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A review of the effects of water containing Uranium on human health

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Abstract
Granite and other mineral deposits naturally contain uranium, a radioactive element. It infiltrates local water, air, and food supplies in different amounts through natural deposit leaching, mill tailings release, nuclear industry emissions, phosphate fertilizer dissolving, and coal and other fuel combustion. (Weir E. (2004) [14]. Water is essential to human life. In nature, it is also widely available. We have gathered four samples close to the Bikar Datia, for the examination. In the months of February, May, August, and November, water samples are being collected. A groundwater sample taken from drinking water supplies close to the Near Bikar Datia contained an extremely high quantity of Uranium, according to physiochemical research. As groundwater is the primary source of drinking water in both rural and urban India, as well as in many other regions of the world, uranium concentrations and contamination in groundwater are currently a topic of worry worldwide due to the serious health issues associated to them. This Research shows harmful effect of Uranium on human health.

Keywords: Radioactive element, mill tailings release, nuclear industry emissions, physiochemical research

Introduction

Uranium is a naturally occurring element that has been present on Earth since its formation around 4.5 billion years ago. It consists of three isotopes: 238U (99.28%), 235U (0.70%), and 234U (0.0054%), which are found in both living and non-living components of the environment. The presence and contamination of uranium in groundwater is a growing global concern due to its link to serious health risks for humans, as groundwater is the main source of drinking water in both rural and urban areas of India, as well as in many regions around the world. In India, uranium concentrations in groundwater from shallow aquifers in states like Punjab, Rajasthan, Karnataka, Telangana, and Madhya Pradesh vary from 0 to 1443 ng/ml, frequently exceeding the WHO's recommended limit for drinking water (30 ng/ml) in several areas. Numerous studies have identified a relationship between uranium exposure in drinking water and chronic kidney disease, lung cancer, and other major health problems (Zamora *et al*., 2009) [15].

Uranium is an element that occurs naturally and exhibits weak radioactivity, being present in various minerals. It is primarily utilized as fuel in nuclear power plants, although certain uranium compounds also serve as catalysts and pigments for staining (Berlin and Rudell, 1986) [2]. The average concentration of uranium in the Earth's crust is 2.8 µg/g with its presence predominantly in acidic magmatic rocks and within accessory minerals such as uraninite, monazite, and zircon (Sasaki *et al*., 2016) [12]. Uranium can be located in trace amounts within igneous, metamorphic, or sedimentary rocks, as well as in soils and waters, which include both terrestrial and oceanic sources. It readily oxidizes to produce several common uranium oxides and oxy-hydroxides, such as uraninite (or pitchblende) and schoepite (including meta- and para). Though the uranium content in sedimentary rocks is very low, compared to other shales or the average crust, black shales are commonly highly enriched in uranium, along with other redox-sensitive and/or sulphide-forming metals and metalloids, which can go up to 400 µg/g. The geology of an area is the most important factor in understanding its concentration in groundwater along with anthropogenic activities such as uranium mining, coal ash disposal from thermal power plants, and the use of phosphate fertilizers during agricultural practices. Uranium can be found in soils and waters due to the breakdown (weathering) of rocks and minerals containing it. Once it is in the soil and water, it can be taken up by plants and consumed by people or grazing animals, or it can dissolve in the water to be consumed by any other organism. Uranium is found in higher abundance in granitic materials and is nearly ubiquitous, due to its presence in different oxidation states such as U(IV) and U(VI), large atomic radius (0.97 Å), high chemical reactivity, relative more solubility of U(VI) compounds in aqueous solution and relative insolubility of U(IV) compounds. In an oxidizing environment the groundwater in fracture contains an appreciable amount of dissolved oxygen, this oxidizes uranium to hexavalent species, which is mobile and easily leaches into water and get transported. Under reducing conditions, uranium is reduced to its tetravalent U(IV) state leading to low concentration in water because of stabilization of the sparingly soluble mineral, uraninite. Hence, deeper groundwater would have low concentration of uranium because of more reducing conditions and less uranium solubility.

Typical range of uranium concentrations in groundwater, coal, fly ash, and a variety of common rocks along with average concentration in Earth's crust (modified after USGS,1997).

O_4^{2-}, F^-, and Sr show quite positive correlations in groundwater (Cho and Choo, 2019) [4]. The variability of the uranium concentrations in the groundwater samples is also due to variable degrees of evaporation, mineral weathering, and uranium contents of the host rocks. When uranium is leached into natural water, it can form complexes mainly with hydroxide and carbonate ions in the solution at neutral pH

(Langmuir, 1978) [8]. Though the main inorganic anions commonly present in water samples are HCO_3^-, SO_4^{2-}, Cl^-,

NO_3^-, NO_2^-, F^-, and HPO_4^-, in slightly alkaline conditions with pH between 7.9 and 9.0, the CO_3^{2-} anion is expected to be the most powerful ligand for UO_2^{2+} compared to other anions (Prath *et al*., 2009).

While the primary source of uranium is geogenic, anthropogenic factors such as uranium, coal, phosphate, oil, and gas mining operations, agricultural practices of using phosphate fertilizers, excess nitrate, and groundwater table decline may further enhance uranium mobilization.

Different sources of uranium are discussed in the following with suitable examples.

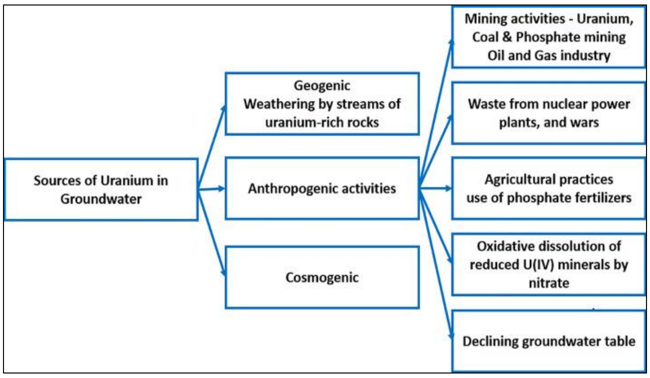
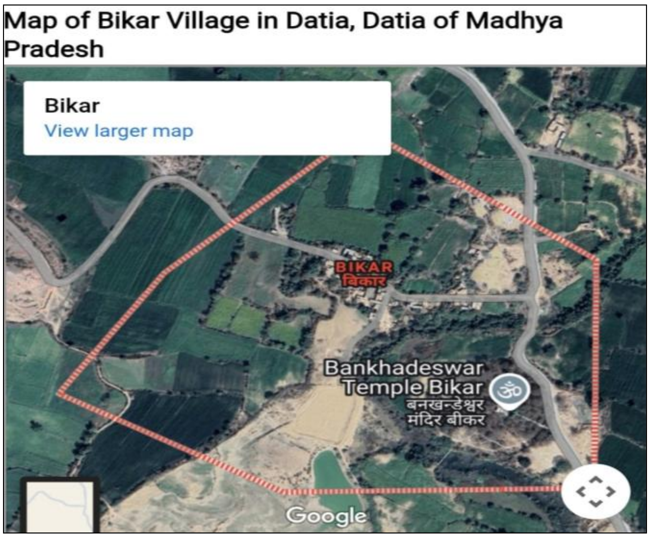


Fig 1: shows Sources of Uranium in Ground water

Research Methodology

1. Research Area,

Bikar Datia M.P (Bundelkhand Region)



Source: Google Map.com

Bikar is a village located in Datia tehsil of Datia district in Madhya Pradesh, India. It is situated 15km away from Datia, which is both district & sub-district headquarter of Bikar village. he village spans a total geographical area of 988.4 hectares, and the pin code of the locality is 475661.

1.1 Population of Bikar

According to the 2011 Census, Bikar has a total population of about 1,951, with approximately 1,053 males and 898 females. The sex ratio is around 852 females per 1,000 males. Children aged 0 to 6 years make up about 267 of the population, showing the young generation present in the village. There are about 561 members of the Scheduled Castes (SC), an important community in the village. The Scheduled Tribes (ST) population numbers around 2. The overall literacy rate is approximately 73.24%, with male literacy at about 80.91% and female literacy near 64.25%. There are around 402 households in the village. Together, these details offer a clear picture of Bikar's population size, gender balance, young residents, literacy levels, and social makeup.

2. Methodology

1.1 Chemical Properties of Uranium

Uranium is a silvery-white metal with atomic number 92. It has three main isotopes: U-238, U-235, and U-234.In water, uranium forms the uranyl ion ($UO2^{2+}$). The uranyl ion is highly soluble and mobile in water. This makes it easy for uranium to spread in aquatic environments.

Uranium can exist in several oxidation states, but +6 is most common in natural waters. This affects its behaviour and interactions with other substances.

Some areas have higher concentrations of uranium in groundwater than others. This variation is linked to the types of rocks and minerals present underground. Granite and other igneous rocks tend to contain more uranium than sedimentary rocks.

1.2 Collection of Sample: The water samples were collected from the hand pump and tap water in and around Bikar, Datia (M.P) and nearer areas. After filtration and preservation with acidification with HNO3 the water samples were stored in plastic bottles of polyethylene (250 mL).

1.3 Parameters which have Analysed

Parameter	Ideal Range (Drinking Water)
Temperature (°C)	Ambient (~20–30°C)
pH	6.5 – 8.5
ORD (Optical Reflectance Density)	—
DO (Dissolved Oxygen, ppm)	> 5 ppm (for clean water)

1.4 Uranium Detection method- - Uranium detection has done by Laser Fluorometer

Fig 2: (Image of Laser Fluorometer)

Result and Discussion

Table 1: Shows Various Physio-Chemical parameter Result in Bikar Datia Ground Water

Feb-Nov 2023						
TEMP.	**PH**	**ORD**	**DO (ppm)**	**µS(km)**	**TDS (ppm)**	**PSU**
22.80	7.83	144.20	1.11	811	404	0.36
25.90	7.71	149.60	1.12	812	406	0.36
24.70	7.61	153.10	1.14	811	405	0.36

1. Uranium Result

Table 2: shows total concentration of Uranium in ground water

Conc.In ppb	$\pm 1\sigma$
15.81	0.03

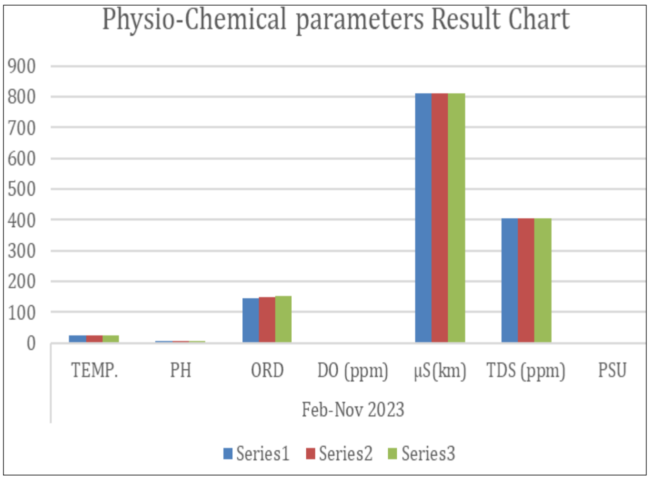


Fig 3: showing all parameters data chart of Table N0.01

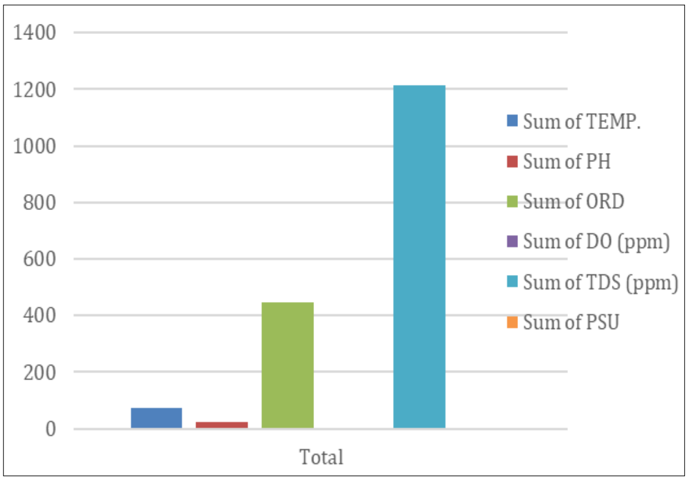


Fig 4: Pivot Chart and table for Table N0.01

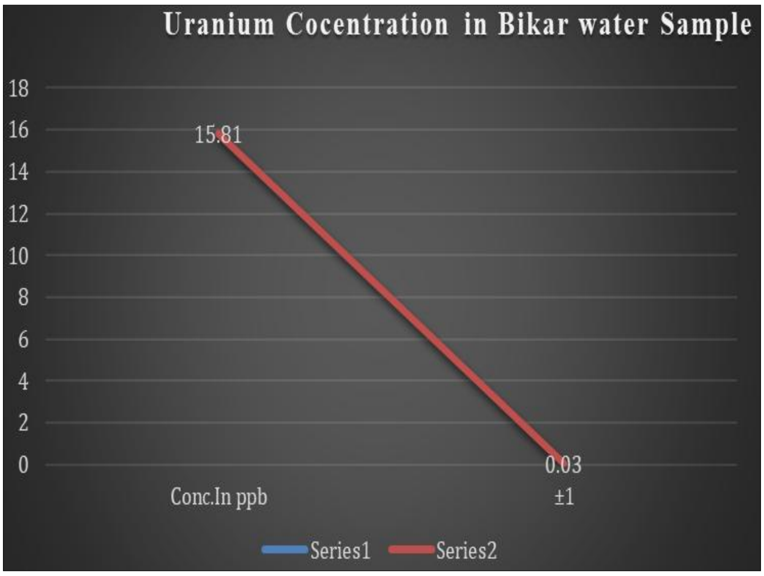


Fig 5: showing chart for table No.02

2. Parameter and data interpretation

Table 3: shows parameters which has been done with data interpretation

Parameter	Meaning	Ideal Range (Drinking Water)	Detected Values	Interpretation
Temperature(°C)	Affects chemical and biological activity in water	Ambient (~20–30°C)	22.8–25.9	Normal, slightly warm in summer
pH	Acidity or alkalinity of water	6.5 – 8.5	7.61–7.83	Neutral to slightly alkaline — safe
ORD (Optical Reflectance Density)	Indicates organic content or turbidity	—	144–153	Relatively high — could suggest organic or suspended matter
DO (Dissolved Oxygen, ppm)	Amount of oxygen in water — important for aquatic life	> 5 ppm (for clean water)	1.11–1.14	Very low — poor oxygenation, possibly polluted or stagnant water
EC (Electrical Conductivity, µS/cm)	Indicates total ion concentration (salts, minerals)	< 1000 µS/cm	~811	Acceptable — moderate mineral content
TDS (Total Dissolved Solids, ppm)	Indicates total dissolved inorganic matter	< 500 ppm (WHO)	404–406	Within safe limit
PSU (Practical Salinity Unit)	Measures salinity (0 for freshwater	0 – 0.5 for freshwater	0.36	Freshwater

pH, EC, TDS, and salinity are all within safe limits for drinking water.
Dissolved oxygen (DO) is very low (1.1 ppm)- indicates the water may be stagnant or organically polluted (bad for aquatic life, though not necessarily toxic for drinking if treated).
ORD values are relatively high → indicate organic contamination or turbidity.
water appears chemically safe for drinking (based on pH, TDS, EC), but low oxygen and high organic content suggest biological or organic pollution — it should be filtered and disinfected (e.g., RO + UV) before consumption.
Uranium found in water sample is 15.81 ppb (parts per billion). It means 15.81 micrograms of uranium per litre of water (µg/L).

3. Safety Limits for Uranium in Drinking Water-

Table 3: shows limits of Uranium concentration according to WHO, EPA, MCL

Organization	Safe Limit for Uranium in Drinking Water	Remarks
World Health Organization (WHO)	30 µg/L (30 ppb	Based on chemical (kidney) toxicity, not radioactivity.
U.S. Environmental Protection Agency (EPA)	30 µg/L (30 ppb)	Maximum contaminant level (MCL) in public water systems.
Maximum contaminant level (MCL) in public water systems.	30 µg/L (30 ppb)	Same as WHO recommendation.

- 15.81 ppb uranium is below the safe limit (30 ppb).
- So, it is considered safe for drinking water according to WHO, EPA, and BIS standards.
- Long-term exposure, even to moderate levels, can accumulate and stress the kidneys.
- If uranium levels rise above 30 ppb, the water should not be consumed without treatment.

4. Main uranium health effects

Natural and depleted uranium have the identical chemical effect on our body. The health effects of natural and depleted uranium are due to chemical effects and not to radiation. Uranium's main target is the kidneys. Kidney damage has been seen in humans and animals after inhaling or ingesting uranium compounds. However, kidney damage has not been consistently found in soldiers who have had uranium metal fragments in their bodies for several years. Ingesting water -soluble uranium compounds will result in kidney effects at lower doses than following exposure to insoluble uranium compounds. Workers who inhaled uranium hexafluoride have experienced respiratory irritation and accumulation of fluid in the lungs. However, these effects were attributed to the irritant hydrofluoric acid rather than the uranium. Inhaled insoluble uranium compounds can also damage the respiratory tract.

5. Uranium in the environment and its health effects

Uranium is present in the environment as a result of leaching from different types of rocks, minerals, uranium ore deposits, and soils, release from the mill tailings, emissions from the nuclear industry, the combustion of coal, and other fuels, and the use of phosphate fertilizers that contain uranium. Like cadmium, lead, and mercury, uranium has been identified as a nephrotoxin (Goodman, DR,1985) [7]. Also, uranium is among the top three harmful, naturally occurring groundwater contaminants along with arsenic and chromium. In addition to being toxic heavy metal, it is also a radioactive element and can cause several adverse health effects ranging from renal failure, diminished bone growth, and damage to the DNA when consumed in high quantities (Brugge *et al*., 2005) [3]. However, uranium's threat to human health comes more from its chemical rather than its radiological properties. Studies by Zamora *et al*. (2009) [15]. revealed that at higher intake levels of uranium through drinking water, the chemical toxicity would be a greater health concern than radio toxicity. Sometimes it becomes difficult to correlate the higher uranium concentrations to the health problems of the people consuming it in the locality. For example, despite very high concentrations of natural uranium in drinking water originating from drilled wells in Southern Finland, no clear clinical symptoms were observed among the exposed population which makes this even more complex issue (Prat *et al*., 2009) [11]. However, several studies indicated that long-term intake of groundwater containing >200 ng/ml may induce internal exposure to radiation as well as the effects of chemical toxicity (Shin *et al*., 2016) [13].

6. Uranium can enter the human body;

1. Through inhalation of gaseous and aerosol uranium,
2. Drinking water, food ingestion,
3. Dermal contact, and may cause health risks, since uranium is naturally present in the soil, surface and groundwater, and air, the primary exposure sources for non-occupationally exposed persons are dietary (especially root vegetables) and drinking water.

The exposure to uranium may rise in cases wherever potable water is obtained directly from geogenically affected groundwater sources or water sources contaminated by anthropogenic activities. Especially the people who work in the uranium mines are greatly affected. Chemical toxicity to kidneys, liver, and lungs can occur occasionally from high occupational uranium exposure leading to acute health problems including even kidney failure. In addition, reproductive and respiratory systems are also affected by uranium exposure (ATSDR, 2013) [1]. Besides uranium exposure, mine workers are exposed to radon gas which is also a radioactive material. In some areas, the maximum concentrations of uranium in private drilled wells can reach more than 200 times the WHO limit (Godoy *et al*., 2019) [6]. If the mine is located in upstream from the community, the uranium contamination problem can be very severe. Uranium is also an α-particle emitter, and many of its radioactive decay products, including radon as the uranium decay chain begin with ^{238}U culminates in ^{206}Pb. Alpha particles are bulky (2 protons and 2 neutrons) and cannot penetrate human skin, but when particulate matter containing α-emitters is inhaled or ingested, it results in internal exposure to radiation. For example, radon gas is responsible for up to 20% of cases of lung cancer in Canada (Dewar *et al*., 2013) [5].

Uranium can enter the human body through inhalation of gaseous and aerosol uranium, drinking water, food ingestion or dermal contact (Left), and induce health problems through impairing the kidneys, bones, liver, brain, lungs, and reproductive system (Right) (reproduced with permission from Ma *et al*., 2020) [10].

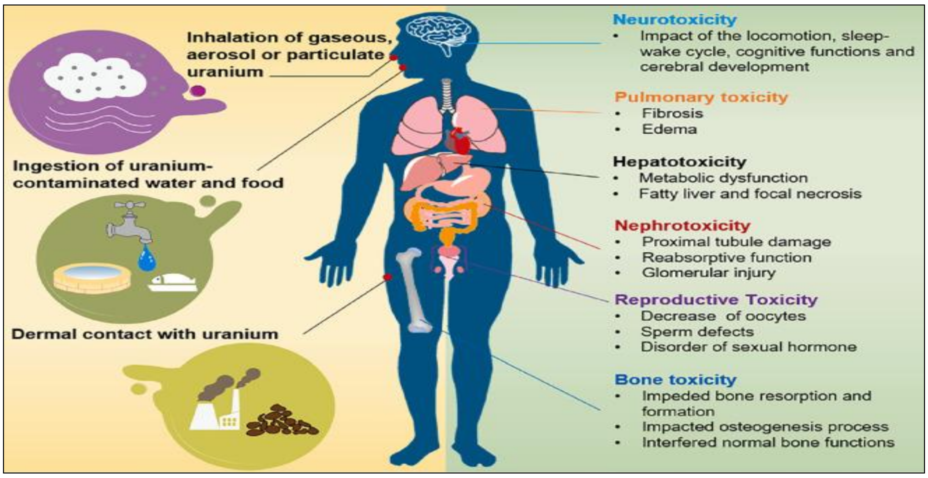


Fig 6: shows primary exposure routes and health risks of uranium

7. Toxic Effects on the Human Body

Table 4: shows toxic Effect of Uranium containing water consumed by people

System/Organ	Type of Toxicity	Effects
Brain & Nervous System	Neurotoxicity	- Affects locomotion, sleep-wake cycle, and cognitive functions - Impairs cerebral development
Lungs	Pulmonary Toxicity	Causes fibrosis (scarring of lung tissue) - Leads to pulmonary edema (fluid buildup)
Liver	Hepatotoxicity	Causes metabolic dysfunction - Leads to fatty liver and focal necrosis (localized tissue death)
Kidneys	Nephrotoxicity	Damages proximal tubules - Impairs reabsorption function - Causes glomerular injury (affecting filtration)
Reproductive Organs	Reproductive Toxicity	Reduces oocytes (egg cells) - Causes sperm defects - Disrupts sexual hormones
Bones	Bone Toxicity	Impairs bone resorption and formation - Disrupts bone growth (osteogenesis) - Affects normal bone function

Uranium can enter the body through inhalation, ingestion, or skin contact. Once inside, it travels through the bloodstream and affects various organs:

- Kidneys are the most sensitive to uranium toxicity.
- Lungs and liver are major targets after inhalation or ingestion.
- Brain, bones, and reproductive organs can also suffer long-term damage.

Conclusion

This research study shows that water which contains uranium particles is not safe for drinking and this water is harmful for our health and responsible for kidney diseases and other chronical disease. Uranium contamination in the aquatic environment is an emerging concern worldwide. With the development of the global economy, uranium contamination has gradually increased in recent years due to industrialization, agriculture practices, and overexploitation of groundwater resources. water appears chemically safe for drinking (based on pH, TDS, EC), but low oxygen and high organic content suggest biological or organic pollution — it should be filtered and disinfected (e.g., RO + UV) before consumption.

Methods to Remove Uranium from Drinking Water

Reverse Osmosis (RO)

Water is forced through a semi-permeable membrane that blocks large ions and molecules (like uranium), allowing only pure water to pass. This process Removes 90–99% of uranium from water. Very effective process Also removes other contaminants (fluoride, nitrates, heavy metals). *RO is the most common household method for uranium.* Maintain pH between 6.5–8.5 for best performance. RO + Activated Carbon filter combination is excellent for households. Always test water periodically to ensure uranium levels stay below 30 µg/L (30 ppb).

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