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Assessment of groundwater quality of Palar basin using Multivariate Analysis

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ABSTRACT

The palar river region is one of the most industrialized area, increasingly deteriorated due to the anthropogenic pollution. Multivariate analysis was used In this study to find the degree of water pollution of palar river in ranipet and arcot. The results of physic-chemical analysis showed that most of the parameters were above the desirable limits and few were above the permissible limit according to BIS standards. Pearson Correlation Matrix showed that the water quality parameters exhibited a good linear correlation. The Principal Component Analysis indicate that the factor responsible for water quality deterioration were mainly related to TDS, Chloride, Nitrate, Alkalinity, Sodium, and Potassium were classified under the first major factor having high factor loading. The findings suggest that the water needs some degree of treatment process and it also needs to be protected from further contamination.

Key Words — Anthropogenic, Correlation, Deterioration, Multivariate analysis, Palar river, Treatment, Water quality.

1.0 Introduction

The Palar River is one of the major rivers flowing through Vellore District (120 km length with 4710 area of river basin) [1]. It is the source of drinking water for 30 towns and 50 villages on its banks and also used for the cultivation purpose [1]. Palar River Basin is a hub of more than 492 tannery industries. Effluent from all these industries is dumped into the Palar River, road sides and agricultural fields [5]. During the pronominal rainfall, the deposited salts on the river basin and land, spread tremendously and seep into the soil, polluting the ground water [13]. Contamination of ground water can result in poor drinking water quality, loss of water supply, degraded surface water systems, high cleanup costs, high costs for alternative water supplies and potential health problems. The impact is felt very much on the drinking water sources which are available for the people, settled on the banks of the river [14]. Due to pollution, peoples around the river suffer from number of diseases such as asthma, skin disease and stomach ailment and thousands acres of fertile land have become wasteland and no more used for cultivation [15]. Water is one of the most peculiar of our natural resources for life; next to air it is likely to become a critical scarce resource in the coming decades [4]. Water quality monitoring has one of the highest priorities in environmental protection policy [17].

In recent years, groundwater quality analysis gained importance to understand the processes contributing to pollution. The factors behind this contamination may be natural or anthropogenic. Important natural processes contributing to pollution in groundwater are rock water interactions, dissolutions, precipitation and geochemical reactios. Anthroprogenic activities such as waste disposals, leaching of salts, fertilizrs, pesticide from the agricultutral fields and salt intrusion due to over exploitation contribute to groundwater pollution [3].

The Ranipet an industrial area present in the bank of Palar river was reported as the most polluted places of world by Blacksmith Institute in 2006 which are heavily contaminated with salts and heavy metals especially Chromium [15]. The major problem with groundwater is that once contaminated, it is difficult to restore its quality [7]. Hence, there is need and concern for the protection and management of groundwater quality. It is well known that no straightforward reasons can be ascribed for deterioration of water quality, as it is dependent on several water quality parameters [5]. The application of different multivariate statistical technique helps in the interpretation of complex data matrices to understand water quality better and it allows the identification of possible factors that influence water system [6]. In this study, the ground water quality assessment using multivariate analysis has been used to identify the factors causing pollution.

2 Materials and methods

2.1 Study Area

The study locations are places in the Palar river basin of Vellore District, which include Ranipet, and Arcot. Ranipet and the nearby industrial estate have the largest number of tanneries, over 200 tanneries and other small scale chemical industries [8]. All tannery industries located in Ranipet are discharging effluents into Puliankannu, Karai, Puliathengal, Vanapadi, and

Thandalam lakes and it is a matter of increasing concern, as these industries are located in Palar river basin [8]. The groundwater near the Palar basin was monitored for a period of six months by taking the sample for once in every two weeks. In this study physicochemical parameters such as pH, Chloride, Hardness, Calcium, Magnesium, Sulphate, Nitrate, Sodium, Potassium, TDS, Chromium, Fluorides and Potassium were analyzed in accordance with American Public Health Association, standard method for analyzing water and wastewater.

2.2 Statistical Analysis

The analysis of the experimental data was carried out by using Multivariate statistical analysis using SPSS 16.0 software for all the water quality variables. In order to perform multivariate statistical analyses, a data matrix, $n \times p$, was generated, where n is the number of groundwater samples and p is the number of the measured hydro chemical parameters. Correlation structure between the variables was studied using the Spearman R coefficient as a non-parametric measure of the correlation between the variables [6]. Correlation coefficient is statistically significant if it is higher than the critical value [7].

Then, Principal Component Analysis (PCA) was applied on the correlation matrix including all elected experimental data, which was standardized through z-scale transformation [6]. PCA is designed to transform the original variables into new, uncorrelated variables (axes), called the principal components [12]. The principal components (PCs) obtained from PCA were further reduced and new variables were constructed, subjected to a varimax rotation (raw) called varifactors (VFs). PC is a linear combination of observable water quality variables, whereas VF can include unobservable, hypothetical, and latent variables. The methods of varimax rotation and Kaiser Normalization were applied [6]. Only factors having Eigen value greater than 1 of the data sets were used as factors [8].

3 Results And Discussion

3.1 Hydrochemictry of the Study Area

The statistical summary of groundwater represented by 13 water quality parameters in the study area during August 2012 – January 2013 is given in Table 1. Most of the parameters were higher than the desirable limit and few were above the permissible limit according to BIS Standards for drinking water. TDS varied from 1200 – 2980 mg/L. It was observed that the mean value of TDS was above the permissible limit. It may be due to leaching of soil contaminants and discharge of industrial effluents. Senthil kumar,(2011) reported that high TDS value of water samples make trouble to cattle's, livestock's and adversely affects the plants by increased soil salinity [10]. He also reported that the increase in TDS tends increase the degree of pollution in the water [10],[18] In this present study based on the chlorides the water quality was poor in certain sample sites. It ranged from 200 – 1000 mg/L and the mean value is 524 mg/L. The existence of considerable amount of chloride in Palar basin may be due to discharge of industrial effluents into it. Sewage water and industrial effluents are rich in Chloride content and discharge of these wastewaters result in greater chloride level in fresh waters [11]. Nitrate concentration in Palar basin ranged between 3 – 52 mg/L and few of the values were well beyond the permissible limits by BIS Standards. High nitrate concentrations in groundwater could pose potential hazard to infant health. The consumption of water with high nitrate concentration decreases the oxygen carrying capacity of blood, causing blue babies or methemoglobinemia [8,9]. The substantial contribution of Nitrate as N in the study area was likely resulted from domestic sewage effluents and industrial inputs to groundwater. The Sulphate level of groundwater averaged between 157 – 831 mg /L. The desirable and permissible limit of sulphate is 200 – 400 mg/L. Elevated Sulphate concentration was observed in certain sites where industrial effluents are discharged. The effluents from tanneries, paper mills and textile mills contribute to the sulphate in natural waters along with some agricultural run-off containing residue of fertilizers [9]. It is possible that, the discharge of effluent would contribute to higher sulphate concentration. Total Hardens ranged between 500 – 1150 mg/L. Hardness of groundwater comes under hard water and very hard water. Calcium content for most of the sample was above the desirable limit. High Ca content in the water makes it unfit for human consumption and damage the industrial machineries where it used for cooling purpose. The magnesium content ranged between 14 – 87.4 mg/L. The mean value is 151.4 mg/L, which was beyond 50 mg/L rendering the water unpalatable. Generally, calcium and magnesium maintain a state of equilibrium in most waters. More Magnesium present in waters will adversely affect the soil quality converting it to alkaline. The Na content ranged from 58 - 384 mg/L, may be due to the percolation of Na^+ ions from the domestic and industrial waste. High Na water breaks the soil aggregates and blocks the soil pores in irrigated fields [18]. An increased level of Potassium was observed in certain sample sites. The average value of alkalinity was above the desirable limits by BIS and the higher alkalinity value indicates pollution. The value of chromium in groundwater ranged between 0.02 to 0.3 mg/L. Permissible level of chromium in drinking water is 0.05 mg/L according to BIS. Chromium levels were found to be elevated in the groundwater sample, which indicates that chromium has leached from the wastewater contaminating the groundwater. Small amounts of chromium that anyone swallow will not hurt one; however, accidental or intentional swallowing of larger amounts has caused stomach upsets and ulcers, convulsions, kidney and liver damage and even death [16].

3.2 Statistical Results

Correlation is the mutual relationship between two variables. Direct correlation exists when increase or decrease in the value of one parameter is associated with a corresponding increase or decrease in the value of other parameter. In this study, the numerical values of correlation coefficient, R for the twelve water quality parameters are tabulated in Table 2. It shows a range from 0.020 to 0.772 for all water quality parameters (Table 2). As we can see the calculated values show strong correlations between Total Dissolves Solid with Chloride, nitrate, calcium, sodium and hardness. Hardness and Calcium and Magnesium having very high positive correlation between them show the dependence of one parameter on the other.

The results obtained from the KMO and Bartlett's sphericity test (Table 3) were 0.619 and 1.138E6 (df= 66, sig 0.001), respectively, implying that Principal Component Analysis (PCA) would be effective in reducing dimensionality. The scree-plot is a graph of Eigen values versus magnitude and is represented in Figure 1. It shows a distinct break between the steepness of the high Eigen values and the gradual trailing off of the rest of the factors. In this study, the 4 factors extracted (Eigen values >1) account for 76.3% of the total variance, while the remaining 8 factors (Eigen values < 1) accounted for only 23.64% of the total variance (Table 4).

In factor analysis the first factor is the combination of variables that represents the most important process or mix process controlling the hydrochemistry, it has the highest Eigen value and accounts for the highest variance among the factors. Factor 1, accounting for 35.577% of the total variance, was highly correlated with major physicochemical variables (TDS, Chloride, Nitrate, Alkalinity, Sodium, and Potassium). It could be related due to wastewater intrusion (Table 5).

The Second factor accounts for about 20.552% in the hydrochemistry and has high positive loading for Ca and Hardness. This factor could be related to hardness of groundwater due to weathering of limestone, sedimentary rock and calcium bearing minerals or by chemical industrial effluent [19].

The third factor accounts for about 12% in the hydrochemistry and was highly associated with Fluoride, Phosphate and Chromium. Phosphate may come from agricultural run-off containing phosphate fertilizer residues and also discharge of effluents into the river. High phosphate content might be attributed to sewage water in the river. In the Palar region, the source of fluoride may be due to ion exchange of F, leaching of F containing minerals, higher evapotranspiration and longer residence time of water [3]. And chromium could be due to leaching of chromium from the wastewater contaminating.

4 Conclusion

The ground water in the study area is deteriorating and needs special attention, as all the parameters such as TDS, Chloride, Sulphate, Hardness, Phosphate, Fluoride and Chromium was found to be above the permissible limit according to BIS standards. It may cause laxative effects on health of the people consuming that water. Hence, ground water must be used for drinking only after proper treatments. The Principal Component Analysis indicate that are responsible for water quality deterioration were mainly related to TDS, Chloride, Nitrate, Alkalinity, Sodium, and Potassium were classified under the first major factor having high factor loading. This study demonstrates the application of multivariate statistical methods in assessing the hydrochemical characteristics of the Palar River Basin and also to provide preliminary assessment of the ground water quality that will serve as a database for future investigations and monitoring of groundwater quality in the study area.

Reference

[1] K.Sundar, R.Vidya, Amitava Mukherjee and N.Chandrasekaran. (2010). "High Chromium Tolerant Bacterial Strains from Palar River Basin: Impact of Tannery Pollution Research." Journal of Environmental and Earth Sciences., 2(2), 112-117.

[2] Sukarma Thareja., Siddhartha Choudhury and Priyanka Trivedi. (2011). "Assessment of Water Quality of Ganga River in Kanpur by Using Principal Components Analysis. Advances in Applied Science Research, 2011, 2 (5):84-91

[3] P.J.Sajil Kumar, P.Jegathambal, E.J.James. (2011). "Multivariate and Geostatistical Analysis of Groundwater Quality in Palar River Basin." International Journal of Geology., 4(5), 108-119.

[4] C.Govindasamy, S.Shahida Begam and R.Kannan. (2011). "Studies on Primary Production and Physico-Chemical Variables in Summer at Vellore Fort Moat, Tamilnadu." African Journal of Basic & Applied Sciences., 3 (6), 290-299.

[5] A.Ravi Kumar, S.M.Mazhar Nazeeb Khan and R.Sivanesan. (2012). "A Correlation and Regression Study on the Ground Water of Vaiyampatti Village, Tiruchirappalli District." Der Pharma Chemica., 4(5), 1847-1852.

[6] Zhen Ma., Xiefa Song., Rong Wan, Lei Gao. (2013). "A modified water quality index for intensive shrimp ponds of Litopenaeus vannamei." Ecological Indicators., 24, 287–293.

[7] P.Lilly Florence, A.Paul Raj, T.Ramachandramoorthy. (2013). "Ground water quality assessment of Gangavalli Taluk, Salem District, Tamil Nadu, India using multivariate statistical techniques." Engineering Science and Technology: An International Journal., l.3(1).

[8] G.Tamma Rao, V.V.S.Gurunadha Rao, K.Ranganathan, L.Surinaidu, J.Mahesh and G.Ramesh. "Assessment of groundwater contamination from a hazardous dump site in Ranipet, Tamil Nadu, India." Hydrgeology Journal., 19 (8), 1587–1598.

[9] Prabhahar, C., Saleshrani, K and Tharmaraj, K. (2012). "Seasonal Variation in Physico-Chemical Parameters of Palar River in and Around Vaniyambadi Segment, Vellore District, Tamil Nadu, India." International Journal of Pharmaceutical & Biological Archives., 3(1), 99-104.

[10] D. Senthil kumar, P. Satheeshkumar and P. Gopalakrishnan. (2011). "Ground Water Quality Assessment in Paper Mill Effluent IrrigatedArea - Using Multivariate Statistical Analysis." World Applied Sciences Journal., 13 (4), 829-836.

[11] P.Mahesh Kumar, and C.Prabhahar. (2012). "Physico - Chemical Parameters of River Water: A Review." International Journal of Pharmaceutical & Biological Archives 3(6), 1304 -1312.

[12] Abbas Ali Zamani, Mohammad Reza Yaftian and Abdolhossein Parizanganeh. (2012) "Multivariate statistical assessment of heavy metal pollution sources of groundwater

around a lead and zinc plant." Iranian Journal of Environmental Health Science and Engineering., 9(29), 1-10.

[13] Shrey Kankaria, Anusha Andukuri, C.GHemamailini, M.krishnaveni. (2011). "Impact of Tannery Effluent on Groundwater and Agriculture with a Remedial Measure - A Case Study." International Conference on Chemical, Biological and Environment Sciences (ICCEBS'2011).

[14] T.S.Dhiviyaa Pranavam, T.Venkatesa Rao, L.Punithavathi, S.Karunanithi, and A.Bhaskaran. (2011) "Groundwater pollution in the Palar Riverbed near Vellore, Tamil Nadu, India." Indian Journal of Science and Technology., 4(1).

[15] K.Sundar, R.Vidya, Amitava Mukherjee and N.Chandrasekaran. (2010). "High Chromium Tolerant Bacterial Strains from Palar River Basin: Impact of Tannery Pollution." Research Journal of Environmental and Earth Sciences., 2(2), 112-117.

[16] Promila Sharma. (2007). "A Compilation of Polluted Places India- Initial Site Assessment Reports". Blacksmith Institutes., 39.

[17] Sukarma Thareja., Siddhartha Choudhury and Priyanka Trivedi. (2011). "Assessment of Water Quality of Ganga River in Kanpur by Using Principal Components Analysis." Advances in Applied Science Research., 2 (5), 84-91.

[18] D.Senthil kumar, P.Satheeshkumar, and P.Gopalakrishnan. (2011). "Ground Water Quality Assessment in Paper Mill Effluent Irrigated Area - Using Multivariate Statistical Analysis." World Applied Sciences Journal., 13(4), 829-836.

[19] Robert C. MacCallum, Keith F. Widaman, Shaobo Zhang and Sehee Hong. (1999). "Sample Size in Factor Analysis." Psychological Methods., l.4.(1) 84-99

Table 1 Descriptive Statistics

	Min	Max	Mean	Std. Deviation	Indian Standard
TDS	1200	2980	2137	397	500-2000
Chloride	200	1000	524	171	250-1000
Sulphate	157	831	442	149	200-400
Nitrate	3	52	25.8	9.73	45-100
Ca	160	352	250	50.4	75-200
Mg	14	87.48	46.12	18.60	30-100
Alkalinity	260	950	516	139	200-600
Na	58	384	151.4	68	50
K	.00	21.5	3.77	3.39	10
Hardness	500	1150	810	147	200-600
Fluorides	1.1	4.72	2.30	.86	1-1.5
Phosphate	.01	1.6	.42	.33	2.2
Chromium	.02	.3	.09	.052	0.05-0.1

Table 2 Correlation Matrix

	TDS	Chloride	Nitrate	Ca	Mg	Alkalinity	Na	K	Hardness	Fluoride	Phosphate	Chromium
TDS	1.000											
Chloride	.772*	1.000										
Nitrate	.533*	.515*	1.000									
Ca	.555*	.379	.182	1.000								
Mg	.338	.291	.380	.127	1.000							
Alkalinity	.326	.350	.115	-.010	-.173	1.000						
Na	.611*	.659*	.389	.004	.073	.428	1.000					
K	.471	.511*	.438	.197	.184	.274	.519*	1.000				
Hardness	.602*	.411	.326	.862*	.578*	-.074	.037	.223	1.000			
Fluorides	-.062	.113	.087	-.063	-.013	.075	.140	.161	-.056	1.000		
Phosphate	.187	.314	.215	-.094	.177	.482	.425	.373	.020	.404	1.000	
Chromium	.098	.170	.163	-.031	.089	.445	.246	.295	.025	.594*	.549*	1.000

Table 3 KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.619
Bartlett's Test of Sphericity	Approx. Chi-Square	1.138E6
	df	66
	Sig.	.000

Table 4 Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.269	35.577	35.577	4.269	35.577	35.577	3.359	27.990	27.990
2	2.466	20.552	56.130	2.466	20.552	56.130	2.202	18.349	46.339
3	1.360	11.335	67.465	1.360	11.335	67.465	2.149	17.905	64.244
4	1.068	8.896	76.360	1.068	8.896	76.360	1.454	12.117	76.360
5	.750	6.248	82.608						
6	.556	4.633	87.241						
7	.531	4.424	91.665						
8	.383	3.189	94.854						
9	.272	2.263	97.117						
10	.199	1.661	98.778						
11	.132	1.099	99.877						
12	.015	.123	100.000						

Extraction Method: Principal Component Analysis.

Table 5 Rotated Component Matrix[a]

	Component			
	1	2	3	4
TDS	**.765**	.525	-.063	.099
Chloride	**.806**	.327	.077	.097
NItrate	**.610**	.086	.062	.495
Ca	.104	**.970**	-.065	-.023
Mg	.178	.208	.090	**.843**
Alkalinity	**.541**	.004	.342	-.554
Na	**.866**	-.098	.129	-.075
K	**.664**	.099	.237	.125
Hardness	.154	**.891**	.003	.378
Fluorides	-.056	-.025	**.830**	.067
Phosphate	.416	-.115	**.688**	.014
Chromium	.161	.033	**.878**	-.060

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 6 iterations.