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Hydrogeochemical Study of Chasnala-Tasara-Sindri Area of Dhanbad District, Jharkhand, India

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Abstract:
Availability and quality of groundwater has become a critical matter of concern for any locality globally and it is particularly so for a densely populated country like India. Groundwater has become a very scarce commodity and it is imperative to have a serious scrutiny and analysis of the prevalent situation in given locality with a particular emphasis on its portability. The present work concerns hydrogeochemical studies in a major coal mining area having cement and recently closed fertiliser industries along with coal washries are meeting the major requirement for water in the area. A systematic monitoring of the water quality under varying seasonal conditions over a large no. of samples collected from the area when subjected to statistical analysis certain conclusions can be drawn such as majority of water samples represent CaHCO3 type followed by mixed CaMgCl type and CaNaHCO3 type. All the parameters selected for the study, except Fl-, are well within the permissible limits. The entire area is fluoride deficient (>0.6mg/l) and can be one of the main reasons of tooth decay in children and bone deformation in elderly persons of the area.

Keywords: *Hydrogeochemistry, correlation co-efficient, piper-diagram, tooth decay ostioporosis*

1. Introduction

Apart from air water is, by far, the most essential requirement for animal as well as plant life and industrial activities. It is one of the natural resources of the earth and is renewed by the hydrologic cycle. The availability/quantity of ground water and also its quality is an important parameter in the development of society. The quantity of ground water is controlled by a number of factors such as climate, aquifer rock type, pattern of use and natural recharge whereas its quality depends on the physical and chemical constituents gathered in due course of completion of hydrologic cycle and manmade activities. The suitability of groundwater for drinking and other purposes like irrigation and industries requires its hydrogeochemical study [1, 14]. The hydrogeochemistry of water include an integrated study of various parameters such as geological setting, natural flow of water, climatic changes, aquifer material type of the area under investigation and additions during percolation of water [2]. So far as India is concerned, availability of safe drinking water is of paramount importance because nearly $1/3^{rd}$ of our urbanand more than $3/4^{th}$ of our rural population still depends on surface or groundwater resources [3]. Hence there is a need and concern for the proper evaluation of the quality of groundwater, its protection and management. It is an established fact that the quality of water is dependent on several factors hence one cannot establish any straightforward reason for the deterioration of water quality of any area [4]. The area under investigation is mainly covered by coal mining and related industries. The main reasons of pollution of groundwater in the area are overburden dumps, surface impoundments, industrial effluents and above all the aquifer rock type [5].

The quality of ground water varies from place to place with the depth of water table. For the proper assessment of water quality, the different water quality parameters have to be tested/analysed periodically. Once data is generated its classification and interpretation becomes an important aspect. An easier and simpler approach based on statistical analysis has been developed in recent years. This methodology uses statistical analysis of the data to establish relationship between different physico-chemical parameters [6]. The statistical analysis of the gathered data may give a set of factors, which can explain a large amount of variance in the analytical data.

The area under investigation comprises of rocks of both older metamorphics and Gondwana deposits and are known for diversified industrial pursuits such as coal mining activities at Chasnala (previously owned by IISCO and now SAIL) and Tasra coal block, cement industry at Sindri and two closed fertiliser plants namely FCI Sindri and Superphosphate factory to the south of Marshalling Yard Railway Station. These features are collectively responsible for the present-day groundwater condition of the area. Because of the geologic and industrial diversity, the whole Dhanbad district and Jharia coal field in particular has been under continuous hydrological investigation since long. V.D. Choubey [7] concluded that water percolating through OCM (open cast mine) dump of

Jharia coalfields is essentially $NaHCO_3$ type with high TDS. Panigrahy et al [8] revealed that the groundwater chemistry is dominated by Ca^{2+} and Mg^{2+} in the cationic and HCO_3^- and Cl^- in anionic abundances.

However, there is a lack of systematic approach in the hydrogeochemical investigation of the entire district. Most of the work is patchy and comprehensive & integrated approach has not been taken into account. In the present work, a relatively smaller area has been selected and a large number of samples were taken for analysis and at the same time petrographic analysis of common rocks were also done with the purpose of establishing the hydrogeochemical facies of the area.

2. Materials and Methods

2.1. Study Area

The area selected for the study is located in the south-eastern part of Dhanbad district, the coal capital of India, of Jharkhand. It lies between longitude 86.441 E to 86.495 E and latitude 23.641 N to23.678 N covering about 20.915 square kms. It stretches from Chasnala in the west to FCI Sindri township in the east through Kandra. The main component of the natural drainage in the study area is Damodar river. There are two streams flowing from north to south and join together before tributing to the river Damodar. Chasnala stream is perennial and is flowing from NW to SE direction whereas the Kandra joria is intermittent and flows in N-S direction.

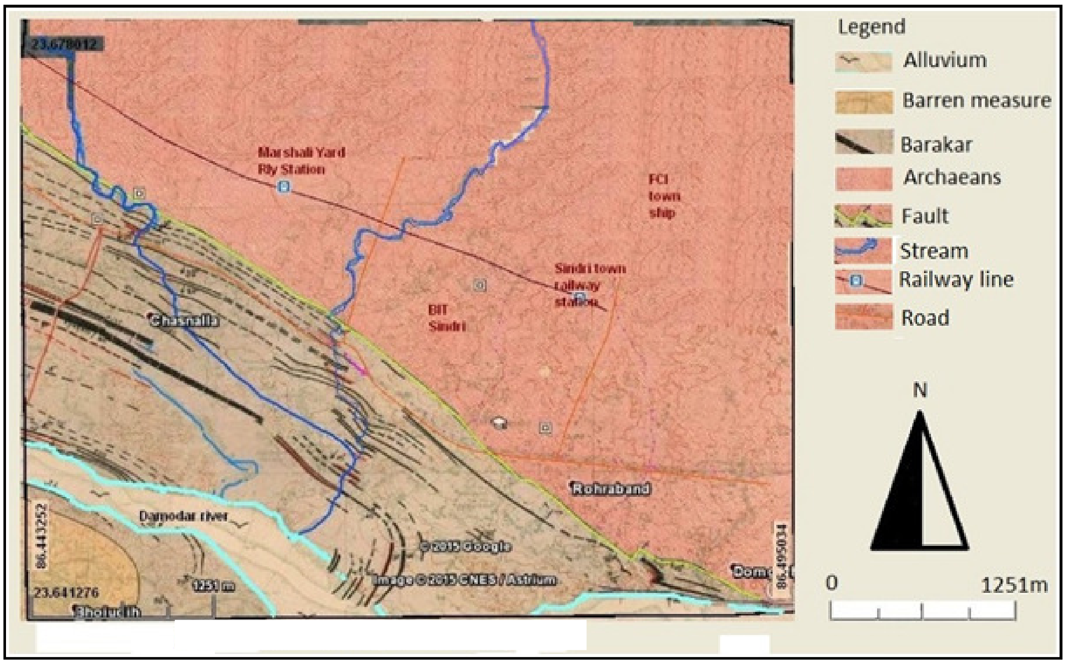

Figure 1: Location map of the study area

The area under investigation is extensively developed and is a storehouse of coking coal. There is a clear-cut boundary between the Gondwana sedimentary basin and the Precambrian metamorphic rocks as shown in fig.1. The precambrians are the oldest formation and provide the basement for the overlying gondwana sequences. The gondwana sequences was deposited in the Damodar river valley grabben. The sedimentary rocks are faulted between Rohrabandh and Domgarh and is also pierced by igneous intrusive of Mesozoic-Tertiary age.

2.2. Sampling

For the assessment of water quality of the area extensive sampling was carried out in pre-monsoon and post-monsoon seasons i.e. June, 2015 and oct., 2015 respectively. Altogether 48 samples were taken from different sampling sites out of which 32 are of hand pumps (HP), 07 of river water(RW),06 of dug well(DW) and 03 of pond water(PW) as shown in fig. 2 below. The samples could not be taken from the northern part of the area and some parts of southern area due to the fact that the northern part is exclusively forest whereas eastern part is with treated water supply of FCI & ACC sindri units.

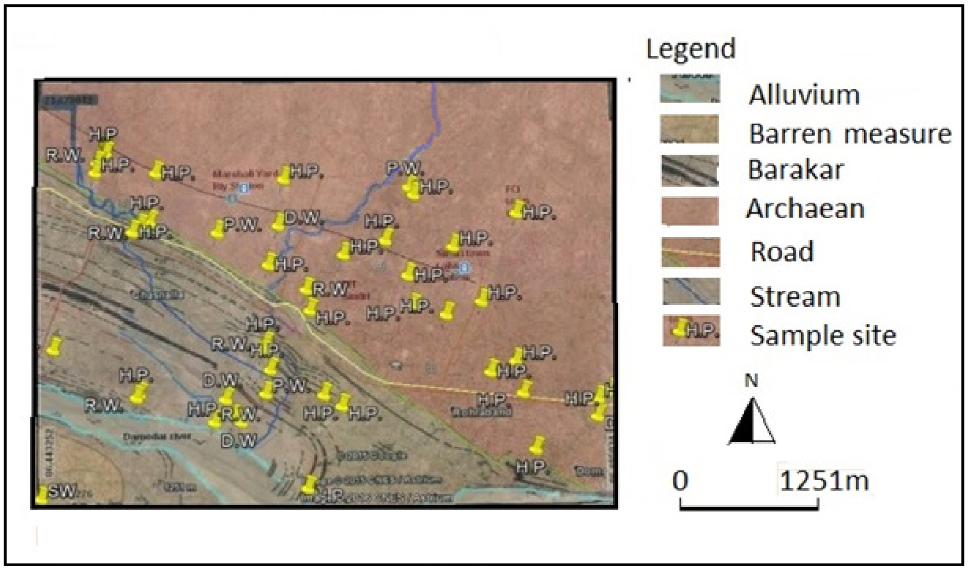

Figure 2: Groundwater sampling location

The samples were collected in one liter narrow mouth pre-washed polythelene bottles. The location of the different sampling sites was recorded using GPS. The physico-chemical parameters such as colour, odour, pH, and electrical conductivity were recorded using portable equipments. The collected samples were carried to the laboratory for the analyses of major water quality parameters such as Total dissolved solid, Total hardness, Alkalinity, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-} SO_4^{2-}, HCO_3^{-}, $NO_3^{-}F^{-}$, and Iron in mg/l. The analytical procedures were conducted using APHA methods.

3. Results and Discussion

The statistical analysis such as mean, median, standard deviation of all parameters both for pre-monsoon and post-monsoon samples was done with the help of "R" software and are presented in tabular form, table no.1 and table no. 2 respectively, below. The Pearson correlation co-efficient was also calculated among different parameters and are presented in table no. 3 for pre-monsoon data, and table no. 4, for post-monsoon data, below.

Statistical analysis of water quality data of pre-monsoon samples with precribed limits of WHO(1997) and BIS (IS-10500) 1991

							WHO Stds 1997		BIS(IS-10500)	
Parameters	No. Of samples	Min. Value	Max. Value	Mean	Median	Std. Deviation	Desirable	permissible	Desirable	permissible
colour (H.U.)	48	1	25	3.1041	1	4.7366	-	-	5H.U.	15H.U.
Turbidity(NTU)	48	1	74	8.1875	2	14.4261	-	-	1 NTU	5NTU
pH *	48	6.5	7.5	7.1458	7	0.2517	7.0-8.0	6.5-9.2	6.5-8.5	6.5-9.2
Alkalinity *	48	60	564	289.8958	290	121.7248	300	600	200	600
T.Hardness *	48	80	606	392.75	393	135.635	100	500	300	600
T.D.S. *	48	125	934	485.4166	492.5	165.6857	500	1500	500	2000
Ca *	48	29	116	60.7083	60	18.7514	75	200	75	200
Mg *	48	2	118	58.4166	57.5	30.1625	30	100	30	100
Fe *	48	0.1	9.6	1.2708	0.7	1.6672	0.3	1	0.3	1
Sulphate *	48	17	135	75.2083	75.5	31.6785	200	600	200	400
Nitrate *	48	1	35	7.875	4	9.4116	50	-	45	-
Fluoride *	48	0.1	0.4	0.1854	0.2	0.0714	1	1.5	1	1.5
Chloride *	48	17	215	71.5833	57.5	42.5255	250	600	250	1000
Conductivity micro S	48	209	1556	808.3541	816.5	274.8683	750	1500	-	-
Na *	48	1	305	76.7625	48.65	77.7286	50	200	-	-
K *	48	0.1	34	8.5729	5.4	8.7071	10	12	-	-
* -ppm										

Table 1: Statistical analysis of water quality data of pre-monsoon samples with prescribed limits of WHO and BIS

Statistical analysis of post-monsoon water quality data with prescribed limits ofWHO and BIS										
							WHO 1997		BIS (IS-10500)	
Parameters	No. Of samples	Min. Value	Max. Value	Mean	Median	Std. Deviation	Desirable	permissible	Desirable	permissible
colour (H.U.)	48	1	20	2.1458	1	3.189	-	-	5H.U.	15H.U.
Turbidity(NTU)	48	1	10	2.2291	1	2.6112	-	-	1 NTU	5NTU
pH *	48	7	7.5	7.05	7	0.1304	7.0-8.0	6.5-9.2	6.5-8.5	6.5-9.2
Alkalinity *	48	48	548	270.6041	271	120.8922	300	600	200	600
T.Hardness *	48	65	600	375.0833	375	135.8767	100	500	300	600
T.D.S. *	48	120	930	478.4791	485	166.8052	500	1500	500	2000
Ca *	48	21	88	48.875	48.5	15.8041	75	200	75	200
Mg *	48	2	106	50.1666	49	26.234	30	100	30	100
Fe *	48	0.1	8.2	0.752	0.3	103041	0.3	1	0.3	1
Sulphate *	48	12	112	66.125	67.5	28.0232	200	600	200	400
Nitrate *	48	1	30	6.5833	2.5	8.2715	50	-	45	-
Fluoride *	48	0.1	0.3	0.1166	0.1	0.0429	-	1.5	1	1.5
Chloride *	48	11	185	54.6458	44	37.5961	250	600	250	1000
Conductivity micro S	48	200	1550	795.4375	809	281.8975	750	1500	-	-
Na *	48	1	254	56.4875	24	67.5126	50	200	-	-
K *	48	0.1	29	6.6187	3	7.5831	10	12	-	-
* -ppm										

Table 2: Statistical analysis of water quality data of post-monsoon samples with prescribed limits of WHO and BIS

The Pearson correlation matrix was applied to all the collected water samples for identifying the possible statistical relationship between different pairs of water quality parameters. A highly strong correlation was observed between electrical conductivity and TDS, EC and Cl^{-} Na^{+} and K^{+}.

Correlation coefficient matrix of ore-monsoon data																
Parameters	Colur	Turbidity	Ph	Alkalinity	T.Hardness	T.D.S.	Ca	Mg	Fe	Sulphate	Nitrate	Fluoride	Chloride	Conductivity	Na	K
Colur	1	0.987	-0.253	0.201	0.031	0.02	-0.1	0.079	0.873	-0.204	-0.241	0.124	-0.016	0.017	0.116	0.118
Turbidity		1	-0.203	0.191	0.0006	0.004	-0.11	0.05	0.87	-0.24	-0.281	0.174	-0.032	0.001	0.123	0.125
Ph			1	-0.191	-0.309	-0.23	-0.1	-0.251	-0.347	-0.254	-0.144	0.12	-0.231	-0.231	-0.04	-0.05
Alkalinity				1	0.704	0.866	0.073	0.705	0.063	0.349	0.133	0.017	0.373	0.864	0.703	0.707
T.Hardness					1	0.835	0.303	0.926	-0.054	0.776	0.267	-0.185	0.622	0.834	0.193	0.199
T.D.S.						1	0.197	0.8	-0.038	0.593	0.357	0.024	0.66	0.999	0.63	0.632
Ca							1	0.046	0.161	0.25	0.303	0.063	0.158	0.202	0.129	0.127
Mg								1	0.014	0.72	0.153	-0.212	0.59	0.796	0.251	0.256
Fe									1	-0.205	-0.255	0.114	0.011	-0.041	0.074	0.076
Sulphate										1	0.238	-0.202	0.477	0.595	0.026	0.027
Nitrate											1	-0.145	0.236	0.36	0.11	0.115
Fluoride												1	0.01	0.025	0.233	0.238
Chloride													1	0.657	0.449	0.451
Conductivity														1	0.63	0.632
Na															1	0.837
K																1

Table 3: Correlation coefficient matrix of pre-monsoon data

Correlation coefficients of post-monsoon data																
Parameters	Colour	Turbidity	Ph	Alkalinity	T.Hardness	T.D.S.	Ca	Mg	Fe	Sulphate	Nitrate	Chloride	Fluoride	Conductivity	Na	K
Colour	1	0.818	-0.03	0.123	0.01	-0.022	-0.137	0.06	0.935	-0.163	-0.2	-0.054	-0.049	-0.016	0.003	0.005
Turbidity		1	0.09	0.269	0.084	0.047	-0.128	0.132	0.664	-0.185	-0.271	0.07	0.079	0.053	0.121	-0.128
Ph			1	0.038	-0.092	-0.028	-0.079	-0.064	-0.091	-0.14	-0.155	-0.114	0.303	-0.037	0.266	0.263
Alkalinity				1	0.7	0.858	0.108	0.715	0.026	0.317	0.148	0.405	0.118	0.86	0.207	0.224
T.Hardness					1	0.833	0.341	0.93	-0.045	0.768	0.257	0.642	-0.055	0.836	-0.185	0.179
T.D.S.						1	0.241	0.812	-0.048	0.591	0.362	0.681	0.12	0.998	0.014	0.023
Ca							1	0.045	-0.145	0.34	0.363	0.15	-0.012	0.242	-0.042	-0.049
Mg								1	0.012	0.694	0.179	0.633	-0.055	0.815	-0.231	-0.22
Fe									1	-0.143	-0.213	-0.029	0.022	-0.042	-0.094	-0.095
Sulphate										1	0.239	0.5	-0.102	0.591	-0.243	-0.26
Nitrate											1	0.24	-0.207	0.355	-0.166	-0.175
Chloride												1	0.081	0.68	-0.197	-0.186
Fluoride													1	0.121	0.182	0.196
Conductivity														1	0.011	0.021
Na															1	0.728
K																1

Table 4: Correlation coefficient matrix of post-monsoon data

A base map of the area under investigation was prepared by superimposing the geological map (C.S. Fox) of the area and was used to draw the contour maps with the help of Surfer 12 software to know the spatial distribution of the different parameters.

3.1. Major ion Concentrations

Major ions are the primary constituents of groundwater, which are responsible for the quality of groundwater of any place and provide general information about the quality status of an aquifer.

pH: The pH is the measure of hydrogen ion concentration in water and ranges from 6.50 to 7.50 with an average value of 7.14 and standard deviation 0.2517 during pre-monsoon and 0.1304 during post-monsoon season. As per WHO standards all samples lie within permissible limits except one (HP-015) which is slightly acidic. The spatial distribution is given in Figure 3 & 4.

Electrical conductivity: According to WHO standards EC is the measure of salinity that affects the taste of potable water and becomes an indicator of dissolved ions present in any water sample. The EC values ranges from 208 µS/cm to1556 µS/cm with an average value of 808 µS/cm during pre-monsoon and 200 µS/cm to 1550 µS/cm with mean value 795.43 µS/cm during post-monsoon. The spatial distribution is given in Figure 5&6.

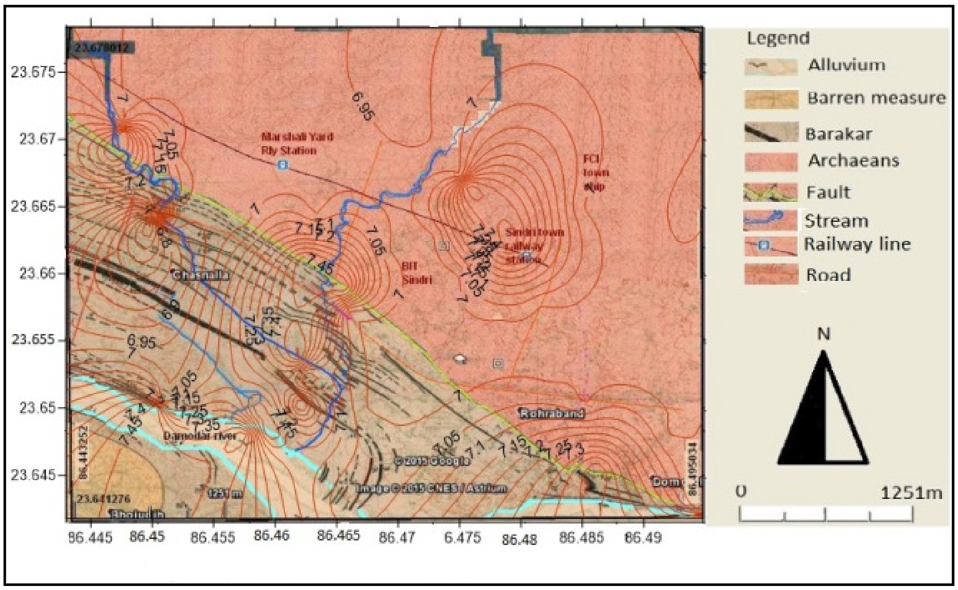

Figure 3: Pre-monsoon pH contour over base map June 2015

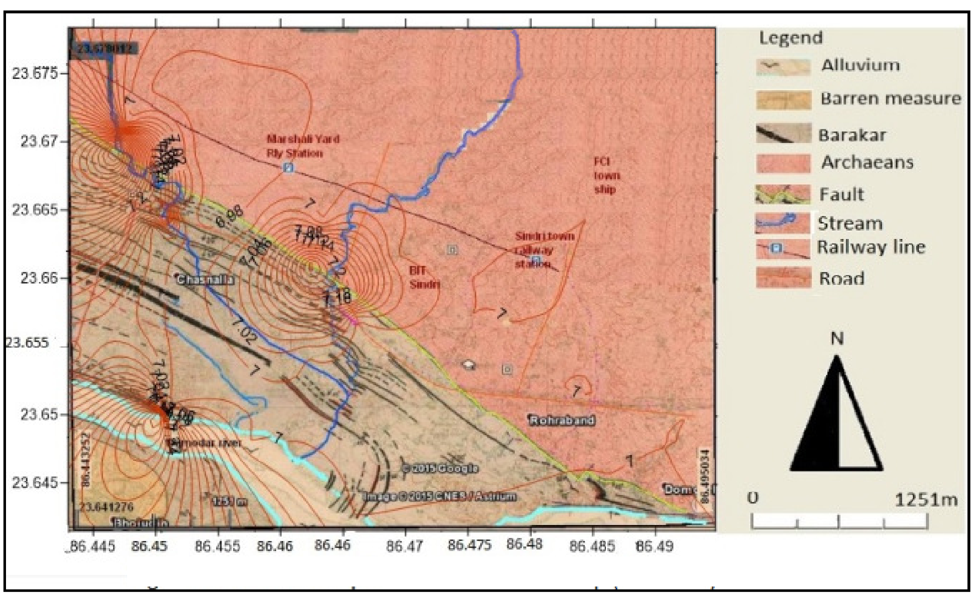

Figure 4: Post-monsoon pH contour over base map (oct. 2015)

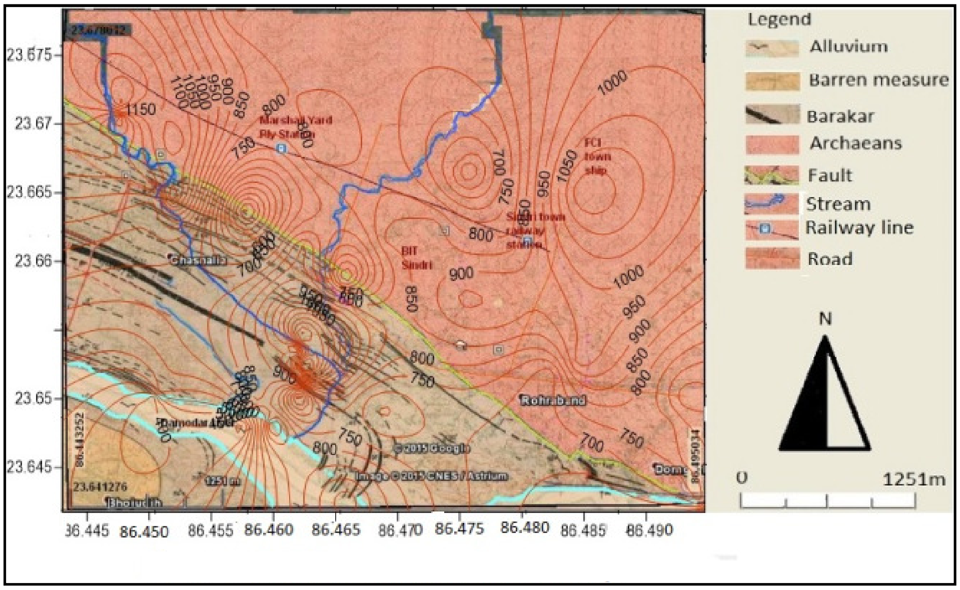

Figure 5: Pre-monsoon EC contour over base map

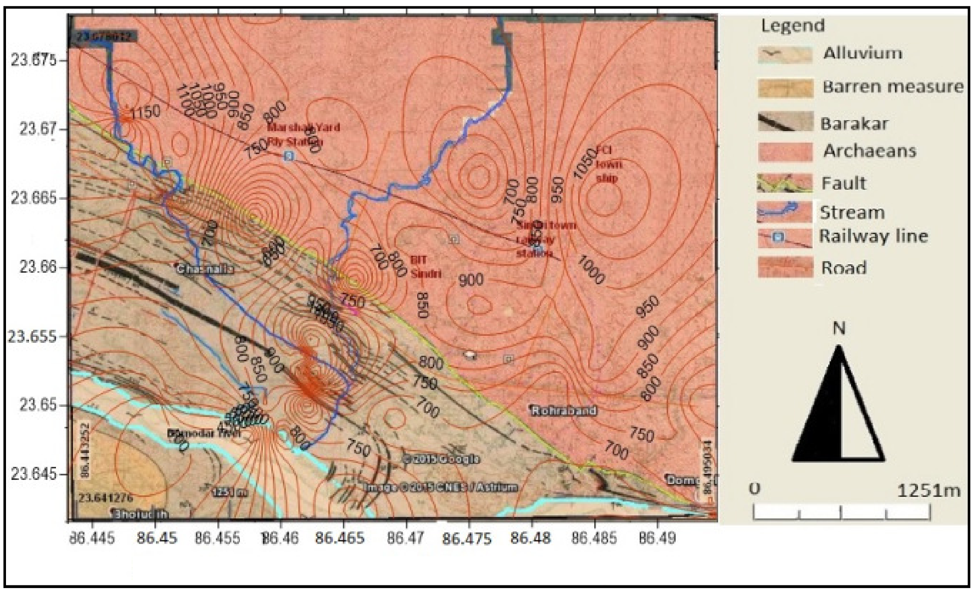

Figure 6: Post-monsoon EC contour over base map

Calcium (Ca^{2+}): Calcium is a very common ion present in water as they are available in most of the rocks and also due to its higher solubility. The range of calcium concentration in pre-monsoon water samples varied from a minimum of 29 mg/l to a maximum of 116 mg/l with an average value of 60.70 mg/l whereas in post-monsoon water samples it ranged from a minimum value of 21 mg/l to a maximum value of 88 mg/l with mean value of 48.87 mg/l. The higher concentration of Ca may cause various dental problems. The contour maps for both pre-monsoon & post- monsoon calcium concentrations are shown in fig. no. 7 & 8 below.

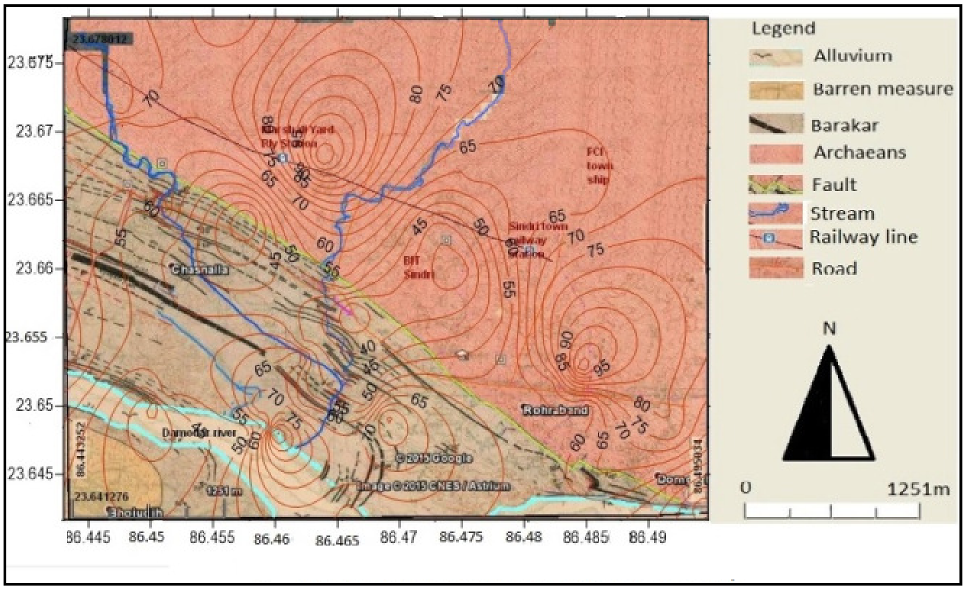

Figure 7: Pre-monsoon Calcium contour over base map

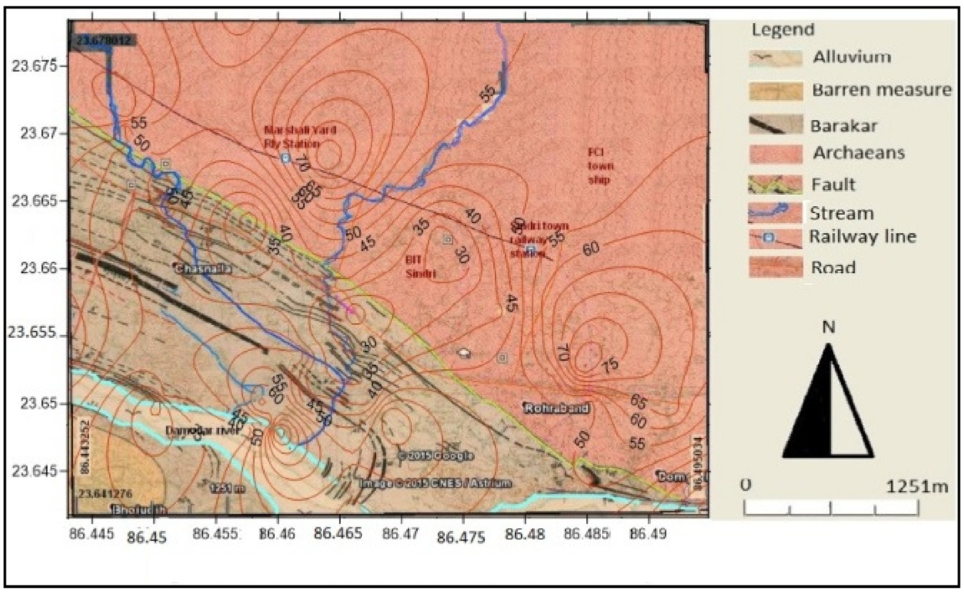

Figure 8: Post-monsoon Caalcium contour over base map

Sodium (Na^+): Sodium is a naturally occurring element in water and is mainly due to dissolution of feldspar and clay minerals. Industrial and domestic wastes also add up in its concentration. Na^+ in excess of 250 mg/l in drinking water may cause cardiovascular and nephrological problems in human beings (WHO, Geneva, 2004). However, the average Na^+ concentration in pre-monsoon samples wa76.76 mg/l and of post-monsoon samples was 56.48 mg/l. Only two samples during pre-monsoon was having higher concentration than the permissible limit and one sample of post-monsoon season. The spatial distribution of Na^+ is shown in figure 9 & 10.

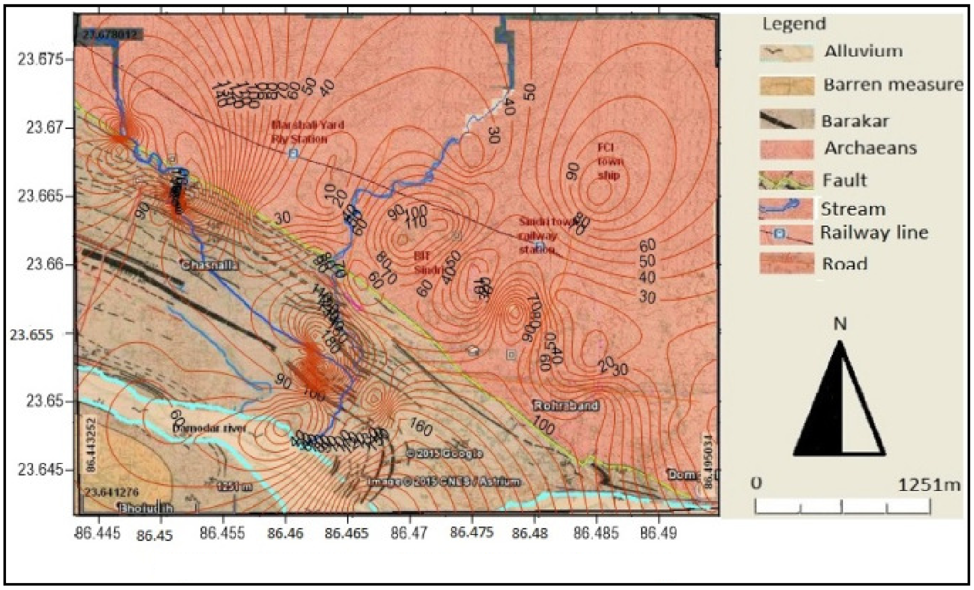

Figure 9: Pre-monsoon Na contour over base map

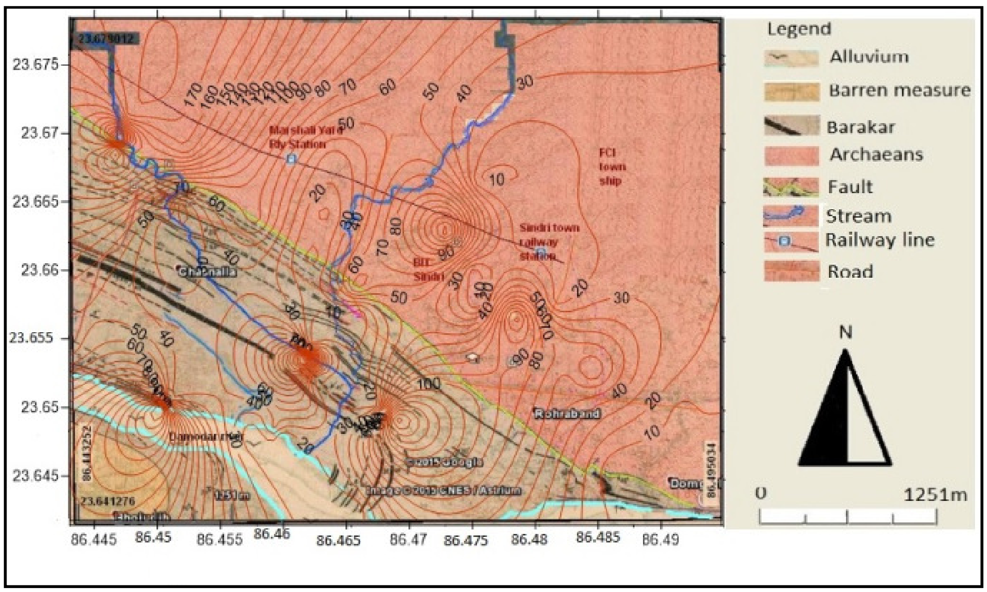

Figure 10: Post-monsoon Na contour over base map

Chloride: In addition to geogenic factors (igneous & metamorphic rocks) sewage waste disposal, fertilizers, human and animal waste are the main sources of chloride in groundwater. It is soluble in water and moves freely with water in form of sodium chloride. The Cl^- concentration in pre-monsoon water samples of the area ranges from 17 to 215 mg/l with mean value 71.58 mg/l and that of post-monsoon samples ranges from 11 to 185 mg/l with mean value 56.48 mg/l. The spatial distribution is shown in fig.11&14 below.

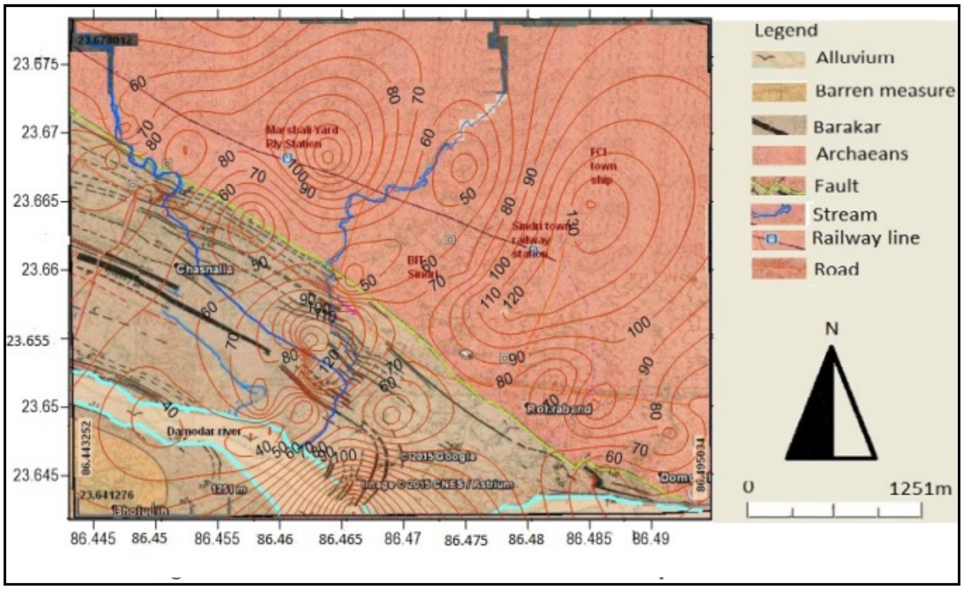

Figure 11:Pre-monsoon Chloride contour over base map

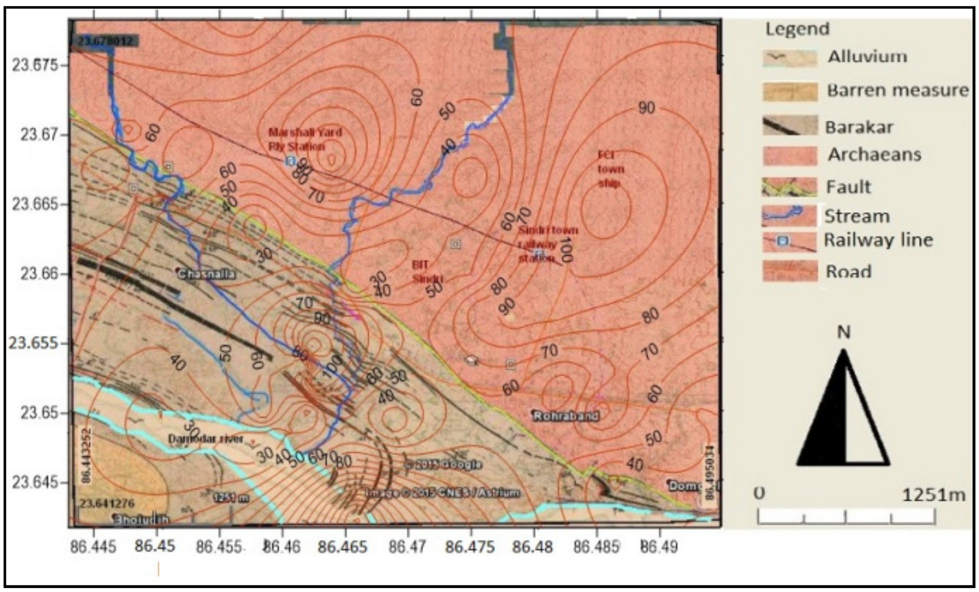

Figure 12: Post-monsoon Chloride contour over base map

Fluoride: Fl^- ion is universally present in water and its concentration is governed by geochemical dissolution of fluoride containing minerals such as Fluorite, Apatite and Mica etc. Fl^- concentration from 0.6 mg/l to 1.5 mg/l is beneficial for human tooth and bone. The water samples of the area are deficient in terms of Fl^- concentration both in pre-monsoon as well as post- monsoon seasons. The spatial distribution of Fl^- ion is shown in figure no. 13 & 14 below. The Fl^- deficiency may cause dental carries, dental mottling in children and bone deformation and osteoporosis in elderly people (Tank R.W.)

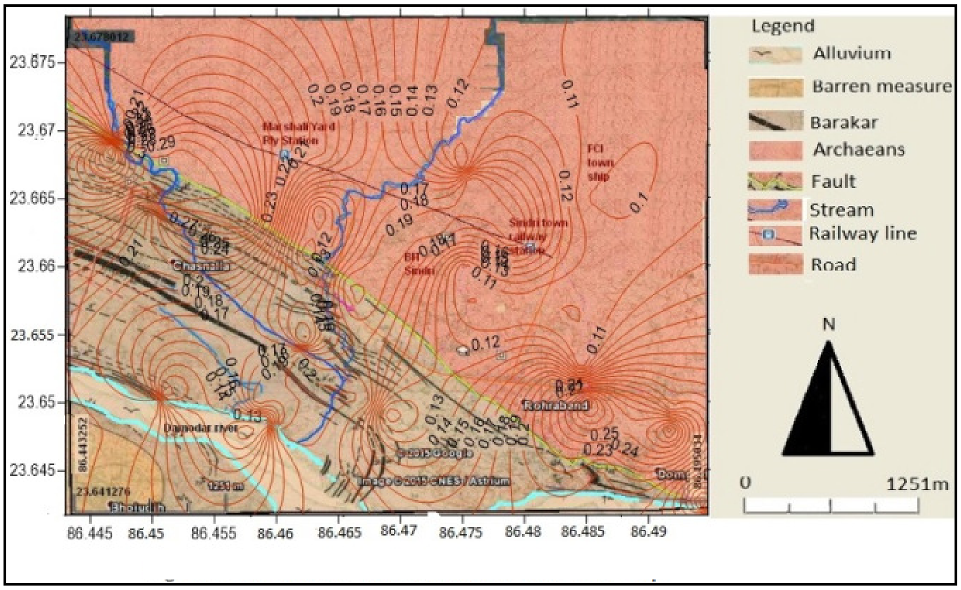

Figure 13:Pre-monsoon Fluoride contour over base map

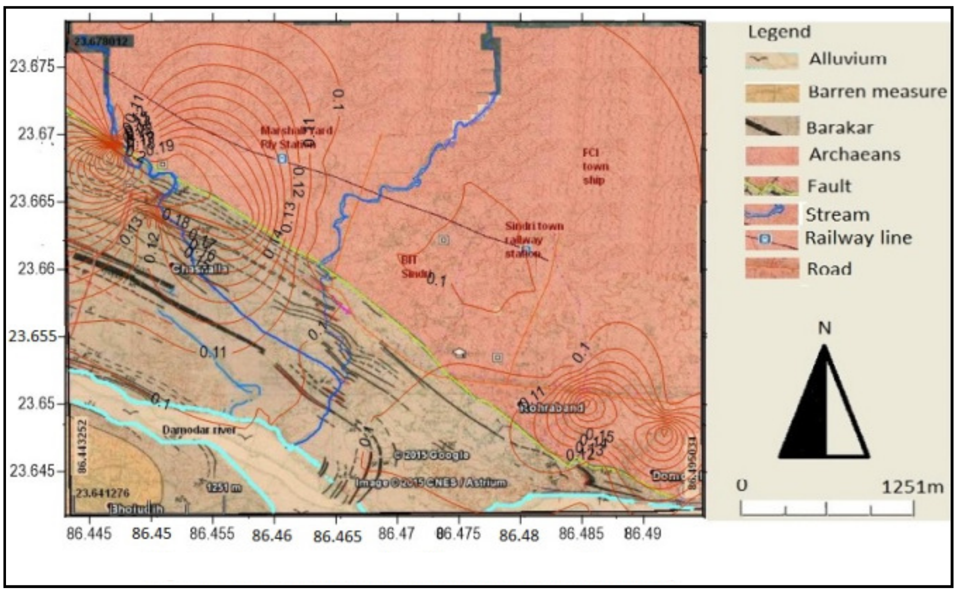

Figure 14:Post-monsoon Fluoride contour over base map

Nitrate: In this study area, the NO_3^- ion concentration ranges from 1 mg/l to 35 mg/l with mean value of 7.875 mg/l in pre-monsoon samples and 1to 35 mg/l with an average value of 6.58 mg/l in the post-monsoon samples. None of the samples exceeds the desirable limit of 45 mg/l for drinking water.

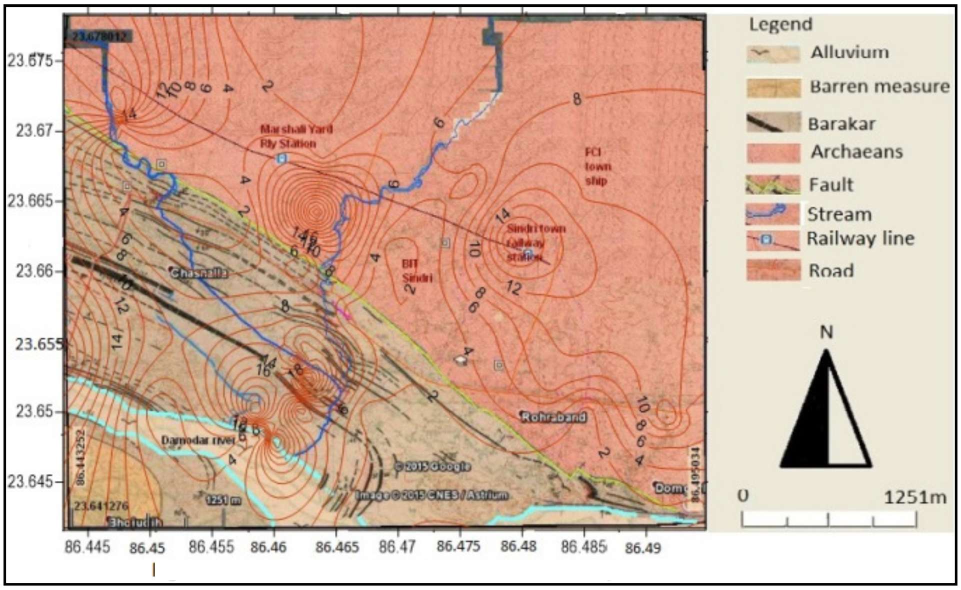

Figure 15:Pre-monsoon Nitrate contour over base map

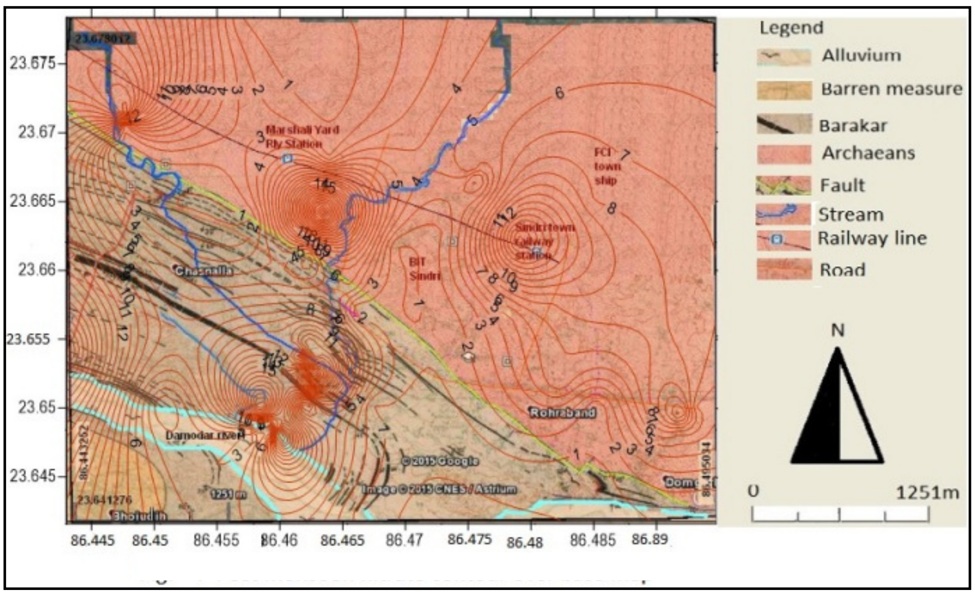

Figure 16:Post-monsoon Nitrate contour over base map

3.2. Groundwater Classification

For the proper understanding of the geochemical evolution of groundwater its classification is a must. Many workers, such as A.M. Piper and Durove, have tried to evolve a suitable classification scheme for groundwater of which the Piper Tri-linear classification is the widely used and mostly acknowledged scheme. In the present work, the concentration of major ions, as required, have been used to plot the Piper-trilinear diagram for pre- monsoon and post- monsoon samples separately as shown in fig. no. 17 & 18 below.

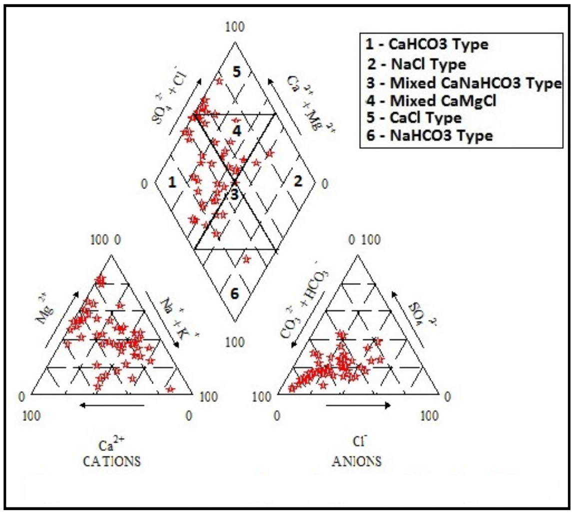

Figure 17: Pre-monsoon piper diagram indicating facies

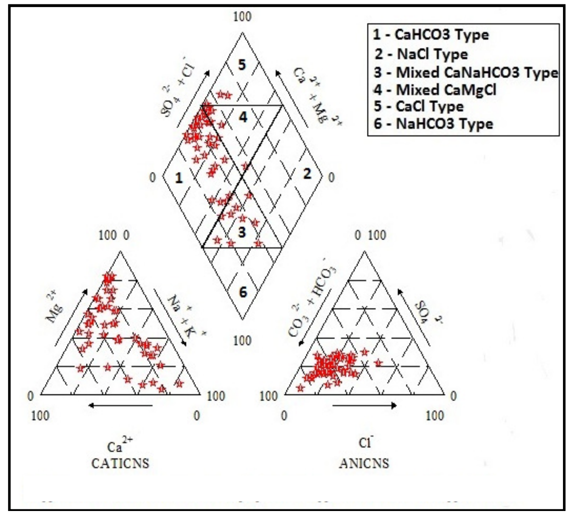

Figure 18: Post-monsoon piper diagram indicating facies

The pre-monsoon plot indicates that most of the groundwater samples represent $CaHCO_3$ type. Some of the samples fall in mixed Ca - Mg - Cl type and a very few samples fall in the rest 4 of the 6 facies. The post-monsoon plot indicates that majority of the samples fall in facies no. 1, only a few in facies no. 3, 4 & 5 whereas facies no. 2&6 are vacant. The facies type variation in pre-monsoon and post-monsoon samples may be due to leaching from the overburdens.

3.3. Conclusion

The hydrogeochemical analysis revealed that the water samples in this study area are potable and safe, after proper filtration, for drinking purposes. The dominant facies such as $CaHCO_3$ type, mixed Ca-Mg-Cl type and $CaNaHCO_3$ type in the entire lithounits of the area were identified using piper-trilinear diagram. All the parameters selected for the study are well within the permissible limits as prescribed by WHO and BIS drinking water standards, except Fl^- ion. So far as Fl^- ion is concerned the entire area is fluoride deficient which is not good for human health. It is the main reason behind soft teeth that decay easily in the children of the area. It can be also a reason for causing osteoporosis in elderly people particularly women. The persons residing in this area may be advised to take ample fluoride rich food-stuffs such as tea and fish.

4. References

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