A Survey Report on Groundwater Contamination of Doaba 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). In this survey report, groundwater quality data pertaining to Arsenic is reported in the districts of Hoshiarpur and Kapurthala of the Doaba belt of Punjab. The occurrence of high Arsenic in groundwater is of geogenic origin and may be attributed to the river basins in Punjab. Methods for Arsenic removal and its health hazard effects are briefly discussed.

Keywords: *Groundwater contamination, Arsenic, acceptable limit, AMRIT, Malwa belt of Punjab*

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INTRODUCTION

Arsenic (As) is a toxic element classified as a human carcinogen that contributes to cancers of both skin and internal organs (liver, bladder, kidney and intestinal) [1]. Arsenic was detected in groundwater for the first time in the early 1990s in Bangladesh and West Bengal of India. It has now been detected in most of the East and Southeast Asian countries including China, Pakistan, Cambodia, Vietnam, Myanmar, Laos, Thailand and Indonesia [2, 3]. According to an estimate by the World Bank, approximately 60 million people in South and East Asia are at risk from high levels of naturally occurring Arsenic in groundwater. Moreover, at least 700,000 people have been affected by Arsenic poisoning (*arsenicosis*), especially in the rural areas of Asia [4].

The State of Punjab is facing a severe crisis situation due to Uranium and heavy metals contamination of the underground water table [5]. The reports published in 'The Tribune' Chandigarh (www.tribuneindia.com) concerning high toxicity of Arsenic and other heavy metals in the groundwaters of Punjab are alarming [6-8]. A high level of heavy metal toxicity has been detected in urine samples of children causing deformities and mental disorders [7]. 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, 2018 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 [8].

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 [8]. 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 has prepared a comprehensive report on Water Quality Monitoring and Mitigation Strategy for the Punjab Rural Water Supply Sector Improvement Project (PRWSSIP) submitted to the World Bank [9].

In this paper, our focus of study is contamination of groundwater of Doaba belt of Punjab due to Arsenic only. Our analysis is 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 [10]. Some other investigators [11-15] have also reported higher levels of Arsenic 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 [16]. 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 0.17 μg/L (ppb). The cancer risk assessment for arsenic in drinking water is calculated by using a Multistage Model based on an epidemiological study by Tseng [17].

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" [18]. 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, Geomorphology and Hydrogeology of Doaba Districts

The Hoshiarpur district [19] falls in the eastern part of the Punjab State and is bounded by North latitudes 30^0 58' 30" and 32^0 08' 00" and East longitudes 75^0 28' and 76^0 30' [Fig. 1]. The district is drained by the river Beas in the north and northwest and Satluj in the south. It shares common boundaries with Kangra and Una districts of Himachal Pardesh in the north east, Jalandhar and

Kapurthala districts (interspersed) in south-west and Gurdaspur district in the north-west. It has an area of 3386 sq. kms. Unconsolidated alluvial sediments lying south of Siwalik foothills mainly occupy the district. The alluvial sediments are classified as piedmont and fluvial deposits. The fluvial comprise of silt, sand, gravel and clay in association with *kankar*. Groundwater is generally fresh at all levels and occurs under unconfined conditions in shallow aquifers and under semi-confined to confined condition in deeper aquifers.

The Kapurthala district [20] is occupied by Indo-Gangetic alluvium. It lies between 31^0 07' to 31^0 39' north latitude and 74^0 55' to 75^0 36' east longitude (Fig. 1). Total geographical area of the district is 1633 sq. km. Kapurthala district is bounded partly in the North and wholly in the West by the Beas river. It is situated in the Bist Doab and comprises two non- contiguous parts, separated by some 32 kms. The major portion of this district lies in the river tract falling between the Beas and Black Bein and is called '*Bet*'. The numerous hill streams coming down from Hoshiarpur district keep the soil moist all the year round. Chemical quality data obtained from the analysis of ground water samples representing shallow aquifers reveals that ground water is alkaline in nature and fresh to moderately saline. The major part of the district is being irrigated through ground water.

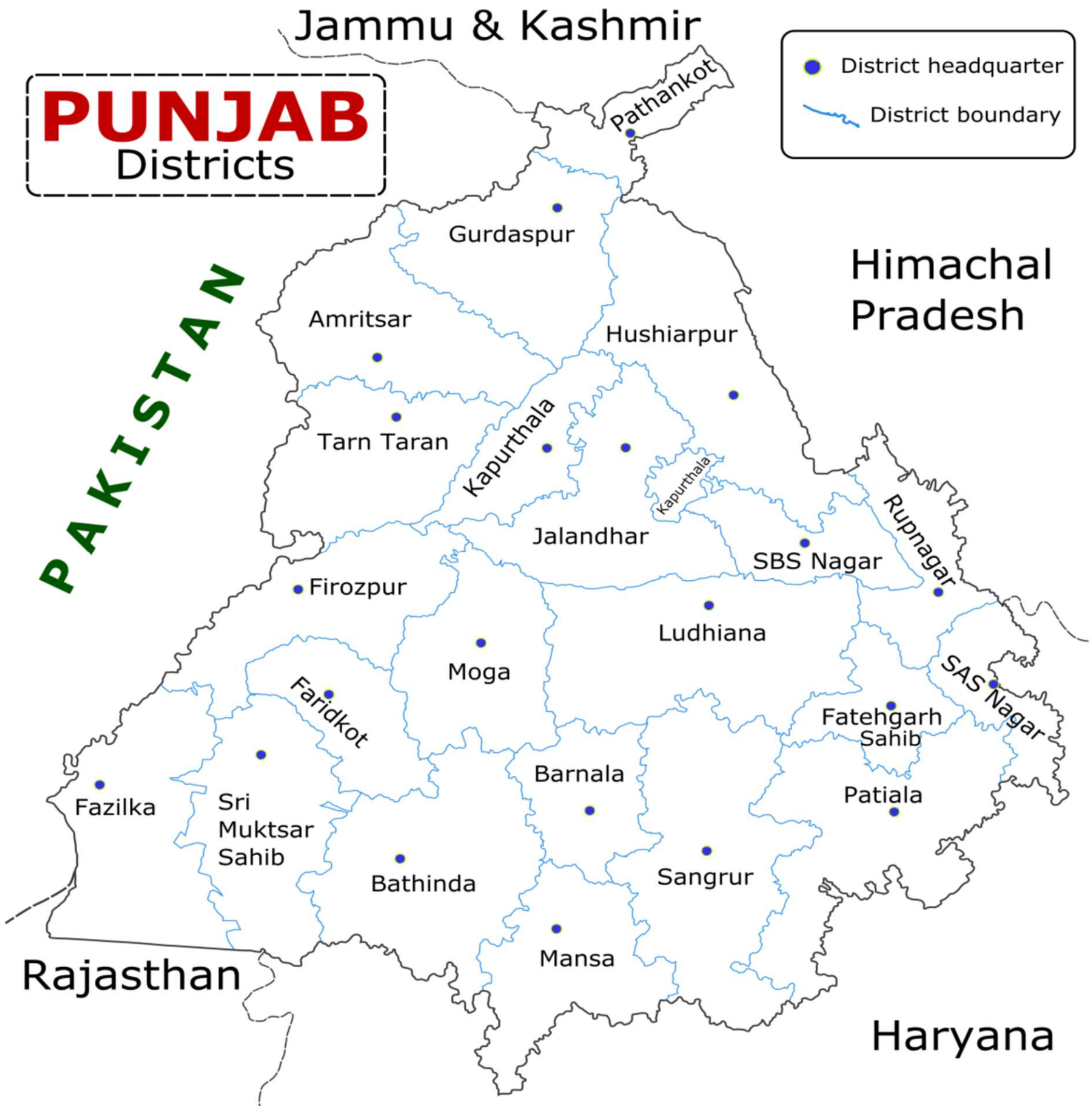

Fig. 1: District Map of Punjab Showing Districts of Hoshiarpur and Kapurthala

Table 1. High Arsenic Content in Hoshiarpur District (>0.015 mg/l)

Sr. No.	Villages Surveyed	Groundwater Source	Depth (ft)	Arsenic (mg/l)
1	Dallewal	Tubewell	450	0.016
2	Saila Khurd	Tubewell	450	0.019
3	Pensra	Tubewell	410	0.017
4	Saila Kalan	Tubewell	410	0.017
5	Chaura	Tubewell	510	0.027
6	Dagham	Tubewell	510	0.027
7	Dehron	Tubewell	510	0.027

8	Fatehpur Kalan	Tubewell	510	0.027
9	Basti No. 1	Tubewell	510	0.027
10	Nasrala	Tubewell	450	0.039
11	Nasrala Colony	Tubewell	450	0.039
12	Basiala	Tubewell	450	0.016
13	S.CI	Tubewell	450	0.016
14	Garhi Mansowal	Tubewell	430	0.021
15	Jhunjowal Surehra Abadi	Tubewell	430	0.021
16	Attowal	Tubewell	470	0.017
17	Marnian Kalan	Tubewell	470	0.017
18	Marnian Khurd	Tubewell	470	0.017
19	Tanuli	Tubewell	480	0.016
20	Chak Musa	Tubewell	430	0.025
21	Kallupur	Tubewell	430	0.025
22	Mananhana	Tubewell	430	0.025
23	Nai Chak	Handpump	180	0.016

Table 2. Arsenic content in Groundwater of Kapurthala District (>0.01 mg/l)

Sr. No.	Villages Surveyed	Groundwater Source	Depth (ft)	Arsenic (mg/l)
1	Jahangirpur	Tubewell	350	0.012
2	Balo Chak	Tubewell	325	0.012
3	Feroz Sangowal	Tubewell	325	0.012
4	Amritpur	Tubewell	370	0.014
5	Baupur Kadim	Handpump	255	0.033
6	Bidhipur	Tubewell	390	0.010
7	Dandupur	Tubewell	350	0.014
8	Gill	Tubewell	370	0.011
9	Haibatpur	Tubewell	375	0.014
10	Jabbo Sudhar	Tubewell	350	0.012
11	Jainpur	Tubewell	385	0.013
12	Kalru	Tubewell	370	0.012
13	Khoker Jadid Kadim	Tubewell	370	0.012
14	Sarai Jattan	Tubewell	350	0.013
15	Sikarpur	Handpump 3	290	0.016
16	Suchet Garh	Tubewell	370	0.012

17	Tibba	Tubewell	340	0.010
18	Ucha Boharwala	Tubewell	370	0.018
19	Buh	Tubewell	380	0.012
20	Desal	Tubewell	330	0.014
21	Fazlabad	Tubewell	330	0.014
22	Ghug Bet	Tubewell	370	0.011
23	Goura	Tubewell	380	0.015
24	Hambowal	Tubewell	240	0.013
25	Mand Sabak Desal	Tubewell	330	0.014
26	Mehmadwala	Tubewell	330	0.045
27	Saflabad	Tubewell	330	0.014
28	Shahpur Piran		330	0.012
29	Ucha	Tubewell	330	0.013
30	Harijan Basti	Tubewell	225	0.013
31	Harijan Abadi	Tubewell	375	0.014
32	Jeorgepur	Handpump	370	0.014
33	Tandi Dakhli	Tubewell	370	0.012

DISCUSSION OF RESULTS

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 [11]. A research report recently prepared by the Indian Council of Agriculture Research (ICAR) has reported arsenic beyond safe limit in 13 districts of Punjab [21]. According to PWSSD report, with acceptance level (AL) set at 0.01 mg/l or 10 ppb [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 Taran districts [22].

Arsenic content in groundwater of Hoshiarpur district with values 50% higher than the acceptable limit (AL) of 0.01mg/l in 23 villages are reported (Table 1). The highest value of 0.039 mg/l is recorded in water drawn from tubewells of Nasrala and Nasrala Colony. In Kapurthala district, 33 villages report Arsenic values higher than the AL (Table 2). The highest value of Arsenic (0.033mg/l) is recorded in the water drawn from a handpump of village Baupar Kadim. A comparison of Arsenic content of groundwater of both districts shows some similarity in the pattern. The only difference is that Hoshiarpur has 60 villages with Arsenic content higher than AL value while Kapurthala has just 33 villages beyond the AL value.

What is the source of Arsenic in the ground waters of Doaba belt? The occurrence of high Arsenic in groundwater is attributed to the flood plains of rivers Satluj and Beas flowing in the Doaba belt of Punjab. It needs to be investigated in greater detail to eliminate health hazard effects of Arsenic beyond the acceptable level set by WHO.

HEALTH HAZARDS OF HIGH ARSENIC CONTENT IN GROUNDWATER

Arsenic effects, once initiated in the human body, are irreversible. Prevention of further exposure is a key recommendation by the World Health Organization (WHO). No case of Arsenicosis has so far been reported from the Punjab State, though this may be due to the absence of surveillance [23].

Human exposure to elevated levels of inorganic Arsenic occurs through drinking contaminated water, using contaminated water for crop irrigation and food preparation, industrial exposure and smoking tobacco grown in arsenic contaminated soils. By far the greatest risk of exposure is from drinking contaminated water. Arsenic has no smell and no taste; and it is not possible to tell if it is present in food, water or air without special tests.

Adverse health effects of Arsenic can occur in acute or chronic settings, though chronic exposure is of greater public health importance. Acute poisoning due to arsenic leads to abdominal pain, vomiting, diarrhea, muscular pain and weakness, with flushing of the skin. These symptoms are often followed by numbness and tingling of the extremities, muscular cramping and the appearance of rash. Chronic effects are most often seen after long term exposure to high levels via drinking water and food for over five years at the minimum. The occurrence of these effects is influenced by the status of nutrition of the exposed individuals; with malnourished individuals showing greater adverse impacts.

Chronic effects can be both carcinogenic and non-carcinogenic. A far greater proportion of the population that shows any effects presents with non-carcinogenic impacts. The signature symptoms are related to the skin, with pigmentation changes and hyperkeratosis (thickening of the skin). Dermal lesions include hyper-pigmentation and hypo-pigmentation, roughened and thickened patches on palms and soles. The arsenic-related skin lesions may also be a possible precursor to skin cancer. Other effects of long term exposure that have been reported include lung cancers and peripheral vascular disease, bladder cancer, cardiovascular disease, diabetes and neurotoxicity. Epidemiological studies are recommended to monitor the health of populations that are at high risk of Arsenic-related adverse health effects [23].

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 [24] 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.* [25] 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´ [26] 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.

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 [27]. Arsenic anomalies in ground waters of Malwa belt may be 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 cancers [28–30].

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.

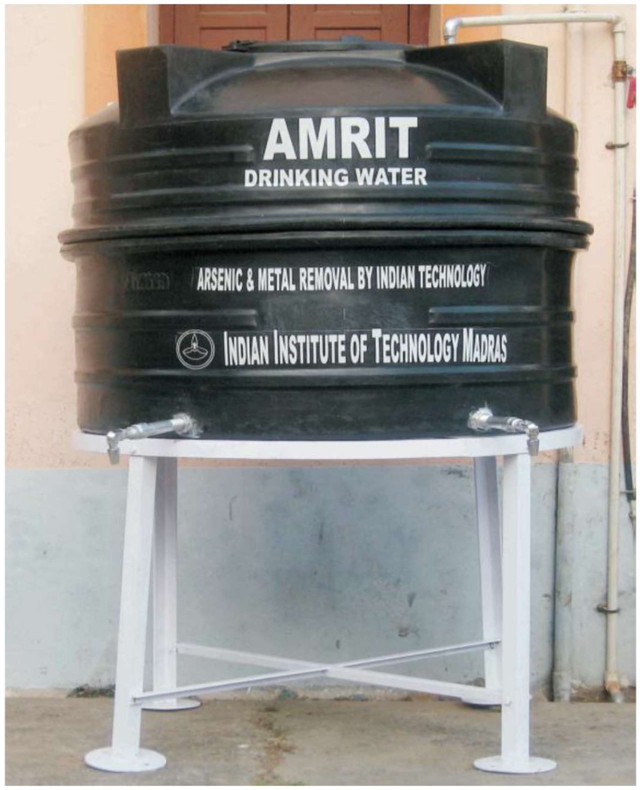

Fig. 2: *AMRIT Community Water Purification Unit Installed in an Affected Area of West Bengal (in Association with Government of West Bengal).*

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 [31]. 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.

It is heartening to note that PWSSD has took initiatives to mitigate the problem of Arsenic contamination of groundwater in the Punjab state. Some pilot plants have been installed in the Majha belt using AMRIT methodology of Arsenic removal from potable water in Amritsar district. The results achieved are commendable as reported by PWSSD for the plants being operated by at the villages Gorey Nangal, Chak Kamal Khan and Budha Theh in Amritsar district. The project has been funded under the World Bank initiative to provide clean water in rural areas of Punjab State.

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