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Research Article

ENVIRONMENTAL IMPACT OF FLUORIDE WITH SPECIAL EMPHASIS ON DENTAL FLUOROSIS IN SOME OF THE VILLAGES OF AGASTEESWARAM TALUK, KANYAKUMARI DISTRICT, TAMIL NADU, INDIA

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ABSTRACT
An effect has been made in order to study the prevalence and severity of dental fluorosis in the population residing areas of 18 villages of Agasteeswaram Taluk, Kanyakumari District, Tamil Nadu, India with normal to high level of fluoride in the drinking water. Clinical assessment of dental fluorosis was done using Dean's Index. Clinical survey was conducted among 5608 subjects (Males = 2993, Females = 2615) in the age groups of 5-60 years. Dental fluorosis (DF%, very mild to severe), defect dental fluorosis (DDF%, moderate to severe), and community fluorosis index (CFI) were calculated with regard to age, gender, and location. The overall dental fluorosis in the study area was 48%. Community fluorosis index was found in the range of 0.5-1.6 which denotes borderline to medium category of public health significance. Correlation and regression between fluoride in drinking water and prevalence of DF%, DDF% and CFI revealed significant positive linear relationship.

Keywords*: Fluoride; Dental Fluorosis; Correlation*

INTRODUCTION
The effects of fluoride on human health can be either positive or negative depending on the amount of fluoride that has been ingested. The main source for fluoride intake is usually the drinking water, which supplies 75-90 % of the daily intake (Meenakshi *et al.,* 2004). Fluoride is regarded as an important trace element, which has a high impact on growth of bone and teeth because it serves as a core of mineralization (Karlson, 1984). Small amounts of fluoride can have a positive effect on our well-being. WHO recommends 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. When the teeth are fully developed fluoride will still help to protect the teeth (WHO, 1984).
The severity of the negative effects is, of course, dependent on the intake of fluoride. An excessive ingestion of fluoride over a long period of time will lead to a chronic fluoride poisoning, 'fluorosis'. This is because fluorine is very electronegative and thus, easily binds to the positively charged calcium ions in teeth and bone. In large quantities fluoride can also affect the kidneys and the thyroid gland and in the most extreme cases it can lead to death (The Canadian Consensus Conference Results, 1997).
Dental fluorosis is a developmental disturbance of dental enamel, caused by successive exposures to high concentrations of fluoride during tooth development, leading to enamel with lower mineral content and increased porosity (Dean, 1942). 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 a brownish decolouration. These signs often appear 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 areas of the teeth (Morbidity and Mortality Weekly Report, 1999; Spak *et al.,* 1989).
A number of studies have demonstrated the association between dental fluorosis and drinking water collected from ground water with high fluoride contents (Choubisa *et al.,* 2001; Bawaskar and Bawaskar, 2006; Ermiş *et al.,* 2003; Vuhahula *et al.,* 2009). In order to access prevalence of dental fluorosis in 18 villages of Agasteeswaram Taluk, Kanyakumari District, Tamil Nadu, India, we previously studied the

fluoride content in water (Kumaresan *et al.*, 2013), soil (Anbuvel *et al.*, 2014) and vegetation (Anbuvel *et al.*, 2015) in the same study area.

MATERIALS AND METHODS

Study Area

Study area consists of 18 villages [Puthugramam, Ramapuram, Sankaranputhoor, Andarkulam, Kottaivillai, Azaganapuram, Padmanabhaputhoor, Marungoor, Eraviputhoor, Nalloor, Athalavilai, Thoopor-Srikrishnapuram, Rajavoor, Ramanathichenputhoor, Amaravathivillai, Azagappapuram, Indira Nagar, and Anjugramam] near the bank of Thovalai and N.P Channel in Agasteeswaram Taluk, Kanyakumari District (K.K Dist), Tamilnadu, India. The district lies between 77°15′ and 77°36′ of the eastern longitudes and 8°03′ and 8°35′ of the northern latitudes. It is bordered by Tirunelveli district of Tamil Nadu in the north and northeast, and Kerala State in the northwest, and sea in the west and the south (Figure 1).

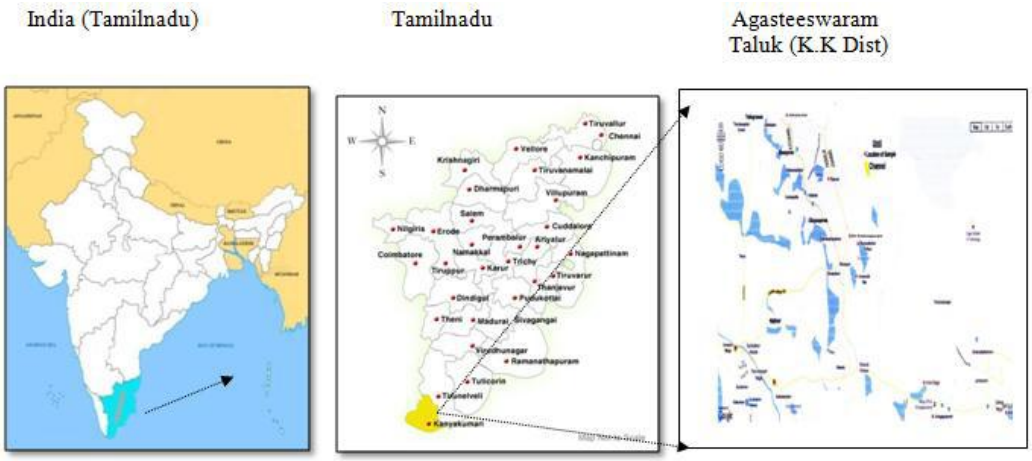


Figure 1: Maps Representing the Location Sites

Training and Calibration

A training programme was completed through fluorosis index website. After which, the kappa value was > 0.75. The diagnostic differentiation between light degrees of dental fluorosis and non-fluoridated opacities were carried out using standard method (Russel, 1961).

Clinical Survey and Sampling

The random multistage and clustering sampling methods were used (Dean, 1942). The rate of prevalence of fluorosis in the selected study area was determined through clinical survey and expressed as percentage of fluorosis incidence. The data collection was made by house-to-house visits during the study period (2013-14) with the help of a questioner. Clinical survey was conducted among 5608 subjects (Males = 2993, Females = 2615) in the age groups 5-60 years exposed to fluoride. Clinical assessment of dental fluorosis was done by using Dean's Index ranging from normal to severe grades (WHO, 1997). This study was done using the World Health Organization (WHO) pathfinder methodology for oral health survey (EPA, 1988).

RESULT AND DISCUSSION

Dental Fluorosis (Grade Wise)

Dental fluorosis is divided into different types of grades such as, normal, questionable, very mild, mild, moderate, and severe. The gender wise incidence of questionable [Male, 21% (Indira Nagar) to 70% (Puthugramam) and Female, 17% (Padmanabhaputhoor, Indira Nagar, Anjugramam) to 71% (Puthugramam)], very mild [Male, 10% (Padmanabhaputhoor) to 36% (Azhagappapuram) and Female, 8% (Kottavillai) to 26% (Ramapuram)], mild (Male, 7% (Andarkulam) to 35% (Azhagappapuram) and

Female, 5% (Anjugramam) to 27% (Nalloor)] fluorosis are shown in Table 1. Both male and female showed in the range of 0-17% moderate and 0-7% severe fluorosis. However, moderate (Anjugramam) and severe (Kottavillai, Marungoor, Eraviputhoor, Ramanathichenputhoor, Amaravathivillai, Indira Nagar, and Anjugramam) fluorosis was not found in male and female samples from some villages. Moderate (17%) and severe (7%) fluorosis were found maximum in male and female samples of Puthugramam.

The incidence of questionable [14.82% (Padmanabhaputhoor) to 31.98% (Kottavillai)], very mild [6.55% (Padmanabhaputhoor) to 22.13% (Azhagappapuram)], and mild [5.98% (Marungoor) to 20.22% (Azhagappapuram)] type of dental fluorosis varied in different villages (Table 2). Puthugramam has maximum moderate (8.4%) and severe (3.9%) fluorosis. Moderate (Anjugramam) and severe (Azhaganapuram, Eraviputhoor, Athalavilai, Amaravathivillai Ramanathichenputhoor, Indira Nagar, Anjugramam) fluorosis was not found in other villages under study.

Dental Fluorosis (Overall Grade)

Overall dental fluorosis is computed by summing up the scores of questionable, very mild, mild, moderate, and severe samples. Gender wise dental fluorosis was found (Table 1) to be more prevalent in male subjects [35.4% (Andarkulam) to 70.6% (Azhagappapuram); overall, 49.9%] in comparison to females [23.3% (Padmanabhaputhoor) to 64.1% (Azhagappapuram); overall 46.5%]. This may be due to joining of females from other villages after their marriage. Similar finding was already reported by Chakma *et al.,* (2000).

The maximum and minimum fluorosis was observed in Azhagappapuram (68.1%) and Padmanabhaputhoor (29.3%) (Table 2). The overall dental fluorosis is found to be 48.3% among 18 villages of Agasteeswaram. Choubisa reported the prevalence of dental fluorosis as 45% among 21 different villages in southern Rajasthan. Another study Bawaskar and Bawaskar, (2006) conducted in village of Maharashtra also found the prevalence of dental fluorosis as 43%. In Turkey, the dental fluorosis prevalence was reported as 29% in normal fluoride area and 77% in high fluoride area among 12-14 year old school children (Ermiş *et al.,* 2003). In Tanzania, Vuhahula *et al.,* (2009) observed the prevalence of dental fluorosis as 96.3%.

Prevalence of Dental Fluorosis (DF%)

The prevalence of dental fluorosis was made according to the rates of dental fluorosis (DF %) by Dean's classification. Prevalence of dental fluorosis (DF %) included the sum of the number of subjects having “very mild” (grade 2) to “severe” (grade 5) dental fluorosis diagnosed by Dean's criteria.

$$\text{Prevalence of dental fluorosis (DF \%)} = \frac{\text{No of cases with very mild to severe dental fluorosis}}{\text{No of cases investigated}} \times 100$$

The result of percentage prevalence of dental fluorosis (DF%) in male [16.6% (Andarkulam) to 52.5% (Azhaganapuram); overall 27.6%] and female [11.6% (Padmanabhaputhoor) to 45.6% (Azhaganapuram); overall 24.5%] was found to be the maximum in male samples (Table 1).

Table 2 revealed that the minimum value was found in Padmanabhaputhoor (14.5%) and the maximum value was found in Azhagappapuram (49.8%). The overall percentage prevalence of dental fluorosis (DF%) was 26.1%.

Prevalence of Defect Dental Fluorosis (DDF%)

The percentage of defect dental fluorosis (DDF%) was reported in WS/T208-2001 scheme (Xiang *et al.,* 2009), which included the sum of the number of subjects having “moderate” (grade 4) and “severe” (grade 5) dental fluorosis diagnosed by Dean's criteria.

$$\text{Prevalence of defect dental fluorosis (DDF\%)} = \frac{\text{No of cases with defect dental fluorosis}}{\text{No of cases investigated}} \times 100$$

Table 1: Prevalence and Severity of Dental Fluorosis (DF%), Defect Dental Fluorosis (DDF%), and Community Fluorosis Index (CFI) in 18 Villages of Agasteeswaram Taluk, Kanyakumari District, Tamil Nadu, India

S. No	Village	M	F	1		2		3		4		5		Over all Fluorosis (%)		Prevalence					
																DF%		DDF%		CFI	
				M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1	Puthugramam	269	240	70	71	29	20	30	24	17	14	7	7	56.9	56.7	30.9	27.1	8.9	8.8	1.2	1.1
2	Ramapuram	232	235	56	49	23	26	16	18	13	17	4	2	48.3	47.7	24.1	26.8	7.3	8.1	1.0	1.0
3	Sankaranputhoor	215	201	51	46	25	21	16	14	13	12	2	2	49.8	47.3	26.0	24.4	7.0	7.0	1.0	0.9
4	Andarkulam	223	209	42	40	20	12	7	14	8	5	2	2	35.4	34.9	16.6	15.8	4.5	3.3	0.7	0.7
5	Kottavillai	187	172	37	52	18	8	11	12	7	9	0	0	39.0	47.1	19.3	16.9	3.7	5.2	0.7	0.8
6	Azhaganapuram	169	154	61	42	22	16	18	17	6	6	4	1	65.7	53.2	29.6	26.0	5.9	4.5	1.2	1.0
7	Padmanabhaputhoor	144	146	26	17	10	9	12	8	2	0	1	0	35.4	23.3	17.4	11.6	2.1	0.0	0.7	0.4
8	Marungoor	179	122	38	21	21	14	11	7	7	3	0	0	43.0	36.9	21.8	19.7	3.9	2.5	0.8	0.7
9	Eraviputhoor	153	116	29	23	15	15	18	8	9	2	0	0	46.4	41.4	27.5	21.6	5.9	1.7	1.0	0.7
10	Nalloor	176	146	40	32	26	19	34	27	8	7	4	3	63.6	60.3	40.9	38.4	6.8	6.8	1.4	1.3
11	Athalavilai	130	90	27	24	11	10	13	7	6	2	0	0	43.8	47.8	23.1	21.1	4.6	2.2	0.9	0.8
12	Thoppor–Srikrishnapuram	141	136	35	30	24	18	20	13	11	4	1	0	64.5	47.8	39.7	25.7	8.5	2.9	1.4	0.9
13	Rajavoor	150	130	30	24	14	13	16	12	4	4	1	0	43.3	40.8	23.3	22.3	3.3	3.1	0.8	0.8
14	Ramanathichenputhoor	128	128	26	26	20	22	11	10	1	2	0	0	45.3	46.9	25.0	26.6	0.8	1.6	0.8	0.8
15	Amaravathivillai	133	129	23	26	25	21	11	14	2	1	0	0	45.9	48.1	28.6	27.9	1.5	0.8	0.9	0.9
16	Azhagappapuram	160	103	29	19	36	22	35	18	10	5	3	2	70.6	64.1	52.5	45.6	8.1	6.8	1.6	1.4
17	Indira Nagar	97	82	21	17	15	10	11	12	2	2	0	0	50.5	50.0	28.9	29.3	2.1	2.4	0.9	1.0
18	Anjugramam	107	76	28	17	16	11	10	5	0	0	0	0	50.5	43.4	24.3	21.1	0.0	0.0	0.8	0.7
	Total	2993	2615	669	576	370	287	300	240	126	95	29	19	49.9	46.5	27.6	24.5	5.2	4.4	1.0	0.9

Table 2: Prevalence and Severity of Dental Fluorosis (DF%), Defect Dental Fluorosis (DDF%), and Community Fluorosis Index (CFI) According to Fluoride Content in Drinking Water (Average) in 18 Villages of Agasteeswaram Taluk, Kanyakumari District, Tamil Nadu, India

S. No	Village	TS	1	2	3	4	5	Over all Fluorosis (%)	Prevalence			Fluoride in Water (mg/L)
									DF%	DDF%	CFI	
1	Puthugramam	509	141	49	54	71	14	56.8	29.1	8.8	1.2	2.33
2	Ramapuram	467	105	49	34	47	6	48	25.5	7.7	1.0	1.77
3	Sankaranputhoor	416	97	46	30	43	4	48.6	25.2	7.0	1.0	1.94
4	Andarkulam	432	82	32	21	29	4	35.2	16.2	3.9	0.7	1.64
5	Kottavillai	359	89	26	23	30	0	42.9	18.1	4.5	0.8	2.84
6	Azhaganapuram	323	103	38	35	41	5	59.8	27.9	5.3	1.1	1.83
7	Padmanabhaputhoor	290	43	19	20	22	1	29.3	14.5	1.0	0.5	1.19
8	Marungoor	301	59	35	18	25	0	40.5	20.9	3.3	0.7	1.57
9	Eraviputhoor	269	52	30	26	35	0	44.2	24.9	4.1	0.9	1.04
10	Nalloor	322	72	45	61	69	7	62.1	39.8	6.8	1.4	2.60
11	Athalavilai	220	51	21	20	26	0	45.5	22.3	3.6	0.8	1.58
12	Thoppor–Srikrishnapuram	277	65	42	33	44	1	56.3	32.9	5.8	1.1	1.77
13	Rajavoor	280	54	27	28	32	1	42.1	22.9	3.2	0.8	1.72
14	Ramanathichenputhoor	256	52	42	21	22	0	46.1	25.8	1.2	0.8	1.28
15	Amaravathivillai	262	49	46	25	27	0	46.9	28.2	1.1	0.9	1.69
16	Azhagappapuram	263	48	58	53	63	5	68.1	49.8	7.6	1.6	1.96
17	Indira Nagar	179	38	25	23	25	0	50.3	29.1	2.2	1.0	1.82
18	Anjugramam	183	45	27	15	15	0	47.5	23.0	0.0	0.8	1.14
	Total	5608	1245	657	540	666	48	48.3	26.1	4.8	0.9	2.33

Table 1 revealed that the prevalence of defect dental fluorosis in male [0% (Anjugramam) to 8.9% (Puthugramam); overall is 5.2%] samples have higher score than female [0% (Anjugramam) to 8.8% (Puthugramam); overall is 4.4%] samples.

The maximum and minimum score of prevalence of defect dental fluorosis was observed in Puthugramam (8.8%) and Anjugramam (0%) (Table 2). The overall prevalence of defect dental fluorosis was found to be 4.8%.

Prevalence of Community Fluorosis Index (CFI)

Community fluorosis index (CFI) was calculated to identify whether dental fluorosis has been a common public health problem in the study area. The public health significance of CFI values (Bhat and Kumar, 2011) are as shown in Table 3.

Table 3: Public Health Significance of CFI Values

CFI Value Range	Public Health Significance
0.0 – 0.4	Negative
0.4 – 0.6	Borderline
0.6 – 1.0	Slight
1.0 – 2.0	Medium
2.0 – 3.0	Marked
3.0 – 4.0	Very Marked

The quantitative assessment of severity of dental fluorosis was done by calculating Community Fluorosis Index (CFI).

CFI was assessed on the basis of dental fluorosis symptoms, which were classified into six categories according to Dean's classification *viz*., normal, questionable, very mild, mild, moderate, and severe and each of these six classifications was given a numerical weight such as 0, 1, 2, 3, 4, and 5 respectively. Subjects with symptoms of dental fluorosis were identified and classified in each category.

CFI was computed by summing up the scores of individual grades of dental fluorosis as described by Dean and dividing the sum by the total sample size. The number of the subjects in each category was multiplied by the corresponding numerical weight.

The products thus obtained for various categories were added up and the sum total divided by the total number of subjects surveyed, gives CFI. Only when the Community Fluorosis Index value exceeds 0.6, fluorosis is considered to be a public health problem in that area. Community Fluorosis Index, using Dean's classification is calculated by the following formula:

$$CFI = \frac{\Sigma (\text{Number of} \times \text{Deans numerical}) \text{ Subjects weight}}{\text{Total number of cases examined}}$$

Community Fluorosis Index (CFI) is a value developed to present the overall degree of severity of fluorosis within a community. Severity of dental fluorosis is assessed when the Community Fluorosis Index value exceeds 0.6 indicating public health problems in those areas, while zero value of CFI shows absence of the disease.

The gender wise results (Table 2) revealed that the male [0.7 (Andarkulam, Kottavillai) to 1.6 (Azhagappapuram); overall is 1.0] have higher CFI than female [0.4 (Padmanabhaputhoor) to 1.4 (Azhagappapuram); overall is 0.9]. Azhagappapuram has maximum (1.6) and Padmanabhaputhoor has minimum (0.5) score of CFI which indicated that CFI of all villages were observed under negative to medium category in public health significance (Table 2). CFI was found to be 0.9 for 18 villages of Agasteeswaram Taluk. Villa *et al*., had conducted a study in two Chilean twin cities and reported community fluorosis index value of 0.59-0.79 whereas our study shows 0.5-1.6 as community fluorosis index value (Villa and Guerrero, 1996).

Fluoride Exposure and Prevalence of Dental Fluorosis

Distribution of dental fluorosis, defect dental fluorosis, and community fluorosis index, according to fluoride concentration of water (ground water) in the study areas are shown in Table 2. The rate of prevalence of dental fluorosis gradually elevated from 29.3% to 68.1% as the water fluoride increased in all the villages (1.04 to 2.84 mg/L). Data from this study, indicate that the prevalence of dental fluorosis increases with increase in fluoride concentration in drinking water of all the villages (Gopal, 2000; Baskaradoss *et al.*, 2008).

McDonagh *et al.*, (2000) reported that the prevalence of dental fluorosis indicates that children are ingesting other sources of fluoride besides drinking water. In areas where drinking water is obtained directly from deep wells, dental fluorosis is often endemic and in many cases, the deeper the wells, the higher the fluoride concentration in drinking water.

These findings demonstrated that, besides water fluoride concentration and duration of exposure, other factors such as dissolved salts in water, nutrition, and habits also affect the incidence of dental fluorosis (Arif *et al.*, 2013). As the concentration of fluoride increased, the prevalence of defect dental fluorosis also increased significantly.

Figure 2: Dental Fluorosis Affected Person from Nalloor Village

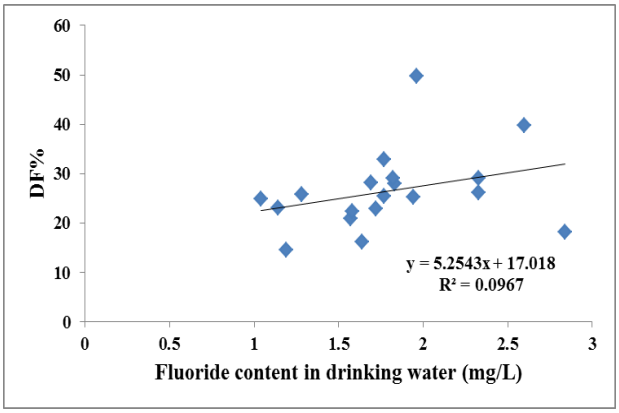
The maximum community fluorosis index (2.4) was observed in Nalloor (Figure 2) and Azhagappapuram where a normal to high fluoride concentration in drinking water (0.75-3.97 mg/L) (Kumaresan *et al.*, 2013) and rice (0.90-1.89 mg/Kg) (Anbuvel *et al.*, 2015) was observed.

Viswanathan *et al.*, (2009) recorded CFI values of 1.03 at 1.72 mg/L of fluoride and 1.3 at 2.5 mg/L water fluoride levels of endemic regions in South India. Results of their study showed that increase of fluoride levels above 1.3 mg/L in drinking water increases the CFI value more than 0.6, an optimal index value above which fluorosis is considered to be a public health problem.

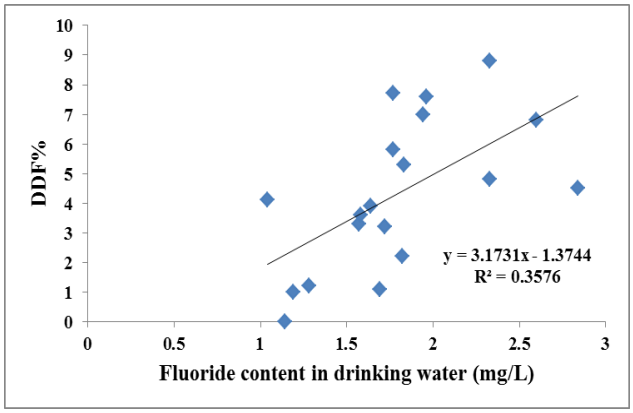
The present investigation, recorded a CFI value for Anjugramam as zero in 5-8 age group showing the absence of dental fluorosis. However, the value of CFI in other age group of the same village and other villages was found to be greater than 0.6 which is due to the high fluoride concentrations in water in those villages.

Results revealed that community fluorosis index was increased linearly with the elevation in water fluoride concentration. These results are in accordance with the previous finding (Chandrashekar and Anuradha, 2004).

Correlation between fluoride concentration in water and DF%, DDF%, and CFI was studied. Results revealed that percentage of prevalence of dental fluorosis increased linearly with elevation in water fluoride concentration. The linear regression fitting equations were obtained through statistical regression analysis of data presented in Table 2.



(3a)



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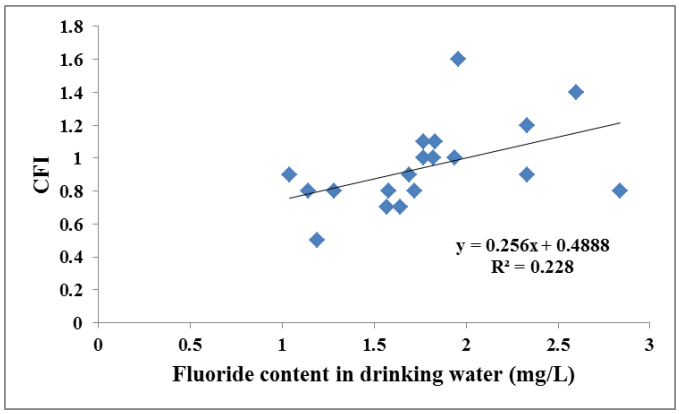

(3c)

Figure 3: Correlation between Maximum Fluoride Concentration in Water and DF% (3a), DDF% (3b), and CFI (3c), [The Pairs are: (a) Fluoride Content of Water and DF% (Figure 3a) (b) Fluoride Content of Water and DDF (Figure 3b) (c) Fluoride Content of Water and CFI (Figure 3c)]

Conclusion and Recommendation

The results of the study indicated that a high prevalence of dental fluorosis exists in some villages of Agasteeswaram Taluk, Kanyakumari District, Tamil Nadu. To identify the different ways of intake-fluoride by people is important to evaluate the sources of causing the risk for the development of dental fluorosis. It can be concluded that most of the water samples collected from some of the villages of Agasteeswaram Taluk, show a high concentration of fluoride in the ground water. Hence, it is not suitable for consumption. The consumption of high fluoride containing water leads to fluorosis. Hence, a possibility of reducing the high fluoride content of ground water either by defluoridization process or by dilution with the surface water seems to be a solution.

In order to prevent fluorosis, the pediatric dentist has to instruct parents about the fluoride content in the drinking water and when it is not known, look for this information in the local water supply service. If a child drinks well water or bottled water, the pediatric dentist may assist the parents or caregivers in getting an analysis of its fluoride content, and afterwards decide together whether the child needs a fluoride supplement or not. Dentists also should educate parents about diet, such as children's formula, food or sodas that need water to be manufactured and can indirectly participate in the development of dental fluorosis.

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