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Implementation of Biopore Infiltration Holes in Increasing Soil Permeability in Sungai Langka Village

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ABSTRACT

This study aims to improve low soil absorption capacity by implementing biopore infiltration hole technology to reduce waterlogging and increase groundwater availability, especially during the dry season. This biopore infiltration hole technology can create additional pores, allowing rainwater to infiltrate more rapidly. The method used was a field experiment with five soil samples taken from Dusun II, Sungai Langka Village. The biopore infiltration holes were constructed to a depth of 100 cm and a diameter of 10 cm, and soil permeability was measured using the falling head method before and after installation. This method was selected because it is suitable for fine-grained soils with low absorption capacity. Observations were conducted for 14 days to monitor changes in the soil permeability coefficient driven by variations in moisture, microbial activity, and the decomposition of organic materials within the hole. The study found a significant increase in the soil permeability coefficient after the application of biopore infiltration holes. The highest increase occurred at sample point 5, where the permeability coefficient rose from 11.9 cm per hour to 45.7 cm per hour. In conclusion, the application of biopore infiltration holes effectively improves soil pore structure and enhances soil water-absorption capacity, providing an alternative solution for water management and reducing waterlogging in residential areas.

Keywords: infiltration, biopore, soil, porosity, moisture content

INTRODUCTION

The increase in population, which leads to higher density, and the reduction of green open spaces, result in a growing area unable to absorb water. This condition affects the balance of the environment, such as water, soil, and air systems, which ultimately causes a decline in environmental quality [1]. This condition leads to increased surface runoff, resulting in rainwater that falls does not infiltrate the soil optimally. Consequently, the risk of waterlogging and even flooding increases, while groundwater reserves that are highly needed for human life instead experience a decline [2].

Soil permeability is the magnitude of the soil's ability to transmit water through its pores. Permeability describes the rate of water movement flowing into the soil and is important for understanding the level of groundwater absorption capacity, which affects drainage systems, water management, and overall water resource management. Soils with high permeability tend to absorb rainwater more quickly, reduce the risk of waterlogging, and contribute to improving soil quality [3]. One important factor determining a soil's ability to absorb water is its permeability coefficient, which reflects its capacity to facilitate water flow through its pores. Interconnected soil pores allow water to flow from higher points to lower points [4]. A simple solution to improve soil water-absorption capacity is to construct a technology that uses biopore infiltration holes. Biopore infiltration holes are constructed to increase soil absorption capacity by creating additional pores that allow rainwater to infiltrate more rapidly into the soil [5]. Biopore infiltration holes can improve water infiltration capacity, and with the presence of earthworm activity inside the holes, biopores will be formed and continuously maintained [6].

Biopore infiltration holes provide benefits by reducing organic waste disposed of in landfills and enriching the soil, because one of the processes in creating biopore infiltration holes involves inserting organic waste, which also helps habituate communities to separate organic and inorganic waste. In addition, they help prevent flooding and reduce waterlogging, as biopore infiltration holes can speed up the infiltration of rainwater into the soil [7].

Sungai Langka Village faces water availability issues: during the rainy season, water becomes turbid, while during the dry season, it becomes unavailable [8]. This condition results in surface runoff that carries soil particles, mud, and sediment, making the water turbid. Low soil permeability will also cause water scarcity during the dry season because groundwater reserves decrease. To overcome these problems, this study examined soil permeability before and after the installation of biopore infiltration holes in Sungai Langka Village.

This study was conducted to analyze the implementation of biopore infiltration holes to improve soil permeability at five points in Sungai Langka Village. This becomes a novelty aspect that has not been widely discussed in the context of rural areas, including Sungai Langka Village. The novelty of this study lies in the analysis of the influence of biopore infiltration holes on changes in soil physical properties, specific gravity, moisture content, and permeability at five different points in Sungai Langka Village, which has specific problems in the form of low infiltration capacity and limited groundwater availability. Until now, no study has examined the quantitative application of biopore infiltration holes in this rural area using laboratory geotechnical parameters. This provides a new contribution to water conservation studies based on simple technology.

RESEARCH METHODOLOGY

1. Location and Time

This study was conducted from February to March 2025. This study used a field experiment with five points and two repetitions before and after the installation of biopore infiltration holes in Dusun II, Sungai Langka Village, over a 14-day period. The locations of the biopore infiltration hole points are shown in **Figure 1**. Testing of soil texture, porosity, and permeability was conducted at the Soil Mechanics Laboratory of Universitas Lampung. The specific gravity testing method refers to SNI 1964:2008 (Indonesian National Standard) [9], while the moisture content test follows SNI 1971:2011 [12]. The falling head permeability test was conducted according to SNI 03-6870:2002 [14].

Figure 1. Location of Biopore Infiltration Hole Points

2. Work Procedure

This study comprised several stages: installation of biopore infiltration holes, soil sampling, laboratory testing, and data analysis.

3. Installation of Biopore Infiltration Holes

Biopore infiltration holes and soil sampling were installed at five points, with a depth of 100 cm. The biopore infiltration holes were installed by drilling into the soil with a hand bore. After that, the pipe was installed, and organic waste and EM4 microorganisms were inserted.

4. Soil Sampling

Soil sampling was conducted using the undisturbed method. The soil was excavated using a hand bore to a depth of 50 cm, then the sample ring/tube was placed vertically. To ensure the sample entered smoothly, it was pressed slowly until it completely filled the ring/tube. After the sample was fully inserted, labeling was performed.

5. Laboratory Testing

The Soil Specific Gravity Test refers to SNI 1964:2008 [9] The soil specific gravity test was conducted using a pycnometer flask. The dry soil sample was placed in a pycnometer flask and heated in a boiling water bath. After that, the obtained results were recorded. The calculation was then performed using the formula based on SNI 1964:2008:

$$W_s = W_2 - W_1$$

$$W_{W1} = W_4 - W_1$$

$$W_{W2} = W_3 - W_2$$

$$G_s = \frac{W_s}{W_{w1} - W_{w2}}$$

Description:

Ws : Soil sample
W1 : Pycnometer
W2 : Pycnometer + soil
W3 : Pycnometer + soil + water
W4 : Pycnometer + water
WW1 : Weight of water first
Ww2 : Weight of water after boiling
Gs : Specific gravity

a. Moisture Content Test referring to SNI 1971:2011 [10][11]

The moisture content test was conducted to obtain the percentage of moisture contained in the soil sample. This test was carried out by weighing the soil sample before and after oven-drying. After that, the calculation was performed using the formula based on SNI 1971:2011 [12]:

$$W_w = W_{cs} - W_{ds}$$
$$Ws = W_{ds} - W_c$$
$$W = \frac{W_w}{W_s}$$

Description :
Ww : Water weight
Wcs : Cup + soil before oven
Wds : Cup + soil after oven
Ws : Dry soil weight
Wc : Cup
W : Moisture content

b. Soil Permeability Test referring to SNI 03-6870:2002 [14]

This soil permeability test used the falling-head method. The prepared soil sample was then vacuumed to remove the air. After that, using the permeameter, the soil sample was tested, and the water heights (h_1 and h_2) were measured for 60 seconds. After the results were obtained, the calculation was carried out using the formula based on SNI 03-6870:2002 [14]:

$$k = 2.303 \left(\frac{aL}{At}\right) \log \frac{h_1}{h_2}$$

Description:
k : soil permeability (cm/second)
a : burette area (cm^2)
L : soil sample height (cm)
A : surface area of the soil sample (cm^2)
t : flow time (seconds)
h1 : water height at t = 0 (cm)
h2 : water height at the calculated time t (cm)

6. Data Analysis

The data analysis in this study did not use inferential statistical analysis because the research was conducted on a small scale. Using descriptive analysis, the data were analyzed in Excel and presented as graphs and comparison tables.

RESULTS AND DISCUSSION

1. Soil Specific Gravity Analysis

The following presents the data from the soil specific gravity measurements at the five sampling points. This table compares soil specific gravity values before and after the installation of biopore infiltration holes.

Table 1. Specific Gravity Test Results (Before and After)

Point	Specific Gravity (gr/cm^3)	
	Before Biopore Infiltration Hole	After the Biopore Infiltration Hole
1	2.57	2.53
2	2.41	2.23
3	2.38	2.11
4	2.57	2.42
5	2.70	2.47

Based on **Table 1**, the average decrease in soil specific gravity is 0.174 g/cm^3. The decrease in specific gravity indicates a reduction in soil bulk density. A lower specific gravity indicates that soil pores become larger and that soil particles have lower density. Soil specific gravity is influenced by moisture content, soil texture, soil structure, and also organic matter. High organic matter indicates the presence of compounds decomposed by microorganisms that form aggregates in the soil, thereby binding soil particles [15]. Organic matter also reduces bulk density because it is lighter than the soil minerals. Soil that contains a high amount of organic matter will show a lower specific gravity value [16].

Soil specific gravity tends to decrease soil activity. The greater the specific gravity value, the lower the soil activity will be. This is caused by the increasing density of solid particles in the soil, which ultimately reduces the ability of the soil to expand [17].

The relationship between specific gravity and permeability is not direct, yet the two remain interconnected. Soils with high specific gravity often exhibit higher particle density, which can hinder water flow. Conversely, low specific gravity indicates soil characteristics that are lighter and more porous, allowing water to pass through more easily. Therefore, in various studies, both geotechnical and agronomic, soil specific gravity can serve as an additional indicator in assessing soil behavior toward water, particularly in terms of infiltration, flow, and the probability of waterlogging [18].

2. Soil Moisture Content Analysis

The following presents the data from soil moisture content measurements at the five sampling points. This table compares soil moisture content values before and after the installation of biopore infiltration holes.

Table 2. Soil Moisture Content Test Results

Point	Moisture Content (%)	
	Before Biopore Infiltration Hole	After the Biopore Infiltration Hole
1	31	36
2	33	37
3	31	35
4	37	40
5	41	47

Based on **Table 2**, the average increase in moisture content is 4.4%. The results of this moisture content test indicate an increase in moisture content at each biopore infiltration hole. The increase obtained from the moisture content test is influenced by soil texture, organic matter content, soil bulk density, soil porosity, and chemical compounds within the soil [16].

High organic matter content can increase soil porosity, thereby increasing water absorption capacity. High soil bulk density indicates that the soil becomes more compact, reducing its ability to absorb water and decreasing moisture content. Chemical compounds such as fertilizers can affect the soil's ability to absorb water. In this case, the EM4 activator was used, which functions as an organic matter degrader utilized in the construction of biopore infiltration holes [15].

When the soil is very wet or even saturated, its ability to transmit water decreases. This occurs because the pores are already completely filled with water, thereby obstructing the flow of additional water. In addition, the presence of water pressure within the pores generates resistance to the entry of additional water [19]. High soil moisture can reduce infiltration rate by saturating the soil, thereby decreasing its ability to absorb water. In this case, although the use of organic waste as filler material may initially increase the infiltration rate, the rate tends to decrease gradually and eventually reaches a constant condition over time due to soil saturation, which reduces water absorption capacity [20].

3. **Analysis of Soil Permeability Improvement**

The following presents the data from soil permeability measurements at the five sampling points. This table compares soil permeability coefficient values before and after the installation of biopore infiltration holes.

Table 3. Soil Permeability Test Results

Point	Permeability (cm/hour)	
	Before Biopore Infiltration Hole	After the Biopore Infiltration Hole
1	14.0	38.4
2	9.8	41.3
3	11.9	42.8
4	9.8	44.3
5	11.9	45.7

Based on **Table 3**, there is an average increase in soil permeability after the presence of biopore infiltration holes, namely 31 cm/h. Based on these results, soil permeability increased more rapidly due to the effect of biopore infiltration holes. Soil permeability itself is the ability of soil to transmit water. Soil structure and texture, as well as other organic elements, play a role in increasing the soil permeability rate [21]. The test results for the five soil samples show that biopore infiltration holes effectively increase the soil's ability to absorb water more rapidly. This occurs because there are affecting factors, namely specific gravity, moisture content, and soil porosity. Higher soil porosity indicates that the soil has sufficient space to absorb water. Porosity and permeability are two physical characteristics of soil that strongly influence the soil's ability to store and transmit both water and air. Porosity shows how much of the soil volume consists of voids or pores between soil particles [22]. High porosity does not always guarantee that the soil also has high permeability. This is because water can only flow smoothly if the soil pores are not only large but also interconnected [23]. Soil management practices such as the use of biopore infiltration holes will lead to the formation of pore spaces, thereby increasing soil pore volume and consequently increasing soil permeability values [19].

4. **The Role of Organic Waste**

In this study, organic waste consisting of vegetable residues and dry leaves collected from nearby households was used, thereby reducing the amount of organic waste generated by the residents of Sungai Langka Village. The organic waste inserted into the biopore infiltration hole pipe was treated with an EM4 microorganism solution to accelerate its degradation. The utilization of EM4 microorganisms also helps to reduce the foul odor produced by organic fertilizer. The unpleasant odor generated will decompose the existing compounds [24]. Organic waste increases the activity of soil microorganisms, thereby helping earthworms create new pores. The activity of these earthworms will increase the volume and connectivity of soil pores, thus improving soil conditions and soil permeability [25].

CONCLUSION

Based on the study's results, it can be concluded that biopore infiltration holes increase soil permeability. This is evidenced by an average increase of 31 cm per hour. Factors related to increased soil permeability include soil specific gravity and moisture content.

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