



## Seepage in Soil from the Difference of Water Viscosity Using Geo-Studio SEEP/W Program



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### Abstract

The soil is an important material for human life. The problem that is often encountered with soil is soil contamination due to the discharge of leachate into the soil. This research aims to observe the influence of leachate viscosity on seepage using Geo-Studio SEEP/W Program. The samples of leachate were taken from ceramic industry and from Suwung landfill site. Soil samples were silty sandy taken from Ida Bagus Oka street, Denpasar, Bali. Seepage modeling in Geo-Studio SEEP/W was conducted on silty sand condition using pure water (without leachate), leachate from ceramic industry, and leachate from Suwung Disposal Site. Seepage modeling on Geo-Studio was conducted on saturated/unsaturated condition. It was found that the leachate viscosity was different each other. The viscosity of leachate from ceramic industry was  $0.01366741 \text{ N s/m}^2$  and  $0.002061309 \text{ N s/m}^2$  from Suwung Disposal Site. Due to mixed with leachate, soil hydraulic conductivity decreased from  $0.001949 \text{ cm/s}$  to  $0.0001029 \text{ cm/s}$ . The largest discharge and velocity of seepage on silty sand material from Ida Bagus Oka street, Denpasar, obtained by using Geo-Studio SEEP/W Modeling was produced by pure water (without leachate), whereas, the smallest one produced by leachate from Suwung landfill site. The influence of seepage discharge and seepage velocity change on silty sand in Ida Bagus Oka street, Denpasar due to the flow of leachate from ceramic industry and leachate from Suwung Disposal Site against pure water seepage discharge and seepage velocity are 70,573% and 5,313%.

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**1. Introduction**

The land is a natural material that plays an important role in human life. Problems related to soil are pollution of soil due to waste disposal to the soil. Wastewater may come from waste processed domestic waste or household waste, industrial and leachate waste discharged from waste piles. Most of the residential, industrial and final disposal sites still do not have adequate wastewater treatment plants. As a result, wastewater from processing or activity and piles of waste directly discharged into water bodies or allowed to flow to the ground.

Soil contamination of wastewater affects the soil properties. Huang & Lu (2014); Sen *et al.*, (2016); Van Olphen & Hsu (1978), conducted researches on the effects of oil and fat contamination on the limits of clay *atterbergs*. Prakash & Arumairaj (2013); Yong *et al.*, (1992), examined the effect of acid and base contamination on the geotechnical properties of clay soil. Ghobadi *et al.*, (2013); Rahman & Nahar (2015); Spagnoli (2012), Sunil *et al.*, (2006), Tajnin *et al.*, (2014), suggest that changes in water pH will affect clay soil characteristics. Nair & Philip (2016), in his research, stated that the addition of 25% NaOH and 50% acetic acid in fly ash mixed soil can increase the value of plastic limit and soil liquid limit but reduce the value of compressive strength and soil cohesion. Reddy & Sivapullaiah (2010); Olgun & Yildiz (2012); Yunus *et al.*, (2011); and Bakhshipour (2016), conducted a study of the effect of acetic acid on changes in structure and shear strength of the soil. One of the effects of pollution is on the value of permeability. Permeability is defined as the nature of the porous material in which the flow of seepage from the liquid flows through the pores (Hardiyatmo, 2012). Knowledge of seepage and the pattern of water flow in the ground can not be separated from Darcy's law. One of the indicators contained in Darcy's legal equation is the permeability coefficient or seepage coefficient. The seepage coefficient depends on several factors such as the viscosity, the grain size, the pore number, the roughness of the surface grain and the degree of saturation of the soil. So other than the soil type, viscosity or fluid viscosity also affects seepage behavior and water flow patterns in the soil.

This study aims to determine the effect of viscosity of a liquid (wastewater) and soil type to seepage in the soil. The viscosity of a liquid is very influential on the specific gravity and the volume weight of the liquid itself even affects the seepage coefficient or soil hydraulic conductivity. In this study, the soil hydraulic conductivity value of wastewater will be used as one of the parameters to be input on the model created using Geo-Studio Seep/W application and to know the flow that occurs in the model. The results obtained from the analysis using the Geo-Studio Seep/W application would be able to explain how the distribution of the rate of seepage of a liquid (wastewater) into the soil. By knowing the seepage discharge of a fluid that seeps into the soil, it can also be calculated the speed of seepage of the fluid into the soil.

**2. Materials and Methods***Method of Collecting Data and Modeling of Holds in SEEP/W Geo-studio*

There are two types of data in this study namely land data and wastewater data. Land data used is silty sandy land on Ida Bagus Oka street, Denpasar. Some soil parameters needed in this study include soil porosity, filter analysis data to determine the type of soil to be analyzed and soil hydraulic conductivity. Calculation of the value of soil. Equation 1.

$$w = \frac{n}{(1-n)Gs} \dots\dots\dots (1)$$

Wastewater used uses leachate from Suwung Landfill and Wastewater from ceramic processing from PT. Cevala Ceramics. Wastewater data includes wastewater pollutant parameter data obtained through experiments at Udayana University's Analytical Laboratory. While the data of viscosity, specific gravity and weight of the volume of wastewater was obtained from the results of research at the Laboratory of Physical Chemistry of Udayana

University. Wastewater viscosity data was obtained through an experiment using Ostwald viscometer. The magnitude of a liquid viscosity can be expressed using the Poiseulle or Poiseulle equation.

Equation 2.

$$\eta = \frac{\pi \rho r^4 t}{8 \nu l} \dots\dots\dots (2)$$

or by multiplying the viscosity of the comparison liquid by comparison of the value of the liquid type and the time of the study results with the type and time of the comparative fluid research as in Equation 3.

Equation 3.

$$\eta_x = \eta_0 \frac{t_x \cdot \rho_x}{t_0 \cdot \rho_0} \dots\dots\dots (3)$$

One of the viscosity values that has been known is the pure water viscosity, which is 0.01008 Poisse or equivalent to 0.001008 Ns/m<sup>2</sup>.

Modeling in the Geo-Studio Seep/W software is a 2D cross-sectional model of the area to be analyzed. Analysis model was made at geometry distance (0.0) cm, (0.100) cm, (100.40) cm, (50.40) cm, (50.30) cm, (45.30) cm, (45.50) cm, and (0.50) cm. The material model is conditioned to be saturated/unsaturated. Water is assumed to flow from the upstream to the downstream with the water level upstream made as high as 2 cm, so that the boundary conditions at the upstream are 52 cm. The analysis model was made with mesh or analysis area every 3 cm as in Figure 2.

The land data will be inputted to estimate the Volume of Water Content Function. Sandy soil and clay soil using the sample functions method and then selected material samples in the form of clay (sand) or sand (sand). While the hydraulic conductivity or seepage coefficient data will be used to estimate Hydraulic Conductivity Functions.

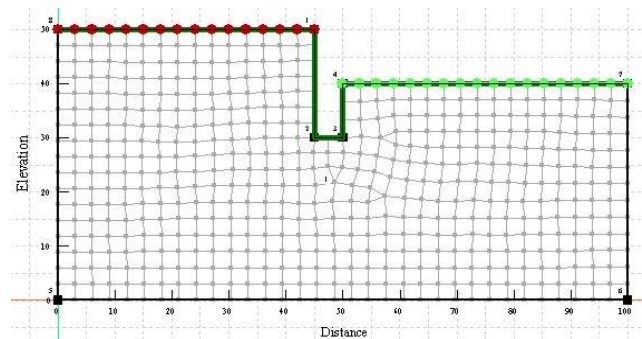


Figure 1. Analysis model with mesh area every 3 cm

### 3. Results and Discussions

#### 3.1 Waste Quality Test Result

Table 1  
Liquid waste quality test results

No	Parameter	Unit	Method	Result	
				Leachate Suwung	Ceramic Waste
1.	COD ( <i>Chemical Oxygen Demand</i> )	mg/L	Titration	3210.00	250.24
2.	BOD ( <i>Biochemical Oxygen Demand</i> )	mg/L	Titration	1506.20	137.15
3.	Oil	mg/L	Gravimetry	480.00	56.00
4.	TDS ( <i>Total Dissolved Solid</i> )	mg/L	Gravimetry	10780.00	590.00
5.	TSS ( <i>Total Suspended Solid</i> )	mg/L	Gravimetry	237.91	0.58

The results of the waste quality test from the analytical laboratory were then compared with the Minister of Environment Regulation No.5 of 2014 concerning wastewater quality standards as described in Table 2.

Table 2  
Wastewater quality standards

No	Parameter	Unit	Highest Level
1.	COD ( <i>Chemical Oxygen Demand</i> )	mg/l	100
2.	BOD ( <i>Biochemical Oxygen Demand</i> )	mg/l	50
3.	TDS ( <i>Total Dissolved Solid</i> )	mg/l	2000
4.	TSS ( <i>Total Suspended Solid</i> )	mg/l	200
5.	Oil	mg/l	10

Source: Minister of Environment Regulation No.5 of 2014

Minister of Environment Regulation No.5 of 2014 provides limits on the quality of liquid waste to further be discharged into nature. However, the results on three types of waste, namely the Suwung landfill leachate waste and ceramics processing waste provide an illustration that these wastes should not be released directly or disposed of directly into the ground because they still contain pollutants that exceed the specified levels. Therefore, these wastes need to be processed in advance to reduce the level of pollution, after which they can be disposed of or released to the ground.

#### 3.2 Waste Viscosity Experiment Results

Table 3  
Liquid waste viscosity test results

No	Liquid Waste Type	Viscosity (N.s/m <sup>2</sup> )
1.	Pure water	0.001008000
2..	Ceramic Waste	0.001366741
3.	Leachate of Suwung	0.002061309

In Table 3, leachate from the Suwung landfill has a higher viscosity and the volume weight is also smaller than the ceramic waste. The various viscosity of liquid waste is influenced by the amount of dissolved material in the waste, such as *TDS (Total Dissolved Solids)* and the oil content in the waste. High TDS and oil in waste will produce greater waste viscosity.

3.3 Groundwater Content

The soil sample used in this study is a sample of surface soil from the Ida Bagus Oka street, Denpasar. The results of the research on the moisture content of the samples of the native soil were not disturbed indicating the water content in the surface layer of the soil at Ida Bagus Oka street, Denpasar was 37.95%.

3.4 Specific Gravity and Weight of Waste Volume

The specific gravity of a fluid is defined as the ratio between the density or density of a fluid to the density of water, while the weight of the volume is defined as the ratio between the weight and volume of the liquid itself. It is known that the density of water in general is  $1000 \text{ kg/m}^3 = 1 \text{ ton/m}^3 = 1 \text{ gr/cm}^3$ . The results of research on the specific gravity of waste are shown in Table 2.

Table 4  
Liquid Waste Specific Weight

Liquid Waste Type	Specific gravity	Volume weight (kN/cm <sup>3</sup> )
Pure water	0,999	$9.8067 \times 10^{-6}$
Ceramic waste	0,991	$9.7184 \times 10^{-6}$
Leachate of Landfill	0,976	$9.5713 \times 10^{-6}$

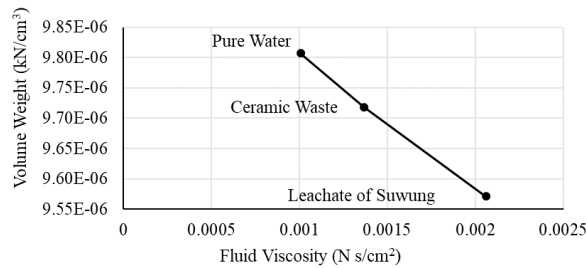


Figure 2. Graph of the relationship of viscosity and volume weight of the fluid.

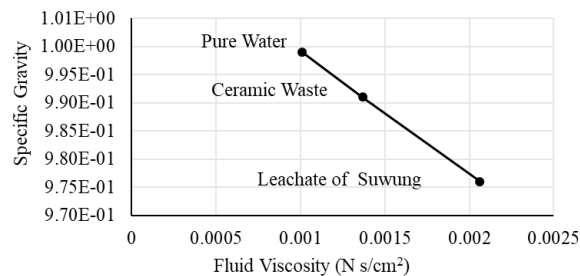


Figure 3. Relationship of viscosity and specific gravity of the fluid

In Figure 2 and Figure 3, it can be seen that the viscosity of a liquid will greatly affect the specific gravity and weight of the liquid volume itself. Figure 2. and Figure 3. shows that the higher the viscosity value of a fluid or liquid, the lower the weight value of the volume and weight of the type of liquid.

### 3.5 Soil Specific Gravity

Soil type gravity experiments (Gs) were also carried out on soil mixed with pure water (without waste), leachate from Suwung landfill and wastewater produced by the ceramic factory. The results are shown in Table 5.

Table 5  
Soil Species Testing Results

Sample	Specific Gravity of Mixed Soil		
	Pure water	Ceramic waste	Leachate of Suwung Landfill
Landsoil on Ida Bagus Oka street, Denpasar.	2.6619	2.5396	2.1871

The results showed a decrease in soil specific gravity when soil was mixed with different types of waste. This can occur because the liquid wastes used in this study have a specific gravity smaller than the specific gravity of the soil tested.

### 3.6 Soil Porosity

Table 6  
Soil Porosity Value

Sample	Specific Gravity of Mixed Soil		
	Pure water	Ceramic waste	Leachate of Suwung Landfill
Landsoil on Ida Bagus Oka street, Denpasar.	51.20%	50.03%	46.30%

The calculation results in Table 4 show that there is a decrease in the value of soil porosity due to the addition of waste. The decrease in the value of soil porosity causes the pores of the soil to shrink so that it will cause the increase in soil density.

### 3.7 Soil Hydraulic Conductivity

The value of hydraulic conductivity is very important in the analysis of seepage of a liquid in a soil layer. Therefore, this study also includes the value of hydraulic conductivity as one of the parameters to be inputted in the Geo-Studio Seep/W. The results of the study are shown in Table 5.

Table 7  
Soil Hydraulic Conductivity

Sample	Hydraulic Conductivity of Soil Mixed with various type of Liquid		
	Pure Water (cm/s)	Ceramic waste (cm/s)	Leachate of Suwung Landfill (cm/s)
Landsoil on Ida Bagus Oka street, Denpasar	0.0018949	0.0012	0.0001191
Average	0.001949	0.0011	0.0001029

3.8 Results of Seepage Analysis Using Geostudio Seep/W

The viscosity or viscosity value of a liquid is inversely proportional to the value of its hydraulic conductivity. This means that the higher the viscosity value of a liquid, the lower the value of hydraulic conductivity as shown in Figure 4.

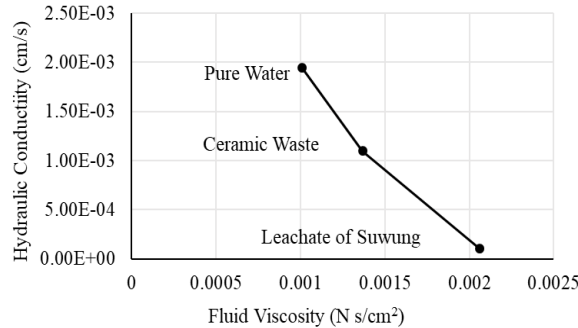


Figure 4. Graph of Viscosity and Hydraulic Conductivity Relations

3.9 Geostudio See/ W Data Input

The analysis model created in Geo-Studio Seep/W is in saturated/unsaturated conditions, which means that the model made is not always flooded with water or pollutants. This is considering the presence of rain which does not always occur at any time so that the soil still has the opportunity to absorb water into it. Some parameters included in the analysis model at Geo-Studio Seep/W are shown in Table 9.

Table 9  
Geostudio Seep/W Data Input

Data Input		Soil on Ida Bagus Oka, Denpasar street
The volume of water (kN/cm <sup>3</sup> )	Pure water	9.8070 x 10 <sup>-6</sup>
	Ceramic waste	9.7184 x 10 <sup>-6</sup>
	Leachate of Suwung (cm/s)	9.5713 x 10 <sup>-6</sup>
<i>Volume Water Content Function</i>		
Soil Porosity	Pure water	51.20%
	Ceramic waste	50.03%
	Leachate of Suwung	46.30%
<i>Hydraulic Conductivity Functions</i>		
Hydraulic Conductivity (kx)	Pure water	0.0019490
	Ceramic waste	0.0011000
	Leachate of Suwung Landfill	0.0001029

Calculation results obtained from the analysis using Geo-Studio Seep/W is the water discharge rate through the porous media. Calculation of the rate of a fluid passing through the soil medium (seepage speed/infiltration) was done by using Equation 4.

$$v = Q / A \dots\dots\dots(4)$$

with the total area of soil media in the analysis, model was 4400 cm<sup>2</sup>.



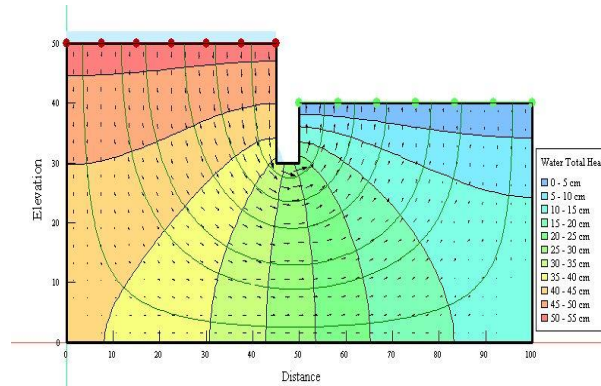


Figure 5. Modeling results of the soil at Ida Bagus Oka street, Denpasar, with pure water/not waste

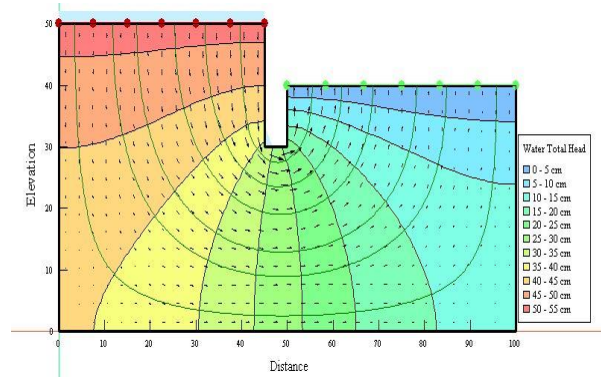


Figure 6. Modeling results of the soil on Ida Bagus Oka Street, Denpasar, with waste from the processing of ceramics

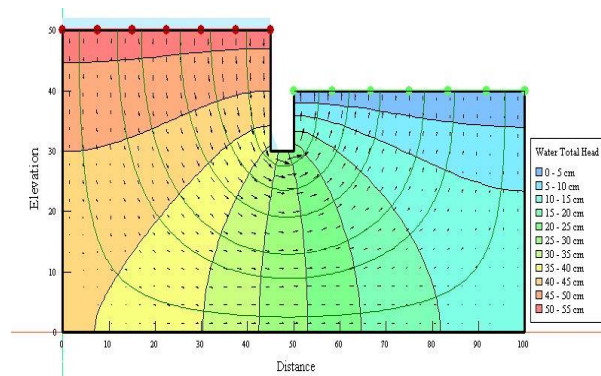


Figure 7. Modeling results of land on Ida Bagus Oka Street, Denpasar, with leachate waste from the Suwung landfill

Figure 5, Figure 6, and Figure 7 are the results of modeling soil media with several types of waste and without waste using GeoStudio Seep/W indicating the existence of equipotential lines and flow lines which indicate the movement of water from the water source in the upstream to the downstream. While the color gradation in the modeling results shows the stress that occurs due to the water pressure in the upstream part. The upstream water pressure will press and drain water from upstream to downstream or from a place that has a high elevation to a place that has a low elevation. The red color on the modeling results shows the part of the land that experiences the greatest stress due to the influence of water in the upstream, while the dark blue shows the part of the land that experiences the least stress.



Table 10  
Seepage discharge and seepage speed in the soil

Fluid Type	Soil on Ida Bagus Oka Street, Denpasar	
	Seepage discharge (cm <sup>3</sup> /s)	Flow Speed (cm/s)
Pure water	0.3840	8.727 x 10 <sup>-5</sup>
Ceramic waste	0.2710	4.932 x 10 <sup>-5</sup>
Leachate of Suwung Landfill	0.0204	4.636x 10 <sup>-6</sup>

The results in Table 7 explain that the type of fluid that flows through the soil media affects the seepage speed and the amount of water that can be passed through the soil. This happens because of the different hydraulic conductivity values, the higher the viscosity value of a fluid, the lower the value of the hydraulic conductivity of the soil so that the ability of the soil to pass water will also be lower. The relationship between the viscosity of the research sample with *remebeate* discharge in the soil is shown in Figure 8.

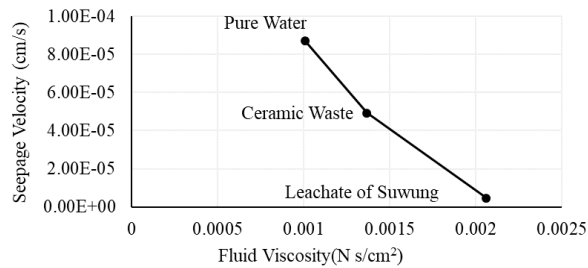


Figure 8. The relationship between fluid viscosity and seepage velocity

Figure 9 shows that the soil that is drained with water (without waste) has the largest seepage discharge rate compared to the soil drained with wastewater. The latter has a greater viscosity than pure water. If expressed in terms of percentage, the amount of decrease in seepage discharge rate or seepage speed in silty sandy land on Ida Bagus Oka street, Denpasar, on seepage discharge or seepage speed due to pure water is 70.573% and 5.313% respectively. The relationship between seepage discharge rate and seepage velocity in the soil is shown in Figure 9.

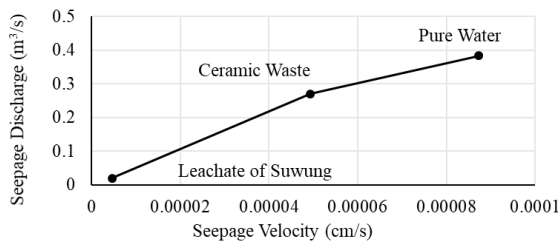


Figure 9. The relationship between seepage discharge rate (Q) to the seepage velocity (v) silty sandy soil on Ida Bagus Oka street, Denpasar.

Figure 9 shows that the seepage speed is directly proportional to the seepage discharge in the soil. This means that the more seepage discharge through a soil medium at a certain time, the faster the fluid through the soil media. Likewise on the contrary, if the resulting seepage discharge is small, the rate of seepage of fluid will be even lower.

#### 4. Conclusion

The conclusions obtained from this study are as follows; Viscosity value of ceramic waste and leachate waste of Suwung landfill has a viscosity of  $0.001366741 \text{ N s/m}^2$  and  $0.002061309 \text{ N.s/m}^2$  respectively. The viscosity of fluid affects the value of soil hydraulic conductivity. As a result of mixing with wastewater, the soil hydraulic conductivity value also decreases. The value of soil hydraulic conductivity decreased from  $0.001949 \text{ cm/s}$  to  $0.0001029 \text{ cm/s}$  for silty sand soil. The magnitude of the effect of changes in seepage discharge or sand seepage speed on Ida Bagus Oka street, Denpasar, due to the drainage of ceramic wastewater and leachate from Suwung landfill to seepage discharge or the rate of seepage of pure water are 70.573% and 5.313% respectively.

##### *Conflict of interest statement and funding sources*

The authors declared that they have no competing interest. The study was financed by personal funding.

##### *Statement of authorship*

The authors have a responsibility for the conception and design of the study. The authors have approved the final article.

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