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Research Article

ASSESSMENT OF GROUNDWATER QUALITY FOR DRINKING AND IRRIGATION USE IN THE GABHARU RIVER BASIN, NORTH-EAST INDIA

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ABSTRACT

The present study focuses on the hydrochemistry of groundwater in parts of Gabharu river basin to assess the quality of groundwater for determining its suitability for drinking and agricultural purposes. A total of 23 ground water samples were collected randomly from open wells and analyzed for major cations and anions. The groundwater samples exhibit pH, Electrical Conductivity (EC), Total Dissolved Solids(TDS), Potassium(K) and Iron(Fe) concentrations above the stipulated guideline values. The Piper classification for hydrochemical facies shows dominance of Ca-Mg-HCO_3 facies, indicating earliest phase of evolution of groundwater system. Sodium absorption ratio(SAR), percent sodium(%Na), permeability index(PI), Kelly's ratio have been studied to evaluate suitability of irrigation use. The calculated values of PI indicate that the water for irrigation uses ranges between good to bad quality. As per Wilcox's diagram and US salinity laboratory classification, most of the groundwater samples are suitable for irrigation purposes.

INTRODUCTION

Groundwater is one of the primary resources available on earth. Groundwater is essential for drinking, domestic, agricultural and other activities in daily life of humankind. Groundwater is constituted of various dissolved minerals, some of which are useful for the soil and plants whereas some may pose as threat to them. Effects of salts on soils, causing changes in soil structure, permeability and aeration, indirectly affect plant growth (Todd, 1980). A qualitative assessment of groundwater quality is therefore important to know whether the groundwater in a certain area is suitable for use or not. In specifying the quality characteristcs of groundwater, chemical, physical and biological analyses are normally required (Todd, 1980). The Gabharu river basin is a fertile area where intense agricultural activities are seen. Since groundwater is the prime source of water in this region, the understanding of hydrochemical reactions in shallow aquifer waters is necessary.

Study Area

The Gabharu river basin is a tributary basin of the river Brahmaputra lying on the northern side of the Brahmaputra river. It is a sixth order basin lying partly in the West Kameng district of Arunachal Pradesh and partly in the Sonitpur district of Assam. The Gabharu river originates from the west Kameng district of Arunachal Pradesh and flows down for about 52 km along a NNW-SSE course through the alluvial plains of Sonitpur distriict before meeting the Brahmaputra near Gabharumukh.

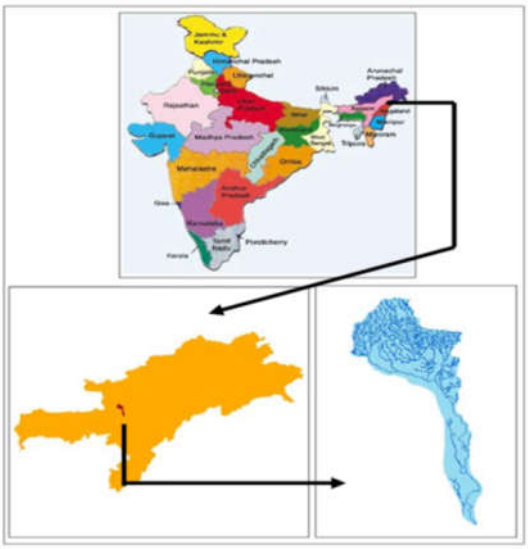

Fig 1 Location of Gabharu river basin

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Geologically the area is constituted of the Siwaliks in the upper catchment whereas the lower part is constituted of the Quaternary. There is also the presence of granite inselbergs in the south near the Brahmaputra. The inselbergs comprise feldspathic gneisses and gneissic granite rocks. The Quaternary formation consists of mainly unconsolidated sediments which can be subdivided into older and younger alluvium.

MATERIALS AND METHODS

A total of twenty three groundwater samples were collected during the pre-monsoon season (2015). The samples were collected in PET bottles from dug wells. Standard laboratory methods were used for the determination of physical and chemical characteristics of the groundwater samples. To determine the suitability for drinking water, the standard guideline values recommended by the World Health Organisation (WHO,2011) for drinking water purposes was compared with parameters of groundwater samples in the study area. For determination of suitability for irrigation use SAR, % Na and PI were calculated and plotted on C-S diagram (Richards,1954), Wilcox diagram(1955) and Doneen diagram(1961;1964) respectively. Together with these, Mg hazard and Kelly's ratio were also taken into consideration. For analysis of hydrochemical facies, Piper plot was used.

Concentrations of ions like calcium(Ca^{2+}), magnesium(Mg^{2+}), sodium(Na^{+}), potassium(K^{+}), chloride(Cl^{-}), bicarbonate(HCO_3^{-}) and sulphate(SO_4^{2-}) were determined for identification of hydrochemical facies.

Table 1 Classification of groundwater into different hydrochemical facies

Hydrochemical Facies	Sample location number
Ca-Mg-HCO_3	1,2,3,5,6,7,8,9,10,11,12,13,14,19,20,21,22,23
Ca-Mg-Cl-SO_4	1,2,3,5,6,7,9,11,13,19,20,22,23
Na-K-HCO_3	4,8,10,11,15,16,17,18,21
Na-K-Cl-SO_4	4,15,16.17,18

RESULTS

Hydrochemical Facies

Analysis of hydrochemical facies is done by using Piper plot (Piper,1953).

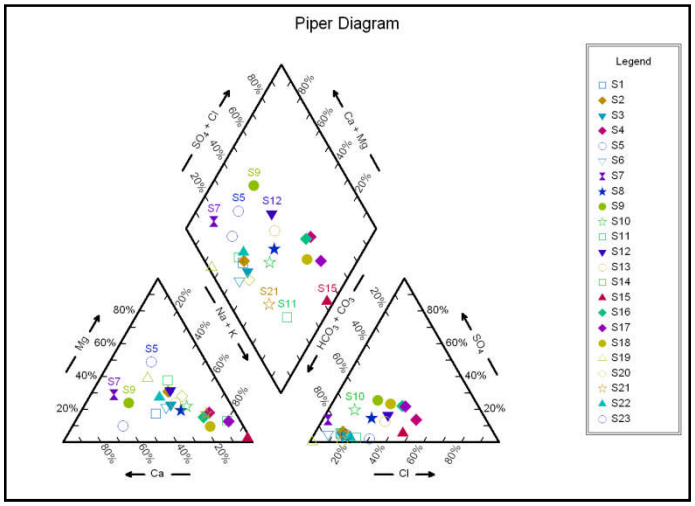

Fig 2 Piper diagram for classification of groundwater into different hydrochemical facies

The Piper plot (Fig 2) reveals four hydrochemical facies (Ca-Mg-HCO_3, Ca-Mg-Cl-SO_4, Na-K-HCO_3 and Na-K-Cl-SO_4) (Table 1). Out of these Ca-Mg-HCO_3 facies dominates the basin. It reflects the earliest phase of evolution of groundwater system and depicts groundwater of recharge zone.

Groundwater Quality for drinking purposes

The results of the physiochemical analysis of groundwater of the study area as compared with the standard guideline values recommended by the World Health Organisation (WHO,2011) for drinking water purposes is given in Table 3.

Table 2 Chemical analysis results of groundwater samples of Gabharu river basin

Sample No.	pH	EC	TDS	Hardness	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	HCO3	Fluoride	Iron
		(µS/cm)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
1	7.4	374.8	346	104	29.6	7.3	29.07	5.98	14	6	107.36	0.11	0.04
2	6.8	302.7	279.2	94	18.4	11.7	18.77	18.08	16	9	122	0.32	0.02
3	6.92	83.02	77.05	24	5.6	2.4	7.92	2.24	6	2	43.9	0.06	0.07
4	6.92	539.6	498.6	82	14.4	11.2	70.17	19.15	68	25	70.76	0.06	0.14
5	6.17	88.97	84.52	32	4.8	4.9	3.62	1.12	12	1	36.6	0.11	0.09
6	6.65	407.9	376.4	118	29.6	10.7	33.11	17.08	10	8	158.6	0.06	0.15
7	6.4	185.6	171.2	98	26.4	7.8	3.53	5.05	2	11	70.76	0.11	0.4
8	5.93	241.9	223.8	50	12	4.9	20.8	8.46	12	9	39.04	0.15	3
9	6.5	257.7	238	76	36	9.7	4.85	21.92	16	23	48.8	0.26	0.04
10	5.86	153.3	141.7	34	7.2	3.9	14.8	6.87	6	11	39.04	0.21	0.14
11	6.3	1170	1082	74	10.4	11.7	109.29	50.54	20	3	87.84	0.41	14
12	6.26	425.1	392.7	102	19.2	13.18	13.44	32.53	38	25	80.52	0.32	0.24
13	6.73	334.4	309.1	84	18.4	9.3	25.01	17.08	40	20	90.28	0.26	4.4
14	6.28	144.9	133.9	44	7.2	6.3	9.83	3.18	6	3	48.8	0.26	18
15	6.11	255.9	236.7	2	0.32	0.3	7.56	32.36	32	5	46.36	0.11	1.56
16	6.5	646.1	597.3	76	16.8	8.3	41.67	48.56	70	54	102.5	0.11	1
17	5.74	249.5	230.4	18	2.4	2.9	21.29	24.18	18	13	24.4	0.06	0.08
18	6.4	786.6	727	80	20.8	6.8	37.35	107.8	38	38	78.08	0.15	0.02
19	7	117.9	109	50	9.6	6.3	5.25	4.52	1	0	82.96	0.2	0.02
20	7.3	352.1	325.4	66	12	8.8	24.03	9.03	14	0	92.72	0.11	1.5
21	6.1	353.9	327.1	50	9.6	6.3	18.13	48.42	12	5	85.4	0.11	0.06
22	6.26	147.5	136.2	60	13.6	6.3	5.31	19.16	16	3	85.4	0.26	12
23	6.79	256.2	236.8	90	31.2	2.9	12.02	5.53	18	6	112.24	0.15	0.6

It is observed from the table that 47.82%, 17.39%, 13%, 56.52% and 26% of the samples show pH, EC, TDS, Potassium and Iron values above the stipulated guideline values and these concentrations in drinking water are below health concern. All the groundwater samples, however have Sodium, Magnesium, Calcium, Bicarbonate, Chloride, Sulphate, Fluoride and Total hardness concentrations below the stipulated guideline values for drinking water.

Table 3 Analysis of groundwater for drinking purposes as recommended by WHO (2011).

Parameters	Range of values measured	WHO(2011) guideline value(mg/l)	No.of samples above stipulated value
pH	5.74-7.4	6.5-8.5	11
EC (µS/cm)	83.02-1170	500	4
TDS (mg/l)	77.05-1082	500	3
Sodium (mg/l)	3.53-109.29	200	0
Potassium (mg/l)	1.12-107.8	12	13
Magnesium (mg/l)	0.3-13.18	50	0
Calcium (mg/l)	0.32-31.2	75	0
Bicarbonate (mg/l)	24.4-158.6	500	0
Chloride (mg/l)	1.00-70	250	0
Sulphate (mg/l)	0-54	250	0
Fluoride (mg/l)	0.06-0.32	15	0
Iron (mg/l)	0.02-18	0.3	6
Total Hardness (mg/l)	2-118	500	0

Groundwater quality for determination of irrigation use

Sodium absorption ratio

One of the methods of determining the suitability for agriculture use is, Sodium adsorption ratio (SAR); because it has a direct relation to the adsorption of sodium by soil (Todd,1980). It is defined as-

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

where the concentrations of the constituents are expressed in milli-equivalents per liter.

SAR values of the groundwater samples ranges from 0.15 to 5.52. The plotting of SAR values in the U.S.Salinity diagram (Fig 3) for classification of irrigation water (USSL,1954), shows that the groundwaters fall in the field of C1-S1, C2-S1, C3-S1 indicating low sodium hazard except one groundwater sample that lie in C3-S2 field indicating medium sodium hazard.

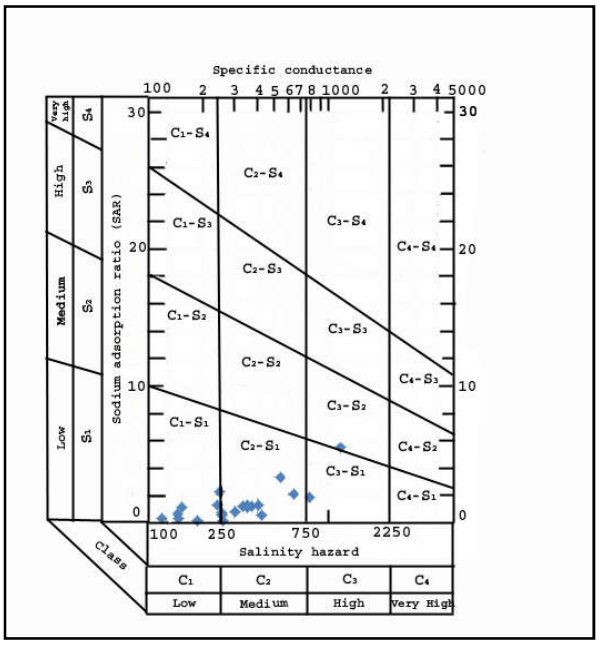

Fig 3 USSL diagram for classification of groundwater quality

Percent Sodium

Sodium concentrations reacts with soil to reduce its permeability (Todd,1980). Sodium content is usually expressed in terms of percent sodium (also known as sodium percentage), defined by-

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

where the concentrations of the constituents are expressed in milli-equivalents per liter.

%Na values in the samples ranges from 12.61% to 96.61%. Percent sodium values indicates that groundwater samples 5,7,9,19 and 23 which have percent sodium values less than 35%, are suitable for irrigation purposes. Percent sodium plotted on Wilcox diagram (Fig 4) shows that out of 23 samples, 20 samples belong to very good to good water category, 2 samples belong to permissible to doubtful category and one sample belong to doubtful to unsuitable category.

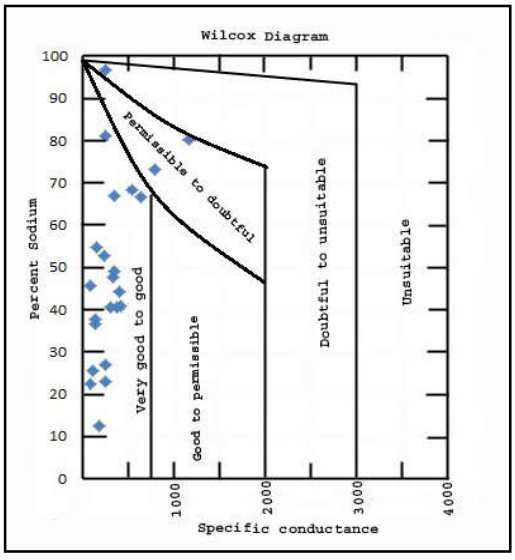

Fig 4 Wilcox diagram for classification of groundwater quality

Table 4 Classification of groundwater samples based on percent sodium in Gabharu river basin

% Na	Water class	Sample location number
< 20	Excellent	7
20-40	Good	5,9,14,19,22,23
40-60	Permissible	1,2,3,6,8,10,12,13,20
60-80	Doubtful	4,16,18,21
>80	Unsuitable	11,15,17

Permeability index (PI)

Permeability index (Doneen,1964) has been used as an important parameter for determination of suitability for groundwater in irrigation use. It is defined as -

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

Where, the concentrations of the constituents are expressed in milli-equivalents per liter.

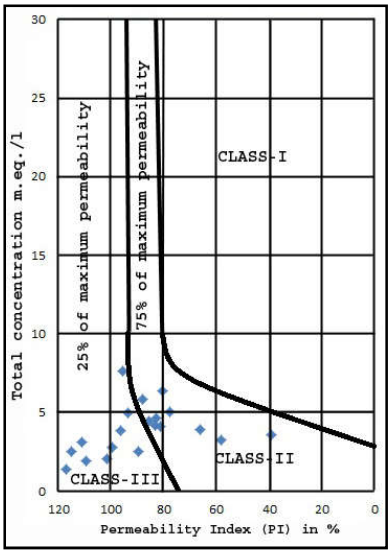

Fig 5 Doneen's diagram for classification of groundwater quality

Permeability index values plotted on Doneen diagram (Fig 5) shows that 50% of the groundwater samples fall in Class-II and the other 50% samples fall in Class-III categories. The waters of Classes I and II are generally good for irrigation purposes.

Table 5 Classification of groundwater samples based on permeability index in Gabharu river basin

Water class	Sample location number	Type of water
Class-I	Nil	Very good water, >75% of maximum soil permeable.
Class-II	1,2,4,6,7,9,12,13,18,23	Good water, 75% of maximum soil permeable.
Class-III	3,5,8,10,11,14,15,16,17, 19,20,21,22	Bad water, 25% of maximum soil permeable.

Kelly's Ratio

Sodium measured against Calcium and Magnesium was considered by (Kelly, 1957) to classify waters for irrigation. Water with the Kelly's ratio less than one is suitable for irrigation, while those with a ratio more than two are unsuitable for irrigation. As per the Kelly's ratio water from the study area are categorized into suitable if KR is <1, marginal, when KR is 1-2 and unsuitable if KR is >2. The majority of groundwater samples are suitable except sample numbers 11, 15 and 17 which are unsuitable for irrigation (Table 6).

Table 6 Classification of groundwater samples based on Kelly's ratio in Gabharu river basin

Kelly's Ratio	Category	Sample location number
< 1	Suitable	1,2,3,5,6,7,8,9,10,12,13,14,19,20,21,22,23
1-2	Marginal	4,16,18
>2	Unsuitable	11,15, 17

Table 7 Irrigation water quality parameters

Sample No.	SAR	Na%	PI	Kelly's Ratio
1	1.25	40.55	77.47	0.61
2	0.85	40.47	82.83	0.43
3	0.73	45.72	147.5	0.73
4	3.35	68.35	88.03	1.87
5	0.28	22.45	116.66	0.23
6	1.33	44.32	80.21	0.61
7	0.15	12.61	58.09	0.07
8	1.27	52.8	89.41	0.91
9	0.18	22.92	39.06	0.08
10	1.11	54.64	109.16	0.95
11	5.52	80.32	95.49	3.23
12	0.58	40.95	65.9	0.28
13	1.19	47.52	83.27	0.64
14	0.65	36.71	101.56	0.48
15	0.74	96.61	337.14	10.66
16	2.08	66.75	93.37	1.19
17	2.25	81.16	122.22	2.71
18	1.84	73.28	85.62	1.02
19	0.32	25.64	115	0.22
20	1.29	49.1	96.17	0.79
21	1.11	67.02	110.79	0.79
22	0.3	37.59	99.29	0.19
23	0.55	27	81.3	0.29

CONCLUSION

The study provides significant information on ground water quality in parts of Gabharu river basin. According to the WHO (2011) guideline for drinking water purposes, the studied parameters present in the groundwater samples occurs at concentrations well below those of health-concern. SAR values ranges from 0.15 to 3.35mg/l and the water falls in C_1S_1,C_2S_1 and C_3S_1 fields indicating good category for irrigation use. Based on the Wilcox classification, the water samples belong to very good to permissible category for irrigation use. Permeability index values plotted on Doneen diagram shows that 50% of the groundwater samples fall in Class-II and the other 50% samples fall in Class-III categories, indicating that some of the waters are not good for irrigation. Kelly's ratio results shows that most of the samples are good to marginal category for irrigation purposes. Thus the overall groundwater quality in the basin is permissible for irrigation use.

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