

Fluoride Levels in Drinking Water across Lahore District Towns and their Link to Dental Fluorosis (2022)

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Abstract

Objective: To measure the concentration of fluoride levels in drinking water and its association with dental fluorosis in various towns of Lahore district, Pakistan in the year 2022.

Methods: This descriptive cross-sectional study was conducted from 27th September to 30th December, 2022 across nine towns in Lahore, where 100 drinking water samples were collected from randomly selected tube wells. The tube wells were chosen using random number tables from a list provided by WASA. Additionally, 400 residents aged 25 years and above (4 residents per area) were interviewed and clinically examined for dental fluorosis in the areas corresponding to the water sample collection sites. Fluoride concentrations in all water samples were analyzed using the spectrophotometric method at the Pakistan Council of Research in Water Resources (PCRWR) laboratory in Lahore.

Results: With 1.5 mg/l as the recommended fluoride level in drinking water, the fluoride concentration ranged from 0.50 to 1.63 mg/l, with a mean of 0.58 ± 0.33 mg/l among individuals with dental fluorosis compared to those without. This difference was statistically significant ($p = 0.013$). Dental fluorosis was observed in 189 participants (47.3%), of whom 48.8% were male and 39.7% were female.

Conclusion: Fluoride levels in drinking water exceeding the recommended limit were significantly associated with a higher frequency of dental fluorosis among residents.

Keywords: Fluoride concentration, Drinking water, Dental fluorosis, Dean's fluorosis index, tube-wells.

Introduction

Pakistan is a developing country where there are limited drinking water sources, and much of the available drinking water comprises of high fluoride concentration, which not only causes dental fluorosis, but also skeletal fluorosis.¹ Fluoride is available to human beings and domestic animals from different sources including drinking fluoridated water, crops and plants grown on the fluorotic soils, certain marine animals that are edible, phosphate supplements that contain fluoride for animal feed, medicines, mineral mixture, cosmetics, industrial fluoride pollution and

dust in the air. Concentration of fluoride in the surface water i.e., rivers is usually lower than 0.1 parts per mg/l.² However, concentration of fluoride in groundwater undergoes great variations and can be higher considerably, depending upon its composition in host rocks, hydrogeology and climate.² The recommended value for fluoride in drinking water is 1.5 mg/l, and there is an increased risk of developing dental fluorosis at concentrations higher than 1.5 mg/l, which may also lead to skeletal fluorosis.³

Dental Fluorosis is a mineralization disorder affecting enamel, due to high fluoride intake during the early tooth formation stages.⁴ It is most likely to develop from infancy period to eight years of age in children, and might develop aesthetic concerns related to teeth from birth to 6 years of age.⁵ Premolars are usually more prone to fluorosis and may sustain greater damage.⁵ Characteristics of dental fluorosis include mottled enamel, brownish discoloration of teeth, pitted appearance of enamel and thin, diffuse, horizontal, and bilateral white striations along with plaque.⁶ A daily fluoride intake of 0.05–0.07 mg/kg/day is recommended for the primary prevention of dental fluorosis.⁶ Fluoride concentrations exceeding 1.5–4 mg/l (above WHO's recommended level) in children can lead to dental fluorosis.⁶ As recommended by WHO, optimum fluoride level in drinking water is from 0.5 to 1 parts per million respectively.³ Excessive consumption of water having high fluoride levels and intake of fluoride containing food products can lead to dental fluorosis.⁷ Fluorosis is considered as a globally occurring phenomenon leading to evident aesthetic issues and defective bones and enamel development.⁸

The age range which is critical for dental fluorosis is from 15-30 months.⁹ Dental fluorosis occurs due to short-term overexposure to fluoride during tooth formation, leading to disrupted ameloblastic function and resulting in enamel hypomineralization.¹⁰ It is associated with changes in subsurface enamel.¹¹ It is an important biological marker in indication and identification of fluoride level in teeth.¹² Dental fluorosis has been classified on basis of clinical appearance by using Dean's fluorosis index (presented by Dean, 1934).¹⁰ Scoring in Dean's fluorosis index is

as follows: 1: Questionable, having occasional white spots and flecks on enamel. 2: Mild, having whitish opaque areas that involve more tooth surface. 3: Moderate and the severe forms, having pitted and brown staining on tooth surface. 4: Tooth corrosion.¹⁰

Skeletal and dental fluorosis are considered as serious public health issues worldwide.¹³ In Asia, dental and skeletal fluorosis is prevalent in China, Sri Lanka, India and Pakistan.¹³ Pakistan has been listed among countries having greater risk of water crisis.¹⁴ Among various regions of Pakistan, Fluoride toxicity in water has been observed in Balochistan, Lahore and Gujrat, Thar Desert, Nagarparkar, Sindh, and D.I.Khan, respectively.¹⁵ Lahore, the second largest city of Pakistan, depends on groundwater for its drinking needs.¹⁶ Past studies have indicated serious violations in groundwater quality for drinking in Lahore.¹⁶ More significantly, high fluoride and arsenic levels were observed in parts of Lahore in these studies.¹⁶ Water & Sanitation Agency (WASA) Lahore, documents that groundwater levels in Lahore city are dropping every year by roughly 1 ft. of its water Table.¹⁶ It is of significant apprehension on both quality and quantity of groundwater.¹⁶

In Pakistan, even though several studies have been conducted to assess the concentration of fluoride in drinking water, literature is scarce regarding its association with dental fluorosis, especially in Lahore, Punjab. Moreover, in most of the studies carried out in Lahore, dental fluorosis has been studied and clinically examined in hospital-based settings, whereas in this study, the association between fluoride concentration and dental fluorosis has been addressed at the community level.

Methodology

This descriptive cross-sectional study was conducted across nine Towns of Lahore District from 27th September to 30th December 2022, after obtaining ethical consent from the

Institute of Public Health, Lahore (182/ME/IPH). Water samples were collected from Shalimar Town, Aziz Bhatti Town, Wahga Town, Ravi Town, Gunj Baksh Town, Gulberg Town, Iqbal Town, Nishter Town, and Jubilee Town. A list of WASA-operated tube wells in Lahore city was identified, and 100 tube wells were randomly selected using random number Tables. Samples were collected in labeled plastic bottles from running water sources to avoid turbidity. Individuals with missing teeth or undergoing orthodontic treatment were excluded. A total of 400 residents aged 25 years and above (4 individuals per area) were interviewed and clinically examined in the corresponding areas. A self-administered questionnaire was used to gather socio-demographic data, income, educational background, and details on fluoride exposure, including dose, duration, and sources. Clinical examinations were conducted using a dental mirror and probe, and dental fluorosis was scored using Dean’s Fluorosis Index. All water samples were transported to the Pakistan Council of Research in Water Resources (PCRWR) to determine fluoride concentration using the SPADNS spectrophotometric method. Each experiment was repeated three times to ensure accuracy, and the average fluoride concentration was calculated. Data were entered, cleaned, and analyzed using SPSS version 26. Frequency Tables were generated for categorical variables, and measures of central tendency were calculated for continuous data. Associations between categorical variables were tested using the Chi-square test, and means were compared using Student’s t-test or ANOVA, where applicable. Categorical data were presented using bar and pie charts.

Results

Table 1 summarizes the demographic characteristics of the study participants, including age, gender, BMI, and clinical history. Dental fluorosis was observed in 189 participants (47.3%), with 48.8% being male and 39.7% female (Table 1).

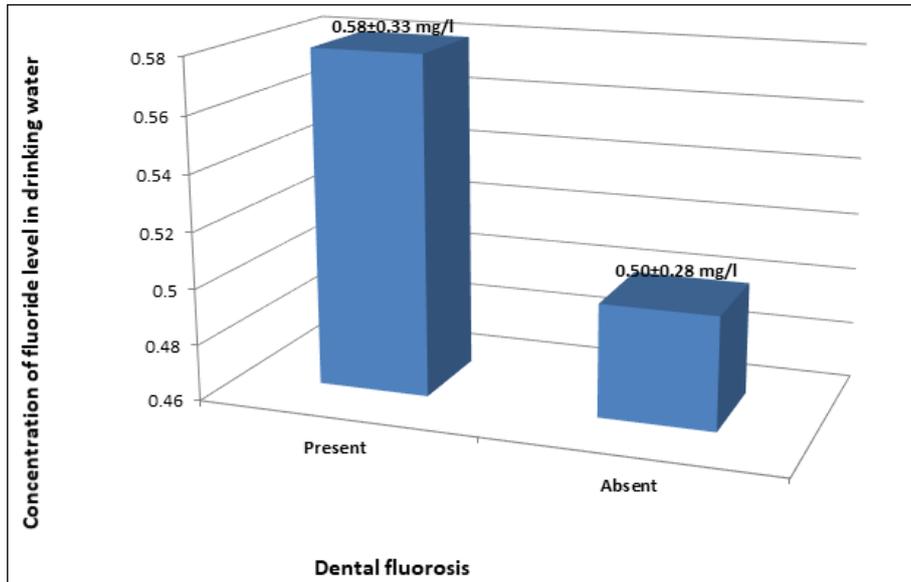
Table 1: Frequency of dental fluorosis among participants across various demographic and lifestyle variables

Variable	Dental Fluorosis				p-value
	Present		Absent		
	n	%	n	%	
Gender					
Male	162	48.8%	170	51.2%	0.171
Female	27	39.7%	41	60.3%	
Age					
25-50 years	161	47.5%	178	52.5%	0.819
Above 50 years	28	45.9%	33	54.1%	
Residence					
Permanent	110	44.9%	135	55.1%	0.24
Temporary	79	51%	76	49%	

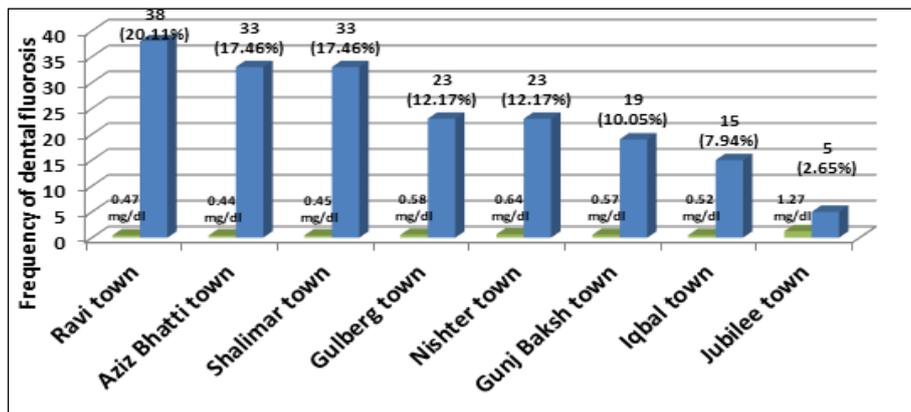
Variable	Dental Fluorosis				p-value
	Present		Absent		
	n	%	n	%	
Economic Status					
Income less than 30,000/ month	168	49.3%	173	50.7%	0.52
More than 30,000 per month	21	35.6%	38	64.4%	
Living in the Area					
More than 10 years	135	51.3%	128	48.7%	0.024
Less than 10 years	54	39.4%	83	60.6%	
Source of Drinking Water					
Tap/ Filtered Water	187	48.7%	197	51.3%	0.004
Bottled Water	2	12.5%	14	87.5%	
Source of Water for Cooking Food					
Tap/ Filtered Water	187	48.4%	199	51.6%	0.013
Bottled Water	2	14.3%	12	85.7%	
Water Consumption per Day					
2 Liters or more	183	49.5%	187	50.5%	0.002
Less than 2 Liters	6	20%	24	80%	
Usage of Fluoride Toothpaste					
Yes	161	44.6%	200	55.4%	0.001
No	28	28.2%	11	71.8%	
Acidic Beverages Consumption					
Yes	164	49.4%	168	50.6%	0.057
No	25	36.8%	43	63.2%	

Table 2: Severity of dental fluorosis among the participants using Dean’s Fluorosis Index

Severity	Dean’s Fluorosis Index	
	Frequency	Percentage
Normal (0)	211	52.7%
Questionable (0.5)	18	4.5%
Very Mild (1)	44	11%
Mild (2)	72	18%
Moderate (3)	47	11.8%
Severe (4)	8	2%
Total	400	100%



Graph 1: Concentration of fluoride in drinking water and its association with dental fluorosis



Graph 2: Town-wise Distribution of Dental Fluorosis and Mean Fluoride Levels in Drinking Water of these Towns

Discussion

This cross-sectional study evaluated the fluoride concentration in drinking water and its association with dental fluorosis across nine towns in Lahore, Pakistan. Multistage sampling was used to select towns, while convenience sampling was employed to examine 400 individuals and collect 100 water samples. Fluoride levels were measured using the colorimetric method, and dental fluorosis was assessed clinically using Dean’s Fluorosis Index. The findings revealed significant fluoride contamination in drinking water, with a high prevalence of dental fluorosis, particularly in areas with elevated fluoride levels. Statistical analysis, including Chi-square and independent t-tests, demonstrated associations between fluoride exposure and socio-demographic factors. The mean fluoride concentration for individuals with dental fluorosis was 0.58 ± 0.33 mg/L, compared to 0.50 ± 0.28 mg/L for those without fluorosis, a difference that was statistically significant (p = 0.013) (Graph 1)

Both high fluoride concentration in drinking water and dental fluorosis are serious public health concerns worldwide. A study by Rojanaworarit et al. in 2020 showed that 22% fluoride contamination has been reported in Balochistan, followed by

Punjab having 19% contamination.² Rana et al. (2020) revealed a shocking 98% prevalence of dental fluorosis in some areas of KPK.⁸ In Balochistan, fluoride concentration in drinking water is among the highest reported levels including Quetta.⁸ This leads to a possibility that there might be high prevalence of dental fluorosis among people residing in Quetta.⁸ Nilchian , Asgary, Mastan (2018) showed that the mean fluoride concentration in drinking water among female students of two towns, Behbahan district was found to be 1.3 ppm.¹⁰

Rehman et al. (2022) determined the fluoride concentration in groundwater of Isa Khel area of Punjab, ranging between 0.02 mg/l – 5.35 milligram/liter with 58.5% of the water samples having high fluoride concentration.¹⁴ This study also showed that Pakistan has been listed among countries having greater risk of water crisis.¹⁴ Among various regions of Pakistan, fluoride toxicity in water has been observed in Balochistan, Kalallan Wala and Gujarat areas of Punjab, Thar Desert, Nagarparkar in Sindh, and D.I.Khan in KPK respectively.¹⁵ Isa Khel, Mianwali, Punjab is located near Indus river. The Indus River comprises of a range of igneous and metamorphic rocks (i.e. fluoride-bearing rocks). This might be directly contributing to fluorosis in this region. Moreover, In Pakistan fluoride levels in drinking water vary widely; Peshawar had extremely low

levels of fluoride in drinking water while Tharparkar had highest levels of fluoride in drinking water.²⁰ Habiyakare T et al. in 2021 found that the prevalence of dental fluorosis in children residing in Gihaya Island, Lake Kivu (Rwanda) was 90.7%.⁴ The presence of fluoride-bearing rocks in Gihaya Island lead to high fluoride levels in groundwater. Most of the rural population there is dependent on groundwater for drinking and irrigation, causing fluorosis in both human population and livestock. Al Warawreh AM and his team in 2020 determined that the frequency of dental fluorosis was 39.9% in Southern region of Jordan (Karak city).⁵

Rana et al. (2020) conducted a comparative cross-sectional study between inhabitants and non-inhabitants of Quetta on basis of frequency of dental fluorosis. Around 71.4% of the inhabitants and 24% of the non-inhabitants had fluorosis.⁸ Quetta valley situated in Balochistan province is surrounded by mountains. These mountains consist of rocks with fluoride-bearing minerals (i.e. granite and gneisses) leading to fluoride contamination of groundwater in this region. This high fluoride concentration in groundwater of Quetta is a leading cause of dental fluorosis in this region. Yasar et al. (2021) determined the toxicity of groundwater caused by fluoride contamination in the southwestern region of Lahore and the fluoride concentration ranged between 0.25 mg/l – 21.3 milligram/liter.¹⁵

The Southwestern zone of Lahore is occupied by a number of chemical, plastic and food manufacturing industries. These industrial units have improper wastewater management. This wastewater might be polluting the groundwater in southwestern part of the city, thus increasing toxicity of groundwater. Fluoride in drinking water is not the sole cause of dental fluorosis; other sources include certain foods, toothpaste, acidic beverages, and fluoride-containing dental materials. Lahore, as a rapidly industrializing metropolitan city, faces challenges like improper waste management and environmental changes, which contaminate its groundwater. Studies have indicated an increase in fluoride and arsenic levels in Lahore's groundwater, likely caused by pollution and seasonal fluctuations. Furthermore, WASA Lahore reports that the city's groundwater levels decrease by around 1 foot per year, significantly impacting both the quality and availability of groundwater.¹⁶

However, in this study the fluoride concentration in these towns has increased, ranging from 0.44 to 1.27 milligram/liter. (Graph 2) Several industries are located in the northern and southern zones of Lahore, with the Lokhiodair Landfill site situated in the northern part of the city. The industrialization and improper waste disposal practices may be contributing to the contamination of groundwater, leading to elevated fluoride levels that exceed the WHO's recommended limit of 1.5 mg/L. Ahmed et al. in 2020 conducted a study to determine frequency of dental fluorosis among residents of Thar who were consuming water high in fluoride concentration, and it was found to be 100%.¹⁷

The Thar dessert of Sindh has high fluoride levels in groundwater. And the groundwater available for drinking purpose is through an open source (i.e. unconfined aquifers), thus leading to higher risk of water contamination. The prevalence of dental fluorosis is relatively lesser in these studies and is aligned with the frequency reported in Lahore among 189 (47.3%) participants. (Table 1) However, in Lahore prevalence of dental fluorosis is 47.3% reported in this study which is much lesser than in Thar and Quetta respectively. This difference is mainly due to geographical variation and changes in climate conditions among these regions.

Demelash in 2019 determined the mean fluoride level in groundwater of the Great Rift Valley of Ethiopia to be 6.03 mg/l and frequency of dental fluorosis was 28%.¹⁸ Shyam et al. (2021) studied that the frequency of dental fluorosis in endemic areas of Haryana (India) was 96.6%.¹⁹ Groundwater in many parts of Haryana contain high fluoride concentration and the rural population in these areas is dependent on groundwater for drinking purposes, thus increasing risk of developing fluorosis. While, in this study dental fluorosis was reported to be 47.3% among participants and out of these participants who had dental fluorosis, 48.8% were male while 39.7% were female. (Table 1) The fluoride concentration was above recommended level in only one area of Lahore (1.6 milligram/liter). Lima-Arsati YBO et al. (2018) conducted a study which showed that 19.2 were exposed to a dose equal to or over the limit of 0.07 mg F/kg who were using toothpaste.⁹ While in this study, the participants using toothpaste were 44.6% had dental fluorosis. Ahmad et al. (2021) found that 22.7% of students exhibited dental fluorosis, ranging from questionable to severe levels.¹²

Nor et al. (2018) conducted a study that demonstrated a significantly higher prevalence of dental fluorosis (Dean's score ≥ 2) among children residing in areas with high fluoride concentrations in drinking water, compared to those in areas with low fluoride levels ($P < 0.001$).²¹ Shruthi and Anil, (2018) reported that among children and adolescents living in high fluoride areas, 16.4% had moderate and 15.6% had very mild dental fluorosis, while in areas with normal fluoride levels, 5.3% and 4.3% had questionable and moderate fluorosis, respectively. Among adults in high fluoride areas, 0.8% and 0.3% had moderate and questionable fluorosis, while in the normal fluoride group, 1.3% and 0.3% had moderate and mild fluorosis.²²

In this study, dental fluorosis was reported in 189 (47.3%) participants, including 18 (4.5%) with questionable fluorosis, 44 (11%) with very mild, 72 (18%) with mild, 47 (11.8%) with moderate, and 8 (2%) with severe fluorosis according to Dean's Fluorosis Index (DFI). (Table 2) The mean fluoride concentration in drinking water was 0.54 ± 0.31 mg/L, ranging from 0.50 mg/L to 1.63 mg/L (Graph 1). Town-wise fluoride levels were as follows: 0.47 mg/dL in Ravi Town, 0.44 mg/dL in Aziz Bhatti Town, 0.45 mg/dL in Shalimar Town, 0.58 mg/dL in Gulberg Town, 0.64 mg/dL in Nishter Town, 0.57 mg/dL in Gunj Baksh Town, 0.52 mg/dL in Iqbal Town, and 1.27 mg/dL in Jubilee Town. (Graph 2). These findings highlight the urgent need for public health interventions to monitor fluoride levels, raise community awareness, and improve oral health policies, while emphasizing the importance of further research into groundwater quality and its public health implications amidst changing climatic conditions.

Conclusion

Fluoride concentration in ground water of few areas of Lahore was significantly above the recommended value, thus increasing the risk of fluorosis. Dental fluorosis was reported among 47.3% of the participants. In this study fluoride intake through drinking water source was found to be the primary cause of fluorosis.

Limitations

This study did not cover the whole city of Lahore, but a few towns, because of the limited time span. Moreover, this study

was community based and dental fluorosis was clinically examined among participants using oral examination set and by recording its concentration in drinking water, while other sources of dental fluorosis were not addressed.

Recommendations

The groundwater quality must be regularly monitored by government and water sanitation agencies operating in the city. For prevention of dental fluorosis community awareness and education regarding effects of fluoride on dental health and general health must be provided at individual as well as community level. Government should develop policies like Reverse Osmosis plant installation in fluoride endemic areas, screening areas with higher than recommended fluoride limit and monitoring fluoride exposure sources other than water etc. by ensuring water safety and referring people encountering dental fluorosis to dentists to meet their treatment needs. Further research like longitudinal study must be done among children and adults to study their behavior, pattern and effect of dental fluorosis and high fluoride levels in drinking water of those areas with high fluoride concentration.

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References

- Khan F, Sabiha Z ul A, Ajmal A, Shawana M, Khurshid AA, Ahmed J. Prevalence of Dental Fluorosis amongst patients attending the tertiary care hospital, Peshawar, Pakistan: Prevalence of Dental Fluorosis amongst Patients. *Pakistan Biomedical Journal*.2022;5(3):23-7.DOI: 10.54393/pbmj.v5i3.31.
- Rojanaworarit C, Claudio L, Howteerakul N, Siramahamongkol A, Ngerthong P, Kongtip P et al. Hydrogeogenic fluoride in groundwater and dental fluorosis in Thai agrarian communities: a prevalence survey and case-control study. *BioMed Central Oral Health*. 2021; 21(1):1-6. DOI: 10.1186/s12903-021-01902-8.
- Aggeborn L, Öhman M. The Effects of Fluoride in Drinking Water. *Journal of Political Economy*. 2021; 129(2): 465-91. DOI: 10.1086/711915.
- Habiyakare T, Schurer JM, Poole B, Murcott S, Migabo B, Mardochee B, Amuguni JH et al. Dental fluorosis among people and livestock living on Gihaya Island in Lake Kivu, Rwanda. *One health outlook*. 2021; 3(1):1-9. DOI: 10.1186/s42522-021-00054-7.
- Al Warawreh AM, Al Tamimi ZH, Al Qatawna MI, Al Momani AA, Al Mhaidat MR, El Naji WS, et al. Prevalence of dental fluorosis among Southern Jordanian population. *International Journal of Dentistry*. 2020; 2020(8890004):1-7 DOI: 10.1155/2020/8890004.
- Shahroom NS, Mani G, Ramakrishnan M. Interventions in management of dental fluorosis, an endemic disease: A systematic review. *Journal of Family Medicine and Primary Care*. 2019;8(10):3108-13.DOI:10.4103/jfmpe.jfmpe_648_19.
- Razvan C, Popa M, Incze AM, Cristina C. The correlation between the mineral drinking water composition and the relevance of dentine in health – A pilot study. *Pakistan Journal of Medical Sciences*. 2020;36(3):349-54. DOI:10.12669/pjms.36.3.1820.
- Rana NA, Jan A, Khan HM. Comparison of dental fluorosis between residents and non-residents of Quetta. *Pakistan Armed Forces Medical Journal*. 2020;70(2):617-21.
- Lima-Arsati YBO, Gomes ARLF, Santos HKA, Arsati F, Oliveira MC, Freitas VS. Exposure to fluoride of children during the critical age for dental fluorosis in the semiarid region of Brazil. *Ciencia & Saude Coletiva*. 2018; 23(4):1045-54. DOI: 10.1590/1413-81232018234.07952016.
- Nilchian F, Asgary I, Mastan F. The effect of dental fluorosis on the quality of life of female high school and precollege students of high fluoride-concentrated area. *Journal of International Society of Preventive & Community Dentistry*. 2018 Jul; 8(4):314-9. DOI:10.4103/jispcd.JISPCD_94_18.
- Idon PI, Ikusika OF, Sotunde OA, Ogundare TO. Are there associations between the occurrence of dental fluorosis and the experience of dentine hypersensitivity? A Cross-sectional Study. *Nigerian Postgraduate Medical Journal*. 2022; 29(2):161-6. DOI: 10.4103/npmj.npmj_7_22.
- Ahmad F, Anwaar A, Mirza B A Q, Qadeer M, Afzal M, Alam A. Is Dental Fluorosis More Prone/ Susceptible to Tooth Erosion? *Pakistan Journal of Medical & Health Sciences*. 2021;15(8):2067-9. DOI: 10.53350/pjmhs211582067.
- Dávila OG. Dental Fluorosis in Children from Aguascalientes, Mexico: A Persistent Public Health Problem. *Water*. 2021 Apr; 13(8):1125. DOI: 10.3390/w13081125.
- Rehman F, Siddique J, Shahab A, Azeem T, Bangash AA, Naseem AA, et al. Hydrochemical appraisal of fluoride contamination in groundwater and human health risk assessment at Isa Khel, Punjab, Pakistan. *Environmental Technology & Innovation*. 2022; 27(102445):1-13. DOI: 10.1016/j.eti.2022.102445.
- Yasar A, Javed T, Kausar F, Shamshad J, Hayat Khan MU, Iqbal R. Ground water toxicity due to fluoride contamination in Southwestern Lahore, Punjab, Pakistan. *Water Supply*. 2021; 21(6):3126-40. DOI:10.2166/ws.2021.084.
- Abbas Z, Mapoma HW, Su C, Aziz SZ, Ma Y, Abbas N. Spatial analysis of groundwater suitability for drinking and irrigation in Lahore, Pakistan. *Environmental Monitoring and Assessment*. 2018; 190(7):1-6. DOI: 10.1007/s10661-018-6775-3.
- Ahmed I, Ali A, Zaheer M, Fatima I, Khan N. Frequency of dental fluorosis in population drinking water with high fluoride level in Thar. *Journal of the Pakistan Dental Association*. 2020; 29(4):259-63. DOI: 10.25301/JPDA.294.259.
- Demelash H, Beyene A, Abebe Z, Melese A. Fluoride

- concentration in ground water and prevalence of dental fluorosis in Ethiopian Rift Valley: Systematic Review and Meta-Analysis. *BioMed Central Public Health*. 2019; 19(1):1-9. DOI: 10.1186/s12889-019-7646-8.
19. Shyam R, Manjunath BC, Kumar A, Narang R, Rani G, Singh S. Prevalence of dental fluorosis and treatment needs among 11-14 years old school children in endemic fluoride areas of Haryana, India. *Indian Journal of Dental Research*. 2021; 32(1):110-14. DOI: 10.4103/ijdr.IJDR_835_18.
 20. Rafique T, Naseem S, Usmani TH, Bashir E, Khan FA, Bhanger MI. Geochemical factors controlling the occurrence of high fluoride groundwater in the Nagar Parkar area, Sindh, Pakistan. *Journal of Hazardous Materials*. 2009;171(1-3):424-30. DOI: 10.1016/j.jhazmat.2009.06.018
 21. Mohd Nor NA, Chadwick BL, Farnell DJ, Chestnutt IG. The impact of a reduction in fluoride concentration in the Malaysian water supply on the prevalence of fluorosis and dental caries. *Community Dentistry and Oral Epidemiology*. 2018; 46(5):492-9. DOI: 10.1111/cdoe.12407.
 22. Shruthi MN, Anil NS. A comparative study of dental fluorosis and non-skeletal manifestations of fluorosis in areas with different water fluoride concentrations in rural Kolar. *Journal of Family Medicine and Primary care*. 2018; 7(6):1222-28. DOI: 10.4103/jfmpe.jfmpe_72_18.