IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 12, Issue 8, August 2022, ||Series -I|| PP 01-09

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

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Received 25 July 2022; Accepted 06 August 2022

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. As a result, some watersheds need to reduce standing water, reducing environmental damage and residential unrest. In Jakarta and densely populated urban areas, space for water infiltration is minimal. A bio-pore infiltration hole is an alternative solution that acts as an eco-drainage system. This method uses organic waste to increase the water infiltration rate into the soil. Therefore, this study aims to investigate the effectiveness of bio pore infiltration holes in reducing flooding. 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

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 Infiltration was used to measure infiltration capacity, resulting in a relatively significant difference between seasons. Except for the poorly drained soil, infiltration capacity exceeded or equaled the five-year return rainfall rate, indicating a low risk of summer overland flow compared to winter capacity. Changes in the way of air and water movement within the soil can have an impact on the infiltration rate. Increased runoff volume, increased flooding potential, and decreased groundwater recharge within watersheds will result from a reduced infiltration rate. Compaction impacts soil hydraulic properties such as water retention, diffusivity, and unsaturated and saturated hydraulic conductivity [1]. 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. Based on a theoretically ideal infiltration (Figure 1), the infiltration rate is the same whether the soil was initially dry or moist. Surface runoff occurs when rainfall exceeds the infiltration capacity. The steady infiltration rate represents the minimum capacity because the soil can absorb additional water in and on the ground. The constant infiltration rate is a conservative design criterion, with an ample safety margin when used to predict runoff risk.

The vertical variation of Infiltration revealed that permeability increased with increasing depth in the control and flood spreading areas [3]. The results of the analyses show that the infiltration rate has decreased following the implementation of flood-spreading companies compared to the previous condition of the area (control area)—this increase in the top 10 cm of soil. The particle size distribution of the suspended materials in the floodwater, total sediment load, and pore geometry of the underlying materials all influenced the rate of infiltration decrease. As a result, the infiltration rate in the flooding zone was negatively related to the fine fraction of the soil (silt + clay). 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.

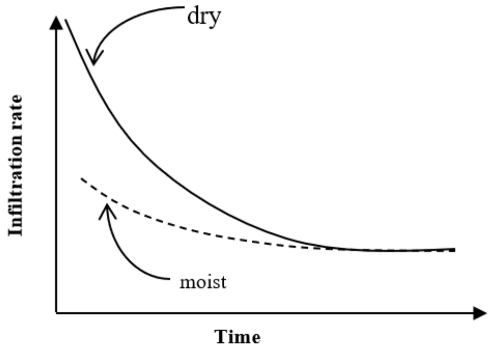

Figure1. Ideal Infiltration Curve

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. The infiltration rate can be measured on a certain depth of vacant or vegetated land at ground level [12]. During the rainy season, runoff occurs, resulting in a reduced area of rainwater infiltrationin densely populated community housing. Increasing development activities resulting in reduced water catchment areas can be replaced with Bio Pore Infiltration Hole Technology as the solution [13]. It is called a bio pore because it uses the activity 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. Bio pore Infiltration Hole is a simple and effective technology. Still, it increases the in-situ permeability coefficient [16,18]. Simply dig a hole in the ground 10-25 cm in diameter and 100 cm in depth and fill it with the household organic trash. The hole depth cannot exceed the depth of the groundwater level when soil permeability is measured. Organisms activate bio pore infiltration holes to conduct their activities through decomposition [20,21,22]. Resulting in supplying an organic waste process as eco drainage technology [19]. This trashwill be an energy source for microorganisms to make porous soil around 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.

Figure2. Configuration of Bio Pore Infiltration Hole for finding in-situ permeability coefficients

Bio pore engineering involves the formation of a gap or pore in the soil by living organisms such as soil fauna and plant roots, which effectively transfer water and air into the ground. Cavities in the bio pore are formed by the growth and development of plant roots in the base, which increases the activity of soil fauna such as termites and ants digging burrows in the dirt. Since plants and seeds are lost, creating bio pore holes is the best solution.

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 following is the calculation of the Horton equation model [18]. Horton claimed that the infiltration capacity diminishes with time until it approaches a constant value (Figure 3). The drop in infiltration ability is governed more by factors at the soil surface than by flow inside the soil.

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

Where f_p = potential infiltration rate at any time t

f_0 = initial infiltration rate

f_c = final infiltration rate

k = constant

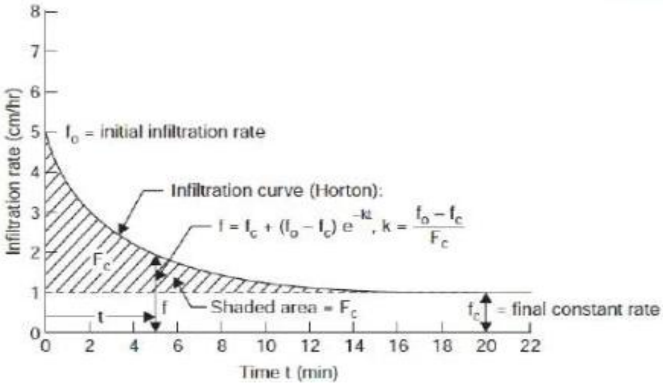

Figure3. Configuration of Bio Pore Infiltration Hole for finding in-situ permeability coefficients

Some surveys measuring infiltration rates and then relating these measured infiltration rates to land development, land types, or levels of compaction have generally been used to quantify the effect of contraction in urban areas in the past. Data show that the contraction associated with urban development harms soil infiltration rates [2]. Although infiltration rates varied considerably between compacted and non-compacted sites, construction activity or compaction treatments reduced infiltration rates by 70 to 99%. It was not significant how the effects of different compaction levels were caused by light and heavy construction equipment. Generally, infiltration rates on compacted soils were significantly lower. Compaction testing was carried out for this study at the Laboratory of Soil Mechanics at the Christian University of Indonesia in Jakarta. This testing examines soil density and water content of bio pore infiltration holes before and after organic matter addition and organic waste degradation activity. The bio pore hole is dug vertically into the ground at a depth of 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 testing point, soil density was higher for PVC of 4-inch diameter and 5-inch diameter with a water content of around 27%. This condition made the infiltration rate become slower. Instead, the highest groundwater content was found in a 3-inch diameter PVC pipe, followed by a 5-inch and 4-inch diameter PVC pipe, respectively, with the lowest water content of 27.37%. When the soil water level is high, the soil density is low, and soil water content and density affect infiltration capacity.

3.2. Infiltration Rate

The PVC pipe is placed 40cm into the ground in this experiment. This test is carried out on 3-in, 4-in, and 5-in diameter lines. The test was repeated twice. Before adding organic material, the infiltration rate in the bio pore infiltration hole was measured. The results of the infiltration rate measurement are shown below. The results of infiltration rate testing on each PVC pipe are shown in Figure 4

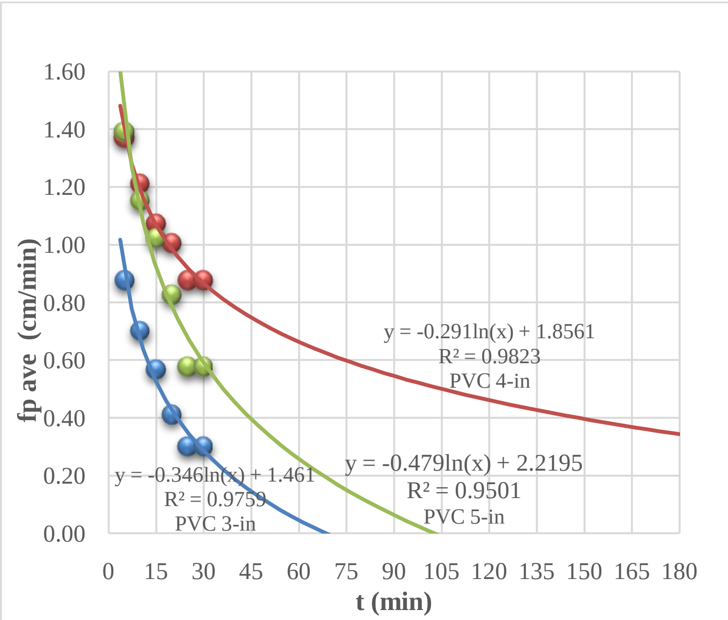

Figure4. Infiltration Curve on a 3', 4', and 5' PVC pipe without Bio Pore

To calculate the initial infiltration rate (f_0) using Horton's equation need to construct a fitting infiltration curve from time data (t) and infiltration rate (f), as shown in Figure 5. Time (t) versus log ($f-f_c$) 3-inch PVC pipe has the most remarkable infiltration capacity, 12.844 cm/hour. Like the 4-inch PVC pipe and 5-inch PVC pipe, according to the results of the infiltration capacity calculations, with 3-inch were carried out, 4-inch and 5-inch diameter PVC pipe- because the faster the infiltration rate, the greater the infiltration capacity.

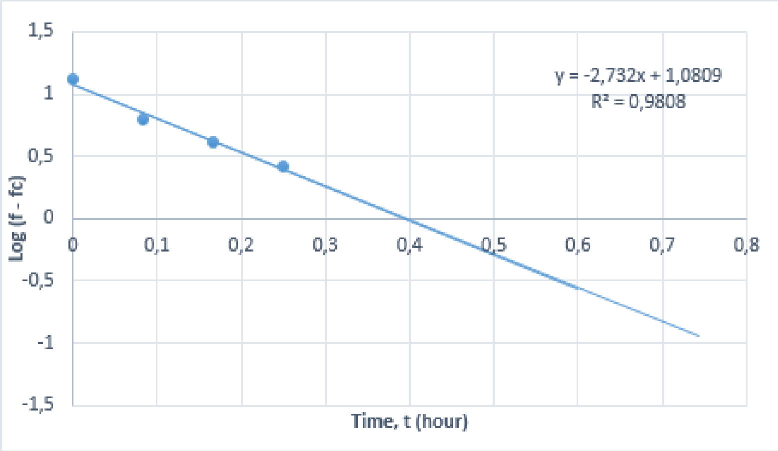

Figure5. Time (t) versus Log (f - fc)

According to Figure 5, the initial infiltration rate is rapid but gradually decreases and slows down over time. The infiltration rate is affected by time; the infiltration rate is longer and slower. The total amount of extraneous water was calculated on an area of 1 m2 for 30 minutes (half an hour). The following Table 2 is the actual drain calculation for each 3-inch, 4-inch, and 5-inch diameter PVC pipe.

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. As a result, the total amount of water that gets into the ground is higher when the infiltration rate is higher. The maximum infiltration rate value is the infiltration capacity. This study uses the infiltration capacity value to study the correlation between soil water content, soil density, and infiltration capacity. The bio pore infiltration hole shows that the 3-inch PVC pipe has the lowest capacity value and total infiltration water volume. The rate of infiltration increases because the soil around the 3-inch PVC pipe is not very dense and has much groundwater. Another experiment examines about 33.48% of the bio pore infiltration holes used to reduce drainage load with discharge absorbed by the bio pore infiltration hole is 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.

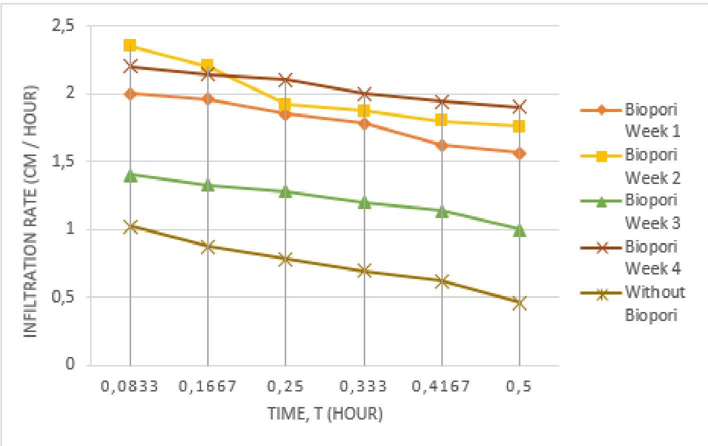

Figure 6. Infiltration rates with and without bio-pores in a 3' PVC pipe

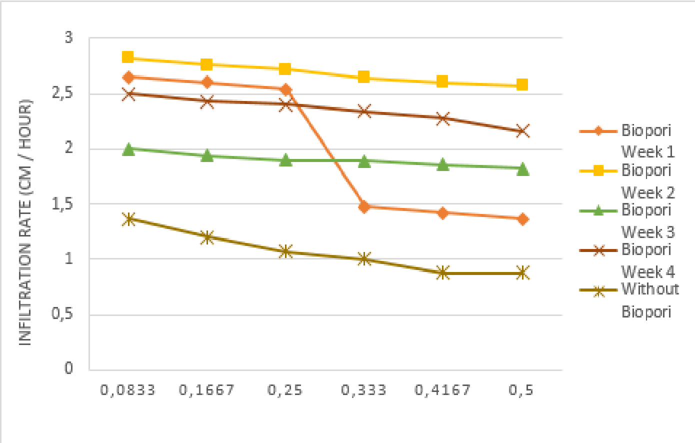

Figure 7. Infiltration rates with and without bio-pores in a 4' PVC pipe

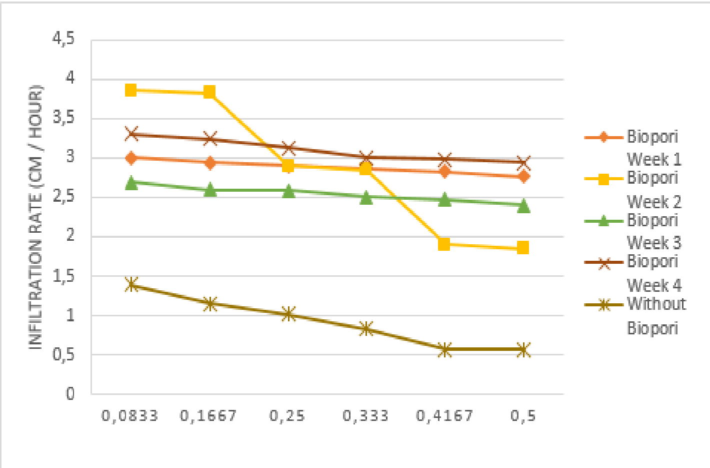

Figure 8. Infiltration rates with and without bio-pores in a 5' PVC pipe

According to the infiltration rate graph presented above, the Bio Pore Infiltration Hole containing household trash has the highest rate value compared to holes containing no organic matter. As a result, the bio pore process of each waste type determines the amount of water infiltrated—the action of microorganisms in degrading or destroying wastes resulted in bio pore pores. Otherwise, household organic materials absorb more water when poured into the bio-pore hole. The addition of organic matter boosts the activity of soil organisms. Soil organisms influence infiltration rate by forming and stabilizing soil texture and constructing pores. The goal of this method is to increase ground porosity. Pore formation will be increased by both macro and micro animal activity, and organic matter must be available as an energy source for organisms.

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.

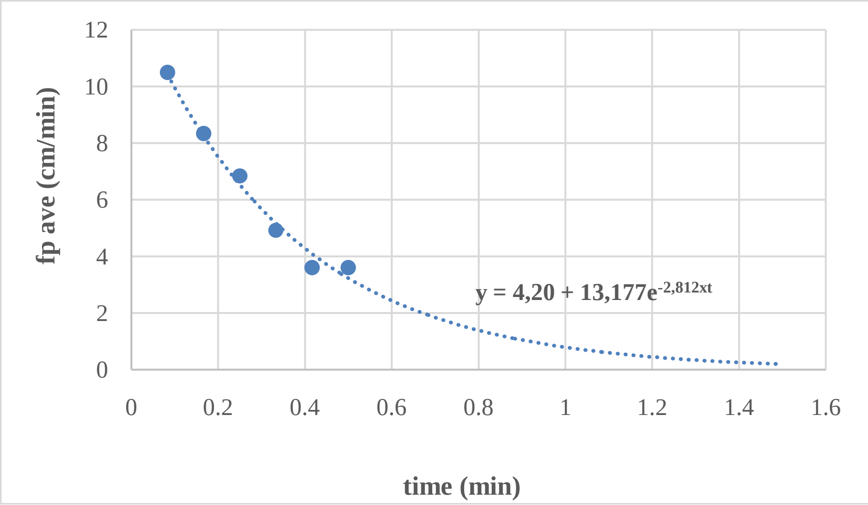

Figure 9. Horton Method PotentialInfiltration in a3' PVC pipe

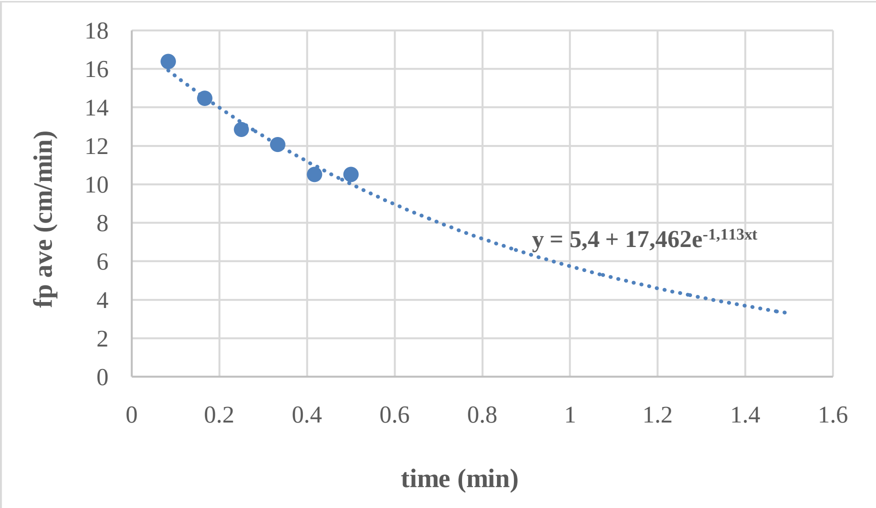

Figure 10. Horton Method PotentialInfiltration in a4' PVC pipe

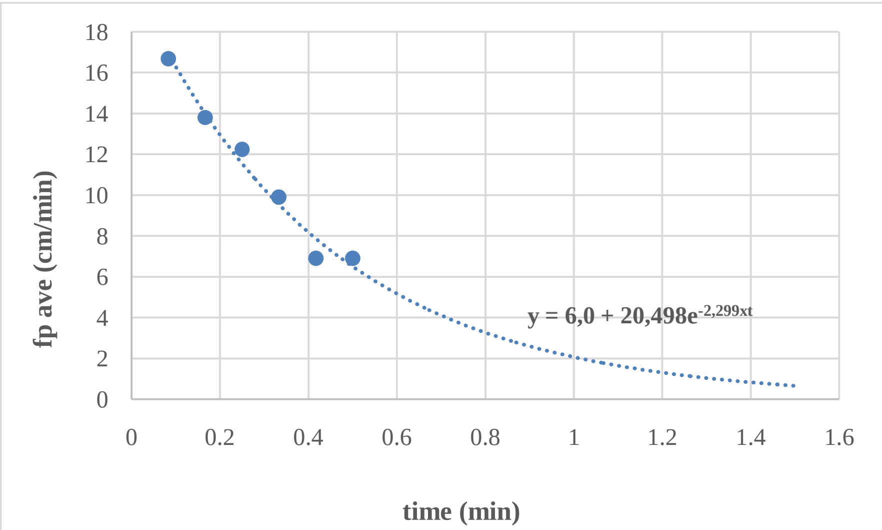

Figure 11. Horton Method PotentialInfiltration in a5' PVC pipe

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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Lolom Evalita Hutabarat. "Using Bio-Pore Infiltration Hole to Reduce Flooding in Densely Population Communities of Jakarta and Surrounding Area." *IOSR Journal of Engineering (IOSRJEN)*, 12(8), 2022, pp. 01-09.