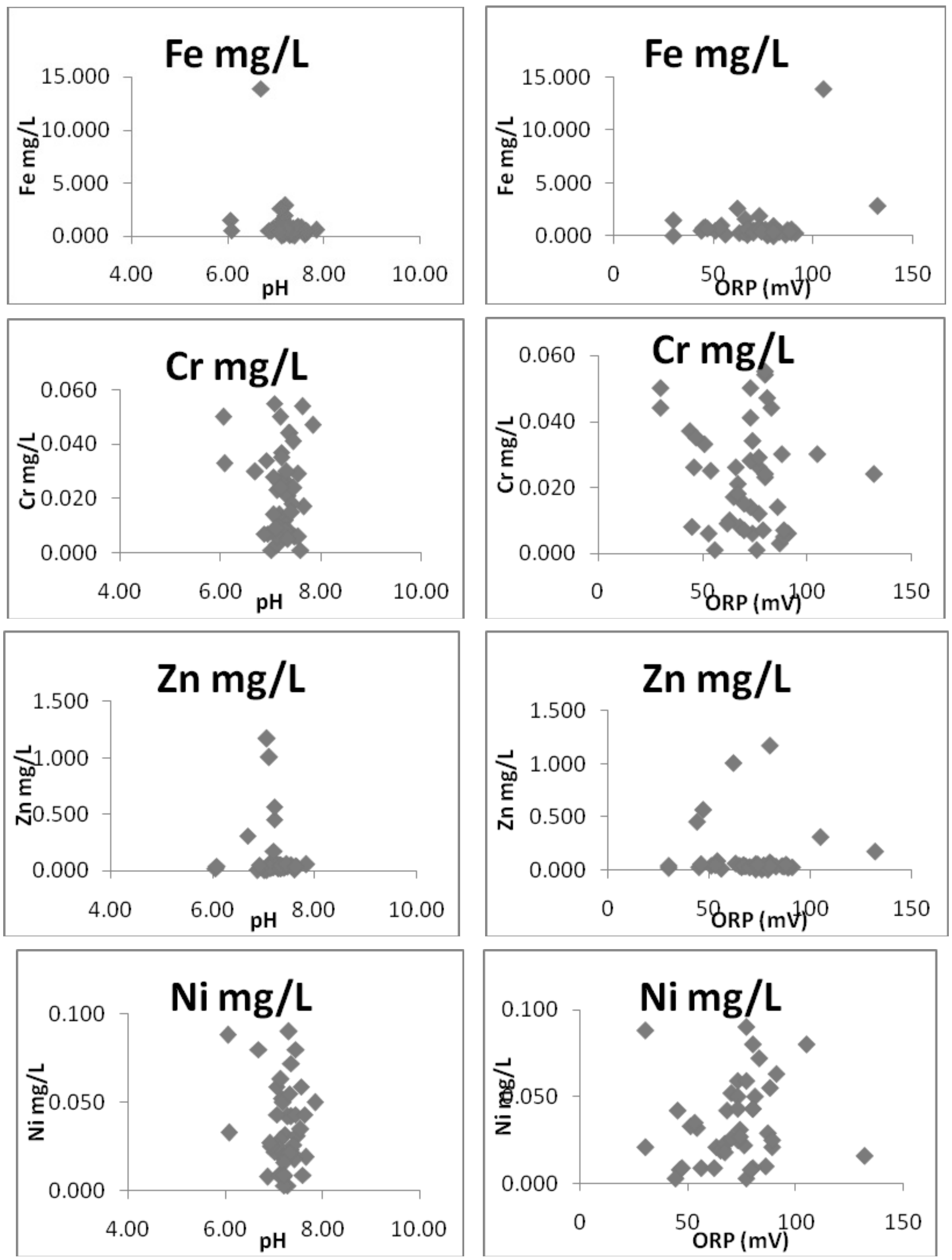


Fig. 10 Spatial distribution of Manganese in groundwater of Karaipottanar sub-basin.

RELATIONSHIP BETWEEN pH, ORP WITH HEAVY METALS

The concentration of most of the heavy metals, such as Cr, Zn Cu, Ni and Mn increase when pH is from 7 to 7.5 and they decrease when pH is above 7.5. The alkaline pH of the medium can also be the cause of low level of Fe and Mn, as heavy metals are precipitated as their salts at high pH and are deposited in sediments. Comparing the ORP with heavy elements, it is found that in oxidation state which ranges from 50 to 100 mV all the said heavy metals occur. It is revealed that strong oxidizing environment that develops due to oxygen that dissolves in the water, dissolved the metals to be precipitated (Muller and Sigg 1992; Peacock and Sherman 2004). Cr, Cu, Ni and Co are do not participate in redox processes directly, but they are affected by redox-dependent mineral precipitation dissolution (Zachara et al 1992). Scatter plots for pH and OPR for each heavy element are in Fig.11.



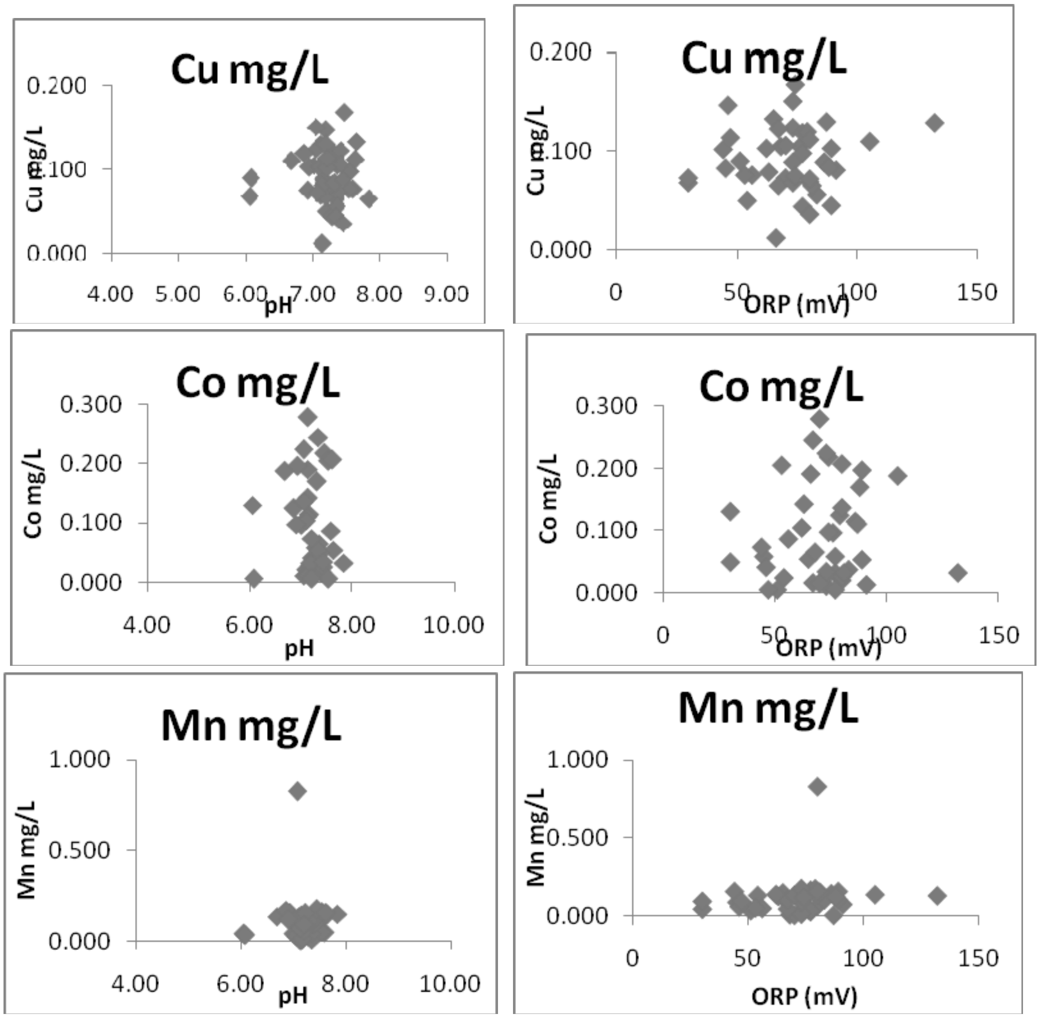


Fig. 11 Scatter plots for pH and OPR for each heavy element

CORRELATION MATRIX

To identify the feasible source of metals in groundwater samples, the bivariate correlation were used (Table 3). Correlation coefficient of <0.5 exhibit poor correlation, 0.5 indicate good correlation and >0.5 represent excellent correlation (Amfo-Out et al. 2104). Good correlation exists between Zn and Mn, whereas no significant correlation was found among the other elements. This indicates that the source of these metals was independent from each other and they have been originated from different sources. Source of Zn and Mn are either from metallurgy industry discharge into Cauvery river. Other elements are being concentrated in the groundwater samples of the study area due to fertilizers and fungicide being used for agricultural activity (Hem 1985; WHO 2011).

Table 3 Correlation matrix between observed parameters

	pH	**Fe**	**Cr**	**Zn**	**Cu**	**Ni**	**Co**	**Mn**	**EC**	**ORP**
pH	1									
Fe	-0.28	1								
Cr	-0.10	0.09	1							
Zn	-0.10	0.20	0.25	1						
Cu	0.00	0.10	-0.18	0.04	1					
Ni	-0.14	0.29	0.36	-0.13	-0.12	1				
Co	-0.09	0.18	-0.13	0.03	0.07	0.11	1			
Mn	0.05	0.02	0.38	**0.69**	-0.06	0.01	0.07	1		
EC	-0.03	-0.14	-0.16	-0.10	0.44	0.01	0.05	-0.17	1	
ORP	0.13	0.31	-0.13	-0.03	0.11	0.15	0.07	0.15	0.07	1

CONCLUSION

The study specifies the various concentrations of heavy metals and their spatial variation in groundwater of the study area, namely, Karaipottanar sub-basin. In most of the samples, Fe and Ni are above the permissible limit and other elements are within the permissible limit. The higher concentration of Fe are observed in neutral pH and in higher concentration of redox potential that suggests that pH and ORP are the governing factors for the dissolution of Fe in groundwater. The concentration of most of the heavy metals, such as Cr, Zn Cu, Ni and Mn increase when pH is from 7 to 7.5 and they decrease when pH is above 7.5. The correlation coefficient shows the association of Zn and Mn. Other elements have no relationship with each other which indicates that the elements may have evolved in groundwater by different sources independently. Fe and Ni exceed the permissible limit in 82% and 73% of the samples collected. Co, Cr, Cu and Ni are from Fissile hornblende gneiss; Fe is from Charnockite; and Mn and Zn are from Alluvium, where rock-water is the process. Cr, Cu, Co and Mn are also from fertilizers and industrial wastes.

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Groundwater- Level Trends and Forecast in Guam Aquifer, USA

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ABSTRACT

The present study aims to assess the groundwater level trends in the Guam aquifer at 9 selected well locations using the groundwater levels data for a historic period of 25 years i.e., from 1984 to 2008 and for a forecasting period of next 25 years i.e., from 2009 to 2033. The Guam aquifer is one of the five American territories located in north western Pacific ocean facing the dynamic fluctuation in the groundwater table movement due to stress in water demands. The monthly groundwater levels are varying rapidly in the study area. In order to perceive the trends in monthly groundwater level variations in the Guam aquifer the widely used Mann-Kendall's test has been used. Further, an attempt has also been made to predict the monthly groundwater levels at the same 9 selected well locations in the Guam aquifer using the widely used Thomson-Fiering model. The statistical parameters like mean and standard deviations have been estimated for both historic and prediction periods. The calibration and verification of statistical parameters is also done in the present study. The results reveal that there is a dynamic variation in the groundwater levels of the Guam study area with an upward and no trends in the groundwater levels when worked out at 5% significance level.

Keywords: Groundwaterm Aquifer, water table, Thomson Fiering Model.

INTRODUCTION

Earth is a unique planet in this universe. It is the only known planet which can sustain different forms of life. One of the reasons for this uniqueness is the abundance of water present in the liquid form. It is available in the surface as well as beneath the surface. In surface it is present in the form of oceans, rivers, lakes etc., whereas in ground it is stored in the aquifers. Groundwater is defined as the water which is found beneath the water table. Water table is the soil layer below which soil is saturated. Above this layer water is present in unsaturated form. This water is very important as it provides water for the sustenance of plants and trees because this is available in the root zone. The importance of groundwater for the existence of human society cannot be overemphasized. It is the major source of drinking water in both urban and rural areas. Besides, it is an important source of water for the agricultural and the industrial sector. In recent past, groundwater is considered as dependable source of uncontaminated water. But, nowadays its quantity and quality is going down due to overexploitation and its contamination through various sources, including industrial waste. According to NGWA (USA), 98% of the total usable fresh water available on the earth is groundwater and this water is about 60 times as plentiful as fresh water found in lakes and streams. Protecting it from contamination and carefully managing its use will ensure its future as an important part of ecosystems and human activity. With increasing population and life standards use of water has grown manifold and is putting a burden on the existing infrastructure. Hence new infrastructures are needed to meet the current and future demand. Therefore, states are moving towards groundwater to meet the demand and quench the parched throats of the people. This overuse of groundwater is a potential threat to quantity and quality of water. Therefore, assessment trends of groundwater drawdowns for the historic and prediction periods play a major role in quantification of groundwater potentials in the aquifers. In this area, many research works are available in literature. Neidhardt et al., (2013) have shown the influences of groundwater extraction on the distribution of dissolved Arsenic in shallow aquifers of West Bengal, India. Chauduri et al., (2014) have assessed the long term trends in groundwater levels in Texas and influence of soils, land cover and water use. Chen et al., 2014, has also worked in long term groundwater variations in northwest India using satellite gravity measurements. Lopez et al., 2015 has used it to identify contaminant concentration in groundwater. Reddy et al., 2016 applied Mann-Kendall's test for trend analysis of drought events at Pali district in western Rajasthan. Rao et al., (2016), have simulated the rainfall using Thomas-Fiering model in western Rajasthan region to forecast the drought trends. Overuse of groundwater resource is a case when recharge of aquifers is less than the water pumped out over a long period of time. This leads to problems like lowering of water table and the wells may not be able to reach groundwater. As the water table lowers, the cost of pumping increases and in some cases may become unviable to pump the water. Excessive pumping in coastal areas results in the intrusion of salt water into the aquifers. Furthermore, ground water and surface water are closely related and in many areas comprise a single resource (Winter et al., 1998). Liu et al., (2011) has also shown the interaction of surface water and groundwater. Groundwater and surface water are linked to each other. In summer periods groundwater contributes water to the surface sources. Hence, falling water table results in diminished supply of water in rivers, lakes, causing concerns about drinking water supplies, riparian areas, and critical aquatic habitat. In terms of quality also groundwater is facing a lot of issues. It is getting contaminated by gasoline, oil and other chemicals which are stored in a storage tank. These tanks corrode and the leakage takes place. Contamination of groundwater by Arsenic is a major problem. Chakraborti et al., 2016 have investigated the extent and severity of groundwater arsenic contamination in 5 blocks of Patna district. Independent septic tanks are also a source of contamination for the ground water. Improper disposal of batteries and electronic gadgets can discharges lead into the groundwater. Dumping of medical waste can leak bacteria, viruses into the groundwater. It can trigger an epidemic in dependent population. Hence, quantity and quality of groundwater must be monitored. Measurements of water levels in wells provide the most fundamental indicator of the status of this resource and are critical to meaningful evaluations of the quantity and quality of ground water (Taylor et al., 2001). Every step must be taken to protect it. Reduce, reuse and recycle must be practiced to save it. Special emphasis has to be given to recharge the aquifers. According to IS 15792-2008 basic requirements for artificial ground water recharge are,

1. Availability of non-committed surplus monsoon runoff of suitable quality in space and time.
2. Identification of suitable hydrogeological environment and sites for augmenting groundwater through cost effective artificial recharge techniques.

Shekhar et al., 2015, have worked in groundwater management in north district of Delhi to meet local water requirements. Conjunctive use of ground water i.e. co-ordinating its use with surface water to improve overall reliability of water supply. In general when surface water is plentiful then it is used by customers in lieu of groundwater or diverted to recharge groundwater reserves. Ground water is used in dry periods when surface water is less. In order to address the above problems related to groundwater present study aim to assess the trends in groundwater drawdowns taking place in the Guam aquifer one of the five American territories located in north western Pacific ocean as this aquifer facing the severe dynamic fluctuations in groundwater table due to stress in water demands. Note that, the groundwater quality aspects in the study area are beyond the scope of this work.

STUDY AREA

Guam is the largest and southernmost of the Mariana Islands in the western Pacific Ocean, being about 48 kilometers long by 6-19 kilometers wide (Simard et al., 2016). The Guam was discovered by Magellan in the early 16th century (John F Mink 1976). Guam lies between 13.2°N and 13.7°N and between 144.6°E and 145.0°E, and has an area of 544 km^2. It is the closest land mass to Mariana trench. This island is an earthquake prone area due to its proximity to the western edge of the Pacific plate and near the Philippine Sea plate. Guam's weather is generally warm and humid. Mean high temperature is 30 ^{0}C and low is 24 ^{0}C. It receives a downpour of 96 inches (2180 mm). It has distinctly two seasons. One is dry that runs from December through June and the remaining period is wet season. January and February months are the coolest months with temperature falling down up to 21 ^{0}C and humidity also shows downward trend. Tropical storms and typhoons are common during wet season. Month of August receives the highest average precipitation with 16 inches (406.4mm) of rain water (Wikipedia). The northwest-southeast trending PagoAdelup fault divides Guam into two physiographic provinces, a southern volcanic upland, and a northern limestone plateau overlying a volcanic basement as shown in figure 1.(Simard et al.,2016).

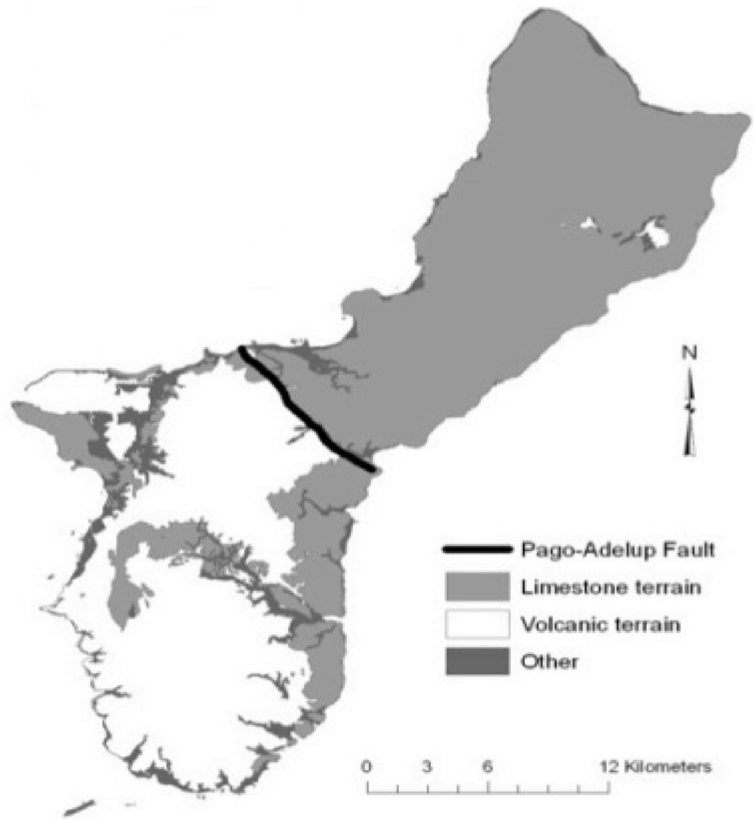

Fig. 1 PagoAdelup fault dividing Guam into two physiographic provinces

Southern Guam volcanics are aquicludes when compared with northern limestone as its storing and transmitting capability is less than limestone (Mink., 1976). Volcanic rocks have uniform aquifer characteristics over a wide area. In the northern Guam characteristics of limestone are highly variable. These are highly permeable compared to volcanics of the southern Guam. This is the source of groundwater for Guam. Water table remains few feet above the sea level (EPA., 2006). Water in these aquifers is not more than 5 to 10 years old. For studying the water level and trends 9 wells at different locations has been selected. These stations Latitude, Longitude and name of the place are given in Table 1 and the location on the map is depicted in Figure 2.

Table 1 Stations with latitude, longitude and place

STATION	LATITUDE	LONGITUDE	PLACE
STATION 1	13°26'30.3"N	144°45'34.7"E	Ramirez, chalan Pago ordot
STATION 2	13°26'47.5"N	144°48'15.6"E	Juan Muna street
STATION 3	13°28'16.9"N	144°47'33.1"E	Kanada Toto loop Road
STATION 4	13°28'59.9"N	144°46'51.8"E	E sunset Blvd, Tamuning
STATION 5	13°28'38.9"N	144°45'00.4"E	Marine corps, Hagatna
STATION 6	13°30'38.2"N	144°49'26.9"E	Dededo
STATION 7	13°30'53.9"N	144°50'07.1"E	Marine corps Dr Dededo
STATION 8	13°31'24.0"N	144°49'26.3"E	Marine corps Dr Dededo
STATION9	13°32'30.6"N	144°50'2.0"E	Swamp road, Dededo

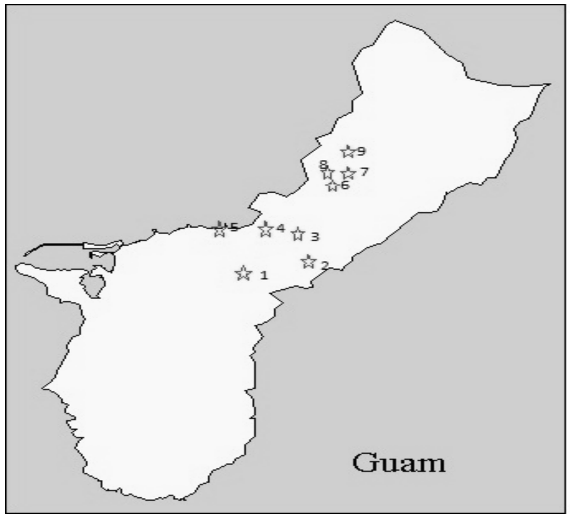

Fig. 2 Guam map showing different stations

The population in the study area is concentrated near streams or springs flowing into the ocean. Northern Guam was least populated because surface water sources were very few. Therefore, exploitation of groundwater started on a large scale. Currently about 80% of potable water in Guam is supplied by Groundwater. This water is supplied by northern Guam lens aquifer (Simard et al., 2016). Over a period of time chloride content in the aquifers are increasing. Some of the production wells have been changed into monitoring wells either due to increased chloride content or due to excessive mining of groundwater. Hence proper monitoring of groundwater is required.

METHODOLOGY

To study the groundwater trends of Guam Island, 25 years of data is collated for 9 well stations. The data corresponds to the period from 1984 to 2008 is accessed from the United States geological survey website (usgs.gov.in). Monthly groundwater elevation from mean sea level is given by the USGS. In order to find the negative (downward) and positive (upward) trend of the water table series the Mann-Kendall's test is being widely used. This Mann–Kendall test is a nonparametric test for monotonic trends. This test has been applied to know the trends in the water table of the Guam aquifer. In order to detect the magnitude of the trend Sen's slope estimator (Sen, 1968) has also been used. The application of the Sen's slope estimator is useful as it can calculate the trend in a single value. Further, synthetic values of groundwater drawdowns were generated using widely used Thomas-Fiering model. This data is generated for next 25 years i.e. from 2009 to 2033. Again to know the trends in the predicted drawdown values in the aquifer, Mann-Kendall's test is applied. Further, Sen's slope estimator is applied to know the positive or negative slope. The data generated by Thomas-Firing model is verified by overlapping the means of the generated data and the observed data for a common period of 10 years i.e., from 1999 to 2008.

RESULTS AND DISCUSSION

Table 2 and Table 3 show the Mann-Kendall's test results obtained for both the historic and predicted periods, respectively. Table 4 and 5 show the results of the Sen's slope estimator obtained for both the historic and predicted periods, respectively. Figure 3 and 4 demonstrates the comparison of means of the observed and simulated data at station 1 and 3, respectively of the Guam aquifer.

Out of the 9 stations only station 1 is in southern Guam and the rest is in northern Guam. The station of southern Guam has water table about 50 feet above the mean sea level. In southern Guam the soil is of volcanic deposits and is uniform in nature. The permeability of soil is less as compared to the limestone deposits of the northern Guam. In northern Guam all the stations are having water table very close to mean sea level. This fact can be attributed to the high permeability of the limestone. Mann-Kendall's test shows that groundwater table has been increasing in the stations which are there in the northern Guam. It is seen from Table 2 that the stations 2, 6, 7 and 9 have all the months with rising trend in the observed period. Further, at the station 4 the trend is rising in 10 out of the 12 months. All other stations are showing rising trend in some of the months except station 1, which shows no trend for all the months. This can be attributed to the fact that the sea water level is escalating after 1998 (Simard et al., 2016). The rainfall which occurs in northern Guam is absorbed by the aquifer and very little goes to sea as surface water flow. So the groundwater of northern Guam is very young i.e. 5 to 10 years old. In case of southern Guam very little is recharged to groundwater and most of the water runs in streams and rivers to join the sea. Further, from Figures 3 and 4 it is seen that, the peak is coming in the later part of the year, i.e., after the month June rising trend is starting and it is rising in the month of September or October mostly falling in the wet (monsoon) period of the Guam aquifer. The results also reveal that no trend is seen for the forecasting period for the next 25 years i.e. 2009-2033 (see Table 3). Further, it is inferred from the Sen's slope estimator that the no of positive slopes are exceeding the no of negative slopes indicating that the magnitudes of the trend is positive i.e., rising in the study area for the historic period (see Table 4) and it is reverse in the predicted period (see Table 5).

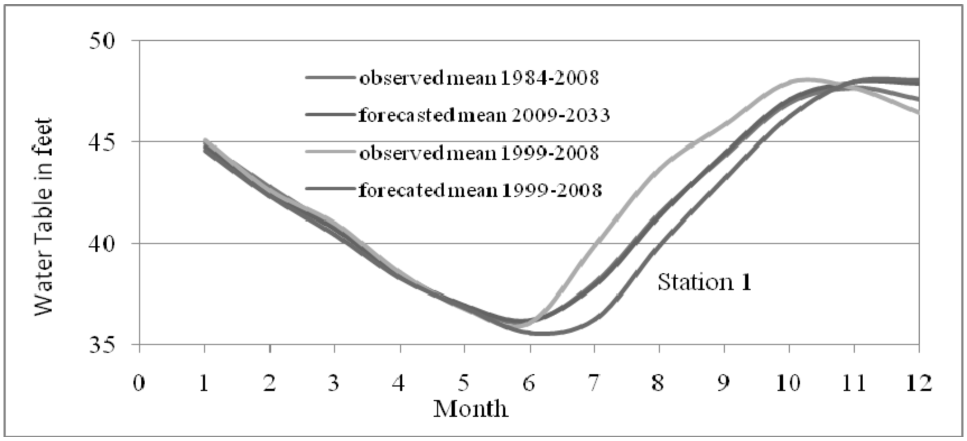

Fig. 3 Comparison of means of the observed and simulated data at station 1 of the Guam aquifer.

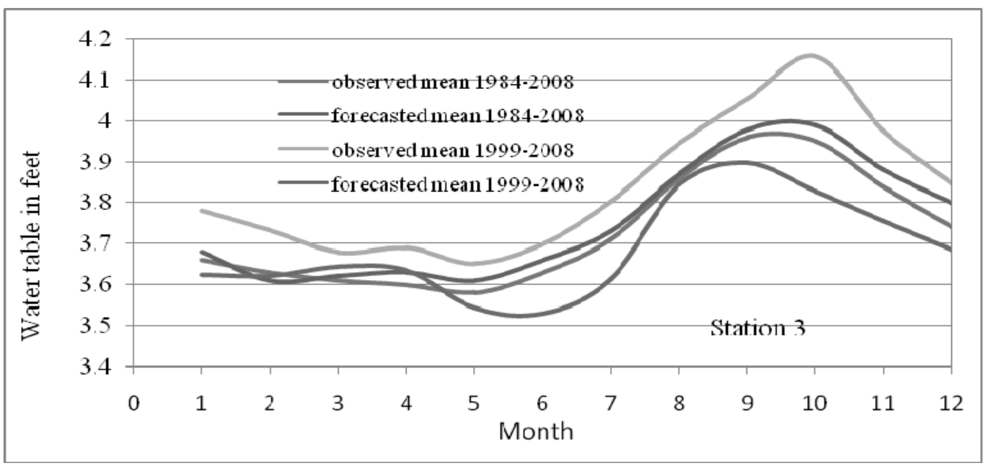

Fig. 4 Comparison of means of the observed and simulated data at station 3 of the Guam aquifer.

Table 2 Showing Mann-Kendall's test results for observed period (1984-2008)

Station/month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
STATION 1	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
STATION 2	RT	RT	RT	RT	RT	RT	RT	RT	RT	RT	RT	RT
STATION 3	RT	RT	NT	NT	NT	NT	NT	RT	RT	RT	RT	RT
STATION 4	RT	RT	NT	RT	RT	RT	RT	RT	NT	RT	RT	RT
STATION 5	NT	NT	RT	RT	RT	RT	RT	RT	RT	RT	RT	NT
STATION 6	RT	RT	RT	RT	RT	RT	RT	RT	RT	RT	RT	RT
STATION 7	RT	RT	RT	RT	RT	RT	RT	RT	RT	RT	RT	RT
STATION 8	NT	NT	NT	RT	RT	RT	RT	RT	NT	NT	NT	NT
STATION 9	RT	RT	RT	RT	RT	RT	RT	RT	RT	RT	RT	RT

NT = No trend; RT = Rising Trend

Table 3 Showing Mann-Kendall's test results for forecasted period (2009-2033).

Station/month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
STATION 1	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
STATION 2	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
STATION 3	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
STATION 4	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
STATION 5	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
STATION 6	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
STATION 7	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
STATION 8	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
STATION 9	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT

NT = No trend; RT = Rising Trend

Table 4 Showing Sen's slope test results for observed period (1984-2008)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
STATION 1	5.61	6.75	5.71	4.81	4.73	3.45	5.25	5.57	3.02	2.84	3.37	3.9
STATION 2	0.17	0.35	0.38	0.31	0.13	-0.07	-0.15	0.2	0.05	-0.1	0	-0.02
STATION 3	0.19	0.36	0.4	0.35	0.15	-0.03	-0.14	0.16	0.08	-0.11	-0.04	-0.06
STATION 4	0.1	0.27	0.3	0.26	0.07	0.02	0.02	0.08	-0.14	-0.17	-0.11	-0.17
STATION 5	0.02	0.26	0.21	0.12	-0.08	-0.3	-0.36	-0.31	-0.4	-0.33	-0.39	-0.53
STATION 6	0.12	0.3	0.33	0.32	0.13	-0.06	-0.11	0.11	0.02	-0.05	-0.08	-0.13
STATION 7	0.26	0.4	0.41	0.4	0.17	0.22	0.38	0.5	-0.18	-0.09	-0.11	-0.03
STATION 8	0.35	0.38	0.39	0.38	0.35	0.22	0.14	0.11	-0.02	-0.16	-0.03	0
STATION9	-0.25	-0.14	-0.1	-0.07	0.05	-0.26	-0.28	0.03	0.03	0	0.03	-0.07

Table 5 Showing Sen's slope test results for forecasted period (2009-2033)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
STATION 1	-2.39	-3.73	-2.93	-1.91	-1.32	-0.63	0.89	-1.6	-1.65	-0.78	-1.86	-1.2
STATION 2	-0.2	-0.4	-0.32	-0.21	-0.13	-0.07	0	-0.2	-0.18	-0.07	-0.18	-0.13
STATION 3	-0.18	-0.47	-0.47	-0.41	-0.3	-0.19	-0.1	-0.23	-0.17	-0.07	-0.18	-0.09
STATION 4	-0.15	-0.35	-0.32	-0.25	-0.17	-0.08	-0.03	-0.19	-0.15	-0.06	-0.18	-0.12
STATION 5	-0.24	-0.33	-0.33	-0.2	-0.12	-0.04	0.06	-0.14	-0.18	-0.09	-0.08	-0.13
STATION 6	-0.21	-0.39	-0.39	-0.3	-0.26	-0.22	-0.16	-0.28	-0.27	-0.22	-0.32	-0.26
STATION 7	-0.31	-0.51	-0.49	-0.37	-0.28	-0.13	-0.01	-0.38	-0.24	0.03	-0.21	-0.13
STATION 8	-0.21	-0.44	-0.21	-0.13	-0.08	-0.02	0.06	-0.1	-0.1	-0.02	-0.13	-0.09
STATION9	-0.16	-0.34	-0.28	-0.21	-0.11	-0.01	0.06	-0.14	-0.16	-0.1	-0.18	-0.11

CONCLUSIONS

- The groundwater level trends in the Guam aquifer at 9 selected well locations using the groundwater levels data for a historic period of 25 years i.e., from 1984 to 2008 and for a forecasting period of next 25 years i.e., from 2009 to 2033 are assessed
- The monthly groundwater levels are varying in the study area
- The results reveal that there is a dynamic variation in the groundwater levels of the Guam study area with an upward in historic period and no trends in the groundwater levels in the predicted period

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Evaluation of Ground Water Quality Assessement and Modelling using Visual Modflow

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ABSTRACT

Hyderabad is one of the metropolitan cities in india.Due to the rapid industrialization and urbanization many industries located in and around the city have released their untreated and semi treated effluents into the environment more particularly to the water bodies. The pollutants present in the effluents moved through the surface water, soil and percolated into the groundwater and changed the soil and groundwater quality. Groundwater is the source for industrial, domestic and drinking purposes in the city. Due to the above reasons, a case study is taken up near Nacharam industrial area, located in greater Hyderabad metropolitan city as this site stands as an example for many industrial activities that possibly influence pollution in water as well as deteriorate the water quality in the study area. The main objective of the study is to examine the ground water quality status of the study area based on physiochemical characteristics and to construct a ground water flow model and mass transport model. The study is classified into two stages. One is the experimental analysis and the second is the numerical modeling. In experimental analysis four surface water samples are taken and twenty one ground water samples are chemically analyzed for the parameters such as alkalinity, chlorides, pH, hardness, calcium, magnesium, total dissolve solids, sulphates, nitrates, sodium, and potassium. Ground water flow and pollutant transport is accessed through modeling. The ground water flow pattern of the industrial development area of Nacharam has been established using the flow model Visual MODFLOW. The results of experimental analysis are found to be high as compared with the permissible limits. The results from modeling shows that the flow pattern in the industrial development area Nacharam is generally found to be from west to east as the head contours are decreasing toward east direction. The model is calibrated with respect to head i.e., water levels obtained from the study area and calibrated head graph is obtained from numerical model, which is acceptable because the normalized RMS is less than 10% and the standard error is also found to be very small. Apart from head one of the parameter, total dissolved solids (TDS) is taken to calibrate the model. The calibrated concentration graph shows that the calculated TDS values are slightly higher than the observed values.

Keywords: Groundwater, Groundwater Modeling, Visual MODFLOW, Water Quality.

INTRODUCTION

Saline water from the oceans and frozen water locked in glaciers and ice-caps is unusable by humans. Therefore groundwater is a major component of the water available for public or private supply. Using groundwater also has several advantages compared to surface water. Groundwater is filtered by the rocks it travels through and therefore needs minimal treatment before it can be used as potable water. Groundwater does not require storage infrastructure, such as reservoirs, which not only saves space but also reduces losses. Groundwater pollution is defined as “the artificially induced degradation of natural groundwater quality." The sources of groundwater contamination are directly or indirectly linked with sanitation , industrial, domestic and agricultural discharge, spillage or dumping. The general mechanisms of groundwater contamination are due to Infiltration, Direct Migration and Inter-aquifer exchange.

The use of groundwater models is prevalent in the field of Water Resource Engineering. Models have been applied to investigate a wide variety of hydro- geologic conditions. In general, models are conceptual descriptions or approximations that describe physical systems using mathematical equations. They are not exact descriptions of physical systems or processes. By mathematically representing a simplified version of a hydro geological system, reasonable alternative scenarios can be predicted, tested, and compared. Groundwater models describe the groundwater flow processes using mathematical equations based on certain simplified assumptions. These assumptions typically involve the direction of flow, geometry of the aquifer, the heterogeneity or anisotropy of sediments or bedrock. Assessment of groundwater flow can be done through modeling. MODFLOW is a widely used model to simulate groundwater flow. The model can be used in an interpretative sense to gain insight into the head distribution and the flow pattern within a watershed.

METHODOLOGY

The methodology followed in this research can be summarized as follows:

- Collection of data, which includes the physical parameters such as hydraulic conductivity, aquifer thickness, recharge, and pumping rates. Geological boundary, distribution of geologic formation, topographic maps and maps show, groundwater flow directions.
- Field estimation of the relevant hydro geological parameters at as many control points as possible, particularly those at boundaries.
- Interpolation / extrapolation of these parameters to characterize the entire area under study.
- Integration of the entire hydrological data to conceptualize and resurrect the full scale natural system.
- An appropriate mathematical equation describing the ground water regime in terms of observable such as ground water levels or concentration of pollution etc.
- Calibration of the model for steady condition.
- A sensitivity analysis of the model to identify those parameters, which need to be estimated more accurately and also to decipher the error bounds.
- The refinement of the model to progressively bring in plausibility and compatibility between field estimates of the various geo hydrological parameters through the process of the model calibration and validation.
- Verification of the model results with the observed data.

Literature

There are lots of studies conducted on groundwater contaminant transport by using mathematical model. Mathematical models provide a framework for understanding the physical, chemical, and biological processes that determine the cycling of elements and compounds through the environment. They provide a basis for relating human activities and environmental impacts and thus for predicting the changes that might occur in response to alterations in the activities. Various studies which are conducted using MODFLOW such as tannery effluent discharge, paper & pulp mill effluent, chromium solid waste dump site and solid waste dump sites were studied to carry out the present work. Hence mathematical modeling study is very essential to the under the system behavior and to take a decision on corrective and remediation measures. Visual MODFLOW is a well-established tool to study the groundwater flow and contaminant transport.

Study Area and data analysis

Nacharam Industrial Area, is located in north-east of Hyderabad, Ranga Reddy district. The Industrial area was developed in an area of approx. 280 hectares and lies between the longitudes 78°32'30"-78°36'30" to east and latitudes 17°23'30"-17°26'30"to north in survey of India topo sheet no.56/11/NW. Approximately 100 industries including steel manufacturing, chemical manufacturing, food products, rubber and plastics and Breweries are located in the study area.

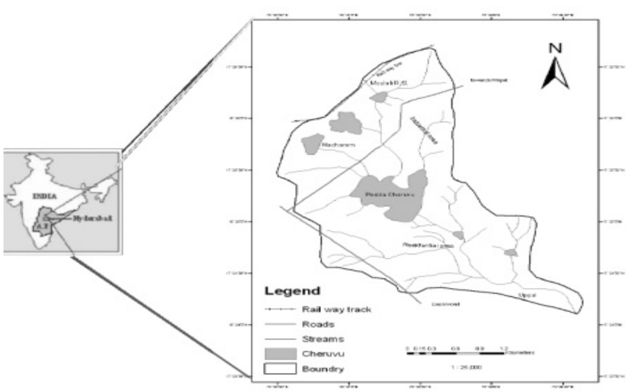

Fig. 1 Location map of study area

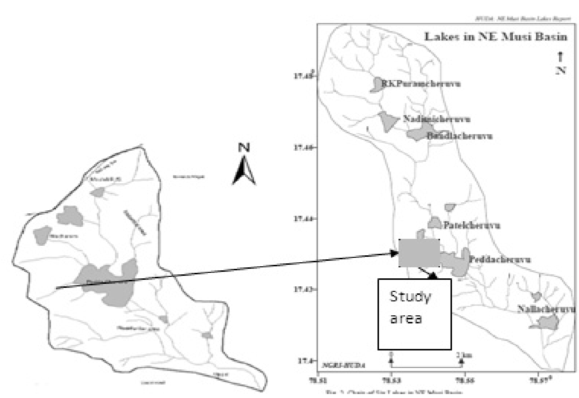

Fig. 2 Site area for ground water modeling.

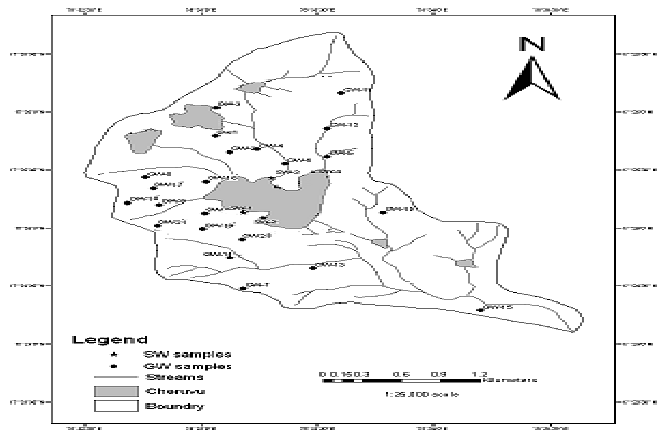

Fig. 3 Groundwater and surface water sampling locations

The project site is a square area of 1.5 km by 1.5 km as shown in the figure 1.2 . The study area is bounded on all the four sides by no distinct land feature topography or geological structure. The study area is relatively flat with an average elevation of 60m above mean sea level (AMSL).The local topography slopes from northwest to southeast towards the Pedda nalla which is located about 608 m east of the site. The Pedda nalla flows from north to south with surface water elevation that ranges from 52 to 53 m AMSL in the north to 51 to 52 m AMSL in the south (depending on the time of year).The average depth of the pedda nalla is approximately 1.5 m.

Experimental Analysis

To determine the general quality of the water in the watershed a total of 25 water samples were taken out of which 21 were from the wells in the area and two samples from each tank. The sampling locations are shown in figure 3 of these locations were later used as calibration points in the modeling process. Most of the well samples were taken from dug wells, since this type is the most common in the area. Only a few wells were of the dug cum bore type. During collection of water samples from wells, the water levels were also measured. The water levels were later used in the calibration process and compared with the result of the MODFLOW simulations. Observed values represent the ground surface in m.a.s.l taken from GMS with a subtraction of the measured values for water levels in field.

Table 1 Water levels measured In field study

Sample No.	1	2	Average (Dug + Bore well)	m.a.s.l	Observed
SW 1					
SW 2					
SW 3					
SW 4					
GW 1	16.3	13.9	15.1	324.1	309
GW 2	15.3	14.8	15.05	343.81	328.76
GW 3	20.5	19.7	20.1	265.8	245.7
GW 4	9	9.7	9.35	240.75	231.4
GW 5	8.4	7.1	7.75	227.15	219.4
GW 6	7.4	7.4	7.4	245.6	238.2
GW 7	13.3	10.9	12.1	246.3	234.2
GW 8	9.3	9.5	9.4	242.2	232.8
GW 9	9	8.3	8.65	242.95	234.3
GW 10	9.3	10.7	10	253.8	243.8
GW 11	12.9	8.4	10.65	275.95	265.3
GW 12	7.6	7.1	7.35	7.35	
GW 13	12.9	11.5	12.2	256.7	244.5
GW 14	8.2	7.6	7.9	256.9	249

Contd…

Sample No.	1	2	Average (Dug + Bore well)	m.a.s.l	Observed
GW 15	24.8	23.3	24.05	24.05	
GW 16	12.2	8.9	10.55	248.55	238
GW 17					
GW 18	11.5	11.1	11.3	250.3	239
GW 19	10.2	9.5	9.85	9.85	
GW 20	11.4	11.3	11.35	269.35	258
GW 21	13.1	12.7	12.9	269	256.1

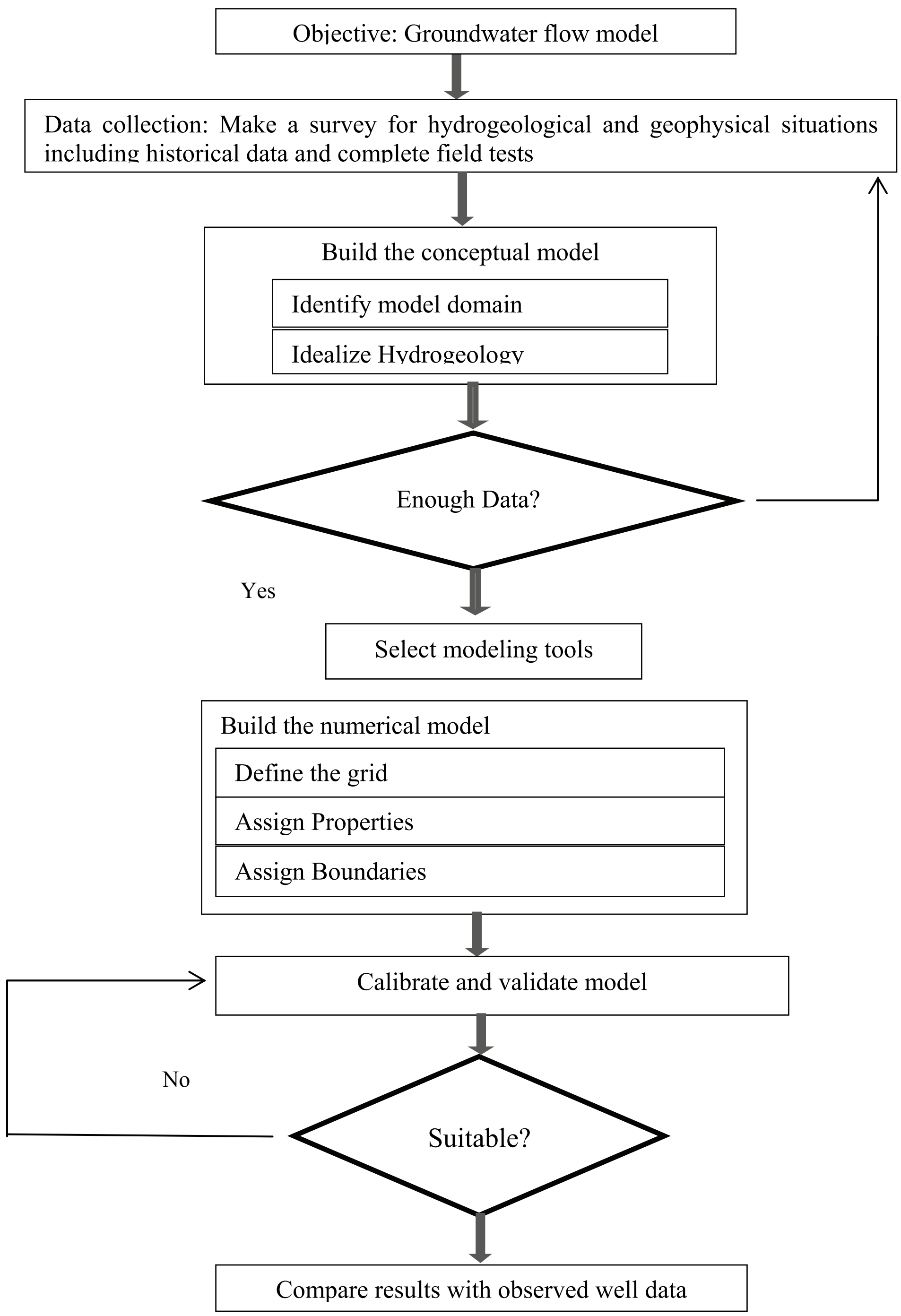

Fig. 4 Flowchart of Groundwater Flow model.

Numerical Analysis

The generated data from the field study, various parameters, water level monitoring data and chemical analysis result of surface water and groundwater TDS mg/l (Total dissolved solids) are used for the development of groundwater flow model. The various steps involved in the modeling in the study that is field work and post field are shown in following flowchart.

With the available literature and the PWD, CGWB study reports the Aquifer properties assigned in the model are as follows.

Table 6 Aquifer properties.

S. No.	Model Properties	Layer 1 (Silty sand and gravel)
1	Hydraulic conductivity in longitudinal direction Kx, m/sec	5.2e-4
2	Hydraulic conductivity in lateral direction Ky, m/sec	5.2e-4
3	Hydraulic conductivity in vertical direction Kz, m/sec	5.2e-5
4	Transmissivity , m^2/sec	2.4e-3
5	Specific Storage Ss (1/m)	5e-4
6	Specific Yield Sy	0.068
7	Effective Porosity	0.2
8	Total Porosity	0.2

Modeling Process

A groundwater model was constructed based upon a conceptual approach. In order to construct the model, boundary conditions, grid and time increments were also estimated. Finally these parameters were tested and adjusted during the calibration procedure with the intention of reproducing a set of historically observed data. Finally the model was evaluated, considering how reasonably it could represent the actual system. In order to setup the model in MODFLOW, the area of interest was divided into a series of grid blocks or cells. A grid size of 30x30x1(total grids=900). The site area is designed in auto cad and the file format .DXF is imported and grid is displayed. The white area of the grid shows active cells which take part in computation process and the color cells in the grids shows the inactive cells which are not taking part in the numerical computation process. The auto cad plan in the grid shows the location of one of the chemical industry in the study area. The figure 5 shows the grid used throughout the simulation process. The grid is refined at the pumping well location and the industrial location to get more detailed simulation results in the areas and also the layer properties can be assigned more correctly on the finer grid. The refined model grid should appear similar to the figure 5 given below throughout the modeling process.

Assumptions used in the Model

The groundwater flow regime model was prepared only for the shallow aquifer zone tapped by dug wells and dug-cum-bore wells (up to 27.68 m thickness). This implies that the deeper fractured zones (extend in the granite) do not take part either in the groundwater flow or the mass transport. The aquifer under weathered zone is also treated as a porous one for modeling purposes. The TDS concentration in the surface effluents was assumed to be more than 8000 mg/l during the period of field study. The quantity of fluid effluents seeping to the groundwater system was assumed to be 30% of the surface effluents. It was also assumed that on a conservative basis the solvent reaching the water table has a solute concentration, which is 30% of that present at the surface. The remaining 70% of the solutes may get absorbed in the unsaturated zones or are carried away by the runoff. An effective porosity of 0.2, longitudinal dispersivity of 30 m, transverse dispersivity of 10 m and 1000 mg/l of TDS as constant concentration were uniformly assumed for the entire interested area.

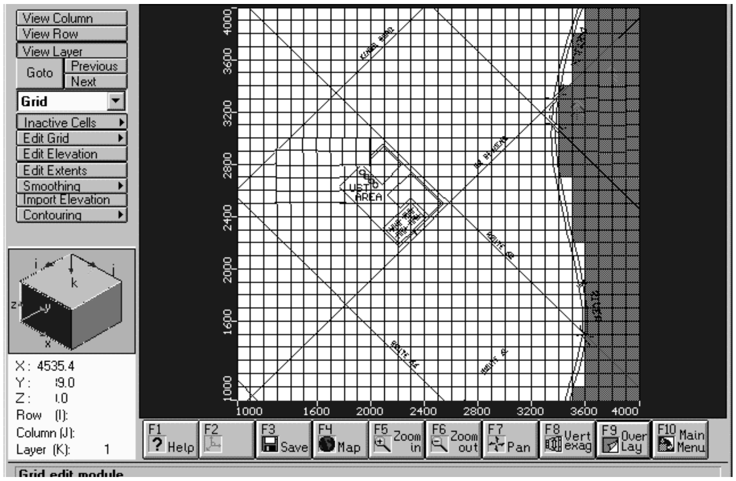

Fig. 5 Grid Appearance in the Model

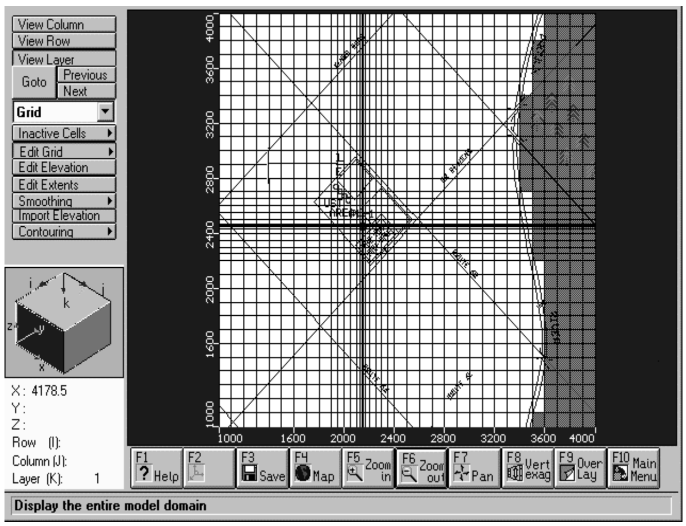

Fig. 5 Refined grid in the simulation process

RESULT AND DISCUSSIONS

Surface water

Four surface water samples (sample number 1 – 4) were collected and analyzed Sample numbers 1, 2, 3 and 4 are from the Pedda cherru located in the study area. The results from the surface water analysis are summarized in Table 2.

The pH values in the Pedda cherru are higher. The values of CO_3^{2-}, SO_4^{2-}, $Na^{+,}$ HCO_3^-, Ca^{2+} and K^+. are higher in the Pedda cherru and the values of TDS are exceeding the tolerance limits due to the discharge of domestic sewage and untreated effluents of the surrounding industries.

Table 2 Surface water analysis results.

Sample	pH	EC mS/m	CO_3^{2-} mg/l	HCO_3^- mg/l	Cl^- mg/l	SO_4^{2-} mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	Na^+ mg/l	K^+ mg/l	TDS mg/l
SW 1	9	328	39.9	507.6	452.2	349.6	176.3	136.8	450.4	15.2	8098.3
SW 2	9	332	48	512.8	456.3	351.3	181.2	139.4	440.2	20	9100.2
SW 3	8.3	338	8.1	516	457.3	353.1	184.2	149.6	415.1	36.8	9648.3
SW 4	8.1	346	9.1	522	455.8	350	190.3	152.2	394.3	33.6	8742.2
Mean	8.6	336	26.2	514.6	455.4	351	183	144.5	425	26.3	8897.25

Table 3 Calculated water quality indices for surface water analysis.

Sample	SAR	Alkalinity	Hardness
SW 1	35.99	547.5	1003.28
SW 2	34.77	560.8	1026.22
SW 3	32.15	524.1	1075.70
SW 4	30.30	531.1	1101.63
Mean	33.22	540.87	1051.71

The water quality index calculated from the values achieved from the table 6.3 shows that the values of SAR, alkalinity and hardness are higher in the Pedda chruu.

Groundwater

Twenty-one water samples were collected from wells in the area. Wells number 12, 16 and 19 are dug cum bore wells, i.e. they are bore wells pumping into an open dug well. The rest of the wells are open dug wells. The results from these analyses are summarized in Table.4 and Table5. As shown in Table 4, well number 14 has the lowest values for all parameters except pH and CO_3^{2-}. For these parameters, it has the highest values. Another well with comparably low values for many parameters is well number 21. High values for most parameters can be found for wells number 6, 8, 9, 15 and 25. The largest exception from this is the pH value. As can be seen in Figure 3 well number 15 and 25 are located close to each other. The wells number 8 and 9 are located at the northeastern part of the watershed. Well number 6 is located in the middle part of the watershed, quite close to well number 14. The values for the dug cum bore wells; number 12, 16 and 19 seems to be medium-low to medium values compared to the rest of the wells

The results from the water quality index shows that well number 14 has the lowest values for all indices. Well number 9, 15, 25 and 8 show high values for SAR, while wells number 14, 21 and 11 show low values of SAR. Wells number 25, 8, 6 and 15 show large values of hardness, and the highest values of alkalinity are found in well number 18, 9 and 10. The values SAR and hardness are both quite low and the alkalinity values are found close to the average values of the wells. Comparing the surface water parameter results with the results from the groundwater samples, it can be seen that the surface water samples have higher values of pH than the groundwater. The EC value is comparably low for the surface water. For the Pedda Cherru the value of CO_3^{2-} is higher than in all the wells, but for Small ponds the values are comparably low. Higher values can be observed for all the other parameters in the surface water than in the ground water. The comparison of the water quality indices between the surface water and the groundwater shows that the values of SAR are quite high in the surface water compared to the values in the wells. The alkalinity and hardness of the surface water is close to the maximum values for the groundwater. As can be seen, the alkalinity mainly depends on the concentration of HCO_3^- for both the surface and the groundwater.

Numerical Analysis results

Model Calibration

The purpose of the calibration of a groundwater flow model is to demonstrate that the model can response field measured heads and flows, which are the calibration values. The purpose of this modeling exercise is to solve an inverse problem, that is, to find a set of parameters, boundary conditions and stresses that reproduce the calibration values within a certain re-established range of error (calibration targets). In this case a trial and error calibration technique has been used. Parameters are initially assigned to each node in the grid. Then these parameter values are adjusted in sequential model runs to match the calibration targets.. The calibration parameters set in this modeling exercise are the generalized head boundary, recharge, evapotranspiration, hydraulic conductivity and specific yield etc..The steady state flow model was also calibrated for the real representation of the study area. The summary of this calibration is presented in Table 7. It shows that the water levels monitored from 21 observation wells in the study area vary from 219.40 to 328.76 m (amsl) whereas the computed water levels from 220.13 to 328.62m (amsl). It indicates the minimum and maximum residuals are 0.02 m and 0.95 m in between observed and calibrated hydraulic heads at the targets with mean 0.45 m but the standard error is 0.04 m.The figure7 display a calculated vs observed head for 22 data points in steady state condition found to be a good fit between the observed and calculated heads. The mean error level is greater than the desired 0.2 value, however the normalized RMS value is less than 10%. Therefore this model has been calibrated to match the observation well data.

Steady State Condition

TDS concentration 'C' was then calculated at all node points for the grid, system was assumed to be in a steady state condition. The observed and computed values of 'C' are obtained by assigning the concentration wells,to get the real representation of the aquifer system, field data was considered for steady state condition and it also run to visualize the mass transport model. The computed versus observed C is illustrated in Figure 6. This indicates that most of the calculated TDS-values are little higher than observed values, but others are fallen along the straight line y = x. The value for well no. 18 is computed as 6370.10 mg/l and the observed is 6220.00 mg/l. For the well no. 13 the observed value was found to be 3910.70 mg/l and the computed value was 4290.10 mg/similarly for well no. 7 the observed value was 865.50 mg/l and the calculate value is 1491.00 mg/l. The error ranges from 4% to 60% for some values. This error may be due to many inaccuracies and deficiency of the historical data available.

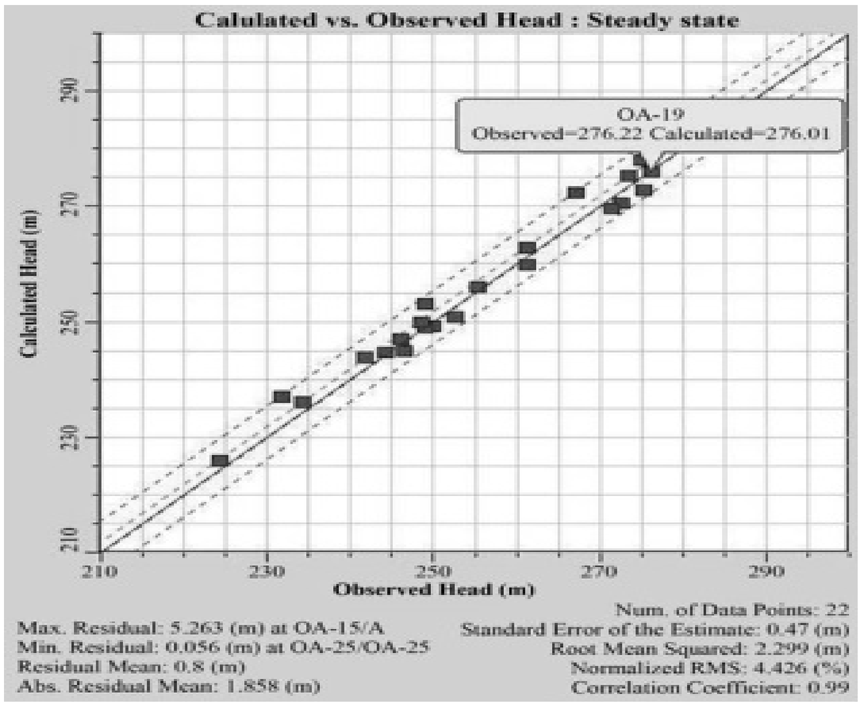

Fig. 6 Computed vs. observed head in a steady state calibration

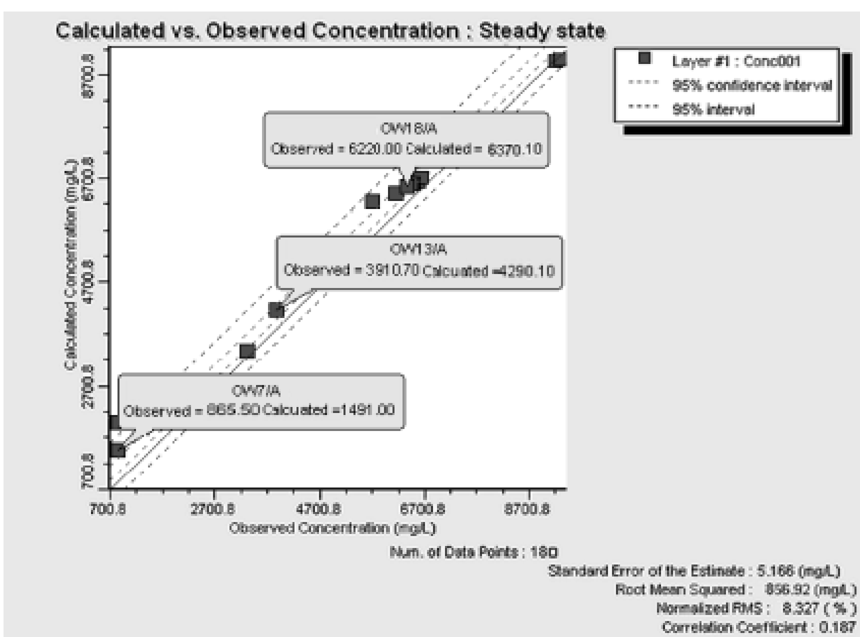

Fig. 7 Computed vs. observed concentration in a steady state calibration

Table 4 Ground water analysis results.

Well no.	pH	EC mS/m	CO^- mg/l	HCO_3^- mg/l	Cl^- mg/l	SO_4^{2-} mg/l	Ca^{2+} mg/l	$Mg2^+$ mg/l	Na^+ mg/l	K^+ mg/l	TDS mg/l
GW1	7.9	518.0	15.9	317.3	420.6	147.4	149.9	75.6	232.0	14.5	3320.3
GW2	8.2	1011.0	12.0	341.7	1796.6	214.6	543.5	257.4	338.0	35.2	6477.5
GW3	7.8	827.0	8.1	520.5	406.2	93.1	348.9	200	469.8	14.5	5299.0
GW4	8.0	142.0	0.0	341.7	514.2	156.0	453.3	452.5	721.0	21.5	9102.3
GW5	7.7	113.0	18.0	665.1	446.0	121.5	112.6	330.0	706.0	13.3	7243.5
GW6	7.4	717.0	12.0	630.3	513.0	49.0	191.2	191.0	309.4	16.0	4593.7
GW7	7.5	235.0	15.9	553.4	404.3	8.2	130.9	169.0	142.6	8.6	865.50
GW8	8.3	259.0	19.8	370.4	661.9	17.8	77.6	89.0	152.4	7.8	1662.3
GW9	7.7	721.0	12.0	516.8	242.1	63.4	151.3	121.8	352.0	17.6	4621.7
GW10	8.4	135.0	24.0	244.1	198.5	6.7	68.1	34.8	115.9	3.5	878.40
GW11	7.9	1263.0	0.0	455.8	406.4	201.6	363.9	319.6	306.5	22.3	8098.3
GW12	8.0	351.0	15.9	447.2	315.7	18.7	84.4	103.9	150.8	19.6	2252.3
GW13	7.6	535.0	8.1	561.3	392.4	50.4	156.3	125.5	242.2	8.6	3910.70
GW14	8.0	542.0	24.0	683.4	250.3	44.6	104.4	113.0	334.3	10.9	3472.3
GW15	8.3	244.0	24.0	407.0	224.0	97.5	116.2	81.5	122.9	10.2	1566.3
GW16	7.6	356.0	0.0	585.8	437.6	25.9	117.1	105.5	142.1	24.2	2282.0
GW17	7.9	233.0	15.9	431.4	460.9	43.7	129.7	75.8	220.9	10.9	1491.0
GW18	7.8	970.0	0.0	414.9	452.2	157.9	285.0	297.3	501.9	27.8	6220.0
GW19	8.2	427.0	8.1	374.0	200.6	62.4	109.8	188.7	239.5	7.0	2735.0
GW20	8.0	432.0	15.9	414.9	167.5	74.9	145.9	201.5	235.5	12.5	2771.3
GW21	7.9	1647.0	15.9	529.0	327.5	189.2	398.0	332.4	704.5	27.8	10555.3
Mean	**7.9**	**665.0**	**12.6**	**466.7**	**461.9**	**87.8**	**201.9**	**178.3**	**339.2**	**15.9**	**4295.6**

Table 5 Calculated water quality indices for groundwater analysis.

Well No.	SAR	Alkalinity	Hardness
GW1	21.86	333.2	685.46
GW2	18.99	353.7	2416.57
GW3	28.36	528.6	1694.40
GW4	33.88	341.7	2994.38
GW5	47.47	683.1	1639.44
GW6	22.36	642.3	1263.58
GW7	11.65	569.3	1022.46
GW8	16.67	390.2	560.09
GW9	30.13	528.8	879.12
GW10	16.16	268.1	313.28
GW11	18.01	455.8	2224.13
GW12	12.56	463.1	638.39
GW13	20.40	569.4	906.83
GW14	32.08	707.4	725.79
GW15	12.36	431	625.60
GW16	13.48	585.8	726.63
GW17	21.8	447.3	635.85
GW18	36.31	414.9	1935.33
GW19	19.61	382.1	1050.85
GW20	17.88	430.8	1193.68
GW21	36.86	544.9	2361.96
Mean	24.61	479.3	1238.02

Table 7 Steady state calibration head

S. No.	Targets	Observed Head (m)	Computed Head (m)	Residual Error
1	OA1	219.40	220.13	-0.73
2	OA2	238.20	237.78	0.42
3	OA3	234.20	235.09	-0.89
4	OA4	234.30	234.43	-0.13
5	OA5	243.80	243.69	0.11
6	OA6	265.30	265.28	0.02
7	OA7	244.50	243.81	0.49
8	OA8	249.00	249.13	-0.13
9	OA9	238.00	238.38	-0.38
10	OA10	239.00	239.26	-0.26
11	OA11	258.00	257.50	0.50
12	OA12	258.44	256.31	2.13
13	OA13	276.18	274.04	2.14
14	OA14	265.80	266.13	-0.33
15	OA15	262.10	261.36	0.74
16	OA16	259.00	258.44	0.56
17	OA17	254.40	254.86	-0.46
18	OA18	274.05	273.10	0.95
19	OA19	276.22	276.01	0.21
20	OA20	249.81	244.55	5.26
21	OA21	252.30	252.01	0.29

CONCLUSIONS

The conclusions drawn from this study are presented based on the results obtained from the experimental and numerical analysis.

Experimental analysis

- The chemical analysis is performed for four surface water samples and twenty one ground water samples. The mean of each parameter is calculated. The mean values of all the parameters of surface water are found to be higher than the ground water.
- The mean values of pH, Cl^-, SO_4^{2-}, K^+ of surface water 8.6, 455.4 mg/l, 351 mg/l, 26.3 mg/l respectively and or groundwater the values are 7.9, 461.9 mg/l , 87.8 mg/l, 15.9 mg/l respectively.
- The total dissolved solids for surface water are higher than 8000 mg/l. The mean value is found to be 8897.25 mg/l whereas for ground water the TDS values vary from 860-9000 mg/l.
- The buffering capacity and sodium hazard are found to be 540.87 mg/l and 33.22 mg/l and for ground water the values are 492.2 mg/l and 24.61 mg/l.
- The condition of both the surface water and ground water in Nacharam industrial area is generally poor. It cannot be used for drinking purpose and even not suitable for irrigation.

Numerical analysis

Groundwater Flow model is constructed using Visual MODFLOW. The main conclusions drawn from numerical analysis.

- The equipotential contours indicate the flow of ground water form west to east direction.
- The water levels monitored from twenty one observation wells in the study area vary from 219.40 to 328.76 m(amsl) whereas the computed water levels in the model from 220.13 to 328.62 m (amsl). It indicates the minimum and maximum residuals are 0.056 m and 5.26 m as can be observed in calibrated heads graph.

- The model is calibrated with respect to the head and the standard error is found to be 0.04m and normalized RMS is 4.42 % which is less than 10% so, the model is in reasonable agreement between observed and calculated heads.
- The model is calibrated for steady state conditions for (TDS) concentration which is obtained at all node points in the grid and calculated verses observed graph is obtained. The graph in the output obtained shows that the calculated TDS values are slightly higher than the observed valued.
- The observed values of some of the wells W18, W13, W17 are found to be 6220 mg/l, 3910.70 mg/l and 865.50 mg/l respectively. The calculated values by the Model are 6370 mg/l, 4290.10 mg/l and 1491.0 mg/l respectively. The root mean square valued is found to be 856.92 mg/l and the normalized RMS is less than 10%.

Scope for future work

Future works should be directed towards the collection of more input data to the model. This could include drilling exploratory wells in the watershed in order to know more about the spatial variations in hydraulic conductivity, storability, porosity and aquifer thickness. It would also be interesting to measure the water levels with a more precise equipment as mentioned above and calibrate the model again. If this type of data were collected, the model could be updated and give a better representation of the real situation as a result. The extent of the effects of the estimations and assumptions made in the conceptual model could be tested with a sensitivity analysis. If such an analysis was performed, it would be possible to see which parameters affect the model the most. These would then be the parameters where more effort was put to improve the estimations. Future works should also include the chemical analysis of parameters that could not be analyzed here, mainly P, N, heavy metals and coliforms. This would give an overall appraisal of the water quality in the Nacharam Industrial area and would also give a better idea of the contaminant transport form the nearby lakes.

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Transient Analysis to Control Hydraulic Transients in Water Conductor Systems for Lift Irrigation Schemes - A Case Study

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ABSTRACT

Lift irrigation schemes have assumed significance owing to their unique features of their adaptability even in the regions where the topography does not permit gravity flow of irrigation from rivers and streams. Last five decades have witnessed the mammoth development of lift irrigation duly impacting the agricultural economy of the country. This method of irrigation envisages lifting water from perennial sources of rivers with heavy electric pumps and distributed through pipe line to nearby fields within its command area. The pressure transients often found to occur in various water supply schemes of Municipal Corporations, Lift Irrigation Schemes, Thermal Power Stations etc. basically due to power failure, main breaks, pump start-up and shut-down operations, sudden valve closure, check-valve slam, etc. Failing to provide adequate transient protection may result in water column separation and catastrophic failure of piping network. The primary objectives of transient analysis are to determine the values of transient pressures that can result from flow control operations and to establish the design criteria for system equipment and devices (such as control devices and pipe wall thickness) so as to provide an acceptable level of protection against system failure. Because of the complexity of the equations needed to describe transients, numerical computer models are used to analyse transient flow hydraulics. The transient analysis of the water conductor system is carried out using WH-2.7 software, which uses explicit finite difference approach for calculating time varying flow and pressure during a time step at each boundary. The present paper mainly focuses on the importance of providing the protection devices to control the adverse effects due to transient pressures occur in the piping system and also optimizing the transient control devices in the piping network. A case study of Palasgaon - Amdi Lift Irrigation Scheme is also discussed to highlight the necessity of transient analysis.

Keywords: Pressure transients, Finite difference, Transient analysis, Transient control devices.

INTRODUCTION

The lift irrigation can be an important component of improved technology which has been diffused widely due to rural electrification. Hydraulic transients in water distribution systems are abnormal pressure situations caused by abrupt changes in flow rates. These are caused by events like power failure, main breaks, pump start-up and shut-down operations, sudden valve closure, check-valve slam, etc. Transient generating events are capable of producing both positive and negative pressure waves which travel at approximately at a speed of sound in water. Transients last for very short periods but could be highly detrimental to the distribution system. They can potentially cause pipes to burst (due to high pressure) or pipes to collapse (due to very low pressure). Failing to provide adequate transient protection may result in significant downtime in process plants and distribution systems thereby reducing life expectancy of the pipeline.

Pressure transient can be avoided through systematic pipeline assessments and protection. Accurate assessment of pressure transients caused by different operating scenarios, based on the pipeline length, profile and configuration of the water conductor system, exact pipeline material, fluid properties, and rate of change of the flow, possible contents of dissolved gases in the water, equipment type and location is needed. In view of above, transient analysis of water conducting systems for lift irrigation schemes assumes importance.

Ideally, a hydraulic system design involves adequate investigation, specification of equipment and operational procedures to avoid undesirable transients. Following are two existing possible strategies for controlling transient pressures:

(a) To control minimum pressures

Air vessels, Air inlet valves, One-way tanks, Pump inertia

(b) To control maximum pressures

Air vessels, Relief valves, Anticipator relief valves, Pump bypass valves, Lower pipeline velocity

FORMULATION

The mathematical model of unsteady flows of compressible liquid in elastic pipe is expressed by the set of two partial differential equations of the first order of hyperbolic type, i.e. a momentum equation (1), stating the dynamical equilibrium of the liquid particles in the cross section of pipe, and the continuity equation (2) derived from the mass conservation of the elastic fluid particles during their flow through an elastic pipe.

Momentum equation:

$$\frac{\partial H}{\partial x} = (-)\frac{1}{gA}.\frac{\partial Q}{\partial t} + f(Q) \qquad \text{.....(1)}$$

Continuity equation:

$$\frac{\partial H}{\partial x} + \frac{a^2}{gA}.\frac{\partial Q}{\partial t} = 0 \qquad \text{.....(2)}$$

The momentum and continuity equations form a set of non-linear, hyperbolic, partial differential equations which cannot be solved by hand. The partial differential equations (PDE) are quasi linear and hyperbolic because the coefficient of PDE are constant but losses due to friction are non linear. A numerical method with an initial condition and two boundary conditions are needed. For a water distribution system, there are many more parameters needed for solving the water hammer problem and every branch of the system requires an additional boundary condition. External boundary conditions take on the form of a driving head, or a flow leaving the system. Internal boundary conditions arise in the form of nodal continuity, energy loss between points, head across valves, pumps, and more.

The complexity of the problem requires the use of modeling software. The most general and exact technique for solving the Euler and Continuity equations of unsteady flow in pipe systems is the method of characteristics which converts the partial differential equation into ordinary differential equations whose validity is constrained to a set of characteristic curves, related to the velocity of the travelling wave. Typically, the method of finite differences is then applied to discretise the equations (temporally and spatially). Finally, for numerical calculation an iterative procedure, known as predictor-corrector method has been applied. In this method of characteristics, liquid is assumed to be slightly compressible if density changes only slightly with finite changes in pressures. It is also assumed that changes in conduit cross sectional area due to finite changes in pressure are finite but small. With these assumptions, the wave speeds is finite, but at the same time both area of conduit and density of liquid can be assumed as constants in the calculations.

METHODOLOGY OF TRANSIENT ANALYSIS

The transient conditions can be analyzed using the computer program WH-2.7, which uses explicit finite difference method for calculating time varying flow and pressure during a time step at each boundary and each conduit section of the water conductor system using the method of characteristics (MOC).

All the data in respect of the system pertaining to passive elements like pipes, fittings, etc. and active elements like pumps and NRVs was sought from the Project Authorities. Based on the input data received, the following iterative procedure shall be followed:

- Prior to calculation of transient – state conditions in a system, it is necessary to determine the initial steady - state conditions. These conditions must be consistent with the boundary conditions and with the transient flow equations. Otherwise disturbances will be induced at every node where the conditions are inconsistent. This may be done by running the program for two or three computational time intervals. The discharge and pressures should not be modified in the system except at and near the boundary nodes where the boundary conditions are to be changed, eg. Opening or closing the valves, load acceptance or rejection, power failure etc.
- Carry out computation of maximum and minimum pressures without any protective device and examine necessity of providing it.

- Carry out computation of maximum and minimum pressures with few air valves at a particular nodes distributed along the rising main and examine necessity of providing optimum nos. of air valves and examine the likely extent of pressure fluctuations.
- Carryout water hammer analyses of the system with air vessel in position at a particular node, air valves distributed along the rising main and examine the likely extent of pressure fluctuations.
- If the protection is found to be inadequate, another location and/or higher size of air-vessel are tried. The vertical location of air vessel at a particular chainage, is also varied to assess the effect on water hammer pressures.
- If the protection is found to be adequate, the volume of air-vessel is slightly reduced, the position along the length is kept the same and iteration is taken to examine the pressures.
- Minor adjustments are also carried out in elevation of air vessel, initial position of water level in air vessel and initial pressure of air (as related to the static pressure at the specified point), and each time the pressures are reassessed.
- The entire procedure is repeated till the least volume of air-vessel leading to acceptable positive and negative pressures is obtained.

CASE STUDY

The irrigation sector in Maharashtra is one of the largest in the country. Lift irrigation envisages lifting water from river, dam &canal by means of pumping system. At present 8% of Maharashtra irrigation is occupied by lift irrigation. The case study of Palasgaon - Amdi Lift Irrigation Scheme is presented to highlight the necessity of transient analysis. This Scheme is located on river Wardha near village Kalmna in Ballarpur taluka district of Chandrapur in Maharashtra State. This scheme envisages lifting water from river Wardha by means of pumping to irrigate 2890 hectare Land in Ballarpur taluka by two rising mains and two delivery chamber. The rising main-I of 1.1 m diameter and its distribution point is approximately 3.4 km away from the lift point. The rising main-II of 0.6 m diameter and its distribution point is approximately 2.7 km away from the lift point. An intake structure is located in the river wherein four vertical pumps are installed. The discharge of three pumps supplied to the rising main-I of 1.1 m diameter and single pump supplied to the rising main-II of 0.6 m diameter through a system of manifold. At the other end, the pipes deliver water into a delivery chamber where the flow changes over from closed conduit to open channels. Water, thereafter, flows by gravity through a network of canals to the command area.

Based on the input data received the program computes maximum and minimum pressures along the length of rising mains (I & II) as a function of time. Only some of the important cases of rising main - I are discussed here to highlight the solution viz. number of air valves and selection of size of air vessel and their locations on the rising mains. The rising main-I of 1.1 m diameter which handle the discharge of three pumps supplied to and through a system of manifold as shown in figure -1. Only some of the important cases of rising mains-I are discussed as below.

Transient Analysis without any Protection Devices

The surge analyses were carried out without using any protective devices on water conductor. From the analysis the results are graphically depicted in figure-2. Unacceptable low pressures are observed at all locations of the water conductor which clearly indicates the need of transient controlling devices.

Transient Analysis with air valves

Case 1: In this case, air valves were provided at 5 selected locations at higher elevation of water conductor. The results are graphically depicted in figure-3. At certain locations unacceptable low pressures are observed in the pipeline which clearly indicates need to provide more air valves.

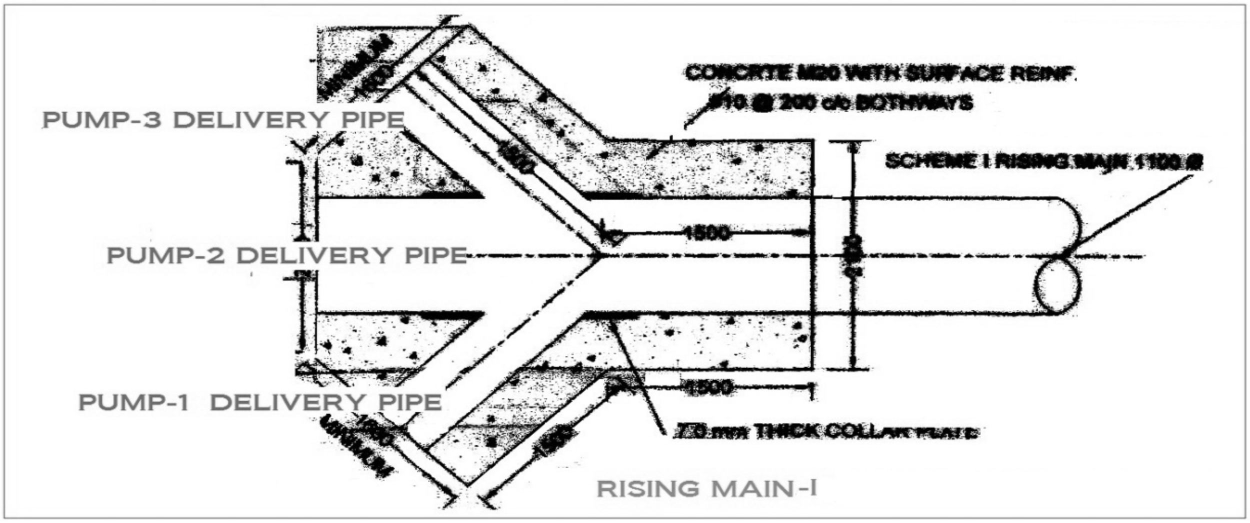

Fig. 1 Details of rising main-I manifold

Case 2: In this case, air valves were provided at 6 selected locations of higher elevation of rising main. The results are graphically depicted in Figure - 4. Unacceptable low pressures are not observed at any locations of the pipeline which clearly indicates no need to provide any more air valve.

Transient Analysis with air valves and air vessel

Case 1: A horizontal cylindrical air vessel of diameter 3.0 m and capacity of 75 m^3 was provided along with air valves at 6 selected locations of rising main. Vertical distance between centerline of air vessel and centerline of rising main was kept as 3.0 m. The results are computed for the critical case which is tripping of all pumps and presented graphically depicted in Figure - 5. It is observed that the maximum minimum transient pressures are well within the acceptable limits. Subsequently, an air vessel of lower capacity was attempted.

Case 2: In this case, a horizontal air vessel of reduced capacity of 50 m^3 was provided. Vertical distance between centerline of air vessel and centerline of rising main was kept as 3.0 m. Again with the critical case of tripping of all pumps, the maximum and minimum pressures were computed with the help of the program. The outcome is graphically depicted in Figure - 6. It is observed that both the maximum and minimum pressures are acceptable. For further reduced size of air vessel, the results are not found in acceptable limits. Hence air vessel of 50 m^{3}capacity was finalized. Details of differential orifice along with connection between rising main and air vessel are shown in Figure -8.

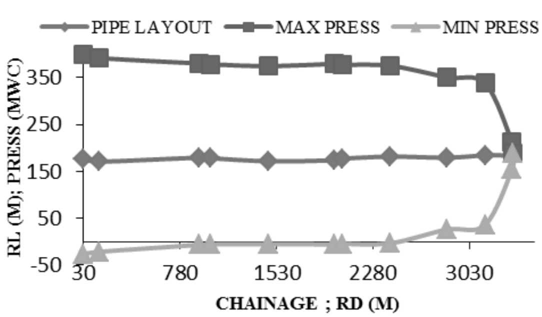

Fig. 2 Transient analysis without protection devices

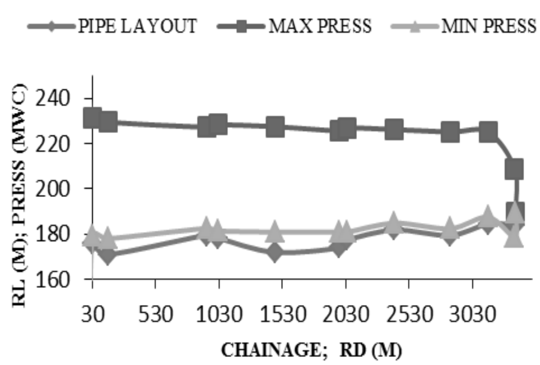

Fig. 3 Transient analysis with air valves – 5 Nos.

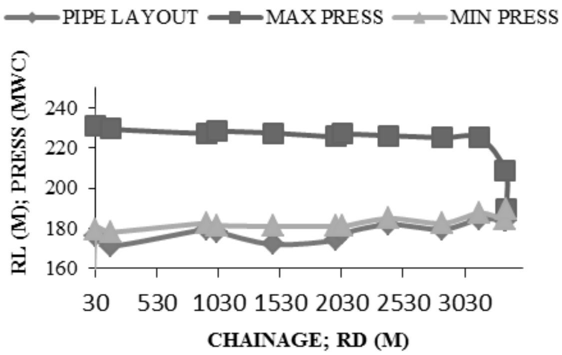

Fig. 4 Transient analysis with air valves – 6 Nos.

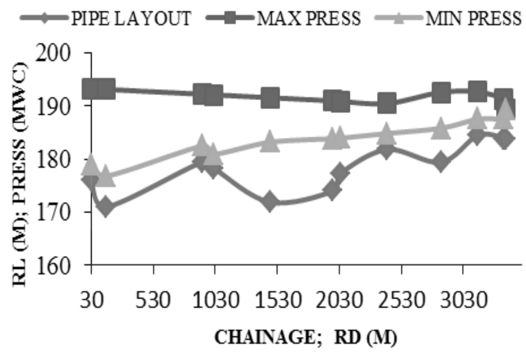

Fig. 5 Transient analysis with air valves – 6 Nos. and 75 m^3 capacity air vessel

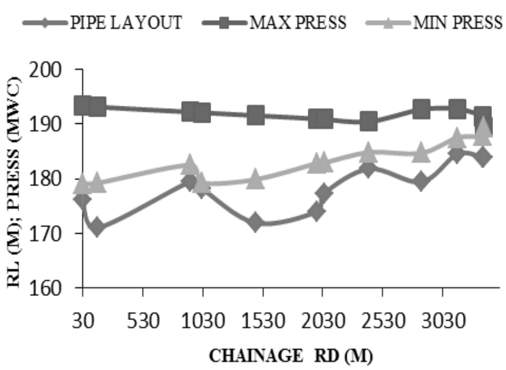

Fig. 6 Transient analysis with air valves (6 Nos.) and 50 m^3 capacity air vessel

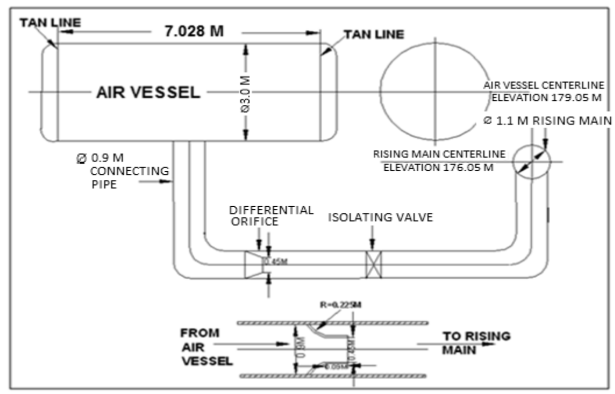

Fig. 7 Details of connection between rising main and air vessel

The absolute maximum and minimum pressure heads for above cases are presented in Table -1. And the graphs are plotted for maximum and minimum pressures above the conduit elevations.

CONCLUSION

Based on transient analysis for Palasgaon - Amadi Lift Irrigation Scheme number of air valves was initially optimized and further analyses were carried out to arrive at optimum size of air vessel along with air valves in the water conductor. A total of six air valves of the "Kinetic air valve" type, conforming to IS 14845:2000[2] and one air vessel optimized capacity of 50 m^3 are provided. From the point of view of longevity, the air vessel shall be internally coated with paint or with hot molten zinc after sand blasting. The air vessel should be designed not only for the rated positive pressures i.e. 10.0 kg/ cm^2 or 100 mwc but also for full vacuum i.e. typically for (–) 1 kg/ cm^2.

To conclude it can be reiterated that transient analysis would help and provide excellent platform to the field engineers to design water conductors for different lift irrigation projects.

ACKNOWLEDGEMENT

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Table 1 Shows the results of transient analysis (The absolute maximum and minimum pressure heads) for various cases

Chainage (M)	Elevation (M)	Abs. Max Press (M)	Abs. Min Press (M)	Abs. Max Press (M)	Abs. Min Press (M)	Abs. Max Press (M)	Abs. Min Press (M)	Abs. Max Press (M)	Abs. Min Press (M)	Abs. Max Press (M)	Abs. Min Press (M)	Air Valve Location
		Without protection devices		**With air valves – 5 Nos.**		**With air valves – 6 Nos.**		**With air valves – 6 Nos. and 75 m^3 Air vessel**		**With air valves – 6 Nos. and 50 m^3 Air vessel**		
30	176.05	229.38	**-208.02**	54.98	3	54.98	3	17.2	3	17.2	3	AV 1
150	176.05	224.55	**-202.2**	58.46	6.97	58.46	6.97	22.1	5.8	22.1	8.19	
930	171	221.18	**-192.34**	47.71	3	47.71	3	12.68	3	12.68	3	AV 2
1020	179.5	200.97	**-186**	50.05	3.14	50.05	3.14	13.84	2.68	13.84	1.03	
1470	178.23	200.36	**-183.74**	55.55	8.97	55.55	8.97	19.64	11.26	19.64	7.96	
1980	171.9	203.01	**-177**	51.6	6.93	51.6	6.93	16.93	9.82	16.93	8.8	
2040	174	205.55	**-179.47**	49.64	3.53	49.64	3.53	13.56	6.64	13.56	5.6	
2415	177.3	200.24	**-181.77**	44.36	3	44.36	3	8.62	3	8.62	3	AV 3
2850	181.8	193.84	**-184.88**	45.74	3	45.74	3	13.15	6.41	13.25	5.28	AV 4
3150	179.4	171.88	**-153.35**	40.59	3	40.59	3	8.1	3	8.26	3	AV 5
3360	184.5	153.4	**-148.41**	25	**-5.05**	25	0.64	7.29	3.76	7.43	3.86	AV 6
3370	183.88	27.83	**-28.57**	5.41	5.41	5.41	5.41	5.41	5.41	5.41	5.41	

*Air vessel is located at a chainage of 10.0m as per request of project authorities

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THEME - V

Operation and Maintenance of Water Treatment Plant at Bhimavaram, West Godavari District, A.P., India.

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ABSTRACT

Safe drinking water, sanitation and infrastructure are three basic rights of an individual for survival on the earth. Rapid growth of population, trend of urbanization has exerted high pressure on water quality emphasizing the development required in treatment and distribution systems. There is a need to study the conventional treatment plant system for their operational status and to find a feasible solution that ensures safety to public. Water quality is assessed by physico-chemical and biological characteristics. Production of biologically and chemically safe water is the primary goal in the design of water treatment plant. The main aim is to study the water quality at each stage of treatment say sedimentation, filtration and disinfection and clearly explain the importance of each stage in treatment. The operation and maintenance of treatment is also very important for supply of safe drinking water at the consumer point. It also emphasizes the interest of consumer in the quality of drinking water at the tap but not at the treatment plant.

Keywords: Sedimentation, Filtration, Water quality, Urbanization, Maintenance.

INTRODUCTION

Water and life have an inseparable relationship and considered as two sides of a coin. All living organisms on our earth are so connected with water that life on the globe is believed to evolve in and around water. Water is equally important to plants, animals, agriculture, infrastructure and industrial uses (Khatavkar et al., 1992). Water resources have been exploited to the maximum extent by man on the earth for all natural and man-made activities. The trend of urbanization has stressed the natural purification of water bodies (Narkhede et al., 2009). Clean drinking water is a basic human need. Unfortunately one in six people still starve for this precious resource in this present developing nation. Hence it is very important to study the process of water treatment plant with all aspects including physical, chemical and bacteriological analysis (Goel et al., 2006). The main purpose of water treatment is to purify the polluted water and make water fit for drinking by removing unpleasant taste, odour, excess metals etc (Abd – Ali et al., 1993). The water quality required varies with the type of consumption (Paul et al., 2002).

The raw water quality in India varies from place to place and it requires different modifications in treatment. The selection of units in a treatment plant change with the raw water quality available. Rapid growth of population has increased water demand which requires extensive treatment of water sources available and developing treatment and distribution systems (CPCB report, 2007). It is a well known fact that a large number of diseases are transmitted through improper water supplies contaminated with human and animal excreta. It is highly impossible to monitor each and every pathogen in drinking water. Therefore, it becomes necessary to detect some non-pathogens that act as indicator species like coliform bacteria. Coliform bacteria are detected by Multiple tube fermentation technique used as an indicator of sewage contamination (WHO Guidelines, 1993).

MATERIALS AND METHODS

Study Area

Bhimavaram town is located in the middle of the Godavari Delta region Narsapuram and Gudivada – Bhimavaram broad gauge section of the south central Railway. It also lies at latitude $16^{\circ}35^{\circ}$ North and longitude $81^{\circ}31^{\circ}$ East. The Municipality was spread over 25.60 sq km with a population of 1,42,184 as per 2014 census. The town serves as a commercial centre, to its hinterland with its agro and aqua based economy. The water treatment plant is situated in the study area at Vendra with a capacity of 8.97 MLD. The source of water for the scheme is Gostani Velpur canal.

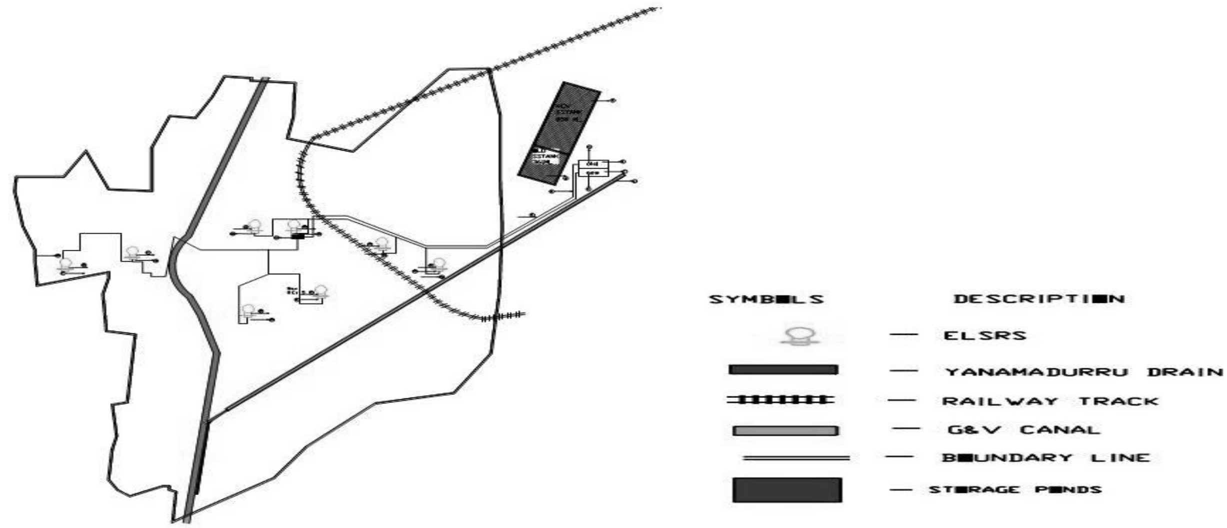

Fig. 1 Study area

Present study has been conducted to observe and access the existing methodologies used for treatment in the study area and to understand the process of treatment. The treatment plant scheme consists of three main unit operations like clariflocculator, rapid sand filter and gas chlorinators.

Conventional Clarification

It typically refers to chemical addition, rapid mixing, flocculation and sedimentation. Removal of particles depends mainly on settling velocity of the particles and the rate of surface loading. In the absence of a chemical coagulant, removal of pathogens is low because sedimentation velocities are low (Medema et al., 1998). On an average, the microbial removals for coagulation and sedimentation range from 32 to 87 % for coliform bacteria (Gimbel & Clasen, 1998). However removal efficiencies are highly site-specific and change from place to place.

Conventional Filtration

Rapid Sand Filters were used in the concerned treatment scheme taken for the study. Without proper chemical treatment, rapid rate filtration works as a simple strainer and is not an effective barrier for microbes. Al-Ani et al., 1986 has studied the removal efficiency of bacteria with and without coagulant addition. Adding chemicals, the removal efficiency in many plants have shown to improve it to 99% for total coliform bacteria and 70 % for turbidity. Backwashing is done to improve the working of filter beds and it is an effective measure to conserve wash water effectively.

Conventional Disinfection

The principal factors that influence disinfection efficiency are disinfectant concentration, contact time, temperature and pH. Gas Chlorinators were used in the treatment plant under study. In this scheme, adequate amount of chlorine was being added. The operators should be properly trained from time to time regarding fatal chlorine gas and its hazards. The Management should take strict measures to avoid accidents in the disinfection zone.

RESULTS AND DISCUSSION

It was found that the turbidity was not too high in raw water. Turbidity was a major indicator for pollution and the use of raw water as a source is acceptable. In this study, four different types of water samples were taken for the analysis at different stages of treatment: raw water, settled water, filtered water and treated water to check the efficiency of treatment at each stage. The samples taken for the analysis were analysed for summer and winter seasons as per APHA, 2003. The objective of the present study is to ensure that water supplied is confirming to BIS, 10500. The water at all the stages was analysed for physical, chemical and biological quality. D.D. water was used for the analysis. The results were as shown in Table 1 and Table 2.

Table 1 Physico-chemical and biological characteristics of water at different stages of treatment in winter

SNO	Parameter	Raw Water	Settled Water	Filtered Water	Treated Water
1	pH	7.96	7.93	7.76	7.5
2	Turbidity	17	10	7	5.1
3	TDS	160	205	210	200
4	EC	240	320	315	300
5	Hardness	140	140	120	110
6	Calcium	20	16	40	20
7	Magnesium	21.86	24.29	4.88	14.58
8	Alkalinity	100	155	175	190
9	DO	5	4.8	5.7	5.4
10	BOD	5.4	4.2	1.8	1.2
11	COD	19.2	16.1	11.1	9.6
12	Chlorides	21.27	67.36	92.17	92.17
13	**RFC**	**0**	**0**	**0**	**0.1**
14	**MPN/100 mL**	**>=2400**	**>=2400**	**157**	**0**
15	**TFC/100 mL**	**>=2400**	**1200**	**0**	**0**

Table 2 Physico-chemical and biological characteristics of water at different stages of treatment in summer

SNO	Parameter	Raw Water	Settled Water	Filtered Water	Treated Water
1	pH	7.5	7.25	6.88	6.77
2	Turbidity	9	12	7	4.5
3	TDS	180	190	190	190
4	EC	280	300	300	300
5	Hardness	140	120	120	140
6	Calcium	32	32	32	24
7	Magnesium	14.5	9.73	9.73	19.4
8	Alkalinity	70	90	90	80
9	DO	6.3	6.2	5.4	6
10	BOD	4.8	4.8	2.4	1.2
11	COD	25.6	19.2	19.2	9.6
12	Chlorides	56.72	70.9	56.72	42.54
13	RFC	0	0	0	0
14	MPN/100 mL	≥2400	1600	140	0
15	TFC/100 mL	≥2400	1100	23	0

The results were clear that the treatment was proper in the treatment plant at each stage and the treated water was completely confining to the drinking water quality standards. The percentage removal was evaluated by the following equation.

Removal efficiency = ((Parameter inside – Parameter outside) / Parameter inside) * 100

The removal efficiencies of each stage of treatment were as shown in Table 3 for both the seasons.

Table 3 Removal efficiency at each stage of treatment in winter and summer seasons

Parameter	**Winter**			**Summer**		
	Sedimentation	**Filtration**	**Chlorination**	**Sedimentation**	**Filtration**	**Chlorination**
pH	0.38	2.14	3.35	3.33	5.10	1.60
Turbidity	41.18	30.00	27.14	-33.33	41.67	35.71
TDS	-28.13	-2.44	4.76	-5.56	0.00	0.00
EC	-33.33	1.56	4.76	-7.14	0.00	0.00
Hardness	0.00	14.29	8.33	14.29	0.00	-16.67
Calcium	20.00	-150.00	50.00	0.00	0.00	25.00
Magnesium	-11.12	79.91	-198.77	32.90	0.00	-99.38
Alkalinity	-55.00	-12.90	-8.57	-28.57	0.00	11.11
DO	4.00	-18.75	5.26	1.59	12.90	-11.11
BOD	22.22	57.14	33.33	0.00	50.00	50.00
COD	16.15	31.06	13.51	25.00	0.00	50.00
Chlorides	-216.69	-36.83	0.00	-25.00	20.00	25.00
RFC	0.00	0.00	**0.00**	0.00	0.00	**0.00**
MPN/100 mL	0.00	0.00	**100.00**	0.00	91.25	**100.00**
TFC/100 mL	0.00	0.00	0.00	0.00	97.91	**100.00**

It was clear that that all the parameters analysed were within the permissible limits and the removal efficiency calculated at chlorination stage was high in summer compared to winter. Total Faecal Coliform (TFC) was found zero and the removal efficiency was found to be 100%. But it was seen that the concentration of residual free chlorine (RFC) was zero and there is a scope for future contamination. RFC of 0.2 mg/L is recommended at the points of consumption.

CONCLUSIONS

The study on water treatment plant at Vendra, Bhimavaram, W.G.Dist, India revealed that an appropriate pattern of operation and maintenance was followed. Regular training to plant operators is suggested for updating. The adequacy of water treatment from health point of view is ensured by maintaining residual chlorine of 0.2 mg/L at the farthest point of distribution system. The water treatment plant should have a facility of MPN testing. The consumer is interested in the quality of the water at the tap, not the quality at the treatment plant. Therefore the water utility operations should be such that the quality is not impaired during transmission, storage and distribution system.

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Low Cost Adsorbents for Removal of Fluoride from Water - An Overview

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ABSTRACT

According to Statistics 783 million people across the globe do not have access to clean and safe water. In fluoride endemic areas, especially small communities with staggered habitat, defluoridation of potable water supply is still a problem. In India large population suffer from dental and skeletal fluorosis due to elevated fluoride concentration in water contaminated from geogenic and anthropogenic sources. The prominent states which are severely affected are Andhrapradesh, Telangana, Rajasthan, Gujarat, Uttar Pradesh and Tamil Nadu. Fluoride is a persistent and non-biodegradable pollutant that accumulates in soil, plants, wildlife and in human beings. Sources of fluoride include dental products, processed beverages and foods, pesticides, tea drinks, fluorinated pharmaceuticals, mechanically deboned meat, Teflon pans and workplace exposure. Studies reveal that fresh foods and fresh water contain very little fluoride hence it is recommended to drink spring water and eat unprocessed fruits, vegetables, grains, eggs, milk and meat while there are some exceptions to this rule (e.g., seafood, tea, water from deep wells, and fresh fruit/vegetables sprayed with fluoride pesticides). Fluoride beyond desirable amounts (0.6 to 1.5 mg/l) in ground water is a major problem in many parts of the world. Therefore, knowledge of its removal, using best technique with optimum efficiency is needed .Taking the severity of the problem into consideration, the present paper aims to provide a retrospective approach on use of effective low cost adsorbents for removal of fluoride from water. Defluoridation capacity of certain low cost adsorbents like concrete, serpentine, crushed lime stone, ragi seed powder, horse gram powder, pine apple peel powder, fly-ash, charcoal, coconut shell, red soil, chalk powder, multhani matti, rice husk, seed extracts of Moringa oleifera and many more have been added to the list and discussed here in brief.

Keywords: Fluorosis, Fluoride, Adsorbents, Adsorption, Biological effects, Defluoridation.

INTRODUCTION

Fluoride is a normal constituent of natural water samples. Although both geological and anthropogenic sources contribute to the occurrence of fluoride in water, the major contribution comes from geological resources. Examples are streams flowing over granite rich in fluoride minerals and rivers that receive untreated fluoride-rich industrial wastewater. There are several fluoride bearing minerals in the earth's crust. They occur in sedimentary (limestone and sandstone) and igneous (granite) rocks. Weathering of these minerals along with volcanic and fumarolic processes lead to higher fluoride levels in groundwater. Dissolution of these barely soluble minerals depends on the water composition and the time of contact between the source minerals and the water. Over the years groundwater has generally been considered to be a protected and safe source of water, fit for drinking without treatment, as the main focus has been on the bacteriological quality of potable water. Little consideration used to be given to the risks of chemical pollution, particularly to the presence of elevated levels of fluoride, arsenic and nitrate in groundwater (Leela Lyengar, 2002). Consumption of water having excess fluoride over a prolonged period leads to a chronic ailment known as fluorosis. Incidence of high-fluoride groundwater has been reported from 23 nations around the globe. It has led to endemic fluorosis, which has become a major geoenvironmental health issue in many developing countries. According to a recent estimate, 62 million people are affected by various degrees of fluorosis in India alone (Susheela, 2001).

HEALTH IMPLICATIONS

Taking health effects into consideration, the World Health Organization (1996) has set a guideline value of 1.5 mg/1 as the maximum permissible level of fluoride in drinking waters. Low dental caries incidence rates demonstrate that fluoride concentrations of up to 1.0 mg/l in potable water are beneficial to the oral health of children and, to a lesser extent, adults. Although water is generally the major route of fluoride intake, exposure from diet and air may become important in some situations. Intake of fluoride higher than the optimum level is the main reason for dental and skeletal fluorosis. Depending upon the dosage and the period of exposure fluorosis may be acute to chronic.

Table 1 Biological Effects on Human Health (Weginwar N. et al, 2008)

Fluoride conc. (mg/lit)	Source	Effects
1	Water	Prevention of dental caries
2	Water	Effect dental enamel
3 to 6	Water	Osteoporosis
8	Water	10 % Osteoporosis
20 to 80	Air & Water	Crippling skeletal fluorosis
50	Food & Water	Changes in thyroid
100	Food & Water	Defective development
>125	Food & Water	Changes in Kidney
2500	Acute dose	Death

Dental Fluorosis

Dental fluorosis, also called “mottled enamel”, occurs when the fluoride level in drinking water is marginally above 1.0 mg/l.Typical manifestations of dental fluorosis are loss of shining and development of horizontal yellow streaks on teeth**.** Since this is caused by high fluoride in or adjacent to developing enamel, dental fluorosis develops in children born and brought up in endemic areas of fluorosis. Once formed, the changes in the enamel are permanent. When the above manifestations are seen in an adult, they clearly indicate that the person has been exposed to high fluoride levels during his or her childhood.

Skeletal Fluorosis

Skeletal fluorosis affects both adults and children and is generally manifested after consumption of water with fluoride levels exceeding 3 mg/l. Typical symptoms of skeletal fluorosis are pain in the joints and backbone. In severe cases this can result in crippling the patient. Recent studies have shown that excess intake of fluoride can also have certain non-skeletal health impacts such as gastro-intestinal problems, allergies, anaemia and urinary tract problems. Nutritional deficiencies can enhance the undesirable effects of fluoride.

DEFLUORIDATION

Conventional methods available for treating water containing fluoride ions include :

- Membrane filtration
- Precipitation
- Nanofiltration
- Ion-exchange
- Electrocoagulation
- Flotation
- Reverse Osmosis
- Adsorption

Most of these methods have high operational and maintenance cost, low fluoride removal capacities, lack of selectivity for fluoride, undesirable effects on water quality, generation of large volumes of sludge and complicated procedures involved in the treatment. Among these methods, **adsorption** is the most effective and widely used method because it is universal, has a low maintenance cost, and is applicable for the removal of fluoride even at low concentrations. In recent years, considerable attention has been focused on the study of fluoride removal using natural, synthetic and biomass materials such as activated alumina, fly ash, alum sludge, chitosan beads, red mud, zeolite, calcite, hydrated cement, attapulgite, and acid-treated spent bleaching earth (Koteswara Rao M et al, 2012).

ADSORPTION METHOD

In the adsorption method, raw water is passed through a bed containing defluoridating material. The material retains fluoride either by physical, chemical or ion exchange mechanisms. The adsorbent gets saturated after a period of operation and requires regeneration.

Selection of adsorbent

To select a suitable defluoridation method following criteria need to be considered:

- Fluoride removal capacity
- Simple design and ease of operation
- Easy availability of required materials and chemicals and their potential for reuse
- Acceptability of the method by users with respect to taste and cost

Advantages of Adsorption process (Renge.V.C et al,2012)

- **Cheap:** The cost of adsorbent is low since they are often made from locally, abundantly and easily available materials.
- **Metal Selective:** The metal adsorbing performance of different types of bio-mass can be more or less selective on different metals.
- **Regenerative:** Sorbent material can be possible to reuse after regeneration
- **No Sludge Generation:** Unlike the problems in other techniques (ex: precipitation), there is no issue of sludge generation in adsorption process.
- **Metal Recovery:** If adsorbate is a metal ion, it is possible to recover the metal ion after being desorbed from the adsorbent materials.
- **Competitive Performance:** Performance of adsorption process in terms of efficiency and cost is comparable with the other methods available.

Table 2 Merits & Demerits of some Defluoridation methods

Method	Merits	Demerits	Estimated relative cost
Nalgonda	Low technology, adaptable at point of use & point of source level	• Large quantity of sludge • High chemical dose • Dose depend on F- level • Daily addition of chemicals and stirring in point of source units	Low-media
Bone Char	Local available media	• May impart taste and odour and result in organic leaching if not prepared properly • Requires regeneration periodically • Effected by high alkalinity • May not be acceptable in some countries	Low-media
Activated Alumina	Effective, much experience	• Periodic regeneration • Skilled personnel for plant operation • Properly trained staff for regeneration of point of use units • Suitable grades may not be indigenously available in less developed countries	Medium -High
Contact precipitation	Not much experience	• Algal growth can occur in phosphate solution • Bone char used as a catalyst may not be acceptable in many countries	High - Very high
Brick	Low cost technology	• May not be universally applicable	High - Very high
Reverse osmosis	Can remove other ions	• Skilled operation • Interference by turbidity • High cost	Very High

REVIEW OF LITERATURE

Different low cost adsorbent materials are available for effective removal of fluoride from water. The naturally available adsorbents are horse gram powder, ragi powder, multhani matti, red mud, calcined clay, concrete, pine apple peel powder, chalk powder, orange peel powder, rice husk, redmud, Moringa oleifera extract, goose berry, activated alumina coated silica gel, activated saw dust, activated coconut shell carbon, coffee husk, bone charcoal, activated soil sorbent, etc. are some of the different materials investigated for adsorptive removal of fluoride from water.

Table 3 Percentage removal of fluoride from water using different low cost adsorbents

S. No.	Adsorbents	Initial concentration of fluoride in mg/l	Final concentration of fluoride in mg/l	% Removal	Reference
1	Red mud	12	3.4	71	Koteswara Rao M et al, 2012 and N. Gandhi et al, 2012
2	Pine apple peel powder	12	1.6	86	Koteswara Rao M et al, 2012 and N. Gandhi et al, 2012
3	Orange Peel powder	12	2.5	79	Koteswara Rao M et al, 2012 and N. Gandhi et al, 2012
4	Horse gram powder	12	3	75	Koteswara Rao M et al, 2012 and N. Gandhi et al, 2012
5	Chalk powder	12	1.6	86	Koteswara Rao M et al, 2012 and N. Gandhi et al, 2012
6	Ragi seed powder	12	4.2	65	Koteswara Rao M et al, 2012 and N. Gandhi et al, 2012
7	Multhani mitti	12	5.2	56	Koteswara Rao M et al, 2012 and N. Gandhi et al, 2012
8	Concrete	12	5.6	53	Koteswara Rao M et al, 2012 and N. Gandhi et al, 2012
9	Rice husk	5	0.85	83	C.M.Vivek Vardhan et al, 2011
10	Moringa oleifera seed extracts	5	0.4	92	C.M.Vivek Vardhan et al, 2011
11	Red soil	10	0.02	99.8	AL Ramanathan et al, 2003 and S. Chidambaram et al, 2013
12	Charcoal	10	9	10	AL Ramanathan et al, 2003 and S. Chidambaram et al, 2013
13	Fly-ash	10	3.4	66	AL Ramanathan et al, 2003 and S. Chidambaram et al, 2013
14	Brick	10	3.7	63	AL Ramanathan et al, 2003 and S. Chidambaram et al, 2013
15	Serpentine	10	3.7	63	AL Ramanathan et al, 2003 and S. Chidambaram et al, 2013
16	Coconut shell activated carbon	4.13	2.97	71.91	Sheetal Bandewar et al,2015
17	Granular charcoal	4.13	2.97	71.91	Sheetal Bandewar et al,2015
18	Cynodon dactylon	3	0.486	83.77	Suman Mann et al, 2014
19	Eggshell powder	5	0.3	94	Suman Mann et al, 2014
20	Activated silica gel	5	0.165	96.7	Suman Mann et al, 2014
21	Activated rice husk ash	5	0.585	88.3	Suman Mann et al, 2014
22	Hydrated cement	5.9	0.45	92.37	Suman Mann et al, 2014
23	Phyllanthus emblica	3	0.537	82.1	Suman Mann et al, 2014
24	Broken concrete cubes	8	1.5	81.2	Suman Mann et al, 2014
25	Citrus limetta	5	0.875	82.5	Suman Mann et al, 2014
26	Bleaching powder	5	0.47	90.6	PaliShahjee et al, 2013
27	Crushed limestone + Citric acid	10	1.74	82.6	Robin K Dutta et al, 2010
28	Crushed limestone + Acetic acid	10	0.977	90.23	Robin K Dutta et al, 2010

Contd…

S. No.	Adsorbents	Initial concentration of fluoride in mg/l	Final concentration of fluoride in mg/l	% Removal	Reference
29	Moringa oleifera seed powder + 212µ alkali treatment using 0.5N NaOH	10	2.4	76	A.S. Parlikar and S.S. Mokashi, 2013
30	Moringa oleifera seed powder + 600µ alkali treatment using 0.5N NaOH	10	3.2	68	A.S. Parlikar and S.S. Mokashi, 2013

CONCLUSIONS

This paper provides an overview of various low cost adsorbents used for the effective removal of fluoride from water, importance of adsorption process and its benefits. The efficiency of different adsorbents in the removal of fluoride depends on dose of adsorbate, characteristics of adsorbent, pH, temperature, contact time, speed of agitation, etc. The removal capacity increases by increasing dose of the adsorbent and decreasing size of the adsorbent. It was noted that Red soil, Moringa oleifera seed extracts, activated silica gel, egg shell powder, hydrated cement and bleaching powder have great potential for defluoridation. Thus the use of commercially available adsorbents can be replaced by effective low cost adsorbents.

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Electrical Conductance and Ph Change in Defluoridation of Water

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ABSTRACT

The paper explores conductance and pH change in defluoridation of water by at 283K – 313K.).The adsorption ability of bio-adsorbent based on pH of adsorbate solution remove fluoride from water aqueous solution has been investigated. The adsorption studies were carried out at 6.8 pH as the functions of contact time, adsorbent dose, adsorbate concentration, temperature and effect of co-anions, which are commonly present in water. Field studies were studies were carried out with the fluoride containing groundwater sample with initial fluoride concentration around 2.7 mg L^{-1} collected from Ookal[H], Geesugonda [M], Warangal to test the suitability of the sorbent at field conditions and obtained good success rate. During adsorption what are the other parameters change by the sorbent. The removal of fluoride was attributed to adsorbed and precipitation as a result of higher supersaturation in the solution. The final F^{-} concentration after treatment with bio-adsorbent was found equal to 1.2 mg L^{-1}, which was below the standard of the World Health Organization with permitable ±0.5pH change and decreased 20 mS electrical conductance.

Keywords: precipitation, electrical conductance, adsorbate.

INTRODUCTION

The chemical nature of water is one of the most imperative criteria that determine its usefulness for a precise need and as such not all the waters are fit for drinking and potable purposes. Apart from fluoride, arsenic and nitrate are few of major water pollutants which cause large scale health issues, but in cutting-edge the most serious pollutant is fluoride [1]. According to the World Health Organization the maximum acceptable concentration of fluoride ions in drinking water lies below 1.5 ppm. Fluoride if taken in small amount is usually beneficial, but the beneficial fluoride concentration range for human health is very small. Depending on the concentrations and the duration of fluoride intake, it could have positive effect on dental caries [2]. On the contrary, long term consumption of water containing excessive amounts of fluoride can lead to fluorosis of the teeth and bones [3]. The excessive intake of fluoride may cause dental [4] and skeletal disorders [5]. Fluoride ion is attracted by positively charged calcium ion in teeth and bones due to its strong electronegativity which results in dental, skeletal and no skeletal forms of fluorosis i.e. high fluoride ingestion, in children as well as adults. Fluorosis in mild version can be evidenced by mottling of teeth and in high version by embrittlement of bones and neurological damage [6], in some of the cases it may even interfere with carbohydrates, proteins, vitamins and mineral metabolism and to DNA creation as well if intake excessively [7]. Studies have shown that major of the Kidney diseases have a great inclination of toxicity of fluoride. On high doses and short term exposure fluoride can exterminate the kidney function. Several research groups have also shows that fluoride can interfere with the function of pineal gland as well as of brain. Pineal gland is one of the major fluoride accrued site in body with concentration more than that of teeth and bones. Workers exposed to high fluoride concentration areas are diagnosed with bladder cancer [8]. Various diseases such as osteoporosis, arthritis, brittle bones, cancer, infertility, brain damage, Alzheimer syndrome, and thyroid disorder can attack human body on excessive intake of fluoride [9]. Fluoride contamination in ground water is a world-wide issue, and some cost effective technologies are required to eliminate excess fluoride in water. The occurrence of high fluoride concentrations in groundwater and risk of fluorosis associated with using such water for human consumption is a problem faced by many countries, notably India, Sri Lanka, and China, the Rift Valley countries in East Africa, Turkey, and parts of South Africa. Conventionally, the fluoride was removed from contaminated water is by liming and accompanying precipitation of fluoride [10]. Various other methods used for the defluoridation of water are ion-exchange [11], precipitation with iron (III) [12], activated alumina [13], alum sludge [14], calcium [15] is widely examined. In addition reverse osmosis [16,17] and electro coagulation [18]. Many of these methods didn't get used on large scale because various unfavourable factors such as high operational and maintenance cost, generation of toxic by-products (pollution) and due to complex treatment. Authors discussed pros and cons of different techniques for defluoridation and it was concluded that the effective method is coagulation but it does not help in bringing down the fluoride concentration at desired level. On the other hand membrane process is expensive in terms of installation and operation cost, there are also more chances of fouling, scaling or membrane degradation. The electrochemical techniques are not popular due to high cost during installation and maintenance.

One of the most popular techniques for defluoridation that is used in countries like India, Kenya, Senegal and Tanzania is Nalgonda technique. In this technique, calculated quantities of alum, lime and bleaching powder are mixed with water, after mixing the water is processed with flocculation, sedimentation, filtReration and disinfection. The entire operation takes about 2–3 hours for around 200 people in batches. Disadvantages of this technique is reported that treated water has high residual aluminium concentration (2–7 mg/L) then the WHO standard of 0.2 mg/L [19-21]. Among these methods, adsorption is the most suitable and widely used technique due to its simple operation, and the availability of a wide range of adsorbents [22].

EXPERIMENTAL RESULTS AND DISCUSSION

In this paper, bio adsorbent like coconut shell powder with calcium rich dried leaves used. In adsorption of fluoride on inorganic calcium based bio-adsorbent used for fluoride removal and showed sorption capacity for fluoride. Fluoride removal results at low pH were very fruitful. The bioadsorbent was prepared by died leaves by keep it in oven for 12 hours at 92^0C. The samples for experiment was prepared by dissolving known amount of NaF in double distilled water. In the fluoride removal, hydroxyl group of calciume based adsorbent played vital role. Experiments showed that low conductance water had high fluoride removal efficiency in comparison to high conductivity sample. With pH up to 5.5, the percentage of fluoride adsorption onto refractory grade bauxite was found to increase but decreased with increase in pH. The adsorption process was found to be exothermic hence the adsorption efficiencies decreased with increase of temperature. The adsorption of fluoride depends upon the porous structure and high surface area of the modified granules. At pH range 3 to 4, maximum fluoride adsorption was found and further decreased as pH increased above 10 and the decreased in defluoridation was found due to the change in surface charge of the adsorbent. At pH 3, maximum defluoridation capacity was found 12.6 mg/g. The order of the reduction of fluoride adsorption at different pH and electrical conductivity is pH 5.3 > 7.3 > 10.3

At pH 6, maximum adsorption capacity was achieved. Due to high zero point potential, the adsorbent was effective in fluoride removal from aqueous solution. At low fluoride concentration the adsorbent exhibited high adsorption potential for fluoride and had selectivity for fluoride ions with coexisting chloride, nitrate and sulphate ions. At pH 3, maximum fluoride adsorption occurred. In case of low fluoride concentration < 0.8 mg/L, the adsorbent was also able to remove fluoride in real waste water. At pH 5, maximum defluoridation capacity of 97.6% was obtained. From the thermodynamic parameters, sorption process was found to be spontaneous and endothermic.

The use of bio adsorbent as an adsorbent for fluoride removal was examined in our earlier paper. The amount of fluoride adsorbed from 4 mgL^{-1} of fluoride solution was found to be 0.029 mg/g. The influence of different parameters such as initial concentration of adsorbent, adsorbent dose, agitation time, co-ions and temperature on defluoridation was studied. The percentage of fluoride removal increased with increase in initial concentration of fluoride, temperature, and adsorbent dose and agitation time up to 40 min. Wide range of pH and high temperature ranges were found as the optimum conditions for fluoride adsorption. The experimental data fitted satisfactorily ($r > 0.97$) to Langmuir isotherm. Thermodynamic parameters such as ΔH^o, ΔS^o and ΔG^o concluded the adsorption was endothermic. Moreover the mechanism of adsorption was found to be physisorption from the magnitude of enthalpy change 20–45 KJ/mol. The optimum adsorbent dose was found to be 5 g/100 mL, the equilibrium contact time was found to be 75 min and maximum adsorption obtained at pH 6. Maximum fluoride removal was found to be 94.2% at optimum conditions. Langmuir isotherm fitted well for defluoridation of water using bio adsorbent. In very recent study, bauxite as an adsorbent for the removal of fluoride from contaminated ground water was used. Adsorption experiments with respect to variation in time, pH, adsorbate and concentrations of other anions namely nitrate, sulfate, carbonate, and phosphate were carried out. To get a better insight into the mechanism of adsorption they were characterized bio adsrobent before and after fluoride adsorption by XRD, FTIR and SEM–EDX. An adsorption rate was rapid and followed first order kinetics with intraparticle diffusion as the rate determining step. They were also estimated thermodynamic parameters ($\Delta H°$, $\Delta S°$ and $\Delta G°$) which are indicating that the adsorption was spontaneous and exothermic in nature.

The paper presents a detailed study of the effect pH and electrical conductance on the defluoridation potential of mixed bed bio adsorbent of the particle size less than 300 μm. Calcium rich collard green leaves dried powder mixed with coconut shell charcoal was added to sample water with weight content from 0.01 to 0.025%. The defluoridation was investigated in static experiments, at pH 5–11 and with contact time of 35 min. The spent sorbent was easily regenerated by NaOH solution. See Table 1 for details.

Table 1 Effect of ph on defluoridation of water by bio mixed bed adsorbent at room temperature (30 ^{o}c)

pH	Amount of fluoride remained in water after defluoridation in mg/L
3.5	1.80
5.5	1.01
6.5	0.82
8.5	1.18
10,0	2.02

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Assessment of Arsenic and Chromium in Hussain Sagar Lake and their effects on Human Health

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ABSTRACT

Due to increased industrialization and unplanned urbanization Hussain Sagar lake has been polluted with potentially toxic elements, other trace elements and heavy metals like As, Cd, Cr, Ni, Pb, Hg, Cu, Fe, Mn, Se, Ba, Zn, Mo, V, Co, Ag, Sr, Rb, Mg, K, Ca, Al, Si, Sb, Na, Li and B due to discharge of untreated sewage containing municipal and industrial effluents, idol immersions, urban runoff and boating activities. The lake currently serves as a tourist spot. Out of the above mentioned pollutants Arsenic and Chromium have severe impact on human health. Several studies have been carried out to assess the level of Cr and As and have reported results exceeding the desirable limits. With regard to human health Arsenic by virtue of its nature is found to be very effective in deteriorating water quality. For improved human health, a systematic strategy for water quality assessment and monitoring needs to be formulated.

Keywords: Heavy metals, Arsenic, Chromium, Health effects.

INTRODUCTION

Hussain Sagar Lake was built during 1550-1580 A.D. It was used as a source of drinking water for the city during 1894 to 1930. India is facing a serious problem of natural resource scarcity, especially that of water in view of population growth and economic development (Garg R K et al, 2009). Most of fresh water bodies all over the world are getting polluted, thus decreasing the potability of water (Gupta S K et al, 2005). However, lakes are considered to be the potential agriculture-residential-industrial areas in the development plans for years because of their high values (Su havzaları et al, 2005). Hussain Sagar is a lake in Hyderabad, Telangana, India, built by Hazrat Hussain Shah Wali in 1562, during the rule of Ibrahim Quli Qutub Shah. It is spread across an area of 5.7 square kilometers and is fed by River Musi. A large monolithic statue of the Gautama Buddha, erected in 1992 which was established by senior N.T.R and it stands in an island in the middle of the lake ("View of Buddha Statue, Tank Bund, Hyderabad, Telangana", 2006). Maximum depth of the lake is 32 feet. Hussain Sagar (Fig 1.) was the main source of water supply to Hyderabad before Himayat Sagar and Osman Sagar were built on river Musi. Recently in the urban lakes conference, the HUDA has brought the problems of enchroachment, pollution from domestic sewage and industrial discharges, weeds and how HUDA is trying to restore the lake environment. It is noted that pollution in the lake has a further impact of nitrates in groundwater. The phosphates and toxic substance adsorb to the sediments and remain in the lakes. Heavy metals are natural components of the Earth's crust. They cannot be degraded or destroyed. They can enter a water supply by industrial and consumer waste, or even from acidic rain breaking down soils and releasing heavy metals into streams, lakes, rivers, and groundwater. They are individual metals and metallic compounds that can impact human health. These are all naturally occurring substances which are often present in the environment at low levels. In larger amounts, they can be dangerous. The toxicity of metals most commonly involves the brain and the kidney, but other manifestations occur, and some metals, such as arsenic, are clearly capable of causing cancer. Generally, humans are exposed to these metals by ingestion or inhalation. Due to the use of contaminated water, human population suffers from water borne diseases. It is therefore necessary to check the water quality at regular intervals of time to safeguard habitat health and environment.

Fig. 1 Hussain sagar lake view

SOURCES OF HEAVY METALS POLLUTION

Heavy metals occur naturally in the ecosystem with large variations in concentration. The primary anthropogenic sources of heavy metals are point sources such as mines, foundries, smelters and coal-burning power plants, as well as diffuse sources such as combustion by-products and vehicle emissions. Waste-derived fuels are especially prone to contain heavy metals, so heavy metals are a concern in consideration of waste as fuel. Electronic waste is also a significant source of heavy metal contaminants.

Sources of heavy metal pollutants include:

- Mining
- Smelting
- Metallurgical industries
- Corrosion
- Waste disposal
- Fossil fuel combustion
- Agriculture & Forestry

REVIEW OF LITERATURE

M.Vikram Reddy, et al (2012) have assessed the effects of municipal sewage, immersed idols and boating on the heavy metal and other elemental pollution of surface water of the eutrophic Hussain sagar lake. Heavy metal analysis was carried out using inductively coupled plasma-mass spectrometry (ICP-MS) model ELAN DRC II, Perkin-Elmer Sciex instrument, USA. Apart from other potential toxic elements Arsenic and Chromium were also found in elevated concentrations in the water at outfall point of the untreated municipal sewage containing industrial effluents coming through Kukatpally nala (site 3) which was the main dominating source of contamination of the lake. The water samples were collected in pre-cleaned, acid-treated high-density polythene bottles with 15 days interval from each sampling location and was later filtered and used for analysis of elements during December 2007 to April 2008.Standard limits for As proposed by ICMR is 0.05 mg/l and CPCB is 0.2 mg/l and for Cr it is 0.05 mg/l and 2.0 mg/l respectively. The results obtained at five sites namely Site 1 with immersed idols (with no sewage input),Site 2 treated sewage (STP) outfall, Site 3 untreated raw sewage outfall, Site 4 treated sewage (through oxygenated pond) and Site 5 middle of lake near Buddha statue were compared to the standard limits as shown in (Fig 2). Arsenic in (ppm or mg/l) was recorded to be 0.0104+/-0.008 at site 1,0.006+/-0.002 at site 2, 0.014+/-0.015 at site 3, 0.005+/-0.001 at site 4 and 5. Similarly Chromium in (ppm or mg/l) was recorded to be 0.098+/-0.033 at site 1, 0.098+/-0.037 at site 2, 0.105+/-0.043 at site 3, 0.093+/-0.032 at site 4 and 0.093+/-0.034 at site 5.

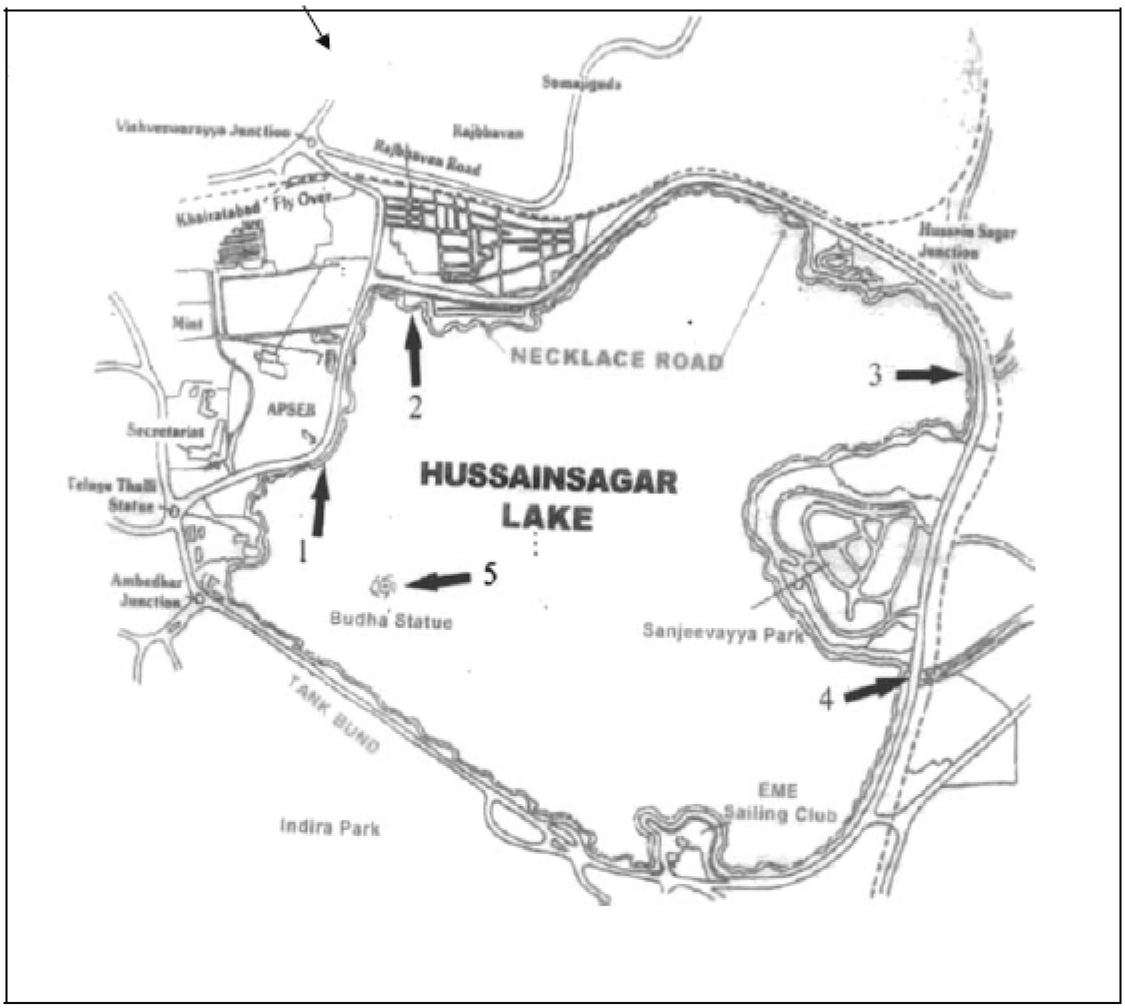

Fig. 2 Hussain sagar lake sampling sites

M. Suneela, et al (2007) have carried out heavy metal analysis in Hussain Sagar Lake by collecting sediment samples during April 2005 at EPTRI using Atomic Absorption Spectrophotometer (AAS 6501F). Five samples were collected namely S1 front of NTR ghat, S2 near boat club, S3 Sanjeeviah Park, S4 near Rock garden and S5 near Buddha statue. Arsenic ranged in between 3.4-163 mg/kg whereas chromium (hexavalent) was found to be below the desired limits. Heavy metal concentrations are attributed to industrial effluents and domestic discharges into the lake.

Sulekh Chandra, et al (2012) have assessed the water quality of Hussain Sagar lake. For this, lake water samples were collected from six different sites. The concentration of chromium in the lake water was quite low and fluctuated widely. Chromium is a specific pollutant providing evidence of industrial pollution like dye or paint operations. The concentration of chromium recorded in the lake was 0.50 mg/l and was compared to BIS 10500, 1991, specification which has to be 0.05 mg/l. The results clearly stated that the chromium concentration is found more than BIS specification for drinking water.

Mitsuo Yoshida, et al (2004) have assessed for heavy metals in Hussain Sagar lake sediments and environmental impact of human activities. NGRI has carried out sediment sampling at 5 locations in the lake during June and august 2003 and JICA has determined the metal concentrations using ICP-MS. They found that the concentrations of As and Cr were exceeding the threshold limits. The concentrations of heavy metals at the entry of Kukatpally channel into the lake have shown relatively elevated levels. The sediments have been collected at a depth ranging from 1.5-2.0 m in the lake. Arsenic levels in the lake at 5 different locations ranged between 3.5 to 36.6 ppm during the month of June and 4.4 to 12.5 ppm during August 2003. Chromium levels ranged between 35.5 to 205.0 ppm during June and 35.6 to 147.7 ppm during August. They strongly recommend the dredged out sediments containing hazardous heavy metals to be sent to TSDF of Hyderabad for safe disposal.

ARSENIC

Significant exposure to arsenic occurs through both anthropogenic and natural sources (Howard Hu,2002). Arsenic is also found in paints, dyes, metals, drugs, soaps and semi-conductors. Animal feeding operations can release high amounts of arsenic to the environment as can industry practices such as copper or lead smelting, mining and coal burning (Sabine Martin et al,2009). Inorganic arsenic is generally more toxic than arsenic (Howard Hu,2002).

Health effects

Arsenic is odorless and tasteless. Inorganic arsenic is a known carcinogen and can cause cancer of the skin, lungs, liver and bladder (Sabine Martin et al,2009).

- Lower level exposure can cause nausea and vomiting, decreased production of red and white blood cells, abnormal heart rhythm, damage to blood vessels, and a sensation of "pins and needles" in hands and feet.
- Ingestion of very high levels can possibly result in death.
- Acute arsenic poisoning is infamous for its lethality, which stems from arsenic's destruction of the integrity of blood vessels and gastrointestinal tissue and its effect on the heart and brain (Howard Hu,2002).
- Chronic exposure to lower levels of arsenic results in somewhat unusual patterns of skin hyperpigmentation, peripheral nerve damage manifesting as numbness, tingling, and weakness in the hands and feet, diabetes, and blood vessel damage resulting in a gangrenous condition affecting the extremities (Howard Hu,2002).

Regulatory limits

- Environmental Protection Agency (EPA) - 0.01 parts per million (ppm) in drinking water.
- Occupational Safety and Health Administration (OSHA) - 10 micrograms per cubic meter of workplace air (10 µg/ m3) for 8 hour shifts and 40 hour work weeks.

CHROMIUM

Chromium, in its hexavalent form, which is the most toxic species of chromium, is used extensively in some industries such as leather processing. The toxicity of chromium stems from its tendency to be corrosive and to cause allergic reactions (Howard Hu,2002).Chromium compounds bind to soil and are not likely to migrate to ground water but, they are very persistent in sediments in water (Sabine Martin et al,2009).

Health effects

Chromium (VI) compounds are toxins and known human carcinogens, whereas Chromium (III) is an essential nutrient.

- Breathing high levels can cause irritation to the lining of the nose; nose ulcers; runny nose; and breathing problems, such as asthma, cough, shortness of breath, or wheezing.
- Skin contact can cause skin ulcers. Allergic reactions consisting of severe redness and swelling of the skin have been noted.
- Long term exposure can cause damage to liver, kidney circulatory and nerve tissues, as well as skin irritation.

Regulatory limits

EPA- 0.1 ppm (parts per million) in drinking water.

- FDA - should not exceed 1 milligram per liter (1 ppm) in bottled water.
- OSHA- an average of between 0.0005 and 1.0 milligram per cubic meter of workplace air for an 8-hour workday, 40-hour workweek, depending on the compound.

CONCLUSIONS

The surface water of eutrophic Hussainsagar Lake is contaminated with heavy metals. Pollutants in the form of lake sediments pose a threat to the surrounding ground water as there is a chance of leaching through the aquifer. Hence, continuous monitoring of the lake water quality need to be carried out in order to ascertain long-term effects of anthropogenic impacts on the lake environment.

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Bio-Monitoring of Himayath Sagar Lake Using Benthic Macro Invertebrates

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ABSTRACT

Bio-monitoring is an important tool for indicating pollution levels in watercourse systems. Rapid Bioassessment Protocols are practical & technical references for conducting cost-effective yet scientifically valid biological monitoring programmes. The study of Bio-Monitoring is a unique way of assessing the water quality of the streams using Macro invertebrates as indicators of pollution. Using Bio Monitoring Bio-Map can be generated which indicates the level of pollution in different parts of the lakes with the different indicating colours. The present study is focused on the bio monitoring of Himayath Sagar lake using Benthic Macro invertebrates, Physico-Chemical Analysis and Plankton Study. For the Miralam Tank. Four sampling are has been carried at an interval of one month. With the results obtained a comparative study is carried out. It was observed that the results were typical for different parts of the proposed lake. Some parts of the lake is moderately polluted and others portion of the lake is clear in quality. After obtaining results the Bio-Mapping has been done accordingly.

Keywords; Himayath Sagar Lake, Benthic Macroinvertebrates, Bio - indicators, Saprobic Score, Diversity Score, Coliform.

INTRODUCTION

Water quality monitoring is an important exercise, which helps in evaluating the nature and extent of pollution as well as effectiveness of pollution control measures. It also helps in determining the water quality trends and prioritizing pollution control efforts. Rapid Bio-assessment Protocols are practical technical references for conducting cost-effective yet scientifically valid biological monitoring programs. Bio Monitoring of water bodies by the use of **benthic macro invertebrates** is a new technique introduced by Central Pollution Control Board (CPCB) in India and the definition of Bio-monitoring can be realize as ***"the systematic use of biological responses to evaluate changes in the environment with the intent to use this information in the quality control program***" CPCB in collaboration with Dutch experts gone through a deep study and research on the various water bodies especially rivers of India and prepared the standard methodology of bio-monitoring and bio-mapping as per Indian conditions.

Present study is based on the standard methodology specified by **CPCB.** For each sampling analysis is carried out and results obtained. According to the results the bio mapping is done . Physico-chemical analysis is also carried out and its implication is discussed. Apart this Plankton study i.e. Zoo plankton and phyto plankton were also identified and its outcomes are discussed.

OBJECTIVES OF BIO MONITORING

It is particularly important that the objectives of a water quality-monitoring program be clearly stated and recorded. They are also important when the program is evaluated to determine whether or not the objectives are being met.

The following is a list of typical monitoring objectives.

- Identifying many of the benthic macro invertebrates living in stream
- To perform the Physico – Chemical analysis and obtain respective results
- To investigate the presence of bio - indicators of pollution

METHODOLOGY

Benthic Macro Invertebrates

Site Selection & Interval of Sampling

First of all the sampling site has to be keenly observed and the sampling points have to be selected so as to cover the whole periphery of the lake and the results has to represent the complete lake's situation. The main motto of taking sample from the periphery is to obtain data, which will help us to draw the bio-map.

For the present study as per the guidelines sampling is taken for an interval of one month for one season.

SAMPLING METHOD

After selecting the site the sampling team has to select the portion of the lake at which the water depth is up to one meter. For lower depths sieves can be used and for difficult sites and larger depths the fishing nets has to be used. Suitable net has to be drained out from the lake water. Various organisms will be retained on the net. Collect the organisms transfer them into the sampling bottles and preserve in formaldehyde.

IDENTIFICATION

There is a need to be aware of basic insect structures before any classification. Parts of the insect body that need to be stressed include head, eyes (compound and simple), antennae, mouth, Abdominal segments, thorax, legs and leg parts, gills and tail etc. Most of the macro invertebrates we will meet are larval or nymph stages, which has to be considered. A typical structure of an Organism is shown in Figure – 1.

The organisms have to be spread randomly on to the tray and the particular block of each organism is to be noted. Identification of each organism with its class and family is to be done using manual. The recording and calculation is to be done in the Bio-Monitoring format.

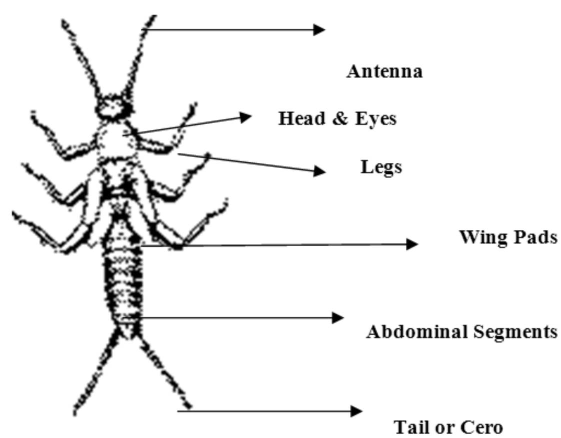

Fig. 1 Picture showing critical structure of a macro invertebrate

BIOLOGICAL WATER QUALITY EVALUATION

Under the project on development of Bio-monitoring methodology, emphasis has been laid for adoption of following methods for biological water quality evaluation. These methods are complementary to each other for biological water quality evaluation. Those methods are Saprobic score i.e. Bio Monitoring Working Party (BMWP), Diversity Score (Sequential comparison)

SAPROBIC SCORE (BMWP)

This methodology involves inventory of the presence of benthic macro-invertebrate fauna up to the family level with taxonomic precision. All possible families having saprobic indicator value are classified on a score-scale of 1 to 10 according to their preference for saprobic water quality. The saprobic scores of all the families are registered and averaged to produce BMWP score as shown in Table 1.

DIVERSITY SCORE (SEQUENTIAL COMPARISON)

The methodology involves pair wise comparison of sequentially encountered individuals and the difference of two benthic animals can be observed up to the species level, where no taxonomic skill is required. **The diversity is the ratio of the total number of different animals (runs) and the total number of organisms encountered**. The ratio of diversity has a value between 0 and 1. For biological water quality evaluation the diversity of benthic animals is compared with the saprobic score with the help of Biological Water Quality Criteria (BWQC), which is given in Table – 1.

Table 1 Biological Water Quality Criteria (BWQC)

Sl. No	Taxonomic groups	Range of saprobic score (BMWP)	Range of diversity score	Water quality characteristic	Water quality class	Indicator colour
1.	**Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Diptera**	7 and more	0.2 - 1	Clean	A	**Blue**
2.	**Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Odonata, Diptera**	6 - 7	0.5 - 1	Slight pollution	B	Light blue
3.	**Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Odonata, Crustacea, Mollusca, Polychaeta, Hemiptera, Coleoptera, Diptera, Hirudinea, Oligochaeta**	3 - 6	0.3 - 0.9	Moderate pollution	C	**Green**
4.	**Mollusca, Hemiptera, Coleoptera, Diptera, Oligochaeta**	2 - 5	0.4 & less	Heavy pollution	D	**Orange**
5.	**Diptera, Oligochaeta No animals**	0 - 2	0 - 0.2	Severe Pollution	E	**Red**

PHYSICO – CHEMICAL ANALYSIS

Primary Water Quality Criteria (PWQC)

Primary Water Quality Criteria as required in the designated for the best uses of all purposes of water sources. The critical pollutants identified for the polluted streams are dissolved oxygen, bio-chemical oxygen demand and total coliforms, pH vlue, Electronic conductivity etc. Based on the results obtained the classificatio will be made as: (A) drinking water source without conventional treatment but after disinfection, (B) outdoor bathing Organized, (C) drinking water source with conventional treatment followed by disinfection, (D) propagation of wildlife, fisheries, (E) irrigation, industrial cooling controlled waste disposal. The PWQC is described in Table – 2.

Table 2 Primary Water Quality Criteria (PWQC)

S. No.	Characteristics	A*	B*	C*	D*	E*
1.	Dissolved oxygen (DO), mg/l, Min.	6	5	4	4	-
2.	Biochemical oxygen demand (BOD) mg/l, Max.	2	3	3	-	-
3.	Total coliform organism MPN/100 ml, Max.	50	500	5,000	-	-
4.	pH value	6.5-8.5	6.5-8.5	6-9	6.5-8.5	6.5-8.5
5.	Free ammonia (as N), mg/l, Max	-	-	-	1.2	-
6.	Electrical conductivity, micromhos/cm, Max.	-	-	-	-	2,250
7.	Sodium adsorption ratio, Max.	-	-	-	-	26
8.	Boron, mg/l, Max	-	-	-	-	2

RESULTS AND DISCUSSIONS

Location of Sampling Points

Sampling site has to be so selected so as to cover the whole periphery of the lake and the results has to represent the complete lake's situation. Here the location of sampling point with reference to satellite (GPS Points) is also taken. For this lake twelve sampling points are selected around the periphery of the lake which is shown in Table – 3 and figure – 1.

Table 3 Location of sampling points

Sl.No	Sample Code	GPS Points
1	H – 1	N 17°21.175′ E 078°26.081′
2	H – 2	N 17°21.035′ E 078°25.886′
3	H – 3	N 17°20.885′ E 078°25.949′
4	H – 4	N 17°20.406′ E 078°25.844′
5	H – 5	N 17°20.589′ E 078°25.906′
6	H – 6	N 17°20.539′ E 078°26.406′
7	H – 7	N 17°20.338′ E 078°26.711′
8	H – 8	N 17°20.167′ E 078°26.797′
9	H – 9	N 17°20.531′ E 078°26.854′
10	H– 10	N 17°20.569′ E 078°26.814′
11	H – 11	N 17°20.695′ E 078°26.757′
12	H – 12	N 17°20.716′ E 078°26.701′

Fig. 2 Areal view of himayath sagar lake

BENTHIC MACRO INVERTEBRATES

The results of the average Saprobic Score and Diversity Score of Miralam Lake is obtained and given in Table – 4. It is observed that the Saprobic Score falls under the range of 3 – 5 and Diversity score as 0.00 – 0.9, which denotes that the lake quality is mostly falls under Class – D that is heavy pollution.

The macrobenthic abundance and composition at the study stations were low. Some important factors governing the abundance and distribution of macro – invertebrate communities include, water quality, immediate substrates for occupation and food availability. Any ecological imbalance arising from any severe alterations of these factors may affect that the low macro benthic invertebrate community abundance, composition and diversity have been greatly affected by the stress imposed by the organic pollution load from several sources.

Table 4 Average results of biomonitoring

Parameter	Sampling Station											
	H-1	H-2	H-3	H-4	H-5	H-6	H-7	H-8	H-9	H-10	H-11	H-12
Sequential Comparison diversity Index [SCT]	0.85	0.85	0.83	0.83	0.75	0.81	0.83	0.83	0.83	0.9	0.76	0.9
Saprobity Index	5.1	5.1	3.4	3.4	4.4	5.0	3.4	3.4	3.4	5.3	5.0	5.3
Water Quality Class	B	B	C	C	C	B	B	A	A	B	C	B
Water Quality characteristics	Slight Pol	Slight Pol	Moderate Pol	Moderate Pol	Moderate Pol.	Moderate Pol	Moderate Pol	Clean Water.	Clean Water	Slight Pol	Moderate Pol.	Slight Pol
Indicator Colour	Light Blue	Green	Green	Green	Green	Light Blue	Light Blue	Blue	Blue	Light Blue	Green	Light Blue

PHYSICO-CHEMICAL ANALYSIS

After getting the Bio-Monitoring results we need to futher investigate the heath of the water body by the usual physio-chemical analysis. For this lake we have taken the water samples and analysed the same with respect to the fresh water criteria (Refer Table – 2, PWQC). The usual physico-chemical results are; pH is in-between 6.1-8.9, DO is 1.9-5.6mg/l, BOD is 15-40mg/l and Total Coliform is 17000-1700000 MPN/100ml at different sampling points of the lake. The low dissolved oxygen content, high BOD, heavy microbial load normal pH range which is recorded could be an indication of the deteriorating water quality with high organic pollution load. The high organic load is probably resulted from the discharge of unknown discharge of industrial and domestic waste in to the lake. The newly formed STP is helping a lot to reduce the pollution load but the inflow from the large catchment area of the lake is responsible for the deteriorating condition of the lake. The various parameters observed are shown in Table – 5.

Table 5 Physio-chemical analysis results

Average Results of Miralam Tank					
Sampling Station	pH	DO	BOD	Total Coliform	PWQC
H-1	7.4	5.0	2	4085	C
H-2	7.5	3.6	2	1400	D
H-3	6.3	4.8	7	867	D
H-4	7.6	2.8	5	560	E
H-5	8.5	7	2	590	E

Contd…

H-6	7.7	3.0	8	365	D
H-7	8.5	4.9	2	215	D
H-8	7.4	5.0	2	408	C
H-9	7.5	3.6	6	140	D
H10	6.3	4.8	7	867	D
H-11	7.6	8	5	560	E
H-12	8.5	1.7	2	590	E

CONCLUSIONS

1. The level of pollution at Himayath sagar Tank is in between moderate pollutiuon to Clean Water.
2. The level of pollution is lesser at bund side and other parts are slightly polluted with different values of Sabrobic score 3.5-5.4 and Diversity Scores 0.63-0.9.
3. The usual physico-chemical results are; pH is in-between 6.1-8.9, DO is 1.9-5.6mg/l, BOD is 15-40mg/l and Total Coliform is 215 -590 MPN/100ml at different sampling points.
4. After analysis the results are integrated and bio-mapping is been done. The map proposed lake is drawn according to the results, particular coloring is been done to indicate the particular level of pollution, so as to have a clear picture of the lake's situation in a simple & better way.

SCOPE FOR FURTHER STUDY

As mentioned earlier that Bio-Monitoring method is a new for India but lot of work is done on this by CPCB. Now many environmental organizations are following this method for the purpose of assessing the water quality of the streams. This methodology can be used to asses Rivers, Lakes, and Ponds etc. And by using Bio-Mapping method particular maps can be drawn which is easy to understand the situation of the water body.

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Assessment of the Quality of Drinking Water: Ground Water Vs Surface Water in West Godavari Western Delta, A.P, India

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ABSTRACT

The goal of National Rural Drinking Water Programme (NRDWP) is "To provide every rural person with safe water for drinking, cooking and other domestic basic needs on a sustainable basis. This basic requirement should meet certain minimum water quality standards and be readily and conveniently accessible at all times and all situations." People obtain their drinking water from surface and underground sources. Both surface and groundwater sources are contaminated by Physico-Chemical and biological pollutants arising from point and non-point sources. In general ground water is less vulnerable to pollution than surface water. In this paper drinking water quality of western delta of West Godavari with seasonal variation is presented. It is observed that the drinking water quality is very poor in both the seasons. In summer season the salt concentrations is further increased and thereby increases in total dissolved salts (TDS), EC, Hardness, Alkalinity and Nitrate values. There is a reduction in the values of dissolved oxygen thereby increase in BOD and COD values in summer when compared with winter.

Keywords: Drinking Water Quality, Nutrient Pollution, Pesticides, Toxic Chemicals, Biological Contamination.

INTRODUCTION

Our drinking water is from different resources. Surface water can be found over the land surface in streams, ponds, lakes or other fresh water sources. Groundwater is water located beneath the surface in soil pore spaces and in permeable geological formations. Sources of groundwater include seepage from the land surface; such as rain water, snow melt and water also that penetrates down from the bottom of some lakes and rivers. Fossil groundwater is water that has been trapped rock formations over geological time scales. The average availability of water remains more or less fixed according to the natural hydrological cycle but the percapita availability reduces steadily due to an increase in population. Some 2.78 million trillion gallons of ground water, 30.1 percent of the world fresh water, are estimated for the entire planet of the Earth.

Each source of water has a unique set of contaminants. Surface water pollution is the pollution of aquatic systems that are above ground, such as streams, lakes and rivers. These waters become polluted when rain water runoff carries pollutants into the water. The pollutants transported by runoff are from things like salts and chemicals from city and highway roads and nutrients and fertilizers from farm and lawn. When pollution is caused by nutrients and fertilizers this is called nutrient pollution. Surface water may also be polluted with pathogens and waterborne diseases, which is usually the result of sewage leaks and runoff from animal factories. These viruses and bacteria that pollute the water may cause dangerous human health problems such as Giardia; typhoid and hepatitis. Toxic chemicals may also lead to surface water pollution. These come from pesticides, synthetic chemicals such as petroleum products, mercury, lead and arsenic from mining drainage. These chemicals are very dangerous for the environment as well as for the health of the organisms that inhabit them. The presence of ammonia in surface waters can be due to direct contamination by agricultural fertilizers, and/ or to microbial degradation of proteins, nucleic acids and urea, implying therefore the presence of a considerable concentration of organic matter in the water. As groundwater flows through sediments, metals such as iron and manganese are dissolved and may later be found in high concentrations in the water. Industrial discharges, urban activities, pesticides and fertilizers used in agriculture and disposal of waste all can affect groundwater quality. Municipal sources of groundwater contamination include open dumpsites, poorly constructed or maintained landfills, latrines and other waste sites. Each of these can contain a range of pathogens and toxins, including heavy metals that can migrate downwards and contaminate aquifer.

Groundwater pollution differs from surface water contamination in several important respects. Among them, it does not typically flow to a single outlet. It can affect people through wells dug in a contaminated aquifer, as it can flow into streams and lakes. Groundwater pollution also occurs on a different timescale than surface water contamination. Flow rates vary widely and can be as slow as 2 miles a year. This is because groundwater experiences far more friction as it moves through the pores in soil than surface water. Surface water more easily contaminated than groundwater. Filtration through the soil helps clean ground water. These distinctions depend on topography, hydrology and the source of ground water recharge and have implications for limiting as well as remediating contamination.

The hydrological cycle interconnects surface and groundwater which means they may contaminate one another. As rain falls on the earth's surface, some water runs off the land to rivers, lakes, streams and oceans. Some water is also evaporated and absorbed by plants or continues to move down to become groundwater. Groundwater very slowly moves towards low areas such as streams and lakes which are once again end up in surface water. This cycle is continuous and shows how the two are interconnected. Neither water source can ever be entirely free from water contaminants. Health effects of groundwater pollution depend on the specific pollutant in the water. Pollution from groundwater often causes diarrhea and stomach irritation. Accumulation of heavy metals and some organic pollutants can lead to cancer, reproductive abnormalities and other more severe health effects. Nitrates in drinking water can cause cyanosis, a reduction of the oxygen carrying capacity of the blood. Lead is a toxic substance and is very dangerous particularly for children. Other heavy metals present in groundwater are cadmium, zinc, mercury etc.

Study Area

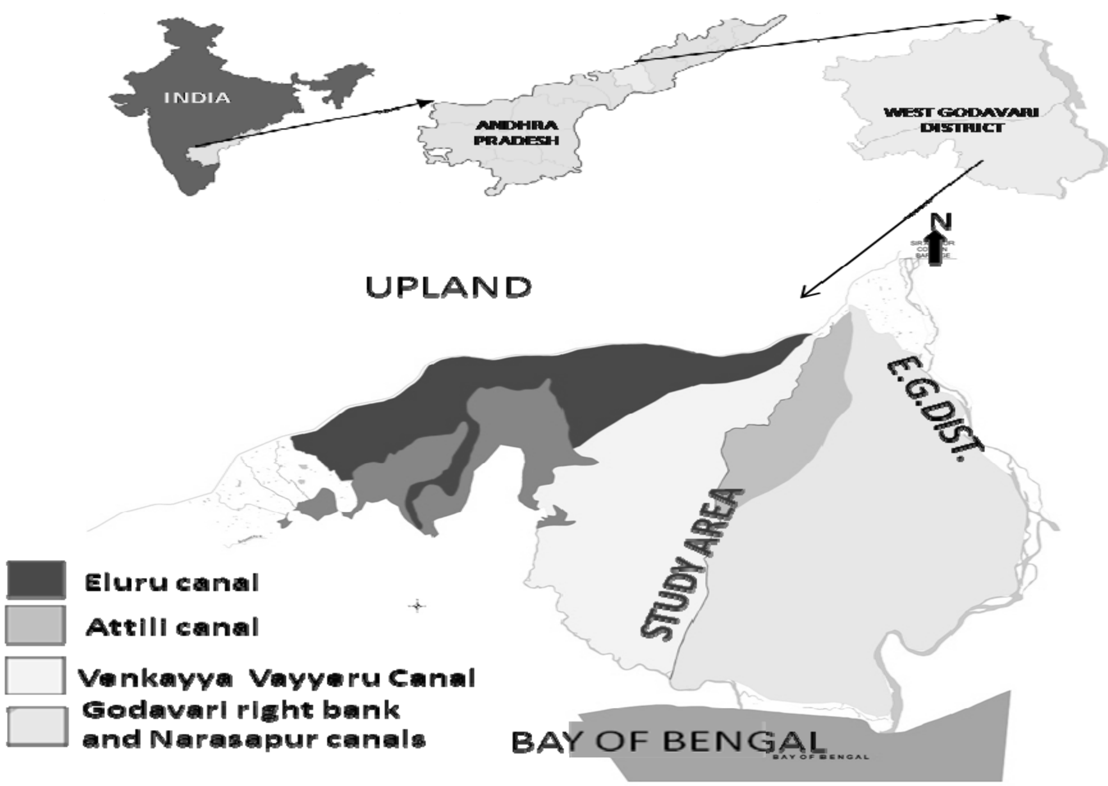

Fig. 1 Study area

The study area is situated in the Southern part of West Godavari District. It is bounded in the East by Godavari River, North by Eluru canal, West by Upputeru river & Kolleru lake and South by Bay of Bengal. The study area lies between 16°19'05.02" to 16°56'08.37" N latitudes and 80°58'16.10" to 81°51'26.10"E longitudes.

Geologically, the Western Delta Region is underlain by coarse sand with black clay of buried channel (BC) zone, black silt clay of flood plain (FP) zone and grey/white fine sand of beach sediment of coastal zone. In

Western Delta of West Godavari District 63% of villages are dependent on irrigation canals and 37% of villages on ground water. Being a deltaic region, most of the ground water is highly saline. Each village has a pond fed by an irrigation canal, storing the required quantity of water. Under Rural Drinking Water Supply (RWS) Scheme, in most villages the water in the pond is passed through slow sand filters and then chlorinated and pumped into overhead tank for distribution through a network of pipes. In case of groundwater, the water is first pumped into overhead tank and treated with chlorine and directly distributed to houses through pipes.

RESULTS AND DISCUSSION

Turbidity: Turbidity is cloudiness of water by a variety of particles and another key parameter in drinking water analysis. It is also related to the content of diseases causing organisms in water, which may come from soil runoff and adding drainage network into canal. The values vary from 0 NTU to 1.0 NTU in groundwater during winter season, 0.2 NTU to 0.8NTU during summer season. Surface water values vary from 0.1NTU to 5.7 NTU during winter season, 0.1NTU to 4.1NTU during summer season.

P^H: This is a measure of the intensity of the alkaline or acid condition of water. It is a way of expressing hydrogen ion concentration. The values vary from 6.9 to 8.3 in groundwater during winter season, 7.5 to 9.8 during summer season. Surface water values vary from 7.7 to 8.6 during winter season, 7.3 to 9.1 during summer season, where as the standard value lies between 6.5 to 8.5. P^H values are high in surface water when compared to that of ground water. Panditavilluru, Poduru, Vadangi, Digamarru, Chitavaram, Narasapuram, Mogalturu have high P^H values in the surface water before treatment but their values are in normal range after treatment.

Total Dissolved Solids (TDS): TDS is composed mainly of Carbonated, Bicarbonates, Chlorides, Phosphates, Nitrates, Calcium, Magnesium, Sodium, Potassium and Manganese. In addition to that organic matter and other salts may also contribute to TDS. The TDS values vary from 330ppm to 1130 ppm in groundwater during winter season, 280ppm to 990ppm during summer season. Surface water values vary from 130ppm to 390 ppm during winter season, 140ppm to 1600ppm during summer season. The desirable range of TDS value is between 150ppm to 500 ppm.

Electrical Conductivity (E.C): The conductivity of water is an expression of its ability to conduct an electric current. As this property is related to the ionic content of the sample which is in turn a function of the dissolved (ionisable) solids concentration, the relevance of easily performed conductivity measurements is apparent. For many surface waters the following approximation will apply: Conductivity (µS/cm) x 2/3= Total Dissolved Solids (mg/l). The TDS and EC values well obeyed this equation.

Total Hardness (TH): Total hardness of water is characterized by content of Calcium and Magnesium salts. It is the total of Calcium hardness and Magnesium hardness.

Calcium Hardness: High levels may be beneficial and waters which are rich in Calcium are very palatable. This element is the most important and abundant in the human body and adequate intake is essential for normal growth and health. The maximum daily requirement is of the order of 1-2 grams and comes especially from dairy products.

Magnesium Hardness: Magnesium is also an essential element of the body particularly for cardiovascular functions. Hardness values vary from 70 ppm to 450 ppm. The maximum permissible value of hardness for drinking water is 300ppm. In ground water almost 50% of samples have higher values than the permissible limit but in surface water samples, all water samples have the values below 300 ppm.

Nitrates: Nitrate is a significant parameter of water showing pollution status and anthropogenic load on water (Suthar et al. 2010).Relatively little of the nitrate found in natural waters is of mineral origin; most of the nitrates are coming from organic and inorganic sources, the former including waste discharges and the latter comprising chiefly artificial fertilizers. However, bacterial oxidation and fixing of nitrogen by plants can both produce nitrates. Interest is centered on nitrate concentrations for various reasons. Rivers with high levels of nitrate are more likely to indicate significant run-off agricultural land than anything else. Nitrate levels in the study area are ranged from 0 ppm to 65.3 ppm. The permissible value of Nitrate in drinking water is 45ppm. Ground water samples have high values of nitrates (crossed the permissible limit in some Villages), when compared to that of surface water samples.

Biological Oxygen Demand (B.O.D): BOD value indicated the presence of organic pollution in the water, which imposes adverse effect on the water quality of aquatic system. BOD determination is a chemical procedure for determining the amount of D.O needed by aerobic organisms in a water body to break the organic materials present in the given water sample at certain temperature over a specific period of time. Drinking water usually has a BOD of less than 1mg/L but when BOD value reaches 5mg/L, the water is doubtful in purity. It is the only parameter, to give an idea of the biodegradability of any sample & self-purification capacity of rivers and streams. The BOD values vary from 1.2 ppm to 12.6 ppm in groundwater during winter season, 1.2 ppm to 4.8 ppm during summer season. Surface water values vary from 1.5 ppm to 4.8 ppm during winter season, 1.2 ppm to 13.2 ppm during summer season.

Chemical Oxygen Demand (C.O.D): COD test is commonly used to indirectly measure the amount of organic compounds in water. Most applications of COD determine the amount of organic pollutants found in surface water, making COD a useful measure of water quality. COD determines the quantity of oxygen required to oxidize the organic matter in water or waste water sample under specific conditions of oxidizing agent, temperature and time.

The ratio of BOD to COD is useful to assess the amenability of waste for biological treatment. Ratio of BOD to COD greater than or equal to 0.8 indicates, that waste water highly polluted and amenable to the biological treatment. The COD values vary from 6.4 ppm to 25.6 ppm in groundwater during winter season, 6.4 ppm to 70.4 ppm during summer season. Surface water values vary from 3.2 ppm to 32 ppm during winter season, 3.2 ppm to 48 ppm during summer season.

Microbiological Quality of Drinking Water: The presence of Total *Coliform bacteria* in water is measured in the form of MPN index, i.e. Most Probable Number in 100 ml water sample. *Coliform bacteria* naturally present in the gastro intestinal tract of humans and animals. The presence of *Coliform bacteria* in water indicates that, water has been contaminated with fecal matter of human or any other animal. Presence of *E.coli* in water indicated recent fecal contamination and may indicate the possible presence of disease causing pathogenic microorganisms. MPN index and *E.coli* in drinking water are used as indicators to measure the degree of pollution and sanitary quality of drinking water

Table 1 Physico-chemical analysis of ground water (before treatment) - winter season

S. NO	PLACE	P^H	TDS	EC	TH	TA	Turb	NH_3	NO_2	NO_3	D.O	B.O.D	C.O.D	Na^+	K^+
1	Ajjaram	8.6	650	990	310	400	0.9	0.00	0.06	32.7	7.1	5.4	9.6	95	7
2	Peravali	8.2	810	1210	170	380	1.0	0.00	0.02	41.8	6.5	3.6	12.8	157	14
3	Kothapalli	7.5	780	1150	340	430	0.8	0.00	0.00	11.4	7.6	3.6	12.8	28	6
4	Kapavaram	8.2	910	1330	270	360	0.8	0.05	0.08	88.9	5.6	6.0	6.4	92	24
5	Thurupuvipparu	7.9	640	930	310	200	0.9	0.00	0.08	25.7	6.8	6.6	9.6	100	27
6	KakulaIllindaparu	8.3	870	1270	120	450	1.2	0.00	0.00	12.8	6.5	2.4	12.8	174	2
7	Surampudi	8.2	330	480	100	240	0.8	0.00	0.00	10.9	4.4	4.8	16.0	104	4
8	Rapaka	7.6	360	490	250	260	0.2	0.00	0.03	15.0	4.5	2.4	19.2	46	12
9	Gollagunta	8.0	390	580	210	250	0.1	0.00	0.00	44.3	4.7	2.4	16.0	86	4
10	Penugonda	6.9	830	1220	410	650	0.4	0.03	0.01	65.3	7.4	2.4	19.2	134	9
11	Mallapudibba	8.2	760	1140	70	400	1.0	0.08	0.31	4.5	5.2	5.4	22.4	168	4
12	Venkataramapuram	8.2	760	1100	130	400	0.6	0.18	0.31	20.9	4.5	3.6	25.6	166	4
13	Neggipudi	8.2	940	1330	410	480	0.7	0.05	0.53	18.9	4.1	1.2	16.0	135	6
14	Maruteru	8.1	660	990	230	300	0.9	0.20	8.10	13.9	6.3	1.8	22.4	140	20
15	Kavitam	8.2	880	1290	200	530	1.1	0.00	0.01	27.0	3.1	12.6	25.6	30	2
16	Jinnuru	8.1	1130	1680	325	460	0.4	0.10	0.03	9.6	4.5	2.4	6.4	145	58

Table 2 Physico-chemical analysis of ground water (after treatment) - winter season

S. NO	PLACE	P^H	TDS	EC	TH	TA	Turb	NH_3	NO_2	NO_3	Na^+	K^+
1	Ajjaram	7.9	720	1050	440	220	0.0	0.00	0.06	7.4	83	7
2	Peravali	8.1	820	1200	320	280	0.6	0.00	0.01	6.7	142	12
3	Kothapalli	8.0	860	1240	320	430	0.4	0.48	2.40	0.0	135	23
4	Kapavaram	7.7	950	1380	370	400	0.0	0.00	0.04	25.0	121	77
5	Thurupuvipparu	8.3	640	920	330	220	0.4	0.00	0.01	11.8	96	22
6	KakulaIllindaparu	8.3	970	1350	120	500	0.0	0.00	0.02	0.0	166	47
7	Surampudi	8.2	330	480	100	240	0.8	0.00	0.00	10.9	104	4
8	Rapaka	7.6	360	490	250	400	0.0	0.00	0.03	15.0	46	12
9	Gollagunta	8.2	530	770	180	340	0.2	0.00	0.00	0.0	119	8
10	Penugonda	6.9	830	1220	410	430	0.4	0.03	0.01	65.3	134	9
11	Mallapudibba	8.2	760	1140	70	500	1.0	0.08	0.31	4.5	168	4
12	Venkataramapuram	8.2	760	1100	130	500	0.6	0.18	0.31	20.9	166	4
13	Neggipudi	8.3	920	1350	440	420	0.4	0.00	0.00	3.8	135	18
14	Maruteru	8.2	920	1320	320	450	0.6	0.18	2.40	3.3	146	12
15	Kavitam	8.2	940	1310	210	440	0.4	0.0	0.01	2.1	162	7
16	Jinnuru	8.1	1130	1680	325	520	0.4	0.10	0.03	9.6	145	58

Table 3 Physico-chemical analysis of surface water (before treatment) - winter season

S. NO	PLACE	P^H	TDS	EC	TH	TA	Turb	NH_3	NO_2	NO_3	D.O	B.O.D	C.O.D	Na^+	K^+
1	Panditavilluru	9.0	140	200	80	90	0.7	0.00	0.00	25.6	7.1	4.2	16.0	33	3
2	Poduru	9.3	120	180	90	100	1.9	0.00	0.01	13.5	4.9	3.0	32.0	30	2
3	Vadangi	8.7	190	280	110	120	0.7	0.08	0.03	5.1	5.1	4.8	16.0	29	3
4	Bollatigunta	8.3	150	220	85	95	0.7	0.08	0.00	0.0	4.8	3.0	6.4	27	3
5	Panumantha	8.7	130	230	90	95	1.7	0.04	0.01	0.0	6.3	3.6	16.0	28	3
6	Uilamparu	8.5	160	240	85	120	0.6	0.01	0.01	12.8	5.8	3.0	9.6	37	4
7	Palakollu	8.6	130	190	80	90	0.5	0.00	0.00	12.5	7.2	1.8	6.4	29	2
8	Chandaparru	8.6	150	220	130	105	0.8	0.02	0.01	1.6	7.2	1.8	9.6	62	3
9	Aggarru	8.9	360	530	150	130	3.2	0.01	0.10	0.0	6.5	3.0	6.4	79	4
10	Gorintada	8.6	260	380	115	130	2.3	0.01	0.00	1.46	6.9	1.5	3.2	60	3
11	Digamarru	8.8	190	280	105	110	5.4	0.01	0.05	0.9	6.0	4.8	16.0	46	2
12	Chitavaram	9.1	150	210	165	100	2.6	0.01	0.01	14.9	7.2	1.8	9.6	31	3
13	Narasapuram	9.1	140	200	90	95	1.9	0.01	0.01	1.4	7.2	1.8	6.4	29	3
14	Mogalturu	9.1	220	330	100	110	0.8	0.01	0.00	1.4	7.2	1.8	3.2	53	3
15	Modi	8.4	160	240	90	100	2.6	0.01	0.00	10.8	5.6	1.8	3.2	33	3

Table 4 Physico-chemical analysis of surface water (after treatment) - winter season.

S. NO	PLACE	P^H	TDS	EC	TH	TA	Turb	NH_3	NO_2	NO_3	Na^+	K^+
1	Panditavilluru	8.1	150	220	90	120	0.1	0.00	0.31	0.0	3	33
2	Poduru	8.6	130	180	90	100	5.7	0.15	0.02	0.0	2	30
3	Vadangi	8.1	290	200	120	120	1.0	0.01	0.01	10.9	3	29
4	Bollatigunta	8.3	150	220	85	95	0.7	0.08	0.00	0.0	3	27
5	Panumantha	8.0	150	230	85	90	3.2	0.1	0.01	12.6	3	28
6	Uilamparu	8.3	160	240	85	110	0.9	0.00	0.01	0.0	4	37
7	Palakollu	8.5	150	230	80	90	0.9	0.00	0.01	2.8	2	29
8	Chandaparru	8.0	300	430	130	140	0.6	0.01	0.02	1.2	3	62
9	Aggarru	8.1	390	560	145	125	2.0	0.01	0.00	0.0	4	79
10	Gorintada	8.2	270	400	115	135	0.3	0.01	0.01	17.7	3	60
11	Digamarru	8.1	220	330	105	120	1.9	0.01	0.12	13.3	2	46
12	Chitavaram	8.3	160	240	165	110	2.9	0.00	0.06	1.4	3	31
13	Narasapuram	7.7	150	210	80	80	0.4	0.01	0.00	0.8	3	29
14	Mogalturu	8.3	230	340	100	110	1.2	0.01	0.00	11.7	3	53
15	Modi	8.4	160	240	90	100	2.6	0.01	0.00	10.8	3	33

Table 5 Physico-chemical analysis of ground water (before treatment) - summer season

S.NO	PLACE	P^H	TDS	EC	TH	TA	Turb	NH_3	NO_2	NO_3	D.O.	B.O.D	C.O.D	Na^+	K^+
1	Ajjaram	7.5	750	1100	514	375	0.2	0.01	0.78	40.3	6.8	1.2	19.2	95	7
2	Peravali	8.0	860	1210	360	355	0.3	0.01	0.01	23.0	7.2	3.6	16.0	158	13
3	Kothapalli	7.5	700	1030	320	425	0.2	0.00	0.01	17.4	6.4	1.2	9.6	124	64
4	Kapavaram	8.2	980	1410	320	390	0.1	0.00	0.00	81.4	6.4	2.4	12.8	134	100
5	Thurupuvipparu	8.0	680	970	410	235	0.1	0.00	0.07	64.5	7.6	1.2	6.4	104	27
6	Kakulillindaparu	8.1	940	1370	280	545	0.1	0.00	0.00	7.38	6.4	2.4	9.6	182	2
7	Surampudi	8.2	340	500	110	250	0.4	0.00	0.00	9.96	6.1	4.8	19.2	100	2
8	Rapaka	7.6	280	420	160	460	0.5	0.00	0.02	6.88	4.8	4.8	70.4	42	12
9	Gollagunta	8.1	420	620	170	395	1.2	0.00	0.00	9.56	6.8	2.6	12.8	90	4
10	Penugonda	7.5	540	780	250	400	0.4	0.00	0.74	55.0	4.5	3.6	35.2	109	8
11	Mallapudibba	8.1	840	1240	75	500	0.6	0.10	0.75	8.39	5.1	2.4	20.6	180	4
12	Venkataramapuram	8.1	870	1250	70	535	0.4	0.10	0.73	32.9	5.3	4.8	19.2	178	4
13	Neggipudi	7.9	2900	4140	450	890	0.5	0.04	0.65	16.5	6.4	3.8	9.6	198	4
14	Maruteru	8.0	950	1410	260	480	0.8	0.10	0.06	59.8	5.1	3.6	25.6	160	18
15	Kavitam	8.2	940	1350	200	460	0.4	0.02	0.00	18.6	5.2	2.4	16.0	168	7
16	Jinnuru	7.8	1240	1800	370	445	0.8	0.02	0.78	26.9	7.6	4.8	12.8	164	60

Table 6 Physico-chemical analysis of ground water (after treatment) - summer season

S.NO	PLACE	P^H	TDS	EC	TH	TA	Turb	NH_3	NO_2	NO_3	Na^+	K^+
1	Ajjaram	7.7	760	1110	385	360	0.4	0.00	0.01	8.39	96	8
2	Peravali	7.8	840	1230	280	385	0.4	0.01	0.10	11.8	160	13
3	Kothapalli	7.9	830	1210	350	450	0.4	0.00	0.00	16.4	142	29

Contd…

S.NO	PLACE	P^H	TDS	EC	TH	TA	Turb	NH_3	NO_2	NO_3	Na^+	K^+
4	Kapavaram	8.2	990	1410	360	415	0.2	0.00	0.00	26.7	134	100
5	Thurupuvipparu	8.3	690	990	370	250	0.3	0.00	0.01	16.5	105	28
6	Kakulillindaparu	8.0	910	1340	120	520	0.2	0.00	0.00	16.6	182	2
7	Surampudi	8.2	340	500	110	250	0.4	0.00	0.00	9.96	100	2
8	Rapaka	7.6	280	420	160	460	0.5	0.00	0.02	6.88	42	12
9	Gollagunta	8.3	500	730	170	340	0.5	0.00	0.00	25.8	127	7
10	Penugonda	7.5	540	780	250	400	0.4	0.00	0.74	55.0	109	8
11	Mallapudibba	8.1	840	1240	75	500	0.6	0.10	0.75	8.39	180	4
12	Venkataramapuram	8.1	870	1250	70	535	0.4	0.10	0.73	32.9	178	4
13	Neggipudi	8.5	960	1380	450	440	0.3	0.00	0.07	12.8	122	16
14	Maruteru	8.0	950	1410	260	480	0.8	0.10	0.06	59.8	160	18
15	Kavitam	8.2	940	1350	210	440	0.2	0.00	0.00	11.07	170	9
16	Jinnuru	9.8	540	780	140	190	0.4	0.00	0.18	10.8	108	24

Table 7 Physico-chemical analysis of surface water (before treatment) - summer season

S.NO	PLACE	P^H	TDS	EC	TH	TA	Turb	NH_3	NO_2	NO_3	D.O.	B.O.D	C.O.D	Na^+	K^+
1	Panditavilluru	9.3	140	220	95	105	3.3	0.00	0.03	6.22	4.8	5.6	12.8	36	3
2	Poduru	9.3	150	220	80	110	1.2	0.00	0.07	13.5	5.2	3.6	19.2	31	2
3	Vedangi	8.7	150	230	140	115	2.4	0.00	0.00	8.85	6.0	1.2	6.4	36	6
4	Bollatigunta	8.9	180	260	140	95	0.1	0.01	0.05	9.86	4.8	1.2	3.2	29	3
5	Panumantha	9.0	170	250	100	130	3.3	0.09	0.01	5.56	5.6	1.2	25.6	36	4
6	Uilamparu	8.4	340	510	165	240	2.5	0.01	0.01	4.85	5.6	6.0	48.0	74	12
7	Palakollu	8.7	160	240	115	95	3.0	0.01	0.00	4.80	4.0	7.2	38.4	30	4
8	Chandaparru	8.3	220	330	130	100	2.6	0.02	0.01	7.89	6.0	4.8	12.8	48	5
9	Aggarru	9.0	250	380	125	215	6.0	0.01	0.18	10.50	4.0	8.4	48	66	6
10	Gorintada	8.2	290	430	150	195	3.9	0.01	0.00	9.15	4.4	6.0	41.6	68	7
11	Digamarru	8.3	250	370	150	155	6.3	0.02	0.00	24.7	4.4	13.2	41.6	65	5
12	Chitavaram	8.9	150	220	110	75	4.6	0.02	0.00	9.71	5.2	8.4	41.6	29	4
13	Narasapuram	9.2	150	220	110	70	4.6	0.08	0.41	7.13	4.4	8.6	41.6	33	4
14	Mogalturu	7.8	170	260	115	80	8.0	0.08	0.03	8.14	5.6	5.6	25.6	41	5
15	Modi	8.3	180	270	100	100	3.8	0.01	0.04	6.42	4.8	1.2	3.2	42	4

Table 8 Physico-chemical analysis of surface water (after treatment) − summer season

S.NO	PLACE	P^H	TDS	EC	TH	TA	Turb	NH_3	NO_2	NO_3	Na^+	K^+
1	Panditavilluru	7.5	1600	2300	410	470	0.8	0	0	5.26	193	6
2	Poduru	9.1	140	210	90	125	0.8	0	0.01	8.49	31	2
3	Vedangi	8.4	160	230	90	100	1.3	0	0	7.79	33	5
4	Bollatigunta	8.9	180	280	140	95	0.1	0.01	0.05	9.86	29	3
5	Panumantha	8.6	170	250	110	100	2.2	0.02	0	5.46	35	4
6	Uilamparu	8.5	530	770	150	375	1.8	0.15	0.01	7.23	98	17

Contd…

S.NO	PLACE	P^H	TDS	EC	TH	TA	Turb	NH_3	NO_2	NO_3	Na^+	K^+
7	Palakollu	8.4	150	230	115	90	2.8	0.01	0	3.79	28	3
8	Chandaparru	8.3	220	340	135	110	0.2	0	0	7.58	48	5
9	Aggarru	8.6	250	380	130	145	3.8	0	0.06	7.58	65	5
10	Gorintada	8.4	280	420	130	155	0.9	0	0	7.33	67	7
11	Digamarru	8.3	260	390	120	175	4.1	0	0	12.1	66	5
12	Chitavaram	8.6	180	270	115	90	2.5	0	0	10.3	30	5
13	Narasapuram	7.3	160	230	95	90	0.3	0.05	0	6.27	32	4
14	Mogalturu	8.1	190	280	105	100	3.2	0.06	0.08	7.38	44	5
15	Modi	8.3	180	270	100	100	3.8	0.01	0.04	6.42	42	4

Table 9 Microbiological parameters of ground water (after treatment) in different villages during winter season vs summer season.

S. NO	PLACE	WINTER SEASON			SUMMER SEASON		
		MPN/100ml	TFC/100ml	E.coli (CFU)/1ml	MPN /100ml	TFC /100ml	E.coli (CFU)/1ml
1	Ajjaram	460	23	$112X10^2$	23	0	0
2	Peravali	0	0	0	240	93	0
3	Kothapalli	≥2400	0	$253X10^2$	0	0	0
4	Kapavaram	0	0	0	≥2400	460	8
5	Thurupuvipparu	0	0	0	≥2400	150	72
6	Kakulillindaparu	0	0	0	460	0	0
7	Surampudi	93	0	0	43	39	0
8	Rapaka	1100	460	$27X10^2$	150	0	0
9	Gollagunta	0	0	0	≥2400	43	98
10	Penugonda	0	0	0	≥2400	0	0
11	Mallapudibba	0	0	0	≥2400	≥2400	32
12	Venkataramapuram	1600	16	$46X10^2$	≥2400	11	6
13	Neggipudi	≥2400	0	$186X10^2$	1600	150	0
14	Maruteru	0	0	0	≥2400	1600	22
15	Kavitam	0	0	0	43	0	0
16	Jinnuru	≥2400	460	$115X10^2$	460	43	0

Table 10 Microbiological parameters of surface water (after treatment) in different villages during winter season vs summer season

S. NO	PLACE	WINTER SEASON			SUMMER SEASON		
		MPN/100ml	TFC/100ml	E.coli (CFU)/1ml	MPN /100ml	TFC /100ml	E.coli (CFU)/1ml
1	Panditavilluru	460	210	147×10^2	0	0	0
2	Poduru	≥2400	460	117×10^2	43	0	0
3	Vedangi	≥2400	1100	96×10^2	≥2400	29	15
4	Bollatigunta	≥2400	240	32×10^2	43	0	0
5	Panumantha	0	0	0	0	0	0
6	Uilamparu	1100	210	0	0	0	0
7	Palakollu	0	0	0	0	0	0

Contd…

S. NO	PLACE	WINTER SEASON			SUMMER SEASON		
		MPN/100ml	TFC/100ml	E.coli (CFU)/1ml	MPN /100ml	TFC /100ml	E.coli (CFU)/1ml
8	Chandaparru	≥2400	1100	146×10^2	23	0	0
9	Aggarru	≥2400	23	0	93	0	0
10	Gorintada	≥2400	23	0	460	43	0
11	Digamarru	≥2400	23	0	240	0	0
12	Chitavaram	≥2400	150	0	0	0	0
13	Narasapuram	23	0	0	0	0	0
14	Mogalturu	0	0	0	93	15	0
15	Modi	0	0	0	≥2400	1600	0

Table 11 Suitability of drinking water in terms of MPN of surface & ground waters with seasons

Season	Ground water	Surface water	Total no.of samples
Winter season	56% (9/16)	27% (4/15)	31
Summer season	38% (6/16)	40% (6/15)	31

Table 12 Average physico-chemical values of source water in different seasons

Sl. NO	Para meter	GROUND WATER				SURFACE WATER			
		WINTER		SUMMER		WINTER		SUMMER	
		Before Treatment	After Treatment	Before Treatment	After Treatment	Before Treatment	After Treatment	Before Treatment	After Treatment
1	P^H	8.0	8.0	7.9	8.1	8.8	8.2	8.7	8.3
2	TDS	731	778	889	736	177	204	197	310
3	EC	1074	1125	1288	1071	262	285	294	457
4	TH	241	271	270	235	104	104	122	136
5	TA	387	393	446	401	106	110	125	155
6	Turbidity	0.73	0.4	0.6	0.4	1.72	1.6	3.7	1.9
7	NH_3	0.04	0.10	0.00	0.00	0.02	0.03	0.00	0.00
8	NO_2	0.6	0.4	0.3	0.2	0.02	0.04	0.10	0.00
9	NO_3	27.73	11.60	29.9	20.6	6.80	5.5	9.2	7.5
10	D.O	5.55	---	6.1	---	6.33	---	5	---
11	B.O.D	4.16	---	3.1	---	2.78	---	5.5	---
12	C.O.D	15.8	---	19.7	---	10.67	---	27.3	---
13	Na^+	112.5	129	136.6	132	40.40	2.9	44	56
14	K^+	12.69	20	21	18	2.93	40.4	4.9	5.3

CONCLUSIONS

The observed quality of treated surface water and groundwater in the region of Western Delta, West Godavari District, Andhra Pradesh shows that the treated Surface water samples, during summer season the values of PH, TDS, EC, TH,TA, Turbidity, Nitrate, BOD, Sodium and Potassium levels were increased but Ammonia and Nitrate values were decreased. COD values in both surface and groundwater samples the levels were increased in summer season when compared to that of winter season. Microbiological contamination is less in summer (40% suitability) than in winter season (27% suitability) In the treated Groundwater samples, during summer season the values were decreased i.e TDS, EC, TH, Ammonia, BOD, Nitrite, Potassium levels were decreased in summer season than in winter season. But the values of PH, TA, Nitrate, Sodium values were slightly increased during summer season. Microbiological contamination is less in winter season (56% suitability) than in summer season (38% suitability).

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Study the Treatment Process in 20 MLD of S.T.P

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ABSTRACT

India is rich in water resources, being endowed with network of rivers, urban lakes that can meet a variety of water requirements of the country. But with the rapid increase in the population of the country and the need to meet the increasing demands of irrigation, human and industrial consumption, the availability water resources in many parts of the country are getting depleted and the water quality has deteriorated. Indian lakes are polluted due to the discharge of untreated sewage and industrial effluents. Sewage Treatment Plant is a facility designed to receive the waste from domestic, commercial and industrial sources and to remove materials that damage water quality and compromise public health and safety when discharged into water receiving systems. It includes physical, chemical, and biological processes to remove various contaminants depending on its constituents. Using advanced technology it is now possible to re-use sewage effluent for non potable uses for gardening and industrial purpose. The present project is aimed to study the treatment process in 20 MLD S.T.P of Preliminary treatment involving i.e. Screening ,Grit chamber, skimming tank and Primary treatment which includes primary sedimentation with or without coagulation i.e. Trickling filters or intermittent sand filters or contact beds or activated sludge process etc…,sludge digestion, drying beds etc…and Tertiary treatment or advanced treatment i.e. Adsorption, Ion exchange ,stripping , Reverse osmosis, Electro dialysis, Disinfection etc…and Miscellaneous treatment methods like septic tank, imhoff tank, oxidation ponds, aerated lagoons, etc…

Keywords: Sewage Treatment, Water Quality, Pollution.

INTRODUCTION

India is rich in water resources, by rapid increase in the population of the country and the need to meet the increasing demands of irrigation, human and industrial consumption, the availability water resources in many parts of the country are getting depleted and the water quality has deteriorated. Pollution in its broadest sense includes all changes that curtail natural utility and exert deleterious effect on life. The crisis triggered by the rapidly growing population and industrialization with the resultant degradation of the environment causes a grave threat to the quality of life. Sewage Treatment Plant is a facility designed to receive the waste from domestic, commercial and industrial sources and to remove materials that damage water quality and compromise public health and safety when discharged into water receiving systems. Using advanced technology it is now possible to re-use sewage effluent for non potable uses for gardening and industrial purpose. The waste water usually requires some type of preparation or treatment before it is rendered fit for disposal or reuse. Generally, in many situations involving domestic wastewater, the treatment consists of removal of suspended solids and 5-day, 20°C BOD, which is the two usual parameters of prime interest.

PROCESS AND DISCRIPTION AT 20 MLD (S.T.P) BALKAPURNALA:

Hussain Sagar, the picturesque lake in the heart of Hyderabad was built during 1562 by Hazarath Hussain Sha Wali of the Qutub Shahi dynasty with a basin area of 240 Sq.Km to fulfil the drinking water requirements of the people. The water in the lake was reasonably good till 1976. Over the years, Hussain Sagar Lake has become polluted through entry of untreated sewage and industrial effluents through the nalas that flow into the lake. Other sources of pollution included cattle washing, vehicle washing, dumping of domestic solid waste along the shore line as well as the immersion of large numbers of Ganesh and Durga Idols during festivals containing paints, clay, gypsum and plaster of Paris, flowers and garlands.

Issues affecting the Hussain Sagar Lake: There are four major Nalas through which domestic sewage, industrial effluents and other debris enter the lake. These four nalas are:

1. Balkapur Nala
2. Banjara Nala
3. Kukatpally Nala
4. Picket Nala

Domestic sewage entering the lake contains levels of Nitrates and Phosphates beyond permissible limits, which promote the growth of algae/water hyacinth in the lake.

20 MLD S.T.P at Balkapur Nala have been constructed with the objective that only treated water with permissible limits of Nitrates & Phosphates and other nutrients enter the Lake

Activated sludge process: This is based on suspended growth process in which an adequate biological mass(aerobic bacteria) in suspension with in the tank, is maintained by either natural or mechanical mixing. Activated sludge process is an improved method of secondary treatment of the effluent from primary sedimentation tank. The sludge of the sewage which is previously agitated under aerobic conditions containing full of aerobic bacteria is called activated sludge. In the activated sludge process the primary effluent is mixed with activated sludge and then aerated so as to oxidize the organic matter and convert it into settle able flocs.

After removing the floating materials and screening in the screen chamber, the flow shall be taken to a 2 Nos. Grit channels constructed downstream of these coarse channels for removal of grit from screened water. Each grit channel is designed for 50% of peak flow. After grit removal, the flow shall be taken to existing 20 MLD STP area via 1000 diaRcc pipe line. Screening shall be disposed off daily through belt conveyor as per rules in practice. Grit shall be removed manually and disposed off as per the rules in practice

Screening: Screening is the first unit operation used at wastewater treatment plants (WWTPs). Screening removes objects such as rags, paper, plastics, and metals to prevent damage and clogging of downstream equipment, piping, and appurtenances. Some modern wastewater treatment plants use both coarse screens and fine screens..

Primary Clarifier: Primary clarifier systems may include both clarification and physical-chemical treatment equipment, depending on the components in the wastewater. Clarification, through the process of sedimentation is the separation of suspended particles by gravitational settling. This operation can be used for grit and solids removal in the primary settling basin, removal of oil and grease, removal of chemically treated solids when the chemical coagulation process is used or solids concentration in sludge thickeners. BOD and TSS removal or even prevent the growth of filamentous bacteria in the biological portion.

A Parshall flume is a fixed hydraulic structure used in measuring volumetric flow rate in surface water, wastewater treatment plant, and industrial discharge applications. The Parshall flume accelerates flow though a contraction of both the parallel sidewalls and a drop in the floor at the flume throat.

Anaerobic tank: Anaerobic tank is to be constructed for biological phosphorous removal under anaerobic conditions. This tank is to be fitted with 4nos. screw mixers to prevent settling of biomass. The mixers shall be under continuous operation and shall be manually operated. After anaerobic tank, the sewage shall be taken to aeration tank via 1000dia pipe line

Aeration tank: The aeration tank is divided in two parts 1) anoxic tank 2) aerobic tank

Anoxic tank: The anoxic tank has been fitted with mixers cum aerators (M04-02) so that the tank can be operated as anoxic or aerobic tank depending on plant performance for nitrogen removal. The mixers shall be under continuous operation (24hr/day) and shall be manually operated.

Aerobic tank: The aerobic tank will house twelve of existing sixteen surface aerators (aerator-1) and nine new aspirating type aerators (aerator-2). Aerator-1(existing surface aerators):Aerobic tank shall be provided with 12nos. surface aerators. The aerators shall be under continuous operation(24hr/day) and shall be manually operated. Aerator-2 (new aspirating type floating aerators)(M04-04):aerobic tank shall be provided with 9 nos. floating aerators. The aerators shall be under continuous operation (24hr/day) and shall be manually operated.

Coagulation: The process of adding certain chemicals for accelerating sedimentation and the effective removal of very fine and colloidal particles is known as coagulation. Alum is the most widely used coagulant in water treatment plants, as it is cheap, and can be easily stored and handled. However, it increases sulphate hardness and corrosiveness of water to a small extent and decreases pH range of water is 6 to 8. When Alum is added to water, it reacts with natural alkalinity in water and forms the aluminium hydroxide. If natural alkalinity is absent, it is necessary to add some lime to inculcate the reactions. The chemical reactions are

Sedimentation: The process of settling the suspended solids by virtue of gravity is known as "SEDIMENTATION"

Plain Sedimentation: In plain sedimentation suspended particles having specific gravity more than 1.2 settle to the bottom of the tank by virtue of gravity.

Decanter: When separator operation is no longer feasible due to high proportions of solids in the suspension to be processed, decanters are used. A CMF-S system includes six CMF-S Cells along with the ancillary process and control systems required to operate them. CMF-S Unit operation is controlled by the plc&scadasystem.once the cmf-s unit is running most operating sequences are automatically initiated by the plc as required by the process.

Disinfection: Treated sewage from sewage shall be taken to the disinfection tank via 450dia DI line. The disinfection tank inlet chamber is isolated by three gates. The isolation gate is to be used for bypassing the entire disinfection process & divert the flow to hussian sagar lake. The sewage can be taken to disinfection tank through isolation tank.

The filtered water from CMF is subjected to disinfection using sodium hypochlorite as disinfectant. This water is let into Hussian Sagar lake.

Analysis for Waste Water Treatment

1. pH principle:
2. Estimation of Total Solids (TS)
3. Estimation of Total Suspended Solids (TDS)
4. Estimation of Total Suspended Solids (TSS)
5. Estimation of Fixed & Volatile Solids
6. Chemical Oxygen Demand(COD) analysis method
7. Biological Oxygen Demand(BOD) analysis method
8. Dissolved Oxygen (DO) analysis method
9. Conductivity analysis method

Advantages

Balakapurnala is one of the water inlet to Hussain Sagar. By purification of water in Balkapurnala 20 MLD (STP), purified water can enter into Hussain Sagar. By this process to some extent water pollution in Hussain Sagar can be decreased and controlled. By this method oxygen content in the water is increased which is essential for aquatic life survival.

Disadvantages

During rainy season and floods flow of water gets increases heavly. When there is a overflow of water unpurified water mixs up with the purified ones and enter into Hussain Sagar. So entire purification gets wasted. This is frequently seen in rainy season.

CONCLUSION

Hussain Sagar is being poluted from many years and in wrost situation now. Water from the lake cannot be purified from taking it out. It is unimaginable. So the government has planned to send purified water into the lake. So that atleast after some years it comes into use. The water into lake enters through four nalas. One among them is Balkapur nala. Water is purified in many stages and used for different purpose. Water still remaining after usage is send into Hussain Sagar. Hussain Sagar has many inlets. If water from all inlets is the purified ones then after some years lake can be seen in good condition.

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A Study on Water Quality Monitoring in Naik Lake, Nagpur City, India

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ABSTRACT

The present study was carried out to assess the physico-chemical properties of Naik lake of Nagpur City, India. Lake is the support and reflection of any urban city or an area on which its economy and life depends. Water samples were collected from five sites of Naik lake pH, temperature, conductivity, total dissolved solids, total suspended solids, turbidity, alkalinity, chlorides, hardness, sulphate, nitrogen, phosphate, sodium, potassium, dissolved oxygen, chemical oxygen demand parameters were analyzed from the water samples of Naik lake. Dissolved oxygen values were found from 3.1 to 3.6 mg/L at five sampling sites of Naik lake. However, dissolved oxygen values found lower than desired values for lakes. Chemical oxygen demand values were ranged from 40 to 80 mg/L at five sampling sites of Naik lake. Nitrogen values were ranged from 90 to 117 mg/L at five sampling sites of Naik lake. High ranges of nitrogen values were found due to organic load in the Naik lake. pH, alkalinity, hardness of water samples were found high range due to carbonate and bicarbonate load. Henceforth, these results might increase the chance of damage of the aquatic eco-system. Governmental bodies should strictly deal with this issue for the sake of the health of the Naik lake.

Keywords: Water quality, Naik Lake, Dissolved oxygen, Chemical oxygen demand.

INTRODUCTION

Freshwater habitats occupy relatively a small part of the earth as compared to the marine environment. These water bodies are priceless assets of a nation which are constantly utilized for the different needs of the society such as drinking, irrigation, industrial usage, recreation and so on. Moreover, Freshwater water body like lake is the support of any urban city or an area on which its economy and life depends. Nowadays, the rapid industrial growth, rapid urbanization and increasing use of pesticides in agriculture constitutes some of the main factors responsible for various forms of pollution of water bodies like lakes. Lakes are also subjected to various natural processes taking place in the surroundings like the hydrologic cycle, with unprecedented development; human beings are guilty for destroying several lakes. The lakes and reservoirs, across India, are in changing degrees of environmental degradation, might be due to encroachments and eutrophication. However, in those lakes that could endure, drinking water supply is either substantially reduced or is non-potable, flood absorption capacity impaired, biodiversity threatened and there is diminished fish production. However, good quality of water is required for living organisms. The quality of water is described according to its physical, chemical and biological parameter. The biological study of water is helpful in problems like pollution control, the construction and renovation of dams or lakes, fish and aquatic life. The current paper deals with the water quality assessment of the Naik Lake of Nagpur city, India and its pollution status. The administration is not undertaking suitable conservation measures to sustain lake's recreational and aesthetic status for the residents of the city.

MATERIALs AND METHODS

Study sites

The study was conducted in Naik lake of Nagpur city (Figure 1). Naik lake is located at the latitude of 21°9'43"N and longitude 79°6'44"E in a dense locality of Nagpur, India. Naik lake is natural fresh water lake. Naik lake is practices for fishing. Naik lake contaminated because of human activities that intersect including traditional small-scale industries, domestic sewage, idol immersion and waste discharge. Therefore, Naik lake resulted to total degradation.

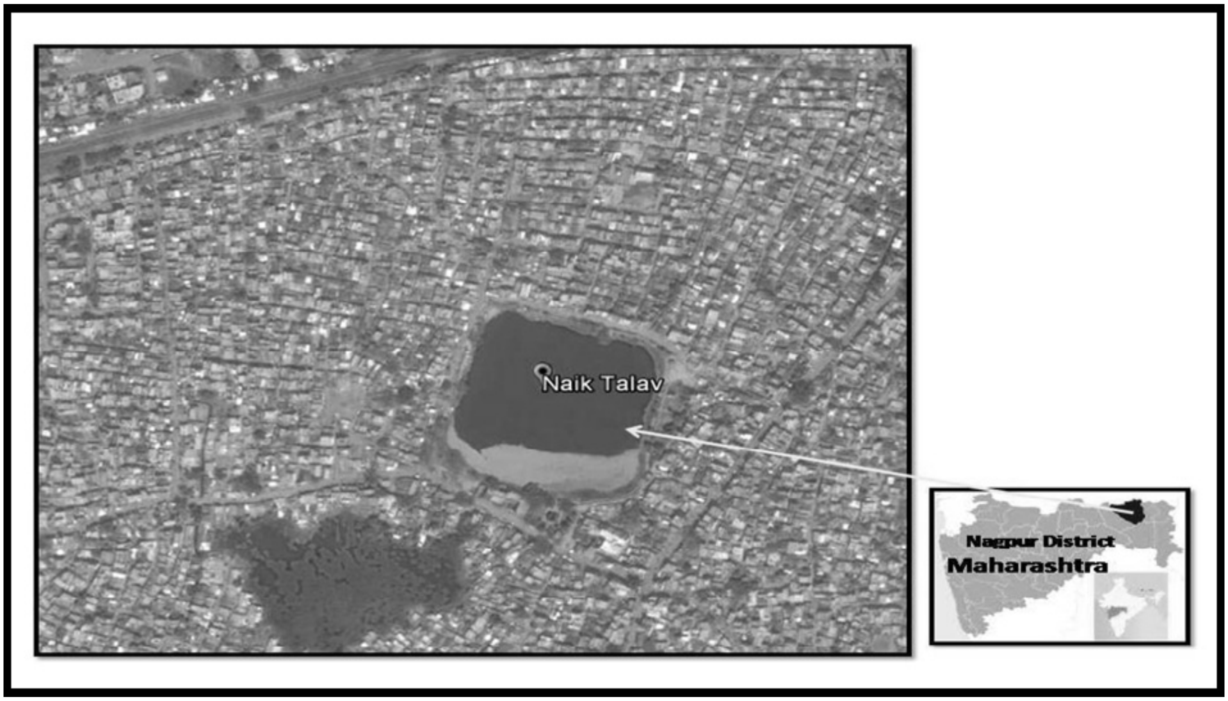

Fig. 1 The map shows the study location of Naik Lake of Nagpur district

Sample collection

Water samples were collected from five sites i.e. garden (east), temple (north), dumping zone (west), residential area (south) and centre of the Naik lake. Water samples were collected in sterilized sampling bottles, below 10 to 20 cm of the surface from study sites. Dissolved oxygen and temperatures were taken on study sites immediately after collection of water samples. All glassware and instrumentation used in this study were pre-washed with chromic acid and rinsed with deionized water.

Analysis of water samples

Water samples were subjected to analysis with the prescribed procedures of pH, Temperature, Conductivity, Total Dissolved Solids, Total Suspended solids, Turbidity, Alkalinity, Chlorides, Hardness, Sulphate, Nitrogen, Phosphate, Sodium, Potassium, Dissolved Oxygen (DO), Chemical Oxygen Demand (COD) (APHA 2005).

RESULTS AND DISCUSSION

Results for water samples of Naik lake were illustrated in Table 5.1 and Figure 2. pH ranged from 7.4 to 7.6 at five sampling sites of Naik lake. pH values were found acidic in Naik lake. pH is an important factor that determines the suitability of water for various purposes, including toxicity to animals and plants. Average water temperatures varied from 24 to 26 ^{o}C at five sampling sites. The temperature of water is one vital parameter which directly controls some chemical reaction in aquatic ecosystem. The significant correlation between ambient temperature and water temperature was studied by Ganapati, 1943. Electric conductivity values were ranged from 528 to 574 µs/cm at five sampling sites of Naik lake. Electrical conductivity values mainly depend on ionic concentration or dissolved inorganic substance. In study, water samples of all study sites of Naik lake exhibited higher values. The common source of solids in lakes are rain and wind erosion of soil surfaces along with municipal and industrial waste waters also originated from domestic wastes, road run off and industrial process. Total solids in all study sites of Naik lake showed lowest value at sites 4 and 5 (800 mg/L). Highest values were found at sites 2 and 3 (1200 mg/L). Generally, in lake, the turbidity is increased due to clay, silt, organic matter and phytoplankton. However, in current study, turbidity values were found 1 to 2 NTU in all five sites of Naik lake that were found lower as per the permissible limit <5 NTU (APHA,2005).

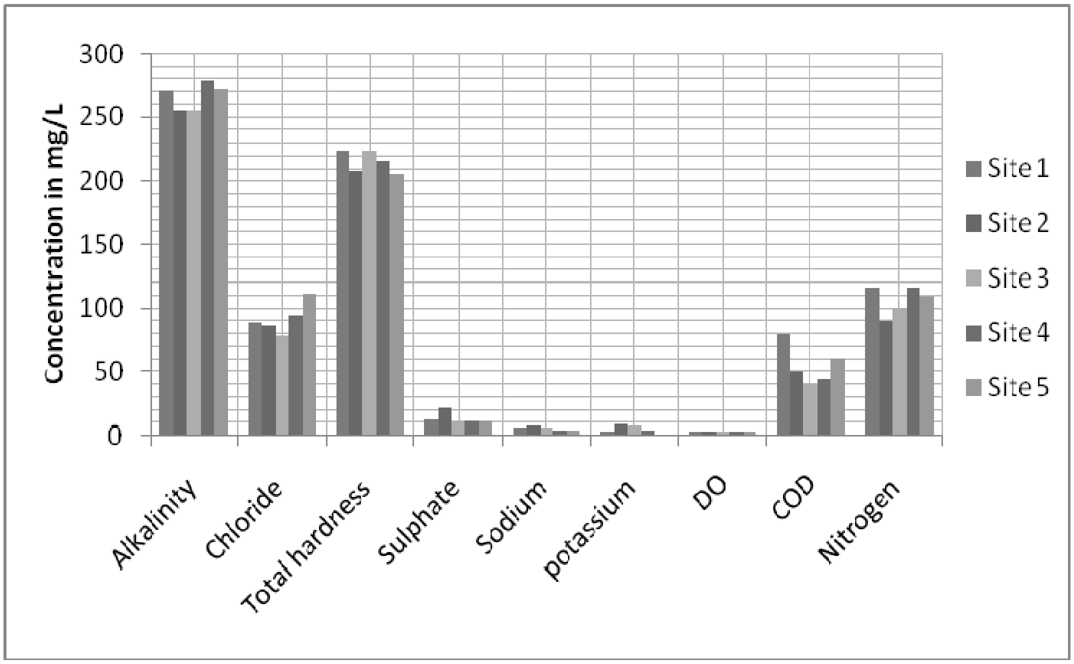

Fig. 2 Concentrations of water quality parameters of water samples in different sites of Naik lake

Alkalinity values ranged from 255 to 279 mg/L at five sampling sites of Naik lake. The high ranges of alkalinity were found due to hydroxide, carbonates and bicarbonates. Alkalinity of water is its capacity to neutralize acid and is characterized by the presence of hydroxyl (OH^-) ions capable of combining with hydrogen (H^+) ions in solution (Kaushik and Saksena, 1999). Chloride values were found from 79 to 112 mg/L at five sampling sites of Naik lake. The high values of chloride in Naik Lake might be due to dumping of large amount of organic matter, bathing activities, urination, faces and wastes of animals (Mathur et al., 2008). Total hardness values were found from 206 to 224 mg/L, indicated hard water in Naik Lake. The hardness of water of Naik lake might be due to the occurrence of high quantity of calcium, magnesium, sulphate and nitrate in Naik lake (Patel and Singh, 1998). Sulphate values were found from 11 to 22 mg/L at five sampling sites of Naik lake. The sulphate ions in Naik lake might be occurred from the sources of industrial effluent, discharged unit and lake discharges. Sodium values were ranged from 5 to 8 mg/L at five sampling sites of Naik lake. Potassium values were ranged from 5 to 8 mg/L at five sampling sites of Naik lake. Dissolved oxygen values were found from 3.1 to 3.6 mg/L at five sampling sites of Naik lake. The low DO values might be due to the process of decomposition of organic matter involve in the utilization of oxygen (Jameel, 1998). Chemical oxygen demand values were ranged from 40 to 80 mg/L at five sampling sites of Naik lake. The sources of COD in study lake might be due to contribution of domestic discharges and use of soap and detergents for washing of clothes at sites of Naik lake (Mathur et al. 2008). Nitrogen values were ranged from 90 to 117 mg/L at five sampling sites of Naik lake. The high values of Nitrogen might be to high rate of decomposition of organic matter. Phosphate values were ranged from 0.01 to 0.06 mg/L at five sampling sites of Naik lake. Phosphate values were found below permissible limit of 0.5 mg/L.

CONCLUSION

Water quality parameters have been analyzed from five sites of Naik Lake, Nagpur. All the parameters were found within permissible limits. However, dissolved oxygen values found lower than desired values for lakes. Water samples were found hard might be due to carbonates and bicarbonates load in the lake. COD values were found in high range might be due to contribution of domestic discharges and use of soap and detergents for washing of clothes at sites of Naik lake. Henceforth, this increases the chance of damage of the aquatic eco-system and also public health. Governmental bodies should strictly deal with this issue for the sake of the health of the Naik lake.

Table 1 Physico-chemical characteristics of Naik Lake, Nagpur

Parameters	Site 1	Site 2	Site 3	Site 4	Site 5	Average
pH	7.5	7.5	7.6	7.4	7.6	7.52
Temperature (^oC)	25	25	26	25	24	25
Electric conductivity (µs/cm)	574	528	544	554	550	550
Total solids (mg/L)	1000	1200	1200	800	800	1000
Turbidity (NTU)	2	1	2	2	1	1.6
Alkalinity (mg/L)	271	255	255	279	273	266.6
Chloride (mg/L)	89	87	79	95	112	92.4
Total hardness (mg/L)	224	208	224	216	206	215.6
Sulphate (mg/L)	13	22	12	11	11	13.8
Sodium (mg/L)	7	8	7	5	5	6.4
potassium (mg/L)	3	9	8	5	1	5.2
Dissolved oxygen (mg/L)	3.5	3.6	3.5	3.1	3.2	3.38
Chemical oxygen demand (mg/L)	80	50	40	45	60	55
Nitrogen (mg/L)	117	90	101	117	110	107
Phosphate (mg/L)	0.06	0.02	0.01	0.02	0.02	0.026

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Assessment of the Water Quality of Hussain Sagar, Fox Sagar and Kattamysamma Lakes of Hyderabad City, Telangana State, India, using Physico-chemical Parameters

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ABSTRACT

The objective of the present study is to assess the water quality of three lakes of Hyderabad city, Telangana State, India viz., Hussain Sagar, Fox Sagar and Kattamysamma Lakes using physico-chemical parameters. For this study systematic sampling has been carried out by collecting sixteen samples from each lake at different locations which covers the entire lake. The collected samples were analyzed for physico-chemical parameters like pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Total Alkalinity (TA), Sodium (Na^+), Potassium (K^+), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Nitrates (NO_3^{2-}), Sulphates (SO_4^{2-}), Fluoride (F^-) and Chloride (Cl^-) according to Standard Methods for the Examination of Water and Wastewater (APHA 2005) and Central Pollution Control Board (CPCB) Guide manual: Water and Waste water analysis. Mean values were taken for interpretation and compared with drinking water quality guidelines (BIS 2012). It indicated that the most of the physico-chemical parameters exceeded the acceptable limit. This is due to various anthropogenic activities like urbanization, industrialization, discharge of domestic sewage, untreated industrial effluents and immersion of multicolored idols of Gods and Goddess made up of Plaster of Paris (PoP)

Keywords: Water Quality, Physico-chemical parameters, Systematic sampling, anthropogenic activities, Industrial effluents.

INTRODUCTION

Water - the main source of life and one of the most important natural resource of the ecosystem. A lake is a large body of water surrounded by land, inhabited by various aquatic life forms. Lakes are important feature of the Earth's landscape which are not only the source of precious water, but provide valuable habitats to plants and animals, moderate hydrological cycles, influence microclimate, enhance the aesthetic beauty of the landscape and extend many recreational opportunities to humankind (Ramesh. N. and Krishnaiah., 2013). They also play an equally important role in flood control (Y. J. An., et. al., 2002). The urban lakes are important in maintaining the surface and ground water balance, in maintaining urban ecosystem apart from its uses for different purposes namely recreational, water supply, fishing etc. (Sanyogita R. Verma, et.al, 2011). Deterioration of surface water quality and especially lake water quality has recently observed in many aquatories. The water quality of urban lakes has deteriorated so much as to cause serious disturbance to the biodiversity of the lake environment. The quality of lake water may vary depending on the geological morphology, vegetation and activities in the catchment basin, as well as on the location of the sampling site (N. Gantidis et. al., 2007). In developing countries like India, urban lakes become sinks of untreated, partially treated municipal sewage and industrial effluents. Most of the urban surface water bodies are found to be polluted due to rapid population growth, urbanization and industrialization. Nonpoint sources of such contamination include domestic and wild animal defecation, malfunctioning sewage and septic systems, storm water drainage and urban runoff, while point sources include as industrial effluents and municipal wastewater treatment plants (Kistemann et al. 2002; Albek 2003; Okoh et al.2007; Igbinosa and Okoh 2009; Odjadjare and Okoh 2010).

The present study aims at analyzing the water quality in terms of physico-chemical parameters of three different lakes viz., Hussain Sagar, Fox Sagar and Kattamysamma Lake of Hyderabad city, Telangana State, India.

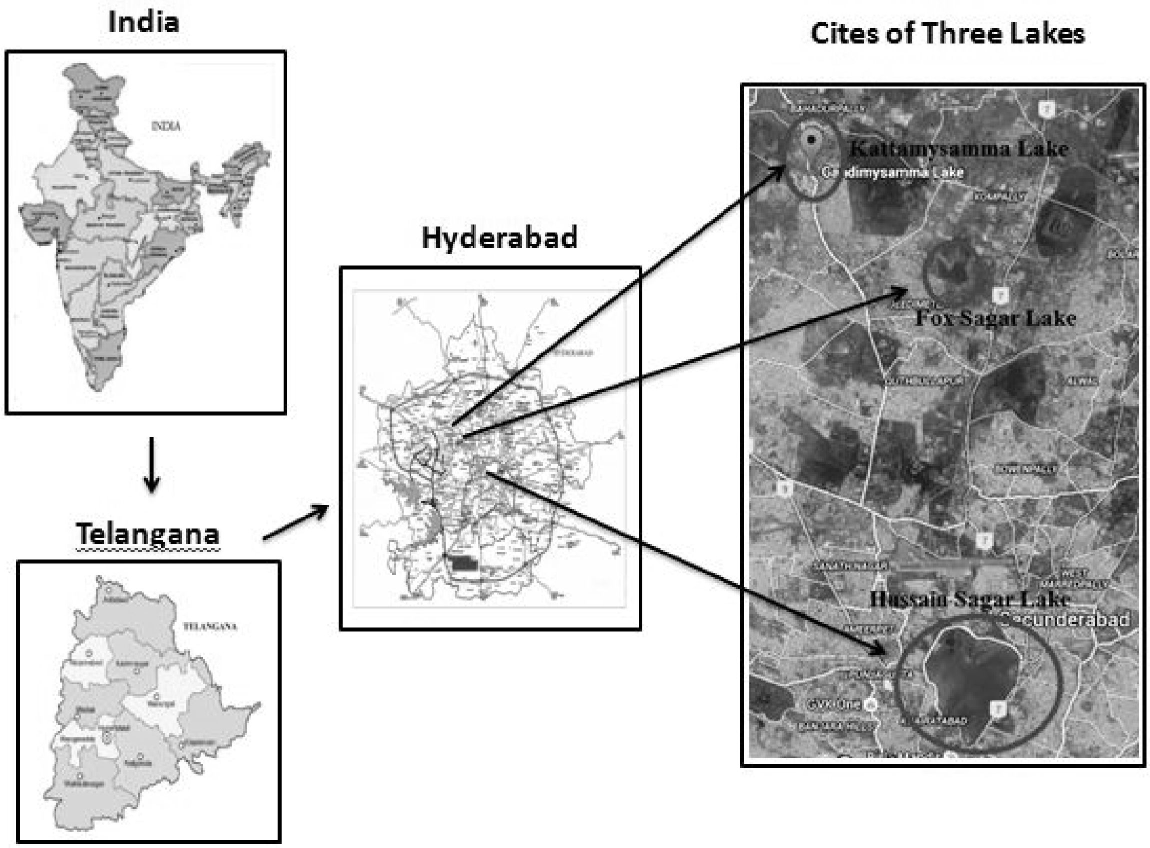

Fig. 1 Location map of the study area

MATERIALS AND METHODOLOGY

Study area

In the present study three lakes of Hyderabad city were selected viz., Hussain Sagar, Fox Sagar and Kattamysamma Lake (Figure.1). Hussain Sagar Lake is located 17°25’22”N, 78°28’28”E, situated between the twin cities of Hyderabad and Secunderabad. It is an ecological and cultural landmark in Hyderabad, built in 1562 AD during reign of Quali Qutub Shah (1550-1580). Fox Sagar Lake, its local name is Jeedimetla cheruvu or Kolla Cheruvu which is the fifth largest lake in India spreading about 2 km^2. Situated (17°30’–17°20’N and 78°30’–78°20’E) 1 km west of Hyderabad-Nizamabad road at Jeedimetla near Kompally, Hyderabad ((Lingaswamy. et.al. 2015). Kattamysamma Lake is also known as Gandimysamma Lake situated between 17°33’–17°42’N and 78°26’–78°20’E near Medak highway in Sooraram, Hyderabad. n the present study systematic sampling (sixteen samples from each lake which covers entire lake) was carried during the monsoon season (September-October) in the year 2014.

Study of Physico-chemical properties

The physico-chemical parameters were analyzed as per the standard procedures recommended by American Public Health Association (APHA); Standard Methods for Examination of Water and Wastewater (APHA, 2005) and Central Pollution Control Board (CPCB) Guide manual: Water and Waste water analysis.

RESULTS

The values of the various physico-chemical parameters of water samples of three lakes were presented in Table 1 and compared with quality guidelines for drinking purpose (BIS, 2012) which were presented in Table.2.

Table 1 Physico-chemical parameters data of three lakes

Parameters		Hussain Sagar Lake	Fox Sagar Lake	Kattamysamma Lake
pH	Min	7.9	7.5	7.3
	Max	8.3	8.2	7.9
	Mean	8.0	7.7	7.5
EC (µS/cm)	Min	1400	1047	1289
	Max	1680	1467	1633
	Mean	1506	1313	1421
TDS (mg/L)	Min	896	670	825
	Max	1075	939	1045
	Mean	964	840	910
TH (mg/L)	Min	205	245	198
	Max	220	395	402
	Mean	214	281	345
TA (mg/L)	Min	415	158	280
	Max	555	775	410
	Mean	467	342	347
Na^+ (mg/L)	Min	91	117	110
	Max	118	199	140
	Mean	96	165	131
K^+ (mg/L)	Min	15	1	12
	Max	20	16	21
	Mean	18	13	15
Ca^{2+} (mg/L)	Min	90	36	115
	Max	158	104	152
	Mean	134	53	129
Mg^{2+} (mg/L)	Min	16	32	6.1
	Max	28	40	30
	Mean	20	36	20
NO_3^{2-} (mg/L)	Min	66	10	14
	Max	84	18	69
	Mean	72	14	28
SO_4^{2-} (mg/L)	Min	60	21	100
	Max	127	73	135
	Mean	77	39	123
F^- (mg/L)	Min	1.5	1.7	0.9
	Max	1.9	3.3	1.3
	Mean	1.7	1.9	1.02
Cl^- (mg/L)	Min	238	469	220
	Max	298	646	302
	Mean	270	600	268

Table 2 Comparison of physico-chemical parameters with Water quality guidelines for drinking purpose (BIS 2012)

Parameters	BIS (2012)	Hussain Sagar Lake	Fox Sagar Lake	Kattamysamma Lake
pH	6.5-8.5	Acceptable	Acceptable	Acceptable
EC	1500	Exceeded	Acceptable	Acceptable
TDS	500	Exceeded	Exceeded	Exceeded
TH	200	Exceeded	Exceeded	Exceeded
TA	200	Exceeded	Exceeded	Exceeded

Contd…

Parameters	BIS (2012)	Hussain Sagar Lake	Fox Sagar Lake	Kattamysamma Lake
Na^+	200	Acceptable	Acceptable	Acceptable
K^+	-	-	-	-
Ca^{2+}	75	Exceeded	Acceptable	Exceeded
Mg^{2+}	30	Acceptable	Exceeded	Acceptable
NO_3^{2-}	45	Exceeded	Acceptable	Acceptable
SO_4^{2-}	200	Acceptable	Acceptable	Acceptable
F^-	1.0	Exceeded	Exceeded	Acceptable
Cl^-	250	Exceeded	Exceeded	Exceeded

DISCUSSION

pH

In the present study, pH of Hussain Sagar ranges from 7.9-8.3 with a mean value of 8.0, Fox Sagar ranges from 7.5-8.2 with a mean value of 7.7 and Kattamysamma Lake ranges from 7.3-7.9 with a mean value of 7.5. Water quality guidelines for drinking purpose (BIS 2012) acceptable pH is 6.5-8.5. It indicates that, all the lakes water samples were found to be within the acceptable limit and alkaline in nature.

Electrical Conductivity (EC)

EC of Hussain Sagar ranges from 1400-1680 µS/cm with mean value of 1506, Fox Sagar ranges from 1047-1467 µS/cm with a mean value of 1313 µS/cm and Kattamysamma Lake ranges from 1289-1633 µS/cm with a mean value of 1421 µS/cm. Water quality guidelines for drinking purpose (BIS 2012) acceptable limit is 1500 µS/cm. It indicates that the EC of Hussain Sagar exceeded the acceptable limit, whereas EC of Fox Sagar and Kattamysamma Lakes were found to be within the acceptable limit. High EC values indicate the presence of high amount of dissolved inorganic substances in ionized form (M. Prasad., et.al 2014). High concentration of municipal water and anthropogenic activities are responsible for the increase of ionic content which results in the increased level of Conductivity (Imran Mithani., et.al 2012).

Total Dissolved Solids (TDS)

In natural water, dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, sulphates, phosphates, nitrates, calcium, magnesium, sodium, potassium, iron and manganese etc[13]. In the present study, TDS of Hussain Sagar ranges from 896-1075 mg/L with mean value of 964, Fox Sagar ranges from 670-939 mg/L with a mean value of 840 mg/L and Kattamysamma Lake ranges from 825-1045 mg/L with a mean value of 910 mg/L. Water quality guidelines for drinking purpose (BIS 2012) acceptable limit is 500 mg/L. It indicates that, all the three lakes water samples were found to exceed the acceptable limit. TDS were high due to discharge of untreated municipal sewage and industrial waste water into these lakes and salts used for road de-icing.

Total Hardness (TH)

Total Hardness of water is the sum of the concentration of alkaline earth metal cations. In the present study, TH of Hussain Sagar ranges from 205-220 mg/L with mean value of 214 mg/L, Fox Sagar ranges from 245-395 mg/L with a mean value of 281 mg/L and Kattamysamma Lake ranges from 198-402 mg/L with a mean value of 345 mg/L. Water quality guidelines for drinking purpose (BIS 2012) acceptable limit is 200 mg/L. It indicates that, all the three lakes water samples were found to exceed the acceptable limit. The high value of TH is due to disposal of untreated or improperly treated sewage, industrial effluents and Ca^{2+} and Mg^{2+} salts used for different anthropogenic activities.

Total Alkalinity (TA)

TA of Hussain Sagar ranges from 415-555 mg/L with mean value of 467 mg/L, Fox Sagar ranges from 158-775 mg/L with a mean value of 342 mg/L and Kattamysamma Lake ranges from 280-410 mg/L with a mean value of 347 mg/L. Water quality guidelines for drinking purpose (BIS 2012) acceptable limit is 200 mg/L. It indicates that, all the three lake water samples were found to exceed the acceptable limit. Alkalinity in the lake waters is caused by the release of waste water containing high caustic from industries (M.S. Nagaraja Gupta and C. Sadashivaiah., 2012).

Sodium (Na^+)

Na^+ values of Hussain Sagar ranges from 91-118 mg/L with mean value of 96 mg/L, Fox Sagar ranges from 110-199 mg/L with a mean value of 165 mg/L and Kattamysamma Lake ranges from 117-140 mg/L with a mean value of 131 mg/L. Water quality guidelines for drinking purpose (BIS 2012) acceptable limit is 200 mg/L. All the three lake water samples were found to be within the acceptable limits.

Potassium (K^+)

K^+ of Hussain Sagar ranges from 15-20 mg/L with mean value of 18 mg/L, Fox Sagar ranges from 1.0-16 mg/L with a mean value of 13 mg/L and Kattamysamma Lake ranges from 12-21 mg/L with a mean value of 15 mg/L.

Calcium (Ca^{2+})

Ca^{2+} of Hussain Sagar ranges from 90-158 mg/L with mean value of 134 mg/L, Fox Sagar ranges from 36-104 mg/L with a mean value of 53 mg/L and Kattamysamma Lake ranges from 115-152 mg/L with a mean value of 129 mg/L. Water quality guidelines for drinking purpose (BIS 2012) acceptable limit is 75 mg/L. It indicates that, Hussain Sagar and Kattamysamma Lakes waters were found to exceed the acceptable limit. High Ca^{2+} is due to discharge of sewage, industrial effluents (Sobha.V et.al.2009) and immersion of Gods and Goddess idols made by Plaster of Paris (POP).

Magnesium (Mg^{2+})

Mg^{2+} values of Hussain Sagar ranges from 16-28 mg/L with mean value of 20 mg/L, Fox Sagar ranges from 32-40 mg/L with a mean value of 36 mg/L and Kattamysamma Lake ranges from 6.1-30 mg/L with a mean value of 20 mg/L. Water quality guidelines for drinking purpose (BIS 2012) acceptable limit is 30 mg/L. It indicates that, the samples of Fox Sagar exceeded the acceptable limit. The main sources of Mg^{2+} ions are sewage inflows and minerals such as dolomite, Mg $(CO_3)_2$ which are present as a result of soil erosion in the catchment of Fox Sagar.

Nitrates (NO_3^{2-})

NO_3^{2-} of Hussain Sagar ranges from 66-84 mg/L with mean value of 72 mg/L, Fox Sagar ranges from 10-18 mg/L with a mean value of 14 mg/L and Kattamysamma Lake ranges from 14-69 mg/L with a mean value of 28 mg/L. Water quality guidelines for drinking purpose (BIS: 2012) acceptable limit is 45 mg/L. It indicates that, Hussain Sagar water samples were found to exceed the acceptable limit. Discharge of domestic sewage and industrial effluents which contain nitrates causes nitrate pollution of Hussain Sagar Lake.

Sulphates (SO_4^{2-})

SO_4^{2-} of Hussain Sagar ranges from 60-127 mg/L with mean value of 77 mg/L, Fox Sagar ranges from 21-73 mg/L with a mean value of 39 mg/L and Kattamysamma Lake ranges from 100-135 mg/L with a mean value of 123 mg/L. Water quality guidelines for drinking purpose (BIS 2012) acceptable limit is 200 mg/L. It indicates that, all the three lakes water samples were found to be within the acceptable limit.

Fluoride (F^-)

F^- of Hussain Sagar ranges from 1.5-1.9 mg/L with mean value of 1.7 mg/L, Fox Sagar ranges from 1.7-3.3 mg/L with a mean value of 1.9 mg/L and Kattamysamma Lake F^- values ranges from 0.9-1.3 mg/L with a mean value of 1.02 mg/L. Water quality guidelines for drinking purpose (BIS 2012) acceptable limit is 1.0 mg/L. It indicates that, all the three lakes water samples were found to exceed the acceptable limit. Discharge of industrial effluents responsible for high fluoride concentration in these lakes.

Chloride (Cl^-)

Cl^- of Hussain Sagar ranges from 238-298 mg/L with mean value of 270 mg/L, Fox Sagar ranges from 469-646 mg/L with a mean value of 600 mg/L and Kattamysamma Lake ranges from 220-302 mg/L with a mean value of 268 mg/L. Water quality guidelines for drinking purpose (BIS 2012) acceptable limit is 250 mg/L. It indicates that, all the three lakes water samples were found to exceed the acceptable limit. High concentration of chloride is considered to be the indicator of pollution due to organic wastes of animal or industrial origin (Ombaka, O., et.al 2013).

CONCLUSION

Most of the physico-chemical parameter's mean values have exceeded the acceptable limit. It is due to the discharge of untreated and partially treated municipal sewage, industrial effluents into the lakes. It can also be due to the religious activities like immersion of thousands of multicolored idols of Lord Ganesh and Goddess Durga made up of Plaster of Paris (PoP) have caused the pollution of these three lakes.

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THEME - VI

Augmentation of Water Supply for Minor Irrigation Tank by Lifting Water from Somasilla Back Water - A Case Study Kadapa District

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ABSTRACT

Irrigation may be defined as the process of artificially supplying water to soil for raising crops. Generally crops are being raised depending on rainfall. Due to insufficient rainfall, the need araised for irrigation. Irrigation is being done in two methods. Surface Irrigation, Lift Irrigation. Surface irrigation will take place when the water is available it higher level than the fields. This will be done through the canals. When the fields are at higher levels and when the water is flowing at lower level, we have to go for lift irrigation. Vontimitta Lift Irrigation project is intended for providing irrigation to the uplands about 1014 acres, and to provide drinking water to 17 villages in Vontimitta and Siddhaout (M) of Kadapa District, Andhra Pradesh. This lift irrigation project is taken up by AP State Irrigation Development Corporation and is planning to commission during March, 2016. The head works of the project is located 40 kms from Kadapa district head quarters. It is proposed to draw 0.18TMC water from Somasila reservoir in this paper. To study various components of the lift irrigation project and to study the performance of the project.

INTRODUCTION

Irrigation may be defined as the process of artificially supplying water to soil for raising crops. It is a science of planning and designing an efficient, low cost, economic irrigation system tailored to fit natural source of water, by the construction of dams and reservoirs, canals and head works and finally distributing the water to the agriculture fields .irrigation engineering includes the study and design of works in connection with river control, drainage of water logged areas and generation of hydro electric power. India is basically agricultural country, and all its resources depend on the agricultural output. Water is evidently the most vital element the plant life. Water is normally supplied to the plants by nature through rains. However, the total rainfall in a particular area may be either in sufficient. In order to get the maximum yield, it is essential to supply optimum quantity of water, and to maintain correct timing of water. This is possible only through a systematic irrigation system-by collecting water during the periods of excess rainfall and releasing it to the crop as when it is needed thus the necessity of irrigation can be summarized in the following four points. When the total rainfall is less than needed for crop , artificial supply is necessary in such a case , irrigation work may be constructed at a place where more water is available , and then to convey the water the area where there is deficiency of water. The rainfall in a particular area may not be uniform over the crop period. During the early period of the crop, rains may be there, but no water available at the end, with the result that either the yield may be less, or the crop may die together. The rainfall in a particular area may be sufficient to raise the usual crop , but more water may be necessary for raising commercial and cash crops .By the construction of proper distribution system, the yield of the crop may be increased.

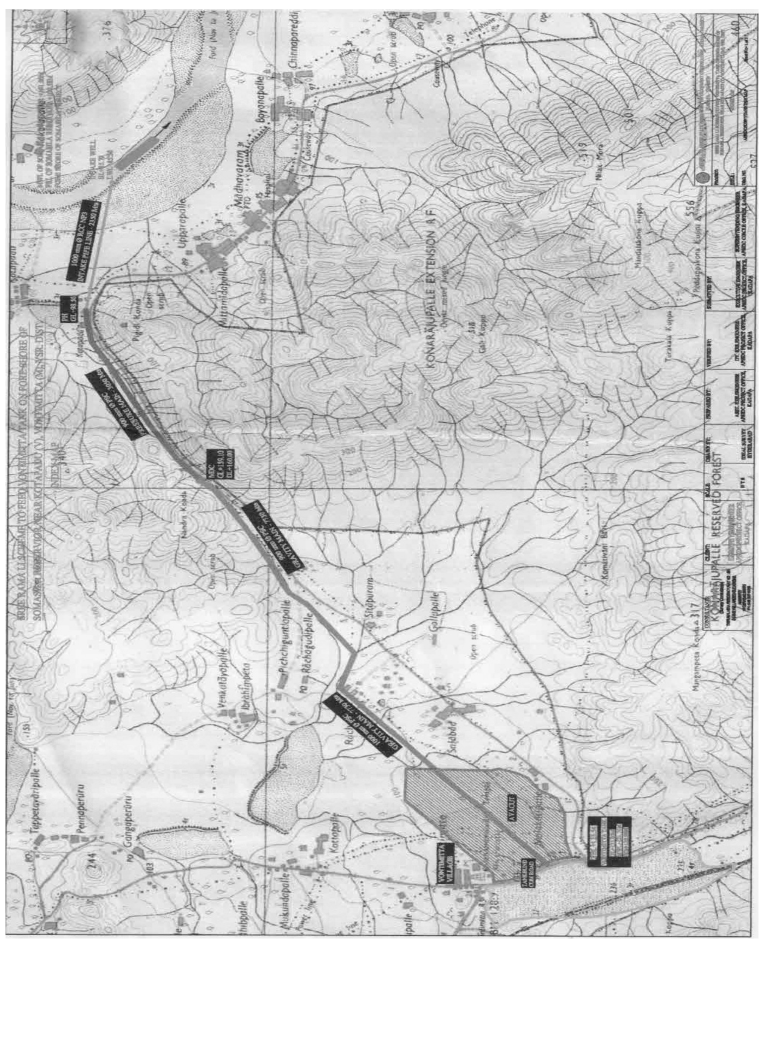
Cuddapah district Is one of the recurring drought effected districts of the Andhra Pradesh the district receives very little rainfall during mansoon. Therefore there is a great need to make use of available water sources properly and efficiently to the fullest extent for irrigation and other purposes .The sources like ground water and sub surface water can be extracted through tube wells, bore wells and infiltration wells the surface source of water can be used through construction of dams and reservoirs and canal system and lift irrigation system. In lift irrigation and canal system the surface source like lakes, rivers small vagu etc., can be used and water will be lifted to be elevated points for irrigating uplands through canal system. A small lift irrigation scheme is proposed on kotapadu village on penna river in Kadapa district the global coordinates are as follows 79-06-29, 14-26-15.,this is lift irrigation scheme is proposed to irrigate an AYACUT 1014 acres in the upland area by making use surplus water in Vontimitta mandal. The drinking water supply to 17 NO. of surrounding villages of Vontimitta and Sidhout mandals having about 4400 population.

OBJECTIVES

- Engineering survey.
- Detailed study of project.
- Design aspects of Lift Irrigation scheme.

STUDY AREA

Vontimitta Lift Irrigation Scheme has been envisaged to lift 0.18 TMC of back water of Somasila to irrigate about 1014 acres in the upland areas covering parts of 17 villages of vontimitta and siddhout mandals. APSIDC undertaking was entrusted with the work of detailed investigation and preparation of detailed project report and approval of state government. After detailed study and investigation, considering the factors like total water availability, irrigable land, cropping pattern, method of irrigation four alternatives of Vontimitta Lift Irrigation Scheme were evolved duly considering the cost criteria, B.C. Ratio, I.R.R. etc., After the detailed examination of techno economic evaluation of the four options by the working group in detail and after detailed deliberations, it was recommended to adopt the B1 alternative. The Scheme (Alternative B1) was also examined at Government level and the proposed alternative is accepted in principle. The LI Scheme is to stabilize the ayacut under Vontimitta MI Tank having an extent of 1014 acres and also to augment the Drinking water supply to 17 Nos. of surrounding villages of Vontimitta and Sidhout Mandals having about 44000 population. The APSIDC has initiated the Hydrological Proposals and as per the directions of the Government, the competent authorities have accorded Hydrological Clearance vide Proc.No. DSC-II/OT1/T1/KDP/Vontimitta LIS /2015, dt 24.03.2015 to lift 0.182TMC of water from the back waters of Somasila Project near Kotapadu village of Vontimitta Mandal to stabilize the ayacut of 1014 acres under Vontimitta MI Tank and to augment the drinking water supply to 17 Nos. of surrounding villages of Vontimitta and Sidhout Mandals The proposed site of head works of Vontimitta L.I. Scheme on back water of Somasila Reservoir is situated near Kotapadu Village in Vontimitta Mandal. The site is about 40 Kms from Kadapa District head quarters. The global co-ordinates are 79° - 06'–29", 14°-26' – 15".



METHODOLOGY

Preliminary survey

The reconnaissance report for a major project shall be initiated by the S.E. The reconnaissance report in respect of medium and minor projects shall be initiated by the E.E. and the S.D.O. respectively. On receipt of orders of the competent authority, the survey estimate for carrying out detailed investigations shall be prepared by the S.D.O. and submitted to the higher authorities for obtaining administrative approval. Master plan of the basin shall be prepared by the C.E. in charge of the basin. Investigation of any project not included in master plan shall be taken up only after obtaining approval of the State Government.

Intake Well

This is a civil structure required for guiding the water in the sump well / jacks well. In some cases, this structure is necessary even for small schemes to take care of water level fluctuations in the river. It also provides silt free water for the pumping operations. However, for small lift schemes, this need not be insisted upon. Many times in water distribution network because the pressures could be very low and we have to meet that minimum seven meters of head of residual pressure and we need to boost up these pressures so the pumping is also required to boost up pressures in water distribution networks in certain cases.

Intake Pipeline

While submitting detailed project report as per directions of higher officials and with the concurrence of Somasila Project Officials the water is to be drawn from Somasila Reservoir during lean flows in Penna River for that purpose the intake well is located at +85.40M level in the main course of Penna River. The Intake pipeline is to be laid for a total length of 2350 mts from Intake well point but due to restriction of the amount provided in the GO.No.207, the intake pipeline was provided up to 1060 mts only and the balance length was provided with open channel.

Jack well

This is called a jack well and here we keep the pump house not inside the river away from the river on the banks not too far away but slightly away from the banks. In this case here you have this intake structure, now this intake structure is placed much below the low water levels so that water can enter in the well even during the low flow season. Here this is the intake pipe (Refer Slide Time: 6:50) and there is a screen here which screens the debris from entering into the intake well or jack well and we have a pump here which has a foot valve. Basically this foot valve is required for priming of the pump and this foot valve or the low end of this suction pipe should be below the river water level.

Pressure Main

All pipe and fittings for Sewer Pressure Mains are as for the Water Supply System, therefore all pipe and fittings (<DN200) listed in the Authorised Items for Water Reticulation System Catalogue are authorised for use**.** Where a PVC pipe system is selected for a pumping main the requirements for the pumping main including class of pipe and all required fittings are to be determined by the designer and detailed on the endorsed design drawings. Only Oriented PVC (PVC-O) and Modified PVC (PVC- M) shall be used for Pressure Mains.

Main Delivery Cistern

Main Delivery cistern is proposed with 6.0mtrs internal dia. The cistern is proposed with 0.30mtrs thick M20 concrete Mat foundation over 0.20 mtrs thick CC (1:4:8) leveling course & 0.20 mtrs thick sand filling as per site condition. The cistern is proposed with 0.30mtrs thick steining walls

Gravity Main

A gravity fed system function thanks to the gravity. Gravity is a force which attracts all objects on the earth surface, due to the attraction exerted by the planet's mass. It is this force which makes that all bodies or things always fall at the lowest point (for example, a mango which falls from a tree). It is thus by gravity that the water stored in tank goes down by its own weight inside the pipes and run out from the taps. But this system works only if the pipes and taps are at a lower level than the water level at the starting point.

Vertical Pumps

Vertical turbine pump [deep well turbine pump] is vertical axis centrifugal or mixed flow type pump comprising of stages which accommodate rotating impellers and stationary bowls possessing guide vanes. These pumps are used where the pumping water level is below the limits of Volute centrifugal pump. They have higher initial cost and are more difficult to install and repair. The pressure head developed depends on the diameter of impeller and the speed at which it is rotated. The pressure head developed by single impeller is not great. Additional head is obtained by adding more bowl assemblies or stage.

Pump element

It consists of propelling shaft, usually made of stainless steel and bronze impellers. Water enters the pump through a screen located between motor and the pump.

Electric Motor

The motor is enclosed in steel case filled with light oil of high electric strength. A mercury seal placed directly above the amateur prevents oil leakage or water entrance at point where the drive shaft passes through the case to the impellers

Pump House

The 10.00 m circular pump house is proposed over jack well with 0.23 thick brick masonry walls to accommodate 3 Nos of pump sets, valves, 350 mm dia delivery pipes and working space, etc., Separate panel room of size 9.0x9.0 mts is proposed to accommodate three numbers of panel boards, soft starters and capacitors bank etc. A framed structure in M20 concrete with columns size 0.30 x 0.30mt and beams at lintel level, above lintel and roof level are proposed

RESULTS AND DISCUSSIONS

From engineering survey the following results are obtained given below.

1.	Ayacut	:	1014 Acres
2.	Source	:	On forshore of Somasila Reservoir near Kotapadu Village
3.	Location	:	Near Kotapadu village (Head Works)
4.	Longitude	:	79° - 06' –29" Latitude 14° -26' – 15".
5.	Basin/ Sub basin	:	Penna
6.	Type of soils with respect to supply of water application efficiency	:	Black cotton red soils suitable for raising paddy under MI tank
7.	Land Slope %	:	1 in 1000
8.	Duty designed (Supplementation)	:	45 acres per cusecs
9.	Designed discharge day for irrigating crops + 6.5 cusecs	:	28.5 Cusecs @ 12 hours pumping / for storage of drinking water purpose
10.	Minimum water level in the source	:	+ 85.50
11.	Deepest bed level of the source at Offtake point	:	+ 84.60
12.	Deepest bed level of the source at 200m either side of the Offtake point U/S	:	+ 85.60
	D/S	:	+ 84.00
	12 G.L. at the end of gravity main at Vontimitta tank bund	:	123.540
13.	FTL of Vontimitta tank	:	120.98
14.	MWL of Vontimitta tank	:	121.70
15.	Delivery level at end of gravity main	:	123.70

Detailed Study of Each Component

Intake Well

An Intake Well of 3.00M internal dia with Steining thickness of 0.20M in M20 concrete is proposed to draw water from river at LWL of 85.50 and to hold the Intake pipe. A Trash Rack of size 2.25 m x 2.25 m at the entrance of the Intake pipe is proposed to avoid the entry of debris and other foreign materials etc.

Intake Pipeline

The Intake pipe line of 1060 Mt length from Jack well is proposed with 1000 mm dia NP3 RCC Pipes. It is also proposed to construct 3 Nos. of inspection chambers along the intake pipeline. Intake channel for a length of 1290 mts length is proposed in the estimate up to Intake well. Craddle bedding in CC (1:4:8) is not proposed in the estimate as the Intake Pipe line is running in foreshore of Somasila Reservoir

Jack Well

A circular type Jack well with an internal dia 10.0 Mt is proposed to accommodate 3 Nos (3+0) of each 465 HP VT Pump sets and panels. The thickness of steining is adopted with a thickness of 0.60m up to 10.00 m and then 0.45m up to 6m depth &0.30 m thickness up to 6.42 m height i.e., up to floor level with M20 Concrete. A mat/raft of Jack well is proposed 0.60 mt thick over CC (1:4:8) leveling course. Total height of steining is 22.42 mts

Pressure Main

A Pressure main of 900 mm dia with PSC Pipes is proposed for a length of 3100 Mt to deliver water to the main DC. Provision is made for MS bends and MS specials in the estimate to align the pressure main. Provision is also made for WHC devices of Air Valves, Zero Velocity Valves, Zero velocity valve chambers and air valve chambers.

CONCLUSION

Based on engineering survey to identify the problems of farmers under Vontimitta tank and Fulfilling by implementing Vontimitta lift irrigation scheme and also the Ayacut commanded area is increased and under Vontimitta 1014 acres will be stabilized. The study of ground water table status before and after the implementation of project ground water table will improved in open bore wells around Vontimitta and 1500 acres indirectly irrigated.

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6-8

A Study on the Use of Alum for Turbidity Removal in Synthetic Water

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ABSTRACT

Turbidity is a principle physical characteristic of water. It is caused by suspended matter or impurities that interfere with the clarity of the water. These impurities may include clay, silt, finely divided inorganic and organic matter, soluble coloured organic compounds, plankton and other microscopic organisms. Excessive turbidity in drinking water is aesthetically unappealing and may also represent a health concern. Turbid waters, containing colloidal particles, are normally treated by coagulation-flocculation followed by clarification. Generally, alum is the first coagulant of choice because of its lower cost and its widespread availability. The coagulation performance of Alum, an inorganic chemical coagulant was tested on synthetic high turbid water (90-140 NTU). In this study, the effectiveness of alum was evaluated at room temperature with initial pH (6-7.4) for two coagulant doses 10 mg/l and 20 mg/l in 250 ml synthetic high turbid water by adopting manual agitation at very low settling time conditions rather than a traditional jar test. Results showed that coagulation process could remove turbidity effectively using relatively low levels of Alum. Studies reveal that turbidity removal is dependent on pH, coagulant dose, as well as initial turbidity of water. The highest turbidity removal efficiency was 46.15 % over the applied range of turbidity. The results of the current study can be used as a baseline data for drinking water treatment facilities which uses Alum as a coagulant.

Keywords: Coagulation, flocculation, Alum, synthetic water, turbidity removal.

INTRODUCTION

Rapid growth of population, urbanization and industrial as well as agricultural activities have increased water pollution, particularly in recent decades. Due to all these activities the demand for clean and safe water is increasing. Water treatment industry is among the most important industries in many countries such as Iran. Coagulation, flocculation, sedimentation, filtration and disinfection are the most common treatment processes used in the production of drinking water. Coagulation/flocculation processes are of great importance in solid-liquid separation practice (Yukselen and Gregory, 2004). The coagulation process is used to destabilize colloidal material in water by the addition of a chemical agent. It requires rapid mixing to quickly disperse the coagulant and subsequently flocculation process. Flocculation is the formation of aggregates of the destabilized colloids and requires gentle mixing to allow effective collisions between particles to form heavy flocs which can be removed from water by settlement. Colloidal particles are small suspended particles in water which cannot be settled or removed by gravity due to their light weight and the charge they carry. These particles cause turbidity to water. Turbidity may contain many contaminants like pathogenic organisms. Turbidity is also associated with many pollutants of concern to human health e.g., metals or some synthetic organic chemicals. Thus, effective turbidity elimination is necessary to ensure removal of many health-related contaminants. In addition effective removal of turbidity may increase the efficiency of further water treatment processes. Alum and Ferric Chloride are the most commonly used chemical coagulants worldwide in the water treatment plants. Findings on various coagulation processes have been reported in literature. In this study Alum, the most common chemical coagulant was used to determine its capacity to reduce turbidity of synthetic water. The removal of turbidity from water is important because colloids may directly or indirectly threaten the human health. Aluminum can be purchased as either dry or liquid alum [$Al_2(SO_4)_3.14H_2O$]. When alum is added to a water containing alkalinity, the following reaction occurs :

$$Al2(SO_4)_3.14H_2O+6HCO^-_3 \rightleftarrows 2Al(OH)_3 + 6CO_2 + 14H_2O + 3SO_4^{2-}$$

Such that each mole of alum added uses six moles of alkalinity and produces six moles of carbon dioxide. The above reaction shifts the carbonate equilibrium and decrease the pH. However, as long as sufficient alkalinity is present and CO_2 is allowed to evolve, the pH is not drastically reduced and is generally not an operational problem. When sufficient alkalinity is not present to neutralize the sulfuric acid production, the pH may be greatly reduced:

$$Al_2(SO_4)_3.14H_2O \rightleftarrows 2Al(OH)_3 + 8\ H_2O + 3H_2SO_4$$

MATERIALS AND METHODS

Coagulation experiment was conducted within a pH range of 6-7.4. Aluminum sulfate (Al2 (SO4)3.18H2O) was used in the current study for removal of turbidity from synthetic water. Tap water was used for preparation of high turbid raw water synthetically using powdered clay. 10 grams of powdered clay was dissolved in 750 ml tap water and left undisturbed for 24 hours for complete hydration of clay materials. As per the requirement stock sample of clay was diluted with tap water to obtain desired turbidity i.e, (90-140 NTU). No pH adjustments were made for raw turbid water. Stock solution of 1% Alum were prepared. All the chemicals used in the study were of Analytical grade. 250 ml of prepared synthetic turbid water were placed in three 250 ml glass beakers and were manually mixed with a stirrer for 2 minutes in order to ensure uniform and homogeneous mixture of the test sample. Supernatant turbidity in NTU and initial pH of raw turbid water was measured using Elico | Water Quality Analyzer PE 138. Out of three glass beakers one was used as a control i.e, no coagulant dose and alum doses 10 mg/l and 20 mg/l were tested for 250 ml raw turbid water. After coagulant dosage, the sample was thoroughly mixed manually using a stirrer for about 2 minutes and was allowed to settle for 10 minutes at room temperature. After coagulation process, the supernatant was filtered using filter paper and the treated water using two different alum doses were analyzed for variation in pH and turbidity. % Removal of turbidity and change in pH was calculated for desired turbid samples using the above procedure.

RESULTS AND DISCUSSION

Figure 1 presents turbidity removal efficiency as a function of aluminum sulfate dose at initial pH range 6-7.4. Initial turbidities of synthetic water samples were adjusted to be 90, 120 and 140 NTU. High initial turbidities were considered in this research because such turbidities commonly occur in many stormwaters (Annadurai et al., 2004). Low turbidity waters are usually hard to coagulate due to low concentrations of stable particles and sometimes turbidity is synthetically added to the water to form heavier flocs which can be settled.

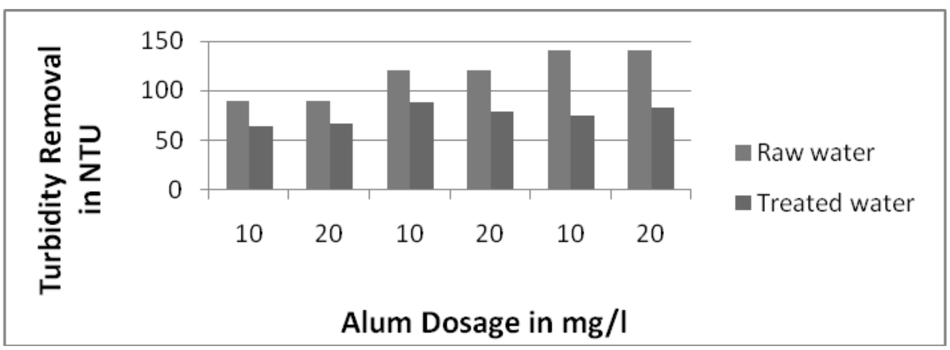

Fig. 1 Plot of Turbidity removal Vs Alum dosage

Table 1 presents change in pH as a function of aluminum sulfate dose with initial turbidities of raw water being 90, 120 and 140 NTU. Final pH was recorded for treated turbid samples.

Table 1 Change in pH Vs Alum dose

	90 NTU Sample (250 ml)		120 NTU Sample (250 ml)		140 NTU sample (250 ml)	
Alum Dose	**Initial pH**	**Final pH**	**Initial pH**	**Final pH**	**Initial pH**	**Final pH**
10 mg/l	6.0	6.2	7.0	6.4	7.4	6.8
20 mg/l	6.0	5.9	7.0	6.0	7.4	6.5

Coagulation Treatment

The best performance of alum was observed at pH 7.4 over the selected range of turbidity but its performance slightly decreased for pH values of 6 and 7. Coagulation efficiency of alum at pH 6 and 7 was almost similar. The highest turbidity removal was attained at pH 7.4 when 10 mg/l alum was used. Turbidity removal efficiencies of alum for doses 10mg/l and 20 mg/l were 46.15, 40.84, 26.5, 34.5, 27.9 and 25.92 percent for initial turbidities of 140, 120 and 90 NTU respectively. Similarly the initial pH of synthetic turbid samples gradually decreased with increase in alum dose as shown in Table 1.

Fig. 2 Stepwise Coagulation treatment of synthetic high turbid water using Alum

Results indicated that turbidity removal efficiency varied by pH, alum dose and initial turbidity of water. Variation of pH considerably affected turbidity removal. Literature reveal highest turbidity removal using alum was observed at optimum pH conditions i.e, 6-7. Apart from coagulant dose and pH, agitation time and settling time also play a vital role in turbidity reduction. The current study can be recommended for further investigation under varying agitation time and settling time conditions in order to enhance turbidity removal efficiency.

Coagulation and flocculation process is a primary and cost-effective process in water treatment plants which can effectively remove turbidity from low to high turbid waters when operational condition is optimized. Optimization of pH and coagulant dose may increase the coagulation efficiency and reduce the sludge volume and subsequently sludge management costs. Coagulant aids may improve coagulation process and turbidity removal. But it should be considered that coagulant aids should not increase water treatment costs significantly. Their accessibility and preparation procedure should also be considered when selecting a coagulant aid.

This study demonstrated that coagulation process can assure turbidity removal for high turbid waters using low levels of aluminum sulfate (10-20 mg/l).

CONCLUSION

The coagulation experiment using alum indicated that coagulation process effectively removed turbidity from synthetic high turbid water using 10-20 mg/l dosage. The highest turbidity removal efficiency was found to be 46.15% using 10 mg/l alum dose at pH 7.4 for 140 NTU high turbid water maintained at room temperature conditions with a settling time of 10 minutes. Coagulant aids could enhance the removal efficiency. Application of different dosage and alternative coagulants to meet allowable limits should further be investigated. However, national standards vary among different countries. Investigating the influence of agitation time and settling time for varying doses and pH conditions on turbidity removal by alum is suggested for future studies.

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Qualitative Study of Pre-monsoon and Post-monsoon status of Different Chemical Parameters of Water Samples Collected from Various Surface Water Bodies in GHMC

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ABSTRACT

The study of the water quality of surface water bodies in Greater Hyderabad Municipal Corporation (GHMC) has carried out to assess the risk to ecology. A Qualitative study has also been done in pre-monsoon and post-monsoon seasons considering the change in various parameters and its concentrations. It had been found that concentration of parameters in pre-monsoon period is higher than post-monsoon which is natural phenomenon. This study is main consideration to assess the quality of water for its best utilization like drinking and to maintain sustainable environment. Water bodies facing degradation due to anthropogenic activities such as directing human waste and changes in land use pattern etc. thus leading to the deterioration of environmental quality as well as a decrease in the surface area and depth of water bodies. Present study is to assess the quality of the water bodies in GHMC by developing a water quality index (WQI) and to predict the future pollution levels. For this purpose, 29 surface water bodies had been selected in GHMC for the study. Only two sample sites named Osman Sagar and Himayat Sagar are found fit for in all studied water quality parameters on comparison with standards.

Keywords: Pre-monsoon, post-monsoon, GHMC, WQI, concentration of parameters, water quality standards.

INTRODUCTION

The unique physical and chemical properties of water have allowed life to evolve in it. The following quote from Szent Gyorgyi illustrates this point of view that "Water function in varieties of ways within the cell cannot be disputed life originated in water, is thriving in water. Water beings its solvent and medium. It is the matrix of life." The effects of urbanization on water bodies have been described as "urban stream syndrome" and include alterations in geomorphology and hydrology, decrease in biodiversity, dominance of toxic, tolerant and invasive species and increase in the concentrations of organic compounds, nutrients and algal biomass. GHMC has individual physical identity characterized by rock formations and water bodies. The last 50 years of its growth have witnessed large scale destruction. Because of urbanization and industrialization, the quality of surface water bodies is polluted, as a result the polluted water infiltrates into the sub surface layers and pollutes the available ground water and it also affects the human health and environment. The reliance of a large population on these polluted water resources has significant implications for public health. Despite steady investment in treatment plants, the current infrastructure used to treat wastewater is inadequate, and 50 percent of sewage is left untreated. The objective of present study is to qualitatively study different chemical parameters of water samples of pre and post monsoon seasons and to develop water quality index.

Study Area

Greater Hyderabad Municipal Corporation is situated at an attitude of 536 meters (1607ft) above sea level. It lies in the Deccan Plateau, housing multiple lakes and large water tanks. Since cities are built on a rocky terrain, the potential for using groundwater is limited. Present study includes four mandals/taluks namely Rajendranagar mandal, Medchal mandal, Hayatnagar mandal, and GHMC. Rajendranagar mandal consists of 14 lakes, Medchal mandal consists of 5 lakes, GHMC consists of 3 lakes, and Hayatnagar mandal consists of 7 lakes. The 29 surface water bodies in GHMC are Durgam cheruvu, Khajaguda cheruvu, Timmidkunta Lake, Sunnam cheruvu, Mullakathuva cheruvu, Malaka cheruvu, Chinna maisamma cheruvu, Kamuni cheruvu, Ambir cheruvu, Ibrahim cheruvu, Langarhouz cheruvu, Osman sagar, Himayat sagar, Peeran cheruvu, Hussain sagar, Jeedimetla cheruvu, Bon cheruvu, Noor Mohammed cheruvu, Safilguda Lake, Ramanthapur cheruvu, Saroornagar Lake, Banda cheruvu, Alwal Lake, Pedda Cheruvu Uppal, Nalla cheruvu, Rama cheruvu, Pedda Cheruvu Balapur, Kapra cheruvu and Shamirpet Lake.

REVIEW OF LITERATURE

The quality of water depends upon its origin. Many factors however, produce variations in the quality of waters obtained from the type of sources. Climatic, geo-graphic and geologic conditions all plays important part in determining water quality (Chatterjee, 1998). Freshwater systems are highly threatened by a range of anthropogenic activities including intensive agriculture, urbanization, industrialization and land cover change (Meybeck 2003). The growing human population combined with the increasing tendency to live in cities has led to an increase in the number of streams flowing through urbanized areas (Meyer et al. 2005). Industrial effluents entering the water bodies are one of the major sources of environmental toxicity and it has deleterious impacts on aquatic ecosystem (Sirohi 2014). Sewage increases the nitrates and phosphates levels in water bodies and causes eutrophication. As a result, the quality of surface water has been degraded due to release of effluents from industries as well as sewage from municipal, domestic communities. Excessive nutrient loads from point and non-point sources cause shifts in the frequency and duration of phytoplankton growth and development, harmful algal blooms and the formation of hypoxic and/or anoxic conditions (Conley et al. 2009; MacLeod et al. 2011; Huang et al. 2014). This degradation of water quality erodes the availability of water for humans and ecosystems, increasing financial costs for human users, and decreasing species diversity (Genevieve 2008).

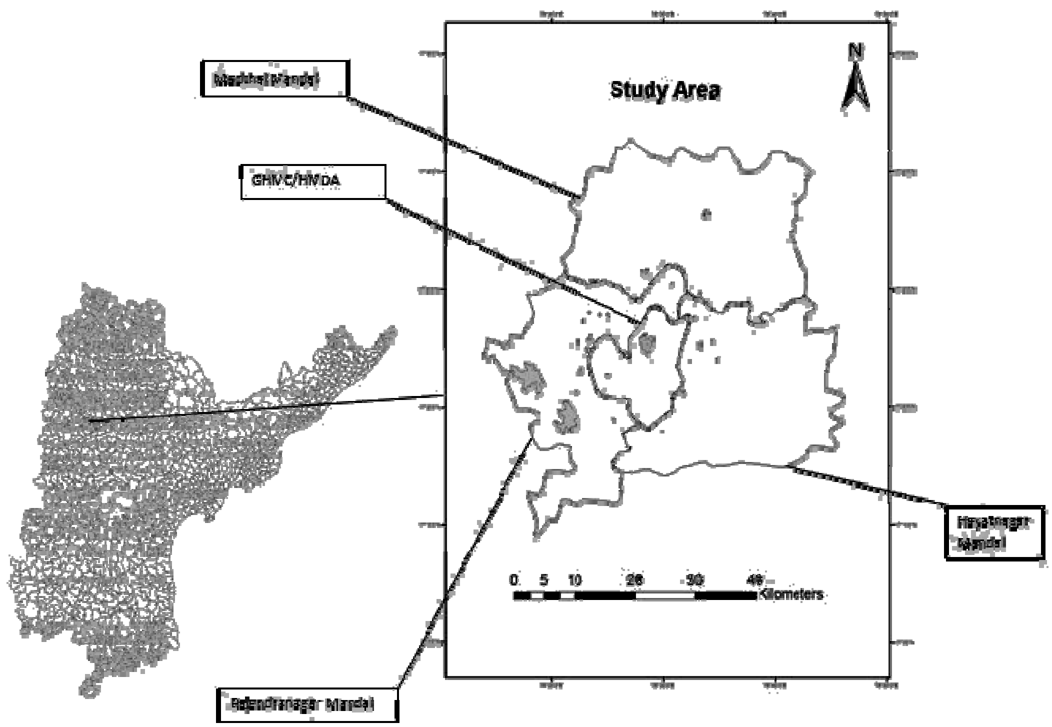

Fig. 1 Study area showing four Mandal boundaries and 29 lakes under study

MATERIALS AND METHODS

Sampling and data collection

The samples were collected from 29 water bodies during pre and post monsoon seasons for the year 2014. The collections were made during day time. Maximum care was taken for the collection of samples, their preservation and storage as per the BIS standards. Latitude and Longitude of the sampling stations are also marked by using GPS.

Measurement and analysis of water quality parameters

Water quality was analyzed for chemical parameters such as pH, Total Dissolved solids, CO_3 as $CaCO_3$, HCO_3 as $CaCO_3$, CL, F, NO_3, SO_4, Na, K, Ca, Mg and Total Hardness as CaCO3 for more accurate value of Water Quality Index. These parameters were measured as per standard methods.

Water Quality Index

WQI has been calculated by using the standard Weighted Arithmetic Water Quality Index method. For assessing the quality of water in this study, firstly, the quality rating scale (Q_n) for each parameter was calculated by using the equation (1)

$$Q_n = \{[(V_{actual} - V_{ideal}) / (V_{standard} - V_{ideal})] * 100\} \quad (1)$$

Q_n = Quality rating of nth parameter for a total of n water quality parameters

V_{actual} = Actual value of the water quality parameter obtained from laboratory analysis (Vn)

V_{ideal} = Ideal value of that water quality parameter can be obtained from the standard tables.

V_{ideal} for pH = 7 and for other parameters it is equaling to zero, but for DO Videal = 14.6 mg/L

$V_{standard}$ = Recommended BIS of the water quality parameter.

Then, after calculating the quality rating scale (Q_n), the Relative (unit) weight (W_n) was calculated by a value inversely proportional to the recommended standard (S_n) for the corresponding parameter using the equation (2)

$$Wn = I/ S_n \quad (2)$$

Where,

W_n = Relative (unit) weight for nth parameter

S_n = Standard permissible value for nth parameter

I = Proportionality constant.

That means, the Relative (unit) weight (W_i) to various water Quality parameters are inversely proportional to the recommended standards for the corresponding parameters. Finally, the overall WQI was calculated by aggregating the quality rating with the unit weight linearly by using the equation (3).

$$WQI = \Sigma Q_n W_n / \Sigma W_n \quad (3)$$

Where,

Q_n = Quality rating

W_n = Relative weight

The Water Quality Rating as per weighted arithmetic water quality index method are divided into 5 types of ratings. Table 1 shows the rating of water quality and grading of water according to the WQI values.

Table 1 Rating of Water Quality

WQI Value	Rating of Water Quality	Grading
0 – 25	Excellent water quality	A
26 – 50	Good	B
51 – 75	Moderate	C
76 – 100	Poor water quality	D
> 100	Undesirable	E

RESULTS AND DISCUSSION

A. ***General***: After conducting detailed survey, identification of main contamination points had been known, shown in (Table 2). The samples were collected during pre-monsoon and post-monsoon seasons and the characterizations of the samples are shown in Table 3 (A&B) & 4 (A&B).

Table 2 List of lakes

Name of the surface water body	Remarks
Durgam cheruvu	Effluents from commercial complexes
Khajaguda cheruvu	Effluents from commercial complexes
Timmidkunta Lake	Effluents from commercial complexes
Sunnam cheruvu	Sewage, waste water discharges from surroundings
Mullakathuva cheruvu	Nutrient rich water flow from surroundings
Malaka cheruvu	Effluents from commercial complexes
Chinna maisamma cheruvu	Sewage, waste water discharges from surroundings
Kamuni cheruvu	Sewage, waste water discharges from surroundings
Ambir cheruvu	Sewage, waste water discharges from surroundings
Ibrahim cheruvu	Sewage, waste water discharges from surroundings
Langarhouz cheruvu	Sewage, waste water discharges from surroundings
Osman sagar	Soil erosion and agricultural activities
Himayat sagar	Soil erosion and agricultural activities
Peeran cheruvu	Sewage, waste water discharges from surroundings
Hussain sagar	Sewage from Households and Effluents from
	Industries and STP's
Jeedimetla cheruvu	Effluents from Industries
Bon cheruvu	Sewage, waste water discharges from surroundings
Noor Mohammed cheruvu	Effluent from sewage treatment plant
Safilguda Lake	Effluent from sewage treatment plant
Ramanthapur cheruvu	Soil erosion and agricultural activities
Saroornagar Lake	Sewage from Households and effluents of STP's
Banda cheruvu	Sewage, waste water discharges from surroundings
Alwal Lake	Sewage, waste water discharges from surroundings
Pedda Cheruvu Uppal	Nutrient rich water flow from surroundings
Nalla cheruvu	Nutrient rich water flow from surroundings
Rama cheruvu	Effluents from Industries
Pedda Cheruvu Balapur	Soil erosion and agricultural activities
Kapra cheruvu	Sewage, waste water discharges from surroundings
Shamirpet Lake	Soil erosion and agricultural activities

B. ***Water Quality Analysis***

Water samples were collected from different surface water bodies and analyzed for different chemical parameters such as pH, Total Dissolved solids, CO3 as CaCO3, HCO3 as CaCO3, CL, F, NO3, SO4, Na, K, Ca, Mg and Total Hardness as CaCO3 for pre and post monsoon seasons. During pre-monsoon water samples from 27 lakes had been collected, two lakes namely Mullakathuva cheruvu and Noor Mohammed cheruvu were dry/no provision to collect sample. During post-monsoon water samples from 23 lakes had been collected, six lakes namely Mullakathuva cheruvu, Noor Mohammed cheruvu, Malaka cheruvu, Bon cheruvu, Rama cheruvu and Pedda cheruvu Balapur were dry/no provision/covered with dense duckweed/horseshoe to collect sample.

Table 3 (A) Characterization of water samples (Pre-monsoon)

25	Pedda cheruvu Balapur	8.30	895	0.0	256	300	2.35
26	Kapra cheruvu	8.97	1240	120	219	320	3.98
27	Shamirpet Lake	8.34	451	20	94.0	130	2.13

Table 3 (B) Characterization of water samples (Pre-monsoon)

S.No	Name of the Sample	NO_3	SO_4	Na	K	Ca	Mg	T.H. as
		mg/lit	mg/lit	mg/lit	mg/lit	mg/lit	mg/lit	$CaCO_3$ mg/lit
	BIS	10.16	200-400	NG	NG	75-	30-100	200-600
	Permissible					200		
	Limits for Drinking water							
1	Durgam cheruvu	12.93	65	142	18	98	42	420
2	Khajaguda cheruvu	10.00	62	124	14	96	44	420
3	Timmidkunta cheruvu	4.00	72	125	12	80	53	420
4	Sunnam Cheruvu	10.00	12	93	26	64	29	280
5	Malaka cheruvu	11.00	68	130	19	112	53	500
6	Chinna maisamma cheruvu	12.73	47	115	20	88	39	380
7	Kamuni cheruvu	12.00	30	112	18	104	49	460
8	Ambir cheruvu	11.00	64	153	20	112	53	500
9	Ibrahim cheruvu	12.00	57	143	25	88	49	420
10	Langarhouz cheruvu	13.04	47	91	25	64	24	260
11	Osman sagar	1.05	15	34	5.0	24	19	140
12	Himayat sagar	2.12	17	41	5.0	40	10	140
13	Peeran cheruvu	3.03	13	113	24	56	29	260
14	Hussain sagar	11.40	99	62	23	64	15	220
15	Jeedimetla cheruvu	5.16	60	337	23	56	68	420
16	Bon cheruvu	11.18	40	131	28	104	44	440
17	Safilguda Lake	14.04	30	126	26	104	44	440
18	Ramanthapur cheruvu	19.20	25	117	26	72	34	320
19	Saroornagar cheruvu	21.40	80	119	14	88	49	420
20	Banda cheruvu	12.50	50	85	11	88	15	280
21	Alwal cheruvu	12.71	15	153	28	112	49	480
22	Pedda cheruvu Uppal	22.90	40	114	17	112	44	460
23	Nalla cheruvu	20.35	50	142	20	112	34	420
24	Rama cheruvu	26.50	41	163	37	104	58	500
25	Pedda cheruvu Balapur	2.60	4.0	123	16	80	53	420
26	Kapra cheruvu	9.05	131	165	30	168	39	580
27	Shamirpet Lake	5.49	30	88	4	40	15	160

Table 4 (A) Characterization of water samples (Post-monsoon)

S.No	Name of the Sample	pH	TDS	CO_3 as CaCO3	HCO_3 as CaCO3	CL	F	NO_3	
			mg/lit.	mg/lit	mg/lit	mg/lit	mg/lit	mg/lit	
	BIS	**6.50 to**	**500-2000**	**200-600**	**200-600**	**250-**	**1.0-**	**10.16**	
	Permissible	**8.50**				**1000**	**1.5**		
	Limits for Drinking water								
1	Durgam Cheruvu	7.3	866	0	180	357.4	1.12	26.35	
2	Khajaguda Cheruvu	7.9	834	0	80.0	397.0	1.12	32.00	
3	Timmidkunta Lake	7.7	733	0	190	357.4	1.69	7.60	
4	Sunnam Cheruvu	7.8	568	0	700	193.6	0.53	28.90	
5	Chinna Maisamma Cheruvu	7.8	686	0	90.0	238.2	0.92	29.95	
6	Kamuni Cheruvu	7.7	734	0	260	307.7	1.28	18.01	
7	Ambir Cheruvu	7.9	860	0	330	376.9	1.01	25.85	
8	Ibrahim cheruvu	7.8	572	0	90.0	282.9	1.43	4.88	
9	Langarhouz Cheruvu	9.0	667	6.6	70.0	183.5	0.84	4.04	
10	Osman Sagar	7.9	233	0	45.7	74.4	0.53	5.04	
11	Himayat Sagar	8.1	181	0	63.9	44.6	0.51	1.35	
12	Peeran Cheruvu	7.8	472	0	20.0	188.6	1.57	6.25	
13	Hussain Sagar	7.8	830	0	80.0	312.4	1.21	30.55	
14	Jeedimetla Cheruvu	7.8	1304	2	180	93.3	1.69	6.85	
15	Safilguda Cheruvu	9.0	1033	18.8	200	372.3	1.19	11.73	
16	Ramanthapur Cheruvu	9.1	788	25.3	270	302.5	1.45	12.30	
17	Saroornagar Lake	9.1	874	17.8	190	332.5	1.16	41.45	
18	Banda Cheruvu	9.5	827	9.4	100	292.8	1.42	12.45	
19	Alwal Lake	8.5	1110	16	170	362.3	1.64	12.55	
20	Pedda Cheruvu	8.4	814	26.3	280	412.0	1.43	45.60	
21	Nalla Cheruvu Uppal	9.0	905	26.3	280	412.0	1.56	54.85	
22	Kapra Cheruvu	8.4	818	10.3	110	352.4	1.53	4.98	
23	Shamirpet Lake	7.8	345	0	457	149.0	1.52	2.16	

Table 4 (B) Characterization of water samples (Post-monsoon)

S.No	Name of the sample	mg/lit	mg/lit	mg/lit	mg/lit	mg/lit	CaCo3
	BIS	200-400	NG	NG	75- 200	30-100	200-600
	Permissible						
	Limits for Drinking water						
1	Durgam Cheruvu	15.0	153	23	168	43.76	600
2	Khajaguda Lake	10.5	148	22	168	58.30	660
3	Timmidkunta Lake	10.5	142	18	176	82.65	800

Contd…

4	Sunnam Cheruvu	12.7	110	20	176	24.31	440
5	Chinna Maisamma Cheruvu	11.0	130	22	120	58.34	540
6	Kamuni Cheruvu	7.50	135	21	208	58.34	760
7	Ambir Cheruvu	14.0	153	22	216	68.0	820
8	Ibrahim cheruvu	10.5	136	20	216	34.0	400
9	Langarhouz Lake	10.0	105	19	120	53.48	520
10	Osman Sagar	8.50	37.0	8.0	48.0	17.01	160
11	Himayat Sagar	5.50	32.0	8.0	64.0	9.72	200
12	Peeran Cheruvu	20.0	110	19	144	24.31	460
13	Hussain Sagar	18.5	149	24	152	126.40	900
14	Jeedimetla Lake	14.0	200	22	152	106.90	820
15	Safilguda Cheruvu	33.5	143	25	200	111.80	960
16	Ramanthapur Cheruvu	11.0	139	25	136	24.31	460
17	Saroornagar Lake	17.0	135	20	152	126.40	900
18	Banda Cheruvu	13.5	124	20	240	68.06	880
19	Alwal Lake	15.5	167	34	440	9.702	1120
20	Pedda Cheruvu	15.5	130	20	120	97.20	700
21	Nalla Cheruvu	21.0	136	21	232	43.76	760
22	Kapra Cheruvu	17.0	145	26	296	19.45	800
23	Shamirpet Lake	13.0	91.0	9.0	96.0	19.45	380

The high concentrations of fluorides are generally observed in groundwater but it is investigated in analysis during pre-monsoon season that, out of 27 samples from different lakes, 24 lakes have the fluoride levels greater than the permissible limits. Nitrates are the nutrient required for the plant growth, which is generally released from agricultural fertilizers. In urban areas, most of the nitrate concentration comes from the sewage released from households and kitchen wastes. During post-monsoon season, it is general observed that in groundwater samples fluoride concentration is more but it is investigated in analysis that, out of 23 samples from different lakes, 7 lakes have the fluoride levels greater than the permissible limits. It is observed that 14 lakes have the nitrate levels more than the desirable limits.

C. Water Quality Index: The water quality index also calculated using weighted arithmetic water quality index method. In pre-monsoon almost all the sample have the WQI of greater than 100; it belongs to undesirable condition. In post-monsoon season the least WQI is for sampling sites Osman sagar and Himayat sagar, which belongs to good condition. All other sampling stations almost goes to undesirable condition. WQI values of pre and post monsoon season are shown in tables 5 & 6.

Table 5 WQI of pre-monsoon season

Name of the Lake	WQI Value	Remarks
Durgam cheruvu	117	Undesirable
Khajaguda cheruvu	118	Undesirable
Timmidkunta lake	131	Undesirable
Sunnam cheruvu	77	Poor water quality
Chinna maisamma cheruvu	100	Poor water quality
Kamuni cheruvu	115	Undesirable
Ambir cheruvu	129	Undesirable
Ibrahim cheruvu	142	Undesirable
Langarhouz lake	104	Undesirable

Contd…

Name of the Lake	WQI Value	Remarks
Osman sagar	84	Poor water quality
Himayat sagar	92	Poor water quality
Peeran cheruvu	97	Poor water quality
Hussain sagar	73	Moderate
Jeedimetla cheruvu	131	Undesirable
Safilguda Lake	129	Undesirable
Ramanthapur Lake	127	Undesirable
Saroornagar Lake	131	Undesirable
Banda cheruvu	98	Poor water quality
Alwal cheruvu	111	Undesirable
Pedda cheruvu Uppal	99	Poor water quality
Nalla cheruvu	118	Undesirable
Kapra cheruvu	176	Undesirable
Shamirpet Lake	96	Poor water quality

Table 6 WQI of post-monsoon season

Name of the Lake	WQI Value	Remarks
Durgam cheruvu	71	Moderate
Khajaguda cheruvu	91	Poor water quality
Timmidkunta lake	105	Undesirable
Sunnam cheruvu	60	Moderate
Chinna maisamma cheruvu	79	Poor water quality
Kamuni cheruvu	89	Poor water quality
Ambir cheruvu	94	Poor water quality
Ibrahim cheruvu	83	Poor water quality
Langarhouz lake	101	Undesirable
Osman sagar	46	Good
Himayat sagar	49	Good
Peeran cheruvu	79	Poor water quality
Hussain sagar	114	Undesirable
Jeedimetla cheruvu	114	Undesirable
Safilguda Lake	139	Undesirable
Ramanthapur Lake	110	Undesirable
Saroornagar Lake	147	Undesirable
Banda cheruvu	143	Undesirable
Alwal cheruvu	116	Undesirable
Pedda cheruvu Uppal	122	Undesirable
Nalla cheruvu	132	Undesirable
Kapra cheruvu	103	Undesirable
Shamirpet Lake	72	Moderate

CONCLUSIONS

The present paper analyzes the water quality data collected from different surface water bodies in GHMC. Important issues include decreasing water quality, alternations in sustainable environment, increase in nutrient concentrations and contaminant migration into the water bodies etc. Nitrates values are ranging from 26 mg/lit to 56 mg/lit, when compared with previous status, this nitrate values shows drastic increase of nutrient contamination due to anthropogenic activities, nutrient loading from sewage and households, in-turn causing eutrophication of lakes. In pre and post monsoon seasons, pH concentration of lake water had been slightly acidic and alkaline in nature. The quantities of fluorides and nitrates are increasing and higher than the prescribed limits. They indicate that the lake is in hypereutrophic condition. In all the seasons water quality index (WQI) almost remained in the undesired category. As per the analysis of the results it can be seen that in the pre monsoon season chemical parameters are higher than post monsoon season. So it can be concluded that during monsoon season dilution of rainwater into the water bodies reduced the contamination migration into the lake, thus result in post monsoon is better in quality of water. Also based on total nitrogen, the lakes whose values greater than permissible limits belongs to hypereutrophic class. If eutrophication and contamination proceed at this rate, within next 5 to 10 years our surface water bodies which serves as constituent body for sustainable environment and ecology will ends up in a miserable condition. Hence the issues revealed in this study will have to be addressed seriously by all concerned.

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Standardization of Irrigation Requirement of Cowpea under Naturally Ventilated Polyhouse

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ABSTRACT

Present study on standardisation of irrigation requirement of cowpea under naturally ventilated poly house was carried out in the experimental plot of PFDC farm, KCAET Tavanur. The objectives of the study were to determine the water requirement of the cowpea using CROPWAT and to schedule irrigation for cowpea inside naturally ventilated poly house. Weather parameters inside and outside the poly house were also compared. Irrigation trial was carried out with five levels of irrigation viz. 80, 90,100,110 and 120 % of daily irrigation requirement and the yield obtained from the irrigation treatments was analysed. The maximum yield was observed for the treatment $I_{2,}$ i.e. 90% of daily irrigation requirement (29620kg/ha). The minimum yield was observed in the case of treatment $I_{5,\ i.e.}$120 % of daily irrigation requirement (13673 kg/ha). With respect to average yield, the different levels of irrigation showed significant difference. Compared to I_2, the yield from other treatments I_1, I_3, I_4, and I_5 were less by 14, 30, 34 and 54%. Irrigation water quantity considerably affected the irrigation water use efficiency (IWUE). It ranged from 25 kg/ha-mm to73 kg/ha-mm. The study revealed that drip irrigation with 90% of the daily irrigation requirement calculated using CROPWAT can give maximum yield of cowpea inside a naturally ventilated poly house.

INTRODUCTION

Water is essential for human civilisation, living organisms and natural habitat. It is used for drinking, cleaning, agriculture, transportation, industry, recreation and animal husbandry, producing electricity for domestic, industrial and commercial use. Due to its multiple benefits and the problems created by its excesses, shortages and quality deterioration, water as a resource requires special attention. However, much of the world's water has little potential for human use because 97.5% of the water on earth is saline water. Out of the remaining 2.5% freshwater, majority lies deep and frozen in the polar region and only about 0.26% in rivers, lakes and in the soils and shallow aquifers which are readily usable for mankind.

Precision Farming

Precision farming is generally defined as the information based and technology enabled farm management system to identify, analyse and manage variability within fields for optimum profitability, sustainability and protection of the land resources. In this mode of farming, new information and technologies can be used to make better decisions about many aspects of crop production. Precision farming helps many farmers worldwide to maximize the effectiveness of crop inputs. Agricultural production system is an outcome of a complex interaction of seed, soil, water and agro-chemicals (including fertilizers). Therefore, judicious management of all the inputs is essential for the sustainability of such a complex system. The focus on enhancing the productivity during the Green Revolution coupled with total disregard of proper management of inputs and without considering the ecological impacts, has resulted into environmental degradation. The only alternative left to enhance productivity in a sustainable manner from the limited natural resources at the disposal, without any adverse consequences, is by maximizing the resource input use efficiency. With drip fertigation, nutrient use efficiency can be increased and the loss of nutrients to the groundwater is reduced. Successful fertigation requires precise calculation of injection rates, motive flow rates, knowledge regarding solubility of different nutrients in water and know how on different fertigation equipment. Since the volume of root medium under protected cultivation is relatively smaller compared to the volume under open conditions, frequent replenishment with balanced amount of plant nutrients is very crucial. The productivity of crop is based on effective utilization of water and fertilizer, along with other agricultural inputs. Micro climate inside a polyhouse is maintained at favourable conditions for plant growth and yield. Cultivation of crops under this condition and varying irrigation and fertigation levels show significant effect on performance of crop which is becoming popular among Indian farmers. Micro climate that can be optimized by different ways is a beneficial impact of structure over open field cultivation.

Polyhouse farming

In India traditional farming is prevalent but new farming technology like polyhouse farming provides better income in a short period of time with less labour. Polyhouse farming is an alternative new technique in agriculture gaining foothold in rural India. It reduces dependency on rainfall and makes the optimum use of land and water resources. Polyhouse cultivation is known as isolated, intensive and protective cultivation, which results in a quality crop produce, which has a high demand in local and overseas market. Normally the people can recover the investment within 3 years. Polyhouse farming also promises to extent the harvest life of vegetables like cowpea by one to one-and-a-half months. Capsicum, salad cucumber, tomato and cowpea have been great success in the polyhouses in Kerala and the number is expected to go up to more than a 1,000 during current financial year. Polyhouse farming process requires expertise in three areas such as construction of the structure, cultivation techniques and marketing. Parameters such as moisture, soil nutrients and temperature in the polyhouse are controlled to ensure timely and abundant yields. *Fernandez (2003)* directed towards studying both the water use and development of the crop coefficients for crops grown in greenhouse. In Mediterranean areas, the seasonal ET of greenhouse horticultural crops is quite low when compared to that of irrigated crops outdoors. This is due to a lower evaporative demand inside a plastic greenhouse, which is 30-40% lower than outdoors throughout the entire cropping season. *Orgaz et al., (2005)* conducted an experiment to determine K_c value for horticultural crops under greenhouse (melon and watermelon). The K_c values were found to be similar to those under open field conditions. *Patel and Rajput* (2016) suggested that polyhouse cultivation gives higher yield, higher productivity, better quality produce and production throughout the year. Capsicum (*Capsicum annum L.)* is a valuable vegetable crop with excellent prospect both for the domestic and export market. To ensure its regular and off-season supply, technology for growing capsicum under protected conditions needs to be standardized. Irrigation is one of the most important inputs, which affects the yield and quality of agricultural produce from polyhouse. Efficient irrigation in polyhouse can be achieved by accurate estimates of evapotranspiration.

Cropwat

During nineties, CROPWAT, a computer program for irrigation planning and management developed by FAO (Smith, 1992), had been getting particular importance among irrigation engineers. CROPWAT is a DOS or Windows based decision support system designed as a tool to help agro-meteorologists, agronomists, and irrigation engineers carry out standard calculations for evapotranspiration and crop water use studies, particularly the design and management of irrigation schemes. It is used as a tool for testing the efficiency of different irrigation strategies (irrigation scheduling, improved irrigation efficiency) under climatic change. CROPWAT does not have the capacity of simulating the direct effects of rising atmospheric carbon dioxide concentration on crop water use. In order for CROPWAT to provide efficient and correct data, the user needs to insert data about the evapotranspiration process, i.e. the quantity of water evaporated from the soil and eliminated by plants into the atmosphere. The data can be entered manually by filling in the forms provided by the inlays from the left side of the main window. CROPWAT is a valuable application for farmers or crop and soil specialists that can supply detailed data about the necessary quantity of water necessary to obtain maximum crop yields

Micro Irrigation

Micro-irrigation systems are immensely popular, not only in arid regions and urban settings but also in sub humid and humid tropical zones where water supplies are limited. Among all the micro irrigation methods, drip irrigation is the most efficient and can be practised in a large variety of crops, especially vegetables, orchard crops, flowers and plantation crops. Drip irrigation, also known as trickle irrigation, is an irrigation method that saves water and fertilizer by allowing water to drip slowly to the roots of plants, through a network of valves, pipes, tubing and emitters. The soil moisture is kept at an optimum level with frequent irrigations. Drip irrigation results in a very high water application efficiency of about 90 - 95 per cent. Micro irrigation systems save irrigation water by 60% and fertilizer by 25%, enhances yield up to 50%, improves water use efficiency by 2 to 4 times with benefit cost ratio of 2.77 (without subsidy) and 3.5 on subsidized cost. Through the good management of micro irrigation systems, the root zone water content can be maintained near field capacity throughout the season providing a level of water and air balance close to optimum for plant growth. The experiment had five irrigation treatments with six replications. Two types of irrigation basin and drip were practiced. The irrigation treatments include drip irrigation with 1, 1.5, 2 and 2.5 lit/day of water. From the study it was found that drip irrigation has a positive effect on growth and yield of crop. Crops drip irrigated with 1.5 l/plant/day performed well with maximum water use efficiency.

The specific objectives of the present study are

- To determine the water requirement of the cowpea using CROPWAT.
- To standardise the irrigation requirement of cowpea under naturally ventilated polyhouse.

MATERIALS AND METHODS

Location

The experiment was conducted using cowpea under naturally ventilated polyhouse (292 m²) located in experimental plot of Precision Farming Development Centre, KCAET, Tavanur, Kerala. The soil type of the experimental plot was sandy loam.

Water Requirement

The water requirement of cowpea was determined by using CROPWAT. The CROPWAT is used for testing the efficiency of different irrigation strategies under climatic change. Computer model simulation is an emerging trend in the field of water management. CROPWAT is one of the models extensively used in the field of water management throughout the world. CROPWAT facilitates the estimation of the crop evapotranspiration, irrigation schedule and agricultural water requirements with different cropping patterns for irrigation planning. CROPWAT for Windows uses the FAO Penman-Monteith method for calculation of reference crop evapotranspiration (Allen *et al.,* 1999). Scheme water supply is calculated according to the cropping pattern provided in the program (Clarke *et al*., 1998).

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} U_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \quad .....(1)$$

where,

ET_φ = Reference evapotranspiration (mm/day)

R_n = Net radiation (MJ/(m^2 day))

G = Soil heat flux density (MJ/(m^2 day))

U_2 = Wind speed at a height of 2 m (m/s)

e_s = Saturated vapour pressure (kPa)

e_a = Actual vapour pressure of the air at standard screen height (kPa)

γ = Psychrometer constant (kPa/°C)

Δ = Slope of the saturation vapour pressure curve between the average air temperature and dew point (kPa/°C)

T = Mean daily air temperature (°C)

ET_c is termed as the crop water requirement (CWR) in mm/day, which is defined as the depth of water needed to meet the water loss through evapotranspiration of a disease free crop, growing in fields under non-restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment (FAO,1979; FAO 1984). The climatic data required for CROPWAT calculations are solar radiation, relative humidity, sunshine hours, maximum air temperature, minimum air temperature and wind speed. From the CROPWAT the value of reference crop evapotranspiration (ET_O) obtained was 4.26 mm/day. Crop evapotranspiration (ET_C) = ET_O * Crop coefficient. Water requirement of the crop varies according to the growth stages, since the crop coefficient values. The crop coefficient values used are 0.45 for initial stage, 0.80 for crop developmental stage and 1.05 for final stage respectively.

Field Experiment

Land Preparation

The land was ploughed thoroughly using mini tiller**.** The soil type of the experiment field was sandy loam. The field was left idle for one week after lime application. Farm yard manure was added to the field and dolomite applied in the rate of 435 kg/ha.

Bed Preparation

Four beds of 16 m length and 0.7 m width were prepared. Area of each bed is 11.2 m². Each bed contains single row of cowpea. Every single bed contains 32 plants at a spacing of 50 cm.

Crop Variety

Cowpea (Vellayani Jyothika) which is of trailing type was used for the trial. The seeds were sown at a depth of 2 cm from ground level. Laterals with inline drippers lay on each bed providing water and fertilizer effectively up to root zone depth.

Inter Cultural Operation and Weeding

Manual weeding was done in a periodic manner. Drip irrigation control the growth of weeds as it gives only sufficient amount of water to each plant. Plant protection measures were adopted for incidents of pest and disease attacks using recommended dose of chemicals on time.

Experiment Details

The field experiment using cowpea mainly involves the standardization of the rate of irrigation water. The irrigation treatments were formulated for different levels of water requirement of the crop. The crop water requirement of cowpea was computed using the CROPWAT model. The fertilizer treatment was selected based on the adhoc recommendation of KAU. The irrigation trial was conducted during 13th September to 28th December, 2014. The objective was to standardize the irrigation requirement of cowpea grown in a naturally ventilated polyhouse. The soil in the field plot was well drained sandy loam. The land inside the polyhouse was levelled and beds were raised. The plot was divided into five rectangular beds having five treatments. Plate 1 shows the experimental plot with emerging plants.

Plate 1 Experimental plot with emerging plants

Irrigation Scheduling

Water requirement of cowpea varies according to the growth stages. In order to determine the optimum water requirement of the crops, five irrigation levels were adopted which were 80, 90, 100, 110 and 120 percent of water requirement of cowpea estimated using CROPWAT. In this study, fertilizers were applied as per adhoc recommendations with different rate of irrigation. The details of irrigation treatments are given below.

I_1 : 80% of the estimated irrigation requirement from CROPWAT

I_2 : 90% of the estimated irrigation requirement from CROPWAT

I_3 : 100% of the estimated irrigation requirement from CROPWAT

I_4 : 110% of the estimated irrigation requirement from CROPWAT

I_5 : 120% of the estimated irrigation requirement from CROPWAT

Collection of Experimental Data

Meteorological Data

Temperature and humidity measurement inside and outside the polyhouse were taken using digital thermo hygrometer (thermo-hygroclock). Humidity is a representation of the concentration of water vapour in the air where value is shown as a percent. Thermo hygroclock has sensors which measure humidity and temperature of the air, both values will be shown as a digital representation and converted in to the desired unit. Comparison in variation of temperature and relative humidity inside and outside were also done.

Yield Data

Harvesting of the crops was done treatment wise after attaining maturity. After the first harvest, harvests were done at an interval of 3-5 days. The first harvest was done one and half month after planting the cowpea. A total of 11 harvests gave the total yield. Fruit weight in each treatment was taken. The fruit characteristics such as number of fruits per bed and fruit length of every tagged plant in every harvest were observed.

Determination of Irrigation Water Use Efficiency

The fruit yield obtained for each treatment was divided by the quantity of water used consumptively for the respective treatments. Irrigation Water Use Efficiency (IWUE) was worked out and expressed in kg/ha and the total water utilized in mm.

$$\mathbf{IWUE} = \frac{\text{Yieldy (kg/ha)}}{\text{Total amount of water applied (mm)}} \qquad .....(2)$$

RESULT AND DISCUSSION

The field study was conducted with the objectives to determine the water requirement of the cowpea using CROPWAT and to standardise the irrigation requirement of cowpea grown under naturally ventilated polyhouse.. The results obtained from the study are analyzed and are presented in this chapter.

Crop Water Requirement

The details of climate, soil and the crop related to the study were fed to the CROPWAT model to estimate the crop water requirement. The crop water requirement of cowpea estimated is shown in Table 4.1.

Table 1 Crop water requirement at different growth stages

Growth stage	ET_0 (mm/day)	Crop coefficient	ET_c (mm/day)
Initial	4.26	0.45	1.917
Crop development	4.26	0.8	3.408
Final	4.26	1.05	4.473

Yield Data

Fruit characteristics

Fruit length is one of the external quality parameter which influences market value. The data on average length and weight of cowpea after 45 days of planting are presented in the Table 4.2. The maximum length of cowpea was found in the treatment I_1 (68 cm). The minimum length was found in treatment I_2 (42 cm). The data did not differ significantly due to the levels of irrigation. The results indicate that the treatments did not influence the length of cowpea. The maximum weight of individual cowpea was obtained in treatment I_1 which was 43.92 g. The minimum weight of individual cowpea was obtained in treatment I_2 and was 12.10 g. The data did not differ significantly in the case of average weight of individual cowpea. The number of fruits per plant is an important factor in the yield of cowpea. Variation in number of fruit with different treatments of irrigation is shown in the Table 4.3. From the observations, treatment I_5 gave the least no of fruits and I_2 gave the maximum number of fruits. The detailed comparison among the treatments shows that the treatment with 120 % of irrigation requirement (I_5) gave the least number of fruits and treatment I_2 gave more number of fruits.

Table 2 Average length and weight of individual cowpea for different treatments.

	I_1	I_2	I_3	I_4	I_5
Average Fruit Length (cm)	50	49	48	47	45
Average Fruit Weight (g)	21	21	19	22	19

Table 3 Variation in number of fruit with different treatments

	I_1	I_2	I_3	I_4	I_5
No. of Fruits	187	193	157	160	119

Yield

Crop yield is always an important effective and economic index in the crop development. The aim of planting any crop is to get the highest yield of good quality fruits. The first yield was obtained 51 days after sowing and continued up for 120th day. Yield was influenced by different treatments of irrigation. The yield obtained from each treatment is shown in Table 4.4. The maximum yield was obtained for the treatment I_2 and the minimum yield was seen for the treatment I_5. The treatment I_1 was on par with treatment I_2. Figure 4.1 shows the significance of irrigation level on yield obtained.

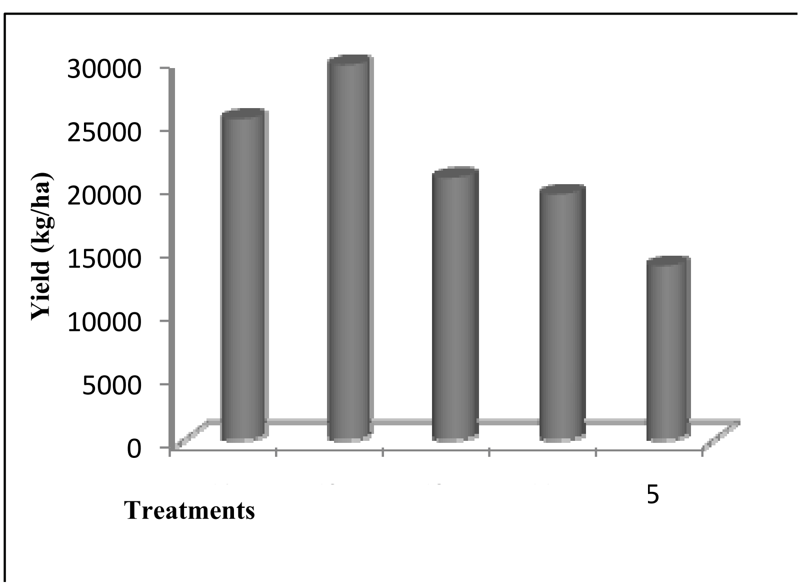

Fig. 1 Yield obtained from each treatment in kg/ha

Table 4 Yield obtained from each treatment

Treatment	I_1	I_2	I_3	I_4	I_5
Yield (kg/ha)	25389	29620	20771	19462	13673

This is in agreement with the experiment done by Harmanto *et al.,* (2005). They reported that an average irrigation rate of 0.5 l /plant/day was found to be optimum amount of water for maximizing the tomato yield. The application of irrigation at lower amount (deficit irrigation) of the water requirement gave lower yield. But increasing the irrigation water over a certain level (over irrigation) did not increase the tomato yield above maximum yield. Hence, irrigation should be given as precise as possible to the plant close to the optimum. The optimum amount of irrigation was very close to the crop evapotranspiration which was calculated from the dynamic microclimate inside the greenhouse during the experiment.

Irrigation Water use Efficiency

The term Irrigation Water Use Efficiency (IWUE) denotes the production of crops per unit of water applied. It is expressed as the weight of the crop produced per unit depth of water over a unit area (kg/mm per hectare). Table 4.5 shows the water use efficiency for different irrigation treatments.

Table 5 Water use efficiency of various irrigation treatments

Treatments	Average yield (kg/ha)	Water used (mm)	Water use efficiency (kg/ha/mm)
I_1	25389	362	70
I_2	29620	407	73
I_3	20771	452	46
I_4	19462	497	39
I_5	13673	542	25

SUMMARY AND CONCLUSION

The present study was taken up with the objective to determine the effect of different irrigation levels on the performance of cowpea under naturally ventilated polyhouse. The crop water requirement of the cowpea was determined using the irrigation management and planning model CROPWAT. The details of climate, soil and the crop were fed to the CROPWAT model to estimate the crop water requirement. The value of reference crop evapotranspiration obtained was 4.26 mm/day. Five levels of irrigation were applied to the five beds. The irrigation trial was carried out with five levels of irrigation such as 80, 90, 100, 110 and 120% of daily irrigation requirement of crop. The yield obtained from the irrigation treatments was observed. The five treatments showed significant difference in the case of average yield (kg/ha). The maximum yield was obtained for the treatment I_2 (29620 kg/ha). The minimum yield was observed in the case of treatment I_5 (13673 kg/ha). With respect to average yield the different levels of irrigation showed significant difference. Compared to I_2, the yield for other treatments I_1, I_3, I_4, and I_5 were lesser by 14, 30, 34 and 54% respectively. The study revealed that drip irrigation with 90% of the daily irrigation requirement can give maximum production of cowpea inside a naturally ventilated polyhouse. Variation in number of fruits with different treatments of irrigation was also observed. Comparison among the treatments shows that treatment with 120 % of irrigation requirement (I_5) gives the least number of fruits. From the results, it is evident that 90% of irrigation requirement is optimum for producing maximum number of fruits in cowpea grown under naturally ventilated polyhouse. Irrigation rate significantly affected irrigation water use efficiency (IWUE). It ranged from 25 kg/ha mm in I_5 to 73 kg/ha mm in I_2.

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Effect of Different Levels of Fertigation on Fruit Yield and Quality of Nagpur Mandarin

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ABSTRACT

A field experiment was carried out in Nimji village on farmer's field, Tq Kalameshwar District Nagpur (MS) on 10 year old Nagpur Mandarin crop consisting of one treatment of soil application (band placement) of NPK fertilizers as per Dr PDKV Akola recommended dose and 5 fertigation treatments i.e. 115%, 100%, 85%, 70% and 55% of the recommended dose of NPK fertilizers. It was found that treatment T_3 with 100 % NPK fertigation showed highest yield of 29.9 t/ha which was at par with fertigation with 115% and 85 % of recommended dose of fertilizers. Lower yields were obtained in soil application of fertilizers and fertigation with 70% and 55% of recommended dose of NPK fertilizers. However, superior fruit quality parameters were shown by treatment T_4 (ferigation with 85% of RDF). This showed that optimum dose of fertigation (85%) is necessary for higher yields, improving fruit quality with saving of fertilizers in Nagpur Mandarin crop.

INTRODUCTION

Citrus is an important commercial fruit crop of India. It occupies third position among fruits after banana and mango in India. Important citrus species in India are Mandarin, Acid Lime and Mosambi. Mandarin (*Citrus reticulata Blanco*) is important citrus cultivar occupying about 40% area under citrus cultivation. In India it is cultivated on 329900 ha i.e. 3.9 % of the total area under fruit crops with annual production of 3431400 MT. In India the average productivity of Mandarin is 10.4 MT/ha. (Indian Horticulture Database 2014). In Maharashtra it is mainly grown in Vidarbha and known as Nagpur Mandarin having average productivity of only 5.5 t/ha. Improper water and fertilizer management is one of the reasons of low productivity and decline of citrus orchards. Traditionally this crop is grown with 6 x 6 m spacing on level field and irrigated with basin method. Because of scarcity of water many orchard growers are adopting drip irrigation. But fertilizers are still applied with band placement or soil application method which requires more labours and also results in low fertilizer use efficiency. This practice does not match with the drip irrigation. Therefore application of fertilizers along with drip irrigation i.e. fertigation is necessary. Fertigation which combines irrigation with fertilizers is well recognized as the most effective, economical and convenient means of maintaining optimum fertility level and water supply according to the specific requirement of crop and resulting in higher yields and better quality fruits (Smith, 1979; Syvertsen, 1996). Fertigation offers the best way of supplying nutrients to the rootzone in areas with scanty rainfall. This novel technology of fertigation can be well adopted by majority of farmers if it is demonstrated on farmer's field. Keeping these points in view, an experiment was conducted at farmer's field during 2015-16 to study the effect of different levels of fertigation on the yield of Nagpur Mandarin in order to find out optimum dose for fertigation.

MATERIAL AND METHODS

A field experiment was conducted to study the effect of different levels of fertigation on yield of 10 year old Nagpur Mandarin crop (budded on rouh lemon) for *ambia bahar* during the year 2015-16 at farmers field (Shri Anantraoji Gharad) at village Nimaji Ta Kalameshwar Dist. Nagpur, Maharashtra. The soil was clay loam with pH 7.25 and EC 0.35 dSm^{-1}. Field capacity, permanent wilting point and bulk density of the soil were 31.12%, 17.45% and 1.17 Mgm^{-3} respectively. Drip irrigation with laterals having inline drippers of 4 lph at 40 cm distance was installed (2 laterals/row). Arrangement of ventury injector was made. A field experiment in RBD with six treatments and four replications was carried out. The treatment details and split schedule of fertigation treatments are given in Table 1 and 2 respectively. Irrigation was applied based on reference evapotranspiration using daily pan evaporation data on alternate day. The water soluble fertilizers 19:19:19, urea and muriate of potash (water soluble) were used for fertigation treatments (T_2 to T_6). Firstly the P dose was fulfilled .by using 19:19:19 fertilizer and thereafter additional N and K were supplied through urea and muriate of potash (water soluble) fertilizers. The soil was found deficient in zinc. Therefore zinc sulfate was applied uniformly initially @ 40 g $tree^{-1}$ by soil application.

Table 1 Details of treatments

Treatment	Specifications
T_1	Soil application with RDF – 1200 - 400 – 600 NPK (g/plant) [332 – 110- 166 (kg/ha)]
T_2	Fertigation with 115% of RDF – 1380– 460 – 690 NPK(g/plant) [382- 127 - 191(kg/ha)]
T_3	Fertigation with 100% of RDF – 1200 - 400 – 600 NPK (g/plant) [332 – 110- 166 (kg/ha)]
T_4	Fertigation with 85% of RDF- 1020 – 340 – 510 NPK (g/plant) [283 - 94 – 141 (kg/ha)]
T_5	Fertigation with 70% of RDF - 840 – 280 - 420 NPK (g/plant) [233 – 76 - 116 (kg/ha)]
T_6	Fertigation with 55% of RDF - 660 – 220 - 330 NPK (g/plant) [183 – 61 - 91 (kg/ha)]

Table 2 Split schedule for fertigation

	Percentage Quantity of fertilizers through drip at each stage		
Stage	N	P	K
At withdrawn of water stress	20	25	20
2nd Month	20	25	20
3rd and 4th Month	20	25	15
5th and 6th month	20	10	15
7th month	10	10	15
8th month	10	5	15

For treatment T_1, as per Dr PDKV Akola recommendation, the circular band placement of granular fertilizers (urea, single super phosphate and muriate of potash at 1 m radius from plant stem under basin irrigation was performed two times a year. Fertilizers were applied through in line drip irrigation system as per the schedule given below. After the withdrawn of water stress fertilizers were started in April 2015. Subsequently the fertilizers were applied as per schedule during 2nd month (May), 3rd and 4th month (June, July), 5th and 6th (August, September), 7th month (October) and 8th month (November 2015).

After harvesting, the number of fruits per tree was counted and the weight of total fruits from each tree under various treatments was recorded. The samples of ten fruits per tree were randomly taken to determine fruit quality parameters (juice percent, acidity and total soluble solids). Juice was manually extracted by juice extractor and its percent was estimated on weight basis with respect to the fruit weight as per Garwell *et.al.* (2000). The total soluble solid (TSS) was determined by digital refractometer by Lacey (2009) and acidity was measured by volumetric titration with standardized sodium hydroxide, using phenolphthalein as an internal indicator (Ranganna, 2001). All the data generated were subjected to analysis of variance (ANOVA) and the critical difference (CD) at 5% probability according to the method described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Fruit yield contributing characters and fruit yield

The fruit yield contributing characters and fruit yield showed significant difference in response of different levels of fertigation and soil application of fertilizers. (Table 3)

Table 3 Fruit yield contributing characters and fruit yield as influenced by different levels of fertigation

Treatments	Fruits/ Plant	Avg.wt of fruit (g)	Fruit yield (Kg/plant)	Fruit Yield (t/ha)
T_1 -Soil application with RDF	534.995	168.150	89.985	24.925
T_2- Fertigation with 115% of RDF	649.550	166.160	107.935	29.895
T_3- Fertigation with 100% of RDF	649.865	166.155	107.985	29.910
T_4- Fertigation with 85% of RDF	643.725	163.425	105.195	29.135
T_5- Fertigation with 70% of RDF	628.765	156.325	98.285	27.225
T_6- Fertigation with 55% of RDF	598.815	150.335	90.045	24.945
F Test	Sig.	Sig	Sig.	Sig
SE (m) $\pm$	9.55	0.681	1.643	0.455
CD at 5%	28.80	2.053	4.952	1.371

The fertigation with five different levels of NPK had a positive effect on the yield as well as fruit quality of the Nagpur mandarin during 2015-16. The Nagpur mandarin fruits were harvested during first fortnight of January month in the year 2016. The average number of fruits per plant, yield, TSS, juice content, and acidity were analysed for the study period and mean values were obtained. The average number of fruits per plant ranged from 598.81 to 649.86. Treatment T_3 (fertigation with 100% of RDF) have shown significantly highest number of fruits(649.86 fruits plant^{-1}) which is at par with T_{2-} Fertigation with 115% of RDF, (643.72 fruits plant^{-1}) and T_4 - Fertigation with 85% of RDF. The lowest number of fruits per plant was observed in T_1 -Soil application with RDF (598.81 fruits plant^{-1}) may be due to the soil application NPK. The various level of fertigation with NPK fertilizers treatments significantly influenced the yield of the Nagpur mandarin. The average Nagpur mandarin fruit yield was ranged from 24.92 to 29.91 tonnes/ha. The highest fruit yield per hectare was obtained in T_3- Fertigation with 100% of RDF (29.91 tonnes/ha) which is at par with T_2 Fertigation with 115% of RDF(29.89 tonnes/ha), T_4 Fertigation with 85% of RDF (29.135). The lowest fruit yield was observed with T_1 -Soil application with RDF (24.92 tonnes/ha). This may be due to leaching and other losses of fertilizers. The higher fruit yield under optimal drip-fertigation over conventional fertilization was also observed earlier studies in case of various citrus cultivars (Duenhas *et al.*, 2005; Morgan *et al.* , 2009). This is clearly indicated that the fruit yield at 85% of RDF through fertigation was at par with 100% and 115% of RDF through fertigation showing that fertigation with 85% of RDF is optimum for achieving higher yield. However, yield of fertigation with 70% RDF and 55% RDF were found statistically inferior to higher doses of fertigation.

`Fruit Quality Parameters

The effect of different levels of fertigation was studied on fruit quality parameters. The recorded observations have shown significant differences among various treatments (Table 4)

Table 4 Fruit quality characters and yield as influenced by different levels of fertigation

Treatments	Fruit length (cm)	Fruit dia. (cm)	TSS (°Brix)	Acidity (%)	TSS:Acidity Ratio	Juice content (%)
T_1 -Soil application with RDF	6.705	6.83	9.315	0.845	11.030	43.892
T_2- Fertigation with 115% of RDF	6.350	6.475	10.645	0.825	12.955	49.655
T_3- Fertigation with 100% of RDF	6.335	6.435	10.765	0.825	13.055	49.555
T_4- Fertigation with 85% of RDF	6.260	6.235	11.065	0.810	13.665	52.322
T_5- Fertigation with 70% of RDF	5.845	6.075	10.225	0.845	12.290	48.615
T_6- Fertigation with 55% of RDF	5.685	5.965	10.08	0.835	12.06	47.125
F Test	Sig.	Sig	Sig.	NS	Sig.	Sig.
SE (m) $\pm$	0.055	0.030	0.079	0.013	0.226	0.495
CD at 5%	0.166	0.090	0.240	0.041	0.684	1.494

The highest average fruit length (6.70 cm), fruit diameter (6.83) is observed in T_1 -Soil application with RDF, Highest TSS (11.06 ^{o}Brix) and juice percent (52.32 %), lowest acidity (0.81) were observed in T_4- Fertigation with 85% of RDF. The higher TSS to acidity ratio is the indicator of sweetness of the fruit. If the TSS to acidity ratio is high means that the fruits have more TSS (total soluble solids) and less acidity. This ratio was analysed and the highest TSS to acidity ratio (13.66) was found in T_4- Fertigation with 85% of RDF which is on par with T_3-Fertigation with 100% of RDF in which this ratio is 13.05. The TSS to acidity ratio was 12.9 with the T_3-Fertigation with 115% of RDF. The lowest ratio of TSS to acidity (11.03) was observed the T_1 -Soil application with RDF (Table 4). The similar fruit yield and quality experimental results are observed in Nagpur mandarin (Panigrahi and Shrivastava 2011) and acid lime (Shirgure *et al.,* 2001).

CONCLUSIONS

The application of irrigation and fertilizers through drip system was found to be a potential water and fertilizer saving method in Nagpur mandarin. Fruit yield was significantly higher under all treatments of fertigation over soil application of RDF. The fruit yield and quality at 85% of RDF through fertigation was at par with 100% and 115% of RDF through fertigation indicating that fertigation with 85% of RDF is optimum for achieving higher yield. However, yield of fertigation with 70% RDF and 55% RDF were found statistically inferior to higher doses of fertigation. Drip-fertigation not only enhanced the fruit yield but also improved the fruit qualities (Juice percent, TSS, acidity) over band fertilization method

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Integrated Reservoir Operation and Irrigation Scheduling

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ABSTRACT

To improve the performance of an irrigation reservoir, the reservoir releases must be in accordance with the crop water requirement. Crop water requirement and yield response to water deficit varies with the nature of crop and growth stage of crop. Reduction in yield is more when the water deficit takes place in certain growth stages of crop when compared to the other stages. Reservoir releases in each time period of a year are to be planned considering the future demands, inflows into the reservoir, storage and spillway capacity of the reservoir and capacity of off-taking channels. Under limited water supply, when reservoir release cannot meet the demand, deficit irrigation is inevitable. When number of crops are competing for water in a given time period, then the deficits are to be distributed optimally among the competing crops in such a way that the effect of shortage of water on yield is minimum. This is possible when irrigation allocations are made in proportional to yield response factor. In the present study, a fortnight reservoir operation model integrating the reservoir release decisions with the irrigation scheduling in a multi-crop environment is developed. The model developed determines irrigation to each crop grown under each off-taking canal, d/s releases, reservoir storages and spills for each fortnight of a year maximizing the weighted releases to each crop while minimizing the reservoir spill. Linear programming is adopted as optimization technique. The model developed is applied to a case study of Nagarjuna Sagar Reservoir project and the results obtained are discussed.

INTRODUCTION

Irrigation scheduling is a water management strategy to prevent over application of water while minimizing yield loss due to water shortage or drought stress. Irrigation scheduling means taking a decision for how much of water is to be allocated to each crop from the reservoir release in a particular time interval. In case of water scarcity, when deficit irrigation is inevitable, these deficits are to be allocated optimally among the competing crops.

Yield Response to Water Deficit

Water deficits in crops and the resulting water stress on the plant have an effect on crop evapotranspiration and crop yield. Water stress in the plant can be quantified by the rate of actual evapotranspiration (ETa) in relation to the rate of maximum evapotranspiration (ET_m). When crop water requirements are fully met from the available water supply, then $ET_a=ET_m$; When water supply is insufficient, $Et_a<ET_m$. The manner, in which water deficit affects crop growth and yield, varies with the nature of crop-growth period (Doorenbos and Kassam, 1979). The reduction in yield of crop with the water deficit is related as

$$\left[1-\frac{Y_a}{Y_m}\right]=K_y\left[1-\frac{ET_a}{ET_m}\right] \tag{1}$$

Where Ya is actual yield with available water; Ym is maximum yield that can be obtained when there is no limitation of water and Ky is yield response factor. The above equation may be written as

$$\left[1-\frac{Y_a}{Y_m}\right]=K_y\left[1-\frac{R}{D}\right] \tag{2}$$

where R is the release made available and D is the demand of a crop. The yield response to water deficit varies from crop to crop and also varies with its growths stages. Therefore, limited available water from the reservoir is to be allocated among the competing crops in such a way that reduction in the yield of crops is minimum. Therefore, reservoir release decisions are to be integrated with the irrigation scheduling in a multi-crop environment considering the yield response to water deficit of all crops grown, expected inflows into the reservoir in each intra-seasonal period, constraints on release, storage and canal carrying capacity.

Optimization models have been used extensively in water resources system analysis and planning (Loucks et al., 1981). The problem of irrigation scheduling in case of limited seasonal water supply has been studied extensively for single crop situation (Bras and Cordova, 1981; Rao and Sharma, 1988). Number of researchers addressed the problem of allocation of limited water supply for irrigation in multi-crop environment (Rao and sharma, 1990; Sunantara et al., 1997; Paul et al., 2000; Uma Mahesh and Raju, 2002; Teixeira and Marino, 2002). Many researchers used Linear programing as an effective tool for optimal cropping pattern and water allocation as they can handle large number of constraints (Khepar and Chaturvedi, 1982; Chavez Morales et al., 1987; Mayya and Ramprasad, 1989; Onta P.R, et al., 1995; Panda et al., 1996; Mainuddin et al., 1997; Singh et al., 2002).

In the present study, a fortnight reservoir operation model integrating the reservoir release decisions with the irrigation scheduling in a multi-crop environment is developed. The model developed determines irrigation to each crop grown under each off-taking canal, d/s releases, reservoir storages and spills for each fortnight of a year maximizing the weighted releases to each crop while minimizing the reservoir spill. Linear programming is adopted as optimization technique. The model developed is applied to a case study of Nagarjuna Sagar Reservoir project and the results obtained are discussed.

Model Formulation

The main objective of the model is to maximize the yield of crop. It is possible when actual evapotranspiration is made equal to potential evapotranspiration. When sufficient water is available, actual evapotranspiration is equal to potential evapotranspiration as releases can be done as per the targets. But in case of shortage of water, releases are to be made considering the yield response to water deficit. Therefore, if releases are maximized giving due weightage of Ky of crops, then maximum yields can be obtained to the extent possible under water scarcity.

The ***objective function*** of the proposed LP model is

Maximize

$$\Sigma_i \Sigma_c \Sigma_t \left(\frac{Ky_{i,c,t}}{D_{i,c,t}} \right) R_{i,c,t} + \Sigma_t \left(\frac{1}{DSD_t} \right) DSR_t - \Sigma_t SP_t \tag{3}$$

Where $R_{i,c,t}$ is the release to crop ‘c’ under canal ‘i’ in time period ‘t’ , DSR_t and SP_t are the d/s release and spill in time period ‘t’. $Ky_{i,c,t}$ and $D_{i,c,t}$ are yield response factor and target irrigation of each crop ‘c’ grown under canal ‘i’ in time period ‘t’. DSD_t is the target d/s release from reservoir. The above objective function is subject to the following constraints.

Upper & Lower bounds on releases

Maximum release to each crop is restricted by its target irrigation requirement and a minimum release of at least 50% of the demand is to be given in any time period.

$$R_{i,c,t} \leq D_{i,c,t} \qquad \forall \quad i, c, t \tag{4}$$

$$R_{i,c,t} \geq 0.5\, D_{i,c,t} \qquad \forall \quad i, c, t \tag{5}$$

Upper & Lower bounds on downstream releases

These are restricted to a maximum value equal to target d/s release and minimum is limited to 50% of target.

$$DSR_t \leq DSD_t \qquad \forall\ t \tag{6}$$

$$DSR_t \geq 0.5\, DSD_t \qquad \forall\ t \tag{7}$$

Reservoir Storage continuity equation

Water balance of reservoir is governed by reservoir storage continuity equation

$$(1+a_t)\, S_{t+1} = (1-a_t)\, S_t + Q_t - e_t A_0 - \Sigma_i \Sigma_c\ R_{i,c,t} - DSR_t - SP_t \qquad \forall\, t \tag{8}$$

Where S_t, Q_t and e_t are reservoir storage, inflow into reservoir and evaporation rate from reservoir in time period t. A_0 is water surface area at the top of the dead storage level, a_t = a e_t /2, and a is the surface area per unit active storage.

Channel capacity constraint on aggregate release into a canal in each time period

$$\Sigma_c\ R_{i,c,t} = CC_i \qquad \forall\ i,t \tag{9}$$

Where CC_i is the maximum carrying capacity of canal ‘i’

Upper bound on Reservoir Live Storage

The live storage of the reservoir in any time period S_t should not exceed its capacity.

$$S_t \leq S_{max} \qquad \forall\, t \tag{10}$$

Where Smax is the maximum limit of live storage of reservoir

Carry over year storage

The carry over year storage is taken is the initial storage of the year in order to ensure steady state model.

$$S_{25} = S_1 \tag{11}$$

Non-Negativity Condition

All the decision variables must be non-negative

$$R_{i,c,t}\ , DSR_t, S_t, SP_t, \geq\ 0 \tag{12}$$

Study Area

The study area considered in the present study to demonstrate the proposed model is the Nagarjuna Sagar Reservoir on the river Krishna in Andhra Pradesh, India (Fig..1). The irrigation project comprises of 124.66 m height masonry dam with two canals taking off from the reservoir on either side. This project also stabilizes irrigation under Krishna delta system through d/s releases. The designed discharge capacity of two main canals is 311.3 m^3/s each and the live storage capacity of the reservoir is 5,733 mcm. Cropping pattern and basic crop data considered in the present study is shown in Table 1. Rice is sown with two different dates. Date of sowing of Rice2 is delayed by a fortnight from that of Rice1 to reduce the peak demand. Mean daily Reference Evapotranspiration and mean monthly rainfall data is obtained IMD stations Rentachintala and Khammam for crops grown under Nagarjuna Sagar right and left canals respectively and is presented in Table.2. is adopted in present study and fortnight inflows of 85% probability of exceedence are calculated from the historical inflow data entering into the Nagarjuna Sagar Reservoir.

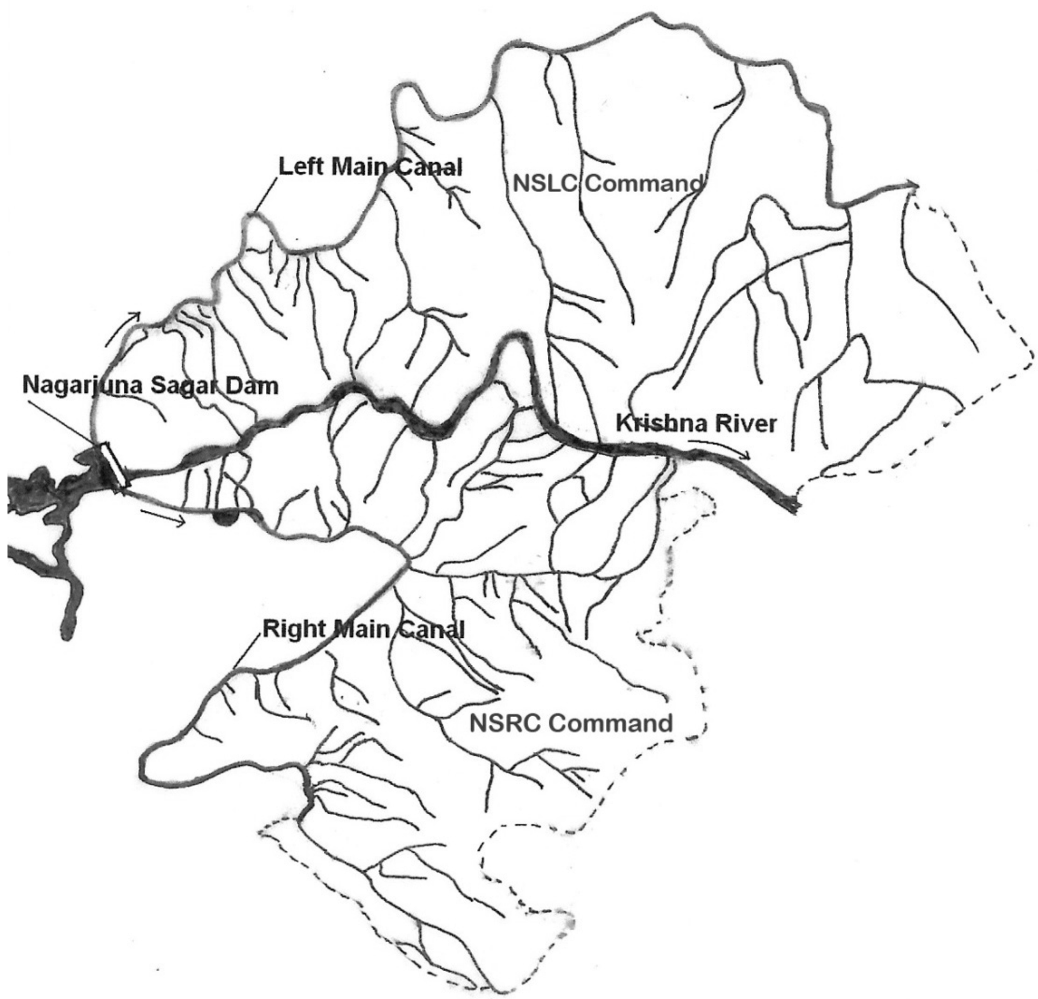

Fig. 1 Schematic representation of Nagarjuna Sagar project

Table 1 Basic data of crops grown under NSRC and NSLC

Crop (Season)	Date of sowing	Crop Coefficients Kc			Area (ha)	Duration of growth stages in fortnights and yield response factors K_y				
		Initial	Mid	End		Initial	Crop Development	Flowering	Grain formation	Ripening
NSRC										
Rice1 (K)	16 July	1.050	1.175	0.902	50000	1, 1.07	2, 1.07	1, 2.15	2, 2.15	1, 0.33
Rice2 (K)	1 August	1.050	1.175	0.902	50000	1,1.07	2,1.07	1,2.15	2,2.15	1,0.33
Groundnut K)	1 July	0.831	1.137	0.562	40000	2, 0.20	1, 0.20	1, 0.80	2, 0.60	2, 0.20
Sorghum (K)	16 July	0.835	0.958	0.489	70000	1, 0.20	2, 0.20	1, 0.55	2, 0.45	1, 0.20
Grams (K)	16 July	0.835	1.016	0.559	100000	1, 0.05	2, 0.05	1, 0.40	2, 0.35	1, 0.20
Cotton	16 July	0.814	1.105	0.702	100000	2, 0.20	2, 0.20	3, 0.50	3, 0.50	3, 0.25
Chilli	16 August	0.863	0.967	0.708	40000	2, 0.40	3, 0.40	2, 0.80	2, 0.80	1, 0.40
Groundnut (R)	1 November	0.761	1.152	0.623	40000	2, 0.20	1, 0.20	1, 0.80	2, 0.60	2, 0.20
Sorghum (R)	1 November	0.761	1.002	0.582	15000	1, 0.20	2, 0.20	1, 0.55	2, 0.45	1, 0.20
Grams (R)	1 November	0.761	1.056	0.625	60000	1, 0.05	2, 0.05	1, 0.40	2, 0.35	1, 0.20
NSLC										
Rice1 (K)	1 July	1.050	1.175	0.902	100000	1, 1.07	2, 1.07	1, 2.15	2, 2.15	1, 0.33
Rice2(K)	1Aug	1.050	1.175	0.902	100000	1,1.07	2,1.07	1,2.15	2,2.15	1,0.33
Cotton	16 July	1.010	1.085	0.690	10000	2, 0.20	2, 0.20	3, 0.50	3, 0.50	3, 0.25
Chilli	16 August	0.971	0.960	0.697	10000	2, 0.40	3, 0.40	2, 0.80	2, 0.80	1, 0.40
Groundnut (R)	16 October	0.884	1.133	0.608	40000	2, 0.20	1, 0.20	1, 0.80	2, 0.60	2, 0.20
Sorghum (R)	16 October	0.884	0.975	0.551	80000	1, 0.20	2, 0.20	1, 0.55	2, 0.45	1, 0.20
Grams (R)	16 October	0.884	1.038	0.601	75000	1, 0.05	2, 0.05	1, 0.40	2, 0.35	1, 0.20

Table 2 Reference evapotranspiration, rainfall and reservoir rate of evaporation

Month	IMD Station Khammam		IMD Station Rentachintala		Rate of Evaporation (mm/day)
	ETo (mm/day)	Monthly Rainfall (mm)	ETo (mm/day)	Monthly Rainfall (mm)	
January	3.890	1.6	4.00	0.4	3.0
February	5.142	7.3	4.72	9.3	3.0
March	6.510	10.5	5.62	6.1	5.8
April	6.934	25.5	6.16	9.6	7.6
May	7.472	27.1	6.44	40.8	8.0
June	6.031	126.5	5.67	86.2	6.0
July	4.016	260.1	4.92	115.3	4.8
August	3.881	185.5	4.64	114.6	4.8
September	3.863	164.5	4.34	146.1	4.8
October	3.699	107.1	4.11	123.8	4.2
November	3.547	33.8	3.81	41.1	3.3
December	3.846	3.9	3.70	13.3	3.3

RESULTS AND DISCUSSION

The intra-seasonal time interval taken in the present study is one fortnight considering a planning horizon of one year comprising 24 fortnights. Fortnight target irrigation requirement for each crop grown under each canal is calculated considering irrigation efficiency as 56% and 42% for Kharif and Rabi seasons respectively. An LP model is formulated for Nagarjuna Sagar Reservoir considering 85% reliable inflows, d/s target releases corresponding to 85% probability of exceedence from the historical data. The decision variables are fortnight release to each crop grown under right and left main canals, d/s release, reservoir storage and spill over reservoir. The total number of decision variables is 221 and the number of constraints is 419. A computer program to solve the LP model by Simplex method is coded in C-language and run with Linux operating system. From the results obtained a typical reservoir release allocations made to crop Grams(k) grown under the Nagarjuna Sagar Right Canal are shown in Table 3

Table 3 Release vs. demand for crop GRAMS (K) under NSRC

Fortnight	Demand (MCM)	Release (MCM)	% Deficit	Ky	Release/Demand
JUL 2	53.54	26.77	50	0.05	0.5
AUG 1	52.27	26.13	50	0.05	0.5
AUG 2	61.83	30.90	50	0.05	0.5
SEP 1	35.93	17.50	50	0.05	0.5
SEP 2	35.93	35.90	0	0.40	1.0
OCT 1	45.79	45.70	0	0.35	1.0
OCT 2	20.68	20.35	0	0.35	1.0

The above Table 3. shows the releases made against demands for all intra-seasonal periods of crop Grams(k). For the first four periods, 50% deficit irrigation is given while full irrigation for the remaining periods. It is also observed that yield response to water deficit is low (Ky=0.05) for the first four periods when compared to the remaining periods. From the above results, it is clear that model allocates deficit irrigation at times of water scarcity to those growth stages of crops having low Ky values. Table 4. shown below represents reservoir releases allocated to various competing crops under NSRC in the first fortnight of January.

Table 4 Release vs. demand of crops grown in Jan-I under NSRC

Crop	Demand (MCM)	Release (MCM)	% Deficit	Ky
Cotton	97.18	48.59	50.0	0.25
Chilli	36.43	36.43	0.0	0.40
Groundnut(R)	66.00	66.00	0.0	0.60
Sorghum(R)	21.58	21.58	0.0	0.45
Grams(R)	90.43	45.21	50.0	0.35

From the above table, it is observed that 50% deficit irrigation is given for Cotton and Grams(R) while no deficits i.e, full irrigation is given for remaining crops. This discrimination is due to the variation of yield response to water deficit of crops in the given fortnight. It can be concluded from the above results that full irrigation is given to those crops having high Ky values to avoid the high reduction in yield when there is competition among crops in a given fortnight. Variation of Reservoir storage, total right canal release, total left canal release, d/s release, evaporation and spill in MCM are shown in Table.5. for all fortnights of a year for the given inflows.

Table 5 reveals that a minimum live storage of 675.663 MCM is to be maintained at the first reservoir operation period to maximize the releases for the given inflows and demands. It is also observed that the reservoir is getting depleted by the end of 3rd reservoir operation period (Jul-II) because of the high irrigation demands of Rice crop. No releases are made in the months of March, April, May and June as no crops are being grown during those months. No spills are found and a huge amount around 378 MCM of water is being evaporated from the reservoir.

Table 5 Reservoir storages, releases, evaporation and spills for all 24 fortnights

Fortnight	Initial Storage	Inflow	NSRC Release	NSLC Release	D/s Release	Evaporation	Spill
Jun-II	675.66	83.51	0.00	0.00	125.41	17.88	0.0
Jul-I	615.88	139.85	175.66	193.68	215.72	13.93	0.0
Jul-II	156.73	531.10	324.39	193.68	156.21	13.49	0.0
Aug-I	0.00	1067.29	205.75	3.35	122.02	13.90	0.0
Aug-II	722.27	1303.96	251.14	10.96	152.03	15.05	0.0
Sep-I	1597.05	1113.72	173.11	50.88	109.28	16.23	0.0
Sep-II	2361.27	656.50	184.82	55.44	157.12	16.95	0.0
Oct-I	2603.45	914.70	222.96	134.07	60.30	15.29	0.0
Oct-II	3085.53	720.21	163.08	184.88	50.68	15.79	0.0
Nov-I	3391.31	367.18	285.25	183.71	21.80	12.49	0.0
Nov-II	3255.25	271.50	219.98	130.18	79.27	12.34	0.0
Dec-I	3084.99	195.06	234.57	245.10	110.98	12.05	0.0

Contd…

Fortnight	Initial Storage	Inflow	NSRC Release	NSLC Release	D/s Release	Evaporation	Spill
Dec-II	2677.35	181.47	254.73	244.42	110.13	11.63	0.0
Jan-I	2237.92	141.27	217.81	199.58	114.37	10.20	0.0
Jan-II	1837.23	131.64	174.20	121.23	121.17	9.88	0.0
Feb-I	1542.38	126.55	97.13	27.33	144.10	9.68	0.0
Feb-II	1390.70	95.69	25.55	0.00	163.35	9.57	0.0
Mar-I	1287.92	80.40	0.00	0.00	131.36	18.35	0.0
Mar-II	1218.61	77.85	0.00	0.00	104.46	18.25	0.0
Apr-I	1173.76	78.98	0.00	0.00	28.31	23.89	0.0
Apr-II	1200.54	23.50	0.00	0.00	0.283	23.92	0.0
May-I	1199.84	15.57	0.00	0.00	125.98	25.01	0.0
May-II	1064.42	1.42	0.00	0.00	204.12	24.58	0.0
Jun-I	837.14	18.97	0.00	0.00	162.36	18.23	0.0
Total		8337.84	3210.11	1978.48	2770.84	378.55	0.0

CONCLUSIONS

A fortnight LP reservoir operation model integrating the irrigation scheduling with the reservoir release decisions in multi-crop environment is formulated considering the yield response to water deficit. The main objective of the model formulated is to obtain release to each crop in such a way that the reduction in the yield of crop is minimum under water scarcity. The model developed is demonstrated through a case study of Nagarjuna Sagar Reservoir. The results obtained reveals that releases to crops are made considering the yield response to water deficit.

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THEME - VII

Review on Impact of Flash Floods in Urban India and its Mitigation

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ABSTRACT

Floods are the most frequent natural disasters in India and world. Sudden and highly unpredictable forms of floods are referred as flash floods which are considered to be one of the worst natural disasters. Flash floods are not much understood because of the uncertainty associated with the events and lack of accurate historical environmental data. Typically urban areas experience higher damage to the flash floods, streets can become fast-moving streams, water-filled basements and viaducts can cause fatalities. Highways, railways, concrete walls, large buildings and pavements may act like temporary embankments that may trap flood water for several days, which further extends the level of damages. Research review shows that, nearly 50 % of losses are damage to private property (vehicles and houses) and 25 % to roads and 30 % to network lines- power, telephone and other cables. The loss to industries and crops etc. depends on the spatial distribution. Damage caused to public works and networks includes - roads, railway networks, bridges, electricity, telephone, water processing, sewage system etc. In this paper extensive review of the causes of flash floods, methods of forecasting flash floods and the quantification of the damage caused to property is done. Innovative methods for flood water absorption into ground through water recharge methods are also proposed in this paper. This paper helps in better understanding and handling of flash floods by policy makers and civil engineering practitioners.

Keywords: Flash floods; Road networks; Property damage; Mitigation measures; Policy makers.

INTRODUCTION

Floods are the most frequent natural disasters in India. Sudden and highly unpredictable forms of floods are referred as flash floods which are considered to be one of the worst natural disasters. Literal meaning of flash flood is a sudden local flood, typically due to heavy rain. Flash floods in eastern part of India such as Odisa, Bengal, Bihar, Uttarakhand and Andhra Pradesh are striking examples for the innumerable loss (Mohapatra and Singh, 2003). Singhroy (2002) says that flash floods are among the most catastrophic hazards in the world causing maximum damage. Mumbai city, having an area of 437 km^2 with a population of 12 million, came to a complete halt owing to the unprecedented rainfall of 994 mm during the 24 hours starting 08:30 on 26 July 2005. At least 419 people were killed as a result of the ensuing flash floods and landslides in Mumbai municipal area, and another 216 as a result of flood-related illnesses. Over 100,000 residential and commercial establishments and 30,000 vehicles were damaged (Gupta, 2007).

Flash floods are natural disasters which cause significant socio-economic and environmental impacts such as loss of human and animal life, destruction of infrastructure and natural environment (Bangira, 2013). Flash floods are caused by excessive amount of rain falling within a short period of time or massive amount of water suddenly released from rivers or dams (Murray and Ebi, 2012). Flash floods are difficult to predict because they are characterised by quick and intense runoff generation that leads to rapid rise of water levels and discharges reaching to peak within less than one hour to few hours after the onset of the generating storm (Borga et al., 2011). The more devastating floods in last three decades are discussed here. In 1987 Bihar flood Kosi, flood caused an estimated loss of Rs 68 million due to damage of crops and public property and 1400 people died. The 1998 Assam Flood due to the Brahmaputra remained above the danger mark for almost three months at 6 major gauge sites on the river. All the 21 districts in the Assam valley were flooded affecting a population of 47 lakhs in 5,300 villages and damaging 9.7 lakh hectares of agricultural land. Besides 30,900 houses were damaged and 156 people died.

In 2004 Bihar floods 885 people had lost their lives and nearly 21.2 million human were affected. At least 5,000 people died in the 2005 Maharashtra flood. People were stuck in offices, houses, for several days due this flood caused by incessant rain. Bihar Floods again occurred due to breach in Kosi embankment at Kushaha in Nepal on August 18, 2008 had triggered floods. The river changed its course, killing hundreds of people and displacing around 30 lakh people. Leh and surrounding region of the Ladakh mountain range in the trans-Himalaya experienced multiple cloudbursts and associated flash floods during August 4–6, 2010. About 71 towns and villages in Leh were affected in the region and at least 255 people died. Because of this disaster, tourism was adversely affected. The disaster would have a long-term economic impact as it would take a long time to rebuild the infrastructure and also to build the confidence of the tourists (Gupta et al., 2012).

Assam floods are due to significant monsoon rains in 2012 and 124 people died. Kaziranga National Park lost 13 great India rhinos and 500 animals. During 15–17 June 2013, incessant rainfall centred at Uttarakhand, caused devastating floods and landslides in the country's worst natural disaster since the 2004 tsunami. Experts say that it is another alarm regarding the impact of rapid climate change on the environment. Unprecedented destruction by the rainfall witnessed in Uttarakhand was attributed to a unique meteorological event by environmentalists due to unscientific developmental activities undertaken in recent decades contributing to loss of lives and property (Durga rao et al., 2014). Nearly one lakh Hindu pilgrims coming to visit the Kedarnath and Badrinath shrines were trapped in all 9 districts of this northern state. Around 1000 people died in this Himalayan tsunami while more than 5,700 people missing. Indian Army had to launch one of its most severe rescue operations in its history to save those trapped, in the valley.

In 2014 Jammu and Kashmir is flooded due to incessant rain. River Jhelum and its tributaries flown above danger mark and 138 people died even after the Indian Army evacuated 11,000 people The Vaishno devi yatra has also been suspended. Recently in October and November 2015, Chennai suffered huge loss of three billion dollars and 347 people died. It was a disregard to town planning. Flash floods are not much understood because of the uncertainty associated with the events and lack of accurate environmental data either for forecasting or for the prevention of damage (Foody et al., 2004). Due to the environmental degradation in the recent decades and climate change, the frequency and intensity of occurrence of natural disasters like flash floods have changed substantially (Pradhan and Lee, 2010). Also heavy rains, change in land-use in the basin areas and various engineering applications determine the frequency and magnitude of the floods (Youssef et al., 2011). The causes of flash floods may be natural but most of them can be attributed as anthropogenic. The incorrigible anthropogenic actions have been so evolved that, they appear to be natural now. Sufficient early warnings are either not made by the hydrologists or not honoured by the policy makers due to obvious reasons. Now the situations have become grim and only the solution left with us, is to manage such disasters like flash floods and focus on the mitigation measures of the damages expected. This review paper deals with causes of flash floods, forecasting methods, quantification of damage to the property and finally the mitigation measures. Then certain innovative suggestions in this context are proposed.

CAUSES OF FLASH FLOODS

As already delineated, sudden and highly unpredictable form of floods are referred as flash floods. Flash floods are characterised by very fast rise and recession of flow of small volume and high discharge, which causes heavy damage because of suddenness. Usually flash flood occurs where heavy rainfall and thunderstorm or cloudbursts are common, especially in hilly areas like eastern part of the India. Cloudburst is a sudden heavy downpour over a small region and causes devastating flash floods. The cloudbursts are among the least known mesoscale weather systems, characterized by very high intensity rainfall greater than 100 mm per hour occurring over short duration (Das et al., 2006).

Depression and cyclonic storms in the coastal areas of Orissa, West Bengal, Andhra Pradesh, Karnataka, and Tamil Nadu also causes flash floods. Arunachal Pradesh, Assam, Orissa, Himachal Pradesh, Uttarakhand, the Western Ghats in Maharashtra and Kerala are more vulnerable to flash floods caused by cloud bursts. They are also called due to breaches in embankments of the rivers. Floods in Assam, Bihar, Uttar Pradesh, Orissa and Andhra Pradesh are generally caused by breaches in embankments. Disastrous floods could occur due to sudden release of waters from upstream reservoirs, breaches and landslides in the dams and breaches in embankments on the banks of the rivers. Severe flash floods in Himachal Pradesh in August 2000 and June 2005, and in Arunachal Pradesh in 2000 are a few examples of flash floods caused by breaches in landslide dams. Incidents of high intensity rainfall over short durations, which cause flash floods even in the area where rains are rare phenomena, are on the rise. Following flash floods during the June, 2013, the Uttarakhand valley was devastated by both channel incision and undercutting of infrastructure, and by burial by coarse boulder debris. Devrani et al. (2015) and Gupta (2007) has listed main causes in city area and suburban area of Bombay, for the flash floods, which is applicable to almost every city in India viz. low ground levels, dilapidated drains, siltation of drains, obstruction of utilities, garbage dumping, increase in runoff coefficient and no access for de-silting.

FORECASTING METHODS

Flash flood forecasting helps in disaster preparedness to avoid the extent of damage. Research into the modelling / forecasting of flash flood has increased over past decade (Hapuarachchi et al., 2011). Forecasting is done by physical based hydrological models or conceptual, statistical and neural network models. Model based on hydrological approach seems to be more reliable (Hapuarachchi et al., 2011). However, the quality of any forecast depends on the quality of rainfall input. Radar (Burton and O'Connell, 2004), satellite observations (Kubota et al., 2007) and multi-sensor observations have gone into the prediction of accurate rainfall data. Further, the accuracy of the models also depends on lead time in rainfall prediction. Statistical techniques such as linear regression, quantile regression, logistic regression, hierarchical models etc are combined with numerical weather prediction model for better prediction capabilities.

Soil moisture content is an important variable in hydrological modelling, it is measured in a catchment area by microwave satellite observations (Meesters et al., 2005). Soil surface temperature can be estimated from thermal infrared and passive microwave data which will help in deriving the evapo-transpiration rates, as an input for hydrological models. The main disadvantage with satellite data is the latency of > 2 hours in predicting the flash floods. However, remote sensing helps in mapping the large scale scenario for detecting the changes in repetitive mode. Foody et al. (2004) have combined hydrological models, soil properties with satellite data for predicting the peak flow of streams and thereby identifying the locations which are sensitive to the flash floods. Vojinovic and Tutulic (2009) have used the mechanistic / physics based models in simulating the damage caused by the floods.

Data-driven model on flow forecast usually comes handy in estimating the real time scenario of flash floods Data-driven models (for example Neural Network models) use statistical relationships derived form the rainfall and river flow data to generate the flow forecasts (Hapuarachchi et al., 2011; Sahoo and Ray, 2006). Detailed historical analysis of the development of models on predicting flash floods is discussed by Hapuarachchi et al. (2011). Ahmed et al. (2015) have utilized remote sensing data such as enhanced Thematic Mapper Plus (ETM +), Shuttle Radar Topography Mission (SRTM), coupled with geological, geo-morphological, and field data in a GIS environment for the estimation of the flash flood risk along the Feiran-Katherine road, southern Sinai, Egypt.

QUANTIFICATION OF DAMAGE

Typically urban areas experience higher damage to the flash floods, streets can become fast-moving streams, water-filled basements and viaducts can cause fatalities. In the last decade i.e. from 2001 to 2011, 2774 towns have been increased and now there are 7935 towns in India. Highways, railways, concrete walls, large buildings and pavements may act like temporary embankments that may trap flood water for several days, which further extends the level of damages (Hapuarachchi et al., 2011). Vinet (2008) has reviewed the percentage of damage caused by the floods / flash floods by analyzing the various incidents recorded in urban areas of Europe. It showed that, nearly 50 % of losses are damage to private property (vehicles and houses) and 25 % to roads and around 30 % to network lines. The loss to industries and crops etc depends on the spatial distribution. Damage caused to public works and networks includes -roads, railway networks, bridges, electricity, telephone, water processing, sewage system etc. Especially the damage occurred to roads and bridges constitute over half the public infrastructure.

Revilla et al. (2015) assessed remote-sensing data from the Global Flood Detection System (GFDS) and MODIS Flood Map (MFM), and ensemble stream flow forecasts from the Global Flood Awareness System (GloFAS) using flood information obtained from global flood disaster databases such as the Dartmouth Flood Observatory (DFO) Archive and the EM-DAT database.

For the flash flood mapping, various factors like Rainfall, Slope, Drainage density, LU/LC, Soil, Micro watershed (MWS) size, and Road per MWS were considered by Vinod et al. (2014). The thematic maps of these factors were prepared by using ArcGIS and ERDAS Imagine software tools. These thematic maps were assigned suitable ranks and weights, and combined by weighted overlay techniques in ArcGIS environment to derive the flood hazard map. The flood hazard areas thus obtained were grouped into five classes; very low, low, moderate, high and very high impact areas. Further, flash flood inundation mapping techniques using HEC-RAS and HEC-GeoRAS models were performed to fully assess the flood potential.

As hazardous weather is emphasized more in the future and the weather issues of importance are going to involve rapidly changing threats and subtle changes in the atmosphere. Hence forecasters must be educated and trained to meet the challenges of forecasting weather events. Dawod et al. (2012) had utilized a GIS-based approach for mapping and quantifying flood assessment measures particularly on road network. The used methodology is based on integrating several data sets in a GIS environment utilizing the SRC CN flood modelling method. A hazard factor has been developed to quantify the expected flood hazards on roads. Ganguly and Ravi Shankar (2014) used multi-temporal Landsat TM/ETM+/Landsat8 and IRS R2 LISS-3 imagery of 1992, 2002, 2009 and 2014 to investigate the influences of urbanization on it biophysical variables in sub-urban zone of Pune city.

MITIGATION MEASURES

The soil of the construction platform gets washed out if the heavy force of water, such as during flash flood, finds its way through the soil structure thus making the structure weak. Thus, stabilization of soil under the construction platform is necessary so as to increase soil strength and make it resistant against flash flood. Generally, runoff from intense rainfall is likely to be more rapid and greater with clay soils than with sand. Hence for the improving strength properties of the affected soil Ahmed et al. (2015) proposed the use of a Terrasil polymer.

According to the estimate of the Indian National Commission on Floods, the area prone to floods in the country is of the order of 400 lakh hectares. It is considered that 80 % of it, i.e., 320 lakh hectares can be provided with a reasonable degree of protection." The case study of flash floods in Leh (Ladak, India) in year 2010 by Gupta et al. (2012) identifies the strategies for the mitigation measures in Indian scenario. They have noted that, preparedness plans, protocols in civil administration and public health system could be helpful in reducing the casualties during natural disasters. Major shortcomings in Indian system while responding to the natural calamities are also discussed in their work. Internet giants Google and Facebook have also played an important role in Chennai floods in 2015. Especially Google maps have provided real time requirement of assistance for the isolated persons, mapping of goods distribution centres, availability of volunteers etc. The knowledge about the aftermath of the flood event is clearly mapped with the community participation for the enhanced rescue operations. Facebook has tagged the users from affected areas as safe or not safe by the natural calamities.

Disturbed road connectivity in the events of floods exacerbates the damage levels caused by inundation. Fatalities in post-flood events can be minimized by organized emergency response and recovery tasks which are only possible with proper road networks. Flash floods forecasting and warning systems using Doppler radars will be installed by the India Meteorological Department (IMD) by September 2009. As a preventive measure, the inhabitation of low-lying areas along the rivers, nallahs and drains will be regulated by the state governments/State Disaster Management Authorities (SDMAs)/District Disaster Management Authorities (DDMAs). Landslides and blockages in rivers will be monitored by the Central Water Commission (CWC)/National Remote Sensing Agency (NRSA)/state governments/SDMAs with the help of satellite imageries and in case of their occurrence, warning systems will be set up to reduce losses. If possible, appropriate structural measures to eliminate the damage in case of sudden collapse of the blockages will also be taken up.

Mishra et al. (2016) have suggested following mitigation measures, to reduce the extent of damage after flash flooding.

1. Slope cutting in the township for construction should be done in a planned way.
2. Construction of multi-storey building and structure on young flood plains should be restricted.
3. Long term master plans for the entire river with potential incidents of flooding, bank cutting are necessary.

4. Strong legal provision should be made and wider public are to be educated for controlling unwanted activities in rivers and high mountains.
5. Construction of big dam should be avoided in the vulnerable areas (with weak lithology). In place of big dams there should be construction of small dam which will be beneficial to control river water discharge for agriculture, etc.
6. More trees should be grown and protected in flood plains.
7. With the early warning system, effective evacuation plans and responsive disaster management group should be prepared with proper guidance and assistance.
8. The natural drainage that passes across the township should not be blocked or narrowed by construction activity in their close vicinity.
9. People should not do expansion of agriculture on the new or old river path.

If all the resources and infrastructure are concentrated in a very small area, the cities must have a monitoring and response mechanism to handle extreme rainfall events and other disasters. Also developments in any major city need to be accompanied by an adequate water supply, wastewater and storm water disposal system based on analysis of extreme rainfall events.

CONCLUSION

This paper reviewed the major causes of flash floods in Indian urban settlements, mathematical forecasting methods of flash floods and also discusses the assessment of damage caused due to flash floods and mitigation measures proposed.

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Smart Monitoring of Rural Water Supply Schemes

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Drinking water is one of the basic needs of life and essential for survival. Still more than one billion people all over the world do not have ready access to an adequate and safe water supply and more than 800 million of those unsaved live in rural areas. In India, ground water is being used as raw water for 85% public water supply. (According to world health report 1998)water supply varies widely in terms of region and country. In 1970s, of the approximately 2.5 billion people in developing world, only 38% has safe drinking water. At the beginning of the 1980s, water supply coverage was 75% in urban areas and 46% in rural areas. In developing countries, 75% of the population had access to water supply. So they are always prone to loss of their lives or cost a big toll to save themselves from the occurrence of different water-borne disease. Water contamination due to pathogenic agents, chemicals, heavy metals, pesticides water disinfectants, and thereby product as a consequence of industrial and agricultural activities leaching from soil, rocks, and atmospheric deposition and other human activities has become a hazard to human health in several regions of world.

Our indispensable water resources have proven themselves to be greatly resilient, but they are increasingly vulnerable and threatened. Day after day, we pour millions of tons of untreated sewage and industrial and agricultural wastes into the world's water systems. Clean water has become scarce and will become even scarcer with the onset of climate change. People obtain their drinking water from surface and underground sources. However both surface and ground water sources could become contaminated by biological and chemical pollutants arising from point and non point sources. Water is essential to life, but many people do not have access to clean and safe drinking water and many die of waterborne bacterial infections.

Need to protect safe drinking water: Water is a fundamental human need. Each person on Earth requires at least 50 liters of clean, safe water a day for drinking, cooking, and simply keeping themselves clean. Polluted water isn't just dirty it's deadly. Approximately 780 million people lack access to any improved water source, while 2.5 billion people do not benefit from proper sanitation. India has major water pollution issues. According to a World Health Organization study, out of India's 3,119 towns and cities, just 209 have partial sewage treatment facilities, and only 8 have full wastewater treatment facilities. Discharge of untreated sewage is the single most important cause for pollution of surface and ground water in India. There is a large gap between generation and treatment of domestic waste water in India. The problem is not only that India lacks sufficient treatment capacity but also that the sewage treatment plants that exist do not operate and are not maintained. In India alone, more than 97 million people lack access to safe drinking water, while more than 800 million do not benefit from hygienic sanitation. So it is most essential to safeguard the available water resources against pollution so as to guarantee the safe drinking water supply for the public.

Water quality: Water quality is the condition of the water body or water resource in relation to its designated uses. It can be defined in qualitative and or qualitative terms.The fresh water is of vital concern for mankind, since it is directly linked to human welfare. Every living being needs water for betterment of their health. Water is one of the vehicles for transferring of wide range of diseases. Supply of safe, clean and portable drinking water to the community is utmost important in maintaining positive health measures.The water required for public water supply schemes should be potable or wholesome water i.e. fit for drinking purpose. The impurities in water are to be removed to a certain extent so that it does not prove harmful to the public health. The term wholesome water is used to indicate the water which is not chemically pure, but does not contain anything harmful to the human body i.e. the water in which there are no pathogenic bacteria, no toxic substances and no excessive organic matter. Thus the wholesome is a must while the palatability of water is desirable.

The overall process of evaluation of the physical, chemical and biological nature of water in relation to natural quality, human effects and intended uses, particularly uses which may affect human health and the health of the aquatic system itself is called water quality assessment. Water quality assessment includes the use of monitoring to define the condition of the water, to provide the basis for detecting trends and to provide the information enabling the establishment of cause-effect relationships.

Water Supply Schemes: The main aspect of any water supply scheme of a locality is the proper selection of the source of water supply. The quality of water will determine the line of treatment and the water from surface sources usually requires exhaustive treatment before supplying it to the consumers.

Following are the points of importance in any water supply scheme:

1. Financial aspect
2. Population
3. Quality of water
4. Rate of consumption
5. Sanitary survey of area
6. Sources of water supply
7. Topography of area
8. Terms of town development

Next to air, the other important requirement for human life to exist is water. It is the nature's free gift to the human race. The importance of water in human life is so much that the development of any city in the world has practically taken place near some sources of the water supply.

Need To Protect Water Supplies: The water when exposed to the atmosphere contains many impurities which are harmful to any living organism. At present, only 16% of towns in this country are equipped with water supply works serving about 5% population of the whole of country. India has yet to make serious efforts to make the treated water available to the most of its population. The line of treatment to be recommended for a particular quantity of water will naturally depend upon its quality.

Disinfection of Water: Many diseases causing organisms are removed during storage, coagulation, sedimentation and filtration, still disinfection is practiced for the satisfactory or complete removal of pathogens. Disinfection is the most important of all the drinking water treatment process and is the only treatment process adopted in several water supply projects. It has been universally recognized that the chlorine is an ideal material for the disinfection for treating water on a large scale. The disinfection at present therefore is mainly carried out by chlorination as it accomplishes great bacterial purification in minutes than storage achieves in an equal number of days.

Smart monitoring of Water Supply Schemes: Smart Water Systems (SWS) present a new approach to promote water security with uncertain but significant future risks from population growth, hydrological variability and extreme events, and intensifying water allocation demands across water supply, agriculture, industry and ecosystems. Strategic and transparent water resource decision making is central for water security to be achieved. This is in turn contingent upon the accurate, timely and reliable collection and communication of information relating to water abstractions and use, and the primary resource base. With mobile networks expanding globally across national territories, SWS offer a mechanism to capture and communicate data on water resources through hydro-informatic systems on abstraction from surface water and groundwater, soil moisture content, storage levels and network leaks or theft. Within a new architecture of accurate, integrated and timely water resource data, water risks can be reduced and water security enhanced.

SWS also has the potential to unlock innovative business models for serving both the urban and rural poor. Communicating water consumption data and electronic payments across large distances and many endpoints can help resolve the enduring challenges that prevent the poor from accessing more sustainable water services. Household connections fees and monthly bills can be made more affordable for the poor by enabling flexible installment payments that accommodate irregular household cash flows via mobile phones and automated meters. Mobile banking and smart metering can pave the way for cashless standpipes that avoid middlemen and their profit margins that currently cost the urban poor. Barriers to rural water supply sustainability can also be tackled with remote monitoring and mobile banking opening up scales of management as alternatives to a community management paradigm that continues to meet with mixed success.

Smart water metering

Smart water metering refers to a system that measures water consumption or abstraction and communicates that information in an automated fashion for monitoring and billing purposes. Smart meters differ from conventional meters in that they measure consumption in greater detailand transmit that information back to the service provider without the need for manual readings.

Smart water metering offers a range of benefits when compared to conventional water metering. These include:

- Faster and more efficient meter reading
- Theft and leak detection
- Greater billing accuracy
- Enabling a flexible tariff structure
- Increased read frequency, resulting in improved debt collection
- Ability to remotely monitor resource use

There are therefore three key aspects to the urban water supply opportunities for SWS:

Smart metering, could reduce the inefficiencies in water supply systems with smart meters (a) remotely detecting leaks and illegal connections (b) increasing billing accuracy to promote payments that reflect consumption, (c) improving data management to introduce smart tariffs, and (d) prevent corrupt practices relating to meter reading and illegal connections. Mobile banking provides a platform for innovative mobile payment/saving and billing solutions which can (a) reduce transaction costs and opportunity costs of water bill payments, (b) increase collection efficiencies, (c) create secure payment systems, and (d) improve customer relations and satisfaction. Standpipe management models that incorporate smart metering and mobile banking would enable cashless and secure water point, whereby the unconnected poor could directly benefit from social tariffs and the utility could enjoy an increased revenue base. Smart technology would also allow for standpipe performance monitoring, regulation and accurate data to guide cost-effective water point expansion, such as in informal settlements.

Mobile banking in the water sector

The global mobile communications revolution presents new opportunities to address water security and poverty reduction challenges. In India, the number of mobile subscriptions is twice the number of individual piped water connections. These milestones mark a new technological era which can transform the way water services are paid for, operated and regulated with the prospect of reducing the multi-billion dollar water service financing gap, crowding-in investment and lessening the fiscal burden, particularly for low-income countries. Mobile banking is already increasing financial access amongst low-income groups with emerging opportunities for innovative saving and payment applications in the water service sector. Smart water metering is rapidly being deployed across the industrialized world, and offers an untapped opportunity to address systemic operational inefficiencies in developing regions and to govern water resource use and allocation more effectively at scale. confluence of mobile network coverage expansion, wide-spread mobile phone ownership, innovative mobile banking applications and smart metering technologies offer new, effective, low-cost and inclusive pathways to water security and poverty reduction.

Gravity Fed Water Systems

Water and hydrological engineers play a large role in addressing water poverty through the creation of appropriate technologies to provide water to developing communities. One common solution, given available topographic relief, is the implementation of gravity-fed water systems that pipe water without pumping or requiring costly energy. Typical gravity-fed system designs include a dam or spring catchment to collect the water, and the water is piped via gravity through a number of treatment processes (sedimentation, filtration, chlorination). When the water reaches the community, it is clean and in ample supply.

Water Resource Management

Mobile banking and water point monitoring innovations provide an exciting opportunity to remove existing scalar constraints and unlock new models of rural water supply management. Existing mobile infrastructure could dramatically enhance rural sector accountability and transparency by providing the platform for innovative technical, financial, and institutional solutions:

Technical innovations that measure water use on daily time-steps and relay packets of data to a central database to (a) alert water point failure and trigger response, (b) integrate into m-payment/billing models, (c) establish and monitor new Service Level Agreements and performance-based contracts with private-sector Rural Water Service Providers, and (d) provide a national database of water points, volumetric use and performance metrics to improve sector transparency and accountability.

Financial innovations that leverage mobile banking innovations for new billing and payment models that respond to (a) seasonal cash-flow economies, (b) existing m-remittances from urban to rural areas, (c) saving constraints of the poor, (d) weaknesses in community financial management capacity, (e) financial transparency and accountability, and (f) increasing service levels (i.e. productive use supplies) where demand exists.

Institutional innovations which can explore supra-community-based management systems and introduce an appropriate regulatory framework with rural-specific performance metrics to monitor and evaluate rural WSPs, and to create incentives for private sector actors to invest in new and sustainable rural water supply models.

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Rainfall Trend Analysis: A Case Study of Godavari Sub Basin – Kadam Water Shed, Adilabad District, Telangana State

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ABSTRACT

The current study is carried out to determine the potential trend of rainfall and assess its significance in Godavari Sub basin up to Kadam water shed in Adilabad district of Telangana State. Rainfall is a key characteristic of any water shed which place a significant role in flood frequency, flood control studies and water planning and management. In this case study, mean daily rainfall has been analyzed to determine the variability in magnitude over the period 2000 – 2014. Trend in daily precipitation data are analyzed using excel.

Keywords: Trend analysis, daily and monthly rainfall.

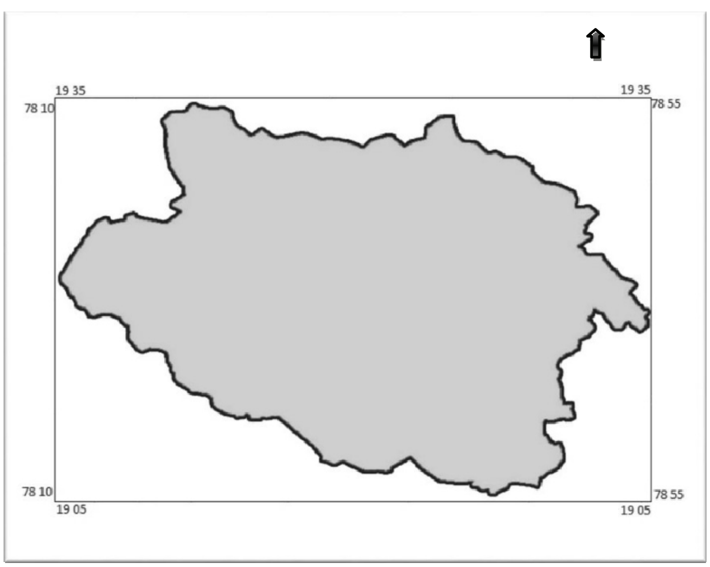
INTRODUCTION

Water resources has become a prime concern for any development and planning including food production and effective water resource management. Considering the importance of agriculture sector for the economy and the estimation of availability of water. In order to have a reliable estimate of varied climate change provisions, it is necessary to analyze the recent and expected future trend of annual and seasonal total rainfall. Rainfall is a renewable resource, highly variable in space and time and subject to depletion or enhancement due to both natural and anthropogenic causes. Knowing the variations in the general rainfall pattern is valid to understand the climate change variations.

Keeping above points in mind the study was carried out for Godavari Sub Basin – Kadam Water Shed of Telangana State.

Study Area

The sub basin lies between $18^0 20'$ and $19^0 35'$ North and longitudes $77^0 36'$ and $79^0 56'$ East. The middle Godavari Sub basin has a catchment area of 17205 km^2 which constitutes 5.5% of the total basin area. IN the present study middle Godavari Sub Basin considered upto Kadam reservoir only. The geographical area of the study area is 2,617 sq km.



CLIMATE

The climate of the sub basin is characterized by a hot summer and mild winter. The monsoon sets early in the month of June and continues up to the end of October. Winter is from November to mid-February and summer starts from Mid-February to end of May.

RAINFALL

The middle Godavari sub basin experiences only the south west monsoon which is from early June to end of October. There are 8 rain gauge stations falling in the study area viz., Khanapur, Kadam, Neradigonda, Boath, Ichoda, Utnoor, Indravally and Bazarhatnoor. The daily data of these 8 rain gauge stations has been collected for a period of 2000 to 2014 from Bureau of economics and statistics, Hyderabad. Average annual rainfall in mm has been recorded in Khanapur, Kadam, Neredigonda, Boath, Ichoda, Utnoor, Indravally and Bazarhatnoor as 1119.8, 1140.5, 1204.1, 1232.2, 1283.3, 1311.1, 1390.5, 1215.7.

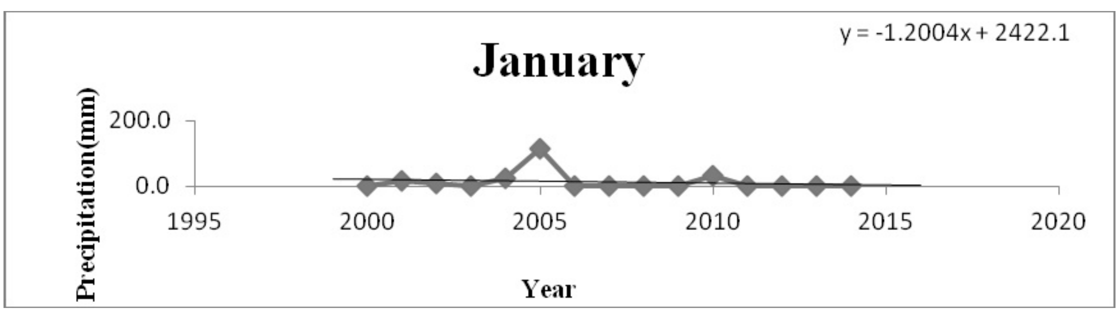
The sub basin experiences pre dominantly south west monsoon. A period of June to November has been considered as monsoon period and December to May has been considered as non-monsoon for hydrological purpose.

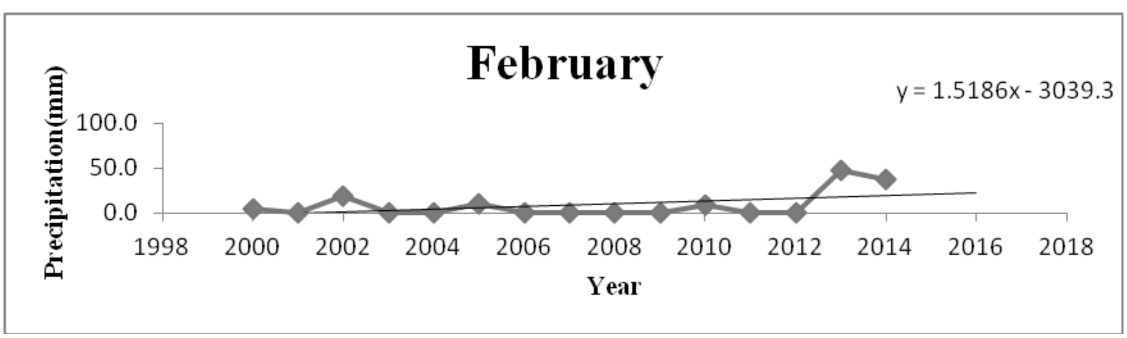
TEMPERATURE

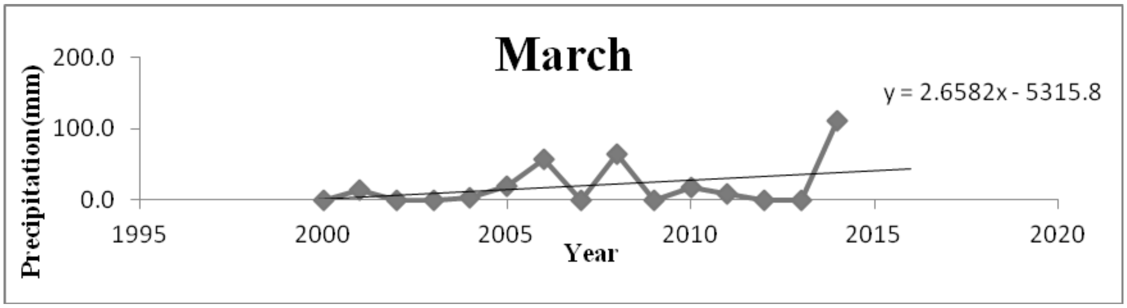
The daily maximum and minimum temperatures in the sub basin recorded at Jagityal Metrological station were collected. It is seen that the maximum temperature recorded in summer and winter as 45.2^0C and 15.3^0C respectively and the minimum temperature as 32^0C and 5^0C.

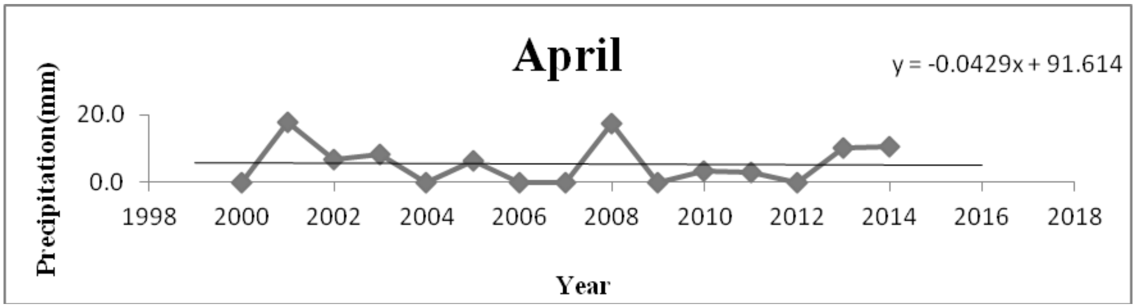
Materials and Methods: Toposheetes collected from Survey of India and study area map delineated. The daily rainfall data have been collected from Buerou of economics and statistics Hyderabad and trend analysis done by Excel. The following daily trend analysis represents the trend of one rain guage station for one month. It is a simple process done using excel. In present study the trend of rainfall over a year is found using the daily rainfall data of eight different rain-gauge stations under Adilabad district. A graph is drawn using this data and a trend line is added along with the equation representing the trend of the rainfall over the area

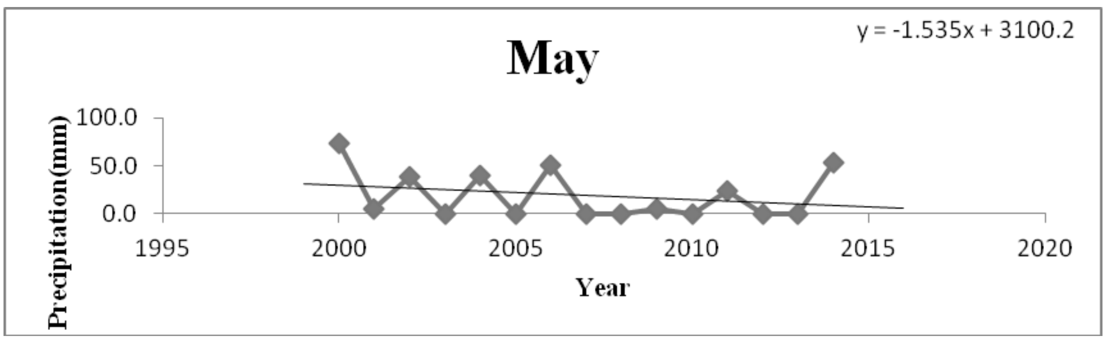
Rainfall trend for Boath rain gauge station:

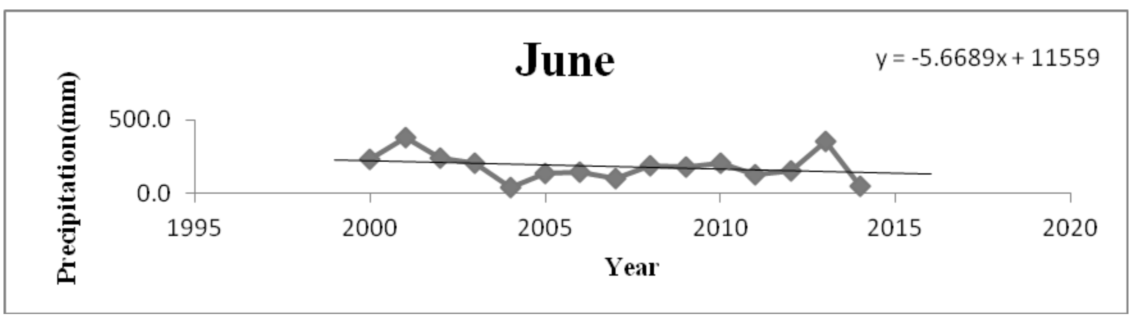


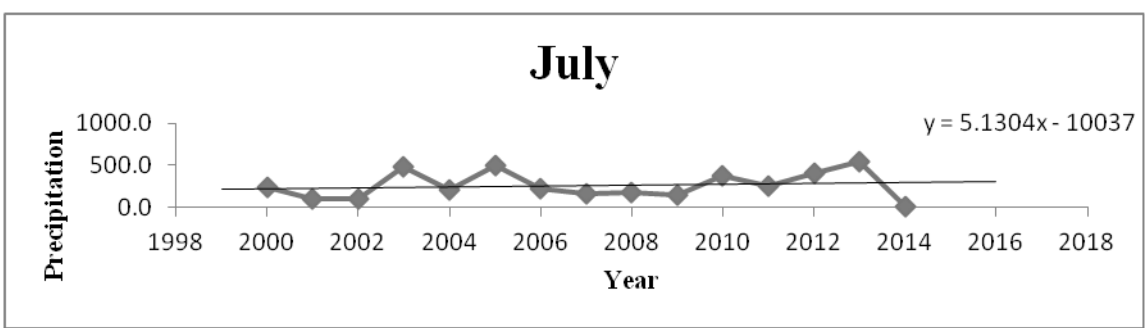


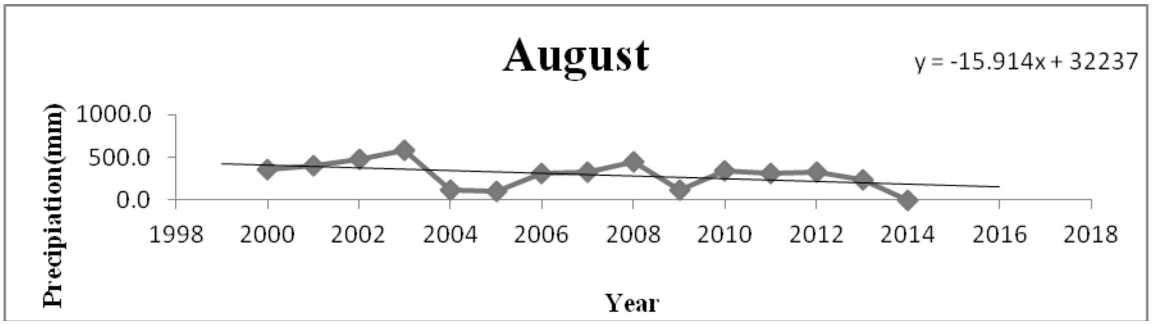

March
y = 2.6582x - 5315.8
Precipitation(mm)
200.0
100.0
0.0
1995
2000
2005
2010
2015
2020
Year

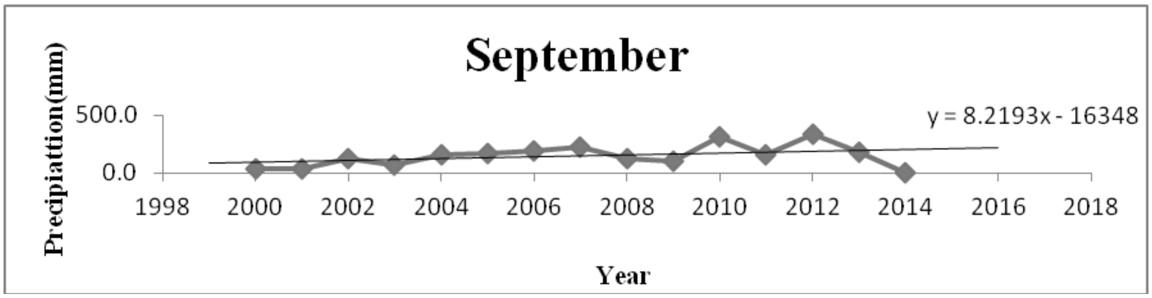

April
y = -0.0429x + 91.614
Precipitation(mm)
20.0
0.0
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Year

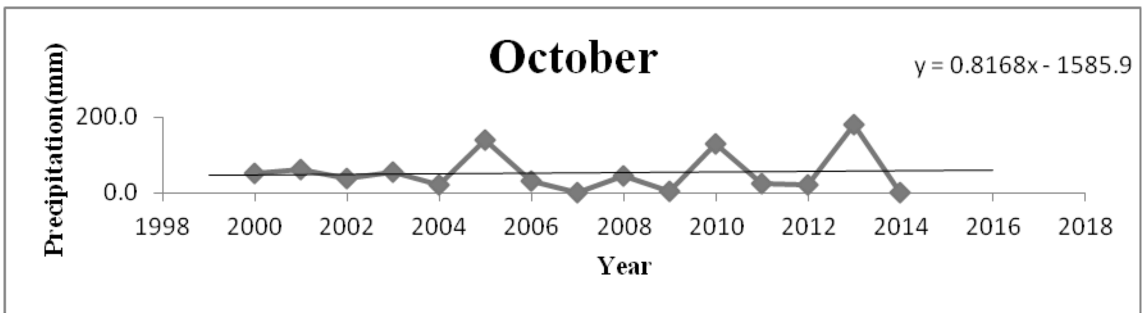

May
y = -1.535x + 3100.2
Precipitation(mm)
100.0
50.0
0.0
1995
2000
2005
2010
2015
2020
Year

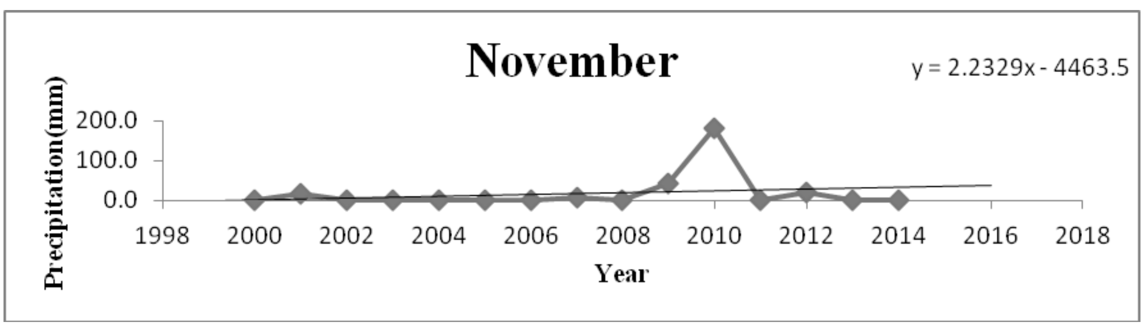

June
y = -5.6689x + 11559
Precipitation(mm)
500.0
0.0
1995
2000
2005
2010
2015
2020
Year

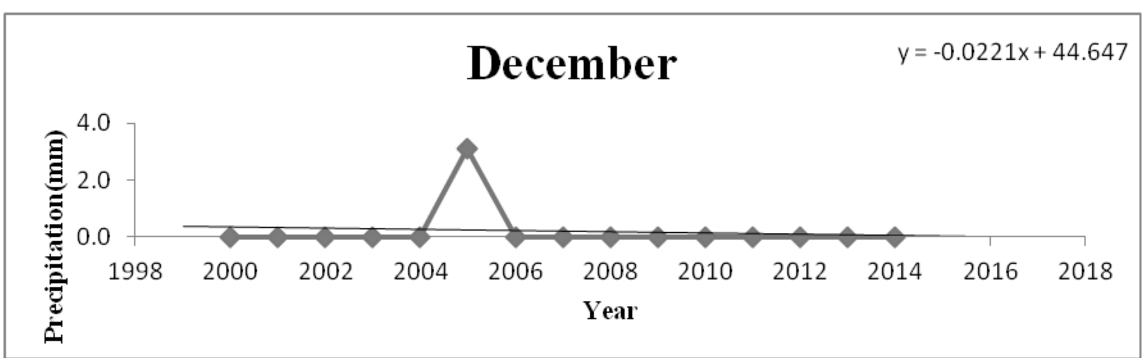

July
y = 5.1304x - 10037
Precipitation
1000.0
500.0
0.0
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Year


August
y = -15.914x + 32237
Precipitation(mm)
1000.0
500.0
0.0
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Year


September
y = 8.2193x - 16348
Precipiattion(mm)
500.0
0.0
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Year


October
y = 0.8168x - 1585.9
Precipitation(mm)
200.0
0.0
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Year

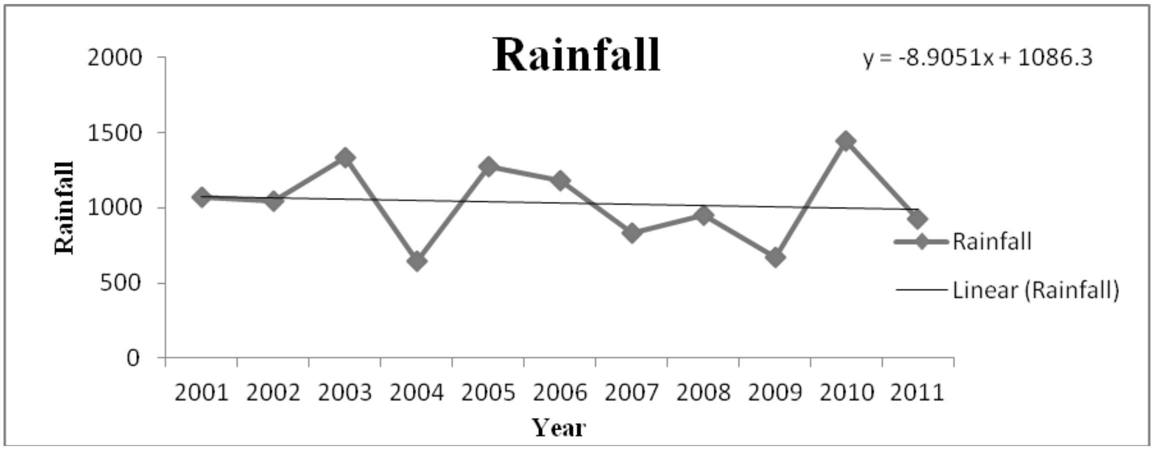

November
y = 2.2329x - 4463.5
Precipitation(mm)
200.0
100.0
0.0
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Year


December
y = -0.0221x + 44.647
Precipitation(mm)
4.0
2.0
0.0
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Year

RESULTS AND DISCUSSIONS

The trend analysis of the precipitation data has been done using the data of precipitation of Neradigonda, Khanapur, Kaddempeddur, Boath, Bazarahotnur, Utnur, Inderavelly and Ichoda rain gauge stations. The following figure shows the variability of the mean annual precipitation data for the entire period of study. There is decline in the annual mean precipitation in the period 2001-2011, whether this will continue needs further research.

Trend line fitted for yearly observed rainfall reflected an decreasing trend given by the equation y = –8.9051x + 1086.3



	January	February	March	April	May	June	July	August	September	October	November	December	Total
2001	1.9	0.0	4.6	12.3	1.82	67.71	29.9	115.2	16.6	32.2	3.2066667	0	285.5
2002	3.0	1.1	0.2	2.6	9.73	78.7	28.99	126.1	20.51	7.7	0	0	278.6
2003	0.0	1.6	3.1	5.48	0	52.73	131.2	118.2	27.91	15.4	0	0	355.5
2004	4.2	0.0	1.5	9.713	9.2	18.39	58.19	33.5	30.12667	5.5	1.5266667	1.2666667	173.2
2005	29.8	3.2	3.2	1.883	0.96	34.64	138.9	46.1	51.69667	25.9	0	3.0233333	339.4
2006	0.0	0.0	11.7	6.973	9.86	40.41	63.49	100.0	72.03	9.0	1.03	0	314.5
2007	0.0	0.0	0.0	0	0	43.01	46.91	55.0	67.17	5.7	3.4133333	0	221.2
2008	0.0	0.0	8.6	0.967	0	38.8	49.76	112.4	38.26	4.1	0.1066667	0	252.9
2009	0.0	0.0	0.1	0	0.24	34.43	39.43	49.4	41.79333	4.7	8.1	0.1466667	178.3
2010	5.8	1.8	1.5	1.113	0.21	33.41	112.6	105.7	64.21333	32.4	26.54	0	385.2
2011	0.0	3.8	0.3	4.4	4.11	36.38	72.88	87.0	33.29333	4.0	0	0	246.2
Total	44.8	11.4	34.7	45.4	36.1	478.6	772.3	948.6	463.6	146.5	43.9	4.4	3030.5

CONCLUSIONS

The minimum rainfall occurred in the year 2004 around 650 mm and 2010 has recorded the maximum of about 1445 mm of precipitation.

The rainfall data analysis of Godavari sub basin region for a period of 14 years (2001-2014) reveals variation in the rainfall amount and points out negative trend of rainfall in future. It is suggested that water resource development projects that depend on surface water as well as ground water sources will provide remedial solution to the prevailing problem of depleting ground water level of the Godavari sub basin region.

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A Simple Approach for Economical Design of Water Distribution Network

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ABSTRACT

Pipe network system includes the distribution of water from reservoirs to the required zones. Hence, the design of the water distribution system in an economic way is more important. An analysis of published research works show that a large number of function evaluations are required to arrive at least cost combination of pipe diameters. In this paper, A simple approach is proposed to get reasonably least cost water distribution network, but not to the level of global minimum cost solution. The proposed method is simple to understand by the practicing engineers. Using commercial software, the network can be optimized locally with meager number of iterations. This approach uses the velocity of flow as a decision parameter to size the pipe from initially assigned pipe size as a start up to the design of water distribution network. In which, pipe having size close to the middle of given options or commercially available in required range of sizes that need to adopted in the design will be assigned as an initialization process to proceed the design. Three case studies are selected to illustrate the proposed approach.

Keywords: pipe network, economical, velocity of flow.

INTRODUCTION

Optimal design of water distribution network is a challenging hydroinformatics problem in which sizing of pipes, and selection of pump and tank capacities are being dominant design components. Several optimization algorithms developed in operations research have been applied to solve various design problems involving various constraints. Over the past three decades, significant amount of research has gone into the development of optimization algorithms and models for the optimal design of water distribution networks due to its computational and engineering complexity (Alperovits and Shamir, 1977; Quindry et al, 1981, Fujiwara and Khang, 1990; Lansey and Mays, 1989; Murphy and Simpson, 1992; Simpson et al., 1994; Dandy et al., 1996; Savic and Walters, 1997; Cunha and Sousa, 1999; Vairavamoorthy and Ali, 2000; Eusuff and Lansey, 2003; Maier et al, 2003; Suribabu and Neelakantan, 2006 a &b; Neelakantan et al, 2008; Suribabu, 2010; Vasan and Simonovic, 2010; Mohan and Jinesh babu, 2010, Suribabu, 2012). Module based on demand driven analysis is widely coupled with optimization algorithm to explore pipe diameters that satisfy the hydraulic-head requirements at least cost. Design of a water distribution network is considered as one of the challenging problems for proving optimization models. Optimal design of a water distribution network is a NP-hard combinatorial optimization problem in which discrete pipe diameters are selected for links in the network to minimize cost while satisfying some constraints. A water distribution network is designed to deliver desired quantity of water to consumers within a range of pressure. The behavior of a network is governed by laws of conservation of mass and conservation of energy which can be represented in the form of simultaneous equations. Among those set of simultaneous equations, some of them are non-linear equations. Pipe-sizing optimization requires selecting optimal pipes from a set of commercially available diameters. Thus this is a combinatorial optimization problem involving non-linear constraints. The feasible region is non-convex, and the objective function is multimodal. Optimization models are also used for operation, reliability constrained designs, calibration and expansion problems of water distribution networks. These optimizations of water distribution networks are very complex and time consuming and hence efficient and faster algorithms are required. This paper shows a new idea, based on starting with median size pipe size available from the selected option for the network design and flow velocity in a pipe has been used.

Optimization model for pipe sizing

A general pipe sizing optimization model is formulated as to find the combination of commercial pipe diameters that gives the least cost network by fulfilling the constraints on pressures for a given layout and demand at various nodal points of the network.

Minimization of the total cost of the distribution system may be expressed mathematically as

$$Minimize\ Cost = f(D_1, D_2, ...D_N) \tag{1}$$

where D_1 represents pipe diameter for link 1 and N is the total number of links in the network. The network cost is calculated as the sum of the pipe costs where pipe costs are expressed in terms of cost per unit length. Total network cost is computed as follows:

$$Cost = \sum_{i=1}^{N} c(D_i) \cdot L_i \tag{2}$$

where $c(D_i)$ is the cost per unit length of the i^{th} link with diameter D_i, and L_i is the length of i^{th} link. For a given layout, lengths are fixed and so diameters are the decision variables. This objective function needs to be minimized subject to a set of constraints as follows.

Continuity of flow in each node should be maintained in the network. The quantity of flow entering the node should be equal to the quantity of flow leaving the node. The quantity of flow leaving the node includes the external demand and flow going out through other pipes emerging from node. This is expressed in the mathematical form as

$$\sum_{i \in in,n} Q_i = \sum_{j \in out,n} Q_j + ND_n \quad \forall n \in NN \tag{3}$$

where Q = pipe flow; ND_n = Demand at node n; in,n = set of pipes entering to the node n; out,n = set of pipes emerging from node n, and NN = node set.

The total head loss around the closed path (loop) should be equal to zero or the head loss along a path between nodes should be equal to the difference in elevation.

$$\sum_{i \in loop\ p} hf_i = \Delta H, \qquad \forall p \in NL. \tag{4}$$

where hf_i = head loss due to friction in pipe i; NL = loop set; ΔH = Difference between nodal heads at both ends, ΔH = 0, if the path is closed.

The Hazen-Williams head loss equation for pipe i of connecting nodes j and k

$$H_j - H_k = hf_i = \frac{\alpha L_i Q_i |Q_i|^{0.852}}{C_{HW,i}^{1.852} D_i^{4.87}} \quad \forall j \in NP \tag{5}$$

where NP = number of pipes; C_{HW} = Hazen-Williams co-efficient; D_i = Diameter of the pipe i; L_I = length of the pipe i; α = Conversion factor which depend on the units, different value of α are found in literature – as low as 10.4516 to as high as 10.9031 (Savic and Walters, 1997)

The pressure head in all nodes should be greater than the prescribed minimum pressure head.

$$H_n \geq H_{\min} \tag{6}$$

where H_n = Pressure head at node, n; H_{min} = Minimum required pressure head.

The diameter of the pipes should be within available commercial size

$$D_j = [D], \quad \forall i \in NP \tag{7}$$

METHODOLOGY

The methodology for sizing the pipe of water distribution network is explained step by step as follows.

Step 1: Prepare the water supply network and set all the pipe size. The pipe size is selected as median diameter from the number of pipe diameters available in the options. If pipe diameters are in even number, then select any one from the middle of two.

Step 2: Simulate the network. Find the velocities in each and every pipe.

Step 3: Find the pipes which has maximum velocity and minimum velocity. Increase the diameter of pipe which is having maximum velocity and decrease the size to next commercial diameter if pipe with minimum velocity.

Step 4: Simulate the network. Find the change in velocities across all the pipes. Repeat step 4, until there is violation of pressure head in any of the nodes.

Step 5: To make more economical, consider the least velocity pipe and decrement its diameter that too without violation of pressure constraint. If first least velocity pipe not able to make difference then move on to the next least velocity pipe and proceed on, up to all pipes. If one of maximum velocity or minimum velocity is reached to extreme ends, do not bother about that operate on only one. In case, two pipes with maximum and minimum velocity have been reached to extreme end, then move on to the next maximum and minimum velocity pipes and proceed as above.

Application of Proposed approach

Example Network 1

The pipe network in this example (Figure 1) is a hypothetical problem and studied first by Alperovits and Shamir (1977) and subsequently many researchers studied using various traditional and non-traditional optimization algorithms for least cost design. The network consists of eight pipes, six nodal points and a reservoir. All the pipe of the network has a length of 1000 m each with Hazen–Williams coefficient as 130. The minimum required pressure at all nodes is 30 m. The network needs to be designed for least cost for average peak demand shown in the layout. Table 1 shows the commercially available pipes and their cost per metre length.

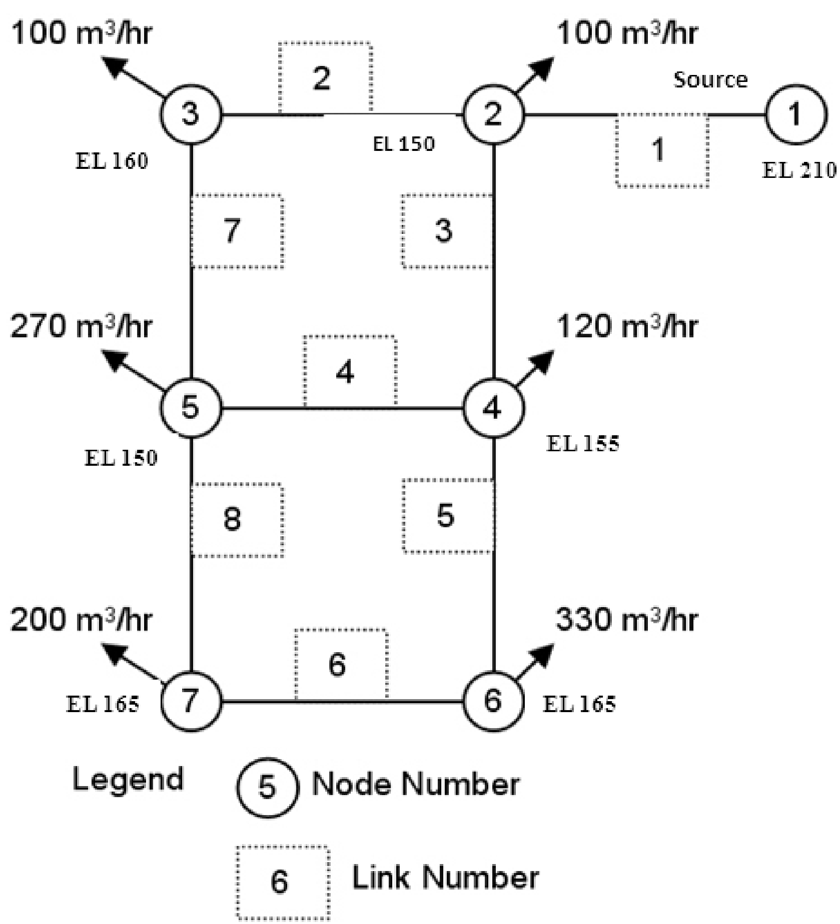

Fig. 1 Layout of two-loop network

Table 1 Pipe cost data for example 1 (two-loop network)

Diameter (in)	Diameter (mm)	Cost (units)
1	25.4	2
2	50.8	5
3	76.2	8
4	101.6	11
6	152.4	16
8	203.2	23
10	254.0	32
12	304.8	50
14	355.6	60
16	406.4	90
18	457.2	130
20	508.0	170
22	558.8	300
24	609.6	550

Example Network 2

The second test network (Fig. 2) is a three-loop water distribution network of Hanoi city water distribution system, which consists of thirty-two nodes, thirty-four pipes and a reservoir. The input data for this problem is given in Fujiwara and Khang (1990) and is presented in Table 2 and 3. The design of this network is restricted to select from the six different commercial diameter pipes assumed to be commercially available (Table 3). Hazen William co-efficient for all the pipes are assumed to be 130. The network is to be designed for average peak demand as given in the Table 3 and for minimum nodal pressure head of 30 m.

Table 2 Node and pipe details for Hanoi Network

Node No.	Demand (m^3/hr)	Pipe Index	Arc	Length (m)
1	-19,940	1	(1,2)	100
2	890	2	(2,3)	1,350
3	850	3	(3,4)	900
4	130	4	(4,5)	1,150
5	725	5	(5,6)	1,450
6	1,005	6	(6,7)	450
7	1,350	7	(7,8)	850
8	550	8	(8,9)	850
9	525	9	(9,10)	800
10	525	10	(10,11)	950
11	500	11	(11,12)	1,200
12	560	12	(12,13)	3,500
13	940	13	(10,14)	800
14	615	14	(14,15)	500
15	280	15	(15,16)	550
16	310	16	(16,17)	2,730
17	865	17	(17,18)	1,750
18	1,345	18	(18,19)	800
19	60	19	(19,3)	400
20	1,275	20	(3,20)	2,200
21	930	21	(20,21)	1,500
22	485	22	(21,22)	500
23	1,045	23	(20,23)	2,650
24	820	24	(23,24)	1,230

Table 2 ***Contd…***

Node No.	Demand (m^3/hr)	Pipe Index	Arc	Length (m)
25	170	25	24,25)	1,300
26	900	26	(25,26)	850
27	370	27	(26,27)	300
28	290	28	(27,16)	750
29	360	29	(23,28)	1,500
30	360	30	(28,29)	2,000
31	105	31	(29,30)	1,600
32	805	32	(30,31)	150
		33	(31,32)	860
		34	(32,25)	950

Table 3 Cost detail for available pipes for Hanoi Network

Diameter (in)	Diameter (mm)	Cost (units)
12	304.8	45.730
16	406.4	70.400
20	508.0	98.380
24	609.6	129.333
30	762.0	180.800
40	1016.0	278.300

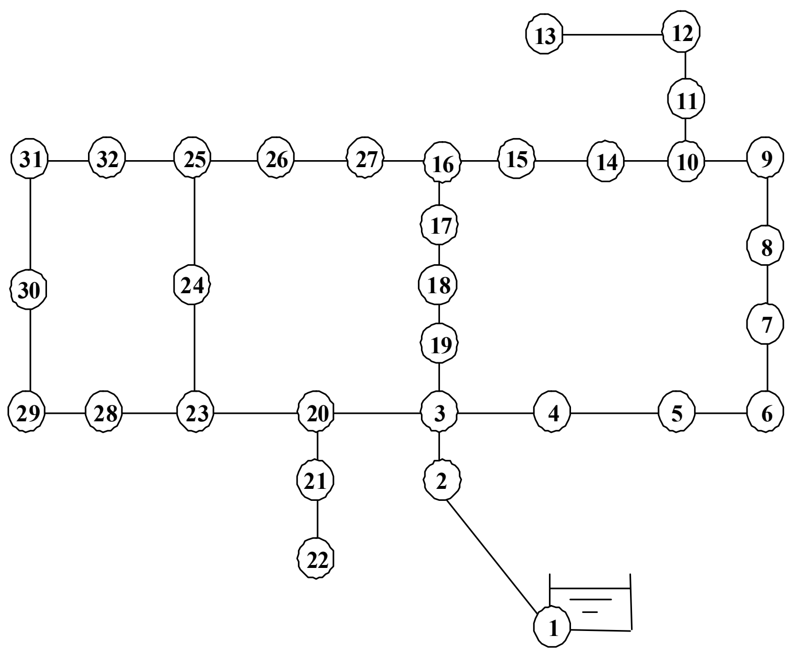

Fig. 2 Layout of Hanoi network

Table 4 Node and pipe properties for two-source network

Node No.	Demand (m^3/min)	Minimum HGL (m)	Pipe ID	Length (m)
1	-	100	1	300
2	-	95	2	820
3	18.4	85	3	940
4	4.5	85	4	730
5	6.5	85	5	1,620
6	4.2	85	6	600
7	3.1	82	7	800
8	6.2	82	8	1,400
9	8.5	85	9	1,175

Table 4 ***Contd…***

Node No.	Demand (m^3/min)	Minimum HGL (m)	Pipe ID	Length (m)
10	11.5	85	10	750
11	8.2	85	11	210
12	13.6	85	12	700
13	14.8	82	13	310
14	10.6	82	14	500
15	10.5	85	15	1960
16	9.0	82	16	900
17	6.8	82	17	850
18	3.4	85	18	650
19	4.6	82	19	760
20	10.6	82	20	1,100
21	12.6	82	21	660
22	5.4	80	22	1,170
23	2.0	82	23	980
24	4.5	80	24	670
25	3.5	80	25	1,080
26	2.2	80	26	750
			27	900
			28	650
			29	1,540
			30	730
			31	1,170
			32	1,650
			33	1,320
			34	3,250

Table 5 Pipe cost details for two-source network

Diameter (mm)	Unit cost (In Indian rupees)
150	1,115
200	1,600
250	2,154
300	2,780
350	3,475
400	4,255
450	5,172
500	6,092
600	8,189
700	10,670
750	11,874
800	13,261
900	16,151
1000	19,395

Example Network 3

To test the potential of the proposed algorithm for sizing the pipes of two sources network, a two-reservoir with 26 nodes, 34 pipes and nine loops network presented by Kadu et al. (2008) is considered. Fig. 3 shows the layout of the network. The pipe and node details are presented in Table 4. The Hazen-Williams co-efficient for all the pipes are 130. The cost of fourteen commercial pipes is presented in Table 5. Kadu et al. (2008) has optimized this network through modified genetic algorithm after reducing the search space using the path and critical path concept from 14^{34} (= 9.3×10^{38}) to $3^{11} \times 4^4 \times 5^{19}$ (= 8.65×10^{20}). In the present study, the same network is optimized using proposed approach.

Table 6 Solutions for Two-loop Network

S. No.	Authors	Technique used	Cost (in units)	Average number of function evaluations
1.	Savic and Walters (1997)	Genetic Algorithm	419,000	65,000
2.	Cunha and Sousa (1999)	Simulated Annealing Algorithm		25,000
3	Eusuff and Lansey (2003)	Shuffled Leap Frog Algorithm	419,000	11,155
4	Liong and Atiquzzaman (2004)	Shuffled Complex Algorithm	419,000	1,019
5	Suribabu and Neelakantan (2006)	Particle Swarm Optimization	419,000	5,138
6	Keedwell and Khu (2006)	Cellular automation network design algorithm	480,000	7
7	Mohan and Jinesh Babu (2009)	Heuristics-based algorithm	445,000	43
8	Suribabu (2010)	Differential Evolution	419,000	4,750
9	Mohan and Jinesh Babu (2010)	Honey-Bee Mating optimization	419,000	1,293
10	Suribabu (2012)	Heuristics-based approach	420,000	63
11	Present work	Median based approach	446,000	20

RESULTS AND DISCUSSION

The proposed methodology is applied to three known bench mark networks and results are presented in the tabular format. Table 6 shows the comparative list of the present result with other works for two loop network. The present approach converged very quickly at local optimum with meager number of function evaluations. For this network, the proposed methodology is initiated with different diameters as indicated in the Table 7. The optimization is started with three different diameter ie, 304.8, 355.6, and 254 mm. The median diameter of 355.6 mm solution is found to be least cost comparing with other two solutions. Table 8 presents result for Honai network. Though the cost of the solution is higher than the other approaches, the proposed approach took less function evaluation to struck up with least cost solution. Third network provides the least cost Rs 15,46,34,570 for median diameter of 600 mm. This solution is obtained with expense of 74 function evaluations. When median diameter is changed to different diameters as given in the table, then its value is found to be higher than the first case. It is clear from the study that there is significant change in cost at final level when different diameter is being started to optimize the network.

Table 7 Optimal solution for two-loop network

Pipe number	Median Diameter – 304.8 mm Pipe diameter (mm)	Median Diameter – 355.6 mm Pipe diameter (mm)	Median Diameter – 254 mm Pipe diameter (mm)
1	508	508	558.8
2	304.8	355.6	304.8
3	406.4	355.6	406.4
4	304.8	25.4	254
5	304.8	355.6	304.8
6	25.4	25.4	25.4
7	254	355.6	254
8	254	254	254 558,000
Total cost	476,000	446,000	

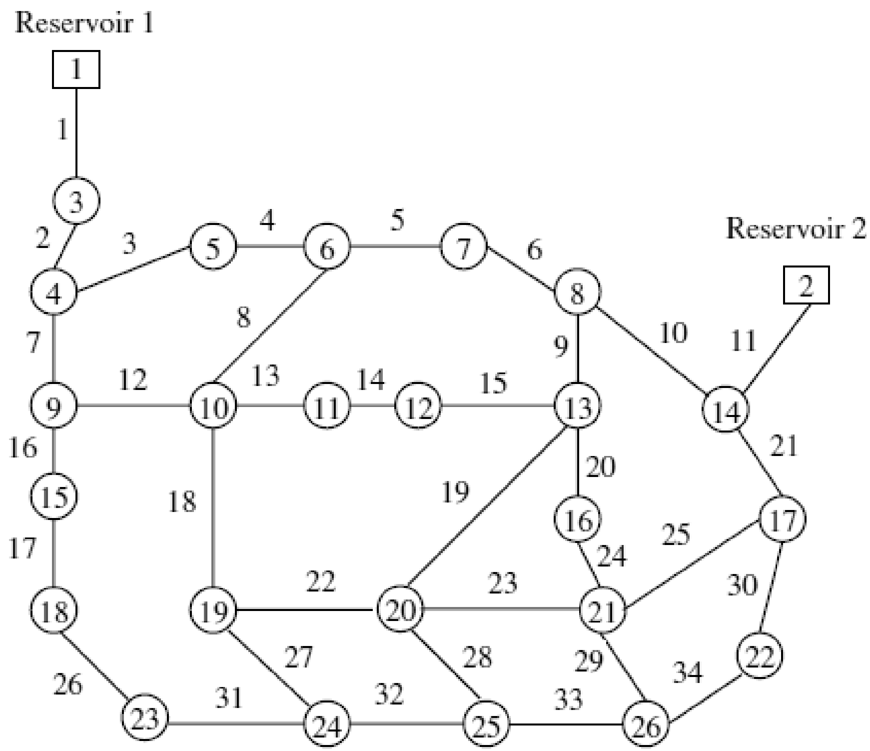

Fig. 3 Layout of two source networks

Table 8 Comparative Solutions statement for Hanoi network

Authors	Algorithms	Number of function evaluation	Cost (units)
Savic and Walter (1997)	Genetic Algorithm	1,000,000	6,073,000
Cunha and Sousa (1999)	Simulated Annealing Algorithm	53,000	6,056,000
Geem et al. (2002)	Harmony search	200,000	6,056,000
Eusuff and Lansey (2003)	Shuffled Frog Leaping Algorithm	26,987	6,073,000
Liong and Atiquzzaman (2004)	Shuffled Complex Algorithm	25,402	6,220,000
Vairavamoorthy and Ali (2005)	Genetic Algorithm Pipe Index Vector	18,300	6,056,000
Suribabu and Neelakantan (2006b)	Particle Swarm Optimization	6,600*	6,081,087
Kadu et al. (2008)	Modified GA 1	18,000	6,056,000
Kadu et al. (2008)	Modified GA 2	18,000	6,190,000
Mohan and Jinesh babu (2009)	Heuristic based approach	70	6,701,000
Suribabu (2010)	Differential Evolution	48,724	6,081,087
Mohan and Jinesh babu (2010)	Honey-Bee mating optimization	15,955	6,117,000
Suribabu (2012)	Heuristic based approach	259	6,232,322
Present work	Median based approach	57	6,604,913

Table 9 Optimized solution for Honai network

Pipe number	Diameter(mm)	Pipe number	Diameter(mm)	Pipe number	Diameter(mm)
1	1016	13	406.4	25	609.6
2	1016	14	304.8	26	304.8
3	1016	15	304.8	27	406.4
4	1016	16	609.6	28	508
5	1016	17	762	29	508
6	1016	18	1016	30	406.4
7	1016	19	1016	31	304.8
8	1016	20	1016	32	304.8
9	1016	21	609.6	33	304.8
10	762	22	304.8	34	406.4
11	762	23	1016		
12	508	24	762		

Table 10 Solution details for two-source networks

Pipe	Median Diameter – 500 mm Pipe diameter (mm)	Median Diameter –600 mm Pipe diameter (mm)	Median Diameter –450 mm Pipe diameter (mm)
1	1000	900	1000
2	1000	800	1000
3	500	600	450
4	500	600	450
5	150	500	150
6	200	600	300
7	800	600	900
8	450	600	350
9	500	600	450
10	500	600	600
11	900	900	900
12	600	600	700
13	500	600	500
14	500	600	450
15	150	500	150
16	450	600	450
17	350	450	400
18	500	450	450
19	150	300	250
20	150	150	200
21	700	600	600
22	350	150	450
23	300	250	150
24	450	400	450
25	500	600	450
26	250	200	200
27	250	350	450
28	150	300	150
29	150	150	350
30	400	500	450
31	150	150	150
32	150	150	250
33	350	450	150
34	500	600	450
Cost (Rs)	15,46,34,570	19,32,52,130	15,68,35,350

CONCLUSIONS

This paper presented a simple approach for optimization of water distribution networks. The optimal network design, be a wired electric network or wireless communication network or water distribution pipe network, is computationally complex and they belong to a group of NP-hard problems. While traditional optimization methods have been limited by their ability to handle the complex nature of these problems, the new heuristic based algorithms are more promising. In this paper, the efficacy of proposed approach was tested by solving three bench mark water distribution network optimization problems. In summary, the results presented in this work are very encouraging and promising for optimal design problems for less functional evaluations. The obtained solution can be started to other optimal procedure to further improve the solution cost. The results confirm the potential of the proposed approach in terms of function evaluation and show its effectiveness and reasonably ease of applicability while comparing with complex operation research approaches.

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In-situ Soil Moisture Conservation Practices for Sustainable Productivity of Rainfed Cotton in Inceptisols under Dryland Conditions of Maharashtra

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ABSTRACT

Drought situations caused due to aberrant weather and erratic rainfall has been routine crises in dryland agriculture. To cope up with such crunch, it is necessary to find out the possibilities to survive the crop under contingent conditions by using some of the simple methods of in-situ moisture conservation. Therefore, a field study was conducted from 2007-08 to 2010-11 on soil moisture management in rainfed cotton in Inceptisols at Research field of AICRP for Dryland Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola with various in-situ moisture conservation practices so as to partially meet out the adverse effect of water stress in standing crop. The experiment was laid out in Randomized Block Design with five treatments and four replications. The *in-situ* moisture conservation practices were furrow opening, mulching, thinning, combination of furrow opening, mulching and thinning and control. Common dose of RDF (50:25:00 NPK kg ha^{-1}) to cotton was applied in all the treatments and soybean straw was used as mulch. The experimental soil was clayey in texture, moderately alkaline in nature, low in available nitrogen, medium in available phosphorus and high in potassium. The results indicated that the treatment T_2 (mulching) showed higher soil moisture percentage at various growth stages of cotton followed by treatment T_4 (combination of furrow opening, mulching and thinning) compared to all other treatments. Considering cotton productivity and total moisture use of cotton the higher moisture use efficiency (2.98 kg ha^{-1} mm^{-1}) was recorded under treatment T_2 (Mulching) followed by combination of furrow opening, mulching and thinning(T_4). In pooled data of four seasons, seed cotton yield was found to be non significant. However, numerically higher seed cotton yield (17.78 q ha^{-1}) was recorded in crop residue mulching treatment (T_2) followed by treatment combination of furrow opening, mulching and thinning, T_4 (17.08 q ha^{-1}). Moisture conservation practice of crop residue mulching resulted in improvement in organic carbon and available nutrients (N, P and K) in soil and recorded higher gross and net monetary returns with higher B:C ratio. Application of soybean straw as a mulch helped to conserve moisture, increase moisture percentage in soil and moisture use efficiency of cotton Hence it can be concluded that *in-situ* moisture conservation through crop residue mulching resulted in improvement in soil fertility, yield and moisture use efficiency of cotton grown in Inceptisols under dryland conditions of Maharashtra.

Keywords: Crop residue mulch, in-situ soil moisture conservation, Inceptisols.

INTRODUCTION

Cotton (G*ossypium spp*.) is an important cash crop globally known as "king of fiber "and play vital role in the economy of farmers as well as the country and is popularly known as "white gold". India ranks first in area under cotton in the world however, stands third in production. It is a fiber crop originated in India and belong to Malvaceae family. Among different species of cotton *Gossypium hirsutum* and *Gossypium arboretum* are commonly grown in Maharashtra and used in textile industries for manufacture of cloth. Besides this, it is also used for several other purposes like making threads and for mixing in other fibers.

In India cotton is grown on 116.14 lakh/ha with production of 334 lakh bales of 170 kg and yield 489 kg ha^{-1}. In Maharashtra, cotton is grown on 41.46 lakh ha with production 74 lakh bales and yield 303 kg lint ha^{-1}. In Vidarbha area under cultivation of cotton is 14.9 lakh ha with production of about 27.4 lakh bales and 312 kg lint ha^{-1} (Anonymous, 2013).

Major causes of low productivity of cotton in Vidarbha is erratic behavior of rainfall, moisture stress mostly during flowering and boll development stage which adversely affect cotton growth, cultivation on marginal and sub-marginal land and less adoption of improved technology resulting in poor crop yield .

In dryland agriculture management of soil moisture needs top most care due to uncertainty and erratic distribution of rainfall which causes severe reduction in success rate. Soil moisture plays an important role in determining the growth and yield of crop, which is directly related to plant water status.

The significance of in-situ soil moisture conservation measure is to conserve maximum possible rainwater at a place where it falls, to make efficient use of it. Soil management and agronomic practices are tailored to store and conserve as much rainfall as possible by reducing runoff and increasing storage capacity of soil profile. As the soil profile act as a reservoir for moisture storage, this facility need to be exploited to maximum extent before we think of storing it elsewhere. This can be achieved by cultural and mechanical methods viz., tillage operation, contour cultivation, vertical mulch, ridges and furrows and farm pond (Chittaranjan, 1981).

Mulching is important in rainfed agriculture for in-situ moisture conservation by way of reducing the runoff and evaporation losses, so as to provide optimum moisture to crop for future use. Use of mulch minimizes the water requirement of crop by soil moisture conservation. Besides this, the live mulches regulate soil temperature which is helpful directly in reducing evaporation losses and also providing adequate micro climate for soil microorganisms and suitable temperature for crops to grow with substantial increase in crop yields.

Land configuration and adding mulches in furrow opened together may elongate period of moisture availability to crop, release of mineral nutrients which plant may absorb and also may drain excess water and also increases infiltration and moisture conservation in-situ (Virmani *et al*., 1981). The practice of opening furrows in between rows of crop is also beneficial for improving the drainage system in field during early monsoon and for decomposing added weed later on. Ridge may serve as micro-watershed accumulating water in furrow. Practice of making ridges by opening furrows may have an advantage in concentration of more rain water on the bed which enriches soil moisture content (Gidda and More, 1981).

MATERIALS AND METHODS

A field study was conducted from 2007-08 to 2010-11 on soil moisture management in rainfed cotton in Inceptisols at Research field of AICRP for Dryland Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola with various in-situ moisture conservation practices so as to partially meet out the adverse effect of water stress in cotton crop. The experiment was laid out in Randomized Block Design with five treatments and four replications. The *in-situ* moisture conservation practices were furrow opening, mulching, thinning, combination of furrow opening, mulching and thinning and control. Common dose of RDF (50:25:00 NPK kg ha^{-1}) to cotton was applied in all the treatments and soybean straw was used as mulch.

The experimental soil was clayey in texture, moderately alkaline in nature having pH 8.1 with electrical conductivity 0.28 dSm^{-1}, organic carbon 5.2 g kg^{-1} and low in available nitrogen (175 kg ha^{-1}), medium in available phosphorus (14.5 kg ha^{-1}) and high in potassium (315 kg ha^{-1}). Soil samples were collected using screw auger from 0-15 cm and 15-30 cm depth at sowing and subsequently (20-30 days interval) till harvest of the crop. Soil sampling followed was from a fixed site in each plot and soil moisture content was determined gravimetrically as described by Piper (1966).

Soil moisture in profile during different period of crop growth

Soil moisture was calculated as follows:

$$\text{Soil moisture (mm)} = \frac{\text{\% gravimetric moisture} \times \text{BD} \times \text{Soil depth}}{100}$$

Moisture use by crop during period

Moisture use by crop during period was calculated as follows:

Moisture use = (mm) during CGP	Soil moisture + (mm) at initial Sampling	Rainfall + during CGP (mm)	Soil moisture - (mm) at subsequent sampling	Runoff + (R) (mm)	Soil water flux (P) beyond root zone (mm)

(R+P) mm =	Rainfall during + CGP (mm)	Increase in profile – water storage(mm)	ET (mm) during CGP

Runoff plus soil water flux beyond root zone (R+P)

Evapotranspiration by crop

Evapotranspiration (ET) by crop during period was calculated as follows:

$$ET\ (mm) = Kc \times pan\ E$$

Where, Kc = crop coefficient & pan E = cumulative pan evaporation during CGP.

Moisture use efficiency (MUE)

Moisture use efficiency for each treatment was calculated on the basis of economic yield of the crop and total moisture use in given treatment by following formula:

$$MUE\ (kg\ ha^{-1}mm^{-1}) = \frac{\text{Crop yield (kg ha}^{-1})}{\text{Total moisture use (mm)}}$$

The plotwise soil samples were collected after last cotton picking and analysed for available nutrients as per standard methods (Black, 1965; Jackson, 1973).

RESULTS AND DISCUSSION

During the *kharif* season 2010-11, the total rainfall received during the crop growing period was 887.3mm as against the normal rainfall of 741.8mm. The rainfall intensity analysis reveals that most of the rainstorms fall in high intensities. The *in-situ* moisture conservation treatments showed variation in seed cotton and stalk yield of cotton. The data in respect of seed cotton and cotton stalk yield during 2007-08 to 2010-11 and pooled yields are presented in Table 1& 2 respectively.

Table 1 Seed cotton yield as influenced by *in situ* moisture conservation treatments

Treatments	**Seed cotton yield(q ha^{-1})**				
	2007-08	2008-09	2009-10	2010-11	Pooled
T_1- Furrow opening	25.60	13.08	10.41	19.16	17.06
T_2- Mulching	24.26	12.54	10.78	23.52	17.78
T_3- Thinning	22.59	11.30	10.06	19.19	15.79
T_4- Combination of Furrow opening+ Mulching+Thinning	23.91	11.93	10.97	21.51	17.08
T_5- Control	22.24	11.09	9.98	19.71	15.76
S.E. (m±)	1.02	1.04	0.51	1.00	0.51
C.D. at 5%	2.87	NS	NS	3.07	NS

The highest seed cotton yield (23.52 q ha^{-1}) was recorded in crop residue mulching treatment (T_2) and found at par with the treatment combination of furrow opening, mulching and thinning, T_4 (21.51q ha^{-1}). In pooled data of four seasons, seed cotton yield was found to be non significant. However, numerically higher seed cotton yield (17.78 q ha^{-1}) was recorded in crop residue mulching treatment (T_2) followed by treatment combination of furrow opening, mulching and thinning, T_4 (17.08 qha^{-1}).

However, the highest cotton stalk yield (43.72 q ha^{-1}) was recorded in treatment combination of furrow opening, mulching and thinning (T_4) and it was at par with crop residue mulching treatment (T_2). In pooled data of four seasons, significantly highest cotton stalk yield (50.15 q ha^{-1}) was recorded in crop residue mulching treatment (T_2) and it was at par with treatment combination of furrow opening, mulching and thinning (T_4).

The data revealed that the yield of seed cotton in mulching was significantly higher over all other treatments. However treatment T_4 combination of furrow opening, mulching and thinning was at par. The increased in yield may be due to the improved soil physio-chemical properties under mulches. Similar results were also reported by Das and Maliwal (1996), Solaiappan and Dason (1998) and Solaiappan *et al.* (1999).

Table 2 Cotton stalk yield as influenced by *in situ* moisture conservation treatments

Treatments	**Cotton stalk yield(q ha^{-1})**				
	2007-08	2008-09	2009-10	2010-11	Pooled
T_1- Furrow opening	64.23	39.06	48.19	36.01	46.87
T_2- Mulching	60.11	46.65	50.76	43.08	50.15
T_3- Thinning	57.29	36.34	45.62	33.44	43.17
T_4- Combination of Furrow opening+ Mulching+Thinning	53.81	40.14	49.47	43.72	46.79
T_5- Control	54.25	36.34	44.34	35.37	42.57
S.E. (m±)	2.61	1.87	2.16	2.28	1.19
C.D. at 5%	7.35	5.25	NS	7.02	3.68

Economics of cotton cultivation

The data on economics of cotton cultivation (Table 3) indicated that the differences in monetary returns were significant due to various moisture conservation practices. Moisture conservation practice of mulching recorded higher gross monetary (Rs 96238) and net monetary return (Rs 73360) per hectare and it was on par with combination of furrow opening, mulching and thinning which have recorded gross monetary (Rs 88245) and net monetary return (Rs 60558) per hectare.

Table 3 Effect of various treatments on economics of cotton cultivation

Treatments	**GMR (Rs ha^{-1})**	**NMR (Rs ha^{-1})**	**B:C ratio**
T_1- Furrow opening	78446	54544	3.3
T_2- Mulching	96238	73360	4.2
T_3- Thinning	78420	54347	3.3
T_4- Combination of Furrow opening+ Mulching+Thinning	88245	60558	3.2
T_5- Control	80626	57152	3.4
S.E. (m±)	4064	4064	-
C.D. at 5%	12523	12523	-

The highest B:C ratio (4.2) was recorded by mulching whereas lowest B:C ratio (3.2) was recorded by combination of furrow opening, mulching and thinning. Similar results were also reported by Sonawane *et al.* (2010) that due to in-situ moisture conservation for dryland soil, higher moisture status in profiles provides a favorable environment for plant growth which leads to increase in yield and B:C ratio.

Fertility status of soil

The available nutrients status of soil was recorded after harvest of cotton. The treatment wise soil samples were collected and analyzed for organic carbon, available nitrogen, phosphorus and potassium to assess the effect of various treatments on fertility status of soil. The experimental soil was initially low in available nitrogen, medium in phosphorus and high in potassium.

Organic carbon

Organic matter is an indication of organic carbon fraction of soil formed due to microbial decomposition of organic residue.

The data (Table 4) pertaining to the organic carbon content of soil as influenced by various treatments was statistically significant and it ranged from 5.25 to 6.25 g kg^{-1} indicating that the highest (6.25 g kg^{-1}) organic carbon was recorded in treatments T_2. The lower value of organic carbon (5.25 g kg^{-1}) was observed in control (T_5) treatment. The higher values of organic carbon content in treatment T_2 may be due to decomposition of soybean crop residue used as mulching material which is responsible for the increase in soil organic carbon content.

Similar results were also reported by Bairathi (1974), Sarkar *et al*. (1988) and Bhat *et al*.(1998).

Available nitrogen status in soil

Application of soybean straw as mulch significantly increased available nitrogen in soil after harvest of cotton. The highest available nitrogen (187.67 kg N ha^{-1}) was observed in treatment T_2 (mulching) and found to be at par with treatment T_4 (187.22 kg N ha^{-1}). The lowest available nitrogen was recorded in control (176.16 kg N ha^{-1}) treatment. Application of soybean biomulch significantly increased available N content over unmulched i.e. control, whereas the values were comparable with combination of furrow opening, mulching and thinning. Under mulch farming, conservation of moisture, build up of organic matter, improvement in physical properties of soil and increased microbial activity would have favoured the mineralization rate and release of nitrogen in greater proportion.

Similar results were recorded by Biswas *et al*. (1971), Prasad *et al*.(1991), Saha *et al.* (1995), Bhat *et al*.(1998) and Surekha and Rao (2004).

Table 4 Effect of various treatments on soil on fertility

Treatments	Organic carbon (g kg^{-1})	Available nutrients(kg ha^{-1})		
		N	P	K
T_1- Furrow opening	5.47	177.24	15.26	315.38
T_2- Mulching	6.25	187.67	16.23	320.79
T_3- Thinning	5.29	170.15	15.71	311.39
T_4- Combination of Furrow opening+ Mulching+Thinning	5.66	187.22	17.65	324.63
T_5- Control	5.25	176.16	15.33	310.82
S.E. (m±)	0.011	3.82	0.36	5.00
C.D. at 5%	0.033	11.76	1.10	NS

Available phosphorus status in soil

Application of soybean straw as mulch significantly increased available phosphorus in soil after harvest of crop. It was observed that highest available phosphorus (17.65 kg P ha^{-1}) was recorded in treatment T_4 (combination of furrow opening, mulching and thinning) which was significantly highest while the lowest available phosphorus was observed in furrow opening (15.26 kg ha^{-1}) treatment.

Available phosphorus content was significantly increased by the incorporation of crop residue in soil. It is likely as organic additives produce organic acids during the course of decomposition which increase availability of phosphorus in soil. Similar results were recorded by Biswas *et al*. (1971) and Bhat *et al*.(1998).

Available potassium status in soil

The available potassium increased at harvest of cotton due to application of soybean straw as mulch. The available potassium ranged from 310.82 to 324.63 kg ha^{-1} and treatment wise variation was found to be non significant The highest available potassium (324.63 kg ha^{-1}) was observed in treatment T_4 (combination of furrow opening, mulching and thinning). Mulching may be conducive for the release of higher available K through solubilization and mineralization process.

Soil moisture (%) at various growth stages of cotton

Moisture content in soil largely depends on climatic factors i.e. rainfall pattern, rate of PET and storage in soil. Soil moisture percentage (gravimetric) at 0-15 cm and 15-30 cm depth, at various growth stages of cotton were determined and are presented in Table 5.

Table 5 Soil moisture (%) at various growth stages of cotton

Treatments	Depth (cm)	Vegetative growth stage	Square formation	Flowering	Boll formation	Boll development
T_1- Furrow opening	0-15	26.79	24.97	28.27	23.55	21.7
	15-30	27.36	22.32	28.18	20.07	23.16
T_2- Mulching	0-15	32.84	25.03	35.3	28.26	23.19
	15-30	28.97	22.48	32.4	26.63	24.14
T_3- Thinning	0-15	27.63	25.29	33.84	22.67	20.73
	15-30	27.43	23.54	30.05	21.92	21.45
T_4- Combination of furrow opening, mulching and thinning	0-15	29.35	28.93	31.3	24.61	22.1
	15-30	30.02	28.94	32.84	22.95	23.15
T_5- Control	0-15	25.4	24.97	31.2	25.43	18.57
	15-30	26.86	22.7	29.63	22.35	20.03

The data shows that treatment T_2 (mulching) showed higher soil moisture (%) at various growth stages of cotton followed by treatment T_4 (combination of furrow opening, mulching and thinning) compared to all other treatments. The increase in soil moisture content in these treatments might be due to incorporation of more green biomass of soybean straw that respond well to conserve more soil moisture, reduce soil temperature and evaporation. Similarly, the reduced level of soil moisture was found with chemical fertilizer which causes more concentration of chemicals creating more heat in soil moisture and utilize more soil moisture.

In general, the higher values of moisture were observed during flowering stage and it decreased during subsequent growth stages. Similar results were reported by Bhan and Kiem (1994), Patil *et al.* (1994) and Pakhale *et al.* (2009).

Moisture use efficiency

Considering cotton productivity and total moisture use of cotton, moisture use efficiency was calculated and the data pertaining to moisture use efficiency (MUE kg ha^{-1} mm^{-1}) values under different moisture conservation treatments are presented in Table 6. In cotton, the maximum moisture use efficiency (2.98 kg ha^{-1} mm^{-1}) was recorded under treatment T_2 (Mulching) and lowest (2.42 kg ha^{-1} mm^{-1}) under treatment T_3 (thinning).

Table 6 Moisture use efficiency of cotton under different treatments

Treatments	**Seed cotton yield (kg ha^{-1})**	**Total moisture use (mm)**	**MUE (kg ha^{-1} mm^{-1})**
T_1- Furrow opening	1916	788.46	2.43
T_2- Mulching	2352	790.36	2.98
T_3- Thinning	1919	791.59	2.42
T_4- Combination of Furrow opening+ Mulching+Thinning	2151	787.33	2.73
T_5- Control	1971	789.92	2.50

Application of soybean straw increased moisture use efficiency of cotton. Maximum moisture use efficiency (2.98 kg ha^{-1} mm^{-1}) was found under treatment T_2 (Mulching) superior over control, while it was followed (2.73 kg ha^{-1} mm^{-1}) by treatment T_4(combination of Furrow opening+ Mulching+ Thinning). Application of soybean straw allowed infiltration of rain water in soil, reduced runpoff and evaporation which helped in stabilization of soil structure to receive good yield and moisture use efficiency. The highest moisture use efficiency under T_2 might be due to the highest yield recorded under T_2 due to better physical condition of soil. Similar resuts were reported by Gabhane *et al*.(2000), Patil *et al*.(2009).

CONCLUSION

Hence it can be concluded that *in-situ* moisture conservation through crop residue mulching resulted in improvement in soil fertility, yield and moisture use efficiency of cotton grown in Inceptisols under semi arid agroecosystem of Maharashtra.

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Development of Rainfall Intensity-Duration-Frequency Relationship Nomograph for Akola Region (M.S)

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ABSTRACT

Rainfall intensity-duration-frequency relationship is required for design of soil and water conservation and runoff disposal structures. It is necessary to develop such relationships for smaller regions so that their reliability and applicability will have greater practical importance. Nomographs eliminate cumbersome computation procedures and enable quick determination of the design rainfall intensity at particular location. Since nomographs are used quickly and easily for estimation of rainfall intensity and hence they are very useful to field workers and professionals. The automatic rain gauge charts of 27 years of Akola were analysis for maximum annual rainfall intensities for selected durations of 0.08, 0.16, 0.25, 0.50, 0.75, 1.0, 2.0, 3.0, 6.0, 12.0 and 24.0 hours. The values of parameter 'a' and 'b' were determine by using graphical method and the values of 'K' and 'd' by least square method. The procedure suggested by Luzadder (1964) was adopted for development of nomograph for Akola station from rainfall intensity-duration-frequency relationship. Per cent deviation of rainfall intensity values estimated from nomograph and those calculated from corresponding mathematical equation range from -3.10 to 6.2 per cent in case of Akola for different return periods.

Keywords: Nomograph, intensity-duration-frequency relationship.

INTRODUCTION

A nomograph is an alignment chart consisting of a set of parallel scales, which are suitably graduated and showing the relationship of rainfall intensity, duration and frequency. Rainfall is the most important component of hydrologic cycle and has a dominant influence of hydrologic phenomena occurring as result of complex interaction between land and water. Rainfall intensity is one of the most important rainfall characteristic which is inversely proportional to its duration of occurrence and directly proportional to the return period. With an increase in duration, there is a decrease in the maximum average intensity of the storm. The design rainfall intensity, I can be obtained from the rainfall intensity-duration- frequency relationship given by Nemec (1973) which is expressed as

$$I - \frac{KT^{a}}{(t+b)^{d}} \tag{1}$$

where,

I	=	Rainfall intensity, cm/h
T	=	Return period, year
t	=	Duration of time of concentration, hour
K, b	=	Derived constants
a, d	=	Derived exponents

The significance of rainfall intensity in design of soil conservation structures is very much important from economic considerations. An over designed structure involves excessive cost and under designed structures will be unsafe and also involves high recurring expenditure on repair, maintenance and replacement. An intermediate design would provide a structure with reasonable initial cost and low maintenance cost values. Thus analysis of rainfall intensity, duration and frequency at any location provides very valuable information for the use of design engineers or hydrologists engaged in designing water control structures for controlling floods from small watersheds. Nomographs eliminate cumbersome computation procedures and enable quick determination of the design rainfall intensity at particular location. Since nomographs are used quickly and easily for estimation of rainfall intensity and hence they are very useful to field workers and professionals. Relationship between rainfall intensity, duration and return period is location specific and mainly depends upon physical characteristics of rainfall occurring at a particular place. Hence such relationship developed for particular station can not be superimposed for other stations owing to different pattern of rainfall characteristics. So, it becomes necessary to develop nomograph for particular station so that their reliability and applicability will have greater practical importance.

MATERIALS AND METHODS

The continuously recorded rainfall data was obtained from Meteorological department of Dr. PDKV, Akola. The altitude of Akola rain gauge station is 283 m above mean sea level while the latitude and longitude is $20^0 7'$ N and $77^0 07'$ E, respectively. The annual average rainfall is 725.9 mm. In present study the rainfall charts of 27 years from 1980 to 2009 (except for 1983, 1999 and 2000) for Akola (Dr. PDKV) were analyzed in the form of annual maximum series of various durations viz. 5, 10, 15, 30, 45 minutes, 1, 2, 3, 6, 12 and 24 hours.

The maximum depth of rainfall for various durations was worked out by using ‘Original trace method’ (Ram Babu et al., 2001). The plotting positions were obtained by using the ‘computing method’ suggested by Ogrosky and Mockus (1957). The adequacy of rainfall data has been ensured based on Mockus (1960) criteria. Using the rainfall intensities obtained for three different per cent chances (50, 15.4 and 84.1 %), the frequency lines were developed on log normal probability paper suggested by Hazen (1914) and rainfall intensities for 1 %, 2%, 4%, 10%, 25% and 50% (2 years) frequency were obtained. The values of rainfall intensities for all durations were plotted on Y-axis and values of return period on X-axis of the log-log paper. The geometric mean slope of the lines represents the exponent ‘a’ in the equation. A line representing the geometric mean slope line was drawn at the base through the origin point. The solid lines parallel to this slope line were drawn at each duration line and extended towards Y-axis cutting the Y-axis against 1-year return period. The values of rainfall intensities of one year frequency on Y-axis and selected durations on X-axis when plotted on log-log paper, these points do not fall in a straight line and in order to aligned them into a straight line, suitable constant b is to be added by trail and error to the values of duration. After adding constant b in the values of duration, the points should align into a straight line. Then the constants ‘K’ and ‘d’ are solved by least square method.

A nomograph is an alignment chart consisting of a set of suitably graduated parallel scales. There are only three variables viz., rainfall intensity, duration and return period and thus the alignment chart has three parallel scales so graduated that a line which joins values on any two scales intersects the third scale at a point which satisfies the IDF relationship for that station. The procedure suggested by Luzzadar (1964) was adopted for development of nomograph.

RESULTS AND DISCUSSION

The minimum acceptable years was found less than 17 years for all durations. The plotting positions were obtained by using computing method. The plotting positions for all the eleven durations were tabulated in Table 1. The frequency lines were developed by using the rainfall values of intensities as shown in Table 1, were plotted on log normal probability paper. The rainfall intensities were plotted on log scale and per cent chance of occurrence of rainfall intensity on probability scale. A straight line passing through all the three points extending on either side was drawn which is the frequency line of rainfall intensity for selected duration. Frequency distribution of rainfall intensities for various durations is shown in Table 2. The geometric mean slope of the line represents the exponent ‘a’ was observed to be 0.1985. The frequency line passing through origin having slope equal to geometric mean was drawn and the parallel lines were drawn cutting Y axis against 1 year return period. The constant b= 0.5 was determined by trial and error basis so as to make all the points fall in a straight line. The constant K and d were determined by least square method and the values of K and d were calculated as 6.165 and 0.8591 respectively. The rainfall intensity-duration-return period relationship becomes as given below.

$$I_{Ak} = \frac{6.615T^{0.1985}}{(t+0.50)^{0.8591}} \tag{2}$$

By using relationship of rainfall intensity-duration-frequency and procedure suggested by Luzaddar (1964) a nomograph was developed. By using the nomograph the rainfall intensity for various durations of time of concentration t up to 24 hours and any return period, T up to 100 years can be determined. Per cent deviation of rainfall intensity values observed from nomograph and those calculated from corresponding relationship for various duration and return period are given in Table 3. The data reveals that maximum deviation between the nomographic solutions and mathematical equation range from -3.10 to 6.2 per cent for different return periods. The per cent deviation is quite low and in acceptable limits (Ram Babu et al., 1979). Such handy tool will be of great use for the designer as well as field workers engaged in soil and water conservation for computing peak runoff rate using rational formula.

Table 1 Plotting positions for development of frequency lines of rainfall intensities for selected duration at Akola

Duration h-min	Rainfall intensity, cm/h		
	15.9 % chance	50.0 % chance	84.1 % chance
00-05	162.18	117.48	83.17
00-10	140.92	94.49	65.162
00-15	123.02	83.17	54.954
00-30	89.12	58.88	38.90
00-45	74.13	47.86	30.19
01-00	64.56	40.73	25.70
02-00	39.81	25.11	15.84
03-00	22.90	14.45	8.91
06-00	18.62	11.22	6.76
12-00	10.23	6.16	3.80
24-00	5.62	3.46	2.13

Table 2 Rainfall intensities for different return period and selected durations at Akola

Duration, h	Frequency, per cent					
	1 %	2 %	4 %	10%	25%	50%
	Return period, years					
	100	50	25	10	4	2
0.08	250	230	208	177	140.3	117
0.16	220	199.8	180	150	120	94
0.25	200	180	133	132	108	83
0.50	155	140	120	100	76	58
0.75	133	119	102	84	64	47
1	120	105	90	73	56	40
2	71	67	54.2	44	34	25
3	41.2	36	31	25	19	14
6	35	30	26	20.8	15.2	11
12	20.3	18	15	12	8.9	6.2
24	10.9	9.4	8	6.4	4.9	3.4

Table 3 Comparison between calculated and nomographic intensities of rainfall (cm/h) for different frequencies for Akola

Duration, h	‘I’$_{cal}$, cm/h			‘I’$_{nomo}$, cm/h			Per cent deviation		
	10 yr	25 yr	50 yr	10 yr	25 yr	50 yr	10 yr	25 yr	50 yr
0.25 h	12.5	14.9	17.2	12.6	14.5	17	1.1	-3.1	-0.9
0.50 h	9.7	11.7	13.4	9.7	11.8	14	0.0	1.1	4.4
1 h	6.9	8.2	9.5	7.3	8.5	9.8	6.2	3.1	3.5
3 h	3.3	3.9	4.6	3.3	4.1	4.7	0.0	2.9	2.8
6 h	1.9	2.3	2.7	2	2.4	2.8	2.6	2.6	4.3

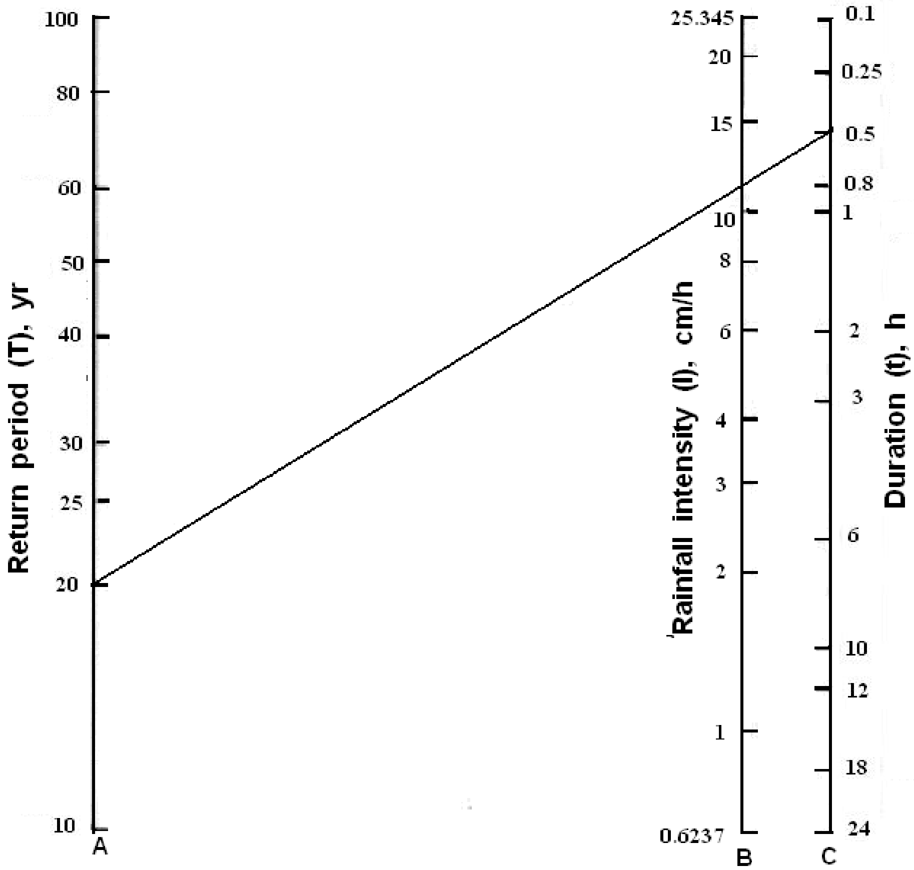

Fig. 1 Station nomograph of intensity-duration-frequency relationship for Akola region

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Analysis on Probability Distribution of Weekly and Seasonal Rainfall for Lalgudi Region, Tiruchirapalli District, Tamil Nadu

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ABSTRACT

A major component of the water-cycle that deposits most of the fresh water on Earth is rain. Determination of the frequency of occurrence of extreme hydrologic events is important in water resources planning and management. A detailed Statistical analysis on weekly and seasonal rainfall for Tiruchirapalli District, Lalgudi Region was carried out using 34 years (1980-2013) of daily rainfall data collected from Indian Meteorological Department. The present investigation was done with a prime objective of ascertaining the type of Probability distribution that best fit the rainfall data of the Region. For the analysis, Weibull method, Gumbel method and Normal method of Probability distribution functions were fitted. Factors such as standard deviation and co-efficient of variation were calculated to study the rainfall pattern. The Goodness of fit was tested by Chi-square test and the values were compared with the tabular values at 5 per cent level of significance. Gumbel's (Extreme value type-III) method was found to be the best method of distribution for the weekly and seasonal rainfall of the region.

Keywords: Rainfall, Probability, Weibull, Gumbel, Normal, Standard deviation, variation, Chi-square.

INTRODUCTION

Rain fall being the main component of hydrological cycle and it provides suitable conditions for many types of ecosystem, as well as water for hydro-electric power plants and irrigation of crops. It is thus important to predict the future rainfall at any instant. This can be done by the usage of Historical rainfall data. An important aspect of hydrology is to interpret the future probabilities of occurrence from past records of hydrological events using frequency analysis. It relates the Magnitude of extreme events to their frequency of occurrence using probability distributions (SJ Reddy, 1993). The accuracy of different probability distribution methods varies and hence, the requirement to find out the most accurate probability distribution method.

A number of studies have been carried out on agricultural planning using rainfall analysis. Senthil Velan (2012) performed the analysis of weekly, monthly, seasonal and annual rainfall variability and probabilities at different level for suitable crop planning. A.K Bhargava., (2010) carried out the frequency analysis of rainy days, heavy rainfall days and also one-day extreme rainfall to observe the impact of climatic changes on extreme weather events and flood risks in India. Srinivasa Reddy et al., (2008) studied and inferred the weekly rainfall probability analysis for crop planning and management.

STUDY AREA AND DATA USED

The study is done for Lalgudi (Tiruchirapalli district), a town situated at a distance of 30 km from Tiruchirapalli city. The region has a latitude and longitude of 10.87^0N and 78.83^0E respectively and is situated in central Tamil Nadu and lies at the Kaveri delta region, the most fertile region of the state. When Tamil Nadu receives most of its rainfall from North-east monsoon, Lalgudi receives adequate rainfall from both the monsoon seasons, making it predominant for agriculture. The Normal annual rainfall (Average of 30 years rainfall) of 842.60 mm, slightly less than the state average of 945.00 mm. The daily Rainfall data is collected from the Indian Meteorological Department (IMD), Lalgudi station, for a period of 34 years (1980-2013). This data is used for the Weekly and Seasonal Rainfall-Probability analysis.

Table 1 Statistical parameters for seasonal and weekly rainfall analysis

SNo.	Description	Mean Rainfall (mm)	Standard Deviation (mm)
1.	Weekly	34.231	35.021
2.	Seasonal (SW)	34.869	32.847
3.	Seasonal (NE)	49.095	51.208

Table 1 shows that the standard deviation is greater than the mean, indicating a larger variation in rainfall pattern.

METHODOLOGY

The methodology adopted in this study is Rainfall Probability analysis using plotting position and probabilistic methods. From the Preliminary study and analysis, variation in results among the plotting position methods is found to be insignificant and hence, only Weibull method is adopted for the analysis among them. From the Probabilistic methods, Gumbel and Normal distribution methods are used.

Seasonal and Weekly Rainfall Analysis

The rainfall data are arranged into a number of intervals with definite ranges. Mean and standard deviation were found out for the grouped data. Chi-square values are calculated for all the methods, with the obtained probabilities. The method that gives the least Chi-square value is found to best fit the distribution.

Weibull Distribution is a continuous probability distribution type where in rainfall amounts are assigned with a rank and the corresponding probabilities are found out using probability density function:

$$P(X) = m/(n + 1) \quad (1)$$

Where, m and n represents the rank and total number of data used in the analysis

Gumbel Distribution is used to model the distribution of the extremities of a number of samples of various distributions. It is given by (KC Patra, 2010)

$$P(X) = \exp.\,((-\,(a + x)/c) - e^{-(-(a+x)/c)}) \quad (2)$$

$$A = 0.450055\ \sigma - X\ avg\ \&c = 0.7797\ \sigma \quad (3)$$

Where, P(X) is the probability density function for Gumbel method and X_{avg} represents the average rainfall in mm

Normal Distribution is a very common continuous probability distribution. Normal distributions represents real-valued random variables whose distributions are not known. It is given by (KC Patra, 2010):

$$B = 0.5\ [1 + 0.196854\ |Z| + 0.115194\ |Z|^2 + 0.000344\ |Z|^3 + 0.015927\ |Z|^4]^{-4} \quad (4)$$

$$Z = (X - avg)/\sigma,\ F(Xi) = B \text{ for } Z < 0\ \&\ F\ (Xi) = 1 - B \text{ for } Z > 0 \quad (5)$$

The Probability Density function for the Normal Distribution method is as follows:

$$P(X) = F\ (Xi + 1) - F\ (X) \quad (6)$$

Where X_i is the rainfall at any instant i = 1, 2, …….n

Goodness of Fit is a test used to find out the best fit probability distribution. The best fit distribution varies for different time period. *Chi-squared test is used in the determination of best fit distribution for weekly and seasonal rainfall in this study. Chi-Squared Test* is used for continuously sampled data only and is used to determine if a sample comes from a population with a specific distribution. Chi-square value is given by (KC Patra, 2010):

$$Xc^2 = \sum\nolimits^{k}{}_{i=1} (O\text{-}E)^{\,2} / E \quad (7)$$

Where, O = Observed frequency, E = Expected frequency, i = Number of observations and K= the total number of data used

Chi-Square Formula adopted in the study is as follows:

$$Xc2 = [(fs\ (Xi) - P(Xi))2/P(Xi)] \times \Sigma\ Ni \quad (8)$$

$$Fs\ (Xi) = Ni/\Sigma Ni \quad (9)$$

Where, Xc is the Chi – squared value , P(X) is the probability density function

RESULTS AND DISCUSSION

Weekly Rainfall Analysis

The rainfall data are arranged into a number of intervals with a range of 20mm and the frequency of occurrence is found out initially to convert the normal data into a grouped data. Corresponding probabilities and Chi-square values are found out. The sum of the chi-square values of all intervals gives the chi-square value of that method. From the Table 2, it is evident that the probability values decreases proportionally to the ordered (descending) rainfall amount. The Chi-squared value is maximum for the interval 40-60 mm. The analysis done in this module includes: Checking data Homogeneity, Computation of basic statistics, fitting of frequency distributions. The Gumbel Distribution thus deals with extreme values of rainfall.

Table 2 Weekly rainfall analysis using weibull distribution

RANGE	RANK	Ni	fs(Xi)	Fs(Xi)	P(Xi)	Xc^2
0-20	23	1325	0.749	0.749434	0.95833	80.51
20-40	22	165	0.093	0.84276	0.91667	1307.47
40-60	21	98	0.055	0.89819	0.87500	1357.21
60-80	20	64	0.036	0.934389	0.83333	1348.11
80-100	19	45	0.025	0.959841	0.79167	1311.11
100-120	18	24	0.014	0.973416	0.75000	1278.43
120-140	17	10	0.006	0.979072	0.70833	1232.41
140-160	16	10	0.006	0.984728	0.66667	1158.75
160-180	15	7	0.004	0.988687	0.62500	1091.04
180-200	14	8	0.005	0.993212	0.58333	1015.40
200-220	13	2	0.001	0.994344	0.54167	953.67
220-240	12	6	0.003	0.997737	0.50000	872.04
240-260	11	0	0.000	0.997737	0.45833	810.33
260-280	10	3	0.002	0.999434	0.41667	730.68
280-300	9	0	0.000	0.999434	0.37500	663.00
300-320	8	0	0.000	0.999434	0.33333	589.33
320-340	7	0	0.000	0.999434	0.29167	515.67
340-360	6	0	0.000	0.999434	0.25000	442.00
360-380	5	0	0.000	0.999434	0.20833	368.33
380-400	4	0	0.000	0.999434	0.16667	294.67
400-420	3	0	0.000	0.999434	0.12500	221.00
420-440	2	0	0.000	0.999434	0.08333	147.33
440-460	1	1	0.001	1	0.04167	71.68

Table 3 Weekly rainfall analysis using gumbel distribution

RANGE	X	Ni	fs(Xi)	Fs(Xi)	P(X)	Xc^2
0-20	20	1325	0.75	0.74943	0.3673	702.83
20-40	40	165	0.09	0.84276	0.2885	233.46
40-60	60	98	0.06	0.89819	0.1756	145.42
60-80	80	64	0.04	0.93439	0.0946	63.69
80-100	100	45	0.03	0.95984	0.0480	18.74
100-120	120	24	0.01	0.97342	0.0237	7.64
120-140	140	10	0.01	0.97907	0.0115	5.30
140-160	160	10	0.01	0.98473	0.0056	0.00
160-180	180	7	0.00	0.98869	0.0027	1.06
180-200	200	8	0.00	0.99321	0.0013	14.25

200-220	220	2	0.00	0.99434	0.0006	0.73
RANGE	**X**	**Ni**	**fs(Xi)**	**Fs(Xi)**	**P(X)**	**Xc^2**
220-240	240	6	0.00	0.99774	0.0003	56.51
240-260	260	0	0.00	0.99774	0.0001	0.25
260-280	280	3	0.00	0.99943	0.0001	67.65
280-300	300	0	0.00	0.99943	0.0000	0.06
300-320	320	0	0.00	0.99943	0.0000	0.03
320-340	340	0	0.00	0.99943	0.0000	0.01
340-360	360	0	0.00	0.99943	0.0000	0.01
360-380	380	0	0.00	0.99943	0.0000	0.00
380-400	400	0	0.00	0.99943	0.0000	0.00
400-420	420	0	0.00	0.99943	0.0000	0.00
420-440	440	0	0.00	0.99943	0.0000	0.00
440-460	460	1	0.00	1.00000	0.0000	5955.25

Contd…

Table 4 Weekly rainfall analysis using normal distribution

RANGE	X	Ni	fs(Xi)	Fs(Xi)	Zi	F(Xi)	P(Xi)	Xc^2
0-20	20	1325	0.749	0.749434	-0.41	0.34	0.34	857.061
20-40	40	165	0.093	0.84276	0.16	0.57	0.22	133.420
40-60	60	98	0.055	0.89819	0.74	0.77	0.20	189.776
60-80	80	64	0.036	0.934389	1.31	0.90	0.13	124.993
80-100	100	45	0.025	0.959841	1.88	0.97	0.07	43.534
100-120	120	24	0.014	0.973416	2.45	0.99	0.02	8.058
120-140	140	10	0.006	0.979072	3.02	1.00	0.01	0.306
140-160	160	10	0.006	0.984728	3.59	1.00	0.00	18.841
160-180	180	7	0.004	0.988687	4.16	1.00	0.00	69.548
180-200	200	8	0.005	0.993212	4.73	1.00	0.00	498.755
200-220	220	2	0.001	0.994344	5.30	1.00	0.00	143.235
220-240	240	6	0.003	0.997737	5.88	1.00	0.00	5681.428
240-260	260	0	0.000	0.997737	6.45	1.00	0.00	0.002
260-280	280	3	0.002	0.999434	7.02	1.00	0.00	21001.528
280-300	300	0	0.000	0.999434	7.59	1.00	0.00	0.000
300-320	320	0	0.000	0.999434	8.16	1.00	0.00	0.000
320-340	340	0	0.000	0.999434	8.73	1.00	0.00	0.000
340-360	360	0	0.000	0.999434	9.30	1.00	0.00	0.000
360-380	380	0	0.000	0.999434	9.87	1.00	0.00	0.000
380-400	400	0	0.000	0.999434	10.44	1.00	0.00	0.000
400-420	420	0	0.000	0.999434	11.02	1.00	0.00	0.000
420-440	440	0	0.000	0.999434	11.59	1.00	0.00	0.000
440-460	460	1	0.001	1	12.16	1.00	0.00	18970654.169

The Co-efficient of Skew-ness represents the distribution of data about the mean. It is zero in the case of Normal distribution method. From Table 4, it is evident that the Normal distribution yields lesser faith for application in the study area since it gives a higher chi-square value.

Seasonal Rainfall Analysis

The weekly rainfall data are segregated in to South-West (June to September) and North-East (October to December) monsoon. They are arranged into a number of intervals with a range of 20mm and their frequency of occurrence is found out. Figure 1 and 2, shows the Chi-square values obtained by Weibull distribution for both North-East and South-West Monsoon. The rainfall amounts were initially converted into intervals of range 20mm.

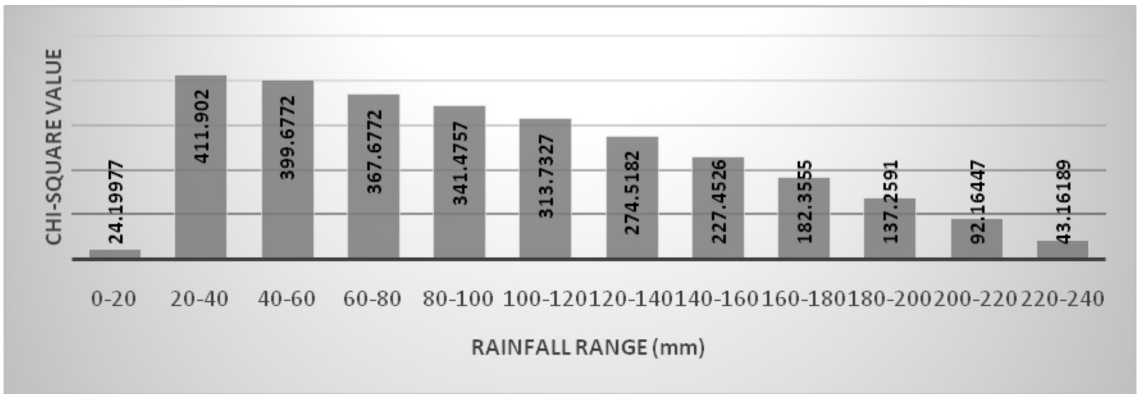

Fig 1 South-west monsoon analysis using weibull distribution

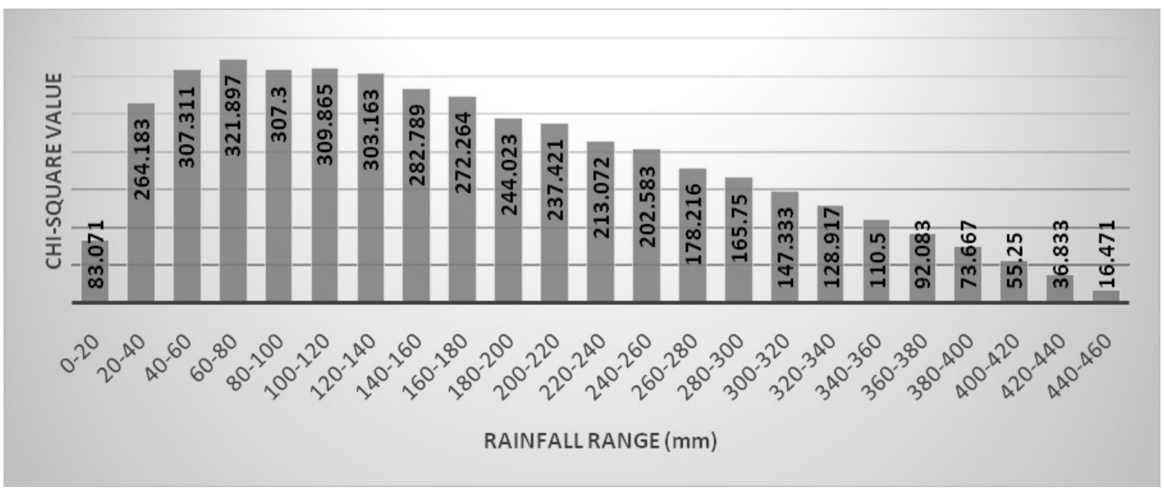

Fig 2 North-east monsoon analysis using weibull distribution

In a similar procedure, analysis of SW and NE monsoon was done by Gumbel and Normal Distribution methods.

Table 5 shows the sum of Chi-squared values obtained from different methods for Weekly and Seasonal analysis. The Chi-squared values were thus obtained from the Seasonal analysis for all the methods and Gumbel method yields the least chi-square values for both the seasons. The results are thus compared to ascertain the best fit distribution type.

Table 5 Total Chi-square value obtained from the analysis

DESCRIPTION	SEASONAL (NE)	SEASONAL (SW)	WEEKLY
WEIBULL	4353.963	2815.576	17860.184
GUMBEL	**371.624**	**403.736**	**7272.892**
NORMAL	141789.611	4964.219	18999424.654

CONCLUSION

From the Rainfall Probability analysis on the Weekly and Seasonal rainfall for Lalgudi Region, It is evident that Gumbel Distribution (Extreme Value Type – I) is ascertained as the best fit distribution type considering its Least Chi-Square Value among all other methods of analysis. The Analysis thus, helps in the efficient Crop Planning and Management in the Lalgudi region by being a pre-requisite to understand the rainfall pattern and showing the water availability of the region.

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Trends in Rainfall and Rainy Days of Akola in Vidarbha Region

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ABSTRACT

The impact of climate change is projected to have different effects within and between countries. Information about such change is required at global, regional and basin scales for a variety of purposes. The impact of climate change on air temperature and precipitation has received a great deal of attention by scholars worldwide. Many studies have been conducted to illustrate that changes in precipitation are becoming evident on a global scale. This study focuses on detecting trends in rainfall and rainy days for the Akola District in Vidarbha Region of Maharashtra State. The non-parametric Mann-Kendall test was applied to detect trends in annual, seasonal, monthly and weekly rainfall and rainy days. It was observed that the annual, south-west monsoon season, August and December months and meteorological week No.16 and 36 showed decreasing trend. There was no trend in annual and seasonal rainy days whereas December month and meteorological week No.32 showed decreasing trend and meteorological week No.36 showed increasing trend. The decreasing trend in rainfall and rainy days creating the moisture deficiency during crop growing period which ultimately losing the productivity in rainfed agriculture. To mitigate the adverse effect of uncertainty of rainfall, it is proposed to adopt the *in situ* soil and moisture conservation practices before and after commencement of the rains and to harvest the excess runoff into farm ponds and recycled for providing protective irrigation for sustainable rainfed agriculture.

Keywords: Rainfall, rainy days, trend, Mann-Kendall test, Vidarbha region.

INTRODUCTION

Global warming can affect land ecosystems especially water cycle. Rainfall is a key input in management of agriculture and irrigation projects and any change in this variable can influence on sustainable management of water resources, agriculture and ecosystems. Mainly, studies of climate change science are focused on the probable changes in the annual series of a variable such as rainfall and variability of this is important. Human activities have increased the atmospheric concentration of greenhouse gases changing the Earth's climate on both global and regional scales. In recent years the potential impacts of climatic change and variability have received a lot of attention from researchers. A comprehensive review of the potential impacts of climatic change is provided in IPCC (1998, 2001). According to IPCC (2001), increases in greenhouse gas concentrations increased the annual mean global temperature by 0.6 ± 0.2°C since the late 19th century.

However, while globally averaged precipitation is projected to increase, both increases and decreases are expected at the regional scale. Temperature drives the hydrological cycle, influencing hydrological processes in a direct or indirect way. A warmer climate leads to intensification of the hydrological cycle, resulting in higher rates of evaporation and increase of liquid precipitation. These processes, in association with a shifting pattern of precipitation, will affect the spatial and temporal distribution of runoff, soil moisture, groundwater reserves and increase the frequency of droughts and floods. The future rainfall trend will have its impact globally and will be felt severely in developing countries with agrarian economies, such as India. Surging population and associated demands for freshwater, food and energy would be areas of concern in the changing climate. Changes in extreme climatic events are of great consequence owing to the high vulnerability of the region to these changes. The 2009 drought in India is a wake up call about the shifting trends of monsoon behaviour in the emerging era of climate change. It brought home the point that weather prediction will be increasingly difficult. Our climate management strategy must be based on the promise that the frequency of drought, unseasonal rains and high temperature will rise. Assam, which normally only faces floods was amongst the first states to declare drought, at the same time there was a crop failure in west- coast regions due to high rain in 2009. Global warming will make the Indian monsoon more variable and less predictable with respect to regions. Pal and Al-Tabbaa (2009) concluded that there is a decrease in precipitation in hilly regions and increase in the precipitation over rest of the Kerala. They noticed that the climate change is having different effects over different topographies and hence suggested the need of work at regional basis. Atre and Deore (2013) studied the weekly trend at Rahuri in Scarcity Zone of Maharashtra.

Considering above suggestions, present study is done to find out the trends in annual, seasonal, monthly and weekly rainfall and rainy days at Akola station, as a representative station in the Vidarbha region of Maharashtra. The jurisdiction of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is entire Vidarbha region which is located in eastern Maharashtra and comprises eleven districts viz. Buldana, Akola, Washim, Amravati, Yavatmal, Wardha, Nagpur, Bhandara, Gondia, Chandrapur and Gadchiroli. It lies in between 17°57'–21°46' N Latitude and 75°57'–80°59' E Longitude having total geographical area of 97.23 lakh ha which is 31.61% of Maharashtra.

Location of Study Area

Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, is located in Eastern Maharashtra Plateau at 20°42'N Latitude, 77°02'E Longitude and elevation of 305 m above msl. The region is classified as hot moist semi-arid climate with medium and deep clayey black soils (shallow loamy to clayey black soils as inclusion). Akola centre receives an average (1971-2000) annual rainfall of 811 mm in 43 rainy days. The average rainfall during monsoon season (June to September) is 687 mm and ranges from 352 to 1155 mm. Peak rainfall occur during 2nd week of August. Day temperature varies from 28.9 °C (1st week of January) to 42.7°C (2nd week of May), while night temperature varies from 10.2°C (3rd week of December) to 27.5°C (3rd week of May to 1st week of June). The major crops grown in the region are cotton, soybean, pigeonpea, green gram and blackgram during *kharif* season and chickpea, safflower and sunflower during *rabi* season.

Data acquisition

The required daily rainfall data at Akola station was obtained from All India Coordinated Research Project on Agrometeorology, Dr. PDKV, Akola. The acquired data were in the form of daily rainfall for 40 years (1975-2014). This daily rainfall data was converted to the annual, seasonal, monthly and weekly rainfall. The rainy days were determined from rainfall data for further use.

METHODOLOGY

Trends in data can be identified by using either parametric or non-parametric methods. In the recent past, both methods have been widely used for the detection of trends (WMO, 1988; Mitosek, 1992; Chiew and McMahon, 1993; Burn and Elnur 2002). The non-parametric tests are more suitable for non-normally distributed, censored data, including missing values, which are frequently encountered in hydrological time series (Hirsch and Slack, 1984).

Mann-Kendall (MK) test

The MK test used in the present study, as suggested by U.S. Army Corps of Engineers (2005), is based on the test statistic, S. The daily / weekly / monthly / seasonal / annual rainfall and rainy days data of Akola for the period 1975 to 2014 (40 years) is taken for the study.

Compared first year data point with 2nd, 3rd, ..., 40th year data point. Assign, +1 if $X1 < X2$; -1 if $X1 > X2$ and 0 if $X1 = X2$. The sum of assigned values will give Mann-Kendall Statistic (S). A very high value of Mann-Kendall Statistic is an indicator of an increasing trend and a very low negative value indicated a decreasing trend. However, it is necessary to compute the probability associated with Mann-Kendall Statistic and the sample size, n, to statistically quantify the significance of the trend. Calculate Variance (S) by the following equation,

$$\text{Variance (S)} = \frac{\left(n(n-1)(2n+5)\right) - \Sigma_{p=1}^{p=g}\left(tp\ (tp-1)\ (2tp+5)\right)}{18}$$

Where,

n = number of years,

g = number of tied groups (a tied group is a set of sample data having the same value,

tp = number of items in the tied group.

The normalised test statistic Z calculated by the following equation,

$$Z = \frac{(S-1)}{\sqrt{\text{Variance (s)}}} \qquad \text{If } S > 0$$

$$Z = 0 \qquad \text{if } S = 0$$

$$Z = \frac{(S+1)}{\sqrt{\text{Variance (s)}}} \qquad \text{if } S < 0$$

Where,

S = p - q [where, p = number of (+1) values and q = number of (-1) values]

The values of test statistic, Z, are computed. If the value of Z is positive and Z > 2.576, Z lies within the limits of 2.576 to 1.96 and Z > 1.645 then there will be increasing trend at 1 %, 5% and 10% level of significance respectively otherwise the null hypothesis of having no trend in the series cannot be rejected. Similarly, if Z is negative and lies within above range then there will be decreasing trend at 1 %, 5% and 10% level of significance respectively using a two-tailed test.

RESULTS AND DISCUSSION

The Mann-Kendall test was applied to annual, seasonal, monthly and weekly rainfall and rainy days data using the methodology explained above. The Z statistic for each was computed and considering the criteria stated above the trends in rainfall and rainy days were decided. The summary of results is presented in Table 1 and 2.

From the analysis of meteorological data for Akola station, following results are observed :

1. **Rainfall**: The annual, south-west monsoon season, August and December months and meteorological week No.16 and 36 showed decreasing trend (Table 1).
2. **Rainy days:** There is no trend in annual and seasonal rainy days whereas December month and meteorological week No.32 showed decreasing trend and meteorological week No.36 showed increasing trend (Table 2).

CONCLUSION

This study focuses on detecting trends in rainfall and rainy days for the Akola District in Vidarbha Region of Maharashtra State. The non-parametric Mann-Kendall test was applied to detect trends in annual, seasonal, monthly and weekly rainfall and rainy days. The decreasing trend in rainfall and rainy days creating the moisture deficiency during crop growing period which ultimately losing the productivity in rainfed agriculture. To mitigate the adverse effect of uncertainty of rainfall, it is proposed to adopt the *in situ* soil and moisture conservation practices before and after commencement of the rains and to harvest the excess runoff into farm ponds and recycled for providing protective irrigation for sustainable rainfed agriculture.

Table 1 Trends in rainfall along with calculated Z statistic.

	Z	Trend			Z	Trend
Annual Rainfall				**Monthly Rainfall**		
Annual	-1.67	Decreasing*		January	-0.27	No Trend
				February	-1.37	No Trend
Seasonal Rainfall				March	0.10	No Trend
Winter (Jan-Feb)	-0.64	No Trend		April	1.43	No Trend
Summer (Mar-May)	0.91	No Trend		May	1.00	No Trend
SW Monsoon (Jun-Sept)	-1.83	Decreasing*		June	-1.34	No Trend
NE Monsoon (Oct-Dec)	-0.59	No Trend		July	-0.15	No Trend
				August	-1.97	Decreasing**
				September	0.94	No Trend

Contd…

				October	0.61	No Trend
				November	-0.05	No Trend
				December	-2.17	Decreasing**
Weekly Rainfall						
MW1	0.00	No Trend		MW27	0.31	No Trend
MW2	-0.33	No Trend		MW28	-1.11	No Trend
MW3	-0.24	No Trend		MW29	0.00	No Trend
MW4	-0.41	No Trend		MW30	1.48	No Trend
MW5	0.37	No Trend		MW31	-0.69	No Trend
MW6	-0.73	No Trend		MW32	-1.47	No Trend
MW7	0.33	No Trend		MW33	-1.49	No Trend
MW8	-0.34	No Trend		MW34	1.07	No Trend
MW9	0.19	No Trend		MW35	-0.40	No Trend
MW10	0.09	No Trend		MW36	2.24	Increasing**
MW11	0.54	No Trend		MW37	0.52	No Trend
MW12	0.69	No Trend		MW38	0.30	No Trend
MW13	-0.64	No Trend		MW39	-0.73	No Trend
MW14	0.45	No Trend		MW40	0.47	No Trend
MW15	0.01	No Trend		MW41	0.63	No Trend
MW16	1.70	Increasing*		MW42	1.37	No Trend
MW17	0.36	No Trend		MW43	-0.02	No Trend
MW18	0.47	No Trend		MW44	-0.41	No Trend
MW19	0.55	No Trend		MW45	-0.66	No Trend
MW20	1.12	No Trend		MW46	1.07	No Trend
MW21	0.55	No Trend		MW47	-0.50	No Trend
MW22	0.30	No Trend		MW48	-0.89	No Trend
MW23	-0.31	No Trend		MW49	-0.41	No Trend
MW24	-0.28	No Trend		MW50	-0.14	No Trend
MW25	-0.80	No Trend		MW51	-0.65	No Trend
MW26	-0.56	No Trend		MW52	-0.35	No Trend

(* - 10 % level of significance, ** - 5 % level of significance)

Table 2 Trends in rainy days along with calculated Z statistic.

	Z	**Trend**			**Z**	**Trend**
Annual Rainy Days				**Monthly Rainy Days**		
Annual	0.04	No Trend		January	-0.23	No Trend
				February	-1.19	No Trend
Seasonal Rainy Days				March	0.25	No Trend
Winter (Jan-Feb)	-0.67	No Trend		April	1.08	No Trend
Summer (Mar-May)	1.02	No Trend		May	1.00	No Trend
SW Monsoon (Jun-Sept)	0.43	No Trend		June	-1.48	No Trend
NE Monsoon (Oct-Dec)	-1.59	No Trend		July	1.16	No Trend
				August	-0.18	No Trend

Contd…

	Z	Trend			Z	Trend
				September	0.88	No Trend
				October	-0.13	No Trend
				November	-0.36	No Trend
				December	-2.35	Decreasing**
Weekly Rainy Days						
MW1	0.31	No Trend		MW27	0.92	No Trend
MW2	0.07	No Trend		MW28	-0.70	No Trend
MW3	-0.68	No Trend		MW29	1.13	No Trend
MW4	-0.23	No Trend		MW30	1.46	No Trend
MW5	0.17	No Trend		MW31	0.18	No Trend
MW6	-0.97	No Trend		MW32	-1.76	Decreasing*
MW7	0.42	No Trend		MW33	-0.75	No Trend
MW8	-1.43	No Trend		MW34	1.39	No Trend
MW9	0.83	No Trend		MW35	-0.38	No Trend
MW10	0.26	No Trend		MW36	1.83	Increasing*
MW11	0.00	No Trend		MW37	0.56	No Trend
MW12	0.44	No Trend		MW38	0.42	No Trend
MW13	-0.65	No Trend		MW39	-0.68	No Trend
MW14	0.44	No Trend		MW40	0.32	No Trend
MW15	0.12	No Trend		MW41	-0.58	No Trend
MW16	0.75	No Trend		MW42	0.65	No Trend
MW17	0.23	No Trend		MW43	-0.63	No Trend
MW18	0.72	No Trend		MW44	-0.23	No Trend
MW19	0.23	No Trend		MW45	-0.52	No Trend
MW20	0.69	No Trend		MW46	0.77	No Trend
MW21	-0.12	No Trend		MW47	-0.98	No Trend
MW22	0.00	No Trend		MW48	-1.13	No Trend
MW23	-0.05	No Trend		MW49	-0.35	No Trend
MW24	0.46	No Trend		MW50	-0.42	No Trend
MW25	-1.29	No Trend		MW51	-0.66	No Trend
MW26	-1.21	No Trend		MW52	-0.37	No Trend

(* - 10 % level of significance, ** - 5 % level of significance)

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Kinetics and Equilibrium Studies for the Removal of Heavy Metals in both Single and Binary Systems using Hydroxyapatite

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ABSTRACT

Removal of heavy metals is very important with respect to environmental considerations. This study investigated the sorption of copper (Cu) and zinc (Zn) in single and binary aqueous systems onto laboratory prepared hydroxyapatite (HA) surfaces. Batch experiments were carried out using synthetic HA at 30^0C. Parameters that influence the adsorption such as contact time, adsorbent dosage and pH of solution were investigated. The maximum adsorption was found at contact time of 12 and 9 h, HA dosage of 0.4 and 0.7 g/l and pH of 6 and 8 for Cu and Zn, respectively, in single system. Adsorption kinetics data were analyzed using the pseudofirst-, pseudo-second order and intraparticle diffusion models. The results indicated that the adsorption kinetic data were best described by pseudosecond-order model. Langmuir and Freundlich isotherm models were applied to analyze adsorption data, and Langmuir isotherm was found to be applicable to this adsorption system, in terms of relatively high regression values. The removal capacity of HA was found to be 125 mg of Cu/g, 30.3 mg of Zn/g in single system and 50 mg of Cu/g, 15.16 mg of Zn/g in binary system. The results indicated that the HA used in this work proved to be effective material for removing Cu and Zn from aqueous solutions.

INTRODUCTION

The heavy metals are of great concern because of their extreme toxicity even at low concentration and the tendency to accumulate in the food chain (Mohan and Singh 2002). The removal of toxic heavy metals from industrial wastewaters is one of the most important issues of environmental remediation. Heavy metals such as Pb, Cd, Cu, Zn, Hg, Cr, and Ni are the main contaminants of surface water, groundwater, and soils. The main sources of these elements are metal plating industries, abandoned disposal sites, and mining industries. Heavy metals are major pollutants in marine, ground, industrial and even treated wastewaters. The presence of toxic heavy metals in water has several problems with animals, plants and human being. Cu and Zn are among the most toxic metals affecting the environment. The primary sources of Cu in industrial wastewater are metal-process pickling baths and plating baths. Cu may also be present in wastewater from a variety of chemical manufacturing processes employing Cu salts or a Cu catalyst. Many studies have shown that these metals are toxic even at very low concentrations. Therefore, a systematic study of the removal of Cu and Zn from wastewater is of considerable significance from an environmental point of view.

Many researchers have conducted studies on various methods for the removal of heavy metals from waters and wastewaters. Conventional physicochemical methods such as electrochemical treatment, ion-exchange, precipitation, reverse osmosis, evaporation and oxidation/reduction for heavy metal removal from waste streams are expensive, not eco-friendly and inefficient for metal removal from dilute solutions containing from 1 to 100 mg/l of dissolved metal (Montazer- Rahmati et al. 2011). Efficient and environmental friendly technologies are, therefore, need to be developed to reduce heavy metal contents in wastewaters to acceptable levels at inexpensive costs (Saeed and Iqbal 2003). One alternate effective process is the adsorption which relies on the utilization of solid adsorbents with no chemical degradation. It is attractive due to its merits of effectiveness, efficiency and free sludge (Chu and Chen 2002). Among the various adsorbents, adsorption onto activated carbon (granular or powdered) is widely used; there is still a need to develop low cost and easily available adsorbents for the removal of heavy metal ions from the aqueous environment. Hence in recent years, research has been focused on the use of various low cost adsorbents.

The present study focuses on the removal of Cu and Zn from aqueous solutions by hydroxyapatite (HA) $[Ca_{10}(PO_4)_6(OH)_2]$. HA is a unique inorganic compound because of its high removal capacity for divalent heavy metal ions.

MATERIALS AND METHODS

Preparation and characterization of HA nanoparticles

The HA synthesized in the laboratory was used as adsorbent for this study. Analytical grade calcium hydroxide [$Ca(OH)_2$], and di-ammoniumhydrogen phosphate [DAP, $(NH_4)_2HPO_4$], were used for the preparation of HA nanoparticles. The amount of the reactants was calculated based on the Ca/P molar ratio (10/6 = 1.67). The 0.3-M DAP solution was added to the 0.3-M calcium hydroxide aqueous suspension in 5 min under high-speed stirring conditions. This solution with a pH of 11 was immediately subjected to the microwave irradiation for about 30 min in a domestic microwave oven. The mixing, crystallization of the HA and its aging occurs under the microwave irradiation in a shorter period. The product obtained after filtration was oven-dried at 70^0C for overnight and the cake obtained after drying was powdered with agate mortar and pestle.

The X-ray diffraction is carried out for the HA powder particles using a Rigaku Ultima III X-ray diffractometer with Cu $K_{\alpha 1}$ radiation (λ = 1.54056 A°) over the 2h range of 20–60^0, using a step size of 0.02^0 and step time of 4 s. The functional groups present in the synthesized HA were ascertained by Fourier transform infrared spectroscopy (FTIR, Perkin Elmer, Spectrum One, USA) over the region 400–4,000 cm^{-1} in pellet form for the powder samples of 1 mg mixed with spectroscopic grade KBr of 200 mg. Spectra were recorded at 4 cm^{-1} resolution, averaging 80 scans. The size and morphological features of synthesized HA powders were analyzed by transmission electron microscope (TEM, Philips, CM12 STEM, Netherlands).For TEM analysis, the powder sample was ultrasonically dispersed in ethanol to form dilute suspensions, and then few drops were deposited on the carbon-coated Cu grids.

Preparation of stock solutions

Metal salts of $CuSO_4.5H_2O$ for Cu and $ZnCl_2$ for Zn were used to prepare metal ion solutions. The stock solutions (1,000 mg/l) were prepared by dissolving appropriate amounts of metal salts in doubly distilled water. The working solutions (each 10 mg/l) were prepared by diluting the stock solutions to appropriate volumes.

Sorption experiments

Batch kinetic study was conducted with the known dosage of adsorbent (0.006 g of HA) for the 100 ml of metal ion (10 mg/l) solution. The samples were shaken at an agitation rate of 250 rpm. The samples were taken out at 1, 3, 6, 9, 12, 24, 36 and 48 h. The sorbent solution mixtures were then centrifuged for 5 min and the supernatant was analyzed for the metal ion concentration using Thermo Scientific S-series model flame atomic absorption spectrometer. The sorption studies were carried out by shaking a series of bottles containing different amounts of HA dosage (0.002–0.3 g) in 100 ml of metal ions solution prepared in the laboratory. The samples were stirred at room temperature at 250 rpm for equilibrium time. The effect of solution pH on Cu and Zn removal was studied over a pH range of 2–10 which was adjusted with 0.1 N HNO_3 or 0.1 N NaOH at the beginning of the experiment and not controlled during the experiment. Optimized dose of HA powder was added into metal solution and shaked at 250 rpm, for equilibrium time. The amount of each metal ion adsorbed onto the HA was calculated by the difference between the content of the metal ion in the influent solution and that of the effluent solution, corrected with the blank, and it is expressed in percentage. After the removal of heavy metals was completed, the HA samples were separated by filtering and dried at 120°C in an oven. FTIR analyses were carried out on the dried samples to find out modifications in the functional groups after adsorption process.

RESULTS AND DISCUSSION

Characterization of HA nanoparticles

In order to characterize HA, XRD, FTIR and TEM analysis were carried out on synthesized HA. A typical XRD pattern of the HA sample is shown Fig. 1. X-ray diffraction (XRD) analysis confirmed the mineralogical identity and the crystallinity of HA. The XRD peaks were markedly boarder, which suggested that HA particles were nano-sized and correspond to the hexagonal HA crystal (JCPDS 9-432). The presence of other calcium phosphate phases was not detected. The peak boarding of the XRD reflection was used to estimate the crystallite size in a direction perpendicular to the crystallographic plane based on Scherer's formula as given Eq. 1 (Gupta et al. 2006).

$$\text{Crystal size} = \frac{0.9\lambda}{\beta \cos\theta} \quad (1)$$

where k is the wave length of X rays, b is full width at half height of peak in radians and h is the angle of diffraction. The diffraction peak at 25.9^0 was considered for calculation of the crystal size; since it is sharper and isolated from others. This peak assigns to (0 0 2) Miller's plane family and shows the crystal growth along c axis of the HA crystalline structure. The estimated crystallite size was 28 nm for the HA sample. The TEM morphology showed that in as-synthesized condition, HA particles are of nano-sized with needle-like morphology, with width ranging from 15–20 nm and length around 50–60 nm, the size comparable to that of bone apatite. The infrared spectra of HA before adsorption in the 4,000–400 cm^{-1}region is shown in Fig. 2. Hydroxyl stretch is observed at 3,560 cm^{-1} (Manjubala et al. 2011) in the spectra of HA powder. Peaks in the region of 1,650–1,300 cm^{-1} are due to v_3 vibrational mode carbonate ion (Rehman and Bonfield 1997). These carbonate bands in the region of 1,650–1,300 cm^{-1} is assigned to surface carbonate ions, rather than to carbonate ions in the lattice of phosphate ions. Hydroxyapatite has three sites for v_3 vibrational mode centerd at 1,608, 1,422 and 1,360 cm^{-1}. Phosphate v_4 band is present in the region of 660 and 520 cm^{-1} and is a well-defined and sharp band, observed in the HA. A single intense v_3 band is present at 1,056 cm^{-1}. The FTIR spectrum of HA after interaction with Cu, Zn and Binary (Cu–Zn) metals are also shown in Fig. 2. FTIR spectra of the solid residues after adsorption are comparable to those of the original HA, suggesting no other phases formed during the heavy metal sorption. Comparing with the FTIR spectra before and after adsorption of Cu and Zn in single and binary system, there were clear band shifts and % transmittance increase for HA. The changes mainly occur in the OH^- and CO_3^{2-} groups of HA that had bound heavy metals.

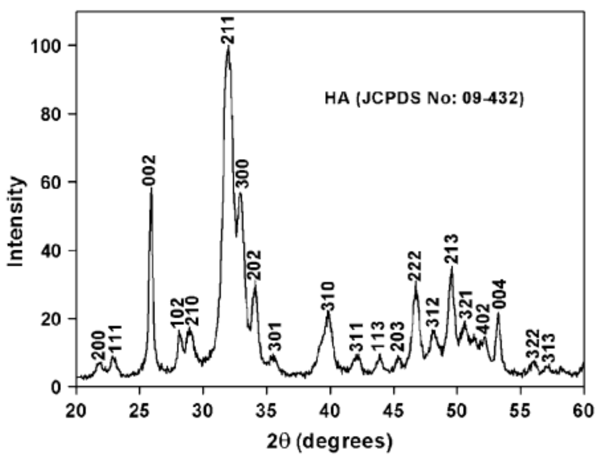

Fig. 1 X-ray diffraction pattern of HA adsorbent in as synthesized condition

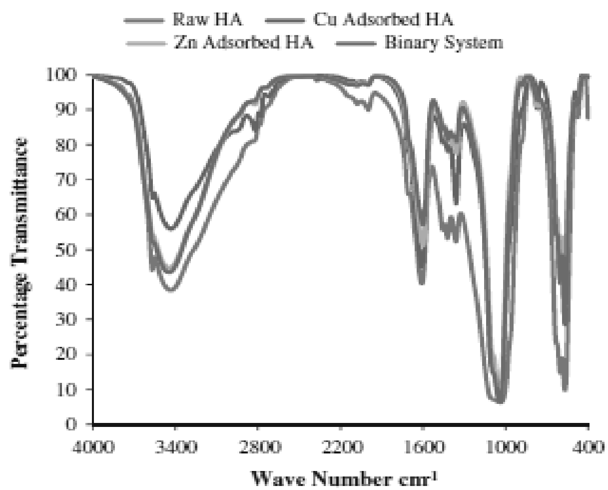

Fig. 2 FTIR spectra for removal of Cu and Zn by HA

Effect of contact time

Metal ion uptake capacities were determined as a function of time to determine an optimum contact time for the adsorption of heavy metal ions on HA. The variation of percentage of adsorbed metal ions with respect to time is shown in Fig. 3. It can be concluded that the removal of metal ions or the adsorption is increasing with increase in the contact time. Initially, the adsorption was low but increases with time quickly. It also shows that the percent removal of Cu and Zn are 50 and 20 % in 3 h, which increased up to 70 and 22 % in 12 and 9 h, respectively. The less removal of Zn at equilibrium, indicating that more HA was needed to remove Zn ions. In the binary system, 41 % of Cu and 16 % of Zn were removed from the aqueous solution with equilibrium time of 12 and 9 h, respectively. The less removal efficiency in binary system compared to the single metal system at equilibrium time is due to competitive sorption of heavy metals by HA.

Effect of mass of adsorbent on heavy metal removal

The effect of adsorbent dosage on heavy metal removal was analyzed by varying the dosage of HA and the results are shown in Fig. 4. It was found that the removal efficiency increases with the increase in HA dose. But the saturation of the adsorbent sites by the adsorption of the metal ions at the dosage levels of 0.4 and 0.7 g/l with the removal efficiency of 99 and 98 % for Cu and Zn, respectively. In the binary system, the same percentage removal has been achieved with very high amount of HA (0.9 g/l for Cu and 3 g/l for Zn).

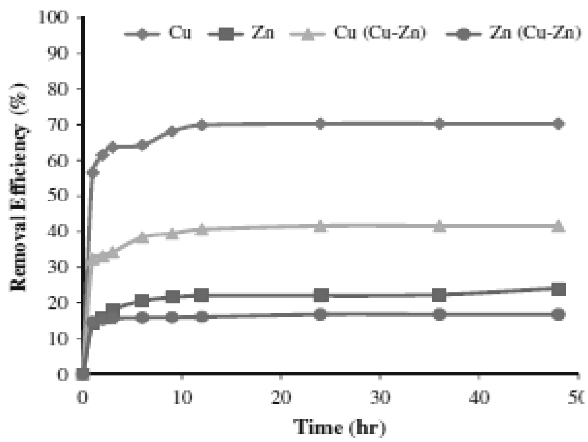

Fig. 3 Effect of contact time on removal of Cu and Zn

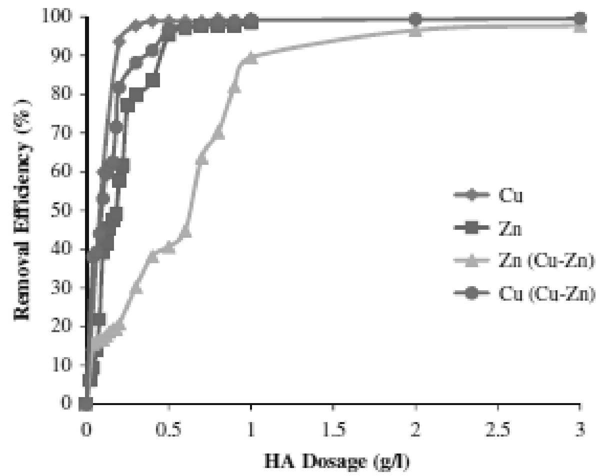

Fig. 4 Effect of dosage on removal of Cu and Zn

Effect of pH

The uptake of Cu and Zn was examined over a pH range from 2.0 to 10. It was observed that the amount of Cu and Zn removal by adsorption increased with an increase of pH up to about pH 6.0 for Cu and pH 8 for Zn, respectively. Then the removal efficiency remains constant over the pH range of 6–10 for Cu and 8–10 for Zn. However, Cu uptake was consistently higher than Zn uptake over the whole range of pH from 2.0 to 6. It is also noted that, for pH 2, the metal uptake for Cu increased at a much greater rate than that of Zn. However, at the solution pH greater than 4.0, the uptakes of both Cu and Zn increased at a similar rate. The behavior observed at pH 2 denotes a strong competition effect between the Zn and the H_3O^+ ion for the active sites of the adsorbent. As a result, the Zn does not become adsorbed (G'omez- Tamayo et al. 2008).

Adsorption kinetics

It is known that adsorption process could be controlled with different kinds of mechanisms, such as mass transfer, diffusion control, chemical reactions and particle diffusion. In order to clarify the adsorption process, several adsorption models were applied to evaluate the experimental data. For this purpose, Lagregren's pseudofirst-order kinetic model and pseudosecond-order kinetic model were considered and fitted with the experimental data. The pseudofirst-order equation is generally expressed as (Lagregren 1898),

$$\log(q_e - q_t) = \log(q_e) - \frac{k_1}{2.303}t \tag{2}$$

where q_e and q_t are the adsorption capacity at equilibrium and at time t, respectively (mg/g), k_1 is the rate constant of pseudofirst-order adsorption (1/min). The second-order Lagergren equation is expressed as

$$\frac{t}{q} = \frac{l}{k_2 q_e^2} + \frac{l}{q_e}(t), \tag{3}$$

where, k_2 is the rate constant of pseudosecond-order adsorption (g/mg/min).

Figures 5 and 6 show the plot of the first-order, and second-order models for adsorption of heavy metals by the HA, respectively. Experimental and theoretically calculated adsorption capacities at equilibrium (q_e) values and coefficients related to kinetic plots are listed in Table 1. It can be seen from Table 1 that the linear correlation coefficients for first order are not good when compared to the second-order model. These results suggest that the adsorption of Cu and Zn metal ions on HA is not pertaining to first-order reaction. It is evident from the results of second-order model that the correlation coefficients for Cu and Zn are very high and the experimental and theoretical q_e values are in good match. These results suggest that the adsorption of the Cu and Zn ions in single and binary system on HA follows the second-order type kinetic reaction.

Rate limiting step in adsorption can be found out from intra particle diffusion model. The Weber and Morris (1963) intraparticle diffusion model is expressed as

$$q_t = k_{id} t^{1/2} + C \tag{4}$$

where C is the intercept and k_{id} is the intraparticle diffusion rate constant (mg/g $min^{0.5}$), which can be evaluated from the slope of the linear plot of q_t versus $t^{1/2}$. Intra particle diffusion model for Cu and Zn removal by HA in single and binary model shows that the adsorption of Cu and Zn onto HA is multi-step process. It is having two regions. The first region is the instantaneous adsorption or external surface adsorption and the second region is the gradual adsorption stage where intraparticle diffusion is the rate limiting (Hammed 2009).

Adsorption isotherms

The equilibrium relationships between adsorbent and adsorbate are best explained by sorption isotherms (Mittal et al. 2010). The experimental values are fitted with Freundlich and Langmuir isotherm equations. The applicability of the isotherm equations was compared by judging the correlation coefficients, R^2. The Langmuir isotherm may be used when the adsorbent surface is homogeneous. The Langmuir isotherm is expressed as (Langmuir 1915)

$$\frac{1}{X/M} = \frac{1}{q_{\max}} + \frac{1}{q_{\max} b} \frac{1}{C_e}, \tag{5}$$

where b is the constant that increases with increasing molecular size (mg/l), q_{max} is the amount adsorbed to form a complete monolayer on the surface (mg/g).

The Freundlich isotherm is a result of the assumption that the adsorption occurs on a heterogeneous surface and non-uniform distribution of the heat of adsorption over the adsorbent surface takes place (Mittal et al. 2010).The Freundlich isotherm is expressed as (Freundlich 1906)

$$\log q_e = \log k = \frac{1}{n} \log C_e \tag{6}$$

Where q_e is the equilibrium adsorption uptake of heavy metal ions, in mg/g, C_e is the equilibrium concentration of heavy metal ions, in mg/l, and k and n are the Freundlich constants which are related to adsorption capacity and intensity, respectively.

Table 1 Adsorption kinetic model rate constants of Cu and Zn removal by HA

System	Heavy metals	Pseudo 1 st-order coefficients			Pseudo 2 nd-order coefficients			q_e exp (mg/g)
		q_e (mg/g)	k_1 (1/min)	R^2	q_e (mg/g)	k_2 (g/mg/min)	R^2	
Single	Cu	37	0.0018	0.97	113	0.012	0.99	110
	Zn	15.69	0.0025	0.95	41	0.0004	0.99	40
Binary	Cu	25	0.0004	0.80	75	0.00012	0.98	78
	Zn	20	0.0002	0.82	39	0.00014	0.92	42

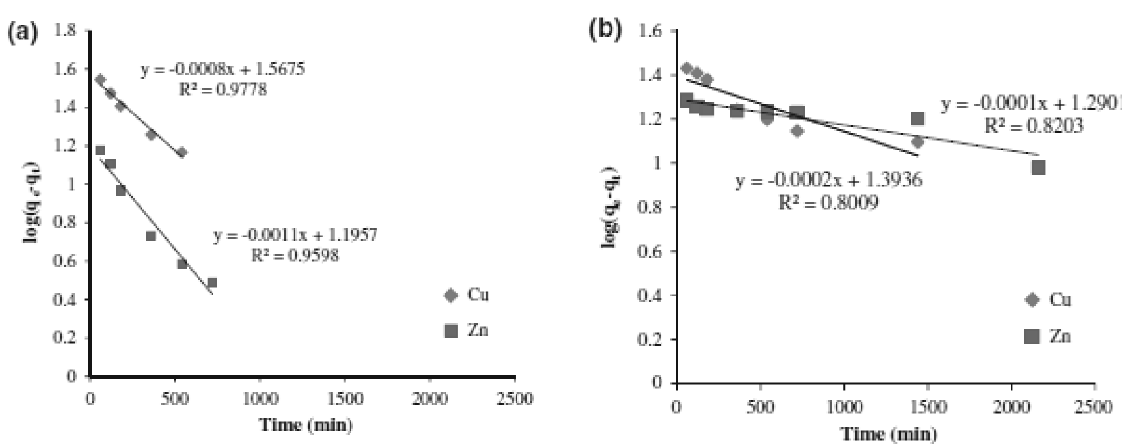

Fig. 5 Pseudofirst-order model plot for soprtion of Cu and Zn by HA (a) single

(b) binary system

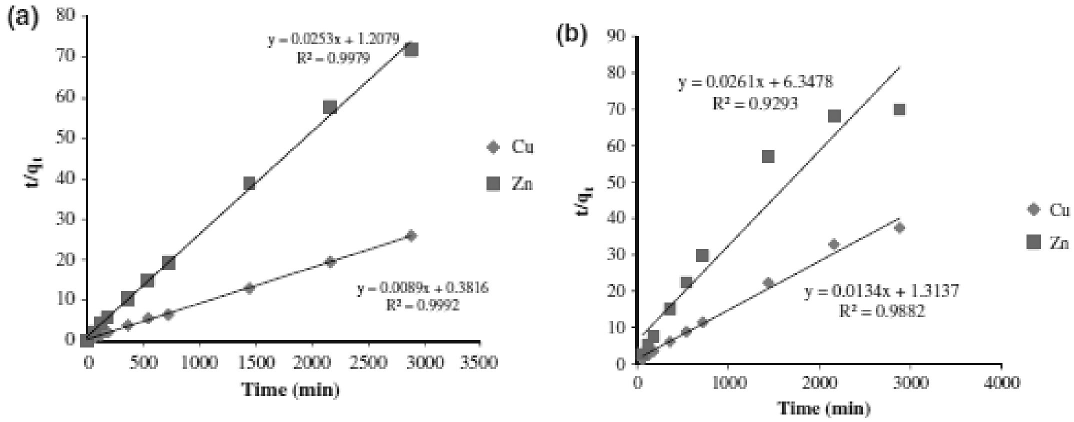

Fig. 6 Pseudosecond-order model plot for soprtion of Cu and Zn by HA (a) single (b) binary system

The isotherm constants for both Langmuir and Freundlich isotherms were evaluated and are reported in Table 2. It is observed that the R^2 of Langmuir model, a plot of which is shown in figure 7, is higher than the Freundlich's (except Cu in single system), which means that the adsorption belongs to the monolayer adsorption (Chen and Chen 2011). The Freundlich constant n value lying in the range of 1–10 for single and binary system confirms the favorable conditions for adsorption (Shokoohi et al. 2009). The adsorption capacity of HA is 125 mg of Cu/g, and 30.3 mg of Zn/g.

In the Cu–Zn system, competitive sorption between the aqueous heavy metals affected retention of metals by HA. Zn sorption (13.16 mg of Zn/g) was lower than that of Cu (50 mg of Cu/g). The same trend has been observed in single metal system. Preferential sorption is the adsorption rate limiting parameter in binary system. Preferential sorption depends on effective ionic radius. For Zn and Cu have effective ionic radius of 74 and 71 ^{o}A, respectively (Shannon 1976). Since both metals have almost same effective ionic radius, the removal from aqueous solution should be equal for both metals. In the present study, the removal of Cu and Zn are 99 and 98 %, respectively. This satisfies the above condition. But the adsorption capacity of HA is higher for Cu than Zn. It was also inferred that the selectivity sequence of HA may be system specific which depended on the properties of the adsorbent and the experimental set-up used (Hui et al. 2005). The maximum adsorption capacity of various adsorbents for Cu and Zn adsorption in single system together with the present study is given in Table 5. HA is found to have a relatively large adsorption capacity compared to other adsorbents. This indicates that HA can be considered as promising material for removing Cu and Zn from aqueous solution.

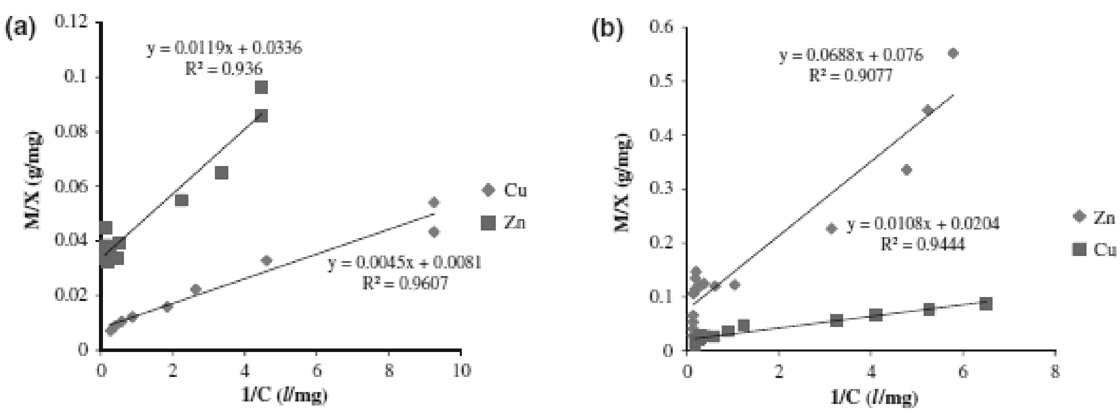

Fig. 7 Langmuir isotherm plot for sorption of Cu and Zn by HA (a) single (b) binary system

Table 2 Isotherm constants of Cu and Zn removal by HA

System	Heavy metals	Langmuir coefficients			Freundlich coefficients		
		q_{max} (mg/g)	b (1/min)	R^2	k (mg/g)	N	R^2
Single	Cu	125	2	0.960	72.41	1.852	0.981
	Zn	30.3	3	0.936	20.50	4.807	0.862
Binary	Cu	50	2	0.944	26.66	2.288	0.933
	Zn	13.16	1.118	0.907	5.02	2.451	0.839

Sorption mechanism

Sorption of Zn and Cu undergoes two step processes. Rapid complexation of heavy metals on specific sites of HA surface is the first step. A metal diffusion into the HA structure or to a heavy metal-containing HA formation is the second step in the sorption process. The sorption mechanisms have been inferred by the values of molar ratios (Q_s) of cations bound by HA to Ca desorbed from HA in single metal system and binary metal system as given in Table 3.

Table 3 Molar ratio values of Cu and Zn removal by HA

System	Metal	Metal disappearance (mg/l)	Solution Ca (mg/l)	Molar ratio Q_s
Single	Cu	9.88	12	0.823
	Zn	9.76	14	0.666
Binary	Cu-Zn	19.65	38	0.515

For the present study all the values of Q_s are less than one for single and binary system. This indicates that dissolution of HA and precipitation of new phosphate phase with lower cation to phosphate molar ratio occurs during sorption process (Corami et al. 2007). The increase in solution Ca increased with increasing metal disappearance was very high for Cu adsorption than that of Zn. In the present study, Q_s is not equal to 1 indicates that the no possibility of ion exchange of cations between the HA and the solution (Corami et al. 2007). The adsorption energies (E) from Dubinin–Radushkevich isotherm plot (not shown) were 4.08, 3.16, 3.16 and 2.3 kJ mol-1 for Cu, Zn, Cu (Cu–Zn) and Zn (Cu–Zn), respectively. For E<8 kJmol^{-1}, indicates that physisorption dominates the sorption mechanism (Argun et al. 2007). Therefore, it can be concluded that no ion-exchange between heavy metal adsorbed and Ca released into the solution.

CONCLUSIONS

The present study has demonstrated that HA has the adsorption capacity for removal of Cu and Zn from an aqueous solution. The equilibrium time for Cu and Zn removal was found as 12 and 9 h in both systems. The optimum dose of HA was found to be 0.4 and 0.7 g/l for Cu and Zn with the removal efficiencies of 99 and 98 %, respectively for single system. Similar efficiency was obtained for HA dosage of 0.9 g/l for Cu and 3 g/l for Zn in binary system. The maximum removal of Cu and Zn were occurred at pH of 6 and 8, respectively. Adsorption of Cu and Zn onto HA followed the pseudosecond-order kinetic model. Langmuir model fitted the experimental data better than Freundlich model, even though adsorption is favorable for Freundlich isotherm. The removal capacity of HA was found to be 125 mg of Cu/g, 30.3 mg of Zn/g in single system and 50 mg of Cu/g, 15.16 mg of Zn/g in binary system. The results showed that HA is a good adsorbent for the removal of Cu and Zn from aqueous solutions.

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Changes in Daily Intensity-Duration – Frequency Relationships for Precipitation under Climate Change Scenario for Warangal

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ABSTRACT

Urban drainage networks designed using conventional methods considering observational records may lack carrying capacities in future due to frequent occurrences of extreme events under changing climate scenarios. Projections from most of the GCM models suggest an increasing trend in return period and intensity of extreme precipitation events over the globe. Effect of climate change on precipitation pattern in future is examined for Warangal city using CCSM4 model for all the scenarios. An increase in trend is observed for both frequency and intensity of precipitation. Three out of four scenarios project drastic increase in intensity of higher return period events for the near future. It is observed that 25-year event in present condition is going to halve in future but not much changes are observed in events with lesser return period (2 and 5 year).

Keywords: Climate change, Precipitation, CCSM4 model.

INTRODUCTION

Climate change is likely to alter the precipitation pattern (IPCC) and most of the General Circulation Models (GCM) simulations show an increase in trend for extreme precipitation events, and frequent occurrences over Indian monsoon region. It is essential to have sufficient knowledge about possible future scenarios of climate change to reduce the risk associated. Urban flooding is one of the main problem in developing cites of which causes damages and inconvenience, which in turn, affect the economy. Urban drainage infrastructure, which may be incapable of carrying capacity under future climate scenarios, can be upgraded accordingly through effective adaptation strategies. Eriksen et al (2011) observe that simply adaptation to changes will not work always and local consequences must be considered, well maintenance is required.

Most of the climate studies carried out in India suggests an increase in trend of both frequency and intensity of extreme events (Manjula et al., 2015; Meenu et al., 2012; Kannan and Ghosh, 2010). Inclusion of effect of climate change in designing the urban drainage infrastructures is suggested (Mailhot and Sophie, 2010; He et al., 2006). The normally used conventional method of design of urban infrastructure may mislead due to possible changes in the future as a consequence of climate change. This study aims to find the possible changes in the extreme precipitation events under future climate scenarios. GCM models are generally used to answer the possible climate change. GCM climate variables are at higher spatial resolution but climate variables at much lower scale are required for hydrologic assessment. Different downscaling techniques ARCC (2014) are available to have information at lower scale. Design of urban drainage system requires Intensity-Duration-Frequency (IDF) relationship for precipitation for return period of 2 to 5 years. The present study develops IDF curves for short return periods for the fast growing city of Warangal.

Study Area and Data

Warangal City is taken up for the present study. The city is the district headquarters of Warangal district in Telangana State of India, and is the second most important and populated city after Hyderabad in the newly formed State. It is growing at a rapid rate and is considered to be an educational hub of the State. It is well connected by road and rail to the rest of the country, Hyderabad being the nearest airport. The city is also the nerve centre for agricultural business in the State. The average elevation of the city is 272 m above MSL, Latitude 18^{o}N and Longitude 79.5^{o}E. The city has reasonably well laid out, but inadequate drainage system.

For the study taken up, observed daily precipitation data for the period from 1982 to 2014 was collected from Regional Agricultural Research Station, Warangal. General Circulation Model outputs for historical and future scenarios are downloaded from IPCC Data Distribution Center (http://www.ipcc-data.org/sim/gcm_monthly/AR5/Reference-Archive.html). Table.1 gives the GCM model and scenarios used along with latitude and longitude used.

Table 1 GCM models and scenarios used and selected latitude and longitude

Modelling Centre	Institute ID	Model name	RCPs Used	Grid Size, Latitude and Longitude	Used Grid, Latitude and Longitude
National Center for Atmospheric Research	NCAR	CCSM4	RCP2.6, RCP4.5 RCP6.0, RCP8.5	0.942406°,1.25°	17.43456°, 78.78°

METHODOLOGY

Non-Stationarity in the Return Levels

Climate change is expected to induce change in intensity and frequency of extreme rainfall events. These non-stationarities can take many forms e.g.

- Change in the distribution as a whole;
- Change in the variability while the average value remains unchanged;
- Changes in both the average and the variability of the variable over time

In non-stationarity condition the parameters of the distribution changes with time which in turn change the changes in the distribution.

$$\mu_t = \mu_o + \Delta\mu_t \tag{1}$$

Where μ_t in Eq.1 represents the parameter of a distribution in future time period, μ_o is parameter at initial time or current period and $\Delta\ \mu_t$ is the corresponding change in the parameter over the time t.

IDF Relationship Generation

Generalized Extreme Value (GEV) Distribution is used for annual maximums, based on the parameters obtained from GEV distribution return levels are calculated. The GEV distribution is given by

$$f(z) = \begin{cases} \exp\left\{-\exp\left[-\dfrac{(z-\mu)}{\sigma}\right]\right\} & k=0 \\ \exp\left\{-\left[1+k\dfrac{(z-\mu)}{\sigma}\right]^{-\frac{1}{k}}\right\} & k \neq 0 \end{cases} \tag{2}$$

$$Z_p = \begin{cases} \mu - \sigma\log\left[\log(1-p)\right] & k=0 \\ \mu - \dfrac{\sigma}{k}\left[1-\{-\log(1-p)\}^{-k}\right] & k \neq 0 \end{cases} \tag{3}$$

Where μ is location parameter, σ is scale parameter k is shape parameter and Z_p is return level corresponding to return period T (= 1/p).

Kothyari and Garde (1992) developed a relationship between intensity, duration and frequency to find the intensities of lower duration events for different return periods for entire India with some regional constants. They have validated the equation with data from stations which are not used for calibration and found the one which gives results with less than ±30% error for 95% of the time. The relationship is given by

$$I_t^T = C\frac{T^{0.2}}{t^{0.71}}\left(R_{24}^2\right)^{0.33} \tag{4}$$

Where C=regional constant which is 7.1 for southern India, I_t^T is intensity in mm/hr for T year return period and t hour duration and R_{24}^2 is rainfall amount for 24 hours and 2 year return period.

Downscaling of daily precipitation

Basic assumption used in downscaling is that local climate is a combination of large-scale atmospheric characteristics and local-scale features. Change factor or delta method is a simple statistical downscaling method used for downscaling the daily precipitation amounts for future scenarios. In this method, a perturbation factor called delta is calculated as ratio between GCM simulations for future and current climate condition in terms monthly means of long length of record. The calculated change factor values are then multiplied to observed time series. Here the assumption is that similar changes will occur in all the regions which come under a particular grid.

$$\Delta P_t = \frac{\text{GCM monthly mean precipitation in future period}}{\text{GCM monthly mean precipitation in control period}} \tag{5}$$

$$P_{ft} = P_{obs} \times \Delta P_t \tag{6}$$

Where ΔP_t represent the perturbation factor corresponding to future time period t, P_{ft} is downscaled future time series and P_{obs} being the observed time series. The perturbation factor ΔP_t is calculated for all the time periods separately and multiplied with the observed time series to get the corresponding downscaled values. Most of the GCMs provide historical simulations up to 2005, and due to lack of availability of long length of observation record, the change factors are calculated for time slices of 20 years. Historical data from 1985 to 2005 and future scenarios are divided into five slices, viz., 2006 to 2025, 2026 to 2045, 2046 to 2065, 2066 to 2085 and 2080 to 2100 and corresponding change factors are applied.

RESULTS AND DISCUSSIONS

IDF for Observed Period

Series of 24 hour annual maximums of the observed precipitation data from 1982 to 2014 are fitted with GEV distribution given in (Eq.2) and the corresponding return levels are found using (Eq.3) for return periods of 2, 5, 10, 25, 50 and 100 years. Using the Kothyari and Garde (1992) equation, the return levels for sub hour durations are calculated for the Warangal city. The plotted IDF relationship is shown in Fig.1.

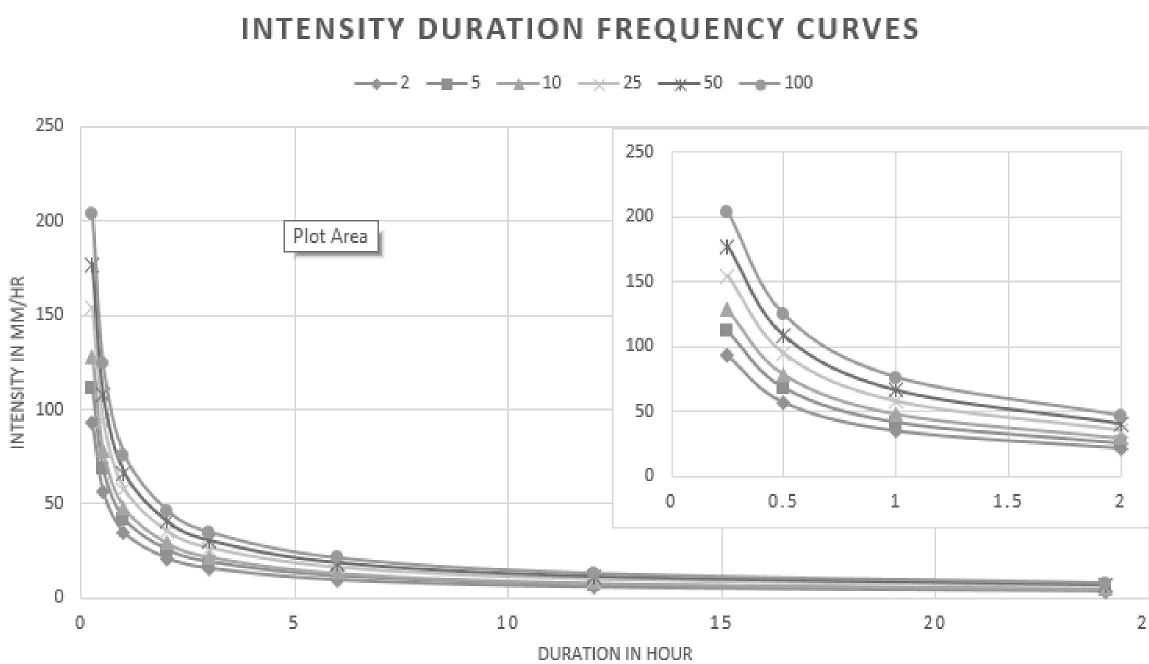

Fig. 1 Intensity duration frequency curves for the observed data from 1982 to 2014 for Warangal city

Downscaling Future Precipitation

To find the possible changes in future precipitation events, one GCM is used and the precipitation projections corresponding to nearest grid point is chosen, which is then downscaled to site scale using change factor method. The observed data from 1985 to 2005 is selected as control period. For the future, five time periods are selected, viz., 2006 to 2025, 2026 to 2045, 2046 to 2065, 2066 to 2085 and 2081 to 2100. The monthly means in the control period and for all the five future periods are calculated. Change factor is calculated in terms of changes in monthly mean precipitation for all the five future time periods and for the four scenarios using (Eq.5). The change factor for all the time periods for RCP4.5 scenario is given in Table 2. Similar change factors are calculated for all the four scenarios. Once the change factors are calculated, they are multiplied by the observed time series for all the corresponding months to get the time series of future year. It is to be noted that the length of year used for calculation of change factor and observed length of time series which is used for downscaling must match. Precipitation is downscaled from 2006 to 2100 for all the scenarios. Fig.2 shows the changes in annual precipitation in future periods for RCP4.5 scenario. Increasing trend in annual precipitation is observed till 2070. A little decrease in the trend in amount annual precipitation for the far future and an increased magnitude corresponding to observed precipitation amounts (control period) are also inferred. Similar type of trend is observed in all the scenarios.

Table 2 Change factors for RCP4.5 scenario in terms of changes in monthly mean precipitation

Month	2006-2025	2026-2045	2046-2065	2066-2085	2080-2100
Jan	0.7855	0.6921	0.6048	0.5476	1.0016
Feb	2.2529	1.0097	1.9162	1.5333	1.5337
Mar	1.5135	0.8445	1.1532	1.6731	0.7252
Apr	1.0523	1.0920	0.9164	1.1067	0.9550
May	0.7673	0.7085	0.8507	0.5743	0.7757
June	1.1518	0.9224	1.2804	1.0136	0.9384
July	0.9842	1.3424	1.2749	1.2709	1.2581
Aug	1.1012	1.1124	0.9315	0.9566	1.0609
Sept	0.9994	1.1489	1.1237	1.1274	1.1722
Oct	1.0834	1.1011	1.3208	1.3827	1.2927
Nov	0.7439	1.5344	1.3514	0.9547	1.9001
Dec	0.7448	1.1106	0.8073	0.8867	1.2734

IDF Relationship for Future Scenarios

The downscaled output is divided into three slices, viz., 2011 to 2040. 2041 to 2070 and 2071 to 2100. Series of annual maximums are taken and GEV distribution is fitted for all the time periods and scenarios. Return levels are calculated for frequency 2, 5, 10, 25, 50 and 100 year events shown in Fig. 3, 4, 5 and 6. All the scenarios showed an increase in extreme events in future periods. RCP2.6 and RCP4.5 projected significant increase in 100 years 24 hours events from 146.6mm to 170.5mmand 181mm respectively for near future and for the far future, it is increased to 175 mm and 182.4 mm for RCP2.6 and RCP4.5 respectively. A continues increasing trend in return level is observed in RCP6.0 scenario from 146.6 mm to 187.7 mm by 2050 and 185mm by 2080 for 100 year return period. Higher return period events are observed to occur more frequently. Fig.7 shows the changes in return period over the time for RCP2.6. For all the scenarios, significant changes are not seen for the lower return period events, but a 25-year event observed to become a 20-year event by 2050 and 13-year event by 2080 under RCP2.6.

CONCLUSIONS

Urban drainage is of primary concern in developing cities proper design of drainage of infrastructure is essential. It is observed that climate change is altering the precipitation pattern, which cause severe floods in urban areas. It is essential to consider changes in climate while designing the urban infrastructures. In this study, impact of climate change on precipitation pattern is studied using one of the GCMs and four scenarios. An increasing trend in both frequency and intensity of precipitation is observed under all the scenarios RCP2.6 and RCP4.5 scenarios are showing much increase for near future RCP8.5 showing the highest for 100 year return period from 146.6mm in current period to 212mm for far future, for 25 year return period changed from 130mm to 170 mm and 2-year event from 80mm to 92mm. use of projections from multimodal ensembles are preferred while assessing the impact of climate change to have robustness. Effective adaptation to climate change can reduce losses during flood in urban areas. Proper maintenance of drainage infrastructure contributes more in reducing the losses due to flood.

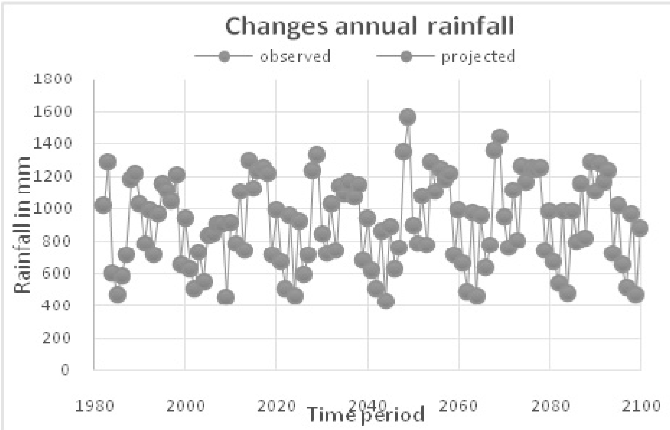

Fig. 2 Changes in total annual precipitation over the time according to RCP4.5 scenario.

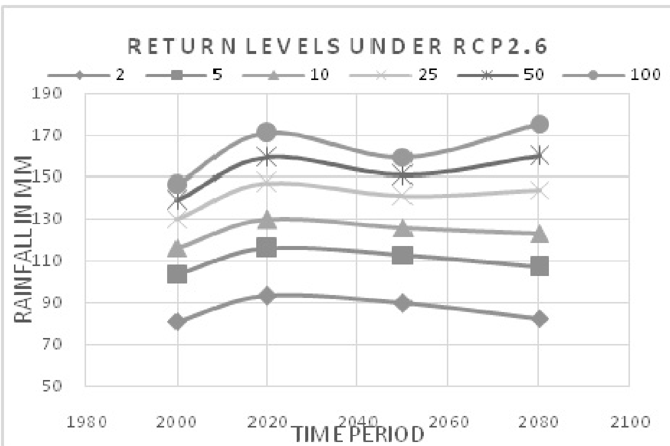

Fig. 3 Changes in return levels over the time under RCP2.6

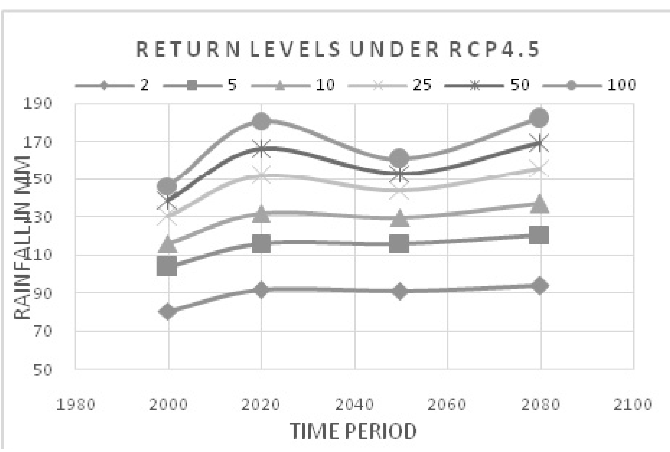

Fig. 4 Changes in return levels over the time under RCP4.5

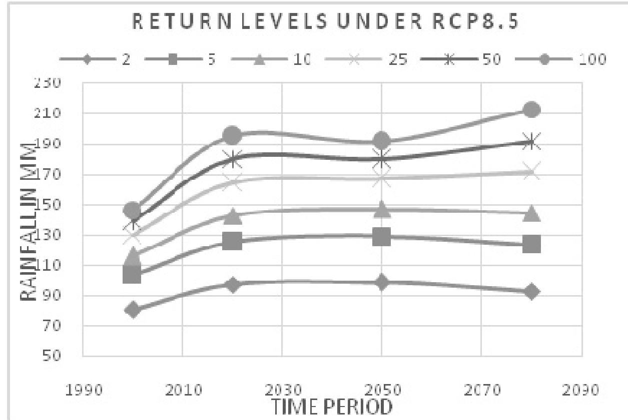

Fig. 6 Changes in return levels over the time under RCP8.5

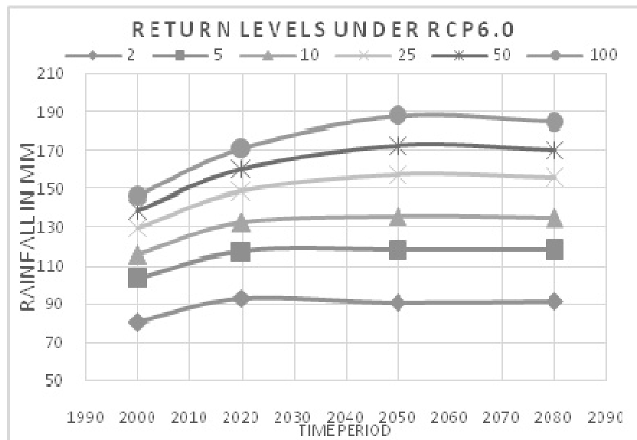

Fig. 5 Changes in return levels over the time under RCP6.0

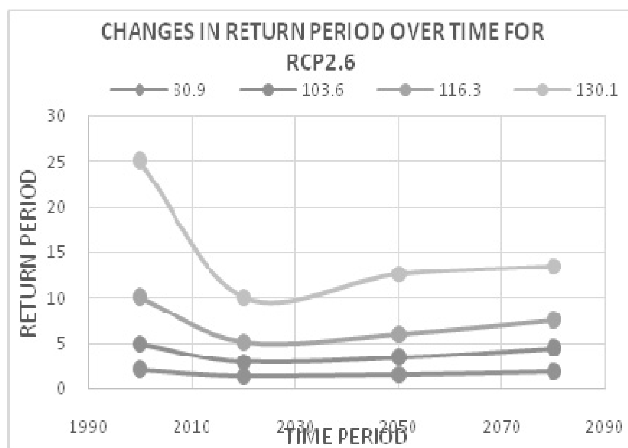

Fig. 7 Changes in return period over the time under RCP2.6 scenario

CONCLUSIONS

Urban drainage is of primary concern in developing cities proper design of drainage of infrastructure is essential. It is observed that climate change is altering the precipitation pattern, which cause severe floods in urban areas. It is essential to consider changes in climate while designing the urban infrastructures. In this study, impact of climate change on precipitation pattern is studied using one of the GCMs and four scenarios. An increasing trend in both frequency and intensity of precipitation is observed under all the scenarios RCP2.6 and RCP4.5 scenarios are showing much increase for near future RCP8.5 showing the highest for 100 year return period from 146.6mm in current period to 212mm for far future, for 25 year return period changed from 130mm to 170 mm and 2-year event from 80mm to 92mm. use of projections from multimodal ensembles are preferred while assessing the impact of climate change to have robustness. Effective adaptation to climate change can reduce losses during flood in urban areas. Proper maintenance of drainage infrastructure contributes more in reducing the losses due to flood.

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THEME - VIII

GIS Approach for Selection of Water Conservation Sites in Deccan Trap Provinces of Central India

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ABSTRACT

In the present work, an attempt has been made to evolve a Decision Support System (DSS) for the identification of suitable sites for water and soil conservation measures and their treatment plans, through integrated analysis using remote sensing and geographical information system (GIS) techniques. The methodology is based on multidisciplinary approach which considers slope, soil and land use/ land cover characters, apart from single hydro-geomorphology theme. The thematic maps, extracted from satellite imagery are taken into consideration in delineating the different potential zones amenable to specific water and soil conservation structures. The recommended method is user friendly, universally applicable and widely useful for the various departments dealing in soil and water conservation and management programs.

Keywords: Decision support system (DSS), GIS, remote sensing, soil and water conservation, multidisciplinary approach, thematic maps, methodology.

INTRODUCTION

The Government of India, on realizing the need of water and soil conservation programs, embarked upon implementation of water and soil conservation programs on large scale under the watershed development programs (Varade *et al.,* 2011a & b). Presently, such programs are being implemented throughout the country India by various Government as well as Non-governmental organizations (NGO), in which lot of efforts are made to collect the baseline data through rigorous hydro-geological fieldwork studies (RGNDWM, 2008). It is experienced that such field based studies, only considering hydro-geological aspects, looses the very essence of holistic approach. Also, these studies are time consuming and cumbersome. Due to this, identification of appropriate sites is a major challenge to the scientists involved in this field (Ravi Shankar and Mohan, 2005).

Till date, many scientists engaged in this field have attempted to evolve methodologies/experimental techniques to find out appropriate sites for water and soil conservation (Wood, 1979; Troch *et al.,* 1980; Walsh, 1992; Deshpande, 2003; Bühlmann *et al.,* 2010; Weerasinghe *et al.,* 2011, *etc.*). Most of these scientists have considered a single line approach in supporting their defined methodology/experimental techniques. However, the individual resources data many a times do not convey proper information on true potentials and problems of the area of interest, if viewed in isolation. Therefore, in order to obtain a realistic output, it is eminent to study all these interrelated resources for identification of potentials and problems on the field level. Thus, there exists a demand for development of spatial technique for estimating watershed characteristics. In view of this, it is felt that the integrated analyses of available resources database would provide better understanding of the terrain condition, as it considers all the interrelated resources, which in turn, facilitates the adoption of holistic approach.

Remote Sensing and GIS as a Decision Support System (DSS) tools

In the recent years, the role of remote sensing and GIS has received much attention in characterization, conservation, planning and management of natural resources in general, and water resources in particular. These techniques facilitate demarcation of suitable areas for groundwater replenishment by taking into account the diversity of related factors (Biswas *et al.,* 2002; Braun *et al.,* 2003; Saptarshi and Raghvendra, 2009; Balachandar *et al.,* 2010; Pandey *et al.,* 2011; Raghu and Reddy, 2011; Weerasinghe *et al.,* 2011). The remote sensing technique provide a sound realistic database on resources, while the geographical information system helps in storage, retrieval and analysis of spatial database in computer system. The GIS technique facilitates the spatial analysis through intersection and manipulation process. This altogether forms an exclusive tool in designing an approach for arriving at decision support system for particular application. Multi-criteria evolution techniques are numerical algorithms that defines the suitability of particular solution on the basis of input criteria and weights together with some mathematical or logical means of determining trends, when conflict arise (Adelman, 1992). As such to arrive at a clear picture of the situation, the controlling factors have to be treated and integrated giving appropriate weights *i.e.,* specific to particular area). In view of this, the spatially geo-referenced database (effectively employed in GIS environment) is considered here to evolve a DSS for identification of appropriate sites amenable to site specific water and soil conservation measures.

MATERIALS AND METHODS

The watershed development program envisages construction of various water conservation structures as well as implementation of appropriate land treatments by adopting the concept of ridge to valley development. Under such programmes, following structures and treatments are generally recommended (Table 1);

Table 1 Hydro-morphic zones and respective water and land treatment measures

Sr. No.	Hydro-morphic Zone	Appropriate Drainage Line Treatment	Appropriate Land Treatment
1.	Runoff zone	Gully plugs, Loose Boulder Structures, *etc.*	Afforestration, Social Forestry, Plantation, Water arresting Trenches, Compact Contour Trenches (CCT), *etc.*
2.	Upper recharge zone	Percolation Tank, Earthen Nala Bund, *etc.*	Agro-Forestry, Social Forestry, Plantation with Compact Contour Trenches (CCT), *etc.*
3.	Lower recharge zone	Earthen Nala Bund	Dry land, Horticulture, Farm Pond, *etc.*
4.	Storage zone	Cement Nala Bund, Underground Bandhara	Interline agricultural practices, Drip or Sprinkler irrigation, *etc*.

It is clear from the table that there exists a good relationship in between conservation structures to be adopted with the different hydro-geomorphological zones (Varade *et al.,* 2011a, d; Varade *et al.,* 2013). Therefore, the formulation of the program would not be possible unless the target area is classified in different hydro-morphic zones. Hence, classification of watershed area in different hydro-morphic zones is the foremost task, for which following methodology is described.

Baseline Input Data

Department of Space (Govt. of India) along with its State government organizations has created a vast resources database in GIS environment. Now it is a high time to evolve definite applications, wherein the database so generated will find its place in the form of major input. Based on this consideration, a universal program is developed for the selection of sites for water conservation measures and land treatment. The program is basically targeted for the micro-watershed area (6 to 10 km^2), where no much variation in thematic layers/units are expected. The basic information required for evolving the methodology is as follows;

1. ***Satellite Image:*** Availability of high resolution multispectral satellite data enables generation of thematic maps on desired scale with desired accuracy for the field level implementation of various programs.
2. ***Land use/ Land Cover:*** The land use/land cover map reflects the human activity on a given land. This theme has a direct relation with the land potential and so reflects groundwater potential of the area under consideration *e.g.,* intensive agricultural activity indicates better availability of groundwater (Varade *et al.,* 2011 b, c). Therefore this layer has relevancy in deciding the water and soil conservation measures.
3. ***Hydro-geomorphology and Groundwater Potential Map:*** Hydro-geomorphology and groundwater potential map indicates qualitative groundwater potential of given area. This theme has a direct bearing on the groundwater regime of any area *e.g.* pediplain generally form the storage zone, implying favorable zone for the development of groundwater in the area. Thus, hydro-geomorphology map has a significant value in the selection of sites for water and soil conservation measures (Varade *et al.,* 2011d).
4. ***Slope Details:*** The groundwater recharge is mainly governed by terrain slope *e.g.* higher slope indicates runoff zone, whereas, very gently sloping areas indicate the storage zone. This way, the slope map has a direct relation with the groundwater potential and therefore this layer is considered as a major ingredient in finalizing the water conservation measures (Varade *et al.,* 2013).

5. ***Land Capability Details:*** The land capability map reflects soil characteristics of the terrain and show a good relation with geomorphology as well as lithology of the area (Varade *et al.,* 2011a, b, c, d). Therefore, land capability map also implies groundwater potential condition of given terrain *e.g.,* land capability–II indicates low lying valley with thick overburden and therefore facilitates the occurrence of groundwater. Similarly, land capability-VIII mostly occurs on the hills which are unfavorable for occurrence of groundwater. The soil layer in form of land capability is also very useful in integrated analysis for identification of sites for appropriate water and soil conservation structures.

An Integrated Approach

The suggested methodology is based on integration of above mentioned thematic layers. Initially the thematic maps on hydro-geomorphology, land use/ land cover, land capability and slope are required to be generated and integrated in two steps by assigning differential weightage values by considering the importance of respective theme. The hydro-geomorphology has a major role in deciding the particular site specific treatment and therefore slightly higher weightage are allotted to this theme. Soil is another important parameter in deciding the feasibility of the structures and generally it maintains harmony with the existing geomorphology. By keeping this in view, slightly lower weighs are given to land capability classes. The slope map also has a good relation with both soil and hydro-geomorphology and in turn helps in increasing the accuracy of results. As a result, low weights are given to slope classes. The weightage are given for individual theme according to its hydro-morphological characters (runoff zone, recharge zone, storage zone). The weightage values are to be allotted in descending order, in which, high weight corresponds to storage zone, while low weight corresponds to runoff zone (Table 2, 3, 4 and 5).

Table 2 Weightage value scheme for soil land capability units

Soil land capability class	Hydro-morphic zone	Weight
I & II	Storage	160
III	Lower recharge	120
IV & V	Upper recharge	80
VI, VII & VIII	Runoff	40

Table 3 Weightage values scheme for slope categories

Slope class	Slope in %	Hydro-morphic zone	Weight
I & II	0-3	Storage zone	80
III	3-5	Lower recharge	60
IV & V	5-15	Upper recharge	40
VI & VII	>15	Runoff zone	20

Table 4 Weightage values scheme for geomorphological units

Hydromorphic zones	Geomorphic units	Weight
Storage zone	Slightly dissected plateau/lower pediplain/alluvial plains	> 200
Lower recharge zone	Moderately dissected plateau/upper pediplains	150
Upper recharge zone	Pediment/ foot slopes/piedmont zone	100
Runoff zone	Hills (residual, denudational and structural)/ highly dissected plateau	50
------------------Continued for all the Geomorphological units in similar manner---------------		

Table 5 Weightage values scheme for land use/ land cover units

Land use/ land cover classes	Description	Land use weights
Crop land	Kharif + Rabi	40
Crop land	Rabi	35
Crop land	Kharif	30
Wasteland	Land with scrub	25
Forest	Dense forest	20
-------Continued for all the land use classes in similar manner---------		

To evolve DSS program, the four thematic maps namely hydro-geomorphology, land capability, slope and land use/land cover are considered. Initially in the first step of program, only three maps (*viz.* hydro-geomorphology, land capability and slope) are required to be integrated to create polygons with unique total weightage values, depending upon their hydro-morphic characteristics *i.e.,* highest weightage to storage zone and low weightage to runoff zone. The maps are then needs to be integrated to form number of polygons of specific total weights in which following maximum possible combinations will emerge (Table 6).

Table 6 Maximum possible polygon combinations and their respective weightage values

Sr. No.	Soil Weightage	Slope Weightage	Hydro-geological Weightage	Total Weightage
1.	160	80	200	440
2.	160	80	150	390
3.	160	80	100	340
4.	160	80	50	290
5.	160	60	200	420
6.	160	60	150	370
7.	160	60	100	320
8.	160	60	50	270
9.	160	40	200	400
10.	160	40	150	350
11.	160	40	100	300
12.	160	40	50	250
13.	160	20	200	380
14.	160	20	150	330
15.	160	20	100	280
16.	160	20	50	230
17.	120	80	200	400
18.	120	80	150	350
19.	120	80	100	300
20.	120	80	50	250
21.	120	60	200	380
22.	120	60	150	330
23.	120	60	100	280
24.	120	60	50	230
25.	120	40	200	360
26.	120	40	150	310
27.	120	40	100	260
28.	120	40	50	210
29.	120	20	200	340
30.	120	20	150	290
31.	120	20	100	240
32.	120	20	50	190
33.	80	80	200	360
34.	80	80	150	310
35.	80	80	100	260
36.	80	80	50	210
37.	80	60	200	340
38.	80	60	150	290
39.	80	60	100	240
40.	80	60	50	190
41.	80	40	200	320

42.	80	40	150	270
43.	80	40	100	220
44.	80	40	50	170
45.	80	20	200	300
46.	80	20	150	250
47.	80	20	100	200
48.	80	20	50	150
49.	40	80	200	320
50.	40	80	150	270
51.	40	80	100	220
52.	40	80	50	170
53.	40	60	200	300
54.	40	60	150	250
55.	40	60	100	200
56.	40	60	50	150
57.	40	40	200	280
58.	40	40	150	230
59.	40	40	100	180
60.	40	40	50	130
61.	40	20	200	260
62.	40	20	150	210
63.	40	20	100	160
64.	40	20	50	110

Since each hydro-morphic zone is unique and amenable to specific water conservation measure, these probable combinations needs to be rationalized in major groups based on hydro-geomorphological zonation. Consequently, in the second step, rationalization of sixty four (64) groups into four (4) major groups is suggested, in which, weightage of 100 is proposed to runoff zone, 200 to upper recharge zone, 300 to lower recharge zone and 400 to storage zone. The final map derived from integrated analysis should be rationalized in four main classes (Table 7).

Table 7 Rationalized classes

Sr. No.	Range of Total weight	Rationalized Modified weight	Corresponding hydro-morphic zones
1	110- 200	100	Runoff zone
2	> 200 to < 280	200	Upper Recharge zone
3	>280 to < 350	300	Lower Recharge zone
4	>350	400	Storage zone

The output so obtained is useful for finalizing the water conservation treatment. However, the treatment needs to be finalized in consultation with surrounding land use/ land cover pattern. Therefore, land use/ land cover map forms one of the important inputs in deciding the feasibility of water and soil conservation measures in an area, as specific measures are amenable to crop land so also wasteland and forest land. Thus, weightage values are required to assign to all the land use classes in two (2) digits. The land use map should be subsequently integrated with the earlier integrated thematic map to decide the feasibility of structures for specific weight value. So, on final integration each polygon will show value in three (3) digits reflecting its hydro-geomorphic zone as well as existing land use/ land cover. This will help in deciding feasibility of specific water conservation structure as well as land treatment. For example, polygon 435 indicates the storage zone having potential for groundwater development. But, the landuse is single crop (i.e. *Rubby*) and appears to be underutilized. Therefore, this polygon is amenable to intensive agricultural practices and for construction of Cement Nalla Bund/ underground Bandhara/water conservation practices. On these lines, the recommendations for land treatment as well as conservation treatments are to be recommended for any polygons. This output should be finally intersected with the drainage layer to identify sites for drainage line treatments as well as land treatments. A look up table of polygon weights and appropriate treatment should be prepared and applied to the integrated map to obtain a map showing polygons suitable for specific water and land conservation measures. The final output incorporating the field observations in the form of action plan will show area/ sites for implementation of appropriate structures or measures. A computer based DSS program developed by using Arc Macro language is prepared and given in table-8. This program accepts the area specific weights and runs the integration mechanisms to arrive at the best results for the recommendations.

Table 8 Extract of various water and soil conservation structures/ measures

```
Select all
resel actionplan wt = 105 or actionplanwt= 205
calc lrdp = 'afforestation with CCT'
calc wrdp = ' Gully Plug or LBS'

Select all
Resel actionplan wt = 110 or actionplanwt= 210
calc lrdp = 'Conservation of Forest'
calc wrdp = ' Gully Plug or LBS'

Select all
Resel actionplan wt = 120 or actionplanwt= 220
calc lrdp = 'Social Forestry Plantation with CCT'
calc wrdp = 'Gully Plug or LBS'
```

Explanation

Lrdp: Land resources development plan; **wrdp**: Water resources development plan; **CCT**: Continuous compact trench; **LBS**: Loose boulder structure

VALIDATION OF THE METHODOLOGY AND CONCLUSIONS

The complex task for preparation of land and water resources development plans, now can be tackled on the basis of watershed as a development unit. The scope is huge and the same can be completed effectively only on the basis of automated approach in GIS environment. The GIS supported program helps to delineate micro-zones with unique characters amenable to specific water and land conservation treatment. The effort in this regard has evolved a user friendly, cost effective and multidisciplinary approached DSS program for the selection of sites for water and soil conservation. The methodology so designed is universal as the major decisive factor is hydro-geomorphology, in which, it is observed that all the hydro-geomorphological classes can be grouped in four hydro-geomorphic zones, which forms a basis of DSS for finalizing the water and soil conservation treatment. The action plans so prepared are found to be realistic, since they are based on spatial database that takes care of all the interrelated resources (*viz.* slope, soil, land use/ land cover, apart from hydro-geomorphology) and thus follows holistic approach. Overall, the approach helps in minimizing the subjectivity for selection of appropriate sites for water and soil conservation. However, there is a good scope for further refinement of the proposed model based on varied terrain conditions. Similarly, even the weightage value system could be devised as per the needs of the task.

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Hyper Spectral Response Pattern of Red Soils under Varying Moisture Conditions

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ABSTRACT

Soil moisture is a critical process in the water cycle. In agricultural production, the spatial variability of soil moisture can be responsible for low or spatially variable crop yields, as soil moisture is required to make nutrients soluble for plant absorption. Soil moisture fluctuates both spatially and temporally due to factors such as soil type, soil horizon, and other site-specific geologic and climatic conditions. Traditional efforts to measure soil moisture have been principally restricted to *in situ* measurements. The spectral analysis is a fast and non-destructive method and has been used in many fields such as oil industry, food industry, Vegetative stress analysis, Forestry Analysis, Marine and Wetlands studies, Mineral identification, and Surface color measurement. Soils darken when wet with little apparent color change. This commonly observed phenomenon is an obvious and dominant characteristic of the reflectance of soils. Several explanations for the darkening have been suggested based on at least two, very distinct theoretical hypotheses. The spectral reflectance curve of bare soil is considerably less variable. The reflectance curve is affected by moisture content, soil texture, surface roughness, presence of iron oxide and organic matter. In the present study, the spectral reflectance of soil is found from the visible/near infrared spectra of sensitive spectral band was applied to develop a method for rapid detection of soil moisture content. From the study it has been studied how reflectance varies with respect to moisture content for red soil using Spectroradiometer. In this study, soil surface reflectance data in the visible and near−infrared regions were analyzed by spectroradiometer and it is observed that the reflectance is more when the soil is dry and the less reflectance is observed when the soil is highly wetted manually. .

Keywords: Hyper spectral, spectral analysis, red soils, Reflectance, Spectroradiometer

INTRODUCTION

Soil moisture is a critical process in the water cycle and its assessment is of paramount importance in forecasting changes in the water balance of a region (Salvucci et al., 2002). In agricultural production, the spatial variability of soil moisture can be responsible for low or spatially variable crop yields, as soil moisture is required to make nutrients soluble for plant absorption. Soil moisture fluctuates both spatially and temporally due to factors such as soil type, soil horizon, and other site-specific geologic and climatic conditions. Traditional efforts to measure soil moisture have been principally restricted to *in situ* measurements traditionally; soil moisture mapping has been accomplished through exhaustive point measurement, which can be cost prohibitive. Gravimetric measurements, while very reliable, are also very time and resource consuming. Several methods for measuring soil moisture with imbedded sensors, such as time and frequency domain reflectometers, have been developed. These sensors do not require quite as large an investment of time and facilities, and generate data that can be automatically logged. However, all of these methods suffer from some of the same disadvantages. *In situ* measurement can often be tedious, and it generally results in poor spatial resolution of soil moisture data. Depending on the topography of an area and the soil characteristics, soil moisture can be quite variable over the land surface. Thus, a method for determination of soil moisture without the necessity for exhaustive manual measurements would be beneficial in characterizing soil moisture within a given region or field. Remote sensing offers the potential for high−resolution, aggregated soil moisture mapping.

Remote sensing measurements of the soil record the amount of radiation in a given wavelength reflected off of or emitted from the surface to the sensor. There are many factors that affect the resulting spectrum from the soil. The color of the soil influences its measured reflectance in the visible wavelengths. Soil texture also affects reflectance, as incoming radiation is scattered differently by coarse particles as compared to fine particles (Thomasson et al., 2001). In general, larger aggregate soil particles will have lower measured reflectance. For the same reason and because of shadowing effects, surface roughness, including the clods and machinery tracks that are especially prevalent in agricultural fields, also affects the measured reflectance from the soil surface (Matthias et al., 2000; King and Pradhan, 2001). Furthermore, surface crusting of soil tends to increase reflectance (Cipra et al., 1980; Baumgardner et al., 1985; Ben Dor et al., 2003). Because of the effects on soil color and texture, the mineral composition of the soil, including the soil organic matter content, also plays a role in the measured Soil moisture also affects the reflectance of the soil, although the manner in which it does so varies across the electromagnetic spectrum. Factors affecting soil reflectance are moisture content, soil texture (proportion of sand, silt and clay), surface roughness, presence of iron oxide and organic matter content. The presence of moisture in soil will decrease its reflectance -this effect is greatest in the water absorption bands at about 1.4, 1.9, 2.2 and 2.7 µm. Soil moisture content is strongly related to the soil texture. The reflectance of the soil in the field is taken using the spectroradiometer which ranges between 400nm to 1050nm.

LITERATURE REVIEW

Sophie Fabre *et.al* (2015) their study was to comparing between new methods to estimate the soil moisture content of bare soil from their spectral signatures in the reflective domain (0.4 - 2.5µm) with widely used spectral indices like Normalized soil moisture index (NSMI) and water index soil (WISOIL).Michael L. Whiting (2009) his study was on measuring surface water in soil and plant with light reflectance using hyper spectral full range imagery and field spectrometers. He realized that The relationship of the albedo lost to band depth, for the same mineral media, is nonlinear. By including water and mineral absorptions in the same fitting, the accuracy of the mineral abundance estimates are shown substantially improved. He created the soil sample with considerable thickness and used optic method of determining the water content measurement and Gravimetric (moisture holds from 4% to 8%) determination of water content in soil is the most common method. he mentioned The differences in soil color and tone due to variation in water, secondary clay mineral and organic matter content in aerial photography has been an early use in soil survey and other inventories. A.L.Kaleita *et.al* (2005) their study was relationship between soil moisture content and soil surface reflectance. They minimize both the effect of time of day on the spectral data and the effect of drying time on the moisture data, every effort was made to perform the data collection within a consistent and minimal time frame. Data collections were limited to approximately a 2hr window.

David B. Lobell and Gregory P. Asner (2001) studied on moisture effects on soil reflectance and vegetation properties from remote sensing with shortwave radiation (400-2500 nm) were acquired in laboratory setting for four different soils at various moisture content. They used an equation in order to find the volumetric water content for each spectral measurement i,e;

$$S = \frac{\theta}{1 - \rho_b / \rho_p}$$

θ = Volumetric moisture content, m = measured mass of soil sample

$m\theta$ = Initial mass of the soil, ρ_w = Density of water, ρ_b = Bulk density,

The degree of saturation also considered in subsequent analysis and was calculated as the ratio of water volume/total soil pore volume:

$$S = \frac{\theta}{1 - \rho_b / \rho_p}$$

ρ_p = Particle density

Finally they concluded reflectance decreased with increasing moisture for all soils, as demonstrated by the measured spectra, exhibiting a clearly non linear response that was well described by the exponential model.

E. L. Skidmore *et.al* (1975) their study was on evaluating surface soil water content by measuring reflectance. Source of infrared radiation, optic system, integrating sphere, detector etc. They examined radiation from an incandescent lamp was filtered with narrow band pass filter, chopped and allowed to strike the test surface, where it was either absorbed or reflected onto the surface of the integrating sphere. Distilled water was added to filter paper until it was nearly saturated. Then, reflectance of the wet filter paper was measured at 1.95 µm. After a slight amount of water had evaporated, reflectance was measured again. This process was repeated until most of the water had evaporated from the filter paper. They used filter paper for water content at 1.30, 1.45, 1.65, and 1.95µm.

Finally they concluded that at lower water content soil properties strongly influenced soil reflectance at 1.95µm and drawn graph was linear trend. They measured the reflectance by reflectometer.

Recent research has suggested that reflectance in certain spectral bands have been correlated with soil properties and could provide inexpensive predictions of soil physical, chemical and biological properties (Ben Dor and Banin 1995; Reeves et al. 2000; Dunn et al. 2002; Daniel et al. 2004; Roy et al. 2006; Stamatiadis et al. 2005; Francis and Schepers 1997; Pocknee et al. 1996; Ehsani et al. 1999). As SOC increases, the soil appears darker, and vice versa (Fig. 1). This general observation formed the basis of the concept that electro-optical sensing of SOC might be feasible (Alexander 1969; Steinhardt and Franzmeier 1979; Hummel et al. 2001). Several researchers have tried to identify SOC using soil reflectance in the laboratory, and the result of their research has led to the development of high resolution spectral sensors. These sensors produce remotely sensed data that can provide ancillary information about the soil.

METHODS AND MATERIALS

Spectroradiometer an instrument for measurement of radiometric quantities in narrow wavelength intervals over a given spectral region. Spectra Vista Corporation proudly offers the SVC HR-512i. Here 512 indicate number of bands that are used in this instrument. This instrument combines the latest technology required to produce exceptional spectral data while capturing digital photographic, GPS and external sensor data. Hyper spectral hundreds to thousands number of spectral band and spectral resolution narrow, few nm, its capability detects and identifies solids and liquids. Measurements are easily acquired by one person by first setting up instrument parameters through the touch screen display and then initiating a measurement. Spectral resolution and low noise ensure that the collected data is of the highest quality and vice versa. Hyper spectral images provide each and every aspects can be analyze easily, spectral information to identify and distinguish between spectrally similar materials.

Hyper spectral imagery provides the potential for more accurate and detailed information extraction than is possible with other types of remotely sensed data. The domain of interest of such data covers a very large area of applications like target detection, pattern classification, material mapping and identification, defense and intelligence, forestry, water quality, Geology, Industrial, Environmental monitoring and Assessment, Agriculture. Spectroradiometer is basically emitting the light which has the properties such as electromagnetic radiation, light exists as photons displaying both wave and particle properties, discrete quanta of energy, energy inversely proportional to wavelength, measurements in 200nm-50µm range of EM spectrum. EMR interacts with objects in micro (voids, constituent particles) and macro levels (overall surface configuration and environmental context is most important). Red color for soil because of diffusion of iron in the form of iron oxide in the crystalline and metamorphic rocks and some time look like yellow when it is in the hydrated form. Red soils are found in Chhotangpur plateau Telangana, Nilgiris, Tamil Nadu, Karnataka, Andhra Pradesh and periphery areas of Deccan Plateau. These soils have been formed due to decomposition of underlying igneous rocks under heavy rainfall. Red soils are mostly cultivation of millets, Pulses, Tobacco etc. More sandy and less clayey poor in phosphorus, nitrogen, lime and rich in Iron, small amount of humus.

Sample Preparation

The experiment was conducted for red soil in disturbed condition and experiment carry out at different stages of moisture content dry to fully saturation by supplying artificial water. Numerous observations were obtained in order to get perfect spectral reflectance for that particular soil. The soil moisture is measured at different stages using the soil moisture meter which gives the moisture content in terms of percentage (%). At a known soil moisture content the reflectance of the soil is taken and the graph is ploted.

Spectra Acquisition:

Spectroradiometer ranges from 350-1050nm and spectral resolution a hyper spectral remote sensing system have four basic parts the radiation (or illuminating) source, the atmospheric path, the imaged surface, and the sensor. The HR-512i features include, integral graphic display, internal camera, low noise indium gallium arsenide (InGaAs) photodiode arrays for the SWIR spectrum, higher resolution throughout, internal GPS with automatic time and location data saved with each data file's meta data. Three interchange foreoptic lenses are included with the system together with a foreoptic light guide giving a wide range of fields of view to suite each application. Alternatively the HR-512i can be mounted on a monopod or hand held for either stand-alone. The spectroradiometer is also calibrated with each foreoptic lens for spectral radiance and with the integrating sphere for spectral irradiance. A selection of tripods and a monopod are available from the facility. Battery chargers and car adaptors are also provided. Scanning Time automatic with programmable options or manual control. Typical multi-scan acquisition time <5 seconds. The reflectance of the soil at different soil moisture contents like 0.1%, 0.4%, 2.3%, 4.1%, 5.2%, 6.4%, 7.3%, 8.9% and 11.20%. are taken and compared and the graphs are drawn over the wavelength and the difference in the reflectance is observed at different soil moisture contents as shown in fig 1.The soil moisture of the red soil at different moisture contents are here with exposed in fig.2.

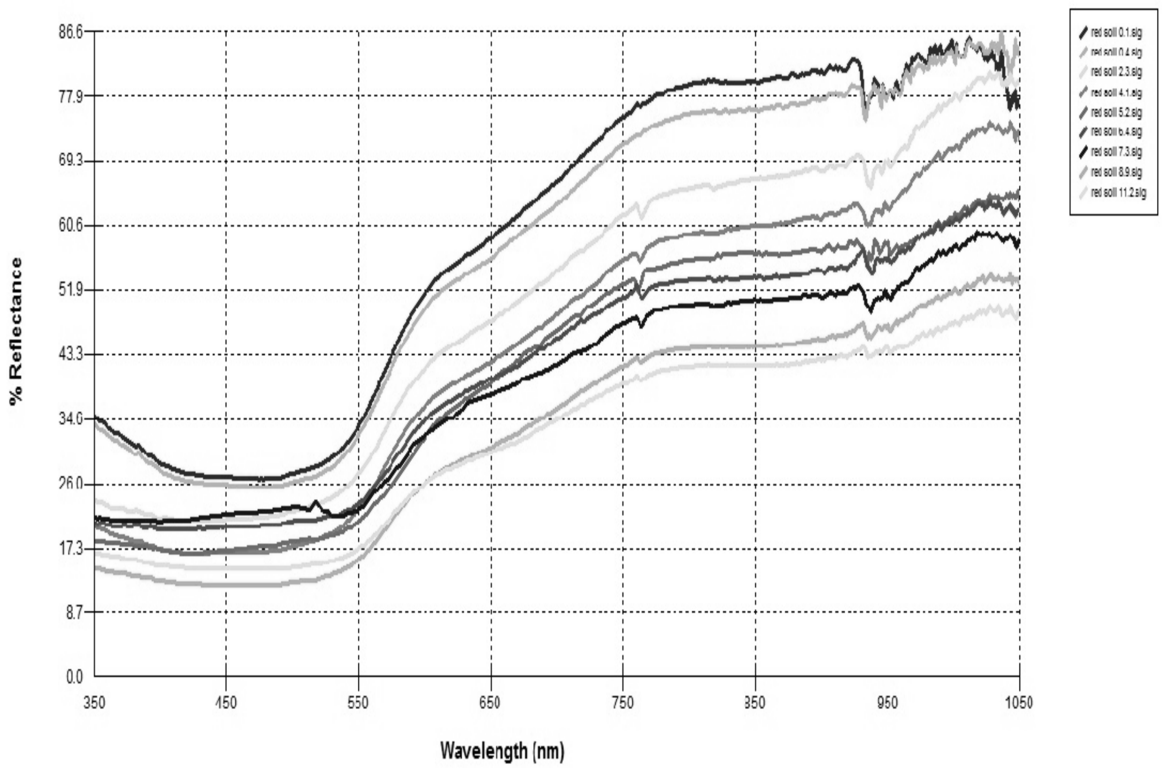

Fig. 1 Graph indicating the reflectance at different soil moisture contents of red soil

		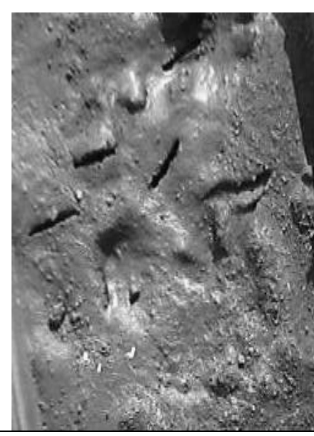	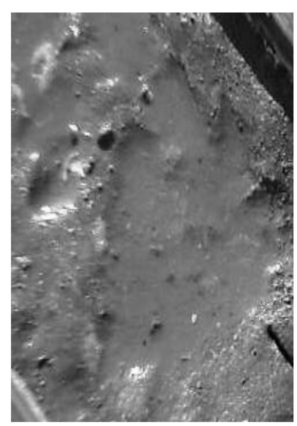
Moisture content 0.1%	Moisture content 4.1%	Moisture content 7.3%	Moisturecontent 11.20%

Fig. 2 Red soil at different soil moisture contents.

RESULTS AND DISCUSSIONS

The reflectance characteristics of Earth's surface features may be quantified by measuring the portion of incident energy that is reflected. This is measured as a function of wavelength (λ) and is called spectral reflectance (rλ). The factors that influence soil reflectance act over less specified spectral bands factors affecting soil reflectance are moisture content, soil texture (proportion of sand, silt and clay), surface roughness, presence of iron oxide and organic matter content. The sensitivity of the spectroradiometer can be affected by several factors, but particularly by photomultiplier sensitivity changes. Frequent calibration is required. Reflectance from a water body can stem from an interaction with the water's surface (specular reflection), with material suspended in the water and with the bottom of the water body. Spectral reflectance drastically varies in water, vegetation, soil. We used spectroradiometer with wavelength of range is 350-1050nm. In case of red soil the portion of spectral reflectance are changes (dips) at 760nm and 950nm. In this study, soil surface reflectance data in the visible and near−infrared regions were analyzed by spectroradiometer and it is observed that the reflectance is more when the soil is dry and the less reflectance is observed when the soil is highly moisture.

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Identification of Potential Zones/Sites for Artificial Groundwater using Remote Sensing, GIS and Multi Influence Factor Techniques

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ABSTRACT

Integrated watershed management requires a host of inter-related informations to be generated and studied in relation to each other. Remote sensing (RS) technology meets both the requirements of reliability and speed and acts as an ideal tool for generating spatial informations. The GIS provides suitable alternatives for efficient management of large and complex databases. In the present study, an attempt has been made to develop groundwater prospect map for Gundal watershed, Gundalpet taluq, Chamarajanagar district. Morphometric analysis has carried out to understand the hydrologic characteristics of the Gundal watershed. By using Multi Influence Factor (MIF) technique, weighted overlay and decision tree concepts groundwater prospect map generation has been identified in alliance with soil, slope, drainage density, rainfall, land use/ land cover, geology and geomorphology data. Further, by using Groundwater prospect map and the Boolean algebra AND and OR operations potential zones for groundwater recharge zones have been identified. The study has demonstrated the use of RS, GIS and MIF techniques for groundwater recharge zones identification.

Keywords: Gundal watershed, Watershed management, RS, GIS, MIF technique, Water resource development plan.

INTRODUCTION

Watershed management implies prudent use of all the natural resources to ensure optimum and sustained productivity. Particularly, concern about widespread soil degradation and scarce, poorly managed water resources in Gundal watershed, Gundulpet taluk, Chamarajnagar district, Karnataka state i.e., study area has led to the implementation of Watershed management activities. Artificial recharge structures such as check dam, nala bunds, form ponds, etc., are extremely important to conserve precious natural resource like, soil and water. Remote sensing technology meets both the requirements of reliability and speed and is an ideal tool for generating spatial information needs. The Geographical Information Systems (GIS) technology provides suitable alternatives for efficient management of large and complex databases. Satellite remote sensing technology is used not only for targeting of groundwater potential zones, but also for identifying location specific activities such as percolation tanks, check dams, farm ponds etc. In this context, chalking out an Identification of artificial groundwater recharge zones that involves targeting groundwater potential zones and identifying suitable sites for artificial recharge assumes importance and holds the promise of making watershed management simpler and more effective. Formulation of proper groundwater prospect map requires reliable and up-to-date information about various factors such as morphologic (Size and shape of the watershed, drainage parameters, topography), soil and their characteristics, land use/land cover, etc. that affect the behavior of a watershed. Further, it is necessary to translate the watershed ecosystem dynamics into predictive statements for the analysis of different spatial information. Chowdary et al., 2010; Arkoprovo et al., 2013 have studied and applied MIF techniques to identify the potential zones; Mohan kumar 2015 has demonstrated the use of remote sensing, GIS and MIF techniques for identification of potential zones for artificial groundwater recharge; Manikandan et al., 2014 used MIF techniques and divided the artificial recharge zones into very good, good, good, moderate, poor and very poor based on the informations drawn from RS and GIS techniques; Jankowski, 1995 demonstrated the use of Boolean AND and OR operations for identification of potential zones.

Study Area

The Gundal watershed is located in the South West of Karnataka state. The location map of the study area is shown in Fig 1. The Gundal watershed lies completely in Gundulpet taluk of Chamrajnagar district and partly in Nanjangud taluk of Mysore district and occupies an area of 1203.85 sq. km. The watershed stretches from 76° 30' to 76° 51'47" E Longitude and 11° 40' 13" - 12° 7' 13" N latitude. The Gundal River is the main tributary of river

Kabini, which originates in Himavadi Gopalaswamy Betta, Gundulpet taluk and flows from south to north direction over a distance of 59 km and its confluence with river Kabini near Nanjangud town. There are nearly 45 tanks within the watershed and they are seasonal. The major source of water for irrigation in this watershed is groundwater.

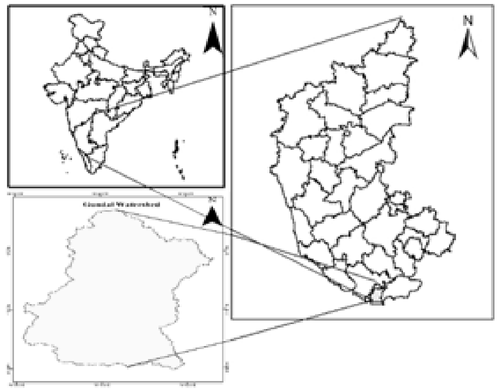

Fig. 1 Location map of Gundal watershed

Data Used

1. Survey of India (SOI) Topomaps: SOI Topomaps numbers 58A/9, 58A/10, 58A/13, 58A/14, 57D/12, 57D/16 of 1:50,000 scale.
2. Remote sensing data: Cloud free digital data of IRS–R2 and IRS-P6 LISS-III data passing along the path 98 and row 66 on 02/11/2009 and 22/05/2011.
3. Rainfall data: Daily rainfall data for 5 years from January 2010 to December 2014 collected from KSNDMC, Bengaluru.
4. Soil data: Soil map prepared by the KSRAC (2012), Bengaluru.
5. Geological data: Geological map prepared by the Geological Survey of India (December 1992).
6. Land use/land cover data: Land use/ land cover map prepared by KSRAC 2012, Bengaluru.
7. Well inventory data: Central Ground Water Board (CGWB), South Western Region, Bengaluru.

METHODOLOGY

The Survey of India (SOI) toposheets on 1:50000 scale for the study area have been procured, scanned and geometrically rectified so that each point represents correct geographical coordinates. Satellite images of IRS-R2 and IRS-P6 LISS-III have been georeferenced with respect to toposheet and mosaiced. The drainage network and the watershed have been identified from the mosaiced toposheet and updated from satellite imagery. The watershed is divided into 6 sub watersheds and morphometric analysis is done. Generation of different thematic layers or digital database creation using ArcGIS 10.1 software and conventional methods. Groundwater prospect map is prepared using Multi influence factor (MIF) technique. Area specific and location specific activities map is generated using a set of logical conditions under GIS environment.

SPATIAL DATABASE ANALYSIS

The Groundwater prospect map has been prepared using Multi Influence Factor (MIF) technique and artificial recharge structures has been identified by using area specific and location specific activities.

Multi influencing factors of groundwater potential zones

Seven influencing factors, such as geology, slope, land-use/land-cover, geomorphology, drainage, soil, and rainfall have been identified to delineate groundwater potential zones. Interrelationship between these factors and their effects are shown in Fig. 2.

Weightage Calculation

The effect of each influencing factor may contribute to delineate the groundwater potential zones. Moreover, these factors are interdependent. The effect of each major and minor factor is assigned a weightage of 1.0 and 0.5

respectively (Fig. 2). The cumulative weightage of both major and minor effects are considered for calculating the relative rates (Table 1). This rate is further used to calculate the score of each influencing factor. The proposed score for each influencing factor is calculated by using the formula.

$$\frac{A+B}{\Sigma(A+B)} \times 100 \quad \text{.....(1)}$$

where,

A is Major effect.

B is Minor effect.

Delineating Groundwater Potential

The identification of groundwater potential zones for the study area was made by grouping of the interpreted layers through weighted multi influencing factor and finally assigned different potential zones. The groundwater potential zone of this study area can be divided into five grades, namely very good, good, moderate, poor, and very poor. The ground water potential zone for the study area is shown in Fig. 3. Spatial distribution ground water potential zone for Gundal watershed is shown in Table 3.

By integrating land use/land cover map, slope map and groundwater prospect map by using Intersection tool in ArcGIS 10.1, with Boolean AND and OR operations and by using set of criteria's mentioned by Integrated Mission for Sustainable Development (IMSD-1995) suitable sites for various area specific activities are identified. Then by integrating land use/land cover map, slope map, stream order map and soil map by using intersection tool in ArcGIS 10.1, using Boolean AND and OR operations and by using set of criteria's mentioned by IMSD suitable site for various locale specific activities are identified.

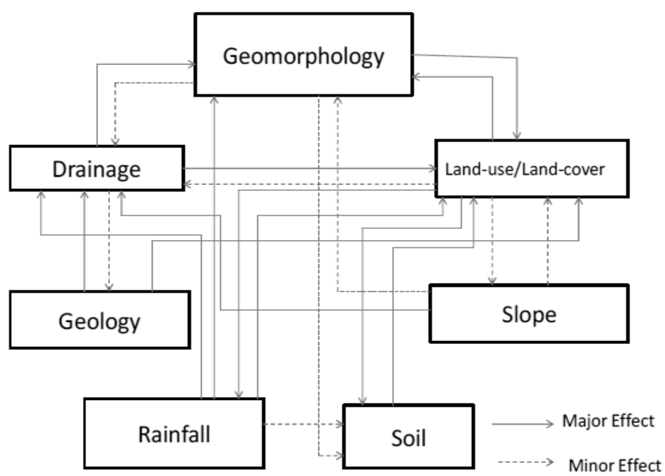

Fig. 2 Interrelationship between multi influencing factors

Table 1 Effect of influencing factor, relative rates and score for each potential factor

Factor	Major effect (A)	Minor effect (B)	Proposed relative rates (A+B)	Proposed score for each factor
Slope	1	0.5+0.5	2	12
Drainage density	1+1	0.5	2.5	15
Rainfall	1+1+1	0.5	3.5	20
LuLc	1+1+1	0.5+0.5	4	23
Soil	1	0	1	6
Geology	1+1	0	2	12
Geomorphology	1	0.5+0.5	2	12
Total			**17**	**100**

Table 2 Classification of weighted factors influencing the potential zones

Factor	Domain effect	Weightage	Ground water prospect
Slope (%)	0 - 1	12	Very good
	1 - 3	11	Very good
	3 - 5	9	Good
	5 - 10	7	Good
	10 - 15	5	Moderate
	15 - 51	2`	poor
Drainage density (km/sq.km)	0.12 – 1	15	Very good
	1.0 – 1.5	13	Good
	1.5 – 2.0	10	Good
	2.0 – 2.5	6	Moderate
	2.5 – 3.7	5	Poor
Rainfall (mm)	484 – 550	8	Poor
	550 – 600	11	Moderate
	600 – 650	14	Good
	650 – 700	17	Very good
	700 – 786	20	Very good
LULC	Forest & plantations	17	Moderate
	Crop land	21	Good
	Hills & settlements	10	Poor
	Water bodies	23	Very good
Soil	Clayey	1	Very poor
	Clayey mixed	3	Poor
	Clayey skeletal	4	Moderate
	Loamy	5	Good
	Loamy skeletal	6	Very Good
Geology	Amphibolites	12	Good
	Granodiorite gnesiss	9	Moderate
	Meta ultramatics	4	Poor
	Metapelite schist	7	Moderate

Table 3 Spatial distribution groundwater potential zone for Gundal watershed

Sl. No.	Groundwater prospect	Area (sq.km)	Area (%)
1	Very good	65.39	6
2	Good	968.10	80
3	Moderate	56.88	5
4	Poor	80.03	7
5	Very poor	24.04	2
		1204	100

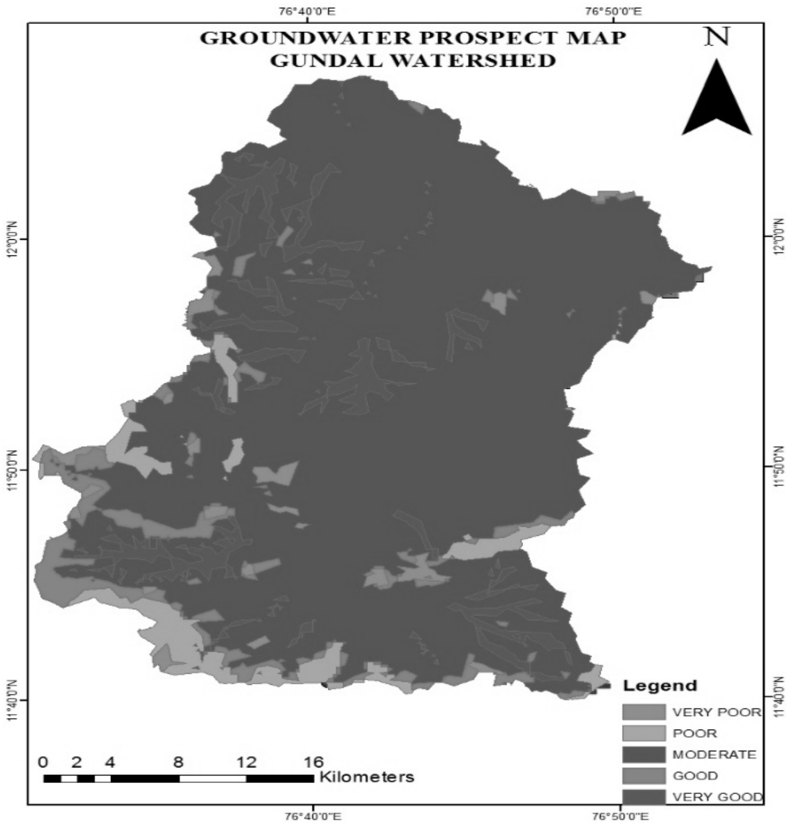

Fig. 3 Groundwater prospect map

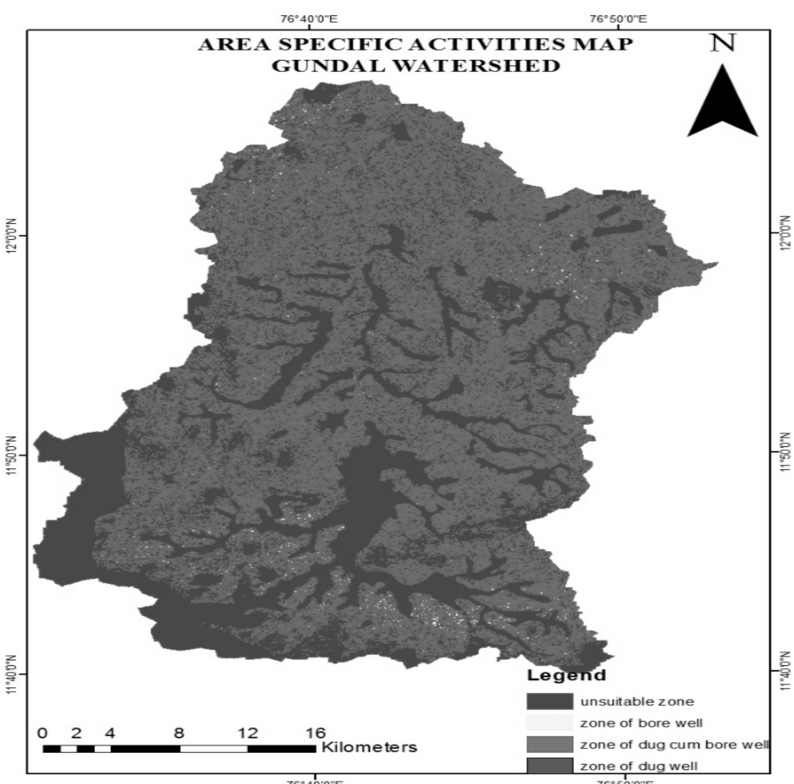

Fig. 4 Area specific activities

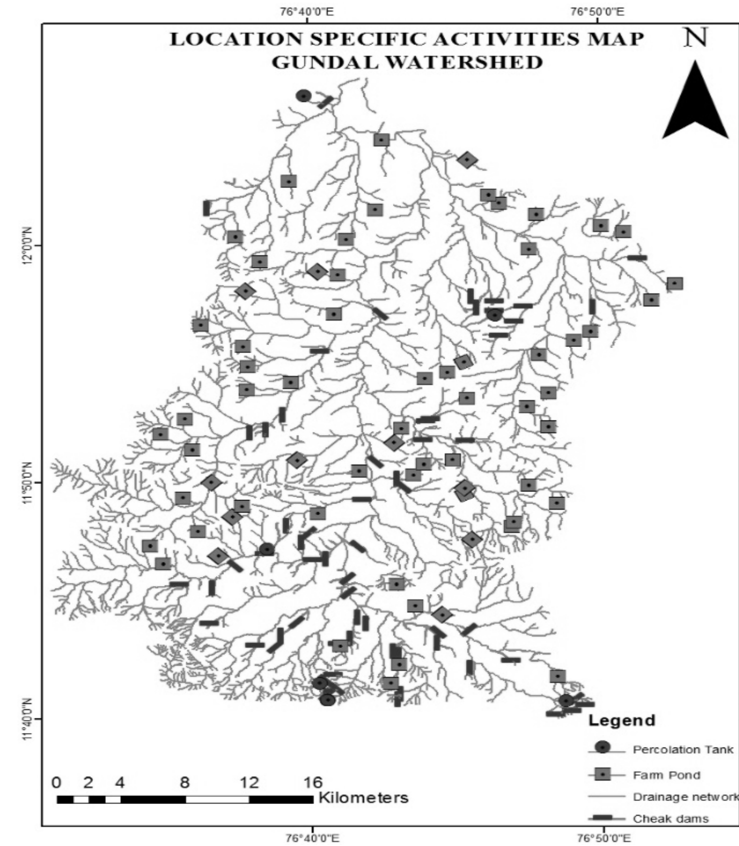

Fig. 5 Location specific activities

RESULTS AND DISCUSSION

To understand the accuracy of prospective groundwater zones, an attempt is made to verify the results of the study area , for this purpose well inventory data or bore wells locations data by CGWB (2012), Bengaluru has been used. There are 26 existing well data taken in the study area for their suitability in terms of GIS environment. . Zone 1, Zone 2 and Zone 3 corresponds to Zone of Bore wells, Zone of Dug-cum Bore wells and Zone of Dug well respectively. Zone 4 refers to unsuitable zone for groundwater exploitation. Out of 26 wells, 2 are found in the Zone 4 i.e. unsuitable for groundwater exploitation, 10 dug cum bore wells are found in Zone 2, 12 bore wells in Zone 1, 2 dug wells in Zone 3.The percentage of accuracy is 92.30%. Area of 968.10 sq.km (80% of the study area) has moderate level of groundwater potential zone. 54 suitable sites for check dams, 57 suitable sites for form ponds, 5 suitable sites for percolation tanks were found in the watershed. These may serve the purpose of soil and water conservations and groundwater augmentation.

CONCLUSION

For generation of integrated water resource development plan, thematic layers such as geomorphology, land use /land cover and lithological features were generated from the remote sensing data and integrated with drainage, soil and slope maps under GIS environment. Further, GIS modeling was done to demarcate the zones of suitable groundwater exploitation structures and artificial recharge structures by using various criteria's and Boolean logical operators like AND and OR. The interpretation of remote sensing data in conjunction with ancillary data and sufficient ground truth information makes it possible to identify and outline various ground features such as geological structures and geomorphic features that serve as direct or indirect indications of groundwater occurrence. Thus, integrated remote sensing and GIS can provide the appropriate platform for convergent analysis of large volume of multi-disciplinary data and decision making for development of integrated water resource development plan. Remote sensing data can especially play significant role in generation of parameters from remote areas of watershed and enable us to arrive at natural resource management solutions by adopting a holistic approach. The methodology developed may be applied to similar terrain conditions, with some local considerations and modifications.

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Groundwater Recharge Assessment using Remote Sensing

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ABSTRACT

Advances in remote sensing create the opportunity for assessment of groundwater recharge (GWR). The spatially varied water resources study was conducted for the year 2008 at Shankergarh block (Allahabad, India). Effective utilization of water resources is an imperative task due to climate change. Yearly assessment of groundwater (GW) recharge was done at regional scale to generate the information about water quality and their management. Remote sensing data sets (satellite derived rainfall and actual evapotranspiration) and Soil Conservation Services–curve number model (SCS-CN) was used to assess annual GWR. The estimated annual GW recharge was 39 cm, which was nearly equal to observed value of GW recharge (36 cm) with 7.7% deviation. The precipitation is distributed evenly through the monsoon season and the generated runoff was very high (Annual runoff = 880 mm) as compare to the ground water recharge (Annual GWR=393.7 mm). The recharge was most prominent during the months of May, June, July, August, September and October. The study gives water accounting of the study area. A major portion of the precipitation was loss as runoff but satisfactory amount of rainfall going as GWR and this can be attributed to the fact that the study region is predominant with agricultural activities.

Keywords: Ground water; MODIS, MOD16, NOAA, Rainfall, GIS, Water Balance.

INTRODUCTION

Water is important natural resources for improvement of health and economy of growing world population. The United Nations Commission on Sustainable Development regards water as one of the main issues facing the world (UNWWD, 2003). Water resources in arid and semi-arid regions are facing many challenges (Leblanc et al. 2007) because river flows are unreliable and large fresh lakes are ephemeral or no longer exist. Groundwater (GW) is the only water source available for round the year. Reliable water supplies, particularly those from GW are the lead input for increasing agricultural yields, reducing agricultural risk and stabilizing farm incomes. Over the past few decades GW exploitation have been increased dramatically with the introduction of advanced drilling technology and mechanized pumps. In practice, declining water levels testify to probable over development and inadequate scientific understanding of the resources (Edmunds et al. 2002). The effects of this include; degradation of GW quality, either as salinity increase or an increase in other undesirable constituents in the water, land surface changes in the form of general or local subsidence, disruption of the natural hydrological cycle due to reduced infiltration and GW recharge (Anuraga et al. 2006; Chowdary et al. 2003; Mishra and Rawat 2010). Hence this ushers in the question of sustainability.

Recharge is vital for the replenishing GW. Scanlon et al. (2002) defined recharge as water which can move vertically downwards from the base of the soil zone. Not only does the rate of GW recharge affect the sustainable volume of water that can be pumped from the aquifer, it also places a limit on the movement of contaminants oozing from landfills and radioactive waste disposal sites (Chomba 2004).Estimating GW recharge is a key component in determining the sustainable yield of GW resources in arid and semi-arid regions (Bekesi and McConchie 1999; Kendy et al. 2004; Mishra and Rawat 2010). GW resources management requires estimating GW recharge on large spatial and temporal scales; site specific studies and short time frames for assessing GW contamination (Rueedi et al. 2005; Vrba and Civita, 1995). Good GW resources management practices require developing a water budget approach on a regional or large scale for an entire aquifer or geographic region (Cherkauer 2004). There are many methods available for estimating saturated GW recharge. However, the amount of information that is needed depends on the complexity of the method (Kumar and Seethapathi 2002; Lin et al. 2008).

In arid and semi-arid regions, GW basins are not a resource in itself but long term storage reservoirs (Jeyaram et al. 1992). These can be viewed as nested system of recharge and discharge areas, with discharge appearing in the form of springs, streams or evapotranspiration (Boonstra and Bhutta 1996). In India, GW recharge is highly variable in space and time and its estimation is quite difficult. First, the recharge estimate depends on the water balance in which actual evapotranspiration is almost equal to effective precipitation (Kumar et al. 2013; Kustas et al. 1994). Another factor which complicates recharge evaluation through desert vadose zones is the large spatial and temporal variability of water fluxes (Dripps and Bradbury 2007; Limbrick2002; Boughton 2005). This is due to low rainfall, high temperatures, low humidity and high rates of potential evaporation which results in a wide range of minimum and maximum amounts of recharge (Finch 1998; Ghulam and Muhammad 1996; Hadanai et al. 1993).

It is important and practical to have knowledge of recharge in any GW management scheme so that the rate of abstraction could be compromised to maintain the desirable GW levels (Lin et al. 2008). The prevailing situation in the area under review is a Laissez-Faire kind of approach where each individual farmer or land owner abstracts the GW resource from their own sources at well, this might, if not controlled, pose danger to the GW storage in the aquifer (Chomba, 2004). However, it is difficult to determine the properties of large aquifers, such as transmissivities, storage coefficients and similar parameters, in sufficient resolution. Modelling large aquifers is difficult and strenuous task (Jaber et al. 2006). For the evaluation of water balance of an underground reservoir many types of remote sensing data are available nowadays that can be employed (Anuraga et al. 2006; Kendy et al. 2004; Wencai and Deliao 1993; Waters et al. 1990; Tateishi and Aim 1996). The water balance of an underground storage reservoir is determined by precipitation, surface runoff and evapotranspiration and of course anthropogenic abstractions (Xu and Chen 2005; Brunner et al. 2007). Directly or indirectly information on all these hydrological components are available in form of remote sensing products in relatively high spatial resolution (Bradford et al. 2002).

The most important aspect of remote sensing systems is that they provide spatially complete and temporal information about the state of the earth's surface which helps hydrogeologists improve their understanding of the hydrogeological system, especially in remote and unexplored areas (Jackson 2002). However, considering that the RS data have limitations with regard to depth penetration, the key for success in GW investigations lies in understanding/establishing the linkage between surface manifestations (observed on remote sensing data) and the subsurface phenomena (Becker 2006). This makes the hydrogeological interpretation/analysis as one of the most difficult tasks of all the hydrological applications of remote sensing (Meijerink et al. 2007; Chiew and McMahon 1990). Protection, enhancement and restoration of GW, ensure a balance between abstraction and recharge of GW (Chatterjee and Purohit 2009; Hoffmann and Sander 2007). GW commission is focusing on quantifying the GW occurrence and abstraction to achieve good GW status. To meet this directive it is prime that the recharge flux be known and quantified in order to formulate the proper GW management system in any environment. With the view to estimate the GW recharge of Shankergarh block, Allahabad (India), this research work was formulated with specific objectives. (i) To estimate evapotranspiration with space and time; (ii) to estimate the regional precipitation over the twelve months of 2008 using satellite NOVAA datasets; (iii) to estimate the regional runoff over the twelve months of 2008 by using Soil Conservation Services (SCS-CN) Model; (iv) use GIS to apply water balance modeling for the estimation of GW recharge over the study area.

MATERIALS AND METHODS

Study area

The study area Shankergarh block is situated in Allahabad district of Uttar Pradesh State, India; and is bounded by latitudes 25°02'40.4" N to 25° 21'41.0"N and longititudes 81°42'33.20"E to 82°00'12.55"E (Fig.1) falling in Survey of India (SOI) topographical maps 63G/11 and 63G/12, respectively. Geologically the area comprises of Upper Vindhayan formations consisting of mainly sandstone and shale. The area shows a nearly flat to a gently undulated topography with small hillocks with rolling topography. The minimum and maximum elevations of this area are 90 m (msl) and 180 (msl) respectively. It is drained by various order of drainage.

Soils of the study area

Basically the Vindhyan soils are formed by disintegration and weathering. Different types of soils in the area are loamy, sandy and alluvial. The physical content of the soil are influenced by the climatic conditions, vegetation cover and other factors. Alluvial soils are formed due to erosion mainly by water and landslips. In process, weathered material is transported and deposited at places other than the origin. In such cases the underlying rock has a little role to play in influencing the vegetation on the alluvial soils. Such soils are found deposited in the basins of river and along the banks of river.

These uplands are covered with loam, except in the south-western part of tehsil Karchhana, where the soil is a mixture of clay and marsh. The southern uplands of Vidhyan series, which are bounded by the Rewa scarps in the south, and 100meter contour in the north, can be sub-divided into three sections viz; (i) the Vidyachal-denuded lower upland, sloping to the north and the south, (ii) the central plateau and; (iii) the Panna range or the Rewa high lands. The Panna range or the Rewa high lands of the south, comprising the highest point of the Trans-Yamuna region of the Allahabad district, U.P., (India) is a highly dissected region. Steep slopes, having free-face, rectilinear and basal concave elements of slopes, and dissected valleys, are the main terrain characteristics the regions.

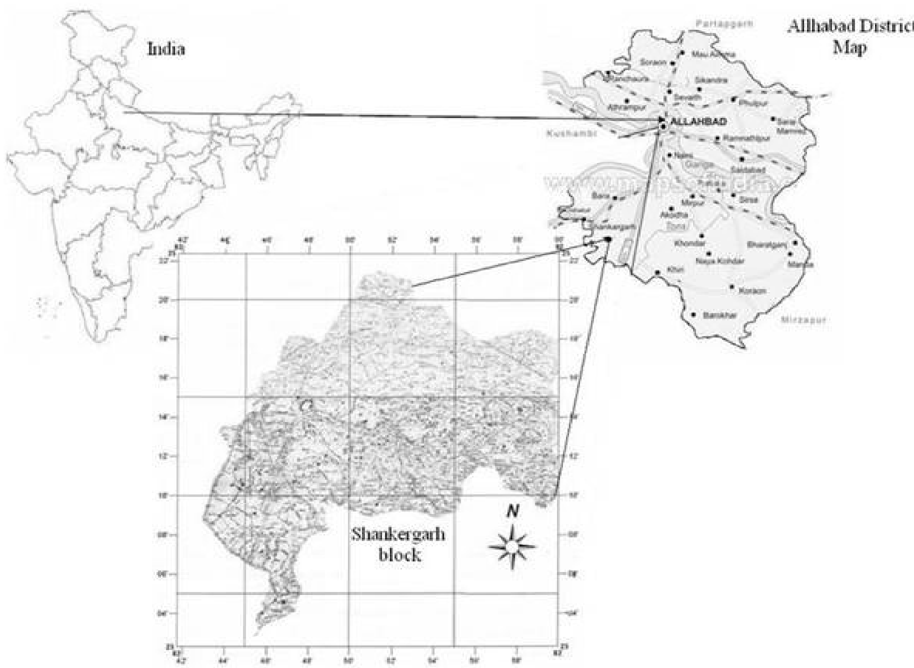

Fig. 1 Location map of Shankergarh block, Allahabad (India)

Climate of study area

The study area is receiving about 91 per cent of the annual rainfall during June to September month under southwest monsoon. The variation in the annual rainfall from year to year is appreciable. The relative humidity is high during the Southwest monsoon and rest of the year air is dry (Table 2.1).There is continuous increase in temperature from March to May. The weather is appreciably hot in summer and in individual days during May and the early part of June. The hottest month with the mean daily maximum temperature of 41°C and the mean minimum temperature of 27°C was observed in May (Table 1).With the onset of the monsoon in the region by about the middle of June, there is an appreciable drop in the day temperature. After the withdrawal of the monsoon nights become progressively cooler. February is generally the coldest month with a mean daily maximum temperature of about 24 °C (Table 1).In the most of the season the climate is pleasant, the sky looks clean and blue, the winters are rainless.

Table 1 Maximum and minimum temperature and average rainfall (based on ten years average (1994-2006))

Month/ Year	Maximum average temp.(°C)	Minimum average temp.(°C)	Average rainfall (mm)
January	22.03	7.75	15.8
February	26.54	11.17	19.0
March	33.09	15.79	3.8

April	38.88	22.9	5.4
Month/ Year	**Maximum average temp.(°C)**	**Minimum average temp.(°C)**	**Average rainfall (mm)**
May	41.41	26.72	9.4
June	39.40	27.84	103.8
July	34.55	26.27	281.0
August	33.18	25.78	266.0
September	32.66	24.49	216.3
October	33.23	20.37	39.1
November	30.02	14.05	10.1
December	24.78	8.61	11.0

Contd…

Source: Air Force Station, Bamrauli, Allahabad

Water balance approach

The different components of the water balance equation were assessed on monthly basis (Ghulam and Muhammad 1996; Waters et al. 1990; Sehgal 1973) to synthesize the GW recharge for the year 2008 (Cherkauer 2004; Xu and Chen 2005).The following water balance equation for small drainage basin underlain by impervious rock was adopted in the present study.

$$P = I + ET_a + OF + \Delta SM + GWR + GW \tag{1}$$

$$GWR = P - (ET_a + OF + 20\% \text{ of rainfall}) \tag{2}$$

Where, P = Precipitation; I = Interception; ET_a = Actual evapotranspiration; OF = Overland flow; ΔSM = Change in soil moisture; GWR = Change in GW storage or GW recharge; GW = Ground water runoff or base flow. Amount for interception and change in soil moisture was assumed as 20% of the rainfall amount.

Precipitation

The term precipitation denotes all forms of water derived from atmospheric vapour and deposited on the earth's surface. Rainfall is the most prominent form of precipitation in the study area. The daily rainfall values for the study region during the year 2008 were acquired as satellite data product from NOAA data centreftp://ftpprd.ncep.noaa.gov/pub/cpc/fews/S.Asia/.The remote sensing rainfall data product RFE2.0 from Climate Prediction Centre (CPC), NOAA was used on daily basis. The daily rainfall images are provided for the Southern Asia (70°-110°E, 5°-35°N) beginning from May 01, 2001. The product is updated three times daily at around 9 am, 1 pm, and 9 pm Eastern Local Time and covers a 24-hour period of accumulated precipitation. Resolution of rainfall estimates is 0.1 by 0.1 degree. The daily rainfall data product was obtained from Global Telecommunication System (GTS) gauged based analysis, satellite estimates of GPI, Special Sensor Microwave/ Imager (SSM/I) and Advanced Microwave Sounding Unit (AMSU-B) and the merged analysis. The merged analysis presents similar spatial distribution patterns with those of satellite estimates while its magnitude is close to the gauge-based analysis over areas with gauge data (Rawat et al. 2011). The rainfall images were georeferenced using coordinates for first pixel and pixel size. The daily rainfall images were converted into monthly rainfall by adding up the 30 or 31 days rainfall for the year 2008.Meteorological rainfall data collected from nearby gauging station (Table 2.2) was used for validation of result from remote sensing data for same year 2008.

Table 2 The rainfall data of Allahabad district for last four year

Months	2007 Rainfall (mm)	2008 Rainfall (mm)	2009 Rainfall (mm)	2010 Rainfall (mm)
January	0.1	0.6	0	3.6
February	75.8	10	0.5	19.5
March	25.1	0	14.4	0
April	1.2	3.1	3.2	0.5
May	21.9	38.5	26.8	7.5
June	77	322.4	3.1	8.5

Contd…

July	295.4	446.9	172.7	201.7
Months	**2007 Rainfall (mm)**	**2008 Rainfall (mm)**	**2009 Rainfall (mm)**	**2010 Rainfall (mm)**
August	295.4	326.1	64.8	160.6
September	209.2	67.5	177.8	126.4
October	2.8	20.3	33.6	45.5
November	0	1.7	15.9	5.3
December	5.4	0	6	0
Annual (mm)	1009.3	1237.1	518.8	579.1

Source: Hydromet Division, India Meteorological Department, Allahabad, (U.P.)

Actual evapotranspiration

The actual evapotranspiration was acquired as a product of MODIS sensor onboard TERA & AQUA satellites. The product is named as MOD16 and gives the 8 daily actual evapotranspiration at a spatial resolution of 1km. MOD16 is a level 4 product and has a temporal resolution of eight days at a spatial resolution of 1 km over the land surface only (Choudhury 1994). The data was provided for the study period and region by the EROS Data Center. The data was in GMAO Meteorological format which was converted into float format using code written in C program. The Float format was directly imported into ILWIS 3.3 where further analysis was carried out.

Runoff or overland flow

Estimation of direct runoff from the study area produced by the given precipitation is done through Soil Conservation Services (SCS-CN) Model. The empirical equation of SCS approach requires the rainfall and a watershed coefficient as inputs. The watershed coefficient is called the curve number (CN), which is an index that represents the combination of hydrologic soil group, land use and land treatment classes. This model involves relationship between land cover, hydrologic soil group and curve number. As satellite data can be use for estimating the land cover distribution, hence these provide useful input support for SCS model. Basic data requirement for this model are as follows:

1. Types of land use/cover such as bare soil, vegetation, impervious surface agriculture land etc. and hydrology conditions (AMC) of each land use (Table 3).
2. The antecedent moisture condition which is the index of the soil condition with respect of runoff potential before the storm; it has three categories.
3. Hydrological Soil Group (HSG) provides four groups based on the basis of intake of water on bare soil when thoroughly wetted. The hydrological soil group classification based on texture of distributed soil is given in Table 4.

The expression used in SCS-CN method for estimating runoff as applied in the analysis under the study is given below.

$$Q = \frac{(P - I_a)^2}{\{(P - I_a) + S\}} \tag{3}$$

where, Q = Accumulated storm runoff; P = accumulated storm rainfall; S = potential maximum retention of water by soil

The Central Soil & Water Conservation Research & Training Institute (lCAR) Dehradun (India) gave empirical relation between S and I_a for Indian conditions were used in the present study. For black soil region under AMC- II and AMC-III, I_a= 0.l S; under AMC- I, I_a= 0.3S; for all other regions I_a= 0.3S. S value is derived from curve number (CN) using following formulae

$$S = \frac{25400 \quad - 254}{CN} \tag{4}$$

where, CN is function of watershed hydrologic land use/land cover units, hydrologic soil groups and antecedent moisture condition. The CN values can be obtained for different land uses and hydrologic condition from Table 4. The CN values (AMC-II) for the different hydrologic soil cover has also given in Table 5. Consequently the CN values for AMC-I & II is obtained using the following empirical equations;

$$CNI = \frac{4.2 \times CNII}{\{(10 + 0.058) \times CNII\}} \tag{5}$$

$$CNIII = \frac{23 \times CNII}{\{(10 + 0.13) \times CNII\}} \tag{6}$$

Table 3 AMC classes as selected for the study area

AMC-Class	Dormant season (m.m)	Growing Season (m.m)	Condition
I	< 12.7	<35.6	Dry soil but not the wilting point
II	12.7-27.9	35.6-53.3	Average conditions Saturated soils; heavy
III	>27.9	>53.3	rainfall or light rainfall

Source: United States Department of Agriculture (1986).Technical Release 55 (TR-55) (Second Edition ed.)

Table 4 Hydrological soil group and physical characteristics

Group	Infiltration rate (mm/hr)		Soil texture
A	High	>25	Sand, Loamy Sand, or Sandy Loam
B	Moderate	12.5-25	Silt Loam or Loam
C	Low	2.5-12.5	Sandy Clay Laom
D	Very Low	<2.5	Clay Loam, Silty Clay Loam, Sandy Clay, Silty Clay or Clay

Source: Hydrological soil groups based on the physical soil characteristics following the USDA (1985) method

Table 5 Runoff curve numbers for hydrological soil cover complexes as selected for the Tons river catchment

Land use description on input screen	***Description and curve numbers from TR-55***					
	Cover description		**Curve number for hydrologic soil group**			
	Cover type and hydrologic condition	**% Impervious areas**	**A**	**B**	**C**	**D**
Agricultural	Row crops-straight rows + crop residue cover-good condition		64	75	82	85
Commercial	Urban districts: commercial and business	85	89	92	94	95
Forest	Woods-good condition		30	55	70	77
Grass/Pasture	Pasture, grassland, or range-good condition		39	61	74	80
High Density Rsidential	Residential districts by average lot size:1/8 acre or less	65	77	85	90	92
Industrial	Urban district: industrial	72	81	88	91	93
Low Density Residential	Residential districts by average lot size:1/2 acre lot	25	54	70	80	85
Open Spaces	Open space (lawns, parks, golf courses, 50%to70%)		49	69	79	84
Parking and Paved Spaces	Impervious areas: paved parking lots, roofs, driveways, etc.(excluding right-of-way)	100	98	98	98	98
Residential 1/8 acre	Residential districts by average lot size:1/8 acre	65	77	85	90	92
Residential 1/4 acre	Residential districts by average lot size:1/4 acre	38	61	75	83	87
Residential 1/3 acre	Residential districts by average lot size:1/8 acre	30	57	72	81	86
Residential 1/2 acre	Residential districts by average lot size:1/2 acre	25	54	70	80	85
Residential 1acre	Residential districts by average lot size:1 acre	20	51	68	79	84
Residential 2acre	Residential districts by average lot size:2 acre	12	46	65	77	82
Water/Wetlands		0	0	0	0	0

Source: United States Department of Agriculture (1986).Technical Release 55 (TR-55) (Second Edition ed.)

Groundwater recharge

The GW recharge was calculated as a residual function of the water balance equation. The monthly values of all other components were been estimated and the GW recharge on monthly basis determined. Here it was assumed that this calculated amount have the capacity to recharge the GWi.e potential amount of water for recharge under prevailing condition. But GW recharge are regulated by several factors such as climate (amount and intensity of rainfall and evaporation), soil and aquifer hydraulic properties, type and amount of vegetation cover and types of land use, topography, nature and geometry of aquifers etc., and only fractional amount of this calculated recharge is take part in actual GW recharge.

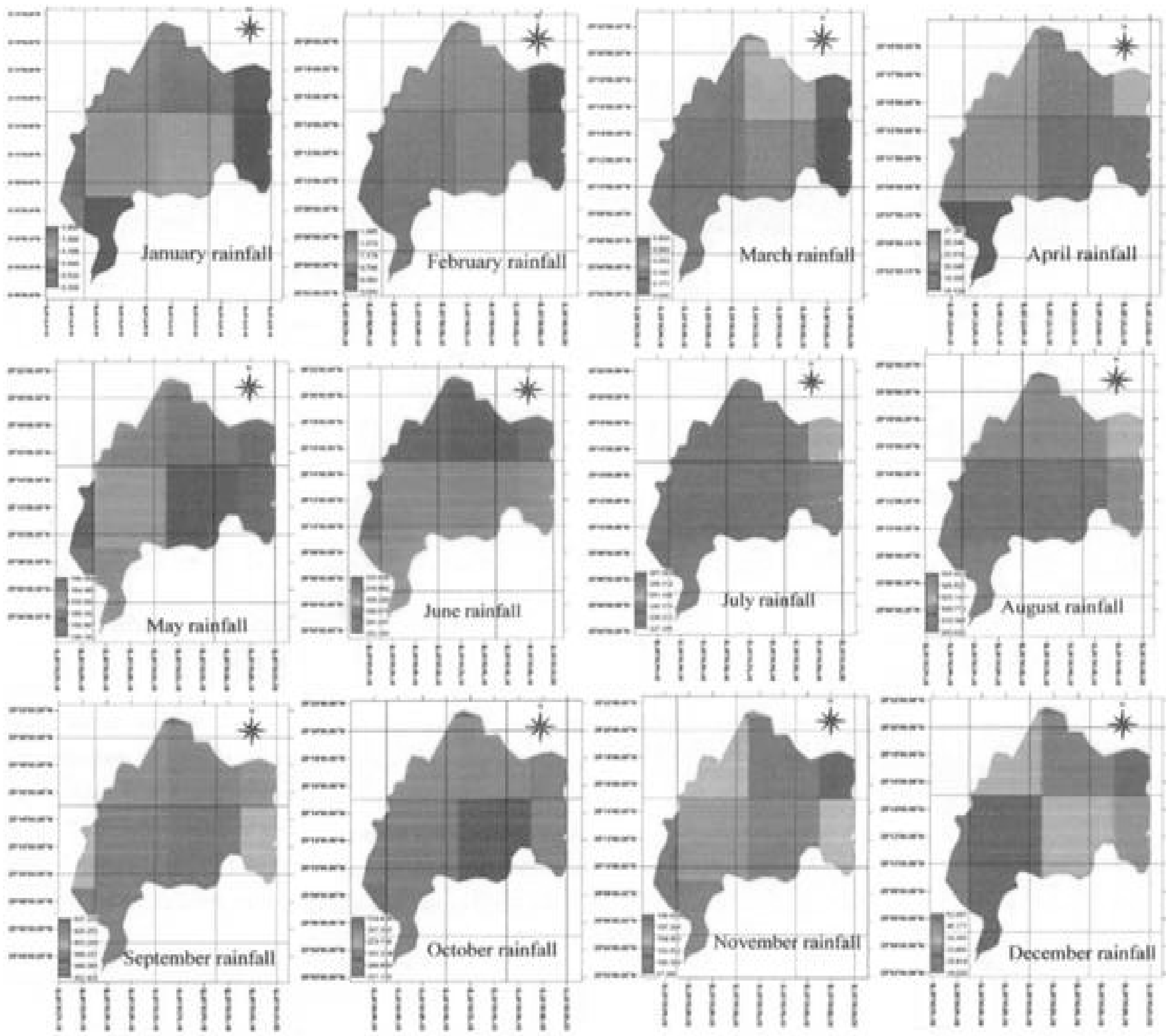

Fig. 2 Spatially distributed monthly rainfall over study area, as derived from NOAA data

Comparison of groundwater recharge by rainfall

Sehgal (1973) developed a formula for estimate of GW recharge, commonly called the Amritsar formula (Equation 7) using regression analysis in 1973 for Irrigation and Power Research Institute, Punjab. This commonly used formula was utilized for estimation of GW recharge through rainfall and compared with the estimated GW recharge obtained through Remote sensing and GIS techniques.

$$R = 2.5 \times (P - 16)^{0.5} \tag{7}$$

where, R is GW recharge and P is Annual Rainfall, both are measured in inches.

RESULTS AND DISCUSSION

Estimation of Precipitation and evapotranspiration

The satellite derived daily precipitation was computed for the study region by taking the weighted average. The daily weighted average value was converted into monthly basis to study the monthly water balance scenario for the study area. The lowest rainfall recorded in the year 2008 was during the month of March (0.29mm) whereas the highest was during the month of September (393.52 mm). The total annual rainfall for the study area was computed as 1811.91 mm (Table 6). The spatially distributed rainfall derived from satellite data, over the study region for the different months is shown in figure4. The spatial rainfall maps show the highly distributive nature of the rainfall. For the study area of 53675.5 hectares the satellite rainfall gives 6 to 8 different values. The daily rainfall values were used to determine the runoff and losses from the study area. The actual evapotranspiration values acquired from MODIS satellite product has been processed to convert into monthly values. The weighted average values were computed from the spatial maps. The lowest evapotranspiration recorded in the year 2008 for the study area was during the month of May (11.80 mm) whereas the highest was for the month of September (32.37 mm). The spatially distributed actual evapotranspiration, derived from MODIS satellite data product, over the study region for the different months is shown in figure 3.

Table 6 The monthly values of the water balance components in Shankergarh block, Allahabad (India)

Months	Rainfall (mm)	ET_a (mm)	Runoff (mm)	20 % loss of Rainfall (mm)	Ground water Recharge (mm)
January	0.97	16.06	0	0.194	0
February	1.17	16.87	0	0.234	0
March	0.29	19.14	0	0.058	0
April	21.48	19.14	0.20	4.30	0
May	144.18	11.80	75.65	28.84	27.89
June	289.51	13.81	125.65	57.90	92.15
July	235.39	19.86	130.16	47.08	38.29
August	319.10	22.15	157.52	63.82	75.61
September	393.52	32.37	212.90	78.70	69.55
October	268.71	29.62	112.66	53.74	72.69
November	102.93	22.62	47.81	20.59	11.91
December	37.09	16.12	13.00	7.42	0.55
Annual (mm)	1811.91	175.49	880.35	362.38	393.69

Estimation of overland runoff (OF)

The study area was agricultural land with soil type clay loamy. According to SCS-CN model runoff discharge was available for only 6 months with highest discharge of 212.90 mm in the month of September. Annual runoff from the study region was estimated to be 880.35 cm which was merely 45 per cent of the total precipitation. Table 6 shows the monthly runoff value for the study area during the year 2008.

Estimation of groundwater recharge

The monthly values of the water balance components are shown in Table 6.The computed monthly GW recharge value show high for month's June (92.15 mm), July (38.29 mm), August (75.61 mm), September (69.55 mm) and October (72.69 mm). The highest recharge was seen in the month of June (92.15 mm) and the lowest was in the month of December (0.55mm). The first four months (January to April) showed no recharge owing to negligible precipitation. A comparative plot showing the variation of water balance component was plotted and is shown infigure4. The GW recharge is seen as a major component in the water balance.

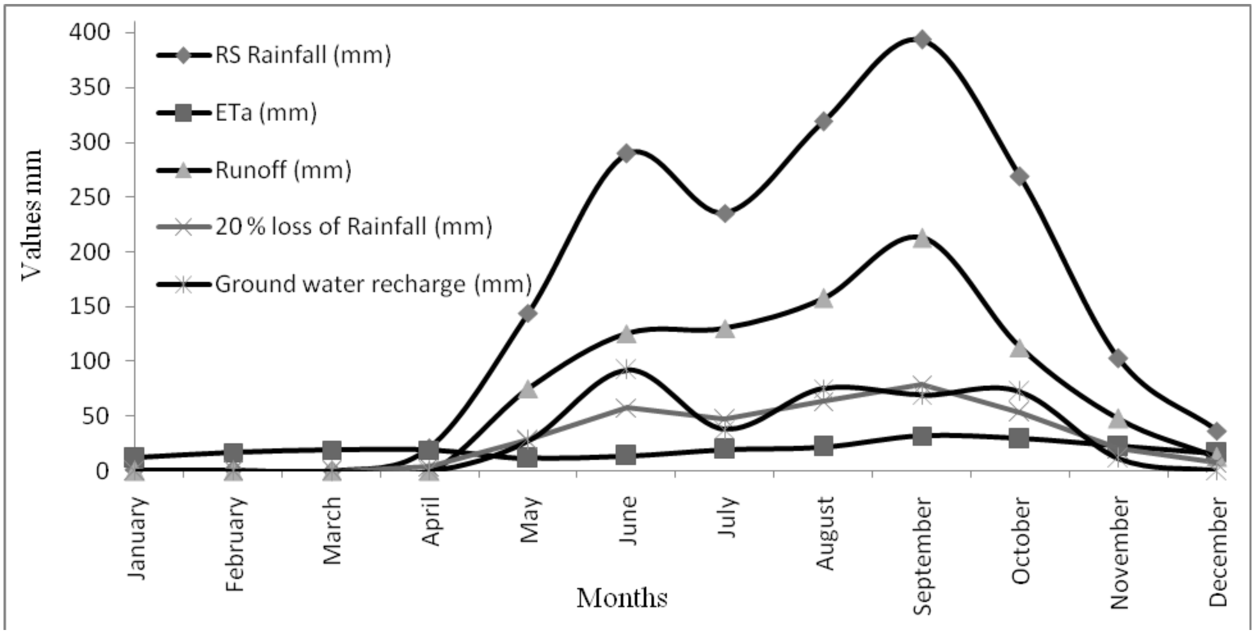

Fig. 3 Monthly water balance components in Shankergarh block, Allahabad(India) during the year 2008.

Comparison of groundwater recharge

Annual GW recharge has been obtained as 0.36 m using Empirical Mode (Amritsar formula). But using remote sensing and GIS WG recharge has been estimated as 0.39 m. The difference amount is only 0.03m from two different ways. Hence the result obtained from empirical model for GW recharge, support to result from remote sensing and GIS. Differences of 0.03meter may be improved if some other factor use in equation 7.

CONCLUSIONS

The present study gave a clear picture of the water accounting. A major portion of the precipitation was going as GW recharge and this can be attributed to the fact that the study region is predominantly an agricultural region. The precipitation is distributed evenly through the monsoon season and the sufficient runoff was generated. The data set used consisted of satellite derived rainfall data; satellite derived actual evapotranspiration data and SCS-CN model runoff values to estimate GW recharge. The annual potential GW recharge was found to 0.39 meter. The recharge was most prominent during rainy season in six months May, June, July, August, September and October. This study gives a deep look of water budgeting for planners, which can be utilized and replicated to other regions having no or limited gauging stations. Information related to water budget and present methodology may be utilized by the policy makers for integrated water resources planning in future.

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Remote Sensing and GIS based Crop Coefficient Approach for Irrigation Water Management

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ABSTRACT

Crop per drop of water is a need of present day. So, efficient management of water resources in crop production is necessary. Higher water use efficiencies can be achieved if crops are irrigated as per their actual water demands during their growth stages. Generally, the crop water demands at any location are determined in the form of actual crop evapotranspiration (ETc) using procedure suggested by FAO-56 which is dependent on reference evapotraspiration and crop coefficient curves. This method is location specific under standard conditions of crop growth and thus having some limitations. By using Remote sensing and GIS techniques, it is possible to estimate spatial crop evapotranspiration which differs from place to place for the same crop. which helps in accurate water management as per water need of the crop. Thus giving smarter solution for better tomorrow. Therefore research work was carried out regarding remote sensing approach for getting quick and accurate estimates of crop coefficients of rabi sorghum and wheat crops and water requirements were obtained. It was found that spatial water requirement of rabi sorghum varied from 324.24 mm to 391.20 mm and that of wheat varied between 378.34 mm to 439.10 mm as per the location. These results show the need of location specific accurate irrigation water management.

Keywords: Remote sensing, GIS, Irrigation, Evapotranspiration.

INTRODUCTION

Crop water requirement is the amount of water required to compensate the evapotranspiration loss from the cropped field. We have to replenish water equal to the amount of evapotraspiration of the crop (ET_c). The most common method to to estimate actual eveapotranspiration (ET_c) is to multiply estimated reference evapotranspiration (ET_o) by crop coefficient (K_c) which reflects the real time vegetation status (Allen *et al.*, 1998, 2005). If sufficient weather data are available, the standard FAO Penman–Monteith method can be used for calculations of daily ET_o (Allen *et al.*, 1998). Actual ET *i.e.* ET_c is then calculated using the estimated ETo as follows:

$$ET_c = K_c \times ET_o \tag{1}$$

The crop coefficients (K_c) are generally developed for crops grown under optimum agronomic conditions and therefore result in approximate values of the actual ET_c and water requirements for a given crop at a given location. Doorenbos and Pruitt (1977) in FAO-24 publication have given tabulated values of K_c for different crops using lysimeters for the major stages of crop development. Since these K_c values are time-based, they often lack the flexibility required to capture unusual crop development. As these K_c values are empirical in nature. It is very often required to make corrections as per local conditions. Therefore, using these traditional crop coefficients for irrigation scheduling can lead to over-irrigation of crops, which can be a serious concern at the field level when irrigation water is in short supply, as well as at the district and regional level of water management, especially in water-short arid and semi-arid areas of the world (Santos *et al.*, 2007).

Satellite remote sensing offers a means to overcome some of the shortcomings of time-based K_c curves by providing real-time and/or near real time spatial information on K_c and captures variability among different fields which occurs due to different dates of sowing, soil and field conditions. Multispectral vegetation indices (VIs) have been acclaimed to be closely related with several crop growth parameters (Moran *et al.*, 1995). Many scientists have shown similarity in patterns of K_c and vegetation indices (VI's) suggesting to use these VI's as surrogates for crop coefficients. Therefore present study was carried out to estimate spatial irrigation water requirement of rabi sorghum and wheat crops by adopting the crop coefficients obtained from the remotely sensed vegetation indices.

MATERIAL AND METHODS

Study area

The study was conducted in five districts of central Maharashtra *i.e*. Pune, Solapur, Ahmednagar, Beed and Osmanabad where spatially, extensive and contiguous sites of rabi sorhum and wheat crops are found in *rabi* season It covers an area of approximately 65,716 Km^2. It is located between 73°17'19"E to 76°47'42"E longitudes and 19°58'57" N to 17°03'56"N latitudes. Most parts of the districts under study are falling in water scarcity zone with average annual rainfall between 500-700 mm with uncertainty and ill distribution.

Remote Sensing data

Satellite images of IRS- P6, AWiFS (Advanced Wide Field Sensor) for five consecutive months of rabi season (October -February) of the year 2012-13 were used for this study (Table 1). These images were processed to generate five most commonly used vegetation indices (VIs) i.e. Ratio Vegetation Index (RVI), Normalized Difference Vegetation Index (NDVI), Transformed Normalized Difference Vegetation Index (TNDVI), Soil Adjusted Vegetation Index (SAVI) and Modified Soil Adjusted Vegetation Index (MSAVI2) on all the dates of satellite pass (Table 2). Eight images of each vegetation index were stacked together to get a stack layer. (Total 5 stacks containing 8 images each were obtained).

Ground truth data

Ground truth work was carried out in first week of December 2012, coinciding with the season of rabi sorghum and wheat crop in the study area. Field data were collected from 34 sites of rabi sorghum and 17 sites of wheat crop, distributed properly in all the districts of the study area. The equipments like handheld GPS, geotagged camera and a mobile with LOCATE software were used to obtain the locations and elevations of the sites. The ground truth of other coexisting crops like chickpea, sugarcane etc was also collected. The information obtained from each site was recorded in ground truth proforma sheets.

Table 1 Multi-date IRS-P6 AWiFS data used for the study

S. No.	Satellite	Sensor	Path	Row	Date of Pass
1	IRS-P6	AWiFS	097	058	19-10-2012
2	IRS-P6	AWiFS	098	059	11-11-2012
3	IRS-P6	AWiFS	098	059	29-11-2012
4	IRS-P6	AWiFS	098	059	11-12-2012
5	IRS-P6	AWiFS	098	062	27-12-2012
6	IRS-P6	AWiFS	097	059	11-01-2013
7	IRS-P6	AWiFS	097	058	23-01-2013
8	IRS-P6	AWiFS	097	059	04-02-2013

Table 2 Vegetation Indices (VIs) used for study

S. No.	Indices	Equation	Reference
1.	RVI	NIR/RED	Jordan (1969)
2.	NDVI	(NIR-R) / (NIR+R)	Rouse *et al.* (1973)
3.	TNDVI	[(NIR - RED)/(NIR + RED) + 0.5]^(1/2)	Tucker (1979)
4.	SAVI	[(NIR - RED) / (NIR + RED + L)] * (1 + L)	Huete (1988)
5.	MSAVI2	$[2*NIR+1-\sqrt{(2*NIR+1)^2 - 8*(NIR-R)}] / 2$	Qi *et al.* (1994)

Image processing

Crop polygon vector layer of fields was prepared based on the ground truth using ArcGIS. Pure crop polygon multidate VIs were extracted by overlaying the crop polygon vector layer on the stack layer images using signature editor function. These VI values were exported to Microsoft Excel and arranged weekwise considering the age of crops at different locations in terms of week on dates of images (dates of pass).

Formulation of VI-K_c Models

The empirical relationships between weekly rabi sorghum and wheat crop coefficients (K_c) recommended by Mahatma Phule Krishi Vidyapeeth Rahuri (MPKV, 2012) and vegetation indices (VIs) were obtained by using linear regression analysis resulting in linear models. The models thus obtained were evaluated by means of statistical parameters. Based on the results of statistical analysis best performing model was selected for further estimation of ETc.

Estimation of Crop water requirement

Meteorological data of the five stations Pune, Solapur , Beed , Osmanabad and Rahuri (Ahmednagar) of the study area was obtained from IMD Pune. Reference evapotranspiration (ET_o) was estimated by applying Penman Monteith equationusing the meteorological data and then actual crop evapotranspiration (ET_c) i.e. water requirement was estimated by multiplying this ET_o by Kc values obtained by models of vegetation indices.

RESULTS AND DISCSSION

VI-Kc Models

The average weekly values of vegetation indices i.e. RVI, NDVI, TNDVI, SAVI and MSAVI2 for rabi sorghum and wheat at all the locations were obtained by image processing. These weekly values of VI's were plotted against weekly crop coefficients (K_c) recommended by MPKV Rahuri Simple linear regression analysis was carried out to investigate the relation between the vegetation indices and crop coefficients. It was observed that fairly good linear relationship exists between these vegetation indices with crop coefficients. It was found that for rabi sorghum and wheat crops MSAVI2-Kc and NDVI-Kc models respectively showed best performance. The best fit models are:

1. For rabi sorghum

$$K_c = 2.838\ \mathrm{MSAVI2} - 0.570 \qquad R^2 = 0.805 \qquad (2)$$

2. For wheat

$$K_c = 6.461\ \mathrm{NDVI} - 1.157 \qquad R^2 = 0.895 \qquad (3)$$

Similar findings showing superiority of NDVI for predicting wheat crop coefficients were obtained by Calera and Gonzalez (2007) in Spain as well as Lei and Yang (2014) in Chin and Farg *et al.* (2012) in Egypt. However, exactly similar studies related to sorghum were not observed in the literature survey

Crop evapotranspiration, ET_c (Water Requirement)

The weekly reference evapotranspiration (ET_o) values were estimated by Penman Monteith equation were multiplied by weekly crop coefficients of rabi sorghum and wheat crops obtained by using best fit models based on MSAVI2 and NDVI respectively to get spatial crop evapotranspiration (water requirements) of rabi sorghum and wheat crops for the five districts of the study which are depicted in Table 3 and Table 4.

It is observed that the total crop evapotranspiration (ET_c) of rabi sorghum crop varies from 324.14 mm in Pune district to 391.20 mm in Osmanabad district. The estimated total crop evapotranspiration (ET_c) of wheat was lowest (378.34 mm) in Pune district and highest (439.10 mm) in Osmanabad district. This difference in ETc of both the crops at different places is because of variation in reference evapotranspiration which depends on conditions of weather and physiography of the area.

Table 3 Spatial crop evapotranspiration (ET_c, mm) for rabi sorghum

Weeks past sowing	District				
	Ahmednagar	Pune	Solapur	Beed	Osmanabad
1	9.90	8.31	7.31	8.41	13.86
2	16.71	16.59	16.04	18.04	22.68

Table 3 *Contd…*

Weeks past sowing	District				
	Ahmednagar	**Pune**	**Solapur**	**Beed**	**Osmanabad**
3	15.72	16.11	19.80	19.07	20.64
4	19.98	14.13	18.08	18.90	19.66
5	22.22	18.56	21.00	22.93	22.51
6	19.04	18.54	18.18	17.94	21.69
7	23.67	21.33	25.58	22.44	25.38
8	21.62	20.53	21.54	26.30	26.32
9	19.54	19.73	19.66	22.00	23.24
10	22.40	21.32	19.25	23.35	26.23
11	19.89	20.17	21.22	20.93	19.90
12	17.72	17.73	22.86	20.66	20.16
13	17.00	15.53	19.74	18.15	18.17
14	14.04	17.41	15.60	16.01	16.48
15	14.14	13.59	14.50	14.84	15.41
16	23.19	19.99	24.53	22.18	24.50
17	11.51	11.06	12.74	13.36	12.24
18	15.85	13.33	16.52	15.58	18.65
19	13.49	12.00	14.38	13.82	14.37
20	8.92	8.14	8.85	8.10	9.11
Total	**346.55**	**324.14**	**357.39**	**363.01**	**391.20**

Table 4 Crop evapotranspiration (ET_c, mm) for wheat

Weeks past sowing	District				
	Ahmednagar	**Pune**	**Solapur**	**Beed**	**Osmanabad**
1	15.00	14.60	14.32	14.14	17.09
2	23.21	20.91	25.08	22.00	24.88
3	19.08	18.12	19.01	23.21	23.23
4	23.55	23.78	23.69	26.51	28.01
5	26.76	25.47	23.01	27.90	31.34
6	29.73	30.15	31.71	31.29	29.73
7	25.87	25.89	33.38	30.16	29.44
8	32.84	30.01	38.14	35.06	35.11
9	26.11	32.37	29.00	29.76	30.63
10	23.80	22.89	24.42	24.98	25.95
11	31.13	26.84	32.93	29.77	32.89
12	23.04	22.14	25.50	26.74	24.50
13	26.81	22.55	27.93	26.34	31.53
14	22.32	19.86	23.79	22.86	23.78
15	16.46	15.02	16.33	14.93	16.81
16	16.16	15.62	16.79	15.88	18.80
17	13.55	12.12	13.84	14.79	15.38
Total	395.41	378.34	418.87	416.33	439.10

CONCLUSION

The study demonstrated the ability of remotely sensed vegetation indices to predict spatial and temporal crop coefficients of rabi sorghum and wheat crops. The vegetation indices, MSAVI2 and NDVI of *rabi* sorghum and wheat crops respectively were found to be highly superior for their linear correlation with crop coefficient. Therefore, these developed VI-K_c models can be incorporated in the FAO-56 procedures in place of conventional tabulated K_c.

Remote Sensing and GIS integrated approach can be applied to supply appropriate amount of irrigation water at different locations as per actual crop water demand leading to proper irrigation water management. This approach can also be used in water scarcity scenario to supply optimum irrigation water as a life saving irrigation to prevent crop failure.

Real time high resolution remotely sensed data combined with automatic weather stations can constitute an expert system for accurate irrigation scheduling.

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Dr. Giridhar visited several countries for dissemination of his research outputs and for exchange of ideas at places like Loss Angles, USA (2008), Honolulu, USA (2008), Bangkok, Thailand (2009) and Hanoi, Vietnam (2010), USA (2015), Thailand (2016). He has participated in more than 40 Conferences at National and International level on themes related to his subject expertise to share his views in the field of water resources.

Dr. Giridhar successfully completed four R&D projects and currently handling four research projects. With the funds received from the Central Ground Water Board, MoWR, AICTE, he constructed 21 recharge bore wells in the University campus and every year 10.0 crore liters of rainwater is being harvested and recharged into the aquifers after proper filtration.

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