Assessment of Drinking Water Quality Index (DWQI) in and around SIPCOT Region of Cuddalore District, Tamilnadu

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ABSTRACT--- ***The coastal groundwater from a fragile ecosystem and it is more affected by groundwater extraction and the situation is more complex if it is industrialized. In order to unravel the status of the drinking water quality 60 groundwater samples were collected during post and pre-monsoon (30 each). The collected samples were analysed for major cations and anions. They were compared to the drinking water standard and Drinking water quality index (DWQI) was derived and studied for both the seasons and it was found that more samples of pre monsoon fall in unsuitable category and it was also inferred that they fall along the coastal region and near the Uppanar river near the SIPCOT region.***

Keywords—Aquifers, brines, groundwater, quality index

1. INTRODUCTION

Industrialization and human activities have totally turned our environment into dumping sites for waste materials. Many water resources have been rendered polluted and hazardous to living systems (Bakare *et al.* 2003). Groundwater quality in coastal aquifers is largely subjected by the interface between the sea and the bordering aquifer systems. In order to understand the groundwater quality and the controlling processes in a coastal aquifer, it is essential to know both the hydrodynamical and hydrochemical behaviour of groundwater.

Temporal changes in the origin and constitution of the recharged water, hydrologic and human factors, may cause periodic changes in groundwater quality. Degradation of groundwater quality in coastal region generally occurs due to natural processes such as saline water intrusion, wind driven sea spray and marine aerosols deposited on the topsoil, evaporation, and interaction of groundwater with brines and sedimentary formations (Polemio *et al.* 2006). Geochemical processes have been shown to have an influence on the prevalence of anthropogenic and natural contaminants in coastal environments worldwide (e.g., Kookana and Aylmore, 1994; Toda *et al.*, 2002).

A continuous supply of fresh water may already be in scarce and vary both seasonally and geographically. A study on the quantity of water alone is not sufficient for hard water management problems because their use for various purposes depends on its quality. Chemical parameters present in groundwater were mainly used as a tool to match its suitability for various uses. Hence, hydro-geochemical characters of groundwater and groundwater quality in different aquifers over space and time proved to be an important technique in solving the problems.

General assessment of water quality includes comparison of parameters by WHO, BIS, ISI standards, but it does not provide the whole picture of the region, but using the drinking water quality index provides the whole and a composite picture of the regions. Water quality index is an important parameter for demarcating groundwater quality and its suitability for drinking purposes (Tiwari and Mishra 1985; Singh 1992; Subba Rao 1997; Mishra and Patel 2001; Naik and Purohit 2001; Avvannavar and Shrihari 2008). 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. Many water quality studies have been carried out in Cuddalore and SIPCOT regions by various authors (Singaraja *et al.* 2014; Devi *et al.* 2012; Alagappan Sethuraman *et al.* 2013; Senthilkumar *et al.* 2008, 2012; Srinivasamoorthy *et al.* 2011) but the studies on the drinking water quality index have not been studied yet. Hence, a study has been carried out to assess the drinking water quality index.

2. STUDY AREA

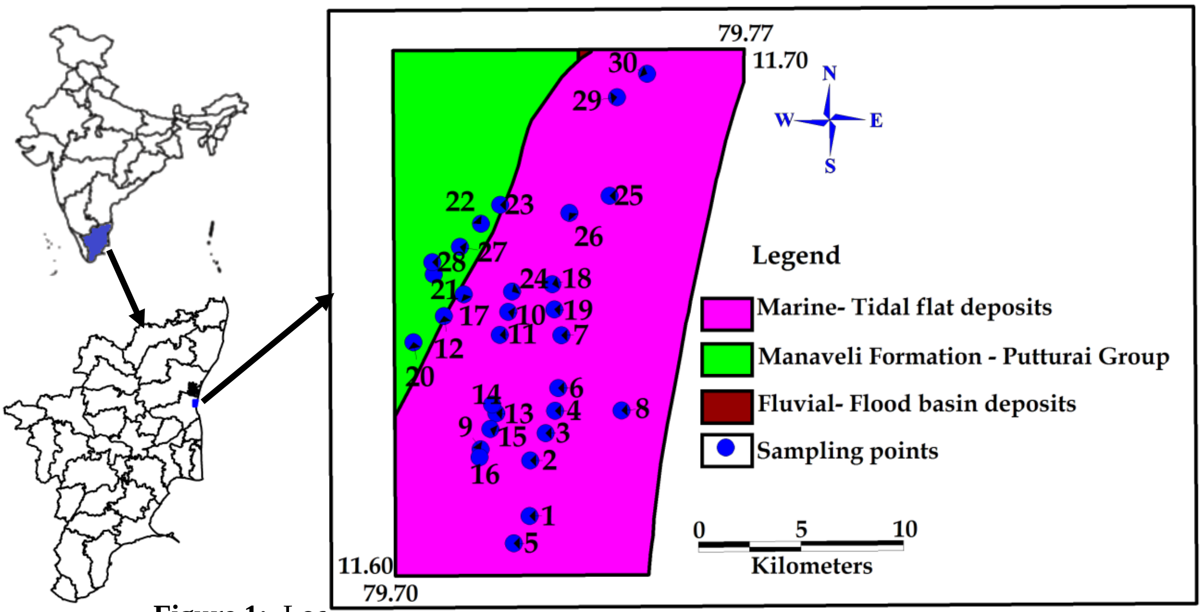

Figure 1: Location and Lithology map of the study area with sampling points

SIPCOT region forms a part of Cuddalore district which lies between east longitude of 79.70 to 79.77 and north latitude of 11.60 to 11.70. SIPCOT has been established in 1984 at an extent of 518.79 acres. It is located 8 km from Cuddalore to Chidambaram road, stretching from Pachaiyankuppam in the north to Semmankuppam in the south. The study area receives an average annual rainfall of 1902 mm. Groundwater has been used for drinking, agricultural and domestic purposes. The majority of the study area is covered by marine-tidal flat deposits. Manaveli formation (putturai group) is covered in the northern west part of the region and some patches of fluvial deposits are observed in the northern part of the study area. The aquifer system is discontinuous confined to semi confined aquifers.

3. METHODOLOGY

Totally 30 samples were collected for two seasons viz. Pre-monsoon (PRM) and Post-monsoon (POM) in and around SIPCOT region (Fig.1). The sampling, analytical procedures were carried out using the standard procedures (Ramesh and Anbu 1996; APHA, 1995). Water samples of 500 ml were collected in polyethylene bottle. pH, Electrical Conductivity (EC) and Total Dissolved Solids (TDS) were determined in the field using the field analysis kit (Eutech hand held instruments). The collected groundwater samples were analysed for major cations and anions. The Calcium, Magnesium, Bicarbonate and Chloride were determined by titrimetric method. Sodium and Potassium were analyzed through flame photometry (Elico CL 378). Sulphate was determined by spectrophotometry (Elico SL 171 minispec). Ferrous and Nitrate was analysed in Consort (Ion selective electrodes). The reliability of the results was determined by the ionic balance of groundwater samples and it was being noted in 5 – 10 % of error percentage.

4. RESULTS AND DISCUSSION

The chemical compositions of the groundwater for PRM and POM samples are shown in Table 1.

Table 1: Maximum, Minimum and average of chemical concentration of chemical constituents

Parameters	**Pre monsoon (PRM)**			**Post monsoon (POM)**		
	Maximum	Minimum	Average	Maximum	Minimum	Average
Ca	244.00	16.00	87.20	136.00	9.60	55.33
Mg	86.00	5.00	29.13	68.00	4.00	22.40
Na	120.00	14.00	51.57	140.00	9.00	45.90

K	62.00	6.00	21.47	52.00	3.00	15.80
Cl	537.00	19.00	152.73	444.00	34.00	128.23
HCO_3	525.00	69.00	237.00	280.00	17.00	131.90
SO_4	50.00	2.00	28.77	194.00	4.00	46.17
NO_3	9.00	2.00	4.43	9.00	1.00	3.97
F	0.40	0.00	0.13	1.00	0.00	0.28
pH	7.60	6.60	6.82	606.00	6.50	6.80
EC	2700.00	205.00	1054.83	1815.00	180.00	774.00

All values are in mg/l except EC in µs/cm and pH

pH ranges from acidic to alkaline in nature. The order of dominance of ions in PRM Ca > Na >Mg > K = Cl > HCO_3 > SO_4 > NO_3 > F and in POM, Na > Ca > Mg > K = Cl > HCO_3 > SO_4 > NO_3 > F. The higher concentrations of ions are observed in PRM due to the leaching of ions. Higher HCO_3 in groundwater is mainly due to the weathering process (Stumm and Morgan, 1996). Calcium may be derived from minerals like Calcite, Plagioclase and Hornblende are the primary sources in groundwater. The source of sodium in groundwater may be due to the dissolution of rock salts, weathering of sodium bearing minerals and also the influence of seawater from the coast. The natural process such as weathering, dissolution of salt deposits and influence of seawater from the coast is responsible for chloride content in the groundwater. Chidambaram *et al.* (2009). The reason behind this may be due to industrial discharges, industrial activitiesand of from illegal dumpings of toxic wastes from SIPCOT.

Spatial distribution of Electrical Conductivity

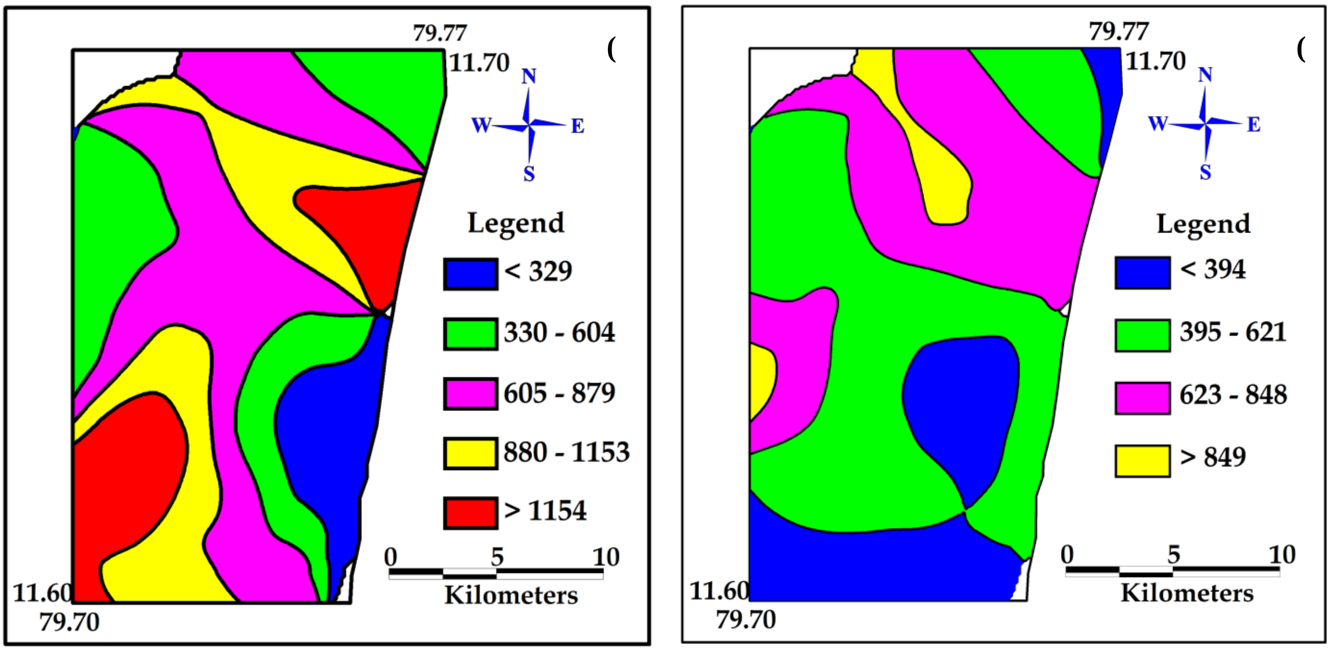

Figure 2: Spatial distribution of electrical conductivity (µs/cm) (a) PRM, (b) POM

The spatial distribution of electrical conductivity gives a general trend of the characteristics of the anions and cations present in water. In PRM, EC ranges from 205 to 2700 µs/cm and in POM it ranges from 180 to 1815 µs/cm. The higher concentration of EC is observed in PRM due to the post-monsoon along the coast due to seawater intrusion (Prasanna et al., 2011) whereas, in POM the higher EC is observed in the northern part of the region may be due to anthropogenic impacts of SIPCOT or the long term extraction of coastal aquifer (Prasanna et al., 2008). Higher concentration of EC was observed in all major litho units. The improper treatment and disposal of domestic sewage may be one of the major sources of salinization in the coastal aquifers (Metcafe and Eddy, 2000).

Drinking water quality index

The quality of groundwater for drinking purpose is calculated using the drinking water quality index (DWQI). The index was computed by assigning weights (W) to the water quality parameters (a) based on their threat to water quality. The relative weight (Wa) is computed using

$$W_a = \frac{w_a}{\sum_{a=1}^{n} w_a}$$

Where, Wa=weight of water quality parameter a and n= number of parameters. The quality parameters were assigned weights (Wa) in a scale of 1–5 based on their importance and role in the determination of drinking water quality as presented in Table 2. The maximum weight of 5 was assigned to pH and total dissolved solids due to their major importance in drinking water quality assessment. Bicarbonate was given a weight of 2 and 1 as it is not very significant in the water quality assessment, as it does not influence drinking water quality in the study area. The other parameters were assigned weights between 1 and 4 based on their importance in the water quality evaluation of the region (modified from Ramakrishnaiah *et al.,* 2009 and Vasanthavigar *et al.,* 2010).

Table 2: Weights of parameters and WHO standards (mg/l) for all seasons

	Weight	Relative weight	WHO standard	Weight	Relative weight
Ca	3	0.10	75	2	0.07
Mg	2	0.07	30	1	0.04
Na	3	0.10	200	3	0.11
K	2	0.07	20	1	0.04
Cl	4	0.14	200	4	0.15
HCO3	2	0.07	350	1	0.04
SO4	1	0.03	200	3	0.11
NO3	1	0.03	50	1	0.04
F	1	0.03	1	1	0.04
pH	5	0.17	8.5	5	0.19
TDS	5	0.17	1000	5	0.19
	Σwa = 29	ΣWa = 1		Σwa = 27	ΣWa = 1

All values are in mg/l except pH

A quality rating scale (q_a) for each parameter was calculated by dividing its concentration in each water sample by its respective WHO standard and is expressed as

$$q_a = \frac{C_a}{S_a} \times 100$$

Where, C_a=concentration of water quality

parameter (a) in milligrams per litre and S_a=WHO standard for water quality parameter (a) in milligrams per litre. The sub index (SI) was determined for each parameter, which is then used to determine the DWQI as follows:

$$SI_a = W_a \times q_a$$

$$DWQI = \sum SI_a$$

The drinking water quality was classified based on DWQI values of less than 500, 500–1000, 1000–1500, 1500–2000, and greater than 2000 as excellent, good, poor, very poor, and unsuitable, respectively presented in Table 3.

Table 3: Percentage of samples of DWQI for all seasons

DWQI	Category	PRM	POM
< 500	Excellent	17%	20%
500 - 1000	Good	27%	43%
1000 - 1500	Poor	30%	20%
1500 - 2000	Very Poor	20%	13%
> 2000	Unsuitable	7%	3%

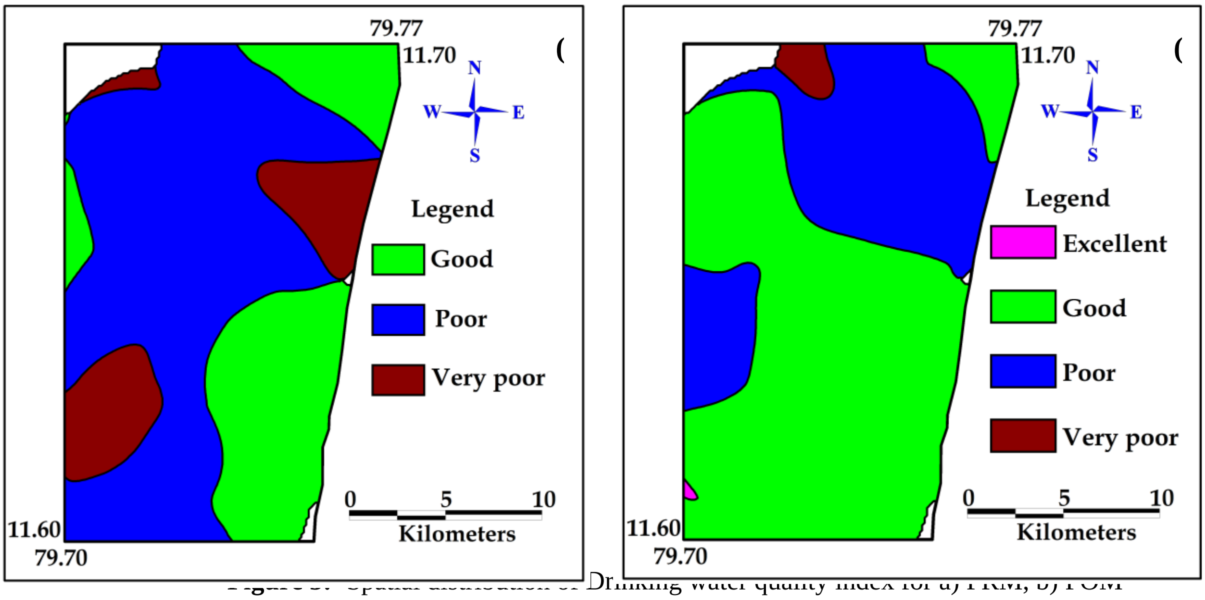

Figure 3: Spatial distribution of Drinking water quality index for a) PRM, b) POM

The DWQI maps of the PRM and POM revealed that most of the samples in these seasons are dominated by good, poor and very poor categories (Fig.3). In PRM, good category drinking water is observed as patches in all parts of the region, very poor category is noted in NE part, whereas the rest of the region is covered by poor categories. In POM, good and poor category is noted same as in PRM, whereas very poor category is observed in Northern part may be due to leaching of ions, over exploitation of groundwater, direct discharge of effluents by SIPCOT. An increase in the category of good quality water during PRM and POM may be due to dilution processes during the monsoon. The poor water quality may be due to the presence of excess amounts of TDS, Na^+, HCO_3^-, and Cl^- in the study area. The good quality of water is observed in POM.

5. CONCLUSIONS

The above study reveals the fact that the majority of the study area is covered by marine- tidal flat deposits. Manaveli formation (putturai group) is covered in the northern west part of the region and some patches of fluvial deposits are observed in the northern part of the study area. The order of dominance of ions in PRM, Ca > Na >Mg > K = Cl > HCO_3 > SO_4 > NO_3 > F and in POM, Na > Ca > Mg > K = Cl > HCO_3 > SO_4 > NO_3 > F. The higher concentration of EC is observed in PRM due to the post monsoon along the coast due to seawater intrusion, whereas in POM, the higher EC is observed in the northern part of the region may be due to anthropogenic impacts of SIPCOT or the long term extraction of coastal aquifer. The water quality index shows that most of the PRM samples are with index >1000 indicating they are poor to unsuitable category, but during most of the POM samples are below <1000 indicating that the fall mostly in the good category. The spatial distribution also reveals the fact that they are more affected near the coast and in the SIPCOT region during the PRM than the POM periods.

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