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Research Paper

Chemometric Analysis of Water Quality Parameters of Dindigul District- A Seasonal Variation Study

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Abstract: *The seasonal variations of water quality parameters of 10 blocks of Dindigul districts were discussed in this study, the ground water quality data for 10 physical and chemical parameters collected from ten blocks of Dindigul district were analysed using PCA and the fluoride endemic regions in two blocks were represented using GIS mapping techniques.*

Keywords: PCA, Statistical analysis, GIS mapping, ground water, fluoride

Introduction

All the living organisms require water for their metabolic activities. Apart from that human beings use water for drinking, agricultural, industrial and power generation purposes. The rapid population growth, technological developments, increases in the living standards etc., resulted in greater demand of good quality of water. On the other hand the pollution of water resources is increasing steadily. Most of the diseases are caused by the poor quality of water when it is consumed or contacted. Since, the public health depends to a greater extend on the quality of drinking water which is to be monitored continuously. Apart from that the ground water contamination is taken place by the seasonal fluctuations. Most of the chemicals are dissolved in the ground water due to its unique polar nature. The quality of water depends on the location of source and the state of environmental protection in a given area. As environmental research cannot be adequately handled with parameters one by one after the preliminary univariate approach. The principal component analysis (PCA) allow us to rationalize the system under study, displaying the experimental data in a bidimentional space, without significant loss of information.

Surface water quality monitoring was done by many researchers since 1959. But for bore wells it's less in number when comphared to the monitoring of surface water quality and the seasonal variations for bore wells are new era of water quality monitoring regarding the bore wells. The aim of the present study is to analyse the 10 parameters of water in 25 habitations each from ten blocks (Palani, Thoppampatti, Sanarpatti and Natham) of Dindigul district for four seasons (Post Monsson, Summer, Pre Monsoon and Monsoon of 2007). The obtained data set is subjected to the multivariate statistical method i.e., PCA to evaluate information about similarities and dissimilarities between sampling habitations, to recognize water quality variables for seasonal variations in ground water quality. The fluoride endemic areas also indicated by GIS technique.

Material and Methods

All the chemicals used in the present study were of commercially available high purity Analar grade (Sd fine/Merck, Sigma Aldrich, India) and were used as received. Aniline and pyrrole were distilled prior to use. The stock solutions were prepared by using doubly distilled water.

Water sample collection

Groundwater samples were collected form 25 habitations (Figure 1) each from ten blocks viz. Palani, Thoppampatty, Oddanchatram, Vedasandur, Guziliyamparai, Vadamadurai, Sanarpatty, Natham, Dindigul and Nillakottai of Dindigul district, Tamil Nadu for four seasons in a 2 L polyethylene bottles employing random sampling technique. The collection of water samples were done in the first week of the middle month of post monsoon (January-March), summer (April-June), pre monsoon (July-September) and monsoon (October-December) seasons during 2007. After collecting the samples, the analyses were carried out within two days.

Analysis of water quality parameters

The groundwater samples collected from the drinking water sources, 25 habitations per block, were analyzed chemically. The important water quality parameters such as total hardness, total alkalinity, pH, electrical conductance, total dissolved solids, calcium, magnesium, chloride, fluoride and sulphate were estimated for the samples by adopting conventional analytical/spectral techniques.

Estimation of Fluoride

The fluoride electrode is an ion-selective sensor. The key element in the fluoride electrode is the laser-type doped lanthanum fluoride crystal across which a potential is established by fluoride solutions of different concentrations. The crystal contacts the sample solution at one face and an internal reference solution at the other.

The cell may be represented as by

Ag/AgCl, Cl^- (0.3M), F^-(0.001M)/LaF_3 /test solution/Reference electrode

The fluoride electrode measures the ion activity of fluoride in solution rather than concentration. Fluoride ion activity depends on the solution total ionic strength and pH, and on fluoride complexing species. Adding an appropriate buffer provides a nearly uniform ionic strength background, adjusts pH, and breaks up complexes so that, in effect, the electrode measures concentration.

The 10 ml of standard fluoride solutions of 1.0 mg/L and 10.0 mg/L were taken in the beakers and 10 ml buffer solution were added to each beaker and immersed in the electrode for calibration of the ion selective meter. 10 ml of water sample was taken in a beaker and 10 ml of buffer solution was added and the electrode was immersed in that sample and the fluoride concentration was read directly.

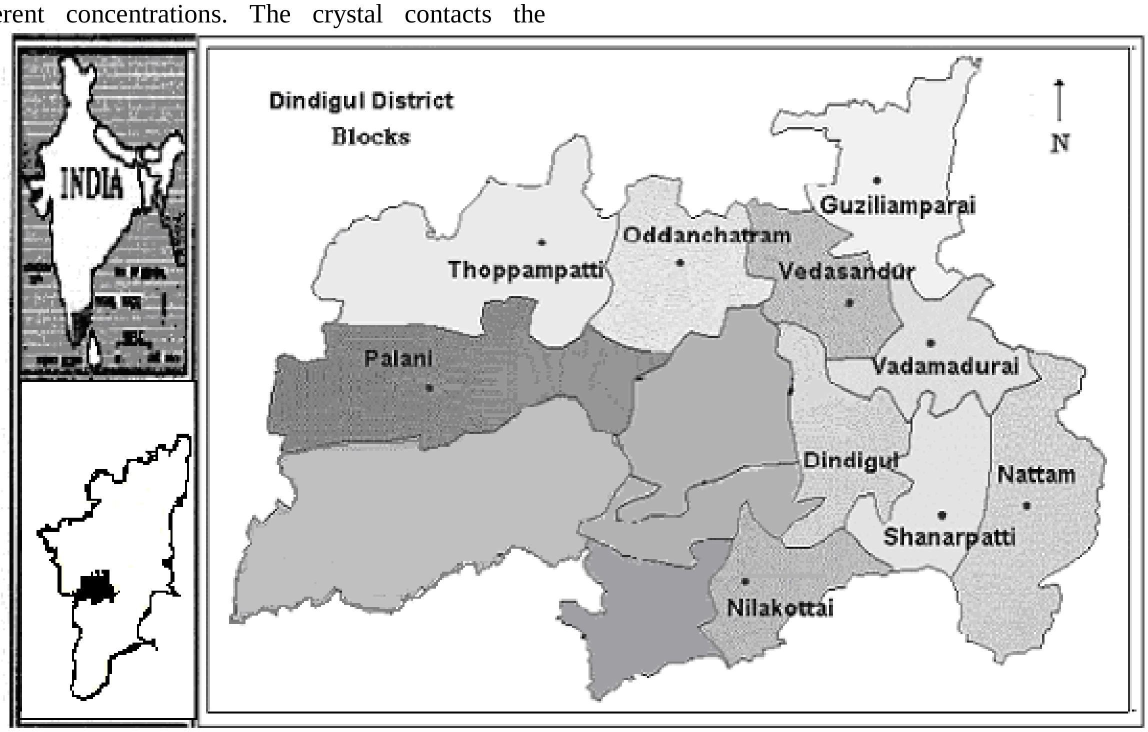

Figure 1: Block wise map of Dindigul district

Results and Discussion

Study area

Dindigul district is situated in the southwestern part of Tamil Nadu in South India. On the west it is bounded by the Coimbatore and Theni districts and in the north by Karur district while in the east by Sivaganga district and south by Madurai district. Dindigul district lies in between the geographic co-ordinates of North latitude 10^0 05" to 10^0 9" and East longitude 77^0 30" to 78^0 20". The geographical area of this district is 6267 sq. km. The population of the district as per the provisional census

2001 is 19,23,014. The district enjoys tropical climate and the period from April to June is generally hot and dry. The average annual rainfall of the district is 813 mm. The major water bearing formations of the district are weathered and fractured Charnockite and Granite Gneisses which are the predominant geological formations in the study area. The groundwater of this district belongs to Ca-Cl, Ca-HCO_3 and Na-Cl type[1] .

Dindigul district consists of fourteen blocks viz. Dindigul, Sanarpatti, Athur, Reddiarchatram, Kodaikanal, Natham, Palani, Thoppampatti, Nilakottai, Vattalakundu, Oddanchatram, Vedasandur, Vadamadurai and Gujiliyamparai (Figure 1).

Out of which ten blocks viz. Dindigul, Sanarpatti, Natham, Palani, Thoppampatti, Nilakottai, Oddanchatram, Vedasandur, Vadamadurai and Gujiliyamparai blocks (Figure 1) were selected for the present study to investigate the effects of seasonal variation on the water quality parameters, in general, and fluoride in particular. These ten blocks were selected for the study as the people of these blocks largely dependent on groundwater for their drinking purpose and also are moderately affected by dental fluorosis. Further, in the remaining four blocks major parts are forest area and hence they were excluded from the present study. The water samples were collected from the bore wells of 25 habitations each from these ten blocks by random sampling technique. This ensures that the composition of the sample is identical to that of water body from which it is collected and the samples share the same physico-chemical characteristic with the sampled water at the time and site of sampling[2] .

The collection of water samples was done in the first week of the middle month of every season viz. post monsoon (PoM), summer (Sum), pre monsoon (PrM) and monsoon (Mon) seasons during the year 2007. The samples were analyzed for important water quality parameters viz. electrical conductivity (EC), total dissolved solids (TDS), pH, total alkalinity (TA), total hardness (TH), Ca(II), Mg(II), chloride (Cl^-), fluoride (F^-) and sulphate (SO_4^{2-}) ions using standard procedure.

Physico-chemical characteristics of water samples

The physico-chemical characteristics of the groundwater samples of the ten blocks of Dindigul districts for four seasons were analysed and the statistical data are presented in Table 1. The EC values were in the range of 170 to 4700 S. The higher EC values may be due to the presence of large quantity of dissolved mineral salts in these water samples thereby making it unfit for drinking purpose. This similar observation was shown by the TDS also which is observed in Dindigul district. TDS of the water samples ranged from 125 to 3290 mg/L. The high value of TDS may be due to the presence of the hard rocks in these areas. The pH values were found to be in the range of 5.0 to 8.2 and are within the permissible limits.

The alkalinity values were almost within the permissible limit (12-1670 mg/L) as recommended by WHO. The TH values of water samples were found to be in the range of 24 to 1680 mg/L, which shows a little bit higher values than the standard values. Although hard water has no known effect on health but it is unsuitable for domestic uses due to the scale formation on utensils and poor leathering of soap. The chloride ions ranged from 3-1160 mg/L shows may harm the metallic pipes and imparts salinity to water. The concentration of sulphate ion ranged from 2 to 420 mg/L shows it falls within the permissible limits. The fluoride in present in water is ranging from 0.1 to 2.88 mg/L. This slight excess amount of fluoride ions is responsible for the observed dental fluorosis in the district.

Mapping of fluoride endemic regions

The fluoride map of Sanarpatti and Natham blocks (as representative cases) for all the seasons were prepared on the basis of the fluoride levels of groundwater sources by GIS mapping technique and are shown in Fig. 2. From this map the areas are identified as the ones containing the maximum fluoride pollution. Such a mapping of fluorotic areas helps in the locating the regions that require immediate attention by the government for remedial measures to minimize fluoride intoxication.

Water Quality Index

A water quality index (WQI) provides a single number that expresses over all water quality at a certain location based on several water quality parameters. The objective of water quality index is to turn complex water quality data into information that is understandable and usable by the public. In this study the following ten parameters were considered to calculate the water quality index for drinking purpose with Central Public Health Environmental Engineering Organization (CPHEEO) standards: EC, TDS, pH, TA, TH, Ca(II), Mg(II), Cl^-, SO_4^{2-} and F^- ions based on the method endorsed by the Canadian Council of Ministers of the Environment.

Table 1: Statistical results of the groundwater samples in Dindigul district

Variable	Post-Monsoon				Summer				Pre-Monsoon				Monsoon			
	Min	Max	Mean	Sd	Min	Max	Mean	Sd	Min	Max	Mean	Sd	Min	Max	Mean	Sd
EC	190	4700	1489	900	190	4700	1574	879	170	4520	1570	891	180	4325	1580	926
TDS	125	3290	1082	1229	145	3290	1077	616	150	3175	1084	624	135	3024	1042	633
pH	7	8.2	8	5	7	8	8	0	7	8	8	0	7	8	8	0
TA	32	1670	343	242	22	1540	338	253	15	1540	334	243	12	1670	347	271
TH	24	1680	447	288	24	1200	416	257	24	1310	447	285	24	1455	472	330
Ca(II)	7	650	108	101	10	620	109	110	10	1070	123	126	10	580	110	92
Mg(II)	8	606	74	76	6	370	71	70	10	642	70	72	10	385	69	68
Cl^-	3	1160	198	203	3	1020	196	184	3	900	193	204	3	1044	191	184
SO_4^{2-}	2	380	60	74	2	350	67	67	2	420	60	73	2	375	55	63
F^-	0.10	2.74	0.90	0.50	0.10	2.86	1.19	0.60	0.20	2.5	1.12	0.87	0.10	2.88	1.10	0.51

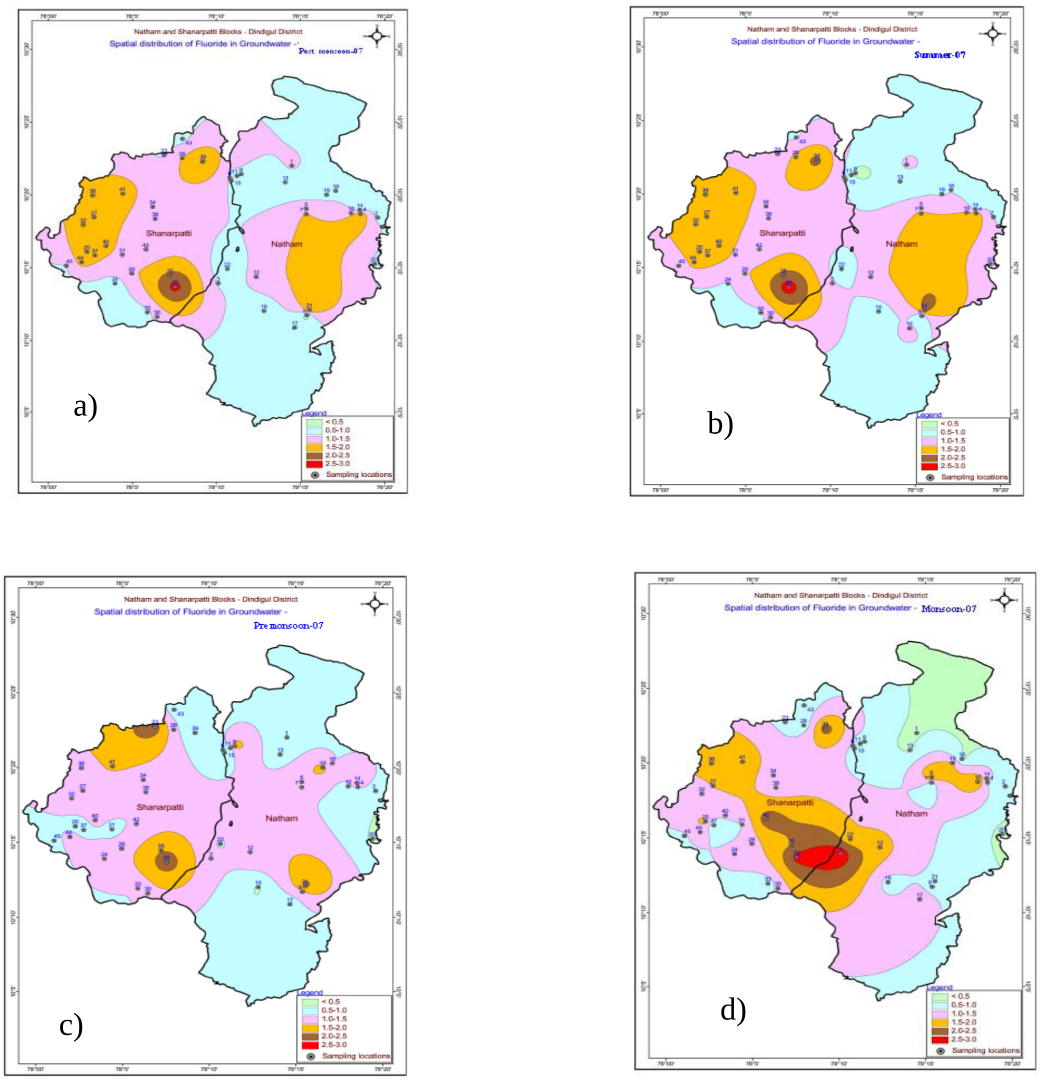

Figure 2: Fluorotic zones of Sanarpatti and Natham blocks a) in post monsoon, b) Summer, c) Pre-monsoon and d) Monsoon of 2007

Table 2: Rainfall data in dindigul district

S. No.	Season	Rainfall (mm)
1	Monsoon 2006	
2	Post Monsoon 2007	27.56
3	Summer 2007	197.9
4	Pre monsoon 2007	178.47
5	Monsoon 2007	626.14

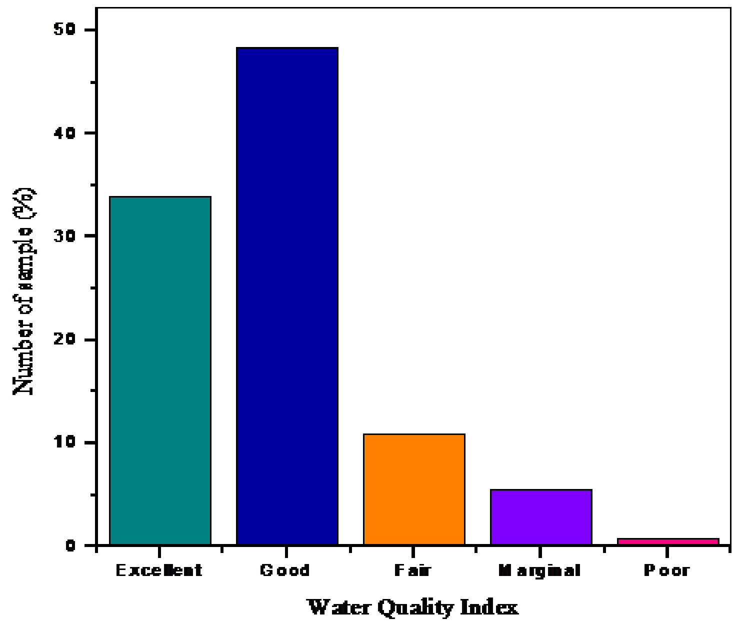

Figure 3: Water Quality Index for Dindigul district (Total no of samples = 250; 25 samples per block)

Seasonal effects on the prevalence of fluoride

People in the study area largely depend on groundwater for drinking purpose. The results in Table 1 indicated that the concentration of fluoride ion in these waters is not very high and a maximum concentration of 2.88 mg/L was recorded during the study period. Though the fluoride ion concentration is not very high, incidence of dental fluorosis is a common feature in this area. Hence an attempt was made to study the effect of seasonal variation on the prevalence fluoride in the district, as a case study. The number of water samples containing fluoride greater than and less than the permissible limit (1.5 mg/L), on a percentage basis, in the district as a function of season is given in Figure 4.

The results indicated that the number of water samples containing fluoride ion concentration greater than 1.5 mg/L decreased during post monsoon and monsoon seasons of 2007. While the number of safe water samples, as for as fluoride is concerned, was found to be minimum during summer. This observation can well be explained using rainfall data of the regions. The season-wise rainfall (in mm) of the region during the study period for the district is collected in Table 2. The rainfall data were obtained from Tamilnadu Water Supply and Drainage Board, Govt. of Tamil Nadu. In 2007 the pre-monsoon and post-monsoon depth of water are 0.12 to13.10 m and 0.90 to 14.90 m below ground level, respectively [2].

Comparison of the data in Table 2 with the results presented in Figure 4 indicated that the concentration of fluoride in the ground waters decreased either during or immediately after rainfall i.e. during monsoon and post monsoon seasons. This observation can most probably be explained in terms of the geology of the regions and the groundwater type as follows. The major water bearing formations of the district are weathered and fractured Charnockite and Granite Gneisses which are the predominant geological formations in the study area. The groundwater of this district belongs to Ca-Cl, Ca-HCO_3 and Na-Cl type [1]. During monsoon, fluoride gets dissolved, from fluoride bearing minerals, in the water and causes the enrichment of fluoride ion. Also during monsoon, the concentration of calcium ion increases significantly as evidence from the ground water type. Such an increase in the concentration of calcium ions might have precipitated fluoride ions as fluorite leading to decreased in the concentration of fluoride ions in the ground waters as observed.

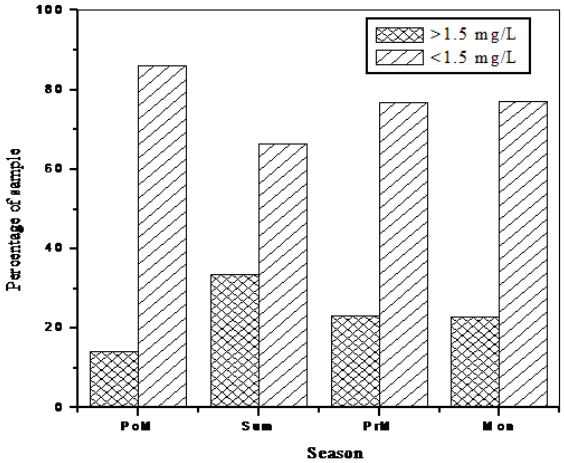

Figure 4: Plot of fluoride bearing water samples (%) versus season

Recharge of ground waters as a result of rainfall may either dilute fluoride ions or increase the concentration of fluoride ions in groundwater by the dissolution of fluoride bearing minerals present in the area. The results of the present study indicated that the concentration of fluoride ions decreases with an increase in rainfall not just by dilution phenomenon but as a result of concurrent dissolution of calcium ions during rainfall which consequently precipitates fluoride ions as fluorite. This perception is well supported by the groundwater type of the study area. To conclude, in the study area, rainfall and concentration of fluoride ions in the ground waters are inversely related to each other i.e. increase of rainfall decreased the fluoride ion concentration in the ground waters.

Principal Component Analysis

Chemistry of water is one of the important factors for determining its use for domestic, irrigation or industrial purposes. People in the study area depend largely on ground waters for their needs. The quality of groundwater depends on several factors, including climate, soil characteristics, manner of circulation of groundwater through the rock type, topography of area. The chemical composition of groundwater depends not only on natural factors such as lithology of aquifer, the quality of recharge waters and types of interactions between water and aquifer, but also on human activities which can alter fragile groundwater systems either by polluting them or by changing hydrological cycle.

Regular drinking water monitoring is essential for supplying people with a high quality and healthy water meeting all requirements of legal regulations. The analysis of groundwater quality is an important and sensitive issue. The water quality is mostly characterized by many variables (parameters) which represent a water composition in specific localities and time. Due to spatial and temporal variations in water chemistry, a monitoring program that provides a representative and reliable estimation of the quality of the ground waters has become an important necessity. Consequently, comprehensive monitoring programs that include frequent water sampling at numerous sites and that consists a full analysis of a large number of physicochemical parameters are to be designed for proper management of water quality in ground waters. These programs often results in a large data matrix, which are often difficult to interpret and draw meaningful conclusions. Further, for effective pollution control and water resource management, it is required to identify the pollution status, pollution sources and their quantitative contributions.

Different multivariate statistic analysis such as factor analysis (FA), cluster analysis (CA) and principal component analysis (PCA) are all used for the interpretation of these complex data matrices with the objective of a better assessment of the water quality and identify the pollution source apportionments. They are designed to reduce the number of variables to a small number of indices while attempting to preserve the relationships present in the original data. They further allow the identification of the possible factors/sources influencing the system and offer not only a valuable tool for reliable management of water resources but also provide rapid solutions to pollution problems. Based on the fundamentals discussed above, an attempt was made to implement principal component analysis method in order to identify practical pollution indicators in the study area. Unlike other statistical methods, PCA is a robust technique which does not require normally distributed and uncorrelated variables. Furthermore, this study also intends to provide a basis on developing realistic tools that could help local decision-makers on the suitable management of the groundwater in the area.

In the present study 250 monitoring stations, 25 habitations each in ten blocks viz. Palani, Thoppampatty, Oddanchatram, Vedasandur, Gujiliamparai, Vadamadurai, Sanarpatty, Natham, Dindigul and Nilakottai (Fig. 1) blocks of Dindigul district, and ten physicochemical parameters obtained from each habitation during 2007 were used for statistical analysis. The analytical results of the water quality parameters in the 250 groundwater samples during post monsoon, summer, pre monsoon and monsoon seasons of 2007 are given in Table 1.

In Dindigul district, during the study period the mean value of majority of the water quality parameters, except EC and TDS, were well within the values recommended by the WHO guidelines for drinking water quality standards for developing countries. During the four seasons the mean EC values in these ground waters are slightly higher than the WHO standard. Similarly the mean values of TDS, during the study period, are slightly greater than that recommended by the WHO but well within the BIS and CPHEEO standards. Though many water samples in the district contain fluoride ion concentrations slightly over the maximum acceptable concentration for health related chemical contaminants as recommended by the WHO, the mean value of fluoride ion concentration was found to be less than that recommended by WHO i.e. less than 1.5 mg/L. It is well established that fluoride bearing waters are soft [3-6]. Hence, in the present study, the low mean values of fluoride ion concentration in the ground waters may due to the high concentrations of TDS in the water samples.

The water quality data collected was subject to principal component analysis (PCA) to understand the influence of various parameters on the quality of the groundwater in the study area. PCA is a powerful pattern recognition tool that attempts to explain the variance of a large dataset of intercorrelated variables with a smaller set of independent variables. PCA technique extracts the eigen values and eigen vectors from the covariance matrix of original variables. The principal components (PC) are the uncorrelated (orthogonal) variables obtained by multiplying the original correlated variables with the eigen vector, which is a list of coefficients (loadings or weightings). Thus, the PCs are the weighted linear combinations of the original variables. PC provides information on the most meaningful parameters, which describe the whole data set while affording data reduction with a minimum loss of original information. PCA assumes that only a limited number of causes or sources (PC) are responsible for most of the variance in the original data array [7].

The eigen values, percentage of variance and cumulative percentage for all the water samples in the system resulted from the PCA are given in Table 3. From the water quality parameters data, four principal components, explaining 70-75% of the total variance, was estimated on the basis of Kaiser [8] 19 criterion of the eigen values greater or equal to 1 and from Cattel scree plots [9]. A scree plot shows the eigen values sorted from large to small as a function of the principal components number. The scree plots are shown in Fig. 5. These plots indicated that after the fourth PC, starting the elbow in the downward curve, other components can be omitted.

The components loadings of the first four retained PCs are summarized in Table 4. The component loading was classified as per Liu et al. [10], who categorized the component loadings as strong, moderate and weak corresponding to absolute loading values of >0.75 as strong, of 0.75-0.50 as moderate and 0.50-0.40 as weak. The higher the loading of a variable the more that variable contributes to the variation accounted for by the principal component. Further, if a given variable has a meaningful loading (if it absolute value exceeds 0.4) on more than one component, that variable may be scratched out and also be ignored from interpretation because such variables are not pure measures of any one construct [11-12].

The PCA of water quality parameters from the 250 habitations indicates that in groundwater; altogether four factors (principal components) explain 70-75% of the total variance. During post monsoon season, principal component 1 (PC1) accounts for 34.9% of the total variance. The PC1 is associated with strong positive loadings of EC, TH and Mg(II) and with a moderate positive loading of TDS (Table 4). EC and TDS levels were found to be slightly higher, than that recommended by the WHO, in these samples. EC varies from 190 to 4700 µS with an average of 1489 µS and TDS varies from 125 to 3290 mg/L with an average of 1082 mg/L. TH concentration varies from 24 to 1680 mg/L with an average of 447 mg/L and Mg(II) varies from 8 to 606 mg/L (average = 74 mg/L). In this component, EC, TDS, TH and Mg(II) correlate significantly ($r > 0.532$) with each other, suggesting a common source. As it is obvious, PC1 can be called as the salt component because it is mainly saturated with EC and TH including Mg(II) ion. All these parameters are typical indicators of natural diffuse inputs [7-8].

PC2 accounts for 13.5% of the total variance. During this season, PC3 exhibits 11.3% of the total variance with moderate positive loading on fluoride. Fluoride varies from 0.10 to 2.74 mg/L with an average of 0.90 mg/L. PC3 can, therefore, be called as fluoride contamination component. PC4 accounts for 10% of the total variance of 69.8% with moderate positive loading on pH. This principal component can therefore be termed as the acidity-alkalinity component. pH varies from 7 to 8.2 with an average of 8. During pre monsoon season, other water quality parameter viz. TA, Ca(II), Cl^- and SO_4^{2-} were ignored from the interpretation as these variables has a meaningful loading (absolute value exceeds 0.4) on more than one component [11,12].

Table 3: Eigen values, percentage of variance (V) and cumulative percent (C) of water quality parameters of Dindigul districts during 2007

Principal component	Postmonsoon			Summer			Pre Monsoon			Monsoon		
	Eigen	V (%)	C %	Eigen	V (%)	C %	Eigen	V (%)	C %	Eigen	V (%)	C (%)
1	3.5	34.9	34.9	4.3	42.8	42.8	4.0	39.9	39.9	4.1	41.8	41.7
2	1.3	13.5	48.4	1.3	13.5	56.3	1.6	15.6	55.6	1.4	13.8	55.5
3	1.1	11.3	59.8	1.1	10.9	67.2	1.1	11.0	66.7	1.0	10.4	66.0
4	1.0	10.0	69.8	1.0	10.0	77.3	1.0	10.4	77.0	1.0	9.7	75.7
5	0.9	9.8	79.6	0.9	9.2	86.5	0.9	8.8	85.9	0.9	8.8	84.5
6	0.7	7.5	87.1	0.8	7.6	94.1	0.7	7.3	93.2	0.8	8.2	92.7
7	0.6	5.9	93.1	0.2	2.4	96.5	0.3	3.4	96.6	0.3	3.0	95.8
8	0.3	3.3	96.4	0.2	1.9	98.5	0.2	2.3	98.8	0.2	2.2	98.0
9	0.3	2.7	99.1	0.1	1.4	99.9	0.1	1.1	99.9	0.1	1.0	99.1
10	0.1	0.9	100.0	0.01	0.1	100.0	0.01	0.05	100.0	0.08	0.8	100.0

Table 4: Loaded values of principal components in Dindigul district during 2007

	Post monsoon				Summer				Pre-Monsoon				Monsoon			
	P1	P2	P3	P4	P1	P2	P3	P4	P1	P2	P3	P4	P1	P2	P3	P4
EC	0.90	0.28	0.07	-0.05	0.94	0.24	0.02	-0.03	0.91	0.31	-0.17	0.01	0.91	0.28	0.01	-0.01
TDS	0.56	0.40	0.09	-0.21	0.94	0.24	0.02	-0.01	0.91	0.30	-0.17	0.01	0.85	0.33	-0.09	0.00
pH	-0.06	0.10	-0.27	0.55	-0.14	0.48	-0.12	0.70	0.12	0.37	0.76	-0.08	-0.24	0.13	-0.56	0.69
TA	0.57	-0.54	-0.08	-0.26	0.65	-0.37	-0.54	0.21	0.65	-0.35	-0.18	-0.39	0.71	-0.36	-0.19	-0.23
TH	0.80	-0.21	0.12	0.32	0.83	-0.29	0.26	-0.02	0.84	-0.28	-0.01	-0.01	0.86	-0.25	0.03	0.12
Ca(II)	0.57	-0.28	-0.09	0.49	0.39	-0.44	0.55	0.09	0.46	-0.48	0.54	0.30	0.58	-0.27	0.05	0.50
Mg(II)	0.74	-0.35	-0.29	-0.15	0.80	-0.32	-0.24	0.22	0.77	-0.43	0.15	-0.16	0.85	-0.34	-0.14	-0.13
Cl^-	0.57	0.58	0.41	0.18	0.58	0.53	0.34	-0.21	0.53	0.63	-0.11	0.08	0.44	0.60	0.02	0.08
SO_4^{2-}	0.42	0.34	-0.56	-0.36	0.45	0.42	-0.05	0.13	0.31	0.40	0.25	0.23	0.21	0.65	-0.05	-0.17
F^-	0.13	-0.33	0.68	-0.24	0.22	0.14	-0.49	-0.59	0.15	-0.23	-0.23	0.84	0.16	0.03	0.82	0.35

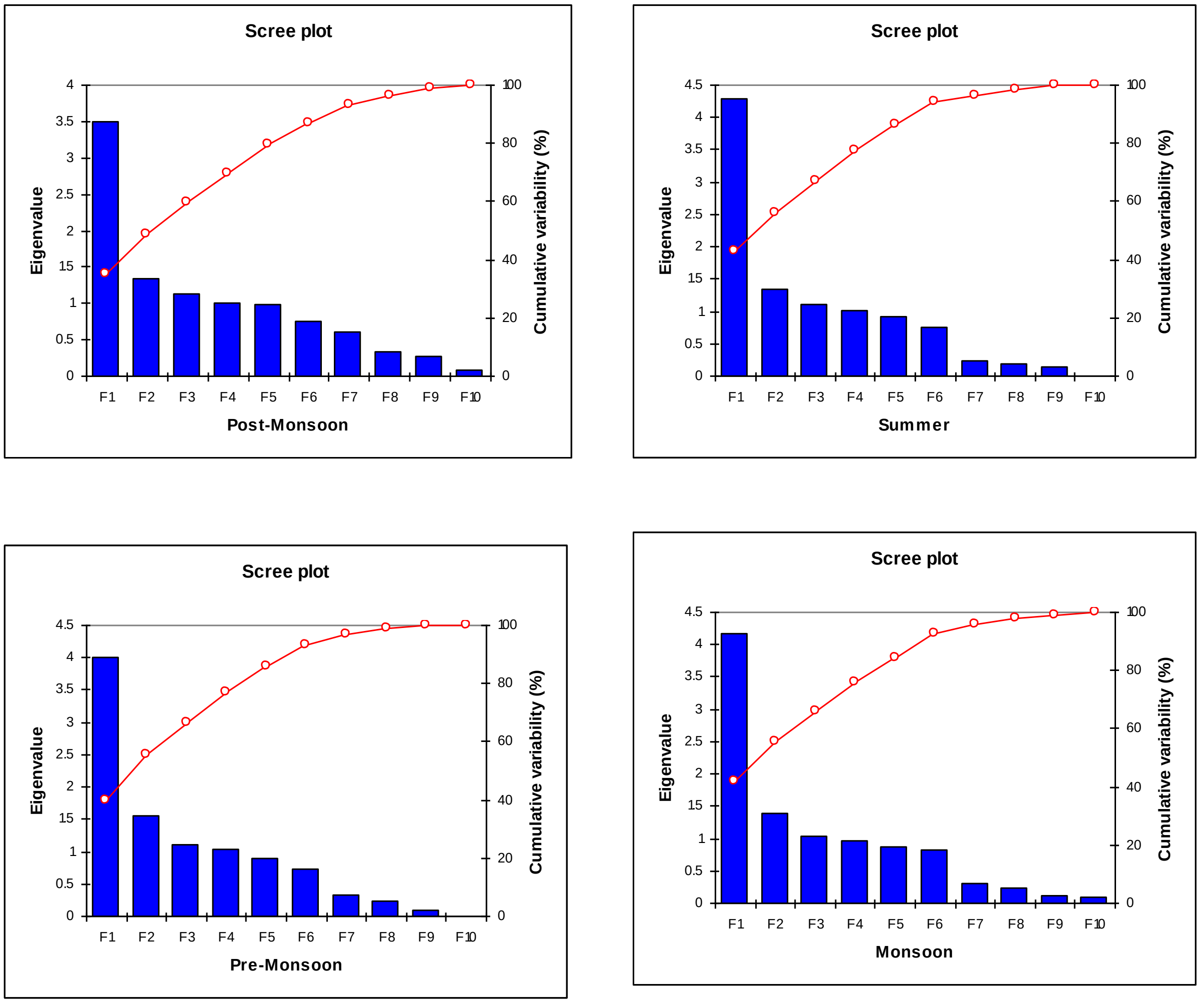

Figure 5: Scree plot for dindigul district

During summer season, altogether four principal components explain 77.3% of the total variance and principal component 1 (PC1) accounts for 42.8% of the total variance. The PC1 is associated with strong positive loadings of EC, TDS, TH and Mg(II). During this season EC and TDS levels were found to be slightly higher, than that recommended by the WHO. EC varies from 190 to 4700 µS (average of 1574 µS) and TDS varies from 145 to 3290 mg/L (average 1077 mg/L). TH concentration varies from 24 to 1200 mg/L with an average of 416 mg/L and Mg(II) varies from 6 to 370 mg/L (average = 71 mg/L). In this component, EC, TDS, TH and Mg(II) correlate significantly (0.990 < r > 0.634) with each other, suggesting a common source. Thus, PC1 can be called as the salt component because it is mainly saturated with EC, TDS and TH including Mg(II) ion. Hence this component can be attributed to common origin in this area from geogenic source. During this season, all other water quality parameter viz. pH, TA, Ca(II), Cl^-, SO_4^{2-} and F^- exhibited absolute values >0.4 on more than one component and thus were ignored from the interpretation [11-12].

The results of PCA, during pre monsoon season, indicate that first four principal components explain 77% of the total variance. Principal component 1 (PC1) accounts for 39.9% of the total variance. The PC1 is associated with strong positive loadings of EC, TDS, TH and Mg(II) and moderate positive loading of TA (Table 4). During this season also EC and TDS levels were found to be slightly higher than that recommended by the WHO. EC, in these water samples, varies from 170 to 4520 µS with an average of 1570 µS and TDS varies form 150 to 3175 mg/L with an average of 1084 mg/L. TA varies from 15 to 1540 mg/L (average = 334 mg/L), TH concentration varies from 24 to 1310 mg/L (average = 447 mg/L) and Mg(II) varies from 10 to 642 mg/L (average = 70 mg/L). In this factor, EC, TDS, TA, TH and Mg(II) correlate significantly (r > 0.507) with each other, suggesting a common source. PC1 can be called as the salt component because it is mainly saturated with EC, TDS, TA, TH and Mg(II) ion. All these parameters are typical indicators of natural diffuse inputs [12]. PC2 accounts for 15.6% of the total variance and is associated with a weak positive loading of SO_4^{2-} ion whose concentration varies from 2 to 420 mg/L with an average of 60 mg/L. During this season, PC3 exhibits 11% of the total variance with strong positive loading on pH which varies from 7 to 8 (average = 8). Hence PC3 can thus be called as an acidity-alkalinity component. PC4 accounts for 10.4% of the total variance and is associated with a strong positive loading of fluoride whose concentration varies from 0.20 to 2.50 mg/L with an average of 1.12 mg/L. PC4 can therefore be called a fluoride contamination component. Other water quality parameter viz. Ca(II) and Cl^- were scratched from the interpretation as these variables has a meaningful loading (absolute value > 0.4) on more than one component [11-12].

First four principal components (PC1 to PC4) explain 75.7% of the total variance during monsoon season in 2007. PC1 accounts for 41.8% of the total variance and is associated with strong positive loadings of EC, TDS, TA, TH and Mg(II) (Table 4). During this season also EC and TDS levels were found to be slightly higher than that recommended by the WHO. EC varies from 180 to 4325 µS (average = 1580 µS), TDS varies form 135 to 304 mg/L (average = 1042 mg/L), TA varies from 12 to 1670 mg/L (average = 347 mg/L), TH concentration varies from 24 to 1455 mg/L (average = 472 mg/L) and Mg(II) varies from 10 to 385 mg/L (average = 69 mg/L). In this component, EC, TDS, TA, TH and Mg(II) correlate significantly (r > 0.520) with each other, suggesting a common geogenic source. PC1 can be called as the salt component because it is mainly saturated with EC, TDS, TA, TH and Mg(II) ion. All these parameters are typical indicators of natural diffuse inputs [13]. PC2 accounts for 13.8% of the total variance and is associated with a moderate positive loading of SO_4^{2-} ion whose concentration varies from 2 to 375 mg/L with an average of 55 mg/L. During this season, PC3 exhibits 10.4% of the total variance with strong positive loading on fluoride which varies from 0.10 to 2.88 mg/L with an average of 1.10 mg/L. PC3 can therefore be called a fluoride contamination component. PC4 accounts for 9.7% of the total variance. pH, Ca(II) and Cl^- were not considered for the interpretation as these variables has a meaningful loading (absolute value > 0.4) on more than one component [11-12].

The foregoing PCA results indicated that PC1 shows nearly 40% of the total variance during all the seasons in the year 2007. This component is associated with moderate to strong positive loading of EC, TDS, TA, TH and Mg(II) and hence is termed as salt component. During the study, there is hardly any deviation from this observation with temporal variations. Further, the results indicated that there is a common source for all these water quality parameters. Groundwater contamination can originate above and below the surface of the earth. The substances that can contaminate groundwater can be basically classified as natural and artificial. Infiltration of polluted surface water causes contamination below the surface of the earth. When compared to water in streams and rivers, the movement of groundwater is very slow and hence once the contaminant reaches the groundwater; there is little scope for dilution and dispersion. Hence, the temporal variation study suggests that these water quality parameter originates from a common source and that could be geogenic in nature. In other words, all these parameters are typical indicators of natural diffuse inputs. The other three principal components are associated with moderate to strong positive loading of mainly pH and fluoride.

The findings discussed above reveal that any water quality parameter represented by the four PCs could be used as an indicator for potential contamination of salts and acidity. In other words, any arbitrarily selected parameter from these PCs could be used as a marker variable to detect potential contamination. Probable candidate for this purpose could be any one of the easily measured parameters such as EC for PC1 and pH for the other PCs. This marker parameter selection might be used as a technical tool for designing water quality monitoring net works. These marker parameters are measured on a continuous basis on several selected stations and any anomaly in the recorded values could be evaluated as a potential contamination risk. Under such circumstances, regular full-spectrum of water quality parameters could be analyzed for assessing the real extent of contamination. This procedure would not only be cost effective and but also save crucial response time to potential contamination risks.

Conclusion

In this study, the ground water quality data for 10 physical and chemical parameters collected from ten blocks of dindigul district were analysed using PCA and the fluoride endemic regions in two blocks were represented using GIS mapping technique.

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