Research Journal of Chemical Sciences ISSN 2231-606X
Vol. **2(1),** 25-31, Jan. **(2012)** *Res.J.Chem.Sci.*

Evaluation of Groundwater Quality and its Suitability for Drinking and Agriculture use in Parts of Vaijapur, District Aurangabad, MS, India

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Available online at: www.isca.in
(Received 7th Octomber 2011, revised 6th November 2011, accepted 9th December 2011)

Abstract

This study was conducted to evaluate factors regulating groundwater quality in an area with agriculture as main use. Fifteen groundwater samples have been collected from Vaijapur taluka of Aurangabad district. The Vaijapur taluka of Aurangabad district covers an area of approximately 1510.5 km^2 and underlain by the Deccan Trap lava flows of upper Cretaceous to Eocene age. Rapid development in recent years has led to an increased demand for water, which is increasingly being fulfilled by groundwater abstraction. A detailed knowledge of the water quality can enhance understanding of the hydrochemical system, to achieve this; a hydrochemical investigation was carried out in the study area. Groundwater samples were chemically analyzed for major physicochemical parameter in order to understand the different geochemical processes affecting the groundwater quality. The analytical results shows higher concentration of total dissolved solids (26.66%), electrical conductivity (26.66%), chloride (33.33%) total hardness (60%) and magnesium (86.66%) which indicates signs of deterioration as per WHO and BIS standards. On the other hand, 40% groundwater sample is unsuitable for irrigation purposes based on irrigation quality parameters. The study revealed that application of fertilizer for agricultural contributing the higher concentration of ions in aquifer of Vaijapur.

Keywords: Groundwater pollution, agricultural activity, irrigation water quality, vaijapur area.

Introduction

Water is essential to the existence of man and all living things. Groundwater occurs almost everywhere beneath the earth surface not only in a single widespread aquifer, but also in thousands of local aquifer systems. Man's activities such as food production, nutrition are dependent on water availability in adequate quantities and good quality[8]. Water is the most common and widespread chemical compound in nature which is a major constituent of all living creatures[6,12]. The quality of water is of great importance as it is commonly consumed and used by households. Ground water which occurs beneath the earth surface is considered free from contamination, hence usable but anthropogenic as well as natural factors are affecting the quality as well as quantity of this valuable resource[10]. It has been estimated that once pollution enters the subsurface environment, it may remain concealed for many years, becoming dispersed over wide areas of groundwater aquifer and rendering groundwater supplies unsuitable for consumption and other uses[18]. Water chemistry differs depending on the source of water, the degree to which it has been evaporated, the types of rock and mineral it has encountered, and the time it has been in contact with reactive minerals [15,2].

Understanding the potential influences of human activity on ground water quality is important for protection and sustainable use of ground water resources, as well as groundwater extraction has been increasing continuously to keep pace with agricultural development in rural areas hence the hydro geochemistry study was undertaken by randomly collected 15 groundwater samples from dug wells and bore wells covering entire Vaijapur taluka area to understand the sources dissolved ions, and to assess the chemical quality of the groundwater through physicochemical analysis. Ground water in the study area is utilized for both agricultural and drinking purposes hence hydro geochemistry is discussed in order to understand water rock interaction process and to investigate the concentration of the total dissolved constituents present in the ground water with respects to the standards of safe potable water.

Study area: Vaijapur taluka, located in the heart of the drought-prone interior of Maharashtra State and situated at the latitude of 19°40' to 20°15' north and longitude of 74°35' to 75°00' east covering an area of approximately 1510.5 sq. km and fall in Survey of India Toposheet No. 46 L/16 and having population 259601 as per 2001 Census.

Climate: The climate of the district is characterized by a hot summer and a general dryness throughout the year except during the south west monsoon season, which is from June to September while October and November constitute the post-monsoon season. The average annual rainfall in Vaijapur taluka is 504.5mm. About 83% of annual rainfall is received during June to September. The variation in rainfall from year to year is large and study area falls in drought prone area hence is characterized by the erratic behavior of the rainfall.

Geology and Hydrogeology: The entire study area is covered and surrounded mainly by basaltic lava flows belonging to the Deccan volcanic province that flooded during upper Cretaceous to Eocene age. The stratigraphic sequence and lithology is as indicated given below.

Formation	Age	Lithology
Alluvium	Recent	Clay, Silt and Sand
Deccan Trap	Upper Cretaceous to Eocene	Vesicular and Amygdule zeolitic basalt and massive basalt inter bedded with red bole

The prominent geological units observed in the study area are the horizontally disposed basaltic lava flows 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. This basaltic lava flows are the only water bearing formations in the area. The weathered and fractured mantles of the traps are forming water table aquifers in the area where ground water occurs under phreatic conditions. A number of lineaments which are fracture zones have been identified on the satellite imagery due to linear pattern, exhibited by darker tone and straight drainage course. These lineaments are favorable for occurrence of groundwater[4].

Material and Methods

The current study was designed to investigate the conditions of groundwater contamination in the study areas. The hydro geochemistry study was undertaken by randomly collected 15 groundwater samples from dug wells and bore wells covering entire Vaijapur taluka during October 2009. Samples were drawn with a precleaned plastic polyethylene bottle. Prior to sampling, all the sampling containers were washed and rinsed thoroughly with the groundwater. Water quality parameters such as pH and electrical conductivity (EC) were analyzed immediately[1]. Other parameters were later analyzed in the laboratories of P.G. Department of Geology, Govt. Institute of Science. Total dissolved solids (TDS) were computed by multiplying the electrical conductivity (EC) by a factor (0.64). Total hardness (TH) as $CaCO_3$ and calcium (Ca) were analyzed titrimetrically, using standard EDTA. Magnesium (Mg) was calculated by taking the differential value between total hardness (TH) and calcium (Ca) concentrations. Chloride (Cl)) was determined titrimetrically by standard $AgNO_3$ titration. The content of Sodium (Na) and Potassium (K) in groundwater was estimated flame photometrically, employing Elico Flame Photometer.

All parameters are expressed in milligrams per litre (mg/l) and milliequivalents per litre (meq/l), except pH (units) and electrical conductivity (EC). The electrical conductivity (EC) is expressed in micromohs/cm (µS/cm) at 25^0C.

Results and Discussion

Fifteen groundwater samples were drawn from the wells which included hand pumps, piped water supplies and mini water supply schemes and also open wells and analyzed for physicochemical parameters. The results of the physicochemical analysis are presented in tables-1 and table-2 shows the critical parameters exceeding the BIS[3] permissible limits along with the permissible limits for these parameters.

pH: pH is one of the important factor of ground water. In the study area pH varies from 7.87 to 8.90 (table 1) indicates the ground water is slightly alkaline. 26.66% samples were exceeds the permissible limit prescribed by BIS[3] (table 2).

Electrical Conductivity (EC): Conductivity is the measure of capacity of a substance to conduct the electric current. Most of the salts in water are present in their ionic forms and capable of conducting current and conductivity is a good indicator to assess groundwater quality. Electrical conductivity is an indication of the concentration of total dissolved solids and major ions in a given water body.

Electrical Conductivity in groundwater varies from 1200 to 16600 µmohs/cm (table 1) where as permissible limit is <1500 micromohs/cm for domestic use. The EC values in majority of samples are higher than permissible limit[14]. Conductivity values are divided in to the three groups from general experience. The division based on conductivity values suggest that any 26.66 % of the wells are below the safe limit of 1500 micromohs/cm while 46.68 % of the wells are in the range of 1500-3000 micromohs/cm and 26.66 % of the wells are above 3000 micromohs/cm range (table 3).

Table- 1

Physico-chemical parameters of bore well and dug well in Vaijapur taluka of Aurangabad district

Well No	PH	EC	TDS	Ca	Mg	TH	Cl	HCO_3	Na	K	SAR	KR	SSP	RSC
		µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ppm	ppm				
1	8.24	1400	910	144.28	96.00	540	170.4	400	83	01	1.31	0.24	19.31	-8.53
2	8.19	1500	975	120.24	107.30	560	156.2	400	82	01	1.31	0.24	19.41	-8.25
3	8.35	2300	1450	144.28	140.47	720	312.4	350	133	53	1.89	0.31	23.59	-12.99
4	7.90	1860	1209	160.32	102.40	580	6248	375	1070	06	16.24	2.84	73.92	-10.26
5	7.95	1200	780	168.33	110.20	620	3266	400	1090	04	16.04	2.72	73.09	-10.89
6	8.24	12100	7865	152.30	114.11	620	4047.0	400	1071	04	15.99	2.74	73.29	-10.41
7	8.00	14300	9295	152.30	114.11	620	4260.0	350	1090	03	16.27	2.79	73.64	-11.23
8	8.58	2600	1690	112.22	153.17	740	468.6	350	145	55	2.09	0.35	25.76	-12.43
9	8.00	12700	8255	152.30	118.99	640	4757.0	400	1093	04	16.13	2.74	73.23	-10.81
10	7.87	16600	10790	160.32	117.04	640	5254.0	350	1084	04	15.88	2.68	72.80	-11.87
11	8.48	2300	1495	128.25	144.38	720	312.4	325	148	53	2.13	0.35	26.07	-12.92
12	8.57	1300	845	152.30	109.23	600	170.4	400	91	01	1.37	0.24	19.28	-10.01
13	8.90	2200	1430	128.25	149.26	740	326.6	350	146	43	2.08	0.34	25.40	-12.91
14	8.56	1500	975	144.28	111.19	600	170.4	400	92	01	1.40	0.24	19.68	-9.77
15	8.22	1300	845	152.30	99.47	560	227.2	400	92	02	1.42	0.25	20.23	-9.21
Min.	7.9	1200.0	780.0	112.2	96.0	540.0	156.2	325.0	82.0	1.0	1.3	0.2	19.3	-13.0
Max.	8.9	16600.0	10790	168.3	153.2	740.0	6248.0	400.0	1093.0	55.0	16.3	2.8	73.9	-8.3
Average	8.3	5468.2	3551.7	144.3	119.8	634.1	2150.0	375.0	510.9	17.1	7.6	1.3	43.1	-10.8

Table -2
Critical parameter exceeding the Permissible limit

Sr. No.	Parameter	BIS Permissible limit (1998)	No. of Sample exceeding permissible limit	Percentage of Sample exceeding permissible limit
1	pH	6.5-8.5	4	26.66
2	Chloride	1,000	5	33.33
3	EC	1500	4	26.66
4	TDS	2,000	4	26.66
5	Total Hardness	600	9	60
6	Calcium	200	-	-
7	Magnesium	100	13	86.66
8	Sodium	200	6	40

Table-3
Classification of groundwater from conductivity values

Conductivity range micromohs/cm	Classification	No. of sample	Percentage of samples
< 1500	Permissible	04	26.66
1500-3000	Not permissible	07	46.68
> 3000	Hazardous	04	26.66

Total dissolved solids (TDS): The total dissolved solids (TDS) are the concentrations of all dissolved minerals in water indicate the general nature of salinity of water. The total dissolved solids in all the study area varies from 780 to 10790 mg/l (table 1). The higher value of total dissolved solids is attributed to application of agricultural fertilizer contributing the higher concentration of ions in to the groundwater[16]. 26.66 % samples were exceeding maximum permissible limit (table 2) prescribed by the BIS[3].

Calcium (Ca): Calcium is naturally present in water. Calcium is a determinant of water hardness, because it can be found in water as Ca ions. Calcium content in the groundwater varies from 112.22 to 168.33 mg/l (table 1). All samples were within maximum permissible limit (table 2) prescribed by the BIS[3].

Magnesium (Mg): A large number of minerals contain magnesium; Magnesium is washed from rocks and subsequently ends up in water. Magnesium has many different purposes and consequently may end up in water in many different ways. Chemical industries add magnesium to plastics and other materials as a fire protection measure or as filler. It also ends up in the environment from fertilizer application and from cattle feed. The values of magnesium ranges from 96.00 to 153.17 mg/l (table 1) 86.66% samples were crosses the maximum permissible limit (table 2) prescribed by BIS[3]. In the study area the rock type is basalt hence source of magnesium in the groundwater is basaltic rock type.

Total hardness (TH): Total Hardness is considered as a major character of drinking water. Hardness is defined as the concentrations of calcium and magnesium ions. Calcium (Ca) and magnesium (Mg) are dissolved from most soils and rocks. A total hardness value varies from 540 to 740 mg/l (table 1) which may be due to presence of Calcium (Ca) and magnesium (Mg). The study concluded that 60% samples were exceeding maximum permissible limit (table 2) prescribed by the BIS[3].

Chloride (Cl): Chloride originates from sodium chloride which gets dissolved in water from rocks and soil. It is good indicator of groundwater quality and its concentration in groundwater will increase if it mixed with sewage or sea water. The chloride content in study area has shown variation from 170.4 to 5254 mg/l (table 1). 33.33% samples were crosses the maximum permissible limit. (table 2) prescribed by BIS[3]. The higher values of Chloride suggest leaching of effluents from Agricultural fertilizer in to the ground water[13]

Bicarbonate alkalinity (HCO_3): Alkalinity is the measure of the capacity of the water to neutralize a strong acid. The Alkalinity in the water is generally imparted by the salts of carbonates, silicates, etc. together with the hydroxyl ions in free State[20]. The bicarbonate alkalinity varies from 325 to 400 mg/l (table 1).

Sodium (Na): Sodium is the sixth most abundant element in The Earth's crust and sodium stems from rocks and soils. Not only seas, but also rivers and lakes contain significant amounts of sodium. Concentrations however are much lower, depending on geological conditions and waste water contamination sodium compounds serve many different industrial purposes, and may also end up in water from industries. The Sodium content in study area has shown variation from 82 to 1093 mg/l (table 1). 40% samples were crosses the maximum permissible limit (table 2) prescribed by BIS[3].

Potassium (K): Potassium is an essential element for humans, plants and animals, and derived in food chain mainly from vegetation and soil. 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[5] (EEC) has prescribed the guideline level of potassium at 10 mg/l in drinking water. As per European Economic Community[5] (EEC) criteria, 26.66% samples exceeding maximum permissible limit while 73.34% samples of the study area fall within the guideline level of 10 mg/l. Though potassium is extensively found in some of igneous and sedimentary rocks, its concentration in natural waters is usually quite low. This is due to the fact that potassium minerals offer resistance to weathering and dissolution.

In the present investigation the ground water samples from different part of the study area revealed that there is marked variation in groundwater quality. The analytical results shows higher concentration of total dissolved solids (26.66%), electrical conductivity (26.66%), chloride (33.33%), and total hardness (60%), magnesium (86.66%), sodium (40%) which indicates signs of deterioration as per WHO (1984) and BIS[4] standards.

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): The sodium adsorption ration (SAR) indicates the effect of relative cation concentration on sodium accumulation in the soil; thus, sodium adsorption ration (SAR) is a more reliable method for determining this effect than sodium percentage[17]. Sodium adsorption ration (SAR) is calculated using the following formula:

$$SAR = [Na^+] / \{([Ca^{2+}] + [Mg^{2+}]) / 2\}^{1/2}$$

Ions are expressed as milliequivalents per liter (meq/L). The potential for a sodium hazard increases in waters with higher sodium adsorption ration (SAR) values. The sodium adsorption ration (SAR) content in study area has shown variation from 1.3 to 16.3 with an average value 7.6 (table 1). 40% Sodium adsorption ratios for groundwater samples of the study area are less than 10 indicate excellent quality for irrigation and samples fall in excellent (S1) category while 60% Sodium adsorption ratios for groundwater samples of the study area are within range 10-18 indicate good quality for irrigation and samples fall in good (S2) category (table 4).

Table - 4
Classification of groundwater on the basis of SAR, KR, SSP and RSC

Parameter	Range	Water Class	Samples	%age
SAR	< 10 10–18 18–26 > 26	Excellent (S1) Good (S2) Doubtful (S3) Unsuitable (S4)	09 04 - -	60 40 - -
KR	<1 >1	Good Unsuitable	09 04	60 40
SSP	<50 >50	Good Bad	09 04	60 40
RSC	<1.25 1.25–2.50 > 2.5	Good Doubtful Unsuitable	All - -	100 - -

KR: Sodium measured against Ca^{2+} and Mg^{2+} is used to calculate Kelley's ratio[11]. The formula used in the estimation of Kelley's ratio is expressed as, Kelley's Ratio (KR) = $Na^+/ Ca^{2+} + Mg^{2+}$

A Kelley's Ratio (KR) of more than one indicates an excess level of sodium in waters. Hence, waters with a Kelley's Ratio less than one are suitable for irrigation, while those with a ratio more than one are unsuitable for irrigation. 60% Kelley's ratio (KR) values for the groundwater of study area are less than 1 and indicate good quality water for irrigation purpose while remaining 40% is more than 1 indicates the unsuitable water quality for irrigation (table 4).

SSP: The Soluble Sodium Percent (SSP) for groundwater was calculated by the formula,

$$SSP = \frac{Na \times 100}{Ca^{2+} + Mg^{2+} + Na^+}$$

Where the concentrations of Ca^{2+}, Mg^{2+} and Na^+ are expressed in milliequivalents per liter (epm). The Soluble Sodium Percent (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 values of Soluble Sodium Percent (SSP) ranges from 19.3 to 73.9 with an average value 43.1 (table 1). 60% Soluble Sodium Percent (SSP) values for the groundwater of study area are less than 50 and indicate good quality water for irrigation purpose while remaining 40% is more than 50 indicate the unsuitable water quality for irrigation (table 4).

Residual sodium carbonate (RSC): Waters containing a carbonate plus bicarbonate concentration greater than the calcium plus magne-sium concentration have what is termed "residual sodium carbonate"

$$[RSC = (CO3 + HCO3) - (Ca + Mg)]$$

The potential for a sodium hazard is increased as Residual sodium carbonate (RSC) increases, and much of the calcium and sometimes the magnesium are precipitated out of solution when water is applied to the soil. Salts become concentrated when the soil dries out, as less soluble ions such as calcium and magnesium tend to precipitate out and are removed from the solution[7] (Glover, 1996). The values of Residual sodium carbonate (RSC) ranges from -8.3 to 13 with an average value -10.8 (table 1). Groundwater having less than 1.25 or equal to 1.25 epm of Residual sodium carbonate (RSC) is safe water for irrigation purpose, water is having less than 1.25 to 2.5 epm of Residual sodium carbonate (RSC) is marginally suitable for irrigation purpose whereas water having more than 2.5 epm of Residual sodium carbonate (RSC) is not suitable for irrigation purposes. Based on Residual sodium carbonate (RSC) values, all the samples of study area having values less than 1.25 and were safe for irrigation (table 4).

Conclusion

The analytical results shows higher concentration of total dissolved solids (26.66%), electrical conductivity (26.66%), chloride (33.33%), total hardness (60%), and magnesium (86.66%) which indicates signs of deterioration as per WHO[21] and BIS[3] standards.

The groundwater of the rural Vaijapur aquifer exhibit conductivities from 1200 to 16600 micromohs/cm. proper drainage systems is required where electrical conductivity (EC) is more than 1500 micromohs/cm. A few wells of the study area record extraordinary values of conductivity and chloride due to the application of fertilizer for agricultural exhibiting the higher concentration of ions contributes to groundwater degradation in varying degrees.

On the other hand, 40% groundwater sample is unsuitable for irrigation purposes according to Soluble Sodium Percent (SSP) and Kelley's Ratio (KR). The data structure shows that application of fertilizer for agricultural contributing the higher concentration of ions in aquifer of Vaijapur.

Recommendations: This study emphasizes the need for regular groundwater quality monitoring to assess pollution activity from time to time for taking appropriate management measures in time to mitigate the intensity of pollution activity.

The remedial measures include: i) Rain water harvesting should be encouraged. Excess rain water stored should be directed to recharging wells. ii) Encourage the framers to use biofertilizers and biopesticides to avoid the soil, surface water and groundwater contamination. iii) Awareness and training programs should be conducted for the NGO's and the local people for the sustainable use and management of groundwater of the region. iv) A short term and long term management action plan should be formulated for the efficient use of groundwater resources and other natural resources after taking into account the population distribution, agricultural activities etc.

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