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Research Article

Hematological and Biochemical and Reflections in Some Selected Districts of Tamil Nadu that are Endemic for Fluorosis

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Abstract

Endemic fluorosis has been a continuing public health concern in many countries worldwide. In spite of the ill effects of fluorosis especially among the growing children it has not been given much emphasis in reality and policy level efforts stop by merely providing alternative drinking water and that too not continued for long and without any concern on the quality of the water. In order to understand the current prevalence of endemic fluorosis in select districts of Tamil Nadu and to create awareness among the policy makers and also the victims a surveillance study was envisaged and executed. Based on the spot screening a heterogeneous group of children and adults from three districts of the Tamil Nadu state, vis-à-vis Dharmapuri, Karur and Dindigul, aged between 12 and 40 years were sampled for spot urine and blood samples. A total of 108 individuals were involved in the screening and study. The study shows that the presence of fluoride in the urine is higher among adults than the children, especially at higher concentrations of above 2 ppm. The range of plasma fluoride is less than 0.1 ppm to above 0.6 ppm. Adults have more plasma fluoride at the lowest concentration of less than 0.1 ppm, implying that remaining is being excreted. There is no correlation between the haemoglobin levels and the plasma and urinary fluoride levels. The levels of calcium among the tested subjects of both children and adult remain normal, implying that there is no calcium deficiency that could facilitate more fluoride binding in the mineralized tissues such as bones and teeth. With regard to the Alkaline phosphatase analysis the data explicitly show that there is higher levels of ALP among children. Correlation could not be made between the Thyroid Stimulating Hormone, TSH levels and the incidence of fluorosis. It is concluded that hydrofluorosis as a public health concern is still persistent in these areas and therefore there is an urgent need to provide safe drinking water in those affected areas of endemic fluorosis.

Keywords: Endemic Fluorosis; Health Concern; Alkaline Phosphatase; Calcium

Abbreviations

ALP: Alkaline Phosphatase; TSH: Thyroid Stimulating Hormone; ICMR: Indian Council of Medical Research; IEC: Institutional Ethics Committee

Introduction

Worldwide there are millions of people being affected by the insidiously serious health problem called fluorosis and it is caused mostly due to the high concentration of fluoride in drinking water of natural and related sources (food, beverages and industrial pollution are other secondary sources). Having been ingested unwittingly fluoride gets accumulated in the mineralized tissues of the body, and the condition is called hydro fluorosis. There are endemic areas of fluorosis where the natural source of drinking water, eventually the local plants and other agriculture produces, is contaminated with fluoride in the soil in excess [1]. India is among the 23 nations around the globe, where health problems are caused due to the consumption of fluoride contaminated water at higher concentrations. An estimated 62 million people in India in 17 out of the 32 states are affected with dental, skeletal and/or non-skeletal fluorosis [2].

Figure 1: A map depicting TamilNadu.

Tamil Nadu is one of the 19 states (Figure 1) with high fluoride contamination in drinking water, and about 121 blocks in 19 districts have high fluoride concentration in its groundwater predominantly in Dindigul, Dharmapuri, Krishnagiri, Karur, with new regions such as Kancheepuram, Rameshwaram, Kanyakumari [3]. Chronic fluoride exposure through the ingestion of drinking water with a high fluoride level will result in its untoward accumulation, predominantly in hard tissues such as teeth and bones, and cause diverse adverse changes, appearing in the form of dental mottling (dental fluorosis) and bone deformities (skeletal fluorosis; *genu valgum*) in both humans and animals [4]. Besides, there are also reports, in humans as well as in domestic and laboratory animals, of non-skeletal fluorosis or toxic effects of chronic exposure to fluoride in soft tissues or organs including gastrointestinal discomforts, neurological disorders, impaired endocrine and reproductive functions, teratogenic effects, renal effects, genotoxic effects, apoptotic and excito-toxic effects [5].

It is well known that skeletal fluorosis is more dangerous than dental fluorosis, and highly significant as it diminishes the mobility of fluorotic humans and animals at a very early age by producing varying changes in the bones such as periosteal exostosis, osteosclerosis, osteoporosis, and osteophytosis [6]. These changes appear clinically in the form of vague aches and pains in the body and joints, causing associated rigidity, lameness, stunted growth, and palpable bony lesions in the body [2,7]. The excess accumulation of fluoride in muscles also restricts movements and the condition leads to crippling and lameness in humans and domestic animals. Neurological complications such as paraplegia and quadriplegia, and the syndromes of genu-valgum or genu-varum can result from severe skeletal fluorosis in human beings.

Materials and Methods

The study was intended to conduct a surveillance in the state of Tamilnadu confirming endemic fluorosis areas in the state through spot screening and sampling, especially the school children and also the general public wherever possible. This is an ongoing programme and about 14 districts have so far been covered. Based on the review of literature the villages of each districts and blocks have been identified and also through local NGOs further screening has been carried out. To begin with the research team reaches the local schools for dental screening followed by documentation. Based on the data gathered the team goes to the villages of endemic fluorosis for spot screening and water sampling. Besides there are awareness programmes conducted in each school and villages through a series of posters and video shows.

During the course of the surveillance study, the team samples blood and urine samples from the general public and also from local children with appropriate consent forms by parents or guardians for which approval was obtained through Institutional Ethics Committee (based on the guidelines of ICMR, Ministry of Health and Family Welfare, Government of India under the National Ethics Committee Registry for Biomedical and Health Research) and additional data sheets such as Fluorosis Brochure as an introductory note, Individual Data Sheet and Parameters Data Sheet. The team has covered the districts of Tamilnadu that include Kancheepuram, Vilupuram, Thiruvannamalai, Salem, Dharmapuri, Krishnagiri, Karur, Namakkal, Trichirapalli, Pudukottai, Dindigul, Madurai and

Chennai. The Institutional Ethics Committee (IEC) approval reference number is CMMHEC/20/17.

About 40% of bone mass builds up during the critical growth phase of adolescence [8] and hence the particular population was targeted in the study along with a small population of adults as well for comparison. Based on the spot screening a heterogeneous group of children and adults from three districts of the Tamilnadu state, vis-à-vis Dharmapuri, Karur and Dindigul, aged between 12 and 40 years were sampled for spot urine and blood samples. A total of 108 individuals were involved in the screening and study. The primary objective of the study is to correlate the dental fluorosis [9] with other biochemical results as well as the fluoride content in the local drinking water (APHA) [10] and also in urine and blood samples following standard methods of analysis. A part of the sample was also tested for residues of agrochemicals, if any, to correlate with the fluoride levels in the urine and blood and the extent of hydrofluorosis assessed through scoring of lesions as dental fluorosis. The biochemical parameters of analysis include haemoglobin (g/dL), calcium (mg/dL), hydroxy vitamin D (ng/mL), TSH (Thyroid stimulating hormone, IU/mL) and alkaline phosphatase (U/L). These parameters are chosen based on the review of literature on endemic fluorosis and recommendations on its prevention.

Results and Discussion

Figure 2: Urinary fluoride levels.

Figure 2 shows the presence of fluoride in the urine is higher among adults than the children, especially at higher concentrations of above 2 ppm. Up to 2 ppm the urinary fluoride between the children and adults remain equal. This is because of the difference in metabolic and physiological functions of the adults and the children and children above 16 years of age are considered adult here. Moreover lower excretion amounts to higher accumulation in the mineralized tissues of the body. At higher concentrations of more than > 2 ppm the excretion concentration of fluoride among children is higher than the adults. Body accumulation of fluoride among the adult's remains saturated due to fluoride binding whereas among children at higher concentrations the fluoride excretion rate is lower implying that there is more binding among the growing children. Total number of samples include 60 adults and 42 children, 102 in total.

Figure 3: Total plasma fluoride levels (ppm).

Presence of fluoride in the plasma of fluorosis affected subjects are presented in figure 3. The range of plasma fluoride is less than 0.1 ppm to above 0.6 ppm. Adults have more plasma fluoride at the lowest concentration of less than 0.1 ppm, implying that remaining is being excreted. The difference in the plasma fluoride range from 0.1 to 0.6 ppm remains higher among the adults than the children. The incidence of higher plasma fluoride levels of > 0.6 ppm among children implies that there is fairly considerable levels of fluoride being absorbed in the body at higher exposure levels and it is confirmed from moderate levels of fluoride excretion through urine at higher concentrations, implying that there is a correlation between plasma fluoride levels and the presence of fluoride in urine at higher concentrations. The total number of samples include 53 adults and 35 children, 88 in total. There was a positive correlation between serum and plasma fluoride levels and a moderate correlation found between urinary fluoride and plasma and serum fluoride levels [11].

Levels of haemoglobin

Figure 4: Levels of haemoglobin (g/dL).

Figure 4 shows the level of haemoglobin among the fluorosis affected subjects and among them are 6 adults and 3 children who show below 12 g/dl of haemoglobin. Anaemic conditions are prevalent in rural areas among adults and children and the data here show that about 9.1% of the adults and 14% children show below normal haemoglobin levels. But the lowest level is 7.4 g/dl found in a male aged fifteen. Other below normal levels remain above 10.4 g/dl which is acceptable. There is no correlation between the haemoglobin levels and the plasma and urinary fluoride levels. Total number of samples include 55 adults and 42 children, 97 in total.

In the areas of endemic fluorosis where there found to be significantly higher urinary fluoride levels it was found that no significance could be made in terms of haematological parameters (complete blood count and ferritin) between the control and affected group of people [12]. Similar observations were recorded by another study as Well C [13,14] and also in the present study.

Calcium levels

Figure 5: Calcium levels (mg/dL).

Fluoride is proved to replace calcium in the mineralized tissues of the body and it binds in the hydroxyapatite portion of the bone thereby causing skeletal and dental fluorosis as represented in figure 5. Total number of samples include 55 adults and 41 children, 96 in total. The levels of calcium among the tested subjects of both children and adult remain normal, implying that there is no calcium deficiency that could facilitate more fluoride binding in the mineralized tissues such as bones and teeth. Though this is favourable for the fluorosis affected subjects there is already expression of serious dental fluorosis in the endemic areas implying that fluoride could still get accumulated in the body despite the normal levels of calcium in the body.

In a study correlating socio-economic strata with the prevalence of fluorosis it was observed that the lower stratum was significantly affected. At the same time, the study did not find any significant correlation between serum vitamin D levels and intake of dietary calcium against the effect of fluorosis. Similarly, there was no incident of skeletal abnormalities due to fluorosis in the same study and it was reasoned that it could be due to efficient dietary calcium absorption among the study population, thereby preventing the severity of fluorosis [15]. The same was observed in the present study where no visible skeletal abnormalities could be found among the study population despite having dental fluorosis.

Figure 6: Level of hydroxy vitamin D (ng/ml).

The hydroxy vitamin D data generated from the fluorosis affected subjects are presented in figure 6. There is a deficiency of hydroxy vitamin D among the adults having about 69% and 17% among children. Deficiency of vitamin D is prevalent in rural areas among adults and children and the data here confirms the condition [16]. Correlation could not be made between the incidence of fluorosis and vitamin D deficiency in the study. Total number of samples include 55 adults and 41 children, 96 in total.

Alkaline phosphatase levels

Figure 7: ALP levels (u/L).

The levels of Alkaline phosphatase among the fluorosis affected subjects are given in figure 7. Alkaline phosphatase found in the liver facilitates bone formation especially among the growth phase of children to adulthood. Lower levels of ALP is normal among the adults in the present study. And it is also proved that ALP levels will increase if there is skeletal fluorosis happening in the subjects. Here the data explicitly show that there is higher levels of ALP among children. Total number of samples include 55 adults and 41 children, 96 in total.

There found to be a statistically significant relationship between fluoride in drinking water and hepatic enzymes such as the activities of cyclic adenosine monophosphate (AMP), alkaline phosphatase (ALKP), acid phosphatase (ACP), aspartate aminotransaminase (AST), and alanine aminotransaminase (ALT) in individuals living in normal and endemic fluorosis areas of Punjab, India [17]. This is suggestive of the impact of serum fluoride on the liver function in human beings and the elevated levels of hepatic enzymes proves the relationship between higher levels of fluoride and osteofluorosis.

However, the same could not be found in a study where school children with dental fluorosis due to higher levels of fluoride in drinking water on the liver and kidney functions in children with and without dental fluorosis. The levels of total protein (TP), albumin (ALB), aspartate transaminase (AST), and alanine transaminase (ALT) in serum among these groups were not significantly different. However, the levels of serum lactic dehydrogenase (LDH), urine N-acetyl-beta-glucosaminidase (NAG), and urine gamma-glutamyl transpeptidase (gamma-GT) were found to be significantly different. Interestingly it was concluded that the prevalence of dental fluorosis in endemic areas was found to be independent of the damage caused to the liver but not the kidneys [18]. In the present study, the impact of increased levels of alkaline phosphatase among the growing children is well supported by the results of dental fluorosis among them.

Figure 8: Thyroid levels (IU/mL).

The TSH data generated from the fluorosis affected subjects are presented in figure 8. There is severe incidence among the adults amounting to about 21% and 8.2% among children with an incidence of hypothyroidism. Correlation could not be made between the TSH levels and the incidence of fluorosis. Total number of samples include 57 adults and 41 children, 98 in total.

Figure 9: Correlation of plasma and urinary fluoride levels with dental fluorosis.

A correlation is attempted in figure 9 among the levels of plasma and urinary fluoride with dental fluorosis score. Figures are arrived comparing the below normal, normal, moderate and severe levels of plasma and urinary fluoride levels with normal, moderate and severe dental scoring both in adults and children separately.

Figure 10: Correlation of the levels of calcium, hydroxy vitamin d with dental fluorosis.

Figure 10 shows a correlation with the levels of calcium, hydroxy vitamin D and dental fluorosis score and compares the below normal, normal, moderate and severe levels of hydroxy vitamin D and calcium with normal, moderate and severe dental scoring both in adults and children separately.

The results of the random sampling of drinking water from the study areas visited are presented in table 1. In one of the studies in Tamil Nadu in South India correlation could not be made between fluoride levels of food grains grown in the research area and total fluoride [19] as it was corroborated that the residents would not consume locally grown grains. However, 30% of children and 40% of adults were found to be affected with dental fluorosis due to higher levels of fluoride in drinking water in Punjab [20]. Also, it was found that exposure to higher intake of fluoride in summer because of the higher concentration of the fluoride and higher volume of water consumption [21].

With regard to the school children, there found to be a significant inverse association between the drinking water fluoride levels

Sample No.	District	Type	Village	pH	TDS	Fluoride ppm
1	Dharmapuri	Borewell	Govt. Middle School, Kothalam	7.02	836	5.47
2	Dharmapuri	Borewell	Kothalam tank water	6.76	472	5.71
3	Dharmapuri	Borewell	Govt School, Koviloor	6.85	779	2.69
4	Dharmapuri	Bore well	Paluthupallam	7.05	472	4.62
5	Dharmapuri	Bore well	Paluthupallam	6.71	507	3.66
6	Dharmapuri	Bore well	Vellavalli	7.18	765	3.08
7	Dharmapuri	Hokenakal dam water	Vellavalli	7.31	263	6.25
8	Namakkal	Bore well	SelurSellampalayam	7.81	828	0.59
9	Namakkal	Panchayat	SelurSellampalayam	8.5	267	0.35
10	Namakkal	Panchayat	Kuttalampatti	8.03	823	2.48
11	Namakkal	Bore well	Thachchankadu	8.53	946	3.1
12	Namakkal	Well water	Thachchankadu	8.04	869	9.55
13	Karur	Bore well	Thottiyamanthai	8.06	127	4.66
14	Karur	Bore well	Uppidamangalam	8.32	406	0.53
15	Karur	Bore well	Uppidamangalam	7.52	151	1.26
16	Trichi	Bore well	Pettavaithalai	7.82	924	0.7
17	Dindigul	Bore well	Kambiliyampatti	8.34	671	2.5
18	Karur	Bore well	Tharagampatti	8.13	196	0.55
19	Dindigul	School bore well	Mangamanoothu	8.29	601	1.81

20	Dindigul	School bore well	Kambiliyampatti	8.27	719	2.34
21	Madurai	Bore well	Theetampatti	8.49	291	0.41
22	Madurai	Vaigai dam water	T. Ramanathapuram	8.45	85	0.42
23	Madurai	Bore well	T. Ramanathapuram	7.68	745	1.68
24	Madurai	School bore well	Pattiyampatti	7.8	976	4
25	Madurai	Bore well	T. Ramanathapuram	8.15	86	2.29
26	Madurai	Bore well	Thadayampatti	7.82	130	1.2
27	Madurai	Bore well	Thadayampatti	7.6	157	0.27
28	Madurai	Vaigai dam water	Thadayampatti	8.3	87	0.25
29	Madurai	Bore well	Solavanthaan	-	0	0.61

Table 1: Water sample analysis.

and IQ in children aged 6-14 years and 7-13 years [22]. Interestingly, a research finding indicates that it could be the exposure of their mothers during pregnancy that could the major cause of the F-induced neurotoxicity rather than the levels of fluoride that the children were exposed to at ages 6-14 years [23]. Though is not in the scope of the current study the subject could be considered in the future study.

In spite of various health complications having been revealed through extensive research efforts for the past four decades, such as haematological, biochemical as well as metabolic, neurological [24] and pathological changes including carcinogenic potential of it, in human beings and animals, many countries are still not considering it as a health problem. In Tamil Nadu, in 2007, a three pronged strategy to control fluorosis at the community level, focussing on the hazardous effect of fluoride prevalent in Dharmapuri and Salem districts, jointly by the officials of Hogenakkal Water Supply and Sanitation Project and Japan Bank of International Cooperation (JBIC) allocating about hundred crores towards implementation of a) health component, b) school education component and c) community component to tackle the problem of fluorosis [25].

Prevention is the bedrock of fluorosis management as suggested by many eminent scientists in India, who have been in the field for more than three decades. Experts emphasise the need for Governments to invest in diagnostic facility for fluorosis in all hospitals. The diagnostic procedure involve testing blood, urine and drinking water for fluoride, along with haemoglobin testing and a forearm x-ray. Children require additional tests in the form of thyroid hormone/thyroid stimulating hormone assay and urinary iodine levels. It involves identifying the source of fluoride entry, cutting out the source and promoting intake of vegetables, fruits and dairy products rich in essential nutrients (calcium, iron, vitamins and other antioxidants). In the Fluorosis Management Programme, the major thrust is on (i) awareness generation, (ii) opting technology for fluoride removal/strategy for providing safe water on a sustainable basis, and (iii) emphasis on importance of consuming calcium, vitamin C, E and antioxidant-rich diet for minimizing the adverse effects of fluoride [26].

Conclusion

As a conclusion, it could be stated that the level of nourishment and health of the individuals, the school students in particular, in the rural areas of the districts studied seemed to be marginally appreciable. That could be the reason for the individuals, be it youngsters or adults, not to have serious health complications due to fluoride induced biochemical and haematological alterations. However, hydrofluorosis as a public health concern is still persistent in these areas and therefore there is an urgent need to provide safe drinking water in those affected areas of endemic fluorosis as it is going to affect not only the wellbeing of the children but also their academic performances that could affect their future.

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Conflict of Interest

There are no conflicts of interest.

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Volume 5 Issue 7 July 2021