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Hydrogeochemistry and ground water quality in and around Joda of Keonjhar District, Odisha, India

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ABSTRACT: The hydrochemical characterstics and quality of ground water in and around Joda have been evaluated collecting seventeen ground water samples in pre-monsoon and post monsoon periods for analysis of various physico-chemical parameters like pH, EC, TDS, total hardness, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-}, HCO_3^{-}, SO_4^{2-}, NO_3^{-}, PO_4^{3-}, Cl^{-}. The recorded pH values ranging from 6.00-7.32 show that all the samples in pre-monsoon and most of the samples in post-monsoon periods are acidic in nature. More or less all samples are suitable for domestic use with respect to other parameters as per the BIS and WHO guidelines. Piper Trilinear plots indicate that the predominant hydro-chemical facies are Ca-HCO_3 type in both the seasons and according to Gibbs diagram the source of ions are mainly due to rock weathering. Along with weathering of rocks and minerals, mining and domestic activities are the contributing factors for the addition of various ions in the water bodies. Wilcox diagram and other indices like % sodium, Sodium adsorption ratio, Residual sodium carbonates and Kelly's ratio reveal that most of the samples are suitable for irrigation. U.S Salinity diagram indicates that the water samples have low to medium salinity hazard and low to medium sodium hazard. All the samples are corrosive with respect to pH in pre-monsoon period and 76 % samples are corrosive in post monsoon period but all are free of incrusting property in both the seasons. The corrosivity ratio indicates that all samples are suitable for industrial use.

KEYWORDS: physico-chemical parameters, hydrochemical facies, weathering, Piper Trilinear plot, salinity hazard, corrosivity.

1 INTRODUCTION

Natural water contains almost every element in the periodic table and also dissolved organic matter of largely unknown composition and colloidal and particulate material, both inanimate and living. The chemistry of water is largely controlled and modified by its medium of contact and directly affects the quality of water for various purposes. It hence needs monitoring and proper assessment. A tremendous increase in the population increased the stress on both surface and groundwater. Ground water, being a key source of fresh drinking water is essential to life as well as for human consumption, irrigation, industrialisation and urbanisation. The quality of ground water also helps for ground water management and development for future water resources development strategies. Ground water quality depends on the quality of recharged water, atmospheric precipitation, inland surface water and sub-surface geochemical processes[1]which is strongly influenced by mineralogy and solubility of rock forming minerals[2].Contamination of ground water occurs due to expansion of industries, mining and socio-economic activities along with unscientific management of water resources. Other potential sources of contamination are waste water treatment lagoons, mine spills, urban and rural run offs and garbage, earthen septic tanks, refuge dumps, barnyard manures. India is a vast country with varied hydro- geological situations resulting from diversified geological, climatological and topographic settings. Hydrochemistry and studies on classification of groundwater are carried out to evaluate its suitability for municipal, agricultural and industrial uses[3]. Majority of metallic mineral mines like Iron, manganese and chromium are concentrated in and around Joda in the district Keonjhar of Odisha. Thus, a large scale mining activities and industrialization based on these metallic minerals are carried out in different mineral-bearing areas, causing a substantial land degradation and contamination of water. The study area in and around Joda is dominated by backward and tribal population. The area is susceptible to be contaminated directly and indirectly at each segment of environment due to industrial and mining activities along with the related activities like transportation of ores, burning of coal, domestic activities and automobiles. Local people are not so conscious about its impacts on their health, socio-economic status, etc. due to lack of awareness. No such extensive studies have been done so far in this area to highlight the extent of contamination particularly for water and its impacts on the locality. This study aims to characterise ground water quality with respect to some physico-chemical parameters alongwith hydrogeochemistry and its usability for domestic, agricultural and industrial purposes.

2 STUDY AREA

The study area under investigation, in and around Joda is the north-west part of Keonjhar district of Odisha, bounded by latitude 21^0 49′ 55″ and 22^0 03′ 49′′ north and longitude 85^0 22′ 08″ and 85^0 32′ 52″ east(fig.1). It comprises Joda Municipality and some part of Joda block as well as Jhumpura block that refers to the Toposheet No. 73 F/8, 73 F/12, 73 G/5 and 73 G/9. The total population of the area is around 1,50,000.The study area forms a part of Singhbhum-Keonjhar- Bonai iron ore formation belonging to Iron Ore Super Group of Pre-Cambrian age. The major rock types of this area belong to Banded Iron formation such as BHJ, BHQ, BHC and banded –ferruginous shale. The BIF along with the volcanic, sedimentary and meta-sedimentary rock piles constitute the Iron Ore group. Other associated rocks are basic rocks and laterites. The geology of the study area comprises various rock types such as sandstone and quarzites of Kolhan Group and Basalt,Tuff, Metagabbro, Shale. BHQ, BHJ, Ferrugenious Shale, Quartzite, Pebbly Quartzite, Grity Quartzite, Singhbhum Granite/ Hornblende Granite and Pellitic Schist. The major mineral deposits are haematite, goethite, pyrolusite and psilomelane and are associated with iron ore group of rocks. There are also some limestone deposits in Joda. The surface of some places is occupied with light textured laterites and medium textured red loam soils. The average minimum and maximum temperature of this region is 8.9^0C and 40.6^0 C respectively with average rain fall of 1501mm for last five years.

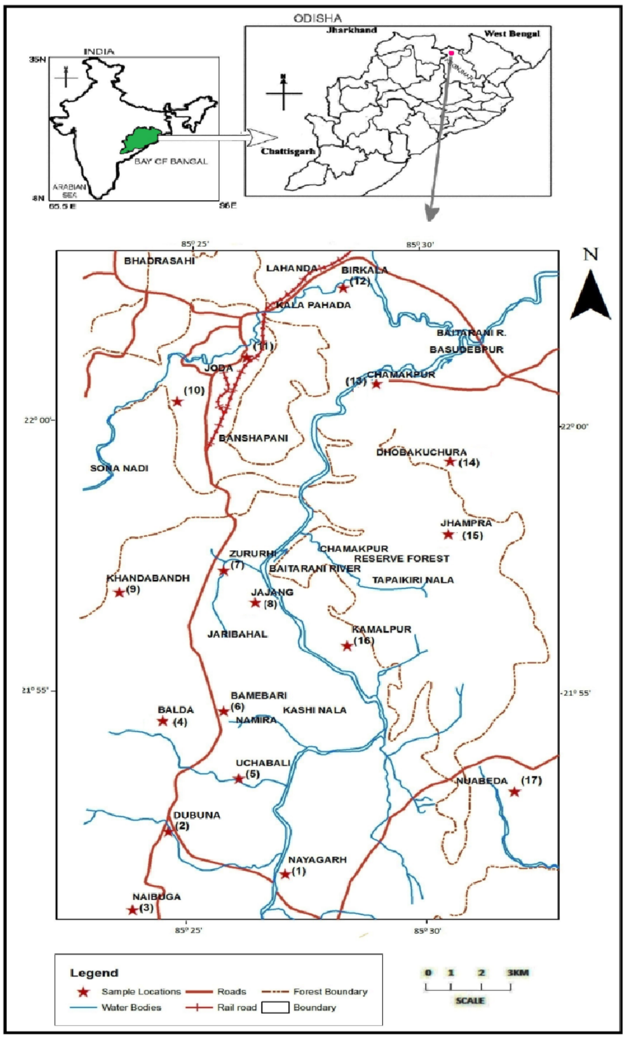


Fig. 1. Study area map,in and around Joda with ground water sampling stations

3 MATERIALS AND METHODS

The present study was carried out for a period of one year 2011-12 and ground water samples were collected from 17 different stations in pre-monsoon(March-June-2011), and post monsoon(November-2011-February-2012) periods at a regular interval of once in a month.Water samples were collected in acid- washed plastic bottles of one ltr. capacity having double stopper facilities to its full capacity without entrapping air bubbles inside. The collected samples were sent to water quality laboratory of Central Water Commission, Bhubaneswar for analysis. Analysis of samples were conducted for various physico-chemical parameters like pH, EC, TDS, total hardness, cations like Ca^{2+},Mg^{2+},Na^{+},K^{+} and anions like CO_3^{2-},HCO_3^{-}, SO_4^{2-}, NO_3^{-}, PO_4^{3-},Cl^{-}. However pH, EC, were measured by using respective digital meters. Other parameters were measured by standard methodology [4], [5]. These parameters were compared with the standard guideline values, recommended by BIS[6] and WHO [7] to assess the potability of the ground water samples. Suitability of these water samples for Irrigation was determined according to various parameters like Salinity, Percent Sodium (Na%), Sodium Adsorption Ratio (SAR), Residual Sodium carbonate **(** RSC), Magnesium Ratio (MR) and Kelley's Ratio (KR)[8], [9],[10].

Percent Sodium (Na%)

It is an important parameter to classify the groundwater samples for irrigation purpose which is calculated by the formula proposed by as under in epm,

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

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 Since sodium replaces adsorbed calcium and magnesium in soil, hence it is expressed as ;

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

Residual Sodium Carbonate (RSC)

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

RSC = $(HCO_3^{-} + CO_3^{--}) - (Ca^{++} + Mg^{++})$ in epm.

Kelley's Ratio (KR)

It is the ratio of sodium ion to calcium and magnesium ion in epm[11] and expressed as;

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

Magnesium Ratio (MR

It is expressed as MR= $[Mg^{++}/ (Ca^{++}+Mg^{++})]$ in epm.

Assessment of the water quality of the study area for industrial use was done by considering various industrial quality criteria like pH ,EC, Cl^{-}, HCO_3^{-}, SO_4^{2-} and Corrosivity Ratio (CR) .

Corrosivity Ratio (CR)

It denotes susceptibility of groundwater to corrosion and is expressed as ratio of alkaline earth to alkali salts in ground water, which is of folloing formula;

$$\text{C.R.} = \frac{Cl^{-}/35.5 + 2\left(\frac{SO_4^{--}}{96}\right)}{2\left(\frac{\text{HCO}_3^{-} + CO_3^{--}}{100}\right)}$$ where all the ions are expressed in ppm.

4 RESULTS AND DISCUSSION

4.1 WATER QUALITY FOR DOMESTIC USE

The chemical analysis data(Table.1) shows that the values of pH, TDS, EC and Total Hardness of the water samples varies from 6.00 - 7.32, 103-409 mg/l, 161-645 µs/cm and 42.89-183.06 mg/l respectively in pre-monsoon and post monsoon periods..The concentrations of various anions HCO_3^-, SO_4^{2-} NO_3^- , PO_4^{3-} and Cl ranges 53.51-191.62, 1.32-25.79-, 0.51-5.33, 0.02-2.37 and 6.10-40.02 mg/l respectively. Various cations such as Ca^{2+},Mg^{2+},$Na^+$and K^+ have the concentrations which ranges from 10.42-48.12, 2.92-16.52, 1.80- 21.10 and 0.20-12.67 mg/l respectively. The values are within BIS and WHO limits. Some samples are of pH values less than 6.5,the lower limit of both BIS and WHO guidelines for drinking water.

Seasonal variations of the recorded parameters of the water samples are not in a particular trend. In most of the cases EC, TDS, $SO^{2-}_{4,}$ PO_4^{3-} and Cl^- have higher concentrations in Pre-monsoon than that of post monsoon period. At the same time some samples are with higher concentrations in post-monsoon than those of pre-monsoon period. Parameters like TH, Ca^{2+},Mg^{2+},Na^+,K^+,, HCO_3^{--} and NO_3^- have higher concentrations in post monsoon with comparison to pre-monsoon period for the most of the samples and few samples having the reverse trends. Higher concentration of cations and anions in pre-monsoon period is because of semi arid type of climate, which promotes higher rate of evaporation causing increase in concentration of ions [12]where as lower concentrations in post monsoon is due to recharge of water body, infiltration and dilution factor as effect of the monsoon period. This trend is specifically remarkable in topographically flat areas with comparison to that of hilly areas[9].On the other hand, mining operations along with associated activities and domestic activities may contribute more dissolved ions during monsoon. Active leaching and subsequent infiltration causes the higher concentration of various ions in post monsoon period by percolation of water through various layers of soil, dissolution of minerals from lithological composition in mining areas[1]. The water samples in study area are nearly neutral to slightly acidic in pre-monsoon and acidic as well as alkaline in various stations in post monsoon periods. Acidic nature is due to the interaction of ground water with iron rich laterite, silicate rocks and iron ores[9]. Water, discharged on the surface during mining ultimately takes route through ground water and surface water and contaminates both[13],[14]. The slightly alkaline nature of some water samples like Balda, Joda, Uchhabali, Birkala is due to the factors like air temperature, which brings about changes in the pH of water. The reduced rate of photosynthetic activities reduces the assimilation of CO_2 and HCO_3^- which are ultimately responsible for increase in pH[15]. Also it indicates the presence of weak basic salts in the soil and maximum pertcentage of CO_2. in water present as bi-carbonate. The variation of pH from 6.00 -7.32 mg/l may be attributed to different types of buffers normally present in ground water[16]. Considering the hardness of different samples, only a few are categorised as soft water both in pre and post monsoon period. Most of the water samples are moderately hard and water samples at Joda, Chamakpur, Dhobakuchura, Jajang are categorised as hard water. Hard water is unsuitable for domestic use. Electrical conductivity of water is a direct function of its total dissolved salts, which is a measure of salinity of water. Comparatively higher EC values of some samples than others may be due to multiple factors like weathering of rocks and minerals, leaching of various ions from mine sites, domestic activities and untreated sewage disposal etc..Generally TDS and EC are higher in ground water because of longer residence time of solutions in sub-surface environment[17].

Sulphates in ground water is principally derived from the dissolution of naturally occurring gypsum. Secondary sources are the weathering of pyrites, dissolving of ammonia sulphates fertilizers, and anthropogenic activities**.** The Sulphate contents in the study area is mainly due to oxidation of traces of pyrites, associated with iron ore deposits, atmospheric precipitations and domestic wastes[18]. Comparatively more concentration of NO_3^- ions in some of the samples is attributed to the leaching of the ions from agricultural land, sewage system, dumping of domestic waste, open animal yards. PO_4^{3-} is of very less amount in all water samples showing less agricultural activities. Maximum PO_4^{3-} concentration is recorded at Dhobakuchura due to cultivated lands in the area. As the chloride content of common rocks and minerals type of the study area is very low, the main source of this ion may be rain water, which might have undergone the base exchange phenomenon[19].Agricultural activities, industries, sewage contamination, invasion of domestic wastes and disposals by human activities also causes significant amount of chloride in water samples [16].

In the study area, the degree of variation of Na content is probably due to the differential weathering of the plagioclase feldspar of the parent rocks. In some localities, the higher value of Na might be due to the base exchange of Ca and Mg, causing a reduction in their amount[20]. Minerals like orthoclase, microline, and muscovite are responsible for the K content in the groundwater of the study area, the range of which is relatively low, because of its resistance towards dissolution and its adherence to clay minerals. Water samples of Zururhi, Chamakpur, Jajang, Joda, Balda have higher concentrations of almost all cations and anions in comparision to other samples may be because of their locations, nearer to surface water bodies, mining sites and densely populated areas. The water samples of Dubuna, Jajang,Bamebari, Zururhi have pH less than 6.5. This indicates that the surface water ground water ineraction, mining activities, domestic wastes and untreated sewages alongwith natural weathering processes are the causative factors leading to the contamination of ground water in the study area. Thus, the overall assessment is that, more or less all the ground water samples of the study area are potable with respect to maximum permissible limits of various physico-chemical parameters except for pH as proposed by BIS (2012) and WHO (2008).

4.2 Hydrogeochemistry

4.2.1 Hydrogeochemical Facies

The plots of major cations and anions in the groundwater samples in Piper Trilinear diagram(Fig.2a and 2b) shows that all samples represent Ca-HCO_3 facies both in pre-monsoon and post-monsoon period. The Ca-HCO_3 facies indicates the predominance of of alkaline earths over alkalis and abundance of weak acids over strong acids[21],[22].No significant change in the hydro-chemical facies is noticed during the study period both pre-monsoon and post-monsoon, indicating the natural origin of most of the major ions [23]. In the normal groundwater systems, the principal origin of Ca and Mg ions is carbonate minerals and their dissolution and depositional processes. Weathering of silicate minerals also contributes towards the enrichment of these minerals. Relatively less abundance of the carbonate minerals in the study area indicate that the major origin of Ca and Mg is silicate weathering. Bicarbonate is the dominant anion in the study area. Apart from the dissolution of carbonated minerals and rocks the major origin of bicarbonates are the sewage systems[18].

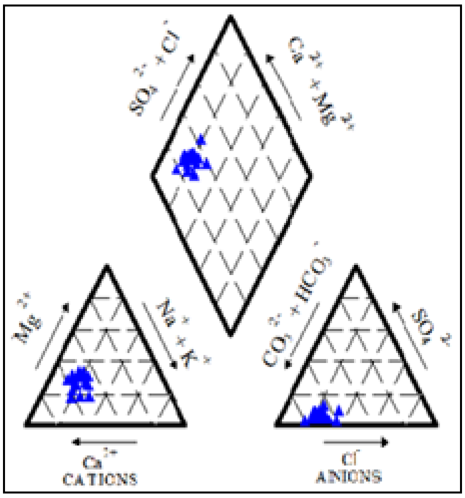


Fig. 2a

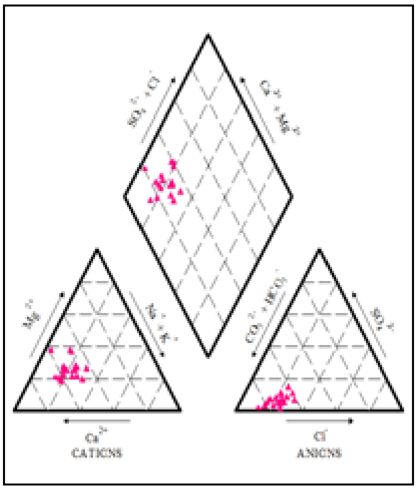
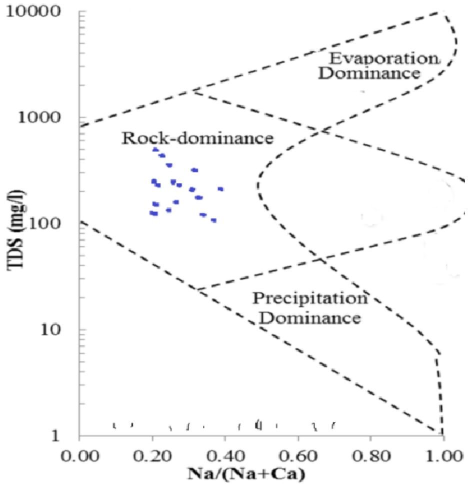


Fig.2b

Fig. 2a & 2b. Piper Trilinear diagram for ground water in pre-monsoon and post-monsoon period

4.2.2 Mechanism Controlling Groundwater Quality

The mechanism controlling chemical relationships of ground water, based on aquifer lithology has been studied to interprete the rock -water interaction [24]. It is observed that the plots of different samples in Gibbs' diagram (Fig.- 3a,3b and 4a,4b)fall in the "rock dominance" field indicate that the chemistry of the aquifers and rock weathering is the major mechanism controlling the ground water chemistry.



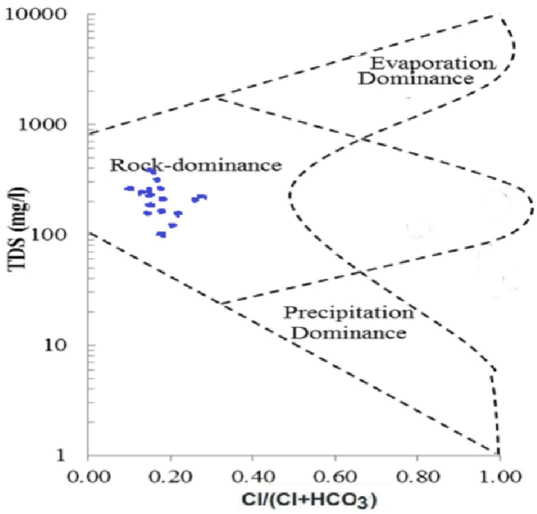
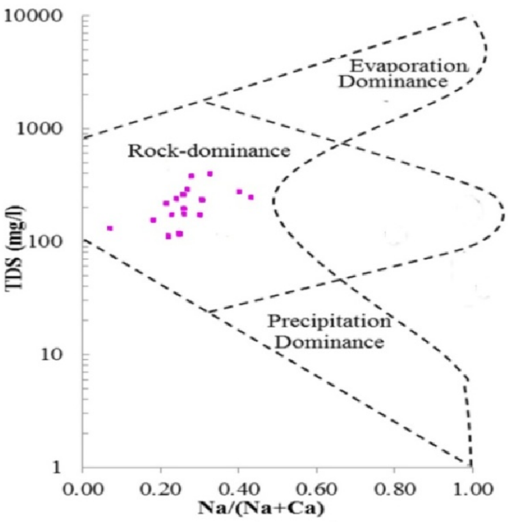


Fig. 3a **Fig. 3b**

Fig. 3a & 3b. Gibbs diagram for ground water in pre-monsoon period



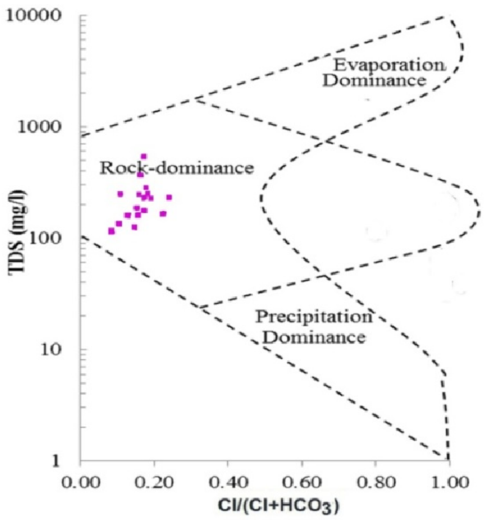


Fig. 4a **Fig. 4b**

Fig. 4a & 4b. Gibbs diagram for ground water in post-monsoon period

4.3 WATER QUALITY FOR IRRIGATION

The suitability of ground water samples for irrigation purpose have been evaluated according to various indices for water quality criteria for irrigation as computed in Table:-2.

4.3.1 SALINITY

The TDS content, which determines the electrical conductance(EC) indicates salinity hazard to irrigation. Most of the water samples of the study area fall under low to medium salinity class.

4.3.2 % SODIUM

In natural water, % of sodium contents is a vital parameter to assess the ground water suitability for irrigation purpose because sodium reacts with soil to reduce its permeability and support a little or no growth. Out of total 17 samples 53 %

belong to excellent and 47 % belong to good in pre-monsoon period but 59 % belong to excellent and 41 % belong to good in post monsoon period. The suitability of water samples for irrigation use was identified from Wilcox diagram(Fig.5a and 5b), based on EC and % Na[25] show that all the water samples are excellent to good quality for irrigation both in pre-monsoon and post- monsoon period.

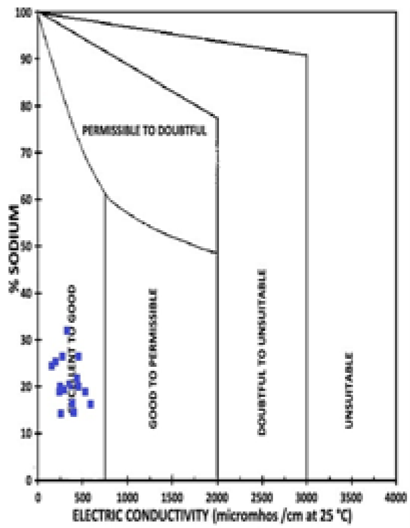


Fig. 5a

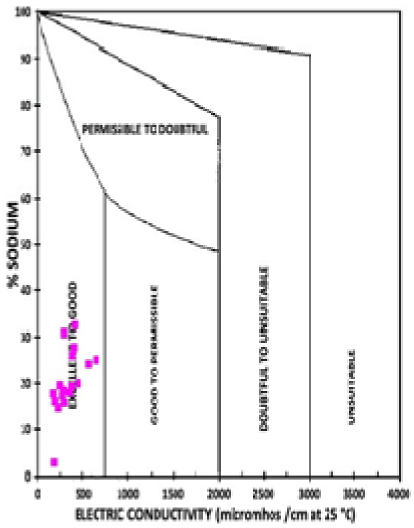


Fig. 5b

Fig. 5a & 5b. Wilcox diagram for ground water in pre-monsoon and post-monsoon period

4.3.3 SODIUM ADSORPTION RATIO (SAR)

The Sodium Adsorption Ratio (SAR) parameter evaluates the sodium hazard in relation to calcium and magnesium concentrations. The classification of water samples with reference to SAR are under no problem category both in post monsoon and pre-monsoon period. According to the U.S. Salinity diagram classification[26] (Fig.6a and 6b), the water samples fall in the field of C_1- S_1 & C_2- S_1 indicating low and medium salinity hazard and low sodium hazard in pre-monsoon period. The samples of post -monsoon period are in C_1-S_1,C_2-S_1 and C_2-S_2 field.12% of the samples are in C_2-S_2 field indicating medium salinity and sodium hazard.

4.3.4 RESIDUAL SODIUM CARBONATES (RSC)

The Residual Sodium Carbonates is the excess of carbonate and bicarbonate concentration over the alkaline earth mainly calcium and magnesium. All the water samples are safe for agricultural purposes with respect to RSC both in pre-monsoon and post- monsoon periods.

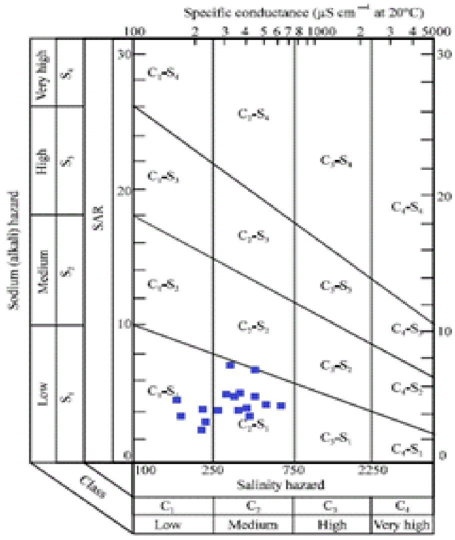


Fig. 6a

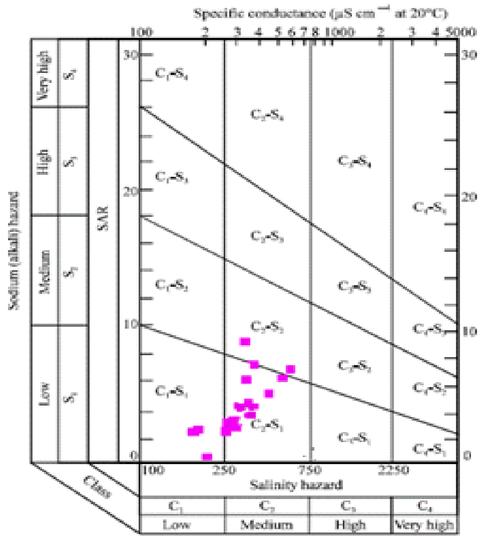


Fig. 6b

Fig. 6a& 6b. US Salinity diagram for ground water in pre-monsoon and post-monsoon period

4.3.5 MAGNESIUM RATIO (MR)

Magnesium ratio (hazard) may be described as the excess amount of magnesium over calcium and magnesium amount where otherwise generally calcium and magnesium will be in condition of equilibrium. The excess of magnesium affects the quality of soil which is the cause of poor yield of crops. The magnesium ratio in water sample in study area was found to be less than the permissible limit (more than 50 %) for all samples in pre-monsoon and post monsoon period.

4.3.6 KELLY'S RATIO (KR)

With respect to Kelly's ratio all the water samples are suitable for irrigation both in pre-monsoon and post monsoon periods as KR < 1.

5 WATER QUALITY FOR INDUSTRIAL USE

5.1 CHEMICAL PARAMETERS

Quality criteria for industrial use vary widely since different industries require water of varying quality. The mining industry is the most important industry in the study area. The quality requirement for water used in the mining industry is highly variable, depending on the stage at which it is required, i.e whether during mining, refining operation or for water supply to industrial township. To understand the chemical action of water on the mine machinery, iron pipes, vessels, casing pipes of tube wells etc. The corrosive and incrusting properties of water of the study area have been analysed and classified using the criteria like pH, EC, CI, HCO_3& SO_4 along with corrosivity ratio (CR).

1.Criteria for corrosion.

a) pH < 7

b) EC> 1500 mhos/cm

c) Cl^- > 500 mg/l

2. Criteria for Incrustation

a) HCO_3^- > 400 (Soft incrustation)

b) SO_4^{2-} > 100 (Hard incrustation)

Depending upon the factors such as pH, alkanity, hardness of more than 200 mg/l will lead to scale deposits in the piping system[27].From the above study, it is clear that all water samples in pre-monsoon period have corrosive property with respect to pH and no samples has incrusting property with respect to HCO_3 and SO_4. In post-monsoon period 76 % of the samples have corrosive property with respect to pH and all samples are free of incrusting property.

5.2 CORROSIVITY RATIO (CR)

Ryner (1944) proposed a ratio to access the corrosive nature of groundwater on metals. Corrosion is an electrolytic process, which attacks and corrodes away the metal surfaces. The effects of corrosion are losses of hydraulic capacity of pipes[28],[29],[30]. The water samples have corrosively ratio less than 1 which are in safe zone both in pre and post monsoon periods.

Table1. Physico-Chemical parameters of ground water samples in and around Joda.

Sample locations	Period	pH	TDS (mg/l)	EC (µs/cm)	TH (mg/l)	HCO_3^- (mg/l)	SO_4^{2-} (mg/l)	NO_3^- (mg/l)	PO_4^{3-} (mg/l)	Cl^- (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^+ (mg/l)	K^+ (mg/l)
S1-Nayagarh (T)	pre-mon	6 .75	103	187	42.89	53.51	1.78	0.83	0.38	9.29	10.42	4.13	5.90	1.17
	post-mon	6.83	112	170	61.24	75.72	1.32	1.02	0.41	6.10	16.63	4.84	4.80	1.10
S2-Dubuna (T)	pre-mon	6.14	145	227	83.80	78.65	7.49	0.51	0.62	11.56	22.85	6.56	5.70	0.80
	post-mon	6.26	138	208	104.69	88.96	4.28	0.53	0.02	10.71	25.65	9.96	1.80	0.20
S3-Naibuga (D)	pre-mon	6.45	120	161	59.86	62.48	3.08	0.73	0.30	15.31	15.63	5.11	8.30	1.40
	post-mon	6.78	125	198	43.89	75.29	2.68	0.98	0.03	11.95	12.83	2.92	4.20	0.80
S4-Balda(T)	pre-mon	6.46	196	298	87.34	112.32	8.25	2.24	0.06	18.50	23.25	7.18	11.79	5.01
	post-mon	7.00	192	300	74.80	97.68	7.93	2.56	0.05	16.02	18.84	6.80	8.10	12.67
S5-Uchabali(T)	pre-mon	6.82	273	427	78.57	86.27	3.75	1.73	0.08	13.29	25.15	3.89	8.21	2.35
	post-mon	7.01	256	407	132.14	165.59	3.84	1.82	0.04	18.65	36.87	9.83	10.80	6.84
S6-Bamebari(B)	pre-mon	6.28	208	320	79.93	78.58	2.16	1.02	0.02	26.87	24.05	4.89	15.80	1.60
	post-mon	6.32	153	259	89.79	101.40	6.87	0.73	0.03	12.30	27.25	5.35	6.09	1.10
S7-Jururhi (D)	pre-mon	6.32	310	482	127.76	145.15	20.70	3.31	0.35	32.97	39.28	7.31	18.76	2.54
	post-mon	6.74	280	460	137.17	137.10	25.79	4.54	0.11	30.77	42.28	7.78	15.30	1.30
S8-Jajanga (D)	pre-mon	6.00	232	343	125.19	111.71	13.06	2.74	0.13	40.02	30.02	11.30	13.20	2.40
	post-mon	6.16	210	316	153.04	100.92	7.88	3.65	0.18	30.91	40.24	8.01	11.70	2.10
S9-Khandbandh(D)	pre-mon	6.61	167	262	88.22	86.88	4.07	0.93	0.04	14.85	22.63	7.78	8.80	1.20
	post-mon	6.63	166	267	77.40	66.38	9.63	1.21	0.02	18.65	24.12	4.23	7.30	1.90
S10-Joda 1 (D)	pre-mon	6.23	284	430	155.98	162.36	16.19	3.60	0.05	33.92	42.24	12.39	15.61	3.10
	post-mon	7.00	409	645	146.62	164.19	12.01	3.53	0.06	32.83	39.68	11.66	19.22	3.70
S11-Joda 2 (D)	pre-mon	6.16	235	367	135.23	148.32	5.72	3.60	0.24	24.10	36.47	10.83	10.60	1.90
	post-mon	6.14	243	380	128.75	158.95	2.43	4.52	0.10	32.61	36.87	9.01	19.40	4.46
S12-Birkala (D)	pre-mon	6.90	241	382	141.61	146.54	2.78	1.19	0.98	16.73	38.28	11.30	9.90	0.80
	post-mon	7.32	228	354	99.75	126.85	12.60	2.36	0.45	30.17	28.86	6.80	21.10	0.80
S13-Chamakpur (T)	pre-mon	6.70	346	540	179.52	163.64	14.94	4.65	0.25	31.73	44.89	16.52	13.80	8.60
	post-mon	6.90	364	557	182.51	191.62	22.66	3.74	0.09	35.52	47.70	15.55	19.20	12.16
S14-Dhobakuchura (T)	pre-mon	6.88	380	610	183.06	168.64	10.90	5.33	2.37	28.68	48.12	15.43	13.49	3.30
	post-mon	6.76	226	349	115.71	115.99	6.39	3.82	1.64	26.16	33.67	7.78	14.70	4.80
S15-Jhampra (T)	pre-mon	6.67	151	230	88.98	74.68	3.46	2.85	0.89	15.10	26.13	5.83	8.00	2.80
	post-mon	6.74	168	265	110.81	85.23	5.96	4.28	1.49	11.41	20.63	9.62	6.50	3.10
S16- Kamalpur (T)	pre-mon	6.83	143	224	95.00	80.78	2.74	2.85	0.76	22.31	24.32	8.40	8.99	2.80
	post-mon	6.81	174	282	108.36	104.09	4.66	3.41	1.08	20.28	24.32	11.66	7.70	1.80
S17-Nuabeda(T)	pre-mon	6.61	229	346	125.20	118.79	7.88	1.26	0.87	25.52	34.67	9.48	13.31	2.30
	post-mon	6.84	228	353	145.01	137.10	7.06	1.87	0.71	24.71	41.02	10.45	12.09	3.50
BIS Standards (IS10500)		6.5-8.5	500	-	200	300	200	45	30	250	75	30	-	-
WHO Standard		6.5-8.5	500	-	500	300	200	50	30	250	75	30	50	10

Table 2. Indices for water quality criteria for irrigation and industrial use of ground water samples in and around Joda

SAMPLE LOCATION	PRE-MONSOON						POST-MONSOON					
	Na%	SAR	RSC	MR	KR	CR	Na%	SAR	RSC	MR	KR	CR
S1-Nayagah (TW)	25.00	0.39	0.017	39.53	0.30	0.279	16.18	0.27	0.01	32.40	0.17	0.13
S2-Dubuna (TW)	13.78	0.27	-0.39	32.14	0.15	0.31	3.82	0.08	-0.64	39.02	0.04	0.22
S3-Naibuga (DW)	24.85	0.47	-0.18	35.00	0.30	0.40	18.76	0.28	0.35	27.26	0.21	0.26
S4-Balada(TW)	26.80	0.55	0.09	33.75	0.29	0.31	31.08	0.41	0.10	37.32	0.23	0.32
S5-Uchabali(TW)	20.93	0.40	-0.16	20.32	0.23	0.26	19.58	0.41	0.06	30.54	0.18	0.18
S6-Bamebari(BW)	31.25	0.77	-0.31	25.11	0.43	0.51	14.00	0.28	-0.14	24.44	0.15	0.24
S7-Zururhi (DW)	25.60	0.72	-0.18	23.47	0.32	0.47	20.26	0.57	-0.50	23.26	0.24	0.51
S8-Jajanga (DW)	20.21	0.51	-0.68	40.32	0.23	0.63	17.42	0.44	-1.01	24.71	0.19	0.51
S9-Khandbandh(DW)	18.96	0.41	-0.34	36.17	0.22	0.29	19.09	0.36	-0.46	22.43	0.20	0.55
S10-Joda 1 (DW)	19.52	0.54	-0.47	32.59	0.22	0.40	24.05	0.69	-0.25	32.64	0.28	0.36
S11-Joda 2 (DW)	15.82	0.40	-0.28	32.87	0.17	0.27	27.07	0.74	0.02	28.71	0.33	0.30
S12-Birkala (DW)	13.71	0.36	-0.44	32.72	0.15	0.18	31.94	0.92	0.08	27.99	0.46	0.44
S13-Chamakpur (TW)	18.56	0.45	-0.92	37.76	0.17	0.37	23.85	0.62	-0.52	34.95	0.23	0.38
S14-Dhobakuchura (TW)	15.46	0.43	-0.91	34.58	0.16	0.31	24.73	0.59	-0.42	27.58	0.28	0.38
S15-Jhampra(TW)	19.04	0.37	-0.56	26.90	0.20	0.33	16.59	0.30	-0.42	43.46	0.16	0.26
S16- Kamalpur (TW)	19.54	0.40	-0.58	36.28	0.21	0.42	14.92	0.32	-0.47	44.15	0.15	0.32
S17-Nuabeda(TW)	20.26	0.52	-0.56	31.08	0.23	0.37	17.47	0.44	-0.66	29.58	0.18	0.31

6 CONCLUSION

The ground water samples in study area show limited seasonal variability in quality.The pH ranging from 6.00-7.32 indicate that most of the samples are acidic in nature. Some samples are of hard water categories and most of the samples are moderately hard. The concentration of various cations and anions along with physical parameters are within the permissible limits of BIS and WHO. Hydrochemistry of ground water samples reveals that the samples are enriched with bicarbonate of Ca and Mg in pre and post monsoon periods. The chemistry of water is controlled mainly by the lithology of the area. Along with natural weathering, mining operations, anthropogenic activities and improper waste disposal are the sources of contamination of ground water. Wilcox classification shows that the water quality is excellent to good for irrigation and U.S. salinity classification indicates that the water samples have low to medium salinity hazards and low to medium sodium hazards. The overall quality of water samples for irrigation purpose is good with respect to sodium %, SAR, RSC, KR and MR. All samples in pre-monsoon and 76 % of samples in post monsoon period have corrosive properties with respect to pH. Considering corrosivity ratio, the ground water samples are safe for industrial use. All these above results confirm that the overall ground water quality is good to use for various purposes though it is not up to the mark with respect to all factors and is slowly degrading. If the present condition of the study area continues in future, the ground water source will be contaminated and may become unfit for domestic and other purposes. Various measures including proper management of mining wastes, improved mining techniques, proper waste and sewage disposal have to be taken up to control the contamination of ground water from different sources. Above all, the public awareness is the most effective means to conserve and protect the valuable ground water resources.

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