Research & Reviews: Journal of Oncology and Hematology
ISSN: 2319-3387 (Online)
Volume 6, Issue 2
www.stmjournals.com

Uranium Content Anomalies in Groundwaters of Fazilka District of Punjab (India) for the Assessment of Excess Cancer Risk

Hardev Singh Virk*
Visiting Professor, SGGS World University, Fatehgarh Sahib, Punjab, India

Abstract
Inductively coupled plasma mass spectroscopy (ICPMS) has been used to measure the uranium content of the ground water samples of Fazilka district of Malwa belt of Punjab (India). Out of total 217 habitations having more than 60 ppb of uranium (safe limit of AERB for India), 30 have been selected for the present investigation. The aim of this study is to investigate the uranium content of the ground water in the Malwa belt of Fazilka district of Punjab and to assess the radiological and chemical risk due to the uranium present through ingestion. The uranium content of the water samples of the studied villages varies from 121.95–366.00 ppb ($\mu g l^{-1}$) with an average value of 198.198 ppb ($\mu g l^{-1}$). The excess cancer risk varies from 3.45–10.37×10^{-4} and hazard quotient varies from 1.56 to 4.67, respectively. The LADD varies from 7.06–21.18 ($\mu g\ kg^{-1}\ day^{-1}$).

Keywords: *Uranium content, radiological risk, chemical risk, cancer risk*

****Author for Correspondence*** E-mail: hardevsingh.virk@gmail.com

INTRODUCTION
Punjab is facing a crisis situation due to high levels of Uranium (U) and heavy metals in underground water being used for drinking and irrigation purposes. More than two dozen reports have been published in The Tribune, Chandigarh during the last decade concerning high toxicity of U in drinking water of Punjab. The author has reported his findings in The Tribune and other research journals during the last four decades [1–10]. The present report is based on the data collected by the Punjab Water Supply and Sanitation Department (PWSSD), Mohali, Punjab, India. It is also available on Ministry of Water Resources, Government of India, and website: www.indiawater.gov.in/IMIS reports

The presence of natural U in rocks, soils, plants and groundwater influences the environment through its easy transportation. The solubility of the U in water in hexavalent (U^{6+}) form and its precipitation as a discrete mineral in tetravalent (U^{4+}) forms makes it easy to get deposited in the earth's surface, provided by the favorable geological or environmental conditions. Surface water and especially ground water plays a vital role in the migration and redistribution of the U nuclides in the earth's crust. Uranium present in water is transferred to plants and hence it enters the food chain and it becomes a source of health hazard to the humans. The World Health Organization (WHO) recommended a reference level [11] of the permissible limit of 30 $\mu g\ l^{-1}$ of U in drinking water.

The accumulation of the uranium inside the human body results in its chemical and radioactive effects for two important target organs being the kidneys and lungs [12–14]. Uranium and radium have the bone seeking properties hence the kidneys, liver and the bones become the principle sites of deposition. The toxicity of uranium depends upon many factors like the route of exposure, particle solubility, contact time, and route of elimination [15]. Drinking water is the major source of the uranium to the human body. Drinking water contributes about 85% and food contributes about 15% of the ingested uranium [16]. An exposure of about 0.1 mg/kg of body weight of soluble natural uranium results in transient chemical damage to the kidneys [17]. Uranium is a radioactive heavy metal, it decays into many other radioactive metals or gases which can further become a health hazard [18]. Though Uranium is a weak radioactive metal, if uranium content of the drinking water is high it may be hazardous. Due to high concentration of uranium in water and its extent of getting ingested into human body, the assessment of health hazards risk is important. Uranium estimation of water systems of the Malwa belt of Punjab State and the neighboring areas has been reported by some workers [19–25]. The objective of present investigations is health risk assessment due to natural uranium in drinking water in Fazilka district of Punjab, India.

THE STUDY AREA

Location

Fazilka district is located in the south-western part of the Punjab state with co-ordinates 30.403°N latitude and 74.025°E longitude, having 314 revenue villages. It has the district of Firozpur to its north, Muktsar Sahib to its east and Sri Ganganagar (Rajasthan) to the south and Pakistan to its west.

Geomorphology and Soil Types

The district area is occupied by Indo-Gangatic alluvium. In the district, soil characteristics are influenced to a very limited extent by the topography, vegetation and parent rock. The variations in soil profile characteristics are much more pronounced because of the regional climatic differences. The soil of this zone has developed under semi-arid condition. The soil is sandy loam to clayey with normal reaction (pH from 6.5 to 8.5). It has been observed that due to heavy rains and adjacent river Satluj and its tributaries cause excessive loss of soil due to erosion.

METHODOLOGY

For collection of samples, 20 ml bottles of superior quality plastic are used. The bottles are washed first with soap solution and then with distilled water. These are rinsed with deionised water and dried. Groundwater from the source is allowed to flow freely before collection in plastic bottles. 10-20 ml of water is collected from the running water source. For dissolved metal determinations, samples must be filtered through a 0.45-μm capsule filter at the field site. Nitric acid (0.5M HNO_3) solubilization is required before the determination of total recoverable Uranium. The preservation and digestion of Uranium in acid is used in order to aid breakdown of complexes and to minimize interferences by polyatoms.

The Uranium analysis of collected water samples has been done using Model 7700 Agilent Series ICP-MS following standard procedure in the Punjab State laboratory set up in Mohali. The method measures ions produced by a radiofrequency inductively coupled plasma. Analyte species originating in a liquid are nebulized and the resulting aerosol is transported by Argon gas into the plasma torch. The ions produced by high temperatures are entrained in the plasma gas and introduced, by means of an interface, into a mass spectrometer. The ions produced in the plasma are sorted according to their mass-to-charge ratios and quantified with a channel electron multiplier. Interferences must be assessed and valid corrections applied. Interference correction must include compensation for background ions contributed by the plasma gas, reagents, and constituents of the sample matrix.

A mass spectrometer with inductively coupled plasma (ICP) suitable for multi-element and isotope analysis is required. The spectrometer should be capable of scanning a mass range from 5 m/z (AMU) to 240 m/z (AMU) with a resolution of at least 1 mr /z peak width at 5 % of peak height (mr = relative mass of an atom species; z = charge number). The instrument may be fitted with a conventional or extended dynamic range detection system. Most quadrupole ICP-MS, high-resolution ICP-MS and collision cell ICP-MS instrumentation is fit for this purpose. Data analysis is done automatically by inbuilt system of ICP-MS. In addition to Uranium, data for 40 more trace elements can be retrieved using ICP-MS.

THEORETICAL FORMULATION

Ingestion of the uranium through drinking water results in both the radiological risk (carcinogenic) and chemical risk (non-carcinogenic). The methodology used for the assessment of the radiological and chemical risks due to uranium concentrations in the water samples are described below:

Radiological Risk Assessment

Calculation of Excess Cancer Risk: Excess cancer risk from the ingestion of natural Uranium from the drinking water has been calculated according to the standard method given by the USEPA [26].

$$\mathrm{ECR} = \mathrm{Ac} \times \mathrm{R}$$

Where 'ECR' is Excess Cancer Risk, 'Ac' is Activity concentration of Uranium (Bql^{-1}) and 'R' is Risk Factor.

The risk factor R (per Bq l^{-1}), linked with ingestion of Uranium from the drinking water may be estimated by the product of the risk coefficient (r) of Uranium (1.19×10^{-9}) for mortality and per capita activity intake I. 'I' for Uranium is calculated as product of life expectancy, assumed to be 63.7 years, i.e. 23250 days and daily consumption of water as 4.05 $lday^{-1}$ [27].

$$I = 4.05\ lday^{-1} \times 23250\ days$$

$$\text{Risk Factor (R)} = r \times I$$

Chemical Risk Assessment

The chemical toxicity risk for Uranium is defined in terms of Lifetime Average Daily Dose (LADD) of the uranium through drinking water intake. LADD is defined as the quantity of the substance ingested per kg of body weight per day and is given by the following equation [28, 29]:

$$\mathrm{LADD} = \frac{\mathrm{C} \times \mathrm{IR} \times \mathrm{ED} \times \mathrm{EF}}{\mathrm{AT} \times \mathrm{BW}\ \times 365}$$

Where 'C' is the concentration of the uranium (μgl^{-1}), IR is the water consumption rate (4.05 $lday^{-1}$), ED is the lifetime exposure duration (63.7 years), EF is the exposure frequency (365 days y^{-1}), BW is average body weight of the receptor (70 kg), and AT is the Averaging time, i.e. life expectancy (63.7 years).

Calculation of Hazard Quotient

Hazard quotient (HQ) is the measure of the extent of harm produced due to the ingestion of uranium from the drinking water.

$$\mathrm{HQ} = \frac{\mathrm{LADD}}{\mathrm{RfD}}$$

Where, LADD is Lifetime Average Daily Dose, and RfD is the reference dose = 4.53 μg $kg^{-1}day^{-1}$.

RESULTS AND DISCUSSION

Groundwater samples were collected from villages falling under three Tehsils (Abohar, Fazilka and Jalalabad) of Fazilka district of Punjab and analysed for Uranium content using calibrated ICP-MS. Uranium content varies from 121.95 ppb (hand pump at Basti Storan Singh) to 366.00 ppb (Tubewell at Kotha Alias Lakhman Pura) with an average value of 198.198 ppb for 30 habitations covered under this survey (Table 1). The safe limit of uranium in groundwater is fixed to be 60 ppb by Atomic Energy Regulatory Board (AERB) [30] in India, while other agencies fix it in much lower limits of 30 ppb (EPA, USA) [26]; 15 ppb (WHO) [11]; 9 ppb (UNSCEAR) [31] and 1.9 ppb (ICRP) [32]. If the observed data of uranium content of water (Table 1) are compared with the guidelines of AERB, all the samples record higher Uranium content than 60 ppb; hence they fail to qualify the safe limit certification of AERB, Government of India.

Radiological Risk: The radiological risk has been calculated due to ingestion of natural uranium in the drinking water of 30 habitations covered in this survey, assuming the consumption rate of 4.05 L/day and lifetime expectancy of 63.7 years for both males and females. The excess cancer risk has been observed to be in the range of 3.45 to 10.37×10^{-4}. The value of the excess cancer risk in the surveyed habitations is higher than the maximum acceptable level of 1.67×10^{-4} according to AERB guidelines. If we assume lifetime water consumption rate of 4.05 L/day with the present uranium content of water, the mean value of excess cancer risk in the surveyed habitations comes out to be 5.01×10^{-4}, which works out to be five per 10,000 people. According to Cancer Registry of Government of India, national average of cancer risk is 80 cancers per million population, for Punjab it is 90 cancers per million but for Malwa belt of Punjab, it is much higher at 136 cancers per million population. Our investigation reveals that for Fazilka district in Malwa belt of Punjab, it has assumed alarming proportions at 500 cancers per million.

Chemical Toxicity Risk: Uranium is a radioactive heavy metal, so it has health impacts due to its both radioactive and chemical nature. If we take into account chemical toxicity of the uranium, the kidneys are the most important target organ. The chemical toxicity of the uranium dominates over its radiological toxicity on the kidney in general at lower exposure levels [33]. The chemical toxicity has been estimated from the value of lifetime average daily dose (LADD) and Hazard quotient. Hazard quotient has been estimated by comparing the value of the calculated LADD with the reference dose level of 4.53 μg $kg^{-1}day^{-1}$. The reference level has been calculated for the maximum contamination level of the uranium in water of 60 ppb (μgl^{-1}). The variation in the values of the LADD and Hazard quotients have been observed from 7.06–21.18 μg/kg/day and from 1.56–4.67, respectively (Table 1).

Table 1: *Uranium Content in Groundwater of Fazilka District and Corresponding Risk Factors.*

S.No.	Location	Source	Uranium Concentration ppb (μgl^{-1})	Uranium Concentration (Bq l^{-1})	Excess Cancer Risk 10^{-4}	LADD ($\mu g\ kg^{-1}\ day^{-1}$)	Hazard Quotient
1	Kotha *alias* Lakhman pura	RO Raw Water	183.366	4.64	5.19	10.61	2.34
2	Kotha *alias* Lakhman pura	Scheme	276.998	7.00	7.85	16.03	3.54
3	Basti Storan Singh	Handpump	121.950	3.08	3.45	7.06	1.56
4	Basti Dilawar Singh	Handpump	157.900	3.99	4.47	9.14	2.02
5	Ram Nagar *alias* Jatwali	Scheme	171.714	4.34	4.86	9.93	2.19
6	Maini Basti	Scheme	171.714	4.34	4.86	9.93	2.19
7	Jala Lakha Ke Hither	RO Raw Water	326.728	8.26	9.26	18.90	4.17
8	Maini Basti	Tubewell	235.500	5.95	6.67	13.63	3.01
9	Ram Nagar *alias* Jatwali	Tubewell	235.500	5.95	6.67	13.63	3.01
10	Basti Bawrian	Tubewell	245.300	6.20	6.95	14.19	3.13
11	Ch. Sotrian	Tubewell	245.300	6.20	6.95	14.19	3.13
12	Dhani Chowdhri Chhanga Ram	Tubewell	245.300	6.20	6.95	14.19	3.13
13	Ch. Chappri Wala	Tubewell	272.900	6.90	7.73	15.79	3.49
14	Ch. Lakho Wali	Tubewell	272.900	6.90	7.73	15.79	3.49
15	Kotha *alias* Lakhman pura	Tubewell	218.800	5.53	6.20	12.66	2.79
16	Boor Wala	Tubewell	129.900	3.28	3.68	7.52	1.66
17	Moran Wala	Tubewell	129.900	3.28	3.68	7.52	1.66
18	Jhari Wala	Tubewell	180.200	4.56	5.10	10.43	2.30
19	Tille Wala	Tubewell	180.200	4.56	5.10	10.43	2.30
20	Mohamad Amira	Tubewell	238.710	6.03	6.76	13.81	3.05
21	Mohamad Pira	Tubewell	238.710	6.03	6.76	13.81	3.05
22	Paka Chisty	Tubewell	130.138	3.29	3.69	7.53	1.66
23	Dhani Alam Shah	Tubewell	122.000	3.08	3.46	7.06	1.56
24	Alam Shah	Tubewell	122.000	3.08	3.46	7.06	1.56
25	Deepulana	Tubewell	180.940	4.57	5.13	10.47	2.31
26	Kotha *alias* Lakhman pura	Tubewell	366.000	9.25	10.37	21.18	4.67
27	Maini Basti	Tubewell	186.400	4.71	5.28	10.78	2.38
28	Ram Nagar *alias* Jatwali	Tubewell	186.400	4.71	5.28	10.78	2.38
29	Bahmni Wala	Tubewell	153.200	3.87	4.34	8.86	1.96
30	Dhani Simrian wali	Tubewell	148.260	3.75	4.20	8.58	1.89

CONCLUSIONS

(i) The concentration of the uranium in ground water samples collected from the hand pumps or other ground water sources of several villages of Fazilka district is found to be much higher than the safe limit of 60 ppb recommended by AERB, India.

(ii) The cancer risk due to presence of U in groundwater is found to be highest for any district in India.

(iii) Our study establishes that uranium content in Fazilka district (Malwa belt) is higher than other districts of Punjab.

(iv) If agricultural practices are similar in all districts of Punjab, e.g., use of fertilizers and crop pattern etc., then what is the source of U enhancement in Fazilka district of Punjab? This needs to be investigated further.

(v) It will be of interest to study epidemiological effects of U in groundwater on the inhabitants of Fazilka district of Punjab, India.

ACKNOWLEDGEMENT

Author is obliged to thank the authorities of PWSSD for supply of Uranium in groundwater data of Fazilka district. The help received from Rajan Jakhu of NIT, Jallandhar for analysis of data is acknowledged.

REFERENCES

1. Virk HS. Cancer in Malwa: Uranium may not be cause. *The Tribune*, Chandigarh, Aug 1 2009.
2. Virk HS. Spread of Cancer: Set up panel to probe water toxicity. *The Tribune*, Chandigarh, Jul 3 2010.
3. Virk HS. Uranium traces in tubewell water: Problem not due to fertilisers. *The Tribune*, Chandigarh, Jul 19 2012.
4. Virk HS. Toxic metals in water should make govt. sit up, says nuclear physicist. *The Tribune*, Chandigarh, Apr 10 2017.
5. Virk HS and Kaur H. Estimation of uranium in plant and water samples. *Curr. Sci*. 1979; 48: 293–295p.
6. Virk HS. Uranium and radon surveys in Siwalik Himalayas. *IARP Bulletin.* 1997; 20(3): 130–142p.
7. Virk HS, Navjeet S, Bajwa BS. Environmental radioactivity: A case study of Himachal Pradesh, India. *Environ. Radioactivity*. 1999; 45: 119–127p.
8. Virk HS, Jakhu R, Bangotra P. Natural Uranium Content in Ground Waters of Mohali and Fatehgarh Districts of North Punjab (India) for the Assessment of Excess Cancer Risk. *Global J. of Human-Social Science*. 2016; 16(4): 12–17p.
9. Virk HS. Measurement of Concentration of Natural Uranium in Ground Waters of Bathinda District (S. Punjab) for the Assessment of Annual Effective Dose. *Global J. of Human-Social Science*. 2016; 16(5): 25–29p.
10. Virk HS. Uranium Anomalies in groundwater of Sangrur district of Punjab (India) for cancer risk assessment. *Curr. Sci*. Forthcoming 25 Oct 2017; 73(8).
11. WHO (World Health Organization). Guidelines for drinking-water quality (4th Edn.). Geneva, Switzerland; 2011.
12. WHO (World Health Organization). Life in the 21st century: A vision for all. Geneva, Switzerland; 1998.
13. ATSDR. Toxicological profile for Radium. Atlanta, Georgia: US Department of Health and Human Services, Agency for Toxic Substances and Disease Registry; 1990.
14. Bleise A, Danesi PR, Burkart W. Properties, use and health effects of depleted Uranium (DU): a general overview. *J Environ Radioact*. 2003; 64: 93–112p.
15. ATSDR. Toxilogical profile for uranium. Atlanta, Georgia: US Department of Health and Human Services, Agency for Toxic Substances and Disease Registry; 1999.
16. Cothern CR, Lappenbusch WL. Occurrence of uranium in drinking water. *Health Physics.* 1983; 45: 89–99p.
17. Tanner AB. Radon migration in the ground, a supplementary review. In: Gesell TF, Lowder WM. (Eds). *The National Radiation Environment III*, National technical Information Services, Springfield, V.A. CONF-780422, 1980; 1: 05–56p.
18. Somogyi G. Technical Reports Series No. 310, IAEA, Vienna. 1990; 1: 229p.

19. Virk HS. Uranium and radon surveys in Western Himalaya. *Curr. Sci.* 1977; 73(6): 536–538p.
20. Bajwa BS, Sharma Navjeet, Walia V, Virk HS. Measurements of natural radioactivity in some water and soil samples of Punjab, India. *Indoor & Built Environ.* 2003; 12: 357–361p.
21. Singh S, Malhotra R, Kumar J, Singh B, Singh L. Uranium analysis of geological samples, water and plants from Kulu Area, Himachal Pradesh, India. *Radiat Meas.* 2001; 34: 427–431p.
22. Kumar M, Kumar A, Singh S, Mahajan RK, Walia TPS. Uranium content measurement in drinking water samples using track etch technique. *Radiat Meas*. 2003; 36: 479 – 481p.
23. Mehra R, Singh S, Singh K. Uranium studies in water samples belong to Malwa region in Punjab by track etching technique. *Radiat Meas*. 2007; 42(3): 441–445p.
24. Tripathi RM, Sahoo SK, Mohapatra S, Lenka P, Dubey JS, Puranik VD. Study of uranium isotopic composition in groundwater and deviation from secular equilibrium condition. *J Radioanal Nucl Chem*. 2013; 295: 1195–1200p.
25. Bajwa BS, Kumar S, Singh S, Sahoo SK, Tripathi RM. Uranium and other heavy toxic elements distribution in the drinking water samples of SW-Punjab, India. *J Radiat Res and Appl Sci.* doi:10.1016/j.jrras.2015.01.002.
26. USEPA (United States Environmental Protection Agency). National primary drinking water regulations, radionuclides. Final Rule. Washington, DC; 2000.
27. HDR (Human Development Report). Mumbai, India: National Resource Centre for Urban Poverty and All India Institute of Local Self Government; 2009.
28. Lee JS, Chon HT, Kim KW. Human risk assessment of As, Cd, Cu and Zn in the abandoned metal mine site. *Environ Geochem and Health.* 2005; 27: 185–191p.
29. Health Canada. Uranium in drinking water. Document for Public Comment Prepared by Federal Provincial Subcommittee on Drinking Water. Ottawa, ON, Canada; 1999.
30. AERB (Atomic Energy Regulatory Board). Drinking water specifications in India. Department of Atomic Energy, Govt. of India; 2004.
31. UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). *Ionizing Radiation: Sources and Biological Effects*. New York, NY, USA; 1982.
32. ICRP (International Commission on Radiological Protection). *Annals of the ICRP* 23(2). ICRP Publication 65, Pergamon Press, Oxford; 1993.
33. Cantaluppi C, Degetto S. Civilian and military uses of depleted uranium: Environment and health problem. *Ann Chim*. 2000; 90: 665–676p.

Cite this Article
Hardev Singh Virk. Uranium Content Anomalies in Groundwaters of Fazilka District of Punjab (India) for the Assessment of Excess Cancer Risk. *Research & Reviews: Journal of Oncology and Hematology*. 2017; 6(2): 21–26p.