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Research Paper

Fluoride Contamination in Drinking Water in Palacode Region, Tamil Nadu

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Abstract *- Occurrence of fluoride in groundwater has drawn worldwide attention due to its considerable impact on human physiology. Fluoride is an essential element, which is good for the teeth enamel and helps to prevent dental caries. In excessive doses, however, it leads to chronic fluoride poisoning or fluorosis. Fluoride contamination of groundwater is a growing problem in many parts of the world. In India, a population of more than 66 million, especially in rural parts are dependants on groundwater for drinking purposes and have a potential risk of developing fluorosis. In the present study a high fluoride concentration in ground water is identified in Palacode region of Dharmapuri district in Tamil Nadu, where it is the only source of drinking water. The other water parameters such as pH, electrical conductivity, total hardness, nitrate, and Fluoride were also measured. The results indicated considerable variations among the analyzed samples with respect to their chemical composition. Total hardness and nitrate concentration are found higher than permissible limit at various locations. Fluoride is also higher concentration in number of locations. The fluoride concentration in the groundwater of these villages varied from 1.4 to 2.4 mg/l, causing dental fluorosis and teeth matting among people in general and children in particular. The geology and over extraction of groundwater sources increases the level of fluoride in groundwater. Overall quality is found unsatisfactory for drinking purposes without any prior treatment except in few villages. Also this study by way of capturing reasons for fluorosis and its implications, attempts to avert the disdained anomaly called fluorosis.*

Keywords: Groundwater quality, Drinking water, Fluoride, Fluorosis, Health hazard.

Introduction

Water is essential for life and access to clean drinking water is a necessity for good health. However, clean drinking water is not available everywhere, due to water scarcity and pollution of existing water resources. The pollution can be in the form of natural or anthropogenic activities. Fluoride contamination of groundwater is a growing problem in many parts of the world. The major sources of fluoride in groundwater are due to fluoride-bearing minerals such as fluorspar, cryolite, fluorapatite and hydroxylapatite in rocks[1]. Some anthropogenic activities such as use of phosphatic fertilizers, pesticides, sewage and sludge, depletion of groundwater table etc., for agriculture have also been indicated that cause an increase in fluoride concentration in groundwater[2]. In India the high concentration of fluoride in groundwater is associated with igneous and metamorphic rocks. Fluoride in minute quantity is an essential element which is good for mineralization of bones, formation of the teeth enamel and helps to prevent dental caries [3].

In excessive doses, however it leads to a chronic fluoride poisoning called fluorosis. In India, fluoride is the major inorganic pollutants of natural origin found in groundwater. There are more than 25 developed and developing nations that are endemic for fluorosis [4]. In the two largest countries India and China, fluorosis is the most severe and widespread. In India, it was first detected in Nellore district of Andhra Pradesh in 1937 [5]. In India more than 66 million people including 6 million children suffer from fluorosis because of consumption of water containing high concentration of fluoride [6]. Seventeen states in India have been identified as endemic for fluorosis and Tamil Nadu is one among them where 23 out of 28 districts are prone to fluorosis in drinking water [7]. In Tamil Nadu, a high concentration of fluoride occurs mainly in the groundwater from Dhamapuri and Salem district closely followed by Coimbatore, Madurai, Trichy, Dindugal, Virudunagar, and Tutiticorin district. The districts having low fluoride are Thirunelveli, Pudukkotai, Vellore, Thiruvanamalai, Ramnathapuram and Kanchipuram districts etc. High concentration of fluoride is often above 1.5 mg/l, results in severe problems over a large part of India. The people living in rural India are dependent on groundwater for drinking purposes water supplies are the worst affected and there is no other alternative source. It is very important to understand the mechanisms of mobilization of fluoride to be able to mitigate the problem as effectively as possible. In the present study the fluoride and other chemical parameters concentration in underground water was determined in Palacode region of Dharmapuri district of Tamil Nadu, where it is the only source of drinking water.

Topography

The study area lies between latitudes 12°16' N to 12°22' N and longitudes of 78°2'E to 78° 7'E (Fig.1) and located at 249 km north-west of Chennai city in Tamil Nadu. Palacode, also spelt as Palkkodu, is a small settlement on the outskirt of Dharmapuri district. The study area experiences a temperature ranging from 17°C to 42°C and average annual rainfall is about 895 mm. Rainfall is the main source of groundwater recharge in this area. Groundwater is the only source for both irrigation and domestic purposes. Dug wells and bore wells are the most common groundwater abstraction structure. The yield of the wells range from 150 to 200 m^3/day in weathered crystalline rocks. Irrigation activities mainly depend on the groundwater and lake water for about 1 or 2 month. Geologically, the area is underlain by a wide range of Charnockite, Granoid gneiss, pink magmatite and epidote of Archaean age. The soil type in the study area ranges from black to mixed loamy soil and red sandy soils. Agriculture is the major activity in the area and chief crops grown are tomato, sugarcane, groundnut, paddy, millets (cumbu), pulses etc. Palacode is popularly known for its tomato market. The slope of the area is towards south-east. Chinnar River is the important tributaries of river Cauvery.

Material and Methods

In order to assess the groundwater pollution due to fluoride, 25 groundwater samples have been collected in the month of February 2011. The water samples collected in the field were tested for electrical conductivity (EC), pH, Calcium, Magnesium, Nitrate and Fluoride in the laboratory using the standard methods given by the American Public Health Association. The groundwater locations were selected to cover the entire study area and attention was given to the contamination influencing fluoride, nitrate and hardness. Sampling was carried out using pre-cleaned polythene containers. The results were evaluated in accordance with the drinking water quality standards given by World Health Organization.

Results and Discussion

Analytical data revealed the presence of pH, EC, TH, NO_3 and F in the groundwater samples (Table 1), collected from Palacode region. The data showed significant variations in the water samples of chemical ingredients. The results were compared with Indian water standards and it shows that 84% (21 out of 25) water has higher salt content and is not acceptable to be used for drinking purpose.

pH and Electrical Conductivity: Groundwater pH ranged from 6.95 to 8.23 which is due to the presence of the carbonates and bicarbonates. The electrical conductivity of water samples ranged 813 μS/cm to 4400 μS/cm is given in Table 1 and is found that 4 samples are within the permissible limit (<1500 μS/cm) and 18 samples exceed permissible limit (1500-3000 μS/cm) and they are marginally poor in quality. Only 3 sample locations can be classified as hazardous (>3000 μS/cm) according to the world health organization standards. The high conductivity in some of the samples is likely due to the prolonged and extensive agricultural practices such as irrigation coupled with the inherent geological conditions acquiring high concentrations of the dissolved minerals.

Total Hardness: Total hardness of water is a measure of dissolved Ca^{2+} and Mg^{2+} in water expressed as $CaCO_3$. Water hardness has no known adverse effects; however, it causes more consumption of detergents at the time of cleaning and some evidence indicates its role in heart disease [8]. Excess hardness is undesirable mostly for economic and aesthetic reasons [9]. TH of the groundwater was calculated using the formula given below, [9-10] with all parameters expressed in mg/l.

$$TH \text{ (as } CaCO_3) = 2.497\ Ca^{2+} + 4.115\ Mg^{2+}$$

The hardness values range from 251 to 407 mg/l with an average value of 289 mg/l (Table 1). The maximum allowable limit of TH for drinking purpose is 500 mg/l and the most desirable limit is 100 mg/l as per the WHO international standards. Hence, classification of the groundwater of the study area based on hardness [11] has been carried out as shown in Figure 2. Accordingly, majority of samples falls in the very hard class category.

Nitrate: Nitrate is a major contaminant of drinking water. It is currently frequently found in aquifer. Conversions of nitrate to much less soluble organic nitrogen forms in soils as well as denitrification have reduced the nitrate concentration in groundwater. There is no geological source of nitrate in this region. Hence, the dissolved nitrates in groundwater are likely to have resulted from anthropogenic activities. Agricultural activities including fertilizer nitrate and nitrate derived from increased mineralization of soil through cultivation, seems to be one of the major source of nitrate in the groundwater [12]. During irrigation, urea and ammonia fertilizers are generally used as a source of nitrogen for the crops. Therefore, the hydration of urea will increase the ammonia concentration in addition with ammonia fertilizers. Nitrate concentration in the groundwater of the study area which varied from 12 to 98 mg/l (Figure 3), was generally 16 samples exceed the recommended limit (45 mg/l) for drinking water by the [13] and [14]. The high concentration of nitrate in drinking water is toxic and causes blue baby disease/methaemoglobinaemia in children and gastric carcinomas[15-16]. Most of the locations the source of nitrate in groundwater occurs by direct anthropogenic pollution (septic tanks etc). In urban areas urbanization is leaching of fertilizers in agricultural area is the source for the high concentration of nitrate in all locations. The result indicates that nitrate concentrations exceed the standards and are not fit for drinking purposes. The studies also advise the farmers about the optimal use of fertilizers with respect to crop requirement and irrigation schedule to preserve groundwater quality of the region.

Fluoride: The fluoride concentration in this region varies from 1.4 to 2.4 mg/l. Groundwater samples with less than

1.5 mg/l are considered normal and can be represented as low fluoride region whereas concentrations greater than 1.5 mg/l can be represented as high fluoride region indicating high incidence to fluorosis and toxic [14]. Excessive fluorides in drinking water damage toot forming cells leading to a defect in the enamel known as dental fluorosis resulting in extensive pitting, chipping, fracturing and decay of teeth [14]. The desirable range of fluoride concentration in drinking water is from 0.6 to 1.2 mg/l according to the Bureau of Indian Standard [13]. Thus, if the concentration of fluoride is below 0.6 and above 1.2 mg/l, the water is not suitable for drinking purposes. However, it is suggested that the maximum permissible limit can be extended upto 1.5 mg/l [13]. Based on the concentration of fluoride, the groundwater samples obtained from the region have been classified into two groups as medium (0.6-1.5 mg/l) and high (1.5-3.0 mg/l). If the samples fall below 0.6 mg/l it is unfit for drinking purpose. Twenty four groundwater samples had more than 1.5 mg/l, except one sample fall below 1.5 mg/l (Table 2). The overall situation of groundwater resources regarding fluoride content is given in Table 2 and shown in Figure 4. In the palacode region fluoride contamination is mainly by a natural process, i.e. leaching of fluorine-minerals, since no man-made pollution has been noticed. Fluorite, fluorapatite, mica, hornblende and various other minerals take part during rock-water interaction and liberate fluoride into the groundwater (Table 3). The semi-arid climate with high temperature and low rainfall and the generally alkaline nature of soil are contributing factors to enhance the fluoride content in groundwater. The area is devoid of hard rock and hence the possibility of a source in the common fluoride bearing minerals. Furthermore, pH is responsible for the dissolution of fluorides from fluoride-bearing rocks during the weathering processes within the aquifers [17]. Persistence of excess fluoride concentrations in the environment poses threat on health. The concentration of fluoride in groundwater is not uniform in the area. This is due to the differences in the presence and accessibility of fluorine-bearing minerals to the circulating water and also due to the weathering and leaching activities.

Health Effects: The main source of fluoride intake is usually the drinking water, which supplies 75-90% of the daily intake [18]. The climate of this region is hot and dry. In summer the temperature raises upto 42^{o}C, so a higher ingestion of water is expected. Therefore the concentration of fluoride in drinking water is an important factor controlling daily intake. If fluoride water is consumed over a period of time, it affects the human health. Excessive intake of fluoride affects the teeth and the bones. In large quantities fluoride can also affect the kidney, thyroid gland and in most extreme cases it leads to death.

The effects of fluoride on human health can be either positive or negative depending on the amount of fluoride that has been ingested. Small amounts of fluoride can have a positive health effect, WHO recommended that drinking water should ideally contain 0.5-1.0 mg/l fluoride, as it helps to prevent dental caries. It is especially effective on children who are still developing their teeth [14]. When teeth are fully developed fluoride still helps to protect the teeth. It also dissolves in the saliva and helps to repair teeth that have been attacked by dental caries. The fluoride can also attach to the surface of the teeth and then be released to help and protect the teeth when needed [14]. The negative effects on excessive ingestion of fluoride over a long period of time will lead to a chronic fluoride poisoning; fluorosis. The first sign of fluorosis is generally mottling of teeth. At first the spots are white but with time and more exposure to fluoride the spots will turn into brownish discolouration. These signs are observed when drinking water contains 1.1-2.0 mg/l fluoride. If the fluoride concentration is above 2.5 mg/l the enamel will cease to be smooth and the brownish mottling will spread to larger area of the teeth [19]. If the drinking water has a fluoride concentration of 3-6 mg/l deformation of bones, skeletal fluorosis, can be observed [14].

It is observed from the Palacode region, the people consumed non-potable fluoride water suffer from yellow, cracked teeth and joint pains. Generally it is observed that drinking water having a fluoride concentration above 1.5 – 2.0 mg/l effects dental mottling, an early sign of dental fluorosis which is characterized by opaque white patches on teeth as shown in Figure 5. In advanced stages of dental fluorosis, teeth display brown to black staining followed by pitting of teeth surfaces [19]. Dental fluorosis produced tooth deterioration. From the survey it was found that males and children (12-16 years age group) have a higher occurrence of dental fluorosis, above this age gradual decrease in the prevalence was observed in palacode region. The harmful effects of fluoride on health are on the increase, not only due to the occurrence of fluoride bearing minerals in the earth crust, but also due to the impact of environment factors and human activities.

The need to avert is to propagate the risk of dental fluorosis with a view to control and eradicate using efficient techniques of defluoridation. Thus, in this area it is an instant need to warn the people against the risk of dental and the people are advised to adopt some techniques to defluoridation of groundwater before using it for drinking purposes.

No one is exempted in palacode from being affected and irrespective of the category children, adult, young men, women and elderly people are also victimized. Even toothpaste and brush could not help them remove this mottling. These results in deteriorated self esteem of the locals with which they do not even open their mouth to talk and even to throw a smile. There is no paste, physician and treatment could help them. The people are stigmatized as ‘yellow teethed’. Above all the problem of getting married is disgusting as young men who come to see women just refuse to marry them as they have mottling.

Recommendations

There are several options available for providing fluoride-free water for Palacode areas are as under.

- Rooftop rainwater harvesting for meeting the drinking and cooking requirements
- Building large number of groundwater recharge structures for diluting the Fluoride levels in aquifers at appropriate locations.
- A government based common Activated Alumina treatment plant will have to be installed to supply fluoride free water for public or a Community-managed defluoridation units with adequate technical support for management could help to control fluorosis with effective monitoring.

- Conducting awareness programmes and educating people on Fluorosis and promotion of calcium and phosphorus rich diet are recommended which are directly associated with a reduced risk of dental fluorosis. Vitamin C ingestion also safeguard against the risk of fluorosis.
- A multi-pronged including participatory approach is required for mitigating the fluoride related health issues in many parts of Palacode region.
- Free medical camps can be arranged to provide right treatment to the victims.

Conclusion

The water samples in the Palacode area evidenced excess fluoride concentrations and were not meeting the BIS/ WHO standards. The samples abstracted from groundwater that is used for drinking purposes showed high fluoride concentration resulted in dental fluorosis among the local residents. The excess fluoride concentration in Palacode area may be attributed to the geological formation and recent exploitation of groundwater. In fact, if the fluoride level in drinking water is more than 1.5 mg/l, risk of endemic fluorosis will exist. The high fluoride content is therefore causing serious environmental degradation. Total hardness and nitrate concentration are found in more than permissible limit at various locations. Nitrate is most likely due to the use of fertilizers and pesticides for agriculture. The water in the Palacode area is suitable for domestic consumption in respect of all constituents except fluoride, hardness and nitrate. The social impact of dental fluorosis amounts from personality disorder as mottling deprives one of their self confidence and ushers self contempt.

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Table 1: Chemical Properties of Groundwater of Palacode Area

S. No.	Name of Village	Type of Wells	pH	EC (µS/cm)	TH (mg/l)	NO_3^- (mg/l	F^- (mg/l)
1	Bellarahally	OW	7.1	2000	800	70	1.8
2	Sembuganattam	BW	7.3	1580	484	13	2.0
3	Mekalampatti	BW	7.6	4400	1500	78	2.1
4	Erranahally	OW	7.8	2300	750	57	1.8
5	Reddiyur	BW	8	3200	720	26	2.1
6	Dalavayhalli	BW	7.9	1600	508	55	2.0
7	Kuppankottai	OW	7.7	3200	1300	16	2.3
8	Palakkodu	OW	7.23	2400	740	54	1.8
9	Chittirapatti	BW	7.84	2709	920	54	2.0
10	Chikkardanahalli	BW	7.07	2037	750	69	2.3
11	Makkankottai	BW	7.5	1894	640	69	2.1
12	Timmampatti	OW	7.45	1700	410	22	1.4
13	Dandakalankottai	BW	7.01	1270	324	23	2.3
14	Maniyarankottai	BW	6.95	1680	860	50	1.8
15	Valattottakottai	BW	8.1	1520	660	95	1.5
16	Sengonthahalli	BW	7.38	1901	418	24	2.0
17	Tittarahalli	OW	7.2	1531	580	31	2.4
18	Peddarahalli	OW	7	1670	500	98	2.0
19	Kommanayakanpatti	BW	7.08	1940	430	35	2.0
20	Parur	OW	7.3	1170	384	61	1.6
21	Madanapatti	BW	8.2	1750	720	12	1.9
22	Kodiyur	BW	7.89	893	288	13	1.7
23	Endapatti	BW	8.23	813	316	18	1.8
24	Gowndanur	BW	7.69	1972	780	48	1.9
25	Bettarahalli	OW	7.45	1583	670	60	1.8

*OW- Open Well, BW- Bore Well

Table 2: Classifying of Groundwater Based On Fluoride Hazard

F^- (mg/l)	Effects of fluoride on Human Health	No. of samples
0.1-0.6	Low limit (dental caries)	Nil
0.6-1.5	Safe limit (bone development and prevent dental caries)	1
1.5-3.0	Dental fluorosis (discoloration mottling and piting teeth)	24
3.0-4.0	Stiffened and brittle bones and joints	Nil
>4.0	Crippling fluorosis (deformities in knee and hip bones and finally leads to paralysis)	Nil
>10	Crippling skeletal Fluorosis, Cancer	Nil

Table 3: Minerals Containing Fluoride

Mineral	Chemical composition	Rocks in which these minerals are available
Fluorite	CaF_2	Pegmatic, penumatolitic, deposit as vein deposit
Fluorapatite	$Ca_5(FCl)PO_4$	Pegmatite and metamorphosed limestone
Micas		
1.Biotite	$K(MgFe^{2+})(AlSiO_{10})(OHF_2)$	Basalt
2.Muscovite	$KAl_2(AlSiO_{10})(OHF_2)$	Pregmatities, amphibolities
3.Lepidolite	$K_2(Li, Al)_5(Si_6Al_2O_3)(OHF)_4$	Gabbro, dolerities
Amphiboles	$Ca_2(MgFe^{2+})(AlFe^{3+})(SiAl)_8$	Genesis Schists, Shales clay
Hornblende	$O_{22}(OHF_2)$	Alkaline rocks, etc
Tremolite	$Ca_2(MgFe^{2+})_5(Si_8O_{22})(OHF)_2$	Clay
Topaz	$Al_2SiO_4(OHF)_2$	Acid igneous rocks, Schists
Rock phosphate	$NaCa_2(MgFe^{2+})(AlFe^{3+})(SiAl)_8O_{22}(OHF)_2$	Limestone, Fossils

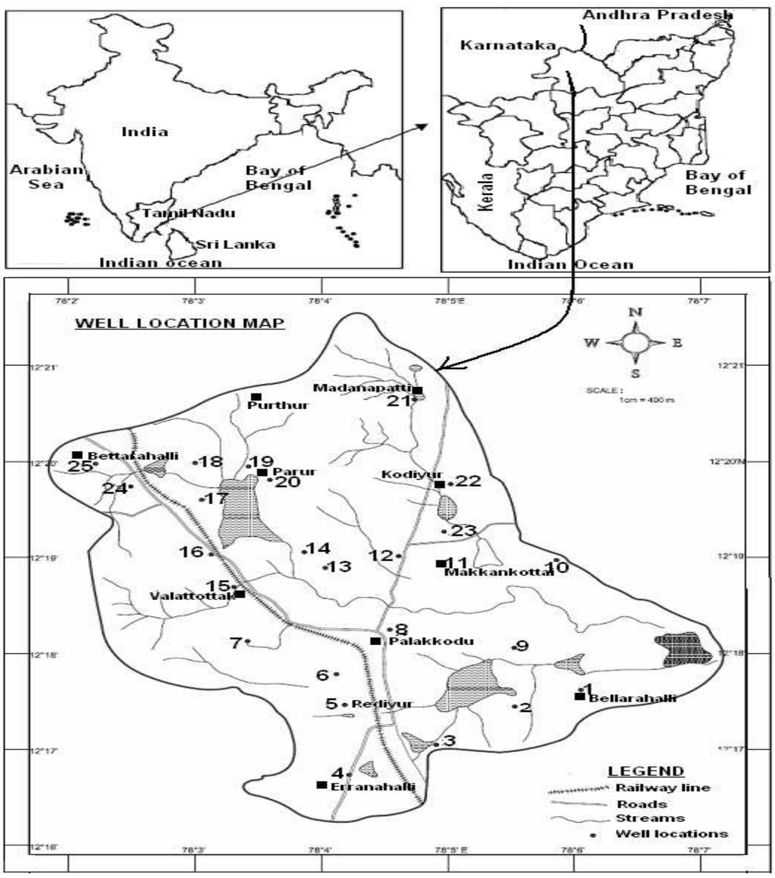

Figure 1: Location Map of the Study

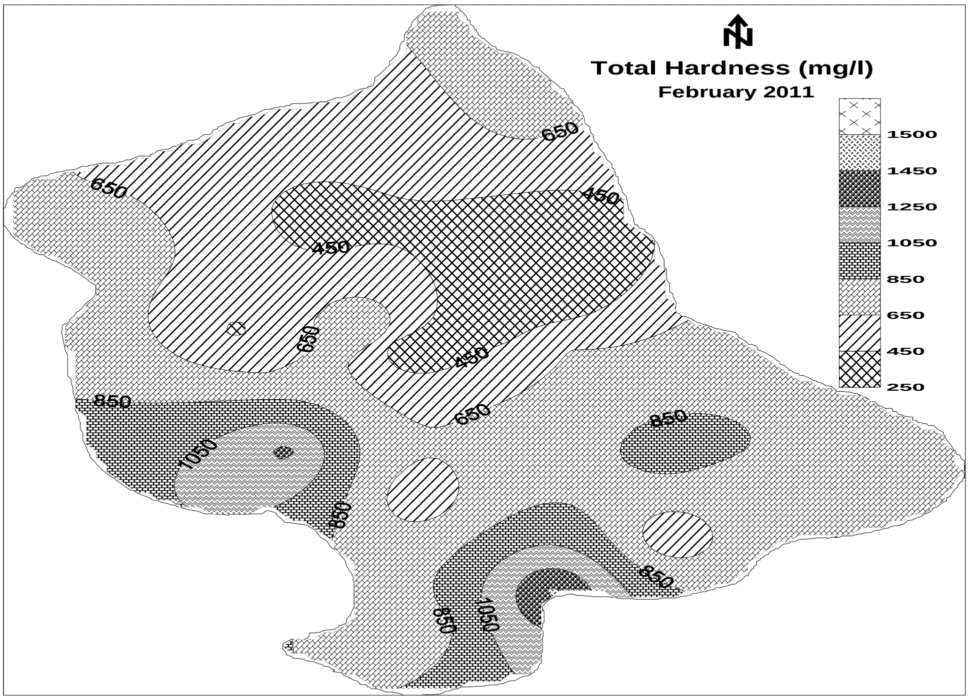

Figure 2: Spatial variation of Total Hardness

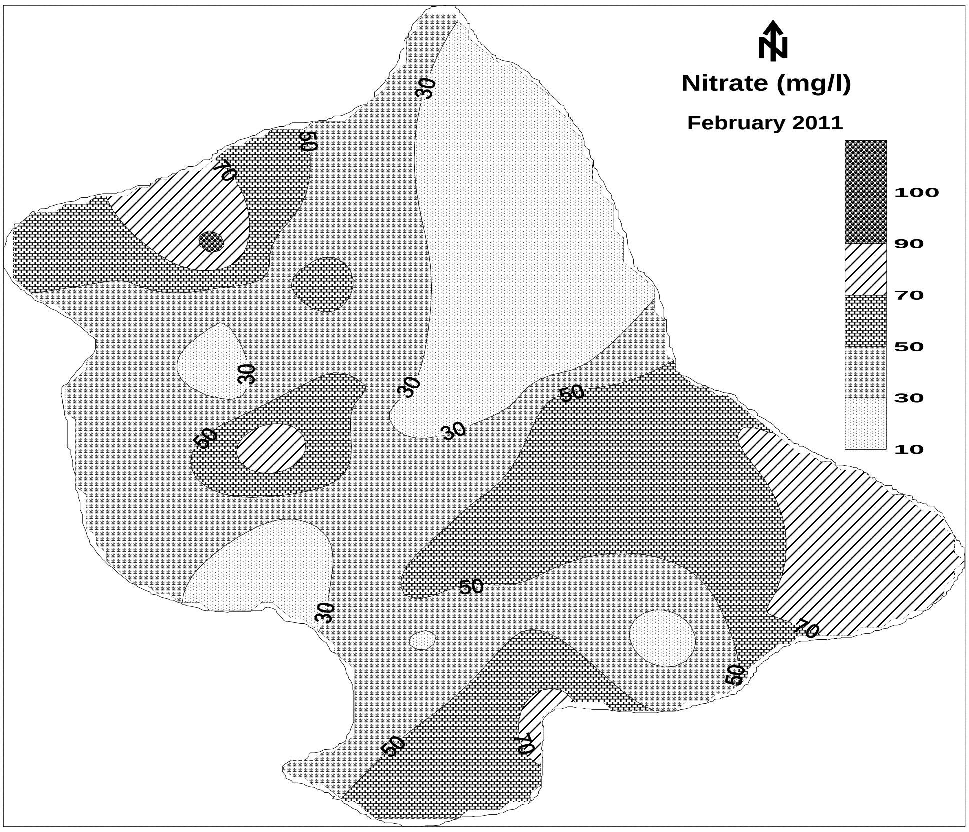

Figure 3: Spatial variation of Nitrate

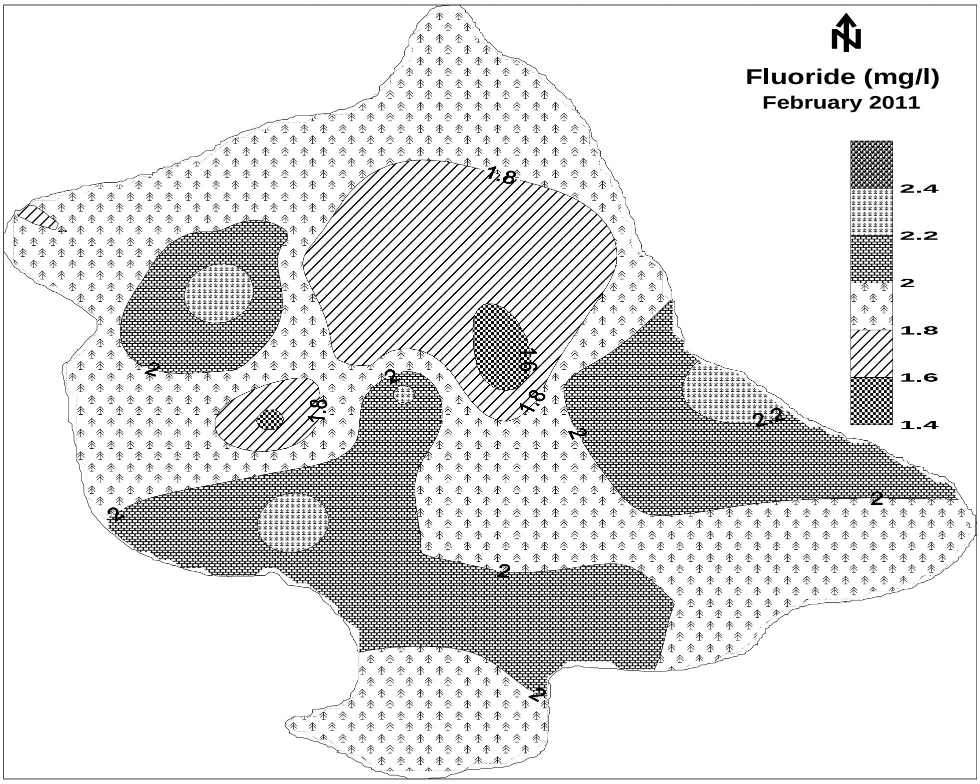

Figure 4: Spatial variation of Fluoride

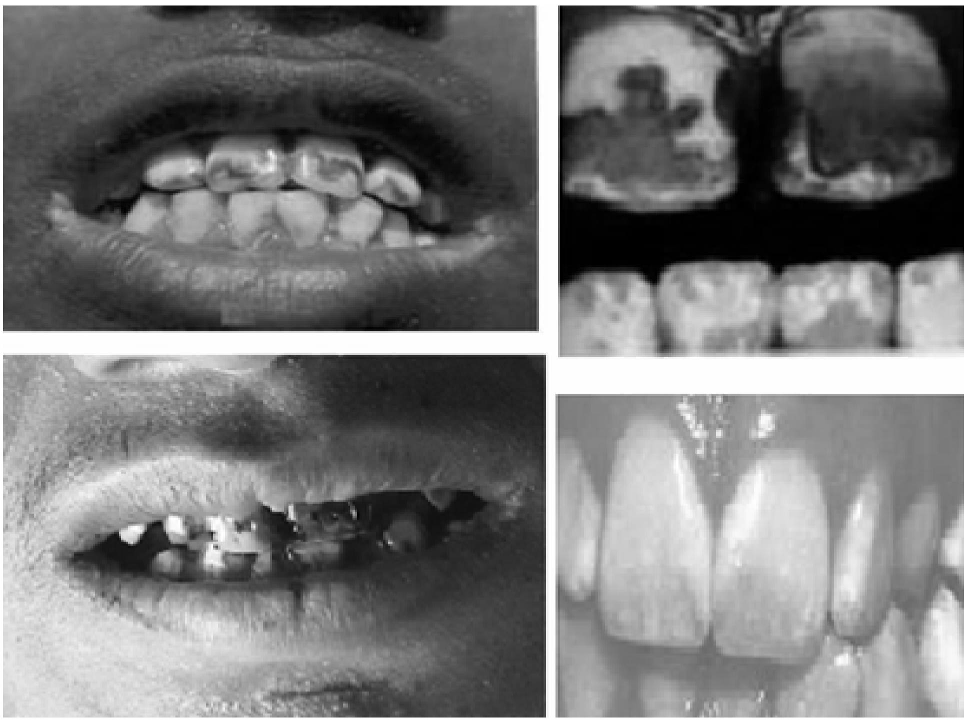

Figure 5: Specific View of dental fluorosis