Indexing Groundwater Quality For Drinking Water From A Complex Aquifers of Perambalur District, Tamilnadu, India

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Abstract- *The present work is aimed at assessing the water quality index (WQI) for the groundwater of perambalur district. This has been determined by collecting groundwater samples and subjecting the samples to a comprehensive physicochemical analysis. For calculating the WQI, 11 parameters have taken into consideration such as: pH, EC, TDS,* Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, HCO_3^{-}, Cl^{-}, NO_3^{-} *and* SO_4^{2-}. *The main objective of this paper is to evaluate the groundwater quality of perambalur district. To full fill the objective WQI has been estimated for 42 groundwater samples and are generated by using the MapInfo software. The WQI for all 42 samples ranges from 35.79 to 209.63, the highest WQI recorded at karapadi and the lowest at malayalapatti. The high value of WQI has been found to be mainly from the higher values of EC, TDS, calcium, sodium, bicarbonate, nitrate and chloride in the groundwater. The WQI maps indicated that the safest zone is in the North-Eastern part of the study area, where nearly all WQI values of the samples are in good water class which is suitable for drinking purpose.*

Keywords- Groundwater, Water Quality Index, Drinking Water, Perambalur

I. INTRODUCTION

Water is one of the most important natural resource for survival of human life. Quantity of water in nature neither decreases nor increases but only changes its form with time. There has been a continuous increase in population and due to that demand for water is also increased and changes have been occurred in agriculture and industrial sector. Due to increase of urbanization leads to increased demand for water. Thus, qualitative deterioration is happening very fatly. Water quality index (WQI) is valuable and unique rating to depict the overall water quality status in a single term, which is helpful for selecting appropriate treatment technique to meet the concerned issues. Whereas, WQI depicts the composite influence of different water quality parameters and communicates water quality information to the public and legislative decision makers. Recent research conducted by (Yisa and Jimoh, 2010) showed that there is an increase in the demand for freshwater due to fast population growth as well as the rabid increase of industrialization in the last few decades. Ground water is a gift of nature, its quality about 210 billion m^3 including recharge through infiltration seepage and evaporation. The main source of drinking is ground water. Now a day's human activity are constantly including industrial, domestic and agricultural waste to ground water reservoirs at an alarming rate (Panda and Sinha, 1991). With growing industrial sectors, urban areas are also developing near the industrial areas. So, the consumption rate of freshwater. Disposal of industrial effluent and sewage into fresh water cause ground water pollution (Panigrahi et al., 2012). WQI is the effective way to describe the quality of water. WQI reduces the data from various parameters into a single value to express the data in a simplified and logical form (Babaei Semiromi, F 2011, Nasirian M, 2007). The dependence on groundwater has increased tremendously in recent years in many parts of India. Hence, physico-chemical analysis of water is important to assess the quality of groundwater that influences the suitability of water for domestic, irrigation, and industrial needs (Prasanna et al. 2011; Thilagavathi et al. 2012; Chidambaram et al. 2011; Singaraja et al 2013). Since the groundwater is an important source of drinking water. Thus, a study has been conducted in perambalur district to assess the drinking water quality index. Thus the main objective of our study is to evaluate the groundwater quality and its suitability for drinking purpose, by comparing the results against drinking water quality standards laid down by WHO, The suitability of ground water for domestic use has been based on water quality index.

II. STUDY AREA

Perambalur is an under developed district in the state of Tamilnadu, India. The district is bounded by Cuddalore district in the north, Tiruchirappalli district in the south, Thanjavur in the east and Namakkal and Tiruchirappalli districts in the west (Fig 1). The total geographical area of the district is 3,69,007 ha, and net sown area and gross sown area are 2,16,422 ha and 2,37,136 ha, respectively. The net area under irrigation is 71,624 ha. The district lies in the Southern

plateau and hill zone of Agro-climate regional planning with characteristics of semi-arid climate. The soil is predominantly red loamy and black soil. The normal annual rainfall of the district is 908 mm/year. The precipitation during northeast monsoon, southwest monsoon and remaining winter and hot weather period account for 52%, 34% and 14% of annual rainfall, respectively. Cauvery is the major river flowing in the region and the composite district has a canal system covering just 47 km stretch and ayacut of 11,610 ha. In the district dominant landuse is cropped area in nearly 80%,and followed by the cropped land wasted land nearly 10% percent, water bodies 2.6%, plantation 2.3%, and the rest of 5% of the landuse that are town, villages, salt affected land and mining and industrial waste, Industries etc, (Manivel 2015). The district is geologically made up of Archaean, cretaceous, tertiary and quaternary formation. Formations of upper Gondwana age are also found in a limited extent. The Archaeans consist of biotite and, hornblende gneisses, charnockites etc., Upper jurassic formations are represented by equivalents of Gondwana in small patches in parts of Perambalur taluk. The major aquifer systems in the district are constituted by (1) Basal crystalline rocks consisting mainly of Charnockites, Granites and Gneisses of Archean age and (2) Sedimentary formations ranges in age from Cretaceous to Recent. The soil is predominantly red loamy and black soil. The drainage pattern is dentritic in sedimentary tract and dentritic to trellis in crystalline area. The main crops grown in the district are Cashew, groundnut, paddy, millet and sugarcane. Cashew is the major plantation crop. At present, maize and onion (small) are produced in large quantity in Perambalur District. In the Cretaceous formation Transmissivity is 234 m2/day and storativity is in the order of 3.527x10-4. Transmissivity ranges from 620 to 1455 m2/day and storativity ranges from 3.29 to 7.74 x 10-5 in Tertiary formation.
(http://www.perambalur.tn.nic.in/district_profile.htm).

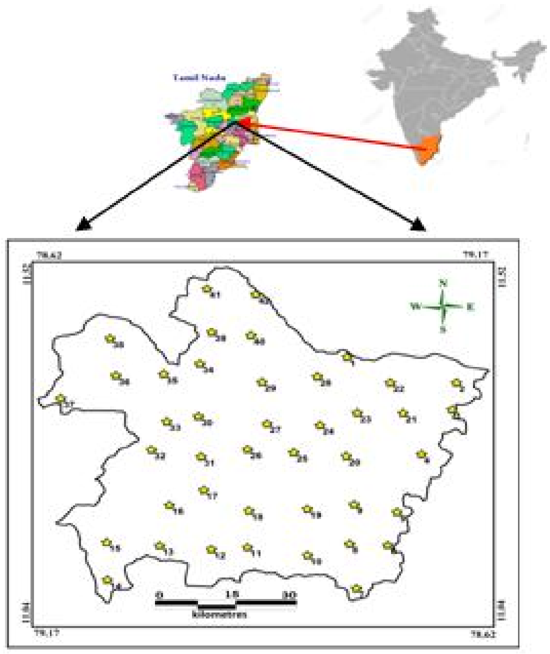

Fig 1: Location map of the study area

III. METHODOLOGY

A total of about 42 water samples were collected from hand pumps representing the entire district. The pH, temperature, TDS and conductivity of the water samples were measured in the field using a portable water-analysis kit. Laboratory and analysis has been carried out using standard procedures (APHA 1998, Ramanathan 1992; Ramesh and Anbu 1996). Calcium, magnesium, bicarbonate, and chloride were determined by ti-trimetric method. Sodium and potassium were analyzed through flame photometry (ELICO CL 378). Sulphate is determined by spectrophotometry (DR 6000). The reliability of the results was determined by the ionic balance of groundwater samples and a 5–10 % of percentage error was noted. Water quality index is calculated from the point of view of suitability of groundwater for human consumption by using the appropriate equation, WQI maps were generated by using MapInfo (8.5) software along, with vertical mapper, the spatial maps were plotted by using IDW method.

Application of WQI

The chemistry of groundwater is often used as a tool for discriminating the drinking and irrigation water quality (Subba Rao 2006; Vasanthavigar et al. 2010). WQI is an important parameter for identifying the water quality and its sustainability for drinking purposes (Subba Rao, 1997; Magesh et al. 2013). WQI is defined as a technique of rating that provides the composite influence of individual water quality parameters on the overall water quality (Mitra and

ASABE Member 1998). WHO (2011) standards for drinking water quality have been used to calculate the WQI. The relative weight (wi) was assigned for water quality parameters based on their relative importance on water quality for drinking purposes (Table 1). Comparison of groundwater quality with drinking water standard (WHO 2011) is given in Table 2. The water quality classification based on WQI values is given in Table 3. The WQI for individual groundwater samples is shown in Table 4. WQI is defined as a technique of rating that provides the composite influence of individual water quality parameters on the overall quality of water for human consumption (Mitra 1998). For this purpose, 11 water quality parameters have been selected. Parameters were selected according to the availability of data as well as their relative importance in defining water quality for human consumption. The standards set for this purpose is according to the guidelines (WHO 2011). For computing WQI three steps are followed. In the first step, each of the 19 parameters has been assigned to a weight (wi) according to its relative importance in the overall quality of water for drinking purposes (Table 1). The assigned weight ranges from 1 to 5. The maximum weight of 5 has been assigned for nitrate and TDS due to its major importance in water quality assessment and 4 for pH, EC, SO_4^{2-}, 3 for HCO_3^-, Cl^-, 2 for Ca^{2+}, Na^+, K^+ and weight 1 assigned for magnesium. Magnesium which is given the minimum weight of 1 as magnesium by itself may not be harmful (Vasanthavigar et al. 2010, Thivya et al.2014).

In the second step, relative weights (*Wi*) were calculated using the equation 1.

$$Wi = wi / \sum_{i=1}^{n} wi \qquad (1)$$

Where

Wi is the relative weight

wi is the weight of each parameter

n is the number of parameters.

The calculated relative weights (*Wi*) of each parameter and water quality standards are given in Table 1.

In the third step, a quality rating for each parameter was calculated by dividing their concentration with respective water quality standards (WHO 2011) this value is multiplied by 100 which is given in equation 2.

$$qi = (Ci/Si) \times 100, \qquad (2)$$

Where

qi is the quality rating

Ci is the concentration of specific chemical parameter in each water sample (mg/l)

Si is the World Health Organization for each chemical parameter in milligram per litre according to the guidelines of the (WHO 2011)

For computing the final stage of WQI, the SI is first determined for each parameter. The sum of SI values gives the water quality index for each sample.

$$SIi = Wi \times qi \qquad (3)$$

$$WQI = \sum SIi, \qquad (4)$$

Where

SIi is the sub-index of *ith* parameter

qi is the rating based on the concentration of ith parameter

n is the number of parameters.

Classification of water based on the WQI values is given in Table 3.

Table 1: Relative weight of chemical of physico-chemical parameters

Chemical parameters	WHO Standards 2011	Weight	Relative weight
pH (on scale)	6.5-8.5	4	0.114
EC (uS/cm)	1500	4	0.114
TDS (mg/l)	500	5	0.143
HCO_3^- (mg/l)	500	3	0.086
Cl^- (mg/l)	250	3	0.086
SO_4^{2-} (mg/l)	250	4	0.114
NO_3^- (mg/l)	45	5	0.143
Ca^{2+} (mg/l)	75	2	0.057
Mg^{2+} (mg/l)	50	1	0.029
Na^+ (mg/l)	200	2	0.057
K^+ (mg/l)	12	2	0.057
		$\sum wi = 35$	$\sum Wi = 1$

Table 2: Comparison of groundwater quality with drinking water standards (WHO)

Parameter	Mini	Maxi	Average	WHO 2011
pH (on scale)	6.70	8.38	7.36	6.5-8.5
EC (uS/cm)	341.00	9970.00	1834.83	1500
TDS (mg/l)	181.00	2550.00	642.83	500
HCO_3^- (mg/l)	84.00	420.00	231.05	500
Cl^- (mg/l)	17.73	771.04	180.18	250
SO_4^{2-} (mg/l)	0.36	40.00	2.92	250
NO_3^- (mg/l)	0.87	180.72	46.40	45
Ca^{2+} (mg/l)	12.00	156.00	60.37	75
Mg^{2+} (mg/l)	7.20	76.80	32.14	50
Na^+ (mg/l)	6.40	606.00	85.12	200
K^+ (mg/l)	0.10	48.10	5.27	12

IV. RESULT AND DISCUSSION

The water quality index of perambalur district is ranged from 35.79 (Malayalapatti) to 209.63 (Karapadi). A total of 42 samples were analyzed for WQI. Among these, 21 % of the samples showed excellent water, 60 % of the samples fell under good water category, 17 % of the samples showed poor water category, 2 % of the samples fell under very poor water quality and water unsuitable for drinking purposes. This may be due to effective leaching and dissolution process of rock salt and gypsum-bearing rock formations. High concentration of EC, chloride, sodium followed by calcium clearly suggests that rock–water interaction process is the main source for degrading the water quality in the study area. Spatial distribution of WQI (Fig 2) shows clearly four zones such as, excellent, good, poor and very poor for drinking purpose. The water in Zone 1 falls on the northern, eastern and southern part of the study area, covers an area of about of 245 km. Zone 2, fall in eastern, south western, north western and central part of the study area, covering a area of about 1460 km. which is hard rocky area characterized by high rainfall. Ground water is comparatively shallow. In shallow groundwater new water is added to this aquifer, therefore recharge is good and water quality is also good. Aquifer recharges with good quality water immediately after good rains. Zone 3 and 4 fall in north eastern part covers an area of 40 and 9 km of the study area with poor to very poor water, is unsuitable for drinking purpose. As per the zone 3 and 4 the badly affected area is karapadi. Geologically, this area is sedimentary terrains which have best percolation capability. Still the groundwater quality is poor. This is exactly following the trend of EC and other dominant cations and anions. WQI model is taking into account of a group of water quality parameters and will be more accurate and representative of the groundwater quality in the study area.

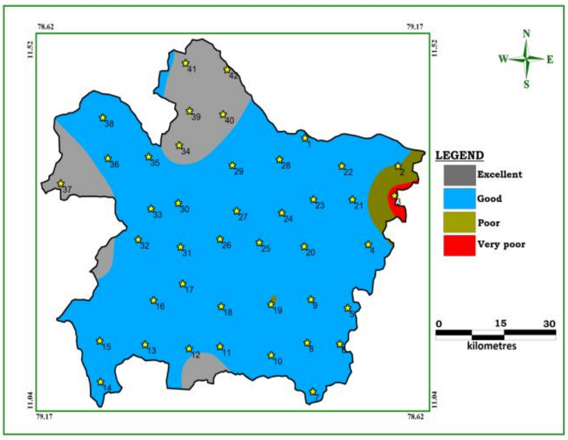

Fig 2: Spatial distribution of WQI in the study area

Table 3: Water quality classification ranges and types of water based on WQI values

Range	Type of water
<50	Excellent water
50-100	Good water
100-200	Poor water
200-300	Very poor water
>300	Water unsuitable for drinking purposes

Electrical conductivity Vs Water quality index

Conductivity is a measure of current carrying capacity. Thus, as concentration of dissolved salts increases conductivity also increases. The relationship between WQI and EC is plotted in figure3. It is interesting to note that EC values increases with increase of WQI that may be attributed to pollution. As the groundwater flows slowly through the subsoil, the human activities impact may affect the groundwater for a long time. A higher index value represents good water quality. Therefore a numerical index is used as a management tool in water quality assessment.

The lower EC concentration in the groundwater samples shows that there is an increasing trend with increase in WQI which may also be due to ions an induced weathering in the aquifer (Chidambaram et al., 2007). There are two groups of the samples represented in the plot. One with high EC and high WQI and the other with low EC and low WQI. But in general there exist a linear relationship between EC and WQI, reflecting the fact that they are directly related and the increase is mainly due to the anthropogenic activities (Thivya et al 2013).

Table 4: Calculation of WQI for individual water samples

S No.	WQI Values	Water quality classification type
1	143.3	Poor water
2	67.26	Good water
3	209.63	Very poor water
4	83.84	Good water
5	38.91	Excellent water
6	76.47	Good water
7	67	Good water
8	102.92	Poor water
9	117.64	Poor water
10	37.41	Excellent water
11	48.43	Excellent water
12	69.71	Good water
13	66.91	Good water
14	97.65	Good water
15	63.72	Good water
16	55.67	Good water
17	90.47	Good water
18	60.75	Good water
19	184.47	Poor water
20	91.34	Good water
21	107.16	Poor water
22	43.66	Excellent water
23	95.52	Good water
24	101.93	Poor water
25	101.36	Poor water
26	89.66	Good water
27	61.68	Good water
28	49.1	Excellent water
29	70.3	Good water
30	77.21	Good water
31	50.54	Good water
32	67.07	Good water
33	66.81	Good water
34	48.9	Excellent water
35	65.34	Good water
36	73.56	Good water
37	35.79	Excellent water
38	80.43	Good water
39	68.43	Good water
40	60.33	Good water
41	73.45	Good water
42	40.34	Excellent water

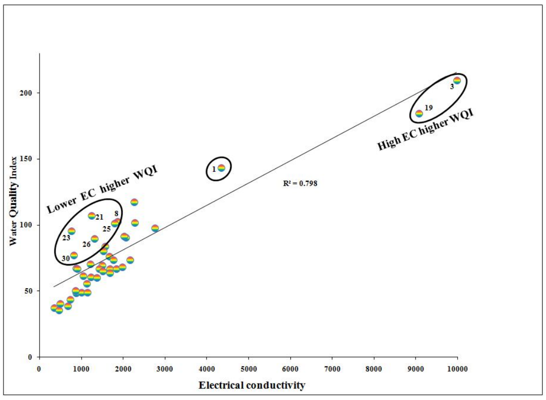

Fig 3: Relationship between EC Vs WQI

V. CONCLUSION

The WQI for 42 samples ranges from 35.79 to 209.63. 19% percent of the samples exceeded 100, which is the upper limit for drinking water. The WQI value above 100 indicated the unsuitability of water for drinking. The poor water quality may be due to the presence of excess amounts of TDS, sodium, bicarbonate, and chloride in the study area. About 62% of water samples are comes under good water in quality category. Location number 3 (Karapadi) have WQI above 200 which is not good for both drinking and irrigation purpose. The WQI maps indicated that the safest zone is in the North-Eastern part of the study area, where nearly all WQI values of the samples are in good water quality. There is a liner relationship of WQI to EC conductivity of the groundwater indicating groundwater pollution. Thus the groundwater of the northeastern part of the area needs very less degree of treatment before consumption, and it is also needs to be protected from the perils of contamination.

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