Using Bio-Pore Infiltration Hole to Reduce Flooding in Densely Population Communities of Jakarta and Surrounding Area

by Lolom Evalita Hutabarat Irene Vista Simanjuntak

Using Bio-Pore Infiltration Hole to Reduce Flooding in Densely Population Communities of Jakarta and Surrounding Area

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Abstract: Along with the family's improved economic situation and the need for more space, the lots that once had much open space began to shrink as residents expanded the land built in their homes. In the end, no land was left open to absorb rainwater into the ground. Stagnant rainwater is a common environmental problem during the rainy season. Environmental harm prevention and public disturbance need some watersheds to limit the amount of standing water. There isn't much room for water infiltration in densely populated cities like Jakarta. A bio-pore infiltration hole can be used as an eco-drainage system. Organic waste is incorporated into the soil to promote water infiltration. As a result, this research aims to determine whether bio pore infiltration holes are beneficial at reducing floods. This method can potentially increase field permeability and soil infiltration rate 3-inch, 4-inch, and 5-inch diameter PVC tubing are used to make bio pore infiltration holes. The efficiency of bio pore technology in PVC pipes with various infiltration hole diameters has the highest value of 70.6%, increasing the field permeability to 95%.

Keywords: rainwater; standing water; bio pore hole; soil infiltration; in-situ permeability coefficient

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I. INTRODUCTION

Water infiltration into the soil separates it into two major hydrologic components: surface runoff and subsurface recharge. Because of the associated pollution risks, assessing runoff risk has become more important. Accurate infiltration rate determination is critical for reliable surface runoff prediction. Research on rainwater infiltration was conducted while adhering to several methods for this technology to be fully utilized while minimizing environmental damage such as flooding. These methods outline the general and technical requirements for planning rainwater infiltration wells for yard land. In one of these methods, double-ring As a result, there was a noticeable difference between seasons in the amount of water that the soil could absorb. There was little risk of summer overland flow compared to winter capacity, except for the poorly drained soil. Infiltration capacity was more significant than or equal to the five-year return rainfall rate. The infiltration rate can be affected by changes in air and water movement inside the soil. Reduced infiltration leads to higher runoff, increased flooding risk, and lower groundwater recharge in watersheds.

Compression affects soil hydraulic parameters such as water retention, diffusivity, and hydraulic conductivity in both the unsaturated and saturated states [3]. These hydraulic properties, in turn, govern the infiltration rate. Gregory [2] measured infiltration rates using a constant head double-ring infiltrometer of 15cm and 30 cm in diameter inserted to approximately 10 cm. Based on Philip's equation, field infiltration (K) was measured at an average of 377 up to 634 mm/hour, with soil moisture content ranging from 5% to 12%. Summer steady-state infiltration capacity was 3.5 times that of winter. For a theoretically ideal infiltration (Figure 1), the infiltration rate is the same regardless of whether the soil was dry or wet at first. Runoff occurs when infiltration capacity is exceeded by rainfall. Because the ground can take in additional water both below and above the surface, the steady infiltration rate indicates the lowest degree. When predicting the risk of runoff, the constant infiltration rate is a conservative design criterion with a large safety margin.

In the control and flood spreading areas, the vertical variation of infiltration revealed that permeability increased with increasing depth [3]. The analyses show that the infiltration rate decreased after flood-spreading companies' implementation compared to the area's previous condition (control area)—this increase in the top 10 cm of soil. The rate of infiltration decrease was influenced by the particle size distribution of the suspended materials in the floodwater, total sediment load, and pore geometry of the underlying materials. As a result, the infiltration rate in the flooding zone was negatively related to the fine fraction of the cohesive soil. Several studies have found a relationship between infiltration rate and soil texture [4]. Infiltration rate is directly and positively related to vegetation cover and negatively associated with clay percentage [5]. If the system is not adequately maintained, it can become hazardous after a few years, as soil infiltration decreases and the vegetation cover is destroyed.

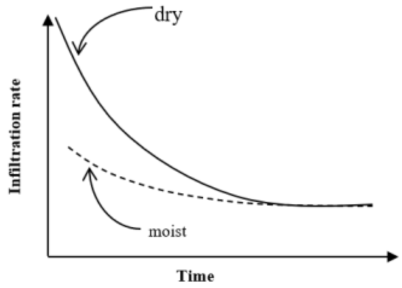

Figure 1. Ideal Infiltration Curve

Another method implemented primarily in Indonesia for measuring infiltration ability is using bio pore infiltration holes [6,7,8,9,10,11]. Benefits of making bio pore infiltration holes include improving the soil ecosystem and absorbing water that was previously a surface runoff to reduce flooding. Increasing groundwater reserves, overcoming drought by storing water underground, simplifying waste management to become an alternative use that can keep cleanliness, and overcoming problems caused by inundation. Undeveloped or vegetated ground-level land can be tested for infiltration rates [12]. There is a decrease in rainwater infiltration in densely populated communal housing during the wet season. Bio Pore Infiltration Hole Technology can be used as a replacement for increasing development activities that reduce water catchment areas [13]. It is called a bio pore because it uses the movement of soil fauna or plant roots (bio) to form small tunnels (pore) in the soil. Organisms in the soil play an essential role in creating bio pores. Earlier studies [9,10,14,15,16,17] show that Bio Pore Infiltration holes can prevent inundation and flooding because it accelerates water infiltration into the ground. After all, the water flow into the environment is also affected by ground elevation differences and high-water pressure (head).

Furthermore, rainfall intensity, duration of rain, soil surface conditions, surface cover conditions, soil transmissibility, and infiltrating water characteristics are all factors that influence the infiltration process. The Bio porous Infiltration Hole is an easy-to-use yet highly effective system. Still, the in-situ permeability coefficient is increased [16,18]. Dig a hole 10 to 25 centimeters in diameter and 100 centimeters deep, then fill it with organic waste from your home. When measuring soil permeability, the hole depth cannot exceed the depth of the groundwater level. Decomposition is the process by which organisms perform their functions [20,21,22]. The Eco drainage technique was developed due to the organic waste process [19]. Microorganisms will use this garbage as an energy source to produce permeable soil to surround the holes. It is an essential and effective technique for using bio pore holes to tackle flood problems to increase water catchment areas [13].

II. METHODOLOGY

The infiltration rate in the soil was measured for three to six months in the rainy season around the Jakarta area using Bio Pore Infiltration Holes. The triangular hole's pattern is implemented with a distance from the point to the point of 1 meter and a hole depth of 40 cm. Soil samples were collected near the hole to analyze the soil's physical properties and test the laboratory's permeability with a constant head of energy. In this study, 3-inch and 4-inch diameter PVC pipes were used, and pile compaction tests were performed in the laboratory. Water drop measurement using a PVC pipe 4 inches long and 100 cm long that has been embedded 30 cm into the ground and filled with 60 cm water.

Figure 2. Configuration of Bio Pore Infiltration Hole for finding in-situ permeability coefficients

The formation of a gap or pore in the soil by living organisms such as soil fauna and plant roots, which effectively transfers water and air into the ground, is referred to as bio pore engineering. Cavities in the bio pore form as plant roots grow and develop at the base, increasing the activity of soil fauna such as termites and ants digging burrows in the dirt. Because plants and seeds are lost, the best solution is to create bio pore holes.

Another test point was in the Bekasi area, divided into three kinds of hole testing at one location, using 3 inches, 4 inches, and 5 inches PVC pipe diameters. Infiltration can be figured out in several ways, including inflow-outflow analysis, analysis of rain data and hydrographs, use of a ring infiltrometer, and field tests. The model calculation of the Horton equation model can be found in the following [18]. According to Horton, the infiltration capacity gradually decreases over time until it finally reaches a number that remains constant (Figure 3). Conditions more strongly influence the decline in infiltration capacity at the soil surface than flow deeper within the soil.

$$f_p = f_c + (f_0 - f_c) \times e^{-kt} \qquad (1)$$

Where f_p = potential infiltration rate at any time t
f_0 = initial infiltration rate
f_c = final infiltration rate
k = constant

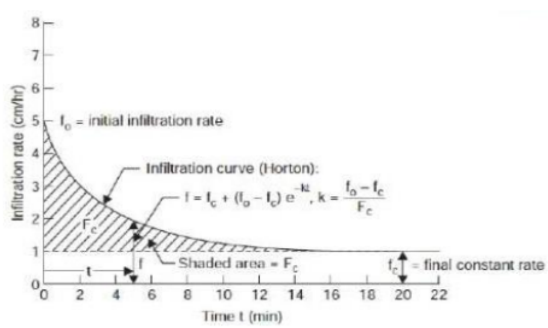

Figure 3. Configuration of Bio Pore Infiltration Hole for finding in-situ permeability coefficients

In the past, some surveys measuring infiltration rates and then relating these measured infiltration rates to land development, land types, or levels of compaction were used to quantify the effect of contraction in urban areas. Data show that urban development's contraction reduces soil infiltration rates [2]. Despite significant differences in infiltration rates between compacted and non-compacted sites, construction activity or compaction treatments decreased infiltration rates by 70 to 99%. It was not substantial how the effects of different compaction levels were caused by light and heavy construction equipment. In general, infiltration rates were much lower on soils packed down. For this study, soil compaction tests were done at the Christian

University of Indonesia in Jakarta in the Laboratory of Soil Mechanics. This test looks at the soil's density, the amount of water in the bio pore infiltration holes before and after an organic matter is added, and organic waste is broken down. The bio pore hole is dug straight into the ground about 100 cm or less than the groundwater level.

Based on a previous study [19], the in-situ permeability coefficient can be calculated using this formula:

$$k = \frac{Q}{2\pi H^3}\left[\log\frac{H}{r} + \sqrt{1+\left(\frac{H}{r}\right)^2} - 1\right] \quad (2)$$

Where k = in-situ permeability coefficient
Q = constant flow debit
r = radius of hole
H = water height in a hole
A = section area

III. RESULT AND DISCUSSION

3.1. Properties of Soil

The amount of water content in a soil sample, density, Specific Gravity, and Atterberg limits are expressed in Table 1. The obtained water content indicates that the soil is clay.

Table 1. Water content, density, Specific Gravity, and Atterberg limits of soil

Location	Hole No.	Soil properties						
		Water Content (%)	Density (gr/cm^3)	Specific gravity	Liquid limit (%)	Plastic limit (%)	Shrinkage limit (%)	Indeks plasticity
Jakarta	1	41.57	1.56	2.74	61.45	50.57	2.85	28.90
	2	39.90	1.45	2.33	63.96	47.15	1.47	30.18
	3	45.30	1.48	2.66	63.42	45.61	1.90	30.64

At another location where tests were conducted, the soil density was more significant for PVC pipes with a diameter of 4 inches and 5 inches that contained approximately 27% water. Due to this condition's presence, the infiltration rate slowed down. On the other hand, the groundwater content that was determined to be the highest was in a PVC pipe with a diameter of 3 inches, followed by PVC pipes with diameters of 5 inches and 4 inches, with the last having the lowest water content of 27.37%. Both the water content of the soil and its density has an impact on its ability to absorb water. Infiltration capacity is directly related to both of these factors.

3.2. Infiltration Rate

In this experiment, the PVC pipe is buried at forty centimeters. This test is conducted on lines with diameters of 3 inches, 4 inches, and 5 inches, respectively. The test was carried out not once but twice. The infiltration rate in the bio porous infiltration hole was measured prior to adding organic material. The following table presents the findings from the measurement of the infiltration rate. Figure 4 displays the results of tests conducted to determine the infiltration rate of each PVC pipe

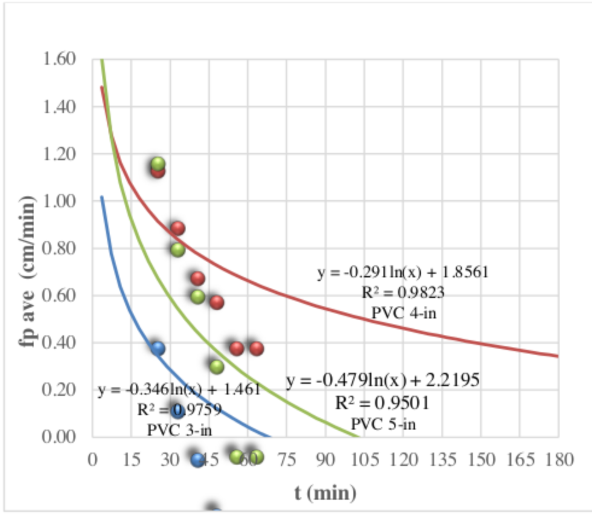

Figure 4. Infiltration Curve on a 3', 4', and 5' PVC pipe without Bio Pore

Constructing a fitted infiltration curve using the data (t) and infiltration rate (f), as shown in Figure 5, is required to compute the initial infiltration rate (f0) using Horton's equation. It can be seen in the figure. Time (t) vs. log (f-fc) PVC pipe with a diameter of 3 inches has an unprecedented infiltration capacity of 12.844 centimeters per hour. According to the calculations used to determine the infiltration capacity of the 3-inch, 4-inch, and 5-inch diameter PVC pipe, the bigger the infiltration capacity, the faster the infiltration rate needs to be for it to be effective.

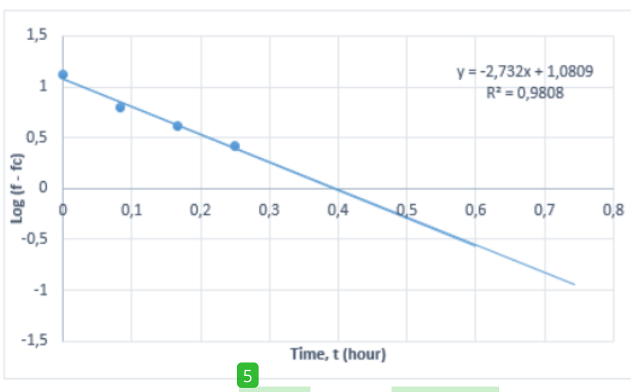

Figure 5. Time (t) versus Log (f - fc)

The initial infiltration rate is relatively quick in Figure 5, but this rate gradually declines and becomes more gradual throughout the experiment. Time affects the infiltration rate; as time passes, the infiltration rate becomes longer and slower. On an area of one square meter and after 30 minutes, the entire amount of water that was not needed was determined (half an hour). The actual drain calculation for each PVC pipe with a diameter of 3, 4, or 5 inches may be found in Table 2, which can be found below.

Table 2. The total volume of infiltration water

Parameter	PVC diameter		
	3 in pipe	**4 in pipe**	**5 in pipe**
Infiltration Capacity, F (cm/hour)	8.7091	16.296	10.9716
Infiltration Water Volume Area, Vt (m^3)	0.87091	0.16296	0.109716

For a 5-inch diameter, 0.87091 m3 is the most necessary amount of water. The least amount of water gets in through pipes that are 3 inches and 4 inches in diameter. If the infiltration rate is higher, the total volume of water that seeps into the ground will be more significant as a direct consequence. The capacity of the infiltration process is equal to the maximum value of the infiltration rate. The value of the infiltration capacity is used in this study to investigate the relationship between the amount of water in the soil, the density of the ground, and the infiltration capacity. The 3-inch PVC pipe has the bio pore infiltration hole that reveals it has the lowest capacity value and the total infiltration water volume of the three pipes. Because the soil surrounding the 3-inch PVC pipe is not very dense and contains a significant amount of groundwater, the infiltration rate is increased. Another investigation investigates approximately 33.48 percent of the bio pore infiltration holes utilized to lessen the drainage load. The discharge absorbed by the bio pore infiltration hole was 0.328125 m^3/s [17].

3.3. Bio-pore Infiltration Rate

In this study, the PVC pipe was thrown into the ground at a depth of 40 cm. This testing is run inside the pipes with diameters of 3, 4, and 5 inches. There are two tries at the test. After adding organic material, the rate of water getting into the bio pore holes was measured. Figures 6, 7, and 8 compare how fast fixes with and without bio pores let water in.

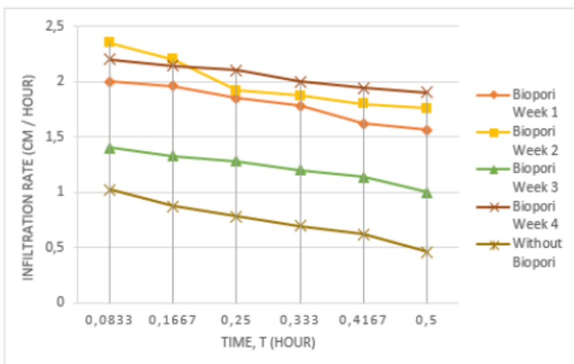

Figure 6. Infiltration rates with and without bio-pores in a 3' PVC pipe

Figure 7. Infiltration rates with and without bio-pores in a 4' PVC pipe

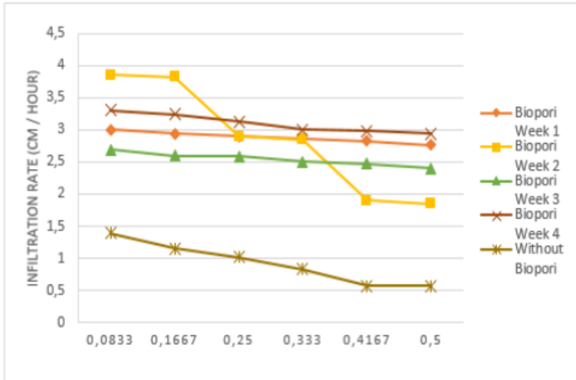

Figure 8. Infiltration rates with and without bio-pores in a 5' PVC pipe

Compared to holes that do not include any organic matter, the Bio Pore Infiltration Hole that contains domestic trash has the most incredible rate value, as seen by the graph shown above regarding the infiltration rate. The action of microorganisms in degrading or destroying wastes resulted in the formation of bio pore pores. Consequently, the bio pore process of each type of waste controls the amount of water that is infiltrated. In any other case, organic materials around the house would absorb more water if put into the bio-pore hole. The incorporation of organic matter stimulates the activity of the organisms that live in the soil. The water penetration rate into the soil can be affected by the formation and stabilisation of the soil texture and the construction of pores by soil organisms. The increased permeability of the ground is the intended result of utilizing this strategy. The activity of both large and small animals will lead to a rise in pore creation, and organic materials must be accessible to organisms for them to have a source of energy.

3.4. Horton Potential Infiltration

Fig.9, Fig.10, and Fig.11 illustrate that the Horton approach can be used to evaluate the value of field data, as the infiltration rate first moves swiftly and decreases with time, using bio-pore pores to calculate infiltration potential.

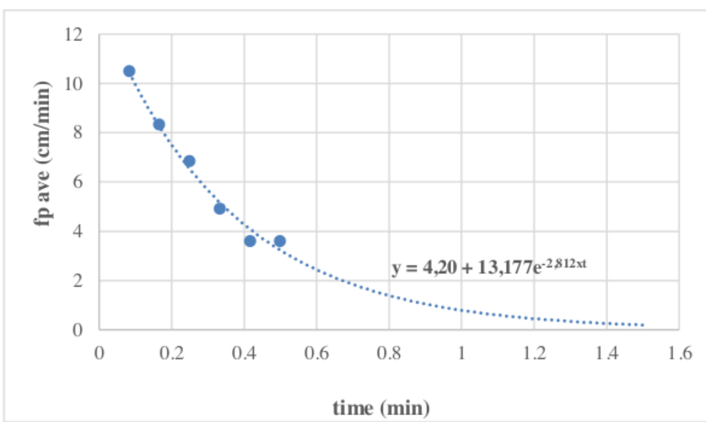

Figure 9. Horton Method Potential Infiltration in a 3' PVC pipe

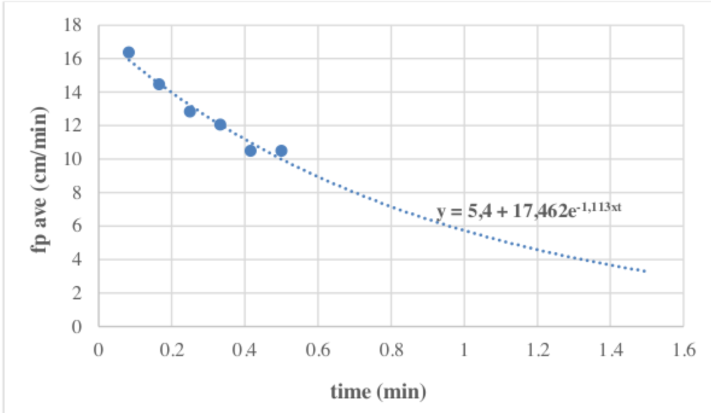

Figure 10. Horton Method Potential Infiltration in a 4' PVC pipe

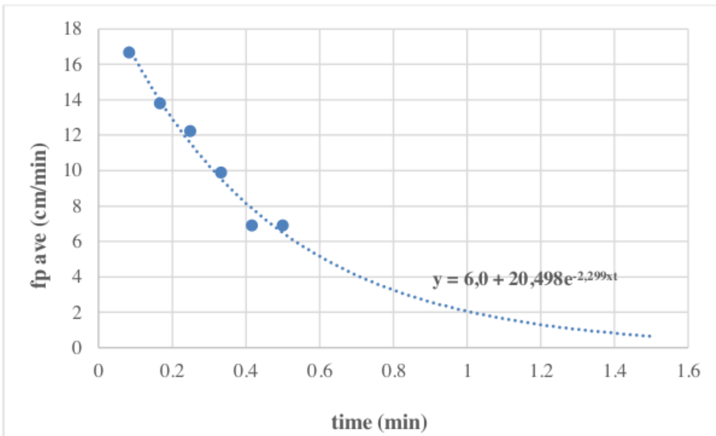

Figure 11. Horton Method Potential Infiltration in a 5' PVC pipe

3.5. In-situ Permeability Coefficient

In general, the field permeability coefficient is aligned the same for each hole, but there is an increase in the value of the k field, which is relatively high in spots using bio pore. Using the average of the field test results, the field K value for the original soil is 4.472810-4 cm/s, 4.395710-3 cm/s for field soil filled with sand, and 6.012010-3 cm/s for the solid ground with a Bio Pore which is increased up to 95%, as shown in Table 5. The permeability value measured in the field is lower than that measured in the laboratory. This condition was influenced by the measurements taken during the rainy season, when the groundwater level was close to the ground surface (35 cm), causing the excavation to fill with water. On the other hand, the permeability coefficient of soil tested in the laboratory showed a good trend with a value of R^2=1.

Table 5. Laboratorium and In-situ permeability coefficient measurement

Hole No.	**Laboratorium permeability coefficient (cm/s)**	**In-situ permeability coefficient (cm/s)**		
		Soil without Bio Pore	**Soil filled with sand**	**Soil with Bio Pore**
BH-1	$3.1456'10^{-3}$	$8.9004'10^{-4}$	$2.0030'10^{-3}$	$5.6963'10^{-3}$
BH-2	$2.7271'10^{-3}$	$2.7271'10^{-4}$	$8.3095'10^{-3}$	$5.2192'10^{-3}$
BH-3	$1.7908'10^{-3}$	$1.7908'10^{-4}$	$2.8745'10^{-3}$	$7.1204'10^{-3}$
Average	$2.5545'10^{-3}$	$4.4728'10^{-4}$	$4.3957'10^{-3}$	$6.0120'10^{-3}$

3.6. Organic Waste Degradation Activity

Bio-pore infiltration holes and wells are among the most effective alternatives since they are applicable in the Jakarta region. Furthermore, it can be constructed concurrently with green open space expansion projects, require minimal construction effort, are simple to produce, and absorb water very well. Bio pore infiltration holes can reduce organic waste ending up in landfills. Before adding organic material, the infiltration rate in the spot was measured twice, refereeing to Indonesian standard testing (SNI 03-2453-2002). Arid urban areas are transformed into eco-friendly areas by utilizing small holes and organic waste.

Furthermore, organic waste stored in the hole can be used as a source of compost, which can be used to fertilize plants. With a diameter of 3-in to 5-in and a 100cm deep hole, it can hold approximately 5 - 10 liters of organic waste, implying that each hole can be filled with consumption waste every 2-3 days. It is just that there will be some odor when the process of waste destruction by microorganisms occurs.

IV. CONCLUSION

The results of an investigation into the efficacy of bio pore technology in each 3-inch diameter infiltration hole showed the value of PVC pipe is 62.92 percent, the value of 4-inch diameter is 70.60 percent, and the importance of 5-inch diameter is 54.11 percent. The 4-inch PVC pipe is the most effective. According to Environment Ministers Regulation 12 of 2009, the standard diameter pipe for bio pore infiltration holes is at least 4 inches. Flooding, garbage accumulation, and various diseases are all controlled by bio pore infiltration holes. It is possible to conclude that bio pore technology is critical for mitigating environmental damage. The in-situ K value for the original soil is 4.472810^{-4} cm/s, 4.395710^{-3} cm/s for the actual ground filled with sand, and 6.012010-3 cm/s for the original soil with a Bio Pore, which is increased up to 95%,

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