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Potable groundwater quality in some villages of Haryana, India: Focus on fluoride

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Abstract: *The fluoride concentration in ground water was determined in ten villages of Rohtak district of Haryana state (India). The fluoride concentration in the underground water of these villages varied from 0.034-2.09 mg/l. Various other water quality parameters, viz., pH, electrical conductivity, total dissolved salts, total hardness, total alkalinity, sodium, potassium, calcium, magnesium, carbonate, bicarbonate, chloride and sulfate were also measured. A systematic calculation of correlation coefficients among different physicochemical parameters indicated considerable variations among the analyzed samples with respect to their chemical composition. Majority of the samples do not comply with Indian as well as WHO standards for most of the water quality parameters measured. Overall water quality was found unsatisfactory for drinking purposes. Fluoride content was higher than permissible limit in 50% samples.*

Key words: *Fluoride, Underground water, Drinking water, Total hardness, Water quality standards*

Introduction

The problem of excessive fluoride in groundwater in India was first reported in 1937 in the State of Andhra Pradesh (Short *et al.*, 1937). In India, approximately 62 million people including 6 million children suffer from fluorosis because of consumption of water with high fluoride concentrations (Susheela, 1999). Seventeen states in India have been identified as endemic for fluorosis and Haryana is one of them. Though fluoride enters the body through food, water, industrial exposure, drugs, cosmetics, *etc.*, drinking water is the major contributor (75-90% of daily intake) (Sarala and Rao, 1993). Due to its strong electronegativity, fluoride is attracted by positively charged calcium in teeth and bones causing dental fluorosis, teeth mottling, skeletal fluorosis and deformation of bones in children as well as in adults (Susheela *et al.*, 1993). Excess fluoride affects plants and animals also. The severity of injury is determined by duration of fluoride exposure and concentration.

The major sources of fluoride in groundwater are fluoride bearing rocks such as fluorspar, cryolite, fluorapatite and hydroxylapatite (Agarwal *et al.*, 1997). The fluoride content in the groundwater is a function of many factors such as availability and solubility of fluoride minerals, velocity of flowing water, temperature, pH, concentration of calcium and bicarbonate ions in water, *etc.* (Chandra *et al.*, 1981; Largent, 1961).

The permissible limit for fluoride in drinking water is 1.0 mg/l (WHO, 1971) and 1.5 mg/l (Indian standard). In some parts of India, the fluoride levels are below 0.5 mg/l, while at certain other places, fluoride levels are as high as 30 mg/l have been reported (Handa, 1975). This study was undertaken to assess the quality of underground water of ten villages in the Rohtak district in Haryana state (India).

Materials and Methods

Study area: The state of Haryana is situated between 27.37°N and 30.35°N latitude and 74.28°E and 77.36°E longitude.

The study was undertaken in ten villages of Rohtak district. The details of population and sampling stations are is given in Table 1. The water is extracted using hand pumps. The water table in the study region varies from 6 to 15 m. Geological formations are alluvial type and the soil is sandy loam. The area is semi arid with scanty to normal rainfall.

Water sampling: The samples were collected in pre cleaned sterilized bottles and stored in an icebox. A total of 63 water samples were collected from different sources, such as shallow handpumps, dug wells and public health water supply taps. All the analyses were carried out in triplicate. The results were reproducible within ±3% error limit.

Methodology: The pH and electrical conductivity of the water were determined on site using pH and EC scan meter (Eutech-Cybernetics). The TDS were calculated using a formula from the United States Salinity Laboratory (1954). Sodium, K and Ca concentrations were determined using ELICO CL-220 Flame photometer. Total alkalinity and total hardness were measured by titrimetric methods using standard sulfuric acid and standard EDTA solutions, respectively (APHA, 1989). Fluoride was determined spectrophotometrically using NaF as standard (ELICO SL-150 ultraviolet spectrophotometer). Sulfate was determined nephalometrically using ELICO CL-52 nephalometer. Chloride was determined by argentometric titration method (APHA, 1989). Statistical analysis was carried out using statistical package for social sciences.

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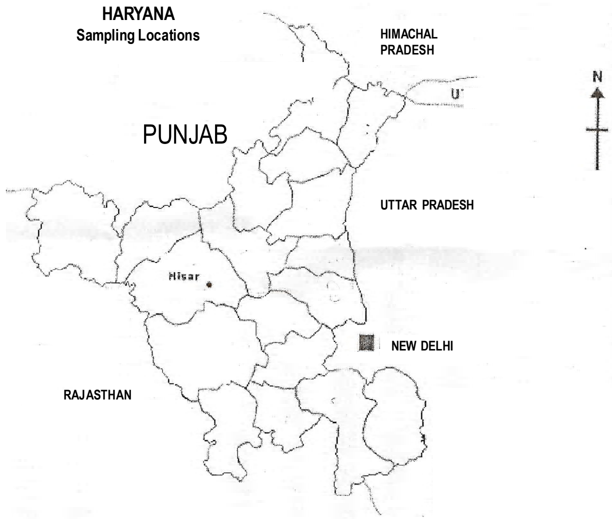

Fig. 1: Location of Rohtak in Haryana, India

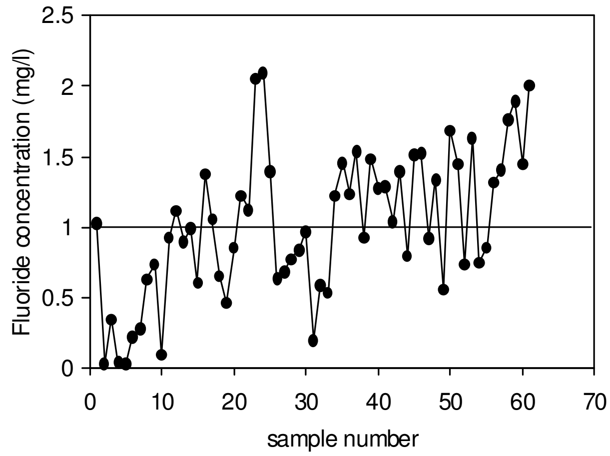

Fig. 2: Floride concentration of underground water in the ten villages as compared to the maximum allowable limit for drinking water in India

Table - 1: Details of population and sampling stations

Name of village	Population	Sampling source			No. of samples
		SHP-W	PHS-W	D.W	
Baniyani	4625	4	2	4	10
Patwapur	2846	4	2	0	6
Gadi	4878	3	2	1	6
Masoodpur	3765	0	2	2	4
Taimurpur	1797	3	2	0	5
Anwal	13667	3	3	0	6
Lahli	8552	2	3	2	7
Kalanaur	31645	4	5	0	9
Nigana	2463	1	1	1	3
Khanaur	22685	4	3	0	7
Total	97025	28	25	10	63

SHP-W = Shallow hand-pump water, PHS-W = Public health supply water, DW = Dug well

The depth of shallow hand-pumps aquifer varied from 20-35 meters. The average depth of dug wells varied from 10-30 meters. The public health water supply system contains either water from deep tube wells (>100 meters) or canal water supply

Table - 2: Comparison of ground water quality at the village under study with drinking water standards (Indian and WHO) [a]

Parameters	Values from collected samples				Indian standards		WHO standards
	Minimum	Maximum	Mean	± SD	Acceptable	Maximum	
pH	6.7	8.8	7.8	0.44	7.0-8.5	6.5-9.2	6.5-9.2
EC	0.31	12.0	2.9	2.57	-	-	-
TDS	200	7700	1848	166.04	500	1500	500
TA	80	940	390	199.50	200	600	-
TH	80	4608	447	939.63	200	600	500
Na^+	6	680	182	192.56	-	-	-
K^+	2	3090	244	570.92	-	-	-
Ca^{2+}	12	600	109	132.02	200	1000	500
Mg^{2+}	1	1085	46	135.96	200	400	50
HCO_3^+	73	573	235	122.026	30	-	150
Cl^-	11	2556	538	649.76	200	1000	200
SO_4^{2-}	31.4	1397.8	258.4	301.82	200	400	200
F^-	0.034	2.09	0.99	0.52	1.0	1.5	1.0

[a] - All the values are in mg/l, except pH and EC. Units of EC are mmho/cm

Table - 3: Classification of underground water on the basis of salinity

Sr. No.	Description of ground water	Salinity (mg/l)	No. of Samples	Percentage
1.	Non saline	< 1000	26	41.26
2.	Slightly saline	1000-3000	24	38.09
3.	Moderately saline	3000-10,000	13	20.64
4.	Very saline	> 10,000	0	0

Table - 4: Classification of underground water on the basis of total hardness

Total hardness (mg/l)	Description	No. of samples	Percentage
0-60	Soft	0	0
61-120	Moderately hard	5	7.9
121-180	Hard	11	17.4
>180	Very hard	47	74.6

Table - 5: Correlation matrix for different water quality parameters

	pH	EC	TDS	TH	TA	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	Cl^-	SO_4^{2-}	F
pH	1.00	-0.518**	-0.492**	-0.335**	-0.420**	-0.436**	-0.178	-0.509**	-0.216	-0.445**	-0.479**	-0.330**	-0.152
EC		1.00	0.923**	0.591**	0.394**	0.839**	0.243	0.799**	0.716**	0.411**	0.881**	0.735**	0.180
TDS			1.00	0.583**	0.358**	0.820**	0.243	0.753**	0.651**	0.374**	0.803**	0.716**	0.217
TH				1.00	0.043	0.778**	0.575**	0.492**	0.393**	0.49	0.547**	0.759**	-0.80
TA					1.00	0.116	0.074	0.412**	0.098	0.989**	0.249*	0.053	0.062
Ca^{2+}						1.00	0.425**	0.679**	0.557**	0.142	0.800**	0.859**	0.114
Mg^{2+}							1.00	0.344**	0.049	0.064	0.290**	0.469**	-0.038
Na^{+}								1.00	0.309*	0.401**	0.864**	0.578**	0.231
K^{+}									1.00	0.100	0.510**	0.591**	0.004
HCO_3^+										1.00	0.252&	0.050	0.106
Cl^-											1.00	0.624**	0.098
SO_4^{2-}												1.00	0.044
F^-													1.00

** Correlation is significant at the p<0.01 level (2-tailed), * Correlation is significant at the p<0.05 level (2-tailed)

Results and Discussion

The groundwater has no colour, odour and turbidity. Taste of the water was slightly brackish at most of the locations. A comparison of groundwater quality of the area under study with drinking water standards (Indian and WHO) is presented in Table 2. The pH of most of the water samples was slightly alkaline. There was a large variation in electrical conductivity even in the samples collected from the same village. According to a salinity classification by Rabinove *et al.* (1958) groundwater was non saline at 26 locations, slightly saline at 24 locations and moderately saline at 13 locations (Table 3). According to Durfor and Becker's (1964) classification of total hardness water was moderately hard at 5 locations, hard at 11 locations and very hard at 47 locations (Table 4). The calcium content in most of the water samples was beyond acceptable limit.

In most of the villages, the total alkalinity was higher than the acceptable limit (200 mg/l). Carbonate was either absent or present in negligible amounts. Bicarbonate ranged from 73 to 573 mg/l in these villages. Except few locations, sodium was higher than the WHO acceptable limit of 50 mg/l. Lower concentration of calcium compared to that of sodium indicated the absence of readily soluble calcium minerals or the action of base exchange, whereby calcium originally present in the water had been exchanged by sodium (Sharma and Rao, 1997). Except at 22 locations, the chloride content was higher than the WHO acceptable limit. Sulfate concentration was found to be within acceptable limits at 46 locations.

At 30 locations, fluoride concentration was higher than the permissible limit Fig. 2. At village Baniyani, all locations have fluoride concentration within the permissible limit except one whereas at Masoodpur and Lahli, only one location in each village had fluoride concentration within the acceptable range. At Kalanaur, two locations had fluoride concentration within the acceptable range. In remaining villages about 50% water sources had fluoride content higher than permissible limit of 1.0 ppm.

The fluoride content in the groundwater is a function of many factors such as availability and solubility of fluoride minerals, velocity of flowing water, temperature, pH, concentration of calcium and bicarbonate ions in water, *etc.* (Khaiwal and Garg, 2006). They had observed uneven distribution of fluoride in the groundwater of Hisar city which was due to uneven distribution of fluoride containing minerals in the rocks. Meenakshi *et al.*,

(2004) have reported the fluoride contamination in the ground water of some villages in Jind district. The results showed that more than 50% water sources had fluoride concentrations higher than permissible limits. A study conducted by Yadav and Lata (2003) in the Jhajjar district of Haryana have reported that fluoride content was higher than 2.0 mg per litre in all the books of this district.

The results of Karl Pearson correlation analysis have been presented in Table 5. Highly significant and positive correlation has been observed between TDS-TH ($r = 0.583$, $p \leq 0.01$), TDS-Ca ($r = 0.820$, $p \leq 0.01$), TDS-Na ($r = 0.753$, $p \leq 0.01$), TDS-K ($r = 0.651$, $p \leq 0.01$), TDS-Cl ($r = 0.803$, $p \leq 0.01$), and TDS Sulphate ($r = 0.716$, $p \leq 0.01$). This suggested that presence of TH, calcium, sodium, potassium, chloride and sulphate in the study area greatly influence the TDS and EC. Total hardness was positively and significantly correlated with Ca ($r = 0.778$, $p \leq 0.01$), Mg ($r = 0.575$, $p \leq 0.01$), Cl ($r = 0.547$, $p \leq 0.01$) and sulphate ($r = 0.759$, $p \leq 0.01$). This showed that there was great dependence of hardness on calcium, magnesium, chloride and sulphate. Total alkalinity was significantly and positively correlated with bicarbonate content ($r = 0.989$, $p \leq 0.01$) indicating that alkalinity was mainly of bicarbonate type. Sodium was significantly correlated with chloride ($r = 0.864$, $p \leq 0.01$) and sulphate ($r = 0.578$, $p \leq 0.01$). Chloride content was significantly and positively correlated with sulphate ($r = 0.624$, $p \leq 0.01$). pH was significantly but negatively correlated with EC, TDS, TA, calcium, sodium and chloride. Fluoride was not significantly correlated with any of the analyzed water quality parameter.

On the basis of physicochemical analysis of the studied water sources in ten villages of Rohtak district (India), it has been concluded that the groundwater and dug well water quality varied spatially. Water at most of the locations is not suitable for drinking purposes as per WHO guidelines. Hardness and fluoride were major health related issues. It is further suggested that some kind of treatment for hardness, fluoride and salinity removal is immediately required in the studied villages to avoid waterborne health problems in residents.

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