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Selenium Contamination of Groundwater of Majha Belt of Punjab (India)

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Abstract

Punjab is facing a crisis situation due to high levels of heavy metals in the underground water table of Punjab. Majha belt of Punjab, namely, Amritsar, Gurdaspur and Tarn Taran districts have high Arsenic and Selenium contents in groundwater. In this preliminary report, groundwater quality data pertaining to Selenium is reported. Selenium Acceptable Limit (AL) for groundwater is fixed at 0.01 mg/l (ppm) by the Bureau of Indian Standards (BIS). The possible health hazard effects of Selenium are reported on the basis of studies carried out in USA and China.

Keywords: *Acceptable limit, heavy metal contamination, Majha belt of Punjab, selenium*

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INTRODUCTION

Selenium is a non-metal and a very useful component in our diet. Selenium is a nutritionally essential element. Selenium is needed for healthy joints, heart, and eyes. Its role in DNA synthesis, the immune system, and the reproductive system is of critical value. It also helps fight cancer and other diseases. But its excess is dangerous for human health. Chronic exposure to selenium compounds is associated with several adverse health effects in humans.

Selenium acceptable limit (AL) for groundwater is fixed at 0.01 mg/l (ppm) by the Bureau of Indian Standards (BIS) [1]. 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). 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 the Ministry of Water Resources, Government of India [2].

Groundwater quality of N-W India (Punjab) has been studied by Lapworth *et al.* and the source of Selenium concluded to be geogenic in origin [3]. Bajaj *et al.* have reported hazardous concentrations of selenium in soil and groundwater in North-West India including Punjab [4]. Dhillon and Dhillon have carried out extensive studies of selenium in groundwater and soil in Punjab and its take up by vegetation, plants, weeds, and cereals [5-9].

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 the study is contamination of groundwater of Majha belt in Punjab due to Selenium.

WHO GUIDELINES ABOUT SELENIUM

The first WHO document dealing specifically with public drinking-water quality was published in 1958 as International Standards for Drinking-Water. It was subsequently revised in 1963 and in 1971 under the same title. In 1984–1985, the first edition of the WHO Guidelines for drinking-water quality (GDWQ) was published in three volumes. Second editions of these volumes were

published in 1993, 1996 and 1997, respectively. Selenium in Drinking-water is the background document for development of WHO Guidelines for Drinking-water Quality published in 1996 [10]. The US EPA has set Maximum Contaminant Level (MCL) for selenium in drinking water at the level of 0.05 mg/l [11]. The utility must take certain steps to correct the problem if the water exceeds the limit and they must notify citizens of all violations of the standard. World Health Organization has set their guideline value for selenium at 0.04 mg/l [12].

Selenium is present in the earth's crust, often in association with sulfur-containing minerals. It can assume four oxidation states (-2, 0, +4, +6) and occurs in many forms, including elemental selenium, selenites, and selenates. Many selenium compounds are odoriferous, some having an odor of garlic [13]. The level of selenium (mostly bound to aerosols) in most urban air ranges from 0.1 to 10ng/m^3, but higher levels may be found in certain areas, e.g. in the vicinity of copper smelters [14].The levels of selenium in groundwater and surface water range from 0.06 – 400μg/l; in some areas, levels in groundwater may approach 6000 μg/l [15-18].Concentrations increase at high and low pH as a result of conversion into compounds of greater solubility in water.

Levels of selenium in tap-water samples from public water supplies around the world are usually much less than 10 μg/l [19-20]. Drinking-water from a high selenium area in China was reported to contain 50–160 μg/l [13]. Vegetables and fruits are mostly low in selenium content (<0.01 mg/kg). Levels of selenium in meat and seafood are about 0.3–0.5 mg/kg. Grain and cereal products usually contain<0.01–0.67 mg/kg. Great variations in selenium content have been reported in China, where those of corn, rice, and soya beans in high- and low-selenium areas were 4–12 and 0.005–0.01mg/kg, respectively [13, 21].

THE STUDY AREA

Location

Amritsar district is located in northern part of Punjab state and lies between 31^0 28' 30" to 32^0 03' 15" north latitude and 74^0 29' 30" to 75^0 24' 15" east longitude (Figure 1) [22]. The total area of the district is 2647 sq km. Major canal in the area is Upper Bari Doab canal which gives 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 is located in the northernmost part of the Punjab state. It shares the boundary with Jammu and Kashmir state and Himachal Pradesh [23]. 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 area is occupied by Indo-Gangetic alluvium [22]. Amritsar district falls in between Ravi River and Beas River. Ravi River flows in the north-west of the district and forms the 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, whereas in the central part of the district soils are fine-loamy, calcareous and are well drained.

Gurdaspur district 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.

RESULTS AND DISCUSSION

In groundwater, selenium occurs due to weathering and leaching of rocks, and dissolution or oxidation of soluble salts in soils. 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 [5-6]. According to PWSSD report, with acceptance level (AL) of Selenium set at 0.01 mg/l (ppm) for groundwater, most of the quality affected habitations fall in the Majha belt of Punjab, namely, Amritsar, Gurdaspur and Tarn Taran districts (Tables 1–3).

The highest value of selenium (0.076 mg/l) was found in the hand pump-driven water of Abadi Harijan Basti of Tarn Taran district. Five other villages have Selenium content in the range of 0.059 mg/l. All other villages fall in the range of AL to double AL value, i.e. in the range of 0.010 to 0.020 mg/l. In Gurdaspur district there are 17 QA villages with two of them, Pandori Bainsa and Katowal, having Selenium content abnormally high of the order of 0.094 mg/l. Amritsar district has 10 QA habitations only. The highest value 0.039 mg/l of Selenium was recorded in villages of Mattey Nangal and Madhu Chhanga, closely followed by Bhakna Kalan in the range of 0.038 mg/l.

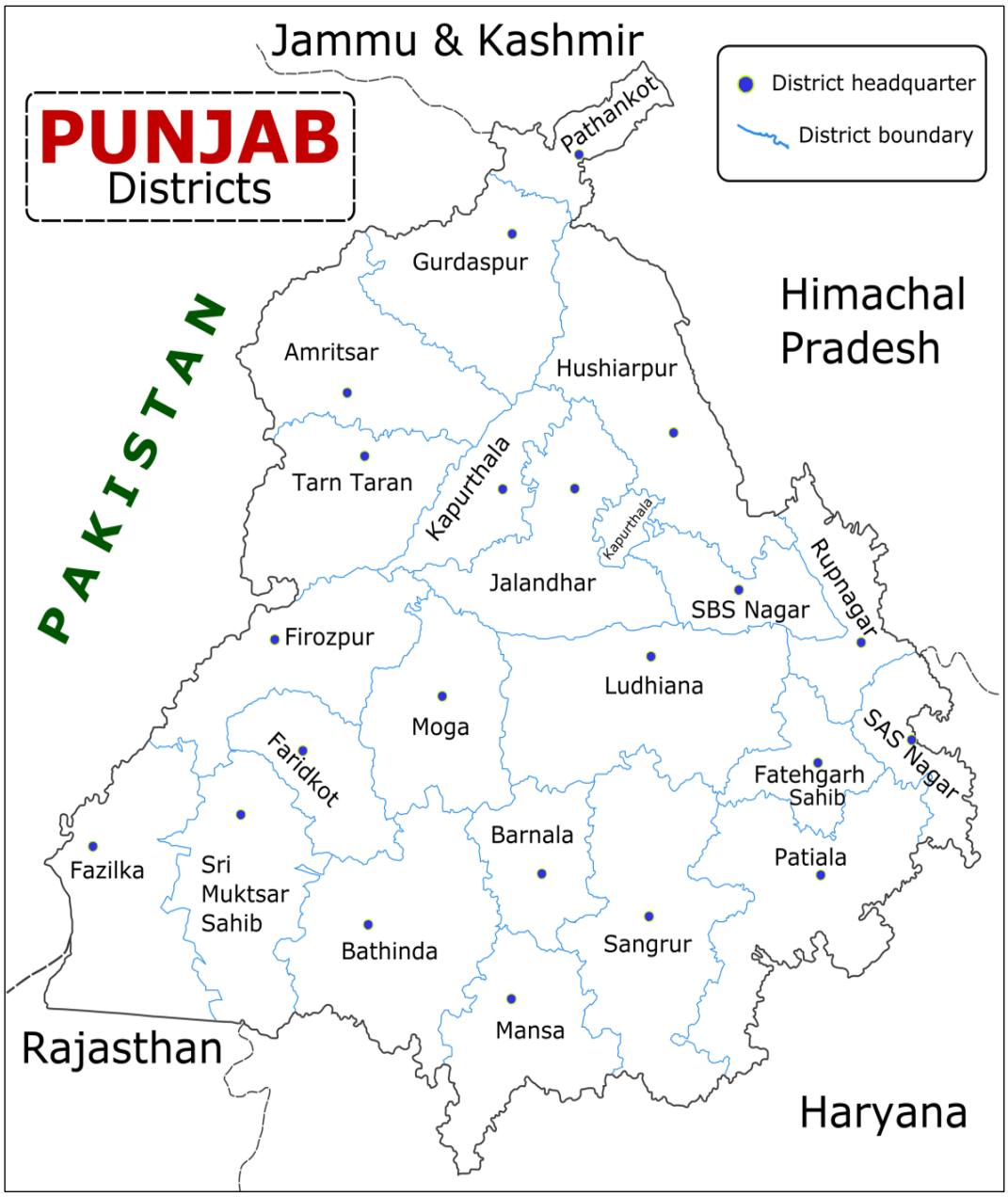

Fig. 1: *District Map of Punjab showing districts of Amritsar, Gurdaspur and Tarn Tarn*

Table 1: *Villages with high Selenium content (>0.01 mg/l) in Tarn Tarn District. The acceptable limit (AL) in groundwater is 0.01mg/l.*

Sr.No.	Villages Surveyed	Groundwater Source	Depth	Selenium
1	Darapur	TUBEWELL	470 ft	0.018
2	Dinewal	TUBEWELL	470 ft	0.014
3	Dulchipur	TUBEWELL	470 ft	0.019
4	Ekal Gadda	TUBEWELL	470 ft	0.014
5	Fatehpur Bideshan	TUBEWELL	470 ft	0.018
6	Fazilpur	TUBEWELL	470 ft	0.018
7	Jahangir	TUBEWELL	470 ft	0.014
8	Kiri Bodal	TUBEWELL	470 ft	0.018
9	Kiri Shahi	TUBEWELL	470 ft	0.018
10	Sarai Talwandi	TUBEWELL	470 ft	0.018
11	Verowal	TUBEWELL		0.016
12	Thatha	TUBEWELL	470 ft	0.014
13	Bhattal Bhaike	TUBEWELL	470 ft	0.059
14	Choudhariwala	TUBEWELL	470 ft	0.059
15	Kheda	TUBEWELL	470 ft	0.059
16	Nand Pur	TUBEWELL	470 ft	0.059
17	Thathian Mahantan	TUBEWELL	470 ft	0.059
18	Malmohri	TUBEWELL	280 ft	0.015
19	Hardo Chak Bamba	TUBEWELL		0.010
20	Madar Mathra Bhagi	TUBEWELL	570 ft	0.010
21	Basarke	TUBEWELL	470 ft	0.012
22	Bhaini Massa Singh	TUBEWELL	470 ft	0.012
23	Hundal	TUBEWELL	470 ft	0.012
24	Bhathal Seja Singh	TUBEWELL	470 ft	0.022
25	Mohanpura	TUBEWELL	470 ft	0.022
26	Waring	TUBEWELL	470 ft	0.022
27	Jaunoke	TUBEWELL	470 ft	0.016
28	Abadi Harijan Basti	HANDPUMP		0.076
29	Abadi Balmik	TUBEWELL	470 ft	0.018
30	Abadi Ahemdpur	TUBEWELL	470 ft	0.018
31	Abadi Jahangir Khurd	TUBEWELL	470 ft	0.014
32	Rattoke	TUBEWELL	470 ft	0.011

Table 2: *Villages with high Selenium content (>0.01 mg/l) in Gurdaspur District. The acceptable limit (AL) in groundwater is 0.01 mg/l.*

Sr.No.	VillagesSurveyed	GroundwaterSource	Depth	Selenium
1	Primary School-Kotli	HANDPUMP	210 ft	0.011
2	Chhal Khurd	HANDPUMP	210 ft	0.011
3	Bahadurpur Rajoa	TUBEWELL	425 ft	0.021
4	Gill Bob	TUBEWELL	425 ft	0.021
5	Khojkipur	TUBEWELL	425 ft	0.021
6	Khokharwal	TUBEWELL	425 ft	0.021
7	Khokhowal	HANDPUMP	210 ft	0.010
8	Mahesh Dogar	TUBEWELL	425 ft	0.021
9	Sidhwan	TUBEWELL	425 ft	0.010
10	Pandori Bainsa	TUBEWELL	302 ft	0.094
11	Haveli Harni	TUBEWELL	120M	0.012
12	Pakhari Harni	TUBEWELL	120M	0.012
13	Saidpur Harni	TUBEWELL	120M	0.012
14	Manesh	TUBEWELL	425 ft	0.011
15	Pajo Chack	HANDPUMP	210 ft	0.011
16	Saidpur Harni	TUBEWELL	120M	0.012
17	Katowal	TUBEWELL	302 ft	0.094

Table 3: *Villages with high Selenium content (>0.01 mg/l) in Amritsar District. The acceptable limit (AL) in groundwater is 0.01mg/l.*

Sr.No.	Villages Surveyed	Groundwater Source	Depth	Selenium
1	Rest House Amritsar	TUBEWELL		0.023
2	Jalalpur Sheron	HANDPUMP	700 ft	0.021
3	Takapur	TUBEWELL	720 ft	0.024
4	Madhu Chhanga	TUBEWELL	195 ft	0.039
5	Mattey Nangal	TUBEWELL	195 ft	0.039
6	Bhakna Kalan	TUBEWELL	500 ft	0.038
7	Lahori Mal	TUBEWELL	500 ft	0.010
8	Mehta	TUBEWELL	450 ft	0.026
9	Dhardeo	TUBEWELL	375 ft	0.027
10	Abadi Dhardeo Sardara	TUBEWELL	375 ft	0.027

Long-term consumption of groundwater with high Selenium contamination has deleterious effects on human health. Marco Vinceti group in Italy carried out an experimental study of a population exposed to unusually high levels of inorganic hexavalent selenium (selenate) through drinking water in the municipality of Reggio Emilia during the 1970s–1980s [24]. They established that Selenium exposure increased melanoma and oropharyngeal, urinary and lymphoid cancer risk. In my knowledge, there has been no such experimental study carried out in India. In our investigations of heavy metal contamination of groundwater of Punjab, Majha belt has been established to have a high content of Arsenic in groundwater. There is a need to study a correlation between Arsenic and Selenium as both are geogenic in nature.

HEALTH HAZARD EFFECTS OF SELENIUM

To my knowledge, there has been no epidemiological study conducted on the health hazard effects of Selenium on the population of Majha belt of Punjab. Dhillon and Dhillon had collected a lot of data on Selenium distribution in vegetables, spices, grains, fruits, fodders, weeds and agricultural crops. Selenium toxicity in animals has been reported by some groups but no data is available on toxicity effects on human population till date in India. Most of these studies have been conducted in America and China [25, 26].

It has been observed that acute oral doses of selenite and other selenium compounds cause symptoms such as nausea, diarrhea, abdominal pain, chills, tremor, and numbness in limbs, irregular menstrual bleeding, and marked hair loss [27]. 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 [28]. Children living in a seleniferous area in Venezuela exhibited more pathological nail changes, loss of hair, and dermatitis than those living in Caracas [29].

In China, endemic selenium intoxication has been studied by Yang *et al.* [30]. Morbidity was 49% among 248 inhabitants of five villages where the daily intake was about 5mg of selenium. The main symptoms were brittle hair with intact follicles, lack of pigment in new hair, thickened and brittle nails, and skin lesions. Symptoms of neurological disturbances were observed in 18 of the 22 inhabitants of one heavily affected village only. In a follow-up study, Yang *et al*. [31, 32] studied a population of about 400 individuals with average daily intakes ranging from 62 to 1438 μg. Clinical signs of selenosis (hair or nail loss, nail abnormalities, mottled teeth, skin lesions, and changes in peripheral nerves) were observed in 5 out of 439 adults having a mean blood selenium of 1346 μg/liter, corresponding to a daily intake of 1260 μg of selenium.

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