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Construction of Temporary Landfill Shield by Utilizing MICP Stabilized Water Treatment Plant Sludge Waste

Priskha Tri Natasya[1], Andi Marini Indriani[2*], Gunaedy Utomo[3]
[1,2,3] Civil Engineering, Civil Engineering and Planning, Universitas Balikpapan Indonesia
[*] Corresponding author, e-mail: andi.marini@uniba-bpn.ac.id

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ABSTRACT

The addition of Bacillus Subtilis bacteria to the mud soil at IPAM (Integrated Wastewater Treatment Plant) Perumda Tirta Manuntung Km.8 in Balikpapan City aimed to enhance its suitability as a temporary cover layer in places like landfills. Initial mud testing revealed key characteristics: Chemical Characteristics: The mud's specific chemical composition was identified, providing a foundation for a deeper understanding of its properties. Physical Characteristics: The mud falls into the fine-grained soil category, with 63% of particles passing through a No. 200 sieve. Moisture content is high at 42.54%, primarily composed of silt (39.8%) and clay (25%). Mechanical Characteristics: Standard proctor tests yielded a maximum dry unit weight of 1.099 gr/cc and an optimum water content of 33.65%. Initial soil permeability met temporary landfill cover criteria, with a permeability value of 5.04×10-4 cm/s. Further research demonstrated that by introducing Bacillus Subtilis bacteria at varying concentrations and incubation periods, mud permeability could be altered. The highest permeability, 4.27×10-4 cm/s, was achieved with an 8% bacteria concentration and a 7-day incubation period, while the lowest permeability, 1.19×10-5 cm/s, resulted from an 8% bacteria concentration and a 28-day incubation period. These findings suggest that Bacillus Subtilis addition can modify mud permeability, making it more suitable as a temporary landfill cover. This presents a potential solution for more effective IPAM management.

Keywords: *Bacillus Subtilis; Mud soil; Landfill cover; Mud permeability.*

INTRODUCTION

Bacillus Subtilis bacteria are aerobic bacteria which are able to grow in the presence of air and can be activated by water[1]. Bacillus Subtilis bacteria has several advantages, namely being able to form a protective endospore which is formed when pressure occurs on the bacteria so that it can survive in extreme conditions. Bacillus Subtilis bacteria are aerobic bacteria which are able to grow in the presence of air and can be activated by water [2]. To find out how contamination occurs in the clay liner layer, several studies have been carried out aiming to analyze the effect of different soil density levels on leachate and groundwater penetration, and how leachate affects soil permeability [3]. In addition, it is necessary to analyze the effect of groundwater on the condition of leachate seepage at each of the different soil density levels, PDAM sludge waste is a by-product of drinking water system processing that originates from surface water [4]. PDAM sludge waste is formed due to colloidal particle deposits which are forced to precipitate faster using aluminum chemicals. Therefore, the aluminum content in PDAM waste sludge is very high. If mud that is too high is allowed to enter water bodies, it will cause pollution. Therefore, proper management and treatment is

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needed to solve the problem of PDAM sludge waste [5]. Research on the effect of using PDAM sludge as a material for making clay liners and knowing the quality of the clay liner strengthened by the MICP (Microbially Induced Calcite Precipitation) method has been widely carried out and has shown positive results [6]. MICP is a soil improvement technique using microorganisms that are able to change and improve physical and mechanical properties [7]. In the method of making landfill cover using PDAM sludge material reinforced with MICP it is important to know the effect of the added cementation solution. Several previous studies have stated that the molarity of the cementation solution plays an important role in the deposition of calcite in stabilized soils. So that researchers are interested in conducting research related to the molarity of the cementation solution used to obtain optimal conditions for the clay liner layer.[8][9]

MATERIALS AND METHODS

Materials

This research began with the preparation of materials, namely the mud of IPAM Perumda Tirta Manuntung Km.8 Balikpapan City, while the mixer that will be used is Bacillus Subtilis bacteria. The additive stabilization in this research was by mixing the mud of IPAM Perumda Tirta Manuntung Km.8 Balikpapan with 8% Bacillus Subtilis bacteria with a culture age of 3 days.

The equipment used to support the completion of this temporary landfill cover research is from the Balikpapan University laboratory, including tools based on sieve analysis tests, water content, specific gravity based on picnometer experiments, atterberg limits, and standard proctor tests [10].

Bacterial Culture

Microbiological culture is a method for multiplying bacteria in culture media by culturing in a sterile, controlled laboratory to determine the type of organism. Based on [18] the composition used for breeding Bacillus Subtilis bacteria includes 20 gr of Urea, 3 gr of Nutrient Broth (NB), 2.12 gr of NaHCO3, 4.14 gr of CaCL2 2H2O, 10 gr of NH4Cl. These materials are put into an Erlenmeyer glass. Then dissolve it with 1000 ml of water (aquades). After that, it is sterilized in an autoclave at a temperature of 121oC.

Mixing with Bacillus Subtilis bacteria and B4 media. First of all, prepare 500 ml of water (aquades) and mix it with 3 grams of Nutrient Broth with 500 ml of water (aquades) without mixing into a different Erlenmeyer glass. After that, put the two Erlenmeyer glasses into the autoclave at a temperature of 1210C and a pressure of 1 atm for 15 minutes. After the medium has cooled, then carry out the bacterial inoculation process, namely mixing the bacterial isolate into the B4 medium that has been made and everything is done in a Laminar Airflow device so that it remains stable, controlled and sterile. Then take a bacterial suspension of 2% of the total B4 medium and put it in an Erlenmeyer tube. Shake the media with a vibrator until the bacteria are evenly mixed with the media. Then culture the bacteria for 3 days before applying it to the soil to be stabilized.

Soil Testing

The implementation of testing results and soil analysis in the laboratory is divided into 3 (three), namely testing regarding chemical characteristics through XRF (X Ray Fluorescence Spectometer Soil) testing, testing regarding physical characteristics can be seen in Table [5].

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Table 1. Test standar physical characteristics

No	Testing	Standar
1	Moisture Content	ASTM D 2216-71
2	Specific Gravity (GS)	SNI 03-1964-1990
3	Limits – Atterberg Limits	ASTM D 4318
4	Sieve Analys	ASTM D 1241

and testing regarding soil mechanical properties can be seen in Table.

Table 2. Test standar soil

No	Testing	Standar
1	Standart Proctor Test	ASTM D 1557
2	Permeabilitas	ASTM 2434-68

The research design for permeability test objects with the addition of bacteria with a variation of 8%, and can be seen in Table 3.

Table 3. Permeability test objects with the addition of bacteria with a variation of 8%,

Testing	Culture age	Bacterial Concentration	Number of Samples			
			Incubation Time			
			7	14	21	28
PERMEABILITAS	3 day	6%	3	3	3	3
		8%	3	3	3	3
		10%	3	3	3	3

RESULTS AND DISCUSSION

Results and Analysis of Mud Samples Before Stabilization IV Chemical Characteristics Based on the results of the XRF (X Ray Fluorescence Spectometer) test carried out in a chemical laboratory with the Horiba Scientific tool which was carried out on the tested mud samples, the results were obtained as shown in Table 4 [6].

Table 4. Chemical laboratory test

Element	Concentration	Unit
Fe	89,4394	%
Ca	4,0651	%
Si	2,9910	%
Al	2,2701	%
S	0,4957	%
K	0,3366	%
Mn	0,2343	%
Ti	0,1354	%
Cl	0,0164	%
Cu	0,0117	%
V	0,0042	%

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The test results showed that the highest content was Fe, namely 89.4394% and Ca, 4.0651%. This Ca element is expected to react with Bacillus Subtilis bacteria to form calcium (CaCo3) [7][8].

Testing Mud Physical Characteristics
To determine the physical characteristics of the sludge, tests were carried out on specific gravity, moisture content, liquid limit, plastic limit, plasticity index, and sieving analysis [9]. The results of testing the physical characteristics of the mud can be shown in table 5.

Tabel 5. Results of testing the physical characteristics of the soil

Types of Assessment	result
(*Specific Grafity,G*)	2,62 gr/cm^3
(*Water Content*)	42,54 %
(*Liquid Limit, LL*)	45,65 %
(*Plastic Limit, PL*)	32,32 %
(*Plasticity index,IP*)	13,33%
Mesh size 200	63 %

Mechanical Properties Testing
To determine the mechanical properties, mud was tested against standard proctor tests and permeability tests. The results of testing the mechanical characteristics of the mud can be shown in Table 6.

Tabel 6. Results of testing the mechanical characteris

Types of Assessment	result
Optimal Water Content (OMC)	1,099 gr/cc
Maximum Dry Density (MDD)	33,65 %
Permeability	3,69.10^{-4} cm/s

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The Proctor Test results can be seen in Figure 1

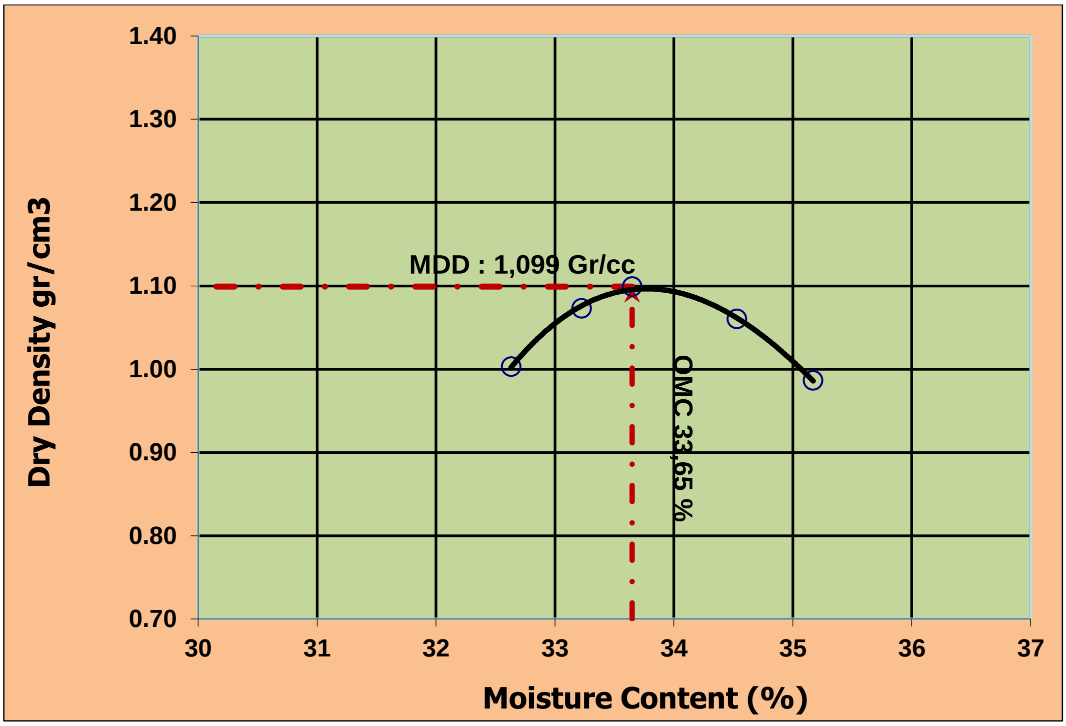

Figure 1. Graph of the Relationship Between Moisture Content and Sample Dry Volume Weight

The result data obtained in the standard proctor test experiment was then plotted as in the picture above, so that the maximum dry volume weight (MDD) was obtained at 1.099 gr/cc and the optimum water content (OMC) was 33.65%.

Figure 2. permeability test

Permeability is carried out to get a coefficient value. Because the soil used includes fine - grained soil, the method in the permeability test used is the high -falling head. Using equation II.13 obtained the results displayed in Table IV which is 5.04.10-4 cm/s.

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Permeability is carried out to obtain a coefficient value. Because the soil to be used includes fine -grained soil, the method in this permeability test used is the high -falling head [9] Obtained the results displayed in Table 8 which is 5.04 × 10-4 cm/s.

Results and Analysis of Materal Samples After Stabilization

After obtaining the maximum dry volume weight value (maximum dry density) and the optimum of the optimum moisture content (optimum moisture content), after the proctor test test results will be obtained, the sample will be continued to make the permeability test with the additional variation of the semination solution and the bacterial bacteria of the bacillus subtilis.

IV. Testing Results of Soil Permeability with the Addition of Bacillus Subtilis Bacteria

Based on the results of adding bacteria Bacillus subtilis with a mixture of variation concentration of 6%, the following results are obtained.

A. Permeability test results with the addition of 6% variation and bacteria Bacillus subtilis at the age of 3 days culture

After testing permeability with the addition of a solution of bacterial bacteria subtilis at the age of a 3 -day culture can be seen in Table 7.

Tabel 7. Permeability with the addition of a solution of bacterial bacteria subtilis at the age of a 3 -day culture

Parameter	Culture Age	Curing Time (Days)			
		7	14	21	28
Permeability (cm/s)	3 Hari	4,03x10-4	3,30x10-4	2,95x10-4	1,98x10-4

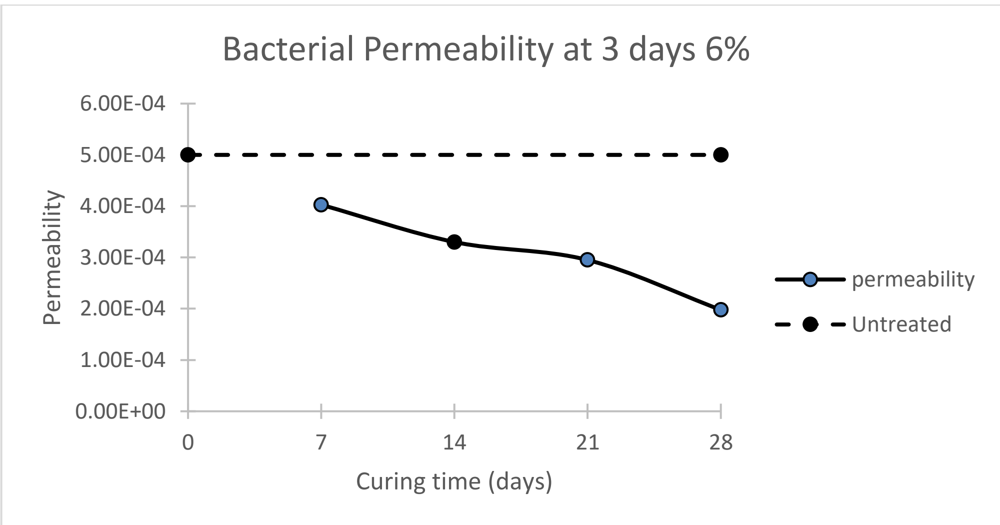

Figure 3. Permeability values with the Addition of Bacillus Subtilis Bacterial Solution at a 3-Day Culture Age.

The graph above shows that with the addition of Bacillus subtilis bacteria experienced a

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decrease in permeability, which means that the soil pores are getting smaller. In the addition of bacteria with a culture age of 3 days during the pelam period 7 to 14 days can reduce the permeability value by 18%. In the peram period 14 to 21 days can reduce the value of permeability while the peak of the permeability value is in the fortune period of 10% At the 28-day curing period, the percentage decrease in soil permeability reached 50,86%, indicating that the most significant reduction in permeability occurred with the addition.

Permeability test results with an additional variation of 8% bacteria bacillus subtilis at the age of 3 days culture. After testing permeability with the addition of a solution of bacterial bacteria subtilis at the age of a 3 -day culture can be seen in Table 8.

Table 8. Value of Permeability with the addition of Bacillus subtilis bacteria at the age of 3 days culture

Parameter	Culture Age	Curing Time (Days)			
		7	14	21	28
Permeability (cm/s)	3 days	4,04x10-4	3,44x10-4	2,04x10-4	1,62x10-4

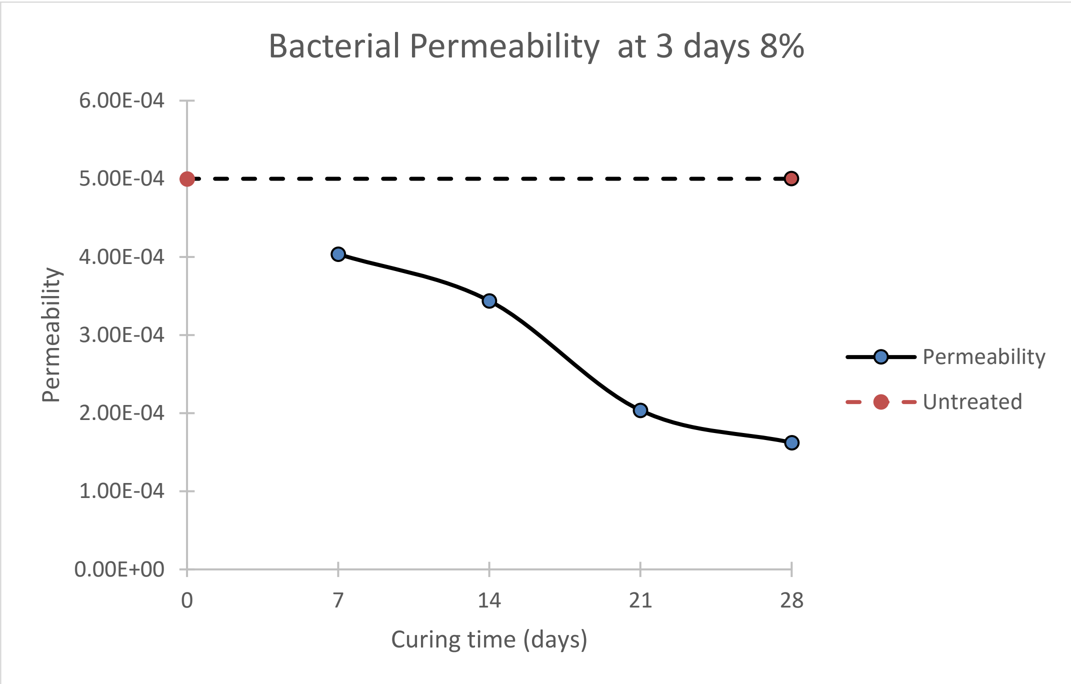

Figure 4. Permeability Values with the Addition of Bacillus Subtilis Bacterial Solution at a 3-Day Culture Age.

The graph above shows that with the addition of Bacillus subtilis bacteria experienced a decrease in permeability, which means that the soil pores are getting smaller. In the addition of bacteria with a culture age of 3 days during the pelam period 7 to 14 days can reduce the permeability value by 14%. In the peram period 14 to 21 days can reduce the value of permeability while the peak of the permeability value is in the fortune period of 40,69% At the 28-day curing period, the percentage decrease in soil permeability reached 59,90%, indicating that the most significant reduction in permeability occurred with the addition.

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Permeability test results with an additional variation of 10% bacteria bacillus subtilis at the age of 3 days culture. After testing permeability with the addition of a solution of bacterial bacteria subtilis at the age of a 3 -day culture can be seen in Table 9.

Table 9. Value of Permeability with the addition of Bacillus subtilis bacteria at the age of 3 days culture

Parameter	Culture Age	Curing Time (Days)			
		7	14	21	28
Permeability (cm/s)	3 days	2,26x10-4	2,16x10-4	1,96x10-4	1,29x10-4

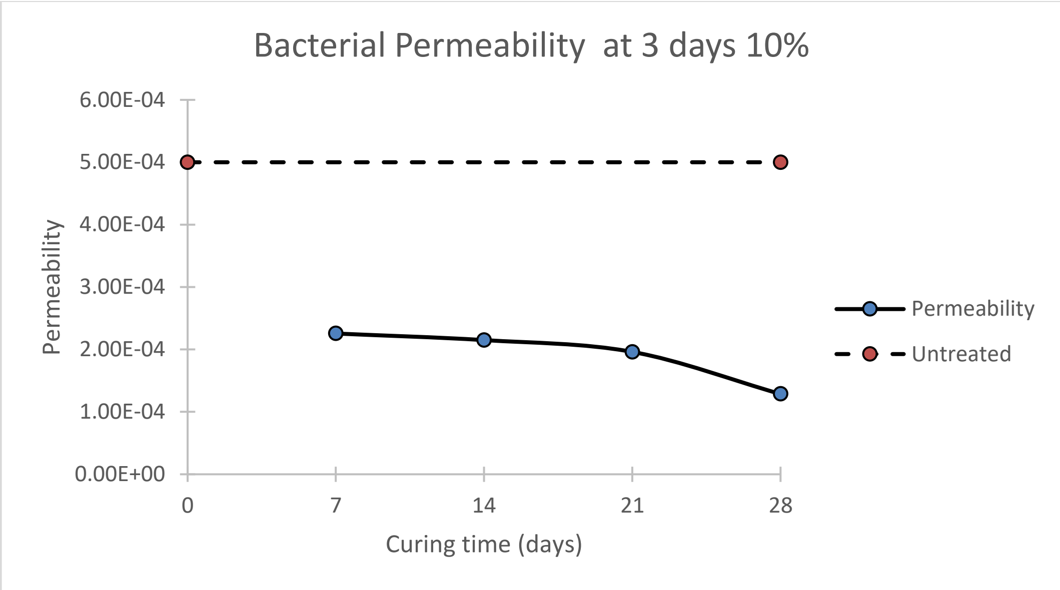

Figure 5. Permeability Values with the Addition of Bacillus Subtilis Bacterial Solution at a 3-Day Culture Age.

The graph above shows that with the addition of Bacillus subtilis bacteria experienced a decrease in permeability, which means that the soil pores are getting smaller. In the addition of bacteria with a culture age of 3 days during the pelam period 7 to 14 days can reduce the permeability value by 4%. In the peram period 14 to 21 days can reduce the value of permeability while the peak of the permeability value is in the fortune period of 9,25% At the 28-day curing period, the percentage decrease in soil permeability reached 42,92%, indicating that the most significant reduction in permeability occurred with the addition.

The result of the comparison of permeability values with the addition of Bacillus Subtilis bacterial variations can be observed in figure 6.

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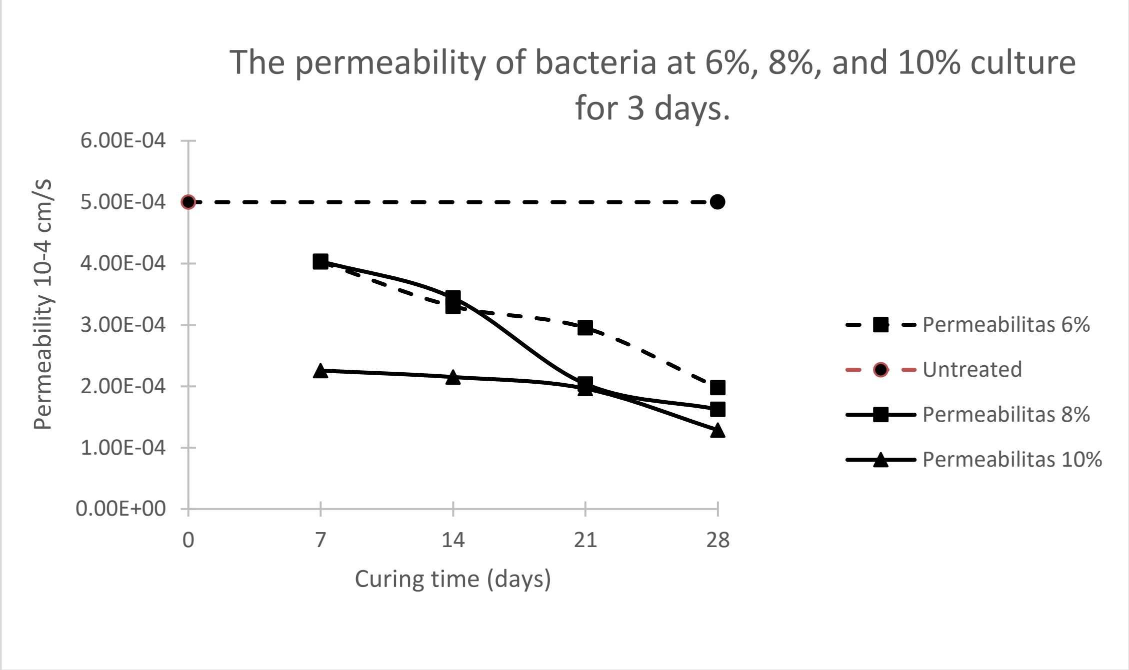

Figure 6. Comparison Graph of Permeability Test Results in Bacteria Mixtures with Variations of 6%, 8%, and 10%.

In Figure 6, it can be observed that there is a difference in the reduction of permeability with varying bacterial mixtures. The sample with the lowest graph is found in the sample with a cementation solution mixture of 8%.

The testing results of the chemical characteristics, physical characteristics, and mechanical characteristics of the soil were directly conducted in the laboratory to determine the changes that occurred in the samples stabilized with various variations of Bacillus Subtilis bacterial solution. This study utilized material from the mud of Ipam Perumda Tirta Manuntung at km. 8 Balikpapan.

CONCLUSION

In the background that has been presented, there are several important points that can be concluded:
Bacillus Subtilis bacteria are aerobic bacteria that can survive in extreme conditions and form a protective endospore. Research on the use of PDAM sludge as a material for making clay liners using the MICP method showed positive results.
Sanitary landfill is a method of waste management that is carried out in a sanitary manner to avoid environmental pollution.

Clay liner is used as a protective layer in landfills to prevent contamination of the soil beneath. PDAM sewage contains high levels of aluminum, and proper management is required to avoid environmental pollution. Clean water produced from the drinking water treatment process by the PDAM can become part of the environment if it is not managed properly. Bacillus Subtilis bacteria is a microorganism used in research to improve the physical and mechanical properties of clay liner. The addition of Bacillus Subtilis Bacteria to the clay liner reduces soil permeability, which indicates that the soil pores become smaller.

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The test results showed that a decrease in permeability occurred at a concentration of Bacillus Subtilis bacteria of 6%, 8%, 10% and a culture age of 3 days. Overall, this research aims to increase effectiveness temporary landfill cover in protecting soil from leachate and groundwater pollution and overcome the problem of PDAM sludge waste in the landfill environment. Bacillus Subtilis bacteria are an important element in efforts to reduce soil permeability.

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