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A Preliminary Report on Groundwater Contamination of Majha Belt of Punjab due to Heavy Metal Arsenic

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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, there are 2748 habitations out of 6884 surveyed in Punjab, which fall under quality affected (QA) category (40% nearly). Out of all QA habitations in Punjab, 60% fall in Majha belt of Punjab, namely, Amritsar, Gurdaspur and Tarn Taran districts. In this preliminary report, groundwater quality data pertaining to Arsenic is reported. Arsenic contamination can be get rid of by using a nanotechnology based technique called AMRIT (Arsenic and Metal Removal by Indian Technology). The final report enumerating the health hazard effects of Arsenic and other heavy metals on population in Punjab will be presented after compiling the data analysis of pilot plants in Majha belt using AMRIT methodology.

Keywords: *Heavy metal contamination, Arsenic, acceptable limit, AMRIT, Majha belt of Punjab*

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INTRODUCTION
Punjab is facing a crisis situation due to heavy metals contamination in the underground water table. Recent reports [1–3] published in 'The Tribune' (www.tribuneindia.com) concerning high toxicity of heavy metals in the groundwaters of Punjab are alarming. The report published on January 28th is exhaustive and is based on a study of health hazards of heavy metals diagnosed in Baba Farid Centre of Special children at Faridkot in Punjab. A high level of heavy metal toxicity has been detected in urine samples of children causing deformities and mental disorders. The report concludes that toxic metals have poisoned the sub-soil groundwater in Punjab to an extent that cancer and heart diseases among adults are rampant. The report published on February 7th states that Punjab accounts for 88 percent of total habitations (villages or cluster of houses) in India that are adversely affected with the presence of heavy metals in groundwater. According to the data compiled by the Central Ground Water Board (CGWB), the total number of villages affected by heavy metal contamination is 2420 in India, out of which 2139 fall in Punjab, 273 in Bengal, 7 in Assam and only one in Karnataka.

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 this data is available on the website of Ministry of Water Resources, Government of India [4].

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 this paper, our focus of study is contamination of groundwater due to Arsenic only. In fact, most of our earlier investigations were focussed on Uranium contamination and excess cancer risk to exposed population due to its health hazards [5–7]. Some other investigators [8-10] have also reported higher levels of Arsenic than the permissible limit of 10 ppb in groundwater of Punjab. Till today, there is no conclusive evidence for source of Arsenic contamination in waters of Majha belt 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 [11]. 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 in drinking water with a view to reducing the concentration of arsenic 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 has been adopted as the standard.

On the basis of observations in a population ingesting arsenic-contaminated drinking-water, the concentration associated with an excess life-time skin cancer risk of $10^{-5}$was calculated to be 0.00017mg/L. The cancer risk assessment for arsenic in drinking water is calculated by using a Multistage Model based on an epidemiological study by Tseng [12].

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. Further, approximately, 10 million cases of diarrhoea, more than 7.2 lakh typhoid cases and 1.5 lakh viral hepatitis cases occur every year a majority of which are contributed by unclean water supply and poor sanitation. 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" [13]. It includes all metals listed in PWSSD analysis except Arsenic. I wonder why such a toxic metal has been ignored in BIS report.

THE STUDY AREA

Location

Amritsar district [14] is located in northern part of Punjab state and lies between 31°28’ 30” to 32° 03’ 15” north latitude and 74° 29’ 30” to 75°24’ 15” east longitude (Figure 1).

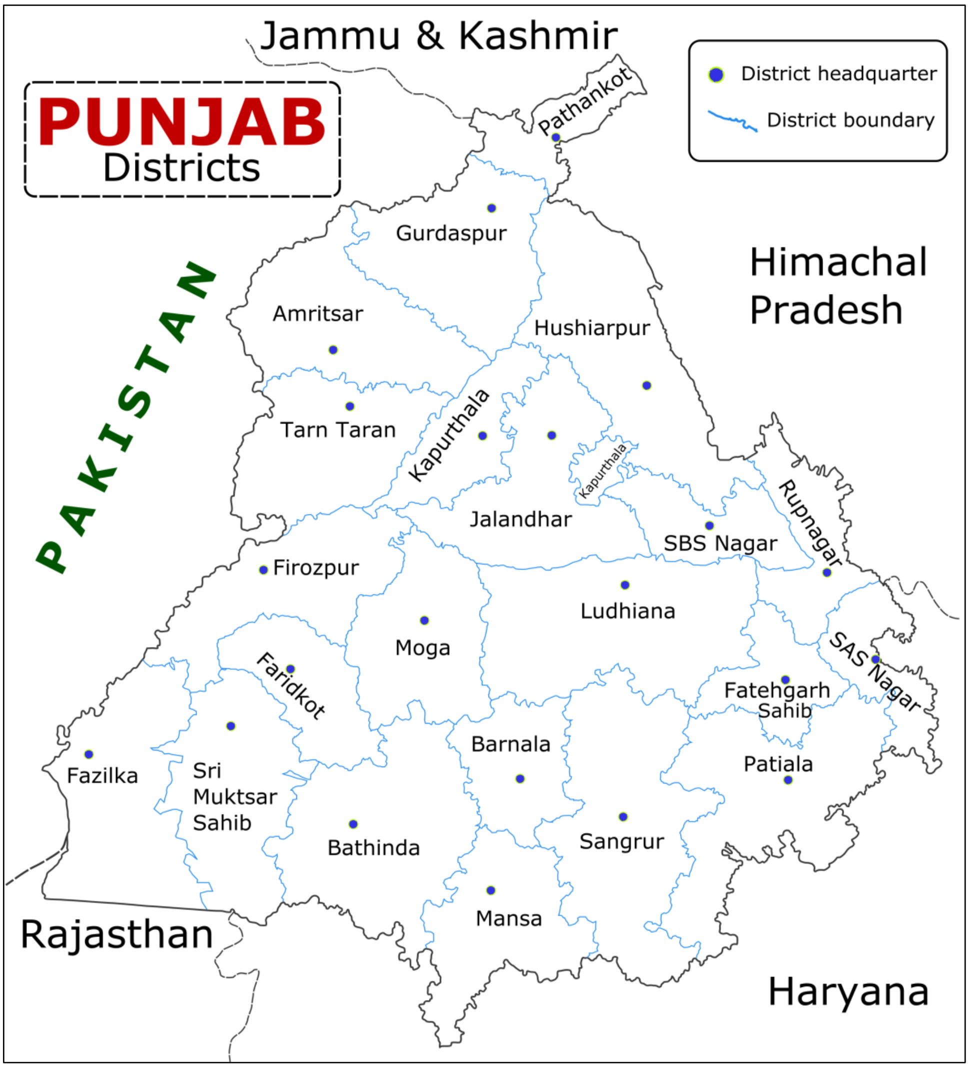

Fig. 1: *District Map of Punjab Showing Districts of Amritsar, Gurdaspur and Tarn Taran.*

Total area of the district is 2647 sq km. Major canal in the area is Upper Bari Doab canal which give rise to various branches as Lahore Branch, Kasur branch etc. Gurdaspur and Tarn Taran are adjoining districts of Amritsar. In fact, Tarn Taran is recently carved out of Amritsar district.

Gurdaspur district [15] is located in the northern most part of the Punjab state. It shares the boundary with Jammu and Kashmir state and Himachal Pradesh. The district is bounded by river Ravi and Beas. It covers an area of 3513sq km and forms a part of upper Bari Doab area. Physiographically the area is divided into three units i.e, Siwalik Hills lying in NE of the district, Kandi Zone lying immediately south west of foothill zone of Siwalik hills, and Alluvial plains lying south west of Kandi.

GEOMORPHOLOGY AND SOIL TYPES

Amritsar district [14] area is occupied by Indo-Gangatic alluvium. Amritsar district falls in between Ravi river and Beas river. Ravi River flows in north-west of the district and forms international border with Pakistan. Beas River flows in the eastern part of the district. Soils in the western part of the district are coarse loamy, calcareous soils, where as in the central part of the district soils are fine loamy, calcareous and are well drained.

Gurdaspur district [15] can be divided into three geomorphological types-Hilly area, Piedmont zone and alluvial plain. Hilly area is predominately on the north-east part of the district and called Siwalik which are mainly clays and clay with boulders. Dharkalan block is predominantly covered by hilly terrain, piedmont comprises pebbles, and cobbles drain from the Siwalik along with sand of medium to coarse grained gravel. The alluvial plain is sand intercalated with little clays deposited by main dry rivers of Ravi and Beas.

ARSENIC CONTENT IN GROUNDWATER AND ITS HEALTH HAZARDS

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 [8]. A research report recently prepared by the Indian Council of Agriculture Research (ICAR) has reported arsenic beyond safe limit in 13 districts of Punjab [16]. According to PWSSD report, with acceptance level (AL) set at 0.01 mg/l (ppm) [11], there are 2748 habitations out of 6884 surveyed in Punjab, which fall under quality affected (QA) category (40% nearly). Out of all QA habitations in Punjab, 60% fall in Majha belt of Punjab, namely, Amritsar, Gurdaspur and Tarn districts (Tables 1–3).

Amritsar district has maximum number of 505 QA habitations in Punjab with highest value of Arsenic in water of the order of 0.111 mg/l in three villages, namely Bath, Khatrai Khurd and Khatrai Kalan (Table 1). In Gurdaspur district, the number of QA habitations is 328 and the highest value of Arsenic is found to be 0.187 mg/l in the water drawn from a hand pump in village Dhande. In Tarn district, 321 habitations are QA and the highest value of 0.100 mg/l Arsenic is found to be in the water drawn from a tube well of Ghurk wind village. No correlation of Arsenic content and the depth of water source is established in PWSSD analysis.

There is hardly any epidemiological investigation to study the health hazard effects of Arsenic in groundwater on the human population in Punjab. Rashmi Verma and Pratima Dwivedi [17] have reported some heavy metal poisoning and bio-toxicity effects in water of Bilaspur State, India, but this study is purely qualitative and not based on any experimental data. Hence, it has no significance and impact at research level.

Wongsasuluk *et al.* [18] have reported a systematic investigation of carcinogenic and non-carcinogenic 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´ [19] 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.

Table 1: *Habitations with high Arsenic Content (>0.08 mg/l) in Amritsar District. Acceptable Limit in Groundwater is 0.01mg/l.*

Sr. No.	Name of Village	Source of Drinking Water	Depth	Arsenic
1	Badhar			0.091
2	Bath	Tubewell	122 m	0.111
3	Boharwala	Tubewell	61 m	0.082
4	Dial Bharang	Tubewell	92 m	0.087
5	Dial Pura	Tubewell	92 m	0.087
6	Gorey Nangal	Water Supply scheme	138 m	0.082
7	Jassar	Tubewell	132 m	0.086
8	Majhi Meun	Handpump	61 m	0.081
9	Makowal	Tubewell	132 m	0.086
10	Urdhan	Tubewell	92 m	0.087
11	Vachhoya	Tubewell	150 m	0.087
12	Barar	Tubewell	450 ft	0.083
13	Kakar	Tubewell	150 m	0.083
14	Mehmadpura	Tubewell	150 m	0.083
15	Odhar	Tubewell	150 m	0.085
16	Saurian	Tubewell	150 m	0.083
17	Tarin	Tubewell	150 m	0.083
18	Chak Kamal Khan	Tubewell	450 ft	0.098
19	Dalam	Tubewell	450 ft	0.086
20	Dharamkot	Tubewell	150 m	0.083
21	Jauns	Tubewell	150 m	0.104
22	Khatrai Kalan	Tubewell	365 ft	0.111
23	Khatrai Khurd	Tubewell	122 m	0.111
24	Mohar	Tubewell	159 m	0.081
25	Mahaddipur	Tubewell	150 m	0.090
26	Budha Theh	Water Supply scheme	148 m	0.168
27	Basti Bazi Garan	Tubewell	152 m	0.086

What is the source of Arsenic in the groundwaters of Majha belt? It needs to be investigated in greater detail to eliminate health hazard effects of Arsenic beyond the acceptable level set by WHO. Heavy metal contamination is potentially a significant problem in several community and agricultural areas because agrochemicals, including plant nutrients and fertilizers can lead to dramatic increases in the concentrations of heavy metals in the water and soil [20]. Arsenic anomalies in ground waters of Majha belt are attributed to excessive use of fertilizers, herbicides and pesticides. Arsenic is a cancer causing agent. The induction of cancer is caused by Arsenic which results from its absorption in the gastro intestinal system. Long term ingestion of low Arsenic concentrations in drinking water can lead to bladder, lung and prostate cancer [21–23].

Table 2: *Habitations with High Arsenic Content (>0.06 mg/l) in Gurdaspur District. Acceptable Limit in groundwater is 0.01mg/l.*

Sr. No.	Name of Village	Source of Drinking Water	Depth	Arsenic
1	Fatehgarh Churian	Water Supply Scheme		0.061
2	Fatehgarh Churian	Tubewell		0.081
3	B.O.P. Nikka	Tubewell	260 ft	0.072
4	Bulowal	Tubewell	425 ft	0.071
5	Dadu Yod	Tubewell	400 ft	0.104
6	Dhande	Tubewell	400 ft	0.104
7	Doger	Tubewell	425 ft	0.080
8	Khussar Tahli	Tubewell	425 ft	0.080
9	Lala Nangal	Handpump	210 ft	0.085
10	Veela Teja	Tubewell		0.065
11	Khokhar	Tubewell	333 ft	0.066
12	Mangal Sen	Tubewell	333 ft	0.066
13	Salimpur Afghana	Tubewell	333 ft	0.066
14	Dhande	Handpump	210 ft	0.187
15	Daburji	Tubewell	425 ft	0.072
16	Gawara	Tubewell	425 ft	0.072
17	Nabi Nagar	Tubewell	425 ft	0.072
18	Shahpur Jajan	Tubewell	425 ft	0.074
19	Tapala	Tubewell	425 ft	0.072
20	Pabarali	Tubewell	425 ft	0.085
21	Mulowali	Tubewell	425 ft	0.074
22	Pabarali Khurd	Tubewell	425 ft	0.085

AMRIT METHODOLOGY OF ARSENIC REMOVAL FROM WATER

The presence of arsenic in various ionic and molecular forms in the aquatic environment is a major concern of the world due to their severe toxicity towards human beings. A number of technologies have been tried in the field and each of them has associated challenges (cost, complexity, efficiency and sludge). Adsorption has earned attention as one of the most widely used methods for decontamination of arsenic. Old technologies using commercial ferric hydroxide are increasingly becoming outdated. For arsenic removal, nanomaterial’s perform 25 times better over activated alumina and 10 times better over commercial ferric hydroxide.

Table 3: *Habitations with High Arsenic Content (>0.05 mg/l) in Tarn Taran District. Acceptable Limit in Groundwater is 0.01 mg/l.*

Sr. No.	Name of Village	Source of Drinking Water	Depth	Arsenic
1	Bhojeke	Handpump	270 ft	0.053
2	Thatha	Tubewell	470 ft	0.057
3	Gandiwind	Tubewell		0.056
4	Leian	Tubewell		0.056
5	Shukar Chak	Tubewell		0.056
6	Jhuggain Kalu	Tubewell		0.071
7	Kotli Vasawa Singh	Tubewell	470 ft	0.077
8	Mianwal	Handpump	280 ft	0.083
9	Sarai Valtoha	Tubewell	470 ft	0.077
10	Bainka	Tubewell	470 ft	0.057
11	Chung	Tubewell		0.053
12	Ghurkwind	Tubewell		0.100
13	Mari Nau Abad	Tubewell		0.053
14	Surwind	Tubewell		0.075
15	Puhla	Tubewell	325 ft	0.054
16	Kot Bhudha	Tubewell	470 ft	0.077
17	Bhahuwal	Tubewell	470 ft	0.077
18	Dhariwal	Tubewell	470 ft	0.051
19	Wara Sher Singh	Tubewell		0.062
20	Wara Telian	Tubewell		0.076
21	Channa Sirja Mirza	Tubewell		0.051
22	Hawelian Jhar Sahib	Handpump	280 ft	0.054
23	Algon Khurd	Tubewell		0.071
24	Algon Kalan	Tubewell		0.069

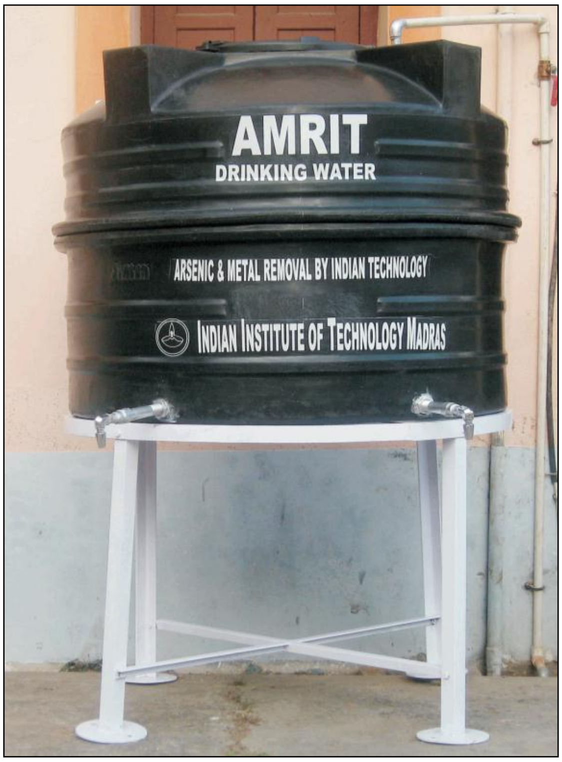

Fig. 2: *AMRIT Community Water Purification Unit Installed in an Affected Area of West Bengal (in Association with Government of West Bengal).*

The acronym AMRIT stands for arsenic and metal removal by Indian Technology (Figure 2). The main component of AMRIT is composed of nanoscale iron oxyhydroxide, prepared with a particle size less than 3 nm. The synthesis of nanoscale iron oxyhydroxide and its efficacy for removal of arsenic from water is described elsewhere [24]. Choice of iron based compounds is based on the fact that they are commonly found in water. Engineering such compounds based on nanotechnology enables them to pick large quantity of arsenic. Particle size below a critical limit increases the number of surface atoms substantially leading to higher surface energy. An important aspect is to ensure that such nanoparticles are strongly anchored onto solid surfaces so as to make sure that they don't leach into water, thereby preventing secondary contamination. Simultaneously, the adsorbed arsenic doesn't get released from the composition, thereby ensuring that spent material can be disposed locally.

What it means in terms of performance and affordability? AMRIT composition can handle up to an input load of 5 ppm of arsenic (equally well for both forms of arsenic, As^{3+} and As^{5+}) and bring the output below the detection limit (<1 ppb). Composition is at least 5–6 times more efficient than any other adsorbent available currently. Since the contact time required for removal is fairly low (less than 1 min), the composition is used in the size of 0.2 mm, thereby offering negligible pressure drop. This helps from several aspects: treatment cost reduces, filtration unit becomes smaller, filtration unit can be operated with minimum pressure, easily maintainable by local community and reduced sludge quantity.

PWSSD has installed pilot plants in Majha belt using AMRIT methodology of Arsenic removal from potable water in Gurdaspur and Taran districts. The project is being funded under the World Bank initiative to provide clean water in a mission mode.

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