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Spatial distribution of uranium and associated water quality parameters in Haryana state (India)

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Abstract
Spatial distribution of uranium and associated water quality parameters in drinking water samples in two districts (Faridabad and Gurugram) of Haryana was evaluated and correlation of uranium and quality parameter has been studied. In this study 150 drinking water samples were collected and analysed for uranium and associated water quality parameters using standard protocol. Uranium levels were found to vary from < 0.5 - 132 ppb and < 0.3 - 143 ppb in pre- and post-monsoon in Faridabad while it varied from < 0.5 - 47 ppb and < 0.3 - 105 ppb in pre- and post-monsoon, respectively. The average uranium concentration is less than the AERB limit in both the districts.

Keywords: Uranium, spatial distribution, Faridabad, Gurugram, water quality

Introduction
Uranium is naturally present in rocks (granites and other mineral deposits) and soils. The average concentration of natural uranium in earth crust is $3x10^{-4}$ % (w/w) and in seawater is ≈3.0 µg/l. It has three isotopes, *viz*., ^{238}U, ^{235}U and ^{234}U. These isotopes disintegrate by releasing alpha and gamma emissions. Natural uranium is mainly ^{238}U which forms 99.284% along with 0.711% of ^{235}U and 0.0055% of ^{234}U. Although, the most abundant isotope is ^{238}U but ^{234}U and ^{235}U are also important due to their higher specific activity [2]. The uranium concentrations in various environmental matrices including soils, rocks, plants, water etc. have been reported in yesteryears [1]. Other sources of uranium in any area may include coal burning, application of phosphate fertilizers, mining, nuclear power generation etc. Anthropogenic activities can also elevate its levels in the environment but they are quite unlikely to cause any significant change in its concentration in the groundwater. It is normally present in the groundwater through weathering of underground parent rocks [4]. The measurements of uranium concentration in drinking water are useful in assessing its dose incorporated to an average person through this pathway. The risk of the uranium consumption to general public depends on various factors including uranium concentration present in the drinking water, water ingestion rate, duration of ingestion along with general health of the person. Drinking water contributes about 85% of total ingested uranium [5]. It is harmful in chemical as well as radiological forms affecting kidneys and liver in the human body [9, 10].
Due to weathering and other geological processes it leaches to groundwater from host rocks and soils. The concentration of uranium in groundwater depends on multiple parameters such as pH, ORP, EC, TDS, anionic ligands, etc. The mechanism of leaching of uranium from host rock to groundwater is a complex process and also depends on factors like contact time, temperature, rock characteristic and elemental geochemistry [1, 6]. Distribution of uranium concentration along with associated water quality parameters are presented in the paper.

Materials and Methods
Study was carried out strictly as per the standard protocol prepared for the National Uranium Project. The samples from districts were divided into optimized grid size of 6 x 6 km using latitude - longitude as reference coordinates for screening. At least one drinking water sample was collected from each grid in pre-acid cleaned polyethylene bottles in both pre-monsoon and post-monsoon season. The samples were collected in 200 ml polypropylene bottles and acidified in the field by HNO3 (AR Grade, Merck). Prior to collecting the samples, the hand pump wells were duly pumped so that the stagnant water, if any, [7]. Values of pH and ORP were measured using multi parameter kit. TDS, EC and salinity were measured by Beck-man Coulter system while DO was measured by LABMAN-DO meter.

Elemental concentration of Sodium (Na), Potassium (K), Calcium (Ca) and Magnesium (Mg) were measured by GBC make Sens-AA model atomic absorption spectrometer.

U concentration in ground water samples was estimated by using Lumex make analytical equipment Fluorat-02-4 M liquid analyzer. Samples were analyzed for uranium content using "Fluorat-02-4M" liquid analyzer. Quality assurance of the data was made by the analysis of QA test solutions with concentration of uranium and by replicate analysis. 5 mL of reagent water was taken into polypropylene vial, pipette 0.5 mL of a sample solution and 0.5 mL of sodium polysilicate solution into this vial. Mixed solution was placed into a cell of the analyzer and measurements were started by liquid analyzer [8].

Results and Discussion

In the present study, 78 drinking water samples were collected and analysed for uranium and other water quality parameters from each districts. Gamma radiation in the district of Faridabad was observed in the range of 80 - 184 nSv/h with an average value of 130 nSv/h. Summary of results is presented in Table 1 and 2 for pre- and post-monsoon, respectively. pH, EC, TDS and salinity in the water samples were found to vary in the range of 6.4 - 8.5; 42.4 - 7580 µS/cm; 18.6 - 6270 ppm and 23.3 - 4169 ppm, respectively. The average TDS level in the district was estimated to be 916 and 1274 ppm in pre- and post-monsoon, respectively. In 60 water samples out of 78 samples, the TDS level was found to be higher than the BIS acceptable limit of 500 ppm [3]. Fluoride and chloride levels in the water samples in pre- and post-monsoon were found to be more than BIS acceptable limits of 1 and 250 ppm, respectively. Nitrate and sulphate levels in the water samples in pre- and post-monsoon were found to be less than BIS acceptable limits of 45 and 200 ppm, respectively. Uranium levels were found to vary from < 0.5 - 132 ppb and < 0.3 - 143 ppb in pre- and post-monsoon, with a median value of 19.2 and 21.1 ppb, respectively.

The distribution of uranium in Faridabad district in pre-monsoon is given in Fig.1. From the figure, it is clear than 28% of samples were found to be in the range of < 0.2 - 5 ppb, 20% samples are more than 30 ppb and 8% samples are more than 60 ppb. The distribution of uranium in Faridabad district in post-monsoon is given in Fig.2. From the figure, it is clear than 26% of samples were found to be in the range of < 0.2 - 5 ppb, 36% samples are more than 30 ppb and 5% samples are more than 60 ppb. In 5 drinking water samples out of 78, the uranium content was observed to be higher than the AERB limit of 60 ppb, prescribed on the basis of radiological toxicity [2] and in 27 water samples, it was more than WHO and US EPA limits of 30 ppb, prescribed on basis of chemical toxicity [10, 11].

Gamma radiation in the district of Gurugram was observed in the range of 90 - 172 nSv/h with an average value of 122 nSv/h. For pH 29 samples had values more than desire limit in pre-monsoon season while in post-monsoon 1 Samples had values above desire limit. TDS values of 58 samples in pre-monsoon and 54 in post-monsoon exceed desire limit. Fluoride values of 13 samples in pre-monsoon and 25 in post-monsoon exceed desire limit. Chloride values of 41 samples in pre-monsoon and 45 in post-monsoon exceed desire limit. No sample exceed Nitrate desired limit in post-monsoon and 7 samples in pre-monsoon exceed Nitrate desire limit. No Sample exceed desired limit for Sulphate in both season in the district. Total Hardness values of 72 samples in pre-monsoon and 65 samples in post-monsoon exceed desire limit. Total Alkalinity values of 66 samples in pre-monsoon and 49 samples in post-monsoon exceed desire limit. Analysis of Uranium was carried out for all 133 samples in both season and only one sample found containing value of Uranium more than 60 ppb (AERB limit).

Table 1: Summary of U and water quality parameters in Faridabad district of Haryana - Pre-monsoon

Parameter	Pre-monsoon				BIS/WHO Limits
	Min	Max	Average	Median	
pH	6.91	8.11	7.60	7.6	6.5-8.5
TDS (ppm)	18.6	2360	915.8	725	500
EC (µS/cm)	42.4	4640	1783.8	1480	-
Salinity (ppm)	23.32	2552	981.1	814	-
ORP (mV)	-56	203	128.5	145	-
F^- (ppm)	4.8	8.6	6.3	6.5	1.0
Cl^- (ppm)	71	958.5	314.9	248.5	250
NO_3^- (ppm)	0.5	7.8	3.5	2.8	45
SO_4^{2-} (ppm)	2.7	34.4	15.6	15.7	200
PO_4^{3-} (ppm)	0.15	9.1	3.5	3.1	-
TH (ppm)	35	530	246.1	260	200
TA (ppm)	50	670	365.1	370	200
U (ppb)	0.4	132.3	25.6	19.2	60(AERB)

Table 2: Summary of U and water quality parameters in Faridabad district of Haryana - Post-monsoon

Parameter	Post-monsoon				BIS/WHO Limits
	Min	Max	Average	Median	
pH	6.4	8.5	7.4	7.5	6.5-8.5
TDS (ppm)	39.2	6270	1274.3	951	500
EC (µS/cm)	60.4	7580	1706.4	1320	-
Salinity (ppm)	33.2	4169	938.5	726	-
ORP (mV)	-104	116	50.5	57	-
F^- (ppm)	0.05	7.4	2.4	2.02	1.0
Cl^- (ppm)	34.9	1229	288.4	187.4	250
NO_3^- (ppm)	0.5	64.5	7.7	3.3	45
SO_4^{2-} (ppm)	4.6	53.3	16	13.8	200
PO_4^{3-} (ppm)	0.5	14.8	5.3	4.1	-
TH (ppm)	70	3130	566.9	460	200
TA (ppm)	18	630	261.5	280	200
U (ppb)	0.2	143.8	26.5	21.1	60(AERB)

Table 1: Summary of U and water quality parameters in Gurugram district of Haryana - Pre-monsoon

Parameter	Pre-monsoon				BIS/WHO Limits
	Min	Max	Average	Median	
pH	7.2	9.7	8.0	8.2	6.5-8.5
TDS (ppm)	162	5310	1369	766	500
EC (µS/cm)	234	6610	1849	1120	-
Salinity (ppm)	128	3635	1017	616	-
ORP (mV)	-97	122	46	41	-
F^- (ppm)	0.05	4.29	1.0	0.05	1.0
Cl^- (ppm)	89	2215	445	284	250
NO_3^- (ppm)	0.5	76.5	14	6.2	45
SO_4^{2-} (ppm)	5.8	34.8	14	13.2	200
PO_4^{3-} (ppm)	2.4	17.1	8.0	7.5	-
TH (ppm)	200	2740	715	540	200
TA (ppm)	100	750	379	370	200
U (ppb)	1.0	46.6	9	7.5	60(AERB)

Table 2: Summary of U and water quality parameters in Gurugram district of Haryana - Post-monsoon

Parameter	Post-monsoon				BIS/WHO Limits
	Min	Max	Average	Median	
pH	6.6	8.9	8.0	7.6	6.5-8.5
TDS (ppm)	190	8100	1696	717	500
EC (µS/cm)	277	9420	2228	1070	-
Salinity (ppm)	152	5181	1225	588	-
ORP (mV)	-92	395	29	23	-
F^- (ppm)	0.05	6.0	1.0	0.45	1.0
Cl^- (ppm)	62	3958	887	479	250
NO_3^- (ppm)	0.36	43.8	6.0	4.3	45
SO_4^{2-} (ppm)	3.4	57.3	14.0	10.0	200
PO_4^{3-} (ppm)	1.2	7.7	2.0	1.8	-
TH (ppm)	190	2880	725	480	200
TA (ppm)	50	750	326	300	200
U (ppb)	0.5	105	14	7.2	60(AERB)

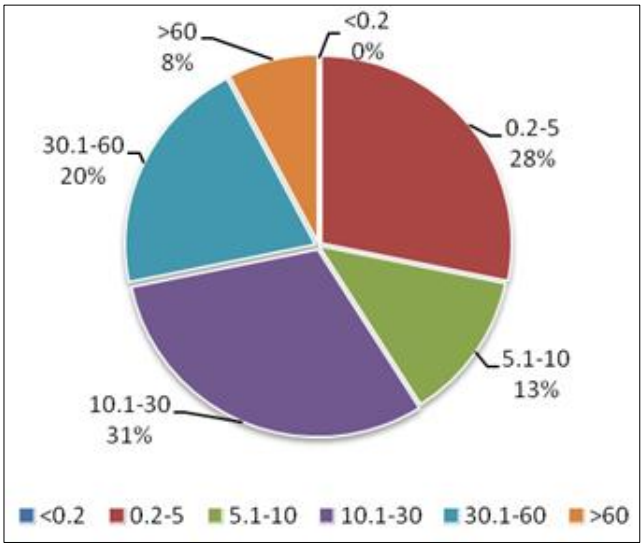

Fig 1: Distribution of uranium in drinking water in the district of Faridabad in pre-monsoon

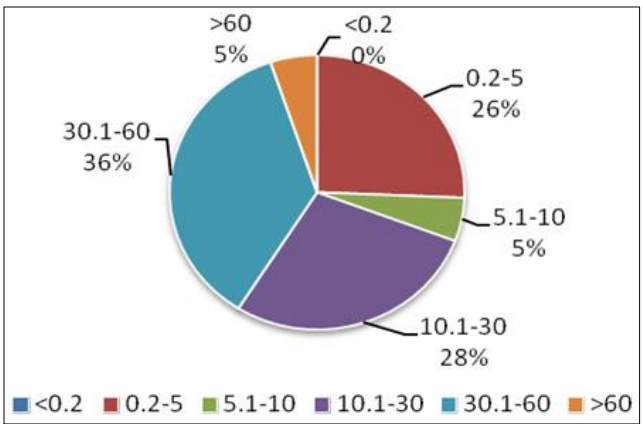

Fig 2: Distribution of uranium in drinking water in the district of Faridabad in post-monsoon

Conclusion

pH, EC, TDS and salinity in the water samples were found to vary in the range of 6.4 - 8.5; 42.4 - 7580 µS/cm; 18.6 - 6270 ppm and 23.3 - 4169 ppm, respectively in Faridabad district while in Gurugram it varied 6.6-9.7;234-9420 µS/cm;162-8100ppm and 128-5181 ppm respectively. Fluoride and chloride levels in the water samples in pre- and post-monsoon were found to be more than BIS acceptable limits of 1 and 250 ppm at some locations in both the districts, respectively. Nitrate and sulphate levels in the water samples in pre- and post-monsoon were found to be less than BIS acceptable limits of 45 and 200 ppm in both the districts, respectively. Uranium levels were found to vary from < 0.5 - 132 ppb and < 0.3 - 143 ppb in pre- and post-monsoon, with a average value of 25.6 and 26.5 ppb, respectively in Faridabad district while Uranium levels were found to vary from 1.0 - 46.6 ppb and < 0.5 - 105 ppb in pre- and post-monsoon, with a average value of 9.0 and 14.0 ppb, respectively in Gurugram district which is well within the AERB limit of Uranium in drinking water.

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