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Uranium Content Anomalies in Groundwaters of Ferozepur District of Punjab (India) and the Corresponding Risk Factors

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Abstract

Inductively coupled plasma mass spectroscopy (ICPMS) has been used to measure the uranium content of the ground water samples of Ferozepur district of Malwa belt of Punjab (India). Out of total 390 habitations surveyed in Ferozepur district, 139 are having more than 30 ppb of uranium (WHO safe limit for drinking water), out of which 30 have been selected with U content > 80 ppb (60 ppb is the safe limit fixed by AERB for India) for the present investigation. The aim of this study is to investigate the uranium content of the ground water in the Ferozepur district of Malwa belt of Punjab and to assess the risk factors (excess cancer risk, LADD and hazard quotient) due to the ingestion of uranium by local population. The uranium content of the water samples of the villages under investigation varies from 80.30–331.42 ppb (μgl^{-1}) with an average value of 106.623 ppb (μgl^{-1}). The excess cancer risk varies from 2.27–9.39×10^{-4} and hazard quotient varies from 1.03 to 4.23, respectively. The LADD varies from 4.65–19.18 ($\mu g\ kg^{-1}\ day^{-1}$).

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

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INTRODUCTION

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+}) form makes it easy to get deposited in the earth's surface, provided the geological or environmental conditions are favourable. 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 [1] of the permissible limit of 30 ppb ($\mu g\ l^{-1}$) of U in drinking water.

Punjab is facing a crisis situation due to the high levels of Uranium (U) and heavy metals in underground water being used for drinking and irrigation purposes. Blaurock-Busch *et al.* [2] made an exhaustive study of toxicity of Uranium and heavy metals in the Malwa belt of Punjab. They reported the cancer prevalence in the Malwa region of Punjab (1089/million/year) is much higher than the national average cancer prevalence in India (800/million/year). Hence, it becomes imperative to investigate the health hazards of U distribution in ground waters of some districts falling in the Malwa belt of Punjab. Uranium and heavy metal contamination of ground waters of several districts of Punjab and Himachal Pradesh has been reported by the present author in recent years [3–11]. The present report is based on the data collected by the Punjab Water Supply and Sanitation Department (PWSSD), Mohali (Punjab) pertaining to Ferozepur district of Malwa belt. It is also available on Ministry of Water Resources, Government of India, website: www.indiawater.gov.in/IMIS reports.

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

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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 and the neighbouring 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 of Ferozepur district of Punjab, India.

THE STUDY AREA

Location

Ferozepur district is located in the south-western part of the Punjab state with co-ordinates 30°56′24″ N latitude and 74°37′12″ E longitude, having 639 revenue villages. It has the districts of Tarn Taran and Kapurthala to its north, district Moga to its east, Faridkot to its south and the Pakistan to its west.

Geomorphology and Soil Types

The Ferozpur district is occupied by Indo-Gangatic alluvium and forms a part of Sutlej sub-basin of main Indus basin. Its soil is sandy and interrupted by clusters of sand dunes. The district area is almost a flat terrain with a gentle slope towards south west direction. The physiographic of the district is broadly classified from north to south into four distinct features i.e. Upland plain, Sand dune tract, younger flood pain and active flood plain of Sutlej. The soil of the district is of two types i.e. sierozem (in northern parts) and desert soils (in southern parts). The development of high productive agricultural practices, industries and changing life style of people have taken place which has affected the quality of ground water and which has become more prone to deterioration. The distribution of various constituents varies greatly in the district and exceeds the maximum permissible limit making water non-potable.

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 (0.5 M 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 is 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].

ECR=Ac×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 Bql^{-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 average 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

Risk Factor (R) = r× 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:

HQ= LADD/ RfD

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

RESULTS AND DISCUSSION

It is unfortunate that no epidemiological studies have been undertaken to assess the cancer risk to the exposed population in the Punjab due to high concentration of Uranium in ground waters. Another predicament faced by the investigators of Uranium contamination of ground waters of Malwa belt of Punjab is to determine the source of Uranium. Patnaik *et al*. [30] have pointed to the possibility of a geogenic contribution in the enhancement of uranium concentration in groundwater of the region.

Groundwater samples were collected from 390 villages falling under six blocks (Ferozepur, Zira, Makhu, Mamdot, Talwandi Bhai and Guru Har Sahai) of Ferozepur district of Punjab and analysed for Uranium content using calibrated ICP-MS. The author shortlisted 30 villages with highest uranium concentration, exceeding AERB safety limit. Uranium content varies from 80.30 ppb (Tubewell water at Jamal Garh) to 331.42 ppb (Tubewell water at Kotha) with an average value of 106.623 ppb for 30 habitations selected under this survey (Table 1). The safe limit of uranium in groundwater is fixed to be 60 ppb by Atomic Energy Regulatory Board (AERB) [31] in India, while other agencies fix it in much lower limits of 30 ppb (EPA, USA) [26]; 30 ppb (WHO) [1]; 9 ppb (UNSCEAR) [32] and 1.9 ppb (ICRP) [33]. If the observed

Table 1: *Uranium Content (>80 ppb) in Groundwater of Ferozepur District and Corresponding Risk Factors.*

S. No.	Location	Source	U Conc. (ppb)	U Conc. (Bq/l)	Excess Cancer Risk (10^{-4})	LADD ($\mu g\ kg^{-1}\ day^{-1}$)	Hazard Quotient
1	Shaikh Morawala	Tubewell	103.134	2.61	2.92	5.97	1.32
2	Kotha	Tubewell	331.420	8.38	9.39	19.18	4.23
3	Doomni Wala	Tubewell	85.400	2.16	2.42	4.94	1.09
4	Ch. Saido Ke	Tubewell	123.088	3.11	3.49	7.12	1.57
5	Jhari Wala	Tubewell	140.476	3.55	3.98	8.13	1.79
6	Tille Wala	Tubewell	140.476	3.55	3.98	8.13	1.79
7	Shain Pari	Tubewell	92.300	2.33	2.61	5.34	1.18
8	Pondori Jattan	Tubewell	82.900	2.10	2.35	4.80	1.06
9	Wara Phowind	Tubewell	82.900	2.10	2.35	4.80	1.06
10	Awan	Tubewell	82.900	2.10	2.35	4.80	1.06
11	Dastool Sahib	Tubewell	85.400	2.16	2.42	4.94	1.09
12	Basti Dabbian Wali	Tubewell	85.400	2.16	2.42	4.94	1.09
13	Basti Bhai Ke	Tubewell	85.400	2.16	2.42	4.94	1.09
14	Basti Marle	Tubewell	85.400	2.16	2.42	4.94	1.09
15	Loombri wala	Tubewell	85.400	2.16	2.42	4.94	1.09
16	Ferozeshah	Tubewell	86.000	2.17	2.44	4.98	1.10
17	Landa	Tubewell	80.800	2.04	2.29	4.67	1.03
18	Basti Mana Singh	Handpump	94.100	2.38	2.67	5.44	
19	Sandhe Hasham	Tubewell	85.600	2.16	2.42	4.95	1.09
20	Sappan Wali	Handpump	122.400	3.09	3.47	7.08	1.56
21	Sur Singh Wala	Tubewell	97.000	2.45	2.75	5.61	1.24
22	Guruharsahai (Rural)	Handpump	92.500	2.34	2.62	5.35	1.18
23	Habib Ke	Handpump	124.000	3.13	3.51	7.17	1.58
24	Mahalam	Tubewell	163.600	4.14	4.63	9.47	2.09
25	Ch. Saido Ke	Tubewell	115.800	2.93	3.28	6.70	1.48
26	Ch. Swah Wala	Tubewell	97.300	2.46	2.76	5.63	1.24
27	Jamal Garh	Tubewell	80.300	2.03	2.27	4.65	1.03
28	Jiwan Arrian	Tubewell	82.500	2.09	2.34	4.77	1.05
29	Pindi	Tubewell	81.900	2.07	2.32	4.74	1.05
30	Sohan Garh *urf* Ratte	Tubewell	102.900	2.60	2.91	5.95	1.31

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 2.27 to 9.39×10^{-4}. The value of the excess cancer risk in the selected 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 litres/day with the present uranium content of water, the mean value of excess cancer risk in the habitations listed in Table 1 comes out to be 3.02×10^{-4}, which works out to be 3 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 Ferozepur district in Malwa belt of Punjab, it works out to be 300 cancers per million of population.

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 [34]. 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 ($\mu g l^{-1}$) allowed by AERB guidelines for India. The variations in the values of the LADD and hazard quotients have been observed from 4.65–19.18 μg/kg/day and from 1.03–4.23, respectively (Table 1).

CONCLUSIONS

(i) The concentration of the uranium in ground water samples collected from the hand pumps and tube- wells of several villages of Ferozepur 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 relatively higher in Ferozepur district in comparison with any other district of Punjab, except Fazilka district [11].

(iii) The value of excess cancer risk to residents of Kotha village [Table 1] is estimated to be 939/million/year, which is higher than the national average cancer prevalence in India [2].

(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 Ferozepur district of Punjab? The hypothesis of geogenic contribution [30] needs to be investigated further.

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

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