Relationship between Water Quality in Coal Mine Voids and Dental Health

Verry Asfirizal¹, Iwan Muhamad Ramdan², Krishna Purnawan Candra³, Swandari Paramita⁴, Krispinus Duma⁴, Ibrahim⁵, Iwan Suyatna⁶

¹. Department of Oral Biology, Faculty of Medicine, Mulawarman University, Indonesia; ². Department of Occupational Health and Safety, Faculty of Public Health, Mulawarman University, Indonesia; ³. Department of Agricultural Product Technology, Faculty of Agriculture, Mulawarman University, Indonesia; ⁴. Department of Community Medicine, Faculty of Medicine, Mulawarman University, Indonesia; ⁵. Laboratory of Silviculture Science, Faculty of Forestry, Mulawarman University, Indonesia; ⁶. Department of Aquatic Resource Management, Mulawarman University, Indonesia

Abstract: Dental and oral health is a major challenge in East Kalimantan, and nearly 73% of the population has problems with oral health. Water quality is an important factor that causes tooth decay through enamel demineralization. In the context of coal mining, high water acidity is primarily due to the presence of pyrite sulfide minerals and low fluoride ion content. Therefore, this study aimed to analyze the relationship between water quality, oral hygiene (OHIS), and the level of dental health in people who consume post-mining void water. The method was analytic observation with a cross-sectional approach, and the instruments used were the oral hygiene index, dental caries index, acidity level of water, and fluorine content test. The population included people who lived in void water areas after coal mining, and the sample included post-coal mining void water users. The sample was selected using a purposive sampling method with inclusion and exclusion criteria. The dependent variable was dental caries, whereas the independent variables were post-mining void acid water, fluorine content, and oral hygiene. The procedure of this study included testing water samples at the location with a pH meter, testing the fluorine content in the laboratory using spectrophotometry, examining oral hygiene with the oral hygiene index, and assessing tooth decay with the DMFT index. The results showed that there was a relationship between the level of acidity (pH), fluorine content, oral hygiene, and the level of dental health (DMFT) in people who use coal mine void water.

Keywords: caries; mine water; water quality; voids

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Paramita\textsuperscript{4}, Krispinus Duma\textsuperscript{4}, Ibrahim\textsuperscript{5}, Iwan Suyatna\textsuperscript{6}

1. Indonesia Mulawarman University Medical School Dental Biology
2. Indonesia Mulawarman University Public Health School Occupational Health and Safety
3. Indonesia Mulawarman University Agriculture School Agricultural Products Technology
4. Indonesia Mulawarman University Medical School Community Medicine
5. Indonesia Mulawarman University Forestry School Forest Science Laboratory
6. Indonesia Mulawarman University Water Resources Management School

Abstract:
Tooth and oral health are major challenges in East Kalimantan, with almost 73% of the population facing oral health issues. Water quality is an important factor contributing to tooth decay. In coal mining, water can become acidic due to the presence of pyrite sulfur minerals and low fluoride levels. Therefore, this study aimed to analyze the relationship between water quality, oral health (OHIS) and tooth health in people using mining void water. The method involved a cross-sectional analysis using the OHIS index, DMFT index, and water acidity and fluoride content analysis. The population consisted of people living in communities using mining void water. The sample was selected using a purposeful sampling method with inclusion and exclusion criteria. The dependent variable was caries, while the independent variables were acidic water post mining, fluoride levels, and oral hygiene. The research process included testing water samples for pH at the site, testing fluoride levels in the laboratory using spectrophotometry, and using the OHIS index to check oral hygiene and the DMFT index to assess tooth health.

Results:
Acidity levels, fluoride concentrations, oral hygiene, and tooth health levels in people using post-mining water showed a significant correlation.

Keywords:
Caries; mine water; water quality; voids

1 Introduction
The WHO Global Status of Oral Health Report \cite{31} estimates that oral disease affects almost 3.5 billion people worldwide, with three out of four affected people living in developing countries. Globally, an estimated 2 billion people suffer from permanent dental caries and 514 million children suffer from primary dental caries. The 2018 Basic Health Research (Riskesdas) \cite{32} found that approximately 45.3% of people in Indonesia had dental caries. Dental health remains a major challenge in East Kalimantan, where almost 73% of the population has problems. Dental caries or cavities are pathological processes that occur due to interactions between factors in the mouth, namely, agents, substrates, and time factors. Caries can also occur because of factors outside the mouth, namely age, gender, behavior, dental and oral health, education, social economy, and race \cite{1}. Dental caries occurs through enamel mineralization. Under acidic conditions, the solution around the hydroxyapatite crystals becomes unsaturated due to increased hydrogen ion (H+) concentration. These hydrogen ions (H+) disrupt the equilibrium of the solution and crystals; hence, more crystals are dissolved \cite{2}. Environmental factors that affect dental and oral health are physical and sociocultural. Physical environmental factors that cause tooth damage include mineral content and the degree of acidity in the water consumed. Socio-cultural environmental factors related to behavior can also make people ignore dental and oral health, supported by bad habits, such as consuming more carbohydrates than fibrous foods and poor tooth brushing \cite{3}. Post-mining void air is among the environmental issues often found in both coal and mineral mining \cite{4}. Most coal mining companies often leave several post-mining void holes, where void water flows into the surrounding environment and is used by the community. Previous studies have found that the acidity potential of coal mine void water is high. Other investigations have found that not all void water is acidic, depending on the iron sulfide or carbonate minerals content \cite{5,6}. Acidic water conditions also cause metal dissolution, and the concentration can be above the set quality.
standard. The disposal of acid mine drainage that flows into the surrounding environment affects environmental conditions, aquatic resources, and human health [7,8].

The results of a preliminary study in the coal mine void area of Bengkuring showed that for 11 years, void water was used by the people for daily water needs. No study has analyzed the impact of void water usage on dental and oral health. Therefore, it is important to analyze the relationship between water quality, oral hygiene, and dental health behavior in people who live near coal mines.

2 Methods

This study used analytic observation with a cross-sectional approach, and the analyzed variables were the level of dental health, water quality (pH and fluorine), and oral hygiene. The study was conducted among residents who live around coal mine voids in Bengkuring, North Sempaja sub-district. Void water was obtained from six locations in the Kutai Kertanegara district and Samarinda. Furthermore, the population consisted of people who lived in coal mining void areas in Bengkuring, North Sempaja sub-district, Samarinda, and the sample consisted of people who used coal mine void water. The purposive sampling method was used with inclusion and exclusion criteria. The sample size was the total number of people who consumed coal mine void water according to the inclusion and exclusion criteria. The inclusion criteria included residents who consumed coal mine void water daily, were aged > 12 years, and had permanent teeth. Meanwhile, the exclusion criteria included residents who did not live in post-mining areas, had baby teeth, and were not willing to be a study sample.

The instrument was the measurement of caries/DMF-T index, where D means “decay,” M is “missing,” and F is “filled.” The DMF-T value is the sum of D+ F+ T. Dental and oral hygiene measurements were performed using the OHI-S value obtained from the sum of the debris index and calculus. Moreover, the acidity of mine water was measured at void locations and in people’s homes using a pH meter or laboratory tool. Fluorine content was measured at every resident’s house, and the solution was examined using spectrophotometry at a wavelength of 570 nm. All obtained data were then processed using the Microsoft Word 2010 application and analyzed using one-way ANOVA and multiple linear regression on IBM SPSS Statistics.

3 Results

3.1 General Description of the Study Location

Void water samples were obtained at the surface of each void, which was used as the study sample at five different locations. The results were analyzed for water quality by acidity (pH) and fluoride content (F) at the Water Quality Laboratory, Faculty of Fisheries, Marine Sciences, Mulawarman University.

3.2 Differences in Acidity (pH) and Fluoride (F) between the Study Voids

In Tab. 2, the average value of water quality with the highest acidity level (pH) was in Void 3 (pH 7.52), and the lowest was in Void 2 (pH 5.81). Furthermore, the highest average fluoride (F) content was found in Void 4 and the lowest in Void 5. For pH and fluorine (F) content, a Sig. value of 0.000 (p < 0.05) was obtained.

The level of dental health of the respondents was very high, meaning that the level of tooth decay was very bad. DMFT value criteria according to the WHO: very low = 0.0-1.1, low = 1.2-2.6, medium = 2.7-4.4, high = 4.5-6.5, very high = 6.5 >.
3.3 Correlation between Acidity (pH), Fluoride (F), Oral Hygiene (OHIS), and Dental Health (DMF)

This study was conducted on voids located in the Bengkuring area, Sempaja Utara District, Samarinda, where they were used for water tourism and fish breeding because PDAM water had not yet entered the area. The people who lived in areas around the voids were examined for oral hygiene and DMFT, and water samples were obtained to analyze acidity and fluorine content.

Tab. 4 shows a significant relationship between pH, Fluor, Oral Hygiene, and DMFT (sig. 0.015, < 0.05), whereas only Fluor (F) has a significant relationship with DMFT (sig. 0.002, < 0.05).

Tab. 4 Multiple linear regression analysis of water quality by acidity (pH), fluorine content (F), and DMFT
(The authors)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Sample</th>
<th>Mean</th>
<th>Sig. Group</th>
<th>Sig. variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>30</td>
<td>7.191</td>
<td>.015</td>
<td>.551</td>
</tr>
<tr>
<td>Fluor (F)</td>
<td>30</td>
<td>0.416</td>
<td>.002</td>
<td></td>
</tr>
<tr>
<td>Oral Hygiene</td>
<td>30</td>
<td>2.596</td>
<td>.065</td>
<td></td>
</tr>
</tbody>
</table>

![Flowchart of the research methodology](image)

Fig. 1 Flowchart of the research methodology (The authors)

4 Discussion

4.1 Void Water Quality Based on Acidity (pH) and Fluoride Content (F)

This study was carried out in a void area of 50.26 ha in the concession area of a coal mining company PT. Mitrabara Adiperdana (MAP) in Malinau District, North Kalimantan, and the measured pH value had a range of 6-7. Studies on void water in China and India showed that the water quality in seven voids in the Shandong region of China had a pH value between 7.05 and 8.22 with an average pH of 7.23. India has the largest coal mine, the Raniganj coal-field (RCF), whose territory is spread across various districts of West Bengal and in Dhanbad district in Jharkhand. Saikat [12] showed an average pH value of different voids ranging from 7.28 to 8.61.

Variations in the pH range in the same mining company area can be caused by differences in the chemical composition of the source rock in the study area [13]. In this study, the six voids had significantly different pH levels, which could be due to variations in the ages of the voids. In certain cases, such as pit lake age, void water may reach a neutral pH without special remedial action, even though the quality is initially acidic. This phenomenon was demonstrated by Lake Nenkersdorf and Lake Bergwitz in Germany, which became neutral within 5 and 25 years, respectively. The results showed that Void WB aged 8 years had a pH value of 8.4. Void KC aged 16 years had a pH value of 8.1, and Void KK aged 17 years had a pH value of 7.8 [14].

Acidity is a key factor in quality that allows the use of void water. Reclamation actions, including the use of mining void water, must be based on an increase in pH and a decrease in salinity. Based on the duration of time in years and the possibility of pH stabilization occurring naturally, the use of mining water environment according to the use time range can occur from 5 to 15 years. Since 2008, PT Adaro Indonesia has become one of the coal mining companies that use coal mine void water as a source of raw water. The use of mine void water as a source has benefited the surrounding community in Balangan Regency, with the distribution of raw drinking water reaching 156 m³/day. The company’s internal needs for raw drinking water also use mine void water reaching 120 m³/day [15]. Meanwhile, chemical analysis of the samples showed the presence of high calcium, magnesium, iron, Fe²⁺, nitrate, NO₃, nitrite, NO₂, and cyanide (CN) concentrations. The results showed very low concentrations of copper, Cu²⁺, Zinc, Zn²⁺, sulfate, SO₄, chloride, and Cl. However, fluoride, chromium, Cr₆⁺ barium, and Ba²⁺ concentrations were slightly above the WHO threshold. The study found that the
calcium content was 32–143 mg/l with an average value of 80.6 mg/l above the WHO standard value of 70 mg/l. Meanwhile, the fluorine value was 0.21–1.42 mg/l with an average of 0.7 mg/l and the WHO standard value of 1.5 mg/l [16]. In [17], using 4 void water samples, the results showed a fluoride content of 0.5 mg/l and calcium content of 2.77 mg/l.

4.2 Relationship between Water Quality (pH and F), Oral Hygiene, and Dental Health (DMFT)

The results showed that water quality and oral hygiene factors had a significant relationship with the level of dental health (DMFT). This is because acidity, fluoride content, and oral hygiene are predisposing factors for tooth decay/dental caries. Moreover, risk factors for tooth decay have a causal relationship with the occurrence of dental caries. Some of the risk factors are a history of dental caries, lack of fluoride use, poor oral hygiene, amount of bacteria, saliva, diet, and type of food [18]. Dental caries occurs when there are four main factors, namely teeth, substrate, microorganisms, and time. Several types of dietary carbohydrates, such as sucrose and glucose, are fermented by certain bacteria and form acid; hence, the plaque pH will decrease below 5 within 3-5 minutes. A repeated decrease in pH for a certain period leads to demineralization of the tooth surface [19].

The impact of acidity (pH) on dental health in the research results showed an insignificant relationship to a high level of tooth decay (DMFT index) in samples that consumed coal void water. This is because the average acidity of void water is still at the standard normal value level of 7.19, where the normal pH value is between 6.5 and 8.5 [20]. The results of this study agree with research that states that high acidity factors (pH < 7) affect the level of tooth decay due to erosion or demineralization of tooth enamel. Demineralization of enamel is the destruction of tooth enamel hydroxyapatite, which is the main component of enamel, due to chemical processes. This condition occurs when the pH of the solution surrounding the enamel surface is lower than pH 5.5 [21].

Suratri et al. [21] obtained different results where it was found that the degree of acidity (pH) of Saliva in preschool children in Banten Province and DIY Province had no effect or was not related to the occurrence of dental caries, where the results obtained were high salivary pH (alkaline) with pH > 7, but the level of tooth decay was also high this could be influenced by other factors that were not included in the research variables [21]. In the results of this study, there is no significant relationship between the oral hygiene variable and the level of dental health in people who consume void water. This is influenced by the fact that the oral hygiene is still good enough, so it does not have a greater impact on the level of tooth decay. This thinking can be explained by [22], which shows that the prevalence and severity of tooth decay are significantly related to the decline in a person’s oral hygiene; risk factors associated with dental caries in school children and the habit of maintaining oral hygiene have an impact on the level of dental health [22].

Furthermore, the risk factors that occur when there are oral hygiene problems [23] include dental caries and periodontal disease of the tissues around the teeth, which causes inflammation of the periodontal membrane. Other factors include plaque, which is a transparent layer attached to the teeth, specifically near the gum margin. Halitosis is bad breath, which is a common problem in the oral cavity due to poor oral hygiene, certain foods, or infectious processes. Kerosis is a disorder of cracked lips, specifically at the corners of the mouth. Stomatitis is an inflammatory condition of the mouth due to contact with irritants, vitamin deficiency, and infection due to poor oral hygiene. Furthermore, glossitis is inflammation of the tongue due to infection or injury, such as burns or bites. Gingivitis is inflammation of the gums usually due to poor oral hygiene or vitamin deficiency. In the study obtained the results of fluoride content has a significant relationship with the level of dental health in people who consume void water. This is due to the average fluoride content value of 0.419 mg/l, which is below the value of fluoride standard water quality standards of 0.7-1.2 mg/l. Fluoride in drinking water with a concentration of 0.5-1 mg/L effectively reduces the prevalence of caries. The calcium content of 100 mg/l has the same protective effect as 0.64 mg/L [24]. Low fluoride (F) content needs to be increased in void water by administering fluoridase in drinking water or topically on teeth, especially in the community at an early age. Fluoride plays a crucial role in maintaining dental health [25]. This study is in line with previous research that highlights the important role of fluoride, which explains the relationship between fluoride and calcium content in drinking water and dental caries in children aged 6-8 years in Bangkalan. There is a significant difference in the caries index of children who consume river water (pH 4.7 and fluoride 0.08 mg/L) and PDAM water (pH 7 and fluoride 0.10 mg/l),
which is influenced by differences in acidity (pH) and fluorine content (F) [24,26]. Nadia et al. [27] found that the caries index of students who brush their teeth using river water is higher than that of students who brush their teeth using PDAM water. Fluorine content (F) of river water is 0.08 and that of PDAM water is 0.107. The degree of acidity (pH) of river water is 6.06 and that of PDAM water is 7.05 [27]. Fluorine can be found in drinking water, which is usually sourced from ground and surface water. Fluorine in groundwater occurs because of climatic changes that lead to the dissolution of minerals. Moreover, the concentration of fluorine in groundwater is generally higher than that in surface water, which has a fairly low fluorine concentration below 0.5 mg/L. The fluorine content will increase due to air pollution due to unprotected activities such as mining, industrial disposal, coal burning, fertilizers, and pesticides. There are industrial activities in surrounding areas, and fluorine content in water is 0.5–3.8 mg/L [24].

Water designated for drinking should have a fluorine content of 0.7-1.2 mg/L. Fluorine can be found in drinking water from gallons, PDAM, and rivers [28]. The mechanism of action of fluorine is related to the period of tooth growth before and after eruption. Moreover, fluorine inhibits the metabolism of plaque bacteria that ferment carbohydrates through hydroxyl apatite. This is achieved by producing acid-resistant enamel because fluorine does not have an anti-bacterial effect [29]. It is necessary to conduct a study that examines the beneficial effect of water fluoridation on caries control in pre-erupted teeth. Well-designed cohort studies have shown that fluoride exposure is important for caries prevention in the pre-eruptive period, particularly for pit and fissure surfaces in permanent molars. Anti-caries protection may occur because of pre-eruptive fluoride uptake in the crystal structure (FS) of developing enamel, adsorption on the crystal surface (FA), or its presence in the enamel fluid (FL). After tooth exposure to acid, FS is released into the fluid phase (FL), thereby inhibiting demineralization and enhancing remineralization [30].

5 Conclusions

In conclusion, this study showed that there was a significant difference in the level of acidity (pH) and fluorine content in void water (sig. .000). There was also a significant difference between the quality of coal mine void water and oral hygiene. There are a significant difference (p = 0.000) in water quality (pH and fluorine) between the coal void waters studied and a significant relationship (p = 0.015) between pH, fluorine, oral hygiene, and the level of dental health (DMFT index). Fluorine content has the most significant relationship with the level of dental health (p = 0.002). The results of this study illustrate the need for good and planned handling of coal void water before it is used or consumed by the community as daily raw water so that the health effects that can be caused can be avoided, especially oral and dental health.

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