

Original Article

The effect of water fluoride concentration on dental caries and fluorosis in five Iran provinces: A multi-center two-phase study

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ABSTRACT

Background: Water fluoride level is unknown in many regions of Iran. Besides, only few non-controlled studies world-wide have assessed the effect of water fluoride on dental fluorosis and caries. We aimed to measure the fluoride level of 76 water supplies in 54 cities and evaluate the effect of fluoride on dental caries and fluorosis in a large multi-project study.

Materials and Methods: In the first phase (cross-sectional), fluoride levels of 76 water tanks in 54 cities/villages in five provinces of Iran were randomly evaluated in five subprojects. In the second phase (retrospective cohort), 1127 middle school children (563 cohort and 564 control subjects) in the high and low ends of fluoride concentration in each subproject were visited. Their decayed, missing and filled teeth (DMFT) and fluorosis states were assessed. The data were analyzed using Chi-square, Mann-Whitney U and independent-samples t-test ($\alpha = 0.05$).

Results: Mean fluoride level was 0.298 ± 0.340 mg/L in 54 cities/villages. Only eight water tanks had fluoride levels within the normal range and only one was higher than normal and the rest (67 tanks) were all at low levels. Overall, a significant association was observed between fluoride level and fluorosis. However, this was not the case in all areas, as in 2 of 5 provinces, the effect of fluoride on fluorosis was not confirmed. In 4 of the 5 areas studied, there was a significant link between fluoride level and DMFT.

Conclusion: Extremely low fluoride levels in Iran cities are an alarming finding and need attention. Higher fluoride is likely to reduce dental caries while increasing fluorosis. This finding was not confirmed in all the areas studied.

Key Words: Community fluorosis index, Dean's fluorosis index, dental caries, dental fluorosis, water fluoride

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INTRODUCTION

Fluoride is one of the very few chemicals that can leave significant effects on human health through drinking water.^[1,2] Different forms of fluoride exposure have shown to affect systemic fluoride content, thus increasing the risk of fluoride-prone diseases.^[1,3] At low concentrations (<1.0 mg/L),

drinking water fluoride has positive effects on teeth such as preventing or decreasing the risk of dental caries,^[1,3-6] which is one of the main concerns of dentists. This ion might prevent the occurrence of new caries and even might allow recovery of some small cavities. Fluoride influences the process of dental caries formation through three ways: Improvement of the enamel chemical structure during its development and making it more resistant to acid attack, facilitation of mineralization with an improved quality of enamel crystals and reduction of the ability of plaque microorganisms to produce acid.^[1,3,5] However, too much fluoride (higher than 1.5-2 mg/L) ingested for longer durations can cause dental fluorosis.^[1,2,4-7]

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The results pertaining to the effect of fluoride on caries prevention are controversial,^[8-14] possibly since the effect of fluoride can be altered by some factors. These include climate, total dissolved solids, the chemical composition and porosity of the rocks, temperature, pH, availability and solubility of fluoride minerals, velocity of flowing water, concentration of calcium and bicarbonate ions in water, lack of calcium/vitamins/proteins and consumed foods.^[1,2,5-7,15-17]

Both dental caries and fluorosis are public health problems world-wide.^[5-7,9] Endemic fluorosis resulting from high fluoride concentration in water can be a major public health issue,^[9] to the extent that many western European countries have halted fluoridation of water supplies in order to prevent exacerbating it.^[6] Since no cure exists, prevention is the only available treatment.^[5]

Monitoring the concentration of fluoride in different areas might help to establish proper preventive measures. Due to the effects of fluoride on health, fluoride levels in water supplies have been the subject of various recent studies.^[4] High levels of fluoride in drinking water have been observed in India, Turkey, Pakistan and China.^[1,9] Several districts of Iran have been evaluated in this regard.^[4,7,14,18-31] However, some major areas like Mazandaran and Lorestan provinces have not been assessed before.^[18] Given the importance of the continuous maintenance of fluoride levels within recommended limits,^[12] one of the three goals of this study was to evaluate five provinces including many overlooked cities. Moreover, to the best of our knowledge, there is no controlled studies on associations between fluoride levels and both fluorosis and caries. The four existing non-controlled studies were mostly small-scale (such as with 120 participants) and/or had evaluated only fluorosis or caries (and all were non-controlled).^[4,9,13,32] The second aim of this study was to compare the dental condition (decayed, missing and filled teeth [DMFT] and fluorosis) of people living in low-, normal- and high-fluoride areas and find potential links between water fluoride concentration and caries and/or fluorosis.

MATERIALS AND METHODS

This study was done in two phases. In the first phase (descriptive cross-sectional), the fluoride level was estimated in water samples taken from 76 tanks of 54 cities or rural districts in Iran. In the second

phase (retrospective cohort), the frequency of dental decays and fluorosis were compared in areas with the highest and lowest fluoride levels in each project. The students consisted of 563 cohort subjects from areas with fluoride levels higher or lower than normal in each project and 564 control subjects from areas in the same project that had normal levels of fluoride. The sample size for each project was determined based on earlier studies in the literature. The sampling was carried out using the multi-step random sampling method. First, list of schools for boys and girls was prepared. Then, some of them were selected using the cluster sampling method. Afterwards, using stratified sampling method, the list of students at each grade was determined and then using simple random sampling method, students were selected. The schools were middle schools (and in one project, the primary schools) in each city/village of interest. The inclusion criteria were having posterior teeth and being habitant of the test region. Ethical approval for the study was obtained from the Research Committee of the Dental Branch of Tehran, Islamic Azad University.

Water was sampled from the city water supplies. The fluoride concentration was measured using a calibrated potentiometer device. After categorizing the areas in each province to low- and high-fluoride areas, DMFT and prevalence of fluorosis was estimated in middle school students of those areas according to standard indices, by 5 last-year dental students, calibrated, trained and tested by an experienced specialist academician in pediatric dentistry. The examinations were performed using dental mirrors, disposable dental explorers and under the light.

Dental caries and its care were counted when any of the teeth fell into the category of decayed, decayed and filled, or missing due to caries (DMFT).^[9,13] The D index was considered positive if a discoloration (or decay) was seen on the tooth surface and the enamel was undermined or soft. Otherwise, even if there was doubt about it, the tooth would be considered intact. The M index indicated teeth missing due to extraction, or teeth which must be extracted. The F index indicated a filled tooth with no secondary caries observed around the restoration or on the tooth.

Dental fluorosis was graded using Dean's index; the grading for dental fluorosis was done as: Questionable (Grade 1), very mild fluorosis (Grade 2), mild fluorosis (Grade 3), moderate fluorosis (Grade 4) and severe fluorosis (Grade 5).^[4,9,13,32] In addition, the

community fluorosis index (CFI) was calculated for each area, based on the Dean's indexes: The scores 0.5, 1, 2, 3 and 4 were assigned to Dean's 1-5 grades, respectively. Afterwards, the total score for each area was calculated. It was then divided by the number of subjects examined in each area, in order to calculate the CFI.

Demographic information was also acquired.

The areas studied were as follows:

1. Kerman province: All 17 cities in Kerman province were assessed in the first phase: Zarand, Ravar, Sirjan, Bam, Anar, Manoojan, Kahnooj, Shahr Babak, Baft, Ghal Ganj, Koohbanan, Jiroft, Kerman, Anbar Abad, Bardsir, Roodbar Jonub and Rafsanjan
 - In the second phase, DMFT and fluorosis was documented in two cities with the highest and lowest water fluoride concentrations: Zarand ($n = 171$) and Rafsanjan ($n = 210$)
2. Khorasan province: 22 cities and villages in Razavi Khorasan province were assessed in the first phase: Mashhad, Neishaboor (2 districts), Sabzevar, Kashmar, Torbat Heidarieh, Mehvalat, Gonabad, Dargaz, Taht Jolgeh, Khalil Abad, Taibad, Sarakhsh, Khaf, Chenaran, Zaveh, Torghabeh, Kashmar, Kalat, Torbat Heidarieh, Fariman, Torbat Jam, Ghoochan, Shandiz, Rashtkhar
 - In the second phase, the DMFT and fluorosis was compared in two cities with the lowest and highest fluoride concentrations: Mahvelat ($n = 88$) and Neishaboor ($n = 110$)
3. Qazvin province: Two villages: Najm Abad ($n = 38$) and Zoyar ($n = 92$) were evaluated in terms of fluoride concentration and in the second phase, regarding its effect on DMFT and fluorosis
4. Lorestan province: All the nine cities in Lorestan province were evaluated. A total of 30 water tanks were evaluated in the cities Khoramabad (12 tanks), Pole Dokhtar, Dorood (5 tanks), Azna (3 tanks), Koohdasht, Borujerd (4 tanks), Noorabad (2 tanks), Aligoodarz and Alshotor
 - In the second phase, DMFT and fluorosis were compared in Pole Dokhtar ($n = 100$) against Borujerd ($n = 60$)
5. Mazandaran province: Three villages in Savad Kooh: Pole Sefid ($n = 166$), Zirab and Versk ($n = 92$) were evaluated in terms of fluoride concentration and its effect on DMFT and fluorosis in the second phase.

Statistical analysis

Descriptive statistics were calculated for fluoride and demographic data. Frequency distributions of districts with high (>1.2 mg/L), normal (0.6-1.2 mg/L), or low fluoride levels (<0.6 mg/L) were calculated in all the cities and in each area. Data were analyzed using independent-samples t , Mann-Whitney U and Chi-square tests of SPSS software (version 16, SPSS Inc., Chicago, IL, USA). The level of significance was predetermined as 0.05.

RESULTS

The results pertaining to 76 tanks in 54 cities/villages of Iran showed that mean fluoride level was 0.298 ± 0.340 mg/L in these provinces (95% confidence interval [CI] = 0.220-0.376 mg/L). Of all the tanks, only eight were within the normal range and only one was higher than normal and the rest (67 tanks) were all at low levels [Figure 1]. The control and cohort subjects were not significantly different in terms of age and parental education status ($P > 0.05$), except in Lorestan.

There were 428 (77.4%), 6 (1.1%), 75 (13.6%), 33 (6.0%), 9 (1.6%) and 2 (0.4%) individuals according to the Dean's categories "normal to very severe" (normal to Grade 5 of fluorosis) in the control groups with higher concentrations of fluoride. These statistics were 502 (89.0%), 0, 53 (9.4%), 0, 9 (1.6%) and 0 people in the categories "normal to very severe fluorosis" in the cohort groups with lower fluoride levels. The difference between the distributions of the fluorosis condition was significant according to the Chi-square ($P < 0.001$), indicating a slightly, but significantly higher occurrence of fluorosis in districts with high fluoride levels.

Kerman province

The mean fluoride concentration was 0.35 ± 0.22 mg/L (95% CI = 0.24-0.46 mg/L). Only one city had normal fluoride and the rest had low fluoride concentrations [Figure 1].

Zarand and Rafsanjan had the highest and lowest fluoride concentrations, respectively. Therefore, 171 students from Zarand (43.3% females) and 210 students from Rafsanjan (47.1% females) were sampled from middle schools, which were randomly selected.

DMFT scores and fluorosis conditions were not different in the two cities [Table 1].

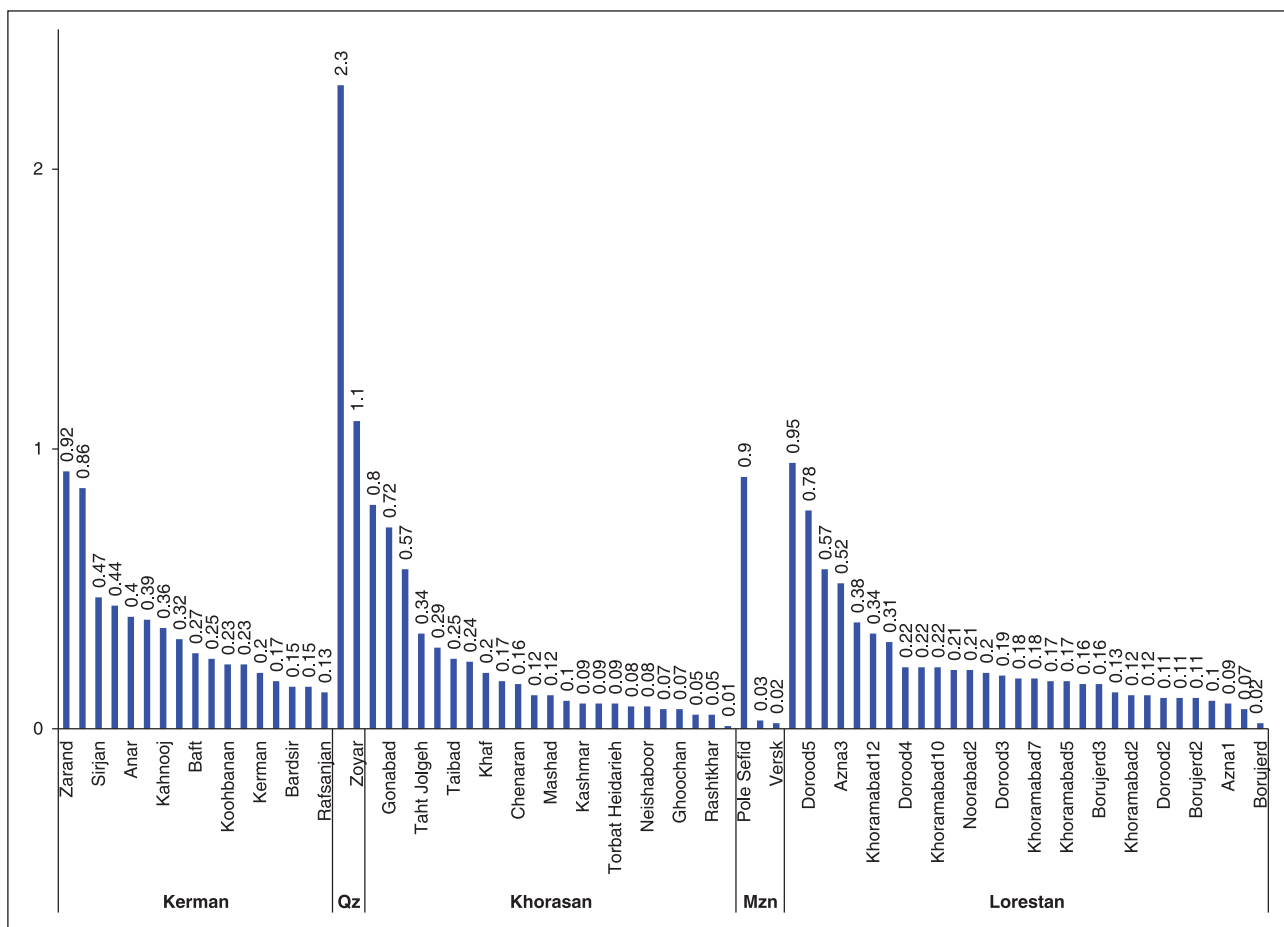


Figure 1: Fluoride concentrations in city water supplies in descending orders for each province. Mzn = Mazandaran; Qz = Qazvin

Khorasan province

The mean fluoride concentration was 0.33 ± 0.49 mg/L (95% CI = 0.13-0.53 mg/L). Three cities had normal fluoride and one had high fluoride. The rest were low-fluoride districts [Figure 1].

This province was studied during two subprojects:

From the 22 cities, Neishaboar and Mahvelat were picked as the lowest and highest fluoride concentrations. A group of 110 students from Neishaboar (46.4% females) and 88 students from Mahvelat (61.4% females) were selected. It was shown that fluoride significantly affects DMFT and fluorosis [Table 1].

Qazvin province

By doing a comparison between the cohort and control groups in villages with high and normal fluoride, it was shown that high fluoride can cause fluorosis while reducing DMFT [Table 1].

Lorestan province

The mean fluoride concentration was 0.24 ± 0.21 mg/L (95% CI = 0.16-0.32 mg/L). The fluoride level was

normal in two tanks from two cities. However, the other tanks as well as other cities had low fluoride levels [Figure 1].

It was found that Pole Dokhtar had the highest fluoride level and Brujerd had the lowest one. Therefore, 100 students were examined in Pole Dokhtar and 60 students were examined in Borujerd. Demographic comparisons showed significantly better life conditions in Pole Dokhtar in terms of smaller family size and the level of parents' education (Chi-square $P < 0.005$).

There were significant differences between the fluorosis prevalence rates in the two cities. Furthermore there were significant differences between the DMFT indices [Table 1].

Mazandaran province

The mean fluoride concentration was 0.32 ± 0.51 mg/L [Figure 1]. One city had normal fluoride and the other two had low fluoride concentrations. Comparing the available extremes (normal with low levels of fluoride) showed that DMFT associates significantly with fluoride [Table 1].

Table 1: Net distribution of fluorosis and mean DMFT values distinguished according to water fluoride in each province, as well as the results of the statistical tests

Province	Fluorosis (Dean's grades)						CFI	DMFT	D	M	F
	Normal	1	2	3	4	5					
Kerman											
Zarand (high F) (n=171)	165	0	0	4	2	0	0.08	3.24±2.10	2.4±1.8	0.01±0.01	0.48±1.0
Rafsanjan (low F) (n=210)	210	0	0	0	0	0	0.00	2.75±2.07	2.6±2.1	0.07±0.26	0.45±1.1
P value			>0.4***					>0.4*	>0.3*	0.001*	>0.5*
Khorasan											
Mahvelat (normal F) (n=88)	54	0	21	0	0	2	0.33	4.44±2.1	3.8	1.2	0.5
Neishaboore (low F) (n=110)	48	0	53	0	9	0	0.73	5.14±2.9	4.2	2.1	1.2
P value			<0.001***					<0.05**			
Qazvin											
Najm Abad (high F) (n=38)	10	6	14	8	0	0	0.87	5.7±2.4	5.2±2.4	0.5±0.7	0.1±0.6
Zoyar (normal F) (n=92)	92	0	0	0	0	0	0.00	4.2±2.6	4.1±2.7	0.44±0.89	0.16±0.63
P value			<0.001***					<0.002*	<0.03	>0.05	>0.05
Mazandaran											
Pole Sefid (normal F) (n=166)	166	0	0	0	0	0	0.00	4±3*	4±2.8*	0.2±0.6*	0.05±1.5*
Zirab+Versk (low F) (n=92)	92	0	0	0	0	0	0.00	4.7±2.9	9.5±2.4	0.7±1.1	0.7±1.7
P value			>0.9***					<0.01*	<0.0001*	<0.005*	<0.2*
Lorestan											
Pole Dokhtar (normal F) (n=100)	33	0	40	21	7	0	1.03	1.54±1.54	5.96±1.63	0.96±1.21	0.06±0.3
Borujerd (low F) (n=60)	60	0	0	0	0	0	0.00	6.25±2.63	1.33±1.33	0.01±0.1	0.1±0.5
P value			<0.0001***					<0.0001**	<0.0001*	<0.0001*	>0.5*

*t-test; **Mann-Whitney U-test; ***Chi-square test. CFI: Community fluorosis index; DMFT: Decayed, missing and filled teeth

DISCUSSION

This study showed that the fluoride concentration of many cities was lower than the minimum recommended value, which is 0.5-0.7 mg/L.^[4,18,32,33] This was consistent with most of other areas researched in Iran,^[4,7,14,18-26] which although all were ≥ 0.01 mg/L (as the minimum necessary level),^[12] many could lead to increased caries (as <0.5-0.6 mg/L).^[1] Sufficiently high and low fluoride levels could affect fluorosis prevalence (which was statistically confirmed in 3 out of the 5 studied areas). Furthermore, there was a significant link between the fluoride level and DMFT in 4 out of the 5 provinces. Our findings were consistent with the literature stating that natural fluoride ion concentrations in water higher than 0.01 mg/L are associated with decreased numbers of teeth with caries.^[12]

Dental caries was less frequent in high fluoride areas in this study, suggesting fluoride's protective effect.^[1,3-6,9] Similar findings and higher prevalence of fluorosis were observed earlier in Africans, Americans, Canadians, Japanese, Indians, Brazilians, Mexicans, Algerians, Chinese, Egyptians, Jordanians,

Libyans, Moroccans, Turks, New Zealanders and Iranians,^[2,4,5,7-9,12,13,18,32,34] with India having the broadest fluoride-rich areas, forming 14% of total fluoride deposits on earth.^[4,32] Dental caries can be prevented by improving the oral hygiene, modifying the diet, or local treatments such as local fluoride application,^[35-37] whereas the only way to prevent fluorosis is a reduction of systemic fluoride exposure.^[9,10] However, the results are controversial. For instance, high concentrations of fluoride in drinking water in Namibia and Iran (Bushehr) did not result in acceptable caries levels.^[9,11,14] Our findings showed that although fluoride can affect DMFT, it is not always the case. For instance, Zarand and Rafsanjan did not show a significant difference in their DMFT.

This study was limited by some factors. Similar to many other studies, there was an absence of radiographs which is necessary for detecting early caries. Previous studies might have ignored this factor due to the difficulty of this method, especially in rural areas and especially in large-scale studies. Another limitation was the similarity of different levels of fluorosis. Moreover, the sampling was done in

summer, while it is known that fluoride concentration can differ from season to season. Thus, the results cannot be generalized to other seasons. Moreover, the amount of fluoride received from other sources was not controlled in this research. The most important factor of endemic fluorosis is the total fluoride,^[1,12,13,33] which is virtually impossible to estimate.^[6] People living in modern societies are increasingly mobile, making studies of chronic exposure to environmental factors somehow impossible,^[9] while in rural areas, it might be less.^[2] While noticing the effect of fluoride in drinking water on dental fluorosis, a confounder may be residents who move between areas with different levels of fluoride.^[9] Since most areas were small cities or villages, our results were less likely affected by this factor. Besides, the age of the assessed subjects was rather low. Hence, there was a short period of time between development of all the permanent teeth (which could last at least until the age of 9 for premolars)^[38,39] and the age of inclusion in this study. Moreover, the rather large sample of this study might partly rule out the possibility of such an influence. Future studies should estimate inter-observer agreements for such large-scale studies. Potentiometry used in this study might be advantageous over the spectrophotometry method.^[40] In addition, this study was benefited from two phases, several subprojects, high numbers of control and cohort subjects and numerous areas assessed. Finally, future studies should use community periodontal index probes suggested by World Health Organization in 1997 for clinical examinations of DMFT, instead of disposable dental explorers.^[41]

CONCLUSION

Within the limitations of this study, it could be concluded that most cities studied had inadequate fluoride levels and needed attention by health authorities. Sufficiently low fluoride concentrations might increase DMFT, while its very high amounts might increase fluorosis. Future studies should aim to find the cut-off point for optimum fluoride level in Iran.

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