Spatial Distribution of Water Quality Parameters in a Mineralized Region of Rajasthan

V. K. Thakur[1], P. Lenka[1], Sumesh C. G. [1], Gopal P. Verma[1,2], Aditi C. Patra*[1,2]

[1]*Health Physics Division, BARC, Mumbai, India*
[2]*Homi Bhabha National Institute, Mumbai, India*

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**Correspondence Author: aditic@barc.gov.in*

Abstract: Water quality parameters, anionic concentrations and uranium levels were measured in groundwater samples collected from Rohil, Sikar District, Rajasthan as a part of radiological baseline survey. This region hosts disseminated uranium deposits. The uranium concentration in water samples showed a mean value of 107 ± 141 µg/L and more than 40% samples crossed the AERB limit. The mean conductivity and TDS of samples were 2221 ± 1513 µS/cm and 1583 ± 1085 ppm, respectively. The mean value of fluoride, chloride, nitrate and sulphate were 2.4 ± 1.4 ppm, 414 ± 466 ppm, 33.70 ± 37.2 ppm and 140 ±133 ppm, respectively. Measured parameters in many samples were above the respective limits set by BIS, AERB and WHO. No particular trend was observed for any of the parameters with increasing distance from the proposed site and no correlation was evident in the measured parameters.

Keywords: Uranium mineralization, Groundwater, Water quality, Ionic composition

1. Introduction: Water is an important renewable resource when managed responsibly and used properly. Water is required for human beings, plants and animals. Water from bore wells, tube wells and hand pumps etc. are used for drinking purposes and irrigation of different crops in different seasons. Ground water flows through various types of soils and rocks, it carries diverse amounts of different compounds, minerals, substances, metals anions and cations. Uranium concentration is also found to vary along with other parameters [1].

Radiological baseline studies are required for environmental impact assessment during the pre-operational, operational and decommissioning stages of any nuclear facility. These studies are carried out for uranium mining facilities only after economically viable grades of uranium deposits are ascertained. The information collected during such studies serve as a pre-requisite for regulatory compliance. The primary purpose of the mining operation is to extract uranium, which is used as a fuel in nuclear reactors to generate electricity. Proper environmental safeguards and regulatory measures are practiced to mitigate any possible environmental impacts that may be caused due to the operation of such facilities [2].

This paper presents the water quality, anionic composition and uranium concentrations of ground water samples collected from the upcoming uranium mining complex at Rohil, Rajasthan. A low grade polymetallic (U, Cu, Mo, Ni and Co) vein type uranium deposit is located in Rohil, Sikar district, Rajasthan. As a part of preoperational radiological survey of the site, environmental groundwater samples were collected at pre-determined locations, for quantification of prevalent trace elements, cations, anions and radionuclides. Factors affecting uranium concentrations, like, water quality and ionic composition have also been presented on spatially resolved domains.

2. Study area: The upcoming Rohil uranium mineralized zone is located in the Sikar district of Rajasthan, India. Uraninite is the main uranium bearing mineral associated with pyrite, chalcopyrite, pyrrhotite and molybdenum in this deposit [3, 4]. Geologically, the area falls under Delhi Super

Group of rocks of Mid-Proterozoic Era of the North Delhi Fold Belt (NDFB). The deposit lies within the albitite zone and occurs within the metasediments. Stratigraphically, rock units exposed in the Rohil area have been grouped into the meso-Proterozoic Ajabgarh Group of the Delhi Super group. The main topographic feature of the area is an isolated N-S trending quartzite ridge with steep eastern and western slopes. The rocks have a general strike of NNE-SSW. Rocks exposed in this area are quartz-biotite schist and quartzite. Quartz-biotite schist underlies the quartzite. Intrusives in the meta-sedimentary rocks are younger pegmatite and quartz veins [3, 4].

3. Material and methods: A total of 31 groundwater samples (borewell) were collected from borewells around the study area and water quality parameters pH, conductivity, salinity and TDS were measured in-situ by Eutech PCS Testr35. The sampling locations for the current study are shown in the below map (Fig-1).

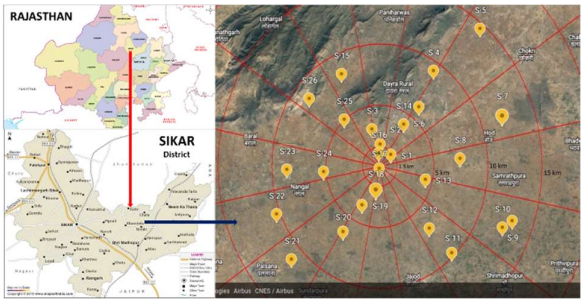

Figure 1: Map showing sampling locations from the study area

The samples were analysed for anions by Ion chromatographic (IC) system 850 professional (Metrohm make) using anion exchange column. The mobile phase was a mixture of millimolar solutions of sodium carbonate and sodium bi-carbonate. 100 mmol solution of H_2SO_4 was used for regeneration of suppresser. The samples were diluted using Millipore ultra-purified water. IC system was calibrated with 0.5 ppm, 1.0 ppm and 5 ppm of mixed anion standards (Fluka). Calibration curve was obtained for each anion and routine instrument blank, standards and duplicate sample analyses were carried out for anions like fluoride (F^-), chloride (Cl^-), bromide (Br^-), nitrate (NO_3^-) and sulphate (SO_4^{2-}).

Water sample was filtered through 0.45 µm membrane filter prior to analysis. Uranium analysis was carried out using LED fluorimetry system following standard addition method. Standard addition method takes care of matrix effect, and other interferences. For QA/QC purposes all the measurements are carried out using micropipettes and analytical micro weighing balance. Further details of analysis and quantification of low levels of uranium can be found elsewhere [5].

The equipments used for analysis of parameters and the methods used for the same are given in table-1.

Table 1: Equipments and standard methods adopted for sample analysis

Sl no.	Parameter	Instrument & Make	Method
1	pH, EC, TDS & Salinity	PCS Testr35 (Eutech)	pH: Potentiometry [6] EC,TDS, Salinity: Specific conductance [7]
2	F^-, Cl^-, NO_3^{2-}, SO_4^{2-}	850 Professional IC (Metrohm)	Ion Chromatography [8]
3	Total Uranium	LED U Analyzer (Quantalase)	Fluorimetry [9]

4. Results and discussion: The uranium concentration in water samples varied from 0.21- 522 µg/L with a mean value of 107 ± 141 µg/L. The concentration of uranium in more than 40% of water samples crossed the limit (60 µg/L) set by AERB [10] and about

52% of samples crossed the limit (30 µg/L) set by WHO [11]. The conductivity of samples ranged from 202 – 7360 µS/cm, with mean of 2221 ± 1513 µS/cm. Range of TDS was found to be 144 - 5210 ppm with mean of 1583 ± 1085 ppm. The TDS and U concentration were observed to have somewhat similar spatial distribution patterns in the mineralised region.

The range of fluoride, chloride, nitrate and sulphate was found to be 0.17 - 8.1 ppm, 17.10 - 2108 ppm, 1.9– 149 ppm, 2.79 - 635 ppm, respectively. The mean value of fluoride was 2.4 ± 1.4 ppm with median of 2.41 ppm. The mean of chloride was 414 ± 466 ppm with median 259 ppm. The mean of nitrate and sulphate were 33.70 ± 37.2 ppm, 140 ±133 ppm with median of 20.8 ppm and 113 ppm, respectively. The BIS limits for anions in drinking water are: fluoride - 1.0 ppm; chloride - 250 ppm; nitrate - 45 ppm and sulphate - 200 ppm. Limit of TDS in drinking water as per BIS is 500 ppm, whereas in the absence of any other source it can be relaxed to 2000 ppm [12]. It can be observed from table 2 that some parameters exceed the drinking water limits. Water quality parameters of Sikar district in the present study are found to be in agreement with that of the study conducted by Central Ground Water Board, Jaipur for Sikar district in 2013 [13]. Similar reports have also been mentioned in several other studies and reports [14-16]. This may be due to the local geology and presence of widespread disseminated mineralization in this region. The local hydrogeology shows that water is contained in a hard rock aquifer and the predominant minerals are quartzite, schist, phyllite, gneiss and amphibole. The water is under overexploited category in this region as per CGWB reports [13, 14].

Duggal et al. 2016 and Khyalia et al. 2023 reported similar results in Sikar district [15, 16]. Several mineralised regions have also reported elevated uranium concentrations in groundwaters. In Gogi, Karnataka; Jaduguda, Singhbhum Thrust Belt; and Tumalapalle, Andhra Pradesh, uranium concentrations in groundwater ranges from 1.3 ppb - 267 ppb, 0.5 ppb - 28 ppb and 0.38 - 79.70 ppb [17-19]. In mineralized zone of Quebec, Canada, 1–845 ppb uranium concentration has been observed in groundwaters [20]. In Mangolia, Northwest Mongolia concentration of uranium upto 1000 ppb in lake waters close to highly U-mineralized areas has been observed.

Table 2: Water quality and U in groundwaters

Parameter	Range	Mean	Median	Limit
pH	6.8 - 9.8	7.75 ± 0.67	7.6	6.5-8.5 (BIS)
Conductivity µS/cm	202 - 7360	2221 ± 1513	1942	----
Salinity (ppm)	99 - 4050	1160 ± 843	1000	----
TDS (ppm)	144 - 5210	1583 ±1085	1380	500 ppm (BIS)
Uranium (ppb)	0.21 - 522	107 ± 141	57.1	60 ppb (AERB)
Fluoride (ppm)	0.17 - 8.1	2.4 ± 1.4	2.41	1.0 ppm (BIS)
Chloride (ppm)	17.1 - 2108	414 ± 466	259	250 ppm (BIS)
Nitrate (ppm)	1.9 - 149	33.7 ± 37.2	20.8	45 ppm (BIS)
Sulphate (ppm)	2.79 - 635	140 ± 133	113	200 ppm (BIS)

Fig. 2 depicts the uranium concentration at the sampling locations of the study area. The reason for such high concentration observed in the studied area mainly can be attributed primarily to the mineralogical profile of the host rock in the region. From the distribution of uranium and TDS (Fig. 2) it can be observed that elevated levels of these parameters are limited to few locations.

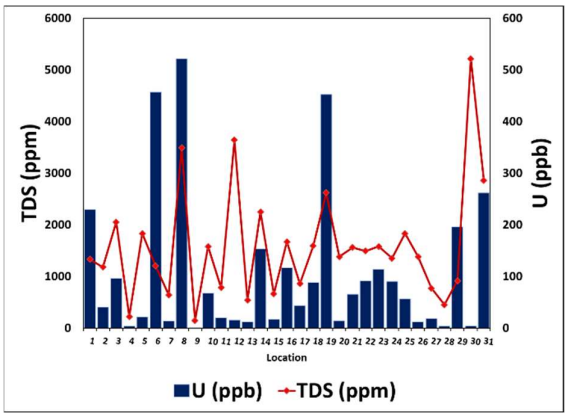

Figure 2: Distribution of total dissolved solids and U concentration in water samples

Table 3: Correlation of water quality parameters and U concentration

Parameter	pH	EC	TDS	Salinity	F^-	Cl^-	Br^-	NO_3^-	SO_4^{2-}	U
pH	1.00									
EC	-0.36	1.00								
TDS	-0.36	1.00	1.00							
Salinity	-0.37	1.00	1.00	1.00						
F^-	0.16	0.12	0.12	0.12	1.00					
Cl^-	-0.37	0.93	0.93	0.94	0.25	1.00				
Br^-	-0.09	0.15	0.15	0.14	-0.18	0.09	1.00			
NO_3^-	0.11	0.02	0.02	0.01	-0.10	-0.07	0.05	1.00		
SO_4^{2-}	-0.37	0.84	0.84	0.84	0.39	0.95	0.05	-0.18	1.00	
U (ppb)	-0.24	0.33	0.33	0.31	0.01	0.28	0.15	0.02	0.22	1.00

The Pearson correlation coefficient as shown in table 3 indicates that the electrical conductivity in these samples is governed mostly by the concentration of chloride and sulphate ions. The uranium concentrations are also seen to be influenced by none of the water quality parameters and anionic concentrations. It is observed that measured water quality parameters are not showing significant correlation with each other.

5. Conclusion

Water quality parameters, anionic concentrations and uranium levels were observed to lie beyond the limits of WHO, BIS and AERB in some water samples around the mineralised region of Rohil in Rajasthan. No particular trend was observed for any of the parameters with increasing distance from the proposed site and no significant correlation was evident between the anions and uranium concentrations. TDS was observed to be influenced by chloride and sulphate concentrations. The study is an important addition in generating baseline data and all future environmental impact assessments for the region.

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Conflict of Interest: Authors declare no conflicts of interest.

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