APPLICATIONS OF WATER QUALITY INDEX FOR GROUNDWATER QUALITY ASSESSMENT ON TAMIL NADU AND PONDICHERRY, INDIA

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ABSTRACT

Groundwater samples were collected from different locations around Karaikal area and analyzed for their physicochemical characteristics. Eight groundwater samples were collected (five from Pondicherry and three from Tamil Nadu, India and studied for the period of January 2011 to October 2011 for two different seasons. The present investigation is focused on the determination of physicochemical parameters such as pH, Electrical Conductivity (EC), Total Hardness (TH), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Chlorides (Cl^-), Sulphate (SO_4^{2-}) and Nitrate (NO_3^-). Groundwater suitability for domestic and irrigation purposes was examined by using WHO and BIS standards, which indicate the groundwater in a few areas, were not much suitable for domestic and agriculture purposes. Thus, the objective of this study is to identify the quality of groundwater especially in the Karaikal and nearby area whether groundwater is used for drinking and domestic purposes.

Key Words : Physico-chemical parameters, Quality parameters, Analysis, WQI, WHO, BIS

INTRODUCTION

Everything originated from the water and everything is sustained by water. All the life on earth depends on water. The origin of water on the earth is not clear so far. However, the current presumption is that the primordial earth had no oceans and perhaps very little atmosphere. It is believed that the volatile constituents bound in the earth's crust oozing to the surface through volcanoes, rock movements and hot springs condensed to form the ocean and the atmosphere. This way perhaps the remarkable combination of hydrogen and oxygen called water came into being and eventually became an indispensable component of the earth's crust. Water is not only essential to life but is the predominant inorganic constituent of living matter forming in general nearly three quarters of the weight of the living cell. The various forms of water are found in every section of ecosphere, the atmosphere, the lithosphere and the hydrosphere. Water is universal solvent and renewable resource. These unique properties of water make it to get polluted. The knowledge of hydrochemistry is essential to determine the origin of chemical composition of groundwater. Water quality is influenced by natural and anthropogenic effects including local climate, geology and irrigation practices.[1] The chemical character of any groundwater determines its quality and utilization. The quality is a function of the physical, chemical and biological parameters and could be subjective, since it depends on a particular intended use. Rapid increase in urbanization and industrialization leads in to deterioration in groundwater quality.[2] Water can be regarded polluted when it changes its quality or composition either naturally or as a result of human activities. Thus, becoming less suitable for drinking, domestic, agricultural, industrial and recreational purposes. The sources for ground water supply mostly depend upon the rainfall and the resulting percolation of the water into the earth. Another important factor is quality of the soil. A total of eight ground water samples were analyzed for pH, Electrical Conductivity (EC), Total Hardness (TH), Total Diss -olved Solids (TDS), Dissolved Oxygen (DO),

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Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Chloride (Cl^-), Sulphate (SO_4^{2-}) and Nitrate (NO_3^-). The quality of ground water was interpreted in terms of Water Quality Index (WQI).

MATERIAL AND METHODS

Study area

The study area Karaikal is located between TamilNadu and Pondicherry, India. Karaikal is a very old temple town in Pondicherry. It is on the east coast, about 135 km from Pondicherry and 300 km from Tamilnadu (Chennai) towards south. The town is small with a total of 161 sq km with marine time climate and located on the Koramandel coast of the Bay of Bengal. This small town is much seen by tourists as well as pilgrims. The town of Karaikal is the second largest region of the Union Territory of Pondicherry on the delta of the Cauvery River.

Geology

The total geographical rural area of the district is 140355-56 hectares, the percentage of cultivable area to total area and percentage of irrigated area to total cultivable area are 84.92 and 82.81 respectively. This shows that karaikal is predominantly an agricultural area. Agriculture is the most important economic activity in the district, both in terms of employment and output. Higher production is due to the existence of the coastal alluvium soil which is very suitable for the cultivation of paddy and pulses **(Fig.1)**.

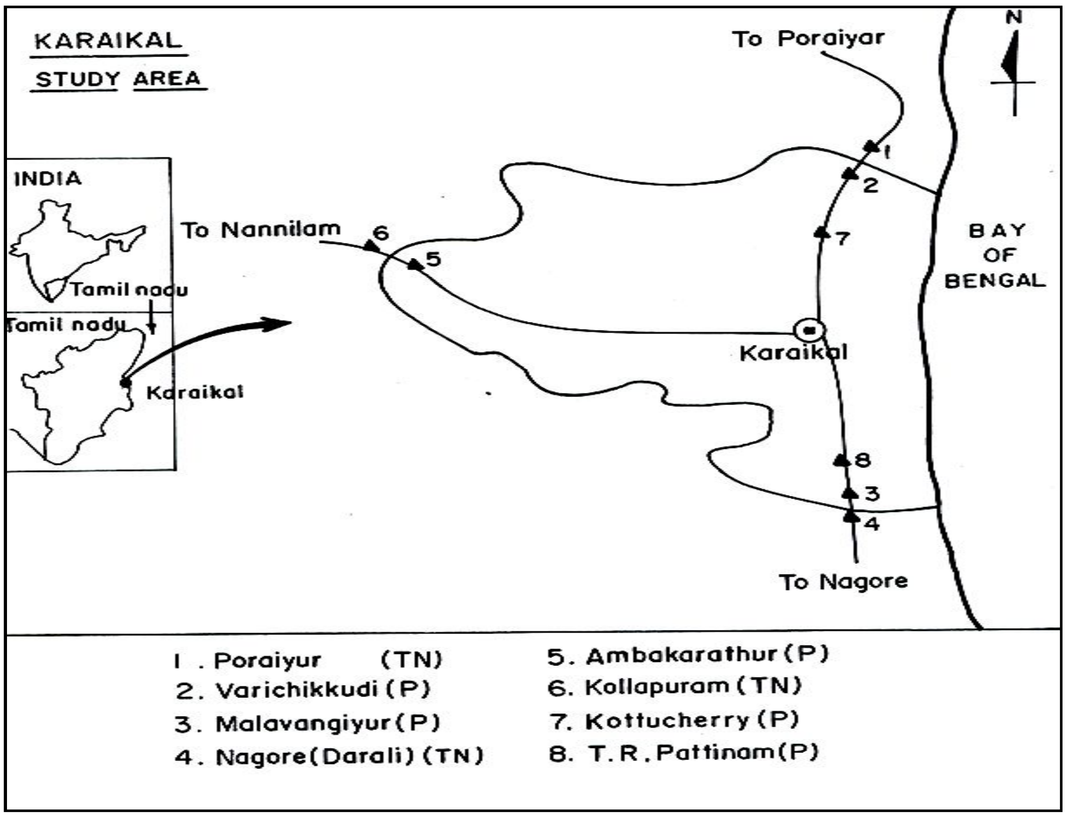

Fig. 1 : Location map of the Karaikal showing sampling stations

Sample collection

The physico-chemical analysis for the ground water samples were performed during Monsoon and Post-monsoon seasons (January-2011 to October-2011). The physico-chemical parameters such as pH, EC, TDS, DO, BOD, COD, TH, SO_4^{2-}, NO_3^- and Cl^- were analyzed. The areas in and around Karaikal were taken for our study. In two different seasons water samples were collected at various stations shown below **(Table 1)**. Water samples were collected in Polythene bottles of 2.5litres. The samples were collected from bore wells as well as from deep hand pumps at different seasons. It was ensured that the concentrations of various water quality parameters do not changes in time that elapses between drawing of samples and the analysis in the laboratory. For DO, BOD and COD separate 2 litres polythene bottles were used. The bottles were thoroughly cleaned with hydrochloric acid and then washed with tap water rendered free of acid and then washed with distilled water twice and again rinsed with the water sample to be collected and then filled up the bottle with the sample leaving only a small air gap at the top, stoppered and sealed the bottle with paraffin wax. Some samples which were turbid or containing suspended matter were filtered at the time of collection. All the glassware, casserole and other pipettes were first cleaned with tap water thoroughly and finally with deionised distilled water. The pipettes and burette were rinsed with solution before final use. The chemicals and reagent were used for analysis were of Analar grade. The pH meter, conductivity meter, spectrophotometer, flame photometer instruments were used to analyze these parameters. The procedure for calculating the different parameters were conducted in the laboratory. The groundwater samples were determined using standard methods and the results were compared with the values of World Health Organization.[3]

Table 1 : Sampling locations and sources

Sample no.	Sampling locations	Source
1	Poraiyur (TN)	Bore well
2	Varichikkudi (P)	Bore well
3	Malavangiyur (P)	Bore well
4	Nagore (Darali) (TN)	Bore well
5	Ambakarathur (P)	Bore well
6	Kollapuram (TN)	Bore well
7	Kottucherry (P)	Bore well
8	T. R. Pattinam (P)	Bore well

Water Quality Index (WQI)

Water Quality index (WQI) is defined as a technique of rating which provides the composite influence of individual water quality parameter on the overall quality of water. It is calculated from the point of view of human consumption. The average means concentration of the ten physico-chemical parameters such as pH, EC, TDS, DO, BOD, COD, TH, SO_4^{2-}, NO_3 and Cl^- was used for the calculation of WQI. The critical pollution index considered unacceptable is 100.[4]

The calculation involves the following steps

First, the calculation of weightage of i^{th} parameter.

Second, the calculation of the quality rating for each of the water quality parameters.

Third, the summation of these sub-indices in the overall index.

The weightage of i^{th} parameter

$$W_i = k/S_i \qquad (1)$$

Where W_i is the unit of weightage, Si the recommended standard for i^{th} parameter (I = 1-6) and k is the constant of proportionality.

Individual quality rating is given by the expression

$$Q_i = 100V/S_i \qquad (2)$$

Where Qi is the sub index of i^{th} parameter, Vi is the monitored value of the i^{th} parameter in mg/l and S_i the standard or permissible limit for the i^{th} parameter.

The Water Quality Index (WQI) is then calculated as follows

$$WQI = \sum_{i=1}^{n}(Qi\,Wi) / \sum_{i=1}^{n} Wi \qquad (3)$$

Where, Q_i is the sub index of i^{th} parameter,

W_i is the unit weightage for i^{th} parameter and n is the number of parameters considered.

Generally, the critical pollution index value is 100.

RESULTS AND DISCUSSION

The results regarding the mean values of various physico-chemical parameters of groundwater collected during the period 2011 at monsoon and post-monsoon are shown below in tables and figures. pH is the measure of acidity and alkalinity of water. The mean values are recorded within the range of 7.3-9.5 and 7.3-8.3 for groundwater samples in both seasons respectively (**Table 2** and **Table 3**).The most of the pH values are found to be within the permissible limit of WHO (6.5-8.5ppm). The pH value is an important factor in maintaining the carbonate and bicarbonate levels in water. The low pH does not cause any harmful effect. The variations in pH are relatively in small. Some of the samples have been found acceptable for usage and the ranges are between 7.3 and 9.5 meeting with WHO guidelines.

Table 2 : Variation of mean values of physico-chemical parameters collected from different stations during January 2011 (monsoon)

Station	pH	EC	TDS	DO	BOD	COD	SO_4^{2-}	NO_3^-	TH	Cl^-
1	9.0	1520	142.1	9.0	26.52	28.6	9.6	0.24	105.9	241.0
2	9.5	700	625.5	6.0	26.52	32.6	4.8	0.36	65.3	106.3
3	7.4	2900	322.8	5.0	9.52	16.0	9.6	0.25	77.8	560.1
4	7.9	4400	476.0	5.0	7.48	28.6	24.0	0.2	194.2	1187.6
5	9.3	1540	151.2	6.0	7.48	24.5	9.6	0.19	88.6	230.5
6	8.1	1160	107.6	5.0	6.12	28.8	4.8	0.37	95.5	191.4
7	7.3	3600	399.8	7.0	5.44	12.57	14.4	0.2	244.6	645.2
8	8.7	2000	219.1	6.0	6.08	36.6	7.2	0.19	62.5	503.3

All the values are expressed in ppm except pH and EC. (EC-µmhocm^{-1})

Table 3 : Variation of mean values of physico-chemical parameters collected from different stations during October 2011 (Post-monsoon)

Station	pH	EC	TDS	DO	BOD	COD	SO_4^{2-}	NO_3^-	TH	Cl^-
1	8.0	1840	123.9	10.0	4.82	53.7	9.6	3.48	105.5	272.96
2	7.3	920	546.4	10.0	0.58	54.2	19.2	5.42	87	141.8
3	7.7	1460	175.9	14.0	1.65	52.5	19.2	3.48	34.4	283.6
4	7.9	1530	245.8	13.0	4.68	52.0	24	5.42	101.7	226.8
5	8.3	1640	356.8	5.0	9.65	53.7	19.2	3.48	38.4	194.97
6	7.9	1350	489.5	5.0	8.24	48.5	19.2	15.11	122.1	124.07
7	7.5	1750	758.3	14.0	1.65	52.4	33.6	12.01	127.3	272.96
8	7.8	1060	425.6	9.0	0.24	50.2	4.8	3.87	48.2	155.98

All the values are expressed in ppm except pH and EC. (EC-µmhocm^{-1})

Electrical conductivity is about the conducting capacity of water which in turn is determined by the presence of dissolved ions and solids. Higher the ionizable solids, greater will be the EC. The mean EC values are within the range of 700-4400 and 920-1840 for the groundwater samples in monsoon and post-monsoon seasons respectively **(Table 2** and **Table 3)**. The EC values are well above the permissible limit of WHO (1400 µmhocm^{-1}) for ground water samples. This is the measure of salinity which greatly affects the taste and thus has a significant impact on the user acceptance of the water as potable[5] **(Fig. 2(a)** and **Fig. 2(b))**.

The mean TDS values are found within the range of 107.6-625.5ppm and 123.9-758.3ppm for groundwater samples in both seasons respectively. Most of the groundwater samples show the TDS values are within the permissible limit of WHO (500ppm). The maximum TDS values are observed at stations 2 and 7 in post-monsoon. High levels of TDS may aesthetically be unsatisfactory for bathing and washing.[6] DO is a measure of the degree of pollution by organic matter.

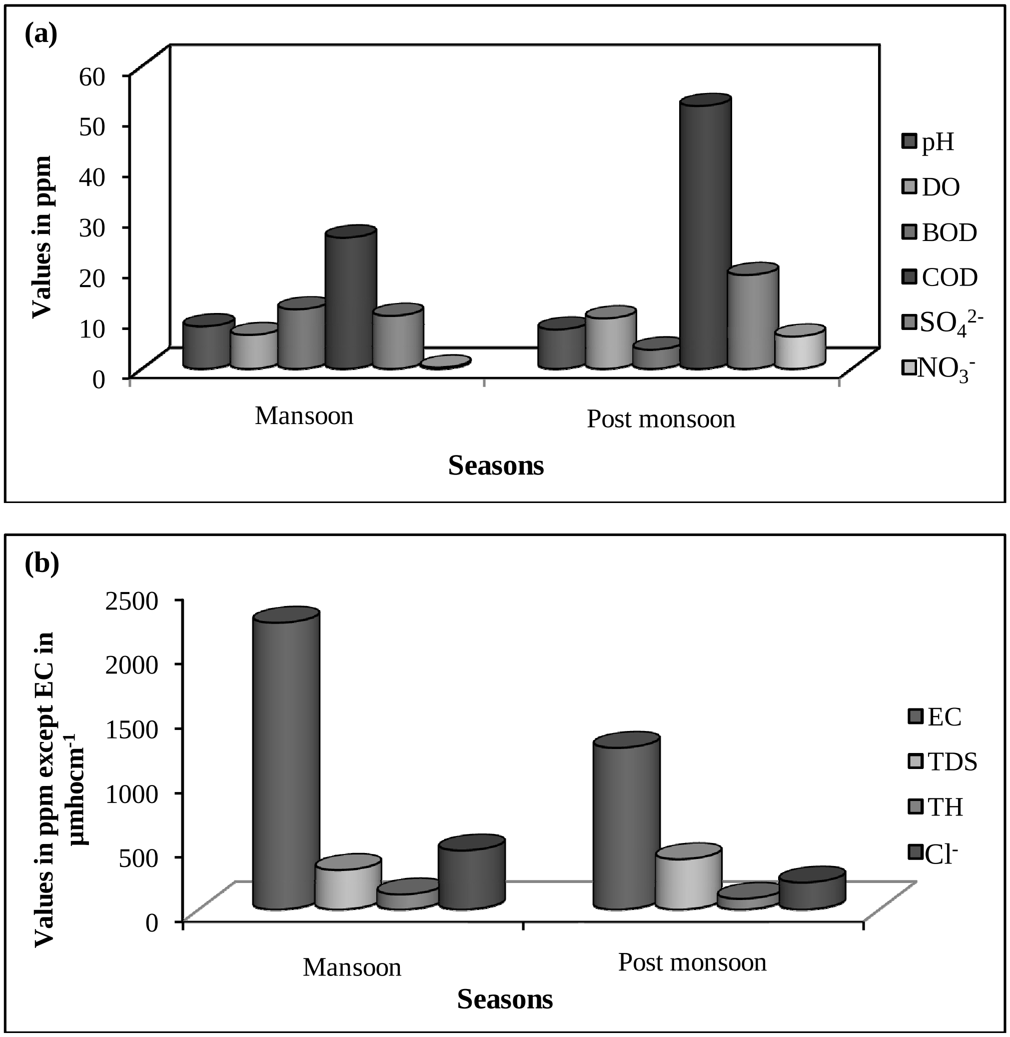

Fig. 2 : Variation of mean values of physico-chemical parameters of groundwater samples collected at different seasons

It is the destructive powers of organic substance as well as the self purification capacity of the wastewater body.

The mean values of DO are recorded with the range of 5.0-9.0ppm and 5.0-14.0ppm for all the groundwater samples in monsoon and post-monsoon seasons respectively **(Table 2** and **Table 3)**. During the study period, the seasonal changes in oxygen content have been recorded. The DO values are to be high than the permissible limit i.e 6 ppm of WHO (6ppm) except few stations are lower the permissible limit. DO reflect the physical and biological process prevailing in the water indicates the degree of pollution in the water bodies.

The quality of water enhanced if it contains more oxygen. The mean values of BOD are between the range of 5.44-26.52ppm and 0.24-9.65ppm for the groundwater samples in both seasons respectively **(Table 2** and **Table 3)**. In the present study, the values of BOD are found to exceed the permissible limit of WHO (5.0ppm) for groundwater samples in monsoon and post-monsoon. it is known that at the surface dispersed oil may spread and increased biological oxygen demand near the mixing zone which have an adverse effect on aquatic life.

The high value of COD is due to the inorganic contaminants from the fertilizers and domestic wastes. The mean COD values are within the range of 12.57-36.6ppm and 48.5-53.7ppm for groundwater samples in monsoon and post-monsoon respectively **(Table 2** and **Table 3)**.

Sulphate occurs naturally in water as result of leaching from gypsum and other common minerals. The mean values of sulphate are found in the range of 4.8-24ppm and 4.8-33.6ppm for groundwater samples in both seasons respectively **(Table 2** and **Table 3)**.

The values of sulphate are within the permissible limit of 250ppm (WHO) in all groundwater samples. The mean nitrate values were observed within the range of 0.19-0.37ppm and 3.48-15.11ppm for all groundwater samples in monsoon and post-monsoon respectively **(Table 2** and **Table 3)**. Nitrate values are within the permissible limit of WHO (50ppm) of all the groundwater samples. The low nitrate content encountered may be due to the less usage of nitrogen fertilizers and less disposal of wastes around these stations. Suppose high nitrate concentrations in groundwater could pose potential hazard to infant health.[7,8]

The Total Hardness (TH) is an important parameter of water quality whether it is used for domestic, industrial or agricultural purpose.TH is the property of water which prevents lather formation with soap.[9] It is due to the presence of excess of Ca, Mg and Fe salts. The mean TH values are within the range of 62.5-244.6ppm and 34.4-127.3ppm for groundwater samples in both monsoon and post-monsoon respectively **(Table 2** and **Table 3)**. TH values were within the permissible limit of WHO (300ppm) in all the stations for groundwater samples in both seasons.

The mean values of chloride are found in the range of 106.3-1187.6ppm and 124.0-283.6ppm for groundwater samples in monsoon and post-monsoon respectively **(Table 2** and **Table 3)**.

The values of chloride exceed permissible limit of 250ppm in most of the stations in monsoon. A chloride content of 600ppm has been considered as the highest acceptable salinity level for human consumption.[10] Based on the above equation 1, 2 and 3 the calculated water quality index for the ground water samples collected between TamilNadu and Pondicherry for monsoon and post monsoon were given in the **Table 4** to **Table 5**. The pollution status of the channel water and ground water were identified by using the **Table 6**. The WQI calculated values ranged above 100 for all seasons, which shows that the water quality of the study area is very poor and not suitable for drinking purpose.

Table 4 : Calculation of WQI values for ground water samples collected in monsoon season

Parameters	**Mean value in ppm (v_i)**	**Highest permitted value (WHO) (s_i)**	**Unit weightage (W_i)**	**$W_i \times Q_i$**
pH	8.4	8.5	0.117	11.5
EC	2227.5	1400	0.0007	0.111
TDS	305.5	500	0.002	0.122
DO	6.7	5	0.02	2.68
BOD	11.8	6	0.166	32.6
COD	26.0	10	0.1	26.0
SO_4^{2-}	10.5	500	0.002	0.042
NO_3^-	0.25	50	0.02	0.01
TH	116.8	500	0.002	0.046
Cl^-	458.1	250	0.004	0.732

WQI $= \sum_{i=1}^{n}(Qi\ Wi) / \sum_{i=1}^{n} Wi$ WQI = 170.2

Table 5 : Calculation of WQI values for ground water samples collected in post-monsoon season

Parameters	Mean value in ppm (v_i)	Highest permitted value (WHO) (s_i)	Unit weightage (W_i)	$W_i \times Q_i$
pH	7.8	8.5	0.117	10.7
EC	1256.2	1400	0.0007	0.06
TDS	390.2	500	0.002	0.15
DO	10.0	5	0.02	4.0
BOD	3.8	6	0.166	10.5
COD	52.1	10	0.1	52.1
SO_4^{2-}	18.6	500	0.002	0.007
NO_3^-	6.4	50	0.02	0.256
TH	83.0	500	0.002	0.03
Cl^-	209.1	250	0.004	0.33

WQI $=\sum_{i=1}^{n}(Qi\ Wi)/\sum_{i=1}^{n} Wi$ WQI = 180.1

Table 6 : Status categories of WQI

WQI	Quality of water
0-25	Very good
26-50	Good
51-75	Poor
Above 75	Very poor (unsuitable for drinking)

CONCLUSION

The study carried out between TamilNadu and Pondicherry on groundwater samples showed that the pH, TDS, DO, TH, SO_4^{2-} and NO_3^- level of groundwater was within the limit. All samples were having Electrical Conductivity, BOD, COD and Cl^- more than maximum permissible Limit. It is said that these water cannot be used for drinking purpose. The value of EC was more than maximum permissible limit in two samples (Darali (TN) and Kottucherry (P)), these samples are not suitable for drinking, but samples which are having EC more that 3000 water cannot be used even for irrigation purposes. The WQI calculated values ranged above 100 for all seasons, which shows that the water quality of the study area is very poor and not suitable for drinking purpose. The need for new institutional economics approach to deal with current and emerging problems has become very crucial. In most of the states, the problem of ground water depletion and quality deterioration has appeared in last few years. India is and will continue to be in the foreseeable future, heavily dependent on groundwater. This high level of dependence on groundwater has not been accompanied by social, economic, technological and community-based action to ensure the sustainability of this critical resource base. Monitoring of groundwater quality should be undertaken regularly to identify the sources of principal contaminants and other inhibitory compounds that affect the potability of water and also to identify the wells which are safe for drinking water and protecting them from further contamination.

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