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Selenium Contamination of Groundwater of Malwa 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. Malwa belt of Punjab, namely, Ludhiana, Ferozepur, Roop Nagar and Fatehgarh sahib 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 Malwa belt is reported. The highest value of selenium content of 0.14 mg/l (ppm) was reported in the water drawn from a handpump in the village Urna of Ludhiana district. Out of 80 villages of Ludhiana district with selenium content above AL value, 38 have selenium contamination levels higher than 0.015 mg/l (ppm). Roop Nagar, Ferozepur and Fatehgarh Sahib districts have 29, 9 and 17 villages with selenium content above the AL value, respectively. The possible health hazard effects of selenium are reported on the basis of studies carried out in the USA, China and Italy.

Keywords: *Selenium, acceptable limit, Malwa 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 its take up by vegetation, plants, weeds, and cereals. In this paper, our focus of study was contamination of groundwater of four districts of Malwa 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 drinkingwater is the background document for 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 10 ng/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 to 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 Malwa Districts

Ludhiana district [22] is located in the Malwa belt of Punjab (Fig. 1). The district is bound between North latitude 30°33' and 31°01' and East longitude 75°25' and 76°27'. The Satluj forms the border of the district in the North with Jalandhar and Hoshiarpur districts. Ropar and Fatehgarh Sahib districts mark the eastern and south eastern boundaries. The western border is adjoining Moga and Ferozpur districts. The geographical area of the district is 3790 sq. km. The district area is occupied by Indo-Gangatic alluvium of Quaternary age. The subsurface geological formations of the area comprise of sand, silt, clay and *kankar* in various proportions. In general, the ground water of the district is fresh except in and around Ludhiana city where the ground water is polluted due to industrial effluents. The shallow ground water is getting polluted by heavy metals such as copper, lead, manganese and iron.

Roop Nagar district [23] 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 forms the main aquifer system. The groundwater in the district is alkaline in nature with medium to high salinity.

Ferozepur district [24], the south-western most district of Punjab State, is located between 29º56'47" and 31º0'7" North latitudes and 72º52'4" and 75º01'11" 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 groundwater 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 tube wells drilled up to the depth of 454 m.

Fatehgarh Sahib district [25] is located in South-Eastern part of Punjab state and lies between 30°25'00" to 30°45' 5" North latitude and 76°04'30" to 76°35'00" East longitude covering an area of 1147 sq. km (Fig. 1). The district falls in cis-Satluj Doab between river Satluj and Yamuna. The Doab forms part of Indo-Gangetic alluvial plains. There are two streams which drain the area. Patiali Rao drains the eastern part of the district whereas Sirhind Choe drains central and western parts of the district. The paleo-channels of river Satluj exist in the district. Soils in the district are loamy sand at the surface and calcareous sandy loam in subsurface layers. Sand constitutes 80% in the soil profile. Silt constitutes 11% and clay 9% in the soils. In deeper aquifers the concentration of heavy metals is low as compared to shallow aquifers. The presence of heavy metals is due to the industrial pollution.

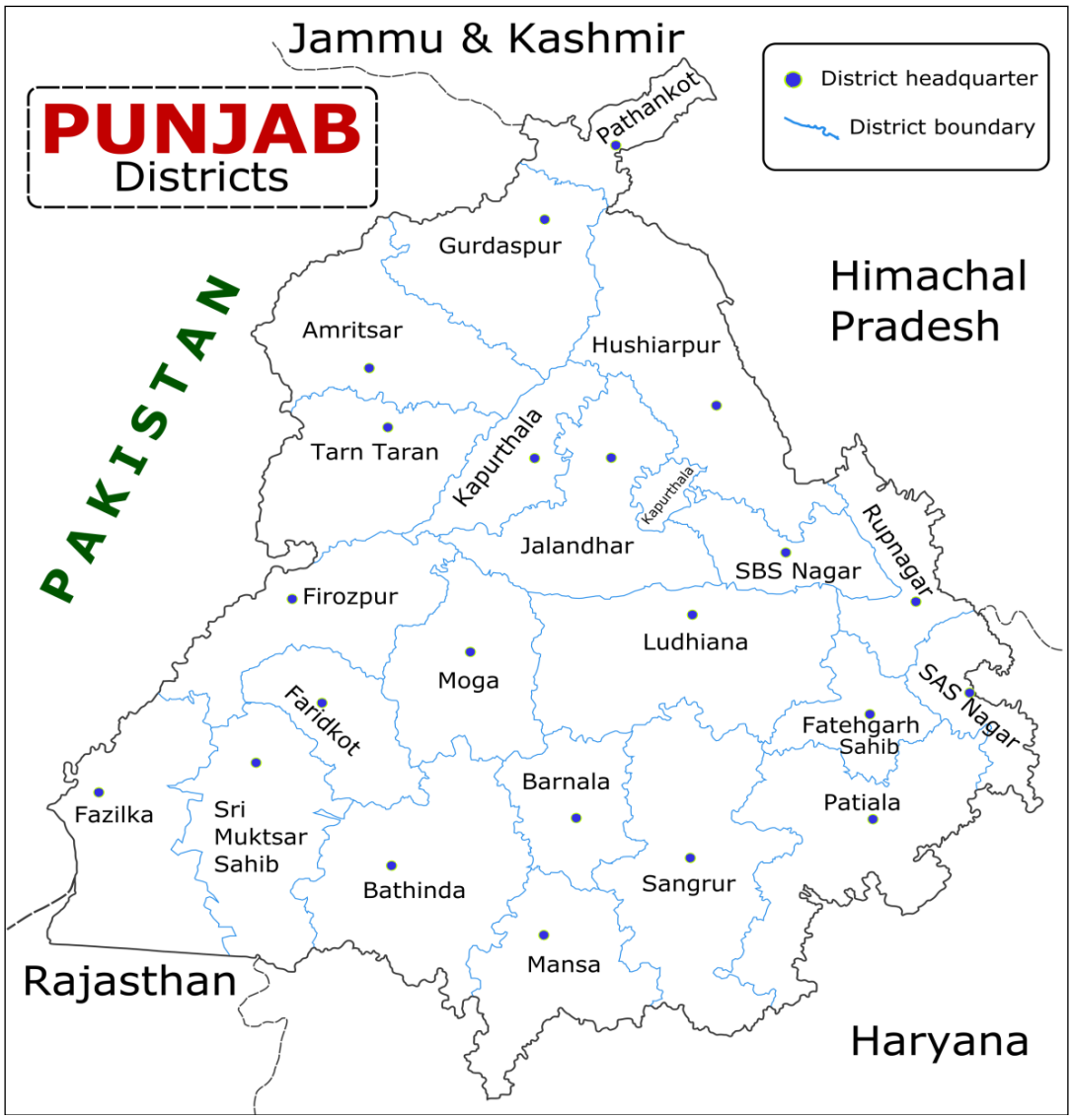

Fig. 1: *District Map of Punjab Showing Districts of Ludhiana, Roop Nagar, Ferozepur and Fatehgarh Sahib.*

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 AL of selenium set at 0.01 mg/l (ppm) for groundwater by the BIS, most of the quality affected habitations (80) fall in the Ludhiana district of Malwa belt of Punjab. Table 1 presents the list of 38 villages of Ludhiana district with selenium content >0.015 mg/l, with highest value of 0.140 mg/l in the groundwater drawn by the handpump of Urna village.

PWSSD survey of Malwa belt of Punjab reveals that the selenium contamination of groundwater exists in the districts of Roop Nagar, Ferozepur and Fatehgarh Sahib also. The number of villages with selenium contamination above the AL value is 29 for Roop Nagar, 19 for Ferozepur and 17 for Fatehgarh Sahib district, respectively (Tables 2–4). The highest values of selenium recorded in other three districts were much lower than the highest value recorded in Ludhiana district. Another interesting feature of the present survey is that the groundwater drawn from the handpumps (Urna in Ludhiana district, Bangian in Roop Nagar and Biro Majri in Fatehgarh Sahib) recorded the highest values of selenium in comparison with the groundwater pumped by the tubewells (Tables 1, 2, 4).

Long-term consumption of groundwater with high selenium contamination has deleterious effects on human health. Vinceti group [26] in Italy carried out an experimental study of population exposed to unusually high levels of inorganic hexavalent selenium (selenate) through drinking water in the municipality of Reggio Emilia during the 1970s–1980s. 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.

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 Malwa 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 [27, 28]. Recent human and laboratory studies carried out in seven villages of seleniferous area of Punjab have suggested the possibility that selenium overexposure may increase blood pressure [29].

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 [30]. 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 [31]. Children living in a seleniferous area in Venezuela exhibited more pathological nail changes, loss of hair, and dermatitis than those living in Caracas [32].

In China, endemic selenium intoxication has been studied by Yang *et al*. [33]. 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*. [34, 35] 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 five out of 439 adults having a mean blood selenium of 1346 µg/l, corresponding to a daily intake of 1260 µg of selenium.

Table 1: *Villages with High Selenium Content (>0.015 mg/l) in Ludhiana District.*

Sr. No.	Villages surveyed	Groundwater source	Depth (ft)	Selenium (mg/l)
1	Ayali Khurd	Tubewell	550	0.016
2	Bahaman Majra	Tubewell	480	0.016
3	Jaspal Banger	Tubewell	480	0.016
4	Mor Karima	Tubewell	550	0.016
5	Ayali Kalan	Tubewell	550	0.017
6	Pawat	Tubewell	550	0.017
7	Hole	Tubewell	480	0.017
8	Kot Mana	Tubewell	480	0.017
9	Bhattian	Tubewell	550	0.018
10	Gurugarh	Tubewell	550	0.018
11	Iraq	Tubewell	550	0.018
12	Rajgarh	Tubewell	550	0.018
13	Daburgi	Tubewell	480	0.020
14	Gidri	Tubewell	480	0.020
15	Chahlan	Tubewell	480	0.021
16	Bodalwala	Tubewell	480	0.022
17	Bhattian Dhaha	Tubewell	550	0.022
18	Ghangas	Tubewell	550	0.022
19	Chaila Bazigar Basti	Handpump	350	0.023
20	Gehlewal	Handpump	350	0.024
21	Raul	Tubewell	350	0.024
22	BAINS	Tubewell	550	0.025
23	Aluna Palla	Tubewell	550	0.025
24	Aluna Palla Basti	Tubewell	550	0.025
25	Kauri	Tubewell	450	0.025
26	Swadi Khurd	Tubewell	450	0.026
27	Tapar Herrian	Tubewell	450	0.026
28	Todarpur	Tubewell	450	0.028
29	ITI - Samrala	Tubewell	450	0.032
30	Bhaini Arayian	Tubewell	550	0.034
31	Issewal	Tubewell	550	0.040
32	Begowal	Tubewell	550	0.042
33	Jullamgarh	Tubewell	550	0.047
34	Sirthala	Tubewell	550	0.047
35	Chaila	Tubewell	550	0.058
36	Chahlan	Tubewell	550	0.064
37	Gehlewal	Handpump	150	0.067
38	Urna	Handpump	150	0.140

Table 2*: Villages with High Selenium Content (>0.01 mg/l) in Roop Nagar District.*

Sr. No.	Villages surveyed	Groundwater source	Depth (m)	Selenium (mg/l)
1	Abadi Gujra	Tubewell	90	0.011
2	Baili Attalgarh	Handpump	40	0.011
3	Abadi Jattan	Tubewell	90	0.014
4	Abadi Rajput	Tubewell	90	0.014
5	Chabrewal	Tubewell	90	0.014
6	Ganurawas	Tubewell	90	0.014
7	Hirpur Ganura	Tubewell	90	0.014
8	Jhangrian	Tubewell	90	0.014
9	Karura	Tubewell	90	0.014
10	Rampur Kalan	Tubewell	90	0.014
11	Sakhpur	Tubewell	90	0.014
12	Phoda	Tubewell	90	0.014
13	Tapprian	Tubewell	90	0.014
14	Saupur	Tubewell	90	0.020

15	Ghahimajra	Tubewell	90	0.020
16	Katta	Tubewell	90	0.020
17	Sabaur	Tubewell	90	0.020
18	Bhatti Basti	Tubewell	65	0.020
19	Gohlni	Tubewell	65	0.020
20	Harijan Abadi	Tubewell	65	0.020
21	Plassi	Tubewell	65	0.020
22	Harijan Basti	Tubewell	65	0.020
23	Passiwal	Tubewell	65	0.020
24	Singhpura Plassi	Tubewell	65	0.020
25	Dola Basti Plassi	Tubewell	65	0.020
26	Lambaranwali Abadi Plassi	Tubewell	65	0.020
27	Bara Makrona	Tubewell	175	0.022
28	Chota Makrona	Tubewell	175	0.022
29	Bangian	Handpump	90	0.023

Table 3: *Villages with High Selenium Content (>0.01 mg/l) in Ferozepur District.*

Sr. No.	Villages surveyed	Groundwater source	Depth (ft)	Selenium (mg/l)
1	Suner College Zira	Tubewell	750	0.011
2	Dhanna Shaheed	Tubewell	440	0.011
3	Mishri Wala	Tubewell	560	0.011
4	BahawalPur	Tubewell	305	0.013
5	Beri Qadrabad	Tubewell	750	0.013
6	Chohla	Tubewell	750	0.013
7	Machi Wara	Tubewell	305	0.013
8	MalloKe	Tubewell	750	0.013
9	Noorpur	Tubewell	750	0.013
10	Tind Wan	Tubewell	750	0.013
11	Ratoul bet	Tubewell	325	0.015
12	Baghale Wala	Tubewell	440	0.015
13	Boola	Tubewell	440	0.015
14	Gadhri Wala	Tubewell	375	0.015
15	Mohkam Wala u*rf* Baggi Patni	Tubewell	440	0.015
16	Shah Abu Bukar	Tubewell	440	0.015
17	Sanda Moja	Tubewell	440	0.025
18	Talli Saidushah	Tubewell	375	0.025
19	Basti Baaj Singh	Tubewell	375	0.025

Table 4: *Villages with High Selenium Content (>0.01 mg/l) in Fatehgarh Sahib District.*

Sr. No.	Villages surveyed	Groundwater source	Depth (ft)	Selenium (mg/l)
1	Chanarthal Naubad	Handpump	270	0.011
2	Shampur	Handpump	270	0.011
3	Kamali	Tubewell	500	0.011
4	Haripur	Tubewell	640	0.012
5	Kasumbri	Tubewell	450	0.012
6	Sempla	Tubewell	450t	0.012
7	Rattangarh	Tubewell	640	0.012
8	RupalHeri	Tubewell	450	0.012
9	Bhambri	Tubewell	500	0.013
10	Bilaspur	Tubewell	450	0.013
11	Nangala	Tubewell	450	0.013
12	Sohavi	Tubewell	450	0.014
13	BhadalThua	Tubewell	500	0.017
14	GhuluMajra	Tubewell	500	0.017
15	Sambla Avtar Singh S/o Babu Singh	Tubewell	590	0.020
16	Cholti Kheri	Tubewell	590	0.022
17	Biro Majri	Handpump	270	0.028

CONCLUSION

1. The number of villages with selenium contamination above the AL value is 80, 29, 19 and 17 for Ludhiana, Roop Nagar, Ferozepur and Fatehgarh Sahib 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 Malwa region of Punjab.
3. Epidemiological studies should be carried out in villages affected by an overdose of selenium in groundwater of Malwa region.

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