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# Correlation of fluoride intake to total bone mass at Asembagus, Situbondo, Indonesia

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## Abstract

Fluoride is a non-organic substance with the most reactive element and the highest electronegativity. Most humans are exposed to fluoride through food and water intake. Groundwater is the main source of fluoride toxicity in humans. Excess fluoride intake can cause serious health hazards in humans, such as dental and skeletal fluorosis. The etiological factor of fluoride toxicity is the high fluoride levels in groundwater that will accumulate. This study aimed to examine the correlation of fluoride intake to total bone mass. This study is an analytical observational study with a cross-sectional approach method. The sample size was 10 wells and 23 people aged 18-25 years. The fluoride intake was measured using the 24-hour food recall technique. Total bone mass was measured using Tanita Innerscan Model BC-541. The results discovered fluoride intake with an average of 2.52 mg and total bone mass with an average of 2.5 kg. Linear regression analysis resulted in fluoride intake having a significant correlation to the total bone mass (p-value <0.05). To sum up, this research concluded that fluoride intake correlated negatively significantly, namely, the higher the fluoride intake, the total bone mass will decrease.

**Keywords:** Correlation; Fluoride; Fluoride intake; Total bone mass

## 1. Introduction

Fluoride is a non-organic substance with the chemical formula F, VIIA halogen group in the periodic table of elements, and is the most reactive element with the highest electronegativity [1]. This substance can be found in soil, water, and air. Groundwater is the main source of freshwater for the world's population. About one-third of the global population consumes drinking water from groundwater [2]. However, some developing countries face serious chemical contamination problems in clean water such as detergents, heavy metals, and fluoride which are contaminants and cannot be overcome or removed by boiling, by the importance of water in human life and health, especially the daily need for drinking water supply, water requirements must be regulated [3].

According to the World Health Organization (WHO), the safe limit of fluoride intake levels is around 1.5 ppm [4]. Indonesian standards, stipulated by SNI 01-3553- 2006 concerning Drinking Water in Packaging, stated that fluoride levels in water bottles should not exceed 1 mg/L. If it exceeds the standard limit set, the risk is referred to dental fluorosis, even at higher levels it can cause bone fluorosis [3]. The Ministry of Environment of the Republic of Indonesia in 2014 set a stricter limit to 0.5 mg/L at water sources, 1.5 mg/L at aquaculture, 2 mg/L at waste in water sources, and not required at irrigation for agriculture [5].

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Fluoride toxicity in humans is a global health concern. Most humans are subjected to fluoride through food and water consumption. The etiological factor of fluoride toxicity is the high fluoride levels in groundwater and then consumed that will accumulate as dental and skeletal fluorosis [6].

Fluoride toxicity is classified into acute and chronic toxicity. Acute toxicity refers to high levels of fluoride intake at once, whereas chronic toxicity refers to low levels of fluoride intake daily over a long period [7]. A study conducted by Kelly et al, on two horses that consumed well water with high fluoride levels (3-22 ppm), euthanized and autopsied the clinical signs findings of chronic dental and bone fluoride toxicity [8]. The study stated that both horses had degenerative diseases in several joints and teeth.

The fluoride levels in water in particular regions are different. Research conducted by Rochmawati in the Asembagus Subdistrict in 2012 found that Gudang Village had a particular maximum fluoride level of 10.96 ppm [9]. Asembagus Sub-District's groundwater is a prominent issue now, especially for people who geographically live in high levels of fluoride locations. The reasons lay in groundwater usage by the people for consumption, agricultural irrigation, and plantations [10]. Previous studies had mostly discussed groundwater and dental fluorosis, which if consumed continuously can even cause skeletal fluorosis which is a debilitating bone disease. Therefore, it is very important to conduct this study due to the uncontrollable dose of fluoride levels consumed every day and its effects on dental and bone health. This study will discuss the correlation between groundwater fluoride levels and fluoride intake to total bone mass.

## 2. Material and methods

Ethical approval for this study (No.1696/UN25.8/KEPK/DL/2022) was provided by the Ethical Committee of Medical Research at the Faculty of Dentistry in Jember University, Jember, on September 27, 2022. This study is an analytical observational study with a cross-sectional approach method. The research was conducted in Asembagus Subdistrict, Situbondo Regency, East Java with the criteria of research subjects as follows: people who use groundwater for daily consumption, live around the groundwater source, in the age range of 18-25 years, have never participated in related research before, is willing to participate in the study by filling out informed consent.

Data collection began with a preliminary survey, followed by ethical clearance. The fluoride intake was examined using the 24-hour food recall interview technique involving recording the type and amount of food and beverage consumed within 24 hours. The result data from daily intake (L) was multiplied by the measured fluoride content (mg/L or mg/Kg) [11]. The data was obtained by examining total bone mass using Tanita Innerscan Model BC-541 digital scales.

The population of this study was people who still use and consume groundwater for daily life in the Asembagus Sub-district, Situbondo District, East Java. The sample of the study was taken from 10 wells that were used by more than 5 heads of households consisting of 23 people aged 18-25 years old, according to Asembagus sub-district health center data. The research sampling utilized a total sampling technique.

The obtained data was analyzed using statistical analysis of Statistical Product and Service Solutions (SPSS) software. The data was tested using a linear regression method to see the correlation of the related variables. For the linear regression model validation, three tests must be checked on the residual data (linear test, normality test of residual data, and heteroscedasticity test).

## 3. Results and discussion

By the required criteria, the characteristics of 23 people of research subjects were chosen from 5 different villages, specifically 4 people from Perante, 4 people from Kedunglo, 5 people from Wringinanom, 5 people from Bantal, and 5 people from Gudang. Table 1 shows that the average age (18-25 years) of the subjects was 21.4. The average height (cm) and weight were 162.96 and 62.65. And, the averages of water consumption (liters) and fluoride intake (mg) were 2.49 and 2.52.

**Table 1** Characteristics of the research subjects

| Frequency distribution of research subjects | Result | | | |
|---|---|---|---|---|
| | n | % | Averages | S.e.m |
| Age (18-25 years) | 23 | 100 | 21.4 | 0.46 |
| Height (cm) | 23 | 100 | 161.96 | 1.98 |
| Weight (kg) | 23 | 100 | 62.65 | 2.80 |
| Water consumption (liter) | 23 | 100 | 2.49 | 0.06 |

The results of the calculation of fluoride intake in each research subject have different results. Fluoride intake consists of foods that contain fluoride and drinking water, but fluoride intake from food cannot be calculated because there are foods consumed that are not listed in the food consumption table. Table 2 examined the lowest average fluoride intake was 0.98 mg in Perante, while the highest average was 3.64 mg in Gudang with a total average of 2.52 mg. The results of the total bone mass calculation showed that the average total bone mass in Perante was 2.9 kg, Kedunglo was 2.9 kg, Wringinanom was 2.6 kg, Bantal was 2.1 kg, and Gudang was 2.2 kg.

**Table 2** Results average based on village

| Village | Number of research subjects | | Result average | |
|---|---|---|---|---|
| | n | % | Fluoride intakes (mg) | Total bone mass (kg) |
| Perante | 4 | 17.4 | 0.98 | 2.9 |
| Kedunglo | 4 | 17.4 | 1.08 | 2.9 |
| Wringinanom | 5 | 21.7 | 2.88 | 2.6 |
| Bantal | 5 | 21.7 | 3.41 | 2.1 |
| Gudang | 5 | 21.7 | 3.64 | 2.2 |
| Total | 23 | 100 | 2.52 | 2.5 |

The results of the linear regression test of the variables of fluoride intake variables to total bone mass. Figure 1 statistically figured a significant correlation to the total bone mass variable with p-value = 0.000 (p-value <0.05). The regression graph also formed a straight-line pattern from the top left down to the bottom right referring to a negative correlation. This means the higher the fluoride intake, the lower the total bone mass. The R square value was 0.583 (58.3%) with r = 0.763. This concluded that the percentage of fluoride intake on total bone mass was 58.3%, while the rest was influenced or explained by other variables out of this research.

Asembagus sub-district is an area in Indonesia that has high fluoride levels in groundwater. This is proven by research conducted by Rochmawati in 2012, found 0.49-10.96 ppm fluoride levels [9]. A recent study conducted by Wacano et al. in 2019 proposed that fluoride levels ranged from 1.4 to 3.3 ppm with a 2.41 ppm total average [11,12]. The Asembagus area is on the slopes and lower ground north of the crater of Mount Ijen. The Banyuputih River, which is polluted by the flow of the Ijen Crater Lake, is the cause of high fluoride levels in rural water around the Asembagus sub-district [13].

In tropical areas with warm temperatures, people regularly consume more water which leads to increasing the fluoride in the body [14]. Groundwater consumption is currently still used as the main source of freshwater for the global population and is used for domestic, agricultural, and industrial purposes [2]. The average water intake of the study subjects was 2.49 L with an average water fluoride intake of 2.52 mg. The recommended drinking water for daily consumption needs 2 L on average, which provides a fluoride intake of about 0.2-2.4 mg, considering the normal fluoride concentration in water [15].

The results of this study exceed the recommended normal limits based on the results obtained. Human consumption of water must be by the requirements. The main requirements that must be met are biological, physical, and chemical. The contaminants that can be overcome are microorganisms that can be removed by boiling water, but some contaminants cannot be removed by boiling alone, including detergents, heavy metals, pesticides, nitrates, and fluoride. The drinking habit of consuming groundwater with high fluoride concentrations provoked health issues for the people [11]. Fluoride intake that exceeds the standard limit can cause the risk of dental fluorosis, and even higher levels can cause bone fluorosis [3].

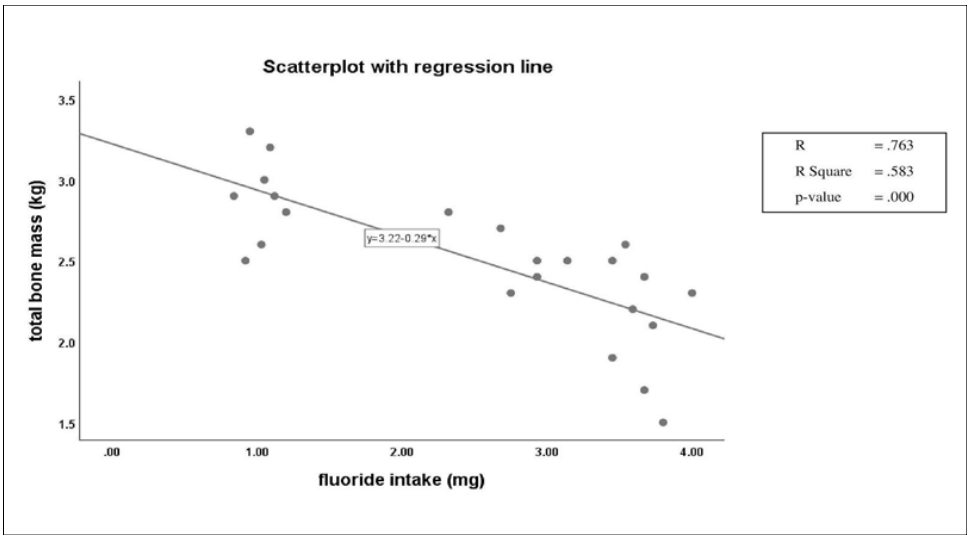


**Figure 1** Test results of variable regression analysis model of fluoride intake to total bone mass

The results of the total bone mass calculation portrayed in Figure 1 confirmed a decreasing bone mass caused by the fluoride intake. Some factors that affect bone mass are heredity and genetics, growth and maturation, physical activity, diet, and nutritional status [16]. Skeletal fluorosis is the most severe form of chronic fluoride toxicity. Skeletal fluorosis usually occurs due to prolonged consumption of tea and well water with more than 4 ppm fluoride levels. However, other cases had also been identified that subjected individuals to fluoride levels under 4 ppm [17].

Research conducted by Choubisa in 2012, found that 1.5 ppm fluoride levels of well water for drinking had a positive correlation to the skeletal fluorosis prevalence in more than 10 years of consumption [18]. Following these findings, the results of the current study in Figure 1 obtained a P-value (P-value <0.05). This indicated that the variables of fluoride intake had a significant correlation in decreasing total bone mass. However, further examination is needed, by using radiographic techniques or Dual-energy X-ray Absorptiometry (DEXA) tools to accurately examine the bone mass [19].

The high fluoride exposure changed the mineral formation and stress on surrounding cells. The fluoride absorption into bone resulted in the bone mineral conversion from hydroxyapatite to fluorapatite which alters the general bone lattice and bone strength. Thus, the high fluoride levels have weaker bones mechanically [1]. Excessive fluoride intake can also affect osteoblast and osteoclast differentiation and ultimately result in an imbalance between bone formation and bone resorption [20].

The mechanism of fluoride's toxic effects on bone is complex. The mechanism of chronic fluoride toxicity binds to several proteins and influencing factors in bone tissue. According to research conducted by Wei et al., 63 proteins were expressed [21]. Most of the proteins belong to collagen proteins, MMPs (Matrix metalloproteinases), PGs (Proteoglycans), proteolytic proteins, and osteoclast osteoclast-associated proteins [22]. Those proteins are involved in signaling pathways of bone mass change, mineralization process, and affect osteoblasts and osteoclasts, and finally contribute to the pathophysiology of bone and chronic fluorosis [23,24].

In conclusion, the Asembagus Sub-district is one of many areas covered with water issues for consumption, especially the fluoride in the groundwater. As this issue threatens people's health, there should be a solution to control the contamination levels and recover the impact so far. The researcher suggested substituting the drinking water alternatively or applying certain defluoridation methods to the water sources for better future health reasons.

## 4. Conclusion

To sum up, this research concluded that groundwater fluoride levels and fluoride intake correlated negatively significantly, namely, the higher the groundwater fluoride levels and fluoride intake, the total bone mass will decrease. Therefore, it is necessary to conduct further research on examining the bone using radiographic techniques or Dual-energy X-ray Absorptiometry (DEXA) tools to accurately elucidate the bone mass. Concerning the health issue, the researcher suggested that people should be well-managed and regularly monitor groundwater fluoride levels. The solutions also lay on applying certain defluoridation methods or changing the source of drinking water.

## Compliance with ethical standards

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### *Disclosure of conflict of interest*

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### *Statement of ethical approval*

Ethical approval for this study (No.1696/UN25.8/KEPK/DL/2022) was provided by the Ethical Committee of Medical Research at the Faculty of Dentistry in Jember University, Jember, on September 27, 2022.

### *Statement of informed consent*

Informed consent was obtained from all individual participants included in the study.

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