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A Study on Groundwater Qualities for Drinking and Irrigation Uses in the Dhanera Taluka of Banaskantha District of Gujarat

Abstract

This paper deals with a study about groundwater quality considering its usage for drinking and irrigation in the area of Dhanera taluka of Gujarat state of India. This study also includes statistical analysis. Groundwater, often a taken for granted reserve, is getting a lot of consideration these days. Like other countries, there is alarming situation in India about the quantity and quality of groundwater. For the present study, different samples of groundwater were collected from the various locations of Dhanera taluka of Gujarat state of India and their physicochemical parameters like temperature, colour, odour, turbidity, electrical conductance (E.C.), pH, total dissolved solids (TDS), total alkalinity and concentrations of ions like fluoride, chloride, sulfate, nitrate, calcium, magnesium sodium and potassium were assessed. The results were compared with the drinking water guidelines of Indian Council of Medical Research (ICMR) and European Union (EU). Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP) and Residual Sodium Carbonate (RSC) were found and along with E.C., they were used to determine irrigation quality. For the statistical analysis was performed by calculating values of mean, standard deviation and correlation co-efficient (r) and the strength of relation between physicochemical parameters is indicated.

Key words: Groundwater, physicochemical parameters, correlation co-efficient, drinking, irrigation, ICMR, EU, SAR, SSP, RSC, people.

Introduction

Groundwater quality is dependent on inland surface water, recharged water, atmospheric precipitation and subsurface geochemical changes. Human activities may change groundwater quality. The quality is becoming worse very quickly due to the issue of population. In today's world, the demand of water is swiftly increasing due to substantial increase in population, industrialization and urbanization.

Today, a big part of the population does not have clean water to drink. Man has yet to perfect his management about the liquid asset like groundwater.

In rural arid and semi arid regions, where well managed water transportation system and related infrastructures are not available, groundwater serves as chief source of drinking water. Groundwater is an excellent reservoir of water but as rivers, lakes and streams are influenced by natural and human factors, groundwater is also facing the same situation around the world. Groundwater pumping increases rapidly with increase in population. Over pumping of groundwater threatens the groundwater sustainability. Similar to other countries, issue of groundwater has become an issue of importance for the progress of India. Many researchers have explored the ground water quality in different parts of India[1-15] and world[16-29].

If the groundwater used for drinking and other domestic activities is contaminated, it creates intimidation to the health of the people. If the ground water is not suitable as to be used in irrigation, it affects farming. Hence, periodical evaluation of water quality requires serious attention. Water quality assessment is pre-requisite to the water quality management. To protect and manage quality and quantity of groundwater is essential for the healthy progress of any nation.

Study area and Experimental

Fig. – 1 Location of Gujarat state (shown as dark part) in India

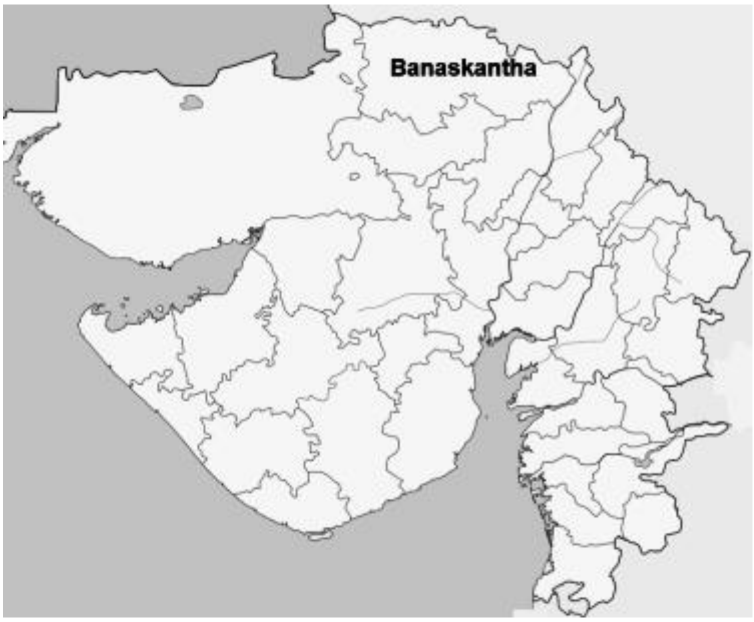

Fig. – 2 Location of Banaskantha district in Gujarat state

Fig. - 3 Talukas of Banaskantha district including Dhanera Taluka

The present study is related to the groundwater quality of some places of the Dhanera Taluka which is situated in Banaskantha district of Gujarat state of India(Fig.1, 2 and 3). Banaskantha district includes the area around the Bank of Banas river. The district lies on the north-west side of Gujarat State. There are twelve talukas in the district and Dhanera taluka is one of them. Dhanera Taluka is situated in Banaskantha district(23.33^o to 24.25^o north latitude and 71.03^o to 73.02^o east longitude) of Gujarat state of India. This taluka is situated at 24^o north latitude and 72.5^{o}east longitude. Sipu and Luni which remain almost dry in all seasons except in good monsoon are only two rivers of this taluka. Dhanera is the only city of the taluka and remainining is a rural area. Weather of this taluka is dry and hot. In winter, temperature goes down to 5 to 10^0 C, while in summer, temperature raises up to 45^{o}C. In this taluka, agriculture and dairy production are the key monetary activities. Wheat, Bajara and Juwar are general crops of the taluka. From this taluka, groundwater samples of bore/tube wells were collected in clean plastic containers during November-December, 2012. The samples were collected from the different places like: (a) Alwada, (b) Dedha, (c) Rajoda, (d) Kunwarala, (e) Bhatram, (f) Vasan, (g) Bapla, (h) Pengiya (i) Valer. These samples were collected, preserved and analyzed for physicochemical characteristics such as temperature, colour, odour, turbidity, electrical conductivity, pH, total dissolved solids, total alkalinity and concentrations of ions like chloride, fluoride, calcium, magnesium, nitrate, sodium, potassium and sulfate by the standard procedures described in the literature [30-38].

Results and Discussion

Values of different physicochemical characteristics of water samples are shown in **Table-1**.

Quality of these water samples is compared with the drinking water standards of Indian Council of Medical Research (ICMR) and guideline suggested by the European Union(EU:1998). Drinking water guideline of ICMR and EU(1998) are shown in **Table-2**.

Temperatures of these samples were in the range of 25.0^{o}C to 26.4^{o}C.

It was noted by direct observation that all the water samples were found colourless and clear. Odour is recognized as a quality factor affecting acceptability of drinking water and food prepared from it. Organic and inorganic substances add taste and odour.

Direct inspection of the samples for odour was done and found that samples were odourless. Turbidity is an important physical property of water. Turbidity indicates dimness of water. Turbidity in water is due to the presence of particulate matter such as slit, finely divided matter and microscopic organisms. The colloidal material exerts turbidity which generates adsorption sites for chemicals that may create disagreeable taste and smell. High value of turbidity indicates presence of many suspended particles in water. Consumer acceptance of such water decreases. Clear water contains low turbidity level while grubby water contains high turbidity level. For all the water samples, turbidity was in the range of 1.65 to

2.35 NTU(Nephelometric Turbidity Unit) having standard deviation of 0.24. It indicates that suspended and colloidal matters are present in very negligible amount in the samples of water.

Table-1: Values of physicochemical parameters

Parameter	a	b	c	d	e	f	g	h	i	Mean	S.D.
Temp^{0}C	25.4	26.1	25.5	25.4	25.0	26.2	25.8	26.4	26.3	25.79	0.49
Colour	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	-	-
Odour	Ol	Ol	Ol	Ol	Ol	Ol	Ol	Ol	Ol	-	-
Tur. (NTU)	2.10	2.00	2.35	1.80	1.65	1.95	2.15	2.20	1.70	1.99	0.24
TDS (mg/l)	1100	744	1385	1470	1301	850	730	1500	696	1086.22	336.56
pH	7.49	7.31	6.17	7.16	9.92	7.42	6.25	6.94	8.01	7.07	0.59
E.C. (μs cm^{-1})	1650	1113	2214	2330	2023	1280	1100	2114	924	1638.89	546.60
T. A. (mg/l)	234	149	102	193	281	227	368	230	301	231.67	79.85
F^{1-} (mg/l)	1.19	0.55	1.93	1.42	0.70	1.10	1.30	1.05	0.40	0.96	0.34
Cl^{1-} (mg/l)	245	139	284	263	196	164	229	210	300	225.56	53.79
SO_4^{2-} (mg/l)	19.02	7.88	10.03	9.35	8.21	24.6	20.37	15.64	8.14	13.69	6.35
NO_3^{1-} (mg/l)	26.68	15.52	12.2	27.92	14.55	18.25	35.44	40.68	29.12	24.48	9.93
Na^{1+} (mg/l)	198	124	181	201	176	122	236	199	245	186.89	42.69
K^{1+} (mg/l)	2.11	14.03	10.17	20.55	7.86	6.05	11.77	9.5	9.8	10.20	5.18
Ca^{2+} (mg/l)	16.45	6.14	16.05	11.28	18.05	22.15	9.31	11.32	13.54	13.81	4.89
Mg^{2+} (mg/l)	19.04	7.22	17.21	15.34	10.9	21.73	14.56	12.19	18.65	15.20	4.54

Cl : Clear, **Ol :** Odourless, **S.D.** : Standard Deviation, **Tur. :**Turbidity, **T.A. :** Total Alkalinity.

The value of TDS describes the general quality of water. Total dissolved solids in water originates from various factors like minerals, sewage, natural sources, the nature of piping which is used to convey the water, agricultural runoff, etc. Many dissolved substances are undesirable in water. TDS values for the samples varied from 696 to 1500 mg/l. For TDS, ICMR suggests 500 mg/l as the desirable limit while 1500-3000 mg/l as the maximum permissible limit. Here, all the samples (a to i) showed TDS values which were exceeding the desirable limit. High TDS value reduces the quality and affects the taste of water. If drinking water contains high TDS, palatability decreases and may cause gastro intentional irritation. The presence of high levels of TDS may also be objectionable to consumers, owing to too much scaling in water pipes, boilers and domestic appliances.

Table-2: Drinking Water Specifications

Parameter	Drinking Water Guideline		
	Indian Council of Medical research(ICMR)		European Union(EU)'s Standards(1998)
	Desirable Limit(DL)	Maximum Permissible Limit (MPL)	Acceptable limit
Odour	Unobjectionable	Unobjectionable	*
Turbidity(JTU)	5.0	25	*
TDS(mg/l)	500	1500 – 3000	-
pH	7.0 – 8.5	6.5 – 9.2	$\geq$ 6.5 and $\leq$ 9.5
E.C. (µs cm^{-1})	-	-	2500 µs cm^{-1}
Total Alkalinity (mg/l)	-	-	-
F^{1-} (mg/l)	1.0	1.5	1.5
Cl^{1-} (mg/l)	200	1000	250
SO_4^{2-}(mg/l)	200	400	250
NO_3^{1-}(mg/l)	20	100	50
Na^{1+}(mg/l)	-	-	200
K^{1+}(mg/l)	-	-	-
Ca^{2+} (mg/l)	75	200	-
Mg^{2+} (mg/l)	50	-	-

[* : acceptable to consumer and no abnormal changes]

The pH value of water is an expression of how acidic or basic the water is on the scale of 0 to 14. pH lower than 4 will produce sour taste and higher value above 8.5 will produce bitter taste. Higher pH accelerates the scale formation in water heating apparatus. pH below 6.5 starts corrosion in pipes, thereby releasing materials such as Zn, Cd, Cu, etc. pH values of water samples were found in the range of 6.17 to 8.01 having mean value 7.07 and standard deviation 0.0.59. Four samples(c, d, f, g) were not in the desired pH range(7.0-8.5) suggested by ICMR.

High values of electrical conductivity (E.C.) exhibits large amount of salts dissolved in water. This kind of property is not desired because it makes water unsuitable for drinking. Electrical conductivity of the water samples varied from 924 to 2330 µs cm^{-1} having standard deviation of 546.60 µs cm^{-1}.

Alkalinity levels vary across India. If alkalinity value in drinking water is higher, the taste of the water becomes unlikeable. In the water samples, total alkalinity was from 102 to 368 mg/l having mean value 231.67 and standard deviation 79.84.

In water resources, concentration of fluoride is increasing due to geochemical dissolution of fluoride containing minerals, fast urbanization and modern industrialization. Fluoride concentrations in water differ with the type of rock from which water flows. Higher concentration of fluoride also causes respiratory failure, variation in blood pressure and general paralysis. Presence of large amount of fluoride (> 1.5 mg/l) is associated with dental and skeletal fluorosis, while inadequate amount of fluoride (<1.0 mg/l) is associated with dental carries. Large population in India is affected by fluorosis. The F^{1-}

concentration in samples was from 0.40 to 1.42 mg/l having mean value 0.96. Four samples(b, c, e, i) were not up to the desirable limit (1.0 mg/l) indicated by ICMR.

Cl^{1-} is one of the major inorganic anion of water. The salty taste is produced by the chloride concentration is variable and dependent on the chemical composition of water composition. High chloride may harm metallic pipes and growing plants. For, Cl^{1-}, ICMR suggests the limit 200 mg/l while EU suggests the limit 250 mg/l. In the water samples, concentration of Cl^{1-} was from 139 to 300 mg/l having mean value 225.56 and standard deviation 53.79. Three samples (b, e, f) were not violating the limit for Cl^{1-} indicated by ICMR while three samples(c, d, i) crossed the limit indicated by EU.

Sulfate is found in most mineral waters. It can cause a pungent odour and taste in water and may have a laxative effect. For SO_4^{2-}, ICMR indicates 200 mg/l as desirable limit. Concentration of SO_4^{2-} was in the range of 7.88 to 24.60 mg/l, having mean value 13.69 and standard deviation 6.35. So, all the samples were within the limit for SO_4^{2-} indicated by ICMR and EU.

In groundwater, nitrate may result due to livestock facilities, agrochemicals and sewage disposal. Increasing nitrate in water is a big peril to the public health. The nitrate rich water is not fit for drinking. Excess of nitrate in drinking water may become the cause of methemoglobinemia (blue baby syndrome). The nitrate values of the samples varied from 12.20 to 40.68 mg/l having mean value 24.48 and standard deviation 9.93. Samples (a, d, g, h) were beyond the limit for nitrate indicated by ICMR(20 mg/l).

Sodium is an essential mineral in our diet. It is generally found in the form of sodium chloride (salt). It dissolves easily in water and gives water a salty taste at levels greater than 180mg/l to 200 mg/l. All natural waters contain some sodium. High level of Na^{1+} is associated with excessive salinity and is found in many minerals in water. Concentration of Na^{1+} was in the range of 122.00 to 245.00 mg/l, having mean value 186.89 and standard deviation 42.69. Samples(d, g, i) have higher concentration of Na^{1+} compared to EU limit for Na^{1+} (200 mg/l).

Potassium is present in rock and soil. Sources of potassium include fertilizer and erosion of potassium-bearing minerals like feldspar. In water, potassium has no smell or colour, but may give water a salty taste. Potassium is vital for the body. Undesirable health effects from exposure to higher potassium in drinking water are unlikely in healthy people. Potassium and sodium maintain the body's water balance. Potassium is also associated with nerve function and blood pressure. Concentration of K^{1+} was in the range of 2.11 to 20.55 mg/l, having mean value 10.20 and standard deviation 5.16.

Hardness of water is caused by the presence of the multivalent cations and is largely due to calcium and magnesium ions. Calcium is a major constituent of different types of rocks. Absolute soft water is tasteless. With the raise in hardness of water, its appropriateness decreases for cooking, cleaning and laundry jobs and if the concentration of magnesium is more than 300 mg/l, it is toxic [39]. Ca^{2+} and Mg^{2+} may combine with SO_4^{2-} causing stable hardness which cannot be removed by boiling. Such water may be softened by ion exchange process that is capable of exchanging Na^{1+} or H^{1+} for Ca^{2+} and Mg^{2+}. In the samples, Ca^{2+} concentration ranged from 6.14 to 22.15 mg/l, while Mg^{2+} content was found from 7.22 to 21.73 mg/l. Thus, the amount of Ca^{2+} present in the samples was within the desirable limit indicated for Ca^{2+} by ICMR.

Statistical Analysis

Statistical analysis can be applied to represent the data of the water research work and useful in understanding the internal relations of various parameters used for the physicochemical analysis. Many research workers have applied statistical analysis to their results [40-54]. As initial part of statistical analysis, mean and standard deviation for the values of different parameters are calculated and are shown in **Table-1**.

Correlation is a broad class of statistical relationship between two or more variables. Hence, it can be considered as a normalized measurement of covariance. The correlation study is useful to find a predictable relationship which can be exploited in practice. It is used for the measurement of the strength and statistical significance of the relation between two or more water quality parameters. Hence, it is helpful for the promotion of research activities. It can put forward possible causal or mechanistic relationships of research work. The correlation coefficients(r) were calculated and correlation matrix was obtained. Here, r is a dimensionless index which is in the range of -1.0 to +1.0 inclusive 0. It exhibits the extent of a relation between variables. The values of r from 0 to 1 and its indications are shown in **Table-3.** The values of correlation coefficients for different variables are listed in **Table-4.**

Table - 3: Indications of values of coefficient r

Value of r	Indication of the relation
0 - 0.2	Very poor correlation
0.2 - 0 .4	Slightly significant correlation
0 .4 - 0.6	Moderate correlation
0 .6 - 0.8	High correlation
0.8 - 1	Very high correlation

Table - 4: Correlation matrix for physicochemical parameters

Para.	Temp.	Tur.	TDS	pH	E.C.	T.A.	F^{1-}	Cl^{1-}	SO_4^{2-}	NO_3^{1-}	Na^{1+}	K^{1+}	Ca^{2+}	Mg^{2+}
Temp.	1.000													
Tur. (NTU)	0.177	1.000												
TDS	-0.429	0.176	1.000											
pH	0.344	-0.616	-0.350	1.000										
E.C. ($\mu s\ cm^{-1}$)	-0.532	0.170	0.987**	-0.409	1.000									
T. A. (mg/l)	0.067	-0.364	-0.418	0.104	-0.461	1.000								
F^{1-}	-0.260	0.368	0.383	-0.407	0.415	0.065	1.000							
Cl^{1-}	-0.187	0.033	0.229	-0.039	0.227	0.077	0.084	1.000						
SO_4^{2-}	0.246	0.378	-0.226	-0.086	-0.242	0.329	0.582	-0.256	1.000					
NO_3^{1-}	0.418	0.134	0.040	0.058	-0.071	0.557	0.379	0.243	0.316	1.000				
Na^{1+}	-0.049	-0.054	0.028	-0.060	-0.019	0.584	0.118	0.788*	-0.108	0.656	1.000			

K^{1+}	**-0.008**	**-0.168**	**0.167**	**-0.173**	**0.209**	**-0.194**	**0.144**	**0.094**	**-0.501**	**0.090**	**0.088**	**1.000**		
Ca^{2+}	**-0.246**	**-0.156**	**0.150**	**0.133**	**0.172**	**-0.003**	**0.072**	**0.055**	**0.385**	**-0.378**	**-0.234**	**-0.628**	**1.000**	
Mg^{2+}	**0.078**	**0.059**	**-0.114**	**0.233**	**-0.104**	**0.109**	**0.300**	**0.468**	**0.539**	**0.050**	**0.187**	**-0.414**	**0.682***	**1.000**

Para.: Parameter, **Temp.:** Temperature, **E.C.** : Electrical Conductance, **Tur. :** Turbidity, **T.A. :** Total Alkalinity.
***** Correlation is significant at the 0.05 level (2-tailed). ****** Correlation is significant at the 0.01 level (2-tailed).

Very high positive correlation was found between E.C. and TDS. High positive relation was found between Na^{1+} and Cl^{1-}, NO_3^{1-} and Na^{1+}, Ca^{2+} and Mg^{2+}. High negative correlation was found between pH and turbidity, K^{1+} and Ca^{2+}.

Very poor positive correlation was of –
temperature with turbidity, T. A., NO_3^{1-}, Mg^{2+},
turbidity with TDS, E.C., Cl^{1-}, NO_3^{1-}, Mg^{2+},
pH with T.A., NO_3^{1-}, Ca^{2+}, Mg^{2+},
T.A. with F^{1-} , Cl^{1-}, Mg^{2+},
NO_3^{1-} with Mg^{2+}, K^{1+},
Na^{1+} with K^{1+}, Mg^{2+},
Cl^{1-} with Na^{1+}, Ca^{2+},
F^{1-} with Cl^{1-}, Na^{1+}, K^{1+}, Ca^{2+},
T. A. with $F^{1-,}$ SO_4^{2-}, Mg^{2+},
E. C. with Ca^{2+},
TDS with NO_3^{1-}, Na^{1+}, K^{1+}, Ca^{2+},
NO_3^{1-} with Na^{1+}, K^{1+}.

Very poor negative correlation was of –
temperature with Cl^{1-}, Na^{1+}, K^{1+},
turbidity with Na^{1+}, K^{1+}, Ca^{2+},
TDS with Mg^{2+},
pH with Cl^{1-}, SO_4^{2-}, Na^{1+}, K^{1+},
E.C. with NO_3^{1-}, Na^{1+}, Mg^{2+},
T.A. with K^{1+}, Ca^{2+},
SO_4^{2-} with Na^{1+}.

Irrigation water quality:

For determining ground water quality suitable for irrigation purpose, SAR, RSC and SSP values were calculated. These values are shown in Table-5. The E.C. values are shown in table-3.

Table-5: Irrigation water quality data of ground water samples

Para.	a	b	c	d	e	f	g	h	i
SAR	7.844	7.998	7.442	9.105	8.041	4.391	11.199	9.729	10.085
RSC	2.090	2.392	1.001	2.879	3.128	1.122	4.487	3.397	2.867
SSP	78.241	86.356	78.425	83.415	81.259	65.166	86.286	84.903	83.013

Para. : Parameter

SAR:

Sodium Adsorption Ratio (SAR) affects infiltration of water. Hence, lower value of SAR is always desirable[55]. The Sodium Adsorption Ratio (SAR) was calculated by the following equation:

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

Here, sodium, calcium, and magnesium ions concentrations are in milli equivalent/liter.

Classification of water samples based on USSL Sodium hazard for irrigation purposes can be done on the basis of SAR values[56]. For the water samples: a, b, c, d, e, f, and h, the values of SAR is less than 10. It indicates samples fall in S_1 category and excellent for irrigation purpose by SAR point of a view. If the values of SAR are in the range of 10-18, in indicates class S_2 having good water for irrigation. Here, two samples: g and i come under S_2 category.

RSC:

Residual Sodium Carbonate (RSC) is expressed in milli equivalent/liter units. The formula for RSC index is:

$$\textbf{RSC index} = [HCO_3 + CO_3] - [Ca + Mg]$$

Residual carbonate levels less than 1.25 milli equivalent/liter are considered safe. Waters with RSC of 1.25- 2.50 meq/l are within the marginal range. If RSC is >2.5, water is unsuitable for irrigation[57]. In the present study, samples c and f are safe, samples a and b were marginally safe, while samples d,e , g h and i were not suitable for irrigation.

SSP:

Soluble Sodium Percentage (SSP) was calculated by the following equation :

$$SSP = \frac{(Na + K)}{(Ca + Mg + Na + K)} \times 100$$

Where, all the ions are expressed in meq/l. According to SSP values, water samples can be classified[58] into four categories: If SSP is less than 20, it is Excellent(class-I), if it is in the range of 20-40, it is Good(Class-II).If the values are in the range of 40 to 80, it is Fair(Class-III). Samples a, c and f falls in class III. If the SSP values are in greater than 80, it shows Poor quality of water for irrigation(Class-IV). Samples: b, d, e, g ,h and i fall in this class.

EC:

Except sample : d, all the samples have EC in the range of 250-750 µs/cm indicating medium to high salinity water and safe with permeable soil and moderate leaching[59]. Sample d is in the range of 2250-4000 µs/cm, hence, it is unfair for irrigation.

Statistical analysis:

Statistical analysis of SAR, RSC, SSP and EC was carried out. Mean and standard deviation values are given in Table-6, while correlation matrix is shown in Table-7.

Table-6: Descriptive statistics of Irrigation water quality data of ground water samples

Parameter	Minimum	Maximum	Mean	S.D.
SAR	4.391	11.199	8.426	1.953
RSC	1.001	4.487	2.607	1.094
SSP	65.166	86.356	80.785	6.580

Table-7: Correlation matix of irrigation water quality data of groundwater samples

Parameter	SAR	RSC	SSP	EC
SAR	1.000			
RSC	0.852**	1.000		
SSP	0.879**	0.729*	1.000	
E.C.	-0.075	-0.150	0.024	1.000

* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

High positive correlation was observed between SSP an RSC, while very high correlation was noticed between RSC and SAR, RSC and SSP. Very poor negative correlation was observed of EC with SAR and RSC, while very poor positive correlation was noticed between EC and SSP.

Conclusion

The present work has led to conclude that the quality of water samples studied were acceptable from the some of the physicochemical parameters but as pH, TDS, F^{1-}, Cl^{1-}, NO_3^{1-} and Na^{1+} values of few the samples were violating the desirable limit suggested by ICMR, the water should be treated properly before its usage as drinking water to avoid probable unpleasant effects. Remedial measures should be taken.

Considering irrigation quality, except one sample(g), all samples showed excellent SAR values. According to RSC values, five samples(d, e, g, h and i) were not found suitable for irrigation. On the basis of SSP values, Samples: b, d, e, g, h and i indicated poor quality for irrigation.

As a result, public should be made aware of water quality. Watchful management of precious natural liquid asset is a need of time. For the welfare of the human being, water quality should be assessed on the regular basis. Monitoring alone will not solve groundwater problems. Active participation of people to keep the situation of groundwater under control is also of a great worth.

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