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Research Article

ASSESSMENT OF WATER QUALITY OF THATIPUDI RESERVOIR OF VIZIANAGARAM DISTRICT OF ANDHRA PRADESH

G V S R PAVAN KUMAR*[1], V S SANAND[2], N SANTHOSH KUMAR[3], B SREERAMA MURTHY[4]

[1,4]Department of Chemistry Maharaj Vijayaram Gajapathi Raj College of Engineering Chinthalavalasa Vizianagaram-535005 Andhra Pradesh, [2]Department of Chemistry Maharaja's Post Graduate College Vizianagaram, [3] Department of B S &H G M R institute of Technology Rajam (AP). Email: prs_ganti@yahoo.co.in

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ABSTRACT

The authors present work deals with the assessment of the water quality of the water samples collected from Thatipudi reservoir situated in Vizianagaram district of Andhra Pradesh, by analyzing some selected physico-chemical parameters and chosen heavy metals. Water quality parameters such as pH, EC, DO, COD, BOD, TDS, total hardness, calcium, magnesium, sodium, potassium, iron, chloride, nitrite, phosphate, carbonate, bicarbonate and heavy metals such as zinc, manganese, lead and chromium were analyzed for the water samples collected from the reservoir. The results were compared with the standard values prescribed by IS 10500. The parameters such as SAR, RSC, and Mg hazardous were analyzed and it was found that all these values were within the prescribed limit value. Saturation index values of the water samples analyzed were found to be in the range of 0.3-0.84 indicating, Water is supersaturated with respect to calcium carbonate ($CaCO_3$) and scale forming may occur, but non corrosive.

Keywords: Dams, Thatipudi reservoir water quality, physico-chemical characters

INTRODUCTION

Reservoirs are man-made lakes with vital aquatic ecosystems that serve important environmental and economic purposes, mainly potable water supply through ground percolation, hydel power, irrigation and fisheries. Expanding human population brought about by the opportunities of good water supply, irrigation, fish production recreation and navigation offered by reservoirs have put enormous stress on the quality of water impounded by the reservoir. The impact of human activities in and around the reservoir leaves mark on the changing physical and chemical properties of water on which the sustenance of fish that inhabit the reservoir. Water quality is determined by the physical and chemical limnology of a reservoir and includes all physical, chemical and biological factors of water that influence the beneficial use of the water. Water quality is important in drinking water supply, irrigation, fish production, recreation and other purposes to which the water must have been impounded.

Water quality monitoring of aquatic systems like dam or reservoir serves as a fundamental tool for planning and management of the river basin. The physical, chemical and biological characteristics of lakes vary widely. The impact of human activities directly influences lake habit and can alter the lake's environment. Water quality index is one of the most effective tools [1-4] to communicate information on the quality of water to the concerned citizens and policy makers. It, thus, becomes an important parameter for the assessment of water quality. Based on the WQI values the water was graded as excellent water quality and etc.

WQI level	Water quality status
0-25	Excellent water quality
26-50	Good water quality
51-75	Poor water quality
76-100	Very poor water quality
>100	Unsuitable for drinking

The water quality index calculations are as follows

$W_i = k/S_i$

Where W_i is the unit weight of and Si is the standard for i^{th} parameter

K is the proportionality constant

$Q = 100V_i /S_i$

Where Qi is the sub index of the i^{th} parameter, Vi is the monitored value of i^{th} parameter and WQI is calculated as follows

$WQI= \sum Q_i W_i / \sum W_i$

A survey of literature [5-8] revealed that several researchers have studied water quality of lakes at global levels. Considering the impacts of industrialization on water quality of many dams and rivers as reported in literature, a study of water quality of Thatipudi reservoir from December 2011 to March 2012, was Reservoirs are man-made lakes with vital aquatic ecosystems that serve important environmental and economic purposes, mainly potable water supply through ground percolation, hydel power, irrigation and fisheries. Expanding human population brought about by the opportunities of good water supply, irrigation, fish production recreation and navigation offered by reservoirs have put enormous stress on the quality of water impounded by the reservoir. The impact of human activities in and around the reservoir leaves mark on the changing physical and chemical properties of water on which the sustenance of fish that inhabit the reservoir. Water quality is determined by the physical and chemical limnology of a reservoir and includes all physical, chemical and biological factors of water that influence the beneficial use of the water. Water quality is important in drinking water supply, irrigation, fish production, recreation and other purposes to which the water must have been impounded.

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(i) To evaluate the physical and chemical parameters of water of the reservoir

(ii) To see its suitability form drinking and irrigation.

EXPERIMENTAL

AREA UNDER STUDY

Gosthani River [9] is east flowing river in Andhra Pradesh, India. It is originated in the Ananthagiri hills of Eastern Ghats. Borra Caves are formed at its origin, probably the result of erosion of the lime stones by flowing waters of this river. It flows down the hills mostly in Vizianagaram [10] and Visakhapatnam districts.

Thatipudi Reservoir [11] Project was constructed across Gosthani River during 1963-1968. The Project is located near Thatipudi village, Gantyada Mandal, Vizianagaram District. The aim of this project is to irrigate a total ayacut of 15,378 acres (62.23 km^2) in Vizianagaram District and to provide drinking water to Visakhapatnam City. The project utilizes about 3 TMC of the available water. The reservoir storage capacity is about 3 TMC. It joins the Bay of Bengal at the historical town Bheemunipatnam.

SAMPLING

In the present study, integrated sampling procedures were adopted, in order to get water samples that truly represent the water quality of the entire reservoir. Ten different sampling stations were identified and samples were collected and mixed to get an integrated sample. The samples were collected from December 2011 to March 2012 on fortnightly basis, to ensure any significant changes in the quality of the water.

MATERIALS AND METHODS

For the physico-chemical characterization, the water samples were collected in PVC bottles and samples for DO in BOD bottles. All the spectrophotometric measurements were made by using scanning visible spectrophotometer SL-177. Sodium and potassium in the samples were determined by using microprocessor based flamephotometer CL-361. All the chemicals used were of AR grade. Standard methods of APHA [12] were used for the analysis of water samples.

Suitability of water for irrigation [13] is evaluated by % Na given by

$Na\% = 100 \times Na^+ / (Na^+ + Ca^{+2} + Mg^{+2} + K^+)$

Bicarbonate is expressed as residual sodium carbonate (RSC) given by the equation

$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{+2} + Mg^{+2})$

Sodium absorption ratio (SAR) used to evaluate alkali hazards is calculated as

$SAR = Na^+ / \sqrt{(Ca^{+2} + Mg^{+2})/2}$

Magnesium hazard ratio [13] is calculated as Mg Hazard = $100 \times Mg^{+2} / (Ca^{+2} + Mg^{+2})$

The Langelier Saturation Index [14] is a calculated value used to predict the calcium carbonate stability of water. It indicates whether the water will precipitate, dissolve, or be in equilibrium with calcium carbonate. The LSI is expressed as the difference between the actual system pH and the saturation pH:

LSI = pH (measured) — pHs

- For LSI > 0, water is super saturated and tends to precipitate a scale layer of $CaCO_3$.
- For LSI = 0, water is saturated (in equilibrium) with $CaCO_3$. A scale layer of $CaCO_3$ is neither precipitated nor dissolved.
- For LSI < 0, water is under saturated and tends to dissolve solid $CaCO_3$.

If the actual pH of the water is below the calculated saturation pH, the LSI is negative and the water has a very limited scaling potential. If the actual pH exceeds pHs, the LSI is positive, and being supersaturated with $CaCO_3$, the water has a tendency to form scale. At increasing positive index values, the scaling potential increases.

In practice, water with an LSI between -0.5 and +0.5 will not display enhanced mineral dissolving or scale forming properties. Water with an LSI below -0.5 tends to exhibit noticeably increased dissolving abilities while water with an LSI above +0.5 tends to exhibit noticeably increased scale forming properties.

LSI Formula

LSI = pH - pHs

pHs = (9.3 + A + B) - (C + D) where:

A = (Log10 [TDS] - 1)/10 = 0.15

B = -13.12 x Log10 (oC + 273) + 34.55 = 2.09 at 25°C and 1.09 at 82°C

C = Log10 [Ca2+ as CaCO3] - 0.4 = 1.78 (Ca2+ as CaCO3 is also called Calcium Hardness and is calculated as = 2.5(Ca2+)

D = Log10 [alkalinity as CaCO3] = 1.53

Scaling index	Likelihood of scaling	Likelihood of corrosion
-0.5 to 0.5	Not likely	Not likely
0.5 to 1.5	Moderately risk	Not likely
>1.5	Strong risk	Not likely
-0.5 to -1.5	Not likely	Moderately risk
<-1.5	Not likely	Strong risk

RESULTS AND DISCUSSION

The physico chemical analysis, parameters related to irrigation such as RSC, SAR, Na%, Mg- hazard report is presented in Table.1, report on concentrations of heavy metals such as zinc. Lead, chromium and manganese is presented in Table.2 and LSI in Table.3

Dissolved oxygen analysis measures the amount of gaseous oxygen (O_2) dissolved in an water. Oxygen gets into water by diffusion from the surrounding air, by aeration (rapid movement), and as a waste product of photosynthesis. Adequate dissolved oxygen is necessary for good water quality. Oxygen is a necessary element to all forms of life. Natural stream purification processes require adequate oxygen levels in order to provide for aerobic life forms. As dissolved oxygen levels in water drop below 5.0 mg/l, aquatic life is put under stress. Lower the concentration, the greater the stress. Oxygen levels that remain below 1-2 mg/l for a few hours can result in large fish kills. In the present study the DO of the water samples analyzed was found to be in the range of 7.3-8.2, and the values are found to be well within the prescribed limit value with lower stress on the aquatic life.

pH is the another important parameter in assessing the quality of water. pH controls many chemical and biological processes that occur in the water. The pH state of surface water is especially important since aquatic organism have a tolerance for very narrow pH ranges. A pH value higher or lower than the 6 to 8 range for stream water can decrease the survival of aquatic organisms and lead to loss of stream ecosystem diversity. It was found that the water samples analyzed have a pH ranging 8.2-8.8. The pH values were found to be beyond the prescribed limit value during January 2012. And in all the other seasons under study the pH was found to be well within the prescribed limit.

The water samples collected from the reservoir were found to have turbidity in the range of 1-3NTU, indicating that the water is free from suspended materials causing turbidity to water. The water samples collected were transparent and clear in appearance.

Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Lower the EC, the water analyzed is found to be having all the cited cations and anions in lower concentrations. In the present study the EC of the water samples analyzed were found to be in the range of 350-425µS/cm, these values are well within the prescribed limit value. TDS for the water samples analyzed were found to be in the range of 100-280 mg/L, indicating that these values are well in accordance with the prescribed limits.

Total hardness of the water samples analyzed was found to be in the range of 200-245mg/L, which is well in accordance with the prescribed limit value. The concentration of Calcium in the water samples analyzed was 45.2mg/L and the concentration of magnesium was found to be 36.5mg/L in each of season under study. These values also found to be below the prescribed limit values.

The concentration sodium and potassium in the water samples analyzed was in the range of 10.5-16.5mg/L and 2.8-7.5mg/L respectively, indicating the lower concentration levels of the two ions such as sodium and potassium in the water samples under study.

Chloride is an important parameter with reference to water quality for both irrigation and drinking purpose. High levels of chloride in water samples lead to corrosion; bleaching of crops etc. the water samples analyzed were found to have 58.2-68.5mg/L of chloride in seasons under study. These values indicate fewer hazards with reference to chloride in the water and can be found that the water is suitable for irrigation with reference to chloride.

BOD and COD of the water samples were found to be in the range of 1.4-1.6mg/L and 6.2-9.2mg/l respectively. As these values are well in accordance with the prescribed standard values, indicates the absence of oxidizable matter both chemical and biological in the water.

Nutrients such as phosphate and nitrite in the water samples analyzed found to have very low concentrations such as 0.01-0.2mg/L for nitrite and in all the seasons under study phosphate was found to have a concentration not detectable range.

Carbonate and bicarbonate in the water samples analyzed was found to be 39.5mg/L and185.9-238.5mg/L respectively in the seasons under study, indicating lower hazard caused to irrigation water. High levels of carbonate and bicarbonates in water causes increase in the RSC value leading to increase in the alkalinity of the soil and the soil becomes sodic over time. But the analysis report indicates lower concentration levels of carbonate and bicarbonate in the water samples under study making the water suitable for irrigation.

Heavy metals such as zinc, chromium, lead and manganese were found to be very low in the water samples analyzed. This indicates that the water samples analyzed are free from heavy metal toxicity.

Other parameters which play an important role in assessing the quality of the water for irrigation studied are, SAR, Na%, Mg hazard and RSC. In the present study, the water samples analyzed at Thatipudi reservoir were found to have all these parameters well within the prescribed limits and are displayed in Table 1. And it was found by the authors that the water samples analyzed are free from boron contamination.

The Langelier Saturation Index of the water samples analyzed was found to be 0.84 in the month of December, in January 0.36, 0.80 in the month of March. From The values of LSI it was concluded that the water samples collected from the Thatipudi reservoir is Water is supersaturated with respect to calcium carbonate ($CaCO3$) and scale forming may occur. Scale forming but non corrosive.

Water quality index (WQI) calculations were reported in tables 3, 4, 5 and 6. From such calculations it was found that the values of WQI are found to be 24.5 in December, 36.7 in January, 33.5 in February and 40.6 in March in and are presented in Fig.4 and Fig.5. It was found that WQI values of the dam in different seasons are in the range of 25-50 and rated as having a good water quality. From the reports obtained from the analysis of the water samples collected from the dam, it was found that all the parameters analyzed such as pH, EC, TDS, DO, Ca, Mg, Na, K, chloride, phosphate, nitrite etc are in well agreement with the prescribed standard limit values prescribed by IS: 10500 [15]. And from the report it was found that the surface waters of the dam are free from adulteration of any effluents. And thus the water from the dam is suitable for irrigation as well as drinking purpose.

CONCLUSION

From the reports obtained from the analysis of the water samples collected from the dam, it was found that all the parameters analyzed such as pH, EC, TDS, DO, Ca, Mg, Na, K, chloride, phosphate, nitrite etc are in well agreement with the prescribed standard limit values prescribed by IS: 10500. And from the report it was also found that the surface waters of the dam are free from heavy metal toxicity with special reference to zinc, chriomum, and lead. And thus the water from the dam is suitable for irrigation as well as drinking purpose.

Table1: seasonal variation in the parameters analyzed

Date	5 Dec 2011	19 Dec 2011	2 Jan 2012	16 Jan 2012	31 Jan 2012	13Feb 2012	27Feb 2012	20 Mar 2012	Standards IS:10500
DO	7.3	7.5	7.4	7.5	7.8	8.2	8.1	7.9	14.6
Temp	20	21	21	21	22	24	27	30	----
pH	8.5	8.6	8.8	8.7	8.4	8.5	8.4	8.2	6.5-8.5
EC	350	385	390	380	420	425	420	395	500
Turbidity	1	2	1	3	1	2	3	1	5NTU
Nitrite	ND	0.01	0.08	0.3	0.1	0.09	0.1	0.2	<1ppm
Phosphate	ND	ND	ND	ND	ND	ND	ND	ND	10ppm
BOD	1.4	1.5	1.4	1.4	1.5	1.6	1.5	1.4	
COD	7.2	8.4	9.1	6.9	6.2	7.5	8.8	9.2	
TDS	100	280	250	210	260	160	210	280	500ppm
Carbonate	39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.5	200
Bicarbonate	195.5	198.5	201.5	185.9	195.5	198.5	225.5	238.5	---
THW	200	215	225	215	220	225	245	245	300ppm
Ca	45.2	45.2	45.2	45.2	45.2	45.2	45.2	45.2	70ppm
Mg	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	30ppm
Na	10.5	12.5	15.2	12.5	16.5	14.8	15.5	16.5	100ppm
K	2.8	3.1	2.8	3.5	7.2	6.8	7.1	7.5	10ppm
Cl	58.2	62.5	58.9	63.5	65.5	68.5	62.5	68.5	250ppm
Parameters for irrigation									
SAR	0.28	0.33	0.40	0.33	0.44	0.39	0.41	0.44	<10
Na%	7.8	9.2	10.9	9.1	11.5	10.5	10.9	11.5	<60
Mg hazard	57.4	57.4	57.4	57.4	57.4	57.4	57.4	57.4	
RSC	-0.78	-0.73	-0.68	-0.93	-0.78	-0.73	-0.28	-0.075	<1.25

Temp in 0C, EC in µS/cm, Trubidity in NTU except pH all other parameters reported in mg/L

Table2: seasonal variations in metal ion concentration

Metal	5 Dec 2011	19 Dec 2011	2 Jan 2012	16 Jan 2012	31 Jan 2012	13Feb 2012	20Feb 2012	13 Mar 2012	Standards IS:10500
Zn	0..01	ND	ND	00.1	0.01	0.01	0.01	0.01	5.0
Cr	ND	ND	ND	ND	ND	ND	ND	ND	0.05
Pb	ND	ND	ND	ND	ND	ND	ND	ND	0.1
Mn	ND	ND	ND	ND	ND	ND	ND	ND	0.1

All the concentrations are reported in mg/L

Table3: Langelier Saturation index

S.No	Month	LSI	Inference
1	Dec	0.84	Water is supersaturated with respect to calcium carbonate (CaCO3) and scale forming may occur. Scale forming but non corrosive
2	Jan	0.36	Water is supersaturated with respect to calcium carbonate (CaCO3) and scale forming may occur. Scale forming but non corrosive
3	Feb	0.80	Water is supersaturated with respect to calcium carbonate (CaCO3) and scale forming may occur. Scale forming but non corrosive
4	Mar	0.65	Water is supersaturated with respect to calcium carbonate (CaCO3) and scale forming may occur. Scale forming but non corrosive

Table4: unit weight calculation

	std		Wi
pH	8.5	0.117647	0.085285
DO	7	0.142857	0.10356
EC	500	0.002	0.00145
TDS	500	0.002	0.00145
THW	300	0.003333	0.002416
Ca	70	0.014286	0.010356
Mg	30	0.033333	0.024164
Na	200	0.005	0.003625
K	20	0.05	0.036246
nitrite	1	1	0.724923
Cl	250	0.004	0.0029
bicarbonate	200	0.005	0.003625
		1.379457	

Table5: WQI in the month of December

pH	Vi	Si	Qi	Wi	WIQi
DO	8.55	8.5	97.8	0.085285	8.340878
EC	7.4	7	105.7143	0.10356	10.94782
TDS	367.5	500	73.5	0.00145	0.106564
THW	190	500	38	0.00145	0.055094
Ca	207.5	300	69.16667	0.002416	0.167135
Mg	45.2	70	64.57143	0.010356	0.668704
Na	36.5	30	121.6667	0.024164	2.939965
K	11.5	200	5.75	0.003625	0.020842
nitrite	2.95	20	14.75	0.036246	0.534631
Cl	0.005	1	0.5	0.724923	0.362461
bicarbonate	60.35	250	24.14	0.0029	0.069999
	197	200	98.5	0.003625	0.357025
				WQI	24.57111

Table6: WQI in the month of January

pH	Vi	Si	Qi	Wi	Wi Qi
DO	8.633333	8.5	101.5686	0.085285	8.662285
EC	7.566667	7	108.0952	0.10356	11.19439
TDS	396.6667	500	79.33333	0.00145	0.115021
THW	240	500	48	0.00145	0.069593
Ca	220	300	73.33333	0.002416	0.177203
Mg	45.2	70	64.57143	0.010356	0.668704
Na	36.5	30	121.6667	0.024164	2.939965
K	14.73333	200	7.366667	0.003625	0.026701
nitrite	4.5	20	22.5	0.036246	0.815538
Cl	0.16	1	16	0.724923	11.59877
bicarbonate	62.63333	250	25.05333	0.0029	0.072647
	194.3	200	97.15	0.003625	0.352131
				WQI	36.69294

Table7: WQI in the month of February

pH	Vi	Si	Qi	Wi	WIQi
DO	8.45	8.5	99.41176	0.085285	8.478337
EC	8.15	7	116.4286	0.10356	12.05739
TDS	422.5	500	84.5	0.00145	0.122512
THW	185	500	37	0.00145	0.053644
Ca	235	300	78.33333	0.002416	0.189285
Mg	45.2	70	64.57143	0.010356	0.668704
Na	36.5	30	121.6667	0.024164	2.939965
K	15.15	200	7.575	0.003625	0.027456
nitrite	6.95	20	34.75	0.036246	1.259554
Cl	0.1	1	10	0.724923	7.249229
bicarbonate	65.5	250	26.2	0.0029	0.075972
	212	200	106	0.003625	0.384209
				WQI	33.50626

Table.8 WQI in the month of March

	Vi	Si	Qi	Wi	WiQi
pH	8.2	8.5	99.9	0.085285	8.519976
DO	7.9	7	112.8571	0.10356	11.68753
EC	395	500	79	0.00145	0.114538
TDS	280	500	56	0.00145	0.081191
THW	245	300	81.66667	0.002416	0.19734
Ca	45.2	70	64.57143	0.010356	0.668704
Mg	36.5	30	121.6667	0.024164	2.939965
Na	16.5	200	8.25	0.003625	0.029903
K	7.5	20	37.5	0.036246	1.35923
nitrite	0.2	1	20	0.724923	14.49846
Cl	68.5	250	27.4	0.0029	0.079452
bicarbonate	238.5	200	119.25	0.003625	0.432235
				WQI	40.60853

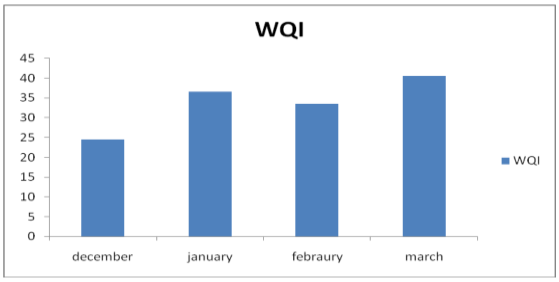

Fig.3: WQI in various seasons analyzed

Fig.4: WQI in different seasons

REFERENCES

1. Kuyucak, N., 2002. Acid mine drainage prevention and control options. CIM Bulletin 95 (1060): 96–102.
2. Filipek, L.H., Hatton, C., Gusek, J. and T. Tsukamoto, 2003. Passive treatment of acid rock drainage (ARD): state of the practice. In: Proceedings of the Tenth International Conference on Tailings and Mine Waste, October, 2003, Colorado, USA, pp. 293–303.
3. Modis, K., Adam, K., Panagopoulos, K. and A. Komtopoulos, 1998. Development and Validation of a geostatistical model for prediction of acid mine drainage in underground sulphide mines. J. Trans. Instn. Min. Metall. (Sect A: Min. Industry), A102–A107.
4. Fiset, J.F., Zinck, J.M. and P.C. Nkinamubanzi, 2003. Chemical stabilization of metal hydroxide sludge. In: Proceedings of the X International Conference on Tailings and Mine Waste, October 2003, Vail, CO, USA, AA Balkema, pp. 329–332.
5. Biswas A K and Tortajada C, Development of large dams: A global perceptive, Inernat J Water Resources Devel, 17, 2001, pp 9-21.
6. Ganesan M, jayabalan N and Jegatheesan K, Environmental status and Seasonal variation in the water quality studies of Pilavakka reservoir at Western Ghats in India, J Plant Archieves, 4, 2004, pp195-201.
7. Hatim E and Ozlem G, Influences of waste water discharges on the water quality of Mamasm dam watershed in Aksaray, Central Anatolian part of Turkey, J.Environ Geology, 48, 2005, pp 829-834.
8. Singh A K, Mondal G C, Singh P K, Singh S, Singh T B and Tewary B K, Hydrochemistry of reservoirs of Damodar river basin, India: weathering process and water quality assessment, J. Environ Geology, 48, 2005, pp 1014-1028.
9. http://en.wikipedia.org/wiki/Gosthani_River
10. http://en.wikipedia.org/wiki/Vizianagaram
11. http://irrigation.cgg.gov.in/dp/VizayanagaramDistrictProfile.jsp
12. Lenore S C, Arnold E G and Trussel R R, Standard methods for the Examination of Water and Waste water, 17th Edn (American Public Health Association, USA) 1989, 2.35-4.133
13. Manivasakam N, Physicochemical Examination of Water, Sewage and Industrial effluents, 4th Edn (Pragathi Prakashan, Meerut) 2002, pp 232-234.
14. http://en.wikipedia.org/wiki/Hard_water
15. http://hppcb.gov.in/eiasorang/spec.pdf