An Investigation of the Quality of Underground Water at Eloor in Ernakulum District of Kerala, India

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Abstract: The physical and chemical properties of groundwater in Eloor, an industrial region, have been investigated to evaluate the extent of pollution. The study area was divided into four zones and a total of 40 water samples from different locations were collected, analyzed and correlation analysis has been carried out among the measured parameters. A comparison of the observed parameters with the limits prescribed by BIS revealed that in some area pH values are lower than the prescribed limit. The concentration of the major cations and anions were found to be significant. Magnesium and chloride exceed the desirable limit in some areas but less than the upper limit prescribed by BIS. Significant linear relationship was observed between pH, electrical conductivity, alkalinity, hardness, Ca^{2+} , Mg^{2+} and chloride. The importance of these parameters in predicting the quality characteristics of groundwater is discussed.

Keywords: Physicochemical parameters, BIS limits, Groundwater, Eloor.

Introduction

The potential and quality of groundwater, is an economic resource and essential component of our life, is getting deteriorated in major cities and urban centers due to pollution caused by population explosion, urbanization and industrialization^{1,2}. Industrialization causes large

volume of effluent to discharge that may affect the groundwater quality since the effluent from discharges or run-off from solid waste disposal sites generally moves vertically downwards³. In India, groundwater is polluted to varying degrees at different industrial regions as evidenced by recent reports⁴. The extent of pollution depends on the rainfall pattern, depth of water table distance from the source of contamination and soil properties like permeability, composition of its recharge components as well as geology and hydrology of the area⁵.

Pollutants may remain concealed for many years, becoming dispersed over wide areas of groundwater aquifer and rendering groundwater supplies unsuitable for consumption and other uses⁶. In industrial regions, physicochemical parameters of water such as hardness, COD, BOD, chloride, nitrate, phenols, cyanides, calcium and heavy metals increases with time. The total potential of groundwater in India is $4.2 \times 10^{10} \text{ m}^3$, a quarter of it is being used for irrigation, industrial and domestic purposes⁷.

Eloor is the industrial belt in the Ernakulam district of Kerala, which covers 11.2sq.km, within the latitude of $10^{\circ}5'$ North and $76^{\circ}16'$ East longitude and is at an elevation of 4.3 m above MSL (Mean Sea Level). There are nearly 8,245 houses in Eloor and a population of 30,092 as per census 2001. The major industries in Eloor include phosphate fertilizer plant, monazite industry, caustic soda unit, pesticide plant, aluminum and zinc smelter and factory for synthetic rutile. In addition, there are small industries manufacturing petrochemical products, pesticides, insecticides, rare earth elements, rubber products, zinc/chromium compounds and leather products. The industrial region in Kerala, Eloor, warrants an assessment of the quality of groundwater to assess the suitability for drinking and other uses as well as to indicate the levels of chemical pollutants to which the local population are exposed. The present paper gives the result of a systematic study carried out in the area.

Experimental

The study area in Eloor region was divided into four zones namely East, West, North and South focusing the major industrial spot as the central point and samples were collected from different points in each zone, during January-February 2008. A total of 40 samples (East -12, West -8, North -10 and South -10) were collected from the open wells in pre-cleaned dry polypropylene bottles. The physicochemical parameters such as pH, electrical conductivity, alkalinity, total dissolved solids, chloride, total hardness, calcium, magnesium, sodium, potassium, nitrate, sulphate were estimated by standard methods⁸. The models of the instruments used for different parameters are shown in Table 1. Analytical grade chemicals were used to prepare reagents and calibration standards. The measured parameters were compared with the guidelines suggested by BIS (Bureau of Indian standards) for drinking water⁹.

Table 1. Analytical methods for quality parameters of groundwater.

Parameter	Method
pH	Digital pH meter(EUTECH Model pH: 510)
Electrical Conductivity(EC)	Digital Conductivity meter (EUTECH Model con :510)
Alkalinity	Titrimetry (using HCl)
Total dissolved solids	Indirect method. $\text{TDS} = 0.64 \times \text{EC}_{\mu\text{s/cm}}^{10}$
Chloride	Mohr's Argentometric method
Total hardness, Calcium, Magnesium	EDTA titrimetric method
Sodium, Potassium	Flame photometer (SYSTRONICS Model: 125).
Nitrate	UV Visible Spectrophotometer, (Hitachi 3210).
Sulphate	Digital Nepheloturbidometer (SYSTRONICS:132)

Results and Discussion

The properties of the water samples, collected from the four zones of Eloor, were analyzed and the parameters obtained are presented in the Table 2 and 3. The data indicate that the water quality parameters vary considerably from location to location.

Table 2. The physicochemical parameters of groundwater samples of Eloor (Eastern and Western) in ppm.

Parameter	East			West		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
pH	3.9	7.6	6.2	6.4	6.6	6.5
EC(μ S/cm)	95.0	399.0	230.0	380.0	910.0	727.0
TDS	60.8	255.4	147.4	243.2	582.4	465.1
Alkalinity	25.0	175.0	70.0	30.0	120.0	72.0
Hardness	30.0	210.0	78.9	175.0	360.0	258.0
Sodium	0.3	4.6	1.9	2.7	23.6	13.4
Potassium	1.0	7.7	3.9	3.8	10.6	8.2
Calcium	10.0	66.0	24.4	24.0	74.0	44.7
Magnesium	1.2	10.9	4.9	28.0	42.6	35.6
Chloride	25.0	150	82.8	75.0	375.0	236.7
Sulphate	1.2	65.0	19.9	12.6	40.0	22.3
Nitrate	2.4	8.9	4.7	2.0	7.1	5.2

Table 3. The physicochemical parameters of groundwater samples of Eloor (Northern and Southern region) in ppm.

Parameter	Eloor North			Eloor South		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
pH	6.2	6.7	6.4	5.2	7.7	6.5
EC(μ S/cm)	254.0	1072.0	446.0	152.0	714.0	319.0
TDS	162.6	870.0	377.6	97.3	457.0	205.4
Alkalinity	25.0	40.0	32.0	20.0	175.0	61.0
Hardness	65.0	250.0	125.0	60.0	240.0	96.0
Sodium	1.6	12.2	3.8	0.4	4.4	1.4
Potassium	6.2	14.5	8.6	2.0	167.0	18.9
Calcium	1.8	70.0	26.8	20.0	50.0	27.6
Magnesium	2.4	20.7	11.9	1.2	38.9	6.8
Chloride	100.0	714.0	234.8	25.0	125.0	46.0
Sulphate	15.0	34.0	25.8	2.5	48.2	18.6
Nitrate	3.5	14.6	8.4	2.9	23.3	9.0

The pH of water samples ranged from 3.9 to 7.7 with low values for samples from east and south region. The low pH may cause desorption of metal cations due to competition by H^+ ions and it alters the taste of water^{11,12}. About 40% of the water samples have pH lower than the BIS prescribed limit of 6.5-8.5.

The conductivity of water is directly related to the concentration of ions and their mobility. Studies revealed that EC value is the indication of dissolved ionizable solids¹³. Electrical Conductivity (EC) varies between 95 to 1072 μ mho/cm and significantly high in few samples from the western and northern region indicating the presence of ionic contaminants (Figure 1).

Total Dissolved Solids (TDS) ranges from 29.8 to 739.2 mg/L (Figure 1), showing high values for the samples from west zone which may be attributed to the leaching of industrial effluents or backwater intrusion. About 23% of samples exceed the desirable limit of 300 mg/L but lies within the maximum permissible limit prescribed by BIS.

Figure 1. Variation of TDS, EC, TH and Cl^- in the groundwater samples of Eloor region.

Alkalinity leads to corrosion and influences the chemical and biochemical reactions. Alkalinity was observed in the range 25 to 175 mg/L, within the permissible limit of 200 mg/L. Low value of alkalinity in eastern region is indicative of low pH value, Table 2. Total Hardness (TH), indicates calcium and magnesium content, ranges from 30 mg/L to 360 mg/L (mean = 138 mg/L), showing high values for the samples from west region. Hardness of water is not a health hazard but its value should remain below permissible limit to restore the taste of water¹⁴. Based on the TH observed, the samples fall into four categories: (i) 17% is very hard water having TH more than 180 mg/L, (ii) 10% is hard water (TH from 120-180 mg/L), (iii) 62% belong to medium hard water (TH from 60-120 mg/L) and (iv) 13% is soft water (TH from 0-60 mg/L).

The concentration of calcium ranges from 1.8 to 74 mg/L with the maximum in the west region (Figure 2). The high concentration of Ca may be due to the discharge of industrial waste and passage through deposits of limestone, dolomite, and gypsum¹⁵. Water containing high calcium is not suitable for washing, bathing and in boilers and linked to the formation of concretion in the body and may cause gastro intestinal diseases and stone formations.

Magnesium is a beneficial metal but toxic at high concentrations, causes hardness and exerts a cathartic and diuretic action¹⁵. The concentration of magnesium ranges from 1.2 - 42.6 mg/L with slight variation in different locations and in some of the samples (west) it exceeds the desirable limit of 30 mg/L prescribed by BIS but lies within the maximum permissible limit of 75 mg/L.

The concentration of potassium ranges from 1 mg/L to 167 mg/L, with maximum value in the south region and minimum in the east region (Figure 2). The high concentration of potassium may be due to the influence of the fertilizer plant located in the study area. The concentration of sodium ranges from 0.3 to 23.6 mg/L, with maximum value in the western region probably due to saline water intrusion. Discharge of domestic and industrial effluent on to the ground is another source of sodium in water.

The chloride content ranges from 25 to 714 mg/L (mean-370 mg/L), with high concentration for samples in the western region indicating industrial sewage pollution as well as ingress of saline water from backwaters and causes salt taste. A few samples in the northern region exceeds the desirable limit of 250 mg/L prescribed by BIS, but lies within the maximum permissible limit of 1000 mg/L (Table 3).

The concentration of sulphate ranged between 1.2 and 65 mg/L (mean-30 mg/L) (Figure 2), showing maximum in the north region and minimum in the south. High concentration of sulphate along with sodium and magnesium in drinking water can lead to gastrointestinal irritation and respiratory illness.

Figure 2. Variation of Na^+ , K^+ , Ca^{2+} , Mg^{2+} , SO_4^{2-} and NO_3^- ion in the groundwater samples.

The concentration of nitrate ranges between 2.0 and 23.3 mg/L (mean-19 mg/L) indicates there may be possibility for leaching of nitrate to nearby groundwater sources. The concentration of nitrate in drinking water causes adverse effects since it is a strong oxidizing agent and NO_2 can react with secondary amines present in human body, it may form nitrosamines. Biological oxidation of nitrogenous substances and bacterial action from sewage is the main source of nitrate¹⁶.

Correlation

Correlation studies are very important in water quality assessment because it determines the effect of one element on the other. The larger the numerical value of the correlation coefficient, the greater is the extend to which correlation holds between the two variables. Significant positive correlation is observed between EC, TH and chloride, Figure 3 indicating that the EC and hardness are caused by dissolved ionic solids. Magnesium and calcium showed a significant positive correlation with TH indicating that the hardness of water may be contributed by calcium and magnesium (Figure 4). Potassium did not show significant correlation with other major ions. Sodium showed significant positive correlations with chloride ion ($R^2=0.52$) may be attributed to the same source of these ions (Figure 5).

Figure 3. Correlation of EC with TH and Chloride.

Figure 4. Correlation of TH with Calcium and Magnesium.

Figure 5. Correlation between sodium and chloride

Conclusion

The important physicochemical parameters of groundwater samples collected from 40 locations in Eloor were estimated. It was observed that the pH is low in the eastern region but TDS, total hardness and chloride are high for the water samples from west zone compared to other zones. The groundwater samples from western zone showed higher values compared to other locations in the case of water quality parameters analysed. Only very few samples showed values above the desirable limits whereas the concentration of parameters in most of the samples are below the limit prescribed by BIS. The parameters EC, TH, sodium, magnesium, calcium, chloride have good correlation in the water sample analyzed and equations obtained from the correlation analysis are very useful in the rapid analysis of groundwater quality of Eloor. It is intended that this study can be extended to monitor the concentration of other parameter including heavy metals to have an overall picture of water quality of Eloor.

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