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Uranium Content Anomalies in Groundwater of Moga District of Malwa Belt of Punjab (India) for the Assessment of Excess Cancer Risk

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Abstract

Inductively coupled plasma mass spectroscopy (ICPMS) has been used to measure the Uranium (U) content of the ground water samples of Moga district of Malwa belt of Punjab, India. Out of the total number of habitations covered under this survey, 203 were having U content more than 30 ppb (WHO safe limit). Out of 203 habitations, we sorted out 56 with U concentration of more than 100 ppb in groundwater. The U content of ground water of Moga district was used to assess the radiological and chemical risk due to U ingestion to the population of the district. The U content of water samples of the villages selected for our investigation varied from 100.20 to 346.70 ppb ($\mu g l^{-1}$) with an average value of 166.11 ppb. The excess cancer risk varied from 2.84×10^{-4} to 9.82×10^{-4}, with an average value of 5.49×10^{-4}. The Lifetime Average Daily Dose (LADD) varied from 5.80 to 12.06 ($\mu g\ kg^{-1}\ day^{-1}$) and hazard quotient varied from 1.28 to 4.43, respectively.

Keywords: *AERB limit, cancer risk, chemical risk, radiological risk, Uranium (U) content*

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INTRODUCTION

The World Health Organization (WHO) [1] recommended a reference level of 30 $\mu g\ l^{-1}$ (ppb) as the permissible limit of uranium (U) in drinking water. The accumulation of U inside the human body results in its chemical and radioactive effects for the two important target organs being the kidneys and lungs [2–4]. The U route to the human body is mainly through drinking water, which contributes about 85% of ingested U and the rest 15% is contributed by the food intake [5]. The transient chemical damage to the kidneys is due to an exposure of about 0.1 mg/kg of body weight of soluble natural U [6]. The natural U is a radioactive heavy metal and its decay products are created as many other radioactive metals or gases in a chain reaction, which can further become a health hazard to the public [7]. U itself is a weak radioactive metal but it may be hazardous to human health if its contamination is high in the drinking water. The assessment of health hazards risk is important, if the concentration of U in water and its extent of getting ingested into the human body is higher than the safe limit provided by the WHO [1].

Punjab is facing a crisis situation due to high levels of U and heavy metals in underground water table of Punjab. More than two dozen reports have been published in The Tribune (www.tribuneindia.com) and other media concerning high toxicity of U in the waters of Punjab setting the alarm bells ringing in the Indian parliament. The author has reported his findings on U contamination and its health hazards in research journals during the past four decades [8–17]. U estimation of the groundwater of Malwa belt of Punjab State and the neighbouring areas in Haryana, Himachal Pradesh, and Jammu has been reported by other workers [18–24]. 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 the Ministry of Water Resources, Government of India, and website: www.indiawater.gov.in/IMIS reports. The objective of the present investigations was health risk assessment due to natural U in drinking water in Moga district of Punjab, India (Figure. 1).

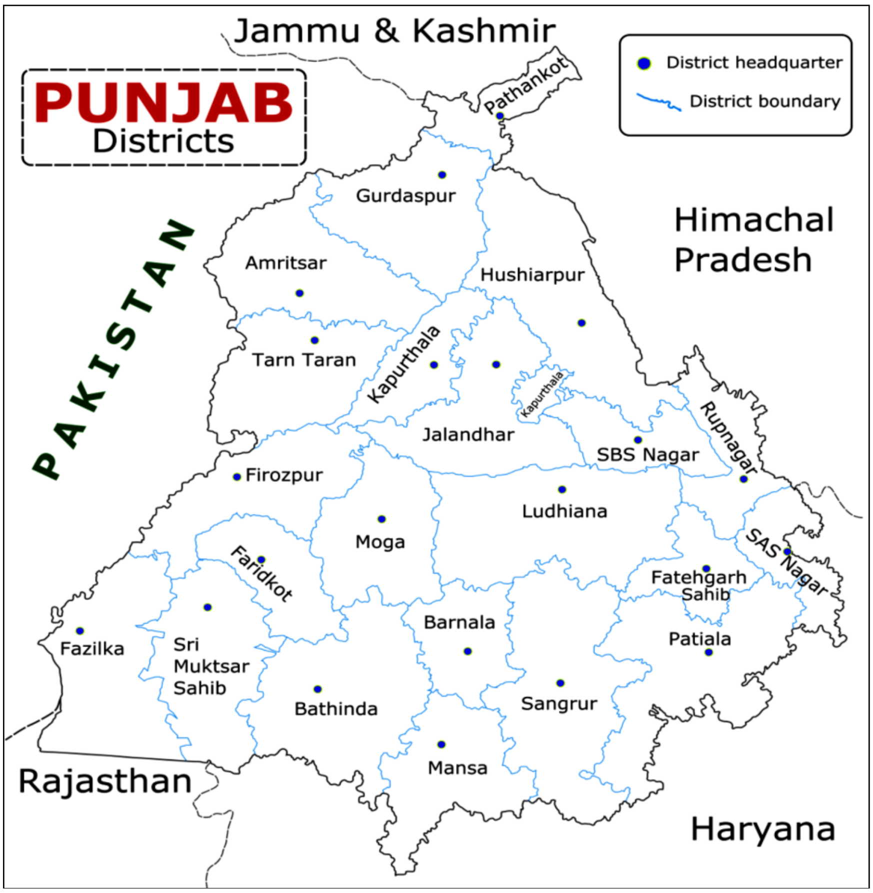

Fig. 1: *District Map of Punjab Showing District of Moga in the Malwa Belt.*

STUDY AREA AND GROUNDWATER QUALITY

Location

The Central Ground Water Board (CGWB) Report throws some light on the nature of soil and geomorphology of the Moga district [25]. It has geographical area of 2071 km^2. Its boundaries are defined by North Latitude 30°28′30′′′ and 31°06′15″ and East Longitude 74°54′40′′′ and 75°24′57″. Moga district is surrounded by Ferozpur and Faridkot in the West, Bathinda and Barnala in the South, Ludhiana in the East and Jalandhar in the North.

Geomorphology and Soil Types [25]

The district forms a part of Indo-Gangetic plain and Sutlej sub-basin of Indus basin. The area as a whole is almost flat with a gentle slope towards the Western and North-westerly direction. The physiography of the district is broadly classified from south to north into four distinct features, i.e., upland plain, sand dune tract, younger flood plain and active flood plain of Sutlej. The Sutlej is an important perennial river, which forms major drainage of the area and runs parallel to the Northern border of the district. There are two types of soils, viz. Sierozem and Desert soils in Moga district. The sierozem soils are found in major parts of the district and desert soils are found in a relatively smaller area towards the western part of the district.

Ground Water Quality [25]

Aquifer material comprises chiefly of fine-to-medium grained sand. In general, shallow aquifers in the area are unconfined down to depth of 80 m in the district and being semi-confined in the depth range of 100–111 m. These two aquifers are separated by a clay layer almost uniformly present in the district. The aquifer down to depth of 50 m is being tapped by shallow tubewells for purpose of irrigation and drinking. However, few deeper tubewells down to depth of 125 m are being tapped by the Government agencies for drinking purpose and by some farmers for irrigation purpose.

The shallow aquifers show groundwater quality to be marginally saline. Groundwater has higher fluoride concentration than the permissible limit in most of the areas of this district. Iron concentrations have been found in shallow groundwater at some places to be higher than permissible limits in South Eastern, North Western and in areas adjoining river Satluj. By and large, the groundwater is suitable for domestic/irrigation purposes in major part of the district.

MATERIALS AND METHODS

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

The U 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 is suitable to measure ions produced by radiofrequency inductively coupled plasma. Analyte species originating in a liquid were nebulized and the resulting aerosol was transported by Argon gas into the plasma torch. The ions produced by high temperatures were entrained in the plasma gas and introduced, by means of an interface, into a mass spectrometer. The ions produced in the plasma were 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 was done automatically by the inbuilt system of ICP-MS. In addition to U, data for 40 more trace elements can be retrieved using ICP-MS.

THEORETICAL FORMULATION

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

Radiological Risk Assessment

Calculation of Excess Cancer Risk

Excess cancer risk from the ingestion of natural U from drinking water has been calculated according to the standard method given by the United States Environmental Protection Agency (USEPA) [26]:

$ECR = Ac \times R$

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 U from drinking water may be estimated by the product of the risk coefficient (r) of U (1.19×10^{-9}) for mortality and per capita activity intake I. 'I' for U 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].

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

Risk Factor $(R) = r \times I$

Chemical Risk Assessment

The chemical toxicity risk for U is defined in terms of Lifetime Average Daily Dose (LADD) of U 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]:

LADD= C×IR×ED×EFAT×BW ×365

Where, 'C' is the concentration of U ($\mu g l^{-1}$); IR is the water consumption rate (4.05 $l day^{-1}$); 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 U 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

Groundwater samples were collected from villages falling under the Moga district of Punjab and analysed for U content using calibrated ICP-MS. U content varied from 33.10 ppb (tubewell in Garden Colony) to 346.70 ppb (tubewell at Chotian Khurd) for all habitations covered under this survey. The variation of U in groundwater for 56 habitations selected (Table 1) for our investigations was 100.20 ppb (tubewell at Khukhurana) to 346.70 ppb (tubewell at Chotian Khurd), with an average value of 166.11 ppb. The safe limit of U 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 U content of water are compared with the guidelines of AERB, all 56 samples record higher U content than 60 ppb (Table 1); 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 U in the drinking water of 56 habitations sorted out for 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 for the population inhabiting these 56 habitations has been observed to be in the range of 2.84×10^{-4}–9.82×10^{-4}, with an average value of 5.49×10^{-4}. The value of excess cancer risk in the surveyed habitations is much higher than the maximum acceptable level of 1.67×10^{-4} according to the AERB guidelines. If we assume lifetime water consumption rate of 4.05 l/day with the present average U content of water, the mean value of excess cancer risk in the surveyed habitations comes out to be 5.49×10^{-4}, which works out to be nearly 5.5 per 10,000 people. According to the Cancer Registry of Government of India, national average of cancer risk is 80 cancers per million population; while for Punjab it is slightly higher with 90 cancers per million. It is much higher for Malwa belt of Punjab [13–16]. Our investigation revealed that for Moga district in the Malwa belt of Punjab, it has assumed alarming proportions at 550 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 U, the kidneys are the most important target organ. The chemical toxicity of U 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 LADD and HQ. HQ has been estimated by comparing the value of the calculated LADD with the reference dose level of 4.53 $\mu g\ kg^{-1} day^{-1}$. The reference level has been calculated for the maximum contamination level of U in water of 60 ppb ($\mu g l^{-1}$). The variation in the values of LADD and HQs have been observed from 5.80 μg/kg/day to 12.06 μg/kg/day and from 1.28 to 4.43, respectively (Table 1).

HQ higher than one is an indication of chemical toxicity risk factor due to ingested U via the drinking water. For overall risk assessment, both radiological and chemical toxicity are to be taken into consideration. It has become possible to estimate age-dependent ingestion and inhalation doses due to intake of U to the exposed population in the area [24].

***Table 1:** Uranium Content in Groundwater of Moga District and Corresponding Risk Factors (WHO limit 30 ppb; AERB limit 60 ppb).*

Sr. No.	Location	Source of Groundwater	Depth (m)	Uranium Conc. (ppb)	Uranium Conc. (Bq l^{-1})	Excess Cancer risk * 10^{-4}	LADD (µg kg^{-1} day^{-1})	Hazard Quotient
1	Khukhurana	Tubewell	131.4	100.20	2.53	2.84	5.80	1.28
2	Bare Wala	Tubewell	108.0	101.00	2.55	2.86	5.84	1.29
3	Budh Singh Wala	Tubewell	108.0	101.30	2.56	2.87	5.86	1.29
4	Sadda Singh Wala	Tubewell	131.06	103.10	2.61	2.92	5.97	1.32
5	Badhni Kalan	Tubewell	118.87	103.30	2.61	2.93	5.98	1.32
6	S.C.Basti	Null	Null	103.35	2.61	2.93	5.98	1.32
7	Sukha Nand	Null	Null	103.35	2.61	2.93	5.98	1.32
8	RamuwalaKalan	Tubewell	Null	104.00	2.63	2.95	6.02	1.33
9	Minian	Tubewell	119.0	104.10	2.63	2.95	6.02	1.33
10	Bode	Null	Null	107.90	2.73	3.06	6.24	1.38
11	Nangal	Null	Null	110.13	2.78	3.12	6.37	1.41
12	Vadda Ghar I	Tubewell	128.2	112.00	2.83	3.17	6.48	1.43
13	Dhurkot Kalan	Null	Null	112.89	2.85	3.20	6.53	1.44
14	Vadda Ghar II	Tubewell	128.02	114.00	2.88	3.23	6.60	1.46
15	Langiana Khurd	Tubewell	137.5	123.00	3.11	3.48	7.12	1.57
16	Abadi of Langiana Purana	Tubewell	137.5	123.00	3.11	3.48	7.12	1.57
17	Bare Wala	Tubewell	108.0	123.10	3.11	3.49	7.12	1.57
18	Baghele Wala	Tubewell	Null	123.60	3.12	3.50	7.15	1.58
19	Chotian Khurd	Tubewell	153.0	123.60	3.12	3.50	7.15	1.58
20	Nihal Garh	Tubewell	118.87	124.50	3.15	3.53	7.20	1.59
21	Longiwind	Tubewell	118.87	124.50	3.15	3.53	7.20	1.59
22	Tehsil Complex	Tubewell	180.0	124.70	3.15	3.53	7.21	1.59
23	Kothe Kartar Singh	Handpump	Null	129.90	3.28	3.68	7.52	1.66
24	Mahlan Kalan	Tubewell	107.0	130.50	3.30	3.70	7.55	1.67
25	Chotian Kalan	Tubewell	137.16	130.60	3.30	3.70	7.56	1.67
26	Saho Ke	Tubewell	86.0	130.60	3.30	3.70	7.56	1.67
27	Kore Wala Khurd	Tubewell	Null	134.00	3.39	3.80	7.75	1.71
28	Nathe Wala I	Tubewell	132.65	134.30	3.40	3.80	7.77	1.72
29	Nathe Wala II	Tubewell	148.5	134.30	3.40	3.80	7.77	1.72
30	Budh Singh Wala	Tubewell	65.0	138.60	3.50	3.93	8.02	1.77
31	Ransih Kalan	Tubewell	114.3	139.60	3.53	3.95	8.08	1.78
32	Kalie Wala I	Tubewell	106.0	140.60	3.55	3.98	8.13	1.80
33	Kalie Wala II	Tubewell	Null	144.50	3.65	4.09	8.36	1.85
34	Bambiha Bhai	Null	Null	148.30	3.75	4.20	8.58	1.89
35	Droli Bhai	Tubewell	Null	148.30	3.75	4.20	8.58	1.89
36	SinghaWala	Handpump	60.96	148.50	3.75	4.21	8.59	1.90
37	Jita Singh Wala	Tubewell	85.0	162.00	4.10	4.59	9.37	2.07
38	Rattian	Tubewell	Null	166.00	4.20	4.70	9.60	2.12
39	Abadi on Talwandi Road	Tubewell	118.87	174.90	4.42	4.95	10.12	2.23
40	Saido Ke	Tubewell	118.87	174.90	4.42	4.95	10.12	2.23
41	Sangatpura	Tubewell	89.0	175.50	4.44	4.97	10.15	2.24
42	Ganji Gulab Singh	Tubewell	107.0	175.90	4.45	4.98	10.18	2.25
43	Kahan Singh Wala	Tubewell	Null	178.80	4.52	5.06	10.34	2.28
44	Ransih Khurd	Tubewell	180.0	185.70	4.69	5.26	10.74	2.37
45	Ganji Gulab Singh	Tubewell	Null	187.00	4.73	5.30	10.82	2.39
46	Harijan Basti	Tubewell	95.0	187.90	4.75	5.32	10.87	2.40
47	Khotte	Tubewell	95.0	187.90	4.75	5.32	10.87	2.40
48	Takhtupura	Tubewell	114.3	188.20	4.76	5.33	10.89	2.40
49	Kore Wala Kalan	Tubewell	Null	202.00	5.11	5.72	11.69	2.58
50	Ganji Gulab Singh	RO Raw Water	Null	232.00	5.86	6.57	13.42	2.96
51	Ganji Gulab Singh	Tubewell	107.0	246.10	6.22	6.97	14.24	3.14
52	Daya Kalan	Tubewell	180.0	248.70	6.29	7.04	14.39	3.18
53	Rau Ke Kalan	Tubewell	107.0	251.30	6.35	7.12	14.54	3.21
54	Harijan Basti	Tubewell	107.0	251.30	6.35	7.12	14.54	3.21
55	Thraj	Tubewell	116.5	275.00	6.95	7.79	15.91	3.51
56	Chotian Khurd	Tubewell	Null	346.70	8.76	9.82	20.06	4.43

***Cancer risk is the likelihood, or chance, of getting cancer.*

We say "excess cancer risk" because we have a "background risk" of about one in four chances of getting cancer. In other words, in a million people, it is expected that 250,000 individuals would get cancer from a variety of causes. If we say that there is a "one in a million" excess cancer risk from a given exposure to a contaminant, we mean that if one million people are exposed to a carcinogen at a certain concentration over their lifetime, then one cancer above the background chance, or the 250,000th cancer, may appear in those million persons from that particular exposure [34].

CONCLUSIONS

(i). The concentration of U in groundwater samples collected from the tubewells, handpumps and RO raw water of 56 villages of Moga district was found to be much higher than the safe limit of 60 ppb recommended by the AERB, India.

(ii). Moga district has second highest number of habitations in Punjab, next only to Fazilka, where U contamination of groundwater has reached alarming levels.

(iii). The cancer risk due to presence of U in groundwater was found to be among the highest for the districts of Punjab with an estimated number of 550 cancers per million population.

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

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