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Water Quality Index For Assessment Of Water Quality In South Chennai Coastal Aquifer, Tamil Nadu, India

Bhuvana Jagadeeswari P.* and K. Ramesh

Centre for Water Resources, Dept of Civil Engineering, Anna University, Chennai – 600 025, India.

Corres.author: bhuvana.palanisamy@yahoo.com, rameshkannan1975@yahoo.com, Contact No: +91 9003882868

Abstract: Water quality of South Chennai coastal aquifer was evaluated by Water Quality Index (WQI) technique. The objective of an index is to turn complex water quality data into information that is understandable and useable by the public. Twenty two groundwater samples were collected and analyzed for the physico-chemical parameters during pre-monsoon (August, 2011) and post-monsoon (January, 2012) seasons. Ten most important parameters such as pH, total dissolved solids (TDS), total hardness (TH), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), bicarbonate (HCO_3^-), chloride (Cl^-), sulphate (SO_4^{2-}) and nitrate (NO_3^-) were taken for the calculation of WQI. The WQI values of South Chennai coastal aquifer ranged from 36.85 to 302.46 in pre-monsoon season and from 32.74 to 262.54 in post-monsoon season. The values of WQI near the seacoast and Buckingham Canal were high due to the seawater influence near the seacoast and presence of clay patches and intrusion of the stagnant water from the Canal respectively, which shows that the water was unsuitable for drinking. It is concluded that WQI can be used as a tool in comparing the water quality of different sources. It gives the public a general idea of the possible problems with water in a particular region. The indices are among the most effective ways to communicate the information on water quality trends for the water quality management.
Keywords: Coastal Aquifer, Seawater Intrusion, Urbanization, Water Quality Index.

Introduction

Water is an essential component for survival of life of Earth, which contains minerals, important for human beings as well as plant and aquatic life. Freshwater is a finite and a vulnerable resource, essential to sustain life, development and the environment. Groundwater though contributes only 0.6% of the total water resources on earth, it accounts for nearly 80% of the rural domestic water needs and 50% of the urban water needs in the developing countries like India (1). The groundwater resources are at higher risk as its remediation is very difficult. The major anthropogenic activities for continuous groundwater quality deterioration are urbanization, industrialization and agriculture runoff.

Freshwater quality and availability remain one of the most critical environmental and sustainability issues of the twenty – first century (2). Assessment of water quality is a critical component of diagnosing overall health of aquatic ecosystems. Assessment requires two components, measurement of water quality parameters and comparison of measures to benchmarks such as guidelines and objectives to assess change. Water quality may be assessed both spatially and/or temporally (3). A water quality index provides a single number (like a grade) that expresses overall water quality at a certain location and time based on several water quality parameters. WQI can be used as a tool in comparing the water quality of different sources. A water quality index is a means to summarize large amounts of water quality data into simple terms (e.g., good) for reporting to management and the public in a consistent manner.

The present study was carried out with the main objective of calculating the water quality index and presents spatial and temporal variations of water quality index of South Chennai coastal aquifer for the months of August, 2011 and January, 2012 in order to assess the suitability of its water for human uses. This region has major difficulties in managing its water resources, which are in decline leads to seawater intrusion; especially that during the pre-monsoon season, it has been suffering from the deterioration of groundwater quality. This alarming situation necessitates the present study to generate the water quality index map for designing suitable water management plans in South Chennai coastal aquifer.

Study Area And Methodology

The area chosen for the study is South Chennai coastal aquifer. The South Chennai coastal aquifer system covers the area between latitudes 12°48’15’’ N and 12°59’15’’ N and between longitudes 80°10’13’’ E and 80°16’30’’ E and lie in part of Chennai city and coastal Kancheepuram district. The study area lies from Thiruvanmiyur to Muttukadu, which is located in the Southern part of Chennai (Figure 1) and falls in the survey of India toposheet nos. 66 D/1 and 66 D/2. Geologically, the study area comprises quaternary sediments made up of clay, silty clay, and sand deposits (4). The presence of Buckingham Canal along the West containing stagnant contaminated water and the Bay of Bengal along the East threatens the aquifer in the form of groundwater contamination. The study area has a humid and subtropical climate. The maximum temperature in this area is about 42°C and a minimum temperature of about 20°C. Summer (April-May) temperature varies from 35°C to 42°C and in winter (December – January) it ranges from 20°C to 34°C. The average relative humidity varies from a maximum of 84 per cent in December to a minimum of 58 per cent during the month of May (5). The annual average rainfall is about 1200 mm. The settlements and urbanization are comparatively high in the Northern part than the Southern part of the area.

Major Elements were analyzed from 22 groundwater samples collected during pre-monsoon (August, 2011) and post-monsoon (January, 2012) seasons from bore wells and dug wells. Water samples collected in the field were analyzed for chemical constituents such as sodium, potassium, calcium, magnesium, chloride, bicarbonate, carbonate, sulphate, nitrate and total dissolved solids (TDS), in the laboratory using the standard methods as suggested by the American Public Health Association (6). Parameters like pH and EC were measured in the field by using portable pH and EC meter respectively. The water sample bottles were thoroughly washed with acid and then with distilled water in the laboratory before filling the bottle with the sample. The precise latitude and longitude of the sampling points were determined by Global Positioning System (GPS). The location of the sampling points is shown in Figure 2.

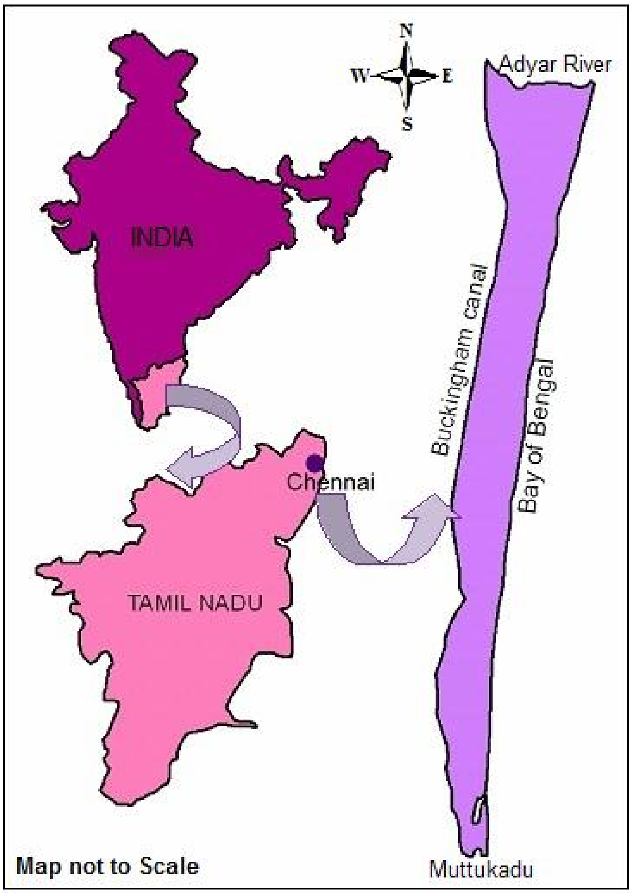

Figure 1: Location of the Study Area Map

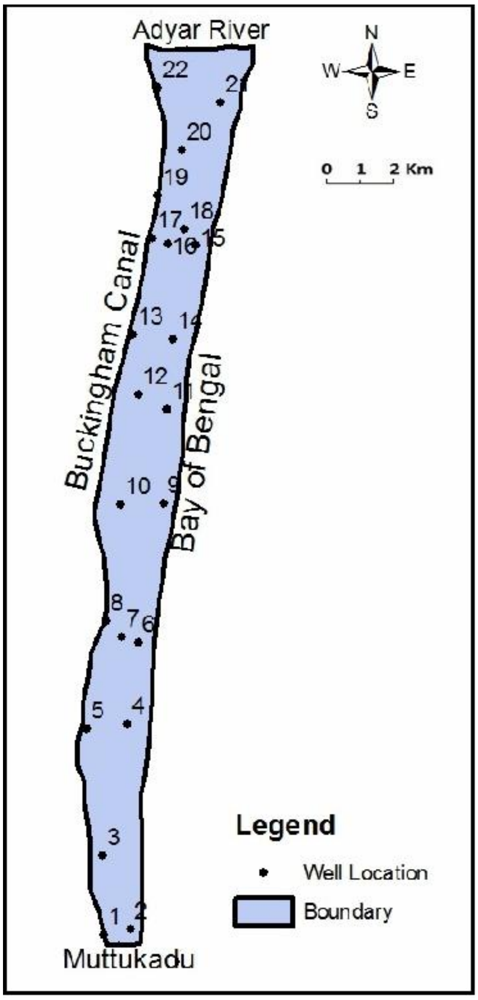

Figure 2: Well Location Map of the Study Area

Results And Discussion

The range and mean of physico-chemical parameters of 22 groundwater samples of the study area for both pre-monsoon and post-monsoon seasons are shown in Table 1. In general, pH of groundwater samples was slightly acidic to alkaline in nature. The EC values vary from 400 to 5600 µS/cm with an average value of 1750 µS/cm in pre-monsoon season whereas in post- monsoon season, it varies from 340 to 5270 µS/cm with a mean value of 1354 µS/cm. Sodium and chloride are the dominant ions of the study area. 40.9% of groundwater samples are above desirable limit of sodium in pre-monsoon season whereas in post-monsoon season, 31.8% of groundwater samples are above desirable limit. The possible source of sodium concentration in groundwater is due to the dissolution of rock salts, weathering of sodium bearing minerals and influence of seawater from the coast. 45.45% of groundwater samples are above desirable limit of chloride in pre-monsoon season whereas in post-monsoon season, 27.3% of groundwater samples are above desirable limit. The natural process such as weathering, dissolution of salt deposits and influence of seawater from the coast are responsible for chloride content in the groundwater. The box and whisker plot for the different water quality parameters are given in Figure 3 for pre-monsoon and in Figure 4 for post-monsoon seasons.

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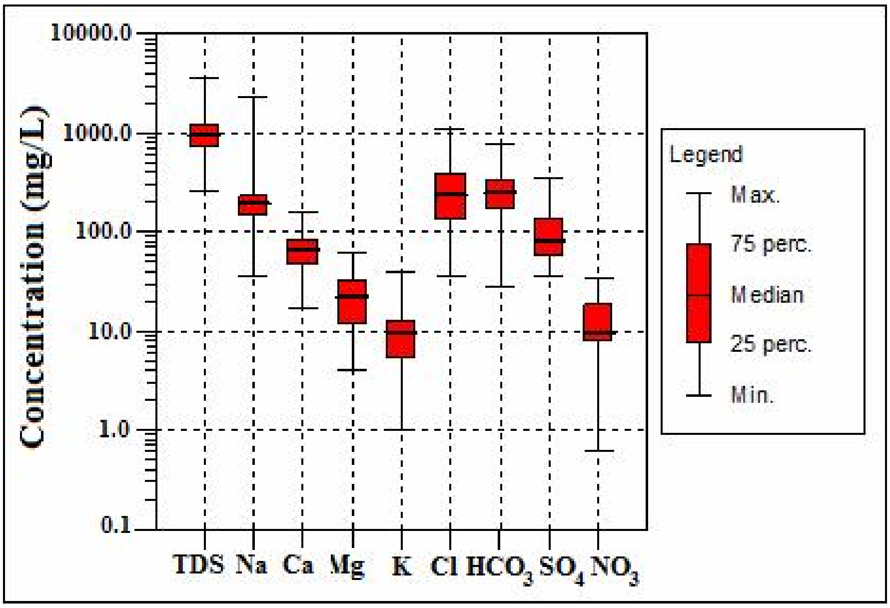

Figure 3: Box and Whisker Plot of Pre-monsoon season for different water quality parameters

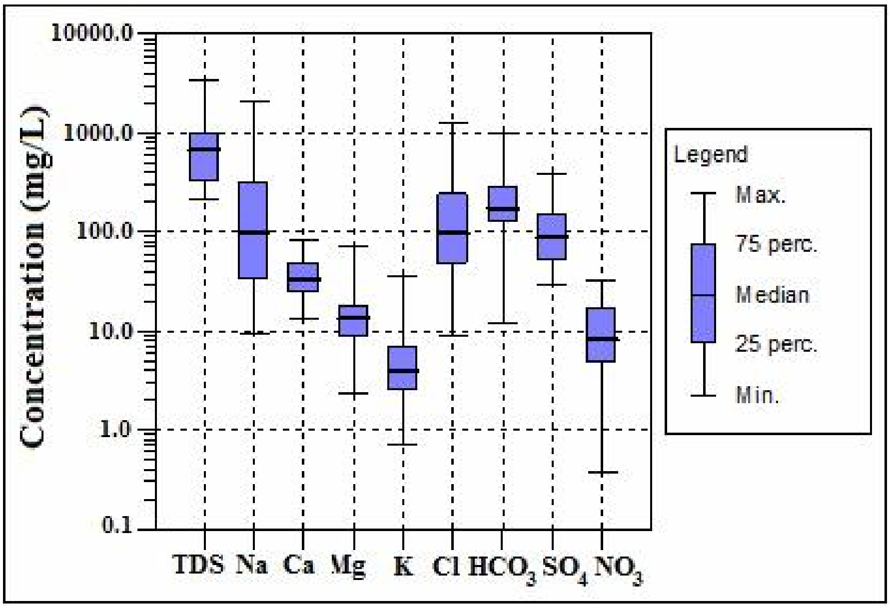

Figure 4: Box and Whisker Plot of Post-monsoon season for different water quality parameters

Table 1: Physico-Chemical Parameters of Groundwater Samples

Water Quality Parameters	Pre-monsoon		Post-monsoon		BIS standard	Samples exceeding desirable limit	
	Range	Mean	Range	Mean	Desirable	Pre-monsoon	Post-monsoon
pH	6.3 - 8.1	7.2	6.7 - 7.9	7.3	6.5	15	Nil
Total Dissolved Solids	256 – 3584	1120	218 - 3373	867	500	1, 2, 4, 5, 6, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21	1, 5, 6, 10, 11, 12, 13, 14, 15, 16, 19, 21
Total Hardness	58.9 - 645.1	270	42.3 - 500.3	167.6	300	1, 2, 10, 13, 15, 16, 19	5, 13,19
Calcium	17 – 158	67.5	13 - 84	37.6	75	1, 2, 6, 10, 15, 16	13, 19
Magnesium	4 – 61	24.7	2.4 - 70.8	17.9	30	1, 2, 10, 13, 15, 16, 19	5, 13
Sodium	36 – 2305	316	9.6 - 2045.2	273.3	200	1, 2, 5, 6, 10, 13, 15, 19, 21	5, 6, 13, 14, 15, 19, 21
Potassium	1 – 39	10.9	0 - 36	6.8	-	-	-
Chloride	36.3 - 1098.3	315	8.86 - 1248.4	208.4	250	1, 2, 5, 6, 10, 14, 15, 18, 19, 21	5, 6, 14, 15, 19, 21
Bicarbonate	27.6 – 788	276	12.2 - 982.1	241.1	300	1, 5, 8, 10, 13, 14, 15, 19	5, 10, 12, 19
Nitrate	0.6 - 34.7	13.6	0.38 - 32.6	11.6	45	Nil	Nil
Sulphate	35 - 341.7	111	29.1 - 379.5	122.5	200	12, 13, 19, 21	5, 13

Note: All units are in mg/L except pH

Water Quality Index

Water Quality Index is a very useful tool for communicating the information on overall quality of water. WQI is defined as a rating reflecting the composite influence of different water quality parameters. WQI is calculated from the point of view of the suitability of groundwater for human consumption (7). The procedure adopted by Sandow Yidana et al., 2010 (8) by developing Water Quality Index to determine the suitability of groundwater for drinking purposes conforming to World Health Organisation (WHO) standards was followed. However for the present study, the Bureau of Indian Standards (9) standard values have been adopted. The parameters considered for the calculation of the index included pH, TDS, TH, Ca^{2+}, Mg^{2+}, Na^{+}, HCO_3^-, Cl^-, SO_4^{2-} and NO_3^-. There were three steps to computing the WQI of a water sample. In the first step, each of the chemical parameters was assigned a weight (w_i) based on their perceived effects on primary health. The highest weight of five was assigned to parameters, which have the major effects on water quality. NO_3^- was assigned the highest weight because of their importance in the water quality assessment. The second step involved computing the relative weight (W_i) of each parameter using the equation given below:

$$W_i = w_i/\sum w_i$$

where $\sum w_i$ is the sum of the weights of all the parameters. In this study, $\sum w_i$ was 31. Table 2 presents the w_i, W_i, and the Bureau of Indian Standards (9) standard for each chemical parameter used in this study. In the third step, a quality rating scale, q_i, was computed for each parameter using the equation given below:

$$q_i = C_i/S_i*100$$

where C_i and S_i respectively refer to the concentration and the BIS standard for each parameter, in mg/L.

For computing the WQI, the SI is first determined for each chemical parameter, which is then used to determine the WQI as per the following equations given below:

$$SI_i = W_i*q_i$$

$$WQI = \sum SI_i$$

Computed WQI values are usually classified into five categories as given in Table 3 (7). The WQI values in this study are presented in Table 4. In this study, the computed WQI values ranges from 36.85 to 302.46 in pre-monsoon season and from 32.74 to 262.54 in post-monsoon season. Therefore, it can be categorized into five types, “excellent water” to “water, unsuitable for drinking”. Although only 18.18% of groundwater samples show “excellent” qualities in pre-monsoon whereas 40.91% in post-monsoon season, 31.82% are “good” quality in pre-monsoon and 36.36% in post-monsoon season, 45.45% are “poor” quality in pre-monsoon whereas 9.09% in post-monsoon season, 4.54% of water samples are “very poor” quality in post-monsoon season and 4.54% of the water samples fall in the category of “water, unsuitable for drinking” in pre-monsoon season. The spatial and seasonal variations of WQI are shown in Figure 5. It shows that the Northern coastal part of the area is more affected by groundwater quality compared to the Southern part of the area during pre-monsoon season which is due to the over-extraction of groundwater leads to seawater intrusion. During post-monsoon season, this area has been diluted by the rainfall occurred in monsoon season, instead the Southern part near the canal is more affected due to the intrusion of contaminated stagnant water from the canal.

Table 2: Relative Weight for Physico-Chemical Parameters

Physico-chemical parameters	**BIS standard**	**w_i**	**W**
pH	7.5	4	0.129032
Total Dissolved Solid (TDS)	500	4	0.129032
Total Hardness (TH)	300	2	0.064516
Bicarbonate (HCO_3)	244	3	0.096774
Calcium (Ca)	75	2	0.064516
Magnesium (Mg)	30	2	0.064516
Sodium (Na)	200	2	0.064516
Chloride (Cl)	250	3	0.096774
Nitrate (NO_3)	45	5	0.16129
Sulphate (SO_4)	200	4	0.129032
Sum		31	1

Table 3: Classification of Water Quality Index

WQI Value	Classification
<50	Excellent water
50–100	Good water
100–200	Poor water
200–300	Very poor water
>300	Water unsuitable for drinking

Table 4: WQI Classification for Pre- and Post-monsoon Seasons

Sample No.	WQI(Pre-monsoon)	Classification	WQI(Post-monsoon)	Classification
1	127.64	Poor	64.91	Good
2	161.22	Poor	34.51	Excellent
3	36.85	Excellent	32.74	Excellent
4	79.76	Good	43.62	Excellent
5	101.71	Poor	262.54	Very Poor
6	120.69	Poor	98.67	Good
7	43.01	Excellent	36.14	Excellent
8	77.35	Good	39.00	Excellent
9	71.14	Good	49.14	Excellent
10	130.43	Poor	77.97	Good
11	78.59	Good	69.49	Good
12	79.82	Good	89.66	Good
13	113.63	Poor	116.05	Poor
14	103.29	Poor	96.56	Good
15	187.48	Poor	118.42	Poor
16	102.20	Poor	67.38	Good
17	40.21	Excellent	38.86	Excellent
18	83.14	Good	45.62	Excellent
19	302.46	Unsuitable	239.12	Very Poor
20	80.83	Good	52.95	Good
21	111.19	Poor	131.45	Poor
22	47.02	Excellent	44.68	Excellent

Conclusions

The analysis of the water quality parameters of groundwater from the 22 different wells in South Chennai coastal aquifer shows that pH, TDS, sodium, potassium, calcium, magnesium, chloride, bicarbonate, nitrate, sulphate are well within permissible limits but above desirable limits. The dominant cation and anion of the groundwater samples are sodium and chloride respectively. The WQI has been calculated for the groundwater samples of South Chennai coastal aquifer which is ranged from 36.85 to 302.46 in pre-monsoon season and from 32.74 to 262.54 in post-monsoon season. The spatial and seasonal variations of WQI shows that the Northern coastal part of the area is more affected by groundwater quality compared to the Southern part of the area during pre-monsoon season which is due to the over-extraction of groundwater leads to seawater intrusion. The Southern part of the area near the canal is more affected in post-monsoon season due to the intrusion of contaminated stagnant water from the canal because of rainfall occurred in monsoon season. In order to save this coastal aquifer from further deterioration, optimization of groundwater extraction and adopting the rainwater harvesting system must be taken in the near future. The Water Quality Indices are among the most effective ways to communicate the information on water quality trends to the general public or to the policy makers and water quality management.

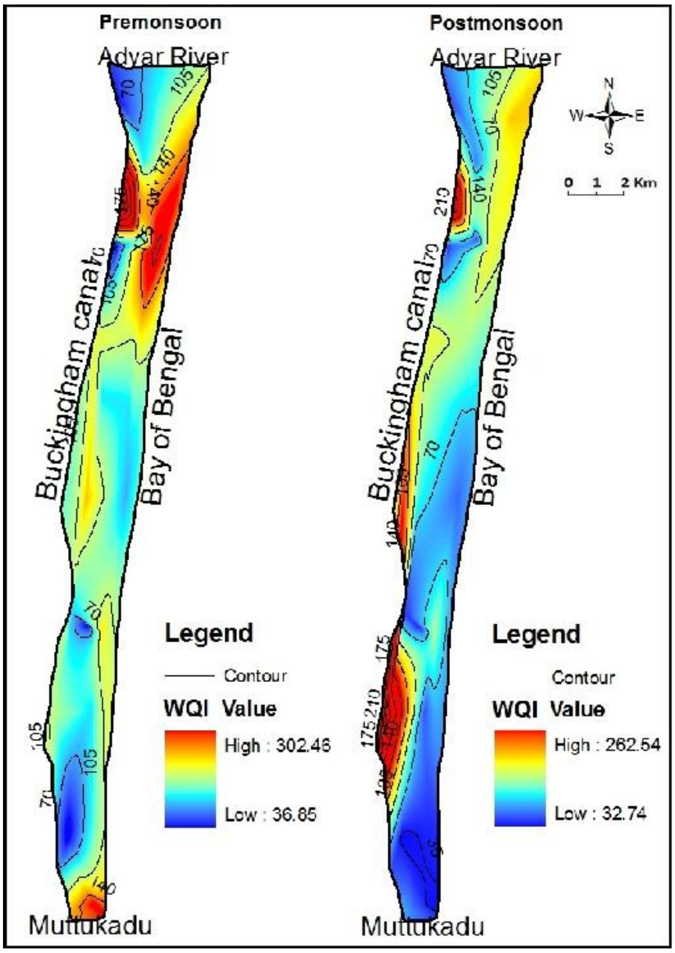

Figure 5: Spatial and Seasonal Variations of WQI

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