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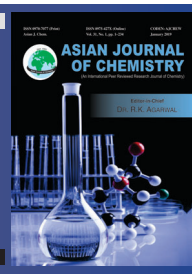

REVIEW

Uranium Levels in Groundwater of North India

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Ionizing radiations are continuously exposed to human being. Natural radionuclides are available in different amount in environment. Uranium is found everywhere in water, rocks, soil and building material. Ground water is the main source of drinking water. So it becomes important to review the water quality of north India in view of uranium. Uranium is inhaled through drinking water in human body. In this regard, an extensive data has been compiled and reviewed in this article from North India and compared with safe limits from worldwide data. The majority of the reported articles are about monitoring of uranium concentration in water samples. Most of the reported data have been obtained using Fission track technique, ICPMS, laser fluorimetery and LED fluorimetery.

Keywords: Uranium, Annual effective dose, Radiations, Radon, Chemical toxicity.

INTRODUCTION

Background radiations are due to natural radioactivity which exists everywhere since the creation of the earth. Uranium (^{238}U) and its decay product radon (^{222}Rn) are two natural radioactive materials which can cause health issues if found in excess content in groundwater. Radiological and chemical health hazards to human being by ^{238}U is present in almost all rocks, soils. Water passing through and over rock and soil formations dissolves many minerals and compounds, including ^{238}U; so different amount of it are found in some sources of water. The average value of ^{238}U in the earth crust is 2.7 ppm [1] and it is very harmful because of its toxicity rather than its radioactivity. The toxicity of uranium depends upon the solubility, ways of elimination, solubility of particle, contact time and way of exposure [2]. ^{238}U enters into human body mostly by drinking of groundwater [3], through air or food in which 85 % uranium enters through water and 15 % due to food [4]. Uranium has been identified as a nephrotoxin which may cause kidney damage [5]. Because high concentration of uranium in groundwater may lead to health issues, so the measurement of ^{238}U concentration becomes very important for health risk assessment. If a human body is exposed to dissolve natural uranium approximate 0.1 mg kg^{-1} weight of body, it can result in serious chemical hazards to lungs and kidneys [6]. Radon is a naturally occurring radioactive with half life of 3.8 days which is colourless, odourless and heavier than air (7.5 times). It is highly soluble in water and its presence cannot be felt during its consumption. It is produced by the decay of radionuclides [7] such as ^{238}U, ^{235}U and ^{232}Th. Activity of ^{222}Rn is different in groundwater and surface water. ^{222}Rn value in groundwater depends upon the concentration of uranium in adjacent rocks whereas in surface water its concentration is very low mainly in water bodies used as drinking water sources [8]. Radon enters into the human body through inhalation (breathing of household water containing radon) and ingestion (drinking water containing radon). Radon gas comes out of water source and mixes with the indoor air in many ways such as washing clothes, bathing, cooking, dish washing and flushing toilets [9]. When radon is inhaled by the living beings, its daughter products, especially polonium-218 and polonium-212 attached to aerosols present in ambient air, constitute a significant radiological hazard to human lungs resulting in lung cancer [10]. Thus, the total inhalation risk due to indoor radon

is also contributed by groundwater radon. Although, groundwater radon is not associated directly to health issues. According to studies in USA, radon gas present in home caused 21,000 deaths per year due to lung cancer. A world average value of ^{222}Rn in groundwater [11] is about 183 Bq L^{-1}.

Uranium is a radioactive element with long half lives which is radiological as well as chemically toxic [12]. In order to know the health effect of uranium on population, it becomes important to know the transfer and distribution of ^{238}U in water, soil, plant and in soil which is used for agriculture purpose. Uranium and other heavy metal impurities may accumulate in the soil and be leached into ground and surface water where they can be taken up by plants and transferred into the food chain. The value of ^{238}U in water mainly influenced by the presence of its in aquifier rock, CO_2, complex agents and oxygen present in the aquifier. Temperature, pH, rate of flow, value and characteristics of dissolved salts and residence time gives the information about the characteristics of water that estimate its capacity to dissolve, carry or deposit elements [13].

Uranium in drinking water is hazardous to health because of its chemical toxicity. Kidney toxicity is the result of uranium chemical toxicity. Uranium enters the bloodstream through food, breathing of aerosol containing uranium then kidneys filter the uranium compounds due to which kidney cells may get damaged. There are two types of affect of uranium, one is stochastic and another is non-stochastic affect. If an individual intake of uranium is about 50 to 150 mg, it may result to acute failure of kidney and even death. Non stochastic risk may arise due to intake of low level about 25 to 40 mg which can be estimated by protein existence and dead cells in the urine and at this stage the kidney recover itself after a several weeks [14].

Uranium produces many health issues in human beings due to exposure to radiations produced from uranium. Most of the isotopes of uranium are α-emitter which has small penetrating power. Through ingestion or inhalation process, uranium compounds enter into human being and produces radiation hazards. However, workers in the region where the uranium storage is high or processing unit are exposed to outdoor radiations of low level from daughter products of uranium. An individual exposed to uranium at the handling and processing unit and radiation may produce health hazards and increased probability of cancer during their life time. A health hazard from the radiations is different from the natural occurring health issues because it happens after many years of exposure. Uranium intake increases the probability of health hazards due to radiations [14].

This paper focuses on the data on uranium in water samples of North India. The main sources of water *i.e.* handpumps, borewells and tubewells are used for drinking purposes as well as irrigation purposes in the North India without any proper treatment.

Summary of the studies conducted in North India

The work concerning measurement of uranium in water of North India and number of articles appeared in international research journals. Table-1 provides summary of the studies of uranium in water of North India [15]. Kullu area of Himachal Pradesh region contained uranium concentration in water samples, which varies from 0.56 to 2.63 µg/L. The uranium concentration in water samples of hand pump and tubewell varied from 1.65 to 74.98 µg/L in Bathinda, Punjab using fission track method [16]. A weak positive correlation has been observed between the concentration of uranium and heavy metals of Pb, Cd and Cu in Bathinda, India.

Uranium concentration in Malwa region of Punjab [17] were measured using fission track technique and varied from 5.41-43.39 µg/L. The uranium concentration in water samples collected from hand pump and natural sources and well of Ropar, Punjab and Upper Siwallik area of Haryana found the

TABLE-1
LIST OF STUDIES CONDUCTED FOR THE URANIUM CONCENTRATION WATER SAMPLES OF NORTH INDIA

Locations	Uranium conc. (µg/L)	Water source	Technique	Ref.
Kullu	0.56-2.63	Handpum	Fission track technique	[15]
Bathinda	1.65-74.98	Hand pump and tub well	Fission track technique	[16]
Malwa Region	5.41-43.39	Handpump	Fission track technique	[17]
Upper Siwallik	1.08-19.28	Handpump, well	Fission track technique	[18]
Ropar	1.93-20.19	Handpump, well	Fission track technique	[18]
Western Haryana	6.37-38.43	Hand pump, tub well	Fission track technique	[19]
Hanumangarh, Rajasthan	4.74-98.7	Hand pump	ICPMS	[20]
Shri Ganga Nagar, Rajasthan	4.42-133.0	Hand pump	ICPMS	[20]
Churu, Rajasthan	10.75-81.3	Hand pump	ICPMS	[20]
Sikar, Rajasthan	2.54-28.38	Hand pump	ICPMS	[20]
Uttar Pradesh	0.20-64.0	Drinking water	Laser fluorimetery	[21]
Kathua	0.26-21.92	Drinking water	Laser fluorimetery	[22]
Kangra	0.64-19.23	Drinking water	Laser fluorimetery	[22]
Hamirpur	1.66-29.5	Drinking water	Laser fluorimetery	[22]
Jammu	0.18-20.8	Groundwater	LED fluorimetery	[23]
Mansa	5.9-645.22	Hand pump	LED fluorimetery	[24]
Bathinda	7.9-323.93	Hand pump	LED fluorimetery	[24]
Faridkot	7.62-375.85	Hand pump	LED fluorimetery	[24]
Jind	7.31-34.05	Hand pump, tub well and submersible	LED fluorimetery	[25]
Rohtak	6.97-37.84	Hand pump, tub well and submersible	LED fluorimetery	[25]
Sonipat	7.11-40.25	Hand pump, tub well and submersible	LED fluorimetery	[25]
Panipat	7.95-39.43	Hand pump, tub well and submersible	LED fluorimetery	[25]
Mahendragarh	0.56-57.53	Groundwater	LED fluorimetery	[26]

variation from 1.93 to 20.19 and 1.08 to 19.28 µg/L, respectively using fission track technique for the calculation of uranium in water samples [18]. The negative correlation between radon and uranium concentration in the Ropar, Punjab and Upper Siwallik area of Haryana [18]. We used Fission track registration technique [19] and also used for evaluating the uranium concentration in water sample of western Haryana. Uranium concentration in Western Haryana varied from 6.37 to 38.43 µg/L.

The uranium concentration in Hanuman Garh district varies from 4.74 to 98.7 µg/L and Shri Ganga Nagar District from 4.42 to 133.0 µg/L, Churu district from 10.75 to 81.3 µg/L and Sikar district varied from 2.54 to 28.38 µg/L used inductively coupled plasma mass spectrometry (ICPMS) for the measurement of uranium in water [20]. Parameters for radiological effect of uranium such as annual effective dose, commutative dose and life time stochastic health effect in Rajasthan was within safe limit [20].

Uranium concentration in water of Uttar Pradesh was 0.20 to 64.0 µg/L. Laser fluorimetery has been used by authors for the measurement of uranium in water in Uttar Pradesh [21] and in Himachal Pradesh [22,23] Jammu area has been analyzed for the point health effect of uranium of the population and the concentration of uranium from 0.18 to 20.8 µg/L. The value of uranium concentration in water samples of Mansa, Bhatinda and Faridkot district of Punjab and values were 5.9 to 645.22, 7.9 to 323.93 and 7.62 to 375.85 µg/L, respectively [24].

Light emitting diode fluorimetery technique has been used by our group [25] for calculating the uranium concentration collecting from hand pump, submersible and well water from the four district of Haryana *viz.* Jind, Rohtak, Sonipat and Panipat. Uranium concentration in water samples in Jind, Rohtak, Panipat and Sonipat districts varied from 7.31 to 34.05, 6.97 to 37.84, 7.11 to 40.25 and 7.95 to 39.43 µg/L, respectively. The radiological parameters were below the safe limit which give the information about the health effect of uranium on population of study area. Whereas uranium concentration in water of Mahendergarh [26] district of Haryana, ranged from 0.56 to 57.53 µg/L.

Many health agencies have prescribed the safe value of uranium in drinking water such ICRP-30, 1979 [27] has recommended this value as 1.9 µg/L while 9 µg/L suggested by UNSCEAR [28]. WHO [5] and U.S.E.P. [29,30] have suggested 30 µg/L of uranium in water as the safe limit. AERB [31] has recommended safe limit of 60 µg/L in water samples.

In uranium rich zones, uranium concentrations higher than 30 µg/L are generally observed in water samples. HHPG region which is present in Bhiwani district may be the one of the region of high radioactivity in groundwater. Kochhar has already reported high heat producing in granite rocks of this area [32]. In some region of Haryana have high uranium concentration such as Sonipat district because of presence of Sohna fault line in the region and this region famous for agriculture. For the agriculture, most of the farmers used phosphate riched fertilizers which increased the concentration of uranium.

The uranium levels in a number of drinking water samples from northern Rajasthan cross the recommended values. This may be attributed to the geological formations of the study area due to the influence of the Aravali hills present in some areas of Rajasthan. From the results, the highest value of uranium was in Mansa and Bhatinda district of Punjab which is famous for radioactivity in soil and indoor. This region is famous for agriculture and use of phosphate fertilizers enhance the concentration of uranium in water. In this region there are many industries and thermal power plants which increase the uranium concentration in Bajwa *et al.* [3]. SW Punjab is the famous for agriculture and mostly farmers used extensive concentration of bicarbonate and phosphate [33], may be reason for high concentration observed in groundwater samples SW-Punjab region which may be because anthropogenic activities. Bathinda region of Punjab is well known for oil refinery, thermal power plants and fertilizer plants which may increase the value of uranium in groundwater. Leaching of uranium from soil also increases with increase in salinity (TDS) and high level of TDS has been reported in this region [3]. Carbonate and phosphate ions form complexes with total dissolved ^{238}U concentration as compared to carbonate, phosphate free water [34]. Phosphate rocks are used for making the fertilizers due to which uranium is high in fertilizers. Thus urbanization and wide spread use of pesticides/fertilizers are mainly the reason of increased uranium concentration. Most of the cancer cases have been reported in this region and which may the effect of uranium on the population. From the results it has been reflected that uranium in water may be depend upon the geology and geographical conditions of the region. Uranium concentration is highest in Punjab and Haryana as compare to other state of north India. These two states used the most of fertilizers for farming. Study revealed that uranium in the water may be increased by using of phosphate fertilizers. Shiwalik Hills and Arravali Hill also effected the concentration of uranium in water and may be the region of high uranium concentration in some locations of study region. The outcomes of the review is that uranium concentration varies according to depth of water source [24].

In the work reported so far for north India, emphasis has been placed on the health hazards associated with the inhalation of uranium from water. Besides measurements of uranium in water, limited data are also available for North India. Most of the studies related to uranium have been conducted using SSNTD. However, in several reported studies; ICPMS and LED fluorimetery technique has been used. The reported values for uranium show a wide variation in the uranium of interest in different types of sources of water. However, work in this area is scarce and requires further research. According to the reported data, uranium is present in water at relatively low concentrations and is within the permissible limits and thus does not pose a serious threat to the public. The lowest reported uranium concentration is 0.18 µg/L for Jammu whereas the highest is 645.22 µg/L for Mansa Region of Punjab. All the reported values of uranium in water of Jammu and Himachal Pradesh are within recommended limits and do not pose a serious threat to the population of North India. Some samples of Punjab and Haryana state shows the uranium concentration in water very high as compared to recommended limits. Data is compared with worldwide studies is given in Table-2. Highest value of uranium in water samples of North India is very high

TABLE-2
URANIUM CONCENTRATION IN WATER SAMPLES OF SOME PARTS OF WORLD

Country	Uranium conc. (µg/L)	Average value of uranium conc. (µg/L)	Ref.
Turkey	0.24-17.65		[35]
New York	0.03-0.08		[36]
USA		2.55	[37,38]
Argentina	0.04-11.0	1.3	[39]
Jordan	0.04-1400	2.4	[46]
Kuwait	0.02-2.48		[40]
South Greenland	0.5-1.0		[45]
Amazonas (Brazil)	0.01–– 1.36		[41]
Southwestern Sinai (Egypt)	328-560		[48]
Northern Greece	0.01-10		[42]
Russia	> 477		[49]
Ulaanbaatar (Mongolia)	<0.01-57		[43]
Switzerland	0.05-92.02		[44]
North India	0.18-645.22		Present work

as compare to Turkey [35], New York [36], USA [37,38], Argentina [39], Kuwait [40], Amazonas (Brazil) [41], Northern Greece [42], Ulaanbaatar (Mongolia) [43] Switzerland [44] and South Greenland [48] while less than Jordan [46,47], Southwestern Sinai (Egypt) [48] and Russia [49].

Conclusion

To conclude, reported data focused on estimation of uranium in water for north India have been compiled in this paper. The results represented by various researchers shows that there are changes in value of uranium according to different sources. This may be due to local geology and geographical conditions of region. Most of the studies used SSNTD, whereas in some studies ICPMS, Laser fluorimetery and LED fluorimetery used. High uranium concentration has been reported 645.22 µg/L in Mansa, Punjab, India. All the reported values of uranium in water of Jammu and Himachal Pradesh are within recommended limits and do not pose a serious threat to the population of North India. While the some samples of Punjab and Haryana state show the uranium concentration in water very high as compared to recommended limits.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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