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GIS-Based Assessment of Groundwater Quality for Drinking in Perambalur District of Tamil Nadu

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***Abstract*:** Water quality parameters such as TDS, Ca^{2+}, Mg^{2+}, Na^{+}, K, Cl, So_4^{2}, F, pH and TH were used to determine the groundwater quality in the Perambalur district of Tamil Nadu. The BIS scale is used to determine the water quality index based on standard weight. The chemical ion indicates that an alkali exceeds alkaline earth and weak acids exceed strong acids in both monsoon periods. The highest numbers of wells where the chemical constituents were above the permissible limit with Mg^{2+}, TDS and total hardness and the lowest was in Ca^{2+}. In 2018, poor water quality covered 1345 sq km in pre-monsoon and 1203 sq km in the post-monsoon season. Therefore, it is imperative to improve water quality using proper water purification and pollution control in areas where poor water quality is noted.

Keywords: Ca^{2+}, BIS standards, Groundwater, Drinking water quality, Monsoon

The groundwater chemistry is unique and its quality is determined by the geological formation, climatic condition and anthropogenic activities. The groundwater is a valuable resource for drinking, agriculture and industrial activities around the world (Adimalla Narsimha et al 2018). Groundwater accounts for nearly 65, 20 and 15% of drinking, irrigation and industrial activities respectively based on recent research (Salehi et al 2018). In India, 90% of the rural community be influenced by groundwater for drinking and domestic purposes (Arya et al 2019). Generally, the groundwater is less vulnerable to contamination but once the groundwater gets polluted it is difficult to retain its original content (Vinothkanna et al 2020). However, the geochemistry of groundwater determines its utilization whether for domestic or agriculture (Vinothkanna 2019). Many studies on groundwater using standard techniques and plots were carried out by various researchers (Divahar et al 2020 for Kalingarayan canal of Erode district; Vinothkanna et al 2020 for Dharmapuri district of Tamil Nadu; Ramprasad et al 2021 for river Cauvery and Vaigai upstream and downstream locations of Tamil Nadu). Water quality index (WQI) is a widely used technique to assess quality (Gorgij et al 2017). The WQI is a frequently used method because of considering important chemical parameters to determine the water quality. The use of a Geographic Information System (GIS) in water resources provides commendable information to the research. Many researchers used GIS techniques in water quality studies (Jasmin and Mallikarjuna 2014 for Araniar River Basin; Vinothkanna et al 2016 for Namakkal district). The main purpose of this study is to assess the quality of groundwater for domestic purposes in the Perambalur district of Tamil Nadu. Understanding groundwater chemistry helps to use this resource optimistic and make it sustain.

MATERIAL AND METHODS

Study area: The spatial extent of Perambalur district is 1757 sq.km and located in the interior part of Tamil Nadu with a geographical extent of 10°54" to 11°30"N and 78°40" to79°30"E (Fig. 1). River Vellar and Pachmalai hill in the north and Kollidam River in the south are the prominent physical features. Sugarcane is one of the main crops cultivated in this district. The major factors which define the geomorphology of the study area are denudational, structural and fluvial processes. Black, alluvial and red loamy soils are the major soil categories distributed in the district. Hydro geologically the aquifer system is constituted by Basalt crystalline rocks comprising Charnockites, Granites and Gneisses of Archean age and sedimentary formation from Cretaceous to recent.

Methods: The groundwater data for 2018 were collected from the state ground and surface water resources data centre, Chennai is the primary source for this analysis. The 19 common groundwater wells from different monsoon seasons (pre and post) were identified using Microsoft Excel and attributed to the ArcGIS platform to show spatially. Based on the Bureau of Indian Standard (BIS) a total of ten water quality parameters *viz*., TDS, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl, SO^{2}_{4}, F, pH and Total hardness were considered to identify the

groundwater quality for domestic purposes (Narsimha Adimalla 2019). The weight was assigned from 1 to 5 (Table 1.) based on the importance of drinking purpose and by using the arithmetic index method relative weight was calculated (Chaurasia et al 2018).

WQI = Σqiwi

Where qi (ground water quality ranking) = 100 X (Va-Vi) / (Vs-Vi),

When Va = authentic value found in the groundwater sample

Vi = ideal value (pH and DO have 7.0 and 14.6 mgL^{-1} respectively and 0 for all other parameters).

Vs = standard value.

Wi (unit weight) = KSn^{-1}

$$\text{Where K constent} = \frac{1}{\frac{1}{Vs1}+\frac{1}{Vs2}\frac{1}{Vs3}\frac{1}{Vs4}\ldots\ldots+\frac{1}{Vsn}}$$

Sn = 'n' number of standard values.

GIS analysis: The district boundary was digitized using Topographic sheets collected from the Survey of India with a scale of 1:50,000 using UTM coordinates. The spatial map for water quality was prepared using the interpolation technique in ArcGIS mainly the Inverse Distance Weight (IDW) method because it is easy to perform. This method gives weightage to the observed point and predicts a value for an unknown location (Elumalai et al 2017).

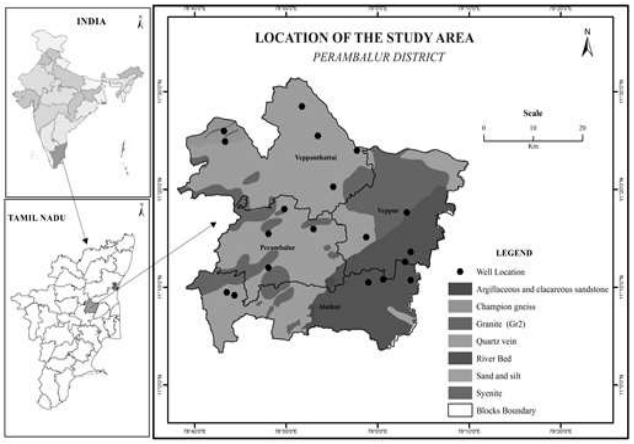

Fig. 1. Location of the study area – Perambalur District

Table 1. Standard limits and their relative weight

Parameters	BIS standards (2012) acceptable limit	WHO limit (2011)	Weight (Wi)	Relative weight
Ca^{2+}	75	100	2	0.068
Cl	250	250	3	0.103
F	1	1.5	5	0.172
K^{+}	12	12	1	0.034
Mg^{2+}	30	50	2	0.068
Na^{+}	50	200	3	0.103
pH	6.5-8.5	6.5-8.5	3	0.103
Sulfate	200	400	3	0.103
TDS	500	1000	5	0.172
TH	200	500	2	0.068

RESULTS AND DISCUSSION

Groundwater chemistry controlling mechanism: On the left side of the plot are cations that constitute Mg^{2+}, Ca^{2+}, Na^{+} and K^{+} and the right-side triangle is anions comprise of Cl, SO^{2}_{4}, CO^{3} and HCO^{3} (Fig. 2). The presence of Na^{+}+K^{+}ions in the groundwater is due to silicate weathering (Lakshmanan et al 2003). Similarly, the anions are dominated by bi-carbonates and were in the order of HCO^{3}>Cl> SO^{2}_{4}. Generally, the diamond field is divided into 4 geochemical categories such as a) Ca^{2+}-Mg^{2+}-HCO^{3}, b) Ca^{2+}-Mg^{2+}-Cl-SO^{2}_{4}, c) Na+-K+-Cl-SO^{2}_{4} and d) Na^{+}-K^{+}-HCO^{3}. The chemical ions are presented in the order of Na^{+}-K^{+}-Cl-SO^{2}_{4}>Na^{+}-K^{+}-HCO^{3}>Ca^{2+}-Mg^{2+}-HCO^{3}>Ca^{2+}-Mg^{2+}-Cl-SO^{2}_{4} indicates alkalis exceeds alkaline earth and weak acids exceed strong acids in both monsoon period.

Characteristics of Chemical Parameters

Calcium: The mean value of Ca^{2+} ranged between 10 to 80 mgL^{-1} and 8 to 60 mg L^{-1} during pre-monsoon and post-monsoon season respectively (Table 2 & Fig. 3a). During pre-monsoon seasons, 18 wells (95%) were in the desirable range and only 1 well located in Esanai village exceeds the desirable limit which is located in the central part depicted on the spatial map. During the post-monsoon season, almost all the wells are under desirable limits during the study.

Chloride: The chloride level in the pre-monsoon season varied from 35 to 596 mg L^{-1} and during the post-monsoon season it is 28 to 709 mg L^{-1} (Fig. 3b). The chloride level in pre-monsoon and post-monsoon season show that 79 and 74 percent of wells are under the desirable limit.

Fluoride: The fluoride in pre monsoons season (0.05 to 1.4 mg L^{-1}) are having an average of 0.48 mg L^{-1}. About 84 percent of pre-monsoon sample wells are under the desirable limit as prescribed by BIS standards (2012). Pasumbalur village of Veppanthattai taluk, Sirumathur and Chittali village of Kunnam taluk fluoride were above the desirable limit. But in the post-monsoon, fluoride values are range from 0.13 to 1.22 mg L^{-1} having a mean value of 0.56 mg L^{-1} (Fig. 3c). The desirable range was in 16 and 3 wells (Mettupalayam village of Veppanthattai taluk, Sirumattur and Kilumattur village of Kunnam taluk) exceeds desirable value during the study period.

Potassium: The concentration of potassium was 0.1 to 196 mg L^{-1} for pre-monsoon and 18 to 98 mg L^{-1} for post-monsoon

was noted during the study period (Fig. 3d). The mean values of potassium are observed as 43.2 mg L^{-1} for pre-monsoon and 50.3 mg L^{-1} for the post-monsoon season. Among the total samples, 58 percent in pre-monsoon and only 16 percent in post-monsoon are under the desirable limit. The samples found beyond the desirable limit are 42 percent (pre-

Table 2. Groundwater chemical parameters - Perambalur district

Parameter	Desirable limit (mgL^{-1})	Pre-monsoon			Post-monsoon			Classification	Pre-monsoon		Post-monsoon	
		Mean	Maximum	Minimum	Mean	Maximum	Minmum		Total well	%	Total well	%
Ca	75	42.7	80.0	10.0	34.21	60.0	8.0	WL	18	94.74	19	100
								AL	1	5.26	0	0
Cl	250	188.9	596.0	35.0	214.68	709.0	28.0	WL	15	78.95	14	73.68
								AL	4	21.05	5	26.32
F	1.0	0.4	1.4	0.05	0.56	1.2	0.1	WL	16	84.21	16	84.21
								AL	3	15.79	3	15.79
K	20	43.2	196.0	0.1	50.37	98.0	18.0	WL	11	57.89	3	15.79
								AL	8	42.11	16	84.21
Mg	30	72.6	167.6	24.3	58.38	98.42	21.8	WL	3	15.79	3	15.79
								AL	16	84.21	16	84.21
Na	200	183.5	621.0	12.0	166.32	495.0	24.0	WL	13	68.42	13	68.42
								AL	6	31.57	6	31.58
pH	6.5-8.5	8.3	8.6	8.1	8.11	8.3	7.7	WL	17	89.47	19	100
								AL	2	10.53	0	0
So4	200)	254.5	864.0	24.0	156.00	600.0	29.0	WL	9	47.37	15	78.95
								AL	10	52.63	4	21.05
TDS	500	1048.3	2697.0	226.0	920.74	1925.0	276.0	WL	3	15.79	5	26.32
								AL	16	84.21	14	73.68
TH	200	405.7	840.0	150.0	325.79	510.0	125.0	WL	4	21.05	4	21.05
								AL	15	78.95	15	78.95

(WL - Within Limit, AL - Above Limit)

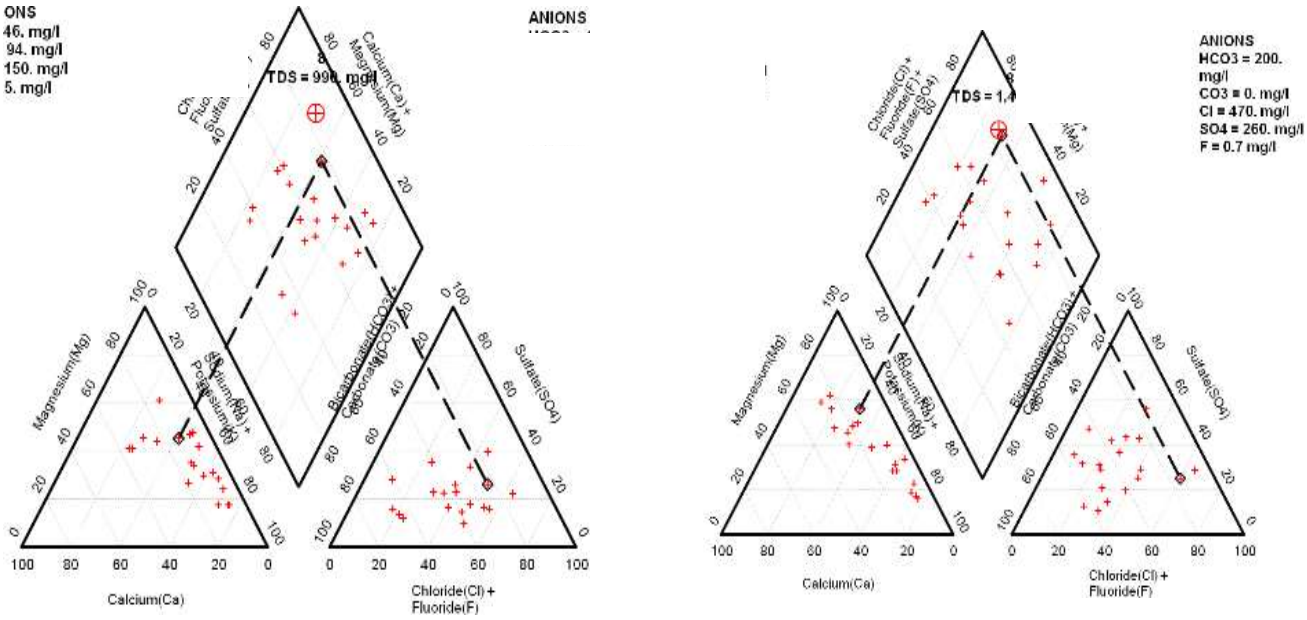

Fig. 2. Pre-Monsoon and post-monsoon season Piper diagram

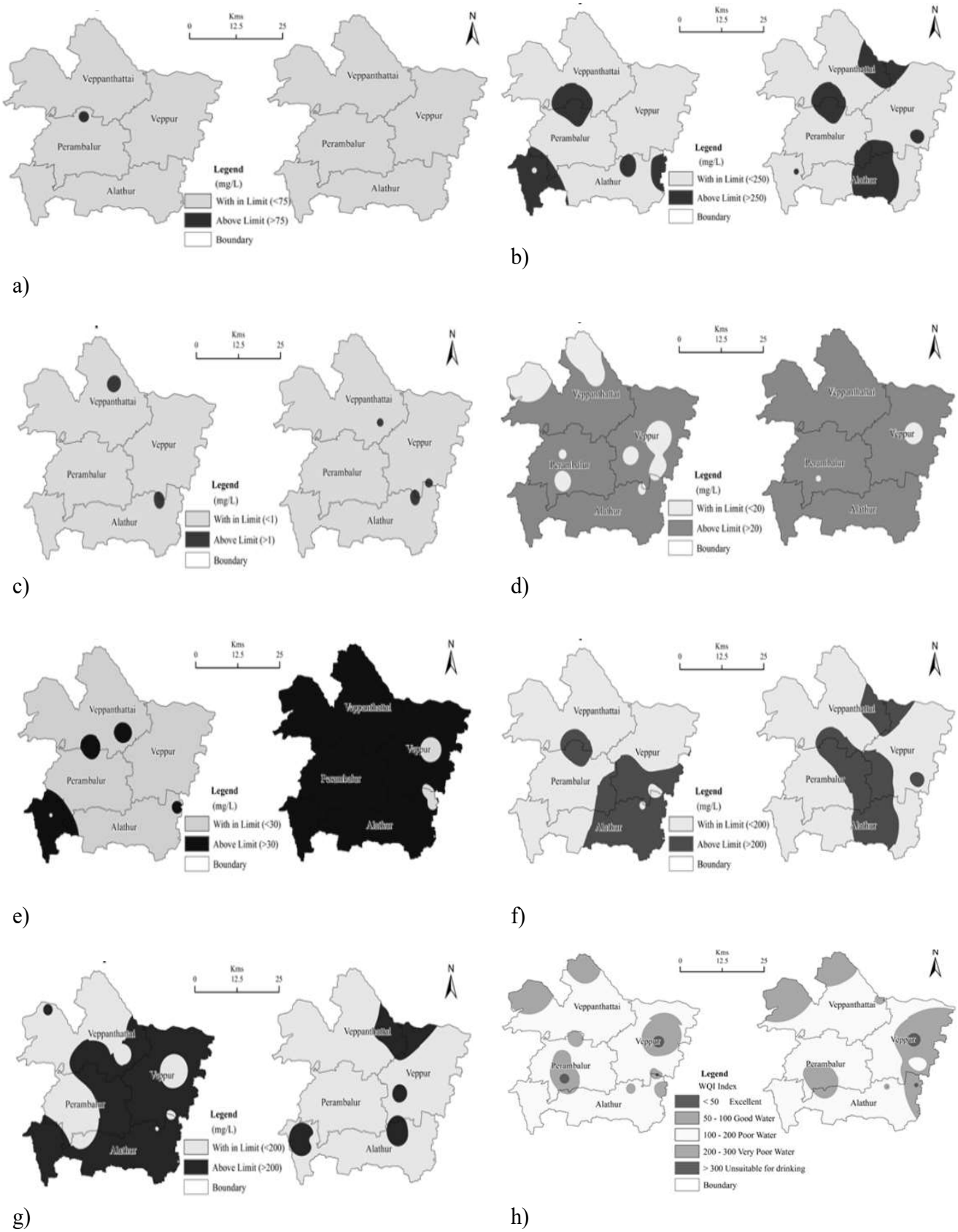

Fig. 2. Spatial distribution map of water quality parameters a) Calcium, b) Chloride, c) Fluoride, d) Potassium e) Magnesium f) Sodium g) Sulfate h) WQI

monsoon) and 84 percent (post-monsoon). The excess amount of potassium is present in the groundwater is due to the high use of potassium fertilizer in the agriculture field leads to percolates into the groundwater (Augustine and Anitha Pius 2018).

Magnesium: The mean values of magnesium for pre-monsoon was 73 mg L^{-1} and in post-monsoon 58 mg L^{-1} (Fig. 3e). The magnesium values are range from 24.3 to 167.67 mg L^{-1} for pre-monsoon and 21.8 to 98.42 mg L^{-1} for the post-monsoon season. Magnesium value indicates that 84 percent of samples are above the desirable limit in both monsoon seasons during the study period. The spatial map shows that except for small patch in the northern and eastern parts all other areas are beyond the limit prescribed.

Sodium: Sodium value during the pre-monsoon season varied from 12 to 621 mg L^{-1} with a mean of 183.58 mg $L^{-1}$and in post-monsoon season 24 to 495 mg L^{-1} with mean value of 166.32 mg L^{-1} (Fig. 3f). The 32 percent of groundwater samples are above the desirable limit during the study period. Excess intake of sodium content in water to humans causes hypertension, kidney and nervous disorders (Subba Rao et al 2012).

pH: During 2018, the pH ranged from 8.1 to 8.6 and 7.7 to 8.3 in pre and post-monsoon season respectively. Among the samples, 89 percent of samples observed in pre and 100 percent in post-monsoon season are under the desirable limit for the period of study. The permissible level of pH in groundwater is 6.5-8.5 (WHO 2011). Only two samples in pre-monsoon are exceeded the desirable limit found in the villages of Periyar in Vepanthattai taluk and Kilmattur village of Kunnam taluk.

Sulfate: The sulfate in the pre-monsoon period varied from 24 to 864 mg L^{-1} with a mean of 254.58 mg L^{-1} and for the post-monsoon season, the values are 29 to 600 mgL^{-1} with a mean value of 156 mg L^{-1}. In the pre-monsoon period, 9 wells are under the desirable range, which is shown in the northwestern part and 10 wells have exceeded the desirable range, which is noted in the southeastern and northeastern part of the area (Fig. 3g). During the post-monsoon season, 15 (78.95%) wells were in the south-western and south-eastern part of the area indicate the desirable range, while the 4 wells such as the villages of ChittaliNakkaselam, Kottarai of Kunnam taluk and Peraiyur village of Veppanthattai taluk were above the desirable range.

Total dissolved solids: The TDS values present in the groundwater ranged from 226 to 2697 mg L^{-1} (pre monsoon) and 276 to 1925 mg L^{-1} (post-monsoon season). Only 3 (16%) wells are in the desirable range found in Perambalur and Kunnam villages, the remaining 16 (84%) wells were above the desirable range and spatially distributed almost the entire study area. But during post-monsoon season, 5 (26%) wells are under the desirable range and 14 (74%) wells fall above the desirable limit during the study period. Selvam et al (2013) studied that the excess presence of TDS is due to salts having a high connection with the subsurface lithology and much time in contact with the aquifer body.

Table 3. Domestic water quality index-Perambalur District-2018

WQI classification	Categories	Pre-monsoon (sq.km)	Post-monsoon (sq.km)
< 50	Excellent	17.36	14.711
50 - 100	Good water	359.10	532.69
100 - 200	Poor water	1345.00	1203.42
200 - 300	Very poor water	36.54	7.4
> 300	Unfit for drinking	-	-

Total hardness: The TH ranged from 150 to 840 mg L^{-1} with a mean of 405.7 mg L^{-1} in the pre and post-monsoon period total hardness value between 125 and 510 mgL^{-1} and an average of 325.79 mg L^{-1}. About 3 villages namely Kilumattur, Peraiyur and Vellore are in the desirable range and 16 wells (84.21%) are above the desirable during the pre-monsoon period. During post-monsoon, 4 wells are within the desired range and the remaining 16 wells (84.21%) which are widely found in the district exceed the desirable limit.

Water quality index: Water quality indexes were categorized as excellent, good, poor, very poor and unfit for drinking. WQI values in the district indicate that 1382 sq.km of the study area falls under the poor quality of drinking water during pre-monsoon season mainly distributed in the entire district except in the northwestern part. But in the post-monsoon season, 1211 sq.km is under poor quality mostly spread in the central part of Perambalur (Table 3). Poor and very poor water is dominantly present in the study period over the study area (Mohamed Ibraheem et al 2014). Only 376 and 547 sq.km are under good water for drinking purposes (Fig. 3h).

CONCLUSION

Domestic groundwater quality index was identified using Bureau of Indian Standards (IBS) considering ten chemical parameters such as TDS, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl, SO^{2}_{4}, F, pH and total hardness. The major factor for governing the groundwater chemistry in the Perambalur district is due to silicate weathering. The dominant cations namely Na^{+} and K^{+} are present in this area. The chemical ions are presented in the order of Na^{+}-K^{+}-Cl-SO^{2}_{4}> Na^{+}-K^{+}-HCO_{3}> Ca^{2+}-Mg^{2+}-HCO^{3}> Ca^{2+}-Mg^{2+}-Cl^{-}-SO^{2}_{4} indicates alkali exceeds alkaline earth and weak acids exceed strong acids in both pre-monsoon and post-monsoon seasons. The majority of groundwater samples

contain chemical parameters such as total hardness, TDS, SO^{2}_{4} and Mg^{2+} are exceed the permissible limit as prescribed by BIS. WQI portrays that majority of index values fall under drinking waterquality character poorly. It is necessary to advise the people about water purification while taking groundwater for drinking purposes in the Perambalur district.

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