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Analysis of Groundwater Quality around Coimbatore Big Tank, Tamil Nadu, India

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Abstract: The pollution of tank water has resulted to the contamination of the groundwater which is a primary source (except drinking purpose) of the habitants around Coimbatore Big tank and Ukkadam, Coimbatore. Two sets of six groundwater samples were collected during the month of January and March 2013. Various Physico – Chemical characteristics like pH, Total Dissolved Solids, Turbidity, Alkalinity, Total Hardness, Chloride, Calcium, Magnesium, Sodium, Nitrate, Sulphate and Dissolved Oxygen were performed on the samples collected. Based on the results obtained from these tests, Water Quality Index (WQI) was calculated using Weighted Arithmetic Index Method for the sample locations. The results of these calculations were revealed that the WQI were ranged between 70 and 115 which represents that the groundwater quality was in the range of very poor to unfit for drinking purposes. G-1 was shown the lowest WQI value (70.18) and indicated that the pollution was less when compared with other samples. The values of all parameters of G-1 sample exhibited reduction in concentrations when compared with the other samples. G-2 showed high WQI value (115) due to extremely high concentrations of all parameters. Samples G-3, G-4 and G-6 had very poor drinking water quality and sample G-1 was poor in quality for drinking. Samples G-2 and G-5 were found unfit for drinking purposes. Except G-2 and G-5, in other sample locations the WQI values decreased when compared to the January month and showed slight improvement in groundwater quality. Based on the SAR value, all the sample locations were come under S1 category. Sample locations G-1, G-4 and G-5 were classified as doubtful (C3) for irrigation usage on the basis on conductivity. When SAR and conductivity values were combined, G – 1, G-4 and G-5 waters might be used for irrigation. Water from other sample locations is not suitable for irrigation purposes also.

Keywords: *physico-chemical characteristics, groundwater quality, water quality index, Ukkadam tank.*

1. Introduction

Groundwater is water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations. Groundwater is recharged from, and eventually flows to, the surface naturally; natural discharge often occurs at springs and seeps, and can form oasis or wetlands. Groundwater is also often withdrawn for agricultural, municipal and industrial use by constructing and operating extraction wells. For the past few decades, there has been an acute demand for water resources. Industrial growth, population growth, and other developmental activities have resulted not only in a high demand for water, but also in the degradation of quality, which aggravated the water crisis. Water pollution is a growing danger in many developing countries including India. A polluted environment has a detrimental effect on the health of people, animal life and vegetation. Pollution of surface bodies has resulted in the contamination groundwater quality. Groundwater is an important source for domestic, agricultural and industrial use. Due to this fact, it becomes essential for continuous monitoring of the quality of groundwater for minimizing ground water pollution.

Coimbatore, also known as Kovai, is the second largest city and urban agglomeration in the Indian state of Tamil Nadu. It is a major industrial, commercial and educational hub of Tamil Nadu and has often been referred to as the "Manchester of South India". The city is located on the banks of the Noyyal River surrounded by the Western Ghats and is administered by the Coimbatore Municipal Corporation. One of the various natural water storage tanks are present in Coimbatore, Coimbatore Big Tank and its sub – basin areas was selected as the study area. The location of the study area is shown in Fig.1.

The study area is located at the western side of Coimbatore City within the corporation limit on the Palghat/Pollachi highway. This tank is located at latitude 10° 59.103' N and longitude 76° 56.959' E**.** The catchment area and storage capacity of Coimbatore Big Tank is around 63 Sq. Km. and 2.75Mm^3. Coimbatore Big Tank receives water during South – West and North

– East monsoons. The tank has a number of outlets where excess water can be sent to other tanks. Since monsoons have failed over the recent years, the tank has dried up. Coimbatore City receives its domestic water supply from Pilloor and Siruvani dams. But in recent years, Coimbatore City has seen a geometrical increase in size and population, so the demand for water has been rising up. Whenever the failure of monsoons occurs, the residents of the city are forced to opt for the alternate which may be groundwater.

The users are not aware of the level of contamination of the water resources which he/she uses for his/her domestic chores. This may lead to a lot of health problems amongst them.

In order to create public awareness of the danger that the contaminated water might cause, water quality must be revealed in a manner that can be understood by the public easily. Simple technique to provide such data can be achieved by a process called Water Quality Index (WQI).

When the other methods express the quality by means of complex individual values, WQI summarizes large amounts of water quality data into simple terms (e.g., excellent, good, bad, etc.) for reporting to management and the public in a consistent manner [3].

The main objective of a water quality index of a sample is to turn complex water quality data into information that is understandable and useable by the public. This index uses the various physico – chemical characteristics that provide a number which gives an idea about the quality of water present in the locality. This number would be clear enough for the users to know about the quality of water, thus creating awareness about what might endanger to them.

The litho-logical characteristics of the tank include gneiss and other basic intrusive. The aquifer of the area is discontinuous with secondary inter-granular porosity and fractures. Due to the inadequate maintenance of outlets except surplus weir may not be used for delivering the excess water. Also, due to the continuous deposit of silt, the storage capacity of the tank has reduced. The water from the Noyyal River may carry some pollutants and that may be adding pollution to the tank water.

To study the impact of this pollution in groundwater, this groundwater quality study was carried out. The outcomes of this study will help to know about the quality of groundwater for domestic purposes and extend of treatment required. Also, to identify the suitability for irrigation purposes

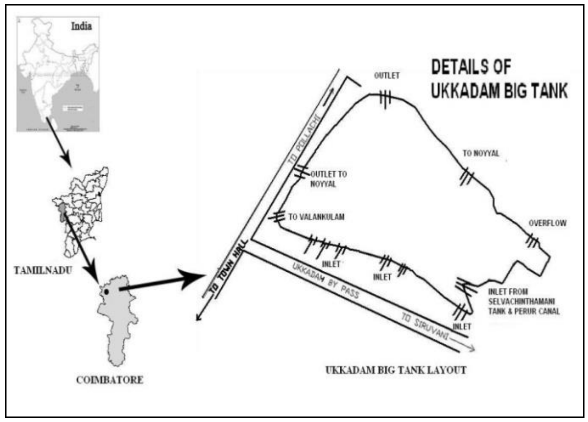

Figure 1 *Location of Coimbatore Big Tank*

2. Review of literature

Rizwan Reza and Gurdeep Singh [9] conducted a research on WQI of groundwater in Angul - Talcher region of Orissa. Twenty four groundwater samples were collected from open and tube wells during summer and post-monsoon seasons. From ten parameters, WQI was calculated by Weighted Arithmetic Index method for the study area. Hariharan et.al. [6] carried out physico – Chemical analysis of well and bore well water samples from eight sampling sites of Guntur rural area for the month of February 2010. The analysis of different parameters namely pH, turbidity, colour, total alkalinity, total hardness (TH), chloride (Cl^-), sulphate(SO^{4-}), nitrate (NO^{3-}), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) were carried out as per standard methods. The study aimed to calculate water quality index (WQI) in order to assess the suitability of water for drinking purposes. The results obtained on WQI from different sampling stations were found to be varied from 38.3 to 42.6. Water quality of river Cauvery in Tiruchirappalli district was monitored by Kalavathy et.al. [7] for a period of 3 months (January - March, 2009). Water samples were assessed by analyzing the various physico-chemical parameters such as pH, total dissolved solids, total hardness, total alkalinity, dissolved oxygen, biological oxygen demand, chloride, sulphate, nitrate and calcium (Ca^{2+}). These 10 parameters were considered to compute the Water Quality Index (WQI). The main objective of their study was to link the quality of water in river Cauvery through WQI in Tiruchirappalli city. Ahmad Khwakram et. al. [1] investigated the quality of water in Qalyasan stream in Sulaimaniyah city, Iraq. Preliminary survey showed that the stream was used as a source for irrigation and drinking water. But, the good quality of the stream changed from protected to impacted and finally degraded. The main objectives of their study was to examine and evaluate the water quality of Qalyasan Stream based on the Physico-chemical characteristics and to identify the most serious pollutant parameters which caused alterations to ascertain the quality of stream water. For this, water quality index (WQI) was calculated by the analysis of thirteen physico-chemical parameters on the basis of Weighted Arithmetic Index method in order to assess the suitability of water for drinking and irrigation. Priya et. al. [8] conducted a research on groundwater quality by using WQI for the Singanallur sub – basin in Coimbatore city. For this study, twenty one samples were collected and tested for nine parameters such as Cl^-, TDS, TH, Ca^{2+}, Magnesium (Mg^{2+}), Dissolved Oxygen (DO), pH, Alkalinity and SO_4^{2-}. The calculated WQI was combined with ArcGIS to easily understand the spatial variations of quality in the study area. Srinivas Kushtagi and Padaki Srinivas [10] studied the groundwater quality index for Chincholi taluka of Gulbarga district. Water samples from tube wells, open wells and hand pumps at various locations were collected using standard procedural methods. The water quality parameters such as pH, total hardness, calcium, magnesium, chloride, total dissolved solids, fluoride, nitrate and iron were analyzed on the samples collected. Their study revealed that groundwater of Chincholi taluka needs some degree of treatment before consumption. The study of Bharti N Katyal [3] concluded that NSF (National Sanitation Foundation), Bhargava, OIP (Overall Index of Pollution), Oregon and Ved prakash water quality indices which uses the weighted arithmetic average and the modified weighted sum provided the best results for the indexation of the general water quality. Similarly, the weighted geometrical average has been widely used, especially where there is a great variability among samples. It stated that, minimum period of one year data is often used in CCME (Canadian Council of Ministers of the Environment) WQI method [5] because data are usually collected to reflect this period (monthly or quarterly monitoring data).

3. Materials and Methods

Two sets of six samples were collected from the bore wells around the Coimbatore Big tank during the months of January and March 2013. The sample well locations are given in Table 1 and the aerial view of the same is shown in Fig.2.

Table 1: *Sample well locations in Coimbatore Big Tank*

Well No.	Sample Locations
G-1	Kempetty Colony, behind ABT maruthi showroom
G-2	Near Petrol bunk, Perur bypass road
G-3	Bharathi colony, Sundakamuthur road
G-4	Near Lorry pettai, Aathupalam road, Ukkadam
G-5	Asad nagar, karumbukadai
G-6	Garden Colony, Ukkadam bypass road

The samples were collected and tested based on the specifications prescribed in APHA [2]. Various Physico – Chemical characteristics like pH, Total Dissolved Solids, Turbidity, Alkalinity, Total Hardness, Chloride, Calcium, Magnesium, Sodium, Nitrate, Sulphate and Dissolved Oxygen were performed on the collected samples. These parameters were selected based on the literatures collected to study the pollution level. The standard permissible values of the parameters are presented in Table 2. For this study, CCME WQI and Weighted Arithmetic Index methods were considered. Since the data available was small, CCME WQI method could not be adopted, Weighted Arithmetic Index method was undertaken in this study. Based on this method, Water Quality Index (WQI) of sample locations was estimated from the test results.

Figure 2 *Aerial view of Coimbatore Big Tank and tank water and groundwater sample locations*

Table 2: *Adopted permissible limits and their recommended agencies.*

S. No.	Parameters	Recommended agencies	Permissible limits
1	Turbidity (NTU)	BIS/ ICMR/ WHO	5
2	Total Dissolved Solids (mg/L)	BIS/ ICMR	500
3	pH	BIS/ WHO/ CPCB	6.5 – 8.5
4	Total Alkalinity (mg/L)	BIS	200
5	Total Hardness (mg/L)	BIS/ ICMR	300
6	Calcium (mg/L)	BIS/ ICMR	75
7	Magnesium(mg/L)	BIS	30
8	Sodium (mg/L)	WHO	200
9	Nitrate (mg/L)	BIS	45

10	Chloride (mg/L)	BIS/ WHO	250
11	Sulphate (mg/L)	BIS/ ICMR	200
12	DO (mg/L)	CPCB	6

The calculation of WQI was done using drinking water standards recommended by the World Health Organization (WHO), Bureau of Indian Standards (BIS), Indian Council for Medical and Research (ICMR) and Central Pollution Control Board (CPCB). The Weighted Arithmetic Index Method [4] was adopted for the calculation of WQI. Further, the quality rating of sub index (q_n) was calculated using the Eq. 1.

$$q_n = 100 \times \left(\frac{V_n - V_{io}}{S_n - V_{io}} \right) \quad (1)$$

Where,

q_n **-** Quality rating for the n^{th} water quality parameter.

V_n - Estimated value of n^{th} at the given sampling station.

S_n - Standard permissible value of n^{th} parameter

V_{io}-Ideal value of n^{th} parameter in pure water (i.e., 0 for all parameters except parameters pH and Dissolved Oxygen (7.0 and 14.6 mg/l) respectively)

Let there may be 'n' water quality parameters and quality rating of sub index (q_n) corresponding to n^{th} parameter reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value. Unit value was calculated by a value inversely proportional to the recommended standard value (S_n) of the corresponding parameter. The Unit weight (W_n) of various water quality parameters is inversely proportional to the recommended standards for the corresponding parameters and the same is shown in the Eq.2.

$$W_n = \left(\frac{k}{S_n} \right) \quad (2)$$

Where,

W_n = unit weight for n^{th} parameter.

S_n = standard permissible value for n^{th} parameter.

k = proportionality constant.

The overall Water Quality Index was calculated by aggregating the quality rating with the unit weight linearly and it can be expressed as in Eq.3.

$$\text{WQI} = \frac{\sum q_n x W_n}{\sum W_n} \quad (3)$$

The water quality of the samples was rated based on Hariharan et.al. [6] and the same is given in Table 3.

Table 3: *Water quality Index Level and water quality status*

Water quality index level	Water quality status
0 -25	Excellent
26 – 50	Good
51 – 75	Poor
76 – 100	Very Poor
>100	Unfit for drinking

Conductivity data can help irrigators assess the suitability of water for irrigation; however, the suitability of water for irrigation is a function of both conductivity and SAR. Sodium Adsorption Ratio (SAR) expresses the relative activity of sodium ions in the exchange reactions with the soil. This ratio measures the relative concentration of sodium to calcium and Magnesium. Sodium Adsorption Ratio (SAR) is calculated based on the eq.4.

$$\text{SAR} = \frac{\text{Na}^+}{\left(\frac{\text{Ca}^{2+} + \text{Mg}^{2+}}{2} \right)^{1/2}} \quad (4)$$

Water quality is assessed based on SAR level and Conducutivity values and their classification [11] are given in Table 4 and 5.

Table 4: *Water quality based on SAR Level*

Sodium Hazard Class	SAR level	Water quality status
S1	10	Excellent
S2	10 - 18	Good
S3	18 - 26	Doubtful
S4 and S5	> 26	Unsuitable

Table 5: *Salinity hazard based on conductivity Level*

Salinity Hazard Class	EC in *micromhos/cm*	Water quality status
C1	100 - 250	Excellent
C2	250 – 750	Good
C3	750 - 2250	Doubtful
C4 and C5	> 2250	Unsuitable

4. Results and Discussions

The test results of samples collected in January and March 2013 are given in Table 6.

Table 6: *Test results of ground water samples – January and March 2013*

PARAMETER	January 2013						March 2013					
	G-1	G-2	G-3	G-4	G-5	G-6	G-1	G-2	G-3	G-4	G-5	G-6
Turbidity	3	2	4	4	3	4	2	5	1	2	4	3
Total Dissolved Solids	1680	2954	2779	1960	1946	2653	1771	2947	2569	2037	2282	2947
pH	6.52	6.56	6.69	7.39	7.35	7.34	7.11	7.26	7.45	7.29	7.35	7.16
Total Alkalinity	438	640	580	490	480	640	480	790	660	540	600	780
Total Hardness	590	1120	1010	690	690	890	660	1090	950	730	890	1100
Calcium	157	299	269	184	184	237	176	291	253	192	236	290
Magnesium	47	90	81	55	55	71	53	87	76	58	71	88
Sodium	238	410	390	295	285	390	228	422	336	286	308	418
Nitrate	44	112	66	50	49	88	45	84	66	54	56	88
Chloride	410	550	840	470	460	600	410	680	630	460	540	660
Sulphate	108	302	120	160	164	280	125	206	152	172	121	216
DO	6.5	6.3	7.1	6.9	6.5	6.8	6.6	6.5	7.4	7.1	6.8	7.1

**except turbidity and pH, unit for all others is mg/l.*

From the Table 6, the following observations were made. pH values were within BIS standards in both the months but in samples G-1, G-2 and G-3, the pH values were slightly increased. But G-4 and G-6 had shown decrease in values during the month of March. In G-5 sample location, the pH values were constant in the case of G-5 sample location. These slight changes in pH may be due to effect of other parameters. In case of turbidity except G-3, all the samples locations were showed more or less no change and were within the permissible limit.

The Total Dissolved Solids were in extreme concentrations in both the months and the values were exceeding BIS standards. The concentration of TDS was found to be more increased in March when compared with January for all the samples. Generally, more concentration of TDS in groundwater may be due to the characteristics of soil strata. Also, the increase in TDS values may be due to the increase in concentrations of Ca, Mg, Na, Cl etc.

The pH alkalinity was zero in both the seasons. The alkalinity values were gone beyond the permissible limits in both the months. The concentration of Total Alkalinity increased in March when compared with January especially in G-6 (640 mg/l to 780 mg/l). The alkalinity was caused mainly due to bicarbonates.

The Calcium values were higher than the standard values in both the months. The concentration of Calcium content was increased in all the samples except G-4 (192 mg/l to 180 mg/l) and G-5 (236 mg/l to 194 mg/l). Magnesium concentrations were exceeding BIS permissible limits in both months. These values were in the ranges between 47 – 88 mg/l. When compared with samples collected in January, the magnesium concentrations increased in March. The high concentrations of Calcium and Magnesium indicates the soil may be high in calcium chloride and magnesium chloride. Due to the increase in calcium and magnesium concentrations, increase in concentration of Hardness was observed. Hardness values exceeded the permissible values in all locations for both the months. Sample G-6 showed increase in concentrations of hardness (890 – 1100 mg/l) between the January and March months.

Sodium concentration exceeded WHO standards (200 mg/l) in all the sample locations. The values of sodium at G-1 location were slightly higher than the permissible value. G-5 (285 to 308 mg/l) and G-6 (390 to 418mg/l) showed increase in concentrations when compared with samples collected in the month of January.

Sample G-2 (112mg/l to 84 mg/l) showed a decrease in nitrate concentration levels when compared with the sample collected in the month of January. Sample G-1 (44 and 45mg/l) was within the BIS permissible limits (45mg/l) for both months. The reason for increased nitrate concentration may be due to the disposal of domestic and animal wastes in and around the tank. This disposal of waste leads to decomposition of the waste which emit a lot of pollutants like methane, NO_3 etc.

In the case of chlorides, except the samples G-1 (410 mg/l and 410 mg/l) and G-3 (840 and 630 mg/l) the rest of the samples exhibited increase in concentrations. In both the months, chloride concentrations exceeded the BIS permissible limits. Sulphate concentrations increased gradually in March when compared with the month of January, except for samples G-2 (302 – 206mg/l), G-5 (164 - 121mg/l) and G-6 (280 – 216mg/l). Sulphate concentrations of Samples G-2 and G-6 exceeded the BIS permissible limits in both the months.

In case of concentration of Dissolved Oxygen, all the values slightly exceeded the CPCB standards in both months. The values ranged between 6.3 and 7.4 in both seasons. These values showed that the domestic sewage might have been disposed in all parts of the tank.

Table 7: *Water Quality Index values for sample locations*

Sample Locations	January	March
G – 1	91.75	70.18
G – 2	106.13	115.07
G – 3	104.25	87.34
G – 4	97.09	79.89
G – 5	89.68	101.75
G – 6	105.47	95.56

From Table 7, it was observed that the WQI values were ranging between 89 and 106 for the month of January. G-5 showed the lowest WQI (89) value indicating the pollution was less when compared with other samples. G -2 showed high WQI value (106) due to very high concentrations of TDS and Hardness. Except G-1, G-4 and G-5, the WQI values of remaining samples were more than 100 which indicated that water in those locations were unfit for drinking purposes. In the month of March, the WQI values were found in between 70 and 115 which was an indication that the groundwater quality varies from very poor to unfit for drinking. G-1 was shown the lowest WQI value (70.18) and indicated that the pollution was less when compared with other samples.

All the parameters of this sample exhibited reduction in concentrations when compared with the other samples. G -2 showed high WQI value (115) due to extremely high concentrations of all parameters. Samples G-3, G-4 and G-6 had very poor drinking water quality and sample G-1 was poor in quality for drinking based on WQI index. Samples G-2 and G-5 were found unfit for drinking purposes. Except G-2 and G-5, in other sample locations the WQI values decreased when compared to the January month and showed slight improvement in groundwater quality.

Quality of water samples were analyzed for irrigation purposes based on SAR values and calculated conductivity values. SAR and calculated conductivity values are presented in Table 8.

Table 8: *SAR and Conductivity values for sample locations*

Sample Locations	January		March	
	SAR	Conductivity	SAR	Conductivity
G – 1	4.28	1939.3	3.87	1746.5
G – 2	5.34	3019.3	5.58	2755.7
G – 3	5.34	3168.3	4.76	2428.4
G – 4	4.9	2250.1	4.64	2039.9
G – 5	4.74	2220.7	4.51	2190.4
G – 6	5.71	2888	5.52	2736.8

SAR values were in the range of 4.28 to 5.71 during January and 3.87 to 5.58 during March. Except in G- 2, SAR values of January were declined when compared with March readings. Based on the SAR value, all the sample locations were come under S1 category (Excellent) and suitable for irrigation.

Conductivity values were in the range of 2220.7 to 3168.3 micro-mhos/cm and 1746.5 to 2755.7 micro-mhos/cm during January and March months respectively. G-1, G-4 and G-5 samples were come under the class C3 which is doubtful for irrigation uses. In other locations, conductivity values were greater 2250 micro-mhos/cm and they come under the class C5 which is unsuitable for irrigation uses. In all sample locations, the conductivity values were decreased during March compared with January.

Based on the SAR values, all the samples were classified as excellent only. But based on conductivity values, all samples were unsuitable for irrigation and they were categorized as very high salinity.

Further, when using both SAR and conductivity values, the samples G-1, G-4 and G-5 were classified as S1 - C3 and while the other samples under S1- C5. So that, water from sample locations G-1, G-4 and G-5 might be used for irrigation.

5. Conclusions

This study clearly revealed that all the samples were polluted and it should be treated before the consumption. From the WQI values it clear that except G – 1and G - 4, all the other samples were highly polluted and they cannot used for domestic purposes without treatment. G-1 was shown lowest WQI value, whereas G-2 exhibited highest. G-1 can be graded as poor; G-2 and G-5 are unfit. G-3, G-4 and G-6 can be considered as very poor quality for drinking purposes. Based on the SAR value, all the sample locations were come under S1 category. Sample locations G-1, G-4 and G-5 were classified as doubtful (C3) for irrigation usage on the basis of conductivity. When SAR and conductivity values were combined, G – 1, G-4 and G-5 waters might be used for irrigation. Water from other sample locations is unsuitable for irrigation purposes also. In future, better water quality can be managed by adopting other methods of WQI to predict the water quality with the increase in volume of data. It will help to monitor the quality of tank water in a better way.

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