Assessment of Cancer Mortality Rates and Morbidity Rates due to Uranium Content in Water for Doaba Region of Punjab

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Abstract **- The uranium concentration values were measured in drinking water samples belonging to different villages/towns of Doaba region of Punjab, India using Laser induced fluorimetry technique. The Radiological risk (carcinogenicity) associated with uranium were estimated to assess the health risks to the residents of the study area. The activity concentrations of uranium in all drinking water samples were found to range from 2.69 μgl^{-1} to 10.25 μgl^{-1} with an average value of 5.98 μgl^{-1}. The radiological risks for cancer mortality risk were found to be low, typically ranging from 8.65×10^{-6} to 3.29×10^{-5}, while that of the morbidity risk ranged from 1.32×10^{-5} to 5.03×10^{-5}.**

Keywords **- Uranium, Laser Fluorimetry, Radiological Risks, Mortality Rate, Morbidity Rate**

I. INTRODUCTION

Natural radiation is the largest contributor to the external dose of the world population .Natural uranium contains 0.7 % uranium-235, 99.3 % uranium-238, and a trace of uranium-234 by weight. In terms of the amount of radioactivity, approximately 2.2 % comes from uranium-235, 48.6 % uranium-238, and 49.2 % uranium-234. Naturally occurring heaviest radioactive toxic element uranium is found in traces in almost all types of rocks, soils, sands and waters. Human beings always experience exposure to certain amount of uranium from food such as root vegetables, and water will provide us with small amounts of natural uranium and we breathe in minimal concentrations of uranium with air. Natural levels of uranium produce no harmful radiation effects, however chemical effects may occur after the uptake of large amounts of uranium and these can cause health effects such as kidney disease. When people are exposed to uranium radionuclides that are formed during the radioactive decay for a long period of time, they may develop cancer. While uranium itself is not particularly dangerous, some of its decay products (viz. ^{226} Ra and ^{222}Rn) do pose a threat, especially radon. Radon (^{222}Rn) is a radioactive, colorless, odorless, tasteless noble gas, occurring naturally as the decay product of radium (^{226}Ra) the fifth daughter product of Uranium (^{238}U). Radon has three isotopes viz. ^{222}Rn (radon) ^{220}Rn (thoron) ^{219}Rn (actinon) which are the immediate daughter products of ^{226}Ra, ^{224}Ra and ^{223}Ra respectively. Among these ^{222}Rn is the most stable isotope. ^{222}Rn, decays with a half-life of 3.82 days into a series of short-lived daughter products out of which ^{218}Po and ^{214}Po emit high-energy alpha particles which are highly effective in damaging tissues. It has been estimated that radon and its progenies constitutes more than 50% of the dose equivalent received by the general population from all sources of radiation, both naturally occurring and manmade [1],[2].

The isotope of ^{238}U occurs with a natural abundance of 99.28%, ^{235}U occurs with a natural abundance of .71%, and ^{234}U occurs with a natural abundance of .0058%. Uranium is prevalent to some degree in all common types of rock and soil. Common rock types contain concentrations of uranium in the range of .5 ppm to 4.7 ppm. These concentrations, however, do not only just refer to ^{238}U itself, but also to the daughter products inherently contained in the uranium decay chain. .

The water-solubility of a uranium compound determines its mobility in the environment, as well as its toxicity. The two main valence states of uranium that are stable in geological environments are the uranous (U^{4+}) and uranyl (U^{6+}) states. Uranous is essentially insoluble. Uranium transport generally occurs in oxidizing surface water and groundwater as the uranyl ion (UO_2^{2+}), uranyl fluoride, uranyl carbonate complexes, or uranyl phosphate. The presence of uranyl phosphate results in prevalent concentrations of uranium in phosphate fertilizers. In addition, this radionuclide is present in food and human tissues. The annual intake of uranium from all dietary sources averages approximately 320 pCi (13 Bq). The intake of 320 pCi of uranium will result in the committed energy release of 11000 MeV of ionizing radiation over a 50 year period.The Uranium concentration in groundwater depends on lithology, geomorphology and other geological conditions of the region. In groundwater uranium is present both in dissolved and particulate form due to minerals

such as Uranitie, Pitchblende and Cornalite or as secondary mineral in the form of complex oxides of silicates phosphates, vanadates, lignite and monazite sands [3] or as secondary minerals in the form of complex oxides, silicates, phosphates, vanadates, lignite and monazite sands. Thus theoretically, the radioactivity of ^{235}U in water is negligible compared to ^{238}U [4].The health effects of uranium in drinking water are chronic (the delayed result of continuous consumption over a long period of time) rather than acute (the immediate result of consumption). Individual risk depends on the concentration, how much water was consumed and for how long, as well as the age and general health of the individual. Water with uranium concentration above the recommended maximum acceptable concentration ranges of 15-30 ppb [5], [6],[7] is not safe for drinking purpose as it can effect internal organs. According to World Health Organization (WHO) guidelines, gross alpha radioactivity includes all the alpha emitters, excluding radon and gross beta radioactivity includes all beta emitters, except ^{3}H. These guidelines ensures an exposure lower than 0.1 $mSvy^{-1}$ assuming water intake rate of 2 liter per day. A TDI (tolerable daily intake) of 0.6 μ kg^{-1} of the body weight per day and an uncertainty factor of 100 (for intra and interspecies variation). This TDI yields a guideline value of 15 ppb, assuming a 60 kg adult consuming 2 liter of drinking water per day and 80% allocation of the TDI to drinking water [5].

The systematic studies are carried out throughout the world for uranium concentration measurements in water [8],[9],[10],[11],[12],[13],[14],[15] for assessment of health effects and environmental effects of uranium.

II. EXPERIMENTAL TECHNIQUE

In the study area 40 villages were chosen for analysis of uranium concentration in water samples. The water samples were collected from the hand pumps or submersible pumps.

Laser Flourimetric Analysis:

The water samples were analyzed using a Scintrex UA-3 uranium analyzer. The UA-3 (Scintrex UA-3) uranium analyzer is a compact electro-optical instrument for the measurement of trace uranium in aqueous solutions including naturally occurring waters such as surface waters from rivers and lakes and ground waters from wells or bore holes. The technique is rapid, sensitive and is used for semi-quantitative analysis. This technique does not require any chemical preconcentration or extraction. The measurements made by UA-3 instrument are based on the flourescence of a uranyl complex formed by the addition of a reagent to the sample during analysis. Ultraviolet excitation is provided by a small nitrogen laser (at λ= 337nm), uranyl salts emit a green luminescence that can be measured quantitatively by a suitable photo detector [16],[17]. The UA-3 analytical procedure involves the addition of a buffering inorganic complexing agent, FLURAN (sodium pyrophosphate, sodium dihydrogen phosphate) to convert the various uranyl species present in the water sample into a single form that has high luminescent yield. The ultraviolet excitation from the nitrogen laser is very intense, but short lived(3.4×10^{-9} sec.) pulse(200µJ/pulse). Triggered by the laser, the electronic gating system accepts delayed signals from the photomultiplier tube after the flourescence from the organic compound has substantially ceased. Thus, the response is almost entirely due to uranium flourescence. To overcome the effect of interfering materials that would be present in the sample, internal standard method is used during analysis. The lower detection limit of UA-3 detector is 0.05µgL^{-1}.The figure 2.9 (in chapter 2) shows the laser Fluorimetry diagram.

III. RESULTS AND DISCUSSION

The uranium concentration in water samples belonging to the study area are presented in table 6.1. The uranium activity concentration in water samples vary from 2.69 µgl^{-1} to 10.25 µgl^{-1} with an average value of 5.98 µgl^{-1}. The values of uranium concentration in water samples of these areas are **lower than** those, Kulu area of Himachal Pradesh [15] and those reported in Malwa region of Punjab [10]. These values are **lower than** in Bathinda Punjab [Singh et al., 1995; Kumar et al., 2003] and are **much lower than** in the regions of Kolar District, South India, [18] where it lies between 0.3 to 1442.9 µgl^{-1}.

Table 6.1 Uranium Concentration values in water samples belonging to Doaba Region of Punjab, India

Sr. No	Sample location	Uranium concentration in water (µg l^{-1})
Jalandhar District		
1	Philaur	06.24±0.19
2	Goraya	10.02±0.22
3	Jalandhar city	08.43±0.17
4	Adampur	03.01±0.09
5	Alawalpur	04.85±0.15
6	Bhogpur	06.36±0.17
7	JanduSingha	05.35±0.12
8	Shahkot	05.32±0.08
9	Nakodar	07.35±0.10
10	Rama Mandi	06.12±0.13
Hoshiarpur District		
1	Talwara	6.78±0.18
2	Badla	5.34±0.09
3	TandaUrmur	4.36±0.15
4	Dasuya	6.98±0.09
5	Mukerian	5.37±0.08

6	Datarpur	8.32±0.17
7	Nasrala	2.69±0.18
8	Garhshankar	10.25±0.10
9	Mahilpur	3.25±0.17
10	Sailakhurd	4.98±0.12
Nawanshahar District		
1	Nawanshahar City	06.42±0.12
2	Balachaur	02.93±0.13
3	Rahon	04.41±0.12
4	Oad	07.28±0.17
5	Banga	04.32±0.10
6	Jainpur	09.43±0.17
7	Behram	06.09±0.16
8	Mahelgela	05.12±0.09
9	Kathgarh	03.98±0.06
10	Pojewal (Nawagraon)	07.86±0.12
Kapurthala District		
1	Phagwara	07.24±0.17
2	Hamira	05.36±0.18
3	Kapurthala	10.23±0.09
4	Sultanpur Lodhi	08.32±0.17
5	Talwandi Chaudrian	03.02±0.18
6	Bhulath	04.07±0.19
7	Begowal	03.96±0.17
8	Dera baba Jaimal Singh	08.35±0.18
9	Kala Sangirian	05.04±0.09
10	Kanjili	04.34±0.12

The measured uranium concentration values in all the water samples are above the recommended value of 1.9 μgl^{-1} [19]. The present calculated values for uranium concentration in water samples are on lower side than the maximum acceptable uranium concentration value of 15 μgl^{-1} [20] and recommended safe value of 30 μgl^{-1} [21]. The measured uranium concentration values for water samples are well below the range of 15-30 ppb proposed by [5],[6],[7]. The present calculated values for uranium concentration are on the lower side of the recommended value 20 $\mu g.l^{-1}$ [22]. Water with uranium concentration above these limits is not safe for drinking purpose as it can affect internal organs.

The health risk assessment of uranium due to its radiological and chemical toxicity were also carried out in water samples belonging to study area. The present measurements for health risks could play a vital role in diagnosis and prognosis of uranium-induced diseases to the local population of the area under investigation.

Radiological Risk Assessment:

We considered the uranium concentration distribution in the groundwater of each measured area and estimated the cancer risks. A cancer mortality rate is the number of deaths, with cancer as the underlying cause of death, occurring in a specified population during a year. Cancer mortality is usually expressed as the number of deaths due to cancer per 100,000 population. That is,

Mortality Rate = (Cancer Deaths / Population) × 100,000

The morbidity is defined as illness and is the term used to refer to measures of illness. Also it may be defined as the frequency with which a disease appears in a population.

The lifetime cancer risks, R, associated with intake of a given radionuclide were estimated from the equation (6.1) [6] given below:

$$R = r.I \qquad \text{----6.1}$$

Where, r= risk coefficient; I= per capita activity intake

The average life expectancy at birth in India is 69.89 year and, an annual consumption of water for an individual is about 730 liters. This brings the lifetime intake of water to 51,019.70. The cancer risk coefficients of uranium of 1.13×10^{-9} and 1.73×10^{-9} Bq^{-1} for mortality and morbidity respectively [23],[2]. Using equation 6.1 and these coefficients the cancer mortality and morbidity risks of uranium over lifetime consumption of water were calculated. The results are presented in table 6.2. From the table, the cancer mortality risk very from 8.65×10^{-6} to 3.29×10^{-5} while for morbidity risk, it ranged between 1.32×10^{-5} and 5.03×10^{-5}. The cancer risk at 10^{-5} is low compared to the acceptable level of 10^{-3} for the radiological risk [24],[25].

Table 6.2: The estimated lifetime cancer mortality and morbidity risk of uranium in the water samples

Sr. No	Sample location	Cancer mortality risk	Cancer morbidity risk
Jalandhar District			
1	Philaur	1.96E-05	3.00E-05
2	Goraya	3.17E-05	4.85E-05
3	Jalandhar city	2.71E-05	4.15E-05
4	Adampur	9.80E-06	1.50E-05
5	Alawalpur	1.56E-05	2.38E-05
6	Bhogpur	2.02E-05	3.09E-05
7	JanduSingha	1.73E-05	2.65E-05
8	Shahkot	1.67E-05	2.56E-05

9	Nakodar	2.36E-05	3.62E-05
10	Rama Mandi	1.96E-05	3.00E-05
Hoshiarpur District			
1	Talwara	2.13E-05	3.27E-05
2	Badla	1.73E-05	2.65E-05
3	TandaUrmur	1.38E-05	2.12E-05
4	Dasuya	2.25E-05	3.44E-05
5	Mukerian	1.73E-05	2.65E-05
6	Datarpur	2.65E-05	4.06E-05
7	Nasrala	8.65E-06	1.32E-05
8	Garhshankar	3.29E-05	5.03E-05
9	Mahilpur	1.04E-05	1.59E-05
10	Sailakhurd	1.61E-05	2.47E-05
Nawanshahar District			
1	Nawanshahar City	2.02E-05	3.09E-05
2	Balachaur	9.22E-06	1.41E-05
3	Rahon	1.38E-05	2.12E-05
4	Oad	2.31E-05	3.53E-05
5	Banga	1.38E-05	2.12E-05
6	Jainpur	3.00E-05	4.59E-05
7	Behram	1.96E-05	3.00E-05
8	Mahelgela	1.61E-05	2.47E-05
9	Kathgarh	1.27E-05	1.94E-05
10	Pojewal (Nawagraon)	2.48E-05	3.80E-05
Kapurthala District			
1	Phagwara	2.31E-05	3.53E-05
2	Hamira	1.73E-05	2.65E-05
3	Kapurthala	3.29E-05	5.03E-05
4	Sultanpur Lodhi	2.65E-05	4.06E-05
5	Talwandi Chaudrian	9.80E-06	1.50E-05
6	Bhulath	1.27E-05	1.94E-05
7	Begowal	1.27E-05	1.94E-05
8	Dera baba Jaimal Singh	2.65E-05	4.06E-05
9	Kala Sangirian	1.61E-05	2.47E-05
10	Kanjili	1.38E-05	2.12E-05

The values of uranium concentration in drinking water samples obtained in the present investigations in the study areas are also compared with those available in literature worldwide (Table 6.4). The measured uranium values in water samples generally lie below the range reported by other workers except those in the Ontario (Canada), New York (USA), Kuwait and South Greenland.

Table 6.4: Range of uranium concentration in drinking water world wide

Sr. No.	Country	Range of Uranium concentration in water (µg l^{-1})	Average value (µg l^{-1})	References
1	Ontario, Canada	0.05-4.21	0.40	OMEE(1996) Moss et al. (1983) Moss (1985)
2	New York, USA	0.03-0.08	----	Fissene and Wlford (1986)
3	USA	-------	2.55	US EPA (1900,1991)
4	Argentina	0.04-11.0	1.3	Bomben et al. (1996)
5	Japan	-------	0.0009	Nozaki et al. (1970)
6	Norweign	18% samples had U conc in excess of 20 ppb	--------	Frengstad et al. (2002)
7	New Mexico	>20 ppb	-------	Hakonson-Hayes et al. (2002)
8	Central Australia	>20ppb	-------	Hostetler et al. (1998)
9	Jordan	0.04-1400	2.4	Gedeon et al. (1994) Smith et al. (2000)
10	Kuwait	0.02-2.48	-----	Bou-Rabee (1995)
11	United States	0.01-652	-------	Drury et al. (1981) Edgington (1965) Cthern and Lappenbusch (1983)
12	South Greenland	0.5-1.0	-------	Brown et al. (1983)
13	Turkey	0.24-17.65	-----	Kumru (1995)
14	India	0.08-471.27	------	Talukdar et al. (1983) Bansal et al. (1985,1988) Singh et al.(1993,2003) Rohit Mehra et al. (2007)

IV. CONCLUSIONS

Uranium concentration in all the studied samples is below the recommended values suggested by [19],[20],[21]. The values of uranium concentrations are not significant from exploration point of view. The radiological risks of uranium in the water samples were found to be low, typically in magnitude of 10^{-5}. It could therefore be inferred that the human risk due to uranium content in water supplies that will result from ingestion in the area may likely be to the chemical toxicity of uranium as a heavy metal rather than radiological risk. Although the average exposure level of uranium in water samples was comparatively low for the study area but it is

suggested that continuous monitoring must be maintained in several high uranium concentration areas in whole country. The radiometric data so collected could be of high significance in radio-epidemiological assessment, diagnosis and prognosis of uranium-induced diseases to the local population of the area under investigation.

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