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Water Quality Assessment for Drinking and Irrigation Purpose of Rewa Block, District-Rewa, Madhya Pradesh, India

Satish Kumar Singh[1*], S. K. Tripathi[2], K. P. Mishra[1], A. K. Pandya[1] and M. K. Awasthi[3]

[1]*Faculty of Engineering and technology, MGCGVV, Chitrakoot Satna (MP), India*
[2]*Department of Science, MGCGVV, Chitrakoot Satna (MP), India*
[3]*Department of Soil and Water Engineering, CAE, JNKVV Jabalpur (MP), India*

**Corresponding author*

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A B S T R A C T

This study, deals with groundwater quality for Drinking and Irrigation purpose of Rewa Block, Ditrict-Rewa, Madhya Pradesh, India. Study area covers an area of 704.17 km^2 and lies between 81˚06'00" and 81˚30'00" E longitudes and 24˚18'00" and 24˚42'00" N latitudes. Geologically, the area is occupied by sandstone and shale of Rewa Group belonging to Vindhyan super-group. The groundwater occurs in semi-confined to confined condition. A total number of fifty ground water samples were collected in pre and post-monsoon seasons of 2018-19 from different locations of the study area and analyzed for comically analysis for various water quality parameters such as PH, electrical conductivity (EC), Total dissolved solids (TDS), Total hardness (TH), chloride (Cl), carbonate, bicarbonate, sodium (Na), Potassium (K) and calcium with magnesium (Ca+Mg). On comparing the results against water quality standards laid by World Health Organization (WHO) and BIS. It is observed that some parameters exceed the standard limits. The ground water is hard to very hard in nature. The overall study reveals that water concentration of various cations and anions suggest that the groundwater of the area is partially suitable for drinking purpose. To overall irrigation water quality of the samples collected, some computed water quality parameters have been considered. The analysis of various parameters like EC, sodium percentage, integrated sodium adsorption ratio (SAR), Soluble Sodium Percentage (SSP), Permeability Index (PI) and Residual Sodium Carbonate (RSC) suggest that ground water of the area is suitable for irrigation purpose.

Introduction

Ground water has been used as major sources of drinking water in both rural and urban areas in the world. In India alone, nearly 80% of the rural population depends on untreated ground water. The quality of ground water in the various part of our country has been studied by various workers. Polluted water is responsible for spread of various water borne diseases. Therefore in present study an attempt has been made to evaluate the physiochemical characteristics of ground water for drinking and irrigation purpose of Rewa block, Rewa district Madhya Pradesh, India.

Fresh water is the most precious material for survival on earth, not only human life but also for flora and fauna. Groundwater quality is one of the most important aspects in water resource studies (Ackah *et al.,* 2011; Sayyed and Wagh, 2011). It is largely controlled by discharge recharge, nature of the host and associated rocks as well as contaminated activities (Raghunath, 1987; Sayyed and Sayadi, 2011; zhang *et al.,* 2011). Only 2 to 3% total water on earth is fresh water. Water pollution is classified into four classes likewise-physical, chemical, biological and physiological pollution of water. Physical water pollution brings about changes in water with regard to its color, density, test, turbidity and thermal properties etc. the chemical pollution of water causes changes in acidity and alkalinity/pH. Biological pollution is caused by bacteria, alge, virus, protozoa etc. physiological pollution of water by caused by several chemical agents such as chlorine, sulphur dioxide, hydrogen sulphide ketones, phenols amines etc. according to WHO organization, about 80% of all the disease in human.

The quality of groundwater is affected by many factors such as physic-chemical characteristics of soil, weathering of rocks, and rainfall etc. (Pureshotham *et al.,* 2011). Groundwater quality assessment of different quality parameters has been carried out by various researches (Hegde, 2006; Pandian and Shankar, 2007; Popleare and Dewalkar, 2007; Mishra, 2010). The groundwater quality assessment for drinking and irrigation purpose in the Vindhyan region has carried out by few researchers (Tiwari *et al.,* 2009, 2010; Mishra *et al.,* 2012).

About study area

Study area covers an area of 704.17 km^2 and lies between 81˚06'00" and 81˚30'00" E longitudes and 24˚18'00" and 24˚42'00" N latitudes. Geologically, the area is occupied by sandstone and shale of Rewa Group belonging to Vindhyan super-group. The groundwater occurs in semi-confined to confined condition. A total number of fifty ground water samples were collected in the study area. Location map of the study area is shown in Figure 1; The Rewa block is bounded on the north by Semaria block and Raipur Krachulian block, on the east and southeast by Sidhi district, and on the west by Satna district.

Materials and Methods

Ground water samples were collected from hand pups/dug well and surface water (River/pond) of the different locations of the study area during pre and post monsoon seasons of year 2018. The sample was collected in plastic bottles of 500 ml capacity. The sampling bottles were thoroughly washed with 1:1 Nitric acid (HNO_3) and then cleaned and rinsed with distilled water. At the sampling site bottles were rinsed two to three times with water samples to be examined finally filling with it (Sankar Prashad Mishra, 2016). During sampling from a hand pump the water was pumped to waste for about four to five minutes and then sample was collected directly from a hand pump. The entire samples were collected from ten to fifty meter depth and lifted water through hand pump.

All samples were labelled and write the GPS location latitude and longitude also mansion. Samples store were brought to laboratory and refrigerated at 4ºC. The physicochemical analysis was done using procedure of standard methods. The methods used for determination of various physicochemical parameters are given Table 1.

Quality of groundwater for irrigation

The suitability of groundwater for irrigation is determined on the basis of physical, chemical and bacteriological characteristics (Table 2). The criteria for suitability of groundwater for irrigation are based on Total Dissolved Solids (TDS), Electrical Conductivity (EC), Sodium Salts and bicarbonate concentration (Richards, 1954; Todd, 1980; Eatson, 1950; Davis and Dewiest, 1966; Singh, 2002).

To assess the overall irrigational water quality of the samples collected, five to six computed water quality parameters have been considered; namely – Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Permeability Index (P.I.), Soluble Sodium Percentage (SSP), Magnesium Adsorption Ratio (MAR) and Kelly's Ratio.

Electrical conductivity

Electrical conductivity is a function of temperature, type and concentration of various ions. Classification of irrigation water based on electrical conductivity is presented in Table 3. A solution offers some resistance to the passage of electric current through it depending on the concentration and type of ions present. Higher the salt contents lesser the resistance to the flow of current. The resistance(R) is defined by Ohm's law as the ration of electrical potential in volt (E) and strength of current in ampere (I).

$$\frac{E}{I} = \frac{Volts}{Curent} = R\ in\ Ohm$$

Electrical conductivity of conductance is the reciprocal of resistance.

1/R=1/ohm=mhos (reverse of ohm) (at present mmhos/cm is expressed in terms of dS/m).

Sodium

If the proportion of sodium is high in groundwater for irrigation purpose, it can destroy soil structure (Table 4). A simple method for evaluating the changes of high-sodium is the Sodium Adsorption Ratio (SAR) and the sodium percentage (soluble sodium percentage, SSP) is calculated as follows:

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

$$NA\% = \frac{Na^{+} + K^{+}}{Ca^{++} + Mg^{++} + Na^{+} + K^{+}} * 100$$

Residual sodium carbonate (RSC)

Irrigation water with high RSC8,9 is considered to be deleterious to the physical properties of the soil. More RSC may reduce permeability of soils and tendency of fixing the sodium in soils (Table 4). The residual sodium carbonate is calculated using the following equation:

RSC (meq/l) = $(HCO_3^{-} + CO_3^{-}) - (Ca^{++} + Mg^{++})$

Permeability index (PI)

Another modified criterion has evolved based on the solubility of salts and the reaction occurring in the soil solution from caution exchange for estimating the quality of agricultural waters (Gupta SK, Gupta, IC, 1987). Soil permeability is affected by long-term use of irrigation water and is influenced by - (a) Total dissolved solids, (b) sodium contents, (c) bicarbonate content.

To incorporate the first three items Doreen had empirically developed a term called, 'Permeability Index' after conducting a series of experiments for which he had used a large number of irrigation waters varying in ionic relationships and concentration (Doneen, 1964). PI is classified under Class I (>75% permeability), Class II (25-75% permeability) and Class III (<75% permeability) orders.

The permeability index is given by the following formula:

$$PI = \frac{Na^{+} + \sqrt{(HCO3^{-})}}{(Ca^{++} + Mg^{++} + Na^{+})} * 100$$

Where, the ions are expressed in meq/l.

Soluble sodium percentage (SSP)

High sodium ion concentration in soil can take a toll on internal drainage patterns in soil as release of calcium and magnesium ions are facilitated due to absorption of sodium by clay particles. SSP categorizes water into two broad classes – water having SSP <= 200 is considered suitable for irrigation whereas water with SSP > 200 is considered unsuitable for irrigation water. Soluble sodium percentage (SSP) was calculated using the following equation:

$$SSP = \frac{(Na^{+} + K^{+})}{(Ca^{++} + Mg^{++} + Na^{+} + K^{+})} * 100$$

Where, concentrations of all ions have been expressed in meq/l.

Kelly's ratio (KR)

Kelly's Ratio was devised by Kelly and is measured considering sodium ion concentration against calcium and magnesium ion concentrations (Kelly WP 1940). Waters with a KI value <1 is considered suitable for irrigation, while those with greater ratios are rendered unsuitable. Kelly's Ratio is calculated using the formula:

$$KR = \frac{Na^{++}}{(Ca^{++} + Mg^{++})}$$

Where, concentrations of all ions have been expressed in meq/l.

Results and Discussion

Water quality for irrigation purposes

To assess the overall irrigational water quality of the samples collected, six computed water quality parameters have been considered; namely- Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP), Permeability Index (PI), Residual Sodium Carbonate (RSC), Kelly's Ratio and Magnesium Adsorption Ratio (MAR).

Sodium adsorption ratio (SAR)

Sodium adsorption ratio is a measure of the sodality of the soil determined through quantitative chemical analysis of water in contact with it. An excess of HCO_3 and CO_3^{--} ions in water react with Na^{+} in soil, resulting in a sodium hazard. SAR values are plotted against EC values over the salinity diagram to categorize analyzed water samples according to their irrigational suitable quotient. In the present study the SAR values range from 0.3 to 7.7me/l in pre-monsoon and 0.3 to 2.8 me/l in post-monsoon. Based on the SAR values all samples have low sodium hazard and on plotting the salinity diagram (Fig. 2), the water sample fall in the C2-S1 and C3-S1classes in pre-monsoon and C2-S1 and C3-S1 classes in post-monsoon, and hence can be considered moderately and highly suitable for irrigation.

Soluble sodium percentage (SSP)

High sodium ion concentration in soil can take a toll on internal drainage patterns in soil as release of calcium and magnesium ions are facilitated due to absorption of sodium by clay particles. The SSP values range from 4.8 to 79.6 me/l in pre-monsoon and 7.5 to 44.4 me/l during post-monsoon. Fig. 3, present the spatial distribution maps of SSP for pre-monsoon and pre-monsoon sessions respectively.

The SSP values and EC values have been plotted on the Wilcox diagram (Wilcox L.V. 1955) and found to fall under the 80% sample very good to good, 33% good to permissible, 6% doubtful to unsuitable and 2% sample unsuitable water quality in pre-monsoon similarly 52% sample very good to good, 39% good to permissible and 6%, 2% sample doubtful to unsuitable and unsuitable water quality respectively in post-monsoon.

Permeability index (PI)

Another modified criterion has evolved based on the solubility of salts and the reaction occurring in the soil solution from cation exchange for estimating the quality of agricultural waters (Gupta S.K. 1987). Soil permeability is affected by ling-term use of irrigation water and is influenced by (a) Total dissolved solids, (b) sodium contents, (c) bicarbonate content. To incorporate the first three items. Doneen had empirically developed a term called, Permeability Index after conducting a series of experiments for which he had used a large number of irrigation waters varying in ionic relationships and concentration (Doneen, 1964). The permeability index varies from 8.44 to 99.89me/l in pre-monsoon and from 10.25 it 59.77 me/l in post-monsoon season. Doneen's chart for pre and post-monsoon sessions have been presented in Fig. 4.

PI is classified under Class-I (>75% permeability), Class-II (25-75% permeability) and Class-III (<75% permeability) orders. Class-I and Class-II waters are categorized as good for irrigation and Class-III waters are unsuitable with 25% of maximum permeability.

Residual sodium carbonate (RSC)

The residual sodium carbonate index of water or soil signifies the alkalinity hazard posed by it and it finds the suitability of water for irrigation in case of clay soil. Residual sodium carbonate values should be preferably <1.25 to be rendered suitable for irrigational purposes and hence in the present study where RSC values variation range between -22.2 to 9.0 in pre-monsoon and -25.2 to 1.48 in post-monsoon season. More than 93% to 100% of the excellent water samples have RSC < 2.5 (Fig. 5); it can be concluded that water in this area poses a suitable irrigation water 93% sample in pre-monsoon period. In the Post-monsoon period though 100% sample of RSC values fall in the safe and excellent category, indicating localized hazard (Table 5).

Kelly's ratio

Kelly's Ratio was devised by Kelly and is measured considering sodium ion concentration against calcium and magnesium ion concentrations. Water with a KI value <1 are considered suitable for irrigation, while those with greater ratios are rendered unsuitable.

During pre-monsoon KR values vary between 0.16 to 8.44 me/l, and post-monsoon and values vary between 0.24 to 1.72 me/l. according to Kelly's ratio water analyzed is suitable for irrigation during pre-monsoon season of 80% sample and 78% sample in post-monsoon season.

Magnesium adsorption ratio (MAR)

MAR categorized water into two broad classes – water having MAR <50 is considered suitable for irrigation whereas water with MAR > 50 is considered unsuitable. Because MAR values should be preferably greater than 50 to be rendered unsuitable for irrigational purpose and hence in the present study where MAR values range vary between 51.33 to 93.28 me/l in pre-monsoon and 74.92 to 92.78 me/l in post-monsoon season. The MAR based on which it can be concluded that almost water samples are unsuitable classes for irrigation during both periods.

Water quality for drinking purposes

In the large and specially semi urban or rural parts of our country groundwater sources in form of fug wells of bore wells are the only source of drinking water standard, the total Hardness of samples have been measured and the use of Hydro geochemical facies (Piper diagram) and Water Quality Index have been make.

Hydrogeochemical facies

A Piper Trilinear diagram is a graphical representation classifying water based on the dominant presence of cations and anions and has widespread use to assess the water type. Piper diagram can predict the water type in three ways- fresh type, sulfate type and saline type.

In Figure 6-a, and 6-b it can be seen the water samples fall under $CaHCO_3$ or the bi-carbonate type during post-monsoon whereas during pre-monsoon groundwater in certain locations falls under the Ca-Mg-Cl-SO_4 types as well. Samples in the top quadrant are calcium sulphate waters, which are typical of gypsum ground water and mine drainage of pre and post monsoon season.

Water quality index (WQI)

Water quality index values depicted through the weighted arithmetic water quality index method were shown in Table 6 indicates range of WQI values according to which the five classes in pre and post monsoon. The pie charts presented in Fig. 7-a, and 7-b depiction clearly explains that the pre and post monsoon values are much suitable for drinking purpose in most of the station where water samples are collected. Whereas in very small sample shows that not suitability for drinking according to the Table 6. The pollution before post monsoon is more than that of pre monsoon in current study.

Gibb's diagram

The Gibb's Diagram is prepared using TDS, Na^+, K^+, Ca^+, Cl^-, SO_4^- and $CHO3^-$ concentrations in groundwater. The predominant samples fall in the rock–water interaction dominance and evaporation dominance field of the Gibbs diagram (Fig. 8-a and 8-b). From these diagrams it can be interpreted that during both sampling sessions' rock- water interaction processes control the levels of all chemical constituents in groundwater of study area.

Table.1 Methods used for analysis of water quality parameters

S. No.	Parameters	Methods
1	pH	pH meter
2	Electrical Conductivity	Conductivity meter
3	Total Hardness	EDTA titration method
4	total Dissolved Solid	Water quality analyser instrument
5	Chloride	Argentometric titration method
6	Calcium and Magnesium	Titration method
7	Sodium, Calcium and Potassium	Flame photometer

Table.2 Standards of water quality by WHO and BIS for drinking purpose

S. No.	Water quality parameters	WHO (1991)		BIS(1991)	
		Max. Desirable	Max. Permissible	Max. Desirable	Max. Permissible
1	pH	7	8.5	6.5	8.5
2	EC	-	1400	-	-
3	TH (mg/l)	100	500	300	600
4	TDS (mg/l)	500	1500	500	1000
5	Ca (mg/l)	75	200	75	200
6	Mg (mg/l)	30	150	30	100
7	Na (mg/l)	-	200	-	200
8	K (mg/l)	-	12	-	-
9	Cl (mg/l)	200	600	250	1000
10	SO4 (mg/l)	200	400	150	400
11	F (mg/l)l	1	1.5	1	1.5
12	Turbidity (NTU)			1	5

Table.3 Calcification of irrigation water based on electrical conductivity

S. No.	Type of water	Classification	Electrical Conductivity (µ/cm)
1	Low Sodium	Excellent	100-250
2	Medium	Good	250-750
3	Saline	Permissible	750-2000
4	Highly Saline	Doubtful	2000-3000
5	Very Highly Saline	Unsuitable	> 3000

Table.4 Classification of water based on Sodium Adsorption Ratio (SAR)

S. No.	Type of water	Classification	SAR Value
1	Low Sodium	Excellent	< 10
2	Medium	Good	10 - 18
3	Highly Saline	Doubtful	18 - 26
4	Very Highly Saline	Unsuitable	> 26

Table.5 Calcification of water based in Residual Sodium Carbonate (RSC)

S. No.	Class	RSC
1	Excellent	< 1.25
2	Good	1.25 - 2.25
3	Unsuitable	> 2.5

Table.6 Classification of samples according to standards specified for water quality index

Parameter	Range	Class	No. of Sample		% of Sample	
			Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
SAR	<20	Excellent	46	46	100	100
	20-40	Good	0	0	0	0
	40-60	Permissible	0	0	0	0
	60-80	Doubtful	0	0	0	0
	>80	Unsafe	0	0	0	0
EC WHO (2008)	<250	Excellent	3	2	7	4
	250-750	Good	14	11	30	24
	750-2000	Permissible	25	29	54	63
	2000-3000	Doubtful	3	3	7	7
	>3000	Unsafe	1	1	2	2
TH (Sawyer & McCarty, 1967)	<75	Soft	1	0	2	0
	75-150	Moderate	4	3	9	7
	150-300	Hard	6	5	13	11
	>300	Very Hard	35	38	76	83
RSC	<1.25	Safe	39	44	85	96
	1.25-2.50	Marginally Suitable	2	2	4	4
	>2.50	Unsuitable	5	0	11	0
MAR	<50	Suitable	0	0	0	0
	>50	Unsuitable	46	46	100	100
SSP	200	Suitable	46	46	100	100
	>200	Unsuitable	0	0	0	0
KR	<1.0	Suitable	35	36	76	78
	>1.0	Unsuitable	11	10	24	22
PI	<80	Good	44	46	96	100
	80-100	Moderate	2	0	4	0
	100-120	Poor	0	0	0	0
WQI	0-25	Excellent	9	12	20	26
	25-50	Good	27	26	59	57
	50-75	Poor	6	4	13	9
	75-100	Very Poor	2	3	4	7
	>100	Unfit for Drinking	2	1	4	2

Note: SAR = Sodium Adsorption Ratio, SSP = Soluble Sodium Percentage, PI = Permeability Index RSC = Residual Sodium Carbonate, KR = Kelly's Ratio, All values meq/l.

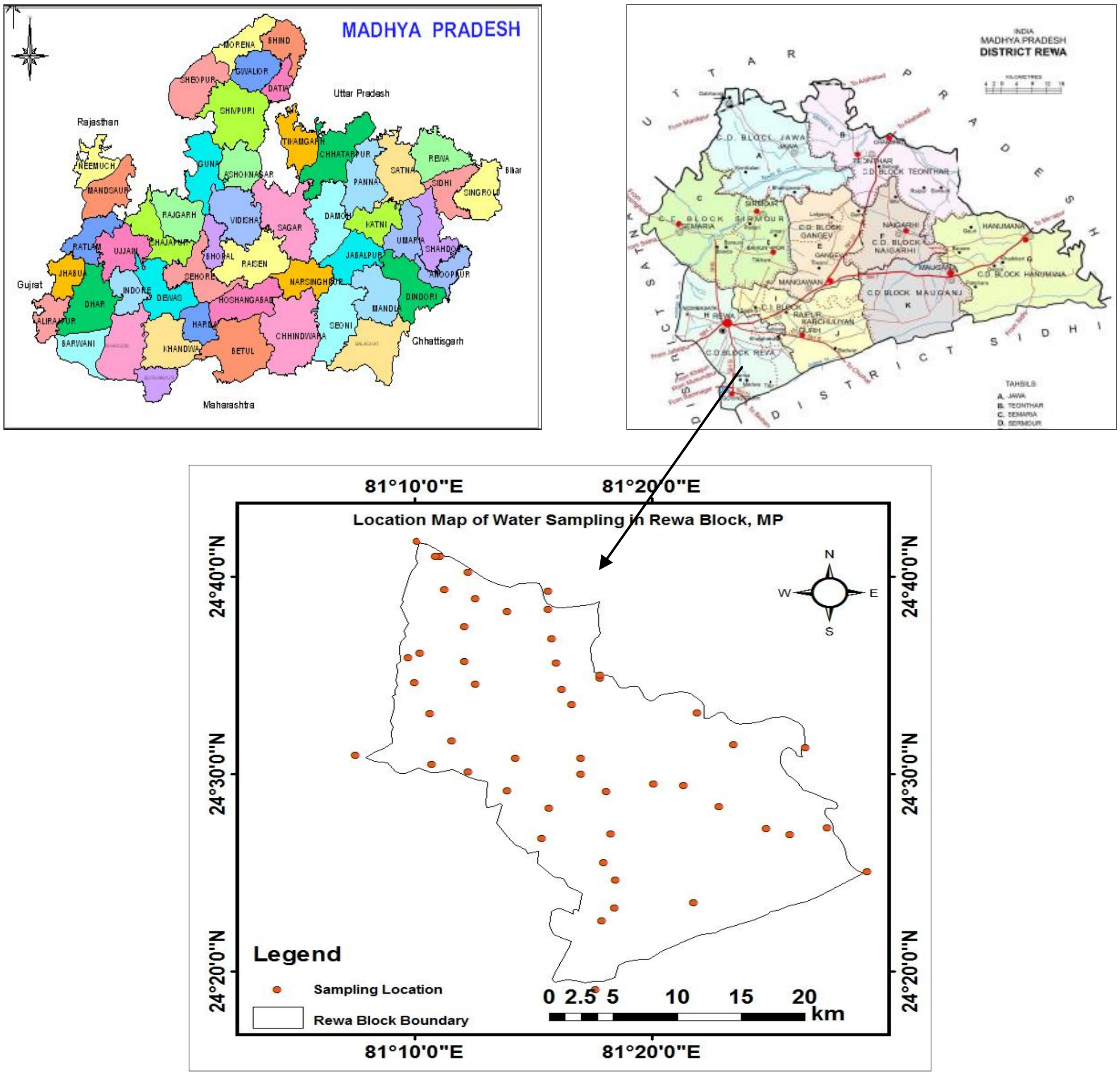


Fig.1 Location map of the water sampling points in the study area

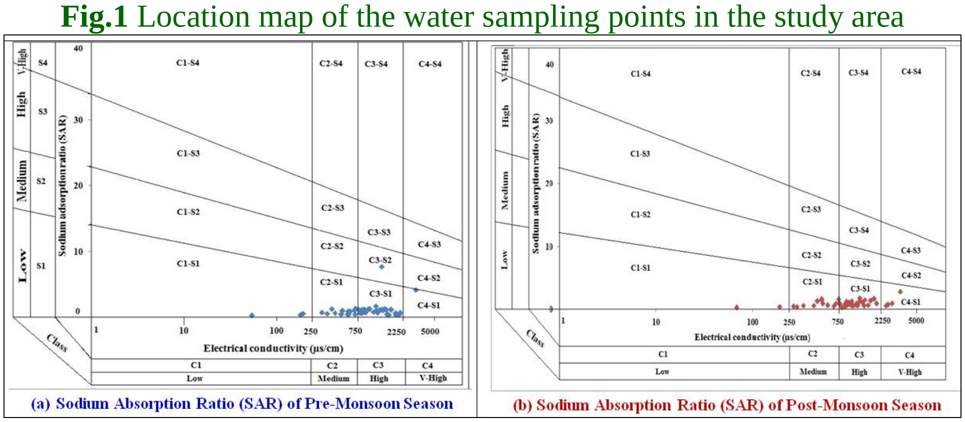


Fig.2 Salinity diagram of pre and post monsoon seasons

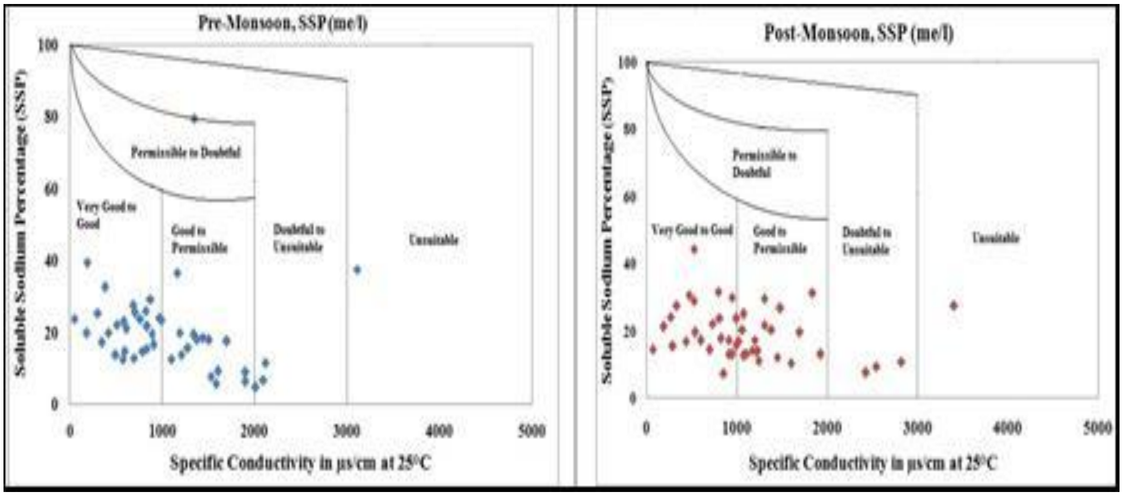


Fig.3 Wilcox diagram for pre and post monsoon seasons

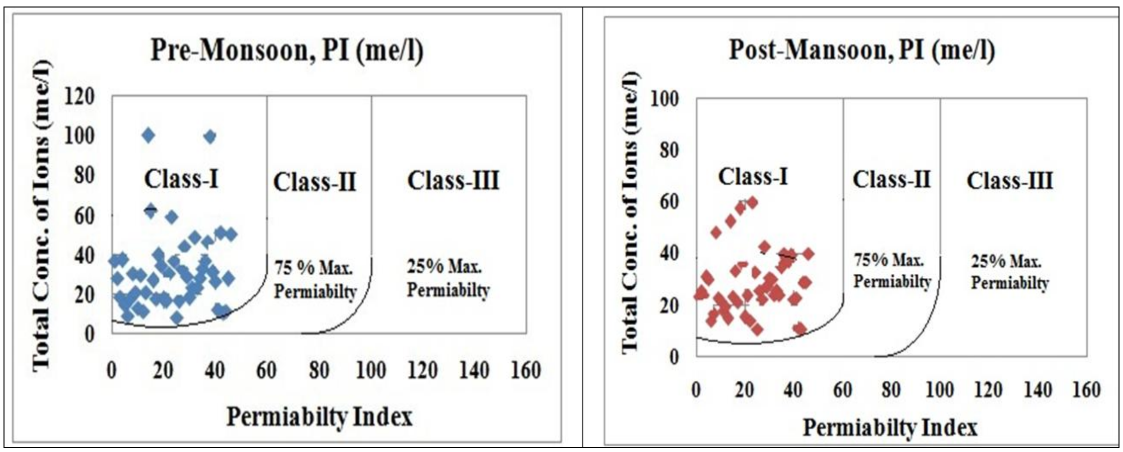


Fig.4 Doneen’s chart for permeability index values of pre and post monsoon seasons

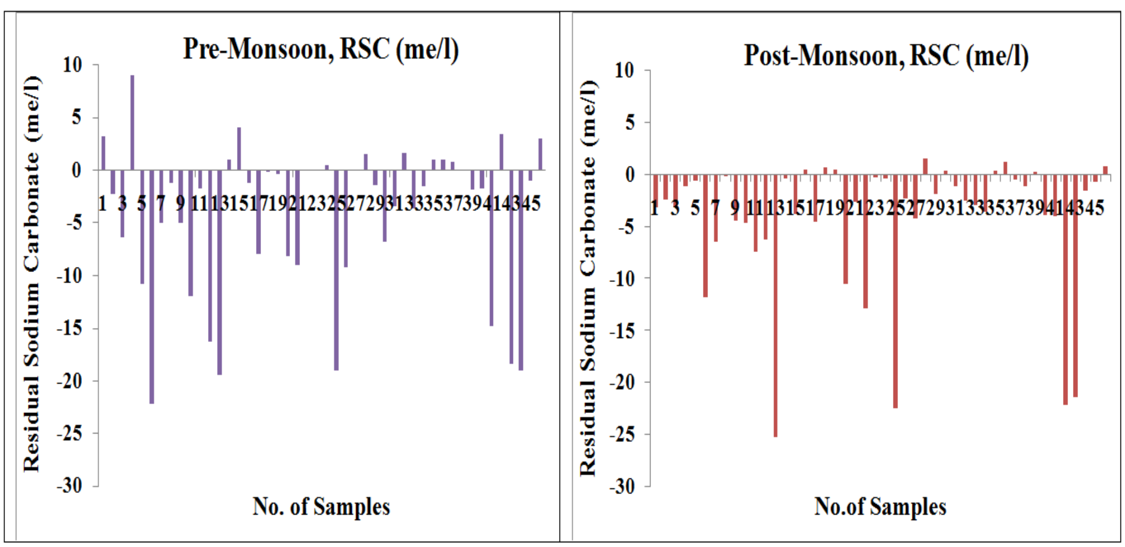
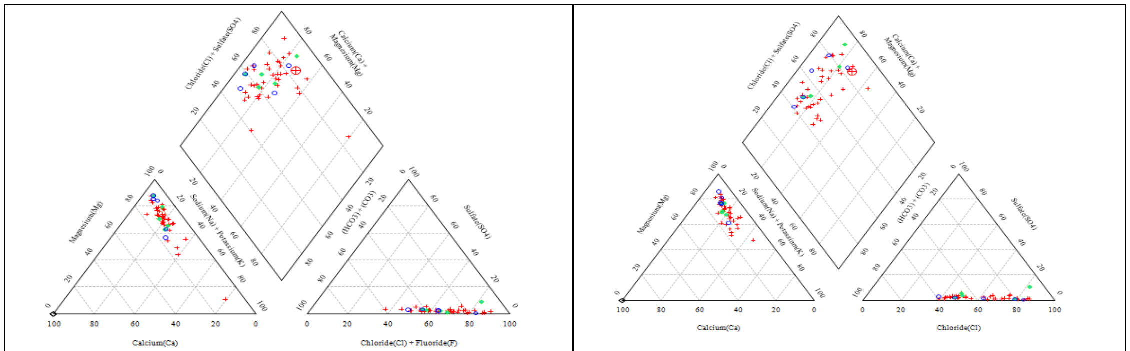


Fig.5 Special distribution of residual sodium carbonate (RSC) for pre and post monsoon seasons



a. Pre-Monsoon Season	b. Post-Monsoon Season

Fig.6 Piper Trilinear diagram (a. pre-monsoon; b. post-monsoon)

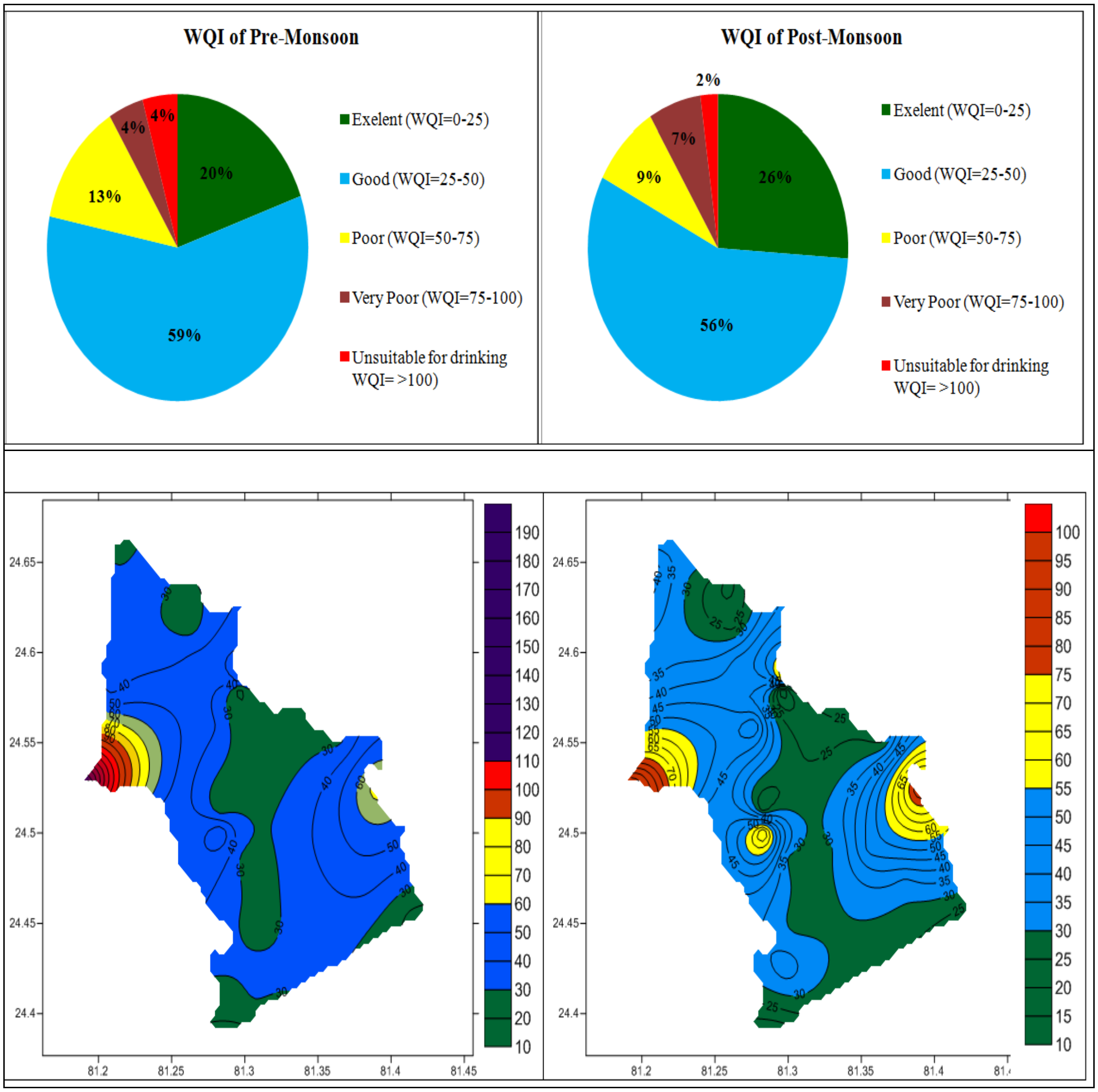


Fig.7 Categorization of groundwater WQI (a. pre-monsoon; b. post-monsoon)

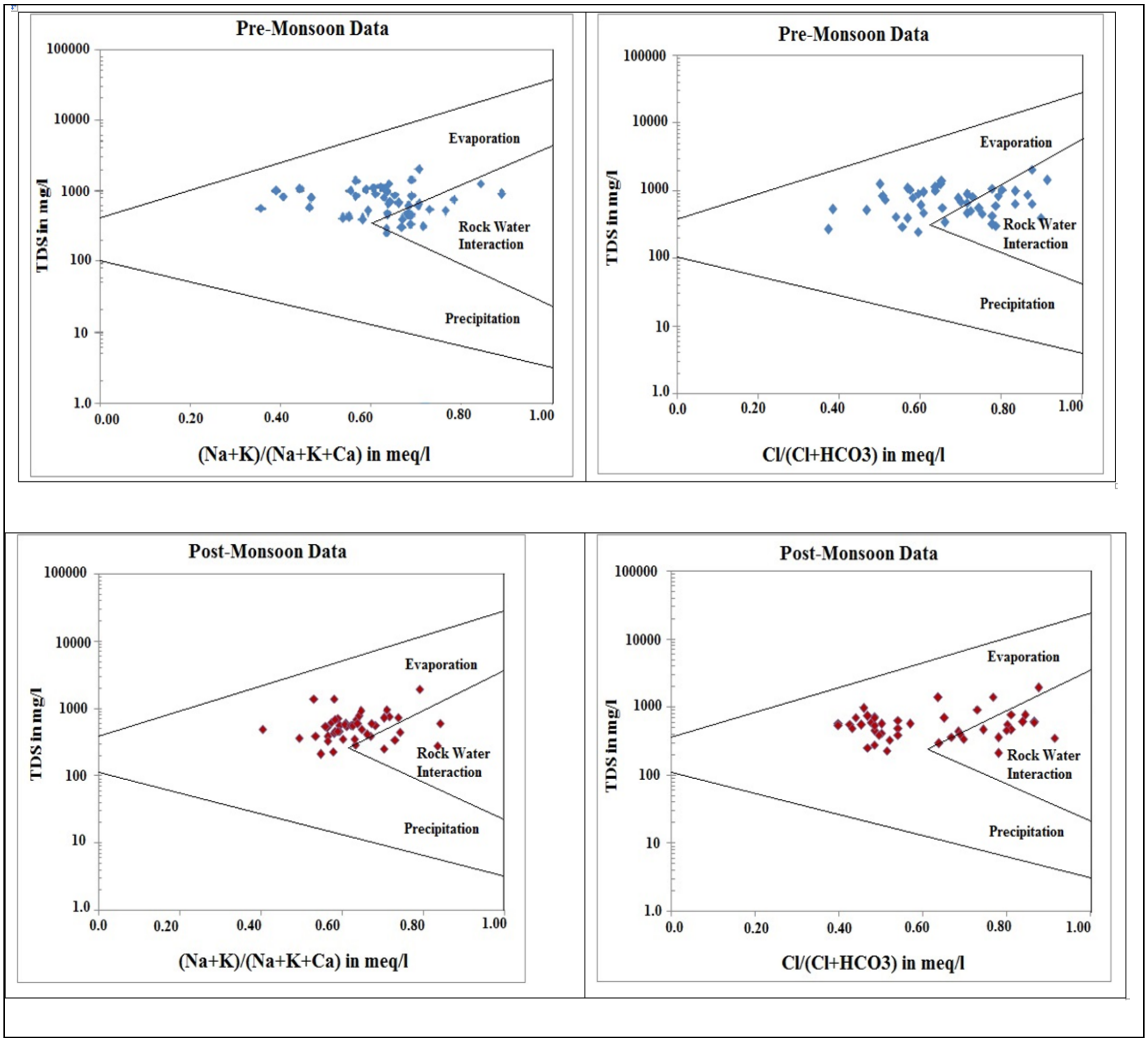


Fig.8 Gibb's Diagrams (a) pre-monsoon and (b) post-monsoon season

The rock–water interaction dominance field indicates the interaction between rock chemistry and the chemistry of the percolated waters under the subsurface. Dissolution and displacement reactions in rocks lining the aquifers are primary reasons behind changing concentrations of major ions in solution.

It is observed that some parameters exceed the standard limits. The ground water is hard to very hard in nature. The overall study reveals that water concentration of various cations and anions suggest that the groundwater of the area is partially suitable for drinking purpose. To overall irrigation water quality of the samples collected, some computed water quality parameters have been considered. The analysis of various parameters like EC, sodium percentage, integrated sodium adsorption ratio (SAR), Soluble Sodium Percentage (SSP), Permeability Index (PI) and Residual Sodium Carbonate (RSC) suggest that ground water of the area is suitable for irrigation purpose.

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