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# Groundwater Contamination in Punjab due to Arsenic, Selenium and Uranium Heavy Metals

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## *Abstract*

*Punjab is facing a crisis situation due to high levels of heavy metals in underground water table of Punjab. ICAR has reported arsenic beyond safe limit in 13 districts of Punjab. According to PWSSD report, out of all arsenic contaminated habitations in Punjab, 60% fall in Majha belt of Punjab, namely, Amritsar, Gurdaspur and Tarn Taran districts. Arsenic contamination can be get rid of by using a nanotechnology based technique called AMRIT (Arsenic and Metal Removal by Indian Technology). Doaba belt of Punjab, namely, Jallandhar, Kapurthala and Hoshiarpur districts have high selenium contents in groundwater. Acceptable limit (AL) for arsenic and selenium in groundwater is fixed at 0.01 mg/l (ppm) by the Bureau of Indian Standards (BIS). The highest number of villages with arsenic and selenium contamination of groundwater above the AL falls in the Amritsar and Jallandhar districts, respectively. The health hazard effects of arsenic, selenium and uranium are discussed on the basis of studies carried out in the USA, China and India. Uranium poisoning is rampant in the Malwa belt of Punjab. In this report, groundwater quality data pertaining to arsenic, selenium and uranium, are reported and measures for their mitigation are discussed.*

***Keywords:*** *Acceptable limit, AMRIT, arsenic, health hazards, heavy metal contamination, selenium, uranium*

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## INTRODUCTION

Punjab is facing a crisis situation due to high levels of uranium 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 report by Ruchika M. Khanna [1] appeared on May 18, 2016 regarding use of Canal water for drinking and toxic groundwater for purposes of irrigation. This report is based on results of uranium reported by a team of scientists of Bhabha Atomic Research Centre (BARC). It also refers to presence of heavy metals in water pumped from tube wells based on data collected by Punjab Water Supply and Sanitation Department (PWSSD).

It will be of interest to general public that Punjab Water Supply and Sanitation Department (PWSSD) has collected groundwater samples from more than 50% habitations of Punjab and analysed it for heavy metal contamination in its sophisticated laboratory set up in Mohali (Punjab), using state of art instrumentation including ICPMS (Inductively Coupled Plasma Mass Spectrometry) and Ion Chromatography Mass Spectrometry (IC-MS). PWSSD Report presented an analysis of groundwater collected from 15384 homes with heavy metal contamination found in 2080 habitations. The analysis presented in this paper is also based on PWSSD data collected in three phases during 2009 to 2016 and compiled in April 2016. Most of the data are available on the website of Ministry of Water Resources, Govt. of India [2].

Heavy metals generally include a long list of elements found in natural form in soil or groundwater. PWSSD data included Aluminium, Iron, Nickel, Cadmium, Chromium, Lead, Mercury, Arsenic, Selenium, and Uranium. In fact, most of our earlier investigations were focussed on uranium contamination of groundwater and its health hazards [3–9]. Arsenic and selenium contamination of groundwater of Majha, Malwa and Doaba belts of Punjab was also reported [10–16]. In this paper, the author is presenting a comprehensive study of contamination of groundwater in the whole of Punjab due to heavy metals arsenic, selenium and uranium. Other investigators [17–22] have also reported higher levels of arsenic and selenium than the permissible limit of 10 ppb in groundwater of Punjab.

## WHO GUIDELINES AND INDIAN STANDARDS FOR WATER

The primary aim of the WHO (World Health Organisation) guidelines for drinking-water quality (GDWQ) is the protection of public health [23]. The guidelines are intended to be used as a basis for the development of national standards that will ensure the safety of drinking water supplies through the process of elimination, or reduction to a bare minimum concentration, of constituents in drinking water that are known to be hazardous to health. The guideline values recommended are not mandatory limits. They are intended to be used in the development of risk management strategies which may include national or regional standards in the context of local or national environmental, social, economic and cultural conditions.

WHO had adopted a public standard on arsenic in drinking water since 1958. The last edition of WHO GDWQ (1993) established 0.01 mg/L (10 ppb) as a provisional guideline value for arsenic and selenium in drinking water with a view to reducing the concentration of both in drinking-water, because lower levels preferred for health protection are not reliably measurable. In a number of countries, the WHO provisional guidelines of 0.01 mg/L have been adopted as the standard.

The Bureau of Indian Standards (BIS), after the draft finalized by the Drinking Water Sectional Committee had been approved by the Food and Agriculture Division Council, is responsible for Indian Drinking Water Quality Standards. This standard was originally published in 1983. A report prepared by the World Health Organization in cooperation with the World Bank showed that in 1975, some 1230 million people were without safe water supplies. These appalling facts were central to the United Nations decision to declare an International Drinking Water Supply and Sanitation decade, beginning in 1981.

As per the eleventh five-year plan document of India (2007–12), there are about 2.17 lakh quality affected habitations in the country with more than half affected with excess iron, followed by fluoride, salinity, nitrate and arsenic in that order. The eleventh five year plan document of India (2007–2012) recognizes dealing with the issue of water quality as a major challenge and aims at addressing water quality problems in all quality affected habitations with emphasis on community participation and awareness campaigns as well as on top most priority to water quality surveillance and monitoring by setting up of water quality testing laboratories strengthened with qualified manpower, equipments and chemicals.

BIS has adopted WHO Guidelines and Standards for most of the heavy metals in Table 2 under the heading "General Parameters Concerning Substances Undesirable in Excessive Amounts" [24]. It includes all metals listed in PWSSD analysis except arsenic. The author wonders why such a toxic metal has been ignored in BIS report.

## DISCUSSION OF RESULTS

Arsenic contamination of groundwater of nine districts of Punjab is listed in Table 1. The highest number of quality affected habitations is recorded in Amritsar district with arsenic content variation in the range of 0.010 to 0.111 mg/l (ppm). Majha belt comprising three districts of Amritsar, Gurdaspur and Tarn Taran are highly contaminated as compared with other districts falling in Doaba and Malwa zones.

Selenium contamination of groundwater of thirteen districts of Punjab is listed in Table 2. The highest number of quality affected habitations is recorded in Jallandhar district of Doaba belt with selenium content variation in the range of 0.010 to 0.044 mg/l (ppm). It is followed by Ludhiana, Patiala and Kapurthala districts. Selenium content variation is different than arsenic. The large range of variation (0.010 to 0.140 mg/l) and the highest value of selenium in groundwater is found in Ludhiana district.

Uranium content in groundwater of ten districts is recorded in Table 3. It is observed that groundwater of Malwa districts of Punjab is highly contaminated as compared with those of Majha districts. The highest number of quality affected habitations occurs in Fazilka district followed by Moga, Barnala and Ferozepur districts. The uranium content variation does not show very high fluctuations from district to district. Its highest value has been recorded in Fazilka district.

We observed a typical pattern in distribution of heavy metals in groundwater of Punjab. The highest arsenic contamination is recorded in Majha belt of Punjab; the highest selenium contamination recorded in Doaba belt, and highest uranium contamination is found in the Malwa belt of Punjab. The sources of arsenic, selenium and uranium are geogenic, but it is proposed that uranium has been transported from Siwaliks to Punjab plains by the rivers flowing in Punjab [25].

***Table 1:*** *Arsenic Content in Groundwaters of Punjab (Acceptable limit=0.01 mg/l=10 ppb).*

| S.N. | Name of District | No. of Affected Habitations | Source of Groundwater | Arsenic Range (mg/l = ppm) |
|---|---|---|---|---|
| 1. | Amritsar | 504 | Tubewell/Handpump | 0.010 - 0.111 |
| 2. | Gurdaspur | 324 | do | 0.010 - 0.104 |
| 3. | Tarn Taran | 322 | do | 0.010 - 0.100 |
| 4. | Roop Nagar | 142 | do | 0.010 - 0.091 |
| 5. | Ferozepur | 127 | do | 0.010 -0.055 |
| 6. | Hoshiarpur | 78 | do | 0.010 - 0.039 |
| 7. | Patiala | 71 | Tubewell | 0.010 - 0.046 |
| 8. | Kapurthala | 33 | Tubewell/Handpump | 0.010 - 0.045 |
| 9. | Pathankot | 17 | Tubewell | 0.010 - 0.012 |

***Table 2:*** *Selenium Content in Groundwater of Punjab (Acceptable limit=0.01 mg/l).*

| S.N. | Name of District | No. of Affected Habitations | Source of Groundwater | Selenium Range (mg/l = ppm) |
|---|---|---|---|---|
| 1. | Jallandhar | 105 | Tubewell/Handpump | 0.010 - 0.040 |
| 2. | Ludhiana | 80 | do | 0.010 - 0.140 |
| 3. | Kapurthala | 30 | do | 0.010 - 0.082 |
| 4. | Tarn Taran | 32 | do | 0.010 - 0.076 |
| 5. | Roop Nagar | 29 | do | 0.010 -0.023 |
| 6. | Ferozepur | 19 | Tubewell | 0.010 - 0.025 |
| 7. | SBS Nagar | 19 | Tubewell | 0.010 - 0.046 |
| 8. | Gurdaspur | 17 | Tubewell/Handpump | 0.010 - 0.094 |
| 9. | Fatehgarh Sahib | 17 | do | 0.010 - 0.028 |
| 10. | Hoshiarpur | 13 | Tubewell | 0.010 - 0.029 |
| 11. | Amritsar | 10 | do | 0.010 - 0.039 |
| 12. | Sangrur | 10 | do | 0.010 - 0.032 |
| 13. | Patiala | 49 | do | 0.010 - 0.038 |

***Table 3:*** *Uranium Content in Groundwater of Punjab (WHO acceptable limit=30 ppb).*

| S.N. | Name of District | No. of Affected Habitations | Source of Groundwater | Range (ppb) |
|---|---|---|---|---|
| 1. | Fazilka | 217 | Tubewell/Handpump | 30.0 - 366.0 |
| 2. | Moga | 203 | do | 30.0 - 346.7 |
| 3. | Barnala | 115 | do | 30.0 - 290.6 |
| 4. | Ferozepur | 139 | do | 30.0 - 331.4 |
| 5. | Patiala | 96 | do | 30.0 - 267.0 |
| 6. | Sangrur | 93 | Tubewell | 30.0 - 230.3 |
| 7. | Bathinda | 52 | Tubewell/Handpump | 30.0 - 325.1 |
| 8. | Ludhiana | 42 | do | 30.0 - 301.0 |
| 9. | Fatehgarh Sahib | 36 | do | 30.0 - 278.0 |
| 10. | Mansa | 10 | Tubewell | 30.0 - 350.3 |

## HEALTH HAZARDS EFFECTS DUE TO ARSENIC, SELENIUM AND URANIUM

Arsenic contamination in groundwater is a matter of immediate concern in Punjab due to its health hazards. Punjab Agriculture University (PAU) scientists were the first to undertake arsenic investigation in groundwater and canal waters in Majha belt of Punjab [17]. A research report recently prepared by the Indian Council of Agriculture Research (ICAR) has reported arsenic beyond safe limit in 13 districts of Punjab [26]. According to PWSSD report, out of all QA habitations in Punjab, 60% fall in Majha belt of Punjab, namely, Amritsar, Gurdaspur and Tarn districts (Tables 1).

Wongsasuluk et al. [27] have reported a systematic investigation of carcinogenic and noncarcinogenic effects of heavy metals on an agricultural area of Thailand. Human health risk assessment has been made for all heavy metals including arsenic. Rapant and Krcmova´ [28] reported that the cancer risk caused by arsenic in groundwater reached as high as $10^{-4}$, or more than 100 people in a million in Slovakia.

Selenium contamination in groundwater is a matter of immediate concern in Punjab due to its health hazards. Punjab Agriculture University (PAU) scientists were the first to undertake selenium investigation in groundwater and soil in Punjab [19–22]. According to the PWSSD report, with AL of selenium set at 0.01 mg/l (ppm) for groundwater, most of the quality affected habitations fall in the Doaba belt of Punjab, namely, Jallandhar, Kapurthala and Hoshiarpur districts (Table 2).

Selenium toxicity in animals has been reported by some groups but no data are available on toxicity effects on human population till date in India. Most of these studies have been conducted in the USA and China [29, 30]. Recent human and laboratory studies carried out in seven villages of seleniferous area of Punjab have suggested the possibility that selenium over exposure may increase blood pressure [31].

It has been observed that acute oral doses of selenite and other selenium compounds cause symptoms such as nausea, diarrhoea, abdominal pain, chills, tremor, numbness in limbs, irregular menstrual bleeding, and marked hair loss [32]. In selenium-rich areas of South Dakota, USA, symptoms in people with high urinary selenium levels included gastrointestinal disturbances, discoloration of the skin, and decayed teeth [33].

The health effects of uranium concentration in water on humans are not well documented. The overall indications are that there is no clear evidence of effects below an exposure concentration of 30 μg/l (ppb). In fact, the evidence for effects on the kidney, which appears to be the most sensitive organ, is equivocal until much higher exposure concentrations. At higher concentrations, above about 100 μg/l (ppb), radioactivity will begin to be a consideration.

## MITIGATION OF HEAVY METALS IN GROUNDWATER

Several methods are available for the removal of uranium from drinking-water, although some of these methods have been tested at laboratory or pilot scale only. Coagulation using ferric sulphate or aluminium sulphate at optimal pH and coagulant dosages can achieve 80–95% removal of uranium, whereas at least 99% removal can be achieved using lime softening, anion exchange resin or reverse osmosis (RO) processes. PWSSD has provided uranium free water by using RO process in most of the quality affected habitations having uranium content more than 60 ppb, the permissible limit set by Atomic Energy Regulatory Board (AERB) of Department of Atomic Energy, Govt. of India [34].

Mitigation of arsenic has been reported by the author using AMRIT technology [13]. There are several methods for mitigation of selenium in groundwater [35]. Selenium can be adsorbed onto iron oxide–coated sand. Practically complete removal of Se (IV) from a 10 mg/l solution in contact with 100 g/l coated sand was achieved within 10 min, whereas Se (VI) removal required about 90 min. The adsorption capacity was approximately 1 mg/g of coated sand [36]. Pilot plant trials have shown that adsorption by soil has the ability to remove selenium from water. Selenium removal of 95% was achieved in the absence of nitrate [37]. The presence of nitrate interferes with the adsorption of selenium. It is reported that activated alumina adsorption using Alcoa F-1 can lead to selenium removals of 98% at pH 5 [38]. Other studies have confirmed that ion exchange using synthetic resins is capable of removing Se (VI) anions from groundwater [39]. Laboratory research suggested that both selenite and selenate may be removed by ion exchange and reverse osmosis [40].

## CONCLUSIONS

1. Groundwater contamination due to heavy metals in Punjab is alarming. It is higher than any other state in India.
2. There is a distinct pattern of occurrence of heavy metals in Punjab, viz. arsenic predominance in Majha belt, selenium prevalence in Doaba belt, and uranium contamination in Malwa belt of Punjab (Figure 1).
3. There is a need to study health hazards effects of heavy metals on population of Punjab by undertaking epidemiological investigations.
4. Punjab Water Supply and Sanitation Department (PWSSD), Govt. of Punjab has created a large database for research and analysis. Implementation of World Bank project report on priority basis is the need of the hour.
5. Mitigation of heavy metals contamination of groundwater is a problem of enormous magnitude in Punjab. The use of canal water for drinking purposes is the cost-effective optimum solution of the problem.
6. There is an urgent need to change the cropping pattern in Punjab to halt the depletion of groundwater table further. Most of the blocks have reached the red alert zone determined by Central Ground Water Board, Ministry of Water Resources, Government of India.

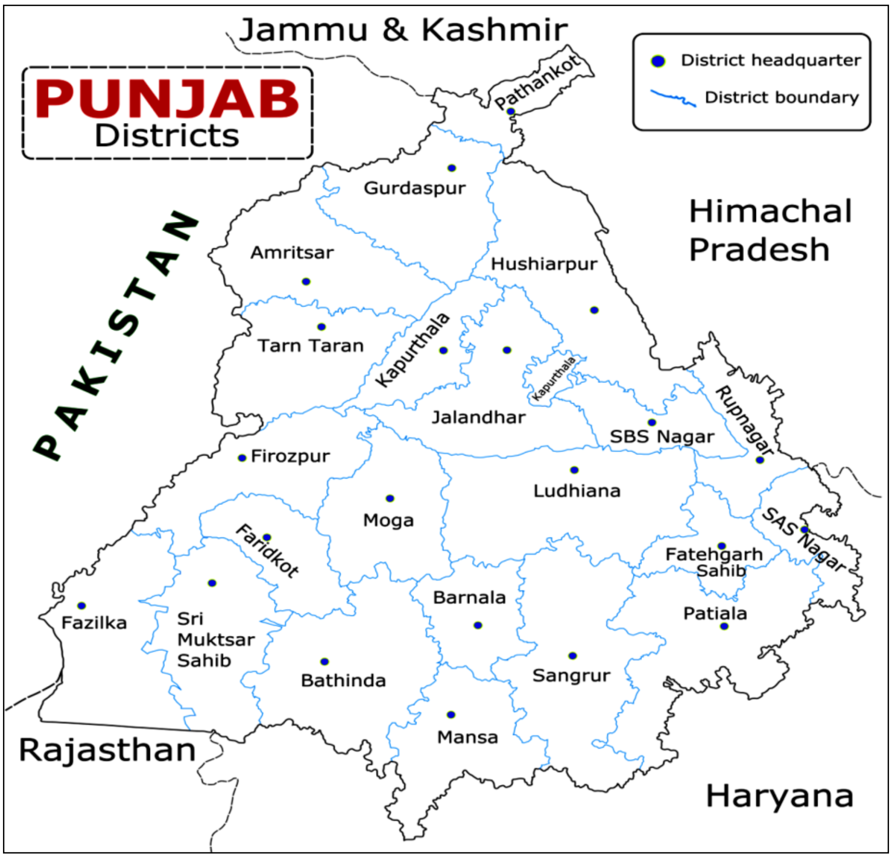


***Fig. 1:*** *District Map of Punjab showing all Districts Affected by High Arsenic, Selenium and Uranium.*

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