International Journal of Chemistry and Chemical Engineering.
ISSN 2248-9924 Volume 3, Number 3 (2013), pp. 215-222

http://www.ripublication.com

Assessment of Indicator Parameters to Investigate the Variations in Groundwater Quality of West Districts of Tripura Using Entropy and Correlation

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Abstract

Groundwater quality of West district of Tripura was assessed in different seasons based on the physicochemical parameters, and water quality index. The water quality index was calculated using indicator parameters viz. pH, electrical conductivity (EC), TDS, turbidity, Fe, Cu, Zn, K, Ca, Mg and total hardness (TH). These are studied on the basis of the different uses like residential and commercial requirements of water, as well as indicator parameters. In addition, index value was compared with quality rating to examine the seasonal variation in groundwater quality. Total 22 numbers of bore-well points were selected for the collection of samples which are located in the study area and samples are collected in different time period. The analysis was carried out for all the eleven parameters. A water quality rating was chosen to determine the level of pollution of corresponding samples from each station. The Water Quality Index values are calculated and IS -1050091 is followed for water quality standard for almost all the parameters except calcium. It was observed that Water quality index for 16 samples tested fall in the category of 'extremely poor quality' and thus unfit for any purpose. One of the sample is of 'poor water quality', three samples are of 'medium or average water quality', one is of 'good water quality' and only one sample comes under the category of 'excellent water quality'. Pearson correlation coefficient 'r' indicated good positive relation between EC and TDS (0.998), turbidity and TDS (0.675), Calcium and EC (0.786), Magnesium and Total hardness (0.832), Calcium and Total Hardness (0.732). Ground water is here severely polluted due to unusual high concentration of iron with value as high as 28.5mg/L found in some sites. Ultimately the results revealed that ground water is unfit in many sites for the purpose of drinking, thus indicating a need of proper treatment before use.

Keywords: Component; information entropy, person correlation, water quality, iron.

1. Introduction

The quality of ground water depends primarily on geological formation of a particular region. Tripura, situated in the North-eastern region of India, is industrially underdeveloped. Other factors such as leachate from a solid waste dumping sites [1, 4], dumping of industrial waste and municipal solid waste etc., therefore, have little effect on underground water quality here. The rivers of the state are not perennial in nature and can't be relied upon as a source for supply of water for any purpose throughout the year. Most poor people of the state use underground water for drinking and agricultural purpose extracted by tube wells constructed across the state. This water is directly consumed without giving any primary or secondary treatment. The water quality of this ground water, until now has not been assessed scientifically. Study area is considered in Agartala city (latitude 23° 50' N, and longitude 91° 25' E) in west Tripura District with a population of about 3,7lakhs at present. The present study was planned by selecting twenty two different sites around the district.

2. Materials and Methods

2. 1 Parameters of water quality

Water quality index method (WQI) is one of the most widely used tools to assess the surface and underground water. The method was used by several researchers across the world in various fields such as groundwater quality assessment (Shah A.N, Ghariya A.S, Puranik A.D, and Suthar M. B. 2008) surface water (Agbaire P.O., and C.G. Obi. 2009). etc. But this method in most of the cases is heavily dependent on subjective judgment while assigning the individual weightage factor to different water quality parameters. Groundwater samples were collected from 22 locations. Samples were collected in pre-cleaned plastic polyethylene bottles for physicochemical analysis of sample. Prior to sampling, all the sampling containers were washed and rinsed thoroughly with the distilled water for analysis. Each of the groundwater samples was analyzed for 11 parameters including pH, EC, turbidity, TDS, Fe, Ca, Mg, K, Cu, Zn and total hardness (TH) using standard procedures recommended by IS 10500-9 1as mentioned in Table 2.0.Papameters like pH.TDS/ Conductivity and Turbidity were measured using digital pH meter, conductivity meter and turbidity metr respectively. Metals are measured in AAS. Total hardness was measured using EDTA titration method.

2.2 Water quality index determination

Authors For computing WQI, usually, three steps must be followed (Rajankar P.N, Gulhane S.R, Tambekar D.H, Ramteke D.S and Wate S.R. 2009). In the first step, a weight must be assigned to each parameter. In the paper, an entropy weight was calculated and assigned to each parameter (Goldman, S. 2005). The concept of information entropy was first proposed by Shannon in 1948 and it was regarded as the uncertainty of a stochastic event or metric of information content9. The steps for calculating entropy weight are described as follows: Suppose there are m water samples taken to evaluate the water quality (i =1,2,…,m). Each sample has ‘n’ evaluated parameters (j = 1, 2,…,n). According to real data, eigen value matrix X can be constructed as presented in eqn. 1.0.

$$X = \begin{bmatrix} x_{11} & x_{12} & x_{1n} \\ x_{21} & x_{22} & x_{2m} \\ \vdots & \vdots \ddots & \vdots \\ x_{m1} & x_{m2} & x_{mn} \end{bmatrix} \tag{1}$$

In order to eliminate the influence caused by the difference of different units of characteristic indices and different quantity grades, data pretreatment must be put into force. According to attribution of every index, the feature indexes may be divided into four types: efficiency type, cost type, fixed type and interval type. For the efficiency type, the construction function of normalization is given by eqn. (2.0) and While for cost type, construction function of normalization is given by eqn. (2.1)

$$y_{ij} = \frac{x_{ij} - (x_{ij})_{min}}{(x_{ij})_{max} - (x_{ij})_{min}} \tag{2}$$

and

$$y_{ij} = \frac{(x_{ij})_{max} - x_{ij}}{(x_{ij})_{max} - (x_{ij})_{min}} \tag{2.1}$$

After transform, the standard-grade matrix Y can be obtained is given in eqn. 2..1.1 and the ratio of index value of the j index and in i sample is given by eqn. (2.2)

$$Y = \begin{bmatrix} y_{11} & y_{12} & y_{1n} \\ y_{21} & y_{22} & y_{2m} \\ \vdots & \vdots \ddots & \vdots \\ y_{m1} & y_{m2} & y_{mn} \end{bmatrix} \tag{2.1.1}$$

$$P_{ij} = y_{ij} \Big/ \sum_{i=1}^{m} y_{ij} \tag{2.2}$$

The information entropy is expressed by the formula below eqn. 2.3 and the smaller value of e_j is the bigger effect of j index. Then the entropy weight w_j can be calculated using eqn. 2.4.

$$e_j = -\frac{1}{\ln m}\sum_{i=1}^{m} P_{ij}\ln P_{ij} \qquad (2.3)$$

$$w_j = \frac{(1-e_j)}{\sum_{j=1}^{n}(1-e_j)} \qquad (2.4)$$

In the formula, j is defined as the entropy weight of j th parameter. Next step for calculating WQI is to assign a quality rating scale q_j for each parameter. The q_j is calculated by the following formula as given in eqn 2.5 and the concentration of physic- chemical parameters in each sample Cj mg/L. S_j is the standard for each of the parameters in mg/L according to IS10500-91. The WQI is then calculated in the third step by the eqn 2.6. ical C_j

$$q_j = \frac{C_j}{S_j} \qquad (2.5)$$

$$WQI = \sum_{j=1}^{n} w_j q_j \qquad (2.6)$$

According to WQI, groundwater is classified into five ranks, “excellent water” to “extremely poor water”. The classification standards are listed in Table 3.

Table 1: Classification standard of ground water quality based on WQI.

WQI	Rank	Water Quality	WQI	Rank	Water Quality
<50	1	Excellent water quality	150 ~200	4	Poor water quality
50 ~100	2	Good water quality	>200	5	Extremely poor water quality
100 ~150	3	Medium or average water quality			

3. Pearson Correlation

The relationship between two or more random variables or observed data values are represented by correlation and dependence of a broad class. The most familiar measure of dependence between two quantities is the Pearson product moment correlation coefficient, or "Pearson's correlation." It is obtained by dividing the covariance of the two variables by the product of their standard deviations. Karl Pearson developed the coefficient from a similar but slightly different idea by Francis Galton(Stigler, Stephen M. (1989). The Pearson correlation is defined only if both of the standard deviations are finite and both of them are nonzero. It is a corollary of the Cauchy–Schwarz inequality that the correlation cannot exceed 1 in absolute value. The correlation coefficient is symmetric: corr(X,Y) = corr(Y,X). If we have a series of 'n' measurements of X and Y written as xi and yi where i = 1, 2... n, then the sample correlation coefficient can be used to estimate the population Pearson correlation r between X and Y. The sample correlation coefficient is written as:

$$r_{xy} = \frac{\sum x_i y_i - n\bar{x}\bar{y}}{(n-1)S_x S_y} = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - \left(\sum x_i\right)^2}\sqrt{n\sum y_i^2 - \left(\sum y_i\right)^2}} \quad (2.7)$$

4. Results and Discussion

4.1 Physico-chemical parameters:

As per the analysis in the laboratory various characteristics of the ground water as given below Table-2

Table 2: Physicochemical Water Quality Parameters of Samples.

Para-meters	pH	EC (µ mho /cm)	TDS (mg/L)	Turbidity (NTU)	Fe (mg/L)	Cu (mg/L)	Zn (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	TH (as $CaCO_3$, mg/L)
WHO	7-8.5	1400	1000	5	0.3	1	5	-	75	30	500
BIS (IS 10500 91)	6.5 8.5		500	5	0.3 1.0	0.05	5		75	30	300
S1	7.03	200.3	100.15	56.60	13.58	0.00	0.583	3.61	2.43	1.18	10.91
S2	6.72	426.7	213.35	15.70	1.23	0.00	0.000	5.67	11.73	7.28	59.16
S3	5.96	241.0	119.1	87.60	3.61	0.00	0.008	4.47	2.80	3.35	20.75
S4	5.09	363.0	182	150.00	4.99	0.023	0.091	4.97	3.25	5.72	31.56
S5	6.83	287.0	142	70.40	3.16	0.00	0.000	5.67	5.50	3.86	29.58
S6	5.40	241.0	121.3	75.00	4.19	0.00	0.046	5.00	4.23	3.90	26.56
S7	5.60	204.0	105	96.80	8.01	0.00	0.000	3.78	2.68	0.49	8.69
S8	5.24	513.0	252.2	304.00	19.44	0.00	0.000	6.14	2.68	11.45	53.61
S9	5.97	287.0	141.3	18.80	6.16	0.00	0.021	1.98	6.15	4.92	35.52
S10	6.00	269.98	138.6	29.00	14.91	0.00	0.000	6.13	6.99	3.21	38.83
S11	5.94	187.0	93.5	321.00	0.94	0.00	0.267	3.27	5.77	1.31	19.79
S12	5.24	153.9	76.95	53.30	0.71	0.00	0.000	4.53	2.78	5.01	27.47
S13	6.39	801.0	419.3	402.00	28.53	0.00	0.035	8.98	15.61	4.26	36.49
S14	7.05	227.0	113.5	31.80	4.86	0.00	0.000	5.23	2.89	6.68	34.61
S15	5.46	100.2	48.3	7.38	0.48	0.00	0.006	7.77	0.69	1.17	6.520
S16	5.49	193.0	96.3	91.80	6.69	0.00	0.000	3.5	2.69	1.13	11.39
S17	6.78	211.0	105.5	88.70	7.55	0.00	0.0261	3.77	2.85	1.15	11.84
S18	5.62	209.0	105.5	188.0	3.38	0.00	0.000	5.34	5.49	3.22	26.93
S19	5.31	334.0	167	113.0	1.64	0.00	0.000	2.23	5.95	5.06	35.61
S20	5.51	167.8	88.6	61.00	11.25	0.00	0.043	3.72	3.60	5.11	29.95
S21	7.27	246.0	128	111.00	11.65	0.00	0.000	4.52	3.45	4.21	25.88
S22	5.61	176.89	98.62	69.00	6.52	0.00	0.000	4.03	1.55	3.00	16.17
Mean ±SD	5.53 ±0.37	279.08 ±149.55	141.63 ±77.31	110.99 ±104.63	7.43 ± 6.89	0.001 ±0.005	0.051 ±0.13	4.75 ±1.63	4.62 ±3.39	4.03 ±2.55	28.08 ±14.90

4.2 WQI Analysis

Most important parameter for WQI calculation is to assign different weights to the respective parameters. As mentioned earlier concept of information entropy is used to evaluate the entropy weights. For this, standard grade matrix is prepared using eqn. 2.1 as shown below and entropy weights to different physical-chemical characteristics of water are calculated using eqn. 2.3 and 2.4 and listed in table 3.

Table 3: Information entropy and entropy weight of parameters.

	pH	EC	TDS	Turbidity	Fe	Cu	Zn	K	Ca	Mg	TH
e_j	0.954	0.979	0.981	0.971	0.976	0.985	0.983	0.969	0.977	0.975	0.952
w_j	0.155	0.068	0.065	0.098	0.082	0.051	0.057	0.103	0.077	0.085	0.159

The WQI values are calculated thereafter using equation and IS-10500-91 is followed for water quality standard for all the parameters except for potassium. IS-10500-91 doesn't specifically mention the permissible value of potassium for drinking water. Permissible value of 12mg/L is used for calculation as per UK Water Supply Regulations, 1989. The calculated WQI data is presented in the Fig.1.It could be seen from the table 4, WQI index for 16 samples tested fall in the category of 'extremely poor quality' (rank 5) and thus unfit for any purpose. S5 is of 'poor water quality', three samples are of 'medium or average water quality', one is of 'good water quality' and only S15 comes under the category of 'excellent water quality'. If the same water samples are treated for iron than only 9 samples fall in the category of 'extremely poor quality' (rank 5), while 5 samples are of 'poor water quality' (rank 4), 3 samples are of 'medium or average water quality' (rank 3), 4 samples come within the 'good water quality' range and one is of 'excellent water quality' category.

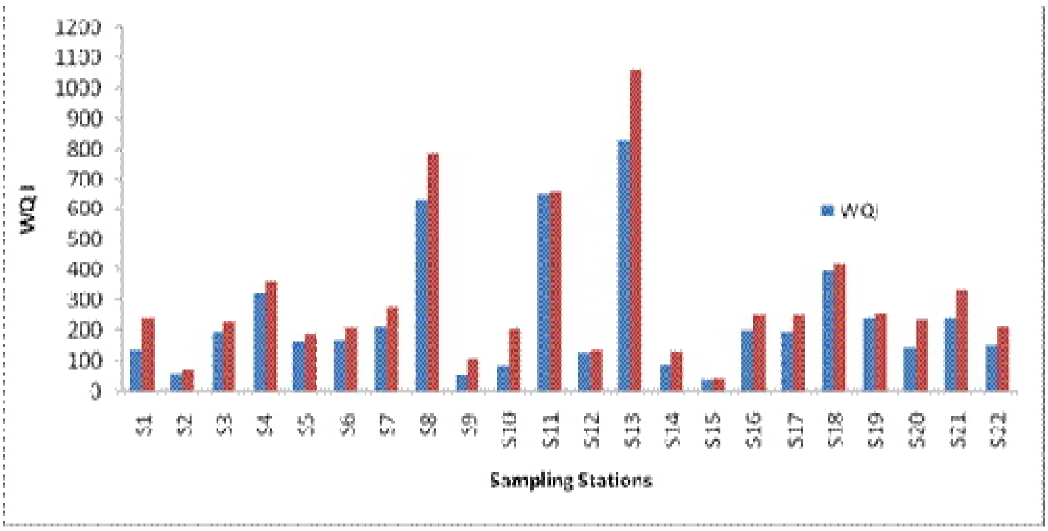

Fig. 1: The plot of WQI at various sampling stations.

The concentrations of iron at various sampling stations are shown in fig. As seen in the figure the ground water of this state contains unusual high concentration of iron ad unfit for domestic consumption by any standard. It is therefore, need pre treatment by some suitable adsorbent before consumption.

4.3 Pearson-Correlation Matrix

Correlation between two variables is expressed by Pearson coefficient ‘r’. There is a direct correlation between two parameters if change in one of them affects the other in a linear way. 9 The correlation coefficients (r) among various quality parameters were calculated and the values are given in Table 5. Pearson correlation coefficient ‘r’ indicated good positive relation between TDS and conductivity (0.998), turbidity and TDS (0.675), Ca and EC (0.786), Mg and TH (0.832), Ca and TH (0.732).

Table 5: Pearson-Correlation Matrix.

	pH	**EC**	**TDS**	**Turbidity**	**Fe**	**Cu**	**Zn**	**K**	**Ca**	**Mg**	**TH**
pH	1										
EC	-0.066	1									
TDS	-0.054	0.998	1								
Turbidity	-0.206	0.668	0.675	1							
Fe	0.073	0.660	0.673	0.527	1						
Cu	-0.269	0.125	0.117	0.083	-0.079	1					
Zn	0.083	-0.130	-0.133	0.106	0.119	0.067	1				
K	0.112	0.520	0.529	0.312	0.423	0.031	-0.218	1			
Ca	-0.117	0.786	0.794	0.421	0.395	-0.091	-0.088	0.389	1		
Mg	-0.171	0.494	0.468	0.146	0.246	0.148	-0.320	0.225	0.232	1	
TH	-0.186	0.794	0.780	0.342	0.397	0.052	-0.274	0.379	0.732	0.832	1

5. Conclusion

Application of entropy weight concept is finding wider application in evaluating water quality index for ground as well as surface water. The method is simple and accurate. Its’ most significant effect is that it avoids any kind of ambiguity for a researcher which often arises in other methods when they assign arbitrarily a weighted average factor to different water quality parameters. Pearson correlation matrix on the other hand establishes relationship between different parameters linearly in either positive or negative way. The matrix finds wider application in water analysis if applied judiciously among different pollutants which are generally present in water.

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