RESEARCH PAPER | Engineering | Volume : 4 | Issue : 10 | October 2014 | ISSN - 2249-555X

Assessment of Groundwater Quality and it's Suitability For Drinking and Agriculture Uses

KEYWORDS: Groundwater quality, Hydro-chemical facies, salinity, SAR, percentage of sodium

Jatin B. Dhimmar
M.E Water Resource Management,4th Semester, Department of Civil Enginnering, Dr.S&S.S Ghandhy, GEC Surat, Gujarat, India

Dr. S. S. Singh
Associate Professor, Department of Civil Engineering, GEC Surat, Gujarat, India

ABSTRACT *Surat district is located at the southernmost tip of Gujarat, near Gulf of Khambhat in the Arabian Sea. In order to evaluate the quality of groundwater in study area, 47 samples were collected and analyzed for various parameters. Physical and chemical parameters of groundwater such as electrical conductivity, pH, total dissolved solids, Na, K, Ca, Mg, Cl, HCO3, CO3, SO4, F were determined. These parameters were used to assess the suitability of groundwater for domestic purpose by comparing with the WHO and Indian standards. TDS, percentage of sodium and sodium adsorption ratio (SAR) were used for irrigation suitability assessment. The sample analysis reveals that the groundwater is not entirely fit for drinking with respect to pH, EC, hardness and TDS. In some of the collected samples, the concentrations of these parameters exceed the permissible limits of WHO and ISI standards. Based on TDS and SAR almost all samples are suitable for irrigation purpose except a few locations, which show values beyond the permissible limits. The abundance of major ions is as follows: Na > Mg > Ca > K and Cl > HCO3 >SO4. Based on TDS 95.7 % of samples are found suitable for drinking purposes.*

INTRODUCTION

Groundwater is the most important source of domestic, industrial, and agriculture water supply in the world. Many countries in India depend heavily on groundwater. Exploitation of surface water has reduced, ensuring an increasing reliance on groundwater abstraction due to increasing pollution with the concomitant rise in the cost of water treatment (kortasi, 2007). Groundwater quality reflects inputs from the atmosphere, soil and water rock reactions as well as pollutant sources such as mining, land clearance, agriculture, acid precipitation, domestic and industrial wastes (Appelo and Postma, 1993).

Suitability of water for various uses depend on type and concentration of dissolved minerals and groundwater has more mineral composition than surface water (Mirribasi et al., 2008). The quality of groundwater is constantly changing in response to daily, seasonal and climatic factors. Continuous monitoring of water quality parameters is highly crucial because changes in the quality of water has far as reaching consequences in terms of its effects on man and biota.

In Surat district, groundwater resources are under increasing pressure in response to threats of rapid population services. A number of factors influence water chemistry-Gibbs (1970) proposed that rock weathering, atmospheric precipitation, evaporation and crystallization control the chemistry of water. The influence of geology on chemical water quality is recognized (Gibbs, 1970; Langmuir, 1997; Lester and Birkett, 1999). The influence of soils on water quality is very complex and can be ascribed to the processes controlling the exchange of chemicals between the soil and water (Hesterberg, 1998). Apart from natural factors influencing water quality, human activities such as domestic and agriculture practices impact negatively on groundwater resources. Pollution of water bodies as a result of metal toxicity has become a source of concern among consumers. This concern has become alarming in response to increasing knowledge on their toxicity to human health and biological systems (Anazawa et al, 2004). The toxicity of trace metals in water depends on the concentration of the metal below a certain level, which could be considered as essential for biochemical processes. However, in certain cases, high levels could bioaccumulation raising toxicity concerns.

Water quality data is essential for the implementation of responsible water quality regulations for characterizing and remediating contamination and for the protection of the health of humans and the ecosystem. Regular monitoring of groundwater resources thus plays a key role in sustainable management of water resources. This study conducted seeks to serve as a preliminary study to assess the groundwater quality in terms of drinking and agriculture uses for a rapidly developing community located in India.

Objective

The objective of this paper is to find the ground water quality at different places of surat district and analyze it's suitability for drinking and agriculture uses.

STUDY AREA

Fig: 1 location of sampling points

Volume : 4 | Issue : 10 | October 2014 | ISSN - 2249-555X

Surat district is located at the southernmost tip of Gujarat, near Gulf of Khambhat in the Arabian Sea. It is located at 20.9667° N latitude and 73.0500° E longitude. Land area of Surat district is 4418 sq. kilometers covering total of 729 villages. There are ten talukas viz. surat city, Bardoli, choryasi, Kamrej, Olpad, Palsana, Umarpada, Mahuva, Mandvi, Mangrol. Average rainfall is 1500 to 2200 mm. Main rivers of the surat districts are tapi, mindhora, purna, kim, ambika. There are unconfined and confined aquifers. Map of sampling points is shown in fig: 1

methodology

Hydro-geochemical sampling procedure The objective of sampling is to collect a portion of material small enough in volume to be transported conveniently and handled in the laboratory while still accurately representing the material being sampled [1] (APHA,1992). Samples, however, have to be handled in such a way that no significant change in composition occurs before the tests are made. A total number of 47 groundwater samples were collected for physico-chemical analysis in two successive pre-and post-monsoon seasons corresponding to Pre-monsoon 2013 and Post-monsoon 2013. The water samples were collected and stored in 1 liter capacity clean plastic bottles. Before collection of samples, the bottles were properly washed. Prior to collecting the samples, the containers were rinsed by the water to be sampled. The wells were duly pumped before collecting their sample so that the stagnant water, if any, is completely removed from storage within the well assembly.

Analytical techniques for major ions The water samples were analyzed as per the standard methods of APHA (1992). Values of pH were measured by a portable digital water analyses kit with electrodes. The instrument was calibrated with buffer solutions having pH values of 4 and 9. Total dissolved solids (TDS) were calculated by summing up the concentrations of all the major cations and anions. The values of electrical conductivity (EC) were measured by portable kit with electrodes in the lab. The concentrations of Ca^{++}, Mg^{++}, Cl^-, $HCO3^-$ and total hardness were determined by volumetric method. Ca^{++} and Mg^{++} were determined by EDTA titration. For $HCO3^-$, HCl titration to a methyl orange point was used. Chloride was determined by titration with $AgNO^3$ solution. Flame emission photometry has been used for the determination of Na^+ and K^+. In this method water sample is atomized and sprayed into a burner. The intensity of the light emitted by a particular spectral line is measured with the help of a photoelectric cell and a galvanometer. Sulphate was determined by gravimetric method.

RESULT AND DISCUSSION

The analytical data of successive pre-monsoon and post-monsoon seasons for groundwater sample corresponding to May 2013 and October 2013 are given in mg/l as shown in Table: 1, Table: 2 & Table: 3.

Physico-chemical attributes of groundwater The properties of groundwater of the area under study, in terms of fundamental parameters, such as, pH, hardness, total dissolved solids and EC are given below.

Electrical Conductivity: The electrical conductivity with 400 μmho/cm at 25° C is considered suitable for human consumption (WHO, 1984), while more than 1500 μmho/cm at 25° C may cause corrosion of iron structures. In the study area, Electrical Conductivity values ranges between 300-28870μmho/cm during May 2013. The EC values during October 2013 ranges between 230-21270 μmho/cm.

Hydrogen Ion Concentration (pH): Values of pH were measured at well sites, which range between 2.8 to 9.2 and 7.0 to 9.7 during pre-monsoon 2013 and post-monsoon 2013, respectively. The groundwater thus is mildly acidic to slightly alkaline in nature.

Hardness: In the area of study the hardness values varies from 37.3 to 3600.8 mg/l and 111 to 13180 mg/l in pre-monsoon and post-monsoon year 2013. It was found that 78.72 % of samples are higher than desirable limit for drinking purposes of >300 mg/l in above periods so it is not suitable for drinking and 21.28 % of samples are fit for drinking purpose within the permissible limit of drinking water standard (BIS, 1991).

Total Dissolved Solids: The TDS values during May, 2013 sample range from 210 to 16880 mg/ l, the average value for the sample being 1664.4 mg/l. The TDS values during October, 2013 range between 49.66 to 768.19 mg/l with an average value of 240.27 mg/l. It was found that 95.7 % of samples are found in permissible limit (≤ 2000 mg/l), 34% samples are found in desirable limit and 4.3 % of samples are found higher than permissible limit. Those samples which are higher than permissible limit may be due to the leaching of various pollutants in to the groundwater which can decrease the pot ability and may cause gastro-intestinal irritation in human and may also have laxative effect particularly up on transits [2]. and those samples (34 % sample) within desirable limit which are used for drinking purpose.

Drinking Water Quality: The groundwater samples for both the seasons i.e. pre and post-monsoons 2013 shows the high TDS concentration and are above the permissible limit of 2000 mg/l WHO 1997 & BIS 1991 and making the water unsuitable for various domestic activities. Based on TDS values Davies and Dewiest (1996) [3] propose a three-fold classification of groundwater. (1) Domestic (TDS < 500 mg/l) (2) Irrigation (TDS range between 500-1000 mg/l) and (3) Industry (TDS > 1000 mg/l). According to this classification 34 % samples of both seasons are in category (1). Sulphate concentration above the desirable limit found for 3 samples and 44 samples are found in desirable limit (≤ 400 mg/l). Those samples cross the permissible limit of sulphate may result in gastrointestinal irritation and respiratory problems to the human system. All samples of pre-monsoon 2013 & post-monsoon 2013 have nitrate concentration lower the desirable limit (< 45 mg/l) so there is no problem of nitrate concentration. In both pre-monsoon and post-monsoon of sample of 2013, fluoride concentration not exceeds the desirable limit of 1.5 mg/l. So there is no problem of fluoride concentration.

Groundwater suitability for irrigation usages: The suitability of groundwater for irrigation is dependent on the effects of the mineral constituents of water of both the plant and soil. Salt may harm plant growth physically by limiting the uptake of water through modification of osmotic processes, or chemically by metabolic reactions effected by toxic constituents. Effects of salts on soils in causing changes in soil structure, permeability and aeration directly affect the plant growth [4]. The irrigation water containing a high proportion of sodium will increases the exchange

Volume : 4 | Issue : 10 | October 2014 | ISSN - 2249-555X

Table:1 Chemical analysis in mg/l (pre-monsoon 2013)

Sr. no.	location	Na	K	Ca	Mg	HCO_3	Cl	SO_4	CO_3	NO_3	F
1	surat city	806.0	6.2	10.0	90.0	390.0	1200.0	86.0	36.0	5.3	0.5
2	kikvad	452.0	3.1	15.0	15.0	524.7	312.3	111.9	0.0	N.M	N.M
3	Madhi	434.0	6.3	25.0	96.0	586.0	312.0	436.0	24.0	N.M	N.M
4	Mota	1065.0	8.6	25.0	123.0	256.0	1200.0	923.0	24.0	N.M	N.M
5	orgam	244.0	2.8	35.0	90.0	134.0	304.0	420.0	12.0	N.M	N.M
6	Sarbhon	259.0	3.5	25.0	90.0	268.0	248.0	380.0	24.0	N.M	N.M
7	kamrej	138.0	25.5	10.0	57.0	305.0	176.0	35.0	36.0	1.8	0.6
8	asta	299.0	1.9	10.0	18.0	317.0	272.0	47.0	36.0	1.8	1.1
9	Kathor	168.0	1.6	20.0	63.0	415.0	112.0	116.0	36.0	N.M	N.M
10	Vav	271.0	2.5	10.0	24.0	427.0	112.0	144.0	36.0	N.M	N.M
11	vihan	234.0	2.1	20.0	48.0	366.0	168.0	158.0	36.0	N.M	N.M
12	Karcheliya	163.0	0.6	20.0	69.0	320.0	152.0	163.0	24.0	N.M	N.M
13	Anaval	27.0	0.5	20.0	15.0	134.0	32.0	168.1	12.0	1.1	0.8
14	kachhal	81.0	0.6	15.0	15.0	232.0	32.0	4.8	24.0	0.8	0.3
15	kasal	52.0	2.0	30.0	24.0	171.0	72.0	27.0	12.0	1.6	0.4

Table: 2 Chemical analysis in mg/l (post monsoon 2013)

Sr. no.	location	Na	K	Ca	Mg	HCO_3	Cl	SO_4	CO_3	NO_3	F
1	surat city	850.0	7.0	35.0	99.0	500.0	1240	192.0	0.0	0.6	1.0
2	kikvad	216.1	0.8	5.0	23.9	488.1	40.1	44.2	0.0	NM	NM
3	Madhi	211.0	4.0	20.0	48.0	451.0	176.0	91.0	0 .0	3.1	0.7
4	Mota	199.0	5.4	40.0	39.0	220.0	296.0	101.0	0.0	1.7	1.2
5	orgam	124.0	2.8	65.0	63.0	159.0	245.0	209.0	0.0	0.9	1.3
6	Sarbhon	128.0	3.5	25.0	36.0	244.0	120.0	122.0	0.0	5.2	1.4
7	kamrej	76.0	26.5	10.0	54.0	378.0	96.0	24.0	0.0	0.3	1.3
8	asta	277.0	2.5	10.0	12.0	366.0	208.0	46.0	24.0	0.3	1.1
9	Kathor	57.0	2.9	40.0	21.0	244.0	48.0	27.0	12.0	5.8	0.4
10	Vav	109.0	8.6	35.0	18.0	293.0	72.0	28.0	24.0	4.4	1.4
11	vihan	131.0	4.3	30.0	39.0	305.0	120.0	66.0	24.0	7.1	1.4
12	Karcheliya	81.0	0.6	10.0	78.0	305.0	136.0	44.0	24.0	3.8	1.4
13	Anaval	32.0	0.5	15.0	21.0	183.0	32.0	120	0.0	0.8	0.1
14	kachhal	106.0	1.0	25.0	36.0	378.0	96.0	0	0.0	0.5	1.2
15	kasal	19.0	0.5	25.0	24.0	183.0	40.0	24	0.0	0.7	0.0

Table: 3 Analysis of pH, EC, TDS, Hardness (pre-monsoon and post monsoon, 2013)

		pre-monsoon year 2013				post-monsoon year 2013			
Sr. no.	location	pH	EC (µmho/cm)	TDS (mg/l)	Hardness (mg/l)	pH	EC (µmho/cm)	TDS (mg/l)	Hardness (mg/l)
1	surat city	8.7	4320.0	2620.0	395.3	7.9	4720.0	494.8	2920.0
2	kikvad	8.7	2180.0	1395.2	99.0	9.4	1170.0	748.8	111.0
3	Madhi	8.5	2830.0	1920.0	457.5	8.0	1430.0	247.5	1000.0
4	Mota	8.5	5810.0	3620.0	568.6	8.1	1410.0	260.4	900.0
5	orgam	8.4	2000.0	1240.0	457.8	7.7	1400.0	421.9	870.0
6	Sarbhon	8.6	2020.0	1300.0	432.8	8.1	1000.0	210.6	680.0

Volume : 4 | Issue : 10 | October 2014 | ISSN - 2249-555X

7	kamrej	8.6	1200.0	780.0	259.5	8.0	900.0	247.2	640.0
8	asta	8.8	1510.0	1000.0	99.0	8.8	1370.0	74.4	950.0
9	Kathor	9.0	1360.0	930.0	309.2	8.4	640.0	186.2	450.0
10	Vav	9.1	1440.0	1030.0	123.7	8.4	830.0	161.5	590.0
11	vihan	8.9	1530.0	1030.0	247.5	8.3	1060.0	235.4	720.0
12	Karcheliya	8.5	1390.0	920.0	333.9	8.3	1060.0	345.9	680.0
13	Anaval	8.3	350.0	240.0	111.7	8.1	390.0	123.9	280.0
14	kachhal	8.6	560.0	400.0	99.2	7.8	890.0	210.6	640.0
15	kasal	8.5	580.0	390.0	173.7	7.8	410.0	161.2	290.0

of sodium content of the soil, affecting the soil permeability, and texture making the soil hard to plough and unsuitable for seeding emergence [5] [6]. If the percentage of Na with respect to Ca + Mg + Na is considerably above 50% in irrigation waters, soils containing calcium and magnesium take up sodium in exchange for calcium and magnesium causing deflocculation and impairment of the quality and permeability of soils [7]. The addition of gypsum or lime may correct the situation of the soil.

The total dissolved solids, measured in terms of specific electrical conductance gives the salinity hazard of irrigation water. The electrical conductivity is a measure of salinity hazard to crop as it reflects the TDS in the groundwater. Based on analytical results, irrigational quality parameters like sodium adsorption ratio (SAR), electrical conductivity (EC) were estimated to assess the suitability of groundwater for irrigation. The salt present in the water, besides affecting the growth of plants directly, also affects soil structure permeability and aeration, which indirectly affect the plant growth [8] [9] [10].

Sodium Adsorption Ratio (SAR) Criterion The interpretation of water quality suitable for the irrigation purposes are given by Richard (1954) [11] in the form of EC versus SAR values. Electrical

Conductivity (EC) has been treated as index of salinity hazards and sodium adsorption (SAR) as index of sodium hazards. SAR is calculated from the ionic concentration (in meq) of sodium, calcium and magnesium according to following relationship (Karnath. 1987) shown in equation (1)

$$SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}} \qquad (1)$$

The data has been plotted using US Salinity diagram into observe the suitability of water for irrigation purposes. The SAR value ranges from 0.4to 100.5 with an average value of 12.5 in the samples collected during pre-monsoon 2013. During post-monsoon of 2013, the SAR values range from 0.5 to 174.3 with an average value of 11.4. Therefore the possibility of sodium hazard may be high in this area. The US salinity diagram is widely used for rating widely for irrigation water, where SAR is plotted against EC. US salinity diagram plotted is shown in Fig. 2 & Table: 4 is derived from US salinity diagram which is shown the class of samples.

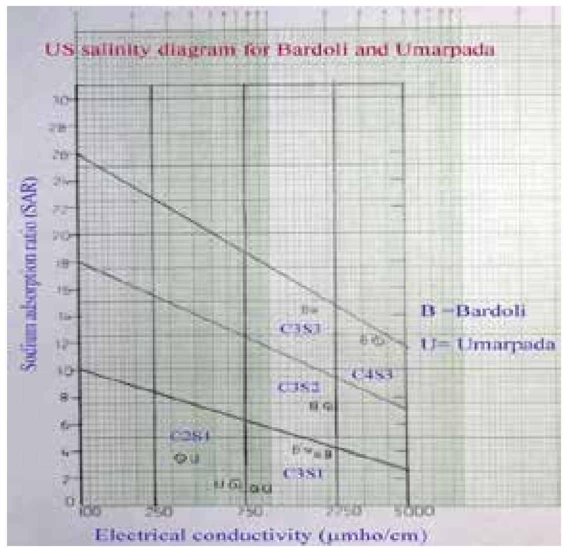

Fig: 2 salinity diagram of groundwater samples from the study area.

Table: 4 Classification of water samples based on US salinity diagram

Class	No. of Samples	Class	No. of Samples
C4-S4	8	C3-S2	6
C4-S3	3	C3-S1	14
C3-S3	4	C2-S1	10
C3-S4	2		

Wilcox (1948) used percentage sodium and electrical conductance in evaluating the suitability of groundwater for irrigation. The percentage sodium is computed with respect to the relative proportions of cations present in water, where the concentrations of ions are expressed in meq/l using the formula ahown in equation (2)

$$\%\,Na = \frac{(Na+K)}{(Ca+Mg+Na+K)} \qquad (2)$$

Excess Na^+, combining with carbonate, leads to formation of alkali soils, whereas with chloride, saline soils are formed. Neither soil will support plant growth (Rao, 2006). Generally, % Na^+ should not exceed 60 % in irrigation waters. The Wilcox diagram showing the position of the water samples is represented by Fig: 3.

Volume : 4 | Issue : 10 | October 2014 | ISSN - 2249-555X

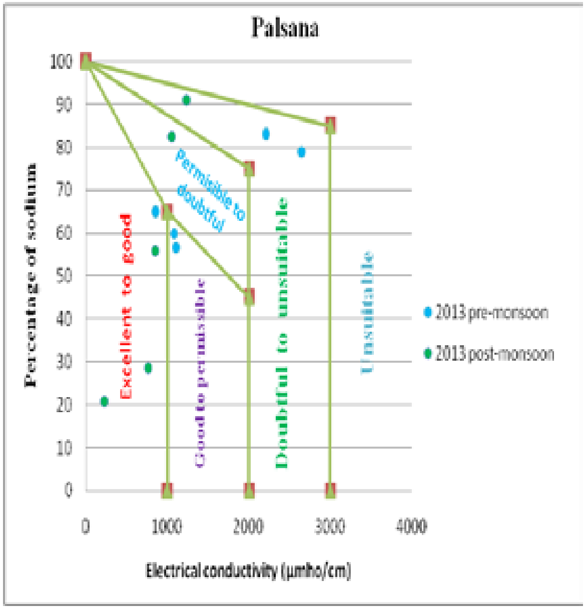

Fig: 3 Position of water samples on Wilcox plot

conclusion

Interpretation of hydro-chemical analysis reveals that the groundwater in study area is fresh, hard to very hard. The sequence of the abundance of the major ions is in the following order: Na > Mg > Ca > K and Cl > HCO_3 > SO_4. According to classification of water based on TDS, 95.7 % of samples are found in permissible limit and 34 % of samples are belonging desirable category and 4.3 % samples exceed the permissible limit. Irrigation water classified based on SAR has indicated that 66 % of samples belong to the excellent, 17 % samples good, remaining samples belong to doubtful category. The Wilcox diagram relating sodium percentage and total concentration shows that 51 % of groundwater samples fall in the field of excellent to good and 13 % of the groundwater samples fall in the field of good to permissible for irrigation. The analytical data plotted on the US salinity diagram illustrates that 29.8 % of groundwater samples fall in the field of C3-S1, indicating high salinity and low sodium water and 21 % of groundwater samples fall in the field of C2-S1, indicating medium salinity and low sodium water.

Remediation measures should be adopted to restore the already highly contaminated aquifers. In view of deteriorating quality of groundwater and degradation of soil cover, it is recommended.

1. To have a constant monitoring of the quality of groundwater in this area and necessary preventive measures have to be adopted to avoid further deterioration.
2. Industries should monitor their air emissions regularly and take measures to ensure compliance with the prescribed emission standards.
3. Industries should strictly follow applicable government regulations on pollution control.
4. Organic waste should be dumped in places far from residential areas.
5. New industrial wastewater collection and treatment facilities must be constructed and existing facilities modernized and upgraded.
6. Industrial wastewater facilities must be more effectively operated.
7. Discharges of industrial wastewater into municipal sewer systems must be pre-treated, especially with regard to hazardous substances.
8. Environmentally sound techniques should be universally applied. Hazardous substances should be properly stored, treated and disposed of.

Acknowledgment

The authors gratefully acknowledge to GWRDC department for providing us the vital information in carrying out this research work.

REFERENCE

[1] APHA: Standard methods for the examination of water and wastewater, 16th edition, (1992) APHA Washington, D.C. | [2] J Sirajuddin et al: archives of applied science research (2013), 5(3) : 21-26 | [3] Davies, S. n., Dewiest, R.J.M: Journal of Hydrogeology, (1966) Vol. 463, New York: Wiley. | [4] Todd. D. K.: Groundwater hydrology 2nd Edition, John Wiley & Sons, (1980) New York, 535p. | [5] Sujatha, D. and Reddy, R.: Environ. Geol., (2003) V.44, pp. 579-586. | [6] Triwedy, R.K. and GOEl, P.K.: Chemical and biological methods for water pollution studies. (1984) Environpubl., Karad, India. | [7] Karanth, K, R: Groundwater Assessment, Development and Management. TaTa Mcgraw Hill Publishing Compony Limited, New Delhi, (1987) pp. 576 - 638. | [8] Alam A,: Aquifer system and groundwater resources evaluation in parts of Hindon – Yamuna watershed in parts of western Uttar Pradesh, Ph. D Thesis (2010), Aligarh Muslim University, Aligar. | [9] Mohan, R. Singh, A. K., Tripathi, J. K. and Choudhary, G. C. Jour. Geol. Soc. India., (2000) V. , pp. 77 – 89 | [10] Umar R, Absar A : Environ Geol (2003) 44 : 535 – 544. | [11] Richard, L. A. : Diagnosis and improvement of saline alkali soils, US Department of Agriculture, (1954) Hand Book No. 60, 160p. |