

# HYDROGEOCHEMISTRY OF FLUORIDE IN AND AROUND SINDRI AREA, DHANBAD, JHARKHAND

**P.K. Singh\***, **Rabindra Kumar\*\*** and **Dr. Purushottam Singh\*\*\***

Key words : Hydrogeochemistry, Fluoride, Aquifer, Dental carries, Dental fluorosis, Osteoporosis.

Seasonal variation of ground water quality in and around Sindri area, Dhanbad was determined by analysing both pre-monsoon and post-monsoon water samples. The entire population of the area is dependent on either shallow water aquifers or surface water in the rural areas and treated supply water in urban areas. The low fluoride content is an endemic problem in the area and special attention was given to the point. The chemical composition of the area is determined by  $\text{CaHCO}_3$  type and mixed  $\text{Ca-Mg-Cl}$  type during the pre-monsoon and  $\text{CaHCO}_3$  type and mixed  $\text{Ca-Mg-Cl}$  type in the post-monsoon season. The microscopic examination of the common rock types revealed that Biotite is that only source mineral of fluoride in the area which is also ferruginised. Preliminary health surveys have revealed that dental carries, dental fluorosis and osteoporosis are prevalent in the study area which further corroborates with the analytical findings.

## INTRODUCTION

The suitability of groundwater for drinking and other purposes like irrigation and industry requires its hydrogeochemical study. (Goyal *et al.* 2010). The hydrogeochemical study of water includes an integrated study of various parameters such as geological settings, natural flow of water, climatic change, aquifer material type of the area and additions during percolation of water (Laurent *et al.* 2010). Although ground water is mostly presumed to be safe for drinking purposes, but its overexploitation may lead to the deterioration of ground water quality. Hence, a periodic evaluation of ground water quality is essential.

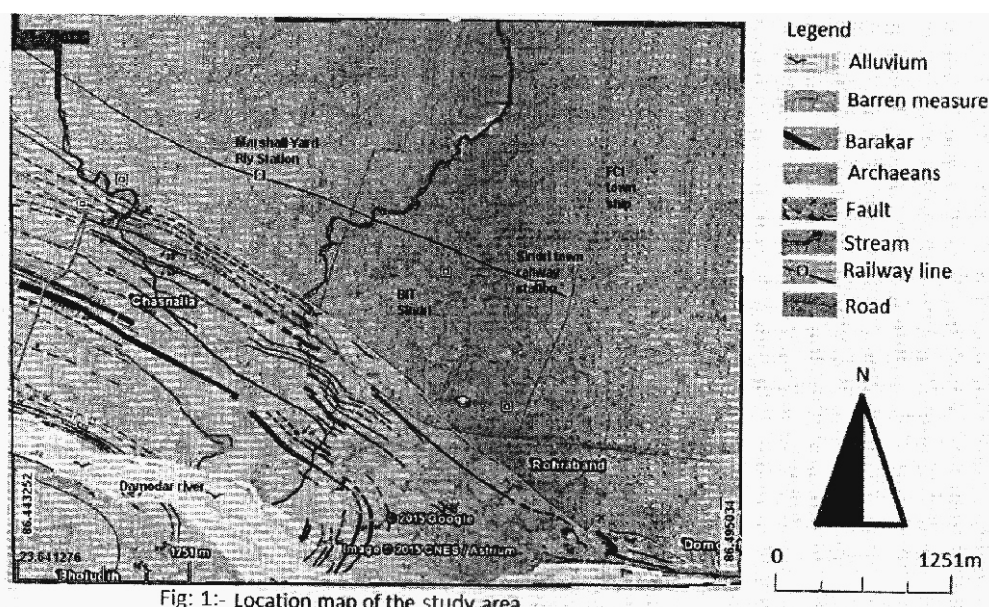
Scientific reports and surveys have revealed that numerous ground and surface water bodies are getting contaminated due to various factors. These contaminants may cause adverse impact on human life. Fluoride contamination is one such problem. Fluoride exists as a minor element in water and has toxic effect if present below 0.6ppm or exceeds 1.5 ppm in water. In both the cases, the effect is almost the same. These effects are very slow and silent and difficult to detect, particularly when the fluoride concentration is low in the natural water system. As a matter of fact, there are many complexities in hydrogeochemical studies of fluoride; the fluoride studies

have not been given priority both in terms of research as well as regulations. The objective of this study is to examine the routine parameters of ground water in the area with their spatial distribution. An analysis has been made to establish relationship of fluoride with key hydrochemical parameters like pH, calcium and total hardness and iron which are known to influence the fluoride geochemistry in ground water of the area (Alagumuthu and Rajan, 2008; Chakraborty and Sharma, 2011; Das *et al.* 2003; Subba Rao, 2010).

## MATERIALS AND METHODS

### Study area

The area selected for the study is located in the south eastern part of Dhanbad district, the coal capital of India. It lies between longitudes 86.441 E and 86.495 E and latitudes 23.641 N and 23.678 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 NS direction.



\* Associate Professor, Department of Geology, B.I.T. Sindri, Dhanbad-828123, E-mail id-singhpromodkumar@gmail.com

\*\* Associate Professor, Department of Geology, Science College, Patna. E-mail id-rabindra.hydrogeologist@gmail.com

\*\*\* Reader, Department of Periodontics, PDCH, Patna.

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 were deposited in the Damodar river valley graben. The sedimentary rocks are faulted between Rohrabandh and Domgarh and is also pierced by igneous intrusive of Mesozoic-Tertiary age.

#### **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 October 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). 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 having treated water supply of FCI & ACC, Sindri units.

The samples were collected in one litre narrow mouth pre-washed polythelene bottles. The locations of the different sampling sites were recorded using GPS. The physio-chemical parameters such as colours, 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,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{HCO}_3^-$ ,  $\text{NO}_3^-$ ,  $\text{F}^-$  and Iron in mg/l. The analytical procedures were conducted using APHA/ISI methods.

#### **GEOLOGY AND GROUNDWATER CONDITIONS :**

The study area can be diagonally divided into two geological formations, the hard rock area (Archaeans) and the soft rock area (Gondwana). The two areas are physically distinct and are separated by Archaean-Gondwana boundary running in NNW-SE direction. The hard rock area, consisting chiefly of the ancient crystalline rocks of the Precambrian age, is confined to the north of the boundary. The soft rock area comprising the Gondwanas is confined to the south of the boundary line. The Talchir and Damuda groups of rocks, including the vast coal deposits of Gondwana Supergroup have been deposited in a slowly sinking faulted trough. Superficial deposits of Damodar river and residual soils of bed rocks are of Quarternary formations. Igneous intrusions of Cretaceous-Eocene age are also incorporated at different places of the area. The Precambrians occupying the northern part of the area consist of metamorphites forming a part of Satpura Orogenic belt. The Precambrians comprise mainly granite- gneiss, quartzites and mica-schists.

Only the lower Gondwana is developed in the area forming a part of Jharia coal fields. Talchir series of rocks are not found widespread in the area, rather it is developed in patches. A very narrow strip of talchir shale can be seen at Archaean-Gondwana boundary in the B.I.T., Sindri campus. These shales are green in colour and are underlain by fine sandstone with boulder beds at the base. The Barakar Series is found to rest directly over the Archaeans in majority of the area except at few places where Talchir is present in between the Archaeans and the Barakar. Buff coloured medium grained sandstone, shale, carbonaceous shale and coal seams are the rock types reported in the Barakar series. The Barren measures are exposed to the south of river Damodar in SW corner of the area. The barren measure consists of sandstone, shale and carbonaceous shale but is devoid of any coal seam. The Raniganj formation is completely missing in the area.

The northern part (about 12sq.kms) of the area is a hard rock terrain. The metamorphic rocks, which are exposed to the north of the Archaean-Gondwana boundary covering more than half of the total area, have virtually no intergranular porosity. The rocks are extensively weathered which creates favourable conditions for infiltration and storage of groundwater. But, what is significant is that the geological conditions vary from one region to another as the fracture systems are related to local lithology and structural features. The fractures developed in the rocks are due to fissures, cooling cracks, joints, faults and weathered intrusive. These fractures create significant porosity and permeability in these rocks and are responsible for their groundwater potential.

The semi-consolidated Lower Gondwana sedimentary rocks, exposed to the south of the Archaean-Gondwana boundary, are productive aquifers. There are two blocks in the study area namely Chasnala coal block and Tasara coal block. The Chasnala block is operational whereas the tasara block is non-operational. Due to intensive mining and sand stowing, the geohydrological balance in Chasnala area is disturbed. The Tasara area has good groundwater potential. In addition to the above described two geological units in the area, there is a third geological unit also, i.e., Newer alluvium of recent age. Recent alluvium is found in very thin veneers in topographic depressions to the south of the Damodar River, but they cannot be considered as potential aquifers.

#### **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 in Table no. 1 and Table no. 2 respectively. 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.

Table No. 1

Statistical analysis of water quality data of pre-monsoon samples with prescribed limits of WHO(1997) and BIS (IS-10500) 1991										
Parameters	No. of Samples	Min. value	Max. Value	Mean	Median	Std. Deviation	WHO stds 1997		BIS(IS-10500)	
							Desirable	permissible	Desirable	permissible
colour (H.U)	48	1	25	3.1041	1	4.7366	–	–	5 H.U.	15 H.U.
Turbidity (NTU)	48	1	74	8.1875	2	14.4261	–	–	1 NTU	5 NTU
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 No. 2

Statistical analysis of post-monsoon water quality data with prescribed limits of WHO and BIS										
Parameters	No. of Samples	Min. value	Max. Value	Mean	Median	Std. Deviation	WHO 1997		BIS(IS-10500)	
							Desirable	permissible	Desirable	permissible
colour (H.U)	48	1	20	2.1458	1	3.189	–	–	5 H.U.	15 H.U.
Turbidity (NTU)	48	1	10	2.2291	1	2.6112	–	–	1 NTU	5 NTU
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

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<sup>-</sup>, Na<sup>+</sup> and K<sup>+</sup>.

**Table No. 3**

Correlation coefficients matrix of pre- monsoon data																
Parameters	Colour	Turbidity	Ph.	Alkalinity	T. hardenss	T.D.S.	Ca	Mg	Fe	Sulphate	Nitrate	Fluoride	Chloride	Conductivity	Na	K
colour	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	2.238	-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 No. 4**

Correlation coefficients of post-monsoon data																
Parameters	Colour	Turbidity	pH.	Alkalinity	T. hardenss	T.D.S.	Ca	Mg	Fe	Sulphate	Nitrate	Chloride	Flouride	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
Flouride													1	0.121	0.182	0.196
Conductivity														1	0.011	0.021
Na															1	0.728
K																1

**PARAMETERS INFLUENCING FLUORIDE :**

For inferring the hydrogeochemistry of fluoride in the area under study, five key water quality parameters such as pH, iron, calcium, total hardness and fluoride were studied in detail to get a comprehensive knowledge of the contamination pattern.

**pH:** pH is defined as the negative logarithm of the hydrogen ion activity and describes whether a solution is acidic (pH < 7), neutral (pH= 7) or alkaline(pH > 7). The results of the

chemical analysis clearly indicate that the mean pH value is 7.14 and standard deviation is 0.2517 during pre-monsoon season with minimum value 6.50 and maximum value 7.50. So far as the post-monsoon samples are concerned the mean pH value is 7.05 and standard deviation 0.1304. As per drinking water standards all the samples lie within the permissible limit except one (HP-015) which is slightly acidic. The spatial distribution of pH is shown in fig. 2 and fig. 3 for pre-monsoon and post-monsoon seasons respectively.

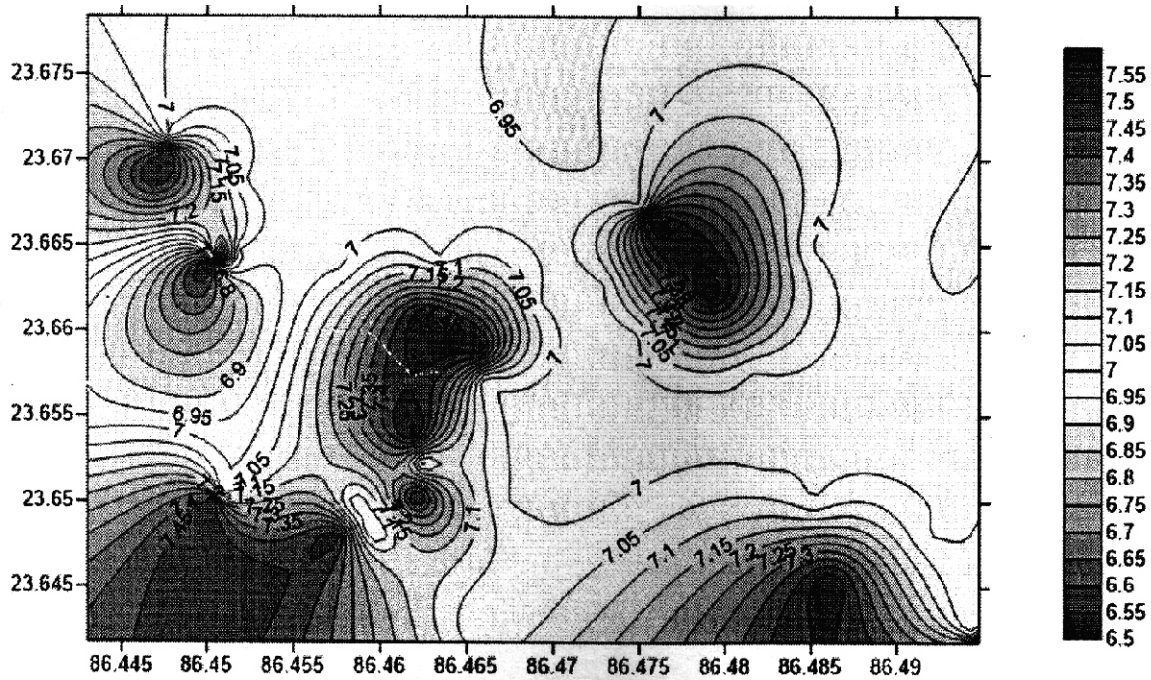


Fig. 2: Pre-monsoon spatial distribution of pH in the area

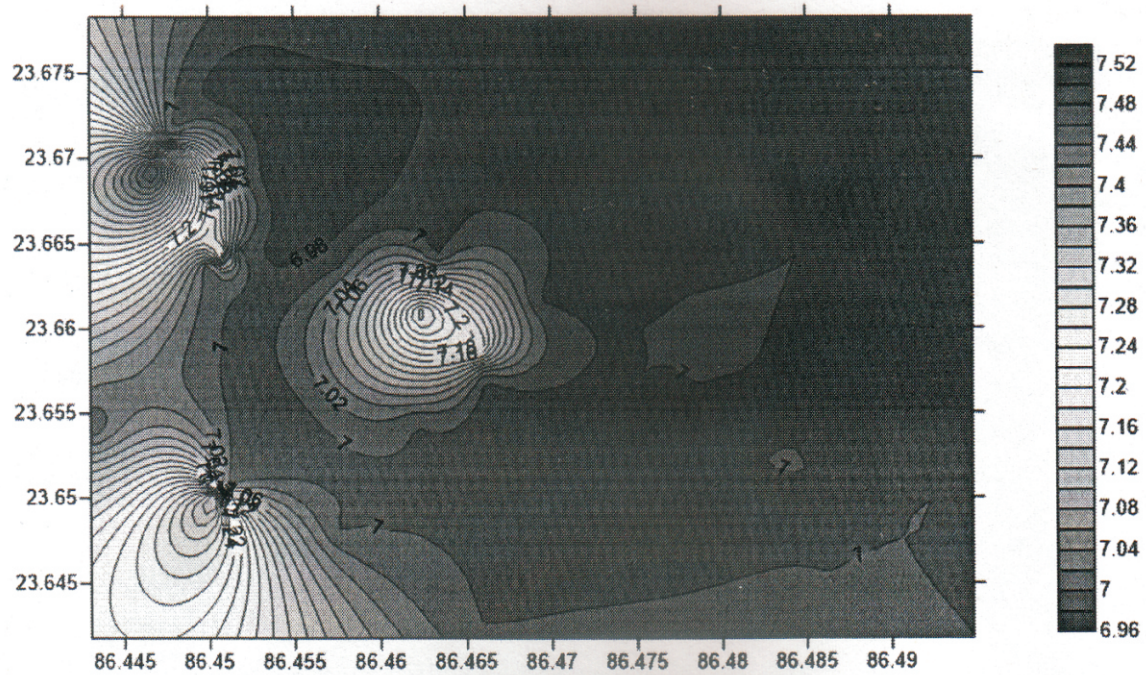


Fig. 3: Post-monsoon spatial distribution of pH in the area

**Total Hardness :**

Total hardness is a measure of the mineral content in a water sample that is irreversible by boiling. Hence, total hardness can be equivalent to the total calcium plus magnesium hardness. Hard water is not seriously harmful to human health but use of hard water is avoided in industrial uses, particularly in cooling towers. All the 48 samples collected from the area under study were analysed for total hardness.

The data presented in table no. 1 and table no. 2 clearly indicate that the total hardness ranges from a minimum value of 80 ppm to a maximum value of 606 ppm with mean value of 392.72 ppm in the pre-monsoon samples. In the post – monsoon samples, it varies from 65 ppm to 600 ppm with an average value of 375.0833 ppm. The spatial distribution of TH in the area is shown in fig. 4 and fig. 5 respectively for pre-monsoon and post-monsoon periods.

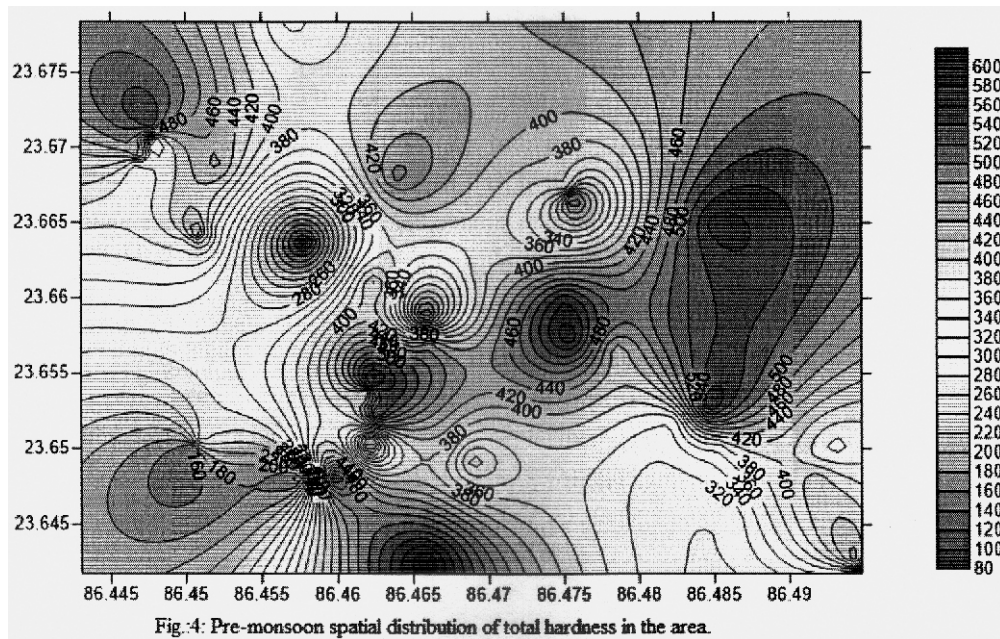


Fig.:4: Pre-monsoon spatial distribution of total hardness in the area.

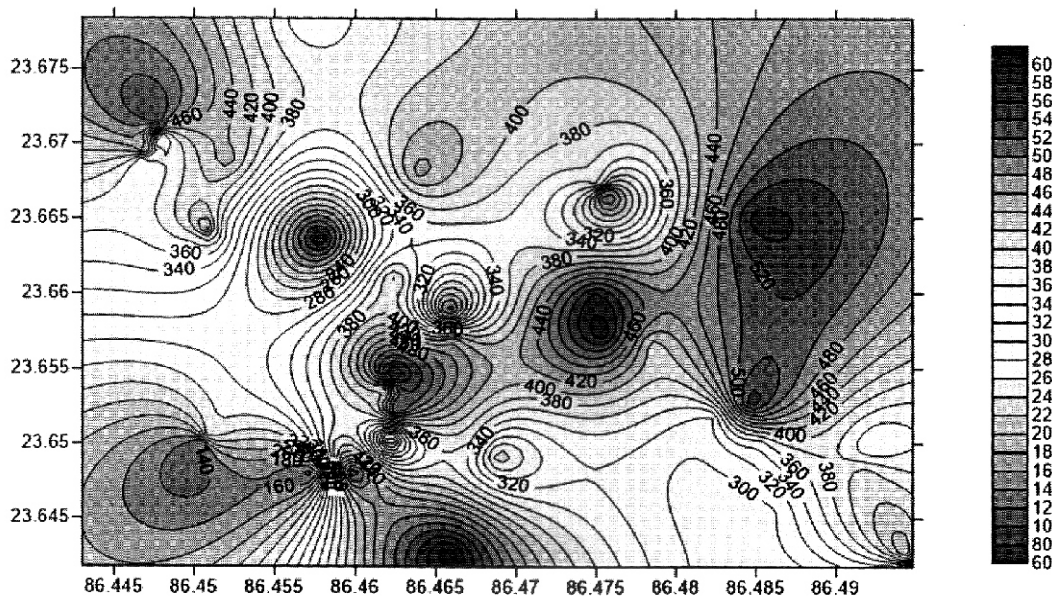


Fig.:5: Post-monsoon spatial distribution of TH in the area.

**Iron :**

Iron is the most common constituent of rocks next only to oxygen, silicon and aluminium and is found in all the three types of rocks. The important iron bearing minerals are pyroxenes, amphiboles, mica, pyrite, chalcopyrite, hematite and magnetite. Weathering of iron bearing minerals releases iron which usually forms relatively insoluble and stable iron oxides, carbonates, hydro carbonates, sulphates and chlorides. The iron content of water is found to be usually small due to the fact that ferric ions are hydrolysed and changed into insoluble ferric oxide when pH is 5. Ferrous ions are also

changed into insoluble hydroxide when the water is neutral. Concentration of iron above 1 ppm in water renders it unfit for drinking purposes. Out of the 48 water samples 9 samples were having higher iron concentration than the permissible limit of 1 ppm. Water of Hetkandra hand pump in the downstream of Chasnala Joria and that of Kali mandir, Chasnala are unfit for drinking water purposes. The mean iron content of ground waters is higher than the desirable limit as per WHO and IS standards. The spatial distribution of iron is shown in fig. 6 and 7.

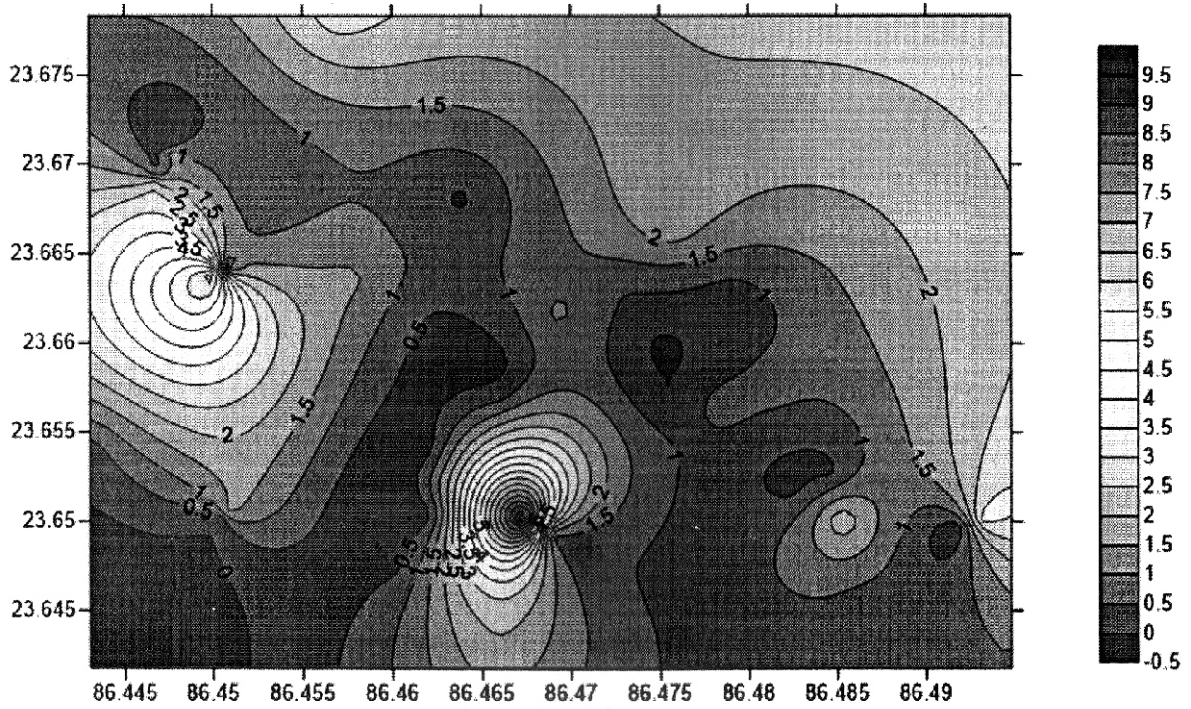


Fig. 6: Pre-monsoon spatial distribution of iron

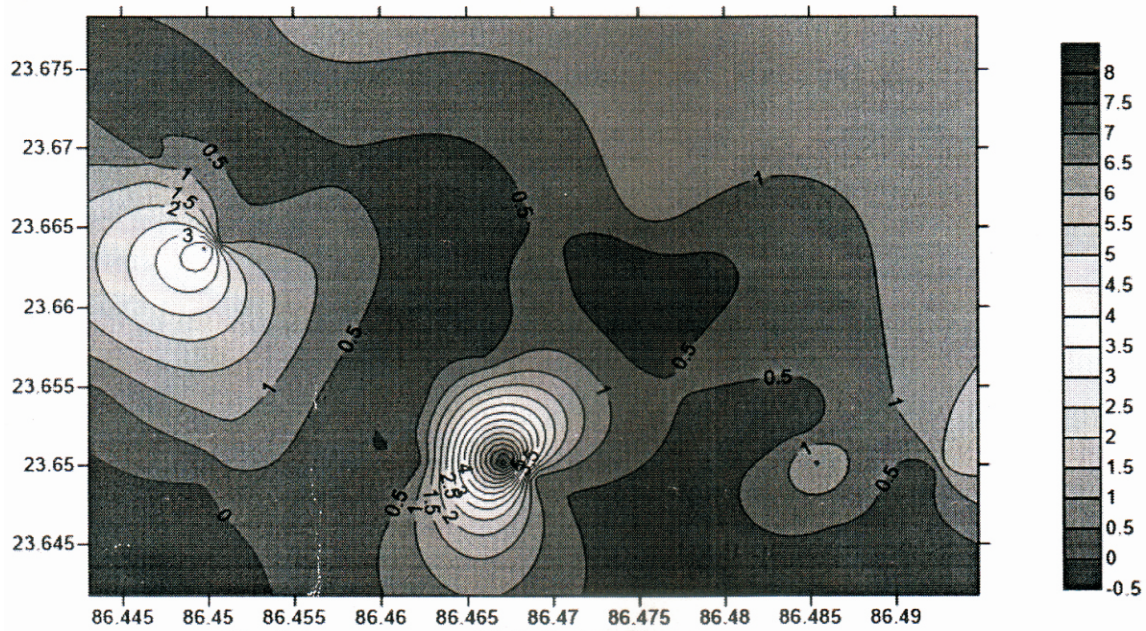


Fig. 7: Post-monsoon spatial distribution of iron

**Calcium** : Calcium is the major constituent in most of the igneous, sedimentary and metamorphic rocks. Principal sources of calcium in groundwater are some silicate minerals like plagioclase feldspar, pyroxene and amphiboles present both in igneous and metamorphic rocks. The silicate minerals are not directly soluble in water, rather weathering breaks down the minerals into soluble calcium products and clay minerals. However, the calcium

carbonate and calcium sulphate are soluble in natural water. Owing to the fact that calcium is found in abundance in most of the rock types, it is present almost everywhere in groundwater. Fig. 8 and 9 clearly illustrate the spatial distribution of calcium in pre-monsoon and post-monsoon seasons respectively.

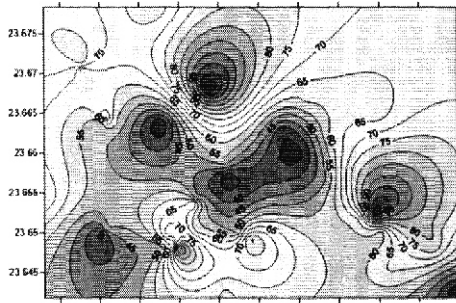


Fig. 8: Pre-monsoon spatial distribution of calcium

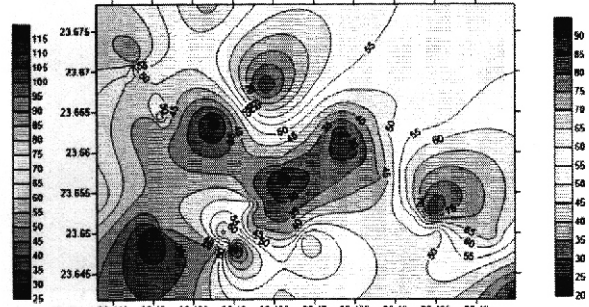


Fig. 9: Post-monsoon spatial distribution of calcium

The contour maps clearly show higher Ca concentration in the northern area (Archaean terrain) of the study area both during pre-monsoon and post-monsoon seasons. A comparatively lower Ca concentration in the southern area (Gondwana area) may be due to the fact that the area is composed of ferruginous sandstones, carbonaceous shale and coal seams. The range of calcium concentration in pre-monsoon water samples varied from a minimum of 29mg/l to a maximum of 116mg/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.

**Fluoride :** The important fluorine bearing mineral are fluorite, apatite, hornblende and micas. The concentration of fluoride in ground water is limited due to low solubility of fluorides. The solubility of fluorite at 25°C in pure water is only 8.7 ppm of fluoride (Aumeras, 1927). The degree of solubility is found to be in the following order; calcium fluoride <

magnesium fluoride < sodium fluoride. Ground water containing less than 1000ppm of total dissolved solids usually contains less than 1 ppm fluoride but in some areas the concentration reaches above 5 ppm. Generally the higher fluoride concentration is reported in arid and semi-arid regions. The fluoride shows positive correlation with iron & pH and negative correlation with total hardness (Chakrabarty and Bhattacharya, 2013). It has been observed that water high in calcium is low in fluoride content (Hem, 1991), i.e., with increasing fluoride concentration the concentration of calcium decreases. The fluoride in water shows negative correlation with calcium.

So far as fluoride concentrations in the study area are concerned, it ranged from 0.1037 to 0.4261 ppm with mean value of 0.1854 ppm in the pre-monsoon samples while in the post-monsoon samples it ranged from 0.0837 to 0.3277 ppm with mean value of 0.1166 ppm. The spatial distributions of fluoride in the pre-monsoon periods are shown in fig.10 and 11 respectively.

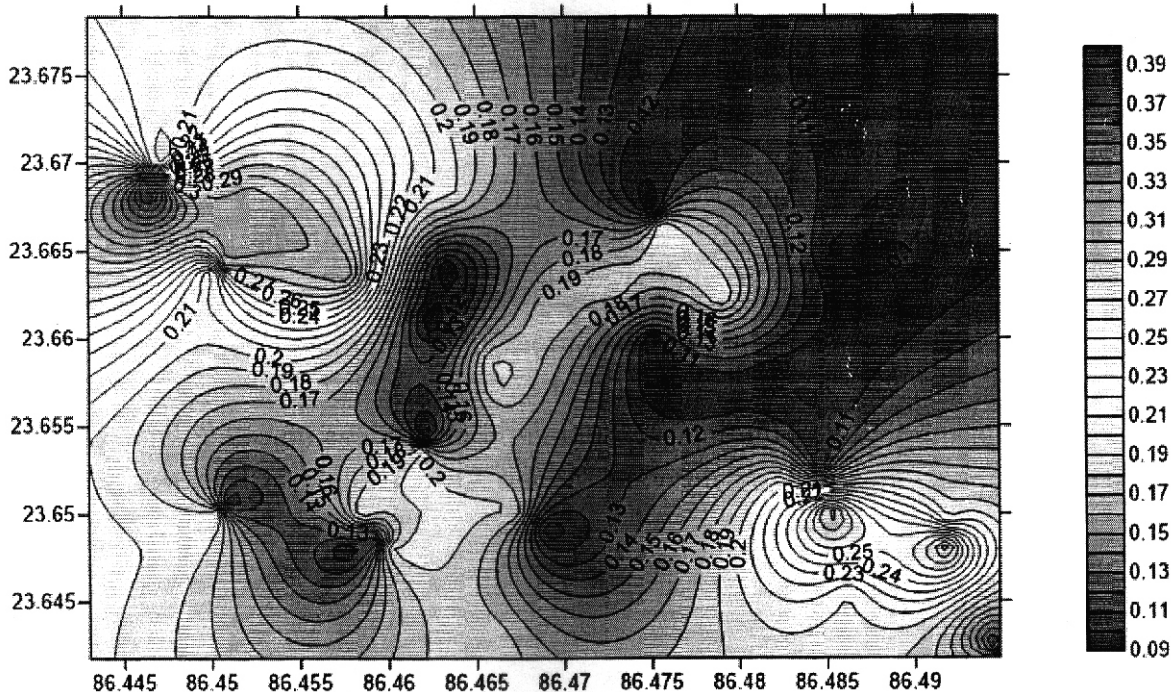


Fig.: 10: Pre-monsoon spatial distribution of fluoride

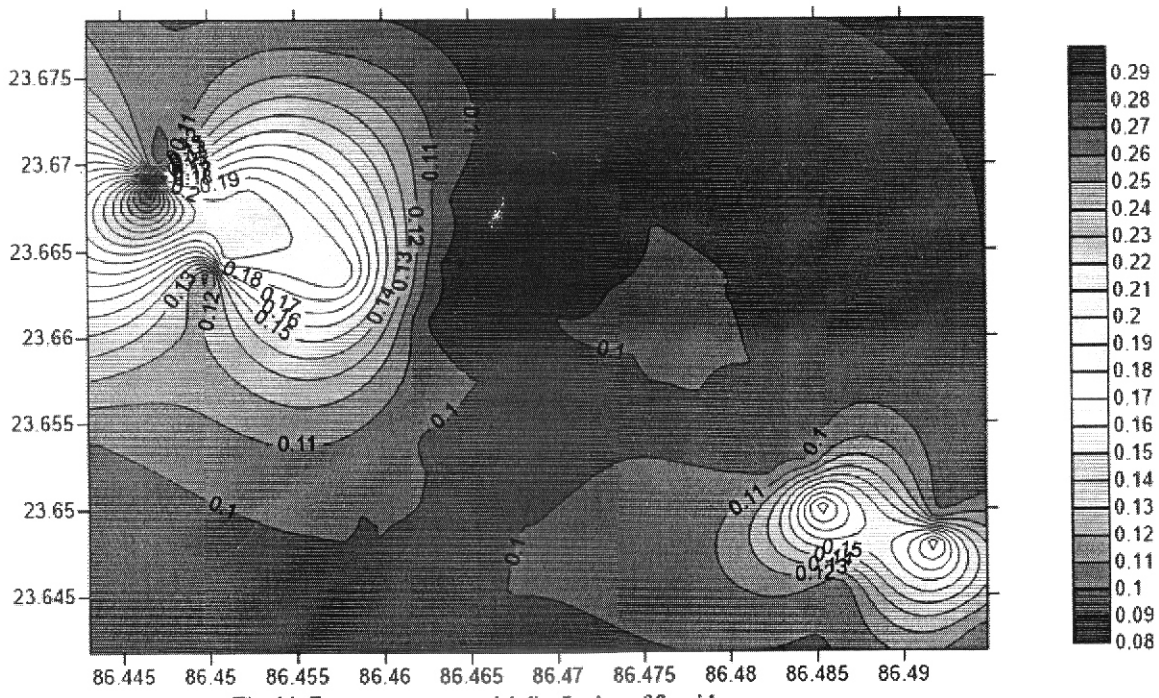


Fig.:11: Post-monsoon spatial distribution of fluoride

An attempt has been made to correlate fluoride with iron, and calcium. Plots of correlation between fluoride and other two parameters (fig. 12, 13) indicate that fluoride concentration in the analysed water samples is governed by these two parameters. The relationship of fluoride with these parameters

is well documented in geological literatures also (Das *et al.* Subba Rao, 2011). Fluoride concentrations in the sampled water have also shown positive correlation with pH. So far as its relationship with TH is concerned it is showing negative correlation.

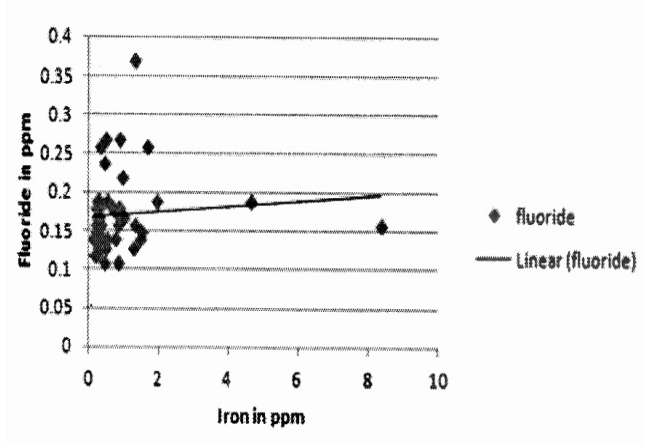


Fig: 12 : Relationship of fluoride with iron

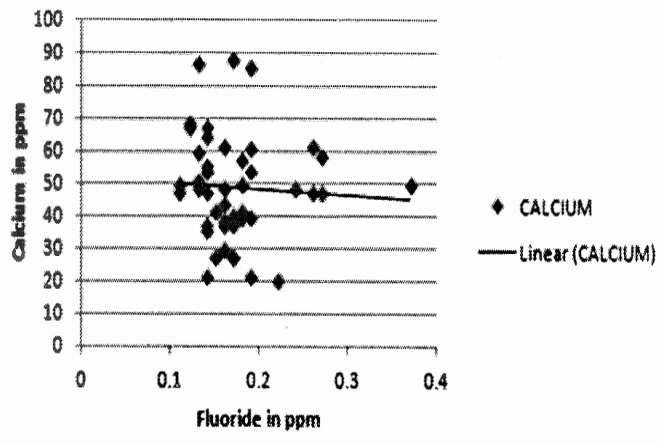


Fig: 13 : Relationship of fluoride with calcium

The element fluorine is utilised by higher life forms in the structure of bones and teeth. As per recent recommendations, the fluoride content in the range of 0.6 mg/l to 1.5mg/l is

beneficial for human tooth and bones. The fluoride dose response curve (fig. 14) clearly indicates that the excessive as well as deficiency in fluoride produces harmful effects on human health.

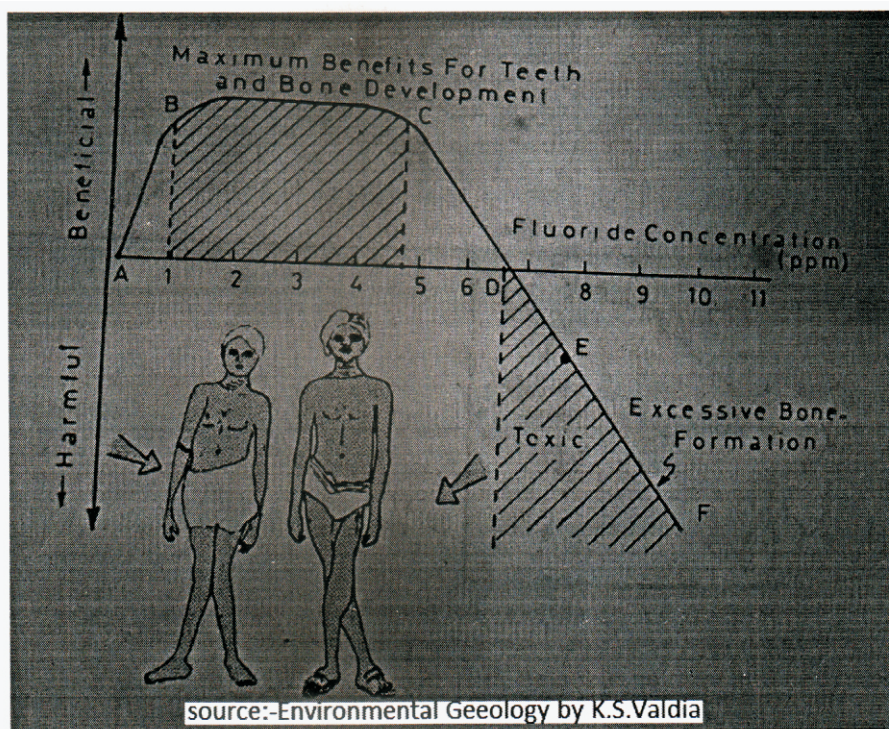


Fig.:14:-Fluoride dose response curve (After E.A.Keller, 1976).

It is clear from the above facts that the fluoride concentration in water below 0.6 ppm and above 1.5 ppm is harmful for the human health. The fluoride deficiency is the principal cause of dental caries and dental mottling in children whereas the excessive fluoride level in drinking water leads to bone deformation in all age groups and osteoporosis in elderly persons, specially women.

## CONCLUSION

The concentration ranges of all water quality parameters, when compared to WHO and ISI specifications, was found well within the permissible range except fluoride. The pre-monsoon groundwater samples are having higher concentration of almost all the parameters than the post-monsoon groundwater samples. This is an indication of low mobility of water during pre-monsoon period. The concentrations of fluoride were found below the safe and beneficial limit as prescribed by ISI (0.5 - 1.5 ppm, ISI, 1991) in both the seasons but in the post-monsoon season it is much lower than the pre-monsoon season. It is observed that the fluoride in groundwater is largely dependent on the availability of source minerals in the area, contact time of water with the formation, pH of water and ion exchange capacity of aquifer material.

The preliminary health surveys have revealed that dental caries and dental fluorosis in children below 15 years of age

and osteoporosis are prevalent in the study area which corroborates with the analytical findings. The inhabitants of the area may be advised to take those food stuffs which are capable of supplementing the fluoride such as tea, fish etc.

## References

- Alagmuthu, G and Rajan, M. (2008) Monitoring of fluoride concentration of ground water of Kadayam Block of Tirunelveli District, India; correlation with physico-chemical parameters, *Rasayan Jour, Chem.*, v. 1(4), pp757-765.
- APHA, standard Methods For Examination of water and Wastewater (19th edition), American Public Health Association, Washington D.C. (1995)
- BIS (1991) Indian Standards Institution-Indian standard specification for drinking water IS: 10500.
- Chakrabarty, S and Bhattacharya, H.N. (2013) *Journal of geological society*, v.82, pp379-391.
- Choubey, V.D. (1991) Hydrological and environmental impact of coal mining, Jharia coalfield, India *Environ. Geol.* 17, 185-194.
- Goyal, S.K. Chaudhary, B. S, Singh, O., Sethi, G.K., and Thakur, P.K. (2010) "GIS based spatial distribution mapping and suitability of ground water quality for domestic and agricultural purpose in Kaithal district, Hyaryana state, India." *Environ Earth Sci*, V61, pp 1587-1597.

Int. J. Mendel, Vol. 34 (1-2), 31-41, 2017

Hem, J.D.(1991), Study and interpretation of the chemical characteristics of natural water. 3<sup>rd</sup> edition.

Kumar, R. Singh, R.D., Sharma., K.D., Curr.Sci 89 794-81; Kumaresan, M Riyazuddin, P., Curr.Sci- 2005 v 9 pp 1668-1677.

Jovithvenkatchalam, K., Nithya, A., Chandra Mohan, S., "Correlation analysis of drinking water quality in and around Perur block of Coimbatore, Tamil Nadu, India." Rasayan Journal Chemistry, 3(4), 2010, 649-654.

Laurent, M., Francoise, A. And Marie, M. J. (2010) "Assessment of groundwater quality during dry season in southeastern Brazzaville, Congo." Int. Jour. Appl, Pharmaceut. Tehc. V.1(3), pp762-769.

Panigrahy, B.P., Singh, P.K., Tiwari, A. K., Kumar, Bijendra, Verma, Poornima., A statistical evaluation of the groundwater quality of Jharia coalfield, India., Int.Jour. of Chem Tech Research vol.7, No.-4, pp-1880-1888. (2014-2015)

*Hydrogeochemistry of Fluoride in.....*

Piper A. M., A graphical procedure in the geochemical interpretation of water analysis, Am. Geophys. Union Trans., 25, 914-923 (1994).

Sarkar, Mitali, Banerjee, A., Permanik, P.P., Chakraborty, S., "Appraisal of elevated fluoride concentration in groundwater using statistical correlation and regression study." J. Indian Chemical Soc., 83, 2006, pp1023-1027.

Singh, P.K., Tiwari, A.K. and Mahto, M.K., "Qualitative assessment of surface water of West Bokaro coalfields, Jharkhand by using water quality index methods." International Journal of Chem Tech Research 2013 5(5).

Subba Rao, N.(2011) High fluoride groundwater . Environ. Monit. Assess., v.176, pp637-645.

Tank, R.W., Water Resources and the Environment. pp457.

Valdia, K. S., Environmental Geology

WHO, Guidelines for drinking water quality, World Health Organisation, Geneva, (2004).