ORIGINAL ARTICLE

Determination of Fluoride in Gravity Feed System Water and Health Risk Assessment of Exposure to Fluoride among Indigenous People in Sungai Mas, Pahang

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ABSTRACT

Introduction: To determine fluoride levels in gravity feed system water of Sungai Mas Village in Sungai Lembing, Kuantan, and its related potential health risk due to fluoride exposure from drinking water among adult indigenous people in the area. **Methods:** Adults who have lived in Sungai Mas Village, Pahang, for more than one year and use gravity feed system water as a drinking water source were selected as respondents. A set of questionnaires was used to determine socio-demographic and information on gravity feed system water usage among the respondents. A handheld Fluoride low-range (LR) Color-imeter and a portable pH meter were used to measure fluoride levels and pH in water samples, respectively. A body weight scale was used to measure the weight of respondents. **Results:** A total of 80 indigenous people in Sungai Mas Village were chosen as respondents. From 80 water samples col-lected, 98.75% had fluoride lower than the Malaysian National Standard for Drinking Water Quality's permissible level (0.4 – 0.6 mg/L), while 1.25% had a fluoride level within the said level. Fluoride ranged from 0.10 to 0.41 mg/L, while pH ranged from 7.67 to 8.20, meaning 100% of the water samples had pH within the permissible level. The Hazard Quotient (HQ) was less than 1 (HQ < 1). **Conclusion:** Water samples in the study area had low natural fluoride, which is insufficient to eradicate dental caries. Meanwhile, the value of the hazard quotient suggests that adults in Sungai Mas Village may not be at risk of developing dental and skeletal fluorosis.
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Keywords: Fluoride; Gravity feed system water; Health risks; Indigenous people; Sungai Mas

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INTRODUCTION

Fluoride is a naturally occurring mineral that is released into the soil, water, and air by rocks (1). Fluoride can be found in all-natural water sources in quantities ranging from barely detectable to more than ten parts per million (ppm). Rainwater contact with windblown soils and other environmental materials results in 0.1 to 0.2 ppm fluoride in rivers, lakes, and surface waters. Fluoride levels in well water vary based on the minerals found in the rock and ores through which the water travels. Fluoride levels in ocean water (96.5 percent of Earth's water) are normally between 1.2 and 1.4 parts per million. Fluoride can be obtained in two ways which occur naturally or chemically. Natural fluoride is prevalent in the environ-ment and is not detrimental to the environment (2).

In developing nations, fluoride levels in ground drinking water that exceed the World Health Organization's recom-mended value represent a severe health, social, and economic hazard (3). Due to significant regional variations in fluoride levels in water supplies, drinking water is susceptible in this regard (2). Fluoride is one of the contaminants listed by the US Environmental Protection Agency and designated as a highly harmful substance by the US Agency for Toxic Sub-stances and Disease Registry (4). Fluoride levels in drinking water, both high and low, have recently been identified as a severe public health concern (5). Fluoride can cause serious adverse effects on human health while having a minor effect on tooth decay prevention. Low levels of fluoride intake in people with low calcium and magnesium in their teeth may make them more sensitive to dental caries. Numerous studies have found that adults and children consume more fluoride than is recommended, contributing to increased dental fluorosis (6). In a previous study, there is evidence that fluoride, arsenic, iron, and salts are all common contaminants in natural water sources in Malaysia (7). Dental fluorosis, osteoporo-sis, renal injury, bone distortion, inactivation of reproductive organs, nerve and muscle degeneration, skeletal fluorosis, and moreish are all caused by fluoride consumption above the permissible levels in new-born, children, adult males, and females (8).

Based on the National Survey of Adult Oral Health, compared to 25% of non-indigenous adults, nearly 60% of in-digenous adults had untreated dental caries. This data suggests that water fluoridation should assist groups with the high-est disease burden in the interests of equity (9). Other than that, (10) found that, despite extensive free access to dental care and preventive measures in childhood and adolescence, adult caries levels were much higher than those of children in Malaysia and tracked throughout adult life. The water gravity feed system is a sustainable practice in the indigenous communities in Malaysia. It harnesses natural elevation to supply clean water to homes, reducing the need for complex infrastructure. This eco-friendly approach enhances access to potable water while preserving the environment. However, the gravity feed system itself does not include a fluoridation process, unlike the water treatment in urban areas. In Malay-sia, there have been no studies yet relating fluoride exposure in non-fluoridated areas among adult indigenous people. To compare it to existing standards, there is a need to provide baseline data on fluoride exposures among indigenous adults. In this study, the estimated daily intake (EDI) and hazard quotient (HQ) were used to quantify the health risks assessment related to fluoride-containing drinking water for adults (4). Thus, the objective of this study was to determine the health risk associated with exposure to fluoride in gravity feed system (GFS) water among Indigenous people in Sungai Mas Village, Malaysia

MATERIALS AND METHODS

This study used a cross-sectional study as a research study design.

Description of the study area

Figure 1 shows the research area, Sungai Mas Village in Kuantan, Pahang. Sungai Mas Village was chosen as the study area because rural people use a gravity feed

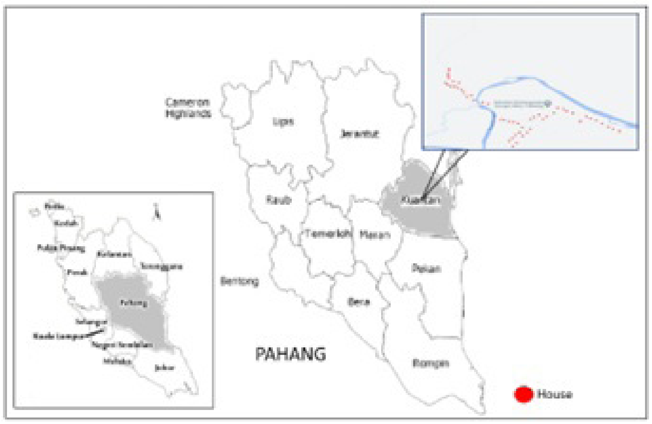

Figure 1 : The location of sampling of Sungai Mas Village, Pahang

water system without any water treatment, including water fluoridation. The decision to conduct fluoride analysis in Sungai Mas Village was made due to concerns regarding potential health implications arising from excessive fluoride consumption, possibly originating from natural sources such as rocks and soil. There are almost 150 indigenous households residing there, and they primarily rely on the gravity feed system for their water needs.

Determination of fluoride and pH levels in gravity feed system water

In this research study, 80 samples of gravity feed system water were taken from 80 houses in Sungai Mas Village in Au-gust 2022. Since glass bottles could affect fluoride levels either by absorption or dissolving of traces of fluoride from the glass surfaces, high density polyethylene bottles were used instead. (11). Water samples were then analyzed using a Handheld Colorimeter Fluoride LR (Hanna Instruments, United States) and pH meter (Eutech Instruments, Singapore) to determine levels of fluoride and pH in gravity feed system water. The SPADNS method was used to determine the fluoride levels of the samples (4). Before the tests began, the researcher ensured that all sample bottles were completely dry and clean. Besides, a pipette was used to ensure an accurate amount of reagent was taken. Aside from that, the tap water was drained for one minute before being collected in a bottle sample for testing. This is to ensure that the tap water taken is free of rust. In addition, all bottles including the caps and stoppers were rinsed thrice with sample water before they were filled up to one to two inches from the top.

Health Risk Assessment

Human risk assessment of fluoride is a process of determining the nature and likelihood of adverse health consequences in individuals exposed to chemicals in polluted environments in the present or future. The non-carcinogenic health risk is assessed by comparing an exposure level over a specific period to a reference dosage acquired over a comparable exposure period (12). The average daily consumption of drinking water (C_d), the level of fluoride in drinking water (C_f), and body weight (B_w) are used to determine the estimated daily intake (EDI) of fluoride. The formula that being used to calculate EDI (4) as follows:

$$EDI = \frac{C_f \times C_d}{B_w}$$

EDI is measured in mg kg^{-1} day^{-1}. A questionnaire was used to gather data on body weight and water consumption. The following equation was used to compute the hazard quotient (HQ), which is a measure of non-carcinogenic risk from fluo-ride exposure via various routes. The formula is being used to calculate hazard quotient as follows:

$$HQ = \frac{EDI}{RfD}$$

The reference dose (RfD) is an estimate of daily human population exposure over a lifetime without a significant risk of adverse consequences. According to the Integrated Risk Information System of the United States Environmental Protec-tion Agency or USEPA, the reference is being used for this formula is 0.06 mg kg^{-1} day^{-1} (13).

Statistical Analysis
Statistical Package Social Science IBM Version 28 (SPSS Ver. 28) was used to analyze the data obtained for this study, and descriptive statistics were used to present the results. Comparison between fluoride levels in gravity feed system water and acceptable Malaysia standard of fluoride in drinking water quality was tested with One sample T-test. Meanwhile, the association between fluoride and pH gravity feed system water levels was tested with the Pearson Correlation Coefficient. The p-value of less than 0.05, ($p<0.05$) was considered statistically significant.

RESULTS

Table I shows the result of level of fluoride in gravity feed system water compared to the Malaysian National Stand-ard for Drinking Water Quality (NSDWQ). According to the standard, the permissible level of fluoride ranges from 0.4 to 0.6 mg/L. Based on the findings, 98.75% of the water samples had fluoride levels lower than the permissible level and only 1.25% of the water samples had fluoride within the permissible level. Meanwhile, the mean pH in water samples was 7.91 with a standard deviation of 0.13. The results showed that pH ranged from 7.67 to 8.20, meaning 100% of the water samples had pH within the permissible level.

Next, Table II presents the outcomes of one-sample T-tests, indicating a p-value of less than 0.001, which is statisti-cally significant at the 95% confidence level. These findings suggest a notable disparity between the fluoride levels in the water samples and the national standard.

Table III displays the results of a Pearson correlation analysis, showing no substantial correlation between fluoride concentrations and pH levels in the water samples. The two-tailed significance value exceeds 0.05 ($p > 0.05$), specifically measuring at 0.594, signifying there is no correlation between fluoride levels and pH within the scope of this study.

According to Table IV, the mean estimated daily intake for respondents was 0.006 with a standard deviation of 0.003. The estimated daily intake ranged from 0.001 to 0.018. The estimated daily intake was determined by using data which included body weight, average daily consumption of drinking water, and fluoride levels in water samples. Meanwhile, the mean hazard quotient calculated was 0.097 with a standard deviation of 0.050. The minimum value of the hazard quotient was 0.02 while the maximum value of hazard quotient was 0.30. The estimated daily intake (EDI) was divided by the safe dose to obtain the hazard quotient value. The reference dose (RfD) is an estimate of the average daily exposure of the hu-man population over a lifetime with negligible chance of harmful effects.

DISCUSSION

According to the results, 98.75% of samples had fluoride below the Malaysian NSDWQ standard. This shows that most of the water received by respondents did not have enough fluoride to prevent dental caries. Increasing low fluoride levels in drinking water is crucial to prevent dental issues and maintain optimal

Table I : Descriptive statistics of fluoride and pH level (N= 80)

	Mean (SD)	Min	Max	Permissible Level MOH
Fluoride Level (mg/L)	0.19 (0.06)	0.10	0.41	0.4-0.6
pH Level	7.91 (0.13)	7.67	8.20	6.5-9.0

Table II : One-sample T-Test Comparing Fluoride Levels in Water Samples Collected from Homes to the NSDWQ

	Permissible Level MOH	GFS (N=80)	p-value
Fluoride Level (mg/L)	0.40 – 0.60	0.19 ± 0.06[a]	<0.001*

* p is significant when <0.05

Table III : Correlation between fluoride and pH levels (N=80)

	Pearson correlation	p-value
Fl * pH	-0.61	0.594

Table IV : Descriptive statistics of EDI and HQ

	Mean (SD)	Min	Max
EDI	0.006 (0.003)	0.001	0.018
HQ	0.097 (0.050)	0.02	0.30

oral health while avoiding dental fluorosis, ensuring the balance between health benefits and potential risks. Adults there might experience issues with dental cavities due to low fluoride in drinking water, which can lead to dental caries because fluoride helps strengthen tooth enamel, making it more resistant to acid attacks from bacteria, and without enough fluoride, teeth are more vulnerable to decay. A study in Sri Lanka found that the dental epidemiology of Sri Lanka has been significantly influenced by the presence of very low levels of fluoride in groundwater. Due to the water's extremely low fluoride level, dental cavities developed among the population. Since the great majority of Sri Lanka's population relies on untreated groundwater for domestic water supply, this environmental health issue is very significant to the island nation (14). Other than that, (15) stated that greater lifetime exposure to water fluoridation was linked to reduced levels of caries experience in this cross-sectional assessment survey of an adult national representative sample of Australians. It means that there is a great likelihood that people may get dental caries if there is insufficient fluoride in their drinking water.

Since the fluoride level in gravity feed system water in Sungai Mas Village was low, it demonstrated that the local en-vironment in Sungai Mas Village contains less natural fluoride. This condition could occur because not all regions on Earth have the same levels of natural fluoride. A study in Paraнba in the north-eastern region of Brazil found that 73% of the water samples taken were presented with low levels of fluoride which was below 0.5 mg/L (16). Other than that, a study in the urban area of Chongqing, China, (17) discovered that the average level of fluoride in drinking water was 0.238 ± 0.045 mg/L, with a range of 0.100 to 0.503 mg/L. Another author (18) reported that in the coastal region of Bang-ladesh, approximately 55% of samples exhibited fluoride deficiency, which was below 0.50 mg/L and may cause dental caries.

Next, for pH in the gravity feed system water was tested as recommended by the Ministry of Health Malaysia where the mean pH was 7.91 with a standard deviation of 0.13. Water samples were safe for consumption as pH still falls under the Malaysian NSDWQ, which is neutral in nature. A study in Dindigul, India found that all groundwater samples had pH values that fall between 7.02 and 7.65 (19). The geographical location of Dindigul is the same as that of Sungai Mas Vil-lage; Dindigul is a region of around 240 km2, with the highest point in the region's hilly terrain (Sirumalai Hill) being within the range of 1350 m. Dindigul shares a geographical location similar to that of Sungai Mas Village, both nestled amidst lush forests and mountains. This serene setting characterizes the surrounding landscape, creating a rural environ-ment for both areas. Also, (20) found that during the pre- and post-monsoon seasons, the pH of water samples ranged from 7.10 to 8.26 and 7.38 to 7.87, respectively in Uttarakhand, India. This leads to the conclusion that pH typically does not cause difficulties, even in hilly areas, unlike chemicals in the water sources as they can originate from other sources such as the discharge of waste from industries and agricultural operations. There is evidence from previous studies which stated that pH might help to increase amounts of fluoride in water. (21) found that the fluoride levels in water were found to be moderately positively correlated with pH, indicating that the more alkaline the water is, the faster the enrichment of fluo-ride happens. However, according to the results of this study, pH and fluoride did not correlate in any way. There is no correlation between pH and fluoride levels in Sungai Mas Village may be attributed to various factors, such as geological formations, mineral composition, and natural variations in water sources, which can affect both pH and fluoride inde-pendently, resulting in no significant relationship between pH and fluoride levels.

The estimated daily intake and the hazard quotient in relation to fluoride in drinking water samples were also deter-mined. The outcome demonstrated that the adult hazard quotient, which was 0.097, is less than one. The level of fluoride in gravity feed system water obtained in this study was excessively low compared to the permissible level suggested by the Malaysian NSDWQ, which, in turn, accounts for the lower hazard quotient. According to the hazard quotient, the risk of dental and skeletal fluorosis would be non-existent, showing that health risks associated with fluoride levels for adults were not considerable from exposure to drinking water alone. In other words, adults in Sungai Mas it is unlikely face the prospect of dental and skeletal fluorosis since these conditions typically occur as a result of prolonged exposure to ele-vated levels of fluoride in drinking water. A study on risk assessment of fluoride in drinking water in Tunisia, (22) found that 22.73 percent of adults had hazard quotients of more than one. However, the range of fluoride level in drinking water, which was from 0.0 to 5.5 mg/L, was very different from what was obtained by this research. Another study on the risk assessment of fluoride in drinking water in Kazerun, Iran, (23) found a maximum fluoride concentration of 0.72 mg/L, with a corresponding mean concentration of 0.52 mg/L. These findings resulted in Hazard Quotient (HQ) values of below 1 for fluoride across all age groups. Another study from (24) found that all age groups which were children, teens, and adults, had hazard quotients (HQ) values of less than one, indicating that there was no possible non-cancer danger of fluoride exposure for this group.

CONCLUSION

Indigenous people in Sungai Mas Village were subjected to low level of fluoride in their drinking water after com-parison to Malaysian National Standard Drinking Water Quality. The hazard quotient value indicated that indigenous adults in Sungai Mas Village were not at risk for having both dental and skeletal fluorosis, but they may be exposed to another oral health-related problem, which is dental caries. Nevertheless, periodic water sampling and determination of fluoride in water consumed by the villagers are recommended to ensure that they are exposed to optimum levels of fluo-ride. Dental checks are also suggested to determine the severity of dental caries present among the population and for the health authorities to take the necessary action.

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Ethical Consideration

Approval was received from the Ethics Committee for Research Involving Human Subjects Universiti Putra Malaysia with the reference number (JKEUPM-2022-388). The questionnaire was distributed with the responsible party's approval. A physical copy informed consent form was also given to the respondents. Respondents also received a brief explanation before receiving the questionnaire. Respondents needed to be willingly orientated to participate in this evaluation. Other than that, necessary approval was also obtained from the Malaysian Department for the Development of Indigenous Peo-ple or JAKOA since this research study involved indigenous people.

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