A Survey Report on Groundwater Contamination of Malwa 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 Ferozepur, Roop Nagar and Patiala of the Malwa belt of Punjab. Acceptable Limit for Arsenic in groundwater is 0.01mg/l. The occurrence of high Arsenic in groundwater is attributed to the flood plains of rivers flowing 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 also been detected in several parts of China, Nepal and Pakistan and most Southeast Asian countries including Cambodia, Vietnam, Myanmar, Lao People's Democratic Republic (Lao PDR), 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 As 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 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 [11-13] 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 [14]. 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 guideline 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 [15].

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.

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" [16]. It includes all metals listed in PWSSD analysis except Arsenic. I wonder why such a toxic metal has been ignored in the BIS report.

THE STUDY AREA

Location, Geomorphology and Hydrogeology of Malwa Districts

Ferozepur district [17], the south-western most district of Punjab State, is located between 29° 56' 47" and 31° 0' 7" North latitudes and 72° 52' 4" and 75° 01' 11" East longitudes [Fig. 1]. The geographical extent of the area is 5850 sq. km. Physiographically, it is characterized by four distinct features i.e. the upland plain, sand dune tracts, younger flood plain and active flood plain. River Sutlej shows both influent and effluent nature in the area. The area is traversed by a dense network of canals. The alluvium forms the principal ground water reservoir and the principal aquifer material comprises fine to medium sand and sand often mixed with *kankar*. The thickness of the alluvium varies from 200 to 300 m. in tubewells drilled up to the depth of 454 m.

Roop Nagar (Ropar) district [18] is occupied by Indo-Gangetic alluvium. The district is located in the eastern part of the Punjab State and geographically lies between North latitudes of 76°19′ and 76°45′ and East longitudes of 30°44′ and 31°25′ [Fig. 1]. The geographical extent of the area is 1440 sq. km. The area is bounded by Himachal Pradesh in the north and north east, Hoshiarpur, Nawanshahr and Ludhiana district in the west, Fatehgarh Sahib district in the South and Mohali district in the south east. The Quaternary alluvial deposits belonging to the vast Indo-Gangetic alluvium occurring in the southern blocks of the district form the main aquifer system. The groundwater in the district is alkaline in nature with medium to high salinity.

Patiala district of Punjab state lies between 29º 49' to 30º 40' N latitudes and 75º 58' to 76º 48' E longitudes. Total geographical area of the district is 3218 sq. km. The Central Ground Water Board (CGWB) Report [19] throws some light on the nature of soil and geomorphology of the Patiala district. The district area is occupied by Indo-Gangatic alluvial plain and consists of three types of region, through the Upland plain, the Cho-infested Foothill Plain and the floodplain of the Ghaggar River. Due to arid climate, the soils are light coloured. Tropical arid brown soils exist in the major parts of the district. The ground water of the district is alkaline in nature. At many places high fluoride and at some places, high nitrate have been recorded in the groundwater thus making it harmful for human consumption.

Fig. 1: *District Map of Punjab Showing Districts of Ferozepur, Roop Nagar and Patiala.*

Table 1. High Arsenic Content in Groundwater of Ferozepur District (>.020 mg/l). Acceptable Limit in Groundwater is 0.01mg/l.

Sr. No.	Villages Surveyed	Groundwater Source	Depth (ft)	Arsenic (mg/l)
1	Bhadru	Tubewell	750	0.021
2	Ugo Ke	Tubewell	750	0.021
3	Ittian Wali	Tubewell	510	0.021
4	Mohkam Wala	Tubewell	510	0.021
5	Yare Shah Wala	Tubewell	540	0.021

6	Suwah Wala	Tubewell	350	0.022
7	Lehra Rohi	Tubewell	750	0.022
8	Boor Wala	Tubewell	750	0.024
9	Ch. Swah Wala	Tubewell	750	0.024
10	Basti Ram Lal	Tubewell	310	0.024
11	Basti Khan Ke	Tubewell	310	0.024
12	Basti Bagicha Singh	Tubewell	375	0.024
13	Basti Walia Wali	Tubewell	375	0.024
14	Basti Bhane Wali	Tubewell	350	0.024
15	Basti Ladhu Wali	Tubewell	350	0.024
16	Basti Chamre Wali	Tubewell	310	0.024
17	Basti Jhuge Kahan Singh	Tubewell	310	0.024
18	Rukna Wala	Tubewell	475	0.026
19	Kamal Middu	Tubewell	750	0.027
20	Sultan Wala	Tubewell	500	0.027
21	Changian	Handpump	375	0.029
22	Hamad Wala	Tubewell	375	0.030
23	Baggu Wala	Tubewell	375	0.031
24	Swah Wala	Tubewell	750	0.031
25	Gillan Wali	Tubewell	750	0.031
26	Nizam Wala	Tubewell	750	0.031
27	Dhindsa	Tubewell	325	0.031
28	Basti Gainder	Tubewell	325	0.031
29	Qutab Wala	Handpump	375	0.034
30	Bhamba Singh Wala	Tubewell	455	0.036
31	Palla Megha	Tubewell	455	0.036
32	Harijan Gura Singh	Handpump	290	0.055

Table 2. High Arsenic Content in Groundwater of Roop Nagar District (>0.02 mg/l). Acceptable Limit in Groundwater is 0.01mg/l.

Sr. No.	Villages Surveyed	Groundwater Source	Depth (m)	Arsenic (mg/l)
1	Kainaur	Tubewell	135	0.021

2	Dulci majra	Tubewell	200	0.021
3	Goslan	Tubewell	200	0.021
4	Dumna	Tubewell	176	0.022
5	Samana Khurd	Tubewell	176	0.022
6	Nangal	Tubewell	90	0.022
7	Barwa	Tubewell	80	0.022
8	Bhatauli	Tubewell	80	0.022
9	Chehar Majra	Tubewell	80	0.022
10	Dher	Tubewell	65	0.024
11	Panj Peda	Handpump	80	0.024
12	Malewal	Tubewell	150	0.026
13	Behbalpur	Tubewell	200	0.028
14	Datarpur	Tubewell	200	0.028
15	Samana Kalan	Tubewell	176	0.030
16	Rasulpur	Tubewell	170	0.030
17	Samrouli	Tubewell	170	0.030
18	Karkhana Bela	Handpump	40	0.039
19	Bhalian	Tubewell	200	0.040
20	Silomasko	Tubewell	200	0.040
21	Khabra	Tubewell	200	0.041
22	Ramgarh	Handpump	40	0.052
23	Haron	Tubewell	150	0.060
24	Kandola	Tubewell	150	0.060
25	Katlaur	Tubewell	150	0.060
26	Baili Attalgarh	Handpump	40	0.067
27	Piple Majra	Tubewell	200	0.091

Table 3. High Arsenic Content in Groundwater of Patiala District (>0.015mg/l). Acceptable Limit in Groundwater is 0.01mg/l.

Sr. No,	Villages Surveyed	Groundwater Source	Depth (m)	Arsenic (mg/l)
1	Binjal	Tubewell	201	0.016
2	Dondi Majra	Tubewell	135	0.016
3	Malikpur Kamboan	Tubewell	135	0.016
4	Bosar Kalan	Tubewell	250	0.016
5	Jogipur	Tubewell	250	0.016
6	Therri	Tubewell	325	0.016
7	Kheri Nagaian	Tubewell	200	0.016
8	Alampur	Tubewell	200	0.017

9	Balamgarh	Tubewell	200	0.017
10	Bahmna	Tubewell	200	0.017
11	Behmna/ Bajigarh Basti	Tubewell	200	0.017
12	Harijan Basti	Tubewell	200	0.017
13	Talwandi Malik	Tubewell	200	0.019
14	Sehajpur Kalan	Tubewell	200	0.020
15	Sehajpur Khurd	Tubewell	200	0.020
16	Hadiana	Tubewell	80	0.020
17	Kachwi	Tubewell	249	0.021
18	Kheri Raju Singh	Tubewell	194	0.022
19	Assarpur	Tubewell	250	0.035
20	Hassanpur Jattan	Tubewell	315	0.046
21	Kaboolpur	Tubewell	315	0.046

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 [20]. 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 [21].

Arsenic content in groundwater of Ferozepur district with values double than the acceptable limit (AL) of 0.01mg/l ppb in 32 villages are reported (Table 1). The highest value of 0.055 mg/l is recorded in water drawn from a handpump of Harijan Gura Singh. Following the same procedure, 27 villages of Roop Nagar record Arsenic content twice the AL value, with highest content 0.091 mg/l recorded in tubewell water of Piple Majra, followed by 0.067 mg/l recorded in water drawn from the hand pump of Baili Attalgarh (Table 2). Patiala district has 21 villages recording Arsenic content 50 % higher than the AL value, with highest content of 0.046 mg/l observed in tubewell water of Hassanpur Jattan and Kaboolpur (Table 3). No correlation of Arsenic content and the depth of water source is established in PWSSD analysis.

What is the source of Arsenic in the ground waters of Malwa belt? The occurrence of high Arsenic in groundwater is attributed to the flood plains of rivers flowing in the Malwa 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 [22].

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 [22].

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 [23] 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.* [24] 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´ [25] 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 [26]. 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 [27–29].

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 [30]. 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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