Effects of Bio-char Application on Mobilization of Organic Matter at Talang Gulo Landfill - Jambi

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Abstract: Talang Gulo landfill in Jambi city will no longer be able to accommodate the solid waste because it has reached the maximum capacity. Mobilization of organic matter through the leaching process can cause pollution of water sources and the soil around the landfill. Knowing the potential of organic matter mobilization from the landfill is the first step to anticipating the possibility of pollution in surrounding area. The aim of this study are to identification the potential of organic matter mobilization from the landfill using three-step sequential extraction protocol and to determine the effect of bio-char position application to reduce organic matter mobilization. Batch experiment method used to identify the potential of organic matter mobilization, and the fixed bed column used to identify the effect of bio-char position in the soil. The extract from both experiments was analyzed by UV-VIS spectrophotometry. The results show that the mobilization of organic matter occurs more in acidic conditions. The mobilization of organic matter in acid condition and neutral condition is 45% and 6%, respectively and bio-char position with layer system was more effective to reduce the mobilization of organic matter in the landfill's soil.

1 INTRODUCTION

Population growth in the urban area is always followed by the increasing of population activities in various sector such as trade, housing and so on (Fatmawinir, 2015). High economic activity have encourage population migration from several region to Jambi City. This has an impact on increasing the production of community solid waste. This solid waste must be managed properly and appropriately so not be a factor that disturb the aesthetic and environmental health aspects.

To overcome the increasing of waste production in Jambi City, the Regional Government provided the transportation that routinely collected and transported solid waste to the processing site located in the Talang Gulo area, a few kilometers from the center of Jambi city. With the increasing of waste production in recent years, it is estimated that the Talang Gulo landfill will no longer be able to accommodate solid waste because it has reached the maximum capacity. Although the problem of solid waste from the community can be found a new alternative landfill location, but the potential for environmental pollution around the landfill such as organic and inorganic materials is still high. Waste in the landfill that has not been stable has the potential to produce leachate which can pollute the environment.

Waste processing by using open dumping system is a simple and cheap method so that method is widely used in handling solid waste, but with the increasing of solid waste, the open dumping method is no longer recommended. Landfill with an open dumping system has the potential to pollute the surrounding environment such as water source pollution due to the potential of organic matter and heavy metal from the waste processing mobilized to the surrounding environment. Organic matter from waste processing can be degraded due to microorganism activity and enter to the groundwater flow. Groundwater pollution occurs by entering the organic matter into underground water bearing formations after being filtered by solid layer (Esakku, 2003) and causing contamination of shallow wells which are used as sources of drinking water for the surrounding community. In the open dumping system, the potential for groundwater pollution by leachate is greater because there is no base layer and soil cover which causes more leachate enters to the groundwater. Leachate usually contains organic

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compounds (hydrocarbons and humic acid) and inorganic compounds (sodium, potassium, magnesium, phosphate, sulfate and heavy metals) (Fatmawinir, 2015). Leachate content depends on the type of waste, in general landfills contain 60% of organic matter from household organic waste (Arif, 2014). More than 200 organic components are found in leachate and around 35 components can pollute the environment and cause public health problems (Shahul, 2013). Leachate that enters to the water body is affected by natural conditions around the landfill such as rainfall, run-off and evapotranspiration. This process is also affected by soil conditions in the landfill such as moisture condition and soil pores.

In general, leachate has a very low BOD5 / COD ratio (<0.4). This low ratio value shows that the organic material found in leachate is difficult to degrade biologically (Erna, 2016). This organic material will cause pollution problems if it enters to the groundwater or surface water. One of the major pollution problems caused by the municipal solid waste landfill leachate can be defined as a liquid that is generated when water or another liquid comes in contact with solid waste (Naveen, 2014).

Organic matter is a material that comes from the remains of plants, animal, and humans that have been decomposed. Organic matter that cause pollution in groundwater are non-humus organic materials such as H_2PO_4, SO_4, H_2S, etc.

Talang Gulo processing waste is a landfill located in Jambi City at Jalan Kebersihan RT 04, Kelurahan Kenali Asam Bawah, Kecamatan Kota Baru, Jambi. This landfill is 15 km from the city center, 1 km from the nearest settlement and 12 km from the river. Talang Gulo processing waste was established in 1996 and began operating in 1997. The area of this landfill is 10 hectares and the reserves is 21.3 hectares with a slope topography is 20%. This landfill uses an open dumping system, the average incoming waste reaches 1000 - 1400 m3/day of waste (Data Talang Gulo, 2015). The Talang Gulo landfill which is only ± 1 km from the population housing and a slope of 20% has the potential to cause pollution through groundwater. In the 2016 local environmental report, there has been a leachate contamination of groundwater around the landfill area. The possibility of groundwater pollution in the open dumping system will be greater because there was no treatment for the solid waste in the landfill.

To overcome this pollution, it is necessary to do study on the mobilization of organic material from this landfill as a potential source of pollutants for public groundwater sources.

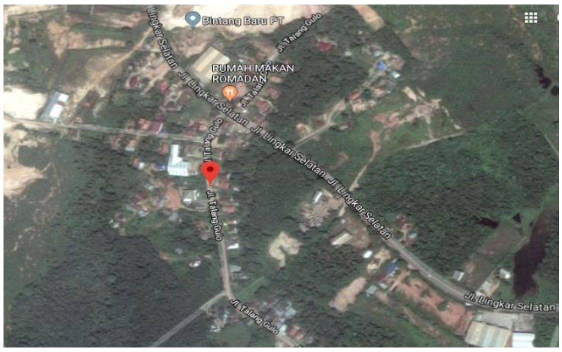

Figure 1: Location of Talang Gulo landfill.

To reduce the entry of leachate from landfill into ground water, the application of bio-char in landfill can be done. Bio-char is a material that contains lots of carbon and an organic material that has a stable nature and can be used as an adsorption because of its pore structure. Bio-char is made from the lignite coal pyrolysis process. Various benefits possessed by bio-char are as a result of the pyrolysis process of transforming biomass to charred material (bio-char) under oxygen-limited environment. During pyrolysis process the volume of pores and specific surface area increases but ratios of H/C and O/C decrease producing material of high aromatic and less polarity (Oliveira, 2018). The extents to which these properties developed are row material and pyrolysis conditions dependent (Cantrell, 2012). High cation exchange capacity (CEC) of bio-char has been related to the presence of negatively-charge functional groups and an increase in pyrolysis temperature decreases the CEC (Buss, 2015). This negatively-charged surface not only adsorbs cations and increases CEC but also is able to adsorb other organic and inorganic compounds (Luchini, 2014).

2 RESEARCH METHOD

This study was conducted on May to August 2018. The samples were collected in Talang Gulo landfill. Solid samples were ocollected randomly from 5 sampling points at Talang Gulo landfill with 0.5 – 1 m depth and mixed composite.

2.1 Soil Samples Incubation

Solid samples (± 600 grams) are dried then put in 1000 ml glass bottles and added 75% of water from the water retaining capacity. Samples were incubated for 5 months and fraction of ± 10-gram solid samples were taken at weeks 0, 2, 6, 12 and 20. The water content was maintained during incubation by adding water to the bottle by weighing.

2.2 Multilevel Organic Extraction

Solid samples from the bottle were extracted with multilevel extraction using water and HCl 1M. Weighed 5 grams of sample and put into a 50 ml centrifuge tube then added with 25 ml of water (1: 5) then agitated for 1 hour. After the agitation process the sample was centrifuged at a speed of 700 rpm for 30 minutes and filtered through a 0.45 µm filter membrane. The solids remaining in the tube were added to 1 M HCL as much as 25 ml and agitated for 1 hour then filtered. The remaining solids are analysed using elemental analysers to determine the carbon residues left in solids. The concentration of organic matter in the water extract and HCl extract was analysed by UV-VIS spectrophotometry with $KMnO_4$ as an oxidizer to determine the organic matter in included in water flow. The absorbance is measured at a maximum wavelength of 565 nm.

2.3 Bio-Char Application

2.3.1 Bio-char Preparation

Bio-char was made from lignite coal. Approximately 1000 g lignite were burned in a sealed metal containers in a pyrolysis reactor at temperature 400-500ºC for 4 hours. Two small holes at the top of the metal containers were to release pressure and gas and limit oxygen entrance. The samples were then cooled and sieved to 2 mm.

2.3.2 Soil Sample Preparation

Soil samples put into an acrylic Fixed Bed Column with 50 cm length, the inside diameter of the column is 4.8 cm with the outside diameter is 5 cm. Column's wall thickness is 1 mm. At the bottom of the Fixed Bed Column is added by a PVC pipe that has been bolted on the top. Then, the hole is connected to a 4 x 1 mm transparent hose. There are gravel in the bottom of column with 5 cm height, in the top of gravel is inserted glass wall with 5 cm thickness, then put 235 grams soil sample and 223.25 grams or as high as 10 cm. Then re-inserted 5 cm glass wall and 5 cm gravel in the top of soil sample. Put bio-char and soil sample with various position in the Fixed Bed column and it ready for use.

Distilled water with pH 4.7 flowed to the fixed bed using a transparent tube from the bottom of the column using the pump. Liquid coming out from the column taken every ratio of Liquid per Solid (L/S) ratio of soil to 1, 2, 5, 8 and 10. The extract was analysed by UV-VIS spectrophotometry with $KMnO_4$ as an oxidizer to determine the organic matter in included in water flow. The absorbance is measured at a maximum wavelength of 565 nm.

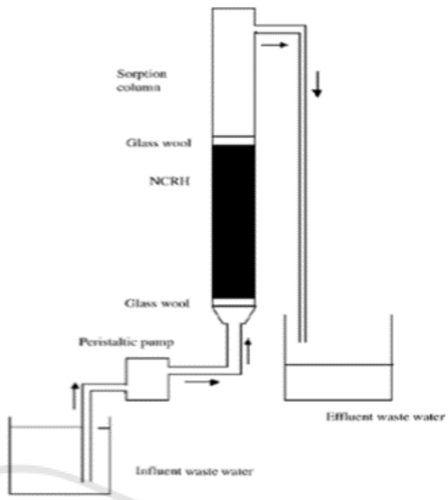

Figure 2: Fixed bed column.

3 RESULT AND DISCUSSION

3.1 Experimental Process

Soil samples from 5 sampling points were mixed and dried and then put into a glass bottle and added 75% water from the water retaining capacity. The samples incubated according to the time specified. The incubated samples shown in Figure 2 below.

Figure 3: Incubation samples.

After incubation with the time specified, 5 grams of sample (dry equivalent) was put into a 50 ml centrifuge tube and then added with 25 ml of water (1: 5) then agitated for 1 hour and centrifuged at a speed of 700 rpm for 30 minutes and filtered through a 0.45 μm filter membrane. The solids remaining in the tube were added to 1 M HCL as much as 25 ml and agitated for 1 hour then filtered. The remaining solid is determined by its carbon content using an elemental analyser to determine the carbon residues left in the solid. This multilevel extraction is analogous to the organic matter which dissolves in leachate and enters to the groundwater flow in neutral and acidic conditions.

3.2 Analysis Result

The extracts from each incubation time and at each level of extraction were analysed base on the $KMnO_4$ calibration curve below.

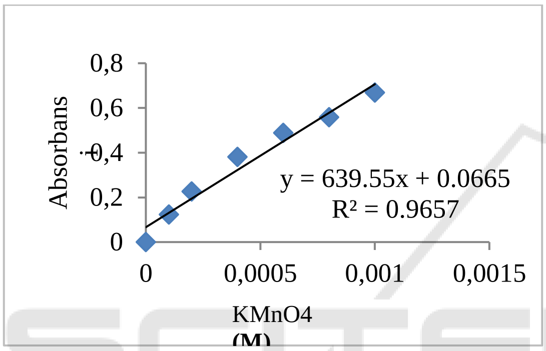

Figure 4: Calibration curve.

The organic matter in residue was a difference between organic matter before extraction and organic matter in the extract. The analysis result of the extract shown in Table 1.

Table 1: Organic matter analysis result in the extract.

Incubation time (week)	Extract from the First extraction (μg/g)	Extract from the Second extraction (μg/g)
0	3.3	13.5
2	1.7	11.5
4	1.2	10.3
8	2.0	10.2

Table 1 shown that the incubation period will affect the stability of organic matter, the longer of the incubation period, makes the organic matter more stable (Naveen, 2014). The organic matter left in residue calculated based on Table 1.

The organic carbon left in residue at each incubation period shown in Figure 5. The figure shown that at 0 week incubation period, the water flow in the first level of extraction causes 8% organic matter involved to the water stream and it means that 92% organic matter still left in the residue. In the second extraction level, the extraction carried out in the acidic condition and 40% of organic matter from the first extraction involved to the water stream. The organic matter involved to the water stream in the first extraction is less than the second extraction.

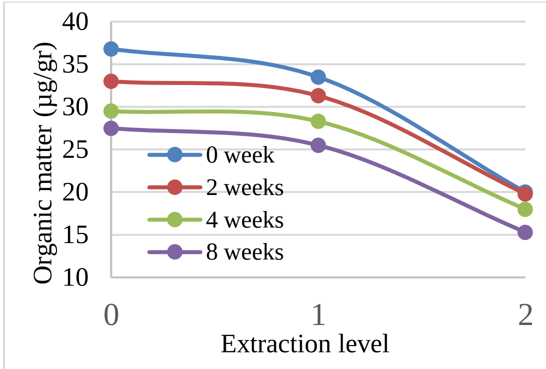

Figure 5: Organic carbon left in residue.

At the 2 week incubation period, the figure shown that at the first level of the extraction 5% organic matter involved in the water stream and 95% organic matter still left in the residue. In the second level of extraction, organic matter in the extract is 11.5 μg/g or 37% organic matter from the first extraction involved to the water stream and 63% left in the residue. It shown that the organic matter involved to the water stream in the first extraction is less than the second extraction.

At the 4 week incubation period, there was 12 μg/g organic matter content in the extract in the first level of extraction, it means that 4% organic matter involved in to the stream water and 96% organic matter still left in residue. In the second extraction, 36% organic matter from the first extraction level involved to the water stream and only 64% left in the residue.

At the 8 weeks incubation period, the figure shown that 25.5 μg/g organic matter left in the residue of the first level extraction, it means that 7% organic matter involved to the water stream. In the second extraction, 40% organic matter from the first extraction involved to the water stream.

All trend-line shown that the highest organic content involved to the water stream occur in acidic condition. It means that in the acidic conditions such as acid rain, the organic matter in the landfill or leachate will be more involved in the flow of water and enter to the groundwater stream. The pH of the soil generally ranges from 6-8 due to the presence of organic matter and mineral metals. If it is drained with the acid, some of the basic organic material and mineral metals will react with acidic conditions and involved to the acidic water flow. The average organic matter enter to the water stream in first extraction is 6% and in the acidic condition at the second extraction is 45%. The organic matter left in the residue in the first and second level of extraction are 94% and 55%, respectively.

The figure shown that the organic content involved in the water stream in the first level of extraction getting lower with the longer of incubation period, it means the longer of the incubation period, makes the organic matter more stable.

3.3 Bio-char Application

Bio-char application is carried out to immobilization organic matter in the leachate from landfill into the groundwater by adsorbing into the bio-char pores. The figure below shown the bio-char morphology. The Specific Surface Area (SSA) determined by using Methylene Blue. The result of SSA value is 9.2 m^2/g. The Cation Exchange is 0.2297 meq/100 g biochar. As a comparison, the SSA of pine biochar is 10.4 m^2/g and the cation exchange is 2.40 ± 0.21 cmol/kg (Luchini, 2014). The morphology of biochar surface area as given in Figure 1 is obviously seen that biochar from low-rank coal lignite exhibited pore-like surface.

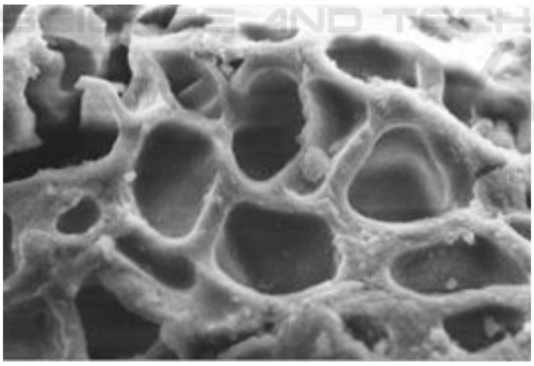

Figure 6: Bio-char surface area morphology.

This application was carried out in 3 options, first with a homogeneous mixture between the landfill's soil and the bio-char, the second option was bio-char placed in one layer above the landfill soil, then the third was through a layer system, where landfill is not mixed with bio-char but the bio-char application is carried out by covering landfill alternately. Homogeneous bio-char position is a method of mixing bio-char with soil which is used to maximize the interaction between soil particles and bio-char. This method can also help minimize the loss of bio-char by wind and water erosion, through burial and soil macro-aggregate formation. The benefits of this method depend on the characteristics of the bio-char and the soil used. In the second option, bio-char placed or sprinkled on the surface of the soil sample in the Fixed Bed column with soil sample and bio-char weight ratio was 10:1. In the bio-char layered position, the soil was divided into three parts, then bio-char inserted between the three layers. The position of the layer from the top to the ground of the column was soil sample - bio-char - soil sample - bio-char - soil sample. Figure 6 shown the option of bio-char application.

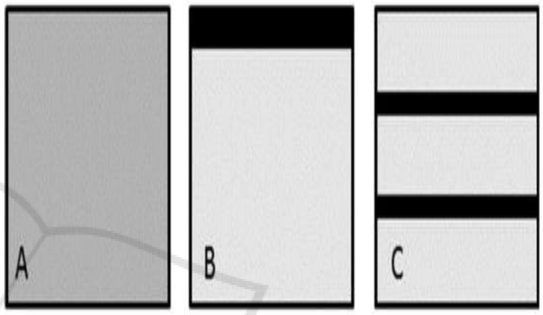

Figure 7: Bio-char application in landfill soil, (a) homogenous mixture, (b) one layer on the above of landfill soil, and (c) a layer system, bio-char and landfill soil covering alternately.

This study using Fixed Bed Column and varying the amount of distilled water flow through the column with acid condition. The water passing through the bio-char layer in 5 variations, namely the L / S ratio (liquid per solid ratio) 1, 2, 5, 8, and 10. The results was obtained as shown in the following figure.

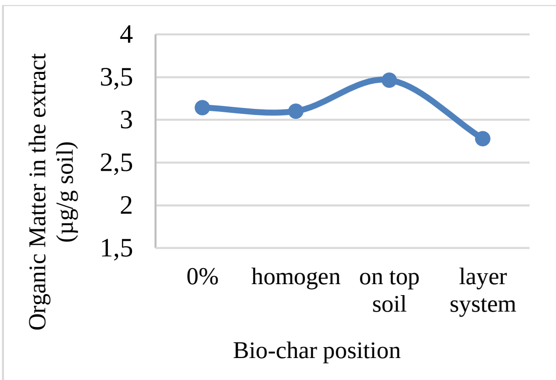

Figure 8: Effect of bio-char position to organic matter in the extract at L/S = 1.

Figure 7 shown the effect of bio-char position to the organic matter if the acid water flowed once into the column and it shown that the lowest organic matter in the extract is at layer system position, it means that in this position the organic matter absorbed by bio-char was highest than other position.

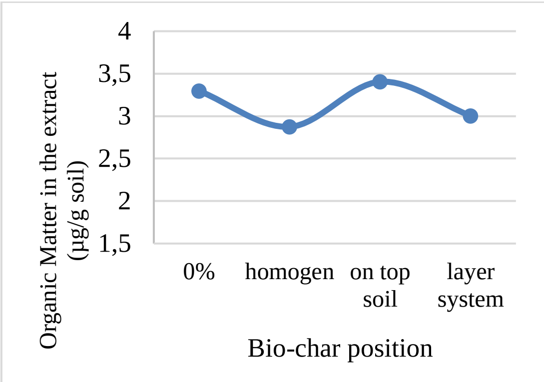

Figure 9: Effect of bio-char position to organic matter in the extract at L/S = 2.

In in Figure 8, the acid water was flow through the column twice. This figure shown that the lowest organic matter in the extract was at homogenous position. It means that homogenous position was suitable for acid water flow through the column twice and the highest organic matter in the extract was at bio-char on top of the soil sample, the organic matter in the extract in this position was higher than soil sample without bio-char, this shown that bio-char did not absorb the organic matter in the soil, but the organic matter in bio-char followed through the water flow.

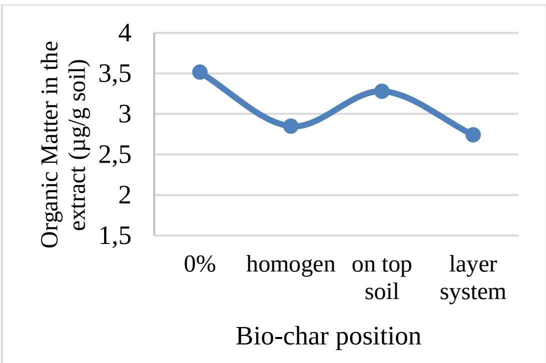

Figure 10: Effect of bio-char position to organic matter in the extract at L/S = 5.

Figure 9 shown that soil sample was filled with acid water five times. The figure shown that the lowest organic matter in the extract was at layer system position.

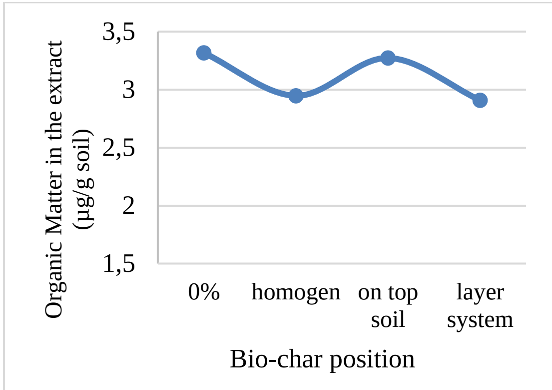

Figure 11: Effect of bio-char position to organic matter in the extract at L/S = 8.

In figure 10 soil sample was flowed by acid water 8 times. In this figure, the lowest organic matter in the extract was at layer system, not too different with homogeneous systems, organic matter in the extract at layer system and homogeneous system are 2.909 µg/g soil and 2947 µg/g soil, respectively.

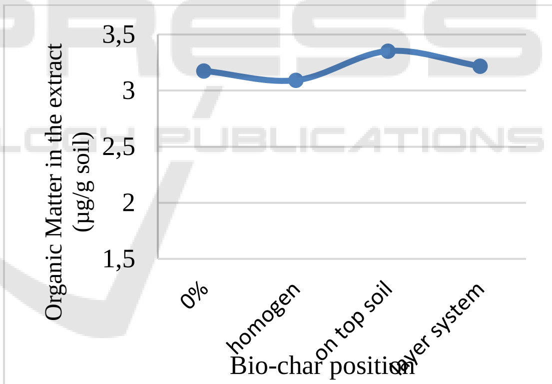

Figure 12: Effect of bio-char position to organic matter in the extract at L/S = 10.

Figure 11 shown the organic matter in the extract where the acid water flow through soil sample ten times. The lowest organic matter in the extract was at homogenous position.

From the above figures, Figure 7 till 11 shown the same trend line, the organic matter in the extract at homogenous and layer system position was lower than other position, it means that the bio-char absorption process in these position was more effective.

The variation of liquid per solid ratio or the cycle of acid water flowed through soil samples shown that the bio-char absorption process has a limit. At soil sample without bio-char, the highest organic matter in the extract was at L/S = 5 or acid water flow through the soil sample five times with the amount of acid water was 180 ml per cycle. At the homogenous position, the average of organic matter in the extract was 2.973 µg/g soil with the highest bio-char absorption was at five times acid water flow through the soil sample. The absorption reduced after that (at L/S = 8 and 10). At the second position, the average of organic matter in the extract was 3.355 µg/g soil with the highest bio-char absorption was at eight times acid water flow through the soil sample. At layer system position, the average of organic matter in the extract was 2.930 µg/g soil with the highest bio-char absorption was at five times acid water flow through the soil sample. As homogenous position, the absorption of bio-char reduced after that (at L/S = 8 and 10).

Generally, the lowest organic matter in the extract was 2.930 µg/g soil at layer system but not so different with the homogenous system. In the relation with the cycle of acid water flow through the soil sample, the lowest of organic matter in the extract was at L/S ratio 5 and increased after that. The correlation of organic matter in the extract, bio-char position and L/S ratio shown in figure below.

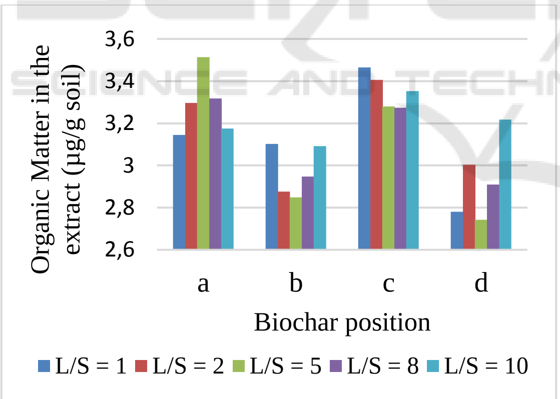

Figure 13: Effect of bio-char position to organic matter in the extract, (a) without bio-char, (b) homogenous mixture, (c) one layer on top soil, (d) layer system, bio-char and landfill soil covering alternately

The figure shown that the lowest organic matter in the extract was at layer system with five time's acid water flow through the soil sample. The reduction of the organic matter in the extract from soil without bio-char to this point was 78.2%. In the layer system, bio-char adsorbed the organic matter without changing the soil structure and with several layers of bio-char the adsorption process occurs repeatedly, while in the homogenous mixture, the soil become loose and easily traversed by water. In one layer bio-char on top the soil, the adsorption process only occurs once, the placement of bio-char layers at the top of the soil is also not effective for the immobilization of the organic matter. So, the optimum condition of bio-char absorption was at layer position and only five time's acid water flow through the soil sample.

4 CONCLUSIONS

Acidic conditions affect the mobilization of organic matter. In this study, 45% organic matter involved in to water stream in the acidic condition and 6% in the neutral condition. It means that in the acidic conditions such as acid rain, the organic matter in the landfill or leachate will be more involved in the flow of water and enter to the groundwater stream. The incubation period will affect the stability of organic matter, the longer of the incubation period, makes the organic matter more stable.

The application of bio-char can be a solution to immobilization the organic matter in the soil. This study was conducted in acid condition and the position of bio-char with layer system was more effective than others position. This system can reduce 78.2% organic matter in the extract compared with landfill soil without bio-char.

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