Ground water quality with special emphasis on Fe Contamination in Chhattisgarh State in Rajnandgaon Distt. at Khairagarh

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Abstract— In the present study, the groundwater quality in Khairagarah at Rajnandgaon District of Chhattisgarh State in Central India is assessed. A total of 41 Groundwater (GW) samples are collected during Monsoon (M) and Pre-Monsoon (PM) periods from various existing bore wells and tube wells in the study area, and they were analyzed for estimating the Fluoride (F^-) concentration in the existing GW with a special emphasis. The Physico-Chemical characteristics, in addition to the concentration of major Anions and Cations in the existing GW were also assessed. The results reveal that the fluoride concentrations in the existing GW in Rajnandgaon District is ranging >0.50 to <1.60 p.p.m. Most of the places in the study area are affected by high fluoride concentrations, and is evident from the 15% of total samples collected showing >3.5 p.p.m. of fluoride concentration, which is a maximum permissible limit recently suggested by Bureau of Indian Standard (BIS) (BIS: 10500, 2010). It is also seen that the fluoride is having poorly and burly positive correlations with calcium and sodium, respectively. Further, the study also includes the verification of suitability of GW for drinking in the study area.

***Index Terms*— Fluoride contamination, Groundwater, Maximum tolerable limit, Rajnandgaon district, Khairagarh.**

I. INTRODUCTION

In recent years, monitoring of Fluoride (F^-) concentrations in the groundwater has become a great interest to the scientific and research community as this problem is universal. According to the Bureau of Indian Standard (BIS) (BIS: 10500, 2010) the maximum tolerable limit of fluoride in Groundwater (GW) is 1.5 ppm. Any dose of fluoride which is >1.5 ppm in the GW effect the human body by causing dental and skeletal fluoresces (Sendesh Kannan, K et al., 2011). However, (AbechiS.E.et al 2013) mere doses of fluoride in the drinking water may have beneficial effects on the teeth by hardening the enamel and reducing the increase of Caries (Billings et al., 2004; Chaturvedi et al., 1999). Many of the countries in the world are facing problem of excess fluoride concentrations in drinking water. At present, 41 villages have reported to be affected from fluoresces and fluoride related problems (Susheela, 1993), and (Yusufu et al2012) India is one among the fluoride affected countries. In India, this problem is noticed in almost all the states such as Andhra Pradesh, Bihar, Chhattisgarh, Gujarat, Madya Pradesh, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh. About 62 million people of India presently are at risk fluoresces from the consumption of high fluoride through the groundwater (Andezhath et al., 1999). Tamil Nadu, one of the important Southern parts of the India is also facing the problem of excess fluoride concentrations (Krishnaraj Srinivasamoorthy et al., 2010). An attempt has been also made by Krishnaraj Srinivasamoorthy et al., (2010) to demarcate the fluoride-vulnerable zones and to identify the major geological process controlling the incidence of fluoride in the groundwater existing in the Mettur taluk of Salem District in Tamil Nadu State of Southern India. Recently, Sendesh Kannan, K et al., (2011) adopted the Geographical Information System (GIS) approach to develop the spatial information and knowledge based database by assessing the fluoride concentrations in the groundwater of Dharmapuri District in Tamil Nadu. Therefore, estimation of fluoride concentrations in the groundwater and identifying its more sensitive areas is having great potential in research field. Considering the above facts, in the present study, assessment of groundwater quality is made with a special emphasis on fluoride contamination at the selected 41 locations in Khairagarh at Rajnandgaon District of Chhattisgarh State of Central India. Apart from fluoride estimation in the GW, the major Anions and Cations along with the Physico-Chemical characteristics are also assessed and presented herein. Note that the de-fluoridation is not the part of the present study.

Manuscript received Jan 15, 2015

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II. MATERIALS AND METHODS

2.1 Location

The Rajnandgaon District (21°06′N 81°02′E) is located in the centre of the Chhattisgarh State in India covering an area of 8,022 km^2. The headquarters of Rajnandgaon District is located on the Mumbai-Howrah line of South-Eastern Railways and the National Highway (NH) 6 is also passing through the Khairagarh town of Rajnandgaon. 41 study locations in Rajnandgaon District such as Mutada Navagaon, Dhaneli, Madara Kuhi, Son Bhattha, Eraikala, Karamtara, Kekaraj Boad, Karamtara, Eraikala, Patewa, Ghumka, Kalewa, Bheisavara, Jogi Dalli, Badai Tola, Bharda Kala, Dabra Tekapar, Sandi, Dholia Pendri Kavhar Pendri, Dhimarin Kuwachowk, Chhuikhadan, Ghirgholi Road Ataria, Narmada Chowk, Gandai, Kukur Muda Chowk, Sakha Koray Chowk, Gopalpur, Padmavatipur, Udaypur, Bazar Atariya Chowk, Keshla Chowk, Bargadha Chowk, Bori Chowk, Mandla Chowk, Dhokara Bhatha Chowk, Jaat Bandha, Saloni Bazar Chowk, Mohandi, Bhandarpur, Bareth Para Khairagarh, Garapar Chowk, Kumhi are selected for the present study as these locations are much affected by high fluoride concentrations. Figure 1 shows the locations of 41

selected study areas of Khairagarh at Rajnandgaon District in Chhattisgarh State of Central India.

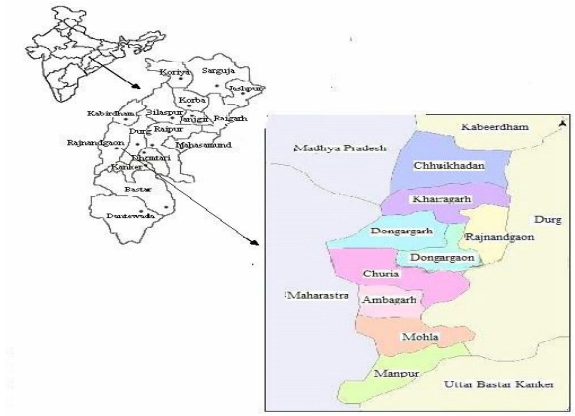

Figure 1: Location map of the study area

Figure 2: Location map of the study area

2.2 Water sample collection

A total 41 groundwater samples were collected from various parts of the 41 selected sites such as Mutada Navagaon, Dhaneli, Madara Kuhi, Son Bhattha, Eraikala, Karamtara, Kekaraj Boad, Karamtara, Eraikala, Patewa, Ghumka, Kalewa, Bheisavara, Jogi Dalli, Badai Tola, Bharda Kala, Dabra Tekapar, Sandi, Dholia Pendri Kavhar Pendri, Dhimarin Kuwachowk, Chhuikhadan, Ghirgholi Road Ataria, Narmada Chowk, Gandai, Kukur Muda Chowk, Sakha Koray Chowk, Gopalpur, Padmavatipur, Udaypur, Bazar Atariya Chowk, Keshla Chowk, Bargadha Chowk, Bori Chowk, Mandla Chowk, Dhokara Bhatha Chowk, Jaat Bandha, Saloni Bazar Chowk, Mohandi, Bhandarpur, Bareth Para Khairagarh, Garapar Chowk, Kumhi in Rajnandgaon District. All these water samples were collected during Monsoon (July-September) and Non-Monsoon (November-January) periods of two consecutive years 2014 and 2015. From each selected site of the study area, a total of 10 water samples (5 in Monsoon (M) period and 5 in Non-Monsoon (NM) period) were collected from various bore wells and deep tube wells which are being used for drinking purposes in the proposed sight. These fresh groundwater samples are collected in the plastic containers (PVC, 250 ml) after flushing out some quantity of water from the source for a period of 5 minutes. The physical parameters i.e. pH, TDS, and Turbidity values were determined at the spot immediately after collection. Preservative (1:1 HNO_3 solution to pH <2, about 3ml/l sample) is added to each water sample at the time of sampling and the containers were sealed. These samples were tested for 16 Physico-Chemical parameters like pH, Dissolved Oxygen (DO), Total Dissolved Solids (TDS), Turbidity, Calcium, Sodium, Nitrate, Bicarbonate, Sulphate, Fluoride and heavy metals like Iron, Manganese, Copper, Zinc, Cadmium and Nickel. The samples without preservatives are also collected for analysis of Nitrate, Sulphate and Fluoride content.

2.3 Analysis of fluoride and other Ions

The fluoride content is monitored with Metrohm ion meter-781 equipped with fluoride ion selective electrode and calomel electrode. The ion meter is calibrated with a standard F^- solution over a range of 0.00-8.00 mg/l containing acetate buffer 1:1 volume ratio (58 g NaCl and 57 ml acetic acid with de-ionized water and neutralized with 5 M NaOH solution to the pH value of 5.5 into final dilution of l liter). Similarly, 10 ml of the sample solution is mixed with 10 ml buffer in a 50-ml plastic beaker in 1:1 volume ratio, and F^- content was measured. The content of ions i.e. Cl^-, NO_3^-, SO_4^{2-}, Na^+, K^+ and Ca^{2+} is analyzed by using Dionex DX120 ion chromatography equipped with anion separation column (AS9-HC,250x4 mm), Cation separation column (CS12A, 250x4 mm) and conductivity detector. The hardness and alkalinity are determined by titration methods. The Varian Liberty AX Sequential ICP-AES and Varian AA280FS atomic absorption spectrophotometer equipped VGA-77 (plasma flow: 15 l/min, auxiliary flow: 1.5 l/min, power: 1KW, PMT voltage: 650 V) are used for analysis of the metals.

III. Results and Discussions

3.1 Physico-chemical characteristics

The results of Physico-Chemical pertinent characteristics such as pH, Dissolve Oxygen (DO), Total Dissolve Solid (TDS) and Turbidity for various samples collected during Monsoon (M) and Pre Monsoon (PM) period from the groundwater existing in Khairagarh at Rajnandgaon district are summarized in Table 1.

The results reveal that the observed pH values are well within the allowable maximum scale pH value 8.5 and slightly fall below the minimum scale pH value 6.5 as per the standards suggested by BIS: 10500 (2010). It is also seen that, in all the samples the minimum end scale of pH value is ranging between >4.0 to <10.1 indicating that the existing GW in Rajnandgaon District is slightly acidic in nature. According to World Health Organization

(WHO), health effects are most pronounced in pH extremes. Any pH value less than 4 causes corrosion in metals (WHO, 2010). Drinking water with an elevated pH above 11 can cause skin, eye and mucous membrane irritation. On the opposite end of the scale, pH values below 4 also cause irritation due to the corrosive effects of low pH levels (WHO,

2010). The Dissolved Oxygen levels in the GW present in the Chhuikhadan site of Rajnandgaon district showing <2 mg/l for both monsoon and non-monsoon periods, which indicates that the DO levels present here are much low and they are not enough to support aquatic life. However, other places of Rajnandgaon District showing moderate to very good DO levels indicating that there is no immediate danger. Further, as per the BIS: 10500 (2010) standards, the desirable limit of the Turbidity for drinking water is 10 and it may be relaxed up to 25 in the absence of alternate. But, it is seen herein the results that, the ranges of Turbidity values are in mixed proportions in all the selected study locations. Furthermore, the TDS values for all the selected study locations in the Rajnandgaon District are <500 which is well within the limit of BIS: 10500 (2010) standards.

Table 1: Physico-Chemical pertinent characteristics of groundwater in Rajnandgaon District

Locations	Periods	PH	DO (Mg/I)	TDS (PPM)	Turbidity
Dhaneli	PM	9.70	5.55	75	1.74
	M	9.00	4.97	64	1.06
Mutada Navagaon	PM	9.64	4.16	129	1.2
	M	8.66	4.00	102	Nil
Madara Kuhi	PM	9.57	6.05	153	25.9
	M	9.11	5.76	120	24
Son Bhattha	PM	9.33	5.55	288	5.9
	M	8.24	5.25	180	5.2
Kekaraj Boad	PM	9.20	5.15	735	48
	M	9.12	4.59	600	40
Karamtara	PM	9.88	5.05	545	23
	M	9.01	4.05	392	21
Eraikala	PM	9.74	4.36	688	34
	M	9.60	4.00	524	21
Patewa	PM	9.57	4.16	72	24
	M	8.97	3.75	50	13
Ghumka	PM	9.84	3.57	871	46
	M	9.21	3.00	766	25
Kalewa	PM	9.74	2.77	737	34
	M	8.98	2.57	688	29
Bheisavara	PM	9.69	2.87	824	31
	M	9.21	2.50	768	26
Jogi Dalli	PM	9.60	3.27	200	7
	M	9.15	3.01	147	2
Badai Tola	PM	9.49	6.74	221	1.9
	M	9.07	6.15	186	0.76
Bharda Kala	PM	9.97	4.86	69	Nil
	M	9.21	4.30	56	Nil
Dabra Tekapar	PM	9.69	4.96	29	7.6
	M	9.21	4.50	14	5.2
Sandi	PM	9.48	5.15	125	46
	M	9.32	4.95	102	39
Dholia Pendri Kavhar Pendri	PM	9.39	2.84	129	9.2
	M	8.65	1.24	111	6.5
Dhimarin Kuwachowk	PM	9.64	3.51	276	3.2
	M	9.22	3.15	210	1.6
Chhuikhadan	PM	9.51	3.42	154	9.8
	M	8.78	2.70	127	7.2
Ghirgholi	PM	8.76	4.15	224	2.3
	M	8.12	4.02	178	1.00
Road Ataria	PM	10.1	10.49	438	Nil
	M	9.56	9.83	397	Nil
Narmada Chowk	PM	9.46	0.41	429	1.9
	M	8.90	2.48	388	1.2
Gandai	PM	9.74	0.94	252	3.7
	M	9.12	2.60	240	2.1
Kukur Muda Chowk	PM	9.71	9.52	622	4.3
	M	9.21	8.76	578	3.4

Sakha Koray Chowk	PM	9.63	3.68	445	5.9
	M	8.96	2.90	329	3.2
Gopalpur	PM	9.13	1.80	178	25.9
	M	8.63	0.53	149	23
Padmavatipur	PM	10.26	1.27	176	4.8
	M	9.76	1.00	96	3.2
Udaypur	PM	9.63	1.82	210	1.2
	M	9.21	1.76	190	Nil
Bazar Atariya Chowk	PM	9.11	3.80	154	3.4
	M	8.76	2.90	139	2.2
Keshla Chowk	PM	9.60	2.51	190	9.17
	M	8.97	1.80	172	8.24
Bargadha Chowk	PM	9.76	1.00	43	23
	M	8.98	0.52	29	18
Bori Chowk	PM	9.79	0.91	69	31
	M	9.12	1.27	64	24
Mandla Chowk	PM	9.57	10.11	190	48
	M	9.11	9.10	174	37
Dhokara Bhatha Chowk	PM	9.58	9.83	159	19
	M	9.22	9.70	128	15
Jaat Bandha	PM	9.33	2.48	125	42
	M	8.76	1.30	110	26
Saloni Bazar Chowk	PM	9.20	1.70	229	7
	M	8.68	1.27	210	2
Mohandi	PM	9.45	0.48	54	1.5
	M	9.17	0.76	47	1.2
Bhandarpur	PM	9.21	10.6	545	1.2
	M	8.46	12.6	469	Nil
Bareth Para Khairagarh	PM	9.19	6.20	640	Nil
	M	8.66	4.76	490	Nil
Garapar Chowk	PM	9.70	5.22	775	Nil
	M	9.26	3.98	640	Nil
Kumhi	PM	9.37	4.66	72	34.5
	M	8.76	3.76	65	26

PM: Pre monsoon, M: Monsoon

3.2 Chemical characteristics

The emphasis of the study is on the estimation of Fluoride (F^-) concentrations in the existing groundwater of the Rajnandgaon District of Chhattisgarh State in Central India. Therefore, all the 41 samples collected from various parts of the study area during the monsoon and pre-monsoon periods of two consecutive years 2013 and 2014 are analyzed and the results obtained were compared with the existing Indian Standards, i.e., BIS: 10500 (2010). The obtained fluoride concentration levels corresponding to each location of Rajnandgaon District are given in Table 2. In addition, the concentrations of ions such as Ca^{2+}, Na^+, HCO_3^- NO_3^-, SO_4^{2-} and F^-, and metals such as Fe, Mn, Cu, Zn, Cd and Ni are subsequently estimated and these results are also summarized in Tables 2 and 3, respectively. The results reveal that, the fluoride concentrations are increased significantly in the existing groundwater of many parts of the study areas of Rajnandgaon District. It is evident from Tables 2 and 3 that, in the study area for monsoon and non-monsoon periods, the fluoride concentration levels are exceeding >1.5, i.e., the maximum tolerable limit of fluoride as suggested by BIS: 10500 (2010).

Table 2: Concentration ranges of ions (Ca^{2+}, Na^+, HCO_3^- NO_3^-, SO_4^{2-}, and F^-) in mg/l in the existing groundwater of Rajnandgaon District at khairagarh.

Location	**Type**	**Ca^{2+}**	**Na^+**	**HCO_3^-**	**NO_3^-**	**SO_4^{2-}**	**F^-**
Dhaneli	PM	27	10.2	2.76	25	48	0.50
	M	12	9.0	1.24	15	38	0.36
Mutada Navagaon	PM	15.2	12.2	8.21	28	121	2.05
	M	14.60	11.2	6.42	14	115	1.55
Madara Kuhi	PM	13.3	4.2	20.11	25.11	125	2.00
	M	10.70	2.4	14.76	23.10	120	1.50
Son Bhattha	PM	29.22	9.0	27.22	28.32	91	1.34
	M	15.25	7.6	15.99	18.21	130	9.8
Kekaraj Boad	PM	24	23.4	25.13	32.4	131	6.53

	M	0.18	21	5.44	15.0	98	1.05
Karamtara	PM	0.21	10.2	22.16	12.53	98	2.50
	M	0.16	9.32	18.44	10.00	75	1.95
Eraikala	PM	26.31	14.11	16.77	8.43	120	2.01
	M	23.13	11.13	12.11	5.00	110	1.99
Patewa	PM	20.14	24.21	18.27	27.8	90	5.07
	M	15.20	13.14	8.66	13.00	82	4.50
Ghumka	PM	13.2	9.11	17.51	11.3	111	3.09
	M	9.76	8.33	13.26	8.51	105	2.88
Kalewa	PM	22.24	13.32	20.33	7.34	101	2.09
	M	15.3	11.11	16.23	6.48	85	1.55
Bheisavara	PM	19.21	10.76	21.66	18.5	47	2.05
	M	14.3	9.42	15.34	15.0	35	1.75
Jogi Dalli	PM	88	13.65	8.28	12.8	124	3.32
	M	75	8.76	6.34	11.0	115	1.88
Badai Tola	PM	3	23.29	10.57	19.3	98	2.30
	M	3	16.31	8.37	14.5	85	1.85
Bharda Kala	PM	12	24.21	11.66	7.31	87	2.10
	M	10	20.00	17.21	4.62	76	1.88
Dabra Tekapar	PM	8	13.14	13.55	6.60	111	1.00
	M	8	9.76	9.66	5.10	87	0.57
Sandi	PM	22	34.4	19.36	1.55	108	2.04
	M	12	24.6	12.51	0.98	100	1.55
Dholia Pendri Kavhar Pendri	PM	29	1.5	8.77	10.9	125	2.07
	M	20	1.2	6.68	8.50	115	1.88
Dhimarin Kuwachowk	PM	21.27	20.6	12.54	1.41	127	1.00
	M	13.8	16.9	10.22	0.90	113	0.85
Chhuikhadan	PM	14.3	4.3	16.87	18.5	92	2.23
	M	9.72	2.1	12.40	17.5	85	1.66
Ghirgholi	PM	4	23.7	15.34	17.67	87	0.95
	M	4	15.2	13.02	14.55	75	0.75
Road Ataria	PM	29.26	12.4	8.07	15.21	78	3.45
	M	21.15	8.6	6.47	13.21	65	2.54
Narmada Chowk	PM	13.5	1.4	10.98	10.03	98	2.82
	M	9.6	11.00	7.27	9.00	82	1.86
Gandai	PM	29	22.0	17.76	23.45	128	6.37
	M	14	0.78	9.24	19.11	35	4.56
Kukur Muda Chowk	PM	25	7.3	8.29	27.87	57	3.42
	M	13	5.2	7.27	17.80	50	2.44
Sakha Koray Chowk	PM	9	6.13	14.55	24.3	76	1.56
	M	8	4.2	12.02	13.50	62	0.99
Gopalpur	PM	12	18.33	8.13	11.96	84	0.95
	M	8	14.22	5.27	8.32	75	0.77
Padmavatipur	PM	10.1	24.96	19.23	18.57	123	2.97
	M	8.2	18.61	15.27	15.31	113	1.88
Udaypur	PM	24	7.61	8.97	12.8	120	2.30
	M	18	5.2	7.77	9.85	102	1.89
Bazar Atariya Chowk	PM	15	11.86	14.7	6.60	97	3.42
	M	9	7.33	9.78	5.00	75	2.43
Keshla Chowk	PM	13.2	3.6	21.21	10.95	82	4.39
	M	8.57	2.9	14.65	8.22	68	3.49
Bargadha Chowk	PM	18.5	1.5	3.54	28.43	87	5.62
	M	7.2	1.2	2.12	5.60	78	4.56
Bori Chowk	PM	21.27	12.7	6.78	31.27	130	5.31
	M	15.96	8.9	5.65	9.50	85	4.57
Mandla Chowk	PM	13.8	1.4	7.54	13.72	112	2.50
	M	10	1.2	4.56	12.00	120	1.99
Dhokara Bhatha Chowk	PM	15.1	2.0	11.34	28.21	145	0.70
	M	12.5	1.3	9.78	23.01	115	0.43
Jaat Bandha	PM	0.16	7.7	12.86	22.32	113	1.47

	M	0.15	6.8	10	18.00	92	0.99
Saloni Bazar Chowk	PM	26	15.25	11.23	16.29	89	2.99
	M	16	11.2	8.54	13.2	75	1.58
Mohandi	PM	14	18.7	14.21	8.13	68	2.87
	M	9	11.24	11.2	7.6	55	2.57
Bhandarpur	PM	19.21	12.44	7.4	10.24	52	2.23
	M	10	8.76	4.2	8.20	45	1.98
Bareth Para Khairagarh	PM	14.5	7.8	6.8	2.98	97	1.00
	M	9.41	6.2	5.4	1.50	75	0.75
Garapar Chowk	PM	25	2.0	8.9	1.46	124	3.09
	M	18	1.8	4.8	0.90	105	2.55
Kumhi	PM	27	13.14	19.78	33.24	135	6.27
	M	8	10.12	7.65	5.11	115	3.55

Table 3: Concentration ranges of metals (Fe, Mn, Cu, Zn, Cd and Ni) in mg/l in the existing groundwater of Rajnandgaon District

Location	**Type**	**Fe**	**Mn**	**Cu**	**Zn**	**Cd**	**Ni**
Dhaneli	PM	0	0.01	0.02	1.12	0.02	0.01
	M	0	0	0	1.92	0.01	0
Mutada Navagaon	PM	0.035	2.10	0.45	0.03	0.1	0.00
	M	0.012	1.00	0.11	0.01	0.05	0
Madara Kuhi	PM	0.03	1.24	0.01	1.21	0.001	0.001
	M	0.01	0.94	0	0.96	0	0
Son Bhattha	PM	0	3.41	1.18	5.33	Nil	0.02
	M	0	2.45	1.3	3.44	Nil	0.01
Kekaraj Boad	PM	0	2.41	2.14	3.24	0.03	0.03
	M	0	1.66	1.95	2.34	0.01	0.01
Karamtara	PM	0	4.25	1.01	0.02	0.003	0.001
	M	0	3.55	0.85	0	0	0
Eraikala	PM	0.04	2.56	0.06	1.13	0.02	Nil
	M	0	1.66	0.01	0.51	0.01	Nil
Patewa	PM	0	2.42	0.05	1.46	0.04	Nil
	M	0	1.55	0.01	0.96	0.01	Nil
Ghumka	PM	0	2.13	2.41	2.14	0.02	Nil
	M	0	1.33	1.57	1.58	0	Nil
Kalewa	PM	0	1.45	0.05	0.02	0.01	0.001
	M	0	1.01	0.02	0	0	0
Bheisavara	PM	0	2.55	1.34	0.01	0.004	0.001
	M	0	1.95	1.11	0	0	0
Jogi Dalli	PM	0	1.27	1.08	1.34	Nil	0.004
	M	0	1.00	1.00	1.22	Nil	0.002
Badai Tola	PM	0	0.01	0.01	4.46	0.03	0.002
	M	0	0	0	1.11	0.01	0
Bharda Kala	PM	0	2.22	0.03	3.56	0.00	0.03
	M	0	1.88	0.01	2.55	0	0.01
Dabra Tekapar	PM	0	3.45	0.05	0.03	Nil	Nil
	M	0	3.00	0.02	0.01	Nil	Nil
Sandi	PM	0	2.56	0	2.21	0.01	Nil
	M	0	1.55	0	1.58	0	Nil
Dholia Pendri Kavhar Pendri	PM	0	1.77	0.01	3.24	0.003	Nil
	M	0	1.55	0	2.44	0.001	Nil
Dhimarin Kuwachowk	PM	0	0.87	0.02	0.77	0.004	0.001
	M	0	0.05	0	3.58	0.001	0
Chhuikhadan	PM	0	0.04	0.04	2.41	0.02	0.003
	M	0	0.01	0.01	2.99	0	0.001
Ghirgholi	PM	0	0.06	0.06	0.03	0.001	0.005
	M	0	0.01	0.02	0.01	0	0.001
Road Ataria	PM	0	1.02	0.04	0.01	0.004	0.02

	M	0	0.93	0.01	0	0.001	0.01
Narmada Chowk	PM	0	1.42	0.06	2.31	0.04	0.03
	M	0	1.11	0.01	1.55	0.02	0.01
Gandai	PM	0.03	2.34	1.5	5.24	Nil	0.005
	M	0.01	1.96	0.95	3.95	Nil	0.004
Kukur Muda Chowk	PM	0	2.16	1.23	3.21	0.02	0.002
	M	0	1.88	0.78	3.01	0.00	0.001
Sakha Koray Chowk	PM	0	3.08	0.04	2.32	0.04	Nil
	M	0	2.85	0	1.33	0.01	Nil
Gopalpur	PM	0	0.04	0.06	0.01	0.01	0.001
	M	0	0	0.01	0	0	0
Padmavatipur	PM	0	0.06	0.03	1.06	0.01	0.001
	M	0	0.01	0.01	0.88	0	0
Udaypur	PM	0	0.04	0.07	0.8	0.001	0.001
	M	0	0.01	0.03	0.6	0	0
Bazar Atariya Chowk	PM	0	0.74	0.04	0.1	0.003	Nil
	M	0	0.55	0	0.05	0.002	Nil
Keshla Chowk	PM	0	0.1	0.9	0.1	0.1	Nil
	M	0	0.05	0.7	0.04	0.05	Nil
Bargadha Chowk	PM	0	0.16	1.32	0.72	Nil	Nil
	M	0	0.11	0.98	0.55	Nil	Nil
Bori Chowk	PM	0	3.4	2.0	0.24	0.002	0.01
	M	0	2.9	1.57	0.11	0.001	0
Mandla Chowk	PM	0	2.74	0.04	2.1	0.004	0.01
	M	0	1.55	0	1.85	0.002	0
Dhokara Bhatha Chowk	PM	0	1.04	0.03	1.5	0.1	0.02
	M	0	0.95	0.01	1.25	0.01	0.01
Jaat Bandha	PM	0	0.98	0.08	1.24	0.04	0.004
	M	0	0.55	0.06	0.98	0.01	0.003
Saloni Bazar Chowk	PM	0	0.44	0.07	1.21	0.01	0.002
	M	0	0.14	0.01	0.95	0	0.001
Mohandi	PM	0	0.92	0.09	3.77	0.06	Nil
	M	0	0.78	0.06	3.07	0.01	Nil
Bhandarpur	PM	0.09	1.34	0	2.02	0.07	Nil
	M	0.04	1.11	0	0.55	0.03	Nil
Bareth Para Khairagarh	PM	0	2.43	1.85	3.21	0.001	0.01
	M	0	1.99	1.52	1.55	0	0
Garapar Chowk	PM	0	0.72	1.25	0.01	0.004	Nil
	M	0	0.35	0.98	0	0.002	Nil
Kumhi	PM	0	0.43	0	0.32	0.006	Nil
	M	0	0.11	0	0.11	0.002	Nil

It is seen in Table 2 that, in the kekraj Boad area the GW is much affected by high fluoride concentrations ranging to a maximum value of 6.53 in fluoride concentrations. In contrast, the GW existing in Khairagarh area is showing almost well within fluoride concentration levels for both the monsoon and pre-monsoon periods. Further, it is evident from Table 2 that, in some of the study areas like patewa (5.07),bargada(5.62) bori(5.31) Kumhi(6.23) , the other area of fluoride concentration levels falling ≤5 which is in rejection range or a minimum value as per the BIS: 10500 (2010). It is felt that, this minimum end point is undergoing slight variations during monsoon periods because of dilution due to rainwater. Figure 2 illustrates the frequency distribution and the concentration ranges of fluoride during monsoon and pre-monsoon period in the study area.

It is evident from Figure 2 that, there is no significant variation in fluoride concentrations for both monsoon and pre Monsoon periods of the study area. However, from Table 2 and 3 one can see the significant variations in the monsoon and pre-monsoon concentration levels of various ions and metals. The ionic concentrations in the groundwater during the monsoon period were generally less than their counterparts during the pre-monsoon period because of dilution by rainwater. It is again seen from the Tables 2 and 3 that the highest values for ions (Ca^{2+}, Na^{+}, HCO_3^{-} NO_3^{-}, SO_4^{2-}, and F^{-}), and metals (Fe, Mn, Cu, Zn, Cd and Ni) in Rajnandgaon District at khairagarh town respectively, observed as 29,24.21,25.13,33.24,135,6.53,23.54,4.25,2.14,5.33,0.1,0.03 in mg/l. Further, the ionic balance of the solution is also calculated for urban industrial dirt, the estimated values are arrived at 1.1 and 1.0, respectively. A good balance of the anion and cation is observed as the positive balance falls under ±10%.

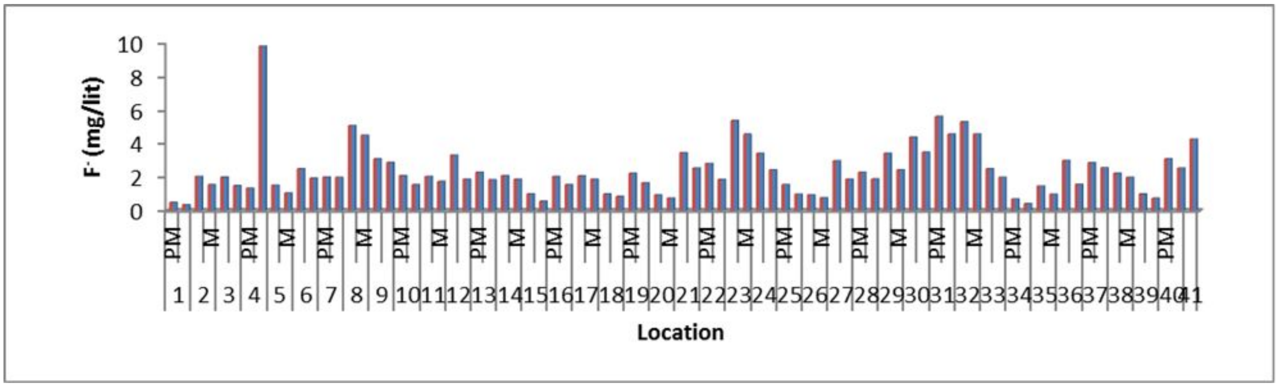

Figure 1: The frequency distribution of fluoride (F^-) during the Monsoon and pre-Monsoon periods

CONCLUSIONS

The groundwater existing at khairagarh in the Rajnandgaon District of Chhattisgarh State in Central India is significantly affected by the excess concentrations of fluoride. The results revealed this alarming concentration of the fluoride in the study area of khairagah. At present, in the study area, the drinking water is being supplied by the Government through the municipal tanks and some other means. Alternatively, the existing groundwater may be effectively utilized in the study area by taking up a pilot projects like de-fluoridation on priority basis. However, the de-fluoridation is beyond the scope of the present study.

ACKNOWLEDGEMENTS

The authors would like to thanks Dr Santosh K Sar Sir for their support.

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