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Variation of fluoride and correlation with alkalinity in groundwater of shallow and deep aquifers

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ABSTRACT

Fluoride in water is an essential element for human beings and its deficiency as well as high concentration both is injurious to human health. It is required for the protection against dental caries and weakening of bones. Groundwater in shallow aquifers that supply water to dugwells in and around Dhampur, Bijnor district of Uttar Pradesh, has higher concentrations of fluoride (F) than those of borewells from deep aquifers. Factors for variation in fluoride content between the two aquifer water types are discussed. The relative merits of the shallow water for potability are pointed out with respect to fluoride concentrations and public health. Fluoride occurs in almost all natural water supplies. Fluorides in high concentrations are not a common constituent of surface water, but they may occur in deterimental concentrations in ground waters.

Key words: Fluoride, groundwater, aquifers, variation.

1. Introduction

The occurrence of high fluoride concentrations in groundwater is a problem faced by many countries, notably India, Sri Lanka and China, the Rift Valley countries in East Africa, Turkey and parts of South Africa. Fluoride epidemic has been reported in as many as 19 Indian states and Union Territories. India is one among the 23 nations in the world, where fluoride contaminated groundwater is creating health problems. The state of Art Report of UNICEF confirms the fluoride problem in 177 districts of 20 states in India. The high fluoride levels in drinking water and its impacts on human health have increased the importance of defluoridation studies (Adler, 1970; Bhussry, 1970 and EPA, 1975). The magnitude of the problem is sinking in and effects are being made towards defluoridation of drinking water, combating the debilitating fluorosis and taking steps to prevent and control the disease (AMA, 1975; Chand, 1999 and Hodge, 1965).

Fluoride is well recognized as an element of public health concern. Fluoride is present universally in almost every water (higher concentrations are found in groundwater), earth crust, many minerals, rocks etc. It is also present in most of everyday needs, viz. toothpastes, drugs, cosmetics, chewing gums, mouthwashes and so on (Subha Rao, 1997 and Thatte, 1994). Though a small amount of it is beneficial for human health for preventing dental carries, it is very harmful when present in excess of 1.0 ppm. World Health Organization (WHO) and IS: 10500 recommend that the fluoride content in drinking water should be in the range of 1.0-1.5 ppm.

An intake of more than 6 ppm of fluoride results in multidimensional health manifestations, the most common being dental and skeletal fluorosis (Hubner, 1969 and Ramamohana, 1974).

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Higher concentration of fluoride also causes respiratory failure, fall of blood pressure and general paralysis. Loss of weight, anorexia, anemia, wasting and cochexia are among the common findings in chronic fluoride poisoning. Continuous ingestion of non-fatal dose of fluorides causes permanent inhibition of growth. Fluoride ions inhibit a variety of enzymes often by forming complexes with magnesium ions and other metal ions (Ramesam, 1985; Rao et al. 1973 and Subha Rao, 1992).

Bijnor occupies the north-west corner of the Moradabad Division and is a roughly triangular stretch of country with its apex to the north. The western boundary is formed throughout by the deep stream of the river Ganges, beyond which lie the four districts of Dehradun, Saharanpur, Muzaffarnagar and Meerut. The Dhampur is a municipal board in Bijnor district in the state of Uttar Pradesh, India. One of the largest sugar producers in India, Dhampur Sugar mills, is located here. Dhampur's main economy is based on agriculture, mainly sugarcane, wheat, and paddy. Hand-woven textile items produced by the weavers living in surrounding areas are known for their utility and designs.

1.1 Site location and Climatology

Dhampur is situated, between latitude 29°19′N and 78°31′E and longitude 29 32°N and 78 52°E at 216 meters above the sea level (Figure 1). The study area has an average monthly temperature varying 41.9°C maximum in summer and 3.2°C in winter. Average weather condition allow to recognize six well-marked traditional seasons, i.e. spring (March-April), summer (May-June), monsoon (July-August), sharada (Sep-Oct), hemanta (Nov-Dec) and winter (Jan-Feb). The average annual rainfall variation is between 1122 and 1054 mm/year.

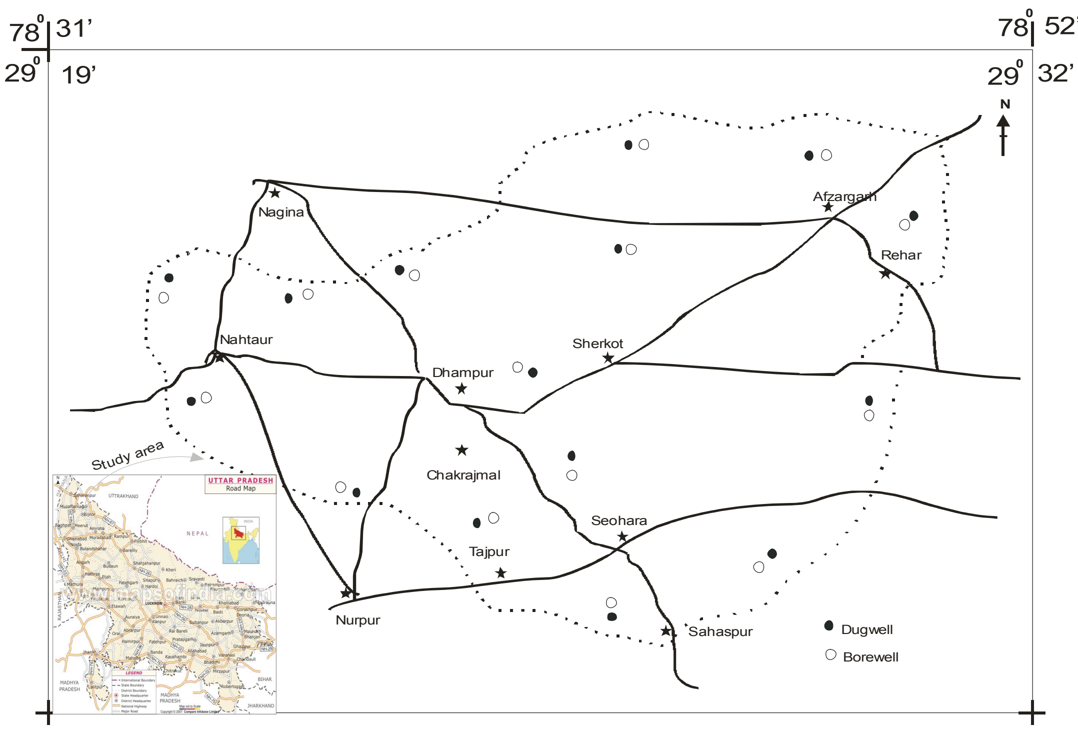

Figure 1: Base map and location map of dugwells and borewells in and around Dhampur, Bijnor

1.2 Geology

Some lethofacies of the deposits of Ganga Plain, are Mottled Silt, thick sheet like or lensoid units of well-sorted silt with little clay fraction. It represents sheet flow deposits on the higher sloping surface (Soman, 1977; Appelo and Postma, 2005), Variegated Clayey silt, thick, highly mottled clay rich sediment with intense burrowing showing clay coated sand grains, small mud pebbled, furriginization and ferruginous nodules. This represent diagenetically modified sandy silt or silty, sand sediments, which can be laterally traced for 50-100m (Lehr et al. 1980). The shallow aquifer yields groundwater at an average rate of 20 m3/day through dugwells and the deep aquifer has average yields of 105 m3/day day through borewells, due to variations in their hydraulic conductivities (Subba Rao, 1992).

1.3 Objectives and Scope

In view of the increased interest in recent years in fluoride (F) concentrations in groundwater and impact to human health, the present study is focused on factors determining F levels in the groundwater of shallow and deep aquifers in and around Dhampur, Bijnor district of Uttar Pradesh and the identification of appropriate aquifer zones for fluoride-safe drinking water.

2. Material and Methods

Thirty samples, 15 each from shallow dugwells and deeper borewells in close proximity, were collected for comparative study and monitoring in May 2008. The dugwells range in depth from 2 to 14m and the borewells range from 20 to 60m with averages of 9 and 34m respectively. Samples were drawn with a precleaned plastic polyethylene bottle. Prior to sampling, all the sampling containers were washed and rinsed thoroughly with the groundwater (Brown et al. 1974 and Soman, 1977). pH was measured using digital meter immediately after sampling.

The fluoride concentration was determined by Ion-Selective Electrode method. This is the most convenient method for estimation of Fluoride, down to 10-5M (0.2 mg/lit), which can be stretched to 10-6M under optimum conditions. It is based on potentiometric measurements with a membrane electrode consisting of a single crystal of Europium doped Lanthanum fluoride, LaF3. The purpose of Eu doping is to improve electrical conductivity (APHA, 1998; Merck, 1974).

3. Results

Table 1 shows the concentration of fluoride in ppm and pH of groundwater from dugwells and borewells in the study area. For the shallow aquifers of study area, pH ranged from 7.1 to 8.2 whereas pH values for deep aquifers were ranging between 6.9 and 8.1. The amount of fluoride ion in all shallow aquifers ranged between 0.5 ppm and 1.4 ppm whereas in deep aquifers ranged between 0.3 ppm and 0.9 ppm.

The observed ranged of fluoride concentration in shallow aquifers are comparatively high as compared to deep aquifers. Fluoride concentration at all shallow and deep aquifers are almost similar for all the study area. Critical analysis of data of fluoride concentration clearly indicates that the deep aquifers are deficient of fluoride at all the study area.

Table 1: The concentration of fluoride in ppm and pH of groundwater from shallow and deep aquifers in the study area

Sample Nos. shown in figure	pH	Fluoride (F-)	Correlation Value	Sample Nos. shown in figure	pH	Fluoride (F-)	Correlation Value
1 D	7.8	1.1		16 B	7.6	0.6	
2 B	7.1	0.7		17 D	7.4	1.3	
3 D	8.0	1.0		18 B	7.5	0.9	
4 B	7.5	0.6		19 D	7.2	1.1	
5 D	8.2	1.4		20 B	7.1	0.7	
6 B	8.1	0.8		21 D	8.2	1.1	
7 D	8.1	1.2		22 B	7.5	0.6	
8 B	7.4	0.7		23 D	7.9	1.0	
9 D	8.0	1.1		24 B	7.2	0.7	
10 B	7.5	0.8		25 D	7.1	1.1	
11 D	8.2	0.5		26 B	7.4	0.6	
12 B	8.0	0.5		27 D	7.4	0.8	
13 D	8.0	1.2		28 B	7.5	0.5	
14 B	6.9	0.7		29 D	7.3	0.7	
15 D	7.5	0.9		30 B	7.4	0.3	
			0.119723				-0.066672

where D= Dugwell   B= Borewell

Elemental fluorine plays a vital role in higher life forms, especially in the skeletal systems. Both deficiency and excess of F might be harmful. Effects associated with the impact of the ion on human health greatly depend on total intake through various media such as water, air and food. For instance, the common food stuffs have fluorine contents as follows: milk 0.07 to 0.22 ppm, wheat 0.05 ppm, rice 0.7 ppm, eggs 1.2 ppm; tea 3.2 to 178.8 ppm, garlic and onion contain 10 to 17 ppm (Kariyanna, 1987). Under these circumstances, it is advisable to consume waters having a low concentration of F to prevent fluorosis problems. The desirable limit of F in water for drinking purpose is 0.6 to 1.2 ppm, while the optimal range for it in the present study area as per temperature conditions (Public Health Service, 1962) is 0.7 to 0.8 ppm. Therefore, the ideal concentration of F may be considered to be 0.6 to 0.7 ppm. Since nearly 73% of the deep aquifer water has an F concentration between 0.6 and 0.7 ppm compared to the shallow aquifer water, the former would be more suitable than the latter for drinking purposes.

By analyzing the data it has been found that nearly all the fluoride concentration had pH level more than seven that means all the pH in the alkaline side (Table 1) for both the aquifers. Correlation analysis had been carried out to find out correlation coefficient value (Table 1). By analyzing the data it was found that correlation value is 0.119723 in shallow aquifers and correlation value has been found in deep aquifers -0.066672. The graph has been plotted showing the basicity is the major factor for fluoride increase in the ground water show in Figure 2 and 3. Mean maximum average value has been calculated in the table for fluoride and pH value (Table 2).

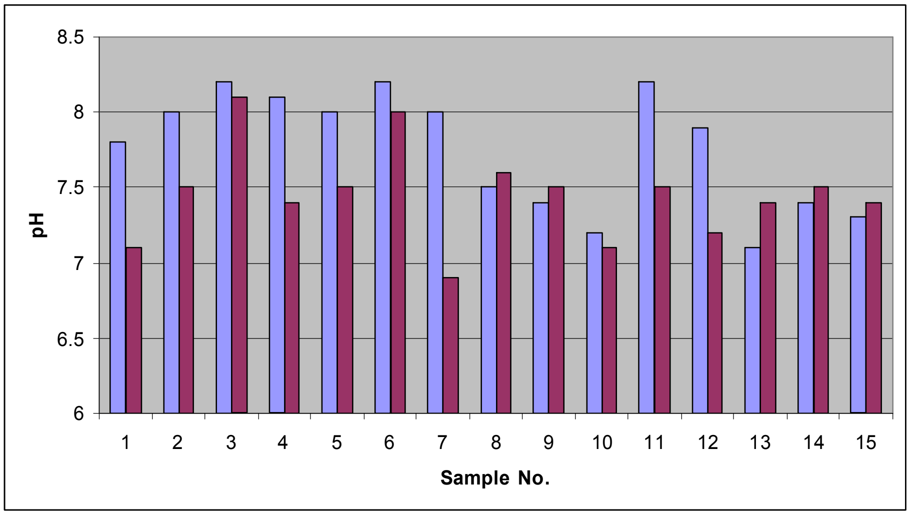

Figure 2: Graphical presentation of pH in shallow and deep aquifers

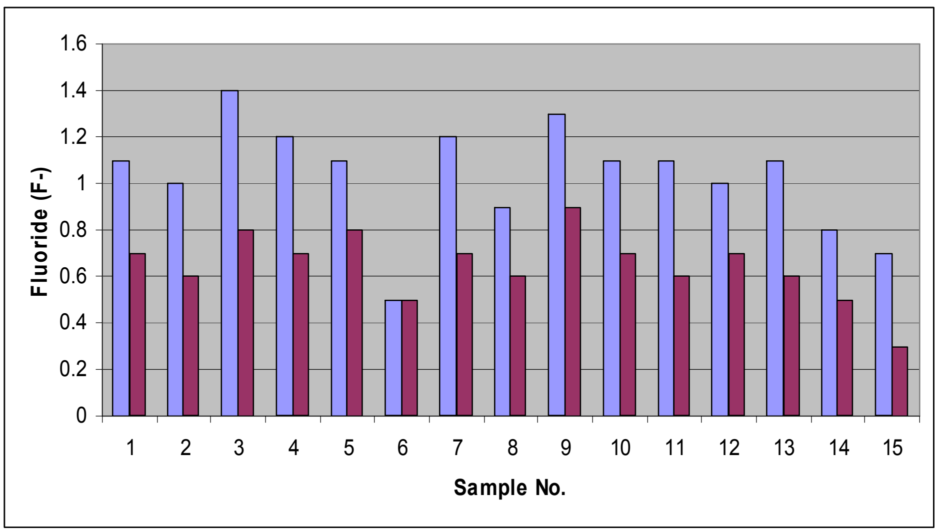

Figure 3: Graphical presentation of Fluoride concentration in shallow and deep aquifers

Table 2: Mean Maximum and Average value for pH and Fluoride

	For pH		For Fluoride	
	Shallow Aquifers	**Deep Aquifers**	**Shallow Aquifers**	**Deep Aquifers**
Sum	116.3	111.7	15.5	9.7
Average	1.0	4.4	5.3	4.25
Max	8.2	8.1	1.4	0.9
Min	7.1	6.9	0.5	0.3

4. Conclusion

It can be concluded that fluoride-bearing water are usually high in the alkalinity and low in hardness and chloride, sulphate (Thergoankar and Kulkarni 1971). In mineralogical study of this area, we found that fluoroapatide and biotite micas contain fluoride ion. It may be because that apatite may perhaps exchange some of its hydroxyl ion for fluoride. Presence of high bicarbonates contributing to the alkalinity can also play an important part in the mineralization process (Thergaonkar et al. 1971 and Wodeyar, 1996). Similar studies in other fluoride problem areas would help to identify safe aquifer zones for drinking water. However, the borewells sampled should tap the fracture zones only. A few exploration deep borewells are also advisable where even the shallow fracture zones which are in close proximity with the weathered zones are sealed to avoid the effects of vertical leakage. It is also recommended to compare groundwater from borewells in outcrop areas (no weathered zone) to areas with weathered zones to understand the behavior of fluoride concentrations. Such studies will help solve the fluoride problem in groundwater by using hydrogeological and geochemical information for well placement rather than spending huge sums of money on alternate supply schemes.

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