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Original Research Paper

Assessment of Groundwater Quality for Agriculture in Gajwel, Andhra Pradesh, India

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ABSTRACT

The hydrochemical study was undertaken to assess the chemical composition of groundwater and its suitability for agricultural purpose in Gajwel region of Andhra Pradesh. The area under investigation is a rural area and main source of occupation is only agriculture with no industries around. In order to evaluate the suitability of groundwater for agricultural purpose, the samples were collected and analysed for all major ions, and studied using the parameters, viz., % Na, SAR, Piper diagram, TDS, KI, PI, Mg Ratio, Ayers classification, etc. Different graphical methods such as Wilcox, USSL and Gibbs were also used to find out the suitability of groundwater for agricultural purpose.

INTRODUCTION

Water is one of the important inputs in agriculture. If considered in right perspective for efficient management of available water resources, the specific role played by soil, plant and environmental factors have to be considered. Agriculture plays more vital role for the economic stability of the area and the country, so there is a vital need for irrigation and agricultural development to keep the rapidly multiplying population adequately fed.

It is necessary to bring more and more land under irrigation and to adopt improved methods of agricultural practices such as better seeds, high yielding varieties of crops, more fertilizers, etc., but the prime necessity would be assured supply of quality water in order to have high yields. An efficient cropping pattern may be defined as the sequence of crops to be raised in an area in accordance with the type of soil and quality of water and the climatic conditions of the area and other available irrigation resources. It looks quite simple, but needs a comprehensive knowledge of all water management aspects (Sankara Reddy 1976, Jensin et al. 1967, Doorenbos & Pruitt 1975, Richards & Richards 1957, Thornthwaite & Mather 1955, Yadava 1972).

The soil acts as a source of storage and supply of water. Both these factors are controlled by the climate. The factors which affect the water requirement are the soil, plant and environment. The total quantity of water that is essential for raising a successful crop has been given by different scientists employing different empirical formulae (Baier 1962, Balaney & Criddle 1950, Anand Reddy & Jain 1978, Kuppa Reddy 1978, Zimmerman 1966).

STUDY AREA

Gajwel lies in the western part of Andhra Pradesh and is bounded by the north latitudes 17°40’ 00’ to 18°01’06’ and east longitude 79°25’54’ to 78°52’45’ and fall in the rain shadow region of the Deccan and semi-arid tracts of Telangana of Medak district. The Medak district comprises of eight revenue divisions, and the study area Gajwel forms one of the revenue divisions. It is located in the southeastern part of the district bordering Nalgonda district in the southeast, Warangal district in northeast and Ranga Reddy district in the south. The area under investigation is one of the backward areas of Andhra Pradesh and falls in the topo sheet No. 56 K/5, 6, 9, 10, 13 and 14 and J/12 of Survey of India (Figs. 1 and 2).

Physiographically the study area comprises of rugged in SE and SW parts and plain in rest of the parts, and slopes generally towards northwest. The relief of the area varies between 629 meters at Nacharam and 520 meters at Mantur AMSL. The general sequence in the weathered mantle of the area is saprolith and soil cover. Soil is a natural part of earth's surface, resulting from modification of parent materials under varying conditions. The soils of the district are mainly covered with red earths comprising red sand soils, sandy loams, black cotton soils and lateritic soils (Fig. 3).

Drainage pattern refers to the particular plan or design which the individual stream courses collectively form. The drainage pattern is influenced by many factors which are extremely helpful in the interpretation of hydrological and geomorphic features, and study of them helps in understanding structural and lithologic control of land form. The area is drained by River Manjeera and its tributaries, the western half forms the part of Haldi basin and the eastern half fall within Kureli river basin. The drainage pattern of the area is of dendritic type. The present study area with the hard rock terrain is underlain by crystalline rocks of Archaean age consisting of granites and gneisses; alluvium is confined along stream courses.

Fig. 1: Location map of Gajwel taluk, Medak dist., A.P.

The average annual rainfall of the area is about 782.46 mm. It is found that the rainfall is highly variable and erratic resulting sometimes in famines. The temperature ranges between 44.5°C and 6°C, the relative humidity between 82.8% and 23.4%, and the wind velocity between 7.2 km and 3.14 km.

MATERIALS AND METHODS

Knowledge of chemical quality of groundwater is important since the presence of certain chemical constituents may make the groundwater unfit for agricultural use. The suitability of groundwater for agriculture is contingent on the effects of the mineral constituents of water on both the plants and the soil (Richards 1954, Wilcox 1955). Different chemical constituents present in the water may harm plant growth physically by limiting the uptake of water through modification of osmotic processes or chemically by metabolic reactions such as those caused by toxic constituents. Effects of salts on soil, causing changes in soil structure, permeability and aeration, indirectly affect plant growth (Ayers 1977). Specific limits of permissible salt concentrations for irrigation water cannot be stated because of the vide variations in salinity tolerance among different plants; however, field plot studies of crops grown on soils that are artificially adjusted to various salinity levels provide valuable information relating to salt tolerance (Todd 1980).

An important factor allied to the relation of crop growth to water quality is drainage. If the soil is open and well drained, crops may be grown on it with the application of generous amounts of saline

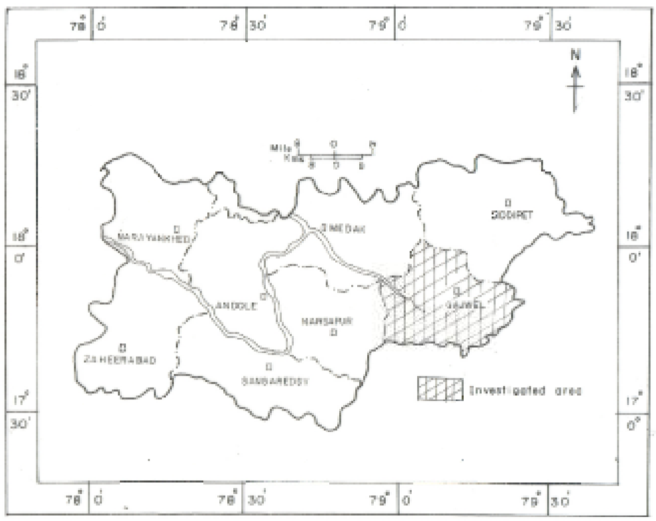

Fig. 2: Location map of Gajwel taluk.

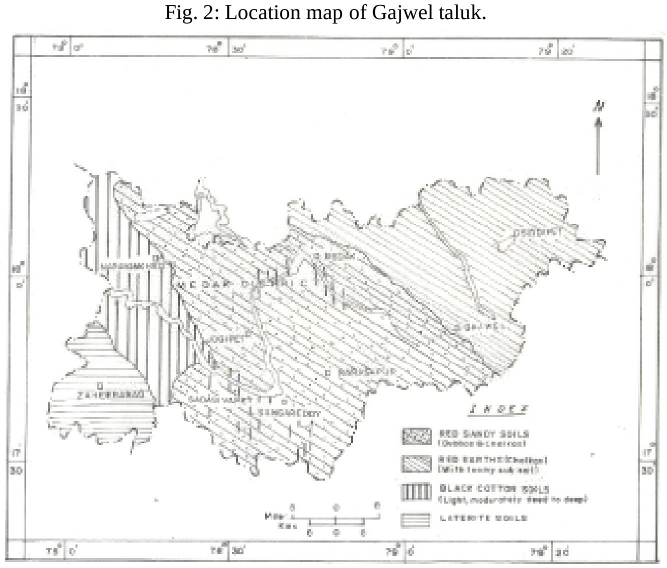

Fig. 3: Soil map of Medak district.

water; but, on the other hand, a poorly drained area combined with application of good quality water may fail to produce a satisfactory crop. Poor drainage permits salt concentration in the root zone to build up toxic proportion (Todd 1980). The necessity of adequate drainage is clearly recognized in order to maintain a favourable salt balance, where the total dissolved solids brought to the land annually by irrigation water is less than the total solids carried away annually by drainage water. It is believed that this factor accounted for the failure of many of the elaborate irrigation systems.

In order to understand the general variation in groundwater chemistry over the study area, a well inventory survey was carried out and the data were used to select the representative wells for groundwater sampling. Sampling wells were selected in such a way that they represent different geological formations as well as pattern at varying topography of the study area.

Thirty five representative groundwater samples were collected following the procedure of Rainwater & Thatcher (1960) and Brown et al. (1974) and were chemically analysed for major ions following the methods of APHA (1980). Different parameters were computed for agricultural suitability, and are given in Table 1. Different parameters were calculated to evaluate the suitability of groundwater for irrigation purpose, as the area under investigation is deficient in surface water resources and also experiences serious water shortages owing to the vagaries of the monsoon.

As agriculture is the only source of income for the people of the area, the hydrochemical data and chemical parameters were computed to evaluate the groundwater quality for agricultural purpose through different graphical methods such as Permeability Index (PI), Doneen (1962), Wilcox (1948), Richards (USSL) (1954), Piper (1953), Ayers classification (1977), Kelley's Index (1940), Residual sodium carbonate (RSC), Eaton (1950), and Magnesium ratio (MR).

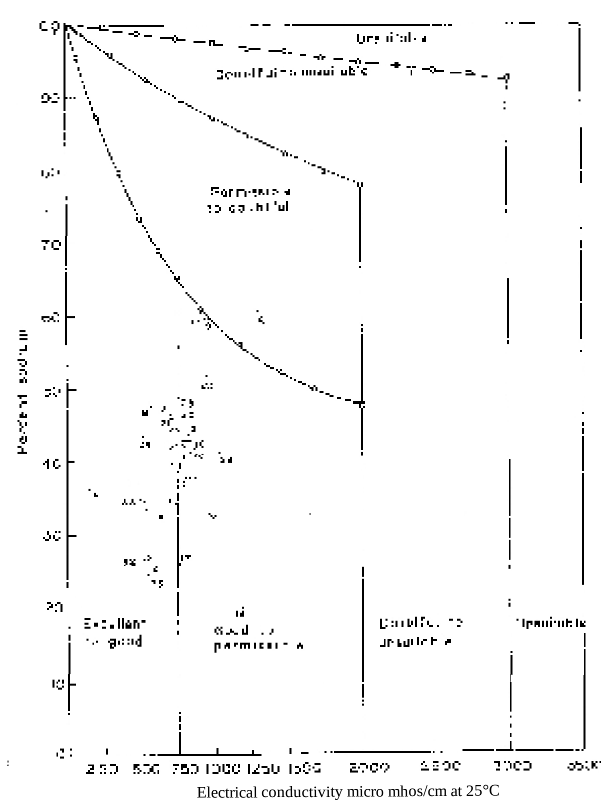

Fig. 4: Classification of irrigation water in Gajwel taluk. Total concentration, epm (after Wilcox 1948).

RESULTS AND DISCUSSION

Assessment of suitability of groundwater for irrigation requires consideration of the total dissolved solids and the concentration of any substance that may be toxic to plants and the relative amount of certain constituents. The following are the important characteristic properties of groundwater to determine its suitability for irrigation purpose in the present study.

Percentage of sodium (%Na): In all natural waters percent sodium content is a parameter to assess it suitability for agricultural purposes (Wilcox 1948).

Sodium combining with carbonate can lead to the formation of alkaline soils, while sodium combining with chloride and sulphate from saline soils. Both these soils do not help growth of plants. A maximum of 60% sodium in groundwater is allowed for agricultural purposes (Ramakrishna 1998).

The chemical quality of water samples was studied with reference to % Na vis a vis specific conductance on the Wilcox diagram (Fig. 4). Of the total samples analysed, all the samples fall in the category of excellent to good and good to permissible limits except one sample which is in the category of permissible to doubtful, indicating that the groundwater of the area is suitable for irrigation purposes.

US Salinity Laboratory Diagram (USSL): Sodium concentration in groundwater is important since

Table 1: Values of various parameters in groundwaters for gricultural suitability.

S.No.	TDS	EC μS/cm	SAR	%Na	RSC	KI	PI	HCO_3	Cl	SO_4	MR
1	320	490	1.85	36.55	0.25	0.57	64.77	5.51	30	TR	46.96
2	356	550	0.93	24.51	0.83	0.32	64.2	5.11	30	TR	66.82
3	340	515	1.53	34.37	1.03	0.53	68.3	5.31	22	TR	51.09
4	440	690	1.45	32.99	1.13	0.49	55.72	5.31	26	TR	52.39
5	410	515	1.2	26.36	0.98	0.34	53.18	5.11	30	TR	65.85
6	850	132	2.35	36.16	1.05	0.56	56.35	7.67	180	TR	45.99
7	610	970	1.73	32.33	2.04	0.47	53.82	4.72	125	TR	61.09
8	530	805	1.7	36.51	1.8	0.53	59.92	3.93	64	TR	72.12
9	580	980	3.69	59.9	2.54	1.47	30.08	5.7	70	TR	92.37
10	510	750	1.65	33.66	0.76	0.5	59.76	4.72	80	TR	53.47
11	610	960	3.91	59.47	2.46	1.45	86.87	6.1	100	TR	36.26
12	970	1300	3.9	60.65	4.38	1.43	94.09	7.87	160	TR	34.35
13	490	760	7.71	78.71	3.65	3.65	98.26	5.9	124	TR	64.44
14	440	770	2.05	41.1	0.02	0.66	67.67	4.92	88	TR	73.33
15	470	750	2.22	42.29	3.12	0.75	23.46	7.47	50	TR	9.96
16	590	860	2.43	41.85	2.54	0.79	69.8	8.26	68	TR	70.1
17	490	760	1.15	25.35	0.23	0.32	53.75	6.13	100	TR	30.97
18	420	580	2.06	47.72	1.22	0.69	72.39	5.7	52	TR	64.29
19	780	1200	2.58	20.12	-1.43	0.66	59.62	6.1	68	TR	80.88
20	660	1060	2.5	41.05	-0.72	0.69	62.49	5.9	180	TR	33.53
21	440	715	2.59	46.1	1.13	0.82	73.13	6.1	138	TR	26.16
22	230	960	3.3	51.67	3.72	1.04	80.32	8.65	52	TR	59.43
23	360	525	2.01	43.23	1.23	0.74	77.1	4.92	44	TR	56.64
24	410	760	2.37	40.01	1.18	0.77	72.61	5.9	80	TR	39.16
25	465	765	2.39	48.26	1.68	0.89	80.15	5.24	101	TR	69.75
26	585	860	2.38	41.37	2.29	0.69	69.5	8.19	60	TR	60.06
27	259	851	2.38	41.55	2.35	0.7	69.98	8.16	69	TR	71.77
28	360	825	2.02	43.5	1.27	0.75	77.59	4.92	43	TR	57.53
29	265	758	2.29	43.23	2.52	0.82	80.99	6.39	61	TR	58.66
30	440	783	2.56	46.02	1.22	0.82	72.36	6.1	138	TR	26.43
31	440	706	2.61	46.51	1.17	0.84	72.96	6.06	113	TR	29.8
32	415	510	1.18	26.25	-0.88	0.34	53.4	5.16	29	TR	65.56
33	335	500	1.56	34.86	1.02	0.53	69.09	5.34	29	TR	48.07
34	525	800	1.73	36.96	-1.2	0.52	60.23	3.9	63	TR	72.35
35	355	550	0.9	23.98	0.85	0.31	63.93	5.13	30	TR	66.82

TDS: Total Dissolved Solids; EC: Electrical Conductance; SAR: Sodium Adsorption Ratio; % Na: Percent Sodium RSC: Residual Sodium Carbonate; KI: Kelley's Index; PI: Permeability Index; MR: Magnesium Ratio

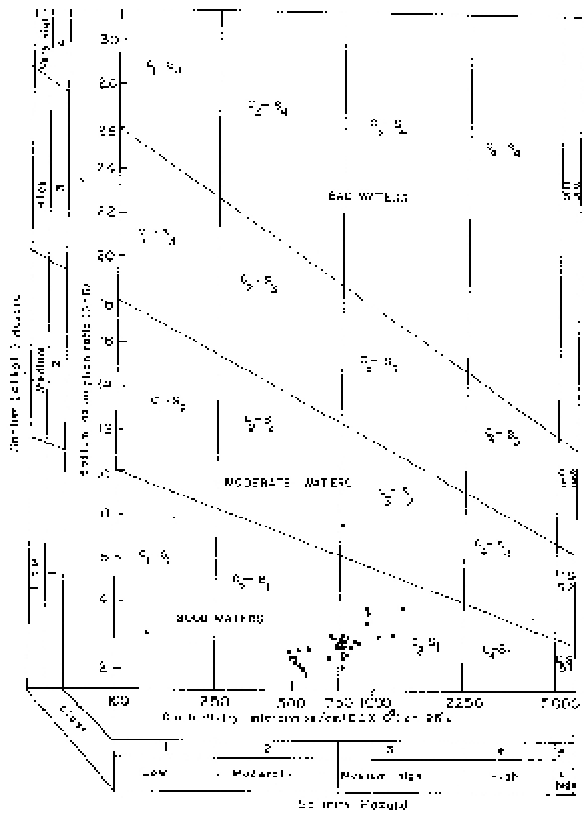

Fig. 5: USSL Salinity classification.

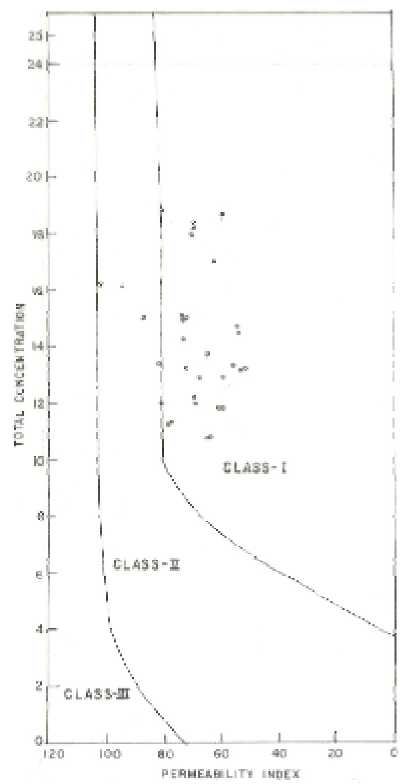

Fig. 6: Classification of irrigation water (Doneen 1964).

increase of sodium concentration in water affect deterioration of the soil properties reducing permeability (Kelley 1951, Tijani 1994, Pandian & Sankar 2007). The processes leading to cation exchange reactions in soil may be studied from sodium adsorption ratio (U.S. Salinity Laboratory 1954). Sodium adsorbed on clay surface as substitute for calcium and magnesium may damage the soil structure making it compact and impervious. USSL diagram based on SAR vis a vis specific conductance values, the two most significant parameters of sodium and salinity hazards, indicate usability of groundwater for agricultural purposes. According to USSL diagram (Fig. 5), different categories are demarcated in terms of salinity hazards and sodium hazards. On the basis of USSL classification of groundwater in the study area, the water samples fall within C2-S1 and C3-S1 categories, i.e., medium salinity and low sodium water and high salinity and low sodium waters indicating that the groundwater is of good quality for irrigational purposes.

Sodium Adsorption Ratio (SAR): Classification of water with reference to SAR (Herman Bouwer 1978, Todd 1980) is presented in Tables 2 and 3. According to Herman Bouwer and Todd classification almost all the samples are of excellent quality for irrigation.

Residual Sodium Carbonate (RSC): The water having excess of carbonate and bicarbonate concentration over the alkaline earths, mainly calcium and magnesium, in excess of allowable limits affects agriculture unfavourably (Eaton 1950, Richards 1954). On the basis of RSC composition the groundwater of the area has been classified and presented in Tables 4 and 5.

Table 2: Classification of sodium adsorption ratio in groundwater (Herman Bouwer 1978).

SAR	Water Quality	% of Samples
0-6	No problems	97.2
6-9	Increasing problems	2.8
>9	Severe problems	Nil

Table 3: Classification of sodium adsorption ratio in groundwater (Todd 1980).

SAR	Water Class	% of Samples
10	Excellent	All samples
10-18	Good	Nil
8-26	Fair	Nil
>26	Poor	Nil

Table 4: Classification of RSC in Groundwater (Eaton 1950).

RSC	Water Class	% of Samples
< 1.25	Safe	60
1.25-2.5	Marginal Quality	29
>2.5	Not suitable	11

Table 5: Classification of RSC in Groundwater (Richards 1954).

RSC	Water Class	% of Samples
<1.25	Good	60
1.25-2.5	Medium	29
>2.5	Bad	11

Table 4 shows that 60% of samples are safe, 29% are marginally suitable for agriculture, and 11% are unsuitable for irrigating low tolerant crops. Table 5 indicates that 60% of samples are of good quality, 29% of medium, and 11% unsuitable for irrigating low tolerant crops.

Kelley's Index (KI): The ratio of the Na to Ca + Mg reflects the alkali hazard of the waters. Kelley (1940) stated that for the good water, this index is equal to or less than one. In the present study only four samples have an index value more than one indicating the alkali hazard. Out of these four samples, three samples (S.No. 9, 11, 12) have index value less than 1.5 whereas one sample (S.No:13) has high index value of 3.65. All these sample locations are nearer to each other. 89% of samples under consideration have an index value of less than one indicating that the alkali hazard is not present and these waters can be used for irrigation.

Piper Trilinear Plotting (PTP): The chemical data obtained from the groundwater samples and on the basis of Piper (1953), the groundwater is classified as carbonate hardness, i.e., secondary alkalinity and the chemical properties of the groundwater are dominated by alkaline earths and weak acids and some samples show that no cation and anion pair exceeds fifty percent.

Magnesium Ratio (MR): It may be described as the excess amount where otherwise generally calcium and magnesium will be in condition of equilibrium (Das et al. 1988). Excess of magnesium affects the quality of soils which is the cause of poor yield of crops. Magnesium ratio of groundwater

Table 6: Classification of groundwaters for agriculture use (Ayers and Westcot 1985).

Potential irrigation problem	Units	Degree of restriction on use			No. of Samples in Study area		
		None (N)	Slight to moderate (SL-MD)	Severe (S)	N	SL-MD	S
Salinity (Affects water availability to plants) EC	µS/cm	< 700	700-3000	> 3000	11	24	-
TDS	mg/L	< 450	450-2000	> 2000	19	16	-
Infiltration (Affects infiltration rate of water into the soil)SAR	SAR	0 - 3	3 - 6	6 - 12	30	4	-
Specific ion toxicity (Affects sensitive crops) Sodium (Na)	me/L	< 3	3 - 9	> 9	14	21	-
Chloride (Cl)	me/L	4	4-10	> 10	32	3	-
Nitrate (NO_3)	mg/L	< 22.5	22.5-135	> 135	35	-	-

in the investigated area ranges from 9.96 to 92.37. Of the total samples analysed, 66% of the samples account for more than 50% of magnesium ratio, out of which 17% of the samples are just above 50% (Table 1).

Permeability Index (PI): The classification of groundwater has been attempted for irrigation on the basis of the Permeability Index (PI) (Doneen 1964, Domenico & Schwartz 1990). According to PI diagram the groundwater may be divided into three classes, Class-I, Class-II and Class-III types. Nearly 90% of groundwater samples of the study area fall in Class-I category. Except one, remaining all samples fall in Class-II category indicating that the groundwater is of good quality for irrigation purposes based on Permeability Index (Fig. 6).

Ayers Classification: Ayers and Westcot (1985) proposed modified water quality guidelines to assess the agricultural water quality. In the proposed guidelines, they have classified and grouped the water quality into four categories, namely salinity, water infiltration, specific ion toxicity and miscellaneous effects. Each of the water quality problems has been further classified into the following three categories based upon the degree of restriction on their use.

1. None restriction category.
2. Slight to moderate restriction category.
3. Severe restriction category.

As per the guidelines of Ayers & Westcot (1985), nitrate concentration up to 22.5mg/L cause no toxic effect, while concentration above 22.5 up to 135 mg/L causes slight to moderate toxicity, and above 135 mg/L nitrate concentration has severe restriction on irrigational use. In the present study, the nitrate concentration varies from 0.8 to 8.8 mg/L (Table 1). The water quality guidelines for agriculture (Ayers and Westcot 1985) criteria clearly indicate that these waters have no restriction with respective to sensitive crops. Different parameters for suitability of groundwater of the study area are given in Table 6.

CONCLUSION

The chemical composition of dissolved constituents in the groundwater determines its quality for agricultural purpose. The quality of water is an important consideration in appraisal of salinities or alkali conditions in an irrigated area. The groundwater of the study area shows that the alkaline earths (Ca^{++} and Mg^{++}) exceed alkalis (Na^{+} and K^{+}), weak acids (HCO_3^- and CO_3^{-2}) exceed strong acids (SO_4^{-2}, Cl^- and NO_3^-). Carbonate hardness exceeds 50% and also at some places none of the cation and anion pairs exceeds 50%. The hydrochemical parameters of the study area, when compared with different guidelines and standards for agricultural suitability like Wilcox, show that the waters are of excellent to good and good to permissible quality. On the basis of U.S. Salinity laboratory classification and Herman Bouwer with reference to SAR, the water samples fall under medium to high salinity and low sodium (good waters) and no problem category. Almost all samples indicate that alkali hazard is not there if these waters are used for irrigation even for low tolerance crops. Based on permeability indices and Ayers classification, the groundwaters of Gajwel are excellent for agricultural purposes. Overall the groundwater quality of the study area is good for agriculture purposes.

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