Effects of Ceramic Membrane Composed of Clay and a Mixture of Rice Husks, Sawdust, Coconut Shell Charcoal, and Coffee Grounds on Reducing Total Coliforms in Well Water

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Abstract

Aim: The study was conducted to determine the effects of a ceramic membrane composed of clay and a mixture of rice husks, sawdust, coconut shell charcoal, and coffee grounds on reducing total coliforms in well water. **Methods:** The materials used were clay and a mixture of materials including rice husks, sawdust, coconut shell charcoal, and coffee grounds. These materials were mixed, molded, dried, and burnt. Total coliforms in well water were measured as the observed parameter, and the different material compositions were compared. Coliforms were assessed with the membrane filter method, while data were analyzed with a one-way analysis of variance. **Results:** The results showed that the greatest reduction in total coliforms was found on the ceramic membrane of clay and coffee grounds with a value of 105.8 CFU, while the lowest was observed in a mixture of clay and coconut shell charcoal at 92.8 CFU. The percentage decline rate in total coliforms caused by ceramic membrane with a mixture of land clay and coffee grounds reached 91.3%. **Conclusion:** Although there was no significant difference in the reduction of total coliforms among the various membrane compositions, the combination of clay and coffee grounds caused a reduction reaching >90%.

Keywords: Ceramic membrane, clean water, total coliform

Introduction

Water is one of the primary human needs used for daily activities, such as bathing, drinking, washing, and cooking. The average water needed for drinking purposes is estimated at 5 L/day, while the overall household requirement for Indonesians is 120 L/day.[1,2] To enhance the quality of drinking water, especially when the source is polluted, processing is crucial to meet the standards set by the Republic of Indonesia Minister of Health Regulation No. 492/MENKES/PER/IV/2010. In terms of physical requirements, drinking water should be odorless, tasteless, colorless, and not cloudy, while bacteriological requirements include the absence of *Escherichia coli*, a group of coliform bacteria. The presence of coliform bacteria in drinks and food shows the existence of enteropathogenic or toxigenic microbes that can endanger health. Consequently, the mandatory parameters for determining the quality of drinking water microbiologically include total coliform bacteria and *E. coli*, with the maximum level allowed being 0/100 mL sample.[3,4]

Several instances of water pollution have been observed in various areas of Indonesia, such as contamination from septic tanks due to inadequate distance between the dug well and the septic tank, which is often <10 m. Furthermore, water pollution causes cases of diarrhea in people who use contaminated sources. Various efforts have been made to obtain clean water free from pollution, including filtering, sedimentation, filtration, and disinfection. However, these purification systems are quite expensive due to the required materials and infrastructure. Other methods used to reduce the number of bacteria in contaminated water include rapid

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sand filtration, ceramic filters, solar disinfection, chemical disinfection, boiling, and desalination.[5]

To overcome the limitations associated with previous methods, membrane technology is a viable solution due to the relatively simple process and accessibility of materials. An appropriate alternative technology for household-scale water treatment is ceramic membranes.[6] This consists of filters made from a mixture of clay and flammable organic materials, including tea leaves, coffee grounds, cork beans, sawdust, corn husks, rice husks, and others.[7] Ceramic water filters are attractive due to the low cost, ease of fabrication and use, as well as ability to filter bacteria from water effectively.[8,9]

The basic material used in making ceramic membranes is clay, a porous material capable of optimal adsorption ion exchange.[10] The additive used in this study was sawdust, which is hygroscopic or easily absorbs water.[11] A previous study used ceramic membranes with sawdust additives to treat well water, rainwater, and wastewater. The results showed a significant reduction in suspended solids and biological oxygen demand (BOD) levels, with a sawdust proportion of 20%, producing an efficiency of 99.5% and 50%, respectively. In addition, a reduction in total coliforms reaching 72% was achieved with sawdust proportions of 20% and 30%.[12]

The components of coffee grounds include 47.8%–58.9% carbon, which plays a role in binding metal ions in the water filtration process, reducing cadmium by 55.75%.[13-15] Coconut shell charcoal is used as an additive due to its characteristics, including several micropores, low charcoal content, high solubility in water, and high reactivity. Therefore, the composition of coconut shell charcoal can be used as a raw material for making ceramic membranes.[16]

This study was conducted to design ceramic membranes for reducing total coliforms in polluted well water. Membrane was produced from clay as the basic material and a mixture of additives in the form of sawdust (pot filter). Different materials were mixed with clay, including rice husks, sawdust, coconut shell charcoal, and coffee grounds. In a previous study, only zeolite and rice husks were used as clay mixing materials. The filter membrane used was a container that is easy to apply in small-scale designs and does not require operational electrical energy. Therefore, this study aimed to determine the effects of ceramic membranes made from clay with a mixture of rice husks, sawdust, coconut shell charcoal, and coffee grounds on reducing total coliforms in well water.

Materials and Methods

This quasi-experimental study was conducted with a one-group pretest–posttest method and a completely randomized design. The experiment was carried out in the Laboratory and Work Workshop of the Environmental Health Department, Health Polytechnic, Ministry of Health, Aceh. The materials used were clay, rice husks, sawdust, coconut shell charcoal, and coffee powder originating from the cities of Banda Aceh and Aceh Besar as well as clean water, aquades, alcohol 70%, and well water samples. The ceramic membrane was made in the form of clay-pot ceramic filters[17] with a mesh size of 60–100 mesh according to a previous study where a 90%:10% (clay: sawdust) ratio was found to be most effective in reducing total coliforms.[17] The subject was dug well water belonging to residents of the Aceh Besar area. The number of repetitions was five times for each test and coliform measurement was carried out using the membrane filter method.

The tools required include 35-L jerry cans, a burning stove, a sieve, a measuring cup, a bucket, scales, a ball mill, measuring tools, a water tap, and a 25 kg paint can (top diameter 29.5 cm, height 36.5 cm, and bottom diameter 26.5 cm, total volume 95.7 m^3). Clay, as the main raw material for making ceramic objects, was subjected to a firing process at a temperature of 600°C. The aim is to obtain a hard, dense clay that cannot be destroyed by air. The pores are also enlarged. The design of the ceramic membrane system is shown in Figure 1.

Data obtained from simplex lattice design calculations (predictions) compared with actual test data were analyzed using one-way analysis of variance (ANOVA) to determine whether there were significant differences between treatments. When the results of the ANOVA test were significant, showed by $P < \alpha$, the analysis proceeded with the least significant difference test.

Results

Data were presented in the form of total coliform value in groundwater after passing through the ceramic membrane, the amount successfully removed, and the efficiency of removal. The values of total coliforms found before and after using ceramic membranes are shown in Table 1.

Based on the results, the greatest reduction in total coliforms was observed in a ceramic membrane mixture of clay and coffee grounds with a value of 105.8 CFU, while the lowest was found in clay and shell coconut at 92.8 CFU. Figure 2 shows the percentage decline in total coliforms using different ceramic membranes.

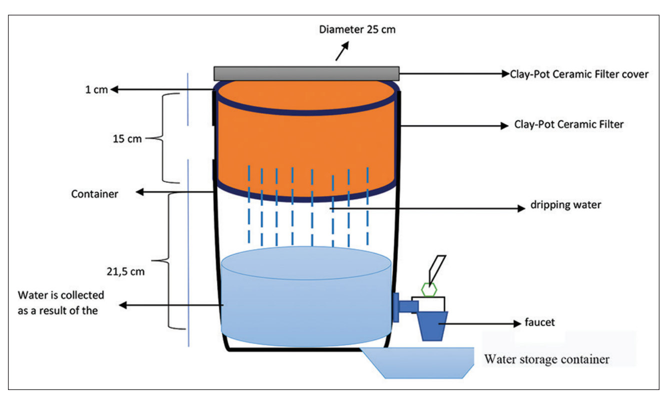

Figure 1: Ceramic membrane system

Table 1: Total coliforms values before and after using ceramic membrane

Mixture of ceramic membrane	Total coliforms value (CFU)														
	1			2			3			4			5		
	Pre	Post	Difference	Pre	Post	Difference	Pre	Post	Difference	Pre	Post	Difference	Pre	Post	Difference
Clay and rice husk (90%:10%)	130	22	108	126	27	99	121	28	93	102	13	89	100	19	81
Clay and powder saw (90%:10%)	130	17	113	126	23	103	121	26	95	102	10	92	100	11	89
Clay and charcoal shell coconut (90%:10%)	130	18	112	126	16	110	121	16	105	102	20	59	100	22	78
Clay and coffee powder (90%:10%)	130	14	116	126	9	117	121	8	113	102	7	95	100	12	88
Control	130	38	92	126	32	94	121	38	83	102	28	74	100	23	77

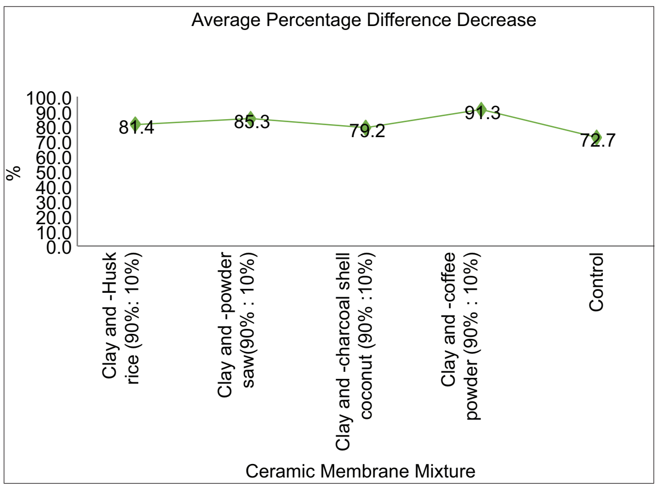

Figure 2: Average percentage of total coliforms before and after using a mixture of ceramic membrane

The decrease in total coliforms obtained with a ceramic membrane mixture of clay and coffee grounds reached 91.3%. The average speed of water flow in the filtration process across the membrane is shown in Table 2.

The fastest speed was observed in the control at 2.5 mL/min followed by clay–coconut shell charcoal membrane at 3.4 mL/min, while the longest was found in clay and rice husk mixture at 5.5 mL/min. ANOVA test results showing the decline in coliform levels are presented in Table 3.

Based on Table 3, the $P = 0.214 \leq \alpha = 0.05$; hence, the null hypothesis was accepted. There was no significant difference in the reduction of coliforms between ceramic membranes made from clay with a mixture of rice husks, sawdust, coconut shell charcoal, and coffee grounds.

Discussion

In this study, filtering was carried out using well water, and the discharge or filtering speed was also observed to determine the filter's effectiveness in reducing coliform content. The results showed that the highest reduction in total coliforms was found on ceramic membranes made with clay and coffee grounds. The capability was almost similar to the effectiveness of Cambodia ceramic filters in reducing *E. coli,* with an average of 99% both in the laboratory and in field trials.[13,18] This study is unique due to the use of mixed materials, including coconut shell charcoal, coffee grounds, sawdust, and rice husk, compared to others that used only two ingredients, namely a filter and zeolite.

The results are in accordance with a previous study that used three variations of clay, rice husk, and zeolite mixtures (50%:20%:30%).[19] Another study examined the performance of ceramic filters supplemented with colloidal silver, showing significant effectiveness in drinking water treatment.[20] The application of natural clay and zeolite-based ceramic filters reduced the levels of total dissolved solid (TDS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), and linear alkylbenzene sulfonate (LAS) contained in laundry wastewater.[21] Other studies examined the effect of grogs on the performance of ceramic water filters. *E. coli* parameter was used with a filter composition ratio of clay: grog: sawdust (4:1:2, 3:1:1, and 4:2:1).[22] A previous investigation used ceramic filters made from clay, rice husks, and iron powder (87%:10%:2.5%) to examine parameters of TDS, electrical conductivity, pH, and turbidity.[23] Furthermore, suspended matter removal efficiency and COD in rainwater, wastewater, and well water were assessed with sawdust proportions of 20% and 30%.[12] Another study focused on developing a water filter using ceramic material was conducted to improve river water quality and assess discharge rate to reduce turbidity.[24] The percentage composition of clay has been used to evaluate parameters such as total coliforms, *E. coli*, turbidity, nitrite, and hardness.[25] A previous study examined the effects of sawdust and rice husk additives on the physical properties of ceramic filters. Based on the results, the turbidity level using the slip-casting method has less removal efficiency than the semi-dry pressure method using rice husk or powder.[26] The efficiency of ceramic filters for water treatment was assessed in the Kambata Tabaro zone, Southern Ethiopia, by varying combustion temperatures.[8] Another study found that ceramic membranes with sawdust composition of 7.5% and 10% effectively reduced *E. coli* by up to 98%.[11]

Table 2: Average speed water flow in the filtration process in ceramic membrane

Filter membrane	Speed water flow (mL/min)
Clay and rice husk	5.5
Clay and sawdust	3.5
Clay and coconut shell charcoal	3.4
Clay and coffee grounds	5.2
Control	2.6

Table 3: Analysis of variance test results on the effect of ceramic membrane composed of clay and a mixture of rice husk, sawdust, coconut shell charcoal, and coffee grounds on reducing total coliforms in well water

	Amount quadrant	df	Mean square	*F*	Significant
Between groups	1275.200	4	318.800	1.596	0.214
Within groups	3994.800	20	199.740		
Total	5270.000	24			

This study adopted a novel approach by using a mixture of coconut shell charcoal and coffee grounds, a combination not previously explored. Although previous studies have used sawdust and rice husks in various proportions, typically alongside zeolite, this study proved to be distinct by using a filter pot and comparing four different clay mixtures.

Membrane is a thin layer between two fluid phases, namely the feed and the permeate phase, which functions as a barrier against certain particles. The semipermeable nature facilitates the retention of materials larger than the pore size while allowing other particles smaller in size to pass through.[27] In this context, filtration not only facilitates separation but also serves as a means of concentrating and purifying a solution passed through the membrane. The advantage of filtration is that the membrane does not change the molecular structure of the substances being separated, making the process simpler.[28]

Clay, formed from the weathering of silica rocks by carbonic acid and partly produced from geothermal activity, contains fused silica and aluminum with fine particle sizes. It forms hard lumps when dry and sticky when wet with water.[29] Meanwhile, rice husk charcoal is porous, light, not dirty, but has low water absorption and good porosity. This ability can be enhanced through chemical activation or by heating at high temperatures, causing changes in physical and chemical properties.[30]

The main components of wood sawdust include cellulose, hemicellulose, lignin, and extractive substances, making it a suitable additive for producing ceramic membranes. Sawdust was selected as the combustible material in this study due to its ability to provide a homogeneous mixture with clay, in contrast to other combustible materials, namely coffee grounds and rice husks.[31] Filtration using coffee grounds containing activated carbon can reduce total coliforms as 1 g of activated carbon has a surface area of 500 m–1500 m, making it an effective material for capturing particles with a size of 0.01–0.0000001 mm.[32]

According to Wrigley and Lowe, coffee grounds are excellent adsorbent material due to the high hydrocarbon content reaching 19.9%.[33] Another study reported that activated charcoal could absorb phosphate contained in detergent waste due to the numerous pores present, with finer activated charcoal, showing higher absorption capacity.[34,35] In the process of reducing coliforms, all tested filters showed comparable capabilities. Therefore, the selection of a filter for further development can be based on effectiveness and efficiency, with a focus on incorporating coffee grounds. Ceramic filters can be an effective and appropriate technology to improve water quality.

Given that all membrane mixtures were integrated with clay, fouling may occur during the filtration process due to various mechanisms. For example, when adsorption occurs, membrane material interacts with the particles in the solution. Therefore, a thin layer of particles attracted to the membrane can cause partial or complete blockage of the pores, affecting the filtration process. Cleaning can be performed through reverse rinsing by spraying clean water with the pot upside down. The costs required for making ceramic membranes vary depending on locally available resources. In this context, clay, rice husks, sawdust, coconut shell charcoal, and coffee powder are widely available in Indonesia, negating the need for additional purchases.

Most of the studies conducted to assess the performance of ceramic filters reported significant effectiveness in removing coliforms from treated water. However, challenges exist precisely in measuring filtration rate due to variations in clay filter density and material longevity. External participation, particularly from the ceramic industry, is crucial in implementing clean water treatment initiatives. Local governments also play an important role in the planning and development of clean water treatment facilities for lower-income communities. Engaging local communities in this participation is essential in designing environmentally friendly programs.

Conclusion

There was no significant difference in the ability of each filter to reduce coliforms. The greatest amount of reduction was observed in ceramic membranes made with a mixture of clay and coffee grounds. This method has great potential due to the use of coffee grounds, which are widely available as a waste material in Aceh Province, Indonesia.

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Ethics code

The authors approved this study with Ethical Number: Dp. 04.03/12./077/2023.

Conflicts of interest

There are no conflicts of interest.

Author's contribution

Aditama W: Conceptualization, Data Curation, Examination, Technique, Approval, Visualization, Financing Sources, Writing-unique draft, Writing-review and editing. Zulfikar: Conceptualization, Data Curation, Assets, Supervision, Writing– review and editing. Sofia: Data curation, Examination, Assets, Supervision, Writing– review and editing.

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