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Assessment of groundwater quality of parts of Gwalior (India) for agricultural purposes

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Abstract: The groundwater of Gwalior region was assessed for its irrigational suitability. Fourteen water samples collected from dug-cum bored wells tapping shallow to deep aquifers from the clay with Kankar, silt, sandstone were used. The Groundwater samples were analyzed for major cations: Na^+, Ca^{++}, Mg^{++}, K^+,and anions: Cl^-,$HCO3^-$, $CO3^{--}$, $SO4^-$ and $NO3^-$. The important constituents that influence the water quality for irrigation are total dissolved solids (TDS), electrical conductivity (EC), sodium adsorption ratio (RSC), sodium percentages (Na%) and permeability index (PI). These parameters were compared with standard limits and were found to be within the safe limit suitable for irrigation purpose. In addition the total dissolved solids in ground water ranged between 256-1324 mg/l during the investigation period, revealed that irrigation using groundwater of the study area would not cause salinity hazards.

Keywords: Groundwater, water quality, residual sodium carbonate (RSC) and permeability index (PI),U.S.Salinity diagram, Gwalior, India.

Introduction

About 80% of the earth's surface is covered by water yet qualitatively 97% of this vast natural resource falls unfit for human use (Rai, 2004). Irrigation of agricultural lands accounted for 70% of the water used worldwide. In several developing countries, irrigation represents up to 95% of water uses, and plays a major role in food production and food security. Future agricultural development strategies of most of these countries depend on the possibility to maintain, improve and expand irrigated agriculture. Groundwater is the major source of fresh water available for irrigation. It is an important renewable resource having several inherent advantages over surface water. The dependence on groundwater is increasing in many regions because of limited surface water as perennial rivers and frequent failure of monsoon. It leads to overexploitation of the resource and thus the aquifer are heavily stressed (Elampooranan, 1999). Continued development and increasing use of groundwater combined with its reuse, the quality of ground water suffers unless consideration is given to protecting it.

Water is practically a universal solvent and dissolves some of everything it comes in contact with. The quality requirement of surface and groundwater depends upon its various uses like drinking, industrial, and irrigational use. The chemical quality of the ground water is a factor which is of paramount importance in its utilization for municipal, irrigational and industrial uses. To establish quality criteria, measures of chemical, physical and bacteriological constituents must be specified.

In this paper an attempted has been to study the chemical and physical suitability of groundwater for irrigation in Gwalior region of India. The water samples were analyzed for major cations i.e., Na^+, Ca^{++}, Mg^{++}, K^+ and anions i.e.,Cl^-, $HCO3^-$, $CO3^{--}$, $SO4^-$, $NO3^-$, total dissolved solids (TDS), electrical conductivity (EC), total hardness and pH. Similar attempts have also been made in different parts of the country (Prakash *et al*., 1989; Amlathe *et al*., 1995; Singh *et al*.,1996; Hounslow, 1995; Jain *et al*., 2000; Rohella, *et al*., 2001; Abdul, 2002; Focazio *et al*., 2006; Srivastava *et al*., 2007).

The Study Area

The study area covers the part of Gwalior district. It lies between Longitudes 78°0' to 78°15' E and latitudes 26°0' to 26°15' N. (Fig. 1). It covers an area of about 500 sq/km. The monthly mean temperature varies from 28°C to 46°C. Geologically, the area covered by the alluvium, sandstone, Quartzite, dolerite and shale. The main aquifer of the area is recharged by precipitation, irrigation, surface water bodies.

Material and methods

For the above study, 14 water samples of dug-cum bored wells were collected around Gwalior (M.P.) during pre monsoon period (April 2006). The samples were collected in 500 litre plastic bottles which were pre-cleaned with concentrated hydrochloric acid followed by rinsing in tap water and finally with distilled water (Hem, 1975, IHD- WHO, 1978). After collection, they were stored in refrigerator until analysis as per the standard methods (APHA, 1985; Trivedy *et al*., 1986). pH and temperature were measured at the site of sample collection. In the laboratory, the water samples were analyzed for major cations and anions such as Na^+, Ca^{++}, Mg^{++}, K^+, total dissolved solids (TDS), electrical conductivity (EC), total hardness. Concentration of Na^+ and K^+ was determined by using flame emission spectrophotometer; Calcium hardness, Cl^-, $HCO3^-$,

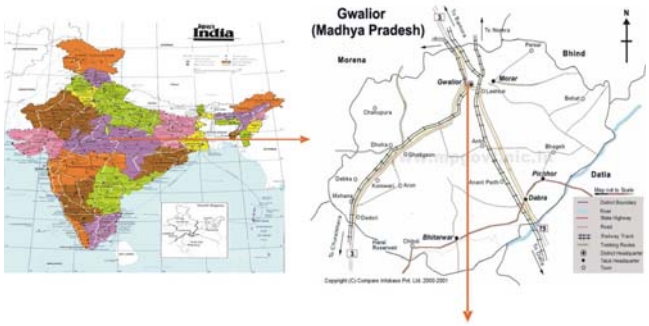

fig 1 Location map of sampling sites of Gwalior

CO_3^{--}, SO_4^{-} and, NO_3^{-} were estimated by volumetric methods. Sodium Adsorption Ratio (RSC), sodium percentages (Na %) and permeability index (PI) were estimated by standard methods; total hardness by EDTA method (ISI, 1983; APHA, 1985; WHO, 1984, 1992; IS:10500, 1991, 1993).

Result and discussion

The analytical results were compared with the standard specification (WHO, 1984; Indian Standards Institution, 1983; IS, 1991; 1993). The range values of analyzed parameters are given in Table 1. On the basis of the parameters the suitability criteria for irrigation purpose were determined.

Suitability of Groundwater for Irrigational purpose

The water quality used for irrigation is essential for the yield and quantity of crops, maintenance of soil productivity, and protection of the environment. At the same time, the quality of irrigation water is very much influenced by the land constituents of the water source. The important parameters affecting the suitability of groundwater for irrigation purposes are: total dissolved solids (TDS), electrical conductivity (EC), sodium adsorption ratio (RSC), sodium percentages (Na %) and permeability index(PI).

Total dissolved solids (TDS)

Salt of calcium, magnesium, sodium, potassium present in the irrigation water may prove to be injurious to plants. When present in

Table 1. Analytical results compared with the standard specifications in the study area

Parameters	Range in the study area	WHO 1984	ISI (1983)		Desirable limits as per IS : 10500, 1991 & 1993
			Highest Desirable	Maximum Permissible	
Physical					
1. Odour	odorless	Unobject-odour	-	-	Unobjectionable
2. Turbidity(NTU)	-	5	-	-	5
3.EC (micromhos/cm)	90-1400	1400			
4. TDS	256-1324	1000	500	1500	500
Chemical					
1. pH	8.3-8.7	6.5-8.5	7.0-8.5	6.5-9.2	6.5-8.5
2. Alkalinity	70-253	-	-	-	200
3. Hardness	110-410	500	-	300	300
4. calcium	35-155	75	75	200	75
5. Magnesium	40-190	50	30	100	30
6. Sodium	28-140	200	-	-	-
7. Potassium	1.9-9.7	55	-	-	-
8. Chloride	39-405	250	250	1000	250
9. Sulphate	3.0-37	400	150	400	200
10. Bicarbonate	58-340	-	300	600	-
11. Carbonate	15-54	-	-	-	-
12. Nitrate	0.9-5.9	50	-	45	45

Units = mg/l

Table 2. Range of total dissolved solids for irrigation use (after Robinove et al., 1958)

Classification	Total Dissolved solids (mg/l)	Samples no. (Study area)
Non saline	< 1000	1,2,4,5,6,7,8,9, 11,12,13,14
Slightly Saline	1000-3000	3,10
Moderate saline	3000-10000	nil
Very saline	> 10000	nil

excessive quantities, they reduce the osmotic activities of the plants and may prevent adequate aeration. The total dissolved solids in the waters were estimated from their specific conductance values by multiplying with a factor of 0.64 which is taken as the conversion factor for most natural waters (US Salinity Laboratory Staff, 1954). According to the classification given by Robinove *et al.*, (1958), groundwater in the study area are mostly non saline except well no. 3 and 10 (Table 2). The irrigation water with TDS less than 200 as excellent, between 200-500 as good, 500-1500 as permissible and 1500-3000 as of unsuitable. The range of total dissolved solids in ground water between 256-1324 mg/l.

Electrical Conductivity (EC)

The salt concentration is generally measured by the determining the electrical conductivity of water. It is related to TDS by the equation:

$$\frac{\text{TDS (in mg/l)}}{\text{EC x } 10^6\text{(Micro- mhos/cm)}} = 0.64$$

Where, the EC is expressed as micro-mhos/cm. On the basis of electrical conductivity, the irrigational classification is given in Table 3.

The range of electrical conductivity of the investigated area is between µs cm^{-1} to 90-1400 µmhos/cm (Table 1) indicates that the EC values comes under WHO (1984) guideline of range 1400 µmhos/cm. except the samples no3. It is observed that in some areas the EC values increase with the increasing amounts of sulphate, carbonate, Bicarbonate & Hardness as $CaCo_3$.

Sodium adsorption ratio

SAR gives the clear idea about the adsorption of sodium by soil. Sodium adsorption ratio is the proportion of sodium to calcium and magnesium, which affect the availability of the water to the crop. SAR is computed by the equation:

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}},$$

Richard (1954) classified the irrigation water with SAR (in epm) as: less than 10 as excellent, between, 10-18 as good,18-26 as fair and greater than 26 as of poor quality. The United States of Salinity Laboratory's (USSL) classification of the

Table 3. Quality of irrigation water is relation to EC (after Richard, 1954)

S.No.	Electrical Conductivity (umhos/cm)	Type of water	Suitability for irrigation	Samples no
1.	Below 250	Low saline water (1)	Entirely safe	2,12
2.	250-750	Moderately saline (2)	Safe under practically all conditions	1,,4,5,6,8,9,11,13,14
3.	750-2250	Medium to high salinity water (3)	Safe only with permeable soil and moderate teaching	3,7,10
4.	Above 2250			
i.	2250-4000	High salinity	Unfair for irrigation	nil
ii.	4000-6000	Very high salinity	Unfair for irrigation	nil
iii.	Above 6000	Excessive salinity class	Unfair for irrigation	nil

Table 4 . Classification of irrigation water based on SAR (epm) and EC values use to plot in USSL diagram.

W.No.	Location	SAR (epm)	EC(µmhos/cm)
w1	Dullpur	1.805	530
w2	Sikroda	2.337	90
w3	Antri	3.692	2070
w4	Adpura	0.558	467
w5	Sithauli	0.679	400
w6	Jorasi	2.227	670
w7	Baraikapura	2.386	800
w8	Makada	0.744	400
w9	Tighra	-	315
w10	Nayagaon	2.744	1400
w11	Panihar	0.879	530
w12	Ghosipura	2.218	90
w13	Mohanpur	1.078	450
w14	Badagaon	1.617	720

water is based on the EC and SAR (Table 4 & Fig. 2). The U.S. Salinity Laboratory of the Department of Agriculture, 1954 has proposed a diagram in which EC is taken as index of salinity hazard and SAR as an index of sodium hazard. The majority of the water samples examined in the present investigation fall under the category of C_2S_1 and C_3S_1 class, indicating good to medium typed water which can be used for irrigation (Richard, 1954). SAR values of the study area varie from 0.558 epm to 3.692 epm. Based on the SAR values alone, the ground water samples come under excellent categories.

Percentage of sodium

The sodium percentages in the study area ranges from 7.55 to 46.39 epm (Table 5) and the percent sodium content is computed by the equation:

$$\% \text{ of Na} = \frac{(Na + K)}{(Ca + Mg + Na + K)} \times 100$$

Residual sodium carbonate (RSC)

According to Richard (1954), the residual sodium carbonate is determined by the formula:

$$RSC = (HCO_3 + CO_3) - (Ca + Mg)$$

If the RSC exceeds 2.5 epm, the water is unsuitable for irrigation. If the value is between 1.25 to 2.5 epm, the water is of marginal quality; while the value is less than 1.25 epm or negative value, probably safe for irrigation. The RSC value in the study area ranges from -3.82 to -28.11 epm (Table 5).

Permeability index (PI)

The soil permeability is affected by the long term use of irrigated water and the influencing constituents are TDS, sodium, bicarbonate and the soil type. Doneen (1964) has assessed the suitability of water for irrigation based on the permeability index.

$$PI = \frac{Na + \sqrt{HCO_3}}{(Ca + Mg + Na)} \times 100$$

The ground water PI, in the study area, ranges from 0.425 to 199.65 epm. On the basis of PI, the groundwater in the study area falls under class II and III and hence the water is considered suitable for irrigation (Table 5).

Table 5. Residual sodium carbonate, sodium % and permeability index in the study area

W.No.	Location	PI (epm)	RSC (epm)	%Na (epm)
w1	Dullpur	69.73	-10.53	19.39
w2	Sikroda	74.97	-12.75	22.32
w3	Antri	199.65	-28.11	23.71
w4	Adpura	45.54	-9.96	7.55
w5	Sithauli	50.06	-10.49	9.03
w6	Jorasi	72.7	-7.6	26.43
w7	Baraikapura	74.08	-9.14	46.39
w8	Makoda	43.8	-11.72	9.72
w9	Tighra	0.425	-3.82	1.12
w10	Nayagaon	80.3	-14.06	24.03
w11	Pannihar	64.06	-10.16	11.43
w12	Ghosipura	68.48	-14.72	20.57
w13	Mohanpur	58.54	-7.66	15.03
w14	Badagaon	68.21	-10.29	18.12

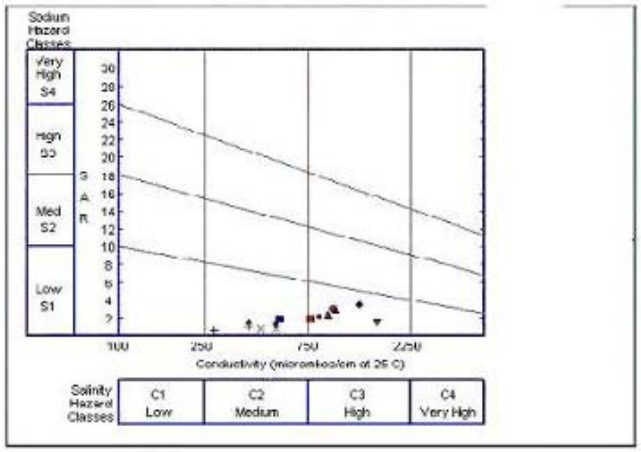

fig 2 Classification of ground water based on SAR and EC for Irrigation purposes (After U.S. Salinity Laboratory, 1954)

Conclusion

Comparing to the standard limits, the constituents of the sampled water are within the permissible level and hence the groundwater is considered to be suitable for irrigation purpose. However, a few parameters fall at higher side of the limit and thus minimizing its suitability for drinking purposes without treatment. But after filtration, naturally present impurities can be removed in water, which can provide its suitability for drinking and domestic purposes. The SAR values of the study area are to be less than 10 and TDS is less than 1500 could be utilized for irrigation. On the basis of U.S. Salinity laboratory diagram, the groundwater samples fall in the class C_2S_1 & C_3S_1 indicating low sodium hazards to crop and hence suitable for irrigation.

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