A Review: Natural Uranium Levels in Ground Water in India

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ABSTRACT

Since groundwater is the primary source of drinking water in rural and urban India as well as in many other regions of the world, uranium concentration and pollution in groundwater has become a topic of worry throughout the world due to the serious health consequences that can result. Uranium concentrations ranges from 0 to 1443 µgm/L in states Karnataka, Punjab, Telangana, Rajasthan and Madhya Pradesh in India. There have been reports of extremely high amounts of uranium concentration up to 1400 µgm/L in several regions of other nations, including the USA, Canada, Pakistan, Jordan, Japan, and Switzerland. Numerous natural factors, such as the geology of the rock layers, the chemistry of the water, and human-caused sources, such as uranium, phosphate rock and coal mining, nuclear action, the utilisation of phosphate fertilizers in farming, and the presence of too much nitrate in some areas, all have an impact on the amount of uranium in groundwater. Several crucial analytical methods, including Laser fluorimetry, Raman spectroscopy (RS), the use of inductively coupled plasma mass spectrometry (ICP-MS) and high-resolution ICPMS are described. The removal of uranium from drinking water using various physical, chemical, and biological techniques as well as different mitigation strategies are discussed. Examples of these strategies include bioremediation using biochar, adsorption by magnesium (Mg)-iron (Fe)-based hydrotalcite-like compounds (MF-HT) and nanoparticle technology.

***Keywords* - Uranium Concentration, groundwater, LED fluorimeter, laser fluorimeter**.

INTRODUCTION

Uranium, radon, and radium are the most frequently discovered radionuclides in drinking water. With an atomic mass of 238 and an atomic number 92, natural radioactivity exists in the element uranium that can be found in specific types of rocks. Water sources contain varying concentrations of uranium, which are dissolved by the water as it passes over and through rock and soil formations. The environment may also be exposed to uranium as a outcome of different human activities, including mining, combustion from coal and from phosphate fertilisers [1]. Uranium (^{238}U) is a toxic element so it is very harmful to our health. Uranium toxicity depends on different factors like solubility of particles, ways of elimination and exposure and contact time [2]. Mostly ^{238}U enters into human body by drinking water, which is 85% [3] and also from air and food which is 15% [4]. ^{238}U as nephrotoxin may harm the kidneys [5]. The evaluation of radionuclides in groundwater which is used for drinking becomes very important[6]. Because high concentration of radionuclides (Uranium) can cause serious health issues. Radon is a natural radioactive element which is produced during decay of ^{238}U, ^{235}U and ^{232}Th. The half-life of radon is 3.8 days, it has no colour or smell, and it behaves differently from air by 7.5 times. It is easily soluble in water [7].

Radon can enter our bodies through breathing radon-containing air and consuming radon-containing water. There are many ways that radon gas might escape from water sources and combine with the interior air, including dishwashing, cooking, bathing, washing clothes, and flushing the toilet [8]. Radon and its daughter product polonium-218 and polonium-212 enter into human body can cause lungs cancer [9]. So total inhalation threat of indoor radon is another outcome that is caused by radon in groundwater. According to research conducted every year, 21,000 lung cancer deaths in the USA are attributable to radon gas in homes. Radon levels in groundwater are typically 183 BqL-1 [10]. Knowing the concentration and of uranium in water, plants and soils is crucial for understanding how uranium affects human health. This article, shows the various aspects of uranium pollution in groundwater, its negative impact on human health and uranium concentration in different states of India as well as in several other places. Additionally, various analytical methods for finding uranium in water as well as some of the latest technology for removing uranium from water are presented.

SOURCESOF URANIUM

The element uranium is one that occurs naturally. A main source of uranium in groundwater is water rock interaction due to which uranium is extracted from rocks and mix with water. Abnormally high uranium level in groundwater is found in granite areas. Uranium in water is affected by presence of it in aquifer rocks, co_2 and oxygen present in aquifer. Ph value, temp, Water properties that evaluate their ability to dissolve different substances [11].

There are some anthropogenic factors also due to which uranium content in groundwater is increases, for example industrial, agricultural, coal mining and military activities. By improperly disposing of uriniferous tailing and garbage in the uranium mine area, water from uranium mining can get contaminated. Additionally, mine water is frequently released into the neighbourhood without being properly uranium-removed. Also discharge of waste water from phosphate rock mine, that containing toxic metals and uranium, into waterways is increasing uranium level in groundwater. In phosphate rock, uranium concentrations are typically 75 g/g. In India, agriculture provides the majority of the country's income, with over 60% of the land being utilised for this purpose. A large amount of fertilizer is used in agriculture due to which uranium is getting into agricultural soil and groundwater. In addition, mostly fertilizers increase leaching of uranium into groundwater and soil pH decline. Uranium accumulates in the soil that can mix with surface water and then moved up the food chain after being absorbed by plants.

URANIUM EFFECTS ON HUMANHEALTH

Uranium is both radioactively and chemically poisonous. Due to its chemical toxicity[12], it has harmful effect on kidney. Uranium enters into our body through water, food and the inhalation of uranium-containing aerosols and then enters the blood stream in kidneys then filter the blood containing uranium which could lead to renal cell damage. The impacts of uranium can be divided into two groups. A stochastic one, which is brought on by consumption of uranium at a level of 50 -150 mg and could lead to fatal acute renal failure. Another is non-stochastic, and it results from low levels (25 to 40 mg) of uranium intake that are estimated by the presence of proteins and urine containing decomposing cells. In this case, the kidney will improve on its own in a few weeks. Uranium produced radiations which cause many health issues in human being. Uranium mostly emitted isotopes is α-emitter which has minor penetrating power. An individual exposed to uranium has increased probability of cancer. In comparison of natural occurring health problem, a health problem due to radiation will occurs following years of exposure [13].

This study focuses on information regarding uranium enrichment in water samples from various regions of India. These water samples are collected from tube-wells and hand pumps from which water is directly used for drinking as well as for irrigation without receiving any appropriate care.

SUMMARY OF RESEARCH DONE IN INDIA

Numerous articles published in top academic journals worldwide discussed the work regarding the measuring of uranium level in water in various parts of India. Summary of that research or work is provided in table -1.

InHaridwar and Dehradun, districts of Uttarakhand, uranium conc. in ground water samples ranged from 0.35-27.53 μgm/L and 0.02-4.97μgm/L respectively which is measured by using inductively coupled plasma mass spectrometry (ICP-MS) techniques and LED fluorimetry [14].Uranium concentrationin both the district is within the WHO-recommended safe range.As safe limit recommended by WHO is 30μgm/L (WHO, 2011). By employing the ICP-MS technique, the uranium content in the Fatehpur district ranges from 4 to 40 μgm/L. According to observations, 83% of samples fall under the safe WHO guidelines [15]. The uranium content of water samples of Uttar Pradesh districts of Khalilabad, Gorakhpur, Maharajganj, and Kushinagar ranged from 0.02-64 μgm/L. 90% of the samples have readings under 30 μgm/L, which is within the WHO's recommended range. The levels of uranium in samples from Kushinagar, Maharajganj, and Khalilabad are all considerably below the safe threshold of 30μgm /L. 2% of the data exceed 60μgm/L the limit set by AERB (AERB 2004), but this is a very small percentage [16]. Uranium concentration in Bhatinda, Punjab were assessed by the fission track method is ranged from 1.65-74.98 μgm/L [17]. In Malwa and Ropar region of Punjab the amount of uranium in water samples from well and hand pump varied from 5.41-43.39 μgm/L and 1.93-20.19 μgm/L respectively which is measured by using fission track method [8,18].In Uranium concentration of water samples offour south- western areas Bathinda, Faridkot, Mansa and Firozpur of Punjab a large variation of 0.5-579μgm/Lhas been observed which is measured by laser fluorimetry method.

The greater concentration of uranium found in the ground water sample from SW-Punjab may be caused by uranium leaching from the region's industrial activity, basement granite-rich rock formation, and phosphate fertiliser use for agricultural purposes [3].

The uranium concentration in collected sample of Jind, Rohtak, Sonipat and Panipat four districts of Haryana is varies from 7.31 – 34.05 μgm/L, 6.97 – 37.84 μgm/L, 7.11 – 40.25 μgm/L and 7.95 – 39.43 μgm/L respectively, with an average of 17.91 μgm/. According to WHO (2011), the allowable level of 30 μgm/L was found to be exceeded in 18.6% of water samples. All water samples, however, are within the 60 μgm/L safe level established by the ACRB, India, in 2004 [19]. Uranium level of water of near Sohna Fault region, Haryana is measured using LED Fluorimetrywhich is varied from 0.10 – 223.16 μgm/. 15.67% samples were observed to be over 30 μgm/L. A fault line is an occurrence in nature that develops as a result of an earthquake or another type of internal ground movement. The greater amount of uranium is caused by its presence in the environment as a result of leaching through natural sources, the burning of coal as well as other fuels, industrial activity, and the use of phosphate fertilisers [20].Uranium concentration varied from 6.37 – 43.3 µgm/L in the groundwater samples of the districts Bhiwani, Hisar, Fatehabad & Sirsa of Haryana as measured by Fission track technique. 15% of collected samples were above the 30 µgm/L limit [21]. ICP-MS technology is used to measure the variations in uranium content, which range from 8.2-202.63 g/l in Sikar, 4.74-98.7 g/l in Hanumangarh, 10.75-81.3 g/l in Churu, and 4.42-133.0 g/l in Shri Ganga Nagar [22]. Water samples from northeast Rajasthan have uranium concentrations ranging from 0.89 to 166.89 gm/l. More uranium than 30 gm/l is present in 30% of the water samples that were analysed. Uranium concentration of northeast Rajasthan (Jodhpur, Nagpur, Bikaner, Jhunjhunu) is measured by using ICP-MS technique [23]. In Gujrat water samples are collected from Dohad, Ahmedabad, Vadodara& Patan district and their uranium concentration varies from 31.9-56.7 µgm/l [24]. The uranium content of water samples taken from all districts of Bihar varies from 1-80 µgm/l only 7% of samples exceed WHO safe limit [25].Uranium levelin water samples taken from different part of different states of India is also measured and the data is reported in table-1.

In table 2, it is listed how much uranium was found in water samples from different nations throughout the world.

Table 1- Showing uranium conc. of state of India.

State	City/town	Uranium concentration	Water source	Remark	Technique/method	Reference
Uttarakhand	Haridwar	0.35-27.53	ground water	Within safe limit of WHO	LED fluorimetry	14
	Dehradun	0.02-4.97	ground water	Within safe limit of WHO	ICP-MS	
Uttar Pradesh	Fatehpur District	4-40	ground water	17% samples exceed WHO limit	ICP-MS & LSC	15
	Kushinagar Gorakhpur Maharajgar Khalilabad	0.02-64	ground water	10% samples above WHO limit	Laser fluorimetry	16
Punjab	Bhatinda	1.65-74.98	ground water		Fissiontrack technique	17
	Malwa	5.41-43.39				18
	Ropar	1.93-20.19				8
	Four districts Of south-west Punjab	0.5-579	ground water	68% samples are above WHO limit	Laser fluorimetry	3
Haryana	Jind Rohtak Sonipat Panipat	7.31-34.05 6.97-37.84 7.11-40.25 7.95-39.43	Handpump tube-well & submersible	18.6% samples exceed WHO limit	LED fluorimetry	19
	Nearby Sohna Fault region	0.10-223.16	ground water	15.67% samples above WHO limit	LED fluorimetry	20
	Bhiwani, Sirsa, Hisar, and Fatehaba district	6.37-43.31	ground water	15% samplesabove WHO limit	Fission track technique	21
Rajasthan	Sikar district	8.20-202.63	Drinking Water	25% samples exceed WHO limit		22
	Hanumangarh	4.74-98.7	ground water	Higher than WHO limit	ICPMS	
	Churu	10.75-81.3			ICPMS	23
	Shree Ganga Nagar	4.42-133.0			ICPMS	
	Northeast Rajasthan	0.89-166.89	Drinking water	Higher than WHO limit.	ICPMS	24
Gujarat	Dohad, Vadodara, Ahmedabad, and Patan districts	31.9-56.7	ground water	These areas are impacted in part by the high uranium concentration.		25
Bihar	Representative	<1-80	ground water	7% values exceed	ICP-AES	26

	sites across all districts (273)			WHO limit		
Himachal Pradesh		0.56-10.11	ground water	within WHO limit	ICP-MS	27
	Kulu	0.3-2.5	ground water	within WHO limit		14
Madhya Pradesh	1191 samples	233.91	ground water	Districts with high uranium concentrations include Balaghat, Datia, Betul, ChhatarpurGwalior, Jhabua, Seoni, Raisen, Shivpuri and Panna.		25
Maharashtra	Aurangabad district	0.01-16.6	ground water	Within WHO limit	LED Fluorimeter	28
Tamil Nadu	Central Tamil Nadu	1.75-46.70	ground water			29
	Tiruvannamalai	0.2-25.8	ground water	below WHO limit	LED Fluorimeter	30
Telangana	Hyderabad	3.03 21.00	Drinking water ground water	below WHO limit Within WHO limit	ICP-MS	31
	Peddagattu and Seripally, Nalgonda district	0.6-521.15	ground water	43% samples exceed WHO limit	Laser Fluorimeter	32
	Hyderabad Secundrabad	0.60-82.6	Ground water	65% samples exceed WHO limit	Laser Fluorimeter	33
West Bengal	Nadia district	0.21-20.9	110 ground water samples	Within WHO limit	Laser Fluorimeter	34
Jharkhand	Jaduguda, Uranium mining area	0.03-11.6	Ground Water	Within WHO Limit	Laser Fluorimeter	43
Andhra Pradesh	Tummalapalle Uranium Mining area,	2.0	19 ground water samples	Within WHO guidelines, but two samples located in more remote body locations revealed that the limit was exceeded	LED Fluorimeter	35
	Kadapa district	0.38-79.70	106 ground water samples	15% samples above WHO limit	LED Fluorimeter	36
	Visakhapatnam	0.6-12.3	ground water	Within WHO limit	Laser Fluorimeter	37
Assam	Nalbari district	0.3-7.1 0.6-10.3	ground water (pre-monsoon) (post-monsoon)	U may have been released from soil sediments during the rainy season, which explains why post-monsoon had a higher concentration of U.	LED Fluorimeter	38

Chhattisgarh	Balod district	0.56-23.42	ground water	Except for one sample from the village of DeurTarai (78.93), all 31 readings fall inside the WHO limit.	Laser Fluorimeter	39
Karnataka	Kolar district	0.3-1442.9	ground water	21.8% samples exceed the permissible limits	ICP-MS	40
	Bangalore	0.2-770.1	ground water	18.9 (mean)	Laser Fluorimeter	41
Kerala	Five districts (830 samples)	<0.5-12.54(pre-monsoon) <0.5-5.93(post-monsoon)	Drinking water sources	Below WHO limit	Fluorimetry Technique	42
Delhi		2.2-20.8	ground water	Below WHO limit		14
Jammu and Kashmir		0.2-20.8	ground water	Below WHO limit		14

Table 2 – Showing uranium concentration in some country of the World.

Country	Uranium concentration	Reference
Turkey	0.24-17.65	
New York, USA	0.03-0.08	48
Utah, Arizona, Mexico, USA	<5-560	49
Argentina	0.04-11	50
Jordan	0.04-1400	45
Kuwait	0.02-2.48	51
South Greenland	0.5-1	41
Quebec, Canada	1-845	53
Japan	0.13-590	54
Russia	0.01-61	44
Switzerland	0.05-100	55
North India	0.18-645.22	46
Sindh and Punjab, Pakistan	0.1-556	56

REGULATORY LIMITSOF URANIUM BY DIFFERENT HEALTH AGENCIES

Different health agencies haveset different safe values of uranium. According to WHO and U.S.E.P.A. safe value of uranium concentration is 30 µg/L[52,57]. AERB, Atomic Energy Regulatory Board, Mumbai, India, has recommended safe limit of 60µg/L [58] while 9 µg/L suggested by UNSCEAR, United Nation Scientific Committee on the Effects of Atomic Radiation [59].

METHODOLOGY FOR MEASUREMENT OF URANIUM

There are various methods for finding uranium in groundwater. The following list includes among the most widely used modern analytical methods for determining the content of uranium in water samples:

A. **Laser fluorimetry:** laser fluorimetry technique is based on the principle of exciting the uranyl radical or ion in the water sample by using EM light of appropriate wavelength and measure the uranium phosphorescence with time after the removal of incident electromagnetic radiation. In this technique some fluorescence – enhancing reagent like polyphosphates is adding in the water sample containing low uranium concentration that will increase initial quantum yield. Depending on the composition of absorbing species present in the water, one should choose a fluorescence-enhancing reagent [60].

B. **LED fluorimetry:** The concept behind this procedure is to measure the groundwater uranium complex fluorescence. One can determine the quantity of uranium in ground water using a photomultiplier tube (PMT) when UV (Ultra Violet) light with the right wavelength strikes a uranium complex. Depending on the intensity of the UV light, the uranium complex is energised, it exhibits measurable green fluorescence [23].

C. **Inductively coupled plasma mass spectrometry (ICP-MS):** This method for detecting uranium in water is among the most precise and quick ones. With the help of this technique, we can accurately measure Various elements, including uranium, can be found in water samples. Balaram provides a comprehensive explanation of this approach.

D. **Inductively coupled plasma optical emission spectrometry (ICP-OES):** This technique is founded on the principle of optical emission spectrometry. In this method plasma energy is given to analysis water sample and spectrum is obtained from the given sample. This spectrum will givethe data of the uranium content in water. This is one of the most versatile methods for inorganic analysis [60].

E. **Raman spectroscopy:** this is the powerful analytic method for chemical characterisation of water. Intensity of uranyl band gives the information about content of uranium in water samples.Other methods, such as Fission track technology and high resolution inductively coupled plasma mass spectrometry, are also available for measuring the presence of uranium in water.

REMEDIAL STRATEGIES

Intake of uranium above the safe limit has harmful effects on human health, so it is necessity to control or remove the high contaminants of uranium and other toxic elements from groundwater. Mitigation strategies depends on uranium speciation, water composition and the presence of other contaminants. There are methods for removing uranium from water that fall under the physical, chemical, and biological categories. Techniques falling within the physical categories of reverse osmosis (RO), coagulation, adsorption, and evaporation. When used at the community level, reverse osmosis is expensive. Precipitation, co-precipitation, defluoridization, ion exchange, and adsorption are examples of chemical methods. According on how the adsorbent and adsorbate interact, the physicochemical process of adsorption can be either chemical or physical. Bioremediation includes biochar, microbial, and phytoremediation. These natural cures work well with water that has less uranium in it. Phytoremediation method is a viable choice for treating large regions of soils with low concentrations of uranium. For the absorption or elimination of uranium from water-based systems, developed a graphite absorbent. Some method for remediation of uranium from drinking water are discussed below: -

Uses of Biochar for the elimination of contaminants including uranium content from water is low-costtechnique. Carbon-rich Biochar was created when biomass, including wood, dried grass, hay, and coconut waste, thermally degraded (at low temperature around 700oC). Pyrolysis is the term for the process of creating biochar from biomass that has been thermally degraded while using a constrained amount of oxygen. Depending on the area of the surface, distribution of pore size, and the dimension of the molecules to be extracted, biochar is capable of extracting uranium from water. There is numerous research now being conducted on the use of biochar for the removing lead and uranium from soil and water.

Magnesium(Mg) and Iron(Fe) based hydrotalcite compound (MF-HT), which have double-layered hydroxide structure can absorb uranium and other element through anion exchange, so these are effectively uses for cleaning out uranium from water.In order to reliably and effectively separate uranium from small scale sources including groundwater, uranium tailing effluent, and seawater, nano particle technology can be applied. In situ electrolytic implantation technique for removing uranium from water was recently disclosed by Graphene oxide foam (3D-FrGOF), which serves as both a catalyst for the reaction of hydrogen evolution and a substrate for the uranium deposition in this approach, is used as the working electrode. The foam made of graphene oxide attracts uranium and can hold large quantities of it. Foam made of graphene oxide can be reused and recycled [60].

CONCLUSION

Uranium concentration in groundwater of some regions in the country is raised due to the factors such as presence of granite-rich rock, industrial waste that is dumped directly into waterways and the widespread use of phosphate fertilisers in agriculture. The amount of uranium in the water supply needs to be checked and drinking water sources with high uranium concentrations need to be cleaned up to lower the concentration before being supplied for drinking. For the detection of uranium there are various techniques among which LED fluorimetry, Laser fluorimetry and ICP-MS are more popular and gives exact results. The data presented in this study ought to be helpful for the identification of areas of high uranium concentration, so the desirable steps can be taken to remove the high uranium contaminant from the water. In summary, concentration of uranium and other toxic element like arsenic, lead and cadmium in groundwater and its detrimental impacts on human well-being and mitigation measures in various regions of India and the world are still a developing field of study.

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