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# The Effect of Adding Probiotic Bacteria on Bauxite Waste Mud: Experimental Research Method

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***Abstract*---*Bauxite waste sludge is quite dangerous when polluted into the surrounding environment. The number is increasing with the higher mining production. The utilization is still not maximized hence it is unbalanced to the increasing number, and it is necessary to use on a large scale. Sub-grade soil could use a lot of bauxite waste sludge but in reality, this waste is unsafe to use and its characteristics are mud the requirements of bearing capacity according to the AASHTO and USCS Classification unfulfilled. This study aims to determine the effect of the use of probiotic bacteria in bauxite waste on its physical characteristics and pH value. This experimental research method develops test objects according to ASTM standards with the same weight of bauxite waste and variations in the number of probiotic bacteria, namely 25 ml, 50 ml, 75 ml, and 100 ml and the incubation time of bacteria is 7 days, 14 days, 21 days, 28 days, 35 days, and 42 days. The results showed that the test specimens with more bacteria and longer incubation times resulted in lower pH values and physical characteristics that fulfilled the requirements for sub-grade soil. Based on the test results showed that due to the addition of probiotic bacteria, the bauxite sewage sludge increased to class A-4, namely silt with medium quality and a pH close to 8, eliminating the hazardous nature of the waste.*
***Keywords*---*bauxite waste sludge, pH value, physical characteristics, probiotic bacteria, subgrade.***

## Introduction

Bauxite reserves in West Kalimantan are 0.84 billion tons of the total national reserves of 1.26 billion tons, around 66.77% and it is hoped that with aggressive exploration the number of reserves will increase (Ministry of Energy and Mineral Resources, 2016). In general, to obtain alumina products, the Bayer process is used, namely washing bauxite ore using caustic soda (NaOH) and water. This process is used by companies because the process is quite cheap, the results obtained are effective and easy (Husaini et al., 2016). However, this process is very unfavorable for the

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environment because it produces dangerous strong alkaline properties and the form of sludge as a result of leaching deposits and the amount is double the amount of production (Jain et al., 2014; Metboki & Ernawati, 2019; Zhang et al., 2019; Oprčkal et al., 2020). Mining companies must be responsible for the consequences of their activities that cause deforestation and the resulting waste. Mining activities have been regulated in government regulations, if they do not comply, they will be subject to high costs for environmental restoration, the risk of environmental damage and the health of the surrounding population, both physically and psychologically, such as stress, which is the body's reaction to situations that seem dangerous or difficult (Suhron, 2007, 2016, 2017), but the landowners may feel the impact the most, because mining companies as land users may at any time leave the land after production activities without repairing damaged land and are at great risk of damaging the environment and causing disasters.

Several studies regarding the utilization of this bauxite waste have been carried out, but the products produced are still on a small scale and none of them has yet reached an industrial scale. Such as materials for making ceramics, cement materials, and materials for roads (Lwin et al., 2018; Amalia & Aziz, 2011; Fathurrozi & Rezqi, 2016). Given its very high alkalinity, this waste is prone to contamination. Subgrade soil is an alternative that can be considered because its use is massive and the use of probiotic bacteria will make it an environmentally friendly material (Sultana et al., 2000; Krasaekoopt et al., 2004). The technology of using microorganism activity is now widely used in concrete conditions for self-healing. Several studies have proven that the activity of microorganisms plays a very large role in the recovery of concrete (Xu & Wang, 2018; Kim et al., 2021; Lima et al., 2017).

The use of bacteria in bauxite waste has also been carried out, as in the patent numbered US 20200148569AI which results show a reduction in the pH value (Zhang et al., 2005). The bacteria used were obtained from cattle (Lucerne Hay) and bagasse which were added with molasses, brown rice, and extracts of vitamins and sugar (Aziz, 2012; Mendu & Pannem, 2021; Yang & Xiao, 2008). The drawback of this research is the stage of generating bacteria which is quite long and difficult to do in the field before it can be used into waste which in the end is quite expensive (PA Publication, 2020). In addition, there is also a patent numbered CN 107309270 which uses the bacterium Pannonibacter phragmitetus BB as a waste recovery agent. Yeast extract and glucose were used as a source of bacterial growth. The results of the study can also reduce the pH value even though the method used is still on a laboratory scale but proves that the role of bacteria is quite significant in bauxite waste sludge and organic matter is very supportive as a growing medium (Patent China, 2020). This is the basic formulation of the research here to explore microorganisms and other organic materials using a simpler, large-scale, and easy-to-use method in the field (Mymrin et al., 2017; Alekseev et al., 2019).

Probiotic bacteria are bacteria that are safe to use and beneficial because they can kill pathogenic bacteria (which can cause disease) (Ganesh et al., 2020). These bacteria were chosen to lower the pH because these bacteria produce lactic acid which has a small pH value. In addition, due to the activity of these bacteria, it produces CaCO3 (calcium carbonate) deposits which can bind the surrounding grains so that it is expected that the granules from this bauxite waste sludge will be bound and form larger granules and have harder properties due to a thicker matrix arrangement congested (ESDM, 2016).

In terms of its physical characteristics, currently, no one has investigated the effect of adding probiotic bacteria in bauxite waste. Therefore, in this study, we will review the effects of giving probiotic bacteria into bauxite waste both in terms of its physical and chemical characteristics, especially the pH value as an indicator of whether or not bauxite waste is safe if applied to the environment (Suhron & Zainiyah, 2021; Suhron & Amir, 2018; Suhron et al., 2019).

The selection of the final product as a subgrade is based on the consideration that from a physical point of view this bauxite waste is in the form of mud, so to apply large amounts of waste is to use it as a subgrade above the subgrade from the bottom layer of highway pavement construction (Kiskira et al., 2021; Kusmanto et al., 2019; Bagaskara, 2018; Hasan et al., 2018). In general, the subgrade soil in the West Kalimantan area is peat soil which is classified A-8 for the AASHTO classification, which a soil is containing high organic matter, while for the USCS classification, it is included in the CH class, namely clay with high compressibility and does not meet the requirements for subgrade (Chen & Lin, 2009). While the requirements for subgrade as a subgrade for road construction pavement are those that do not include high plasticity soils, which are classified as A-7-6 from the AASHTO M 145 requirements or as CH in the USCS classification system (Training on the use of materials, 2020). Currently, generally, the material used as a subgrade is a type of silt soil close to sand to gravel obtained from natural exploitation, especially in mountains and hills. In addition to this activity depleting resources, the direct impact is deforestation of forests to the cause of natural disasters in the future (Muthawali, 2018; Krishna et al., 2014; Segui et al., 2013; Kisnawati, 2016). This is a challenge for researchers to find alternative solutions for alternative materials that are environmentally friendly, sustainable, and can mainly utilize waste.

This new product from bacterial bauxite waste may be a product that can be utilized more than subgrade. Much further research is needed to make it a more useful and sustainable advanced material (Doniyor & Khabibulla, 2021).

It is hoped that this research can be the first step in realizing human goals and expectations to better protect and preserve nature (Damayanti & Khareunissa, 2016; Suhron et al., 2020). Especially for landowners from mining companies who are directly affected by bauxite production activities. Because after land users have completed their production activities, the waste will still be left on the land and will become a pollutant that is at risk of environmental damage in a very large area (Álava et al., 2020). By taking a little from the earth but being able to replace it more for the earth, it becomes a motivation for researchers to continue to develop according to their knowledge.

## Method

The method used is experimental, namely conducting a direct test to obtain data and results connecting the variables studied. The research was carried out at the Civil Engineering Soil Laboratory of the Pontianak State Polytechnic.

### *Material*

Bauxite waste sludge used is from PT. ICA (Indonesia Chemical Alumina) Tayan, Sanggau Regency, West Kalimantan. This waste is made with 2 conditions, namely disturbed (disturbing condition) and undisturbed (undisturbing condition) as a control variable. Disturbing condition is that the test object is given active probiotic bacteria while it is not disturbed where the test object is attempted to be tested as soon as possible to get its original condition. The tests carried out refer to the ASTM (American Society for Testing and Materials) standard which consists of a water content test (ASTM D 2216-80), a specific gravity test (ASTM D 854-83), a volume weight test (ASTM D-2937-00), consistency limit test (ASTM D 4318), filter analysis test (ASTM D 6913-04), hydrometer test (ASTM D 1140-00) and pH indicator paper test (SNI 6371, 2015).

The probiotic bacteria used are finished products such as fertilizers for agriculture, fisheries, and animal husbandry. The bacteria contained are photosynthetic, lactic acid bacteria, yeast, actinomycetes, and yeast fungi. These bacteria must first be activated by providing molasses as an energy source. After the activation period was carried out for 48 hours, the bacteria continued to grow and were ready to be used.

### *Objects test*

Objects designed in this study were made with 2 conditions. The first condition as a control variable is waste without bacteria (RM) while the second condition is waste using bacteria (A, B, C, D, E, and F). The weight of the bauxite sewage sludge was designed to be the same, namely 200 grams but the amount of bacterial solution was varied, namely 25ml, 50ml, 75ml, and 100ml. Furthermore, the incubation time of bacteria and waste also varied, namely 7 days, 14 days, 21 days, 28 days, 35 days, and 42 days. Variations of test objects can be seen in the following table.

Table 1
Variation of a test object

| No. | Name | Number of specimens | Weight of bauxite waste (grams) | Weight of bacteria | Incubation time |
|---|---|---|---|---|---|
| 1. | RM1, RM2, RM3 | 3 | 200 | 0 | 0 |
| 2. G. A | A1-1, A2-1, A3-1 | 3 | 200 | 25 ml | 7 days |
| | A1-2, A2-2, A3-2 | 3 | 200 | 50 ml | |
| | A1-3, A2-3, A3-3 | 3 | 200 | 75 ml | |
| | A1- 4, A2-4, A3-4 | 3 | 200 | 100 ml | |
| 3. G. B | B1-1, B2-1, B3-1 | 3 | 200 | 25 ml | 14 days |
| | B1-2, B2-2, B3-2 | 3 | 200 | 50 ml | |
| | B1-3, B2-3, B3-3 | 3 | 200 | 75 ml | |
| | B1- 4, B2-4, B3-4 | 3 | 200 | 100 ml | |
| 4. G. C | C1-1, C2-1, C3-1 | 3 | 200 | 25 ml | 21 days |
| | C1-2, C2-2, C3-2 | 3 | 200 | 50 ml | |

| | | | | | |
|---|---|---|---|---|---|
| | C1-3, C2-3, C3-3 | 3 | 200 | 75 ml | |
| | C1- 4, C2-4, C3-4 | 3 | 200 | 100 ml | |
| 5. G. D | D1-1, D2-1, D3-1 | 3 | 200 | 25 ml | 28 days |
| | D1-2, D2-2, D3-2 | 3 | 200 | 50 ml | |
| | D1-3, D2-3, D3-3 | 3 | 200 | 75 ml | |
| | D1- 4, D2-4, D3-4 | 3 | 200 | 100 ml | |
| 6. G. E | E1-1, E2-1, E3-1 | 3 | 200 | 25 ml | 35 days |
| | E1-2, E2-2, E3-2 | 3 | 200 | 50 ml | |
| | E1-3, E2-3, E3-3 | 3 | 200 | 75 ml | |
| | E1- 4, E2-4, E3-4 | 3 | 200 | 100 ml | |
| 7. G. F | F1-1, F2-1, F3-1 | 3 | 200 | 25 ml | 42 days |
| | F1-2. F2-2, F3-2 | 3 | 200 | 50 ml | |
| | F1-3, F2-3, F3-3 | 3 | 200 | 75 ml | |
| | F1-4, F2-4, F3-4 | 3 | 200 | 100 ml | |
| Total | | 75 samples | 15,000 grams | 4500 ml | |

*G= group

Mixing between bauxite wastes with a bacterial solution is done manually with stirring time adjusted to the conditions of all ingredients until evenly mixed. Furthermore, the test object is placed in a clear plastic container with a lid with a diameter of 20 cm and a height of 10 cm. The need for bacteria as living things becomes a reference for the design of storage of test objects during the incubation period. As a source of energy, bacteria will get from molasses which is mixed into the solution. For the need for air exchange, the plastic container used is closed but given a small hole with a diameter of 5mm. And for the need for sunlight, storage of test objects is carried out under direct sunlight under a transparent roof and protected from rain.

*Test procedure*

Testing on the test object consists of testing the physical characteristics and pH indicator. Tests on the test object were carried out for two conditions. For the first condition, the test object (RM) will be tested for water content, specific gravity, bulk weight, filter analysis, hydrometer analysis, consistency limit, and pH test (Kavas, 2006; Gadepalle et al., 2007; Friesl-Hanl et al., 2009).

*Water content testing the water*

Content on the test object to determine the ratio between the weights of water contained in the soil to the weight of solid grains (dry soil) expressed in percent. The method of determining the moisture content can be done with several wet soils which are dried in an oven at a temperature of $100^0$C - $110^0$C for a certain time. The water lost due to drying is the amount of water contained in the soil. The method of testing the water content in this study refers to ASTM D 2216 – 80.

The test object is prepared and put into a cup that has been weighed. Furthermore, the cup containing the test object was placed in an oven at $110^0$C for 24 hours. Then the test object that has been baked in the oven is weighed and calculates the percentage of water content with the formula:

$$w = \frac{Ww - Dw}{Dw - Tw} \times 100\%$$

Where w is water content, Ww is the weight of wet soil+container, Dw is the weight of dry soil+container, and Tw is the weight of the container.

*Specific gravity testing specific gravity*

Testing is carried out to find the specific gravity of a soil sample. The soil density is the ratio between soil grains and the weight of distilled water in the same volume of air at a certain temperature. The working method is based on the ASTM D 854 – 83 standard. Prepare all test objects and equipment to be used. Weigh a dry and clean pycnometer. Add about 10 grams of soil and weigh. Add distilled water to 2/3 parts and let stand approximately 24 hours. Tilt and shake to release the trapped air. Add distilled water to the brim and cover and dry the outside and weigh. Calculate the specific gravity with the formula:

$$\mathrm{Gs} = \frac{\mathrm{W2} - \mathrm{W1}}{(\mathrm{W4} - \mathrm{W1}) - (\mathrm{W3} - \mathrm{W2})}$$

Where Gs is the specific gravity, W1 is the weight of the pycnometer, W2 is the weight of the pycnometer and dry soil, W3 is the weight of the pycnometer, soil, and water, and W4 is the weight of the pycnometer and water.

*Volume weight test volume*

The weight of the soil is the unit weight of the soil per unit volume. The unit weight of the soil is determined by comparing the weight of the soil with the volume influenced by the weight of solid grains, moisture content, and total volume. This weight-volume test method refers to ASTM D – 2973 – 00. A cylindrical ring is inserted into the soil by pressing it to a certain depth, then carefully dismantled so that the volume of the soil does not change. Soil samples were dried for 24 hours at 105 C and then weighed.

*Consistency limit*

Test this test aims to determine the water content of a soil sample at the liquid limit and in the plastic limit state. This consistency limit test method refers to ASTM D 4318. Atterberg Limit is a method used to determine the consistency of fine-grained soils with different moisture content. Each level has a density and behavior that is also different so that the technical nature also has an effect. In this research, the liquid limit and plastic limit was tested.

The liquid limit is the state of the soil where the water content lies between the liquid state and the plastic state. Preparation of Casagrande tools and materials to be used. The sample is filtered with No. 40 is given water and then put into a bowl and made a groove in the middle. The tool lever is rotated and counts the number of beats. Then the sample was taken partly to test the water content.

The plastic limit is the soil at the boundary state between plastic and semi-solid. The test object is prepared to pass sieve No. 40. Given water and rolled on a glass plate to a diameter of 3.1 mm (1/8 inch) until it cracks or breaks. Then weighed and tested for water content.

*Sieve analysis test sieve*

The analysis is sifting or vibrating the soil sample through a set of sieves where the sieve holes are progressively smaller. This test aims to determine the gradation of grain distribution from a coarse-grained soil sample retained by a No. sieve. 200, to classify the soil and to determine the coefficient of uniformity (Cu) and coefficient of gradation (Cc). This test method refers to ASTM D 6913 – 04.

The test object is prepared to weigh 100 grams, soaked for 24 hours, washed not to damage the soil components, and then sieved with a 0.075mm sieve. The test object is left on the filter in the oven, while the one passes for hydrometer analysis. After being weighed in the oven, the difference in the weight of the dry test object before washing and the test object after washing is the mud. Furthermore, the test object is sieved through a sieve from 4.75 to 0.075 in size. Place the filter arrangement on the vibrating machine, insert the test object into the topmost arrangement and close the lid tightly (Shin & Kim, 2016; Yusuf et al., 2019). Tighten the machine clamp and the vibrator is turned on for 15 minutes. Any specimens left in each sieve are taken and weighed. Group each remaining in the sieve and calculate the percentage.

*Hydrometer*

Analysis The purpose of hydrometer analysis is to determine the grains that pass through the No. sieve. 200 (0.075 mm) or in other words to determine the percentage of mud content in the soil. This test follows the ASTM D 1140 –

00 standard. This hydrometer device moves downwards the longer the mud settles, so the hydrometer at a certain time shows zero and this means that the mud has settled.

*pH test pH*

The parameter is used to express the level of acidity of a solution. Acidic solutions have a pH less than 7, alkaline solutions have a pH greater than 7 while neutral solutions have a pH = 7. Testing the pH value in this study used universal indicators or table pH indicators.

**Results and Discussion**

The test object visually shows that when the conditions are wet, the test object is in the form of mud for both non-bacterial (RM) and bacterial (AF) conditions. However, when in a dry condition after being oven-dried, the non-bacterial specimens were very fine, like dust, while the bacterial specimens hardened following the mold and were very difficult to crush. It is necessary to do further research on the effect of bacteria in the hardening.

Figure 1. Non-bacterial test object & bacterial test object (AF)

*Water content test results this water content*

The test was carried out for all test objects following variations in the number of bacteria and the number of days of incubation of bacteria and bauxite waste. For each variation, 3 test objects were prepared for which the average value would be taken. The result is shown in the following image.

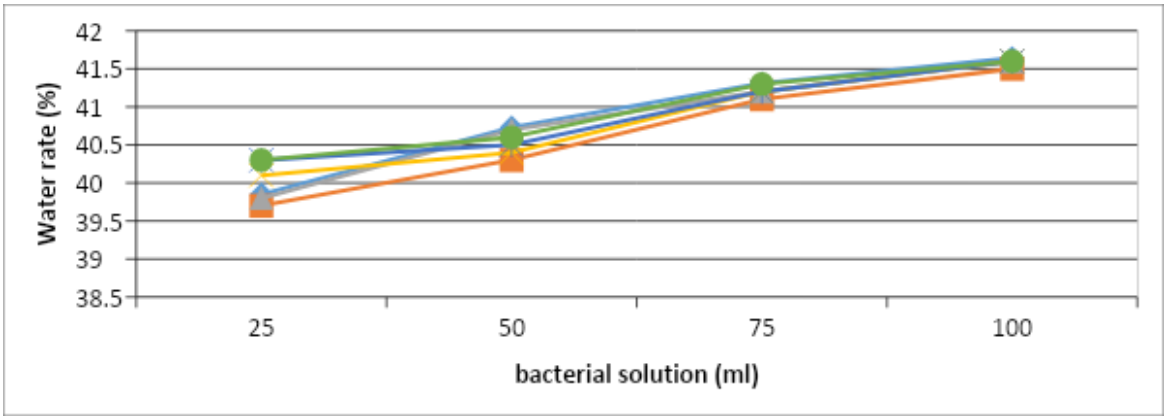


Figure 2. The results of the water content test

In Figure 2 it is known that the higher the amount of bacterial solution given, the higher the water content. This needs to be investigated further than what occurs by bacterial activity on a micro-scale, but it should be noted that from the completion of the research time the longer the water on the test object disappears and hardens. For further research, observations of the length of the day need to be added so that the data obtained will be clearer.

*Specific gravity test results*

Figure 3. Specific gravity test results

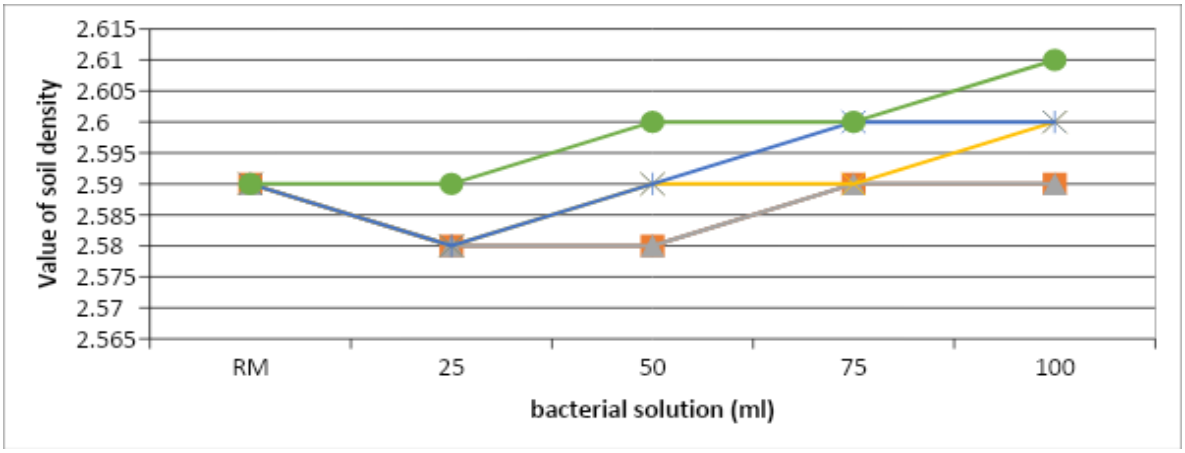


Figure 4. Specific gravity test results

In Figure 4 it is known that the specific gravity values obtained are not significantly changed. The value ranges from 2.58 to 2.6 the longer the incubation day, the higher the specific gravity value.

*The results of the volume weight test the results of the volume weight*

Test on the non-bacterial (RM) and bacterial (AF) test objects and the calculation of the physical parameters can be seen in the following table.

Table 2
The results of testing the weight of the volume of the test object test

| Object | Weight of wet soil ($gr/cm^3$) | Weight of dry soil (gr) | Pore number (e) | Porosity (n) | Degree of saturation (%) | Soil volume (%) | Air volume (%) | Water volume (%) |
|---|---|---|---|---|---|---|---|---|
| RM1 | 1.88 | 1.35 | 1.74 | 0.64 | 61.13 | 36 | 24.88 | 39.12 |
| RM2 | 1.79 | 1.03 | 1.37 | 0.58 | 100 | 42 | 0 | 58 |
| RM3 | 1.82 | 1.62 | 0.6 | 0.38 | 54.74 | 62 | 17.2 | 20.8 |
| A-1 | 1.84 | 1.32 | 0.95 | 0.49 | 100 | 51 | 23.88 | 25.12 |
| A-2 | 1.85 | 1.31 | 0, 97 | 0.49 | 100 | 51 | 23.88 | 25.12 |
| A-3 | 1.85 | 1.31 | 0.98 | 0.49 | 100 | 51 | 23.88 | 25.12 |
| A-4 | 1.86 | 1.31 | 0.98 | 0.49 | 100 | 51 | 23.88 | 25.12 |
| B-1 | 1.84 | 1.32 | 0.96 | 0.49 | 100 | 51.2 | 0 | 48.8 |
| B-2 | 1.85 | 1.32 | 0.96 | 0.49 | 100 | 51.2 | 0 | 48.8 |
| B-3 | 1.85 | 1.31 | 0.98 | 0.49 | 100 | 50.6 | 0 | 49.4 |
| B-4 | 1.86 | 1.31 | 0.98 | 0.49 | 100 | 50.6 | 0 | 49.4 |
| C-1 | 1.84 | 1.32 | 0.96 | 0.49 | 100 | 51.2 | 0 | 48.8 |
| C-2 | 1.85 | 1.31 | 0.97 | 0.49 | 100 | 50.8 | 0 | 49.2 |
| C-3 | 1 ,85 | 1.31 | 0.98 | 0.49 | 100 | 50.6 | 0 | 49.4 |
| C-4 | 1.86 | 1.31 | 0.98 | 0.49 | 100 | 50.6 | 0 | 49.4 |
| D-1 | 1.85 | 1, 32 | 0.96 | 0.49 | 100 | 51.2 | 0 | 48.8 |
| D-2 | 1.86 | 1.32 | 0.96 | 0.49 | 100 | 51.0 | 0 | 49.0 |
| D-3 | 1.86 | 1.32 | 0.96 | 0.49 | 100 | 51.0 | 0 | 49.0 |
| D-4 | 1.86 | 1.31 | 0.99 | 0.49 | 100 | 50.4 | 0 | 49.6 |
| E-1 | 1.86 | 1 ,33 | 0.94 | 0.49 | 100 | 51.6 | 0 | 48.4 |
| E-2 | 1.86 | 1.32 | 0.96 | 0.49 | 100 | 51.0 | 0 | 49.0 |
| E-3 | 1.87 | 1.32 | 0, 97 | 0.49 | 100 | 50.8 | 0 | 49.2 |
| E-4 | 1.87 | 1.32 | 0.97 | 0.49 | 100 | 50.8 | 0 | 49.2 |
| F-1 | 1.87 | 1.33 | 0.95 | 0.49 | 100 | 51.4 | 0 | 48.6 |
| F-2 | 1.87 | 1.33 | 0.96 | 0.49 | 100 | 51.2 | 0 | 48.8 |
| F-3 | 1.88 | 1.33 | 0.96 | 0.49 | 100 | 51.2 | 0 | 48.8 |
| F-4 | 1.88 | 1.33 | 0.96 | 0.49 | 100 | 51.0 | 0 | 49.0 |

*The results of the test of the consistency limit*

The results of the test of the consistency limit on the non-bacterial (RM) and bacterial (AF) test objects as well as USCS classification can be seen in the following table.

Table 3
Results of testing the limits of the test specimen consistency

| Test specimen | Liquid limit (%) | Plastic limit (%) | Plastic index (%) | Classification |
|---|---|---|---|---|
| RM1 | 45.32 | 30.21 | 15.11 | CL |
| RM2 | 38.27 | 23.88 | 14.39 | CL |
| RM3 | 47.14 | 33.79 | 13.35 | CL |
| A-1 | 44.36 | 39.81 | 4.55 | ML |
| A-2 | 39.97 | 36.49 | 3.48 | ML |
| A-3 | 39.73 | 35.37 | 4.36 | ML |
| A-4 | 37 ,35 | 35.23 | 2.12 | ML |
| B-1 | 41.7 | 37.6 | 4.13 | ML |
| B-2 | 39.9 | 35.9 | 4.02 | ML |
| B-3 | 39.7 | 35.8 | 3.98 | ML |
| B- 4 | 37.4 | 34.2 | 3.2 | ML |
| C-1 | 41.4 | 37.1 | 4.28 | ML |

| | | | | |
|---|---|---|---|---|
| C-2 | 39.9 | 35.8 | 4.18 | ML |
| C-3 | 39.8 | 35.9 | 3.97 | ML |
| C-4 | 39.9 | 36.2 | 3.67 | ML |
| D-1 | 41.0 | 36.3 | 4.78 | ML |
| D-2 | 39.8 | 35.4 | 4.45 | ML |
| D-3 | 39.3 | 35.2 | 4, 03 | ML |
| D-4 | 38.4 | 34.4 | 3.99 | ML |
| E-1 | 40.3 | 36.1 | 4.15 | ML |
| E-2 | 39.8 | 35.8 | 4.02 | ML |
| E-3 | 39.5 | 35.5 | 3.93 | ML |
| E-4 | 38.9 | 35.1 | 3.87 | ML |
| F-1 | 38.8 | 34.2 | 4.55 | ML |
| F-2 | 39.7 | 35.3 | 4.49 | ML |
| F-3 | 39.8 | 35 ,5 | 4,33 | ML |
| F-4 | 39.5 | 35,5 | 4,12 | ML |

In table 3 it can be seen that the test object is not bacteria (RM) indicating the classification according to USCS is classified as CL, namely inorganic clay with low to moderate plasticity. Because the liquid limit is less than 50%, this RM is clay. For group A, with an incubation time of 7 days, the classification of the test object changed to ML, namely silt with low plasticity with a liquid limit below 50% and a low plasticity index. This shows that there is an increase in the category from clay to silt although it is still in the low plasticity category.

*Results of sieve analysis and hydrometer*

The results of sieve analysis and hydrometer analysis are one unit whose results will explain the classification of soil according to AASHTO. The parameters obtained for non-bacterial (RM) and bacterial (AF) specimens can be seen in the following table.

Table 4
The results of sieve analysis and hydrometer

| Test object | Clay (%) | Silt (%) | Sand (%) | Classification |
|---|---|---|---|---|
| RM | 21 | 34.48 | 44.52 | A-7-6, |
| A-1 | 73.42 | 26.58 | | A-7-6, |
| A-2 | 65.34 | 34.66 | | A-4 |
| A-3 | 76.52 | 23.48 | | A-4 |
| A-4 | 64.06 | 35.94 | | A-4 |
| B-1 | 72.5 | 27.5 | | A-7-6 |
| B-2 | 66.4 | 33.6 | | A-4 |
| B-3 | 75.4 | 24.6 | | A-4 |
| B-4 | 65.0 | 35.0 | | A-4 |
| C-1 | 71.2 | 28.8 | | A-7-6 |
| C-2 | 68.3 | 31.7 | | A-4 |
| C-3 | 73.9 | 26.1 | | A-4 |
| C-4 | 70.5 | 29.5 | | A-4 |
| D-1 | 69.9 | 30.1 | | A-7-6 |
| D-2 | 69.8 | 30.2 | | A-4 |
| D-3 | 65.2 | 34.8 | | A-4 |
| D-4 | 64.8 | 35.3 | | A-4 |
| E-1 | 70.2 | 29.8 | | A-5 |
| E-2 | 68, 1 | 31.9 | | A-4 |
| E-3 | 67.5 | 32.5 | | A-4 |
| E-4 | 69.1 | 30.9 | | A-4 |
| F-1 | 68.1 | 31.9 | | A-4 |
| F-2 | 67.5 | 32 ,5 | | A-4 |
| F-3 | 67.4 | 32.6 | | A-4 |
| F-4 | 66.3 | 33.7 | | A-4 |

In table 4, it can be seen that the test object without bacteria RM is classified according to AASHTO as A-7-6, i.e. clay soil with poor grades is not recommended for embankment soil. For the specimens A-1, B-1, C-1, and D-1, namely 25 ml of bacteria, it has not changed much and because the liquid limit is more than 41%, it is still classified as A-7-6. For the test object E-1, which is 25 ml of bacteria, the test object changes to A-5, which is a condition where the ordinary silt soil quality is less than A-4. However, starting from the test specimens with 50 ml – 100 ml bacterial solution and the incubation time is getting longer, the liquid limit continues to decrease from 40 and the plasticity index is less than 10 indicating a significant change to the A-4 classification, i.e. silty soil and can be suggested as embankment soil.

*The results of the pH indicator test pH*

Value test was carried out with two variations of bacterial incubation time, namely on day 7 and day-28. The test was also carried out under two conditions, namely the condition of the bauxite waste before being given bacteria as a comparison and after being given bacteria.

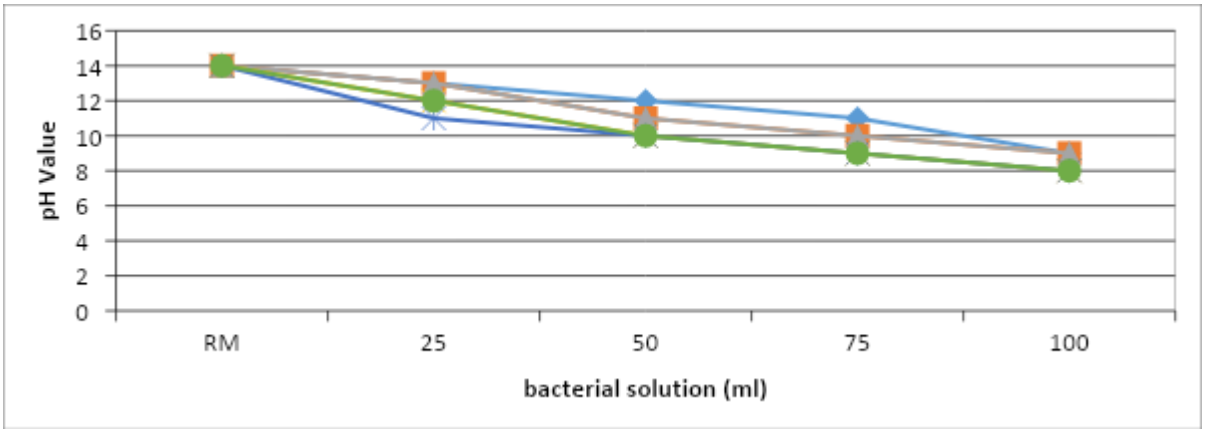


Figure 5. The results of testing the pH indicator

Figure 5 shows the results of testing the pH indicator which can be seen that with an increase in the amount of probiotic bacteria solution given and the longer incubation time of bacteria in the bauxite waste it can decrease the pH value. In the condition of the bauxite waste before being given bacteria or the original state of the waste, it shows a pH value of 14, meaning that the bauxite waste is a strong base and can be very dangerous if it is contaminated with soil and water. Due to the effect of probiotic bacteria, the pH value is close to a neutral value, namely 8, this can explain that the harmful properties of bauxite waste are lost.

By using the five senses, it can also be explained that the condition of the waste before being given probiotic bacteria, has a pungent smell and when touched, the hands feel itchy and slippery. Meanwhile, when the bauxite waste was given probiotic bacteria the smell disappeared and when it was touched the hands did not feel itchy or slippery.

**Conclusion**

Probiotic bacteria given to the bauxite waste had a significant effect. Based on the results of the test on the characteristics of the test objects compared between non-bacterial and bacterial bauxite waste, the activity of probiotic bacteria is very influential. Visually, it can be seen that the two conditions of the bauxite waste after being baked are very different, namely, the non-bacterial bauxite waste is in the form of powder and fine, while the bacterial bauxite waste is in the form of stone and is very hard and difficult to crush. Bauxite waste treated with probiotic bacteria in this study showed a significant change, namely from the condition of the waste classified as A-7-6, namely clay soil which is not recommended as subgrade soil to ordinary silt soil with moderate conditions, namely A-4 and can be suggested as landfill.

The results of the pH indicator test showed results that were following several previous studies, namely due to the activity of probiotic bacteria affecting the pH value with an increase in the number of bacteria and a longer incubation time, it was proven that the pH value fell to near neutral and the hazardous properties of the waste were

lost. So it can be concluded based on the research results here that bauxite waste that has been given probiotic bacteria will change the physical characteristics and pH value for the better and safer if applied to the environment.

With the results obtained from new materials that are better and can be used to overcome waste problems, probiotic bacteria have a fairly good effect and the application process is also easier because using ready-made bacterial products does not need to be cultured in a laboratory environment and is cheap because it uses waste. so that it can be applied directly to waste collection ponds. Furthermore, the bacterial bauxite waste material can be used as a subgrade on subgrade for massive road construction pavements.

*Suggestion*

To find out more about the activity of probiotic bacteria in bauxite waste, it is necessary to conduct micro-examinations in the biology laboratory for further research to explain the changing characteristics of bauxite waste. With the disappearance of the harmful properties of bauxite waste due to the influence of probiotic bacteria, research is needed to make the waste into a plant growth medium because as is known if in a strong alkaline state, the soil is polluted and plants are difficult to grow. In future research, it is necessary to do it directly in waste collection ponds to get real conditions if the results of this research will be carried out at the applied and development stages.

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