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Uranium concentration and health risk assessments in groundwater samples taken different location of Korba District, Chhattisgarh, India

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ABSTRACT

In this research we report comprehensive data from the Korba district of Chhattisgarh that has been obtained and examined. The plurality of the reports discussed uranium concentration testing in groundwater samples. Fission-track technique, ICPMS, laser fluorimetry and LED fluorimetry were used to collect the majority of the data reported. Uranium concentration in groundwater samples collected from various sites of my research region was investigated using an LED Fluorimeter. During the month of May 2021, uranium concentrations range from 0.031 µg/l to 140.10 µg/l. The concentration of uranium in 30 samples of groundwater in the Korba district of Chhattisgarh, as well as the corresponding ADD, excess lifetime cancer risk, and HQ, were determined. Uranium concentrations in 33.33% of the samples were found to be greater than the WHO and USEPA-established Maximum Contaminant Level (MCL) of 30 µg/l. Katghora1 has an HQ value of 2.52, suggesting a high risk of chemical toxicity.

Key words : *LED fluorimetry, ADD, HQ, Maximum Contaminant Level, Excess lifetime cancer risk*

Introducton

Uranium is found in the Earth's crust in a dispersed form. The most soluble of the long-lived radionuclide's, uranium salt produces ions with oxidation states of +4 (UO_2 and $U^{4+)}$ and +6 (UO_3 and UO_2^{2+}) (Banks *et al.,* 1995). Uranium in the Earth's crust is transferred to water, plants, dietary nutrients, and eventually humans. Uranium (atomic number 92) is a naturally occurring alpha-emitting radioactive metal with a molar mass of 238.03 g/mol (Hon *et al.,* 2015). Uranium is a technologically important element because of its chemical and radiological properties. Since it is found in varying concentrations of rock, dirt, air, and water, it is an inherent part of our climate. Background radiations are caused by inherent radioactivity, which has existed on the planet since its inception. Uranium (^{238}U) and its decay component Radon (^{222}Rn) are two naturally occurring radioactive substances that can cause health problems if they are present of high concentrations in groundwater (Panghal *et al.,* 2019). Water flowing through and over rock and soil composition dissolves a variety of minerals and compounds, including ^{238}U, to the point that varying amounts of it can be contained in different water bodies. ^{238}U has an average concentration of 2.7 mg/l in the earth's crust (Skeppstorm and Olofsson, 2007) and its toxicity, rather than its radioactivity, makes it extremely dangerous. The toxicity of uranium is caused by its solubility, elimination processes, particle solubility, contact time, and exposure process. Uranium is a radioactive element with a long half-life that is both chemically and radiologi-

cally toxic (Takeda *et al.,* 2006). To understand the health effects of uranium on people, it's essential to understand the conversion and distribution of ^{238}U in water, soil, plants, and agricultural soil. Uranium and other heavy metal impurities can build up in the soil and then be leached into groundwater and surface water, where they can be absorbed by plants and then passed on to the food chain. The existence of ^{238}U in aquifer rock, CO_2, dynamic agents, and oxygen in the aquifer all affect the value of ^{238}U in water. Temperature, pH, flow rate, value and characteristics of dissolved salts, and residence time are all characteristics of water that can be used to estimate its capacity to dissolve, hold, or deposit elements (Khater *et al.,* 2008). ^{238}U enters the human body mostly by consuming groundwater (Bajwa *et al.,* 2015), breathing air, or eating food, with 85% of uranium entering through water and 15% through food (Santos Amaral *et al.,* 2005). Uranium has been described as a nephrotoxin that has the potential to damage the kidneys (WHO, 2011). Since high uranium concentrations in groundwater can cause health problems, measuring ^{238}U concentrations is critical for determining health risks. If a human body is exposed to dissolve natural uranium at a concentration of 0.1 mg/kg body weight, significant chemical dangers to the lungs and kidneys may occur. Because of its nuclear toxicity, uranium in drinking water is harmful to one's body. The chemical toxicity of uranium causes kidney toxicity. Uranium reaches the body by food or inhaling uranium-containing aerosols, during which the kidneys filter the uranium particles, potentially damaging kidney cells. The effects of uranium are divided into two categories: stochastic and non-stochastic. When a person consumes 50 to 150 mg of uranium, it can cause acute kidney failure and even death. Non-stochastic risk will result from low-dose consumption of 25 to 40 mg, which can be determined by the presence of protein and dead cells in the urine and the kidney can regenerate after a few weeks (Sztajnkrycer and Otten, Mil. Med, 2004).

The World Health Organization (WHO, 2004) formerly recommended a reference standard of 15 µg/l, but the WHO now recommends a maximum of 30 µg/l for ^{238}U in drinking water (WHO, 2011). The reference standard was developed based on the hypothesis of a 60 kg adult eating 2 litter of drinking water per day and allocating 80% of the Tolerable Daily Intake (TDI) to drinking water in epidemiological studies. On December 7, 2000, USEPA introduced a radionuclide provision to the Safe Drinking Water Act (SDWA), establishing a maximum contaminant level (MCL) of 30 µg/l for uranium (USEPA, 2000). It is advised that the ^{238}U content of various drinking water supplies be monitored to avoid the negative health effects of uranium in drinking water. In the Korba district of Chhattisgarh State, India, there is no information on the radiological and chemical health effects of uranium in groundwater. The purpose of this research is to use laser-induced fluorimetry to estimate the uranium content in groundwater obtained in the Korba district of Chhattisgarh, India, and to calculate the health risk associated with drinking this water.

Materials and Methods

Study area

Korba district is one of Chhattisgarh's mineral-rich districts. It is well-known for its coal mines, which include the Gevra field, Kusmunda, and Dipka, among others. In addition, this district contains Granite, Dolerite, Bauxite, Fireclay, and Limestone. Many quarry leases for various minor minerals have been approved and are operational. Korba district located Lattitude 22°01′ to 23°01′ N and Longitude 82°07′ to 83°07′ E. Geologically the district exhibits lithology of Archean to Cainozoic age. Granites and Gondwana occupy more than 90% of the area. The unclassified metamorphic is composed of quartzite, mica schist, dolomitic marble and phyllite shown in Figure 1.

Sampling

During the month of May 2021, 30 groundwater samples from various places were chosen as the research region. The vendor had a capacity made of polypropylene with airtight lids. They were vigorously washed (along with the lids) in a diluted liquid detergent and then rinsed with clear water. The bottles and lids were immersed in an aqueous solution of nitric acid for 24 hours after being allowed to dry overnight. The bottles were rinsed with distilled water and thoroughly dried before extracting samples. To ensure that a fresh sample of water was collected, water was allowed to flow out of the pump for a few minutes before sample collection at each sampling site. When filling the sampling tubes, extreme caution was taken to avoid contamination of the sample. On the same day, each sample con-

tainer was neatly labelled (location ID), put in the bottle rack, and transported to the laboratory.

Laser-induced fluorimetry

The LED Fluorimeter LF-2a, developed by Quantalase Enterprises Pvt. Ltd., Indore, was used to quantify uranium concentration in water samples using a laser-induced fluorimetric technique. Pulsed UV LEDs in this instrument excite fluorescence in uranium (VI) complexes in the sample. Uranium complexes emit green fluorescence after excitation which can be detected using a sensitive Photomultiplier Tube (PMT). Fluorescence yield is proportional to the intensity of the excitation source and the uranium concentration in the sample, so measuring fluorescence can provide details about the uranium concentration in the sample.

Fluorimeter calibration

The LED Fluorimeter is calibrated using a standard Uranium solution. The device was measured in the range of 1-100 µg/l with a regular stock solution made by dissolving 1.78 g $(CH_3COO)_2UO_2.2H_2O$ (uranyl acetate dihydrate) in 1L Millipore elix-3 water comprising 1 ml of HNO_3. The uranium content was also determined in a blank sample containing the same volume of fluorescing reagent. As a fluorescence reagent, 5% phosphoric acid in ultrapure water was used. All of the reagents used in the experiments were analytical grade.

Analysis

For the removal of suspended particles, samples were filtered into 0.45 micron Whatman filter paper. To resolve the matrix effect, the instrument was calibrated with standard uranium solutions until water samples were analyzed using the standard addition procedure (recommended by the Atomic Energy Regulatory Board). Since the fluorescence yield of various uranium complexes varies, the sample is treated with the inorganic reagent SPP (Sodium pyrophosphate) to transform all of the complexes into

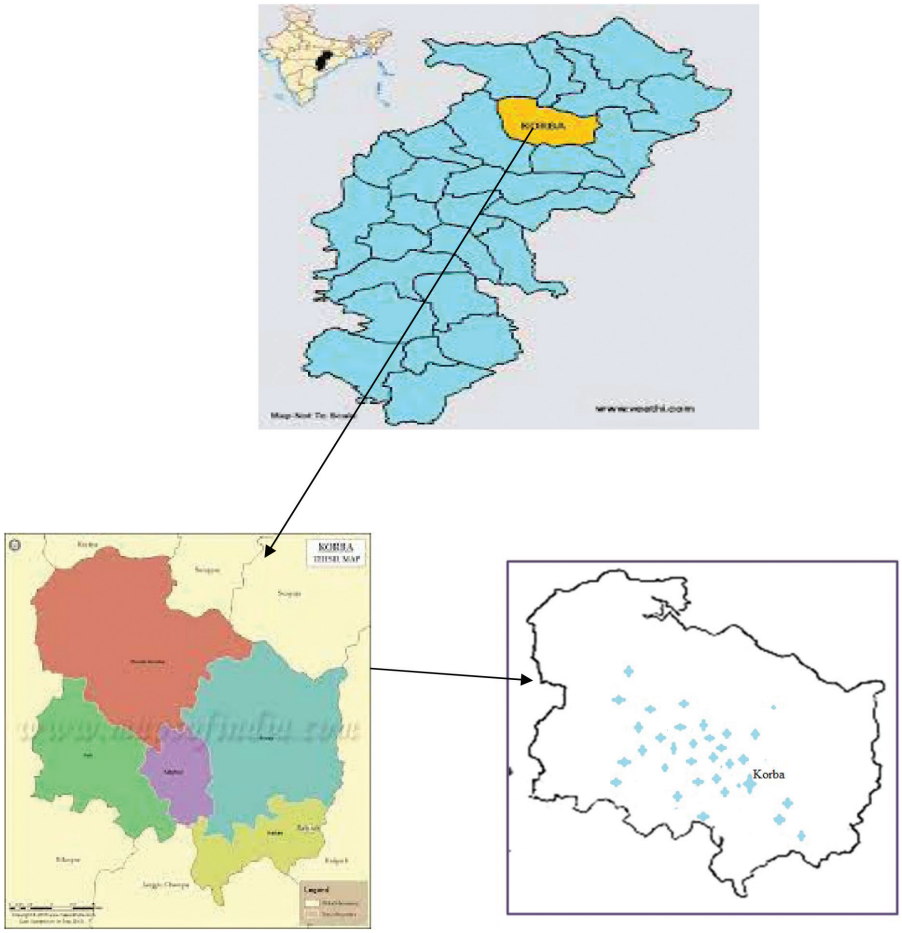

Fig. 1. Location of research areas in Korba district

a single form of the same fluorescence yield. This procedure can calculate concentrations as low as 0.5 µg/l.

Chemicals and Regents

a. Preparation of buffer solution

In double distilled water, a 5 % solution of sodium pyrophosphate was prepared, and orthophosphoric acid was applied to adjust the pH to 7. The optimal buffer solution, also known as FLUREN, is this. When a buffer solution is added to a uranium sample, the fluorescence yield increases by orders of magnitude, It is suggested that 1 part buffer solution be mixed with 10 parts uranium sample solution before being used for measurements.

Standard uranium solution preparation

Dilution of uranium plasma emission standard solution from Accu Std, USA Lot No 216035031 was used to make standard uranium solutions.

Health risk assessment

There are two kinds of health risks from uranium intake by drinking water: excess lifetime cancer risk (radiological risk) and non-carcinogenic effects (chemical risk).

Excess lifetime cancer risk assessment

The excess lifetime cancer risk was estimated by multiplying average daily dose (ADD), duration of life (63.7 years) and slope factor (SF).

Risk = ADD × SF × 23250.5 (63.7 Years)

Where,

ADD = Average Daily Dose (pCi)

SF = Slope Factor (Risk/pCi)

The average water intake rate was calculated to be 4.05 litres per day (HDR, 2009). The activities are translated to pCi units using the conversion factor 1 Bq = 27 pCi in the HEAST table of USEPA cancer slope factors for radionuclides. The slope factor for uranium is 6.2×10^{-1} Risk/pCi (USEPA, 1997).

Assessments of Chemical risk

The Hazard Quotient (HQ) is used to assess uranium's non-carcinogenic impact. HQ indicates the severity of the damage caused by consuming uranium-contaminated water.

$$HQ = \frac{ADD\ (\text{mg/ kg body weight/ day})}{RfD\ (\text{mg/ kg body weight/ day})}$$

The ADD was determined by dividing the intake by the average Indian man's body weight, which is 53 kg. RfD stands for reference dosage, which is equal to 0.0003 mg/kg of body weight per day (USEPA 1989a, 1997).

Results and Discussion

The concentration of uranium, the corresponding ADD, excess lifetime cancer risk, and HQ of 30 samples of the groundwater in Korba district of Chhattisgarh state, Table 1 shows the results of the Laser-fluorimetric method analysis. The concentration of uranium in water samples obtained in the study area ranged from 0.031 to 140.10 µg/l. Minimum uranium concentration is found in nagar panchayat Pali (0.031 µg/l) and maximum in Nonbirra village (140.10 µg/l) shown in figure 2 and Spatial variation for uranium concentration in groundwater of Korba district shown in figure 4. The concentration of uranium in 33.33 % samples was found to be higher than the Maximum Contaminant Level (MCL) of 30 µg/l established by WHO and USEPA.

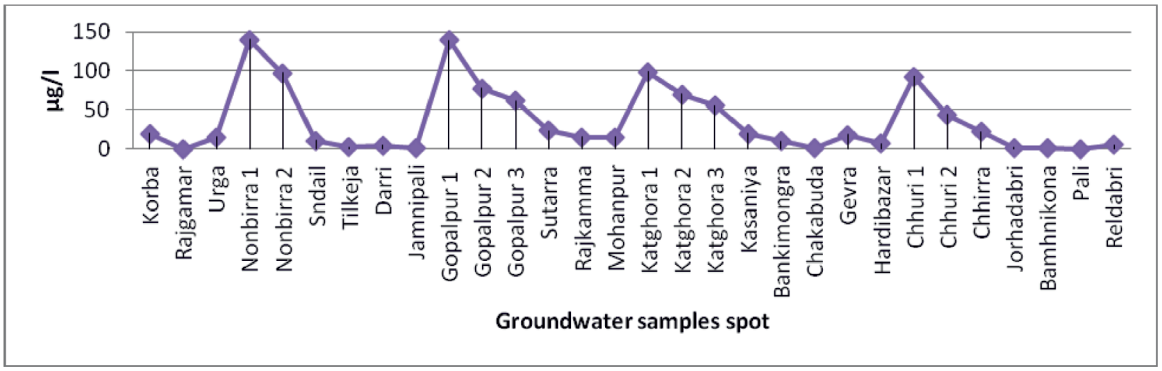

Fig. 2. Uranium concentration of groundwater samples.

During a national assessment by the BARC to assess uranium concentration in drinking water sources across India, uranium was found in 83.6% of all water samples collected. For the survey, 55,554 surface and groundwater samples were collected. Tables 2 and 3 show the concentrations of uranium in drinking water samples in states of India and other global countries, respectively. If consumed, uranium's direct radiation effect is due to its alpha emission, which can cause gene mutation, cancer, and deformities in children and developing fetuses (Sar *et al.*, 2017). The major contribution of uranium from any source, including drinking water, has been shown in studies to increase the risk of kidney in-

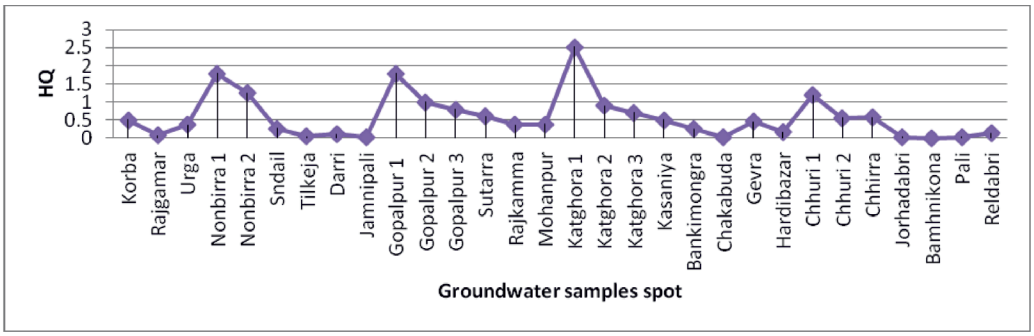

Fig. 3. HQ value.

Table 1. Uranium concentration and activity in groundwater, as well as radiological and chemical risk

S. N.	Location	Water source	Activity (Bq/l)	Uranium Concentration (µg/l)	Excess life time cancer risk	ADD (mg/kg body weight/ day)	HQ
1	Korba	Bore well	0.495	19.57	7.80×10^{-5}	1.50×10^{-3}	0.50
2	Rajgamar	Bore well	0.076	0.076	1.20×10^{-5}	2.31×10^{-4}	0.08
3	Urga	Bore well	0.370	14.65	5.84×10^{-5}	1.12×10^{-3}	0.37
4	Nonbirra1	Handpump	3.54	140.10	3.97×10^{-4}	8.11×10^{-3}	1.79
5	Nonbirra2	Handpump	2.45	96.90	2.74×10^{-4}	5.61×10^{-3}	1.24
6	Sndail	Handpump	0.27	10.6	4.21×10^{-5}	8.07×10^{-4}	0.27
7	Tilkeja	Handpump	0.05	1.90	7.41×10^{-5}	1.42×10^{-4}	0.05
8	Darri	Handpump	0.11	4.40	1.74×10^{-5}	3.33×10^{-4}	0.11
9	Jamnipali	Handpump	0.02	0.90	3.75×10^{-6}	7.18×10^{-5}	0.02
10	Gopalpur1	Handpump	3.54	139	3.96×10^{-4}	8.09×10^{-3}	1.79
11	Gopalpur2	Handpump	1.96	77.55	2.20×10^{-4}	4.49×10^{-3}	0.99
12	Gopalpur3	Handpump	1.56	61.62	1.75×10^{-4}	3.57×10^{-3}	0.79
13	Sutarra	Bore well	0.592	23.42	9.33×10^{-5}	1.79×10^{-3}	0.60
14	Rajkamma	Handpump	0.370	14.65	5.84×10^{-5}	1.12×10^{-3}	0.37
15	Mohanpur	Handpump	0.3	14.80	5.90×10^{-5}	1.13×10^{-3}	0.38
16	Katghora1	Bore well	2.50	99.0	3.94×10^{-4}	7.55×10^{-3}	2.52
17	Katghora2	Handpump	1.76	69.57	1.97×10^{-4}	4.03×10^{-3}	0.89
18	Katghora3	Bore well	1.41	55.64	1.58×10^{-4}	3.22×10^{-3}	0.71
19	Kasaniya	Handpump	0.49	19.57	7.80×10^{-5}	1.50×10^{-3}	0.50
20	Bankimongra	Handpump	0.24	9.65	3.84×10^{-5}	7.37×10^{-4}	0.25
21	Chakabuda	Bore well	0.015	0.60	2.38×10^{-6}	4.57×10^{-5}	0.02
22	Gevra	Bore well	0.45	18.0	7.17×10^{-5}	1.38×10^{-3}	0.46
23	Hardibazar	Bore well	0.17	6.8	2.69×10^{-5}	5.17×10^{-4}	0.17
24	Chhuri1	Bore well	2.35	92.96	2.63×10^{-4}	5.38×10^{-3}	1.19
25	Chhuri2	Handpump	1.11	44.09	1.25×10^{-4}	2.55×10^{-3}	0.56
26	Chhirra	Bore well	0.56	22.19	8.82×10^{-5}	1.70×10^{-3}	0.57
27	Jorhadabri	Handpump	0.35	1.37	5.47×10^{-6}	1.05×10^{-4}	0.03
28	Bamhnikona	Handpump	0.015	0.58	2.30×10^{-6}	4.42×10^{-5}	0.01
29	Pali	Handpump	3.36	0.031	4.85×10^{-6}	9.30×10^{-5}	0.03
30	Reldabri	Bore well	0.131	5.16	2.06×10^{-5}	3.95×10^{-4}	0.13

Table 2. Concentrations of uranium in drinking water from City/ State of India.

S.N.	City/ State of India	Uranium in Groundwater (µg/l)
1	Vishakhapatnam, AP.	0.6-12.3
2	Bathinda, Punjab	1.65-74.58
3	Bangalore, Karnataka	0.2-770.1
4	Chamarajnagar, Karnataka	0.3-4.63
5	Jharkhand	<0.5-27.5
6	Kerala	0.31-4.92
7	Jadugunda	0.5-28
8	Kulu, Himachal Pradesh	0.3-2.5
9	Rajasthan	2.54-133
10	Uttar Pradesh	0.20-64.0
11	Hanumangarh	4.74-98.7
12	Faridkot	7.62-375.85
13	Panipat, Haryana	7.95-39.43
14	Kathua	0.26-21.92
15	Jammu	0.18-20.8

Table 3. Concentrations of uranium in drinking water from throughout the world.

S. N.	Country	Uranium in Groundwater (µg/l)
1	South Greenland	0.5-1.0
2	Kuwait	0.02-2.48
3	Argentina	0.04-11.0
4	Brazil	0.01-1.36
5	Egypt	328-560
6	Russia	>477
7	Switzerland	0.05-92.02
8	Greece	0.01-10
9	Jordan	0.04-1400
10	Mongolia	<0.01-57

jury. The kidney is the most vulnerable organ to uranium poisoning.

The evaluation of radiological and chemical toxicity is critical in this regard. For uranium-contaminated groundwater in the study area, the excess lifetime cancer risk varied from 2.30×10^{-6} to 3.97×10^{-4} for uranium-contaminated groundwater in the study area. Normally from 1×10^{-4} to 1×10^{-6} is a tolerable risk range for 66.6 % of the water samples the values reported for cancer risk are low compared to the acceptable level.

If HQ values >1.0, then there may be a concern for potential non-cancer effect (USEPA 1989a). Nonbirra1 (1.79), Nonbirra2 (1.24), Gopalpur1 (1.79), Katghora1 (2.52) and Chhuri1 (1.19) the

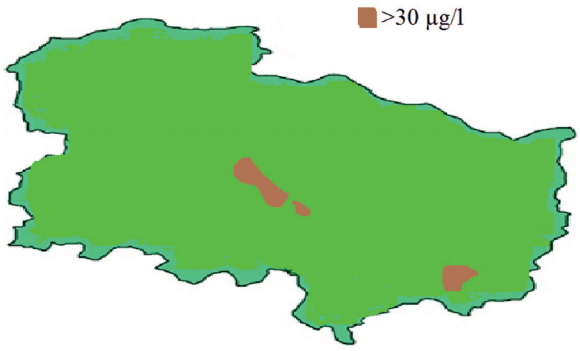

Fig. 4. Spatial variation for uranium concentration in groundwater of Korba district.

HQ values of the water samples were above the threshold value. HQ value for Katghora1 was found 2.52 indicating a significant risk due to chemical toxicity as shown in Figure 3. Because uranium toxicity of groundwater occurs across such a large area, the source is unlikely to be localized. Because of the dangers connected with internal uranium exposure, greater levels of uranium are a major issue for public health (Bhangare *et al.*, 2013). Uranium is an environmental pollutant (Virk, 2013), more research will be done using environmental isotopes to confirm its existence and release mechanism in groundwater.

Conclusion

In this research article which focuses on uranium concentrations in different locations of groundwater samples in Korba district of Chhattisgarh. During the month of May 2021, Uranium concentration in water samples in the study area ranged from 0.031 to 140.10 µg/l.

Minimum uranium concentration is found in Nagar panchayat Pali (0.031 µg/l) and maximum in Nonbirra village (140.10 µg/l). Uranium can cause gene mutation, kidney effect, cancer, and deformities in children and developing fetuses in this area.. For uranium-contaminated groundwater in this study area, the excess lifetime cancer risk varied from 2.30×10^{-6} to 3.97×10^{-4}. The HQ value of all samples collected was above the threshold value of Nonbirra1 (1.79), NonBirra2 (1.24), Gopalpur1 (1.79), Katghora1 (2.52) and Chhuri1 (1.19). 2.52 suggesting a high risk owing to chemical toxicity for Katghora1 were observed. Katghora1 and other sample spots which HQ was found to be greater

than1 which requires proper attention and remedial action are required in this area. Finally, it was concluded that Nonbirra1, Nonbirra2 Gopalpur1, Katghora1 and Chhuri1 there was excess lifetime cancer risk and chemical risk to humans, pets and animal kingdom due to uranium-contaminated water in this study area.

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