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Assessment of Uranium Concentration in Drinking Water around Khetri Copper Mine Region in Rajasthan, India

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Due to serious consequences for human health, it's crucial to know how much uranium (U) is present in our drinking water. The samples of water from various means, *viz*., hand pumps (HP), tube wells (TB), and public submersible pumps (PSP) from depths of 190 to 1200 feet, with an average depth of 694feet around the Khetri Copper mine in the Sikar and Jhunjhunu district of Rajasthan, India have been tested for Physico-chemical contents and their uranium levels. The Pulsed LED Fluorimetry method is used to determine the U conc. in water samples. Uranium levels in water samples have been measured to range from 0.68 - 233 µg/l. The U conc. in 28.34% of samples is higher than the WHO & USEPA recommended limit of 30 µg/l and 18.34% of the samples have U conc. higher than the AERB threshold limit of 60µg/l. The annual effective dose is also calculated and its mean value is found to be12.29 µSv/y due to the ingestion of ground-water. The average cancer mortality risk and average morbidity risk are found to be 9.5×10^{-5} to 1.47×10^{-4} lower than the threshold limit of 1.67×10^{-4} indicating the absence of carcinogenic risks. The chemical risk estimated in terms of LADD (life-time average daily dose) value is found to be in the range of 0.05–17.15 µg/kg/day. The Hazard Quotient (HQ) for 18.34% of samples is found greater than unity which indicates the health risk due to the chemical toxicity of U in groundwater. Total Dissolve Salts (TDS) values in some of the water samples are greater than the acceptable limits for drinking water recommended by BIS (500-2000 ppm).

Keywords: Groundwater; LED Fluorimetry; Mining zone; Physicochemical parameters; Risk factor; Uranium

1 Introduction

The nuclear irradiations on earth emanate from both extra-terrestrial and terrestrial sources. The radionuclides uranium, thorium, and potassium that occur naturally on Earth constitute the primary source of background radiation that affects people residing nearby. These radionuclides are absorbed into the human body by eating and inhalation. These primordial nuclei are ubiquitous in numerous geological formations, including soils, rocks, plants, sand, and water[1]. U is one of the radioactive elements that occur naturally in the earth's crust[2]. It is frequently found in trace amounts in pitchblende, uraninite, carnotite, tyuyamunite, torbernite, autunite, and others[3]. Uranium occurs naturally in three isotopes, namely ^{234}U, ^{235}U, and ^{238}U. Due to their greater specific activity, the irradiation contribution of ^{234}U and ^{235}U isotopes are significant despite their low abundance[4].

The rural populace of a region, particularly in developing nations, uses groundwater for agricultural and drinking needs. Nonetheless, groundwater can include a number of radionuclides[5]. They may be naturally occurring from geogenic sources and enter water aquifers after precipitation, or they may be introduced anthropogenically into an ecological zone[6]. The conc. of natural U in groundwater relies on the lithological, geomorphological, and other geological parameters of the region[7]. Although igneous rocks enrich soils during pedogenesis, uranium can also be found in air and water (USEPA)[8]. Human activities such as mining and nuclear fuel production may potentially contribute U to ecological processes. In addition to the usage of phosphate fertilizers and pesticides, agricultural practices also contribute to the U pollution of ground-water[9]. Dissolved uranium can be found in the majority of surface water systems[10]. WHO has set a limit of 100 µSv/y for the total dosage of radionuclides that can be ingested by drinking water[11]. Approximately 85% of a person's uranium

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intake comes from drinking water, while the remaining 15% comes from food[12]. U has both chemical and radiological effects; the kidneys and lungs are its primary target organs[13,14]. Consuming around 0.1 mg/kg of body weight of soluble natural U may cause temporary renal impairment[15]. U is a radioactive heavy metal that decays into a variety of other radioactive metals or gases that pose additional health risks[16]. Chronic exposure to U through water ingestion, even at low quantities, can cause irreversible kidney damage[17].Uranium estimation of water systems of the Mahendergarh district, Haryana[18] is found to be 0.56 µg/l - 57.53 µg/l.U conc. in drinking water samples of Punjab[19] were reported in a range of 0.5 µg/l – 579 µg/l. In 2021, Duggal[20] reported 1 to 300 µg/lU conc. in water samples in the district of southwest-central in Haryana State, India. Pant[21] reported 5 to 145 µg/lU conc. in drinking water samples in the Jaipur and Dausa districts of Rajasthan State, India. Rani[22] measured the U conc. in drinking water samples in Jhunjhunu, Churu, Hanumangrah, and Sri Ganganagar districts in a range of 2.54 to 133.0 µg/l of Rajasthan State, India. Higher dosages of uranium have been linked to increased risks of cancer and cardiovascular disease, and the effects on the respiratory and reproductive systems are also well documented in the literature. Hence, the measurement of U concentration in groundwater is essential for the estimation of health risks associated with ingestion. In the present study, U concentrations in groundwater have been measured at different locations around the Khetri copper belt. Physico-chemical parameters such as pH, EC, TDS, salinity, *etc*. are also measured along with uranium concentration.

2 Study Area

The sampling area lies mainly in the Jhunjhunu & Sikar districts, Rajasthan, India, and is shown in Fig. 1 along with the sampling locations. Groundwater samples are collected from the region around the Khetri copper belt. Khetri copper belt is situated in a range of the Aravalli hills, which is host copper mineralization. The Khetri Copper Belt KCB) extends from Singhana (28°05′: 75°49′) which lies in the Jhunjhunu district to the northeast to Sangarwa (27°34′: 75°18′) situated in the Sikar District with a total extension of about 80 km.Khetri Nagar is known for its Copper Project of Hindustan Copper Limited (HCL), a public sector undertaking run by the Government of India, which built and now runs the city. It is situated at an average elevation of 484 meters (1588 feet). In the Khetri copper belt, there are mainly three mines (a) Madhan Kudhan mines are the largest underground metal in the country (b) Chandmari is located 1km northwest of Khetri town (c) Kolihan is located 10km southwest of Khetri Nagar.

The Khetri copper belt area is split in two by a small seasonal river named Kantli, which flows along the Kantli Fault. Khetri Copper Belt rocks originate from the Delhi Super group and can be further subdivided

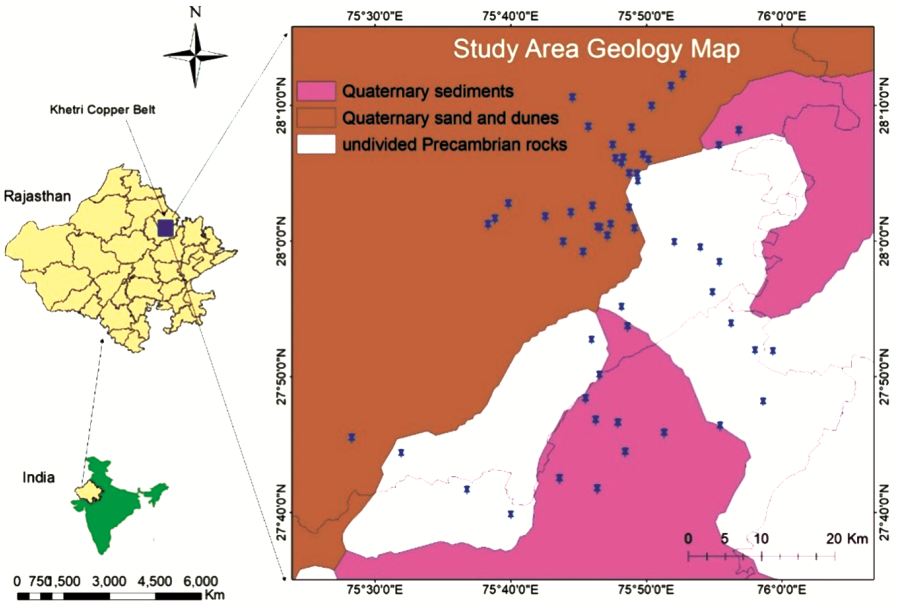

Fig. 1 — Geologicalmap of the study area.

into (1) the Alwar Group and (2) the Ajabgarh Group. Most of the study area is covered by the Ajabgarh group of the Delhi super-group. The Ajabgarh group is represented by phyllites, biotiteschists, calc gneisses, *etc*. intruded by post-Delhi intrusive viz. amphibolites, granites, pegmatites, epidiorites, *etc*. The basic intrusive include, diorite epidiorites, amphibolite, etc.

The climate of the district is largely arid. The weather in this area has summer, winter, and monsoon seasons. In winter, the temperature may go below 0 °C while in summer it may increase up to 50 °C. The soil of the studied area is generally lithosols and regisols of hills type. Light-textured, moderately well-drained, and ranging in colour from reddish brown to greyish brown, these gravels can be found just beneath the surface. Limestone, schist, quartzite, phyllite, and gneisses predominate in the region's aquifer. In general, groundwater is found in an unconfined state in the worn mantle (with a thickness of 10–15 meters) and in an unconfined to semi-confined state in the deep-seated secondary porosity (*i.e*., cracks, contacts, joints, *etc*.) of hard formation.

3 Materials & Methods

3.1 Sampling

Before sample collection, the 250 ml polypropylene bottles were washed with a dilute detergent solution followed by an aqueous 10% nitric acid solution (HNO_3), and well rinsed with double distilled water. A total of 60 water samples were collected in February 2022 from 60 different places around the Khetri copper belt situated in the district of Jhunjhunu Rajasthan, India. Various sources of drinking water were collected, including water supply by the Rajasthan government, water is drawn from a tube well (powered by electricity), and hand pumps (operated manually to obtain groundwater for home use). The sample was taken after letting the water from the source run for 10-12 minutes, or when the pH, electrical conductivity, and temperature stabilized[9]. To prevent contamination, the samples were obtained by holding bottles from the bottom. Samples of water for uranium analysis were filtered on-site using Whatman filter paper No. 42 to eliminate sediment. Within 24 hours after collection, the samples were coded and delivered to the lab, where the uranium content was determined[23].

3.2 Preparation of FLUREN (Buffer Solution)

A buffer solution was prepared by mixing 5 grammes of sodium pyrophosphate powder with 100 milliliters of double-distilled water. Thereafter, drop-by-drop addition of ortho-phosphoric acid is carried out (while keeping an eye on the solution's pH) until a pH of 7 is obtained. This is the preferred buffer solution, commonly known as FLUREN. The fluorescence production from a uranium sample is improved by several orders of magnitude when a buffer solution is added. For measurements, it is suggested that 1 part of the buffer solution be added to 10 parts of the U sample solution before proceeding with the analysis.

3.3 Measurement of Uranium

A Pulsed LED fluorimeter is used to determine the U content of the samples (Uranium Analyzer model LF-2a by Quantalase, Indore, India). The equipment can detect concentrations as low as 0.2 g/l. To ensure reliability, we ran blank samples of distilled water and calibrated the device using a uranium standard solution (10.0 g/l)[24,25]. In a plastic beaker, 6.0 ml of distilled water and 0.6 ml of fluren were mixed. Next, the cuvette was used to take the sample, and the device was used to record the amount of uranium present[26]. The results from each sample's analysis were averaged after being performed three times. Chloride-rich samples were diluted with sterile water before uranium testing[27].

The conc. of the U in the water sample is calculated as follows:

$$\mathrm{CF} = \frac{\mathrm{C}_U}{\mathrm{F}_S - \mathrm{F}_{dw}}$$

C_U = The conc. of U in the standard solution, CF = Calibration Factor, F_S = Fluorescence from the standard solution,F_{dw} = Fluorescence from distilled water.

U conc.in potable water = CF × (Fluorescence from the sample - Fluorescence from the distilled water). The equipment itself performs all of these calculations.

3.4 Physico-Chemical Parameter

The physico-chemical parameters such aspH, EC, TDS, temperature, and PPT (salinity) were measured on-site with the help of Combo pH/Conductivity/TDS Tester (Low Range) - HI98129 meter. The physicochemical properties of the water samples are compared to the drinkable water criteria established by BIS[28] and WHO[29].

3.5 Theoretical Formulation

The radiological (carcinogenic) and chemical toxicity concerns of ingesting uranium through

drinking water are obvious (non-carcinogenic). Water samples were analyzed for uranium concentrations in order to determine the yearly effective dosage, and radiological, and chemical toxicity hazards.

3.5.1 Annual radiation dose

The following calculation was used to determine an individual's annual radiation dose from ingesting uranium.

$$A_{rad} = U_{act} \times W_{intake} \times \text{DCF} \quad (1)$$

Where, A_{rad} = Dose of Radiation Per Year (Sv); U_{act} = U Activity concentration (Bq/l); W_{intake}=Water Consumption Per Year (L), and DCF = Radioactivity Dose Conversion Factor = 4.5×10^{-8} (Sv/Bq) which is given by ICRP.[2]A conversion factor of 1 µg/l= 0.02528Bq/l is used to convert the U concentration in drinking water from µg/l to Bq/l[30].

3.5.2 Radiological risk assessment

The US Environmental Protection Agency standard approach has been used to determine the increased cancer risk associated with drinking water containing natural uranium[31].

$$ECR = U_{act} \times R \quad \ldots (2)$$

Where ECR = Excess cancer risk, U_{act}= Activity conc. of U (Bq/l), and R = Risk Factor. The risk factor R (per Bq/L), related with ingestion of U from the drinking water and is assessed by the product of the risk coefficient (r) of U (1.19×10^{-9} for mortality and 1.84×10^{-9} formorbidity[18])and per capita activity intake I. 'I' for U is calculated as the product of life expectancy as 65 years, i.e., 23725 days, and daily water consumption 4.05 L/d[34].

I = 4.05 L/d × 23725 days

Risk Factor (R) = r× I … (3)

3.5.3 Chemical Toxicity risk

U's chemical toxicity risk is measured by the LADD of U that is taken in through drinking water. The amount of a substance taken per kilogram of body weight per day is used to determine LADD. The next equation shows how to do this[32,33].

$$LADD = \frac{EPC}{AT} \times \frac{IR}{BW} \times EF \times LE \quad \ldots (4)$$

Where 'EPC' =Uconc. (µg/l), IR = Water consumption rate (4.05 L/d), LE=Life-time exposure duration (65 years), EF = Exposure frequency (350 days/y), BW = Average body weight of the human (53kg), and AT = Average duration of time 23725 days, i.e., life expectancy (65 yrs)[3].

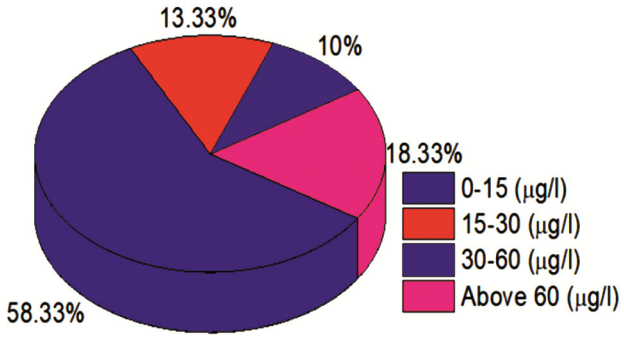

Fig. 2 — No. of water samples in different intervals of the U conc.

The HQ is a measure of the extent of harm caused by uranium ingestion from drinking water.

$$Hazard\ Quotient = \frac{LADD}{R_fD} \quad \ldots (5)$$

Where R_fD = Reference Dose,(R_fD= 4.4µg/ kg/day (AERB)[36] and R_fD = 1.2 µg/ kg/day(WHO)[37]).

4 Results and Discussion

4.1 Uranium concentration analysis in groundwater samples

A total of 60 ground-water samples were collected from 60 different places around the Khetri copper belt in Jhunjhunu district Rajasthan, India, and analyzed for U conc. using calibrated LED Fluorimeter. It is found that U conc. varies from 0.68 µg/l to 233.99 µg/l and its average value is 32.87 µg/l. The recommended limit of U in ground-water is fixed to be 60 µg/l by AERB[36] in India, while other agencies fix it much lower of 30 µg/l(USEPA[38] and WHO[29]), 9 µg/l(UNSCEAR[39]) and 1.9 µg/l(ICRP)[40]. The observed U conc. is shown in the form of a pie chart below (Fig. 2). In comparison with USEPA[38] and WHO[29], 17 (28.34%) samples exhibit higher U concentrations than recommended limits. Also, 34 (56.57%) and 51 (85%) water samples show U concentrations higher than UNSCEAR & ICRP recommended limits, respectively. If the observed data of the U conc. in water is compared with the guideline of AERB[36], 11 (18.34%) water samples exceed the proposed conc. level of 60 µg/l. Hence, it is evident that the values of U conc. in ground-water samples are significantly higher than recommended limits of different agencies. The observed high values of U conc. in groundwater may be due to the location of the investigated area in Aravalli hills and due to the large-scale copper mining in this area. The large-scale mining activities since the nineteenth century could

result in the release of uranium and other contaminants in the groundwater of the area, which leads to a high amount of uranium in groundwater. The higher U conc. in some of the areas might also be due to the water aquifer system present underneath. The variations noticed in U conc. concentration in different locations might also be because of the varying depth from which water samples were collected. The high U conc. found in this investigation support the earlier reported measured values[41,42].

4.2 Annual effective dose, Radiological risk, & chemical toxicity risk analysis

The annual ingestion dose is found to be lying in the range of 0.25-87.44 μSv/y with an average value of 12.28 μSv/y. It is found that none of the samples exhibit an annual ingestion dose higher than the recommended safe limit of 100 μSv/y(WHO[29]). The radiological risk due to the ingestion of natural U in drinking water has also been calculated. The excess cancer risk (mortality; - no. of people's death due to cancer per 100,000 populations) has been observed to be in the range of 1.97×10^{-6} – 6.67×10^{-4} with a mean value of 9.50×10^{-5}. Cancer morbidity refers to the state of being unhealthy due to cancer within a population and its values varied from 3.04×10^{-6} – 1.05×10^{-3} with an average value of 1.47×10^{-4}. The observed values of U conc., ECR, and ingestion dose are shown in Table 1. According to theAERB[36] guidelines, the value of the ECR in the studied area is greater than the maximum acceptable level of 1.67×10^{-4}. U is a radioactive heavy metal having both radiological and chemical toxicity and is more harmful especially due to its chemical toxicity.

Table 1 — Conc. of U in different water samples and their radiological and chemical toxicity risks

Sample Id	Depth (Feet)	Latitude	Longitude	U Conc. (μg/l)	Activity (Bq/l)	Annual Dose Rate (μSv/y)	Cancer Risk		LADD (μg/kg/d)	Hazard Quotient (AERB)
							Mortality	Morbidity		
N-1	350	28°0'57"	75°46'24"	13.88	0.35	5.19	4.01E-05	6.21E-05	1.0173	0.231
N-2	250	28°0'56"	75°46'36"	6.56	0.17	2.45	1.90E-05	2.93E-05	0.4804	0.109
N-3	200	28°1'9"	75°47'22"	25.08	0.63	9.37	7.25E-05	1.12E-04	1.8377	0.418
N-4	540	28°2'23"	75°48'44"	233.99	5.92	87.44	6.76E-04	1.05E-03	17.1456	3.897
N-5	350	28°4'20"	75°49'22"	12.04	0.30	4.50	3.48E-05	5.38E-05	0.8822	0.201
N-6	810	28°4'53"	75°49'19"	1.04	0.03	0.39	3.01E-06	4.65E-06	0.0762	0.017
N-7	565	28°5'56"	75°50'9"	228.07	5.77	85.23	6.59E-04	1.02E-03	16.7118	3.798
N-8	400	28°6'5"	75°48'18"	30.51	0.77	11.40	8.82E-05	1.36E-04	2.2359	0.508
N-9	580	28°5'42'	75°48'11"	21.92	0.55	8.19	6.34E-05	9.80E-05	1.6062	0.365
N-10	600	28°6'1"	75°47'43"	4.25	0.11	1.59	1.23E-05	1.90E-05	0.3117	0.071
N-11	300	27°53'38"	75°48'37"	1.18	0.03	0.44	3.41E-06	5.28E-06	0.0866	0.020
N-12	190	27°55'5"	75°48'11"	17.82	0.45	6.66	5.15E-05	7.96E-05	1.3055	0.297
N-13	1050	27°52'39"	75°45'57"	12.53	0.32	4.68	3.62E-05	5.60E-05	0.9184	0.209
N-14	620	27°50'5"	75°46'31"	68.95	1.74	25.77	1.99E-04	3.08E-04	5.0523	1.148
N-15	1000	27°48'20"	75°45'31"	82.50	2.09	30.83	2.38E-04	3.69E-04	6.0452	1.374
N-16	950	27°46'44"	75°46'16"	1.44	0.04	0.54	4.16E-06	6.44E-06	0.1055	0.024
N-17	350	27°41'41"	75°46'22"	8.02	0.20	3.00	2.32E-05	3.58E-05	0.5874	0.134
N-18	600	27°42'25"	75°43'35"	31.84	0.80	11.90	9.20E-05	1.42E-04	2.3328	0.530
N-19	350	27°39'45"	75°40'0"	147.11	3.72	54.97	4.25E-04	6.57E-04	10.7792	2.450
N-20	550	27°41'35"	75°36'46"	45.58	1.15	17.03	1.32E-04	2.04E-04	3.3401	0.759
N-21	650	27°44'18"	75°31'54"	28.82	0.73	10.77	8.33E-05	1.29E-04	2.1120	0.480
N-22	540	27°45'26"	75°28'15"	1.97	0.05	0.74	5.69E-06	8.80E-06	0.1444	0.033
N-23	750	27°59'7"	75°45'20"	3.04	0.08	1.13	8.78E-06	1.36E-05	0.2225	0.051
N-24	400	27°59'52"	75°43'51"	3.54	0.09	1.32	1.02E-05	1.58E-05	0.2596	0.059
N-25	450	28°2'31"	75°46'2"	1.77	0.04	0.66	5.11E-06	7.90E-06	0.1295	0.029
N-26	500	28°4'55"	75°48'44"	2.05	0.05	0.76	5.92E-06	9.15E-06	0.1500	0.034
N-27	600	28°8'5"	75°56'50"	63.21	1.60	23.62	1.83E-04	2.83E-04	4.6315	1.053
N-28	1000	28°6'58"	75°55'23"	85.12	2.15	31.81	2.46E-04	3.80E-04	6.2374	1.418
N-29	900	28°13'4"	75°4056"	12.99	0.33	4.86	3.76E-05	5.81E-05	0.9521	0.216
N-30	825	28°10'30"	75°44'34"	0.68	0.02	0.25	1.97E-06	3.04E-06	0.0498	0.011
N-31	850	28°8'22"	75°45'43"	7.77	0.20	2.90	2.25E-05	3.47E-05	0.5696	0.129
N-32	900	28°7'1"	75°47'32"	4.92	0.12	1.84	1.42E-05	2.20E-05	0.3608	0.082
N-33	920	28°6'18"	75°49'46"	17.99	0.45	6.72	5.20E-05	8.04E-05	1.3180	0.300
N-34	900	28°8'18"	75°48'56"	9.86	0.25	3.68	2.85E-05	4.41E-05	0.7225	0.164

(*contd.*)

Table 1 — Conc. of U in different water samples and their radiological and chemical toxicity risks (*contd.*)

Sample Id	Depth (Feet)	Latitude	Longitude	U Conc. (µg/l)	Activity (Bq/l)	Annual Dose Rate (µSv/y)	Cancer Risk		LADD (µg/kg/d)	Hazard Quotient (AERB)
							Mortality	Morbidity		
N-35	1000	28°9'53"	75°50'24"	1.27	0.03	0.47	3.67E-06	5.68E-06	0.0931	0.021
N-36	950	28°11'21"	75°51'50"	9.70	0.25	3.62	2.80E-05	4.33E-05	0.7105	0.161
N-37	900	28°12'12"	75°52'42"	23.37	0.59	8.73	6.76E-05	1.04E-04	1.7127	0.389
N-38	1000	28°0'52"	75°49'8"	216.16	5.46	80.78	6.25E-04	9.66E-04	15.8391	3.600
N-39	1000	28°59'58"	75°49'5"	95.47	2.41	35.68	2.76E-04	4.27E-04	6.9953	1.590
N-40	900	27°59'50"	75°52'5"	9.46	0.24	3.53	2.73E-05	4.23E-05	0.6929	0.157
N-41	550	27°59'28"	75°54'0"	26.18	0.66	9.78	7.57E-05	1.17E-04	1.9186	0.436
N-42	1000	27°58'22"	75°55'24"	78.13	1.98	29.20	2.26E-04	3.49E-04	5.7247	1.301
N-43	1200	27°56'10"	75°54'53"	6.52	0.16	2.44	1.89E-05	2.92E-05	0.4780	0.109
N-44	1000	27°53'51"	75°56'16"	55.98	1.42	20.92	1.62E-04	2.50E-04	4.1022	0.932
N-45	900	27°51'53"	75°58'2"	17.53	0.44	6.55	5.07E-05	7.83E-05	1.2843	0.292
N-46	650	27°51'49"	75°59'22"	33.63	0.85	12.57	9.72E-05	1.50E-04	2.4640	0.560
N-47	900	27°48'06"	75°58'38"	13.64	0.34	5.10	3.94E-05	6.10E-05	0.9995	0.227
N-48	850	27°46'19"	75°55'28"	0.94	0.02	0.35	2.73E-06	4.22E-06	0.0692	0.016
N-49	800	27°45'48"	75°51'19"	61.25	1.55	22.89	1.77E-04	2.74E-04	4.4878	1.020
N-50	300	27°44'22"	75°48'27"	10.71	0.27	4.00	3.10E-05	4.79E-05	0.7848	0.178
N-51	1000	27°46'32"	75°47'54"	4.39	0.11	1.64	1.27E-05	1.96E-05	0.3214	0.073
N-52	800	28°2'1"	75°44'26"	36.05	0.91	13.47	1.04E-04	1.61E-04	2.6416	0.600
N-53	850	28°1'43"	75°42'32"	0.90	0.02	0.34	2.60E-06	4.02E-06	0.0659	0.015
N-54	550	28°2'42"	75°39'49"	5.93	0.15	2.22	1.71E-05	2.65E-05	0.4345	0.099
N-55	550	28°1'34"	75°38'49"	6.30	0.16	2.35	1.82E-05	2.81E-05	0.4614	0.105
N-56	600	28°1'10"	75°38'19"	3.89	0.10	1.45	1.13E-05	1.74E-05	0.2853	0.065
N-57	500	28°59'54"	75°39'26"	3.12	0.08	1.16	9.01E-06	1.39E-05	0.2284	0.052
N-58	700	28°58'5"	75°42'31"	4.44	0.11	1.66	1.28E-05	1.98E-05	0.3251	0.074
N-59	700	28°58'5"	75°42'31"	1.80	0.05	0.67	5.21E-06	8.06E-06	0.1321	0.030
N-60	700	28°0'20"	75°47'7"	7.19	0.18	2.69	2.08E-05	3.22E-05	0.5271	0.120

Table 2 — Ranges of various Physico-chemical parameters of ground-water samples

	Minimum	maximum	Average	BIS Limits	WHO Limits
pH	6.77	8.16	7.3357	6.5 – 8.5	6.5 – 9.2
EC (mS/cm)	0.35	2.07	0.8402	-	1.5
TDS (ppm)	175	1035	420.08	500 - 2000	1500

Taking into account how dangerous the chemicals in uranium are, the kidneys are the most important organ to attack. At lower levels of exposure, the chemical toxicity of U is more dangerous to the kidney than its radiological toxicity. The LADD and the HQ have been used to figure out how dangerous a chemical is. By comparing the calculated LADD value to the reference dosage level of 4.4 µg/kg/day, the HQ has been estimated. The reference level has been set at 60 µg/l, which is the maximum amount of uranium that can be found in the water according to AERB standards. The LADD and HQ values vary between 0.050µg/kg/day-17.15µg/kg/day and between 0.011-3.90, respectively. It is seen that 18.34% of samples have HQ values greater than 1, which shows that uranium is chemically dangerous in the area that was studied. Our research shows that the average number of people with mortality risk in the area, we looked at, is about 7 per 10,000 people and the morbidity risk is estimated to be 10 out of every 10,000 people.

4.3 Physico-Chemical Parameters

The measured values of Physico-chemical parameters are summarized in Table 2 below. It is observed that the pH values of all the groundwater samples lie within the safe limit recommended by BIS[28] with a minimum of 6.77 to a maximum of 8.16. A slight negative correlation (-0.12) is observed between the pH and U conc. of water samples as shown in Fig. 3. The EC values are found to be lying in the range of 0.35-2.07 with a mean value of 0.84. Few of the water samples are found to be showing EC values greater than the recommended limit of WHO[14]. A positive correlation is observed between U conc. And electrical conductivity (0.515) (Fig. 4).The TDS (Total Dissolved Solid) value of all the samples lies between 175 ppm to 1035 ppm

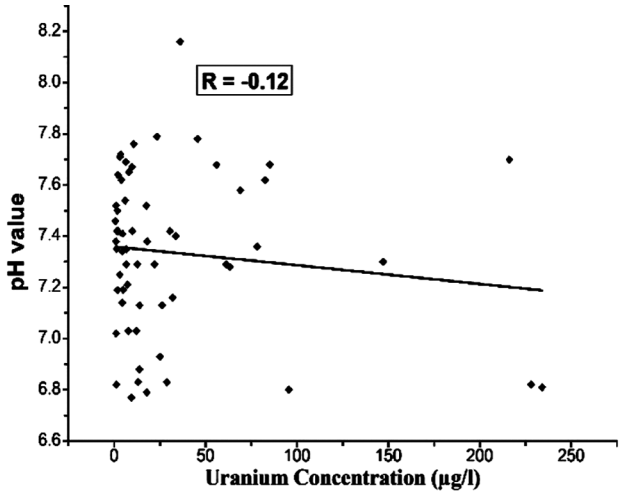

Fig. 3 — Uranium concentration vs pH in water samples.

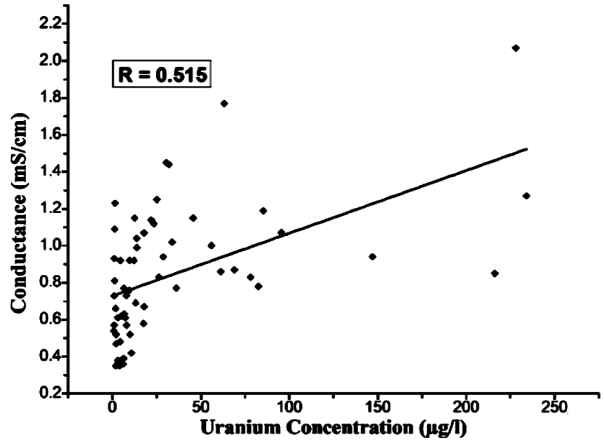

Fig. 4 — Uranium concentration vs conductance in water samples.

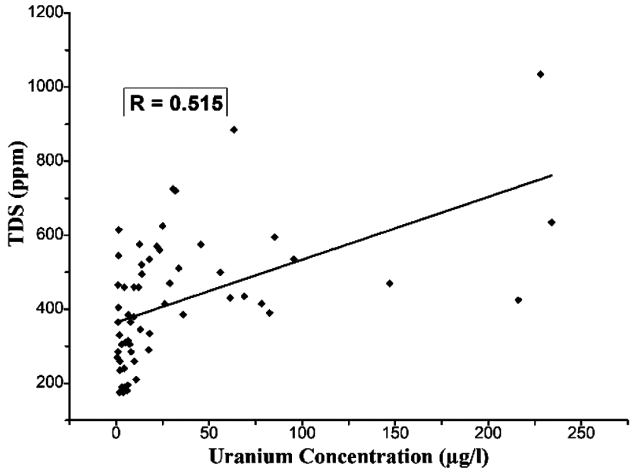

Fig. 5 — Uranium concentration vs TDS in water samples.

indicating that the TDS of all samples is within the safe limit prescribed by BIS[28]. A correlation of 0.515 is obtained between U conc. And TDS value indicating that water with high TDS will have a higher uranium conc. The correlation graphs are shown in Fig. 5.

5 Conclusions

The U conc. in the 60 groundwater samples, collected from different locations via HP, TB, and PSP around the Khetri Copper Belt in Rajasthan, is estimated by using the LED Fluorimetry technique. U conc. is found to be in the range of 0.68 to 233.99 µg/l. The U conc. is high in 17 out of 60 groundwater samples than the threshold limit of 30 µg/l (WHO and USEPA) with an overall U conc. of 32.87 µg/l. The possible reason for the high U conc. in collected ground-water samples may be due to the Aravalli hills terrane and nearby mining zones. In the research area, the conc. of U in drinking water is not spread consistently. The annual ingestion dose is found to be lying well within the acceptable range of 100µSv/y for all the samples. The cancer mortality and morbidity risk were found the higher than the safe limit in 18.34% and 21.67% of samples respectively. The HQ value is found to be higher in 11 out of 60 groundwater samples indicating the possible chemical toxicity risk of uranium.

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