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Hydro-chemical Characteristics and Evaluation of Groundwater Suitability for Irrigation Use in the Interfluves of the Rivers Brahmaputra and Kolong, Assam

Abstract

In the present study an attempt has been made to understand the hydro-chemical characteristics of groundwater in the area and its suitability for irrigation use. Groundwater chemistry in the study area is dominated by Ca followed by Mg>Na>K. The order of abundance in anionic chemistry is HCO_3>Cl>SO_4.The integration of SAR and EC, and, integration of Na % and TDS shows that groundwater in the study area is suitable for irrigation. In some locations, MAR content in groundwater is more than 50%, which may affect the crop yield. Permeability index in three locations in pre-monsoon season were found as unsuitable for irrigation purposes.

Keywords: Groundwater, Irrigation, Interfluves.

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Introduction

Groundwater plays an important role in irrigation. In the study area, most of the people depend on agriculture for their livelihood and groundwater forms the primary source of water for irrigation. The area makes a significant contribution to the state's agricultural productions.

Study Area

The study area, spreading over 2100 sq km, is centrally located in Assam and comprises of parts of two districts Nagaon and Morigaon. It is bounded by the rivers Brahmaputra at the north and Kolong at the south (Figure1). The area falls between 26º9'21" to 26º37'17"N latitudes and 91º57'6" to 93º4'46"E longitudes.

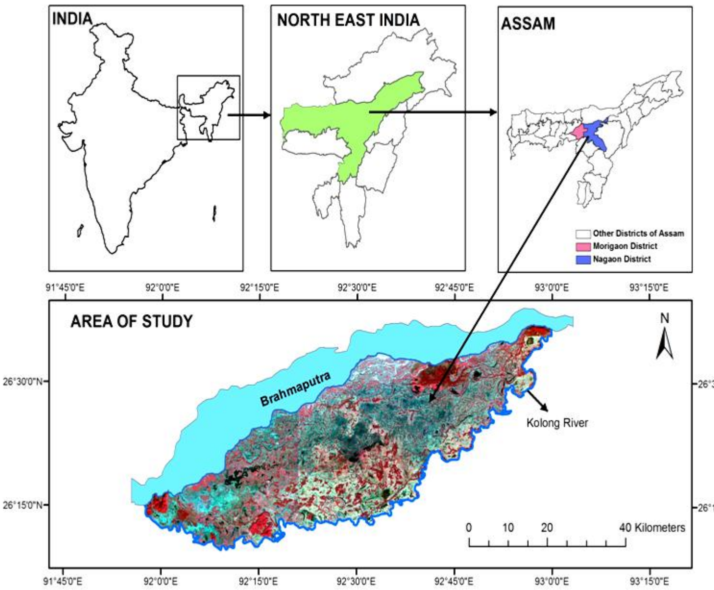


Figure 1: Location Map of the Study Area

Geology

Geologically the area is underlain by unconsolidated alluvial sediments deposited on a granite basement which outcrops as inselbergs within the alluvial terrain (Figure 2). The slope of the basement gradually steepened from south to north, towards the river Brahmaputra.

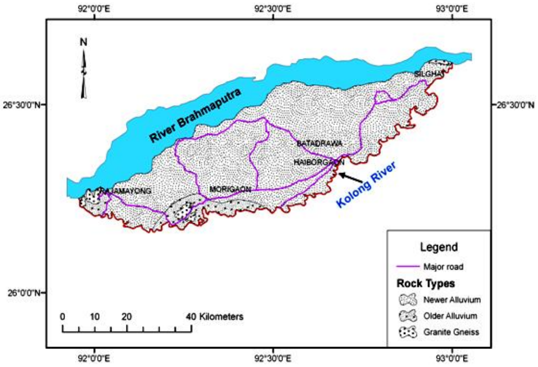


Figure 2: Rock types in the Study Area

Hydrogeology

Groundwater in the area occurs under unconfined to semi-confined conditions. The depth to water level varies between 3.35 m and 7.16 m in Pre-monsoon and from 1.66 m to 5.60 m in post-monsoon. In a major part of the study area groundwater fluctuations remain within 1.5 m to 2 m.

Objective of the study

The present study is aimed at defining the hydro-chemical characteristics in terms of major ion chemistry of groundwater occurring in shallow subsurface zones and assessment of suitability of groundwater for irrigation purpose in the area. The resultant database will be of enormous use in taking site specific necessary measures for the sustainable development of groundwater resources in the area.

Review of Literature

In India, more than 50% of total irrigated area is dependent on groundwater (CWC, 2000) and approximately 60% of irrigated food production depends on irrigation from groundwater (Shah et al., 2000). Hydrochemical investigation and groundwater quality assessment have been studied in many places in India like Pratapgarh District, Uttar Pradesh by Tiwary and Singh (2014); in the Vaippar River Basin, Tamil Nadu by Pandian and Sankar (2007). Assessment of groundwater quality index for Jimeta-Yola area, Northeastern Nigeria has been studied by Ishaku, J.M. (2011). Eaton (1950), Kelley (1951), Richards (1954) and Wilcox (1955) have proposed certain indices by considering the individual or paired ionic concentrations, to find out the alkali hazards and Residual Sodium Carbonate (RSC). These indices can be used as criteria for finding out the suitability of water for irrigation. Quality of groundwater for irrigation purposes have been discussed by Raju et al. (2009) in the upper Pillaperu river basin in Nellore district, Andhra Pradesh.

Concept & Hypothesis

Hydro-chemical results provide a basis for the characterization of groundwater within each hydro-geological unit. With the help of this information, it is possible to draw inferences about the suitability of groundwater for various uses.

Permeability of soil is influenced by the sodium content of the irrigation water. An excess of Ca and Mg ions over Na in irrigation water inhibits 'Base Exchange' so that the soil does not lose its permeability. Sodium concentration is very important in classification of irrigation water because sodium by the process of base exchanges replaces calcium in the soil which reduces the permeability of soil. High Na% causes deflocculation and impairment of the permeability of soils (Karanth 1987).

Research Design / Database and Methodology

Groundwater samples were collected from 36 dug well and bore well locations in the study area following standard norms in both pre monsoon (April – May) and Post monsoon (November – December) seasons from the same well sites. Sample locations are plotted in Figure 3 to display their spatial distribution in the study area.

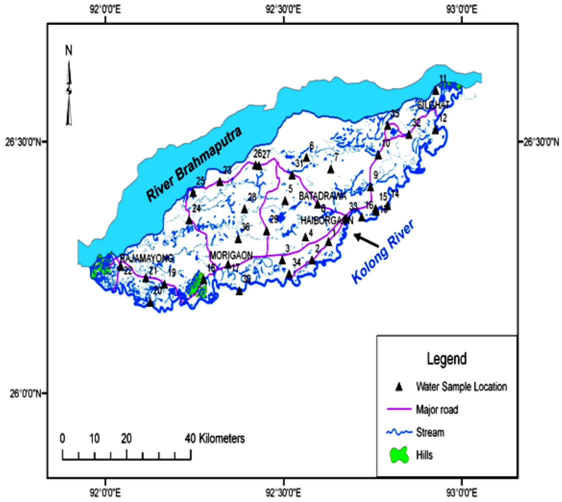


Figure 3: Map showing Groundwater Sampling Locations in The Study Area

Chemical analyses were carried out in the laboratory of Pollution Control Board, Assam, Guwahati, employing standard methods. Ions were converted from milligram per litre to milliequivalent per litre and anions balanced against cations as a control check of the reliability of the analyses results. The chemical data were plotted on Piper-tri-linear diagram (1953) for pre-and post-monsoon seasons to infer hydro-geochemical characteristics. In order to evaluate the groundwater quality for irrigation purpose, different indices for irrigation such as Electrical Conductivity (EC), Total Dissolved Solids (TDS), Sodium Adsorption Ratio (SAR), Sodium Percentage (Na%), Residual Sodium Carbonate (RSC), Magnesium Adsorption Ratio (MAR), Permeability Index (PI) and Kelly's Ratio (KR) were calculated from standard equations.

Results and Discussions

Summary of geochemical parameters for defining the hydro-chemical characteristics and the parameters determined for evaluation of irrigation water quality in the study area are presented in Table1. To find out more specific nature of ground water, Piper (1953) subdivided the central diamond into 9 areas (Figures 4).These diagrams reveal the analogies, dissimilarities and different types of waters in the study area, findings of which are presented in Table 2.

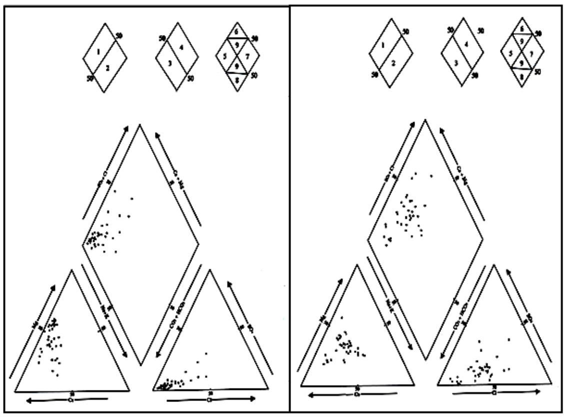


Figure 4: Piper-Trilinear Diagram showing hydrogeochemical character of groundwater (a) Pre- and (b) Post-monsoon

It has been observed from the Piper-Trilinear Diagrams (Fig. 4a&4b) that alkaline earths dominate over alkali (i.e., Ca+Mg > Na+K) and weak acidic anions exceed strong acidic anions (i.e., CO_3+HCO_3 > SO_4+Cl). Analysis of hydrochemical facies reveals that Ca-Mg-HCO_3 (alkaline Water) and Ca-Mg-Cl are the dominant hydrochemical facies with appreciable percentage of the groundwater having mixed hydrochemical facies. The groundwater chemistry is dominated by Ca followed by Mg>Na>K except in some sampling locations where Na replaces Mg in cationic abundance in post monsoon season. The order of abundance in anionic chemistry is HCO_3>Cl>SO_4 for both seasons. However, SO_4 exceeds Cl in some post monsoonal groundwater samples.

Electrical Conductance (EC)

The salinity or total concentration of soluble salts is usually measured as electrical conductivity (EC) in irrigation work and the US salinity laboratory has established guide groupings of water based on this parameter. The EC values of groundwater in most part of the study area are within the permissible limit (Table 3).

Sodium Percentage (Na %)

The sodium percentage is calculated as:

Na%= Na+K /(Ca + Mg+ Na+ K) x100

Where, all ionic constituents are expressed in meq/l.

Wilcox presented a diagram with TDS (Total Dissolved Solids) in epm as abscissa and sodium percentage (Na %) as ordinate (Figure 5)

Table1: Summary of the Geochemical Parameters

Parameter	Pre-Monsoon				Post-Monsoon			
	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD
pH	7.4	8.6	7.9	0.2	7	8	7.8	0.25
EC (µmhos/cm)	582	3600	1268.5	626.16	328	1800	810	385.25
TDS (mg/l)	372	2305	812	401.36	210	1312	538	258.65
Hardness as CaCO3	229	1550	530	320.75	116	580	293	131.35
Ca (mgl^{-})	52	320	105.2	55.2	28.8	158	69.2	32.46
Mg (mgl^{-})	16.2	240	66	49.87	6.7	72	31.7	18.87
Fe (mgl^{-})	0.1	1.3	0.48	0.34	0.08	1	0.36	0.28
Cl (mgl^{-})	16	250	55	47.66	12	232	83.4	52.58
SO_4 (mgl^{-})	7.7	232	30.4	47.31	2	204	41.1	39.89
Na (mgl^{-})	5.4	49.7	19.6	13.35	5.1	84.6	33.8	19.21
K (mgl^{-})	0.45	24.4	7.1	6.62	1.25	87.7	14.2	16.33
CO_3(mgl^{-})	0.78	6.3	2.62	1.42	0.39	4.48	1.92	0.99
HCO_3 (mgl^{-})	195	1255	524.8	266.38	101.3	854.2	257.27	169.53
NO_3 (mgl^{-})	0.1	0.6	0.254	0.145	--	--	--	--
SAR	0.04	1.05	0.38	0.268	0.18	1.84	0.841	0.408
% Na	2.64	24.69	9.981	6.462	8.18	43.15	23.22	9.25
RSC (meq/l)	-25.99	0.18	-1.98	4.49	-7.87	0.94	-1.809	1.94
MH (%)	22.91	61.62	47.33	11.31	21.47	61.58	41.44	9.08
PI (%)	12.12	52.29	36.66	9.02	26.34	70.45	49.49	11.59
KR	0.02	0.26	0.1	0.07	0.07	0.63	0.26	0.14

Table 2: Characterization of Groundwater in The Study Area Based on Piper Tri-Linear Diagram

Subdivision of the Diamond	Characteristics of corresponding subdivisions of diamond -shaped fields	Percentage of samples	
		Pre-Monsoon	Post-Monsoon
1	Alkaline earths (Ca+Mg) exceed alkali metals (Na+K)	100	100
2	Alaklies exceeds alkaline earths	-	-
3	Weak acids (CO_3+HCO_3) exceed Strong acids (SO_4+Cl)	92	61
4	Strong acids exceeds weak acids	8	39
5	Magnesium bicarbonate type	94	72
6	Calcium-chloride Type - -	-	8
7	Sodium-chloride Type	-	-
8	Sodium-Bicarbonate Type	-	-
9	Sodium calcium-Bicarbonate type	-	-
9	Calcium Magnesium-Chloride Type - -	6	19

Wilcox has classified irrigation water into zones as Excellent to Good, Good to Permissible, Permissible to Doubtful, Doubtful to Unsuitable and Unsuitable. Classification of Irrigation Water in the study area after Wilcox is presented in Table 4.

Sodium Absorption Ratio (SAR): The relative activity of sodium ion in the exchange reaction with soil is expressed in terms of a ratio known as Sodium Absorption Ratio (SAR) which is an important parameter for determination the suitability of irrigation water. SAR is defined as follows:

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

Where all ionic constituents are expressed in meq/l.

There is a close relationship between SAR values in irrigation water and the extent to which Na^+ is absorbed by the soil (Subba Rao, 2006). If water used for irrigation is high in Na^+ and low in Ca^{2+}, the cation-exchange complex may become saturated with Na+, which can destroy the soil structure due to the dispersion of the clay particles (Todd, 1980) and reduces the plant growth.

According to Richards (1954), irrigation waters are rated based on sodium adsorption ratio values. The groundwater samples of the study area in both pre-monsoon and post-monsoon are excellent because in none of the samples the value of SAR exceeded 10 (Table:3).

Table 3: Quality Parameters (Range) for Irrigation purposes [Parameter standards for EC and % Na are after Wilcox, (1955), SAR after Richards (1954) and RSC given by USSL (1954)]

. No	Geochemical Parameter	Parameter Range	Classification	No. of Samples (% of Samples)	
				Pre-MonSoon	Post-Monsoon
1	EC (µS/cm)	<250	Excellent	Nil	Nil
		250 – 750	Good	7 (19%)	17 (47%)
		750 – 2000	Permissible	25 (70%)	19 (53%)
		2000 – 3000	Doubtful	3 (8%)	Nil
		>3000	Unsuitable	1 (3%)	Nil
2	SAR	<10	Excellent	36 (100%)	36 (100%)
		10 – 18	Good	Nil	Nil
		18 – 26	Permissible	Nil	Nil
		>26	Unsuitable	Nil	Nil
3	RSC (meq/l))	<1.25	Excellent	36 (100%)	36 (100%)
		1.25 – 2.50	Permissible	Nil	Nil
		>2.50	Unsuitable	Nil	Nil
4.	(Na %)	<20	Excellent	32 (89%)	14 39%)
		20 – 40	Good	4 (11%)	20 (55%)
		40 – 60	Permissible	Nil	2 (6%)
		60 – 80	Doubtful	Nil	Nil
		>80	Unsuitable	NIL	Nil
5	MAR	<50%	Suitable	20 (56%)	34 (94%)
		>50%	Unsuitable	16 (44%)	2 (6%)
6	PI	Class I (>75%)	Very Good	Nil	Nil
		Class II (75% - 25%)	Good	33 (92%)	36 (100%)
		Class III (<25%)	Poor	3 (8%)	Nil
7	KR	<1.0	Suitable	36 (100%)	36 (100%)
		>1.0	Unsuitable	Nil	Nil

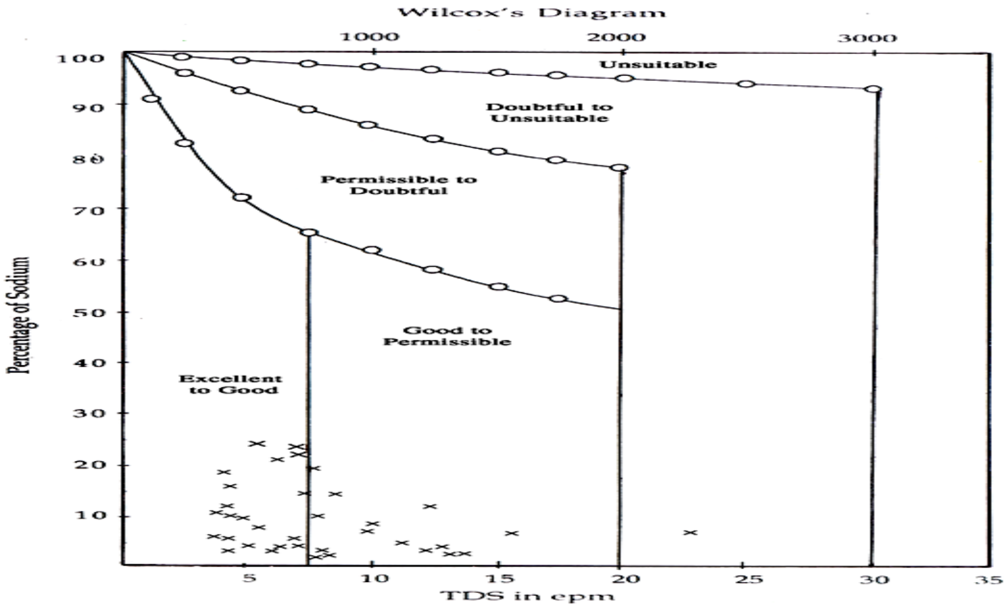
Table 4: Classification of Irrigation Water in the Study Area (after Wilcox(1955)

Classification	No. of Samples		% of Samples	
	Pre- Monsoon	Post- Monsoon	Pre-Monsoon	Post-Monsoon
Excellent to Good	20	29	56	81
Good to Permissible	25	07	69	19
Permissible to Doubtful	Nil	Nil	---	---
Doubtful to Unsuitable	1	Nil	03	---
Unsuitable	Nil	Nil	---	---

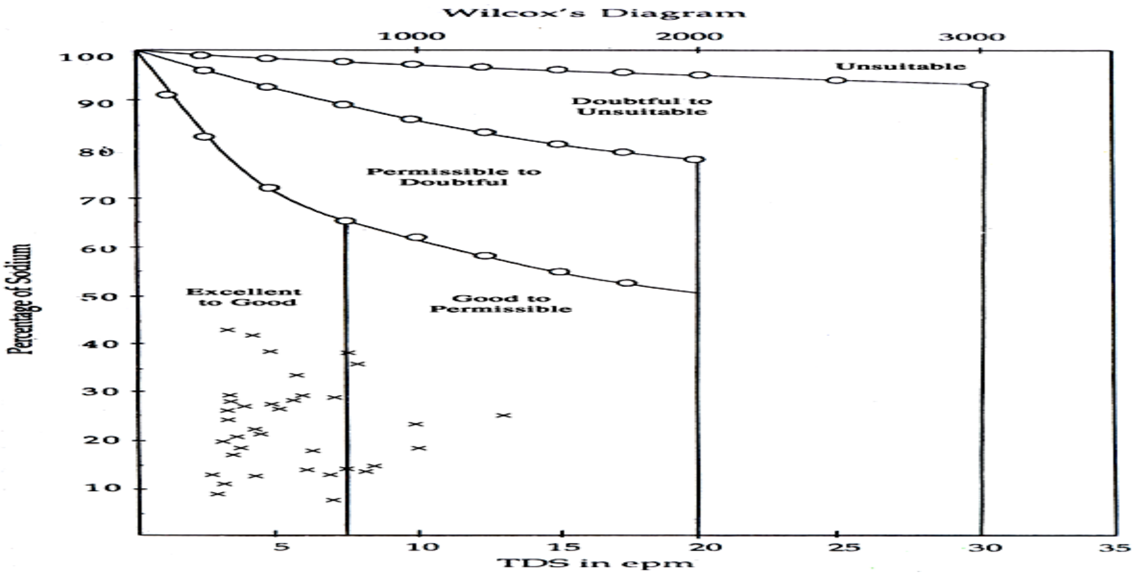
Integrated Effect of EC and SAR

The values of SAR and EC of groundwater samples of the study area were plotted in the irrigational water field in Richards diagram (1954) (Fig. 6.a and 6.b).

The result (Table 5) Indicates that the majority of the groundwater samples show medium to high salinity and low alkali water, which can be used for irrigation in most soil and crops with little danger of development of exchangeable sodium and salinity in both seasons.



(a)



(b)

Figure 5: Quality Classification of Water for Irrigation (After Wilcox, 1955) of (A) Pre-Monsoon and (B) Post-Monsoon Period

Residual Sodium Carbonate (RSC)

A high value of RSC in water leads to an increase in the adsorption of sodium on soil (Eaton, 1950). Residual sodium carbonate has been calculated to determine the hazardous effect of carbonate and bicarbonate. RSC is determined by the following formula-

$$RSC = (CO3+HCO3) - (Ca+Mg)$$

Where all ionic constituents are expressed in meq/l. RSC values of groundwater samples from the study area are found to be excellent category (Table 3).

Magnesium Adsorption Ratio (MAR)

MAR was calculated using the following equation (Raghunath 1987):

$$MAR = Mg^{2+} / (Ca^{2+} + Mg^{2+})x100$$

Where, all ionic constituents are expressed in meq/l.

44% samples from the pre-monsoon period and 6% samples from the post-monsoon period contain more than 50% of magnesium adsorption ratio in the groundwater of the study area (Table 3), which may affect the crop yield as the soils become more alkaline.

Permeability Index (PI)

The soil permeability is affected by long-term use of irrigation water and is influenced by sodium, calcium, magnesium and bicarbonate contents of soil. Doneen (1964) classified irrigation waters based on the Permeability Index (PI). The Permeability Index (PI) was calculated employing the following formula:

$$PI = (Na^+ + \sqrt{HCO^-}) / (Ca^{2+} + Mg^{2+} + Na^+)$$

Where, all ionic constituents are expressed in meq/l.

According to permeability index, out of 36 groundwater samples in the study area 33 samples from pre-monsoon season belong to class II category (25 to 75 %); which indicates good groundwater quality for irrigation. Three groundwater samples from pre-monsoon period fall in class III category (<25%) which is designated as unsuitable for irrigation purposes (Table 3).

Kelley's Ratio (KR)

Sodium measured against calcium and magnesium was considered by Kelly (1951) for calculating Kelley's index by using the formula:

$$KR = Na^+/(Ca^{2+} + Mg^{2+}),$$

Where, all ionic constituents are expressed in meq/l.

The values of Kelley's Ratio in both pre- and post-monsoon periods are below 1 (one), hence groundwater in the study area is suitable for irrigational practice (Table 3)

Table 5: Integrated Effect of Electrical Conductivity and Sodium Adsorption Ratio (after Richards 1954) in the Study Area

Classification	Percentage of Samples	
	Pre- Monsoon	Post- Monsoon
C2S1(moderate salinity , low sodium)	22%	47%
C3S1(medium to high salinity, low sodium)	72%	53%
C4S1(high salinity, low sodium)	6%	- NIL-

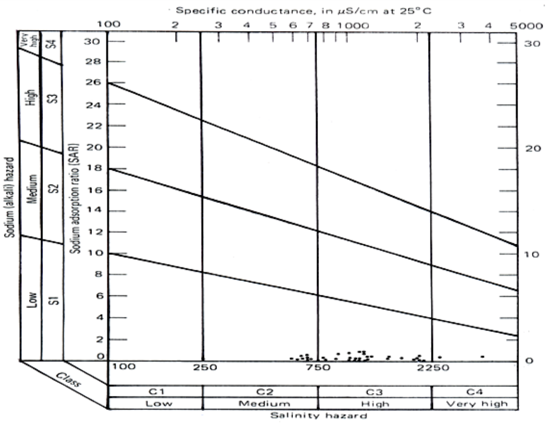


Figure 6.a: Classification of irrigation water (after Richards 1954) Pre Monsoon

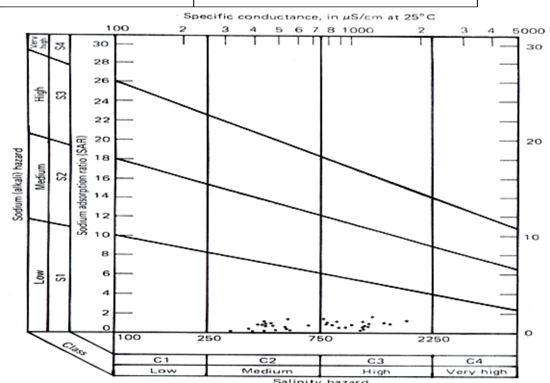


Figure 6.b: Classification of irrigation water (after Richards 1954) Post Monsoon

Conclusion

The groundwater chemistry in the study area is dominated by Ca followed by Mg>Na>K except in some locations, where Na replaces Mg in cationic abundance in post monsoon season. The order of abundance in anionic chemistry is HCO_3>Cl>SO_4 in both pre- and post-monsoon seasons. However, SO_4 is found to be in excess of Cl in some groundwater samples in post monsoon. Ca-Mg-HCO_3 and Ca-Mg-Cl are the two dominant hydrochemical facies with appreciable percentage of the groundwater having mixed hydrochemical facies. The integration of SAR and EC and the integration of Na% and TDS show that groundwater in the study area is suitable for irrigation. MAR values in some places is more than 50%, which may affect the crop yield as the soils become more alkaline. PI values of three locations belong to poor category (<25%) which can designated as unsuitable for irrigation purposes. The dilution and quality enhancement in few locations during the post-monsoon period may be the effects of rainfall recharge.

Suggestions

The locations having poor groundwater quality for irrigation purpose may yield poor agricultural returns and thus require proper attentions.

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