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RISK ASSESSMENT OF FLUORIDE IN DRINKING WATER AND CORRELATION WITH CHILDREN'S INTELLIGENCE QUOTIENT IN RURALS OF BUSHEHR PROVINCE

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ABSTRACT: Excessive fluoride (F) intake during infancy and early childhood causes some irreparable structural and functional changes in memory, learning and intellectual deficits. The aim of this study was risk assessment of F in drinking water and correlation with children's Intelligence Quotient in rurals of Bushehr province. This cross-sectional study was conducted among 8–12-years-old school children of 12 rurals (30 points) in Bushehr province, Iran on 140 children. The F levels were determined by using UV-Vis Shimadzu (UV-1601, PC) spectrophotometer. Children's intelligence was measured using the Raven's Standard Progressive Matrices. Data was statistically analyzed using the ANOVA test and Pearson correlation by Statistical Analysis Software (SPSS v. 23). The mean concentration of F was ranged from 0.55 to 8.63 mg/l. Most of the children's who were assessed were in categories D and E of Raven's Test. There are a negative and significant correlation between the IQ and F concentration level in drinking water (r= –0.279, p-value= 0.002). But, no significant correlation observed between the IQ and sex of children's (r= –0.084, p-value= 0.361). Results supports that children exposed to F are at risk for impaired development of intelligence. For the benefit and health of future generations, immediate and basic attention needs to be focused on this significant public health problem.

Keywords: Fluoride, Drinking water, Intelligence Quotient, Children, Bushehr.

INTRODUCTION

Fluoride (F) has both useful and adverse effects on human's beings [(1-4)]. The safe dose range of F can prevent dental caries [(5, 6)], and it is favorable to bone metabolism as a crucial trace element in the human body [(7)]. Evidences have shown that long term exposure to immoderate F will not only increase the risk of dental fluorosis and skeletal [(8, 9)], but also influence gene and protein expression, enzyme activity and induce oxidative stress [(10)]. The effects of F on the nervous system have been proved in intellectual development of mice [(11)]. Previous studies show that F can result in structural changes in the brain which affect the mental development, learning disorders, and decrease intelligence and hyperactivity in children during cognitive stages, such as learning and memory, specifically in the fetal and first 8 years of life [(12-18)]. On the other hand, some studies did not show significant correlation trend or between F and the intelligence quotient (IQ) of children [(19-21)]. Because of the different populations and areas in previous studies, the conclusion that excessive F causes loss of children's IQ still lacks strong evidence [(22)].

Geographically, Bushehr province rests on a high-fluoride belt and showcases fluorosis of endemic origin in Iran. The rurals of Bushehr province mostly use the wells as drinking water source and these sources had high concentration of F levels. Due to the hot and dry climate and the special geographical location of Bushehr province, the per capita water consumption is relatively high. Therefore, investigating the harmful effects of F on the inhabitants of this province is important. To the best of our knowledge, there is no literature published, which shows that F

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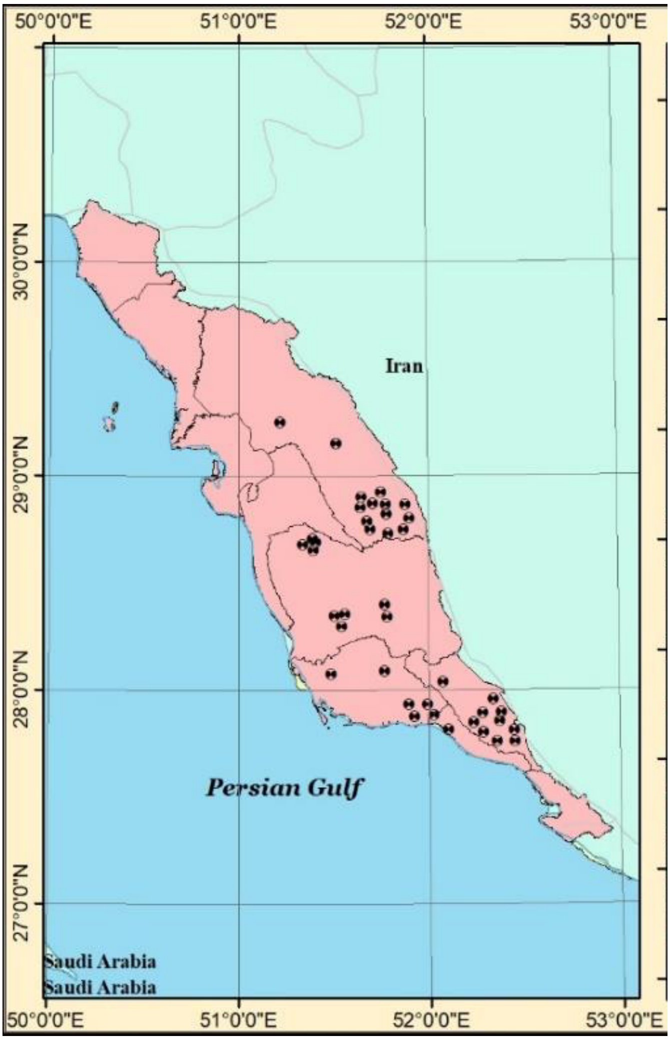
exposure has an effect on the intellectual function of children in Bushehr province. Hence, this study was undertaken to answer the lack of knowledge about F concentrations in drinking water and to assess and correlate the varied levels of F in ingested water on the IQ of children aged 8–12 years in Bushehr province, Iran.

MATERIALS AND METHODS

This cross-sectional study was conducted among 8–12 years old school children of 12 rurals in Bushehr province, Iran and the number of children studied was 140. Participation in the study was voluntary. Informed consent for the same was obtained from the parents and respective school authorities. Inclusion criteria were children who were permanent/continuous residents of the areas and drinking ground water since birth, and children who shared like socioeconomic condition. From each sampling point (Figures 1A and 1B).

1A

Figure 1A. Location of study area.



1B

Figure 1B. Location of sampling points.

A sample of 200 ml of drinking water was collected in a polyethylene bottle from water wells in different rurals and were brought to the laboratory in an icebox to retain majority of its physical, chemical and biological characteristics. The water samples were analyzed for F levels by using the sodium-2-arasulphophenylazo-1-8-dih ydroxy-3, 8 naphthalene disulphonate (SPADNS) by UV-Vis Shimadzu (UV-1601, PC) spectrophotometer

Children's intelligence was measured using the Raven's Standard Progressive Matrices [23]. The IQ test was conducted in the school classrooms. Each child had an independent desk. Students completed the answer sheets independently under the supervision of trained investigators and consistent with the protocol of the Combined Raven's Test. The classification basis for children's IQ were excellent (IQ scores ≥130), superior (IQ scores 120–129), high normal (IQ scores 110–119), normal (IQ scores 90–109), dull normal (IQ scores 80–89), marginal (IQ scores 70–79) and retarded (IQ scores ≤69) [24]. Data was statistically analyzed using the ANOVA test and Pearson correlation test was used to determine the correlation between F and IQ by Statistical Analysis Software (SPSS v. 23). p-value <0.05 was considered statistically significant.

RESULTS AND DISCUSSION

The study was conducted in school children in Bushehr province with a mean age of 10.6 ± 1.40 years, 47.5% were female and 52.5% were male. The mean, standard deviation, minimum and maximum amount of F in water samples are provide in Table 1. The mean concentration of F was ranged from 0.55 in Tang-e-eram to 8.63 mg/l in Dayyer. Rurals that standard deviation is zero, only one well was sampled. Also there was a significant difference between F concentrations among the rurals (p-value<0.0001).

Table 1. The mean, standard deviation (SD), minimum and maximum amounts of F in water samples (mg/l)

Rurals	Max (mg/l)	Min (mg/l)	Mean (mg/l)	SD	p-value
Abdan	4.9	1.36	3.84	0.56	
Anarestan	3.22	0.55	1.56	0.45	
Kangan	5.61	2.9	3.9	0.30	
Borazjan	3.15	0.95	1.83	0.41	
Kaki	2.9	1.72	2.21	0.61	
Shonbeh	3.44	2.36	3.4	0.06	<0.0001
Boushigan	1.48	0.24	0.83	0.34	
Barde khoon	3.8	2.74	3.27	0.75	
Dayyer	8.9	8.2	8.63	0.38	
Jam	0.93	0.39	0.62	0.19	
Khormuj	3.34	0.62	2.4	0.86	
Tang-e-Eram	0.59	0.52	0.55	0.05	

Figure 2 shows the comparison of the average of F concentration levels in drinking water of selected rurals with WHO standard. As shown, the mean concentrations of F in Dayyer, Bardekhoon, Shonbeh, Kaki, Abdan, Borazjan, Kangan and Khormuj rurals, were more than the mean value of WHO standard (1.5 mg/l). The mean amount of F in the water samples of Dayyer rural is significantly high.

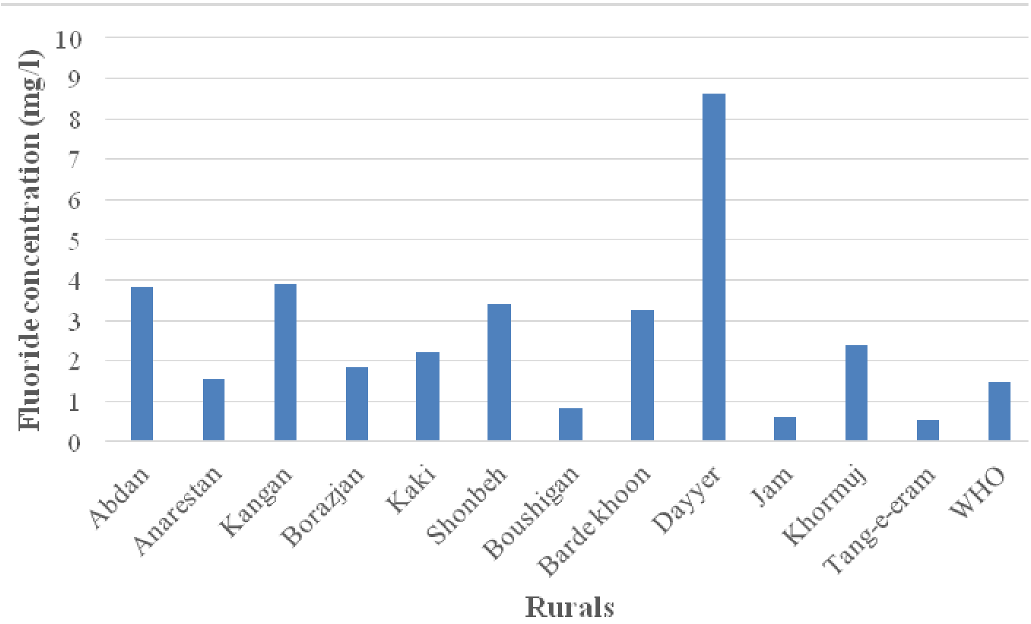
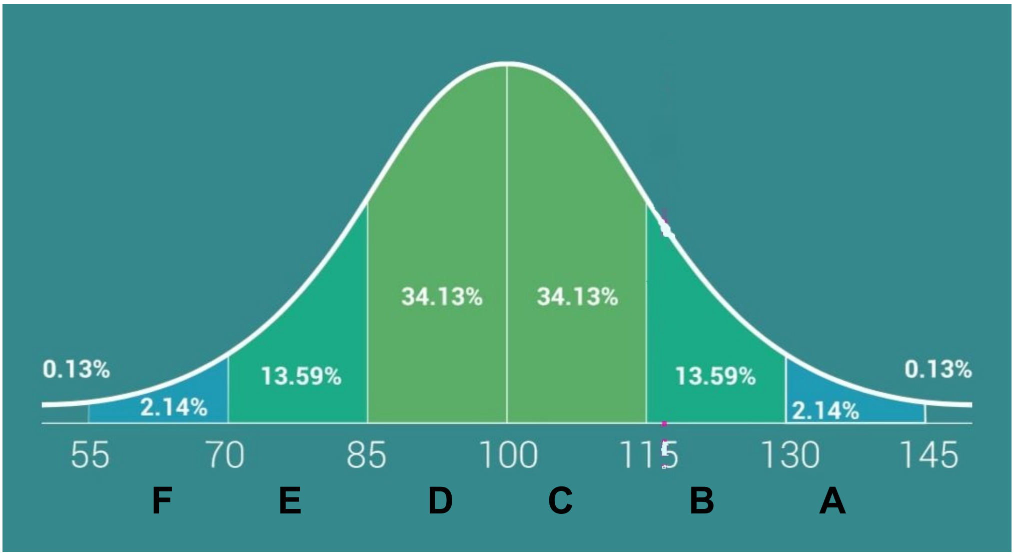


Figure 2. Comparison of F concentrations in drinking waters of rural areas in Bushehr province with WHO standard of 1.5 mg/l.

IQ was rated qualitatively for each child after the Ravens Test and belonged in the categories from B to F. As shown in Figure. 3, Kangan and Shonbeh rurals have the highest number of children with relatively low IQ (category E) (6 cases). Also, Kangan and Abdan rurals, which use wells No. 11 and 1, respectively, have two cases in F category. Also, in Jam (Chah Norouzi) and Kangan (well No. 1), one case was in category B. In general, most of the children who were assessed were in categories D and E.



≤69 70–85 85–100 100–115 115–130 ≥130

Figure 3. Different IQ classes and percentage of children in each class for a normal population.

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The F ecological risk values for different stations were calculated by considering toxicity factor, bio-production and toxicity response factor (Table 2).

Table 2. The F risk factor values (F-values) in rurals

Rural	F-value
Abdan	31.44
Anarestan	2.03
Kangan	33.76
Borazjan	10.06
Kaki	16.6
Shonbeh	28.22
Boushigan	0.73
Barde khoon	26.5
Dayyer	82.85
Jam	1.34
Khormuj	17.4
Tang-e-Eram	0.66

Table 3. The correlation and significance of the relationship between IQ, the amount of F in water and the sex of children

		Correlation		
		Sex	IQ	F
Sex	Pearson	1	–0.084	0.000
	Sig. (2-tailed)		0.361	1.000
	N	120	120	120
IQ	Pearson	–0.084	1	–0.279**
	Sig. (2-tailed)	0.361		0.002
	N	120	120	120
Fluoride	Pearson	0.000	–0.279**	1
	Sig. (2-tailed)	1.000	0.002	
	N	120	120	120

**: Correlation is significant at the 0.01 level (2-tailed).

As shown in Table 3, the results show that there is a negative and significant correlation between the IQ and F concentration level in drinking water (r= –0.279, p-value= 0.002). As increasing F concentration in water, the score of IQ decreases. But, no significant correlation observed between the IQ and sex of children's (r= –0.084, p-value= 0.361). Distribution of IQ scores of children living in rurals with normal, medium and high F levels in drinking water are provide in Table 4. As shown, the highest percentages in all three levels of F (normal, medium and high) belong to the class E.

Table 4. Distribution of IQ scores of children living in rurals with normal, medium and high F levels in drinking water

Number of rurals	F concentration (mg/l)	IQ score (IQ points)				
		(<70) F	(70–85) E	(85–100) D	(100–115) C	(115–130) B
1	Normal 0.555	0	40	30	20	10
2	Normal 0.62	0	40	20	30	10
3	Normal 0.82	0	50	20	20	10
4	Medium 2.21	0	45	30	20	5
5	Medium 2.4	10	40	35	15	0
6	High 3.27	0	40	40	20	0
7	High 3.4	0	60	30	10	0
8	High 3.84	20	50	20	10	0
9	High 3.9	20	50	20	10	0

The present study was a cross-sectional study conducted on a stratified random sample of 140 children selected from 12 rurals in Bushehr province whose water consumption was supplied by wells. In this study there was a negative and significant correlation between the IQ and the F concentration level in the drinking water (r= –0.279, p-value= 0.002). These results were dissimilar to the research conducted by Kundu et al., which showed a positive correlation of F in drinking water with IQ (r = 0.417) [(14)].

The impact of F on IQ has been reported in previous studies in Iran [(25, 26)]. Several studies reveal that chronic exposure to high levels of F and water is associated with lower IQ [(1, 12, 27-29)]. Similarly, Chinese researchers in several studies on the impact of F on IQ [(19, 30-32] reported that a relationship exists between F exposure and intelligence with the average IQ of the high F group being lower than that in the control group.

Possible mechanisms for the neurotoxic effects of F maybe revealed by a number of animal studies which found a decreased thickness of post-synaptic density, increased width of synaptic cleft, and high cholinesterase activity in brain tissues of mice exposed to high F levels [33, 34]. A clear-cut mechanism of action of F in reducing IQ is not well determined. F may effect oxygen metabolism and induce oxygen free radicles which have a role in decreasing cognitive functioning including learning and memory [35].

Absorbed F in the blood through diet, forms lipid soluble complexes which pass the blood brain barrier to accumulate in the brain tissues and affect the neurological development by various neurotoxic mechanisms, including free radical generation, and inhibition of anti-oxidants, mitochondrial energy enzymes, and of glutamate transporters [36, 37]. However, it is also due to other reasons involving variation in biological susceptibility, environmental conditions, and measurement errors [1]. Given that, before the age of 6 years, the human brain is in its fastest stage of development, and some basic structural development is completed at this time, the brain is most vulnerable to harm from excessive F intake at the early stages of life before the age of 6 years [38]. In addition to main influence of a high F environment, other factors, can also affect the IQ development, e.g., education of parents, dietary status, mother's diet during pregnancy, parental education/care, and endemic lack of iodine [39]. In present study the possible effects of these bias factors were not taken into consideration and it is highly suggested that these limitations be considered in future studies

CONCLUSIONS

In conclusion, the results of this study support that children exposed to F are at risk for impaired development of intelligence. A large number of children around the world are exposed to high levels of F in drinking water, and are therefore, potentially at risk. For the benefit and health of future generations, immediate and basic attention needs to be focused on this significant public health problem. Also more studies are required on a large scale in Iran on the accurate monitoring of F levels in local water supplies and implementing public health measures, including defluoridation, to decrease the F exposure levels to a permissible level (1.5 mg/l) in high F areas are essential.

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CONFLICTS OF INTEREST

There are no conflicts of interest

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