Research Journal of Engineering Sciences ISSN 2278 – 9472
Vol. **2(11),** 1-5, November **(2013)** *Res. J. Engineering Sci.*

Evaluation of Groundwater Quality and its Suitability for an Agriculture use in, District Vadodara, Gujarat, India

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Available online at: www.isca.in, www.isca.me
Received 6th May 2013, revised 20th August 2013, accepted 8th November 2013

Abstract

In this study, ground water quality of Vaghodia taluka and Vadodara taluka of Vadodara District was studied based on different indices. Ten groundwater samples were investigated for TDS, Sodium Adsorption Ratio, Kelly's ratio and Soluble Sodium Percent (SSP) for irrigation suitability assessment. The analytical results shows higher concentration of total dissolved solids (20%), electrical conductivity (50%), chloride (10%), total hardness (30%) and magnesium (40%) for pre monsoon and total dissolved solids (30%), electrical conductivity (40%), chloride (0%), total hardness (30%) and magnesium (40%) for post monsoon which indicates degradation of water quality as per BIS Standards.On the other hand, 50% groundwater sample is unsuitable for irrigation purposes based on irrigation quality parameters.

Keywords: Groundwater pollution, irrigation water quality, SAR, KR, SSP.

Introduction

Huge quantities of groundwater, particularly from the shallow aquifers, are used for irrigation. The water quality management is essential for long-term irrigation system as it persuades the soil properties. In irrigation water evaluation, emphasis is given on chemical and physical characteristics of water. The toxicity or suitability of groundwater is determined by varying amounts and different ions. Irrigation water quality is generally judged by some determining factors such as Sodium absorption ratio (SAR), Soluble Sodium percentage (SSP), residual sodium carbonate (RSC), and electrical conductance (EC) [1, 2, 3].

Ground water quality assessment for drinking and irrigation has become a necessary and important task for present and future groundwater quality management and sustainability of groundwater. Unplanned growth of industrialization and urbanization leads to increase in addition of anthropogenic sources to ground water and soil. Hence the hydro geochemistry study is important. Ground water in the study area is utilized for both agricultural and drinking purposes.

Study Area: Vadodara is located at 22°18'N 73°11'E 22.30°N 73.19°E in western India at an elevation of 39 meters (123 feet). It has the area of 148.95 km² and a population of 4.1 million according to the 2010-11 censuses. The city sites on the banks of the River Vishwamitri, in central Gujarat. Vadodara is the third most populated city in the Indian State of Gujarat after Ahmedabad and Surat. The city has Nandesari Industrial Estate which is comprised of around 1,200 small and large- scale industries i.e. dye industries, engineering, textile, and Pharmaceutical and petroleum industries. Study Area: Taluka: 1) Vadodara, 2) Vaghodia

Geology and Hydrogeology: The study of geo hydrological condition is very important as far as the exploration and recharge of the ground water is concerned. The study needs special attention to the city like Vadodara which is highly complicated. Some of the areas are having good aquifers which are good for exploration and recharge, but some of the areas are having non productive saline aquifers which are not good for exploration as well as recharge[4]. Geohydrology is recent to sub recent alluvium formation (comprises of alluvium Sand, clay, silt, gravel etc.) with alternate clay, sand, silt gravel etc.

Material and Methods

The hydro geochemistry study was undertaken by randomly collected ten groundwater samples from dug wells. Samples from open well for confined aquifer of the study area during May (Pre Monsoon) and October (Post Monsoon) for year 2010 were drawn and analysed as per the Indian standards. The hydrological study was undertaken by groundwater samples for different parameters shown in the table-1and table- 2.

Water quality parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), CO_3, HCO_3, Calcium (Ca), Magnesium (Mg), Chloride (Cl), Sodium (Na) and Potassium (K), NO_3 and Fluoride were estimated by standard methods[5].

Results and Discussion

Ten groundwater samples were drawn from the wells and analyzed for physicochemical parameters. The results of the physicochemical analysis are presented in table-1 for pre monsoon and table-2 for post monsoon for the year 2010.The critical parameters exceeding the BIS permissible limits along with the permissible limits for these parameters are presented in table-6[6].

pH: pH is one of the important factors of ground water. Almost all samples were within maximum permissible limit prescribed by BIS for Vaghodia taluka and Vadodara Taluka (Table-1 and 2)[6].

Electrical Conductivity (EC): Conductivity is useful as a general measure of groundwater quality. Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Conductivity is also affected by geology and temperature, the warmer the water the higher the conductivity. For this reason, conductivity is reported as conductivity at 25 degrees Celsius (25 ^oC).

Electrical Conductivity in groundwater varies from 320 to 8940 µmohs /cm (Table-1 and 2) where as permissible limit is<1500 micromohs/cm for domestic use (table-3). The EC values in majority of samples are higher than permissible limit. As per the classification on conductivity values, 50% of the wells are below the safe limit of 1500 micromohs/cm while 20% of the wells are in the range of 1500-3000 micromohs/cm and 30% of the wells are above 3000 micromohs/cm range for pre monsoon and 60% of the wells are below the safe limit of 1500 micromohs/cm while 10% of the wells are in the range of 1500-3000 micromohs/cm and 30% of the wells are above 3000 micromohs/cm range for post monsoon of Vadodara Taluka[6].

Total Dissolved Solids (TDS): Total Dissolved Solids is an important parameter for assessing groundwater quality.TDS is usually affected mainly by topography, lithology of aquifer, recharge, runoff and discharge conditions of groundwater. The total dissolved solids in all the study area varies from 230 to 5090 mg/l (table-1 and 2). The large variation of TDS may be attributed to the lithological composition and anthropogenic activities like application of fertilizer is prevailing in this region. 20% samples for pre monsoon and 30% of post monsoon were within maximum permissible limit for Vaghodia taluka and Vadodara Taluka (table-6) by BIS[6].

Calcium (Ca): Cations are contributing in the water quality which is naturally present in the water. Temporary hardness is a type of water hardness caused by the presence of dissolved bicarbonate minerals (calcium bicarbonate and magnesium bicarbonate).When dissolved these minerals yield calcium and magnesium cations (Ca^{+2}, Mg^{+2}).The presence of the metal cations makes the water hard. Calcium content in the groundwater varies from 15 to 215 mg/l. Almost all samples were within maximum permissible limit for Vaghodia taluka and Vadodara Taluka (table-6) prescribed by the BIS[6].

Magnesium (Mg): Magnesium is washed from rocks and in a large quantity from minerals subsequently ends up in water. Magnesium has many different purposes and consequently may end up in water from many anthropogenic sources e.g. Chemical industries, fertilizer application and cattle feed. The value from Magnesium ranges from 12 to 411 mg/l (table-1 and 2).40% samples (pre monsoon) and 40% samples (post monsoon) of Vadodara taluka were crosses the maximum permissible limit prescribed by BIS[6].

Table-1
Physico-chemical parameters of dug well of Vadodara District (Pre Monsoon)

Well No	pH	EC	TH	TDS	HCO_3	Cl	Ca	Mg	Na	K	SAR	KR	SSP
		µS/cm	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**ppm**	**ppm**			
W-1	8.2	3640	927.93	2110	146	896	45	198	404	1.30	0.49	0.95	48.73
W-2	8.8	1680	111.45	1130	281	240	10	21	332	4.30	6.50	6.50	86.67
W-3	8.5	2360	581.56	1550	415	240	35	120	265	11.40	2.03	0.99	49.86
W-4	8.1	550	124.20	380	146	72	25	15	55	21.50	0.15	0.96	49.10
W-5	8.3	1390	148.64	940	293	184	15	27	248	1.20	5.45	3.64	78.45
W-6	8.4	1040	272.57	720	378	104	30	48	95	27.50	0.12	0.76	43.19
W-7	7.4	8940	2229.35	5090	329	2600	215	411	1016	4.50	4.11	0.99	49.85
W-8	8.7	1190	161.39	830	366	120	20	21	192	9.60	8.35	3.07	75.42
W-9	8.5	660	247.60	450	281	40	20	48	33	3.30	1.44	0.29	22.53
W-10	8.2	3320	816.28	2000	329	744	35	177	379	3.30	9.42	1.01	50.34
Min	**7.4**	**550**	**124.20**	**380**	**146**	**40**	**15**	**15**	**33**	**1.20**	**0.12**	**0.29**	**22.53**
Max	**8.7**	**8940**	**2229.35**	**5090**	**415**	**2600**	**215**	**411**	**1016**	**27.50**	**9.42**	**6.50**	**86.67**

Note: All parameters are expressed in milligrams per liter (mg/l) except pH (units). The electrical conductivity (EC) is expressed in micromohs/cm. (µS/cm) at 25^0C.

Table-2
Physico-chemical parameters of dug well of Vadodara district (Post Monsoon)

Well No	pH	EC	TH	TDS	HCO_3	Cl	Ca	Mg	Na	K	SAR	KR	SSP
		µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ppm	ppm			
W-1	7.7	3860	792.88	2340	366	944	85	141	518	2	3.93	1.42	58.76
W-2	8.3	730	99.23	510	220	80	15	15	117	6.00	2.93	2.57	71.99
W-3	8.3	2200	705.36	1450	512	224	45	144	173	9.50	1.32	0.54	34.87
W-4	7.8	990	346.31	760	305	72	15	75	49	29.20	0.19	0.31	23.60
W-5	8.4	1360	185.83	940	366	176	20	33	225	1.30	4.93	2.64	72.53
W-6	8.2	3300	644.77	2050	342	720	90	102	456	2.00	1.22	1.54	60.66
W-7	8.3	880	161.52	600	220	104	35	18	123	4.00	0.39	1.66	62.38
W-8	8.2	320	111.84	230	134	32	25	12	17	4.50	0.11	0.33	24.87
W-9	8.0	720	247.87	500	281	64	30	42	48	0.70	1.39	0.42	29.69
W-10	8.3	3320	593.65	2030	281	736	25	129	486	1.50	16.91	1.79	64.12
Min	**7.7**	**320**	**99.23**	**230**	**134**	**32**	**15**	**12**	**17**	**0.70**	**0.11**	**0.31**	**23.60**
Max	**8.4**	**3860**	**792.88**	**2340**	**512**	**944**	**90**	**144**	**518**	**29.20**	**16.91**	**2.64**	**72.53**

Table-3
Classification of groundwater from conductivity value

Conductivity range micromohs/cm	Classification	Percentage of Sample (Pre monsoon)	Percentage of Sample (Post monsoon)
<1500	Permissible	50	60
1500-3000	Not Permissible	20	10
>3000	Hazardous	30	30

Table-4
Irrigation water quality

Sr. No.	Parameter	BIS-Limit (1998)
1	pH	6.5-8.5
2	Chloride	1000
3	Electrical Conductivity(EC)	1500
4	TDS	2000
5	Total Hardness	600
6	Calcium	200
7	Magnesium	100
8	Sodium	200

Sodium (Na): Sodium generally comes from weathering of soil, leaching of salts dissolved from geologic marine sediments into the soil solution or groundwater, and flushing of salts off of roads, landscapes and stream banks during and following precipitation events. It also serves from many anthropogenic sources like industries. The Sodium content in the study area has shown variations from 17 to 1016 mg/l (table-1 and 2). 60% samples (pre monsoon) and 40% samples (post monsoon) of Vaghodia and Vadodara taluka were higher value prescribed by BIS[6]. (table-6)

Irrigation water quality: Groundwater is the main source of irrigation in entire study area.The most critical factor in predicting, managing, and reducing salt-affected soils is the quality of irrigation water being used. Besides affecting crop yield and soil physical conditions, irrigation water quality can affect fertility needs, irrigation system performance and longevity, and how the water can be applied. The quality of irrigation water depends primarily on the presence of dissolved salts and their concentrations. Sodium Absorption Ratio (SAR), Kelly's Ratio (KR) and Residual Sodium Carbonate (RSC) are the most important quality criteria, which influence the water quality and its suitability for irrigation[7, 8, 9, 10, 11].

Sodium Adsorption Ratio (SAR): The Sodium adsorption ratio (SAR) is commonly used as an index for evaluating the sodium hazard associated with an irrigation water supply. The formula derived by Suarez is generally recognized as the most applicable technique for determining the adjusted SAR hazard index.

The SAR is defined as the square root of the ratio of the Sodium (Na) to Calcium + Magnesium (Ca + Mg), i.e.:

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

All cation measurements are expressed in millimoles/ liter (mmol/l).

Alternatively, if the cation measurements are expressed in milliequivalents/ liter (meq/l), then the SAR is defined to be:

$$SAR = \frac{Na^{+}}{\sqrt{Ca^{+2}+Mg^{+2}/2}} \quad (2)$$

Irrigation water having high SAR levels can lead to the build-up of high soil Na levels over time, which in turn can adversely affect soil infiltration and percolation rates(Due to soil dispersion).

Additionally, excessive SAR levels can lead to soil crusting, poor seedling emergence, and poor aeration.

Measurements of the Electrical conductivity (EC, dS/m) and Total dissolved solids (TDS, mg/L) also represent commonly used indexes for evaluating the salinity hazard of the irrigation water. Generally, the potential for water infiltration and soil dispersion problems can only be adequately addressed when the salinity and SAR indexes are considered together. Increasing EC levels tend to mitigate negative sodium effects, but can simultaneously induce crop stress (by degrading the quality of the available water for the crop via salinization). Hence, to properly assess the suitability of a particular irrigation water supply, the apparent salt tolerance of the specific crop must also be taken into consideration.

SAR is the estimation of the degree to which Sodium will be absorbed by the soil. High value of SAR means Sodium enhance the dispersion of colloids or clays when it comes in contact with the soil and may replace Calcium and Magnesium ions in the soil resulting in damage to the soil structure and reduction in its capacity to conduct water and air. 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[12, 13].

When waters having appreciable concentrations of Calcium (Ca^{+2}) and bicarbonates (HCO^{-}_3) are employed for irrigation, a variable fraction of this constituent will precipitate in the soil as $CaCO^{-}_3$ according to the equation:

$$Ca^{+2} + 2HCO^{-}_3 \longrightarrow CaCO_3 + H_2O + CO_2$$

KR: The Kelly's Ratio was calculated using the equation (Kelly's 1963) as:

Sodium measured against Ca^{+2} and Mg^{+2} is used to calculate Kelley's ratio. The formula used in the estimation of Kelley's ratio is expressed as,

$$KR = \frac{Na^{+}}{Ca^{+2} + Mg^{+2}}$$

Where, all the ionic concentrations are expressed in meq/L.

Table-5
Classification of groundwater on the basis of SAR

Parameter	Range	Water Class
SAR	<10	Excellent
	10-18	Good
	18-26	Doubtful
	>26	Unsuitable

A Kelley's Ratio (KR) of more than one indicates an excess level of Sodium in waters. For pre monsoon 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-7).While for post monsoon 40% 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 60% is more than 1 indicates the unsuitable water quality for irrigation (table-7).

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

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

Where, the concentrations of $Ca^{+2,}$ Mg^{+2} and Na^{+} are expressed in milliequivalents per liter (epm).

Table-6
Critical parameters exciding the permissible reading

Parameters	BIS Standards (1998)	No. of sample exceed permissible limit	Percentage of sample exceeding permissible limit	No. of sample exceed permissible limit	Percentage of sample exceeding permissible limit
		Pre Monsoon		**Post Monsoon**	
pH	6.5-8.5	-	-	-	-
Chloride	1000	1	10	-	-
EC	1500	5	50	4	40
Total Dissolved Solids	2000	2	20	3	30
Total Hardness	600	3	30	3	30
Ca	200	-	-	-	-
Mg	100	4	40	4	40
Na	200	6	60	4	40

Table-7
Limits of some parameter indices for rating groundwater quality and its sustainability in irrigation

Parameter	Range	Water Class	% of sample exceed permissible limit of Pre Monsoon	% of sample exceed permissible limit of Post Monsoon
SAR	<10	Excellent	100	90
	10-18	Good	-	10
	18-26	Doubtful	-	-
	>26	Unsuitable	-	-
KR	<1	Good	60	40
	>1	Unsuitable	40	60
SSP	<50	Good	50	40
	>50	Bad	50	60

The value of Soluble Sodium Percent (SSP) ranges from 22.53 to 86.67. (table-1) For pre monsoon 50% 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 50% is more than 50 indicate the unsuitable water quality for irrigation (table-7). For post monsoon 40% 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 60% is more than 50 indicate the unsuitable water quality for irrigation (table-7).

Conclusion

The study of Physico-chemical parameters has been conducted to evaluate factors regulating ground water quality in an area with agriculture as a main use of Vadodara district. Based on TDS 20% samples for premonsoon and 30% post monsoon, according to values of KP 40% for premonsoon and 60% for post monsoon and as per SSP indices 50% for pre monsoon and 60% sample for post monsoon shows higher values as per BIS standards. As per SAR all samples for pre monsoon and 90% samples for post monsoon falls under the category of Excellent.

The higher values of conductivity and Chloride in some samples for pre monsoon shows that application of fertilizer for agricultural contributing the higher concentration of ions in aquifer of Vadodara.

Acknowledgement

Authors are thankful to the Gujarat water resource development centre for their support for acquiring data of the study area.

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