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Selenium Contamination of Groundwater of Doaba Belt of Punjab, India

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Abstract
Punjab is facing a crisis situation due to high levels of uranium, arsenic and selenium in underground water table of Punjab. Doaba belt of Punjab, namely, Jallandhar, Kapurthala and Hoshiarpur districts have high selenium contents in groundwater. Selenium Acceptable limit (AL) for groundwater is fixed at 0.01 mg/l (ppm) by the Bureau of Indian Standards (BIS). In this report, groundwater quality data pertaining to selenium in the Doaba belt is reported. The highest value of selenium content of 0.082 mg/l (ppm) is reported in the water drawn from a handpump in the village Nangal Naraingarh of Kapurthala district. However, the highest number of villages (102) with selenium contamination of groundwater above the AL falls in the Jallandhar district. The possible health hazard effects of selenium are reported on the basis of studies carried out in the USA, China and India.

Keywords: *Selenium, acceptable limit (AL), Doaba belt of Punjab, health hazards of 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 and selenium contamination in its sophisticated laboratory set up in Mohali (Punjab), using state of the art instrumentation including Inductively Coupled Plasma Mass Spectrometry (ICPMS) 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 are available on the website of Ministry of Water Resources, Government of India [2].

Groundwater quality of North-West India (Punjab) has been studied by Lapworth *et al.* [3] and the source of selenium was concluded to be geogenic in origin. Bajaj *et al.* [4] have reported hazardous concentrations of selenium in soil and groundwater in North-West India including Punjab. Dhillon and Dhillon [5–9] have carried out extensive studies of selenium in groundwater and soil in Punjab and it take up by vegetation, plants, weeds, and cereals. In this paper, our focus of study was contamination of groundwater of Doaba belt in Punjab due to selenium content beyond the AL value.

WHO GUIDELINES ABOUT SELENIUM

The first World Health Organization (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 the development of WHO GDWQ published in 1996 [10]. The US Environmental Protection Agency (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. The WHO 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 sulphur-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 odour 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 μg/l to about 400 μg/l [15–17]. In some areas, levels in groundwater may approach 6000 μg/l [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 mg/kg and 0.005–0.01 mg/kg, respectively [13, 21].

THE STUDY AREA

Geomorphology and Hydrogeology of Doaba Districts

Jallandhar district [22] (Fig. 1) is located in the Doaba belt of Punjab on the intensively irrigated plain between Beas and Sutlej rivers. Jallandhar city is situated at 30°33' north latitude and 71°31' east longitude. Total area of the district is 2624 sq km. It is surrounded by Ludhiana district in East, Kapurthala in West, Hoshiarpur in North and Ferozepur in South. The district is part of Bist Doab Tract, which is inter-alluvial plain between Beas and Satluj rivers. Physiographically, the district is characterised by two distinct features, i.e., vast upland plain and Satluj flood plain. The Bist Doab canal system is the major source of canal irrigation which is 43 km long and its distributaries irrigate southern parts of the district.

The Kapurthala district [23] is occupied by Indo-Gangetic alluvium. It lies between 31°07' to 31°39' north latitude and 74°55' to 75°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 km. 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 groundwater.

The Hoshiarpur district [24] falls in the eastern part of the Punjab State and is bound by North latitudes 30°58'30" and 32°08'00" and East longitudes 75°28' and 76°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 Pradesh 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. km. 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.

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 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 (Tables 1–3).

PWSSD survey of Doaba belt of Punjab reveals that selenium contamination of groundwater is maximum in the Jallandhar district. The total number of villages with selenium contamination recorded above the AL value (0.01 mg/l) was 102. The number of villages with selenium contamination above the AL value was 30 and 13 for Kapurthala district and Hoshiarpur district, respectively. The highest value of selenium content of 0.082 mg/l (ppm) was reported in the water drawn from a handpump in the village Nangal Naraingarh of Kapurthala district (Table 2). The highest value of selenium (0.04 mg/l) in Jallandhar district was recorded in four villages, viz., Dosanjh Kalan, Ladian, Lehal and Nanu Majra (Table 1). Hoshiarpur district recorded the lowest number of villages with selenium contamination above the AL value (Table 3).

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 Doaba belt of Punjab. Dhillon and Dhillon had collected 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 are available on toxicity effects on human population till date in India. Most of these studies have been conducted in the USA and China [26, 27]. 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 [28].

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 [29]. 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 [30]. Children living in a seleniferous area in Venezuela exhibited more pathological nail changes, loss of hair, and dermatitis than those living in Caracas [31].

In China, endemic selenium intoxication has been studied by Yang *et al*. [32]. Morbidity was 49% among 248 inhabitants of five villages where the daily intake was about 5 mg 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*. [33, 34] studied a population of about 400 individuals with average daily intakes ranging from 62 to 1438 μg/l (ppb). Clinical signs of selenosis (hair or nail loss, nail abnormalities, mottled teeth, skin lesions, and changes in peripheral nerves) were observed in five out of 439 adults having a mean blood selenium of 1346 μg/l, corresponding to a daily intake of 1260 μg/l (ppb) of selenium.

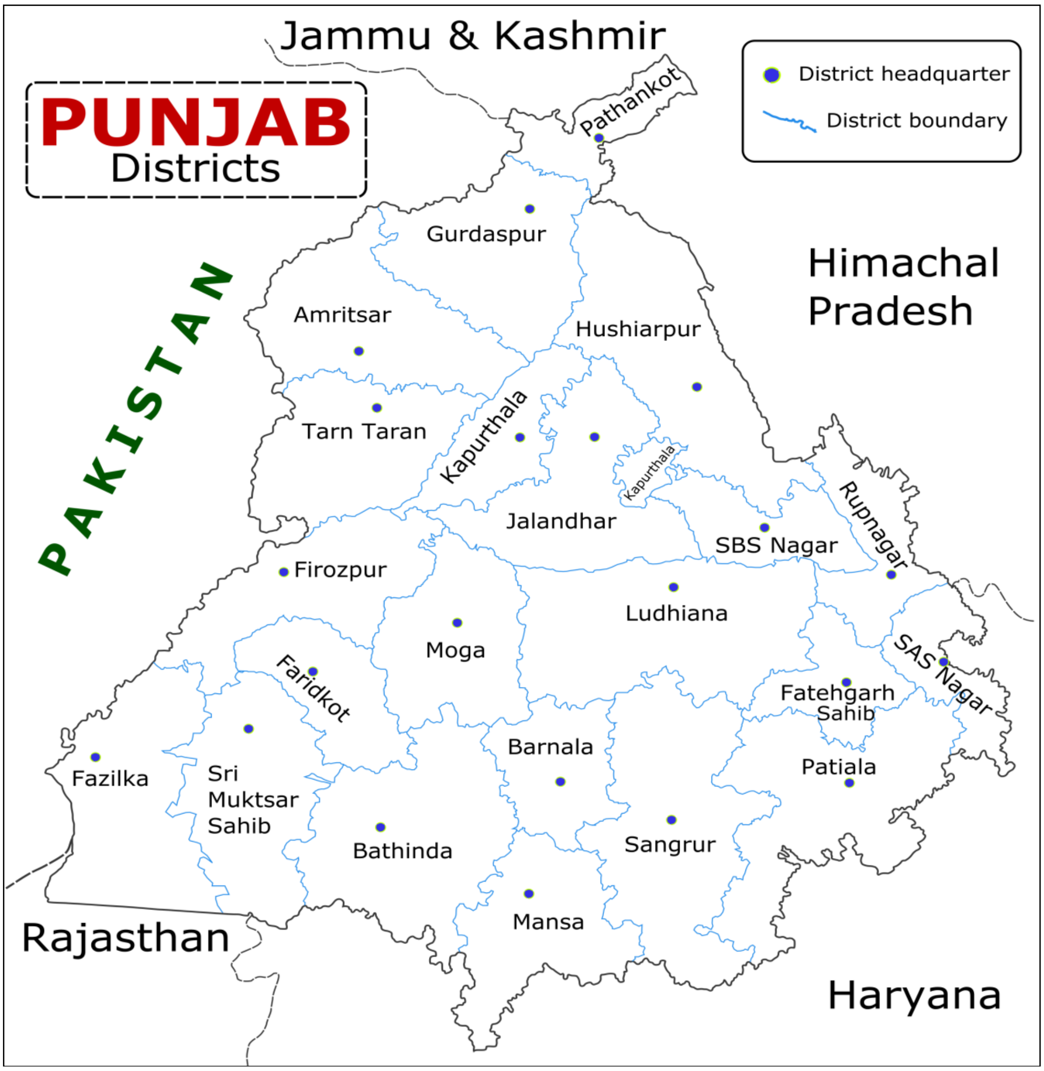

Fig. 1: *District Map of Punjab Showing Districts of Jallandhar, Kapurthala and Hoshiarpur.*

Table 1: *Villages with High Selenium Content (>0.015 mg/l) in Jallandhar District. Acceptable limit in groundwater is 0.01mg/l.*

Sr. No.	Villages surveyed	Groundwater Source	Depth (ft)	Selenium (mg/l)
1	Chanian	Tubewell	400	0.016
2	Anihar	Tubewell	400	0.016
3	Gurah	Tubewell	400	0.016
4	Kala	Tubewell	400	0.016
5	Kot Grewal	Tubewell	415	0.016
6	Cheeman Khurd	Tubewell	375	0.017
7	Sidham Hari Singh	Tubewell	375	0.017
8	Cheeman Kalan	Tubewell	375	0.017
9	Cheeman Khurd	Tubewell	375	0.017
10	Lohgarh	Tubewell	375	0.017
11	Dhindsa	Tubewell	400	0.017
12	Langrian	Tubewell	400	0.017
13	Sunner Kalan	Tubewell	400	0.018
14	Bakhu Nangal	Handpump	225	0.020
15	Balchoohi	Handpump	225	0.022
16	Sitalpur	Handpump	225	0.022

Sr. No.	Villages surveyed	Groundwater Source	Depth (ft)	Selenium (mg/l)
17	Dhesian Kahna	Tubewell	225	0.027
18	Nathewal	Tubewell	225	0.027
19	Kang Jagir	Tubewell	415	0.027
20	Tarkhan Majra	Tubewell	415	0.027
21	Batura	Tubewell	225	0.028
22	Bhangala	Tubewell	225	0.028
23	Chuheki	Tubewell	225	0.028
24	Mandala	Handpump	225	0.028
25	Chuheki	Handpump	375	0.030
26	Uppal Bhupa	Tubewell	375	0.031
27	Chak GaddaiPur	Handpump	225	0.034
28	Dhesian Sang	Tubewell	350	0.036
29	Randhawa	Tubewell	350	0.036
30	Surja	Tubewell		0.036
31	Ranwan	Handpump	375	0.036
32	Dosanjh Kalan	Tubewell	225	0.040
33	Ladian	Tubewell	225	0.040
34	Lehal	Tubewell	225	0.040
35	Nanu Majra	Tubewell	225	0.040

Table 2: *Villages with High Selenium Content (>0.01 mg/l) in Kapurthala District.Acceptable Limit in Groundwater is 0.01mg/l.*

Sr. No.	Villages surveyed	Groundwater source	Depth(ft)	Selenium (mg/l)
1	Lakhpur	Tubewell	370	0.010
2	Mayo Patti	Tubewell	350	0.010
3	Harijan Basti	Tubewell	375	0.010
4	Ahmedpur	Tubewell	350	0.011
5	Alamgir	Tubewell	350	0.011
6	Bhait	Tubewell	350	0.011
7	Gobindpur	Tubewell	350	0.011
8	Gosal	Tubewell	350	0.011
9	Kala Sanghian	Tubewell	350	0.011
10	Manga Roda	Tubewell	370	0.011
11	Babeli	Tubewell	440	0.011
12	Bhakriana	Tubewell	375	0.011
13	Chaheru	Tubewell	360	0.011
14	Dhak Narangpur Shahpur	Tubewell	360	0.011
15	Dug	Tubewell	440	0.011
16	Khatti	Tubewell	370	0.011
17	Mauli	Tubewell	350	0.011
18	Mehat	Tubewell	360	0.011
19	Nangal	Tubewell	360	0.011
20	Rampur Sunnran	Tubewell	440	0.011
21	Sahni	Tubewell	370	0.011
22	Harijan Basti	Tubewell	260	0.011
23	Jalo Bhati	Handpump	370	0.013
24	Dera	Handpump	370	0.019
25	Hazara	Handpump	370	0.021
26	Khutabpur	Handpump	240	0.029
27	Chak Gajiwal	Handpump	370	0.033
28	Gokalpur	Handpump	370	0.041
29	Dhandal	Handpump	370	0.077
30	Nangal Naraingarh	Handpump	230	0.082

Table 3: *Villages with High Selenium Content (>0.01 mg/l) in Hoshiarpur District. Acceptable Limit in Groundwater is 0.01mg/l.*

Sr. No.	Villages surveyed	Groundwater source	Depth (ft)	Selenium (mg/l)
1	Khun Khun Kalan	Tubewell	455	0.011
2	Tilluwal	Tubewell	455	0.011
3	Rurki Khas	Tubewell	495	0.011
4	Sikanderpur	Tubewell	495	0.011
5	Tehsil Complex	Tubewell	495	0.011
6	Dogarpur	Tubewell	450	0.013
7	Rasulpur	Tubewell	450	0.013
8	Kotli	Tubewell	530	0.014
9	Mian-ka-Pind	Tubewell	530	0.014
10	Mirpur	Tubewell	530	0.014
11	Sagran	Tubewell	530	0.014
12	Dhamai	Tubewell	450	0.029
13	Staff Colony 1	Tubewell	450	0.029

CONCLUSION

1. The total number of villages with selenium contamination recorded above the AL value (0.01 mg/l) is found to be 102, 30 and 13 for Jallandhar, Kapurthala and Hoshiarpur districts, respectively.
2. Keeping in view the health hazard effects of selenium beyond the AL value, mitigation of selenium in potable water must be a top priority of PWSSD in Doaba region of Punjab.
3. Epidemiological studies should be carried out in villages affected by an overdose of selenium in groundwater of Doaba region.

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