FLUORIDE DISTRIBUTION IN GROUNDWATER AND SURVEY OF DENTAL FLUOROSIS IN VILLAGES OF DIDWANA TEHSIL OF NAGAUR DISTRICT OF CENTRAL RAJASTHAN, INDIA

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ABSTRACT

This study was carried out to assess the fluoride concentration in groundwater of Central Rajasthan, India, where groundwater is the main source of drinking water. Water samples collected form deep aquifer based hand-pumps of rural area of Didwana Tehsil of Nagaur district were analysed for fluoride content. Fluoride in presently studied sites was recorded in the ranges of 1.1 and 8.5 ppm. The minimum concentration was recorded from 3 villages viz. Koliy, Singrawat Kalan and Beri Kalan while maximum concentration was recorded from village Didwana (8.4 ppm). Out of 54 villages studied no village have fluoride concentration below 1.0 ppm. 8 villages have fluoride above 1.0 ppm but below 1.51. Maximum 25 villages were found to have fluoride above 1.5 ppm but below 3.01 ppm. 19% villages have fluoride concentration above 3 ppm but below 5.01 ppm and 24.1% villages have fluoride above 5.00 ppm. As per the desirable and maximum permissible limit for fluoride in drinking water, determined by WHO and Bureau of Indian Standards, all groundwater sources is unfit for drinking purposes. Due to the higher fluoride level in drinking water several cases of dental and skeletal fluorosis have appeared at alarming rate in this region. After evaluating the data of this study it is concluded that there is an instant need to take ameliorative steps in this region to prevent the population from fluorosis.

Keywords*: Ground water, Fluoride, Fluorosis, Didwana Tehsil, Rajasthan*

INTRODUCTION

It is well established that India has two acute public-health problems induced by utilization of groundwater as a source of drinking water having excess fluoride and arsenic. Fluorine is the most electronegative of all chemical elements and is therefore never found in nature in elemental form. Combined chemically in the form of fluorides, it ranks 17^{th} in abundance of elements in the earth's crust representing about 0.06–0.09% of the earth's crust (WHO, 1994). Fluoride is one of important life elements to human health. It is essential for normal mineralization of bones and formation of dental enamel with presence in small quantity (Chouhan and Flora, 2010). When fluoride is taken up more then permissible limit, it become toxic and causes clinical and metabolic disturbance in animals and human being such as dental and skeletal Fluorosis (Hussain et al., 2002, 2004a, 2010, 2011, 2012; Singh et al., 2007).

Owing to the universal presence of fluorides in earth's crust, all water contains fluorides in varying concentrations ranging from trace levels to several milligrams per litre (WHO, 1994). In surface fresh water such as rivers and lakes, fluoride concentrations are usually low, ranging from 0.01 to 0.3 mg/l (Murray, 1986). However, exceptionally high values can be found such that some lakes in Kenya have fluoride content >2000 mg/l. For example, Lake Nakuru, which is situated in the rift valley in Kenya, has a fluoride concentration of 2800 mg/l and it is reported that this is the highest natural fluoride concentration ever found in water (Murray, 1986). Generally most groundwater sources have higher fluoride concentrations than surface water. As groundwater percolates through the weathered rock in the aquifers, it dissolves fluoride bearing minerals hence releasing fluoride into solution (Cairncross and Feachem, 1991; Falvey, 1999). The main source of fluoride in groundwater is basically from the rocks minerals shown in table 1. These minerals are commonly associated with the country rocks through which the ground water percolates under variable temperature conditions. Besides these minerals, alkali rocks, hydrothermal solutions may also contribute to higher concentration of fluoride in groundwater. Robinson and Edington (1946) reported that the main source of fluoride in ordinary soil consists of clay minerals. The weathering and leaching process, mainly by moving and percolating water, play an important role in the incidence of fluoride in groundwater. When fluoride rich minerals, which are present in rocks and soil, come in contact with water of high alkalinity; they release fluoride into groundwater through hydrolysis replacing hydroxyl (OH) ion. The degree of wreathing and leachable fluoride in a terrain is more important in deciding the fluoride bearing minerals in the bulk rocks or soil. Due to weathering of rocks the Ca-Mg / carbonate concentration which form in arid and semi arid areas appears to be good sink for the fluoride ion (Jacks et al., 2005). While fluoride is present in air, water and food, the most common way it enters the food chain is via drinking water.

High groundwater fluoride concentrations associated with soil and rock minerals have been reported from India, Pakistan, West Africa, Thailand, China, Sri Lanka, and Southern Africa (Ayoob et al., 2006). It is estimated that around 200 million people, from among 25 nations the world over, are under the dreadful fate of fluorosis. India and China, the two most populous countries of the world, are the worst affected. In Indian continent, the higher concentration of fluoride in groundwater is associated with igneous and metamorphic rocks and about 62 million people are at risk of developing fluorosis from drinking high fluoride water. The problems are most pronounced in Andhra Pradesh, Bihar, Gujarat, Madhya Pradesh, Punjab, Rajasthan, Tamil Nadu, and Uttar Pradesh (Hussain 2001; Hussain et al. 2000, 2003, 2004a, 2004b, 2005a, 2005b, 2007; Godfrey et al. 2006; Ayoob and Gupta 2006; Sharma et al. 2007; Khaiwal and Garg 2007).

Rajasthan is the largest state of India having 342,239 km^2 area and with relatively low population density i.e. 165 persons per square kilometer. According to physiographic divisions the north and western part of the state is under The Great Plain of north India while, south and middle as well as eastern part is classified under the Peninsular Plateau (Census 2001). Rajasthan is unique as all the 32 districts have been reported to have variable fluoride contamination in groundwater. Most of the fluoride related groundwater studies in Rajasthan have been focused on the western and southern parts of the state which are conventionally described as ‘high fluoride’ areas (Maithani et al. 1998; Choubisa et al. 2001;). Review on the literature showed that no studies have been undertaken in the study area with regard to fluoride and fluorosis problem yet. So the objective of this study was to investigate the quality of drinking water (underground water) with special reference to the concentration of fluoride in most rural habitations of Didwana Tehsil of the Central of Rajasthan, India and a general observation was also conducted with respect to incidence of dental and skeleton fluorosis.

MATERIAL AND METHOD

STUDY AREA

Didwana Tehsil of Nagaur district is located between latitude 26^{o}25$^’$ and 27^{o}40’ N and longitude 73^{o}18’ and 75^{o}15’ E in Central Rajasthan. Because of its central situation in Rajasthan, it shares its border with several other district of the state .To the north it is bounded by Bikaner and Churu district, to the east by Sikar and Jaipur district, to the south by Ajmer and Pali district and to the west by Jodhpur district. The district has its general slope towards the west. Its average elevation is about 300 meters; ranging below 250 meters in the south and 640 meters in the north. Its geographical spread is a good combination of plain, hills, sand mounds & such ass it is a part of the great Indian Thar Desert (Census 2001).

WATER SAMPLE COLLECTION

Groundwater samples of a total of 54 villages located in Didwana tehsil of Nagaur district, Central Rajasthan were collected in pre cleaned polythene bottles with necessary precautions (Brown et al. 1974). The samples were collected, during the year 2011, from manually operated hand pumps of privately owned or established by government of Rajasthan in residential localities of studied habitations.

METHODOLOGY

The fluoride concentration in water was determined electrochemically, using fluoride ion selective electrode (APHA 1991). This method is applicable to the measurement of fluoride in drinking water in the concentration range of 0.01–1,000 mg/l. The electrode used was an Orion fluoride electrode, coupled to an Orion electrometer. Standards fluoride solutions (0.1–10 mg/l) were prepared from a stock solution (100 mg/l) of sodium fluoride. As per experimental requirement, 1 ml of Total Ionic Strength Adjusting Buffer Grade III (TISAB III) was added in 10 ml of sample. The ion meter was calibrated for a slop of −59.2 $\pm$2 (APHA 1991). The composition of TISAB solution was as 385.4 gm ammonium acetate, 17.3 gm of cyclohexylene diamine tetraacetic acid and 234 ml of concentrate hydrochloric acid per liter. All the experiments were carried out in triplicate, and the results were found reproducible with $\pm$ 2% error.

RESULT AND DISCUSSION

FLUORIDE DISTRIBUTION:

Fluoride concentration in groundwater of 54 villages of Didwana tehsil was examined. The village code wise concentration of fluoride is shown in table 2. All the villages were categorized according to following concentration range (Table 4).

1. Category I :Fluoride concentration below 1.0 mg/l (Green Colour)
2. Category II : Fluoride concentration between 1.0 - 1.5 mg/l (Yellow Colour)
3. Category III : Fluoride concentration between 1.5 - 3.0 mg/l (Red Colour)
4. Category IV :Fluoride concentration between 3.0 - 5.0 mg/l (Brown Colour)
5. Category V : Fluoride concentration above 5.0 mg/l (Grey Colour)
6. Category VI : Uncovered / No Source Village (White Colour)

The abstract of fluoride distribution is shown in table 3. A coloured tehsil map is also prepared using 6 colours as shown in figure -1.

Fluoride concentration in the tehsil ranges from 1.1 mg/l to 8.5 mg/l. The minimum concentration 1.1 mg/l was recorded from 3 villages viz. Koliya, Singrawat Kalan and Beri Kalan while maximum concentration was recorded from village Didwana (8.4 mg/l). The present survey reveals that no one villages fall in category I (Green colour) in which fluoride concentration is below 1.0 mg/l, maximum desirable limit of standards for drinking water recommended by Bureau of Indian Standard (BIS) in IS: 10500, 1991.

Out of 54 villages of Didwana tehsil 8 villages (14.81 %) have fluoride concentration above 1.0 mg/l and below or equal to 1.5 mg/l. and fall in category II (Yellow colour in Figure – 1) the maximum permissible limit of fluoride in standard for drinking water is 1.5 mg/l (IS 10500; BIS 1991). Population of these habitations, fluoride intake through drinking water is more than 4 mg/day in an individual. Therefore, an incidence of first and second degree dental fluorosis is possible in local residents of these habitations.

25 villages (46.29 %) have groundwater with fluoride concentration above 1.5 mg/l and below or equal to 3.0 mg/l., (Red colour in Figure - 1) which is above the maximum permissible limit as recommended by BIS. At this concentration, teeth lose their shiny appearance and chalky black, gray, or white patches develop known as mottled enamel (Dean 1942). In 8 villages (14.81 %) fluoride concentration in groundwater is above 3.0 mg/l and below or equal to 5.0 mg/l and this fall in category IV (Brown colour in Figure – 1).The intake of fluoride per day by population in these habitation is very high and cause dental as well as skeletal fluorosis.

In the entire study the 13 villages (24.07 %) falls in category V (Grey Colour in Figure – 1) in this village, fluoride concentration is above 5.0 mg/l, which may result in all types of fluorosis among inhabitants. In the second clinical stage, the affected persons may have pain in bones, which causes further calcification in ligaments. It has been reported that such persons may suffer from stiffness in joints. At this concentration, the vertebrae partially fuse together crippling the patient which is known as “crippling skeletal fluorosis”.

FLUOROSIS STUDY:

Fluorosis study in 12 villages having fluoride concentration above 5.0 mg/l in groundwater was conducted. The entire sources of fluoride in these villages were examined. A total of 3126 individuals of these villages were examined in the survey for dental fluorosis using method maintained in methodology. Data indicate that 1,468 individual (46.96%) are without dental fluorosis. A high percentage of individuals (53.04% or 1,658 persons) were reported with dental fluorosis. It is clear that in villages with high fluoride concentration in groundwater, the percentage of dental fluorosis cases are also high.

Data from this study corroborate a number of other recent investigations indicating that the prevalence of dental fluorosis increases with fluoride concentration in drinking water (Choubisa 1997; Choubisa et al. 2001; Hussain et al., 2010; Gopal 2000; Dhar et al. 2007). In the present study, 30–94.85% children revealed dental fluorosis. This suggests that prevalence of dental fluorosis can vary widely between different geographical locations having almost the same fluoride concentration in drinking water. These findings suggest that, besides water fluoride concentration and duration of exposure, other factors such as dissolved salts in drinking water, nutrition, and habits also affect the prevalence of dental fluorosis.

Water is the major source of fluoride intake. WHO (1991) guidelines suggested that, in areas with a warm climate, the optional fluoride concentration in drinking water should remain below 1.0 mg/l (1.0 ppm) while in cooler climates it can increase to 1.2 mg/l. The differentiation derives from the fact that we perspire more in hot weather and consequently drink more water. The WHO guideline value for fluoride in water is not universal. India, for example lowered its permissible limits from 1.5 to 1.0 ppm in 1998. Fluoride concentration in the environment is closely associated with human health. Fluorosis is a result of the destruction of metabolic calcium and phosphorus, leading to inhibition of active enzymatic process in the human body, which interrupts the function of the endocrine system, leading to fluorosis (Xiang et al. 2004). It has long been known that excessive fluoride intake causes serious toxic effects. The enamel of human tooth, which is the hardest part of the human body, consists of the mineral hydroxyl apatite [$Ca_5(PO_4)_3OH$]. When excessive fluoride is ingested, the fluoride ions begin to replace the hydroxyl ions in the apatite structure, thereby converting it to fluoroapatite [$Ca_5(PO_4)_3F$], which makes the tooth brittle and discolored. This is known as dental fluorosis. Dental fluorosis, which is characterized by discolored, blackened, mottled or chalky white teeth, is a clear indication of overexposure to fluoride during childhood when the teeth were developing. Chronic intake of excessive fluoride can lead to the severe and permanent bone and joint deformations of skeletal fluorosis. The physical damage that fluorosis may cause to teeth is not, however, the only concern. Another concern, as detailed over 20 years ago by the National Institute of Mental Health (NIMH), is the psychological impact that dental fluorosis may have on a child. According to the study, children with severe dental fluorosis are more likely to be perceived by their peers as less intelligent, less attractive, less social, less happy, less careful, less hygienic, and less reliable, which could have a major effect on a child's self-esteem (Elias-Boneta et al. 2006; Williams et al. 2006). Whether dental or skeletal, fluorosis is irreversible and no treatment exists. The only remedy is prevention, by keeping fluoride intake within the safe limits. Fluoride poisoning can be prevented or minimized by using alternative water sources, by removing excess fluoride, and by improving the nutritional status of the population at risk. Clinical data indicate that adequate calcium intake is clearly associated with a reduced risk of dental fluorosis (Teotia et al. 1987; Pius et al. 1999). Vitamin C may also act as a safeguard against the risk. Hence, measures to improve the nutritional status of an affected population—particularly children— appear to be an effective supplement for and antidote against fluorosis.

Consequently, in these villages fluorosis is caused mainly by fluoride in drinking water. As found here, there were significant dose–response relationships between water fluoride, serum fluoride, and prevalence of dental fluorosis, which are consistent with findings of Xiang et al. (2004). This study gives an overview of the existing caries and the treatment needs in school children of Didwana Tehsil of Nagaur district Rajasthan and helps in implementing programs to achieve optimal health for children.

ACKNOWLEDGEMENT

I am thankful to Dr. Manoj Sharma, Junior Chemist, Public Health Engineering Department, Nagour and Mrs. Nishy, P. Scientist E-II, NISCAIR, New Delhi, for helping and necessary guidance.

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- **Table 1: Source of Fluoride in Ground water**

Minerals	Chemical Composition
1. Fluorite (Fluorspar)	CaF_2
2.Fluorapatite (Apatite)	$Ca_5(F,Cl)PO_4$
3.Micas	
a. Biotite	$K(MgFe^{+2})_3(AlSi_3)O_{10}(OHF)_2$
b. Muscovite	$KAl_2(AlSi_3O_{10})(OHF)_2$
c. Lepidolite	$K_2(Li,Al)_5(Si_6Al_2)O_{20}(OHF)_4$
4. Amphiboles	
a. Hornblende	$NaCa_2(MgFe^{+2})_4(AlFe^{+3})(SiAl)_8O_{22}(OHF)_2$
b.Tremolite Actinolite	$Ca_2(MgFe^{+2})_5(Si_8O_{22})$ $(OHF)_2$
5. Topaz	$Al_2SiO_4(OH.F)_2$
6. .Rock Phosphate	$NaCa_2(MgFe^{+2})_4(AlFe^{+3})(SiAl)_8O_{22}(OHF)_2$

Table 2 – Fluoride Distribution in Didwana Tehsil

S. No.	Name of habitation	Population	Fluoride	S. No.	Name of habitation	Population	Fluoride
1	Doodoli	2103	2	28	Beri kalan	2949	1.1
2	Khardiya	917	1.8	29	Chhapri kalan	1255	5.9
3	Madam	633	2.5	30	Barangana	2100	1.7
4	Kalwani	1138	1.7	31	Saniya	2522	2.2
5	Naurangpura	469	5.6	32	Ruwan	2107	5.8
6	Palot	1723	2.2	33	Loroli khurd	682	7.1
7	Amarpura	1321	7.1	34	Sherani abad	6532	3.2
8	Thanu	1242	1.6	35	Indrapura	390	1.8
9	Pandorai	1278	8.1	36	Khuri	1135	4.1
10	Dayalpura	3133	6.2	37	Kodiya	892	1.6
11	Bardawa	2489	5.1	38	Bhawad	1063	5.3
12	Sewa	2287	3.1	39	Barawara	1575	4.2
13	Manaksar	234	6.5	40	Peedwa	2846	3.6
14	Manda basni	861	1.2	41	Tosina	4713	2.4
15	Koliya	6579	1.1	42	Khojas	1597	2.6
16	Chomu	694	1.8	43	Dasana Khurd	1126	2.9
17	Mamroda	1719	1.3	44	Begsar	1560	2.3
18	Kairap	2933	2.3	45	Kurli	1774	2.1
19	Ransisar	1890	3.4	46	Ladariya	4909	1.8
20	Beechawa	1850	4.1	47	Bhadliya	3262	5.1
21	Agoonta	2296	3.1	48	Molasar	6370	1.2
22	Godras	1142	1.8	49	Nimba ka Bas	1369	2.6
23	Khunkhuna	5373	2	50	Bansa	2289	1.2
24	Singrawat kalan	1150	1.1	51	Dakipura	1211	1.8
25	Moriyawat	1552	5.4	52	Dhankoli	6508	1.6
26	Sudrasan	3957	1.4	53	Khanri	1765	1.9
27	Noowa	2604	1.6	54	Didwana	44675	8.5

Table: 3 - Abstract of fluoride distribution in Didwana Tehsil

No. of Village	Fluoride Concentration in mg/l						
	Minimum	Maximum	<1.01	1.0 - 1.51	1.5 - 3.01	3.0 - 5.01	>5.0
54	1.1	8.4	0	8	25	8	13

Table 4: Fluoride Categorization of Villages of Didwana Tehsil

Category I (Below 1.0 mg/l)	Category II (Above 1.0 mg/l & below or equal to 1.5 mg/l)	Category III (Above 1.5 mg/l & below or equal to 3.0 mg/l)	Category IV (Above 3.0 mg/l and below or equal to 5.0 mg/l)	Category V (Above 5.0 mg/l)
	Manda basin(1.2) Koliya (1.1), Mamroda (1.3) Singrawatkalan (1.1) Sudrasan(1.4), Beri kalan (1.1), Molasar (1.2), Bansa (1.2)	Doodoli (2.0) , Khardiya (1.8), Madam (2.5), Kalwani (1.7), Palot (2.2), Thanu(1.6), Chomu (1.8), Kairap(2.3), Godras(1.8), Khunkhuna (2.0), Noowa(1.6), Barangana(1.7), Saniya (2.2), Indrapura(1.8), Kodiya (1.6), Tosina (2.4), Khojas (2.6), Dasana Khurd(2.9), Begsar(2.3), Kurli(2.1) Ladariya (1.8), Khanri (1.9) Nimba ka Bas (2.6) Dakipura (1.8), Dhankoli (1.6)	Sewa- 3.1 Ransisar- 3.4 Beechawa- 4.1 Agoonta - 3.1 Sherani abad-3.2 Khuri-4.1 Barawara-4.2 Peedwa-3.6	Naurangpura- 5.6 Amarpura- 7.1 Pandorai-8.1 Dayalpura-6.2 Bardawa - 5.1 Manaksar- 6.5 Moriyawat-5.4 Chhaprikalan-5.9 Ruwan-5.8 Loroli khurd- 7.1 Bhawad-5.3 Bhadliya-5.1 Didwana -8.5

Figure – 1: Fluoride Distribution in Didwana Tehsil of Central Rajasthan