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Critical Analysis of Fluoride Contaminated Water in the Malwa Belt of Punjab and its Impact on Health

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Abstract. Contamination in ground water with flouride is one of the foremost challenge in Indiaparticularly in certain states of India including Punjab.Natural sources of presence of fluoride in groundwater include dissolution of fluoride bearing rock minerals, whereas anthropogenic sources include the use of phosphate fertilizers, sewage sludge, coal burning, etc. Fluoride when ingested beyond the permissible range causes dental and skeletal fluorosis. Fluoride toxicity is causing serious health hazards in residents of Punjab. Various cost-effective and simple water defluorination techniques like adsorption, coagulation-precipitation, ion-exchange, etc. are known. Due to lack of awareness, rural population has not been benefitted much from such techniques. There is an urgent need to undertake a geological and geophysical survey to analyze the fluoride content in groundwater in the Malwa belt of Punjab so that workable strategy can be planned and developed to make groundwater potable. This paper presents the analysis of the Malwa belt of Punjab, which is highly contaminated with fluoride, and its impact on health and also suggests different remedial measures which can be adopted to decrease the fluoride content from water in rural areas.
Keywords: fluoride, groundwater, contamination, fluorosis, remedial measures

INTRODUCTION

Water is indispensable for life. It is the largest contributor of fluoride intake by humans [1]. Groundwater is the major source of drinking water and serves 50 % of agricultural requirement and 80% of the total drinking water requirement in rural India [2]. Due to the use of groundwater for various purposes, there is overexploitation of this resource which has led to its contamination. Groundwater is getting polluted due to rapid rise in population, urbanization and industrialization. Various contaminants that have been reported in underground water from different parts of India are fluoride, nitrate, arsenic, pesticides, other heavy metals etc. [3-7]. The range of fluoride prescribed by World Health Organization (WHO) suitable for human consumption in drinking water is from 0.6 to 1.5 mg/L [8] and by Bureau of Indian Standards (BIS) is 0.6 to 1.2 mg/L [9]. Small concentrations of fluoride have beneficial effects on the teeth while concentrations beyond the permissible limit result in dental and skeletal fluorosis.

There are around 20 nations in the world where fluorosis is widely distributed [10]. From the scientific studies available, it has been found that fluorosis is prevalent in 17 states of India. In Punjab, the districts known to be endemic for fluoride include Mansa, Faridkot, Bhatinda, Muktsar, Moga, Sangrur, Ferozpur, Ludhiana, Amritsar, Patiala, Ropar, Jalandhar and Fatehgarh Sahib [11].

Punjab is an agricultural dominated Indian state, which is divided into three geographical regions: Majha, Doaba and Malwa. The Malwa region extends from 29° 30’ to 31° 9’ North latitude and from 73° 55’ to 76° 35’ East longitude. The Malwa region in the south is partitioned by the Sutlej river. Himachal Pradesh and Haryana border on the east, south east and south. The Malwa region of Punjab covers 14 districts. In Punjab, in 2017-18, Barnala (100 percent), Patiala (80 percent), Fatehgarh Sahib (60 percent) were the regions where fluoride affected habitations were

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prominent [12]. Many regions of Punjab have high fluoride concentrations, but some areas have not analyzed fluoride levels in drinking water. In order to combat this problem, it is important that we understand the occurrence and distribution of fluoride in groundwater and formulate strategies for its mitigation.

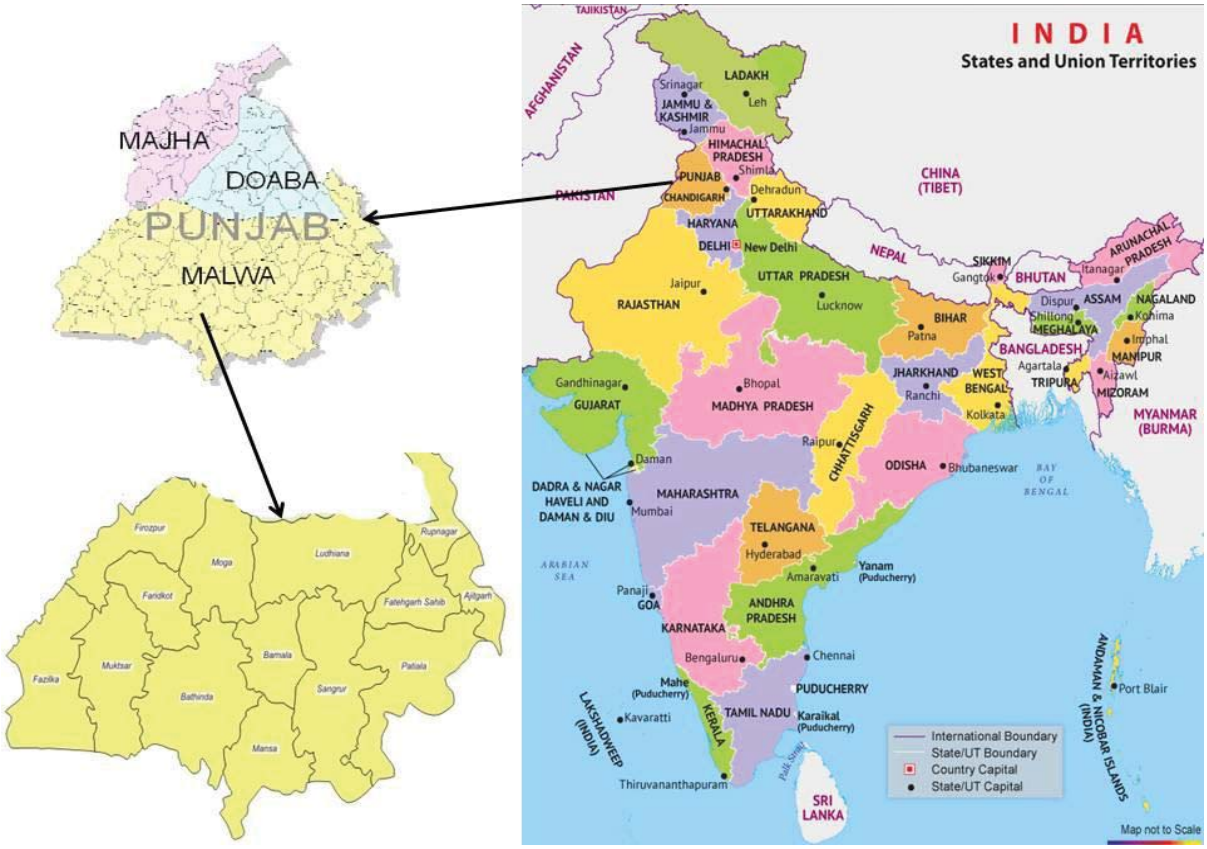

FIGURE 1. Map of Malwa, Punjab

OCCURRENCE AND SOURCES

Approximately 12 million of the 85 million tons of fluoride deposits are found in the earth's crust in India [13]. Fluoride is found in the atmosphere, soil and water. Fluoride is naturally present in groundwater due to fluoride-bearing minerals in the rocks, sediments and soil. The important fluoride bearing minerals are fluorite (CaF_2), cryolite (Na_3AlF_6), phosphorite ($3Ca_3(PO_4)_2.CaCO_3.CaF_2$) sellaite ($MgF_2$), fluorapatite ($Ca_{10}(PO_4)_6F_2$), etc. [14-16]. Natural causes are type of rocks, solubility of fluoride bearing minerals, inherent geological conditions like arid climatic conditions which enhance evapotranspiration of groundwater, temperature, etc. Presence of low calcium concentration, high sodium and bicarbonate concentrations and alkaline pH also affect the concentration of fluoride in groundwater [17].

Anthropogenic causes mainly include rapid urbanization, wastewater from industries and sewage treatment plants, leakage from underground storage tanks, runoff from agricultural fields, improper disposal of solid waste etc. Use of phosphate containing fertilizers also adds fluoride content in groundwater and soil. Fluoride enters the human body through various sources like water, food, medicaments, cosmetics and air, though drinking water is the main source. Tea, fish, and certain drugs are among the foods which are rich in fluorides [18]. Considerable amounts of fluorides are present in carbonated soft drinks and sweetened iced teas [19-20]. Another source of fluoride entry into the body is occupation of the people. The people working in the welding and aluminium industries inhale fumes of fluoride

and dust [21]. Most of the people who live in tropical countries are affected by fluoride contamination in water due to prevailing climatic conditions. Central Ground Water Board, Ministry of Water Resources, Government of India (2018) has provided latest data on fluoride contaminated locations in different districts of Punjab as given in Table 1.

TABLE 1. Locations having high F^- concentrations in groundwater in different districts of Punjab

S. N.	District	Block / Mandal	Location	F^- > 1.5 (mg/l)
1	Amritsar	Bhikiwind	Bhikiwind	1.64
2	Amritsar	Bhikiwind	Khalra- PZ	6.35
3	Bathinda	Bathinda	Gulabgarh 2 (S)	2.16
4	Bathinda	Phul (West)	Gurusar	4.5
5	Bathinda	Sangat	Kot Guru	1.59
6	Mansa	Bhikhi	Bhikhi 1(S)	7.33
7	Mansa	Bhikhi	Ralla	1.83
8	Mansa	Budhlada	Mofar	2.32
9	Moga	Moga-II	Dara Pur	2.43
10	Patiala	Dera Bassi	Gholu Majra 07PZ	2.9
11	Patiala	Rajpura	Rajpura	3.5
12	Patiala	Rajpura	Thuha	2.89
13	Sangrur	Andana	Bhulan	1.91
14	Sangrur	Andana	Haryao	2.18
15	Sangrur	Andana	Haryao (D)	2.18
16	Sangrur	Lehragaga	Churak Kalan	5.16
17	Sangrur	Lehragaga	Chural Kalan M	5.16
18	Sangrur	Lehragaga	Lehragaga-PZ	5.16

Source: Central Ground Water Board, Ministry of Water Resources, Government of India (2018)

In Punjab, during the last few decades, groundwater has been extracted excessively, which has resulted in a decline of the water table and deterioration of groundwater quality [22-24]. Drinking water is collected from the hand pumps, wells, tube wells, rivers, lakes, streams etc. in Indian villages. Heavy pumping from the wells is one of the major causes of groundwater quality deterioration which results in the migration of saline and mineralized water from surrounding areas to the wells. In Punjab, especially Malwa region, fluoride contamination is causing hardships to the local population and is a serious problem. It has been reported that out of 2500 habitations surveyed in Punjab, 80% are affected by fluoride contamination. The National Rural Drinking Water Programme (NRDWP) Integrated Management Information System (IMIS) report has provided the data on fluoride contaminated habitations in Majha, Malwa and Doaba regions of Punjab (Table 2).

TABLE 2. Fluoride contaminated habitations in Majha, Malwa and Doabaregions of Punjab

S.No.	District	TotalHabitations	Total Contaminated	Total Fluoride Contaminated	Percent of Total Fluoride Contaminated
	Total (Overall)	**15038**	**1556**	**354**	**23**
			MAJHA		
1	Amritsar	879	377	3	1
2	Gurdaspur	1200	151	3	2
3	Pathankot	579	5	2	40
4	Taran Taran	618	142	3	2
	Total(Majha)	**3276**	**675**	**11**	**2**
			MALWA		
5	Barnala	152	4	4	100
6	Bathinda	514	5	3	60
7	Faridkot	345	14	1	7
8	Fatehgarh Sahib	461	92	55	60
9	Fazilka	444	40	20	50
10	Firozpur	941	136	11	8
11	Ludhiana	1119	35	6	17
12	Mansa	297	0	0	0
13	Moga	411	34	0	0
14	Muktsar	405	0	0	0
15	Patiala	1142	243	194	80
16	Rupnagar	792	109	7	6
17	S.A.S Nagar	382	26	13	50
18	Sangrur	618	49	24	49
	Total(Malwa)	**8023**	**787**	**338**	**43**
			DOABA		
19	Jalandhar	1053	11	1	9
20	Kapurthala	688	37	1	3
21	Hoshiarpur	1513	44	3	7
22	Shaheed Bhagat Singh Nagar	485	2	0	0
	Total(Doaba)	**3739**	**94**	**5**	**5**

Source: NRDWP IMIS Report (2017-2018)

HEALTH RISK ASSESSMENT (HRA)

Drinking of excess fluoride contaminated water can cause various health risks in an individual. Health risk assessment is an effective method to estimate the health risk of consuming high fluoride contaminated water which was established by The United States Environmental Protection Agency (USEPA 1989) [25]. United States Environmental Protection Agency has considered fluoride parameter as non-carcinogenic risk for human health. In this regard, the average daily dosage (ADD)offluorideingestion was calculated according to the following Eq. (1)

$$ADD = CGW \times IR \times ED \times EF / ABW \times AET \quad (1)$$

where, ADD is the average daily dosage of F^- intake (mg/kg-body weight/day), CGW is the concentration of F^-in groundwater (mg/L), IR is the ingestion rate of drinking water (L/day; IR=1.5 L/day for adults and 0.7 L/day); EF represents the exposure frequency (days/year; EF=365

days/year); ED is the exposure duration (years; ED=30 years for adults and 12 years for children), which were obtained from the US 1989. ABW is known as the average body weight of a person (kg) and AET indicates the average exposure time.

The hazard quotient (HQ) was applied to estimate fluoride risk using the following Eq. (2)

$HQ_{Fluoride}$ = ADD/ RfD (2)where RfD is reference dose. If $HQ_{Fluoride}$>1, it is considered noncarcinogenic risk, while the safe limit for

$HQ_{Fluoride}$ is equal to 1 and the values of $HQ_{Fluoride}$< 1 are an acceptable level of non-carcinogenic risk in individuals due to intake of fluoride contaminated groundwater.

HEALTH IMPACTS OF FLUORIDE

Fluoride has both beneficial and detrimental effects on human health, depending upon its concentration present in drinking water. At low concentrations, it has beneficial effects on teeth, but long exposure to fluoride results in dental and skeletal fluorosis. Fluoride is used in dentistry to strengthen enamel and helps to prevent cavities and the growth of oral bacteria. F^-< 0.5 promotes dental caries; 0.5-1.5 promotes development of strong bones and teeth; 1.5-4.0 promotes dental fluorosis; 4.0-10.0 induces skeletal fluorosis and >10 causes crippling fluorosis [26].

Dental fluorosis

Dental fluorosis can be mild, moderate and severe, depending on the amount of fluoride ingested during the stages of formation of the teeth. Consuming large amounts of fluoride contaminated drinking water during childhood leads to dental fluorosis. Dental fluorosis, also called as hypo-mineralization is the incorporation of fluoride into dental enamel. It is a condition which is characterized by the discoloredor mottled teeth [27].

Skeletal fluorosis

Skeletal fluorosis is a disease of bone caused by excessive accumulation of fluoride in the bones. In advanced cases, skeletal fluorosis causes painful damage to bones and joints. Due to a high fluoride concentration in the body, the bone is hardened and thus less elastic, resulting in an increased frequency of fractures. Prolonged exposure to high fluoride concentrations (> 4 mg/L) promotesskeletal fluorosis[28].

Excessive fluoride ingestion may also produce osteosclerosis (hardening and calcification of the bones), muscle weakness, low hemoglobin count, deformities in RBCs, changes in DNA structure, genotoxical effects, excessive thirst, nausea, reduced immunity, skin rashes, nervousness, abortions or stillbirths, neurological manifestations, diminished immune responsiveness and other physiological disorders [29-32]. As fluoride is excreted in urine through the kidneys, it affects the effective functioning of the kidneys as well [33].

REMEDIAL MEASURES OF FLUORIDE TOXICITY

Everybody needs safe water. Natural, physical, chemical, social, environmental and various other parameters are responsible for the fluoride contamination in groundwater. To reduce the effects of fluoride toxicity, defluoridation techniques are adopted, but removing contaminants from water supplies to make them safe for domestic use is a difficult and expensive process. However, artificial recharge techniques such as constructing check dams, rainwater harvesting, etc. may be used to improve water quality by dilution [34]. Various defluoridation techniques adopted to remediate the groundwater with high fluoride include: adsorption, coagulation followed by precipitation, ion-exchange, nanofiltration, membrane processes which include reverse osmosis and electro-dialysis [35-39]. Each technique has its own advantages and disadvantages. The literature survey and experimental studies have suggested that the actual applications of the defluoridation techniques depend on local needs, initial fluoride concentration, source and prevailing conditions which include geographical and economic conditions.

CONCLUSION

Fluoride contamination is widespread in India. Therefore, endemic fluorosis has become an important, challenging and vastly studied national health problem. Groundwater is the primary source of drinking water in Punjab but people don't have access to potable water. In the Malwa region of Punjab, the deterioration in groundwater quality is due to high fluoride concentrations, salinity, etc. The rural communities in Punjab are greatly affected by fluoride toxicity due to installation of deep bore-wells to meet their needs of water. There is overexploitation of underground water for irrigation purposes in Punjab. Central Ground Water Board (CGWB) has issued warnings to Punjab in this regard. In the near future, the areas with increased water level can get water logged. Therefore, a geological and geophysical survey is required to determine the source of fluoride contamination in groundwater and to analyze fluoride levels in drinking water. To mitigate fluoride contamination, we can explore alternative sources like rain water harvesting as the first option otherwise various types of water defluoridation techniques which are simple and cost effective can be used. There is an instant need to organize a mass awareness program to educate the people regarding the harmful effects of fluoride contaminated groundwater consumption on the human body.

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