Gac Sanit. 2021;35(S2):S159–S163

The influence of fluoride in drinking water on the incidence of fluorosis and intelligence of elementary school students in Palu City☆

Sri Indah Yani[a,b,*], Arifin Seweng[c], Anwar Mallongi[c], Rosmala Nur[d], Muh Tahir Abdullah[c], Ummu Salmah[c], Saifudin Sirajuddin[c], Muhammad Basir-Cyio[e], Mahfudz[e], Alam Anshary[e]

[a] Tadulako General Hospital, Palu, Central Sulawesi, Indonesia
[b] Faculty of Public Health, Universitas Hasanuddin, Indonesia
[c] Public Health Faculty, Universitas Hasanuddin, Indonesia
[d] Public Health Department, Faculty of Public Health, Universitas Tadulako, Indonesia
[e] Agrotecnology Department, Faculty of Agriculture, Universitas Tadulako, Indonesia

ARTICLE INFO

Article history:
Received 28 June 2021
Accepted 30 July 2021

Keywords:
Fluorine water level
Dental fluorosis
Intelligence quotient

ABSTRACT

Objective: This research aims to know the influence of fluoride in drinking water towards Fluorosis and the Intelligence Level of Elementary School Students in Palu City.
Method: This cross-sectional study was performed through descriptive analysis on 100 students aged 6–12 years old selected by stratified random sampling from two different areas with different levels of fluoride in drinking water in Palu City. The samples were collected from two different elementary schools which were SDN 2 Talise and SDN Inpres 1 Birobuli. The examination was performed by a dentist using Dean's Fluorosis Index and philology, who measured students' IQ using Raven's Coloured Progressive Matrices.
Results: High level of F in drinking water affects the fluorosis status of students ($p = 0.001$), in which among 40 students (40%) who experienced fluorosis, 38 (38%) of them are from the area whose F level is high. The high level of F also affected the children's IQ, obtaining a p-value of 0.001, showing that there were no students with low IQ found in the area with low F level. For the status of Fluorosis and IQ, $p = 0.001$ was obtained. Among the 60 students who did not experience fluorosis, 96.6% of them had a high IQ level.
Conclusion: The recent research found that fluorosis was found more often in the area of which F level was high, where the IQ level of the students was found to be lower compared to the students who loved in the area with low F level.

Introduction

Fluorine is spread in nature, mostly in the form of fluoride. In the case of the human body, fluoride has a beneficial role for tooth and bone enamel. It is only useful if it is used in small amounts within the permitted limit. However, the amount is excessive; it will have a bad influence on the human body.[1,2] The influence of ingesting excessive fluoride can occur at any age, but the effect becomes very dangerous if it happens to pregnant women and developing children.

Fluoride has the ability to form a lipid-soluble complex that can penetrate the blood barrier of the fetal brain and accumulate in the brain tissue before birth so that it can affect the intelligence. Several previous research projects explained that fluoride could induce the changes in the physical and biochemical structure of the brain which can affect the mental development of the children during cognitive processes, such as learning and memory, especially during the fetal period and the first eight years of life.[3,4]

In several locations, such as several parts of China, India, and Bengal, the drinking water contains very high levels of fluoride (>1.2 mg/L), which causes serious health problems.[2] HV et al. in their study that was conducted in Bharatpur City, India, reported total fluorosis cases of 18.821% in which 18.21% of them occurred in female children and 19.51% of them occurred in male children.[5,6]

In the last several years, research has been conducted on fluoride and reported that high fluoride intake can damage the central nervous system and that it can pass through the placental barrier to damage the fetus. The high level of fluoride can affect children who live in high fluoride areas negatively, the causes among them are: (i) proper developmental disorders in the uterus because the mothers consume fluoride which is passed on to the fetus through the placenta, or (ii) childhood in high fluoride environment. One or both of them can cause neuron damage, developmental difficulties, or neurotransmitter dysfunction.[7]

The most-reported effect occurred on children is concerning cognitive capacity, specifically intelligence decrease. Children who live in areas with a high level of fluorosis are found to have five times higher opportunity of having low IQ compared to those who

☆ Peer-review under responsibility of the scientific committee of the 3rd International Nursing, Health Science Students & Health Care Professionals Conference. Full-text and the content of it is under responsibility of authors of the article.

* Corresponding author.
E-mail addresses: sriindahyani21@gmail.com, pmc@agri.unhas.ac.id (S.I. Yani).

https://doi.org/10.1016/j.gaceta.2021.07.010

live in areas with no fluorosis or areas of low fluorosis level.[8] Fluorosis is experienced by more than 200 million people in almost 25 countries.

Thus it has become a global issue (WHO). According to WHO, drinking water containing high concentrations of fluoride is one of the main sources of fluorosis.[6,8]. There were at least 25 countries in the world encounter fluorosis endemic (UNICEF). About 80% of diseases throughout the world are caused by poor drinking water quality parameters, and 65% of fluorosis endemic in the world spread due to fluoride contamination in drinking water. The global prevalence of fluorosis is around 32%.

According to UKGS guidelines (2012), there was still a little research that was conducted in Indonesia regarding the relationship of fluorine levels with dental fluorosis. Some areas such as Cipatat, Situbondo, Madiun, Donggala, Buol, Toli-Toli, Palu, Poso, and Banggai have high fluorine levels (0.75–3.4 ppm) so that dental fluorosis cases were commonly found there. In Palu 2016, especially in the elementary school area of Talise Public Health Center, there were 356 (28.8%) cases of fluorosis obtained from a total of 1,235 students from 15 elementary schools in Talise Public Health Center working area. The examination of fluoride level in three sub-villages shows that Talise Sub-Village had the highest water fluoride level of 1.6 ppm, while Tondo Sub-Village had 0.9 ppm.

Method

Research location and design

This analytical research was done through Cross-Sectional research design on elementary school students in the age range of 8 and 12 years old in Talise Sub-Village with a water fluoride level of 1.6 ppm and Birobuli Sub-Village with a water fluoride level of 0.10 ppm. One elementary school was chosen respectively from both sub-villages, which were SDN Inpres 2 Talise and SDN Inpres Birobuli.

Population and sample

The sampling techniques used were random sampling obtaining 100 children to be examined, consisting of 40 children from Birobuli Sub-Village and 60 children from Talise Sub-Village. Sociodemography data was collected from children, including the source of drinking water and the duration of drinking water from the wells. The inclusion criteria of the children selected were permanent residents of the examination location, did not have a history of trauma on the head, did not have a history of chronic disease, or were not undergoing treatment.

All of this was confirmed by the parents through a form that was entrusted to the child a week before the examination. The dental fluorosis status of all children was recorded according to the Dean index., while the IQ measurement was carried out using the Color Progressive Matrix component. Tests were given individually for each child, according to the guidelines and directions of Raven's progressive matrix manual.

Data analysis

Univariate analysis was employed in this research to describe the frequency distribution of each variable. Bivariate analysis was also used to see the relationship between independent and dependent variables.

Table 1
Characteristics.

Variable	High fluoride area	Low fluoride area
Fluoride level in drinking water	1.6 ppm	0.3 ppm
Gender		
Male	20	16
Female	40	24
Averaged age	9.78 years old	8.18 years old

Result

This research was performed on elementary school children in the age range of 9.78 years old in high fluoride area and 8.18 years old in low fluoride area. The results of the study are presented in Tables 1 and 2 as follows.

From the total sample, there were 40 students who suffered from fluorosis, in which 38 students were from high water fluoride area, while the remaining two students from low water fluoride area. Based on the statistical test results in Table 2, the *p*-value obtained was 0.001 <0.05, which means that Ho is rejected, or it can be concluded that: there was an influence of high Fluorine levels in drinking water with the Fluorosis status in children. Distribution of dental fluorosis case in two areas is presented in Fig. 1 as follow.

Fig. 1 showed that no dental fluorosis or normal (score 0) was found among 22 children in the high fluoride area compared to 38 in the low fluoride area. As many as two students from low F area and one person from high F area were collected for a score (1) or questionable dental fluorosis. Very mild dental fluorosis (Score 2) was found among ten students in high fluoride area and 1 in low fluoride area. Mild, moderate and severe dental fluorosis (scores 3, 4, and 5) were found in 11 (11%), 8 (8%) and 7 (7%) children, respectively, in high fluoride area compared to the low F area, the three of them were 0 (0%) for mild, moderate and severe dental fluorosis. The following Table 3 shows the IQ status from 2 areas.

There were 17 students from high fluoride areas who had low IQ, but no students with low IQ were found in low fluoride areas. Based on the statistical test results, the *p*-value obtained was 0.001 < 0.05, which means that Ho is rejected, or it can be concluded that: there is an influence of high fluoride levels in drinking water with IQ status in children. The following Table 4 shows the relationship between IQ status and fluorosis status.

From a total of 40 students who suffered from fluorosis, 62.5% of them had high IQ scores. Meanwhile, for students who did not suffer from fluorosis, 96.6% of them had high IQ. Based on the statistical test results, the *p*-value obtained was 0.001 < 0.05, which means that Ho is rejected, or it can be concluded that: there is an influence of Fluorosis status with student intelligence. The distribution of IQ scores in 2 areas is presented in Fig. 2 as follows.

Fig. 2 showed that in the high F level area, it was obtained that there were six children with an IQ score below the average category and 11 people with IQ scores in the average category. Meanwhile, there were no children found with IQ scores in the category below the average and the average in the low F area. For the IQ score above the average category, 15 children were found from the high F area and five children from the low F area. Meanwhile, for the intelligent category, 28 children found from the high F area and 35 children from the low F area.

Discussion

The effect of fluoride in drinking water on the incidence of fluorosis and IQ status

Table 2
Dental fluorosis value in two areas.

Area	Dental fluorosis total				Total	*p*-Value
	No fluorosis		Suffered from fluorosis			
	n	Percentage	*n*	Percentage		
High fluoride area	22	36.7%	38	63.3%	60	0.001
Low fluoride area	38	95%	2	5%		

Source: Primary Data, 2020.
Test: Chi-Square.

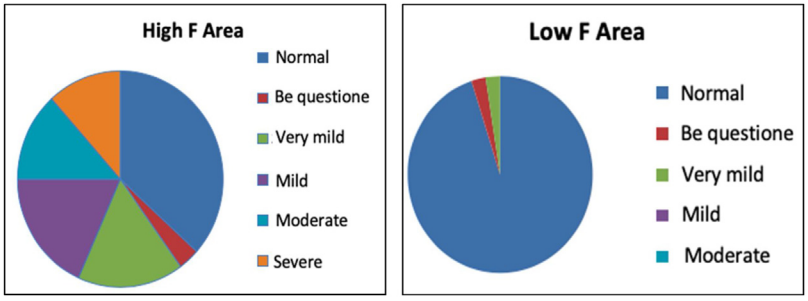

Fig. 1. Distribution of dental fluorosis case in two areas.

Table 3
IQ status from two areas.

Area	IQ status				Total	*p*-Value
	Low		High			
	n	Percentage	*n*	Percentage		
High F area (%)	17	28.3%	43	71.7%	60	0.01
Low F area (%)	0	0	40	100%	40	

Source: Primary Data, 2020.
Test: Chi-Square.

Table 4
The relationship between IQ status and fluorosis status.

Fluorosis status	IQ status				Total	*p*-Value
	High		Low			
	n	Percentage	*n*	Percentage		
Fluorosis	25	62.5%	15	37.5%	40	0.01
No fluorosis	28	96.6	2	3.3%	60	

Source: Primary Data, 2020.
Test: Chi-Square.

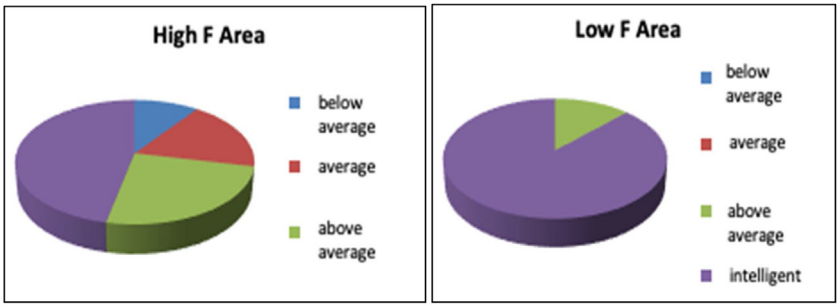

Fig. 2. Distribution of IQ score in two areas.

A number of research projects have confirmed the safety of fluoride in drinking water. However, several research projects found that exposure to fluoride in drinking water can affect fetal intelligence if it is consumed excessively by pregnant women and developing children. Table 3 shows a comparison of the IQ scores of children in the two areas. The majority of children from high fluoride areas, Birobuli Sub-Village (100%), had high IQ, while there were 17 children from Talise Sub-Village (28%) who had Low IQ.

This research found that children who lived in areas with high fluoride levels in drinking water had lower IQ compared to children who lived in areas of low Fluoride levels in drinking water with ($p < 0.001$).

This is consistent with research conducted by Sudhir et al., and Shivaprakash et al. who analyzed the relationship between various levels of dental fluorosis and IQ scores showing that children's intellectual capacity decreases as the fluorosis increases.[6] Karimzade et al. (2014) have reported the effect of fluoride on IQ in Iran. They reported that the average IQ of children living in low fluoride drinking water area was higher than the IQ of children living in high fluoride drinking water area.[9]

In a similar study, Liu et al. found that children who lived in areas with high water fluoride levels had significantly higher IQ scores than children who lived in areas with low water fluoride levels ($p < 0.01$). Likewise, Chen et al., in their study, stated that the average IQ scores were significantly lower in children who lived in areas with high fluoride levels compared to children who lived in areas of low fluoride levels. Seraj et al. in their study also showed that children who lived in areas with higher than normal F water concentrations had lower IQ score.[10]

The United Arab Emirates (UAE) in four different emirates, revealed that higher fluoride content in tap water was found in Ajman while the lower one was in Abu Dhabi and Dubai with fluoride ranges between 0.04 and 0.3 mg/L. Similarly in India, Nagarajappa et al., Shivaprakash et al. and Sudhir et al. revealed that chronic exposure to high fluoride level and water was associated with lower IQ score.[11]

Research that was conducted in Africa by Dirisu et al. in drinking water showed that IQ obtained was less than 90, while the average fluoride obtained was (0.86 ± 0.30 mg/L). They concluded that the fluoride content of public tap water was within the WHO minimum limit. In India, Aravind et al. found that IQ levels were negatively correlated with fluoride levels. In a study of the chemical quality of tap water versus bottled water containing an evaluation of several heavy metals and elemental content of drinking water in the Dakahlia-Egypt.

Khan et al. showed that the overall IQ of children exposed to low fluoride levels in drinking water was higher than those exposed to high fluoride levels and had dental fluorosis in a cross-sectional study conducted among 429 children aged 6–12 years in and around the Lucknow district of India.[1] A study was done on 299 mother-child pairs in Mexico, finding a relationship between decreased intelligence and fluoride exposure. The team measured the fluoride level from the mothers through urine samples and followed up their children until they were between 6 and 12 years old. The results showed that high fluoride exposure during pregnancy was related to low IQ levels in children between the ages of 6 and 12 years.

One mechanism for the adverse effects of F on brain development is the ability of F to interfere with the activity of the thyroid gland. High-dose exposure of fluoride can also cause dental fluorosis, bone fluorosis, an increase in bone fracture rate, a decrease in birth rate, and an increase in urolithiasis (kidney). When it is ingested during pregnancy, F can affect the human fetus across the placenta and enter the fetal organs and tissues.[12–14]

Fluoride is known to interfere with the thyroid function, which in turn, is very important for fetal brain development. After being absorbed in the blood through the diet, fluoride forms a fat-soluble complex that passes through the brain's blood barrier to accumulating in brain tissue. The penetrated fluoride complex negatively affects the development of the SSP by different neurotoxic mechanisms, such as free radical generation, inhibition of antioxidant enzymes and mitochondrial energy enzymes and inhibitors of glutamate transporters.[9,15]

Studies on aborted human fetuses show disruption of neurotransmitters, receptors in nerve cells, increased density of neurons and undifferentiated neuroblasts. There was also evidence of a reduction in the number of mitochondria, rough endoplasmic reticulum, and free ribosomes. Structural and functional changes in the SSP, especially in the fetal period and the first eight years of life, can cause learning and intellectual deficits and cognitive dysfunction.[14,15]

Previous research revealed that since fluoride interferes with the activity of the thyroid gland and secretion of its hormones, the increased fluoride can cause iodine deficiency in fluorinated individuals, even when they are in iodine-deficient areas, thereby affecting the brain development. However, further research is needed to investigate the effects of environmental or other geological contaminants.

The main factor affecting the decrease in intelligence in children in high F level area is the ability of F to pass through the blood–brain barrier, producing biochemical and functional disorders of the nervous system during the prenatal period and the development of early childhood. IQ score is affected by many factors, including differences in biological vulnerability, environmental conditions, and measurement errors.[16]

Conclusion

There is a relationship between Fluoride level in well water and the incidence of fluorosis in students, where the incidence of fluorosis was higher in the high fluorine area than in the low fluorine area.

The intelligence of children who suffered from fluorosis is lower than the intelligence of children who do not suffer from fluorosis.

The level of intelligence of students who live in the high-fluorine area is lower than students who live in low fluorine area.

Conflict of interest

The authors declare no conflict of interest.

References

1. Khan SA, et al. Relationship between dental fluorosis and intelligence quotient of school going children in and around Lucknow district: a cross-sectional study. J Clin diagnostic Res. 2015;9:ZC10.
2. Wei W, Pang S, Sun D. The pathogenesis of endemic fluorosis: research progress in the last 5 years. J Cell Mol Med. 2019;23:2333–42.
3. Ashraf S, Khalid MU, Jamil H. Dental fluorosis. Prof Med J. 2018;25:242–5.
4. Nur R, et al. The smart book effect of pregnancy–postpartum care towards the husband's knowledge and reduction of reproductive health problems. Fam Med Prim Care Rev. 2020;22:133–9.
5. Akuno MH, et al. Factors influencing the relationship between fluoride in drinking water and dental fluorosis: a ten-year systematic review and meta-analysis. J Water Health. 2019;17:845–62.
6. Nagarajappa R, et al. Comparative assessment of intelligence quotient among children living in high and low fluoride areas of Kutch, India—a pilot study. Iran J Public Health. 2013;42:813.
7. Yadav S, et al. Prevalence of fluorosis among school going children in district Mahendergarh, Haryana, India. Int J Basic Appl Res. 2018;8(9.).
8. Shivaprakash PK, Ohri K, Noorani H. Relation between dental fluorosis and intelligence quotient in school children of Bagalkot district. J Indian Soc Pedod Prev Dent. 2011;29:117.
9. Karimzade S, Aghaei M, Mahvi AH. Investigation of intelligence quotient in 9–12-year-old children exposed to high-and low-drinking water fluoride in West Azerbaijan Province, Iran. Fluoride. 2014;47:9–14.
10. Green R, et al. Association between maternal fluoride exposure during pregnancy and IQ scores in offspring in Canada. JAMA Pediatr. 2019;173:940–8.
11. Nur R, Fitrasyah SI, Mallongi A. Women's reactions and health disorders caused by abuse during the pregnancy-postpartum period. Med Leg Updat. 2020;20:1329–34.

12. Nur R, et al. The culture and age of first marriage on female teenagers in West Marawola. Med Leg Updat. 2020;20:2–7.
13. Grandjean P. Developmental fluoride neurotoxicity: an updated review. Environ Health. 2019;18:1–17.
14. Nur R, et al. The effect of moringa leaf extracton increasing hemoglobin and bodyweight in post-disaster pregnant women. Enferm Clin. 2020;30:79–82.
15. Nur R, et al. Detection mapping of women with high-risk pregnancy in antenatal care in kamonji public health center, Palu City, Indonesia. Syst Rev Pharm. 2020;11:642–7.
16. Nicole W. Comparing fluoride exposures in pregnant canadian women: fluoridated versus nonfluoridated drinking water. Environ Health Perspect. 2019;127:74002.