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Comparative study of fluoride toxicity in ground water of hilly terrain area and Banas river basin area of eastern Bhilwara (Rajasthan, India) and its impact, causes and prevention

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ABSTRACT

Fluoride is required by the human being for mineralization of bones and teeth. Hydro-Chemical condition is the main source of fluoride contamination in ground water but run off and atmospheric depositions are also responsible for additional fluoride concentration. This study was carried out to assess the fluoride concentration in ground water of Banas River Basin area and hilly terrain area of eastern Bhilwara (Rajasthan, India), effects on populace, possible sources and prevention and a comparison was made. For this purpose 98 ground water samples were collected from different locations of study area and analyzed. The fluoride toxicity in ground water of Banas river basin area determine comparatively much higher than the hilly terrain area. The maximum fluoride concentration in Banas river basin area determined is 5.2 mg/l and average concentration is 1.366 mg/l whereas in hilly terrain area is 2.33 mg/l and 0.306 mg/l. In 38.46 % samples of Banas river basin area F^- concentration did not comply with BIS and WHO standard whereas 1.7% samples in hilly terrain areas. More population of Banas river basin area is affected from dental and skeletal fluorosis and others fluoride related health hazards than the hilly terrain area. The possible sources of fluoride in study area are geogenic activities, presence of fluoride bearing minerals, decrease in rainfall, slow rate of water flow etc. In society impacts of fluoride contaminated water in study area is inequitably distributed and the impact was inversely related with the income and education level of people.

Key words: Dental Fluorosis, Skeletal Fluorosis, Mineralization, Geogenic, Physiology.

INTRODUCTION

The F^- content in the ground water is a function of many factors such as availability and solubility of F^- minerals, velocity of flowing water, Temperature, pH, concentration of Ca and HCO_3^- ions in water. Fluorine is the most electronegative and reactive of the all elements. It occurs as F^- ion naturally in soil and water due to chemical weathering of some fluoride containing minerals. Fluorides are ubiquitous in air, water and the lithosphere, where they are seventh in order of frequency of occurrence (0.06-0.09% of the earth crust) [1]. The natural sources of fluoride in ground water are various types of rocks (Fluorspar CaF_2, Cryolite (Na_3AlF_6), Fluoroapatite ($Ca_3(PO_4)_2$ Ca $(FCl)_2$) and volcanic activities. Fluorite is principle bearer mineral of fluoride and is found in granite, gneisses and pegmatite [2, 3]. In general F^- rich sediments exist with Ca-poor ground water, and these sediments are mostly acidic and intermediate volcanic origin in subducting areas of the earth crust. High F^- in ground waters are mainly associated with relatively low Ca and Mg concentration water types and usually have high pH value. The arid regions are prone to high F^- concentration here, ground water flow is slow and the reaction time with rocks is therefore long, but in humid regions F^- increase is less pronounced because of high rainfall inputs and their diluting effect of ground chemical composition [4]. Apart from natural sources of fluoride in ground water anthropogenic activities also contribute fluoride, burning of coal, manufacturing of steel, bricks, phosphate fertilizer industries, aluminium processing [2, 5, 6]. The strong electro negativity of fluorine is attracted by Ca-ions in teeth and bones, the excessive intake can causes teeth and bone fluorosis [7]. Though fluoride enters in the body through food, water, industrial exposure, drugs and cosmetics etc, but drinking water is the major contributory (75-90%) of daily intake among them [8]. According to Whiteford (1997) [9] the 75-90% of ingested fluoride is absorbed by body. In an acidic stomach fluoride converted into HF and once absorbed into blood, fluoride readily distributes throughout the body, with approximately 99% of body burden of fluoride is retained in Ca-rich areas such bones and teeth (Dentine and enamel) [10]. In body fluoride associates with calcified tissue (bone and teeth), and has been to be useful in the control of caries development for more than hundred years [11]. The teeth which contain fluoroapatite are less likely to develop caries because of greater resistance to ingested acids or acids generated from ingested sugars by the oral bacteria [12, 13]. Fluoride epidemic has been reported mostly in granite and gnissis geological belts of different states of India [14, 15, 16]. As per reports of UNICEF [17] and WHO a total of 17 (out of 32) States are reported to have endemic fluorosis in India, 20% of the fluoride affected villages in the world are in India and out of these 10% are in Rajasthan. This is indicating that fluorosis has emerged as one of the most alarming public health problem of the country. The most seriously affected areas are Andra Pradesh, Punjab, Hariyana, Rajasthan, Tamilnadu, Utter Pradesh [18]. In India F^- in ground water was first reported at Nellore district of Andra pradesh in 1937 [19] since then considerable work has been done in different parts of india to explore the F^- water sources [20]. In Rajasthan all 33 district are endemic for fluorosis [21]. Fluoride level in ground water is spread in all the 33 districts and become a health hazard in 25 districts.

MATERIALS AND METHODS

2.1 Study Area

Rajasthan 60% land is part of Great Indian Desert, Thar Desert that suffering from acute water crisis, Rajasthan state being largest state of the country having 10.4% of total geographical area of the country with only 1% of water resources available to the state for 5.5% population. The Banas River originates in the Khamnor Hills of Arawali range, about 5 Km from Kumbhalgarh in Rajsmand district and meets the Chambal river near the village of Rameshwar in Swai Madhopur district. It lies entirely within Rajasthan and it flows in Rajsmand, Chittorgarh, Bhilwara, Tonk and Swai madhopur district in Rajasthan, is located in east-central Rajasthan, between latitudes 24^0 15’ and 27^0 20’N and longitudes$73^0$25’ and 77^0 00’ E. It is a seasonal river that dries up during the summer, total length of the river is about 512 km. In eastern part of Bhilwara Jahazpur tehsil is located that comprises with plan Banas river basin and hilly terrain and is situated between $25^0$21’6”N to $25^0$46’23”N longitude and $75^0$2’50”E to $75^0$27’42”E latitude (**Figure 1**). Jahazpur belt rocks are considered as early proterozoic [22] and these rocks are encompassed by quartz, soda feldspar, biotite, potash feldspar, hornblende, actinoite along with zircon and apatite.

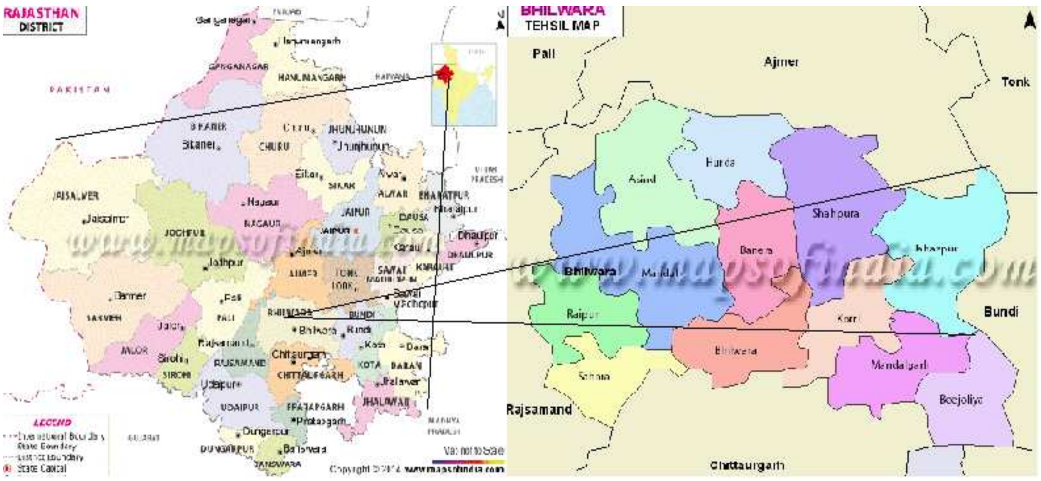

Figure 1. The location map of study area

2.2 Methodology

Ground water samples from 98 villages located in Banas river basin area and hilly terrain area of eastern Bhilwara (Rajasthan, India) were collected in pre cleaned polythene bottles during June 2014 with necessary precautions. The samples were collected from dug wells, bore wells and hand pumps. The fluoride concentration was determined by using fluoride ion selective electrode APHA, 2012 [23] that measures fluoride concentration of range 0.01 mg/l to 1000 mg/l. Colour, Odour and Taste, Hardness and Ca^{+2} and Mg^{+2} by conventional methods and Temperature, pH and TDS were determined on site using by potable instruments.

RESULTS AND DISCUSSION

The result of fluoride concentration obtained from 59 from hilly terrain area and 39 samples from Banas river basin area of eastern Bhilwara (Rajasthan, India) is represented in **Figure 2**, In most of the samples from Banas river basin area the F^- content determined higher than the hilly terrain area eastern Bhilwara (Rajasthan, India).

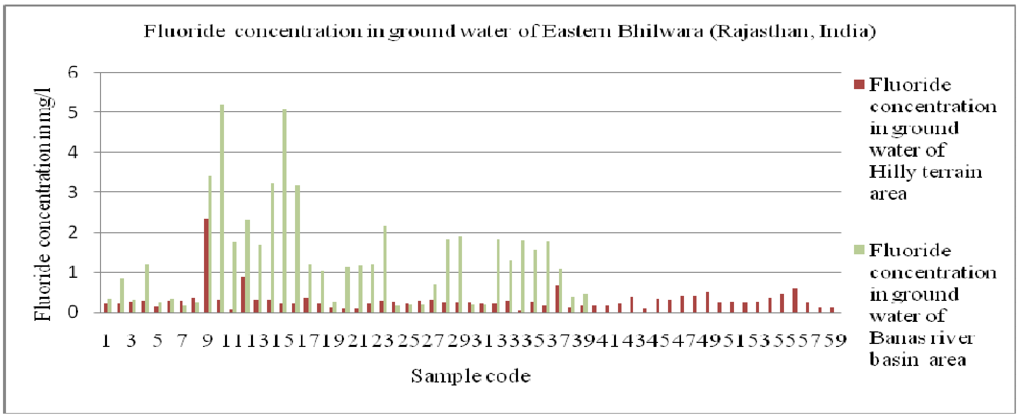

Figure 2-Fluoride concentration in ground water of Banas river basin area and hilly terrain area of eastern Bhilwara (Rajasthan, India)

Based on fluoride concentration in ground water the water samples are classified in five categories (**Table 1**) 75.5 % water samples fall in category-I in which fluoride content is <1.00 mg/l, 8.16 % samples fall in category-II in which range of fluoride is 1.00-1.5 mg/l, 16.32 % samples included in categories- III, IV and V where fluoride content is above the prescribed limit (>1.5 mg/l) of WHO standards. Water of these categories is not suitable for drinking purpose, it need proper treatment before consuming.

Table 1-Categorisation of ground water of ground water of Banas river basin area and hilly terrain area of eastern Bhilwara (Rajasthan, India) based on fluoride concentration

Category of Samples	Range of Fluoride Concentration in mg/l	Eastern Bhilwara	
		No. of Villages	% of Sample
Cat I	Below 1.00	74	75.5
Cat II	1.00-1.5	8	8.16
Cat III	1.5-3.00	10	10.2
Cat IV	3.00-5.00	4	4.08
Cat V	above 5.00	2	2.04

Comparison of fluoride concentration in ground water samples of eastern Bhilwara with WHO and BIS standard as shown in **Table 2**, total 16.32 % samples exceeding the prescribed limit, 38.46 % samples of Banas river basin area and only 1.7 % samples of hilly terrain area. 83.67 % samples comply with WHO [10] and BIS (2012) [24] standard, 98.3 % of hilly terrain area and 61.52 % of Banas river basin area. A comparison study of fluoride content in ground water of Banas river basin area and hilly terrain area is represented in **Figure 3** the average concentration of fluoride in ground water of Banas river basin area is 1.366 mg/l and in hilly terrain area is 0.306 mg/l.

Table 2- Fluoride Concentration in ground water of eastern Bhilwara (Rajasthan, India) comparison with WHO Standards

Para meter	Area	No. of samples	% of the Samples Exceeding Limits 1.5 mg/l	No. Villages Exceeding Limits 1.5 mg/l	% of the Samples within Limits 1.5 mg/l	No. of Villages within Limits 1.5 mg/l
F^-	Total area	98	16.32 %	16	83.67 %	82
	Hilly Terrain area	59	1.7 %	1	98.3 %	58
	Banas River Basin area	39	38.46 %	15	61.52 %	24

98.3% water samples of hilly terrain area and 41% of Banas river basin area fall in category-I in which fluoride content is <1.00mg/l, 20.5% and 25.64% samples of Banas river basin area fall Cat-II and Cat-III whereas in hilly terrain area no sample fall in these categories, In Cat-IV 7.7% samples of Banas river basin area and 1.7% of hilly terrain area included in which high fluoride content is determined (3.00-5.00 mg/l), Extremely high fluoride content (> 5.00 mg/l) is determined in Cat-V 5.13% sample of Banas river basin fall in this category but no sample fall from hilly terrain area. The most alarming condition of fluoride health hazards was observed in villages falling in category III, IV and V in which fluoride content exceeded WHO limits. In hilly terrain area only 1.7 % samples are falling in these categories whereas in Banas river basin area 38.47% samples fall, ground water of these villages is unfit for drinking purpose, hence this water cannot be used for drinking purpose without proper treatment. A chronic intake of excessive fluoride can lead to severe permanent bone joint deformations as skeletal fluorosi and morphological and physiological changes in calcified tissues (teeth and bones) dental fluorosis which is characterized by discoloured, blackened, mottled or chalky white teeth, is a clear indication of overexposure to fluoride during childhood when the teeth were developing.

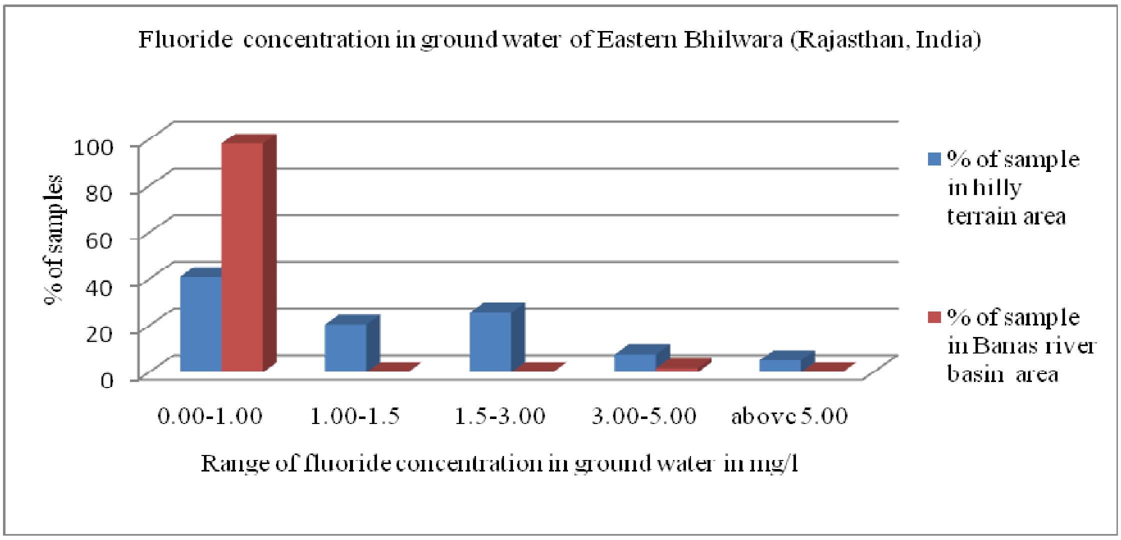

Figure 3- Comparison study of fluoride content in ground water of Banas river basin area and hilly terrain area of eastern Bhilwara (Rajasthan, India)

Figure 4- Skeletal fluorosis and dental fluorosis

Excess fluoride content have adverse effects on the structure and functions of the animal nervous system (25, 26], problems of Thyroid gland and skin of animals [27], adverse effects on fertility of human being, level of mental work capacity and intelligence quotient of children [28] and functioning of Ca [29]. A lack of fluoride intake increase susceptibility of enamel to acid attacks eruption [30]. Fluoride is not an essential nutrient for human growth and development but it protects from the dental caries and lack of fluoride intake may increase susceptibility of enamel to acid attacks after eruption. Low concentration exerts an anticaries effect on erupted teeth through constant with enamel during ingestion, excretion into saliva, and uptake of biofilms on teeth [13]. During the field visit cases of fluoride affected health hazards dental fluorosis and skeletal fluorosis (**Figure 4**) was identified. In Banas river basin area people suffering more comparatively than the hilly terrain area because people of Banas river basin area consuming more fluoride concentration than hilly terrain area through ground water. The possible sources of fluoride in ground water of Banas river basin area of eastern Bhilwara are weathering of fluoride bearing rocks, more fluoride in rocks, slow rate of water flow due to plan terrain, low rainfall compare to hilly terrain, higher pH of ground water, lack of Ca, Mg, and P content. In hilly terrain area more rainfall, higher flow rate of water, more presence of Ca, Mg, and P contenting rocks and low pH of ground water compare to Banas river basin area decreasing the fluoride content in ground water. The fluoride concentration with pH for ground water revealed that alkaline pH favouring higher concentration of fluoride since alkaline pH increases solubility of fluoride from minerals of fluoride [31] and acidic pH favours adsorption of fluoride in clay. Distribution in the body and renal excretion are pH dependent. At low pH it occurs as HF and less as ionic F- [32]. The concentration of fluoride in ground water is inversely related to Ca- concentration in earth crust, higher concentration decrease solubility of F^- because Ca binds with F^- to form CaF_2. Ca, Mg, Al and phosphorus decrease absorption of F^- since they get bind with F^-. Absorbed F^- which not deposited in calcified tissues is mainly excreted via the kidney -60 % [33]. The social, health, and economic impacts of contaminated ground water depends on spatial distribution of fluoride, dependence of the populace on fluoride contaminated water, awareness of water quality, levels education and economic status of populace at risk. Socioeconomic impact study of fluoride concentration in eastern Bhilwara indicating the impacts of poor quality water are distributed inequitably within the studied society and the percentage of fluoride debility cases found less with rising income. Good nourishment and medical care could be reason for this decline. Higher income group of society could escape the ill effects of fluoride contaminated water.

CONCLUSION

This study revealed that fluoride is nonuniformly distributed in ground water of eastern Bhilwra, 16.32 % sample of study area exceeding the prescribed limit of fluoride content and populace of 16 villages is at higher risk due excessive intake of fluoride through drinking water and populace of 83 villages is safe. In 38.46 % sample of Banas river basin area the fluoride content is exceeding the prescribed limit of fluoride content whereas in hilly terrain area only 1.7 % samples. The fluoride concentration range reported in ground water of eastern Bhilwra is 0.053 mg/l to 5.2 mg/l, in Banas basin river area ranges is 0.151 mg/l to 5.2 mg/l and hilly terrain area 0.053 mg/l to 2.32 mg/l. The populace of Banas river basin area of eastern Bhilwara is at higher risk compare to hilly terrain area due to excessive intake of fluoride concentration and the people of Banas river basin area are suffering from the fluoride related health hazards (teeth and skeletal fluorosis) but in hilly terrain area no such cases identified. The major contributory source of higher fluoride concentration in ground water of Banas river basin area of eastern Bhilwara are natural activities such as weathering of fluoride bearing rocks, slow rate of water flow, less amount of rainfall, higher pH of water, low content of Ca, Mg and P in rocks. In hilly terrain area low fluoride in ground water compare to Banas basin river area is due to more rainfall, higher flow rate of water, more presence of Ca, Mg, and P contenting rocks and low pH of ground water. The effect of fluoride contaminated water in society is distributed inequitably, and lower income group people are at high risk since there approach for recourses and good quality water is limited. The uneducated and economically poor people of the study area are more vulnerable for fluoride related health hazards than educated and economically rich people. Excessive fluoride intake may be prevented by using alternate sources of drinking water using surface water and rain water, consuming adequate Ca rich foods items and vitamin C, Ca and P reduce fluoride retention capacity of body. This risk can be minimised by educating the people about the fluoride toxicity and disfunctions of excessive fluoride, about good quality water and fluoride health hazards. The fluoride in drinking water can be removed by adsorption, flocculation and others techniques. The techniques should be village friendly, and cheap and reliable.

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