Geochemistry and Assessment of Groundwater Quality for Drinking and Irrigation Purposes: A Case Study of Sukhana River Sub basin, District Aurangabad, Maharashtra, India

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Research Article

Abstract: An attempt has been made to check the quality of groundwater of Sukhana river sub basin of Aurangabad district, Maharashtra, India for drinking and irrigation purposes. Thirty five groundwater samples were collected from different dugwells and borewells. The quality assessment is made through the estimation of pH., EC, TDS, total hardness as $CaCO_3$, Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^-, CO_3^{2-}, HCO_3^- and SO_4^{2-} and Based on these analyses, parameters like sodium adsorption ratio, sodium soluble percentage and residual sodium carbonate were calculated. The value of TDS, Cl^- and SO_4^- ion concentration is within the limits in majority of the samples. The excess amount of Ca^{++}, Mg^{++}, TH and Na^+ in the groundwater is due to anthropogenic factors and geological characteristics of the aquifer. The correlation of the analytical data has been attempted by plotting different graphical representations such as Wilcox and US Salinity Laboratory for the classification of water, and results show that most of the samples are fit for irrigation

Keywords: Sukhana river, physicochemical parameter, water quality, irrigation purpose, Aurangabad.

Introduction:

Groundwater is a vital source of clean drinking and irrigation water. This is increasingly the case due to the effects of population growth and climate change, which are causing severe stress to surface water supplies in these areas (Edmunds 2003; Shanmugam & Ambujam, 2011). The chemical composition of groundwater is controlled by several factors that include composition of precipitation, anthropogenic activities, geological structure and mineralogy of the watershed and aquifers and geological processes within the aquifer medium (Andre et al. 2005). Chemistry of groundwater is an important factor determining its use for domestic and irrigation purposes. Interaction of groundwater with aquifer minerals through which it flows greatly controls the groundwater chemistry. Hydrogeochemical processes that are responsible for altering the chemical composition of groundwater vary with respect to space and time. The hydrogeochemical processes of the groundwater system help to obtain an insight into the contributions of rock and soil–water interaction and anthropogenic influences on groundwater. These geochemical processes are responsible for the spatiotemporal variations in groundwater chemistry (Matthess 1982; Kumar et al. 2006). Groundwater chemistry, in turn, depends on a number of factors, such as general geology, degree of chemical weathering of the various rock types, quality of recharge water and inputs from sources other than water–rock interaction (Domenico 1972; Schuh et al. 1997; Toth 1984; Singh Kuldip et al.2011). The quality of ground water is the resultant of all the processes and reactions that have acted on the water from the moment it condensed in the atmosphere to the time it is discharged by a well. Therefore, the quality of ground water varies from place to place, with the depth of water table, and from season to season and is primarily governed by the extent and composition of dissolved solids present in it. Worldwide, aquifers are experiencing an increasing threat of pollution from urbanization, industrial development, agricultural activities and mining enterprises. In recent years, an increasing threat to ground water quality due to human activities has become of great importance (Aher K.R., 2012; Reddy et al, 2012; Deshpande and Aher, 2012). The geochemical study reveals the quality of water that is suitable for drinking and irrigation uses, therefore an attempt has made to identify the hydrogeochemical characteristics and quality factors of the Sukhana river subbasin of Aurangabad district.

Geological setting

The Sukhana river sub basins area is underlain and surrounded mainly by basaltic lava flows belonging to the Deccan volcanic province that flooded during upper cretaceous to Eocene age in the Deccan plateau. The Deccan traps sequence consists of multiple layers of solidified lava flows. The prominent geological units observed in study area are the horizontally disposed basaltic lava of dark grey in color. The lava flows are horizontal and each flow has distinct two units. The upper layers consist of vesicular and amygdule zeolitic basalt whiles the bottom layer consists of massive basalt. The lava flows are individually different in their ability to receive as well as hold water in storage and to transmit it. The difference in the productivity of groundwater in various flows arises as a result of their inherent physical properties such as porosity and permeability. The groundwater occurs under water table conditions and is mainly controlled by the extent of its secondary porosity i.e. thickness of weathered rocks and spacing of joints and fractures. The highly weathered vesicular trap and underlying weathered jointed and fractured massive trap constitutes the main water yielding zones. The soil is mostly formed from igneous rocks and are black, medium black, shallow and calcareous types having different depths and profiles (Deshpande and Aher, 2011; Aher, 2012).

Material and methods

To assess the groundwater chemistry, a total of 35 groundwater samples were collected from the study area. The samples were collected in sterilized polythene bottles and prior to sampling all the sampling containers were washed and rinsed with the groundwater. Then they were sealed and brought to the laboratory for analysis. The pH and electrical conductivity (EC) were measured, using digital instruments immediately after sampling. The parameters analyses include major ions of Ca^{2+} and Mg^{2+} by Titrimetry, K^{+} and Na^{+} by Flame Photometer, Cl^{-} and CO_3^{2-}, HCO_3^{-} by Titrimetry and SO_4^{2-} by spectrophotometer. The analyses were done, using standard procedures recommended by the American Public health Association (APHA, 2002) and Trivedi and Goel (1984). The analytical precision for the measurements of cations and anions is indicated by the ionic balance error, which was computed on the basis of ions expressed in milliequivalents per liter. The values were observed to be within a standard limit of 5%.

Results and Discussions

Geochemistry of Groundwater and its Suitability for Drinking Use

Groundwater quality assessment was carried to determine its suitability in terms of drinking purposes, the hydro chemical analysis of groundwater samples is presented in (Table 1). The physical and chemical parameters of the analytical results of groundwater were compared with the standard guideline values recommended by the BIS (1991) for drinking and public health purposes. Table. 2 show the maximum desirable and most allowable limits for various parameters.

Table. 1 Physicochemical analysis summary of groundwater samples in the study area

Sr.No.	Parameter	Unit	Maximum (N=35)	Minimum	Average
1	pH		8.5	7.4	7.9
2	EC	µs/cm	2855	687	1299
3	TDS	mg/L	1856	447	845
4	Ca++	mg/L	698	94	208
5	Mg++	mg/L	158	5	60
6	Na+	mg/L	226	21	77
7	K^{+}	mg/L	59	1	6
8	HCO_3^{-}	mg/L	392	188	273
9	SO_4^{-}	mg/L	176	29	67
10	Cl^{-}	mg/L	436	36	140
11	TH	mg/L	762	230	405

Table 2 Quality of groundwater with BIS standards for drinking purposes

Parameters	BIS, 1991		Wells exceed Max. allow. limit
	desirable limit	Max. allow. limit	
pH		6.5 to 8.5	NIL
TDS	500	2000	NIL
Ca++	75	200	20,21,22,23,25,26,27
Mg++	75	100	7,35
Na+	-	200	7,22,35
Cl^{-}	250	1000	NIL
SO_4^{-}	200	400	NIL
TH	300	600	7,22,25,35

pH is a measure of activity or concentration of the hydrogen ions present in water. It is a quantitative expression for acidity or alkalinity of water. The pH of groundwater ranged from 7.4 to 8.5 with an average value of 7.9 indicating alkaline nature of the groundwater. All natural waters contain mineral salts in solution. The presence of dissociated ions renders the solutions conductive. Electrical current is the ability of an object to conduct electric current. It depends upon the presence of various ionic species in the water. Electrical Conductivity in groundwater varies from 687to 2855 µs/cm with an average value 1299 µs/cm. To ascertain the suitability of the groundwater for any purpose, it is essential to classify the groundwater depending upon its hydrochemical properties based on the total dissolved solids (TDS) values (Freeze and Cherry 1979). The value of TDS ranges from 447 to 1856 mg/L. The value of TDS of the groundwater samples is within the maximum allowable limit as per the standard prescribed by BIS (1991). Calcium is one of the most abundant substances of the natural water. The calcium concentration ranges from 94 to 698 mg/L with a mean value of 208 mg/L, seven samples were exceeds maximum permissible limit prescribed by the BIS. A large number of minerals contain magnesium; magnesium is washed from rocks and subsequently ends up in water. Magnesium also ends up in the environment from fertilizer application and from cattle feed. The value of magnesium ranges from 5 to 158 mg/L. Two samples were crosses the maximum permissible limit. In the study area the rock type is basalt hence source of magnesium in the groundwater is basaltic rock type. Total Hardness is considered as a major character of drinking water. A total hardness value varies from 230 to 762 mg/l which may be due to presence of calcium and magnesium. The study concluded that four samples were exceeding maximum permissible limit prescribed by the BIS (1991). Chloride ions are generally present in natural waters and its presence can be attributed to dissolution of salts. The concentrations of ions such as Cl^-, $SO_4{}^-$, and $HCO_3{}^-$ are within the maximum allowable limits for drinking standards. Though the Cl^-, $SO_4{}^-$, and $HCO_3{}^-$ concentration in the groundwater exceeds the desirable limit of standards, the values are within the allowable limits prescribed by the BIS (1991). Sodium content in study area has shown variation from 21 to 226 mg/L with an average value 77 m/L. Three samples were crosses the maximum permissible limit prescribed by BIS (1991). The main sources of potassium in ground water include rain water, weathering of potash silicate minerals, use of potash fertilizers and use of surface water for irrigation. The European Economic Community (EEC, 1980) has prescribed the guideline level of potassium at 10 mg/L in drinking water. As per European Economic Community (EEC, 1980) criteria, two samples exceeding maximum permissible limit while remaining samples of the study area fall within the guideline level of 10 mg/L.

Irrigation water quality

Groundwater is the main source of irrigation in entire study area. Quality of water is assuming great importance with the rising pressure on industries and agriculture and rise in standard of living. The adequate amount of water is very essential for proper growth of plants but the quality of water used for irrigation purpose should also be well within the permissible limit otherwise it could adversely affect the plant growth. Questions have been raised as to the social and environmental sustainability of this intensive mode of crop production. The continuous use of poor quality water without drainage and soil management may lead to saline and sodic soil, particularly in clayey soils. The water used for irrigation is an important factor in productivity of crop, its yield and quality of irrigated crops. The quality of irrigation water depends primarily on the presence of dissolved salts and their concentrations. Sodium Absorption Ratio (SAR) and Residual Sodium Carbonate (RSC) are the most important quality criteria, which influence the water quality and its suitability for irrigation.

Sodium Absorption Ratio (SAR) is an expression pertaining to cation make up of water and soil solution and is used for characterizing the sodium hazard of irrigation water. SAR value is used to calculate the degree to which irrigation water tends to enter into cation exchange section in the soil. The main problem with high sodium concentration is its effect on soil permeability. Sodium also contributes directly to the total salinity of the water and may be toxic to sensitive crops such as fruit trees. The higher value of SAR indicates soil structure damage. The sodium adsorption ratio values for each water sample were calculated by using equation given by Richard (1954). Sodium adsorption ratios for groundwater samples of the study area are less than 10 indicate excellent quality for irrigation and all the samples fall in excellent (S_1) category (Table 3). When the SAR and specific conductance of water are known, the classification of the water for irrigation can be determined by graphically plotting these values on the US salinity (USSL,1954)) diagrams (Fig.1). Waters have been divided into low (C_1), medium (C_2), high (C_3) and very high (C_4) types on the basis of salinity hazard and low (S_1), medium (S_2), high (S_3) and very high (S_4) types on the basis of sodium hazard. The SAR values ranges between 0.55 to 4.40. In the study area 14% samples fall in C_2-S_1 classes, 83% of samples fall in C_3-S_1 classes and 3% samples fall in the C_4-S_1 classes of USDA diagram (Fig.1) indicating medium to high salinity/ low sodium, and high to very high salinity/low sodium type, respectively (Fig. 1). Three percent of the samples fall in the field of C_4-S_1 indicating a high salinity and low alkalinity hazard. This water will be suitable for plants having good salt tolerance, but it restricts its suitability for irrigation, especially in soils with limited drainage.

Wilcox (1955) classified groundwater for irrigation purposes by correlating percent sodium and electrical conductivity, which illustrates that 17%, of the samples fall in the field of excellent to good, 80 %, fall in the field of good permissible and 3 % of the samples fall in the field of doubtful to unsuitable for irrigation (Fig.2).

The SSP values less than 50 or equal to 50 indicates good quality water and if it is more than 50 indicates the unsuitable water quality for irrigation. The SSP values for the groundwater of study area are less than 50 and indicate good quality water for irrigation purpose (Table 3).

Residual Sodium Carbonate (RSC) is considered to be superior to SAR as a measure of sodicity particularly at low salinity levels. In water having high concentration of bicarbonates, there is tendency for calcium and magnesium to precipitate as carbonates. To qualify this effect, an experimental parameter termed as residual sodium carbonate, can be calculated. Groundwater having less than 1.25 or equal to 1.25 epm of RSC is safe water for irrigation purpose, water is having less than 1.25 to 2.5 epm of RSC is marginally suitable for irrigation purpose whereas water having more than 2.5 epm of RSC is not suitable for irrigation purposes. Based on RSC values, all the samples of study area show the values less than 1.25 and were safe for irrigation (Table 3).

Table.3 Classification of groundwater on the basis of SAR, SSP and RSC,

Parameter	Range	Water Class	Samples
SAR	< 10 10–18 18–26 > 26	Excellent (S_1) Good (S_2) Doubtful (S_3) Unsuitable (S_4)	All
SSP	<50 >50	Good Bad	All
RSC	<1.25 1.25–2.50 > 2.5	Good Doubtful Unsuitable	All

Conclusions

Hydro chemical parameters of the study area are compared with BIS (1991) shows that groundwater of the study area is suitable for drinking purposes and public health. The value of Ca^{++}, Mg^{++}, TH and Na^{+} ion concentration is higher in few of the samples when compared with the BIS standard. The value of TDS, Cl^{-} and SO_4^{-} ion concentration is within the limits in majority of the samples. The excess amount of Ca^{++}, Mg^{++}, TH and Na^{+} in the groundwater is due to anthropogenic factors and geological characteristics of the aquifer. The suitability of water for irrigation is evaluated based on SAR, SSP and RSC. Most of the samples in the Sukhana river sub basin fall in the suitable range for irrigation purpose, either from the SAR, SSP or RSC values. The values of EC and SAR of groundwater samples have been plotted in U.S. salinity diagram indicating that all samples fall in C_2-S_1, C_3-S_1 and C_4-S_1 category showing moderate to very high salinity and low sodium hazard. On basis of Wilcox diagram it is concluded that 17%, of samples fall in the field of excellent to good and 80%, fall in the field of good permissible and 3 % of the samples fall in the field of doubtful to unsuitable for irrigation. Overall the groundwater quality of the study area is suitable for the domestic and irrigation purpose except few which indicates signs of deterioration in the study area.

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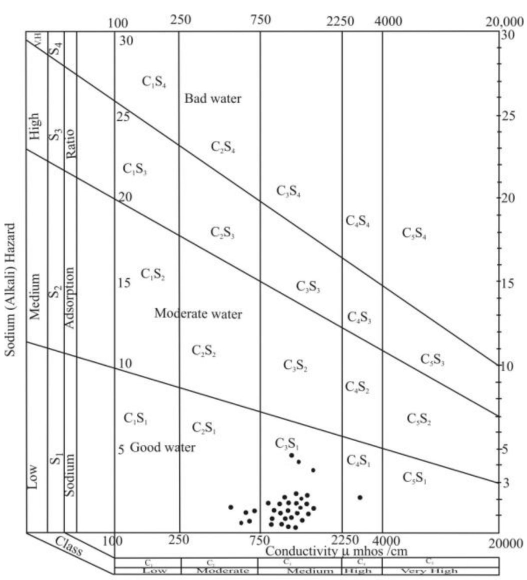

Fig.1 U.S.Salinity diagram of groundwater of the study area

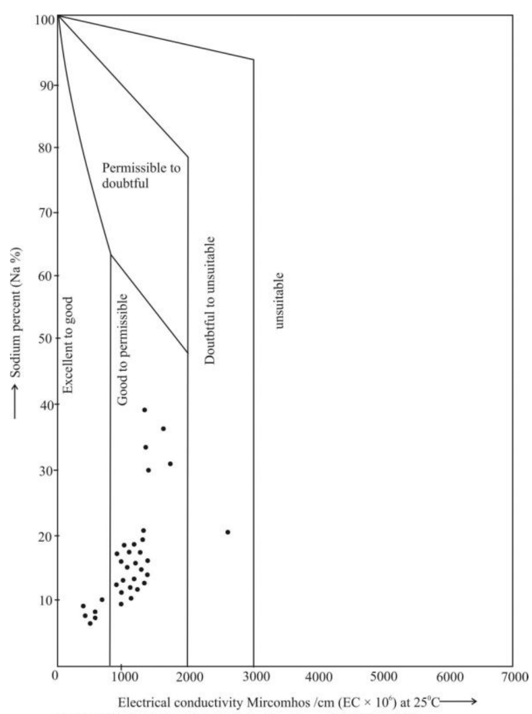

Fig. 2 Suitability of groundwater for irrigation in Wilocx diagram (After Wilcox, 1995)