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Research Article

Physico-chemical analysis of ground water samples of Veppanthattai Taluk in Perambalur District, Tamil Nadu, India

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ABSTRACT

Ground water samples of open wells and bore wells collected from different locations inVeppanthattai Taluk in Perambalur District were analyzed for their physico-chemical characteristics. The ground water samples were studied during pre-monsoon and post-monsoonseasons from twelve different villages. The present study was undertaken to characterize thephysico-chemical parameters such as temperature, pH, Total Alkalinity (TA), ElectricalConductivity (EC), salinity, Calcium Hardness (CH), Magnesium Hardness (MH), Total Hardness(TH), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Solids (TS) andfluoride. Each parameter was compared with the standard permissible limit of the parameter asprescribed by World Health Organization (WHO). The Langelier Saturation Index (LSI) showsthat majority of samples have the border line corrosive nature with negative LSI values. The WaterQuality Index (WQI) reflected that out of 12 samples 6 are under acceptable quality. The KarlPearson Correlation matrix has approved the influence of CH on TH, EC, Salinity and TDSwith significantly positive correlation. The study reveals that in few villages, water has highhardness and fluoride content. Hence, ground water must be used for drinking after propertreatments viz., softening and defluoridation.

Keywords: Dental fluorosis, physico-chemical parameters, Water Quality Index.

INTRODUCTION

Water is the precious gift of nature to all the living beings for sustenance. The suitability of waterfor domestic, agricultural and industrial purposes mainly depends on the chemical composition of surface and subsurface. Ground water is the major and preferred source for drinking all over the world even though its contribution is very less (i.e. only 0.6%) to the total water resources on earth. The degradation of water quality is mainly due to the increasing population, urbanization, industrialization and over-utilization of water resources. The ground water is getting polluted because of disposal of industrial effluents, hazardous wastes, sewage disposal and deep percolation of pesticides and fertilizers from activated fields. (Meenakshi et al., 2006).

Presence of various hazardous elements like arsenic, nitrate, sulphate, fluoride, other heavy metals etc., in underground water have been reported from different parts of India and world.(Deepti Mishra et al.,2009; Khaiwal Ravindra et al., 2007; Mufeed I. Batarseh, 2006).Fluoride is an essential trace element for human metabolism. Its concentration in drinking water is the prime factor to decide whether fluoride is beneficial or harmful. In India, research on the assessment of water quality especially with reference to fluoride has been carried out by various workers (Surindra Suthar et al.,2008;Yadav JP et al.,2009; Jha SK et al., 2010; Patil VTet al., 2010;Meta KV, 2010). Ingestion of excess of fluoride, most commonly in drinking water, can cause fluorosis which affects the teeth and bone.

(Mariappanet al., 1999; AKM Fazul Hoque et al., 2003)

The present study was therefore undertaken to investigate the qualitative analysis of some physicochemical parameters including natural fluoride levels in Veppanthattai Taluk in Perambalur District,Tamil Nadu, India.

Details of study area

Geological setup

Perambalur is a District which is located in the centre part of Tamil Nadu in India. The total geographical area of the District is 3, 69,007 ha. But only about 71,624 ha area is used for irrigation. This District has 2, 37,136 ha of gross sown area and 2, 16,422 ha of net sown area. Veppanthattai Taluk is taken as the study area for this research in Perambalur District. The Talukhas very good amount of mineral deposits. Celeste, lime stone, shale, sand stone, canker and phosphate are found in various places in Veppanthattai Taluk. A considerable quantity of building stone is quarried in Veppanthattai Taluk. (en.wikipedia.org/wiki/Veppanthattai_taluk)

Location and climate

Veppanthattai is one of the prominent Taluks in Perambalur District of Tamil Nadu. This town islocated 13 km away from Perambalur on the way to Attur. The town faces Krishnapuram in theNorthern side, Esanai in the Southern side and Valikandapuram in the Eastern side. The study arealies in the southern plateau and hill zone of agro-climate regional planning with characteristics ofsemi-arid climate. The average rainfall of the District is 908 mm. In a year the study area getsabout 52% rainfall during Northeast monsoon, about 34% in the Southwest monsoon timing andapproximately14% in the winter and summer seasons.

Hydro-geological conditions

In the study area, the ground water resource through bore wells and open wells contribute about68% for irrigation.

Agriculture and irrigation

Cashew, paddy, groundnut, sugarcane and millets are the major crops cultivated in this District. At present, maize and onion (small) are produced in large quantity in Perambalur District.

Population

As per 2011 census 564,511 people live in Perambalur District in which 281,436 were male and283,075 were female. The literacy rate of this District was 74.68. Total area of this district is about1,750 km2.The population density (persons per sq.km.) is of 323 as per census 2011. (Source:"2011 Census of India" Directorate of Census Operations - Tamil Nadu).

MATERIALS AND METHODS

Physico-chemical Analysis of Water Quality Parameters

Selection of water sources and villages was done by random sampling procedure. Water samples of 24 in number (12 in the pre-monsoon and 12 in the post-monsoon) have been collected from bore wells and open wells of Veppanthattai Taluk during June-July, 2009 and December 2009 –January 2010. The samples were assessed for seasonal variations in their water quality profile. Twelve locations selected for water sampling were Agaram, Arumbavur, Kaikalathur, Neikuppai,Peraiyur, Pillangulam, Poolambadi, Thondamandurai, Thondappadi, Valikandapuram,Veppanthattai-North and Veppanthattai-South. The samples were collected in sterilized bottles and analyzed for various physico-chemical parameters. To analyse various parameters the standard procedures given in APHA (1998) was followed. The temperature of water samples was recorded on the spot using thermometer. pH meter (Systronicsdigital model 335)was used to determine the hydrogen ion concentration. The samples were analyzed for EC using Conductivity meter. Total Alkalinity (TA) was estimated by neutralizing with Standard HCl acid. Salinity and Total Dissolved Solids (TDS) were estimated using Systronics water analyzer. Total Hardness (TH) and Calcium Hardness (CH) as $CaCO_3$ was determined titrimetrically, using standard EDTA. The calculation of Magnesium Hardness (MH) was done by subtracting the CH from TH value. Fluoride was analyzed by SPANDS [2-(psulphophenylazo)1,8-dihydroxy-naphthalene-3,6-disulphonic acid tri sodium salt),$C_{16}H_9N_2O_{11}S_3Na_3$] colorimetric method.

Statistical Analysis

The statistical parameters like mean, SD, SE, correlation coefficient and t-test were calculated for physico-chemical parameters. (i) The mean and standard deviations are used to know the chemical parameters which are deviating from WHO standard. Whenever mean exceeds the permissible limit fixed by WHO, it is concluded that those particular places are all contaminated with respect to that chemical parameter. (ii) Correlation analysis was used to know the increasing or decreasing tendency of the physico-chemical parameter related with monsoon. Paired t-test is used to know the impact of monsoon on the parameters.

Student's t-test

A student's t-test was carried out between the means of parameters for pre-monsoon and post-monsoon seasons. To examine the significant

difference between the means, the student's t-test is computed by adopting the formula, which follows t-distribution with (n-1) degrees of freedom, is given by

$$t = \frac{\bar{x}_1 - \bar{x}_2}{S_2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}$$

where x_1 is the mean variable of pre-monsoon, x_2 is the mean variable of post-monsoon, S_2 is the variance of combined sample, n_1 is the number of observations on variable of pre-monsoon and $n_2$is the number of observations on variable of post-monsoon. If the computed value is greater than the critical value, the difference is significant (Murray JJ,1986).

Langelier Saturation Index

The Langelier Saturation Index (LSI; also called Langelier Stability Index) is a calculated number used to predict the calcium carbonate stability of water; that is, whether water will precipitate, dissolve, or be in equilibrium with calcium carbonate. Usually the LSI value ranges from -3 to +3.The LSI is expressed as the difference between the actual system pH and the saturation pH.

LSI = pH - pHs

pHs = (9.3 + A + B) - (C + D)

where **pH** = -log[H^+],

A = (Log_{10} [TDS] - 1) / 10

B = -13.12 x Log_{10} (T°C + 273) + 34.55

C = Log_{10} [Ca^{+2} as $CaCO_3$] - 0.4

D = Log_{10} [alkalinity as $CaCO_3$]

pHs = pH for a saturated solution of $CaCO_3$,

T= Temperature in ˚C

If the actual pH of the water is below the calculated saturation pH, the LSI is negative, which makes the $CaCO_3$ to dissolve in water and the water has a very limited scaling potential. If the actual pH exceeds pHs, the LSI is positive, and being supersaturated with $CaCO_3$, the water has a tendency to form a scale. At increasing positive index values, the scaling potential increases. According to Langelier, the corrosive action of water is mainly due to the presence of excess freeCO_2 and carbonates of calcium and magnesium. The interaction of free CO_2 with calcium and magnesium carbonates affects the carbonate equilibrium that leads to corrosion. The lower the pH with high free carbon dioxide, the higher will be the potential level of corrosion compared to the higher pH with low free CO_2 (Langelier, 1946).

Water Quality Index (WQI)

Water quality index (Tiwari and Mishra 1985) expresses overall water quality based on several water quality parameters. Water Quality Index is computed by the following formula

WQI = Antilog [SWn, n-1 1log 10qn]

where, $\mathbf{W_n}$, Weightage = K/S_n and **K**, constant = $1/S_{n,\ n=1}\ 1/S_i$

$\mathbf{S_n}$ and $\mathbf{S_i}$ correspond to the WHO / ICMR standard value of the parameters. Quality rating (q) is calculated as

Qni= [(Vactual – V ideal) / (Vstandard - V ideal)] x 100

where $\mathbf{q_{ni}}$ = quality rating of i^{th} parameter for a total of n water samples

$\mathbf{V_{actual}}$= value of the water quality parameter obtained from the laboratory analysis.

$\mathbf{V_{standard}}$ = value of the water quality parameter obtained from the standard tables.

$\mathbf{V_{ideal}}$ **for pH** =7 and for the other parameters it is equivalent to zero.

RESULTS AND DISCUSSION

Season-wise chemical compositions of 12 water samples of Veppanthattai Taluk, Perambalur District in the pre-monsoon and post-monsoon seasons are presented in Table 1. Descriptive statistics of water samples in pre-monsoon and post-monsoon of Veppanthattai Taluk, Perambalur District is shown in Table 2. Potable status of ground water samples in the Veppanthattai Taluk of Perambalur District in pre-monsoon and post-monsoon seasons is shown in Table 3.The temperature mean values of Veppanthattai region water samples were 32°C and 28.6°C in the pre-monsoon and post-monsoon seasons respectively. It is obvious that the samples collected from bore wells were found to have higher temperature than open wells.The increase in temperature decreases the portability of water due to expel of taste imparting $CO_2$and other gases. Thus, the taste of sample differs from place to place (Karunakaran et al., 2009).

The pH mean values of the water samples in the pre-monsoon and post-monsoon seasons were7.26 and 7.24 respectively. This approves that the nature of ground water samples vary from slightly acidic to slightly alkaline. All the samples were registered with the pH values between 6.5and 8.5 as per WHO. The TDS content of Valikandapuram was recorded as 307.7 mg/l with 0.482mS of EC during the pre-monsoon which gets diluted to 272.4mg/l (EC 0.465 mS) in the post - monsoon.

The TDS content of water samples in the pre-monsoon (mean 423.8 mg/l) wascomparatively greater than in the post-monsoon (mean 376.5 mg/l). The TDS values of watersamples were found

within the desirable limit of WHO (i.e.) 500mg/l except Neikuppai (579.8mg/l) and Veppanthattai_north (501.5 mg/l) in pre-monsoon. EC value is an index to represent thetotal concentration of soluble salts in water. The mean total alkalinity (TA) of the water samples ofVeppanthattai area were 274.8mg/l and 276 mg/l in the pre-monsoon and post-monsoon seasons. The salinity values of water samples ranged from 280.0 to 498.8 mg/l and 241.4 to 430.2 mg/l in the pre-monsoon and post-monsoon seasons respectively. The samples were registered with high TA and salinity values than the values recommended limit of WHO (200 mg/l). The impact of rainfall at the sampling stations has influenced marginal changes with respect to carbonate and bicarbonate ions. The same trend has been reported in Ramanathapuram District also. (Sivasankar,V. et al.,2009). In the pre-monsoon and post-monsoon seasons, Ca^{2+} was observed with the mean values of 195.4 mg/l and 174.9 mg/l respectively. The Mg^{2+} mean values of the water samples in the pre-monsoon and post-monsoon seasons were 104.1mg/l and 92.2 mg/l respectively. The $Ca^{2+}$and Mg^{2+} concentrations get decreased during post-monsoon (except Thondamandurai) as compared to the pre-monsoon. The presence of CH and MH in all water samples is more than the recommended limit of WHO (CH= 75 mg/l; MH=30 mg/l). The total hardness of the water samples varied between 237.7 mg/l and 373.1 mg/l in pre-monsoon and between 197.9 mg/l and328.5 mg/l in post-monsoon.

The ground water samples of Veppanthattai Taluk also were found to be hard (100-300 mg/l) to very hard (> 300mg/l) as suggested by Sawyer and Mc Carty (1967). The ground water samples were observed with the 33.3% and 25% of very hard nature in the pre-monsoon and post-monsoon respectively. The very hard nature was converted to hard nature in the study area Veppanthattai_north (373.1mg/l to 277.5mg/l) thus revealed the change in the quality of soil when the water table gets raised in post-monsoon. The total ground water samples of study area wereregistered with 100% belonging to fresh type (TDS<1000mg/l) in both pre-monsoon and post-monsoonseasons as per TDS classification given by Fetter (1990). The fluoride content of the

samples varied from 0.89 mg/l to 2.00mg/l and 0.81 mg/l to 1.76 mg/l in the pre-monsoon and post-monsoon respectively. There were 6 out of 12 samples in pre-monsoon and 2 out of 12samples in post-monsoon have exceeded the permissible limit of 1.5 mg/l (WHO). As reported earlier (Ramachandramoorthy et al., 2009), the dissolution of fluoride bearing minerals may be contributing the high percentage of fluoride in water samples. In this attempt, the suitable conditions for the dissolution of CaF2 in the potable water are slightly alkaline pH and moderate EC and being approved by the positive correlation value of F-CH (r=0.3705 in pre-monsoon; r =0.5334 in post-monsoon).Fig. 2 Comparison between total hardness and fluoride content for water samples of the study area during (a) pre-monsoon season and (b) post-monsoon season. Scatter Diagram for EC and TDS (a) Pre-monsoon season (b) Post-monsoon seasons is shown in Fig.3.

Student's t-tests are carried out for the combined data of pre-monsoon and post-monsoon seasons to determine the seasonal effect on groundwater. Results of t-tests are shown in Table 1. The critical value of t-test for df = 22 is 2.074 which is greater than the computed values of t-test for allthe variables (pH, EC, TA, SAL, CH, MH, TH, TDS, TSS, TS and fluoride content), the difference of means is not significant at 0.05 level in both of the seasons pre-monsoon and post-monsoon. It is inferred clearly from the results that there is no seasonal effect on the mean values of groundwater quality.

The Karl Pearson Correlation matrix has been calculated for the water quality parameters are displayed in Table 4. The correlation between CH and TH is significantly positive (r > 0.7) which ensures the utmost contribution of calcium for the TH. The correlation between salinity, EC and TDS is quite significant with respect to one another. The 'r' values for CH- Salinity, CH-TH and CH-TDS in both the seasons were good and they substantiate a direct influence and contribution of calcium ions to the salinity, TH and TDS which is in agreement with the studies conducted by Lagenegger (1990), Edet (1993) and Suman Mor (2003) et al. The correlation between pH and F was found to be negative in the pre-monsoon season(-0.021) and positive in the post-monsoon season (0.035). It was reported that the negative correlation between pH and F indicates that an increase in pH decreases the dissolution of F ions. The positive nature of 'r' values for F-CH in the pre-monsoon season was0.371 and in the post-monsoon season was 0.534 confirm that the elements behave non-conservatively.

Langelier Saturation Index was computed to understand the corrosive action of water samples.Fig.4 illustrates that 8.3 % of the samples were observed to show the tendency to cause corrosion (-LSI value) in both the seasons. The positive LSI values of about 50 % and 67% were observed to show the tendency for slightly scale forming and corrosive in the pre-and post-monsoon seasons respectively. 42% of water samples in the pre-monsoon and 25% of water samples in the post-monsoon season were observed with positive LSI values account for scale forming but non-corrosive nature. The very hard nature of the water samples may be the reason for $CaCO_3$ deposit, but in the pre-monsoon season, the concentration of the constituents causing deposition gets decreased as a

result of intensive evaporation in the hot climatic condition. The samples which cause corrosive action may be due to the low alkalinity.

From Fig.5, it is found that WQI for12 samples ranges from 29.37 to 112.66 and 30.59 to 102.09 in the pre-monsoon and post-monsoon seasons respectively. The WQI of water samples of study area in the pre-monsoon and post-monsoon seasons haveregistered 50% of good category, 25% and 33.33% under the poor category, about 16.67 and 8.33% under very poor categoryand about 8.33% under unfit category respectively.

CONCLUSION

The present study was confined to Veppanthattai Taluk. The pHs of water samples vary from slightly acidic to slightly alkaline. The influence of rain fall on the carbonate and bicarbonate ions of water samples was observed. The water samples were found to have hard (66.7% in pre-monsoon and 75%in post-monsoon) and very hard nature (33.3% in pre-monsoon and 25% in post-monsoon).The TDS values of total water samples of study area have been registered with100% belonging to fresh type in both pre-monsoon and post-monsoon seasons. In the areas where the fluoride content of water is more than the permissible limit of 1.5 mg/l (WHO)defluoridation has to be done and supplied to the children and public. The rate of accumulation of fluoride in the human body can be reduced by calcium and phosphorous rich food (JanardhanaRaju et al, 2009).

Most of the samples were observed with positive LSI value indicate the slightly scale forming and corrosive nature while few samples were observed with high positive LSI value explaining the scale forming and non-corrosive nature. Only one sample with negative LSI in each season was also observed.

The WQI of water samples of study area in the pre-monsoon and post-monsoon seasons have registered 50% of good category, 25% and 33.33% under the poor category and about 16.67 and 8.03%under very poor category respectively. About 8.33% of samples are under unfit category in both the seasons with respect to WQI value.

Management Plan

Proper treatments of water viz., water softening and defluoridation should be done to minimize the hardness and fluoride content in drinking water.

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Table 1: Physico-chemical parameters of 12 groundwater samples of Veppanthattai Taluk, Perambalur District in the pre-monsoon and post-monsoon seasons

Water Samples	Source	Temp °C		pH		EC(mS)		TA (mg/l)		Salinity (mg/l)		CH (mg/l)	
		PM1	PM2	PM1	PM2	PM1	PM2	PM1	PM2	PM1	PM2	PM1	PM2
Agaram	BW	33	30	7.61	7.47	0.627	0.568	170.8	161	420.3	353.3	207.5	178.8
Arumbavur	OW	30	26	7.02	7.06	0.562	0.532	302	308.3	346.5	315.8	188.2	151
Kaikalathur	BW	34	29	6.81	6.99	0.536	0.509	328.1	356.4	303.3	272.6	190.8	163.3
Neikuppai	BW	33	30	7.97	7.78	0.879	0.858	197.3	246	498.8	430.2	226.2	202.7
Peraiyar	OW	29	25	6.77	6.96	0.513	0.52	300.1	287.3	317.9	325	205.1	192.8
Pillangulam	OW	29	26	7.38	7.31	0.67	0.503	290.8	272.2	390.3	298.6	171.6	147.7
Poolambadi	BW	32	30	6.56	6.68	0.51	0.503	306	294.4	315	300.3	165.6	142.2
Thondamandurai	BW	34	30	7.17	7.01	0.581	0.56	278.2	250.6	403.9	353.2	197.7	208.1
Thondappadi	BW	33	31	7.82	7.6	0.678	0.54	337.1	349	467.3	369.6	235	226.8
Valikandapuram	OW	30	25	7.12	7.27	0.482	0.465	277	289.5	280	241.4	158.8	127.2
Veppanthattai_North	BW	34	31	7.98	7.68	0.719	0.606	208.5	213.5	463.3	392.2	206.1	176.8
Veppanthattai_South	BW	33	30	6.9	7.03	0.523	0.503	301.6	283.2	328.2	300.4	192.3	180.8
t-test		3.851		0.117		1.149		-0.055		1.876		1.893	

BW Bore well, OW Open well, EC Electrical Conductivity (mS), TA Total Alkalinity (mg/l),
CH Calcium Hardness (mg/l), PM1 Pre-monsoon, PM2 Post- monsoon

.

Table 1a: continued

Water Samples	Source	MH (mg/l)		TH (mg/l)		TDS (mg/l)		TSS (mg/l)		TS (mg/l)		Fluoride	
		PM1	PM2	PM1	PM2	PM1	PM2	PM1	PM2	PM1	PM2	PM1	PM2
Agaram	BW	90.3	93	297.8	271.8	479	408.3	106.71	13.3	585.7	521.6	1.67	1.28
Arumbavur	OW	79.2	84.2	267.4	235.2	402.1	361.6	260.3	278.6	662.4	640.2	1.01	0.95
Kaikalathur	BW	101.6	80.4	292.4	243.7	358.3	306.8	97.8	90.3	456.1	397.1	2	1.62
Neikuppai	BW	121.7	105	347.9	307.7	579.8	497.1	127.1	138.6	706.9	635.7	1.91	1.76
Peraiyar	OW	88.2	83.1	293.3	275.9	376.3	397	179.8	203.2	556.1	600.2	1.17	1.2
Pillangulam	OW	96.8	98.2	268.4	245.9	428.8	390.7	270	306	698.8	696.7	0.98	0.81
Poolambadi	BW	89.7	96.3	255.3	238.5	351.7	364.2	148.2	135.9	499.9	500.1	1.82	1.44
Thondamandurai	BW	138.8	120.4	336.3	328.5	445	396.8	190	167.6	635	564.4	1.19	1.37
Thondappadi	BW	108.3	97.9	343.3	324.7	488.1	376.2	89.9	94.6	578	470.8	1.65	1.33
Valikandapuram	OW	78.9	70.7	237.7	197.9	307.7	272.4	198.2	210.5	505.9	482.9	0.89	0.82
Veppanthattai_North	BW	167	100.7	373.1	277.5	501.5	428.8	128.3	114.5	629.8	543.3	0.98	1.17
Veppanthattai_South	BW	88.2	75.9	280.5	256.7	367	318.3	103.9	112	470.9	430.3	1.46	1.42
t-test		1.379		1.97		1.671		-0.198		1.156		0.9	

BW Bore well, OW Open well, MH Magnesium Hardness (mg/l), TH Total Hardness (mg/l),
TDS Total Dissolved Solids (mg/l), TSS Total Suspended Solids (mg/l), TS Total Solids (mg/l), PM1 Pre-monsoon, PM2 Post- monsoon.

Table 2: Descriptive statistics of ground water samples of Veppanthattai Taluk, Perambalur District in pre-monsoon and post-monsoon seasons

Parameter	Pre-monsoon season					Post-monsoon season				
	Minimum	Maximum	Mean	σ	CV	Minimum	Maximum	Mean	σ	CV
Temp.	29	34	32.00	1.95	3.82	25	31	28.58	2.35	5.54
pH	6.56	7.98	7.26	0.49	0.24	6.68	7.78	7.24	0.34	0.11
EC	0.482	0.879	0.61	0.11	0.01	0.465	0.858	0.56	0.10	0.01
Salinity	280.00	498.80	377.90	73.05	5335.63	241.40	430.20	329.30	52.76	2783.86
TS	456.10	706.90	582.13	86.46	7475.11	397.10	696.70	540.28	90.66	8219.72
TDS	307.70	579.80	423.78	78.02	6086.41	272.40	497.10	376.52	59.38	3525.49
TSS	89.90	270.00	158.35	61.70	3806.93	90.30	306.00	163.76	71.62	5128.72
TH	237.70	373.10	299.47	41.85	1751.84	197.90	328.50	267.00	38.93	1515.73
CH	158.80	235.00	195.41	22.87	523.07	127.20	226.80	174.85	29.75	884.81
MH	78.90	167.00	104.06	26.47	700.54	70.70	120.40	92.15	13.92	193.75
TA	170.80	337.10	274.79	53.33	2844.01	161.00	356.40	275.95	54.13	2929.78
F	0.89	2.00	1.39	0.40	0.16	0.81	1.76	1.26	0.30	0.09

Temp = Temperature in ºC; pH in units; EC = Electrical conductivity in mS; all other parameters are expressed in mg/l;
σ Standard Deviation ; CV coefficient of variance

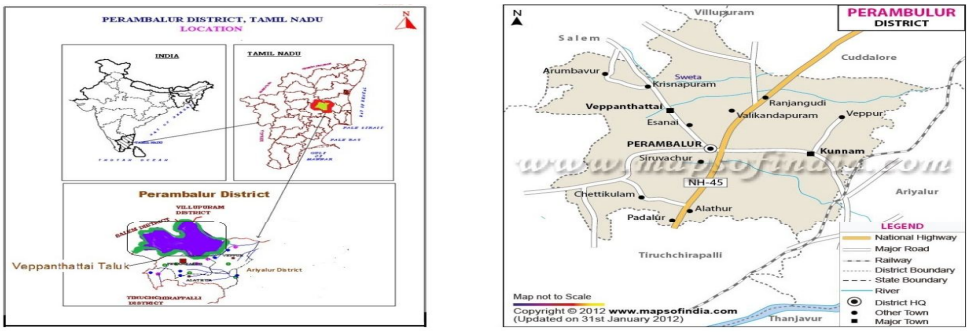
Table 3: Potable status of ground water samples in the Veppanthattai Taluk of Perambalur District in pre-monsoon and post-monsoon seasons

Parameter	WHO (2006)	Pre-monsoon			Post-monsoon		
	Permissible Level	BPL	WPL	APL	BPL	WPL	APL
pH	6.5-8.5	-	12	-	-	12	-
EC (mS)	1.4	12	-	-	12	-	-
Salinity (mg/l)	200-600	-	12	-	-	12	-
TS (mg/l)	500-1000	3	9	-	4	8	-
TDS (mg/l)	500-1000	10	2	-	12	-	-
TSS (mg/l)	0-5	-	-	12	-	-	12
TH (mg/l)	300-500	8	4	-	9	3	-
CH (mg/l)	75-200	-	7	5	-	9	3
MH (mg/l)	30-150	-	11	1	-	12	-
TA (mg/l)	200	2	-	10	1	-	11
F (mg/l)	0.5-1.5	-	7	5	-	10	2

Table 4: Karl-Pearson correlation matrix

Seasons	Parameters	pH	EC	TA	Salinity	CH	MH	TH	TDS	TSS	TS	F
Pre-monsoon	pH	1										
Post-monsoon												
Pre-monsoon	EC	.869**	1									
Post-monsoon		.636*										
Pre-monsoon	TA	-.619*	-.568	1								
Post-monsoon		-.391	-.364									
Pre-monsoon	Salinity	.912**	.918**	-.547	1							
Post-monsoon		.674*	.829**	-.452								
Pre-monsoon	CH	.644*	.643*	-.265	.765**	1						
Post-monsoon		.395	.464	-.060	.729**							
Pre-monsoon	MH	.602*	.574	-.385	.667*	.436	1					
Post-monsoon		.275	.491	-.359	.693*	.528						
Pre-monsoon	TH	.732**	.714**	-.388	.840**	.822**	.871**	1				
Post-monsoon		.400	.530	-.174	.804**	.953**	.761**					
Pre-monsoon	TDS	.873**	.945**	-.615*	.979**	.782**	.624*	.822**	1			
Post-monsoon		.553	.822**	-.539	.914**	.536	.722**	.667*				
Pre-monsoon	TSS	-.230	-.171	.161	-.262	-.544	-.248	-.454	-.251	1		
Post-monsoon		-.181	-.222	.046	-.319	-.475	-.082	-.392	-.051			
Pre-monsoon	TS	.624*	.731**	-.440	.696*	.318	.386	.418	.723**	.487	1	
Post-monsoon		.219	.363	-.317	.346	-.025	.408	.127	.615*	.756**		
Pre-monsoon	F	-.021	.213	-.010	.156	.371	-.056	.167	.222	-.717**	-.312	1
Post-monsoon		.035	.556	.052	.451	.534	.284	.509	.335	-.756**	-.378	1z

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)



(a) **(b)**

Fig. 1: Map of the study area

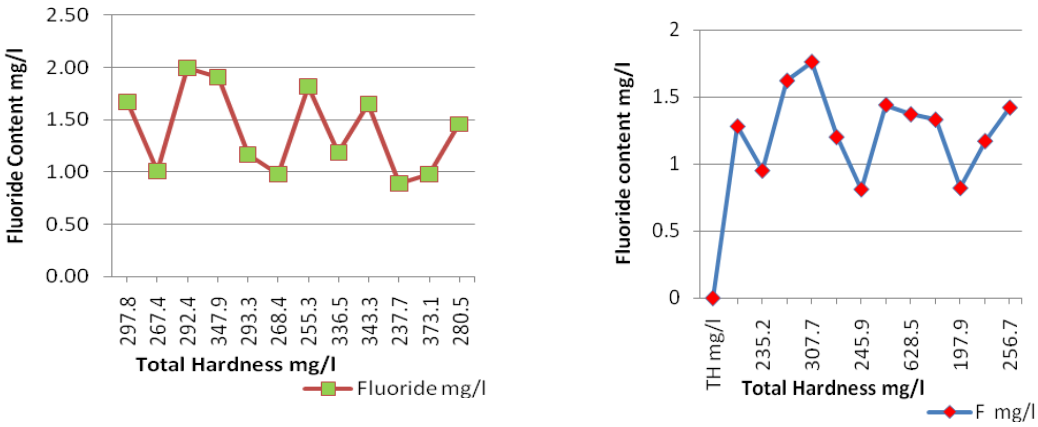


Fig. 2: Comparison between total hardness and fluoride content for water samples of the study area during (a) pre-monsoon season and (b) post-monsoon season

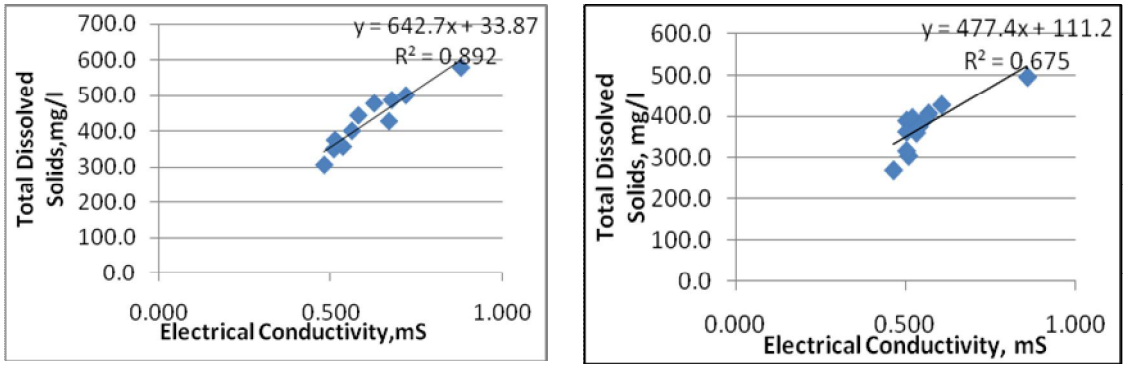


Fig. 3: Scatter Diagram for EC and TDS (a) Pre-monsoon season (b) Post-monsoon Season

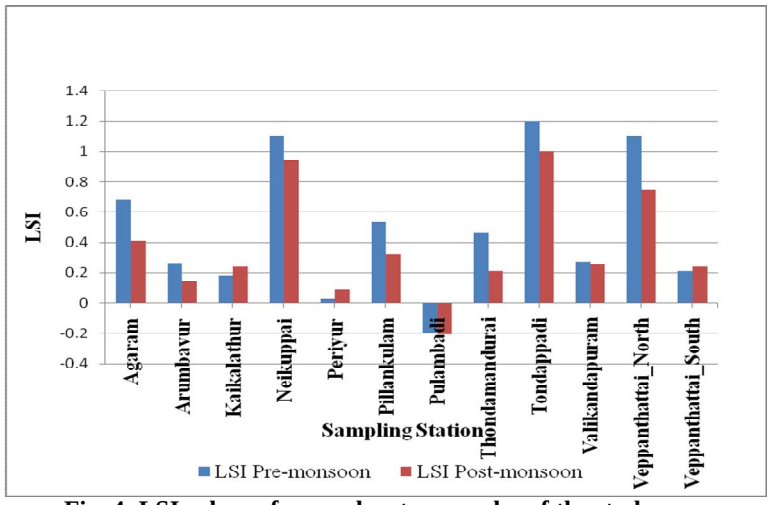


Fig. 4: LSI values of ground water samples of the study area

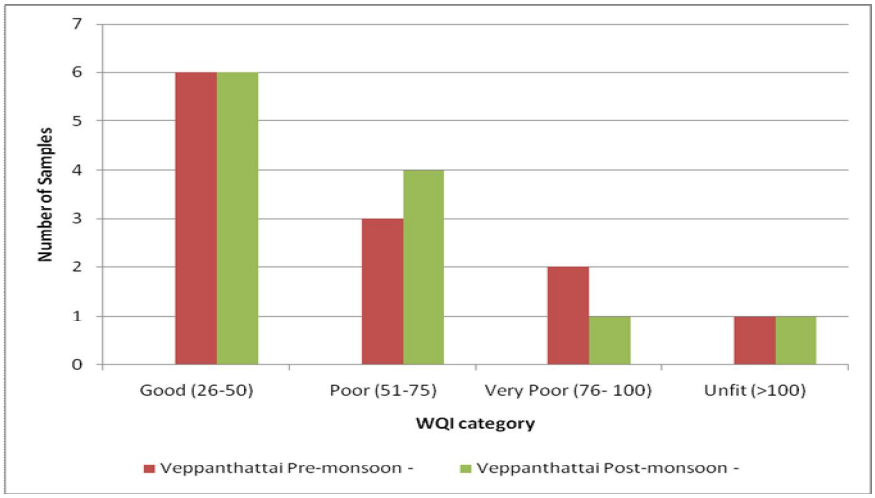


Fig. 5: WQI status of ground water of Vappanthattai Taluk

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