

Analysis of Calcium Levels in Groundwater and Dental Caries in the Coastal Population of an Archipelago Country

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Abstract

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BACKGROUND: The coastal region is the largest region in Indonesia as a country of the archipelago. Characteristics of groundwater content in coastal areas are very influential on dental health, especially dental caries. The main elements contained in 1-1000 mg/litre groundwater are calcium, magnesium, sodium, potassium, chlorine, bicarbonate, and sulfate groups. Calcium is an essential ingredient for living organisms that play a role in the formation of bone and tooth along with permeability of cell walls.

AIM: This study aimed to analyse the relationship between calcium in groundwater with dental caries.

METHOD: Analytical observational study with cross-sectional approach was implemented was coastal communities in Watu Ulo Jember Regency in February 2018 (3,686 inhabitants), with sample criteria of the minimum age of 12 years and consumed groundwater as drinking water at least 2 years by purposive side. The variables in this study were calcium levels as the independent variable and dental caries as the dependent variable. Calcium was measured using the spectrophotometric method. Caries measurements were performed using the DMF-T index. Data were presented descriptively in the table and analysed by Spearman Correlation test to analyze the relationship between groundwater calcium with dental caries.

RESULTS: Average groundwater calcium content was 126.75 mg/litre (high category), and average dental caries was 2.2 (low category). Spearman correlation analysis showed $p = 0.029$ ($p < 0.000$), which means there was a correlation between groundwater calcium level with dental caries.

CONCLUSION: There is a positive relationship between the calcium content of groundwater with dental caries.

Introduction

Indonesia as an archipelago country extended geographically in such a way that major part of it is coastally located. About 60% of Indonesia's population is in 50 km range from the coastline, and more than 42 cities and 181 districts are in coastal areas [1]. Watu Ulo Jember Regency, East Java can represent the condition of coastal areas in Indonesia. Coastal areas have special characteristics that occur due to the interaction between processes found on land and in the oceans. These characteristics can have an effect on dental caries in the population living in the area, one of which is the groundwater content in

coastal areas.

Data of Susenas (2017) stated that the majority of drinking water sources of Indonesian society is obtained from groundwater, bottled water and protected wells. Quantity, continuity, and affordability are the reasons for the use of groundwater as drinking water for the majority of Indonesians [2]. Groundwater is formed in the recharge area and flows into its surrounding area through the space between the constituent rocks. Groundwater quality from one place to another varies, depending on the type of rock, and where the groundwater location is pervasive, flowing, accumulating, as well as environmental conditions. Groundwater quality is determined by physical

properties, chemical content, and bacteriology [3].

The main elements that dissolved ions in water and contained in 1-1000 mg/litre groundwater are calcium, magnesium, sodium, potassium, chlorine, bicarbonate and sulfate groups. Calcium levels in freshwater are usually less than 15 mg/litre, in waters around the carbonate rocks are between 30-100 mg/litre and in ocean waters are around 400 mg/litre [4].

Calcium is an essential ingredient for living organisms that play a role in bone and teeth formation, along with permeability of cell walls [5]. Calcium is an important constituent of enamel and dentine structures in teeth bound in apatite crystals to form calcium hydroxyapatite ($\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$) [6]. Calcium hydroxyapatite is the most stable phase of calcium phosphate compounds in physiological pH, temperature, and liquid compared to other phases [7]. Ca ion in calcium hydroxyapatite can be dissolved and displaced so that the process of demineralisation leading to dental caries. Dental caries is a disease of hard tooth tissue characterised by the destruction of enamel and dentine caused by the activity of bacterial metabolism in plaque, resulting in changes in enamel and dentine. Based on the Basic Health Research in 2013, the prevalence of dental caries in Indonesia in 2013 reached 53.2% [8], according to another research conducted in 2014 in coastal population, the prevalence of dental caries is 46.11%, which lower than the nationwide score [9].

To compensate for the demineralisation process in caries, it is necessary to have a calcium ion intake freely to assist the remineralisation process [4]. Based on the description, this study aimed to analyse the relationship between groundwater calcium content with dental caries.

Method

This was an observational analytic study with the cross-sectional method. The research approach was implemented coastal communities in Watu Ulo Jember Regency in February 2018 (3,686 inhabitants), with sample criteria of the minimum age of 12 years and consumed groundwater as drinking water at least 2 years by purposive side with the assumption that calcium in water had been absorbed by the body. Sampling was done by purposive sampling [10]. The variables in this study were calcium levels as the independent variable and dental caries as the dependent variable. Method of taking calcium in this study was done by taking groundwater from the well with a bucket then inserting the empty bottle into a bucket and opening bottle cap, filling water until full then closing and labelling bottle. The bottle was covered with plastic and put in a cool box

and sent to Perum Jasa Tirta I laboratory in Malang, East Java to test the level of calcium by spectrophotometric method [11]. The caries data retrieval method was done with Decay, Missing, Filling-Teeth (DMF-T) index. The caries examination was done by drying the tooth surface, examined by the probe and dental mouth mirror. Caries cannot be filled but excavated; the tooth cavity can be filled with the restoring material. (decay), extracted teeth or indication of retraction due to caries (missing), and tooth filling because caries (filling). Then DMF-T component was summed up [12]. The results were presented in the form of frequency distribution tables and continued by Spearman correlation test to analyse the relationship of groundwater calcium content with dental caries. This research had been approved by the Health Ethics Committee of Faculty of Dentistry, Universitas Jember (No. 087/UN25.8/KEPK/DL/2018) on February 8, 2018.

Results

The results regarding the sex in this study can be seen in Table 1.

Table 1: Data of Respondents Characteristics by sex

Sex	Total	Percentage
Male	11	36.7
Female	19	63.3
Total	30	100

Table 1 63% of the respondents are female. The results regarding the age can be seen in Table 2.

Table 2: Data of Respondents Characteristics by age

Age (Depkes, 2009)	Total	Percentage
Early teenage (12-16 y.o.)	4	13.3
Late teenage (17-25 y.o.)	5	16.7
Early adulthood (26-35 y.o.)	6	20
Late adulthood (36-45 y.o.)	8	26.7
Early elderly (46-55 y.o.)	2	6.7
Late elderly (56-65 y.o.)	5	16.6
Total	30	100

Table 2 shows that most of the final adult respondents ranged from 36-45 years old (26.7%), The minority aged 46-55 years (6.7%). The results regarding the occupation can be seen in Table 3.

Table 3: Data of Respondents Characteristics by type of occupation

Occupations	Total	Percentage
Student	7	23.3
Housewife	8	26.7
Fisherman	9	30
Merchant	5	16.7
Civil servant	1	3.3
Total	30	100

Table 3 shows that most respondents work as fishermen (30%), but 3.3% works as civil servants. The results regarding the average calcium level of

groundwater and caries can be seen in Table 4.

Table 4: Mean Calcium Levels (mg/litre) and Incidence of Dental Caries

Variables	N	Mean
Calcium	30	126.75
Caries	30	2.2

Table 4 shows the average groundwater calcium content of 126.75 mg/litre (high category) and the DMF-T index average of 2.2 (low category). The results regarding the relationship of the calcium content of groundwater with dental caries can be seen in Table 5.

Table 5: Spearman correlation test results with variable levels of calcium and dental caries

Variable	Sig	Note
Calcium-Caries	0.029	There is a correlation

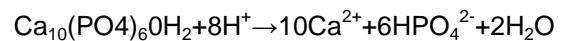
Table 5 shows a correlation of groundwater calcium content with dental caries with a significance value of 0.029 ($p < 0.05$).

Discussion

The Majority of respondents are female on the age between 36-45 years, working as a fisherman. Based on the results of a study that had been done, the average calcium water level was 126.75 mg/litre in which was categorised as high. There are four category regarding the calcium content (concentration) in water, ie low (< 60 mg/liter), medium (60 mg/liter-119 mg/liter), high (120 mg/liter-179 mg/liter), and very high (> 180 mg/liter) [13]. Several studies have shown a distinctive relationship of calcium, sodium, and fluoride content in a water source — the higher the fluorine level, the lower the calcium level. This might be caused by the exchange of Na with Ca in the underground water circulation [14]. Seawater is naturally water with a salt content of about 3.5%. Seawater contains salts, such as calcium` magnesium elements, belonging to elements of Group II A (alkaline earth), dissolved gases, organic materials and unsolved particles. The presence of salts affects the physical properties of groundwater in coastal areas [15]. Well water in the coastal area, based on geographical studies, undergoes an intrusion process from seawater so that the original freshwater soil turns into hard water. The intractable hard water of these seawater contains high calcium [16]. According to WHO standards, the average calcium content in drinking water is 75 mg/L, and the maximum allowed limit is 200 mg/L. Water with calcium levels the maximum limit can cause digestive problems, kidney problems, bladder stones, and urinary tract obstruction in humans [17]. Human activities can also affect water quality in coastal areas,

especially in tourist-dense areas that still use groundwater as the main source of water [18]. Watu Ulo is also located between the sea and rice fields that utilise groundwater for irrigation purpose so that it can affect the hardness of groundwater in the region.

The average DMF-T score of 2.2 indicates the low category. According to the DMF-T index there are five categories of, very low (0.0-1.0), low (1.2-2.6), moderate (2.7-4.4), high (4.5-6.5), and very high (> 6.6) [19], [20]. Caries occurs because of four interplaying factors: diet, time, microorganism, and host. Caries occurs when all four factors contribute to the demineralisation process [21]. Teeth demineralisation may occur if saliva has an acidic pH level where enamel dissolves by acid resulting in partial loss of ions in the enamel by the following reaction [22], [23].

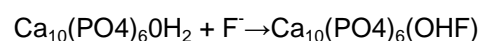


The DMF-T index of coastal communities in Watu Ulo, Sumberejo Village, Ambulu Sub-district, Jember Regency is low possibly because of the community behaviour in maintaining good oral hygiene as they consume a non-cariogenic nutritious diet.

Also, the average community in Watu Ulo, Sumberejo Village consumed groundwater with high calcium. Calcium plays a role in preventing the demineralisation process to decrease caries.

Spearman correlation results showed that there was a relationship of the calcium content of groundwater with dental caries. This occurs because calcium levels in groundwater are known to decrease dental caries which can be measured using the DMF-T index. Dental caries is inversely related to the concentration of calcium and fluoride contained in drinking water. This is supported by a study of Arvin et al., in 2018, stating that decreasing the calcium concentration from 120 mg/l to 33 mg/l can increase caries by 46% [5].

Another effect of groundwater calcium on caries suggests a positive relationship between calcium ions and fluoride levels in plaque. Calcium diffuses into the plaque and provides a bond for fluoride. The free ionic calcium ion in drinking water and fluoride causes the process of precipitation and dissolution of the fluoride ion into the biofilm fluid on the tooth surface to prevent the caries process [5]. Fluoride acts by inhibiting plaque bacterial metabolism that can ferment carbohydrates through alteration of apatite hydroxy in enamel to apatite fluorine by chemical reactions:



Apatite fluorine may cause the enamel to be more acid-resistant, thus inhibiting demineralisation and discontinuation of carious lesions [22]. WHO recommends that the ideal drinking water should contain at least 0.5-1.0 mg/L of fluoride [26]. The

lowest fluoride concentrations in drinking water of 0.5 to 1 mg/litre effectively reducing the prevalence of caries and the concentration of 100 mg/litre of calcium has the same protective effect as 0.64 mg/litre fluoride [5]. Fluoride level of < 0.5 mg/L resulted in dental caries, 0.5 to 1 mg/L was the most acceptable body-safe level, while 1-3 mg/L resulting in dental fluorosis, 3-4 mg/L causing fragile bone, and levels > 4 mg/L cause knee deformities and even paralysis [26]. The optimum F concentration for dental health is generally between 0.5 and 1.0 mg/L [27].

Saliva is a major source of minerals that rebuilds demineralised enamel. The hydroxyapatite (HA) crystals in tooth enamel, consisting of Ca, Mg, and Pi (Phosphate) are more susceptible to dissolution by acids. If the pH is more than 4.5, the lost HA is immediately replaced by fluorapatite by the F ions available in oral biofilms which is more resistant to acid dissolution. This process leads to a decrease in demineralisation and is not considered as remineralisation since it is replaced by different minerals. In addition to the reduction of enamel demineralisation, F also increases remineralisation when pH rises. Ca assist this process by providing F with a place to bind with. Minerals in drinking water are the main source of Ca and Mg which are absorbed by the body. These elements play an important role in the body's physiological functions. Fluor has anticariogenic effects. The optimum Ca and Mg level in drinking water that is beneficial for health ranges from 40-80 mg/L for Ca and 20-30 mg/L for Mg. Ca concentration in saliva to helps repair early carious lesions ideally should not exceed 90 mg/L. Ca and F together caused 45% decrease in DMF-S index, supporting the role of Ca in teeth remineralisation [27].

The average calcium content in the sample was 126.75 mg/litre equivalent to 0.81 mg/litre fluoride, which showed an effective level to decrease the prevalence of caries. Calcium obtained from the diet will be absorbed by the body and affects serum calcium levels and also in saliva secreted by the salivary gland [28]. The total concentration of calcium in drinking water is 2 mmol/litre at 25°C, whereas, the whole human saliva contains about 1 mmol/litre of calcium. Human saliva also contains high concentrations of bicarbonate as protein and phosphorus, both of which will bind to calcium saliva. This causes free calcium ions in the saliva to be reduced to half of the total saliva calcium concentration so that the process of remineralisation is less than optimal. Free calcium ions will be more effective in enhancing the remineralisation process when binding to fluoride ions to form calcium fluoride (CaF₂). From both of these things, a higher intake of free calcium is required than the calcium in saliva [4], [5]. During the demineralization process, calcium is released from the enamel, dentine, and cementum before phosphate release. Therefore the use of calcium to inhibit the demineralisation process is

considered more effective than the use of phosphate [29].

However, it is important to remember that individuals with high levels of calcium and phosphate in saliva are known to have higher resistance to caries, but are more susceptible to periodontal disease due to faster calculus buildup [30]. Therefore it is recommended to perform effective dental cleansing to prevent rapid formation of calculus as a result of high calcium intake.

Based on the research results, it can be concluded that there was a relationship of calcium levels in groundwater with dental caries. The higher Ca levels in groundwater the lower dental caries.

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