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Status of Groundwater Quality of Lalsot Urban Area in Dausa District, Rajasthan

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ABSTRACT

Management of groundwater resource is determined by its accessibility and utility in terms of quantity and quality. The results of chemical analysis for pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), total alkalinity (TA), calcium (Ca^{+2}), magnesium (Mg^{+2}), sodium (Na^{+}), potassium (K^{+}), chloride (Cl^{-}), nitrate (NO_3^{-}), sulphate (SO_4^{-2}) and fluoride (F^{-}) of 18 water samples collected from Lalsot urban area in Dausa district are presented. Based on the results, certain parameters like sodium adsorption ratio (SAR) and percent sodium (% Na) were also calculated. Statistical analyses have been carried out using chemical data to classify geo-chemical evaluation of the aquifer system based on the ionic constituents. Salinity and nitrate contamination are the two major problems in the area, which is alarming considering the use of this water for drinking. The major factors influencing the water quality are local geo-chemical formation, water-rock interaction, flow direction of groundwater and rainfall that control the overall mineralization.

INTRODUCTION

Less than 1% of earth's water is available for human consumption and more than 1.2 billion people still have no access to safe drinking water. Over 50% of the world's population is estimated to be residing in urban areas, and almost 50% of mega cities having population over 10 million are heavily dependent on groundwater, especially in the developing world. Nearly 40% of global food production is attributed to irrigated abstraction and 70% of the world groundwater withdrawals are used for irrigation purposes.

Groundwater is often defined as water occurring within the subsurface geological environment. Groundwater forms one of the primary resources for developmental activity. Several interrelated processes control the chemical composition of the water and it is essential to understand the processes in order to arrive at the distribution and quality of various types. Underground water plays an important role in the overall water balance of the environment. The main factors that control the quality of water are associated with lithology and soil. The ratio of different elements in the subsurface water is dependent on the associated rocks and sediments that form the aquifers and the time it has been in contact with this geological material.

Human activities such as industrialization and urbanization may also alter the water quality by polluting the environment (Pojasek 1977, Salomons 1995). The quality of water plays a prominent role in affecting both agricultural production and human health. The contamination and pollution of water in the natural surroundings and in the storage are due to pesticides, fertilizers, industries, inorganic and organic salts from topsoil and geological strata (Nanoti 2004). Studies conducted on the chemical quality of groundwater of Manglore city in Karnataka State and Chennai in Tamil Nadu, India revealed that the groundwater quality has deteriorated due to over-exploitation of groundwater (Narayana & Suresh 1989, Ramesh et al. 1995). Sreedevi (2004) has studied the groundwater quality of Pageru river basin in Cuddapah district and the assessment of water samples from various methods proved that majority of the water samples were good either for drinking or for agricultural purposes. The interpretation of correlation co-efficient among water quality parameters of groundwater greatly facilitates the task of rapid monitoring that was extensively studied by several workers (Meenakshi et al. 2002, Gaikwad 2004).

The objective of the present investigation is to assess the quality of groundwater of Lalsot urban area in Dausa district, and to study the correlation among various parameters. As correlation may exist among the water quality parameters, a systematic calculation and interpretation of correlation co-efficient give an idea of water quality. Percent sodium and sodium adsorption ratio (SAR) evaluate the groundwater quality for irrigation purposes.

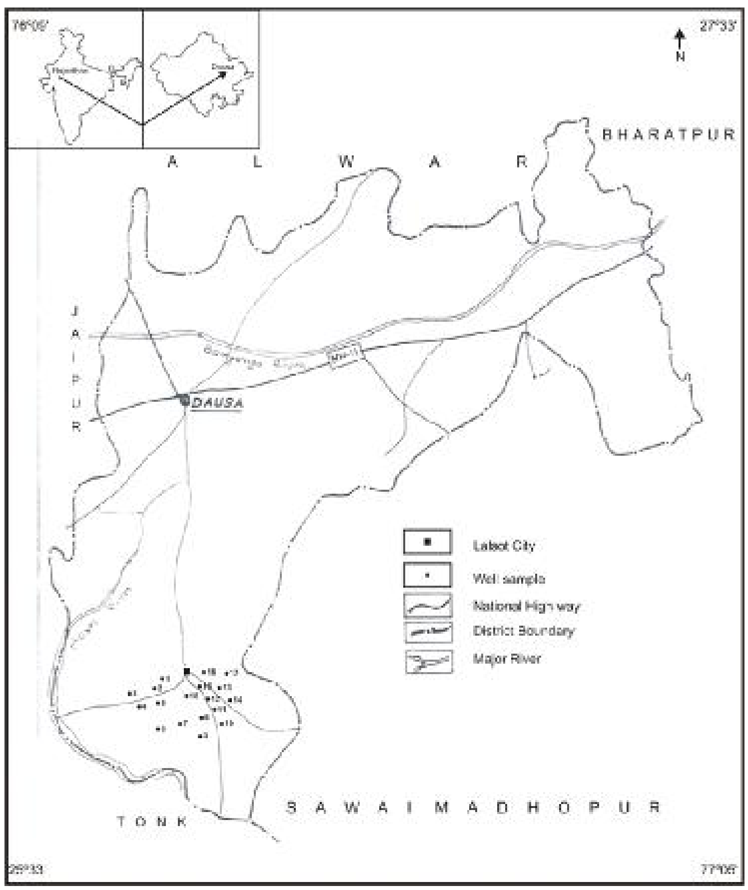

Fig. 1: Location map of Lalsot Urban Area of Dausa district, Rajasthan, India.

Table 1: Physico-chemical properties of groundwater from Lalsot city, Dausa district, Rajasthan.

Site	pH	EC	TDS	TA	TH	Na^+	K^+	Ca^{+2}	Mg^{+2}	Cl^-	F^-	NO_3^-	SO_4^{-2}	$Na^+ + K^+$	$Ca^{+2} + Mg^{+2}$	$Ca^{+2} + Mg^{+2} / Na^+ + K^+$
1	7.9	469	309	200	170	2.48	0.13	60	8	30	0.06	5	10	2.61	68	26.06
2	8.0	670	442	240	200	1.79	0.05	20	60	60	0.36	7	6	1.84	80	43.47
3	8.2	804	530	270	250	3.04	0.08	32	68	80	0.10	10	6	3.12	100	32.05
4	7.9	402	265	110	130	1.26	0.05	40	12	20	0.08	15	6	1.31	52	39.69
5	8.4	1005	663	220	420	4.78	0.08	56	112	100	0.10	50	20	4.86	168	34.56
6	7.6	1139	757	510	320	11.74	0.13	64	64	110	0.10	10	7	11.87	128	10.78
7	7.6	1541	1017	440	420	6.80	0.10	72	96	190	0.52	75	45	6.90	168	24.34
8	7.5	1675	1105	430	480	5.22	0.08	112	80	260	0.60	80	43	5.30	192	36.22
9	7.4	1943	1282	410	730	19.50	0.15	160	132	400	0.52	90	47	19.65	292	14.86
10	7.6	1340	884	620	310	4.35	0.08	52	72	90	0.68	15	36	4.43	124	27.99
11	7.3	1206	795	440	380	2.70	0.10	100	52	130	0.44	50	27	2.80	152	5.42
12	7.3	1072	707	350	320	3.25	0.15	68	60	110	0.52	25	14	3.40	128	37.64
13	7.4	1273	840	460	350	5.50	0.08	80	60	130	0.56	40	20	5.58	140	25.08
14	8.5	2077	1370	330	550	13.90	0.10	104	116	450	0.22	30	85	14.00	220	15.71
15	8.4	1206	795	380	240	3.04	0.08	52	44	120	0.42	75	12	3.12	96	30.76
16	8.5	1273	840	140	280	6.50	0.05	16	96	250	0.36	97	20	6.55	112	17.09
17	8.7	737	486	180	170	1.79	0.05	16	52	90	0.62	31	25	1.84	68	36.95
18	8.7	804	530	190	170	2.40	0.08	12	56	110	0.36	54	35	2.48	68	28.33

All the units are in mg/L except EC (micomhos/cm).

CLIMATE AND RAINFALL OF THE STUDY AREA

The study area has a dry climate except during the southwest monsoon season. December to February is the cold season after which the hot season commences and continues till about third week of June when the southwest monsoon sets in. The southwest monsoon season is comparatively short in this region only till mid-September. The period from March to June is one of continuous rise in temperature, May and first half of June being the hottest period of the year. The mean daily maximum temperature in May is 40.6°C and mean daily minimum temperature is 25.8°C.

The average annual rainfall in the study area is 584 nm. The rainfall generally increases from northwest to southeast. The rainfall during the period June to September constitutes nearly 90% of the annual rainfall.

MATERIALS AND METHODS

The study provides a detailed description of the chemical composition of groundwater. Eighteen samples were collected in study area, and analysed for pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), total alkalinity (TA), calcium (Ca^{+2}), magnesium (Mg^{+2}), sodium (Na^+), potassium (K^+), chloride (Cl^-), nitrate (NO_3^-), sulphate (SO_4^{-2}) and fluoride (F^-) using standard methods (Rainwater and Thatcher 1960, Hem 1985, APHA (1995). The sodium adsorption ratio (SAR) and percent sodium (%Na) were also calculated. The sample locations in the study area are depicted in Fig. 1. Wilcox (1948) method was used for rating irrigation waters based on percent sodium and electrical conductivity (Fig. 2.)

Standard deviation and coefficient of variation are the two statistical parameters considered for variability measurement among the parameters. The correlation coefficient (r) has been calculated between each pair of parameters using experimental data given in Table 1. Standard deviation, coefficient of variation and mean values are given in Table 3.

RESULTS AND DISCUSSION

The results of the study are presented in Tables 1 to 5.

pH: The pH values in the groundwater samples of the study area range from 7.3 to 8.7 with the mean value of 7.93 ± 0.4984. The groundwaters are alkaline in pH. According to WHO (1992) specification, all the samples fall under desirable limit of pH (6.9-9.2).

Electrical conductivity (EC): A high concentration of salts in irrigation water renders the soil saline. This also affects the salt intake capacity of the plants through roots. Electrical conductivity of water samples ranged from 402 to 2077 µmhos/cm with the mean of 1146.44 µmhos/cm. The US Salinity Laboratory (1954) classified groundwaters on the basis of electrical conductivity (Table 4) : Up to 250 µmhos/cm as excellent; 250 to 750 µmhos/cm as good; 750 to 2250 µmhos/cm as fair and > 2250 µmhos/cm as poor category. Based on this classification 78% of samples belong to fair category and remaining 22% of samples belong to good category.

Total dissolved solids (TDS): The total dissolved solids range from 265 to 1370 mg/L with a mean of 756.5 ± 301.24 mg/L. According to WHO specification, TDS up to 500 mg/L is highest desirable and up to 1000 mg/L is maximum permissible category, thus 78% of samples belong to maximum permissible category, and remaining 22% of samples to below the WHO specification. Based on the concentration of TDS (Wilcox 1955) groundwater can be classified as follows: Up to 500 mg/L as desirable for drinking; up to 1000 mg/L as permissible for drinking and up to 3000 mg/L as useful for irrigation. Based on this classification it was observed that out of 18 samples 8 are desirable for drinking and remaining 10 are permissible for drinking.

Total hardness (TH): Hardness results due to the presence of divalent cations of which Ca^{+2} and Mg^{+2} are the most abundant in groundwaters. Hardness in water is also derived from the solution of carbon dioxide released from bacterial action in soil in percolating water (Sawyer & McCarty 1967). In the present study, the hardness of water samples ranged from 130 to 730 mg/L with a mean of 327.22 mg/L. The waters of the study area are classified according to hardness based on WHO (1984), which revealed that 89% of samples belong to permissible limit and 11% to out of permissible limit.

Total alkalinity (TA): Most of the natural waters contain substantial amounts of dissolved carbon dioxide, which is the principle source of alkalinity, and this can be conveniently evaluated by acid titration. An increase in the temperature or decrease in the pressure causes a reduction in the solubility of CO_2 in water. In the present study, alkalinity ranges between 110 and 620 mg/L with a mean of 328.88 mg/L. According to WHO classification, 56% of samples belong to out of permissible limit, 33% of samples to optimum permissible limit, and 11% of samples to below permissible limit.

Sulphate (SO_4^{-2}): Health concerns regarding sulphates in drinking water have been raised because of reports of diarrhoea associated with the ingestion of water with high levels of sulphates. Although there is little information describing the acute toxicity of sulphates in humans, animal data suggest that sulphate salts are not very toxic (Lorraine 2000). In the present study, sulphates range from 6.0 to 85 mg/L with a mean of 25.44 mg/L. According to WHO classification, 78% of samples belong to below the permissible limit and 22% samples to permissible limit.

Fluoride (F^-): Fluoride concentration ranged from 0.06 to 0.68 mg/L with a mean of 0.36 mg/L.

Table 2: Geo-chemical parameters of groundwater samples of the study area.

Site No.	Total Dissolved Solids (mg/L)	Electrical Conductivity (μmhos/cm)	Percent Sodium(%Na)	Sodium Adsorption Ratio (SAR)
1	309	469	3.69	0.42
2	442	670	2.24	0.28
3	530	804	3.02	0.43
4	265	402	2.46	0.25
5	663	1005	2.81	0.52
6	757	1139	8.48	1.47
7	1017	1541	3.94	0.74
8	1105	1675	2.68	0.53
9	1282	1943	6.30	1.61
10	884	1340	3.44	0.55
11	795	1206	1.81	0.31
12	707	1072	2.59	0.41
13	840	1273	3.83	0.66
14	1370	2077	5.98	1.33
15	795	1206	3.15	0.44
16	840	1273	5.52	0.87
17	486	737	2.63	0.31
18	530	804	3.52	0.41

Fluoride values of all groundwaters are below the WHO limit (1.5 mg/L). 61.11% of drinking water samples contained fluoride less than 0.5 mg/L. Consumption of drinking water with such low fluoride content is insufficient to prevent dental caries.

Chloride (Cl^-): The acceptable range of chloride is 200 to 600 mg/L by WHO (1992). The chloride concentration varied from 20 to 450 mg/L with a mean of 151.66 mg/L. In all, 22% of samples belong to optimum permissible limit, while 78% of samples fall below the permissible limit. When the excess chloride concentration is present with excess sodium concentration it may cause congestive heart failure (Brooker et al. 1984).

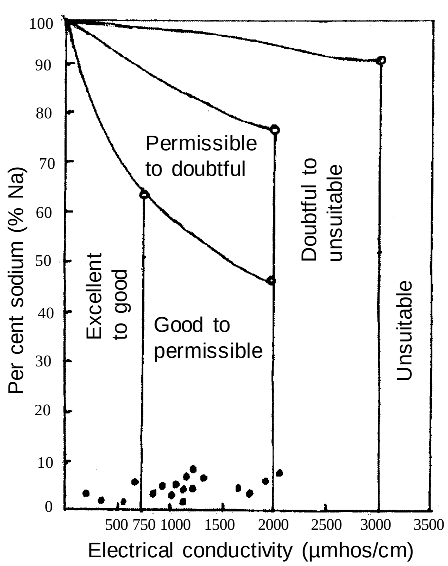

Fig. 2: The quality of groundwater in relation to electrical conductivity and percent sodium (Wilcox diagram).

Nitrate (NO_3^-): The acceptable range for nitrate is 45 mg/L by WHO (1992). The nitrate concentration varied from 5 to 97 mg/L with a mean of 42.16. In all, 11% of samples belong to optimum permissible limit, 33% to out of permissible limit, and 56% to below the permissible limit.

Percent sodium (% Na): Sodium concentration is important in classifying irrigation water because sodium reacts with soil to reduce its permeability. Soils containing a large proportion of sodium with carbonate as the predominant anion are termed alkali soils; those with chloride or sulphate as the predominant anions are saline soils. The role of sodium in the classification of groundwater for irrigation was emphasized because of

Table 3: Basic statistics of various physico-chemical parameters of groundwater samples in the study area.

Component	No. of Samples	Minimum	Maximum	Mean	Standard Deviation	Co-efficient of Variance
SO_4^{-2} (mg/L)	18	6.0	85.0	25.44	20.32	79.87
NO_3^- (mg/L)	18	5.0	97.0	42.16	30.56	72.48
F^- (mg/L)	18	0.06	0.68	0.36	0.21	58.33
Cl^- (mg/L)	18	20.0	450.0	151.66	117.73	77.62
Ca^{+2} (mg/L)	18	12.0	160.0	62.00	37.20	60.00
Mg^{+2} (mg/L)	18	8.0	132.0	68.88	34.66	50.31
Na^+ (mg/L)	18	1.26	19.50	5.55	4.84	87.20
K^+ (mg/L)	18	0.05	0.15	0.09	0.032	35.88
TH (mg/L)	18	130.0	730.0	327.22	139.73	42.70
TA (mg/L)	18	110.0	620.0	328.88	142.28	43026
TDS (mg/L)	18	265.0	1370.0	756.5	301.24	39.82
EC (µmhos/cm)	18	402.0	2077.0	1146.44	465.26	40.58
pH	18	7.3	8.7	7.93	0.4984	6.28

Table 4: Water quality classification (After U.S. Salinity Laboratory, 1954)

Quality of water	Electrical conductivity (µmhos/cm)	Sodium adsorption ratio (mg/L)
Excellent	Up to 250	Up to 10
Good	250-750	10-18
Fair	750-2250	18-26
Poor	> 2250	> 26

Table 5: Correlation co-efficient values among the parameters.

	pH	EC	TDS	TA	TH	Na^+	K^+	Ca^{+2}	Mg^{+2}	Cl^-	F^-	NO_3^-	SO_4^{-2}	Na^+ $+K^+$	$Ca^{+2}+$ Mg^{+2}	$Ca^{+2}+$ $Mg^{+2}/$ Na^++K^+
pH	1.00															
EC	-0.25	1.00														
TDS	-0.25	0.99	1.00													
TA	-0.66	0.58	0.58	1.00												
TH	-0.38	0.89	0.89	0.48	1.00											
Na^+	-0.20	0.77	0.77	0.36	0.84	1.00										
K^+	-0.54	0.35	0.35	0.43	0.51	0.54	1.00									
Ca^{+2}	-0.62	0.74	0.74	0.55	0.88	0.70	0.64	1.00								
Mg^{+2}	0.01	0.79	0.79	0.26	0.83	0.73	0.18	0.46	1.00							
Cl^-	-0.01	0.90	0.90	0.21	0.84	0.82	0.28	0.66	0.78	1.00						
F^-	-0.31	0.42	0.42	0.49	0.26	0.02	-0.03	0.22	0.22	0.23	1.00					
NO_3	0.03	0.57	0.57	0.05	0.50	0.34	-0.01	0.34	0.53	0.57	0.41	1.00				
SO_4^{-2}	0.05	0.80	0.80	0.27	0.68	0.58	0.17	0.54	0.64	0.83	0.32	0.37	1.00			
Na^++K^+	-0.21	0.77	0.77	0.36	0.84	0.99	0.54	0.71	0.73	0.82	0.02	0.34	0.58	1.00		
$Ca^{+2}+Mg^{+2}$	-0.38	0.89	0.89	0.48	1.00	0.84	0.51	0.88	0.82	0.84	0.26	0.50	0.68	0.84	1.00	
$Ca^{+2}+Mg^{+2}/$ Na^++K^+	0.23	-0.51	-0.51	-0.39	-0.47	-0.59	-0.43	-0.46	-0.32	-0.48	0.04	-0.27	-0.36	-0.60	-0.47	1.00

the fact that sodium reacts with soil and as a result clogging of particles takes place, thereby reducing the permeability (Todd 1980, Domenico & Schwartz 1990). The percent sodium value in study area varies from 1.81 to 8.48. Wilcox (1948) proposed a method for rating irrigation waters to be used, based on percent sodium and electrical conductivity. The diagram consists of five distinct areas such as excellent to good, good to permissible, permissible to doubtful, doubtful to unsuitable and unsuitable. The percent sodium is obtained by the equation:

$$\% Na = \frac{Na + K}{Ca + Mg + Na + K} \times 100$$

Wilcox diagram has revealed that out of 18 samples, 4 fall under excellent to good, 13 fall under good to permissible and one falls under doubtful to unsuitable (Fig. 2). The agricultural yields are observed to be generally low in lands irrigated with waters belonging to permissible to doubtful category. This is probably due to the presence of sodium salts, which causes osmotic effects in soil plant system.

Sodium adsorption ratio (SAR): Excess sodium in water produces undesirable effects of changing soil properties and reducing soil permeability (Kelly 1951). Hence, the assessment of sodium concentration is necessary while considering the suitability for irrigation. The degree to which irrigation water tends to enter into cation-exchange reactions in soil can be indicated by the sodium adsorption ratio (US Salinity Laboratory 1954). Sodium replacing adsorbed calcium and magnesium is a hazard as it causes damage to the soil structure. It becomes compact and impervious. SAR is important parameter for the determination of suitability for irrigation water because it is responsible for the sodium hazard (Todd 1980).

$$\mathrm{SAR} = \frac{\mathrm{Na}}{\sqrt{\mathrm{Ca} + \mathrm{Mg}/2}}$$

As per the classification based on SAR values (Table 4), 18 samples in study area are in excellent category because none of the samples exceeded the value of SAR = 10.

A correlation analysis is a method applied to describe the degree of relation between two parameters. A high correlation coefficient (near 1 or – 1) means a good relationship between two variables and its value around zero means no relationship between them. More precisely, it can be said that parameters showing r > 0.7 are considered to be strongly correlated, whereas r between 0.5 and 0.7 shows moderate correlation. In this study, the relationship between various parameters has been studied using linear correlation coefficient (Table 5). The resultant matrix shows negative correlation of pH with most of variables. Electrical conductivity is showing high positive correlation with TDS, TH, Na^+, Mg^{+2}, Cl^-, SO_4^{-2} and Ca^{+2}+ Mg^{+2}. Thus, it can be inferred that electrical conductivity values can be used to estimate the concentration of cationic and anionic contents in water; cations and anions are major contributors to the electrical conductivity. High positive correlation was found between Na^+ and Cl^- (0.82), Na^+ and Ca^{+2} (0.70). Very high positive correlation (0.90) was found in total dissolved solids with both Cl^- and total hardness. The correlations between TDS and NO_3^- (0.57), F^- (0.42), K^+ (0.35) are low but also significant (r = 0.3) at 1% level. Since the correlation coefficient between Na^+ and Cl^- is positively high, it can also be deduced that for most of the groundwater samples Na^+ and Cl^- originate from a common source. So, it can be concluded that there are several salts such as NaCl (0.82), $MgCl_2$ (0.78) and Na_2SO4 (0.58), which are present in the study area.

CONCLUSION

The groundwater quality of the study area has a primary problem of salinity followed by nitrate contamination, which needs special attention. Based on TDS concentration, about 50% samples are permissible for drinking, 28% samples desirable for drinking, 22% samples not suitable for drinking, and all samples suitable for irrigation. Wilcox classification has revealed that most of the samples fall under good to permissible category, 4 samples fall under the excellent to good category, and one sample falls under the doubtful to unsuitable category. Classification of irrigation waters, based on SAR values, has indicated that all the samples fall under the excellent category. Most significant correlation was observed between Na^+ and Cl^- pair. Significant correlations were also observed between Mg^{+2}- Cl^- and Na- SO_4^{-2}. Except for few parameters, the overall quality of groundwater is poor for drinking and irrigation purposes.

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