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Original Research Paper

Assessment of Groundwater Quality for Drinking and Irrigation Purposes in Banasthali Village, District Tonk, Rajasthan

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ABSTRACT

A study on variation in groundwater quality in Banasthali village of District Tonk in Rajasthan was conducted. Sampling in pre monsoon of 2011 and 2012 at 10 selected locations from running tube wells and hand pumps was carried out and the samples were analysed for their physico-chemical characteristics. Analysis results were compared with BIS, WHO and ICMR standards of drinking water quality parameters like EC, pH, TDS, Na^+, K^+, Ca^{+2}, Mg^{+2}, Cl^-, SO_4^{-2}, total alkalinity, NO_3^- and F^-. The usefulness of these parameters in predicting groundwater quality characteristics has been discussed and it was found that the area under study was badly affected by salinity as well as hardness and fluoride contents. Higher values of RSC and SAR make the groundwater unfit for irrigation purposes. In this study, some important physico-chemical parameters of groundwater of the area were evaluated for the criteria of drinking and irrigation water quality.

INTRODUCTION

Groundwater quality deterioration has become a major problem in Rajasthan. Due to tremendous increase in the demand for freshwater for rapid urbanization, growing population and speedy industrialization have lead to the pressure on demand for water. Groundwater is used for domestic, industrial and irrigational purposes all over the world. Water is a universal solvent and it dissolves the minerals from rocks in which it is stored and then chemical and physical attributes of groundwater depend on geology of particular area. Rapid urbanization especially in developing countries like India has affected the availability and quality of groundwater. The quality of groundwater may also vary with depth of water table, seasonal changes and composition of dissolved salts depending upon sources of the salt and sub surface environment.

Intensively irrigated agricultural fields discharges into the groundwater bring about considerable change in the groundwater quality. The socioeconomic growth of a region is severely affected by unavailability of safe drinking water.

Assessment of groundwater quality and its suitability for drinking and irrigation is the objective of the present study by comparing the results against drinking water quality standards laid down by Bureau of Indian Standards (IS: 10500, BIS 1991), World Health Organization (WHO 1984) and Indian Council of Medical Research (ICMR 1975) depicted in Table 1.

STUDY AREA

Banasthali, the area under study having longitude 75°91’84” E and latitude 26°35’93” is a village situated in Newai block of District Tonk, Rajasthan. It is 6.1 km from Newai town, 25.6 km from Tonk city and 58 km from the State capital city Jaipur. Banasthali Vidyapeeth University, a centre of learning for girls from nursery to post-graduate level, is well known and famous education centre located in village Banasthali. Most of the people in this area depend upon agricultural activity and therefore water quality as well as quantity is playing an important role in their social life. The groundwater in this area is very much affected from salinity, hardness and fluoride. Occurrence of fluoride in drinking water above the permissible limits leads to fluorosis in human being and animals. It was also found that the fluorosis is now become an aesthetic and social problem of the area. Children and adults of the area are facing the problem of mottling and discoloration of teeth.

MATERIALS AND METHODS

Ten water samples in two years (i.e. pre monsoon of 2011 and 2012) were collected in polyethylene bottles from running tube wells and hand pumps, which were used by local community in their daily needs. Utmost care was taken during the collection of samples to avoid any kind of contamination. Volumetric and instrumental techniques were adopted for analysis of the water samples using standard procedures (APHA 1995). The analysis was carried out immediately for pH, EC and for all other parameters in minimum time.

RESULTS AND DISCUSSION

The chemical parameters in the groundwater samples were

Table 1: Groundwater quality standards for drinking purposes.

S. No.	Parameter	Units	ISI: 1991	ICMR: 1975	WHO: 2006
1	EC	µS/cm at 25^{0}C	NG	500	600
2	pH	-	6.50-8.50	7.0-8.50	6.50-8.50
3	TDS	mg/L	500	500	500
4	Na^+	mg/L	NG	NG	200
5	K^+	mg/L	NG	NG	NG
6	Ca^{+2}	mg/L	75	75	75
7	Mg^{+2}	mg/L	30	50	30
8	Cl^-	mg/L	250	200	200
9	SO_4^{-2}	mg/L	200	200	200
10	HCO_3^-	mg/L	NG	NG	NG
11	NO_3^-	mg/L	45	20	50
12	F^-	mg/L	1.00	1.00	1.50
13	TH as $CaCO_3$	mg/L	300	300	200

NG - No Guideline

analysed and the results are depicted in Table 2.

Electrical conductivity, total dissolved solids (TDS) and pH: The electrical conductivity of the water samples in the area was from 1380 to 4500 µS/cm in pre monsoon 2011 with an average value of 2234 µS/cm, while in pre monsoon of 2012 it was minimum 1450 µS/cm and maximum 4620 µS/cm with an average value of 2488 µS/cm at 25°C. It reveals that the ionic conductance of the water has increased by 10.21%. The same trend of variation was found with respect to TDS of the area (Fig. 1) and the distribution in different ranges is depicted in Fig. 2. It was observed that the TDS of most of the groundwaters ranges from 500-2000 mg/L.

pH values varied from 7.40 to 8.60 and the variations are insignificant and fall within the permissible limits as per BIS specification (Fig. 3).

Alkalinity and fluoride: The problem of high fluoride in groundwater resources has now become one of the most important toxicological and geo-environmental issues in India (Wavde & Shaikh 2008). Geologically, the fluoride-affected areas are occupied by the alluvium of the recent to sub-recent age underlain by hard rock formations of Precambrian age (Sinha & Musturia 2004). During the last three decades the high fluoride concentration in water and the resultant disease fluorosis is being highlighted considerably throughout the world. Extensive studies have been carried out by various workers in other parts of the country. Chandra & Prasad (2008) carried out a study of groundwater quality variation during a year in Singhana town in District Jhunjhunu of Rajasthan. To avoid health problems, high-fluoride water should not be used for household purposes. In arid or semiarid areas, however, alternative, low-fluoride water sources may not be available and de-fluoridation is needed to render the water potable (WHO 1984).

Lower pH values diminish CO_3^{-2} alkalinity, while HCO_3^- contents were found in higher side indicating the presence of most vulnerable and toxic contaminant fluoride. Fluoride concentration was obtained from 1.00 to 4.95 mg/L with an average of 2.70mg/L in pre monsoon 2011 and 1.20 to 5.72 mg/L in pre monsoon 2012 with an average value of 3.31 mg/L (Fig. 4). Fluoride content of 1.0mg/L in drinking water has no biological side effect (Prajapati & Raol 2008). It is observed that the average concentration of fluoride in the area exceeds the permissible limit 1.0 mg/L as per BIS specification. An increasing average annual variation in fluoride concentration was observed to be 18.43% indicating increasing fluoride toxicity in the study area. During the study, it was observed that the fluoride concentration in groundwater was increasing (Fig. 5). The geological formation of the area is 'older alluvium' with an average depth of 5-10 meters, and in lower 'schist' formation enrich the aquifer with fluoride bearing rocks. High fluoride concentration in groundwater is common in areas where rocks contain fluoride bearing minerals (Handa 1975). In areas where water is hard due to calcium and magnesium, the prevalence of skeleton fluorosis is much less. In Rajasthan, low community fluorosis index was reported from fluorotic belt where calcium intake of people was found to be high (Singh et al. 2011). A direct relationship exists between alkalinity and fluorosis. It is evident that relatively high alkalinity has played an important role in the enrichment of fluoride in groundwaters of the study area. Most of the waters having fluoride more than 2.0 mg/L have lower hardness and higher alkalinity.

Nitrate: Nitrate contamination of groundwater is common problem throughout world. The problem is prevalent in many parts of the country also. In urban areas, it exceeds the relaxable limits. The primary health risks associated with elevated nitrate are methaemoglobinaemia, which causes the 'blue

Table: 2. Physico-chemical characteristics of the groundwater of village Banasthali, District Tonk, Rajasthan (Units in mg/L except pH or as stated).

S. No.	Location	EC μS/cm at 25°C	pH	TDS	Na^+	K^+	Ca^{+2}	Mg^{+2}	Cl^-	SO_4^{-2}	CO_3^{-2}	HCO_3^-	NO_3^-	F^-	TH	Na%	RSC meq/L	SAR meq/L	Source
									Pre monsoon 2011										
1	S1	2100	7.80	1282	405	1	22	44	248	29	0	1037	15	3.10	235	78.85	12.30	11.48	H/P
2	S2	1760	7.90	1038	345	1	14	28	92	19	0	1013	32	3.85	150	83.19	13.60	12.25	H/P
3	S3	2300	7.90	1431	405	1	20	62	206	48	0	1098	140	4.95	305	74.17	11.90	10.08	H/P
4	S4	4500	7.60	2580	851	2	26	120	822	48	0	1367	27	1.00	560	76.68	11.20	15.64	H/P
5	S5	2300	7.85	1340	451	2	12	45	333	19	0	891	32	1.45	215	81.84	10.30	13.37	H/P
6	S6	2400	7.75	1419	480	3	18	46	383	29	0	854	32	1.40	235	81.39	9.30	13.63	H/P
7	S7	2080	7.90	1165	416	1	12	36	213	24	0	915	5	4.65	180	83.29	11.40	13.49	H/P
8	S8	1820	8.60	1024	345	1	8	40	255	48	48	500	29	2.15	185	80.13	6.10	11.03	H/P
9	S9	1700	8.40	961	280	4	22	54	248	48	24	513	25	1.10	275	68.54	3.70	7.36	T/W
10	S10	1380	8.50	769	234	2	14	43	156	58	48	415	7	3.30	210	70.64	4.20	7.04	T/W
									Pre monsoon-2012										
1	S1	2230	7.70	1293	416	1	32	41	284	29	0	940	20	3.90	250	78.25	10.40	11.45	H/P
2	S2	1800	8.55	1067	384	2	16	21	99	24	24	915	39	5.48	125	86.75	13.30	14.94	H/P
3	S3	2380	7.70	1431	425	2	32	61	220	29	0	1025	150	5.60	330	73.59	10.20	10.18	H/P
4	S4	4620	7.85	2710	885	2	40	100	872	67	0	1391	48	1.20	510	78.96	12.60	17.05	H/P
5	S5	2660	7.70	1473	510	4	38	43	291	29	0	1025	46	1.52	270	80.14	11.40	13.51	H/P
6	S6	3680	7.50	2092	584	3	86	86	766	77	0	891	44	1.40	570	68.87	3.20	10.64	H/P
7	S7	2260	7.40	1296	464	1	20	32	220	29	0	1001	30	5.72	180	84.77	12.80	15.06	H/P
8	S8	1980	8.50	1143	384	2	16	39	305	77	36	488	40	2.60	200	80.52	5.20	11.81	H/P
9	S9	1820	8.15	1013	299	4	30	51	269	48	0	561	31	1.50	285	69.11	3.50	7.70	T/W
10	S10	1450	8.40	829	251	2	24	36	177	58	48	439	14	4.20	210	71.95	4.60	7.52	T/W

H/P = Hand Pump; T/W = Tube Well

baby' syndrome in infants and the potential formation of carcinogenic nitrosamines. Nitrogen is first fixed from the atmosphere and then mineralized by soil bacteria to ammonia. Under aerobic conditions nitrogen is finally converted in to NO_3^- by nitrifying bacteria (Mirza et al. 2009). In children, the higher pH of their upper respiratory tract accelerates the conversion of NO_3^- to NO_2^-. The NO_2^- in turn oxidizes the infants haemoglobin to methaemoglobin, which is unable to carry oxygen in the blood stream. Removal of nitrates from drinking water is an important and developing area of research (Archana et al. 2012).

The maximum contaminant limit for nitrate in drinking water is 45mg/L set by Indian Bureau of Standards. A similar guideline of 50mg/L as NO_3^- has been set by the WHO. In the study area, the groundwater is almost free from NO_3^- contamination and only one location has crossed the limit resulting nitrate of 140mg/L in pre monsoon 2011 and 150 mg/L in pre monsoon 2012. This is due to pollution by domestic wastewater or waste seepage in local area (Fig. 6). The distribution of nitrate in different ranges, i.e. permissible limit, maximum relaxable limit and above are depicted in Fig. 7.

Chloride and sulphate: People who are not accustomed to high chloride in water are subjected to laxative effect. Its concentration is high in groundwater where the temperature is high with less rainfall (Loganayagi et al. 2008). It is harmless up to 1000mg/L but produce a salty taste above 250 mg/L.

The chloride concentration of the area varied from 92 to 822mg/L in pre monsoon 2011 with an average value of 296mg/L crossing the permissible range of 200mg/L as per BIS limits. In pre monsoon 2012, it was observed from 99 to 872mg/L with an average value of 350mg/L. Therefore, it is interpreted that the groundwaters of the area are saline in nature and the salinity has increased by 15.43% in a year. The annual variation in chloride in groundwater is presented in Fig. 8 and distribution in different ranges are depicted in Fig. 9. Sulphate was found in permissible limits of 200mg/L set by BIS.

Total hardness: It is defined as the sum of the concentrations of calcium and magnesium ions expressed as mg/L of $CaCO_3$. As per BIS standards, the groundwater having up to 250mg/L of total harness is essential which relaxes up to maximum of 600mg/L. The average total hardness in the area under investigation was found to be 255mg/L, with minimum of 150mg/L and maximum of 560mg/L in pre monsoon 2011. In pre monsoon 2012, it ranged from 125 to 570mg/L with an average value of 293mg/L. The groundwater is slightly contaminated due hardness and it can be used for domestic purposes after taking suitable measures. The

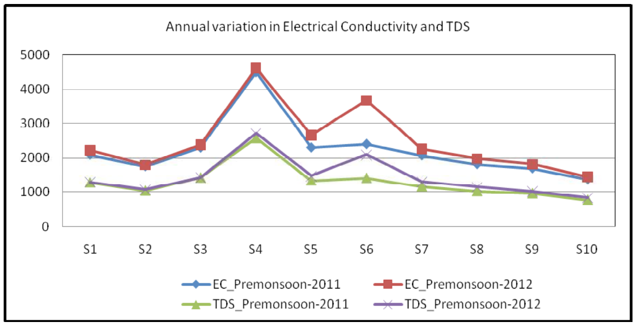

Fig. 1: Annual variation in electrical conductivity and TDS.

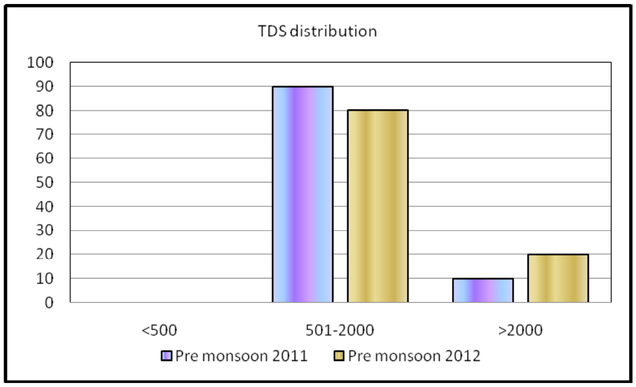

Fig. 2: TDS distribution in different ranges.

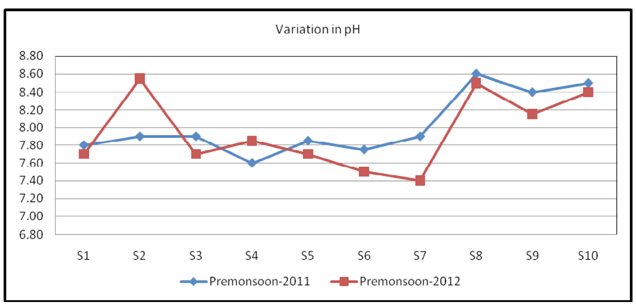

Fig. 3: Annual variation in pH.

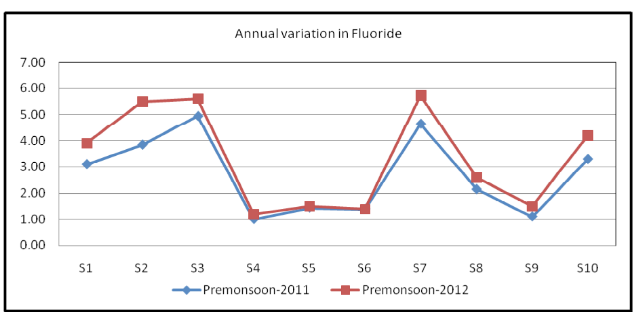

Fig. 4: Annual variation in fluoride.

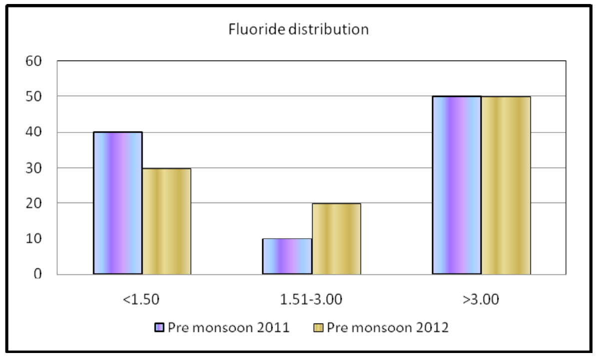

Fig. 5: Fluoride distribution in different ranges.

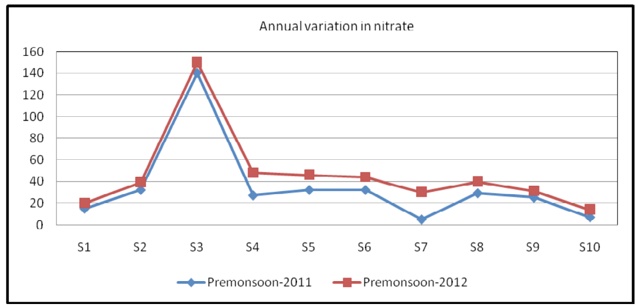

Fig. 6: Annual variation in nitrate.

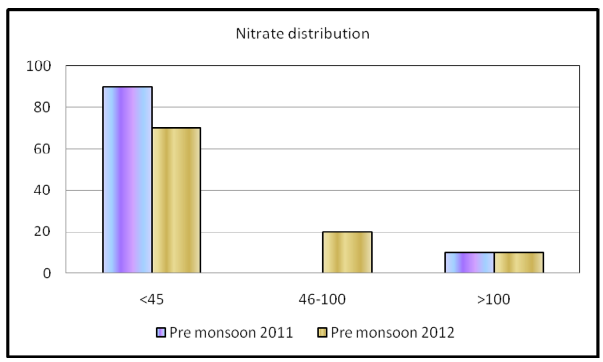

Fig. 7: Nitrate distribution in different ranges.

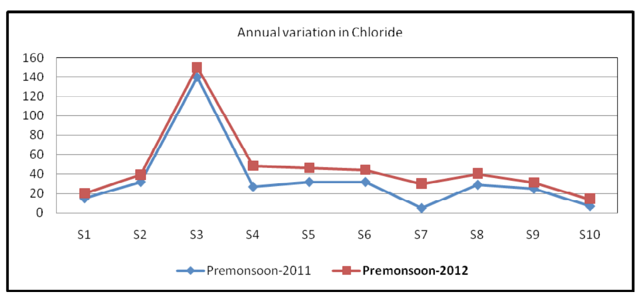

Fig. 8: Annual variation in chloride.

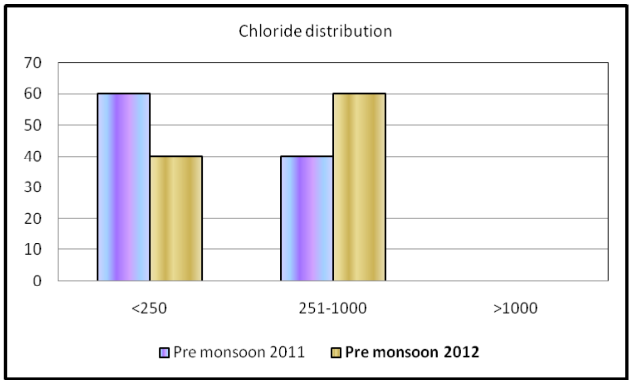

Fig. 9: Chloride distribution in different ranges.

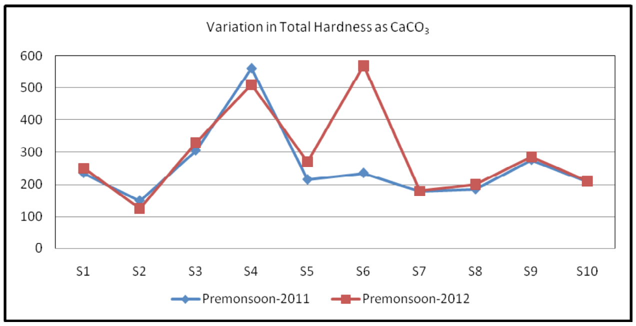

Fig. 10: Annual variation in total hardness (as $CaCO_3$).

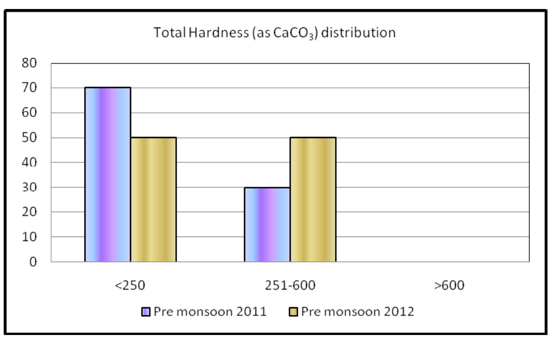

Fig. 11: TH distributions in different ranges.

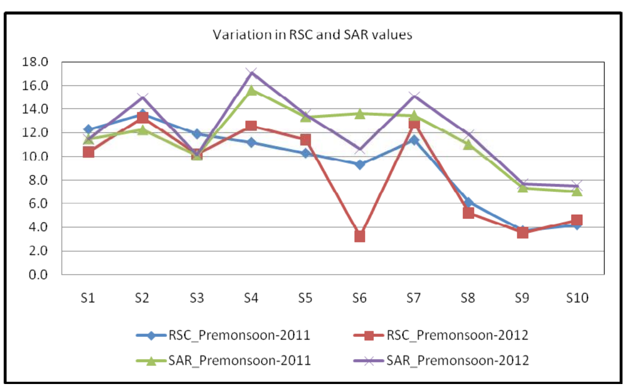

Fig. 12. Annual variation in RSC and SAR values.

annual variations are shown in Fig. 10 and distribution in different ranges is depicted in Fig. 11.

Irrigation water quality: The most damaging effect of poor-quality irrigation water is excessive accumulation of soluble salts and/or sodium in soil. Highly soluble salts in the soil make soil moisture more difficult for plants to be absorbed, and crops become water stressed even when the soil is moist. When excessive sodium accumulates in soils, it causes clay and humus particles to float into and plug up large soil pores. This plugging action reduces water movement into and through the soil, thus crop roots do not get enough water even though water may be standing on the soil surface.

When total carbonate levels exceed the total amount of calcium and magnesium, the water quality may be diminished. When the excess carbonate (residual) concentration becomes too high, the carbonates combine with calcium and magnesium to form a solid material, called scale, which settles out of the water. The end result is an increase in both the sodium percentage and SAR. The poor irrigation water can be managed by increasing salt tolerance of plants and improving irrigation management technologies (Nishanthiny et al. 2010).

Residual sodium carbonate (RSC): The residual sodium carbonate (RSC) is expressed in units of equivalents per million (epm). Residual carbonate levels less than 1.25 epm are considered safe. Waters with RSC of 1.25-2.50 epm are within the marginal range. These waters should be used with good irrigation management techniques and soil salinity monitored by laboratory analysis. Risk is lowest with waters for which the RSC is at the low end of the range and which are being applied to permeable, well-drained, coarse-textured soils in high rainfall areas. RSC values of 2.50 epm or greater are considered too high making the water unsuitable for irrigation use. In the study area RSC ranged from 3.70 to 15.64 epm (meq/L) with an average value of 9.40 meq/L (Fig. 12). Modification of RSC by soil applied gypsum may permit use of waters with RSC values above the safe level. RSC values were obtained from calculation, and it defines the suitability of the groundwater for irrigation as follows:

$$RSC = (Ca^{+2}+Mg^{+2}) - (CO_3^{-} + HCO_3^{-}) \text{ in meq/L}$$

Sodium Adsorption Ratio (SAR): Sodium adsorption ratio (SAR) is a measure of the suitability of water for use in agricultural purposes, as determined by the concentrations of solids dissolved in the water. It is also a measure of the sodicity of soil, as determined from analysis of water extracted from the soil. The formula for calculating sodium adsorption ratio is:

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

Where sodium, calcium and magnesium are in milli equivalent/litre.

Although SAR is only one factor in determining the suitability of water for irrigation but higher the SAR, the less suitable the water is for irrigation. Irrigation using water with high SAR may require soil amendments to prevent long term damage to the soil.

Irrigation water which has a high sodium hazard (SAR or RSC) may be used if the soil contains gypsum or if gypsum can be added to the soil. The amounts of gypsum required will depend on the excess sodium or residual carbonate in the water and how much water is applied.

Water that has an SAR below 3.0 is safe for irrigating turf and other ornamental landscape plants. Water that has an SAR greater than 9.0 can cause severe permeability problems when applied to fine textured soils (a silty clay loam) and should be avoided. Proper agricultural management practices need to be introduced avoiding over-irrigation by farmers (Savci & Belliturk 2013).

CONCLUSION

It was observed that the overall water quality of the study area is getting deteriorated. The cause of water quality variation may be attributed to the rainfall, drawdown of water and geological formations/structures of the area.

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