Studies of Hydrogeochemical in Groundwater Quality around Chakghat Area, Rewa District, Madhya Pradesh, India

[1]A.K.Tripathi, [2]U.K.Mishra, [3]Ajay Mishra, [4]Saras Tiwari and [5]Parul Dubey
[1]*Principal, Shriyut College Gangeo Rewa–486111, Madhya Pradesh India*
[2]*Department of Geology Govt. P.G. College Satna –485001, Madhya Pradesh India*
[3,5]*Department of Geology, Govt. P.G. College Rewa–486001, Madhya Pradesh India*
[4]*Department of Chemistry, I.V. P.G. College Jawa Rewa–486223, Madhya Pradesh India*

Abstract : *The area is drained by a fourth order Tons river and its tributaries having dendritic to subparallel drainage pattern. The paper deals with studies of hydrogeochemical in groundwater around Chakghat area, Rewa district, Madhya Pradesh. Geologically, the area is occupied by Upper Rewa sandstone of Rewa Group; Ganurgarh shale and Bhander limestone formations of Bhander Group, Vindhyan Supergroup. Total of twenty five groundwater samples collected in post monsoon season of 2011 and were analysed to see their suitability for drinking and irrigation purposes. The water samples from Karstic limestone and shaly aquifers are moderately hard to very hard in nature. The higher amount of total dissolved solids in a few samples is due to impervious nature of shale aquifer. The concentration of fluoride in a few samples exceed maximum permissible limit (1.5mg/l) due to fluoride mineral associated with Bhander limestone aquifer. The study reveals that groundwater samples is more or less within prescribed limits as per World Health Organisation (WHO) and Indian Standard Institute(ISI) for drinking purpose. As per Chadha's scheme of classification, the groundwater of the study area is Ca-Mg-HCO_3 and Ca-Mg-SO_4 -Cl type. The calculated sodium adsorption ratio values suggest excellent quality for irrigation. The other parameters such as percent sodium, Kelley's ratio, Permeability index and Residual sodium carbonate suggest that the groundwater of the study area is suitable for irrigation purpose. The samples plotted on U.S. salinity diagram indicate that groundwater of the region is medium to high saline and low alkaline in nature.*

Keywords: *Groundwater Quality, Chakghat, Rewa, Madhya Pradesh, India*

I. Introduction

Groundwater is a most vital natural resources required for drinking and irrigation. The quality of groundwater is largely controlled by discharge-recharge pattern, nature of host and associated rocks as well as contaminated activities. Moreover, the nature and amount of dissolved species in natural water is strongly influenced by mineralogy and solubility of rock forming minerals (Raymahasay, 1996). The quality of groundwater is function of various parameters which determines its suitability for drinking purposes (WHO 1984; Trivedy and Goel 1986; ISI 1991; APHA 1998). In the present study, an attempt has been made to interpret the drinking and irrigation water quality of groundwater around Chakghat area, Rewa District, Madhya Pradesh (Fig.1).

The study area is drained by Tons river and its tributaries and bounded by latitude $24^0$30' to $24^0$45' N and logitude 81^0 00' to $81^0$25' E covering an area of about 900 km^2. The climate is semi arid to humid type and average rainfall of the area is about 1000 mm however in the year 2011 it was recorded 550 mm. The temperature in summer months goes up to 46^0c while as low as 3^0c during peak winter month. The relative humidity of about 75 percentage.

II. Geology and Hydrogeology

The study area is part of northern extension of Vindhyan Sedimentary Basin; one of the thickest sedimentary basin of India. The main rock types are Govindgarh Sandstone of Rewa Group, Ganurgarh Shale and Bhander Limestone of Bhander Group, Vindhyan Supergroup. The sandstone is red and purple in colour, hard and compact, fine to medium grained and quartzitic in nature. The Ganurgarh Shale is buff to purple, thinly laminated and well bedded. The Bhander Limestone is main litho-unit occupying about seventy percent of the study area is massive to karstified, light to dark grey in colour. Limestone is stromatolitic and non-stromatolitic types. The stromatolitic type shows well bedded branching and non-branching columns. Locally bioherms and biostromes are well developed (Tiwari and Dubey, 2005). The non-stromatolitic are generally well bedded, light pink, light grey to dark grey in colour. Both limestones have been affected by silicification in the form of nodular cherts (Dubey et.al., 2009).

Hydrogeologically, the area lies in Precambrian sedimentary province (Karanth,1987). Due to high silica cementation in sandstone, the primary porosity is low whereas secondary porosity in the form of joints, fractures form the source of groundwater. The groundwater occurs in confined and semi-confined conditions. The various karstifications-Rillen, Rinnen and Kluft Karrain developed in the study area are potential source of groundwater.

III. Methodology

A total of twenty five groundwater samples from bore well have been collected during post-monsoon season of 2011. The pH and electrical conductivity of the water samples were measured in the field using portable water analysis kit. The cations and anions of the groundwater samples were analysed using standard methods (Ramteke and Moghe,1986, Trivedi and Goel, 1986, APHA 1998, Mishra et al. 2012; Tripathi et al. 2012). Total dissolved solids (TDS) was calculated by multiplying 0.6 HCO_3 plus other cations and anions.

IV. Result and Discussion

Drinking water Quality

As evident from geochemical analyses of ground water smples presented in table-1, the pH is in range of 7.5 to 8.9 indicating alkaline nature of groundwater. The higher pH values observed in certain samples suggest that carbon dioxide, carbonate-bicarbonate equilibrium is affected more due to change in physico-chemical conditions (Karanth, 1987; Tiwari et al. 2009). Groundwater with pH above maximum desirable limit can affect the mucous membrane. A most of the groundwater samples possess higher electrical conductance indicate that the groundwater was in contact with impervious shale and enough time to react with mineral constituent which added into the groundwater. The total dissolved solids lie between 478.28 mg/l to 1151.80 mg/l; in which most of the samples exceed desirable limit. Water with TDS up to 1000 mg/l is considered to be suitable for drinking (Pophare and Dewalkar, 2007). The higher amount of TDS may cause gasterointestinal irritation in human body. The total hardness of groundwater samples ranges from 299.02 mg/l to 671.68 mg/l. A thirteen samples exceed the maximum permissible limit of hardness as per WHO (1984) and ISI (1991) norms. As per Sawyer and McCarty (1967) classification scheme, the groundwater samples of the study area is very hard in nature may be due to the limestone aquifer which provided the calcium to the groundwater. As a result, the encrustation of carbonate is noticed in water supply pipe lines. The concentration of sulphate varies between 47.4 mg/l to 437.1 mg/l; in which a higher concentration is due to the presence of thin bands of Gypsum ($CaSO_4.2H_2O$) assciated with shale aquifer. The concentration of fluoride ranges between 0.50 mg/l to 2.50 mg/l. The fluoride concentration greater than 1.5 mg/l may cause dental problem however it was not noticed in the area. The higher concentration of fluorite in few groundwater samples may be due to the presence of fluorapatite [$Ca_5(PO_4)_3F$] mineral in limestone aquifer as reported by Tiwari (2000). As evident from Table1, higher concentration of fluorite is strongly related with pH indicating that higher alkalinity of the water promotes the leaching of F^- and thus affects the concentration of F^- in the groundwater (Saxena and Ahmed, 2001; Madhnure et al. 2007). To ascertain the suitability of groundwater for drinking purpose the geochemical parameters of the study area are compared with the guidelines as recommended by WHO(1984) and ISI (1991) which indicate that groundwater of the study area is more or less suitable for drinking purpose (Table 2). Groundwater samples of the study area have been plotted on Chdha's diagram (1999). In this scheme, the difference in millequivalent (epm) percent between alkaline earth (calcium + magnesium) expressed as percentage reacting value is plotted on the x-axis and the difference in milliequivalent (epm) percentage between weak acid anions (carbonate +bicarbonate) and strong acid anions (chloride, sulphate and nitrate) is plotted on the y-axis. The millequivalent percentage difference between alkaline earth and alkalies and between weak acidic anions and strong acidic anions is plotted on one of the four possible sub fields of the diagram. In the present study 12 samples fall in subfield 5 of Ca-Mg-HCO_3 type of water; 13 samples fall in subfield 6 of Ca-Mg-SO_4 -Cl type of water whereas only 1 sample fall in subfield 8 of Na-K-HCO_3 type.

Table 2: Comparison of the quality parameters of groundwater of the study area with WHO and ISI for drinking purpose.

S.No.	Water Quality Parameters	WHO (1984)		ISI (1991)		No. of locations which exceed max. permissible limit (WHO)	Concentration in Study Area	Undesirable Effect Produced Beyond Maximum Allowable Limit
		Max Desirable	Max. Permisible	Max. Desirable	Max. Permisible			
1.	pH	7.0 to 8.5	6.5 to 9.2	6.5 to 8.5	No relaxation	0	6.5 to 8.9	Taste, effects mucus memberane and water supply system.
2.	TH mg/l	100	500	300	600	13	299.02 to 671.68	Encrustation in water supply and adverse effect on domestic use.
3.	TDS mg/l	500	1500	500	1000	0	478.28 to 1151.8	Gastrointestinal irritation.
4.	Ca mg/l	75	200	75	200	0	46.3 to 182.0	Encrustation in water supply, scale formation.
5.	Mg ml/l	30	150	30	100	0	24.3 to 109.8	Encrustation in water supply and adverse effect on domestic use.
6.	Na mg/l	-	200	-	200	0	13.7 to 92.6	--

7.	Cl mg/l	200	600	250	1000	0	38.7 to 208.0	Salty Taste
8.	SO_4 mg/l	200	400	150	400	2	47.4 to 437.1	Laxative effect.
9.	F mg/l	1	1.5	1	1.5	7	0.50 to 2.50	Dental Problem in children and adults causes Fluorosis

V. Irrigation water quality

The important parameters which determine the irrigation water quality of the study area are discussed below;

Percent Sodium (Na%)

It is an important parameter to classify the groundwater samples for irrigation purpose. It is calculated by the formula proposed by Doneen (1962) as under ;

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

Sodium along with carbonate forms alkaline soil; while sodium with chloride forms saline soil; both of these are not suitable for the growth of plants (Pandian and Shankar, 2007). The quality classification of irrigation water based on the values of sodium percentage as proposed by Wilcox (1955) suggest that the groundwater of study area is good to permissible category (Table. 3).

Electrical Conductivity (EC)

It measures the capacity of substance or solution to conduct electric current. The EC of groundwater increases with the rise in temperature and varies with the amount of TDS. The conductivity in the groundwater samples of the area ranges from 746.1 to 1796.8 µs/cm at 25^0C indicating good category of irrigation water.

Sodium Adsorption Ratio (SAR)

The degree to which the irrigation water tends to enter into cation exchange reaction in soil can be indicated by the sodium adsorption ratio (U.S. Salinity, 1954). Since sodium replaces adsorbed calcium and magnesium in soil, hence it is expressed as ;

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

Excess sodium in groundwater gets adsorbed on soil particles, thus change soil properties and also reduce soil permeability (Ayers and Bronson, 1975). U.S. Salinity Laboratory (1954) proposed to plot SAR against EC for rating irrigation water (Table 3). The sixteen classes in the diagram indicate the extent that the waters can effect the soil in terms of salinity hazard. These classes are : low salinity(C_1), medium (C_2) , high (C_3) and very high salinity (C_4) and similarly sodium hazard as low (S_1), medium (S_2), high (S_3) and very high (S_4). The groundwater samples of the study area fall in C_3S_1 (26 samples) and C_2S_1 (1 sample) categories, hence suitable for irrigation purpose indicate that most of the groundwater samples of the study area are medium to high saline and low sodium hazard zone. Hence high salinity water should be used only in those soils where adequate drainage is available to leach out the excessive water.

As per classification of Wilcox (1955), water with SAR $\leq$10 is considered as an excellent quality, between 10 to 18 is good; between 18 to 26 is fair and greater than 26 is said to be unsuitable for irrigation purpose in its natural form. As evident from Table 3, most of the groundwater samples having $\leq$10 SAR; hence excellent for irrigation purpose.

Kelley's Ratio (KR)

It is the ratio of sodium ion to calcium and magnesium ion in epm(Kelley, 1951) and expressed as;

$$\mathrm{K.R.} = \frac{Na^{+}}{\mathrm{Ca}^{++} + Mg^{++}} (epm)$$

The Kelley's Ratio (KR) have been computed for all groundwater samples of the study area and presented in Table 3. In the study area KR ranges from 0.07 to 0.88 indicating that water is suitable for irrigation purpose as the value is less than 1.

Permeability Index (PI)

The classification of irrigation waters has been attempted on the basis of permeability Index, as suggested by Doneen (1962). It is defined as;

$$\text{P.I.} = \frac{Na^{+} + \sqrt{\text{HCO}_3^{-}}}{\text{Ca}^{++} + Mg^{++} + Na^{+}} \times 100 \text{ (epm)}$$

The groundwater samples of the study area fall in class-I. As per Doneen chart (Domenic and Schwartz, 1990), the groundwater samples of the study area is of good quality for irrigation (Fig. 4). The increased percentage of groundwater samples under class–I is due to dilution subsequent lower values of permeability index.

Magnesium Ratio (MR)

It is expressed as:

$$\text{M.R.} = \frac{Mg^{+}}{\text{Ca}^{++} + Mg^{++}} \times 100 (epm)$$

(Palliwal,1972)

If the Magnesium Ratio is greater than 50 percentage it is considered as suitable for irrigation purpose (Palliwal, 1972). In the present study 89 percent samples are good for irrigation whereas 11 percent samples are unsuitable (Table-3).

Corrosivity Ratio (CR)

It is defined as alkaline earth and alkaties and expressed as ;

$$\text{C.R.} = \frac{Cl^{-}/35.5 + 2\left(\frac{SO_4^{--}}{96}\right)}{2\left(\frac{\text{HCO}_3^{-} + CO_3^{--}}{100}\right)}$$

The groundwater with corrosivity ratio < 1 is considered to be safe for transport of water in any type of pipes, whereas >1 indicate corrosive nature and hence not to be transported through metal pipes (Ryner, 1944, Raman, 1985). The calculated values of groundwater samples of the study are presented in Table-3, which suggests that 18 samples are safe whereas 09 samples are corrosive in nature and need non-corrosive pipe for transporting and lifting of groundwater.

Residual Sodium Carbonate (RSC)

It refers to the residual alkalinity and is calculated for irrigation water by the following formula;

$$\text{RSC} = (\text{HCO}_3^{-} + \text{CO}_3^{--}) - (\text{Ca}^{++} + \text{Mg}^{++}) \text{ (epm)}$$

The RSC values > 1.25 mg/l are considered as safe for irrigation while those from 1.25 mg/l to 2.5mg/l are marginally suitable for irrigation. If RSC values are > 2.5 the groundwater is unsuitable for irrigation (Eaton, 1950; Richards, 1954).
The RSC values of groundwater samples of the study area ranges from -9.29 to +1.87 mg/l; hence marginally suitable to safe for irrigation purpose.

VI. Conclusion

The results of geochemical analyses of groundwater samples of the study area indicate that water is slightly alkaline in nature due to pH values of more than 7. The calcium ion associated with limestone aquifer and gypsum bands associated with shale aquifer made groundwater samples moderately hard to very hard. The high fluoride concentration in few groundwater samples of the study area may be due to fluorapatite mineral associated with limestone aquifer. In the study area where concentration of fluoride is high; drinking water should be met from surface water or from shallow dugwells and borewells water may be used for other domestic purpose and not for drinking purpose. The higher values of electrical conductance are due to high concentration of ionic constituents in water (Jasrotia and Singh, 2007, Tiwari et.al., 2010). The higher amount of total dissolved solids (TDS) in a few samples is due to impervious nature of shales which provided longer residence to groundwater (Gopalkrishnan, 2006, Pophare and Dewalkar, 2007). Defluoridation techniques and ion exchange technique may be adopted in area where no alternative source is available with community involvement. The Chadha's (1999) diagram indicates that groundwater samples of the area are Ca-Mg-SO_4 – Cl and Ca- Mg-HCO_3 type. The comparison of analysed data with WHO (1984) and ISI (1991) indicate that groundwater samples of the area are more or less suitable for drinking purpose.

The groundwater samples have also been evaluated for their irrigation quality. The plot of Sodium percentage vs electrical conductance of groundwater samples of the study area suggests that majority of samples fall in good to permissible category. The samples plotted in U.S. Salinity diagram fall in medium to high salinity and low sodium hazard zone (C_3S_1); hence a high salinity bearing water samples should be used only in those soils adequate drainage is available to leach out those waters. The area having higher corrosivity ratio (>1) need non-corrosive pipe during water supply. The other parameters such as Kelley's Ratio, Residual sodium carbonate, Magnesium Ratio, Permeability Index suggest that groundwater of the study area are suitable for irrigation purpose.

REFERENCES

[1] APHA (1998). Standard methods for the examination of water and waste water 20th edition, American Publ. Health Assoc. Washington; pp.10-161.

[2] Ayers,R.S. and Bronson, R.L. (1975). Guidelines for interpretation of water quality for Agriculture University of California, Extension Mimeographed, 13 p. t

[3] Chadha, D.K. (1999). A proposed new diagram for geochemical classification of natural waters and interpretation of chemical data. Hydrogeol. Jour., v.7,pp. 431-439.

[4] Domenico, D.A. and Schwartz, F.W.(1990). Physical and chemical Hydrogeology. John wiley and sons, NewYork, pp. 410-420.

[5] Doneen, L.D. (1962). The influence of crop and soil on percolating water. Proc. 1961 Biennial conference on Groundwater Recharge, pp.156-163.

[6] Dubey, D.P., Tiwari, R.N. and Shrivastava, R.K. (2009). Petrography of Chert Nodules from the Bhander Limestone Formation, Rewa Distric, Madhya Pradesh, Gond. Geol. Magz. v. 24(2), pp. 157-160.

[7] Eaton, E.M. (1950). Significance of carbonate in irrigation water. Soil Science. v.69. pp. 123-133.

[8] Gopalkrishna, G.S., Harinarayanan, P. and Balasubranian, A. (2006). Groundwater quality in twin micro-watersheds near Keralapura, Hassan District Karnataka, Jour. Geol. Soc. India, v.67.pp.802-808.

[9] Hegde, G.V. (2006). Evaluation of chemical quality of groundwater in Dharwad District, Karnataka, Jour. Geol. Soc. Inida v.67 pp.47-58.

[10] ISI (1991). Indian standard specification for drinking water. IS : 10500, Indian Standard Institution, pp. 1-5.

[11] Jasrotia, A.S. and Singh, R.(2007). Hydrochemistry and groundwater quality around Devak and Rui watershed of Jammu Region, Jammu and Kashmir, Jour. Geol. Soc. India, v.69, pp. 1042-1054.

[12] Karanth, K.R. (1987) Groundwater Assessment Development and Management Tata McGraw Hill publishing company Ltd., New Delhi, 725p.

[13] Kelley, W.P. (1951). Alkali soils-their formation properties and reclamation. Reinold Publ. Corp., New York.

[14] Madhnure, P. Sirsikar, D.Y. Tiwari, A.N., Ranjan, B. and Malpe, D.B.(2007). Occurence of fluoride in the groundwaters Pandharkawada area, Yawatmal district, Maharastra, India. Curr. Sci, v. 92(5), pp.675-679.

[15] Mishra, U.K.,Tripathi A.K., Tiwari Saras and Mishra Ajay (2012). Assessment of Quality and Pollution Potential of Groundwater around Dabhaura Area, Rewa District, Madhya Pradesh. Earth Science Research; Canada. v.1,No.2;pp.249-261(2012).

[16] Palliwal, K.V. (1972). Irrigation with saline water, ICARI Monograph No.2, New Delhi, 198 p.

[17] Pandian, K. and Sankar, K. (2007). Hydrochemistry and groundwater quality in the Vaippar river basin, Tamil Nadu. Jour. Geol.Soc. India, v.69, pp. 970-982.

[18] Pophare, A. M. and Dewalkar, M. S. (2007). Groundwater quality in Eastern and Southeastern parts of Rajura Tehsil, Chandrapur District, Maharastra. Gond. Geol. Magz. Spec. Vol. pp.119-126.

[19] Raman, V. (1985). Impact of corrossion in the conveyance and distribution of water. Jour. I.W.W.A; v. xv(11) pp. 115-121.

[20] Ramteke, D.S. and Moghe, C.A. (1986). Manual on water and waste water analysis. NEERI, Nagpur, 340p.

[21] Raymahashay, B.C. (1996). Geochemistry for hydrologists, CBS Publisher New Delhi; 190p.

[22] Richards, L.A. (1954). Diagnosis and improvement of saline and alkali soils. Agri. Handbook 60, U.S. Dept. of Agriculture, Washington. D.C. 160p.

[23] Ryner, J.W. (1944). A new index for determining amount of calcium carbonate scale formed by water, Jour. Amer. Water Assoc. v. 36. pp. 472-486.

[24] Saxena, V.K. and Ahmed S. (2001). Dissolution of fluoride in groundwater. A water-rock interaction study. Environ. Ged. v.40, pp. 1084-1087.

[25] Sawyer, C.N. and McCarty, P.L. (1967). Chemistry for sanitary Engineers, IInd edition, McGraw Hill, New York, 518 p.

[26] Singh, D.H. and Lawrence, J.F.(2007). Groundwater quality assessment of shallow aquifer using geographical information system in part of Chennai City, Tamil Nadu. Jour. Geol. Soc. India, v.69.pp.1067-1076.

[27] Tiwari, R.N. (2000). Sedimentological and Geochemical studies of Bhander Limestone of Vindhyan supergroup, Rewa and Satna District, Madhya Pradesh, unpublished Ph.D. thesis, A.P.S. University Rewa 138 p.

[28] Tiwari, R.N. and Dubey, D.P. (2005). Stromatolites and depositional environment of Bhander Limestone, Rewa area, Madhya Pradesh. Gond. Geol.Magz. v. 19(1) pp. 131-134.

[29] Tiwari, R.N. and Singh, A.K. (2010). Groundwater quality and pollution potential of Mahana River Basin, Rewa District, Madhya Pradesh, India, Proc. International Conference on Hydrology and Watershed, JN&T Hyderabad, pp. 49-59.

[30] Tiwari, R.N., Bharti, S.L., Mishra, Umesh (2010) Hydrogeochemical Studies of Groundwater from Odda River Basin, Rewa District, Madhya Pradesh, Gondwana Geological Magazine, Special v. No. 12, pp.85-93.

[31] Tiwari, R.N., Dubey, D.P. and Bharti, S.L. (2009). Hydrogeochemistry and groundwater quality in Beehar River Basin, Rewa district, Madhya Pradesh, India. Inter. Jour. Earth Eng. Sci., v.2(4), pp. 324-330.

[32] Tripathi, A.K., Mishra U.K., Mishra Ajay and Dubey Parul(2012). Assessment of Groundwater Quality Gurh Tehseel, Rewa District Madhya Pradesh, India International Journal of Scientific and Engineering Research[IJSER]v.3, Issue 9, pp.1-12 (2012).

[33] Trivedy, R.K. and Geol, P. K. (1986). Chemical and biological methods for waste Pollution studies. Environmental Publication, Karad, pp. 35-96.

[34] U.S. Salinity Laboratory Staff (1954). Diagnosis and improvement of saline and alkali soils. U.S. Dept. Agriculture Hand book, No. 60, 160p.

[35] WHO (1984). Guidelines for drinking water quality v. I Recommendations. World Health Organization Geneva. 130p.

[36] Wilcox, L.V. (1955). Classification and use of irrigation waters, U.S. Depatment of Agriculture. Circ. 969, Washington, D.C.

Table 1 : Geochemical analyses of groundwater samples of the study area
(Except pH and EC, all values are in ppm)

S.No.	Location	PH	EC	TDS	TH	Na	K	Ca	Mg	F	Cl	SO_4	HCO_3
1.	Chandrapur	6.7	1283.0	822.44	546.68	75.06	3.10	108.3	67.3	1.08	66.3	117	640.0
2.	Pahari	8.5	847.0	542.95	530.13	41.20	4.70	123.0	54.30	1.85	53.7	81.2	305.0
3.	Janeh	8.0	915.7	587.01	469.92	69.80	5.20	95.8	56.2	1.38	90.3	102.0	278.3
4.	Sohagi	7.1	1033.1	662.26	582.16	91.70	7.30	89.2	87.6	1.56	58.6	107.3	365.0
5.	Chakghat	7.2	999.3	640.60	671.68	68.50	5.30	88.6	109.8	0.50	163.0	52.5	254.0
6.	Chandi	6.8	1148.9	736.50	410.23	113.00	5.40	69.3	57.8	0.80	78.30	198.3	356.0
7.	Khatiya	7.1	793.9	508.96	464.28	80.70	9.20	127.0	35.8	0.56	57.9	115.0	138.0
8.	Pancha	8.9	900.8	577.47	513.59	74.30	8.40	103.1	62.4	2.01	83.7	51.9	321.1
9.	Sohagi	7.3	858.6	550.38	413.86	33.20	6.70	47.3	72.1	0.78	176.0	85.30	215.00
10.	Barageon	7.5	902.2	578.32	518.33	75.1	7.90	102.7	63.8	1.00	84.2	52.1	319.2
11.	Raipur	7.6	926.0	593.60	591.02	15.70	3.20	118.0	72.2	1.30	45.0	95.2	405.0
12.	Sonauri	6.9	1164.2	746.25	374.13	25.40	15.30	109.8	24.3	1.05	40.2	415.0	192.0
13.	Sonvarsha	6.8	1117.9	716.60	434.15	73.70	2.40	89.2	51.5	1.00	85.7	162.0	418.5
14.	Magee	7.2	860.9	551.87	560.25	52.60	11.20	182.0	25.6	1.40	64.8	47.4	278.0
15.	Satpura	8.3	881.2	564.85	419.99	75.20	4.30	87.8	48.9	1.85	57.3	112.5	295.0
16.	Loni	7.6	758.7	486.37	426.24	72.90	3.20	89.2	49.6	1.00	45.6	115.7	182.0
17.	Chunari	6.8	1199.3	768.77	574.16	92.60	3.70	101.3	78.3	1.20	203.0	78.7	350.0
18.	Malpar	7.2	1290.0	826.90	433.40	74.70	2.60	84.8	54.0	0.70	83.6	278.0	417.5
19.	Antarsuai	8.2	746.1	478.28	299.02	33.80	6.70	75.0	27.2	1.50	55.7	79.0	332.0
20.	Phuthaudha	7.4	1796.8	1151.80	612.37	24.30	3.40	108.5	83.2	1.20	92.1	437.1	670.0
21.	Neebi	8.5	1042.4	668.18	386.41	23.70	18.0	109.3	27.6	2.50	38.7	95.5	585.2
22.	Naribari	8.0	1068.2	684.72	579.62	18.70	4.40	120.0	68.2	1.68	43.8	141.8	475.7
23.	Bharat Nagar	7.4	836.9	536.50	348.84	26.32	3.20	83.4	34.2	0.85	208.0	79.7	168.0
24.	Bagheri	7.2	787.2	504.62	542.28	13.70	4.30	109.0	65.8	0.50	59.2	142.5	182.7
25.	Chunri	6.9	1244.5	797.77	618.71	40.00	1.30	70.2	108.1	0.75	86.1	157.0	557.2

Table-3 Characteristic ratio and indices of ground water samples of the study area.

SN.	Location	Soluble Na%(SSP)	Sodium Adsorption Ratio(SAR)	Permeability Index(PI)	Kelley's Ratio(KR)	Mg Hazard (MR)	Residual Sodium Carbonate(RSC)	Corrosivity Ratio(CR)
1.	Chandrapur	30	1.39	46.2	0.42	38.3	-0.45	0.3
2.	Pahari	21	0.78	32.4	0.23	30.6	-5.60	0.5
3.	Janeh	33	1.38	41.6	0.45	36.9	-4.84	0.8
4.	Sohagi	35	1.64	41.1	0.51	49.5	-5.67	0.5
5.	Chakghat	27	1.14	30.5	0.34	55.3	-9.29	1.0
6.	Chandi	48	2.43	55.8	0.88	45.4	-2.37	0.8
7.	Khatiya	35	1.63	39.2	0.49	21.9	-7.01	1.3
8.	Pancha	33	1.43	40.8	0.45	37.7	-5.01	0.5
9.	Sohagi	25	0.71	34.1	0.27	60.3	-4.77	1.5
10.	Barageon	33	1.42	40.6	0.45	38.3	-5.13	0.5
11.	Raipur	09	0.28	26.1	0.08	37.9	-5.18	0.3
12.	Sonauri	23	0.57	33.6	0.18	18.1	-4.32	2.5
13.	Sonvarsha	35	1.54	48.9	0.52	36.6	-1.83	0.6
14.	Magee	23	0.96	32.8	0.25	12.3	-6.64	0.4
15.	Satpura	36	1.59	46.7	0.55	35.7	-4.43	0.6
16.	Loni	35	1.52	41.9	0.52	35.8	-5.54	1.0
17.	Chunari	34	1.67	41.4	0.51	43.5	-5.75	1.0
18.	Malpar	35	1.56	49.1	0.54	38.9	-1.83	0.9
19.	Antarsuai	28	0.93	51.1	0.33	26.6	-0.53	0.4
20.	Phuthaudha	12	0.43	32.7	0.12	43.4	-1.27	0.8
21.	Neebi	23	0.52	47.2	0.17	20.1	+1.87	0.2
22.	Naribari	11	0.34	29.0	0.09	36.2	-3.80	0.4
23.	Bharat Nagar	20	0.61	34.6	0.22	29.0	-4.22	2.1
24.	Bagheri	09	0.25	20.3	0.07	37.6	-7.85	1.2
25.	Chunri	18	0.70	33.6	0.22	60.6	-3.26	0.5

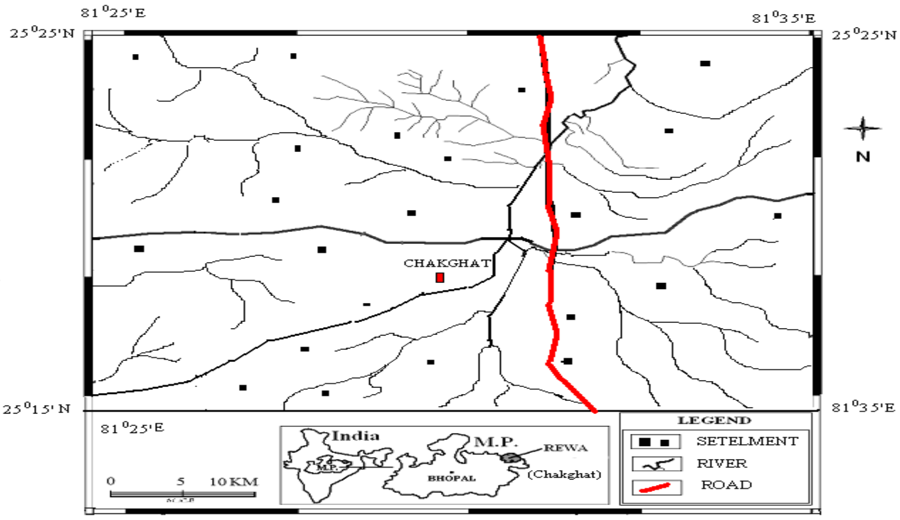

Fig. 1 Location Map of the Study Area.

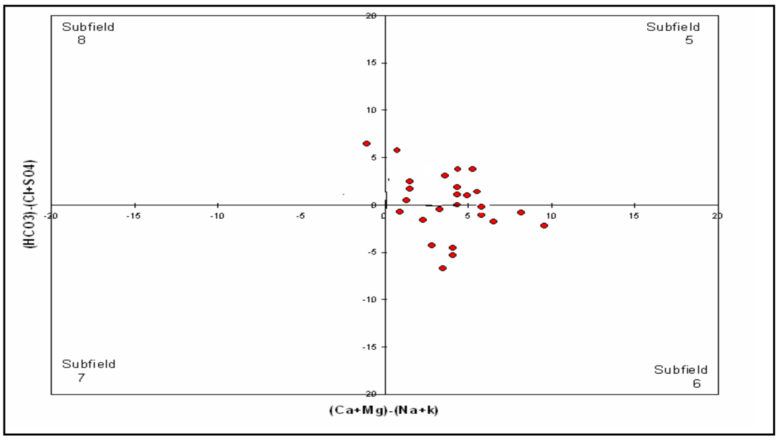

Fig.2: Classification of Groundwater samples as Per Chadha's (1999) Scheme.

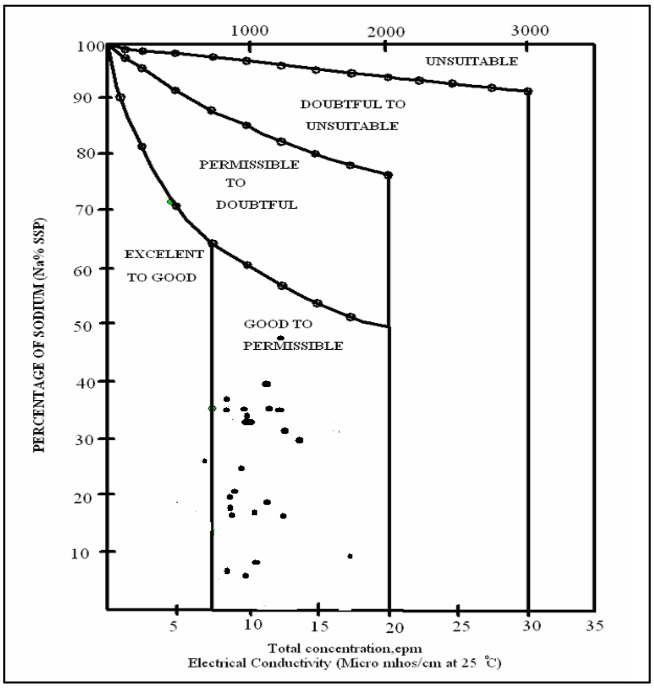

Fig. 3: Plot of Sodium percent vs. Electrical conductivity (after Wilcox 1955).

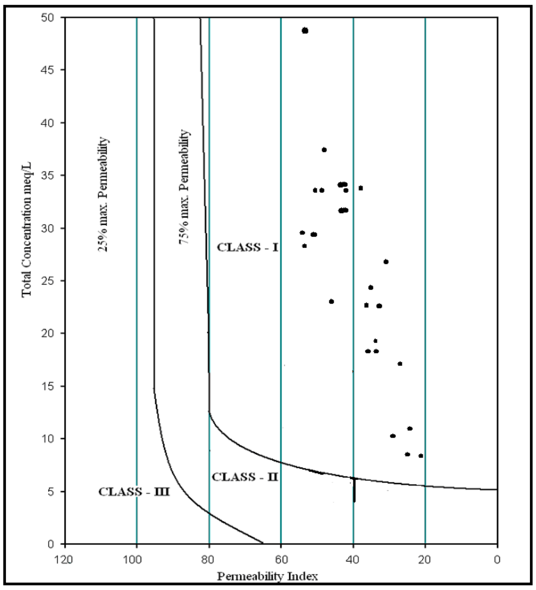

Fig.4: Classification of irrigation water (Doneen, 1962)

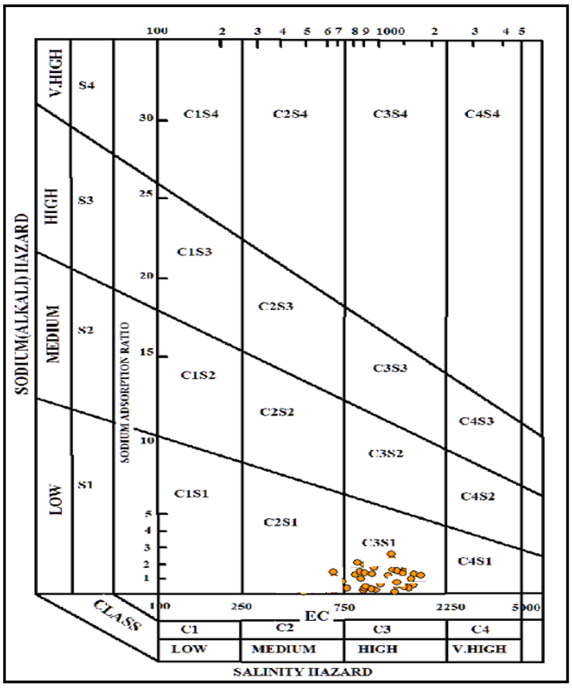

Fig. 5: U.S. Salinity Diagram for classification of irrigation water [after Richards (1954)]