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# Assessment of Excess Cancer Risk due to Uranium Content Anomalies in Groundwaters of Bathinda District of Malwa Belt of Punjab (India)

**Hardev S. Virk**

Professor of Eminence, Punjabi University, Patiala (Punjab), India

**Abstract:** ***Inductively coupled plasma mass spectroscopy (ICPMS) has been used to measure the uranium content of the ground water samples of Bathinda district of Malwa belt of Punjab (India). Out of total number of habitations covered under this survey, 40 are having uranium content more than 30 ppb (WHO safe limit). The aim of this study is to investigate the uranium content of the ground water of Bathinda district of Malwa belt 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 villages under investigation varies from 32.10–325.10 ppb (μgl$^{-1}$) with an average value of 108.42 ppb (μgl$^{-1}$). The excess cancer risk varies from 0.91–9.21×10$^{-4}$ with average value of 3.07 ×10$^{-4}$ and hazard quotient varies from 0.41 to 4.15 with average value of 1.38, respectively. The LADD varies from 1.86–18.81 (μg kg$^{-1}$ day$^{-1}$) with average value of 6.27 (μg kg$^{-1}$ day$^{-1}$).***

**Keywords:** Uranium content, radiological risk, chemical risk, excess cancer risk, Malwa belt of Punjab

## 1. Introduction

The World Health Organization (WHO) [1] recommended a reference level of 30 μg l$^{-1}$ (ppb) as the permissible limit of Uranium in drinking water. The accumulation of the uranium 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 major source of supply of the uranium to the human body is drinking water, which contributes about 85% of ingested uranium 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 uranium [6]. The natural uranium is a radioactive heavy metal; it decays into many other radioactive metals or gases which can further become a health hazard to the public [7]. Uranium 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 uranium in water and its extent of getting ingested into human body is higher than the safe limit provided by WHO [1].

Punjab is facing a crisis situation due to high levels of Uranium (U) and heavy metals in underground water table of Punjab. More than two dozen reports have been published in The Tribune (www.tribuneindia.com) during the last decade concerning high toxicity of U in the waters of Punjab. The author has reported his findings in The Tribune and other research journals during the last four decades [8–17]. Uranium estimation of the groundwater of the Malwa belt of Punjab State and the neighbouring areas in Haryana 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 Ministry of Water Resources, Government of India, and website: www.indiawater.gov.in/IMIS reports. The objective of the present investigations is health risk assessment due to natural uranium in drinking water in Bathinda district of Punjab, India.

## 2. Study Area and Groundwater Quality

### 2.1 Location

Bathinda district is situated in the southern part of Punjab State. It lies between 29$^{o}$ 33' and 30$^{o}$ 36' North latitude and 74$^{o}$ 38' and 75$^{o}$ 46' East longitude. It covers an area of 3367 sq. km. The district is surrounded by Sirsa and Fatehabad districts of Haryana State in the south, Sangrur and Mansa districts in the East, Moga in the North-East and Faridkot and Muktsar districts in the North-West.

### 2.2 Geomorphology and Soil Types [25]

The district area is occupied by Indo-Gangetic alluvim. The master slope of the area is towards Southwest. The soil in the district is mostly sandy. The district has two types of soils, the arid brown soils and siezoram soils. The arid brown soils are calcareous in nature, these soils are imperfectly to moderately drained. Salinity and alkalinity are the principal problems of this soil. Presence of high amount of calcium carbonate and poor fertility is the main problem of this soil. The arid brown soils are found in mostly eastern parts of the district and siezoram soils are found in the western part of the district.

### 2.3. Ground Water Quality

Central Ground Water Board (CGWB), Ministry of Water Resources, Government of India has carried out studies [25] for chemical quality of ground water in the area. The top aquifer ranges from 40 to 56 m. The depth of the top aquifer in the North is up to 56 m, in the south it is up to 58 m, in the East it is 38 m. and in the west it is 40 m. The ground water of the district is alkaline in nature with pH values ranging from 7.54 to 8.0. Well waters in the area are

generally medium to highly saline. However, pockets of fresh water are also found.

## 3. Materials & Methods

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 poly-atoms.

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.

## 4. 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:

### 4.1 Radiological Risk Assessment

**4.1.1. 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 ($1.19\times10^{-9}$) 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
Risk Factor (R) = r × I

### 4.2 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]:
LADD= C×IR×ED×EFAT×BW ×365
Where 'C' is the concentration of the uranium ($\mu gl^{-1}$), 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 $daysy^{-1}$), BW is average body weight of the receptor (70 kg), and AT is the Averaging time, i.e. life expectancy (63.7 years).

### 4.3 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 $\mu g\ kg^{-1}day^{-1}$.

## 5. Results and Discussion

Groundwater samples were collected from villages falling under the Bathinda district of Punjab and analysed for Uranium content using calibrated ICP-MS. Uranium content varies from 32.10 ppb (Jethuke village handpump) to 325.10 ppb (Tubewell at Bhunder) with an average value of 108.42 ppb for 40 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 are compared with the guidelines of AERB, 32 samples out of 40 record higher Uranium content than 60 ppb (Table 1); hence they fail to qualify the safe limit certification of AERB, Government of India.

### 5.1 Radiological Risk

The radiological risk has been calculated due to ingestion of natural uranium in the drinking water of 40 habitations covered in this survey, assuming the consumption rate of 4.05 litre/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 $0.91–9.21\times10^{-4}$ with average value of $3.07x10^{-4}$. The value of the excess cancer risk in the surveyed habitations is higher than the maximum acceptable level of $l.67\times10^{-4}$ according to AERB guidelines. If we assume lifetime water consumption rate of 4.05 litre/day with the present uranium content of water, the mean value of excess cancer risk in the surveyed habitations comes out to be $3.07\times10^{-4}$, which works out to be nearly 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 Bathinda district in Malwa belt of Punjab, it has assumed alarming proportions at 307 cancers per million.

### 5.2 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 ($\mu gl^{-1}$). The variation in the values of the LADD and Hazard quotients have been observed from 1.86–18.81 μg/kg/day and from 0.41– 4.15, respectively (Table 1).

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

| S.No. | Location | Source | Depth | Uranium Conc. (ppb) | Uranium Conc. (Bq $l^{-1}$) | Excess Cancer risk * $10^{-4}$ | LADD (μg $kg^{-1}$ $day^{-1}$) | Hazard Quotient |
|---|---|---|---|---|---|---|---|---|
| 1 | Bhunder | Tubewell | 500 ft | 325.100 | 8.22 | 9.21 | 18.81 | 4.15 |
| 2 | Dulewala | | 500 ft | 205.800 | 5.20 | 5.83 | 11.91 | 2.63 |
| 3 | Patti Karam Chand | Tubewell | 590 ft | 164.000 | 4.15 | 4.65 | 9.49 | 2.09 |
| 4 | Mehraj Patti Kala | Tubewell | 590 ft | 164.000 | 4.15 | 4.65 | 9.49 | 2.09 |
| 5 | Basti Talwal Khiali Gurusar | Tubewell | 590 ft | 164.000 | 4.15 | 4.65 | 9.49 | 2.09 |
| 6 | Kothe Maha Singh | Tubewell | 590 ft | 164.000 | 4.15 | 4.65 | 9.49 | 2.09 |
| 7 | Basti Kothe Ratia | Tubewell | 590 ft | 164.000 | 4.15 | 4.65 | 9.49 | 2.09 |
| 8 | Kothe Piple | Tubewell | 590 ft | 164.000 | 4.15 | 4.65 | 9.49 | 2.09 |
| 9 | Basti Tapahan Wala | Tubewell | 590 ft | 164.000 | 4.15 | 4.65 | 9.49 | 2.09 |
| 10 | Basti Rampura Road | Tubewell | 590 ft | 164.000 | 4.15 | 4.65 | 9.49 | 2.09 |
| 11 | Gurusar Mehraj | Tubewell | 590 ft | 164.000 | 4.15 | 4.65 | 9.49 | 2.09 |
| 12 | Gidder | Tubewell | 590 ft | 140.500 | 3.55 | 3.98 | 8.13 | 1.79 |
| 13 | SC Basti | Tubewell | 500 ft | 140.500 | 3.55 | 3.98 | 8.13 | 1.79 |
| 14 | Dulewala | Tubewell | 500 ft | 139.900 | 3.54 | 3.96 | 8.09 | 1.79 |
| 15 | Dhinger | RO Raw Water | 36.58 | 123.580 | 3.12 | 3.50 | 7.15 | 1.58 |
| 16 | Kothe Hardev Singh | RO Raw Water | 36.58 | 123.580 | 3.12 | 3.50 | 7.15 | 1.58 |
| 17 | Sema | Tubewell | NULL | 101.000 | 2.55 | 2.86 | 5.84 | 1.29 |
| 18 | Basti Himatpura | Tubewell | NULL | 98.126 | 2.48 | 2.78 | 5.68 | 1.25 |
| 19 | Gurusar Mehraj | Tubewell | NULL | 98.126 | 2.48 | 2.78 | 5.68 | 1.25 |
| 20 | Kalyan Malki | Tubewell | NULL | 94.100 | 2.38 | 2.67 | 5.44 | 1.20 |
| 21 | Kalyan Sadda | Tubewell | NULL | 94.100 | 2.38 | 2.67 | 5.44 | 1.20 |
| 22 | Kalyan Sukha | Tubewell | NULL | 94.100 | 2.38 | 2.67 | 5.44 | 1.20 |
| 23 | Bhai Rupa | Tubewell | NULL | 88.600 | 2.24 | 2.51 | 5.13 | 1.13 |
| 24 | Dhapali | Tubewell | NULL | 87.000 | 2.20 | 2.46 | 5.03 | 1.11 |
| 25 | Rayia | Tubewell | 590 ft | 83.700 | 2.12 | 2.37 | 4.84 | 1.07 |
| 26 | Adampura | Tubewell | NULL | 77.375 | 1.96 | 2.19 | 4.48 | 0.99 |
| 27 | Kotra Kaureana | Tubewell | 500 ft | 72.300 | 1.83 | 2.05 | 4.18 | 0.92 |
| 28 | Bhaini | Tubewell | NULL | 66.500 | 1.68 | 1.88 | 3.85 | 0.85 |
| 29 | Ghurelli | Tubewell | 590 ft | 66.100 | 1.67 | 1.87 | 3.82 | 0.84 |
| 30 | Pitho | Tubewell | 590 ft | 65.000 | 1.64 | 1.84 | 3.76 | 0.83 |
| 31 | Sandhu Khurd | Tubewell | 590 ft | 62.900 | 1.59 | 1.78 | 3.64 | 0.80 |
| 32 | Salabatpura | Tubewell | NULL | 61.600 | 1.56 | 1.74 | 3.56 | 0.79 |
| 33 | Gurdit Singh Wala | Tubewell | NULL | 52.000 | 1.31 | 1.47 | 3.01 | 0.66 |
| 34 | Jamine Basti | Tubewell | NULL | 52.000 | 1.31 | 1.47 | 3.01 | 0.66 |
| 35 | Diyalpura Bhaika | Tubewell | NULL | 52.000 | 1.31 | 1.47 | 3.01 | 0.66 |
| 36 | Basti Surjitpura | Tubewell | NULL | 52.000 | 1.31 | 1.47 | 3.01 | 0.66 |
| 37 | Basti Pitho Road | Tubewell | NULL | 39.500 | 1.00 | 1.12 | 2.29 | 0.50 |
| 38 | Badiala | Tubewell | NULL | 39.500 | 1.00 | 1.12 | 2.29 | 0.50 |
| 39 | Basti Market Committee | Handpump | NULL | 32.100 | 0.81 | 0.91 | 1.86 | 0.41 |
| 40 | Jethuke | Handpump | NULL | 32.100 | 0.81 | 0.91 | 1.86 | 0.41 |

*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].

## 6. Conclusions

1) The concentration of the uranium in ground water samples collected from the Tubewells, handpumps and RO raw water of several villages of Bathinda district is found to be higher than the safe limit of 60 ppb recommended by AERB, India.
2) The cancer risk due to presence of U in groundwater is found to be among the highest for the districts of Punjab.
3) Our study establishes that uranium content in the Malwa belt is higher than Majha or Doaba belts of Punjab. 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 Bathinda district of Punjab? This needs to be investigated further.
4) It will be of interest to study the epidemiological effects of U in groundwater on the inhabitants of Bathinda district of Punjab, India.

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## Author Profile

**Prof. H.S. Virk** received his Masters in Physics from AMU, Aligarh (1963) and Doctorate in Nuclear Physics from Marie Curie University, Paris (France) in 1972 with highest citation. He has published 450 research papers in national & international journals; 40 books and 135 articles on Science Education & Science Policy in India. His research publications cover a vast range of fields: Elementary Particles, Geochronology, Radiation Damage in Solids, Earthquake Prediction Studies using Radon & Helium as Precursors, Heavy Ion Irradiation Effects in Polymers, Nanotechnology and History & Philosophy of Science. Professor Virk retired from Guru Nanak Dev University, Amritsar in June 2002 after serving as Head of Physics Department, Dean Science Faculty, Director Research and Dean Academic Affairs.