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Assessment of physico-chemical characteristics of groundwater: A case study

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ABSTRACT

Aims: This study focused on the determination of various physico-chemical characteristics of groundwater and to perform a statistical analysis to determine the relationship between the measured parameters.
Materials and Methods: The study was carried out during April-May 2011, in Vellore city, India. The various physico-chemical characteristics such as pH, turbidity, chlorides, acidity, alkalinity, sulphates, dissolved oxygen, and hardness were determined by following the procedure prescribed by American Public Health Association standard methods. This study was carried out to ensure the quality of groundwater to make use of it for domestic purpose by comparing the analytical results with the Bureau of Indian Standards (BIS) and World Health Organization (WHO) drinking water quality standards. A statistical study such as correlation analysis and one-way analysis of variance (ANOVA) has been carried out using Statistical Package for the Social Science (SPSS) ver. 20 software. The correlation analysis was performed for measured parameters to determine the relationship between the variables. The One-way ANOVA was applied to estimate the uncertainty in measured values.
Results: All the measured parameters are within the permissible limit as per WHO and BIS. The statistical analysis for all the parameters has revealed a positive correlation and the *F* test values are significant at 95% level.
Conclusion: From the investigation results, it can be concluded that the water quality of the study area is fit for domestic purposes. The descriptive statistics of the parameters analyzed along with correlation matrix and one-way analysis proved that there is no variation among the measured parameters.

Key words: Groundwater, physico-chemical characteristics, statistical analysis

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INTRODUCTION

The main resource of fresh water is the groundwater, which is commonly used for domestic, irrigation and industrial purposes. The domestic and agricultural activities in towns and villages entirely depend on the groundwater and hence, the importance of groundwater quality.[1-3] The quality of water and its environment is subjective to the geologic formation of an area and mostly, the groundwater contains

more mineral contents than the surface water. It is due to the fact that the groundwater movement is slow and hence, longer contacts time with the sediments.[4] Furthermore, the hydrologic conditions have a significant role in the change of groundwater quality over a period of time.[4]

The main cause for the outbreak of chronic diseases in human beings is the polluted groundwater.[1,4-6] Hence, it becomes essential to ensure the quality of groundwater to utilize it for various purposes. Rapid growth of industrial activities, dumping of industrial waste and improper disposal of garbage are among the major factors that affects the groundwater quality.[5] Due to less rainfall and the non-availability of surface water, groundwater is considered to be the only source for water in the Vellore city. Increase in industrial waste due to industrialization in the nearby area of Vellore city necessitates monitoring of groundwater resources. Hence, the present study has been carried out to assess the groundwater quality in Vellore city, Tamil Nadu, India. The various physico-chemical groundwater quality parameters were assessed and the values obtained are compared with the permissible/desirable values prescribed by the Bureau of Indian Standards (BIS) and World Health Organization (WHO) in order to ensure the quality of groundwater to make use of it for domestic purpose. Acquiring the relationship between various physico-chemical parameters helps in reducing the uncertainties associated with decision making and also, it helps in promoting the advancement in research.[7] Hence, in the present study, an attempt has been made to perform statistical analysis using Statistical Package for the Social Science (SPSS) ver. 20 software to determine the relationship between the measured parameters.

MATERIALS AND METHODS

About study area

The present study has been carried out in Vellore city of Tamil Nadu in India, which is located at 12.93°N79.13°E with a population of 0.186 million. Vellore is a cosmopolitan city and people from other parts of the state and the country approach for medical tourism and education. The city covers approximately 10 km and total area of the city is 87.915 km². Vellore has a tropical wet- and -dry climate, reaching high temperatures during summer. The city has an elevation of about 224 m and experiences wet winters and dry summers. The mean maximum and minimum temperatures during summer and winter vary between 38.5°C and 18.5°C. The highest temperature ever recorded is 45°C, and the lowest is 10°C. The average annual rainfall in the city is about 996 mm.[8]

The bore well water samples were collected from eight different locations of the entire city. From each location, the sample has been collected twice during the period of April-May, 2011. The sampling location and the sample designation are presented in Table 1 and the study area is presented in Figure 1.

Table 1: Details of samples

Sample location	Sample designation
Silk mill	S1
Salavanpet	S2
Kaghithapparai	S3
Kangeyanallur	S4
Katpadi	S5
Bagayam	S6
Thorapadi	S7
Kaspa	S8
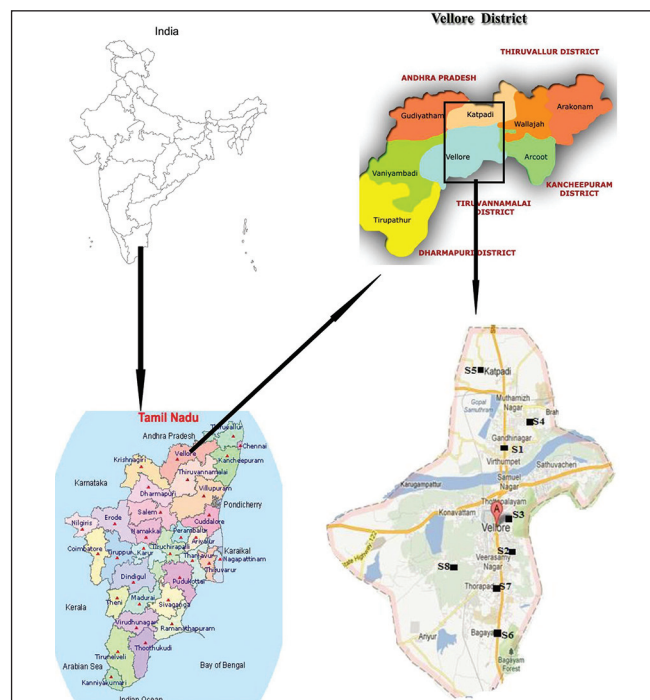
Figure 1: Map of study area

Sample collection and analysis

The samples were collected in a pre-cleaned, sterilized polyethylene bottles and the utmost care was taken to fill the bottles without air bubbles. The collected samples were labeled and taken to the laboratory using a refrigerator box at 4°C. All the chemicals used in the study are purchased from Thomas Baker (Chemicals) Pvt. Ltd., Mumbai, India and the reagents were prepared using double distilled water. the samples were analyzed for various physico-chemical parameters such as pH, acidity, alkalinity, chlorides, sulphates, total hardness, turbidity and dissolved oxygen by following the standard procedure prescribed by the American Public Health Association (APHA).[9] The parameters pH and turbidity were measured by employing pH meter (Make: ELICO, India) and Nephelometer (Make: ELICO, India), respectively. The APHA methods[9] adopted for analyses of water samples are presented in Table 2.

Statistical analysis

Statistical analysis has been carried out in this study to reduce the range of uncertainty and to select proper treatment to minimize the contaminations of groundwater. Statistical tests

with the analysis of variance (ANOVA) to assess the groundwater quality, which provides evidence that there is no difference in the concentrations of the parameters tested. The correlation analysis was performed for measured parameters to determine the relationship between these variables. The statistical analysis one way ANOVA was applied to estimate whether it is statistically significant among the groups in analysis and the significance reported that the ($P < 0.005$) is based on Pearson's co-efficient. The statistics were performed within batches and between batches using SPSS ver. 20 software. The F test analysis was applied to find out the null hypothesis.

RESULTS

The various physico-chemical characteristics such as pH, turbidity, sulphates, chlorides, alkalinity, dissolved oxygen, hardness, and acidity were analyzed for different groundwater samples and the results were compared with the BIS[10] and WHO standards[11] and the results are presented in Table 3. Further, a correlation and one-way ANOVA analysis have been carried out using SPSS Software ver. 20 and the results are presented in Tables 4 and 5.

DISCUSSION

Physico-chemical characteristics

From the observations in Table 3, it can be noted that the experimental results of all the parameters are within the limit as prescribed by the WHO and BIS. From the observations it can be noted that the turbidity value is high in the sample S8 as compared to other sampling locations. The higher pH value was found at the sampling site S7. Further, the concentration of sulphates in the site S2 is very high, which could be due to the movement of water through the soils and rocks that contains the minerals, which results in dissolution of sulphate into the groundwater thereby increases the concentration. The concentration of chlorides values was more in the site S3. Alkalinity in the S3 is high compared to other sampling sites, which indicates that the water contain more bicarbonate ions. Hardness is more in S3 as compared to other sampling sites which are due to the presence of salts like calcium and magnesium in the water.

Statistical analysis

The results of the statistical analysis of each analyzed parameter and the values of F test and significance are presented in the Table 4. The calculated F value were observed in the range of 0.000-0.019 which were less than F critical of 3.328 for a stated level of confidence (typically 95%), which proves that the difference being tested is statistically significant at 95% confidence level.[12] The values of correlation matrix have been developed by SPSS ver. 20 software and the values are presented in the Table 5. It can be observed from the table that there is a high positive correlation between all the parameters and is statistically significant at 0.01 levels.

Hence, it can be concluded that the water quality of the study area is fit for domestic purposes. The descriptive statistics of the parameters analyzed along with correlation matrix and

Table 2: Analytical methods used for determination of physico-chemical parameters	
Parameter	**Analytical method**
pH	Potentiometry
Turbidity	Nephelometry
Acidity	Titrimetric
Alkalinity	Titrimetric
Sulphates	Turbidity
Chlorides	Titrimetric
Dissolved oxygen	Titrimetric
Hardness	Titrimetric

Table 3: Physico-chemical characteristics of groundwater samples								
Sample	**Parameters**							
	pH	**Turbidity (NTU)**	**Sulphate as SO_4^- (mg/L)**	**Chlorides (mg/L)**	**Alkalinity as $CaCO_3$ (mg/L)**	**DO (mg/L)**	**Hardness as CaCO3 (mg/L)**	**Acidity as CaCO3 (mg/L)**
S1	6.99	BDL	25.00	40.50	30.00	0.719	215.00	350.00
S2	6.89	BDL	106.50	78.00	60.00	0.945	568.50	514.60
S3	6.39	BDL	30.00	331.25	170.00	0.778	815.00	275.00
S4	7.72	BDL	65.00	287.50	110.00	0.729	305.00	401.60
S5	7.33	BDL	70.00	147.50	70.00	0.758	400.00	198.50
S6	7.83	3.20	50.00	167.50	130.00	0.788	370.00	404.80
S7	8.13	0.40	85.00	115.00	45.00	0.689	627.00	337.50
S8	7.35	3.40	37.50	52.75	50.00	0.591	587.00	312.50
Minimum	6.39	BDL	25.00	40.50	30.00	0.591	215.00	198.50
Maximum	8.13	3.40	106.50	331.25	170.00	0.945	815.00	514.60
Average	7.33	0.87	58.70	152.50	83.12	0.750	485.94	438.45
BIS	6.50-8.50	5.00-10.00	200.00-400.00	250.00-1000.00	200.00-600.00	NA	300.00-600.00	NA
WHO	7.00-8.50	5.00	250.00	250.00	120.00	NA	200.00	NA

BDL: Below detectable limit, NA: Not available, NTU: Nephelometric Turbidity Units, DO: Dissolved Oxygen, BIS: Bureau of Indian standards, WHO: World health organization

Table 4: One way analysis of variance

Parameters	Sum of squares	df	Mean square	F	Significance
pH					
Between groups	2498.483	6	416.414	1680.579	0.000
Within groups	0.991	4	0.248		
Total	2499.474	10			
Chlorides					
Between groups	1697.076	6	282.846	10.813	0.019
Within groups	104.634	4	26.158		
Total	1801.710	10			
Total acidity					
Between groups	5612033.543	6	935338.924	64.161	0.001
Within groups	58311.752	4	14577.938		
Total	5670345.295	10			
Total alkalinity					
Between groups	317917.971	6	52986.329	21.895	0.005
Within groups	9680.000	4	2420.000		
Total	327597.971	10			
Sulphates					
Between groups	46.074	6	7.679	11.591	0.016
Within groups	2.650	4	0.662		
Total	48.724	10			
Total hardness					
Between groups	10819868.365	6	1803311.394	31.996	0.002
Within groups	225444.800	4	56361.200		
Total	11045313.165	10			
DO					
Between groups	26.074	6	4.346	513.345	0.000
Within groups	0.034	4	0.008		
Total	26.108	10			

DO: Dissolved Oxygen

Table 5: Correlation matrix of different parameters in groundwater

Parameters	pH	Chlorides	Acidity	Alkalinity	Sulphates	Hardness	Turbidity	DO
pH	1							
Chlorides	0.959	1						
Acidity	0.994	0.952	1					
Alkalinity	0.975	0.953	0.987	1				
Sulphates	0.954	0.920	0.957	0.958	1			
Hardness	0.985	0.963	0.979	0.964	0.958	1		
Turbidity	0.808	0.746	0.806	0.801	0.713	0.802	1	
DO	0.998	0.961	0.996	0.983	0.958	0.986	0.791	1

DO: Dissolved Oxygen

one way analysis proved that there is no variation among the parameters. The statistical analysis for the study area showed a high positive correlation between the values which helps to reduce the degree of uncertainty range among the parameters.

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