https://doi.org/10.20896/saci.v10i4.1253

RESEARCH OPEN ACCESS

Prevalence of Dental Fluorosis Amongst School Children in West Bengal, India

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Abstract

Dental fluorosis, a disease, results from excessive fluoride consumption mainly through drinking water during early childhood, which damages tooth-forming cells in children. This study examines the prevalence of dental fluorosis amongst school children in the Puruliya district, located in West Bengal, India. This is because the Puruliya district is one of the worst-affected fluoride areas in India. When compared to the World Health Organization's 1.5 mg/l permitted limit for fluoride in drinking water, the highest fluoride levels were found to be 8.28 mg/l in the Kashipur block of the district. Therefore, to perform a study to ascertain the prevalence of dental fluorosis among school-going children between the ages of 6 and 14 based on the Dean's Index, the Kashipur block of the Puruliya District was selected. The fluoride levels of drinking water sources are tested in the public health and Engineering department in the Puruliya district. The average level of fluoride discovered in drinking water ranges from 0.42 mg/l to 5.23 mg/l. The data were analysed with SPSS-20 statistical software, and mapping was done with Arc-GIS 10.5. Linear regression is applied to test the correlation. The findings demonstrate a very strong positive correlation (r = 0.92) between fluoride concentration and the frequency of childhood dental fluorosis. Dental fluorosis was observed to afflict 45.20% of the children in the research area, and it was more common in female children (46%) than in male children (44.40%). There were 226 students with dental fluorosis between the ages of 6 and 15, of whom 16.4% were in Grade I, 13.2% in Grade II, 10.0% in Grade III, and 5.6% in Grade IV.

Keywords: Children; Public Health; Dean's index; Dental Fluorosis; Fluoride; West Bengal; India

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Introduction

Worldwide 200 million human beings in 25 nations have developed fluorosis by consuming fluoride-rich drinking water (Ayoob and Gupta, 2006; Rasool et al., 2018). The situation in India concerning fluoride-contaminated groundwater is the worst, and almost 62 million populations are in danger of fluorosis by drinking this toxic water (Hem, 1959; Bulusu and Pathak, 1980; Jacks et al., 2005; Mukherjee and Singh, 2018). In India, 20 out of 29 states have excess fluoride in their groundwater, which is unsafe for drinking purposes (Siddiqui, 1955; Teotia and Teotia, 1984; Susheela et al., 1993; Karthikeyan et al., 1996; Adimalla and Venkatayogi, 2017). The health impact of fluoride on human being depends on the type, quantity and time of its ingestion (ATSDR, 2001). Fluoride consumption below 0.5 mg/l induces tooth decaying, formation of cavities, and underdeveloped bones, while excessive fluoride of more than 1.5 mg/l can cause skeletal fluorosis and dental fluorosis (Susheela, 2002; Goankar et al., 2017). Besides, children consuming too much of fluoride in their early years may develop dental fluorosis (Yadav et al., 2009). Dental fluorosis cases have been found in 150,000 villages across 14 states in India, although mild forms of dental fluorosis cases have been reported in many other regions (Saxena and Ahmad, 2003; Dave et al., 2010; Sethuraman et al., 2013).

Dean established the connection between dental fluorosis and fluoride levels in drinking water in the early 1930s (Dean, 1942). Food and water consumption are the main ways that fluoride enters the human body, and drinking water is the main source of fluoride ingestion (Dissanayake and Chandrajith, 2009; Chen et al., 2012). Dental fluorosis results from excessive fluoride in the body, disrupting enamel development by decreasing the mineral content in the tooth. Children are more susceptible to dental fluorosis as 80% of the absorbed fluoride is retained in their bodies (WHO, 1984).

The symptoms of dental fluorosis arise on the tooth's surface between 6 to 8 years when the formation of the tooth is completed (Heikens et al., 2005). Therefore, dental fluorosis symptoms will not be evident on the tooth surface if tooth growth is complete before the person is exposed to fluoride-contaminated water (WHO, 1984; Gautam et al., 2011). Dental fluorosis causes the surface of the permanent tooth to become rough, acidic, and discoloured with spots that range in colour from yellow to dark brown. When it is severe, teeth become mottled and pitted and are occasionally eroded by attrition (Larsen et al., 1985). Fluoridated mouthwashes, toothpaste, and medicinal sodium fluoride pills also increase the body's fluoride level in addition to fluoride in drinking water. Controlling the effects of fluoride on the human body requires a healthy diet because a deficiency in vitamin C, calcium and poor nutrition can worsen a child's illness (Reddy et al., 2003).

Puruliya district in West Bengal is the worst impacted of the seven fluoride-contaminated districts, with all 20 blocks having fluoride-contaminated villages that are above the permissible limit of 1.5 mg/l (ICMR, 1975; WHO, 2006; BIS, 2012; NRDWP, 2020). Fluoride levels in groundwater in the Puruliya district range from 0.126 to 8.28 mg/l, with the Kashipur block having the highest concentration. A sub-surface lithology enriched with fluoride bearing minerals and semi-arid climate conditions with frequently occurring drought has given rise to fluoride contamination in the groundwater in the district (Chakrabarti and Ray, 2013). As children are the most susceptible to fluoride poisoning in Kashipur Block, where the greatest amount of fluoride is present in the groundwater, the study's purpose is to ascertain the effects of fluoride intake at various levels in children.

Many dental and skeletal fluorosis cases have been found in several villages in the district with a high fluoride concentration in the Puruliya district (Mondal and Nath, 2015). A report from the district's fluorosis control cell states that over 45% of the children of primary schools are affected by dental fluorosis (NPPCF, 2014). Kashipur block has been chosen as our study region to examine the spatial analysis of groundwater fluoride concentration and its

correlation with the incidence of dental fluorosis in children.

The study introduces earlier research work on the prevalence of dental fluorosis in children and its relationship to fluoride in drinking water at the onset. The reason for the selection of the study area and the major objectives are then discussed, followed by the geographical background in relation to high concentration of fluoride in groundwater and the high prevalence of dental fluorosis among the children is explicated. The methodology of the study is then thoroughly outlined to carry out the work. The findings of the study are supported with images of children with various degrees of dental fluorosis, are covered in the next section. In addition, recent research is also referred to validate, supplement and explain the findings of the present study. The overall scope, major recommendations, and specific remedial measures in the context of the study area are also suggested.

Study Area

Kashipur block is located on the north-eastern side of the Puruliya District, which is a part of the Chotanagpur plateau predominantly underlain by the igneous and metamorphic rock of the Precambrian era, for example, granite and gneiss, which leads to the fluoride enrichment of groundwater (Mandal and Sanyal, 2019) (Figure 1).

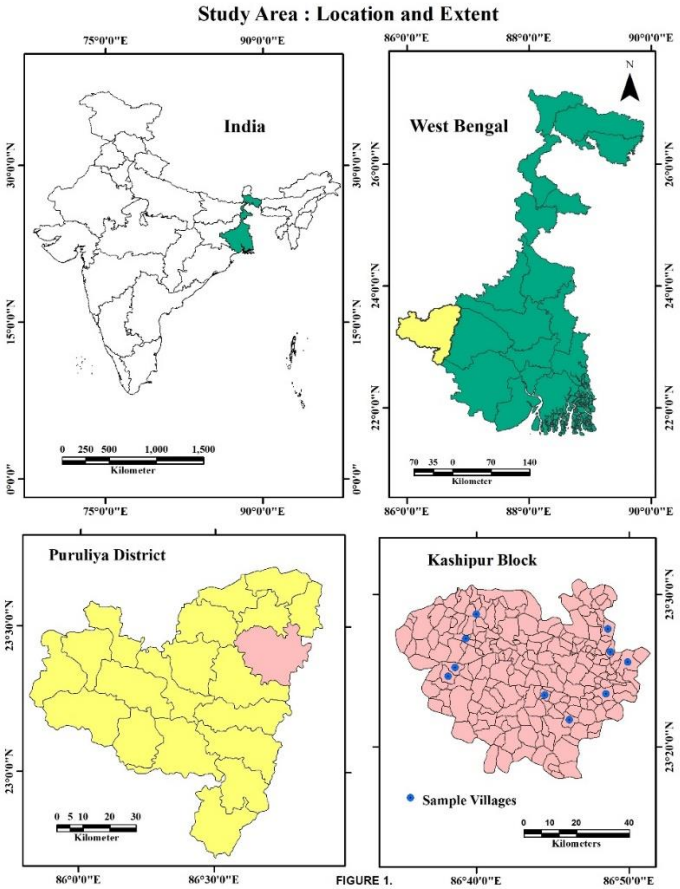

Figure 1: The Geographical Location of the Study Area with the Sites of Sample Villages. Source: Authors

Because the fluoride-rich rocks in the deeper aquifer have more time to dissolve in the groundwater, deep tube wells—the area's main source of drinking water—have a high fluoride content. (CGWB, 1989; Bhattacharya and Chakrabarti, 2011).

A semi-arid tropical climate characterises this region with a scorching summer and short rainy season. Although the area receives an average of 1200 mm rainfall each year, maximum water flows through runoff due to the undulant rugged landscape resulting in regular drought incidence

in the entire district (Rudra, 2012; Mandal and Sanyal, 2019). Further, fluoride enrichment in groundwater in this region is due to high evaporation and low water infiltration rate. As deep tube wells are the primary source of drinking water, people are forced to intake this contaminated water, resulting in excess fluoride deposition in the human body, leading to several forms of fluorosis (Jha et al., 2013).

Methodology

Sample Collection and Analysis

Based on the summary of fluoride level and its health impact by Dissanayake in 1991 based on WHO's report from 1970, the study area has been divided into three categories for the collection of the drinking water sample to estimate the fluoride concentration: fluoride concentration below 1.5 mg/l in drinking water, 1.5 to 4.0 mg/l, and above 4.0 mg/l (Adler and WHO, 1970; Dissanayake, 1991). Taking into account fluoride levels and the prevalence of dental fluorosis, 20 sampling tube wells from each of the ten sampled villages have been chosen. A sample of water was then taken from each two tube wells, one near the primary school and the other from the community. (Table 1; & Figures 1 & 2). Water testing has been conducted at the laboratory of the Public Health and Engineering Department, Puruliya district.

Table 1: Distribution of Sampled Villages, Kashipur Block, Puruliya District

Range (in mg/l)	Sampled Village	
	Name	Number
Below 1.5	Agrabad, Haridi	2
1.5 to 4.0	Barra, Chhelia, Dhanera, Gamarkuri, Kumardih, Manihara	6
Above 4.0	Kharai, Rangaladi	2
Total		**10**

Source: Dissanayake, 1991; WHO, 2011; NRDWP, 2020.

Selection of Sample Population

Using a purposive stratified sampling technique, 500 children between the ages of 6 and 15 from each of the ten sampled villages were selected as the study's sample size. Fifty children were selected from each village (an equal number of girls and boys) from different socio-economic backgrounds. Inclusion criteria were school children being residents of the study area for the past six years (the first six years of their life in which dental fluorosis may affect the permanent teeth) (Malek et al., 2017).

Field and Questionnaire Survey

A self-administered questionnaire based on the recommendations of the report of the fluorosis control programme and prior studies in this field of study was created to examine the prevalence of dental fluorosis among the children in the chosen sample (NPPCF, 2014). Prior written consent from parents and teachers were taken to allow students to participate in the survey.

Photographic Examination

Digital images were taken for maxillary central incisors with the help of the Canon 200 Digital Single-Lens Reflex camera under indirect sunlight. The digital images were then transported to the computer and documented with the individual information. These images were then examined in consultation with the Fluorosis Control Cell, Ministry of Health and Family Welfare, Puruliya District.

Dean's Dental Fluorosis Grading Index

For the grading of the tooth of the children of the study area, Dean's Index (1942) of dental fluorosis has been used to determine its severity. It is an assessment index of a six-point scale to assess the extent of dental fluorosis based on the tooth's characteristics and symptoms of identification. Our study has taken only five categories (Table 2).

Table 2: Dental Fluorosis Assessment Index		
Classes	**Grading**	**Symptoms and characteristics of the tooth for identification**
Normal	0	Creamy white opaque smooth tooth surface.
Very mild	1	10 – 25 % of the surface of the tooth is affected by irregular white scattered spots.
Mild	2	25 – 50 % of the tooth surface area is covered by white to light yellow stains.
Moderate	3	100 % of the tooth enamel surfaces are affected and covered by dark yellow to brown stains with horizontal streaks subject to attrition show wear.
Severe	4	100 % (brown to black staining is widespread and extensive with confluent pitting of the tooth.)
Source: Trendley H. Dean, 1942		

Data Analysis and Representation

The data collected from the survey is analysed using the SPSS 20 software, and charts are made in Microsoft Excel. The mapping of the study area is conducted through Arc.GIS 10.5 software with village shapefile of the district sourced from the BHUVAN portal of the Indian Space Research Organization (ISRO).

Results and Discussion

The outcomes from the current study disclose the incidence of dental fluorosis amongst surveyed children and its association with fluoride content in drinking water, with a preponderance of the female sex. The study also reveals that grade I dental fluorosis is more prevalent among children, which is mild. However, with the rise in fluoride concentration, the severity of the disease also increased. Similar findings from other studies indicate that dental fluorosis is more common in places with high water fluoride concentrations and that children, mainly females, account for a higher percentage of cases (Gopalakrishnan et al., 1999; Choubisa, 2001; Saravanan et al., 2008; Veeresh et al., 2010; Narayanamurthy & Santhuram, 2013).

Fluoride Concentration in Kashipur Block

All 20 blocks of the Puruliya district are affected and comprises 23.25 % of villages with fluoride level beyond the acceptable level of 1.5 mg/l. (Mandal and Sanyal, 2019). Maximum fluoride concentration (8.28 mg/l) and mean concentration 1.63 mg/l in groundwater have been found in the Kashipur block. In Kashipur, 17.56 % (36) villages are above 1.5 mg/l, while, 82.44 % of the villages have been reported to be within the safe or permissible limit (Table 3). Among the villages with fluoride concentration above the permissible limit, 15.61 % are within the range of 1.5 to 4.0 mg/l, while 1.95 % have above 4.0 mg/l. However, a large number of villages (82.44%) have fluoride concentrations within the permissible limit as per the WHO guidelines (Figure 2).

Table 3: Distribution of Villages with respect to Fluoride Level in Drinking Water, Kashipur Block, 2020						
Block	**Total Villages**	**Fluoride Concentration (mg/l)**				
		Range	**Mean**	**Below 1.5**	**1.5 - 4.0**	**>4.0**
Kashipur	205	0.16-8.28	1.63	169 (82.44%)	32(15.61%)	4(1.95%)
Source: WHO, 2006, NRDWP, 2019-20 and Personal Computation						

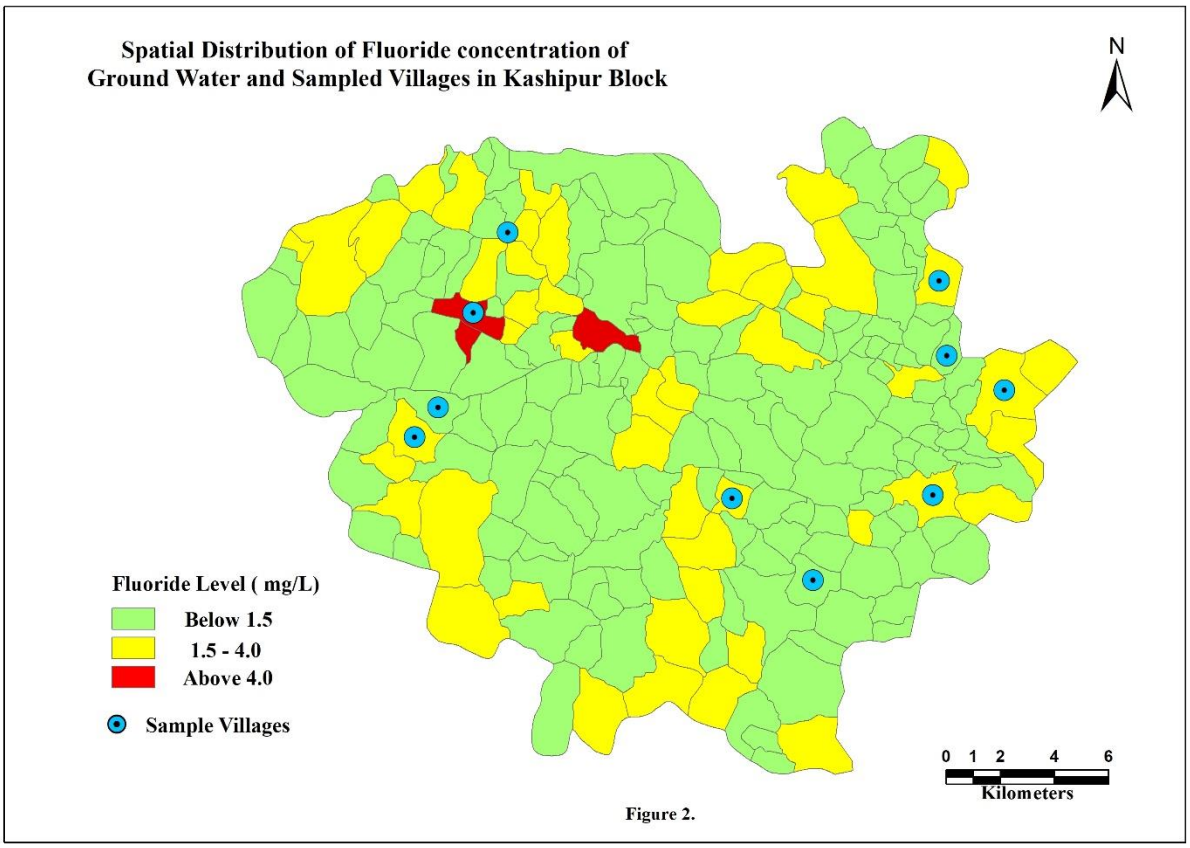

Figure 2. Distribution of Fluoride Concentration in Kashipur Block
Source: Authors

Dental Fluorosis Among School Children in Kashipur Block

In the examined villages, the mean fluoride content ranged from 0.42 to 5.23 mg/l. The lowest mean concentration (0.42 mg/l) has been observed in Agrabad village, while the highest (5.23 mg/l) (mean of two samples 8.28 mg/l and 2.18 mg/l) has been found in Kharai village. Agrabad and Haridi villages have a mean concentration (0.42 mg/l and 1.3 mg/l, respectively) below the acceptable limit (<1.5 mg/l). In contrast, villages like Chhelia, Barra, Dhanera, Gamarkuri, Manihara and Kumardih have mean fluoride concentrations of 1.5 to 4 mg/l (1.76, 2.22, 2.5, 2.6, 2.8 and 3.12 mg/l respectively). Rangaladi and Kharai villages have fluoride concentrations above 4 mg/l (4.28 mg/l and 5.23 mg/l, respectively). Maximum cases of dental fluorosis amongst school children have been found in those villages which are affected by high fluoride concentrations. Kharai village had the highest mean fluoride content (5.23 mg/l) and the highest percentage of dental fluorosis cases (82 %). At the same time, Agrabad village, with the lowest fluoride concentration of 0.42 mg/l has no cases of dental fluorosis. Similar characteristics are identified in other sampled villages (Table 4).

The incidence of dental fluorosis and fluoride concentration are significantly positively correlated. The correlation value, r = 0.92, shows a strong positive correlation between dental fluorosis among school children in the Kashipur block and fluoride levels in drinking water. As cases of dental fluorosis increase, so do fluoride levels (Figure 3).

Table 4: Dental Fluorosis Prevalence Among Tested Villages in the Kashipur Block of the Puruliya District of West Bengal in 2020

Sl. no.	Name of Sampled Village	Mean Fluoride Concentration(mg/l)	Total Surveyed	Cases	
				In Numbers	In Percentage
1.	Agrabad	0.42	50	0	0
2.	Haridi	1.3	50	4	8
3.	Chhelia	1.76	50	16	32
4.	Barra	2.22	50	19	38
5.	Dhanera	2.5	50	22	44
6.	Gamarkuri	2.6	50	24	48
7.	Manihara	2.8	50	30	60
8.	Kumardih	3.12	50	32	64
9.	Rangaladi	4.28	50	38	76
10.	Kharai	5.23	50	41	82
Total			**500**	**226**	**45.2**

Source: Personal Survey, 2019-20

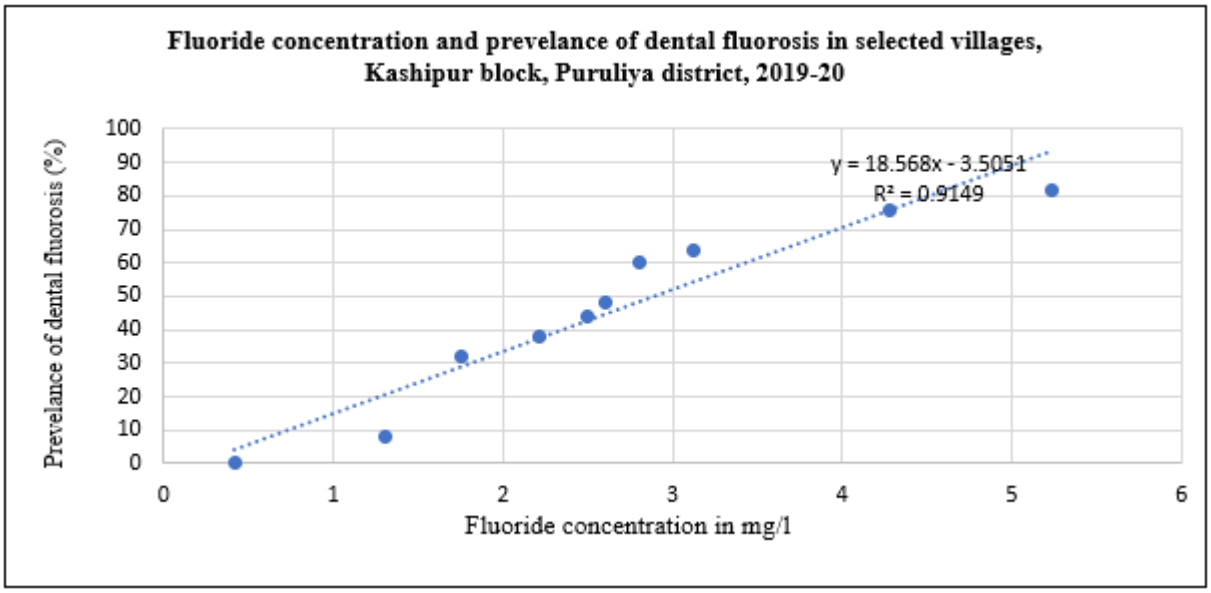

Figure 3: Relationship between the Quantity of Fluoride in the Water and the Frequency of Dental Fluorosis in Sample Villages in the Kashipur Block of the Puruliya District (2019-20). Source: Authors

Gender-Specific Prevalence of Dental Fluorosis in School Children

There is not much difference in gender and dental fluorosis incidence in the study area. Girls (46%) have been found to have a higher incidence of dental fluorosis than boys (44.40%) (Table 5). While some research indicated a higher female preponderance, others revealed that males were more likely to suffer dental fluorosis (Biazevic et al., 2008; Narayanamurthy and Santhuram, 2013; Das et al., 2020). According to several studies, a patriarchal society in which boys are preferred and even provided with better and more wholesome food than girls may be the likely cause of our studies' high female dental fluorosis prevalence. Moreover, the underprivileged socio-economic status of the family with prevailing discrimination in society further deteriorates the health condition of female children and becomes more prone to dental fluorosis (Gupta, 1997; Kadam, 2012; Lone et al., 2020).

Table 5: Prevalence of Dental Fluorosis Across the Gender-Group, Kashipur Block

Sampled Village	Gender				Total	
	Boy		Girl			
	Surveyed	Affected	Surveyed	Affected	Surveyed	Affected
Agrabad	25	0 (00.00)	25	0 (00.00)	50	0 (00.00)
Barra	25	10 (40.00)	25	9 (36.00)	50	19 (38.00)
Chhelia	25	9 (36.00)	25	7 (28.00)	50	16 (32.00)
Dhanera	25	9 (36.00)	25	13 (52.00)	50	22 (44.00)
Gamarkuri	25	11 (44.00)	25	13 (52.00)	50	24 (48.00)
Haridi	25	3 (12.00)	25	1 (04.00)	50	4 (08.00)
Kharai	25	19 (76.00)	25	22 (88.00)	50	41 (82.00)
Kumardih	25	17 (68.00)	25	15 (60.00)	50	32 (64.00)
Manihara	25	13 (52.00	25	17 (68.00)	50	30 (60.00)
Rangaladi	25	20 (80.00)	25	18 (72.00)	50	38 (76.00)
Total	**250**	**111 (44.40)**	**250**	**115 (46.00)**	**500**	**226 (45.20)**

Source: Personal Survey, 2020
Note: the numbers given in the brackets are in percentage

The Categorisation of Dental Fluorosis Using Dean's Index

Out of the total 500 school children surveyed and physically examined, 45.20 % of them have symptoms of dental fluorosis ranging from Grade I to Grade IV. Of these, 16.40 % have symptoms of Grade I dental fluorosis, 13.20 % of Grade II, 10.00 % of Grade III and 5.60 % of Grade IV. The rest 54.80 % are normal or under Grade 0 (Table 6).

Table 6: Grading of Dental Fluorosis Using Dean's Index Among School Children from Sampled Villages, Kashipur Block, 2020

Sampled Village	Grades of Dental Fluorosis										
	Normal or 0		Grade 1		Grade 2		Grade 3		Grade 4		Total
	no.	%	no.	%	no.	%	no.	%	no.	%	
Agrabad	50	100	0	0	0	0	0	0	0	0	50
Barra	31	62	8	16	6	12	4	8	1	2	50
Chhelia	34	68	7	14	5	10	3	6	1	2	50
Dhanera	28	56	9	18	7	14	4	8	2	4	50
Gamarkuri	26	52	10	20	8	16	4	8	2	4	50
Haridi	46	92	4	8	0	0	0	0	0	0	50
Kharai	9	18	9	18	11	22	12	24	9	18	50
Kumardih	18	36	11	22	10	20	7	14	4	8	50
Manihara	20	40	12	24	9	18	6	12	3	6	50
Rangaladi	12	24	12	24	10	20	10	20	6	12	50
Total	274	**54.8**	82	**16.4**	66	**13.2**	50	**10**	28	**5.6**	500

Source: Personal Survey, 2019-20

Due to the low fluoride content in the drinking water in the study area, the majority of children in the Agrabad village have normal dental health and fall under the Dean's Index Grade 0 type of dental fluorosis, which shows no tooth mottling, the surface is even, shiny, and typically pale milky white in colour. While, Manihara and Rangaladi villages (mean fluoride concentration of 2.8 & 4.28 mg/l respectively) have the highest percentage of **Grade 1** cases (24.00% each) in

the block. Grade 1 class is characterised by a mild form of dental fluorosis when 10 to 25 % tooth surface becomes uneven with scattered paperwhite spots (Figures 4a & 4b). The severity of the sickness among the study region participants likewise rises as the dose of fluoride content in the drinking source water does.

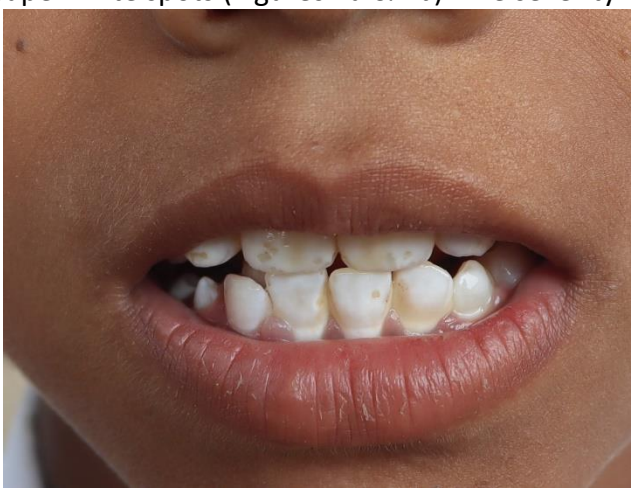

Figure 4a: Grade 1 Dental Fluorosis—Small White Strikes in Teeth
Source: Authors

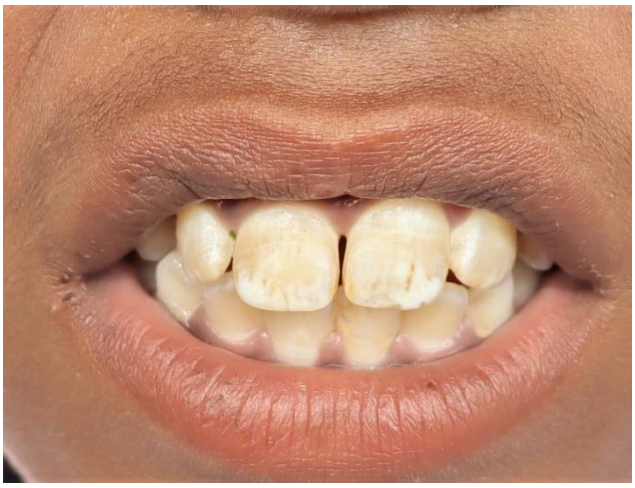

Figure 4b: Grade 1 Dental Fluorosis— Mild Yellow Strikes in Teeth
Source: Authors

In **Grade 2** dental fluorosis, the symptoms are more extensive and spread at least 25 to 50% of the children's tooth surface. The distinctive characteristics are white to light yellow spots with a corrosive surface. The highest percentage of cases in the block has been found in Kharai village (22%), followed by Kumardi and Rangaladi villages with 20% cases each of Grade II dental fluorosis (Figure 5).

Figure 5:Grade 2 Dental Fluorosis (White Stains are More Extensive in Grade II)
Source: Authors

In **Grade 3** dental fluorosis, the entire tooth surface gets affected with dark yellow to brown stain with horizontal streaks with mottling of enamel, leading to wearing the teeth in some cases. Children of the Kharai village have the highest percentage (24%) of grade 3 type of dental fluorosis with a mean fluoride concentration of 5.23 mg/l in the drinking water source. Other than Kharai Kumardi, Manihara Rangaladi also has more than 10% of surveyed children with grade III dental fluorosis. All these villages have a fluoride concentration that is way above the prescribed limit of fluoride in drinking water sources (Figures 6a & 6b).

Figure 6a: Grade 3 Dental Fluorosis— Dark Yellow Stains in the Teeth
Source: Authors

Figure 6b): Grade 3 Dental Fluorosis— Brown Staining of Teeth
Source: Authors

Grade 4 is the severe condition of dental fluorosis; teeth are corroded and covered with widespread staining and pitting with dark brown spots. Kharai and Rangaladi villages have (9 & 6 cases, respectively), while the rest of the sampled villages either have none or cases vary from 1 to 4 (Figures 7a & 7b).

Figure 7a: Grade 4 Dental Fluorosis Discrete Brown Pitting of Teeth
Source: Authors

Figure 7b: Grade 4 Dental Fluorosis Extensive Brown Staining in the Entire Teeth Surface
Source: Authors

Discussion

According to the current study, there is a direct correlation between the amount of fluoride in drinking water and the severity of dental fluorosis. Our findings bear similarity with many studies conducted in the past (Warren et al., 2001; Choubisa, 2001; Viswanathan et al., 2009; Gautam et al., 2011). With an increase in fluoride content from 0.42 to 5.23 mg/l in drinking water in the Kashipur district, the incidence of fluorosis rises from 0% to 80%.

Children are especially susceptible to dental fluorosis because this is the time when their body tissues are forming and growing. Fluoride only discolours developing teeth while they are forming, therefore, the amount consumed up until the age of 8 to 10 determines how severe dental fluorosis will be (Susheela, 2002). Most children with dental fluorosis come from poorer socioeconomic backgrounds and have extremely poor nutritional conditions. Numerous variables, such as the duration of fluoride exposure, its concentration and frequency of intake, habits,

and nutrition, can affect the variation and severity of dental fluorosis among people in any given geographic area, in addition to an individual's susceptibility, biological response, and genetics (Choubisa, 2007).

The grade I dental fluorosis rate among the study's participants is the highest at 16.80%. Similar research found a higher prevalence of very mild dental fluorosis than other types of dental fluorosis among elementary school pupils in Kaiwarahobli's rural regions (Arvind et al., 2012). In the current study, dental fluorosis affects both boys and girls, with a higher prevalence in females, which indicates a lower nutritional status in women. As stated above, the majority of the impacted children come from lower socioeconomic backgrounds, where girls are treated less favourably than boys.

Conclusion

Geographical location is the most significant aspect of studying the origin and spreading of any disease. As water fluoride content varies in different parts of the world, dental fluorosis also differs from place to place. A direct and positive relationship exists between fluoride concentration and the degree of dental fluorosis in our study of the Kashipur block of the Puruliya district. So to monitor the risk of developing dental fluorosis, it is essential to know the source of drinking water and the time someone is exposed to the fluoride-rich water in their life. Puruliya district is one of the least developed, poverty-stricken regions, with most people belonging to the tribal community. Children in this region merely go to school to get food provided by the government through a mid-day meal scheme with poor nutritional value to prevent any disease. Preventive measures are better for fluorosis because the disease is not curable in its fully developed form. Therefore, geospatial techniques to assess health problems will be beneficial to detect the locational spread of the disease and to allocate health resources properly for the people in need.

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Conflict of Interest

The authors declare that there is no conflict of interest. For this research, consent forms were obtained from each eligible participant who volunteered to participate.

Funding

The study is part of an ongoing PhD thesis of the first author (corresponding author) under the University Grant Commission fellowship programme, New Delhi, India.

Acknowledgements

The authors are thankful for the water testing facilities provided by West Bengal Public Health and Engineering Department (WBPHED), Puruliya. For screening of dental fluorosis, necessary help and facilitates were provided by Fluorosis Control Cell, Puruliya District. The authors are grateful to Headmasters, Teachers and Parents for their cooperation and support. The authors are also thankful to the anonymous reviewers for their valuable suggestions.

Author Contribution Statement

Juthika Mandal (Corresponding Author): conceptualisation, methodology, and software contribution; curation of data, developing the first draft; Conducting empirical research and visualisation of data; preparation and reproduction of the maps; re-writing the final draft.

Srabani Sanyal: Conceptualisation and methodology revising; checking and correcting maps and tables; initial reviewing and cross-checking for references; final reviewing of the draft and final editing.

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