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Fluoride Distribution in the Groundwater of Upper Banas River Basin, Rajasthan, India

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Abstract:

In order to assess the fluoride contamination in the groundwater of Upper Banas River Basin, the study was conducted in the months June 2019, November 2019, June 2020 and November 2020. The fluoride concentration along with pH, EC and TDS in the groundwater samples was determined for samples collected from various open wells of Basin. It is observed that the pH of groundwater in all three seasons was ranging between 6.74 to 8.59. About 50.47 per cent area of Upper Banas River basin has pH ranges between 7.50 to 8.00 in pre monsoon period and 85.86 per cent area during post monsoon period.The EC of the groundwater of the basin ranges between 0.51to 6.64 ds/m during all thee seasons. about 68.63 per cent of the study area during pre-monsoon and about 81.07 per cent area during post monsoon show the EC less than 2.25 dS/m which is suitable for drinking purpose The TDS of the groundwater of the basin varies fron 265 to 4160 meq/l during three seasons. the 72.72 per cent area in pre monsoon and 83.43 per cent area in post monsoon shows concentration of total dissolved solids within its maximum permissible limit (<1500 meq/l). The fluoride concentration in groundwater varies from 0.33 ppm to 8.30 ppm during pre-monsoon seasons and 0.16 mg/L to 7.30 mg/L during post monsoon season. In Upper Banas River basin 54.35 per cent area during pre-monsoon period and 68.86 per cent area in post monsoon period showing permissible limit of F (< 1.50 mg/L) for drinking purpose.

Keywords: *Fluoride, Groundwater, Uppar Banas Basin, Drinking Water, River Basin*

Introduction:

Fluoride is one of the very few chemicals that cause significant influences on human health through drinking water (Hamilton, 1992& Kumar, *et al* 2015). The optimal concentration of fluoride in drinking water varies according to climatic conditions; the range of 0.5-1.5 mg/L is generally recommended by WHO 1994. Fluoride contributes to dental health and to the maintenance of appropriate bone density. Fluorine is the lightest halogen and also the most electronegative element, which indicates its strong tendency to acquire a negative charge and form

F^- ions in solution (Helm, 1985). Due to its high reactivity Fluorine is found as fluoride in the environment, which together represent about 0.06–0.09 % of the earth's crust. Fluoride occurs naturally in rock, soil, water, plants, and animals (Walna, *et al* 2007, Ozsvath, 2009 & Dhoke, *et al* 2018). Groundwater gets contaminated due to various geogenic and anthropogenic activities. Fluoride (F^-) concentration is an important aspect of hydro geochemistry, because of its impact on human health.

The problem of high concentration of fluoride in groundwater resources has become one of the most important toxicological and geo-environmental issues in Rajasthan, India. In most of the fluorosis endemic areas, the average summer temperature is above 37.5°C and average drinking water consumption is more than 4 liters per day (Deshkar, *et al* 1999). In India, about 62 million people, including 6 million children, suffer from fluorosis due to the high content of F- in water (Susheela, 1999). Most parts of Andhra Pradesh in India have highly endemic fluorosis zones (Sunitha, *et al* 2004). The first case of endemic fluorosis in India was reported as long ago as 1937 in Podili, Darsi and Kanigiri taluks of Prakasam district, Andhra Pradesh (Pandit, *et al* 1940). The fluoride is beneficial to certain extent when present in the concentration of 0.8 to 1.0 mg/L for classification of dental enamel especially for children below 8 years, whereas causes dental fluorosis if present in excess of 1.5 mg/L and skeletal fluorosis beyond 3.0 mg/L if such water is consumed for 6 months to several years (Tiwari, *et al* 2003).

The main F^- accumulation in the human body occurs through F^- contaminated drinking water, substantial amounts of F^- can also be ingested through crops and vegetables irrigated with F-contaminated water (Gupta and Banerjee 2011). In the present study, occurrence of fluoride in Upper Banas River basin is highlighted.

1.1 Study area:

The Upper Banas River basin is the main tributaries of the Chambal River basin. It is located in the Rajsamand, Udaipur Chittorgarh and Bhilwara districts which fall in the semi-humid region of Rajasthan bounded by 73°22'55.603" to 75°01'27.048" E Longitude and 24°43'21.982" to 25°24'22.925" N Latitude. Upper Banas River basin area belongs to agro-climatic zone IVa of Rajasthan having a moderately warm climate. The mean daily maximum temperature ranges from 24.2^{0}C in January to 38.6^{0}C in May. Hence, the maximum temperature on some days rises as high as 46^{0}C. Likewise, the mean daily minimum temperature ranges from 7.8^{0}C in January to 25.3^{0}C in June (Upadhyay, *et al* 2019 and Hirapara, *et al* 2020). The area is composed four districts having 17 blocks with 1064 villages having total area of 4940 km^2. The location map of the Upper Banas River basin is shown in Fig. 1.

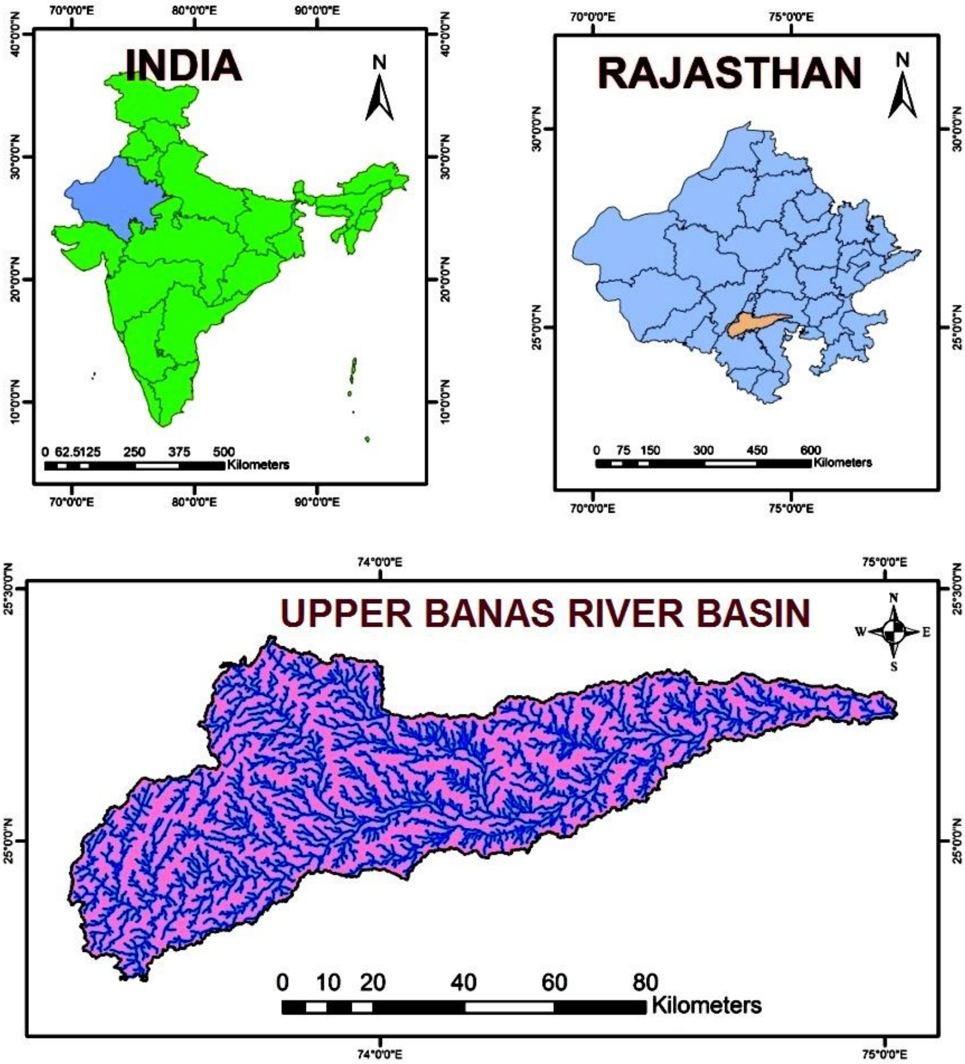

Fig. 1: Location map of the Upper Banas River basin

Materials and Methods:

The whole upper Banas basin has been divided in 100 systematic squire grids of 7.5 km x7.5 km (Singh, *et al* 2014, Singh, *et al* 2018, Singh, *et al* 2019, Srivalli & Singh 2019 and Singh, *et al* 2021) Shown in Fig. 1a. In each grid dug wells are selected for groundwater sampling and locations were recorded by Osm And android application. Groundwater samples were collected from selected dug well's location map of the groundwater samples is presented in Fig.1b. During pre-monsoon season (June 2019) and (June 2020), post monsoon (November 2019) and (November 2020), groundwater samples were collected from each selected well of each grid (Singh, 2002, Singh, 2005, Singh & Urmila 2012a-b and Srivalli & Singh 2017). The samples were collected in clean half liter polythene bottles and analyzed for pH, electrical conductivity (EC), total dissolved solids (TDS)measured with hand hold pH, EC and TDS meters, respectively and fluoride (F^-) measures with Ion meter as per standard methods (Sudarshan, *et al* 2014). The analytical results are presented in the Tables 1, 2 and 3.

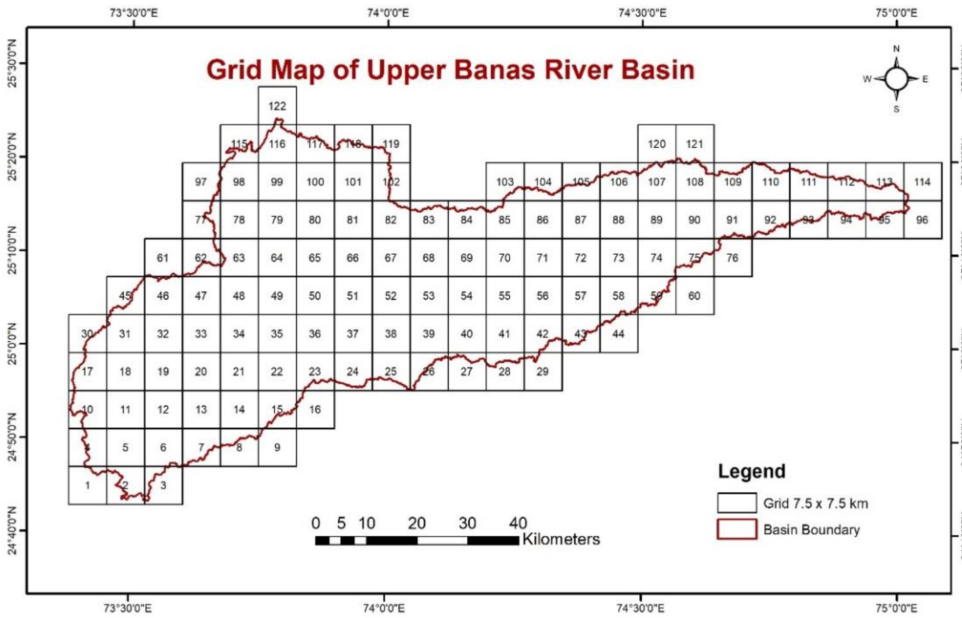

Fig. 1a Systematic Squired grid map

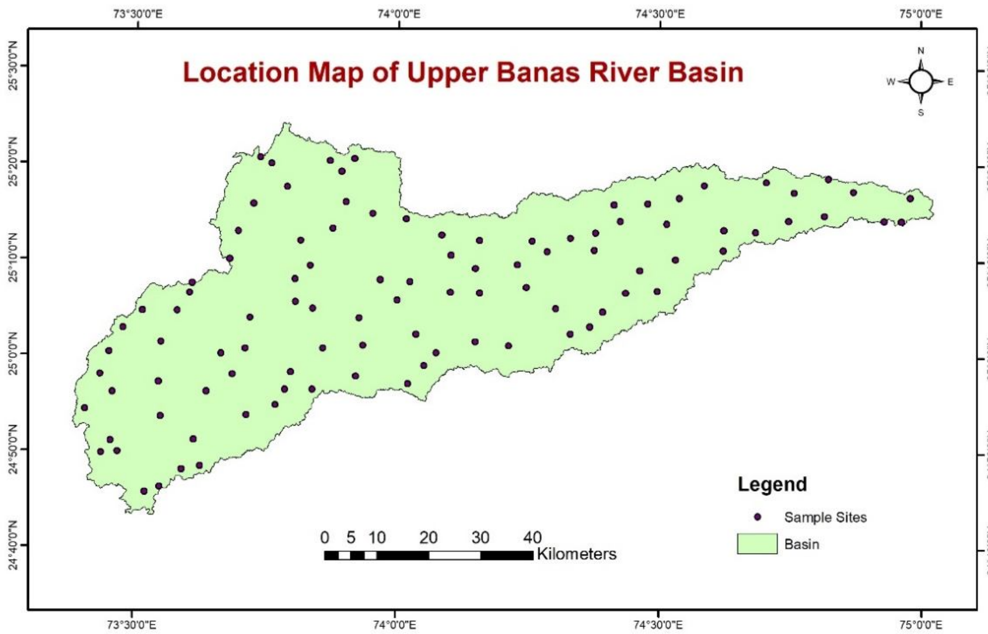

Fig. 1b Sample sites location map

Results and discussion:

pH

The pH of groundwater varied from 6.89 to 8.14 with a mean of 7.50 in pre monsoon period and 6.74 to 8.59 with a mean of 7.78 in post monsoon period. About 50.47 per cent area of Upper Banas River basin has pH ranges between 7.50 to 8.00 in pre monsoon period and 85.86 per cent area during post monsoon period. In pre monsoon period 49.00 per cent area has pH ranges between 7.00 to 7.50 (Fig. 2a). The highest pH was observed in the Sadri, Sathiya, Roopaheli, Ban ka khera etc. villages during pre-monsoon period and highest pH observed in Chandana ki bhagal, Sansera, Pharara, Bhatoli, Sadri, Gegpura, Mundol, Kishanpuriya, Gopalpura, Kalan, Pahoona, Majhera, Richhed, Sahara, Lasadiya Kalan, Newariya, Gangapur, Biliya Kalan, Haled, Roopaheli etc. villages in post monsoon period (Fig. 2b).

Electrical Conductivity (EC)

The electrical conductivity (EC) varies from 0.51 to 6.64 ds/m with an average of 1.86 ds/m during pre-monsoon and 0.42 to 6.04 ds/m with an average of 1.58 dS/m during post monsoon period. Fig. 3a and Fig.3b reveals that about 68.63 per cent of the study area during pre-monsoon and about 81.07 per cent area during post monsoon show the EC less than 2.25 dS/m which is suitable for drinking purpose. The middle part of the study area particularly Bijnol, Sansera, Piparda, Soniyana, Kelwa, Sakroda, Chhapri, Khakhla, Lasadiya Kalan, Googli, Rawon ka khera, Moorda, Bhopalgarh, Pur, HazariKhera, Gaphesara etc. villages in pre monsoon period and Bijnol, Piparda, Soniyana, Sakroda, Chhapri, Khakhla, Lasadiya Kalan, Googli, Rawon ka khera, Moorda, Bhopalgarh, Pur, Gaphesara etc. villages in post monsoon EC found more than 2.25 dS/m.

Total Dissolved Solids (TDS):

The concentration of TDSranged from 320 to 4160 meq/l with a mean of 1172 mg/l during pre monsoon and 265 to 3835 mg/l with a mean of 1001 meq/l in post monsoon period. Fig. 4a and Fig. 4b shows that the 72.72 per cent area in pre monsoon and 83.43 per cent area in post monsoon shows concentration of total dissolved solids within its maximum permissible limit (<1500 meq/l).The middle part of the study area, namely Bijnol, Sansera, Piparda, Soniyana, Sakroda, Chhapri, Khakhla, Lasadiya Kalan, Googli, Rawon ka khera, Moorda, Bhopalgarh, Pur, HazariKhera, Gaphesara etc. villages in pre monsoon period and Bijnol, Piparda, Soniyana, Sakroda, Chhapri, Khakhla, Lasadiya Kalan, Googli, Bhopalgarh, Pur, Gaphesara etc. villages in post monsoon shows TDS is more than 1500 mg/l.

Fluoride (F-):

In Upper Banas River basin 54.35 per cent area during pre monsoon period and 68.86 per cent area in post monsoon period showing permissible limit of F^- (< 1.50 mg/L) for drinking purpose (WHO 2004). The highest F^- was found in the Chikalwas, Sadri, Khandel, Kishanpuriya, Potlan, Sahara, Lasadiya Kalan, Newariya, Googli, Moorda, Gangapur, Gatheela, Haled etc. villages during pre-monsoon period and Khandel, Kishanpuriya, Sahara, Lasadiya Kalan, Kardon ka Gurha, Moorda, Gangapur, Gatheela, Sathiya, Amratiya, Haled etc. villages shows more F^- (> 3 mg/L) in post monsoon period shown in Fig. 5a & 5b.

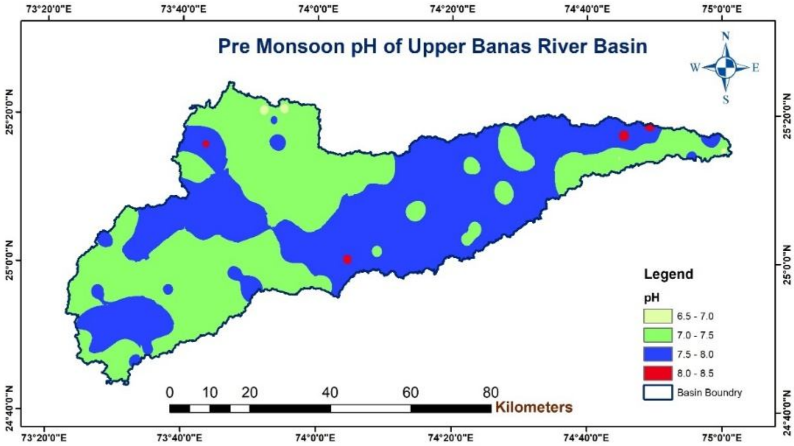

Fig. 2a: Variation of pH during pre-monsoon

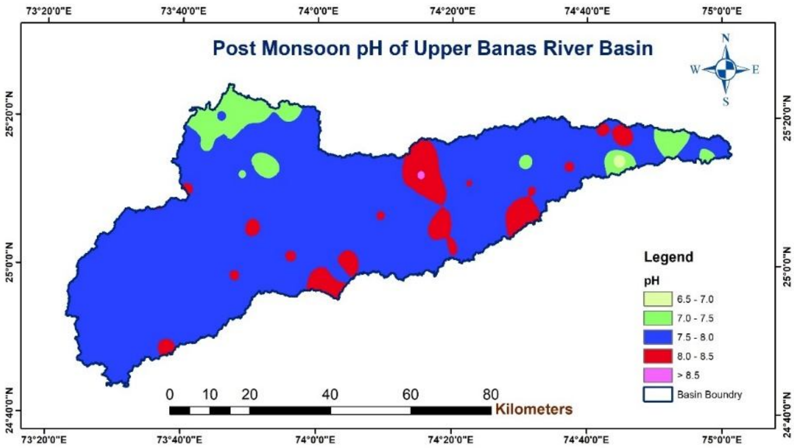

Fig. 2b: Variation of pH during post-monsoon

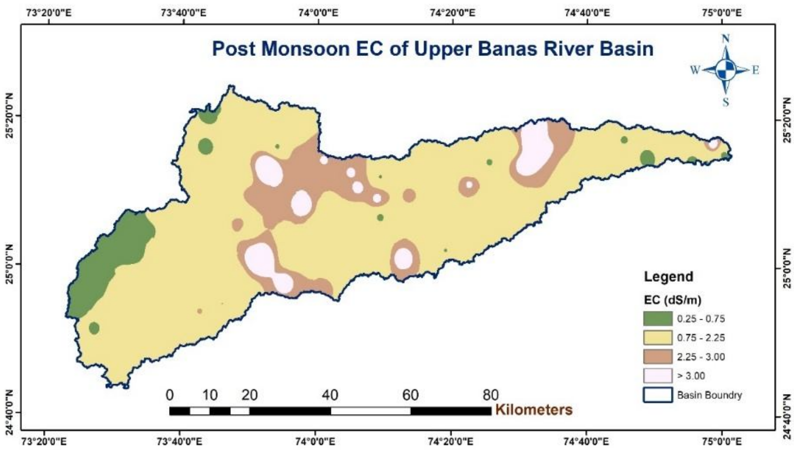

Fig. 3a: Variation of EC during pre-monsoon

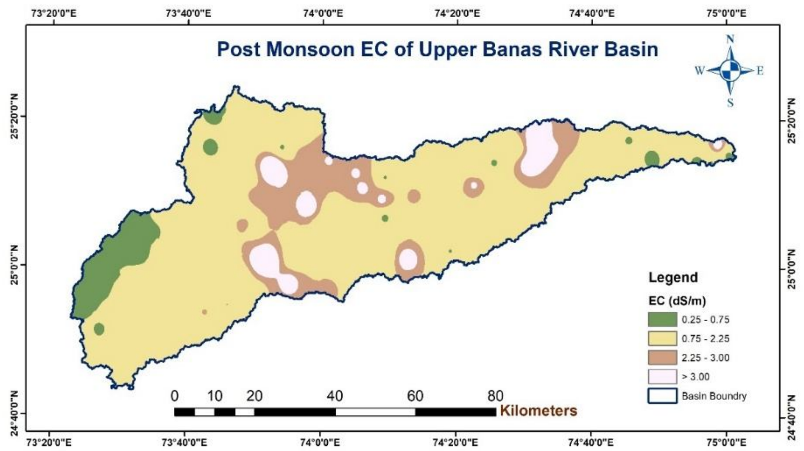

Fig. 3b: Variation of EC during post-monsoon

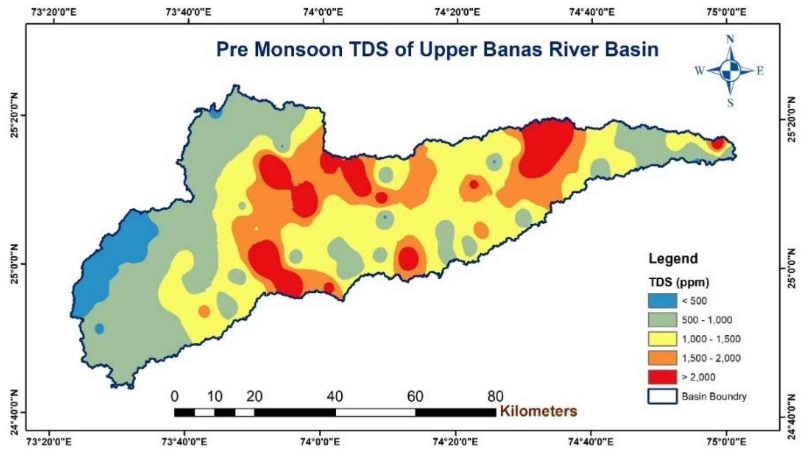

Fig.4a: Variation of TDS during pre-monsoon

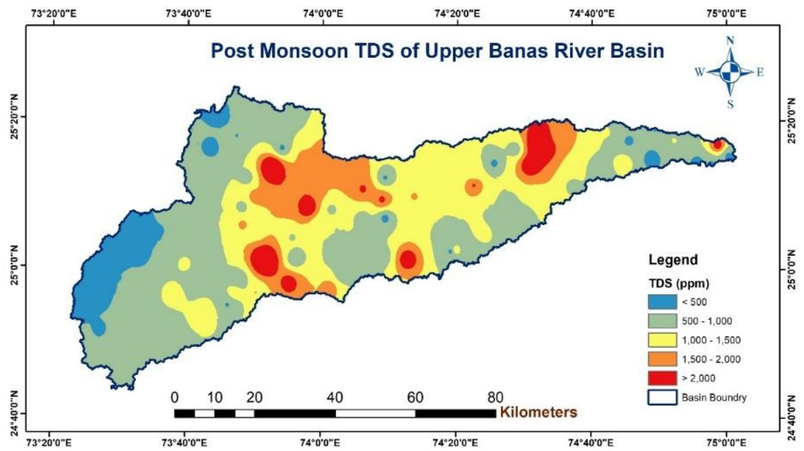

Fig.4b: Variation of TDS during post-monsoon

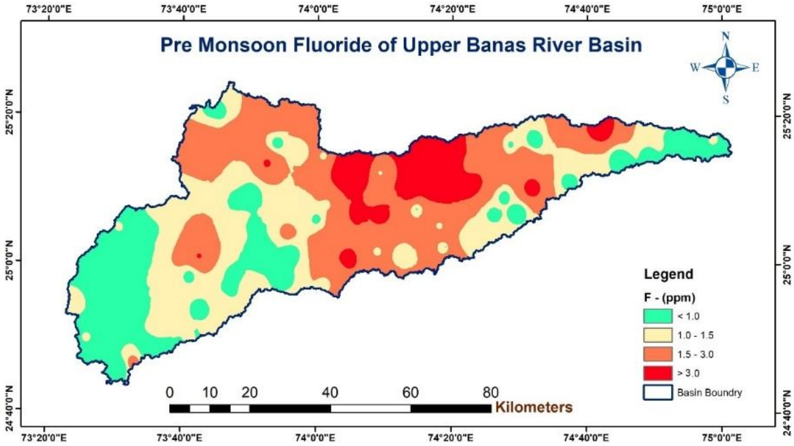

Fig. 5a: Variation of fluoride (F) during pre-monsoon

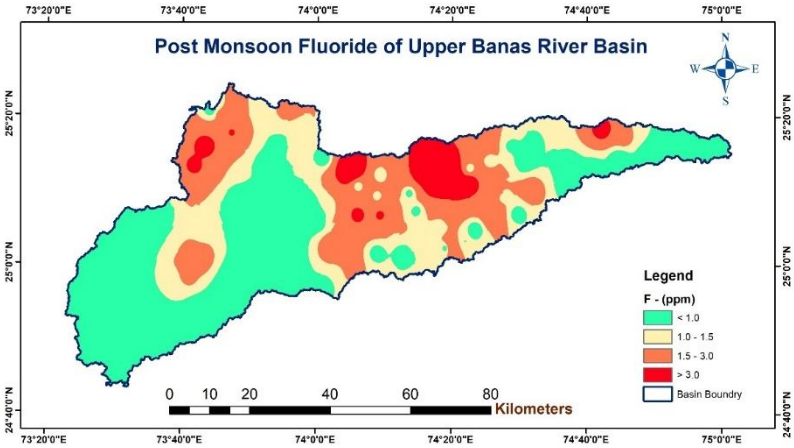

Fig. 5b: Variation of Fluoride (F) during post-monsoon

Table 1: Maximum and minimum value of water quality parameters

Parameters	Pre-monsoon samples (meq/l)			Post-monsoon samples (meq/l)		
	Min.	**Max.**	**Mean**	**Min.**	**Max.**	**Mean**
pH	6.89	8.14	7.5	6.74	8.59	7.78
EC	0.51	6.64	1.86	0.42	6.04	1.58
TDS	320	4160	1172	265	3835	1001
F	0.33	8.30	1.61	0.16	7.30	1.26

Table 2: Average pre monsoon water quality parameter classes and area

Parameters	Classes		Pre monsoon	
	From	**To**	**Area (Km^2)**	**Per cent Area**
pH	6.89	7.00	10.88	0.22
	7.00	7.50	2420.65	49.00

Parameters	Classes		Pre monsoon	
	From	To	Area (Km^2)	Per cent Area
	7.50	8.00	2492.98	50.47
	8.00	8.14	15.49	0.31
EC	0.51	0.75	150.29	3.04
	0.75	2.25	3240.33	65.59
	2.25	3.00	948.8	19.21
	3.00	6.64	600.58	12.16
TDS	320	500	255.11	5.16
	500	1000	1616.61	32.72
	1000	1500	1720.85	34.84
	1500	2000	878.22	17.78
	2000	4160	469.21	9.50
F-	0.33	1.00	1147.49	23.23
	1.00	1.50	1537.32	31.12
	1.50	3.00	1773.51	35.90
	3.00	8.30	481.68	9.75

Table 3: Average post monsoon water quality parameter classes and area

Parameters	Classes		Post monsoon	
	From	To	Area (Km^2)	Per cent Area
pH	6.74	7.00	7.45	0.15
	7.00	7.50	317.83	6.43
	7.50	8.00	4241.21	85.86
	8.00	8.50	370.66	7.50
	8.50	8.59	2.85	0.06
EC	0.42	0.75	322.85	6.54
	0.75	2.25	3681.74	74.53
	2.25	3.00	661.53	13.39
	3.00	6.04	273.87	5.54
TDS	265	500	392.43	7.94
	500	1000	2194.75	44.43
	1000	1500	1534.39	31.06
	1500	2000	608.20	12.31
	2000	3835	210.24	4.26
F	0.16	1.00	2225.31	45.05
	1.00	1.50	1176.37	23.81
	1.50	3.00	1239.00	25.08
	3.00	7.30	299.33	6.06

Conclusions:

The groundwater investigations carried out in Upper Banas River basin indicated that 45.65% (2255.19 km^2) and 31.14% (1538.33 km^2) of the basin area inpre and post monsoon seasons exhibit excess fluoride than prescribed by WHO (1.5 mg/l). In Moorda, Gatheela and Haled villages fluoride concentration on groundwater during pre and post monsoon season recorded unusually high i.e5-8 mg/L. The pH of groundwater in pre and post monsoon seasons having 99.47% and 92.29% area of the basin between 7.0 to 8.0 pH, respectively. The basin 31.37% area in pre monsoon and 18.93% area in post monsoon having EC more than 2.25ds/m. High fluoride ground water is mainly associated with water which usually has high pH. In the middle part of Upper Banas basin at Piparda, Googli and pur villages during pre and post monsoon electrical conductivity was extremely high i.e.5.0 -6.5ds/m, and total dissolved solids also more than 3500 mg/l which is an indication of high concentration of dissolved solids.

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