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Fluoride Contamination of Ground Waters of Two Punjab Districts and Its Implications

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Abstract

Fluoride is one of the important micronutrient in humans which is required for strong teeth and bones. Groundwater with fluoride concentration above the permissible limit set by WHO, i.e. 1.5 mg/l (ppm), have been recorded in several parts of the world. Fluoride contamination is widespread, intensive and alarming in India as 14.5% of total fluoride deposits on the earth's crust are found in India. Our investigations have revealed that out of 2500 habitations surveyed in Punjab state, 80% are affected by fluoride contamination. The highest fluoride contamination is recorded in Patiala and Fatehgarh Sahib districts of Punjab. There is a need to delineate the source of groundwater fluoride in these districts and to decontaminate groundwater to make it potable. The health implications of high fluoride contamination of water are also discussed.

Keywords: *Fluoride, contamination, groundwater, WHO, fluoridise*

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INTRODUCTION

World's water needs are met from surface and groundwater resources. However, the use of groundwater is advantageous, as it is comparatively fresh and widely distributed unlike the surface water. Threats to groundwater have been increasing everyday due to rise in population and their needs. Thus, with the increasing demand of groundwater for domestic, industrial and agricultural needs, the pressure on this resource has become enormous. Overexploitation and improper management has also lead to contamination of this resource. The degradation of groundwater may be due to natural or anthropogenic processes. Natural causes are inherent geological conditions while anthropogenic causes include wastewater from sewage treatment plants, discharge from industries, improper solid waste disposal, agrochemicals, runoff from agricultural fields, leakage from underground storage tanks etc. When the chemical composition of groundwater is not within the prescribed standards for drinking or irrigation or industrial water, they become unsuitable. Arsenic, fluoride, nitrate, iron, manganese, boron, most heavy metals and radio-nuclides are few contaminants that are of great concern if not present within permissible limits [1].

Fluoride is one of the important micronutrient in humans which is required for strong teeth and bones. In humans, about 95% of the total body fluoride is found in bones and teeth. WHO (World Health Organisation) [2] has prescribed the range of fluoride from 0.6 to 1.5 mg/l in drinking water as suitable for human consumption. A Bureau of Indian Standards (BIS) [3] has set a required desirable range of fluoride in drinking water to be between 0.6 and 1.2 mg/l.

However, this standard suggests the maximum permissible limit can be extended up to 1.5 mg/l. This required fluoride is supplied to the human body usually through drinking water. Consumption of water with fluoride below or above the prescribed range is detrimental to human health. Hence, it is essential to monitor the groundwater quality regularly which is used directly without treatment as drinking water.

Of the 85 million tons of fluoride deposits on the earth's crust, 12 million are found in India [4]. Hence it is natural that fluoride contamination is widespread, intensive and alarming in India.

FLUORIDE IN GROUNDWATER AND RISK OF FLUOROSIS

Groundwater is considered as the major source of drinking water in most places on earth. Usually people use groundwater for drinking and other domestic household purposes such as cooking without any physical or chemical treatment. This is not a healthy practice and

may lead to number of health disorders. However, this practice cannot be avoided due to lack of treated piped water supply system in several parts of developing countries, including India.

Groundwaters with fluoride concentration above the permissible limit set by WHO, i.e 1.5 mg/l (ppm), have been recorded in several parts of the world. In 1984, WHO estimated that more than 260 million people living all over the world consume water with fluoride concentration above 1 mg/l [5]. The problem of high fluoride in groundwater has been reported by several researchers in India, China, Japan, Sri Lanka, Iran, Pakistan, Turkey, Southern Algeria, Mexico, Korea, Italy, Brazil, Malawi, North Jordan, Ethiopia, Canada, Norway, Ghana, Kenya, and USA. Most of the people affected by high fluoride concentration in groundwater live in the tropical countries where the per capita consumption of water is more because of the prevailing climate conditions.

The risk of fluoridise is higher in these places. However, incidence of fluoridise in people living in other parts of the world has also been reported. The intensity of fluoridise problem is very serious in the two heavily populated countries of the world namely India and China [6]. In most cases, fluoride in groundwater is contributed by the host rocks which are naturally rich in fluoride. Because of rock water interaction, long residence time and evaporate-transpiration, the concentration of fluoride increases. Overall, the natural concentration of fluoride in groundwater depends on the geological, chemical and physical characteristics of the aquifer, the porosity and acidity of the soil and rocks, the surrounding temperature, the action of other chemical elements, depth of the aquifer and intensity of weathering [7].

STATUS OF GROUNDWATER FLUORIDE CONTAMINATION IN PUNJAB

The present report is based on the data collected by the Punjab Water Supply and Sanitation Department (PWSSD), Mohali (Punjab) pertaining to Uranium, heavy metals and basic parameters including Fluoride [8]. The groundwater samples were collected by field survey in three phases from 2009 to 2016 and analysed in the sophisticated laboratory of PWSSD using state of art instrumentation including ICPMS (Inductively Coupled Plasma Mass Spectrometry) and Ion Chromatography Mass Spectrometry (IC-MS). It is also available on Ministry of Water Resources, Government of India, website: www.indiawater.gov.in/IMIS reports.

Our investigations have revealed that out of 2500 habitations surveyed, 80% are affected by fluoride contamination. The acceptable limit (AL) set by Ministry of Water Resources, Government of India is 1.0 ppm (mg/l) and permissible limit (PL) as 1.5 ppm (mg/l). Taking into account the PL value for Fluoride, which is also the WHO limit, the quality affected (QA) habitations exist in almost all districts but their number is negligible in comparison to the two districts under consideration for this study. The numbers of QA habitations are 4 in Gurdaspur, 3 in Amritsar, 1 each in Taran Taaran, Hoshiarpur and Jallandhar districts and 13 in SAS Nagar (Mohali). However, the highest numbers of QA habitations reaching up to 194, with Fluoride content higher than the PL value, have been located in Patiala district. Table 1 provides the list of QA habitations of Patiala district with Fluoride content more than 3 ppm (mg/l), i.e., double than the PL value set by WHO. Next to Patiala, 34 QA habitations (Table 2) have been reported in Fatehgarh Sahib District, which has boundary contiguous with Patiala.

QUALITY OF GROUNDWATER IN PATIALA DISTRICT

The Central Ground Water Board (CGWB) Report throws some light on the nature of soil and geomorphology of the Patiala district [9]. Patiala district of Punjab state lies between 29^{o} 49' to 30^{o} 40'N latitudes and 75^{o} 58' to 76^{o} 48'E longitudes. Total geographical area of the district is 3218 sq. km. 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. The elevation of land ranges from 240 to 278 m amsl. Due to arid climate, the soils are light

coloured. Tropical arid brown soils exist in the major parts of the district. Here soils are deficient in nitrogen, phosphorus and potassium. In Patran and Samana blocks, soils are arid brown. These are calcareous in nature and in most cases kankar layers occur.

Table 1: *Fluoride Content (>3ppm) in Groundwater of Patiala District.*

Villages Covered	Source of Scheme	Depth	Flouride Content (ppm)
Sahal	Tube well	1200 ft	8.517
Kattumajra			3.146
Bhoglan			3.610
Dhakansu Kalan			3.780
Akbarpur	Tube well	1200 ft	3.470
Bathonia Kalan	Tube well	1200 ft	8.300
Gandian	Tube well	1200 ft	8.300
Chalheri	Tube well	820 ft	3.540
Chatar Nagar	Tube well	1050 ft	8.240
Gandian	Tube well	1200 ft	8.300
Ghagar Sarai	Tube well	932 ft	8.500
Ghungran	Tube well	600 ft	5.800
Hassanpur Jattan	Tube well	950 ft	4.940
Kaboolpur	Tube well	950 ft	4.940
Khairpur Sheikhan	Tube well	1200 ft	5.800
Khanpur Gandian	Tube well	750 ft	3.400
Kutha Kheri	Tube well	300 ft	3.500
Lochwan	Tube well	900 ft	5.850
Lohakheri	Tube well	300 ft	3.500
Magar	Tube well	900 ft	5.700
Nardu	Tube well	750 ft	3.040
Pahairpur	Hand pump	210 ft	3.560
Pipal Mangoli	Tube well	900 ft	5.650
Sahal	Tube well	NA	7.806
Salempur Jattan	Tube well	900 ft	9.220
Salempur Sekhan	Tube well	980 ft	8.700
Sanoulian	Tube well	970 ft	3.100
Shahpur Raian	Tube well	600 ft	5.800
Sheikhupur	Tube well	900 ft	5.700
Sheikhupur Rajputan	Tube well	210 ft	6.465
Bhappal	Tube well	1100 ft	3.067
Bhoglan	Tube well	900 ft	3.910
Dhakansu Khurd	Tube well	NA	3.701
Dhakansu Khurd	Tube well	700 ft	3.520
Dhakansu Majra	Tube well	970 ft	3.749
Faridpur	Tube well	1080 ft	3.020
Gado Majra	Tube well	780 ft	4.080
Islampur	Tube well	855 ft	3.326
Jandoli	Tube well	870 ft	3.620
Khanpur Baring	Tube well	540 ft	3.956
Kharajpur	Tube well	870 ft	4.079
Kheri Gandian	Tube well	510 ft	4.170
Mangpur	Tube well	515 ft	3.020
Mehma	Tube well	840 ft	5.350
Nalas Kalan	Tube well	820 ft	3.220
Nalas Khurd	Tube well	820 ft	3.220
Rangian	Tube well	820 ft	3.220
Sehri	Tube well	855 ft	4.050
Shamdoo	Tube well	885 ft	3.280
Sural Khurd	Tube well	950 ft	3.305
Sural Khurd	Tube well	900 ft	3.240
Alampur	Tube well	210 ft	3.140

Table 2: *Fluoride Content (>1.5ppm) in Groundwater of Fatehgarh Sahib District.*

Villages Covered	Source of Groundwater	Depth	Flouride Content (ppm)
Sambla Sukhbir Singh s/o Balwant Singh			11.160
Behlolpur	Tube well	570 ft	1.740
Jago Chanarthal	Tube well	450 ft	1.598
Reona Niwan	Tube well with RO	450 ft	1.677
Reona Ucha	Tube well with RO	450 ft	1.677
Bhagrana	Tube well	580 ft	1.690
BhainiKalan	Tube well	580 ft	1.570
BhuaKheri	Tube well	580 ft	1.660
Bibipur	Tube well	450 ft	1.500
BiroMajri	Hand pump	270 ft	1.610
ChunniKalan	Tube well	620 ft	3.240
Chunni Khurd	Tube well	610 ft	2.155
Dhollan	Tube well	580 ft	1.570
Harna	Tube well	580 ft	2.400
Hindupur	Tube well	450 ft	1.500
Jamitgarh	Tube well	500 ft	1.895
Jhampur	Tube well	500ft	1.550
Kasumbri	Tube well	450 ft	2.280
Loha Kheri	Tube well	450 ft	1.680
Manhera Jattan	Tube well	910 ft	1.640
Naraingarh	Tube well	580 ft	1.570
Patarsi Khurd	Tube well	450 ft	2.620
Salempur	Tube well	590 ft	2.220
Sempla	Tube well	450 ft	2.280
Sindhran	Tube well	590 ft	2.220
Timberpur	Tube well	590 ft	2.640
Badali	Tube well	500 ft	1.731
Mundrian	Tube well	450 ft	1.731
Dadiana	Tube well	450 ft	1.720
Kamali	Tube well	500 ft	1.560
RupalHeri	Tube well	450 ft	2.280
Shergarh	Tube well	450 ft	1.623
Dera Behlolpur	Tube well	570 ft	1.740
Chunni Majra	Tube well	450 ft	1.860

The ground water occurs in alluvium formations comprising fine to coarse sand, which forms the potential aquifers. In the shallow aquifer (up to 50 m) ground water occurs under unconfined/water table conditions, where as in deeper aquifer, semi-confined/confined conditions exist. The traditional dug wells tapping the shallow aquifer are not in use and most of them have been abandoned, however, this aquifer is being tapped by the hand pumps and shallow tube wells, which are widely used for domestic purposes. The deep tube wells have been constructed by CGWB, which has drilled 10 exploratory boreholes, one slim hole and six piezometers to delineate and determine potential aquifer zones, and evaluation of aquifer characteristics. CGWB has carried out studies for chemical quality of ground water in the area. The ground water of the district is alkaline in nature. The EC in the area ranges from 687–4100 micromhos/cm. Nitrate values ranges between 0.40–200 mg/l and fluoride concentration ranges from 0.20–2.8 mg/l [9]. At some places both fluoride and nitrate have been observed beyond the safe limits suggested by WHO, thus the ground water in these places is harmful for human consumption. Is there some correlation between nitrate and fluoride contents? It is yet to be determined.

DISCUSSION OF RESULTS

What is the source of Fluoride contamination in Punjab? Why these two districts report highest QA habitations? These questions demand immediate answers. To our surprise, there is no mining activity going on for mineral exploration in these districts. However, both these districts have been overexploited for underground water for purposes of irrigation required for intensive agriculture purposes. CGWB has issued warnings to Punjab in this regard. Hence, there is an urgent need to undertake a geological and geophysical survey of both districts to determine the source of Fluoride in groundwater.

Singh *et al.* [10] reported high Fluoride concentration in groundwater of Pokhran area of Rajasthan state. They showed strong correlation of fluoride with pH, EC, TDS and Na^+, and strong negative correlation with Ca^{2+}. Strong correlation of F and pH (r=0.65) showed that fluoride in groundwater has resulted from leaching of fluoride containing minerals. Gopal Krishan et al. [11] reported high Fluoride concentrations in the Bathinda district, in the semi-arid zone of Punjab. Their conclusion is almost identical with that of Singh *et al.* [10] that high fluoride content in groundwater is due to (i) its geo-genic origin, and (ii) high rate of evaporation. Due to evaporation, the groundwater gets oversaturated with calcic minerals, resulting in precipitating of calcite, resulting in dissolution of fluorite. Chae *et al.* [12] have reported high Fluoride concentrations in groundwater of South Korea which are linked to high sodium contents, high pH and low Ca^{2+}concentrations.

Considering the comprehensive report of Punjab groundwater survey, the highest value of Fluoride content of 11.39 ppm was recorded in village 'Jala Lakha Ke Hither' in Fazilka district of Punjab [8]. The next highest value of 11.16 ppm is recorded in village Sambla Sukhbir Singh in Fatehgarh Sahib District (Table 2). Patiala district has most of the QA habitations (villages) in Punjab and the highest value of 8.157 ppm is reported in tube well water of village Sahal. No correlation of Fluoride content with depth of water source is visible from the data. Normally RO (Reverse Osmosis) technique has been considered to be the best available technology for decontamination of water to render it free of Uranium and Fluoride. However, the efficacy of RO system is doubtful as reported in Table 2.

HEALTH IMPLICATIONS OF FLUORIDE CONTAMINATION IN WATER

Intake of fluoride higher than the optimum level is the main reason for dental and skeletal fluoridise. Depending upon the dosage and the period of exposure, fluoridise may be acute to chronic. Ayoob and Gupta [6] quoted that around 200 million people, from among 25 nations all over the world are under the dreadful influence of fluoridise of which India and China, the two most populous countries of the world, are the worst affected. In India 62 million people including 6 million children are estimated to have serious health problems due to consumption of fluoride contaminated water [13].

Tooth enamel is principally made up of hydroxyapatite (87%) which is crystalline calcium phosphate [14]. Fluoride which is more stable than hydroxyapatite displaces the hydroxide ions from hydroxyapatite to form fluoroapatite. On prolonged continuation of this process the teeth become hard and brittle. This is called dental fluoridise.

Exposure to very high fluoride over a prolonged period of time results in acute to chronic skeletal fluoridise. It was stated in 1993 that crippling skeletal fluorosis might occur in people who have ingested 10–20 mg of fluoride per day for over 10–20 years [15]. India and China have been largely affected by crippling skeletal fluoridise with 2.7 million people being affected in China. Of the 32 states in India, 17 have been identified as endemic areas with 6 million people affected by skeletal fluoridise. Apart from ingestion of fluoride through drinking water, skeletal fluoridise also may be caused due to indoor use of coal as fuel and by air borne fluoride. Ingestion of fluoride through inhalation in factories and industries is one of the occupational health problems. Skeletal fluoridise does not only affect humans but also animals fed with fluoride rich water and fodder. Fluoridise is also now associated with heavy consumption of tea [16, 17]. Early stages of

skeletal fluoridise start with pain in bones and joints, muscle weakness, sporadic pain, stiffness of joints and chronic fatigue.

In the advanced stage the bones and joints become completely weak and moving them is difficult. The vertebrae in the spine fuse together and the patient is left crippled which is the final stage. Skeletal fluoridise is usually not recognized until the disease reaches an advanced stage. Other health disorders that occur due to consumption of high fluoride in drinking water may be muscle fibre degeneration, low haemoglobin levels, deformities in RBCs, excessive thirst, headache, skin rashes, nervousness, neurological manifestations, depression, gastrointestinal problems, urinary tract malfunctioning, nausea, abdominal pain, tingling sensation in fingers and toes, reduced immunity, repeated abortions or still births, male sterility, etc. [18]. As fluoride is excreted in urine through the kidneys, it affects the effective functioning of the kidneys. They facilitate in the formation of kidney stones. Li *et al.* [19] reported that fluoride might have genotoxical effects.

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