INTERPRETATION OF GROUNDWATER CHEMISTRY USING PIPER AND CHADHA'S DIAGRAMS: A COMPARATIVE STUDY FROM BALANGIR AND PUINTALA BLOCKS OF BALANGIR DISTRICT, ODISHA, INDIA

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Abstract: The groundwater plays an important role in agriculture, industry and domestic purposes. Hence, it is very much important to assess the quality groundwater before consumption. The study area selected was Balangir and Puintala blocks of Balangir district, Odisha. Altogether 100 numbers of groundwater samples were collected during pre-monsoon period in 2017 and analysed the various physico-chemical parameters. In the present study, groundwater sampling was carried out with an aim to assess the quality and to compare the water type using Piper and Chadha's diagram. Majority of the samples were behaved in more or less same way except few samples. Piper diagram suggest that majority of the samples of the study area belonged to Ca–HCO_3, mixed Ca–Mg– Cl and Na–Cl. representing alkaline earth exceed alkali metal. In Chadha's diagram the majority of the samples are plotted in the 5th field, representing Ca–Mg–HCO_3 type; Field 6th represents the Ca-Mg-SO_4/Cl type of water. Hence the groundwater quality according to Chadha's diagram is alkaline earth and weak acid anion exceeds both alkali metal and strong acid anion, alkaline earths exceed alkali metals and strong acidic anions exceed weak acidic anions.

***I`ndexTerms* - Hydrogeochemistry, Piper diagram, Chadha's diagram, Balangir and Puintala Blocks.**

I.INTRODUCTION

The demand of groundwater has increased due to growth of population, rapid industrialization and development in agricultural activities. The development of groundwater resources can play an important role in the economic development of the area (Mahanta et al.,2012) Groundwater is the key source of water for industrial, agricultural and domestic uses and its contamination has been recognized as one of the most serious problems (Belkhiri et al., 2010). The quality of groundwater is dependent on nature of the topography, bedrock, climate, geology, soils, atmospheric precipitation and quality of the recharged water in addition to anthropogenic pollution sources in terms of industrial and agricultural activities. Groundwater quality is also affected by means of subsurface geochemical reactions such as weathering, dissolution, precipitation, ion exchange and various biological processes (Todd, 1980; Sakram et. al., 2013, Mahanta et al, 2016). The hydrochemical facies is used to denote the diagnostic chemical character of water in hydrologic systems. The facies of groundwater reflect the effect of complex hydrochemical processes (Sajil Kumar, 2013) occurring between the minerals of groundwater and lithologic formation to investigate the spatial variability of groundwater chemistry in terms of hydrochemical evolution. The main objective of this research work is to find out the groundwater chemistry using Piper and Chadha´s diagrams.

II.STUDY AREA

The present study area is located in Balangir and Puintala blocks of Balangir district, which is western part of Odisha bounded by latitude 20^{0}34′N to 20^{0}51′N and longitude 83^{0}13′30″E to 85^{0}40′E falling in Survey of India Toposheet numbers 64P/5, 64P/6, 64P/9 and 64P/10. The study area is bounded by Sonepur district in the east and by Nuapara in the west and by Bargarh and Kalahandi districts in the north and south respectively. The major drainage system is controlled by Suktel river and its tributaries. According to hydrogeological surveys and satellite imageries studies, it is revealed that the drainage pattern of the area is controlled by the fracture system which is developed due to tectonic activity. Hence, the drainage system is dendritic in nature.

The annual rainfall of this area is 1289.8 mm. This area occupies an Eastern Ghat Supergroup of rocks consisting of Charnockite, Khondalite, and Gneissic rocks/Migmatites as one of the oldest rock groups exposed in the area. Granite and granite gneisses are the most predominant rock type of the area.

The soil of the major part of the study area is vertisols, which include medium black soils underlain by anorthosites. The soils are highly argillaceous and contain high amount of iron, calcium, magnesium and poor in organic matter, nitrogen and phosphorous but rich in potash, and lime. The texture is loam to clayey loam. The location map of the study area is shown in Fig. 1.

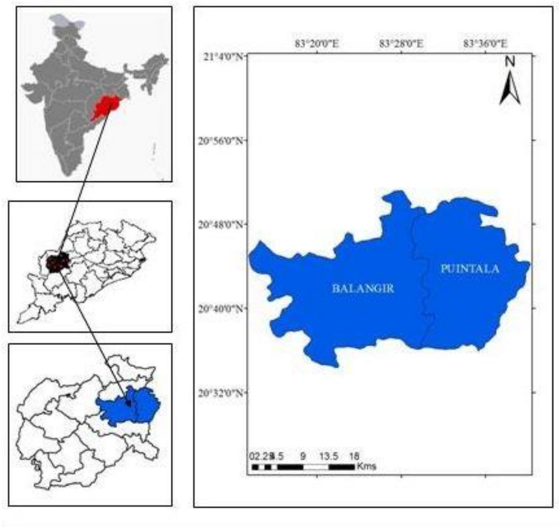

Fig. 1 Location map of study area

III.MATERIAL AND METHODS

There are 100 numbers of groundwater samples and were collected from different locations of study area during premonsoon season in 2017. The temperature, EC, TDS are measured in the field and other parameters such as Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, HCO_3^{-}, Cl^{-}, SO_4^{-2}, TA, and TH were measured in the laboratory. The average groundwater quality is shown in Table.-1, and status of groundwater quality parameters as prescribed by BIS (2012) for drinking purpose in the study area is given in Table-2. Piper trilinear diagram (1944) is a graphical representation of the chemistry of a water sample; whereas the Chadha's diagram (1999) is plotted for better understanding the hydrochemistry and comparing the water types. In Piper diagram, the cations and anions are plotted in separate triangle. The apices of the cations plotted were calcium, magnesium and sodium plus potassium. The apices of the anion plotted were sulphate, chloride and carbonate plus bicarbonate ions. The two ternary plots were then projected into a central diamond field, which provides the character of the water. In contrast to that, in Chadha's diagram, the difference in milliequivalent percentage between alkaline earths (calcium plus magnesium) and alkalies (sodium plus potassium), expressed as percentage reacting values (milliequivalent percentages), is plotted on the X axis, and the difference in milliequivalent percentage between weak acidic anions (carbonate plus bicarbonate) and strong acidic anions (chloride plus sulphate) is plotted on the Y axis. The resulting field of study is a square or rectangle, depending upon the size of the scale chosen for X and Y co-ordinates. The milliequivalent percentage difference between alkaline earth and alkali metals, and between weak acidic anions and strong acidic anions, are plotted in one of the four possible sub-fields. The major advantage of this diagram is that it can be drawn in any spreadsheet software packages. (Chadha 1999, and Sajil Kumar, 2013) Analytical precision was maintained throughout the experiments. GW Chart calibration software package was used to plot the Piper diagram and the Chadha's diagram was created using MS Excel spreadsheet.

IV.RESULTS AND DISCUSSION

WATER QUALITY

The minimum, maximum and average water quality of various physico-chemical parameters of the study area are represented in Table 1 and comparison of groundwater quality with BIS (2012) for drinking purpose are represented in Table 2. Maximum numbers of samples were alkaline in nature; with pH value varies from 5.8 to 7.98, whereas the TDS values were varied between 150.1 to 3343.7 mg/l. Among the 100 samples, TDS value of 61 numbers of samples exceeded the acceptable limit as per BIS (2012). The calcium concentration in the groundwater samples ranges from 16.8 to 257.3 mg/l with an average of 77.99 mg/l. With respect to BIS (2012), 43% of samples exceeding acceptable limits for drinking purposes. The magnesium content in the water samples of the study area ranges between 1.9 and 102.3 mg/l with an average of 30.01 mg/l. The Table 2 shows that 40% of samples exceeding the acceptable limit for drinking purposes as specified by BIS (2012). Weathering of silicate minerals is important for enrichment of these minerals. Relatively less abundance of the carbonate minerals in the study area indicate that the major origin of calcium and magnesium is silicate weathering (Sajil Kumar, 2013). The concentrations of sodium in the study area varies from 3.6 to 242.8 mg/l with an average of 60.81 mg/l and potassium from 0.09 to 34.36 mg/l. Sodium and potassium in the study area is derived from the weathering of the hard rocks, especially the granitic rocks. Bicarbonate concentration in the study area varies between 26.8 and 357.8 mg/l with an average 175.96 mg/l. Apart from the dissolution of carbonated rocks, the major origin of bicarbonates are the sewage systems (Sajil Kumar, 2013). The chloride concentration of the groundwater is varies from 7.44 to 404.8 mg/l with an average of 68.60 mg/l. The concentration of sulphate in the study area varied from 0.45 to 242.9 mg/l. The major origin of sulphate is the dissolution of gypsum and anthropogenic activities. Fluoride concentration of the study area ranges from 0.12 to 2.58 mg/l with an average 0.59 mg/l. The occurrence of fluoride in groundwater is primarily due to the geogenic processes. The main sources are fluorite, cryolite, fluoroapatite, topaz, villaumite, amphiboles such as hornblende, micas and also rock phosphate.

Table 1Physico-chemical parameters of the study area

Parameters	Minimum	Maximum	Average
pH	5.80	7.98	6.82
EC	218	2260	936.19
TDS	150.1	3343.7	654.51
TA	26.8	357.8	175.56
TH	10.4	781.6	305.86
Ca^{+2}	16.8	257.3	77.99
Mg^{+2}	1.9	102.3	30.01
Na^{+}	3.6	242.8	60.81
K^{+}	0.09	34.36	3
Cl^{-}	7.44	404.8	68.60
HCO_3^{-}	26.8	357.8	175.96
SO_4^{-2}	0.45	242.9	42.70
F^{-}	0.12	2.58	0.59

All the values are in mg/l except EC and pH. EC is in µmho/cm.

Table 2 Comparison of pre-monsoon groundwater quality with drinking water standards (IS10500:2012)

Parameters	**BIS 10500:2012**		**No. of Samples exceeding acceptable limits**	**% of samples exceeding acceptable limit**	**No. of Samples exceeding Permissible Limit**	**% of samples exceeding Permissible Limit**
	Acceptable Limit	**Permissible Limit**				
pH	6.5-8.5	No relaxation	27	27	Nil	0
TDS	500	2000	61	61	1	1
TH	200	600	84	84	5	5
Ca^{+2}	75	200	43	43	3	3
Mg^{+2}	30	100	40	40	1	1
Cl^{-}	250	1000	3	3	Nil	0
SO_4^{-2}	200	400	1	1	Nil	0

All the samples are express in mg/l except pH.

WATER TYPES

The Piper diagram (Fig. 2) was plotted for water samples of the Balangir and Puintala Blocks using the analytical data obtained from the hydrochemical analysis. The Piper diagram is divided into 6 fields. They are namely ;(1) Ca-HCO_3 type (2) Na-Cl type (3) Ca-Mg-Cl type (4) Ca-Na-HCO_3 type (5). Ca-Cl type (6). Na- HCO_3 type (Sajil Kumar, 2013). However, in the present study, the majority of the samples are plotted in the calcium bicarbonate (Ca-HCO_3) type, followed by calcium sulphate (Ca-SO_4) type. A few numbers of samples were found in sodium chloride (Na-Cl) and sodium bicarbonate (Na-HCO_3) field. The Piper plot suggests that the water types of the area is due to contribution from the weathering of pyroxenes and amphibole bearing hard rocks.

For the better understanding of hydrochemistry of groundwater of the area, Chadha's diagram was plotted (Fig. 3). The eight fields are mentioned by Chadha (1999) to describe different types of water, which are named as (1) Alkali earths exceed alkali metals, (2) Alkali metals exceed alkaline earths (3) Weak acidic anions exceed strong acidic anions; (4) Strong acidic anions exceed weak acidic anions, (5) Alkaline earths and weak acidic anions exceed alkali metals and strong acidic anions, respectively, (6) Alkaline earths exceed alkali metals and strong acidic anions exceed weak acidic anions, (7) Alkali metals exceed alkaline earths and strong acidic anions exceed weak acidic anions, (8) Alkali metals exceed alkaline earth and weak acidic anions exceed strong acidic anions. In the present study, the majority of the samples fall in the 5th field; representing Ca–Mg–HCO_3 type followed by the 6th field i.e. Ca-Mg-SO_4/Cl type. A few numbers of samples in plotted in field 7 and 8 in the Chadha's diagram indicating sodium chloride and sodium bicarbonate type of water. This is exactly similar to the results obtained from the Piper diagram.

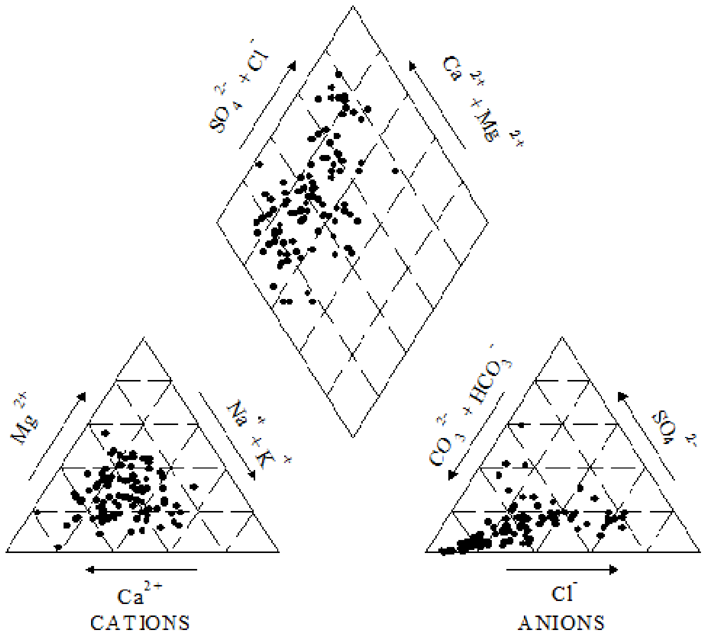

Fig. 2 Piper diagram

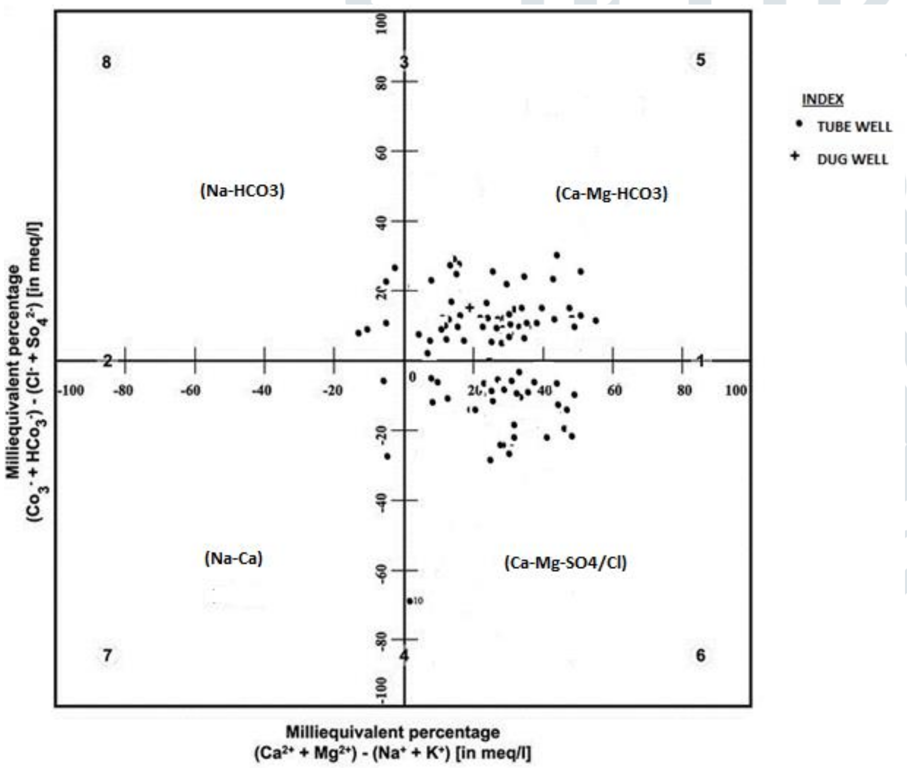

Fig. 3 Chadha's diagram

V. CONCLUSIONS

Results of the hydrochemistry suggest that most of the water samples are alkaline in nature. Major process controlling the water quality is the silicate weathering, mineral dissolution, cation exchange and inverse cation exchange processes. The types of the groundwater were assessed and compared with Piper and Chadha's diagrams. In both the cases, there is a similarity in the final result. In Piper diagram, the majority of the samples are plotted in the Ca-HCO_3 type, followed by Ca-SO_4 type, where as in Chadha's diagram, most of the water is Ca–Mg–HCO_3 type followed by Ca-Mg-SO_4/Cl types of water. So, by comparing the result in both the cases, it is concluded that the final result is similar in both the cases.

VI. ACKNOWLEDGMENT

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