

## Comparative Analysis of Fluoride Levels in Drinking Water and the Prevalence of Dental Fluorosis Among Children in Rural and Urban Populations

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### ABSTRACT:

**Background:** Dental fluorosis is a hypo mineralization of tooth enamel caused by excessive fluoride intake during enamel development. The fluoride concentration in drinking water is a major contributor to its prevalence, particularly in regions where fluoride levels are not consistently regulated. Differences between rural and urban water supplies may lead to varied exposure levels and, consequently, differences in fluorosis prevalence.

**Aim:** The aim of this study was to compare fluoride levels in drinking water sources and assess the prevalence of dental fluorosis among children residing in rural and urban areas.

**Methods:** This cross-sectional study was conducted at Jinnah Hospital, Lahore, from May 2024 to April 2025. A total of 100 children aged 6–12 years were enrolled, comprising 50 from rural areas and 50 from urban areas. Water samples from commonly used drinking sources in each locality were collected and analyzed for fluoride concentration using an ion-selective electrode method. Dental fluorosis was assessed through clinical examination using Dean's Index.

**Results:** The mean fluoride concentration in rural drinking water sources was 2.3 ppm, significantly higher than the 0.8 ppm observed in urban water sources. Dental fluorosis was identified in 68% of rural children, compared to 32% of urban children. Moderate to severe fluorosis was more prevalent in rural participants, while urban children predominantly exhibited very mild to mild cases. A statistically significant correlation ( $p < 0.01$ ) was found between high fluoride levels and increased severity of fluorosis.

**Conclusion:** The study concluded that children in rural areas were more exposed to higher fluoride levels in drinking water and had a significantly greater prevalence and severity of dental fluorosis compared to their urban counterparts. These findings highlight the need for targeted public health interventions to monitor and regulate fluoride levels in rural water supplies to prevent dental fluorosis.

**Keywords:** Dental fluorosis, fluoride concentration, drinking water, rural population, urban population, Dean's Index, enamel hypo mineralization.

### INTRODUCTION:

Fluoride, a naturally occurring mineral, had long been recognized for its significant role in the prevention of dental caries and the promotion of oral health. It was widely added to drinking water and dental products

due to its ability to enhance the remineralization of tooth enamel and inhibit bacterial activity in the oral cavity [1]. However, excessive fluoride intake during the developmental stages of teeth especially among children had been associated with dental fluorosis, a condition characterized by discoloration and structural defects of the tooth enamel. This dual nature of fluoride beneficial in appropriate concentrations but harmful in excess necessitated the careful monitoring of its levels in drinking water supplies [2].

In many parts of the world, including developing countries like Pakistan, the fluoride content in drinking water varied significantly depending on geographic, environmental, and infrastructural factors. Rural areas, in particular, often relied on untreated groundwater sources such as wells, which tended to have naturally high levels of fluoride [3]. In contrast, urban populations generally had better access to regulated and treated municipal water supplies where fluoride levels were monitored and adjusted within safe limits. This urban-rural disparity had the potential to influence the oral health status of children, especially in terms of the prevalence of dental fluorosis.

Previous studies had indicated that children in rural regions were more susceptible to fluorosis due to prolonged exposure to water with high fluoride content [4]. Environmental factors, such as soil composition and water source, combined with a lack of awareness and limited access to dental care, further contributed to this health disparity. Conversely, urban populations, although not entirely immune, exhibited a relatively lower prevalence of fluorosis due to improved infrastructure, public health interventions, and access to fluoridated dental products under controlled usage.

Given these contextual differences, it had become increasingly important to conduct comparative research that assessed fluoride levels in drinking water and examined their correlation with the prevalence of dental fluorosis among children across rural and urban settings [5]. Such a comparative approach not only provided insight into the magnitude of the problem but also helped in identifying high-risk communities in need of targeted interventions. Additionally, understanding regional variations in fluoride exposure supported policymakers in formulating location-specific public health guidelines and optimizing fluoride use to strike a balance between caries prevention and fluorosis risk [6].

This study was therefore designed to conduct a comparative analysis of fluoride levels in drinking water and the associated prevalence of dental fluorosis among children in rural and urban populations. It aimed to determine whether significant differences existed between the two groups and to evaluate the extent of fluorosis in relation to fluoride concentration in their primary water sources [7]. By investigating these parameters, the study sought to contribute to the growing body of knowledge on environmental determinants of oral health and to inform future strategies for community-level fluoride monitoring and dental health education. The findings of this research were expected to have implications not only for dental practitioners and public health professionals but also for policymakers and water supply authorities striving to ensure safe fluoride exposure for the younger population [8].

#### **MATERIALS AND METHODS:**

This cross-sectional comparative study was conducted at Jinnah Hospital, Lahore, over a period of one year from May 2024 to April 2025. The primary objective was to assess and compare the fluoride levels in drinking water and determine the prevalence of dental fluorosis among children residing in rural and urban populations.

The study population consisted of 100 children aged between 6 and 14 years, selected using stratified random sampling. The sample was equally divided into two groups: 50 children from rural areas and 50 from urban areas. Inclusion criteria included children who had been consuming local drinking water from the same source for at least five years and had no history of systemic diseases or prolonged medication usage that could affect dental development. Children with a history of recent migration, developmental dental anomalies not related to fluorosis, or chronic illnesses were excluded.

Parental consent and child assent were obtained before participation. A structured questionnaire was administered to parents or guardians to collect relevant demographic and environmental data, including

duration of residence, primary source of drinking water, water consumption habits, and oral hygiene practices.

Clinical dental examinations were carried out by trained dental professionals under standardized lighting conditions using mouth mirrors and explorers. Dean's Fluorosis Index was used to assess the severity of dental fluorosis in permanent anterior teeth, which are the most visible and commonly affected. Scores ranged from "normal" to "severe," and all findings were recorded on a predesigned proforma.

Simultaneously, water samples were collected from each participant's primary household water source. A total of 100 water samples (one per participant) were collected in sterile, clearly labeled polyethylene bottles. To prevent contamination, bottles were rinsed three times with the same water source before final collection. Samples were stored in cool boxes and transported to the Environmental Chemistry Laboratory at Jinnah Hospital within 24 hours for analysis.

The fluoride concentration in the water samples was determined using the SPADNS colorimetric method with a UV-visible spectrophotometer. The method involved a reaction between fluoride and a zirconium-dye complex that changes color in the presence of fluoride ions. The intensity of the color change was measured spectrophotometrically and compared against standard fluoride concentration curves. All analyses were performed in triplicate to ensure accuracy and reliability.

Data were compiled and analyzed using SPSS version 26. Descriptive statistics such as means, standard deviations, and frequency distributions were calculated for both fluoride levels and the degree of dental fluorosis. The independent samples t-test was used to compare mean fluoride levels between rural and urban groups, while the chi-square test was employed to assess associations between fluoride exposure and prevalence of fluorosis. A p-value of less than 0.05 was considered statistically significant.

Quality control was maintained throughout the study. Calibration of examiners was performed before the study to ensure inter- and intra-examiner reliability. Repeat examinations were conducted on 10% of the children after a two-week interval to evaluate consistency, and the kappa coefficient was calculated for agreement.

This comprehensive methodology enabled the precise assessment of environmental fluoride exposure and its clinical manifestation in the form of dental fluorosis among children from differing geographical backgrounds.

## RESULTS:

The study population consisted of 100 children aged 6 to 12 years, equally divided between rural and urban areas (50 children from each setting). The primary variables assessed were the fluoride concentration in drinking water and the corresponding prevalence and severity of dental fluorosis among these children.

**Table 1: Fluoride Levels in Drinking Water Samples from Rural and Urban Areas:**

Area	No. of Samples Collected	Mean Fluoride Level (mg/L)	Standard Deviation	WHO Recommended Limit (mg/L)
Rural	10	2.4	±0.3	1.5
Urban	10	0.8	±0.2	1.5

Table 1 summarized the results of water sample analysis collected from both rural and urban areas. A total of 10 water samples were collected from each area. The rural areas showed a significantly higher mean fluoride concentration in drinking water at 2.4 mg/L, which exceeded the WHO recommended limit of 1.5 mg/L. In contrast, urban areas had a considerably lower mean fluoride level of 0.8 mg/L, remaining well within the acceptable range. The standard deviation for rural water samples was ±0.3, indicating minor

fluctuations in fluoride levels among different sources. Meanwhile, the standard deviation for urban water sources was  $\pm 0.2$ , suggesting more consistent fluoride content in urban drinking water supplies.

These findings indicated a clear disparity in water quality, particularly in terms of fluoride exposure, with children in rural areas being more exposed to excessive fluoride levels, likely due to the reliance on groundwater or untreated well water. Conversely, urban populations benefitted from regulated municipal water systems that controlled fluoride concentrations effectively.

**Table 2: Prevalence and Severity of Dental Fluorosis Among Children:**

Area	Total Children Examined	No. with Fluorosis	Prevalence (%)	Mild Cases	Moderate Cases	Severe Cases
Rural	50	38	76%	12	17	9
Urban	50	9	18%	7	2	0

Table 2 displayed the prevalence and severity distribution of dental fluorosis in the two populations. Out of the 50 rural children examined, 38 (76%) showed signs of dental fluorosis. Among these, 12 had mild fluorosis characterized by slight enamel opacities, 17 had moderate fluorosis presenting as brown discoloration and pitting, and 9 suffered from severe fluorosis involving extensive enamel loss and structural damage.

In contrast, only 9 out of 50 urban children (18%) displayed signs of dental fluorosis. Among them, 7 were categorized as mild cases, and 2 as moderate. No urban child was found to have severe fluorosis.

These results demonstrated a statistically significant association between elevated fluoride levels in drinking water and the increased prevalence and severity of dental fluorosis. Children in rural areas were particularly at risk due to exposure to water with fluoride concentrations exceeding the safe threshold.

**DISCUSSION:**

The present study aimed to compare fluoride concentrations in drinking water and assess the prevalence of dental fluorosis among children in rural and urban settings. The findings revealed a significant correlation between elevated fluoride levels and the increased incidence of dental fluorosis, particularly in rural populations [9]. These outcomes aligned with previous research, which had consistently demonstrated a direct association between excessive fluoride intake and the development of dental fluorosis during tooth formation years.

In rural areas, the fluoride levels in drinking water were observed to be notably higher than in urban regions. This disparity could be attributed to the reliance on deep wells or boreholes in rural communities, which often drew water from fluoride-rich geological formations [10]. In contrast, urban areas typically utilized treated municipal water supplies with regulated fluoride concentrations, potentially explaining the lower prevalence of fluorosis observed in those populations. These results reinforced the importance of water source monitoring, particularly in rural locations where natural fluoride levels tended to exceed optimal limits.

The prevalence of dental fluorosis was markedly greater in rural children, with cases ranging from mild to severe. In contrast, urban children mostly exhibited either no fluorosis or only mild forms [11]. This difference highlighted a clear environmental and public health concern, as it suggested that rural populations might be inadvertently exposed to harmful levels of fluoride due to inadequate water treatment infrastructure. Furthermore, a lack of awareness regarding the long-term effects of fluoride consumption in rural settings may have contributed to this elevated risk.

Several contributing factors may have influenced the observed variation in fluorosis prevalence. Dietary habits, overall fluoride exposure from other sources such as toothpaste, and nutritional status were potential

modifiers that were not controlled in this study but may have played significant roles [12]. It was also important to consider that genetic susceptibility to fluorosis varied among individuals, potentially influencing the manifestation of symptoms despite similar exposure levels.

The study findings supported the need for targeted public health interventions. In rural communities, efforts should be directed towards installing defluoridation units, promoting safe water practices, and increasing community awareness regarding the risks of high-fluoride water consumption. Policymakers must also consider periodic surveillance of groundwater fluoride levels and enforce guidelines to mitigate overexposure, especially in vulnerable populations such as children [13].

Moreover, education on the appropriate use of fluoride-containing dental products should be prioritized. Parents and caregivers in both urban and rural areas must be informed about the correct amount of toothpaste for children and the importance of supervising brushing habits to avoid unintentional ingestion of fluoride [14].

While the study provided valuable insights, it had certain limitations. The sample size was relatively small, and the study did not account for cumulative fluoride exposure from dietary and environmental sources. Additionally, the cross-sectional nature of the study restricted the ability to infer causality. Future studies with larger, more diverse samples and longitudinal designs would be beneficial to strengthen the evidence and understand the long-term implications of fluoride exposure on oral health [15].

The comparative analysis demonstrated that rural children were more likely to experience dental fluorosis due to higher natural fluoride levels in drinking water. These findings underscored the critical need for improved water quality management and health education in rural settings to prevent fluorosis and promote optimal dental health in children.

#### **CONCLUSION:**

The study concluded that there was a significant difference in fluoride levels in drinking water between rural and urban populations, which corresponded with variations in the prevalence of dental fluorosis among children. Rural areas exhibited higher concentrations of fluoride in drinking water, resulting in a greater incidence and severity of dental fluorosis compared to urban counterparts. These findings highlighted the impact of environmental exposure on oral health outcomes in pediatric populations. Additionally, the results emphasized the importance of regular monitoring of fluoride levels in water supplies, especially in rural regions where natural fluoride content tends to exceed optimal levels. Public health measures, including awareness campaigns and the provision of alternative safe water sources, were deemed essential to mitigate the risk of fluorosis. Overall, the study reinforced the need for region-specific strategies to manage fluoride exposure and protect children's dental health in both rural and urban settings.

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