Treatment of Aging Leachate using Bio-char Derived from Gaharu Waste

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Abstract—**The present work demonstrates the preparation of bio-char using gaharu waste for the treatment of aging leachate. The physical and chemical properties of gaharu bio-char were evaluated by pore structural analysis by BET analyzed. The effect of retention time, solution pH and adsorbent dosage on adsorption performance were examined. The absorption efficiency of the gaharu bio-char was determined by a series experiment using jar test. In this study, the parameter that evaluate the adsorption performance of leachate is turbidity, colour, total suspended solid, chemical oxygen demand and heavy metals. The BET surface area, Langmuir surface area and total pore volume were identified to be 1.073m^2/g, 1.095m^2/g and 1.246 cm^3/g. The findings of optimum conditions is at pH 10 and dosage at range 1-2 gram of gaharu bio-char, according to the examination through variation effect at pH 5, 9, and 10 and gaharu bio-char dosage at 1g, 2g, 4g and 6g. For the heavy metal analysis, every variable were analyzed to study the adsorption uptake of metal ions from gaharu bio-char. The result shows the capabilities of the gaharu bio-char to adsorb metal ions depend on the variable parameter.**

***Keywords*— Leachate, bio-char, gaharu waste, adsorption, adsorbent and adsorption uptake.**

I. Introduction

Generally, landfill is classify based on the decomposition process which is anaerobic landfill, anaerobic sanitary landfill with daily cover, improved aerobic sanitary landfill with buried leachate collection pipes, semi-aerobic landfill with natural ventilation and leachate collection facilities [1] The composition of biodegradable organic matter (COD and BOD5) is decreases rapidly with the aging of landfill. Throughout recent decades, the wastewater treatment industry has identified the emission of organic, inorganic and heavy metals compounds due to leachate seepage into the waterways as a risk to the natural environments. The adverse impacts of overloading in the sensitive ecosystems are becoming increasingly noticeable with several substances with confirmed carcinogenic or co-carcinogenic potential were indicated in the landfill leachate while others were expected to be persistent and highly bioaccumulative.

In Malaysia agarwood are generally known as gaharu, is a dark resinous heartwood that forms in *Aquilaria spp.* trees when become infected with a type of mould. Gaharu wood uses as fragrance wood, traditional medicine practices, religious purpose, cosmetic and pharmaceutical product [2]. Gaharu is a valuable due to the majority of the wood is traded into a various form of product pallet, powder and bark. According [2] there are four grade of gaharu wood, grade A, B, C and D can be differentiate by the physical properties and scent of the gaharu. Due to the growing interest to the gaharu oil, Malaysia is one of the producer to the gaharu wood and also producer of the extraction of the gaharu oil cause the gaharu waste is produced more.

In this study, the utilization on adsorption process from bio-char, were carried out by varying pH of leachate, adsorption dosage from bio-char and contact time. Bio char as wood, manure with little or no oxygen which is pyrolysis which can be applied to soil for both agricultural gains and carbon sequestration. Bio-char can slacken carbon release to the atmosphere from burning or degrading by carbon stabilization into a form resembling charcoal (carbon negative). By burying it in fields, it can store carbon in soil and improve soil properties. In addition, the bioenergy produced from pyrolysis process provides potential substitute for carbon neutral As discussed [4], the specific properties of bio char including large specific surface area, porous structure, enriched surface functional groups and mineral components make it possible to be used as proper adsorbent to remove pollutants from aqueous solutions. Generally bio char has porous structure similar to activated carbon, which is the most commonly employed and efficient sorbent for the removal of diverse pollutants from water throughout the world. Meanwhile bio char comes to be a new potential low-cost and effective adsorbent. The production of activated carbon needs higher temperature and additional activation process. In addition production of bio char is cheaper and lower energy requirements.

The Jeram Sanitary Landfill is one of the Malaysia landfill located at Kuala Selangor, Malaysia which is located in an oil palm plantation. In order to study the aging treatment for the landfill, JSL is selected to investigate the leachate characteristic in order to study either meet to the standard discharge limit to the environment. Based o the previous study, in Jeram Sanitary Landfill the waste is collected from the domestic waste and others were compacted and covered to reduce odor and the ingress of water to make sure safety and efficiency of the equipment. The system in Jeram Sanitary Landfill, on controlling pollution of the landfill by using rain water and other useful energy. Today's, the treatment method in Jeram Sanitary Landfill site by constantly drained rain water into contact with waste and leachate treatment [5]. But this method still not enough to overcome the aging of Jeram Sanitary Landfill site for a years more. Recently the adsorption technology from the bio-char has upgrade the promising to the treatment of the landfill leachate. This treatment methods were depend on the characteristic of the leachate that discharge from the Jeram Sanitary Landfill to the environment.

This study using the jar test method in order observe the changes of the leachate before and after treated. The analysis of the result finding by the quality test and characteristics of the bio-char. The example of the quality test is chemical oxygen demand, total suspended solid, color, turbidity and heavy metal present in the leachate. The bio-char surface area is study to analyzed the adsorption capacity of the bio-char. Generally, the contaminant of the leachate can easy removed through adsorption into the surface carbon material of the bio-char [4]. Thus, the objective of this study to prepare bio-char from gaharu waste via pyrolysis within the temperature range of 300°C, to characterize the prepare bio-char according to the surface area (BET), using N_2 adsorption and to evaluate the prepared bio-char according to the performance of water quality test.

II. METHODOLOGY

A. Landfill leachate

The leachate sample were collected from the Jeram Sanitary Landfill and were handled by standard methods for the investigation.

B. Preparation of bio-char

Preparation of the bio char sample, the sample are collected from waste industrial of gaharu in Malaysia. Raw of gaharu waste was collected once the oil has been extracted from hydrodistillation process. The raw of gaharu waste is burn into bio char using tube furnace at 300 °C in 60 minute. Then the sample are store at room temperature.

C. Jar test

The study involved rapid mixing, slow mixing and sedimentation in a batch process. Glass beakers of 500 ml capacity were filled with the leachate samples and agitated simultaneously, and the rotational speed were varied accordingly, allowing simulation of different mixing intensities and resulting flocculation process.

Table 1: Jar Test Method

Step	Rotation Speed (rpm)	Duration (minute)
1	250	5
2	100	24
3	No speed	60

Adsorption studied was conducted by varying pH and adsorbent dose in treatment process, while varying bio char dose and pH leachate during final treatment process. Treatment process was conducted to find the optimum dosage of adsorbent of bio char and optimum pH of leachate. Final treatment process was carried to find out the optimum dosage of adsorbent of bio char and pH of leachate.

D. Analysis of treatment leachate and heavy metals

The parameters analyzed include turbidity were measure by HACH spectrophotometer (2100P Turbidimeter), chemical oxygen demand (COD) concentration were measure COD Reactor (HACH) and total suspended solid (TSS) and colour were measured by HACH spectrophotometer (DR2700). The analysis of heavy metal concentration in the sample leachate solution such as Ferum (Fe), Aluminium (Al), Magnesium (Mg), Potassium (K) and Sodium (Na) were measured using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). The results sample were evaluated for each analysis from three sampling.

III. RESULTS AND DISCUSSION

A. Characterization of raw leachate

The characterization of the raw leachate sample from Jeram Landfill is shown in Table 2. According to the result analysis, the value of the total suspended solid (TSS) shown the value more then the standard condition which is 76.33 mg/L. By referring to the Malaysia's Environment Law, Environmental Quality (Control of Pollution From Solid Waste Transfer Station and Landfill) Regulations 2009 the acceptable conditions for discharge of leachate for total suspended solid is 50 mg/L. Thus, it is important for leachate before discharge to environment to be treated. This is because by increasing the age of the landfill the value of the turbidity, colour, total suspended solid, chemical oxygen demand, pH and heavy metal will be increasing. By treated the leachate discharge it can reduce the impact of the pollution to the environment.

Table 2: Characteristic of raw leachate samples from JSL

Characteristics	Value	Standard
Turbidity (NTU)	13	NA
Colour (PtCo)	5282	NA
TSS (mg/L)	76.33	50
COD (mg/L)	186.40	400
pH	8.65	6.0-9.0
Al (ppm)	1995.72	NA
Fe (ppm)	1.76	5.0
K (ppm)	690.28	NA
Mg (ppm)	14.28	0.20
Na (ppm)	939	NA

The analysis of the heavy metal shows that only five element of heavy metal detected in the raw leachate sample which is Aluminium (Al), Iron (Fe), Potassium (K), Magnesium (Mg) and Sodium (Na). From the Malaysia's Environment Law, Environmental Quality (Control of Pollution From Solid Waste Transfer Station and Landfill) Regulations 2009, only two element can be refer which is Iron and Magnesium, another three is not stated. Characterization of leachate is key to find the most critical pollution present in the leachate in order to introduce the suitable treatment technologies [3].

B. Characterization of the bio-char

The specific surface area was measured by the Brunauer-Emmett-Teller (BET). The data findings was BET surface area, Langmuir surface area and total pore volume of gaharu bio-char was 1.073 m^2/g, 1.095 m^2/g and 1.246 cm^3/g.

Table 3: Porosity structures of gaharu bio-char

Properties	Gaharu bio-char
BET surface area (m^2/g)	1.073
Micropore surface area (m^2/g)	0.000
External surface area (m^2/g)	1.073
Langmuir surface area (m^2/g)	1.095
Total pore volume (cm^3/g)	1.246
Average pore size (Å)	4.64

C. The effects of pH solution on adsorption uptake by bio-char

The study of the effect of pH from the leachate on the adsorption of bio-char is important in order to identify the optimum pH for adsorption. For this experiment the pH range that selected to analysis is 5, 9 and 10. By using 0.1 M of NaOH and 0.1 M of HCl as the indicator to get right pH of the diluted leachate. The dosages of the bio-char were kept constant at 1 gram at 500 ml of diluted leachate respectively. The experiment was performed using jar test equipment .

The chemical oxygen demand means the amount of oxygen required to degrade the biodegradable and non biodegradable portion in the waste. From the graph (b) Fig. 2 shows the concentration of chemical oxygen demand increase significantly as the pH value increases. This is because across the increase of pH value, the adsorption uptake of from the bio-char efficiency going down.

D. The effects of adsorbent dosage on adsorption uptake by bio-char

The influence of bio-char dosage on the turbidity, colour, total suspended solid and chemical oxygen demand in the Fig 3 The study is performed by fixing the pH value at pH 10 and varying the dosages from 1g/500ml - 6g/500ml. The optimum dosage is selected based on the higher concentration of removal rates of the parameter.

According to the Fig 3. the graph shows the how dosage of bio-char influence the changes before and after the leachate is treated. From the observation study, the turbidity and colour of the treated leachate can be by naked eyes which turning into more dark brown as the dosage increase. Which the colour and turbidity is increase as the dosage of the bio-char is increase. This phenomena linked to the affected of the total suspended solid high.

The hypothesis that suggest that by raising the amount of dosage would be increase the present of surface area and exchangeable binding sites from biochar. So from this preliminary studies, the biochar dosage.

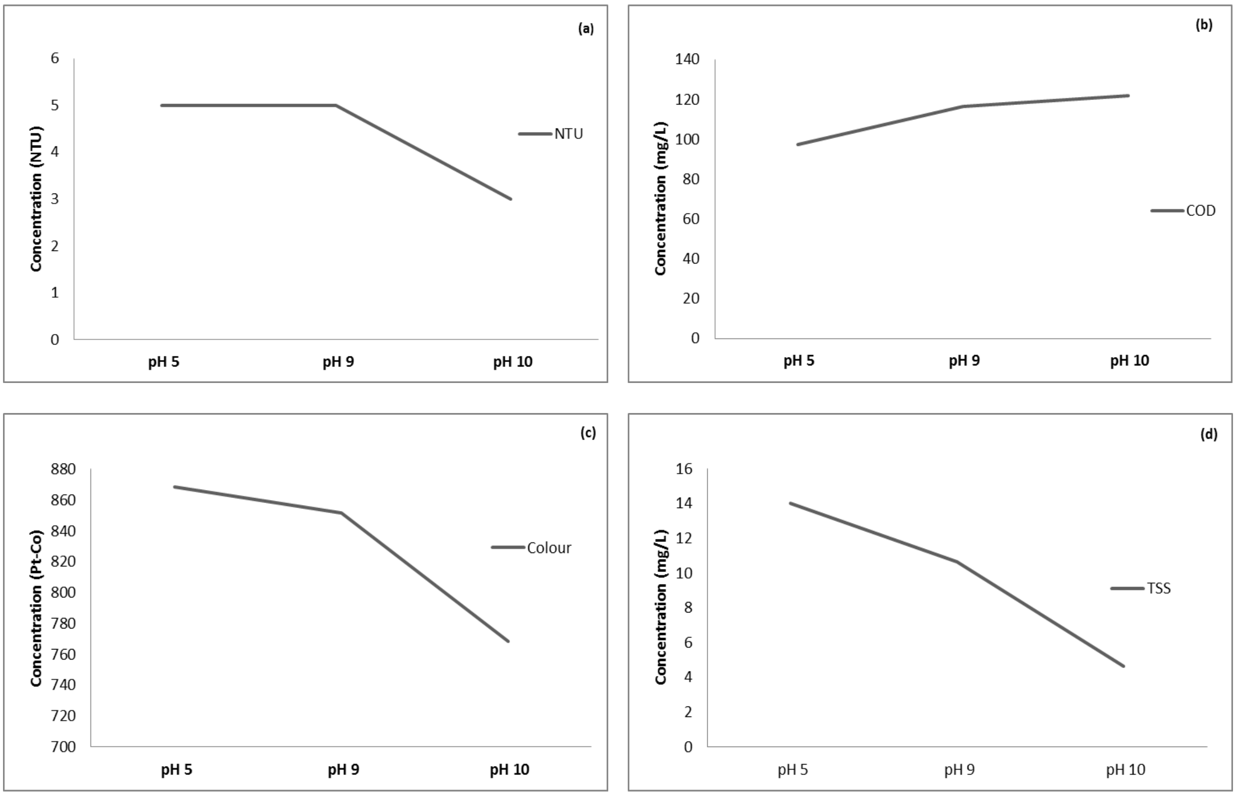

Fig. 2: Variation of pH solution on the leachate of (a) turbidity (b) chemical oxygen demand(c) colour and (d) total suspended solid

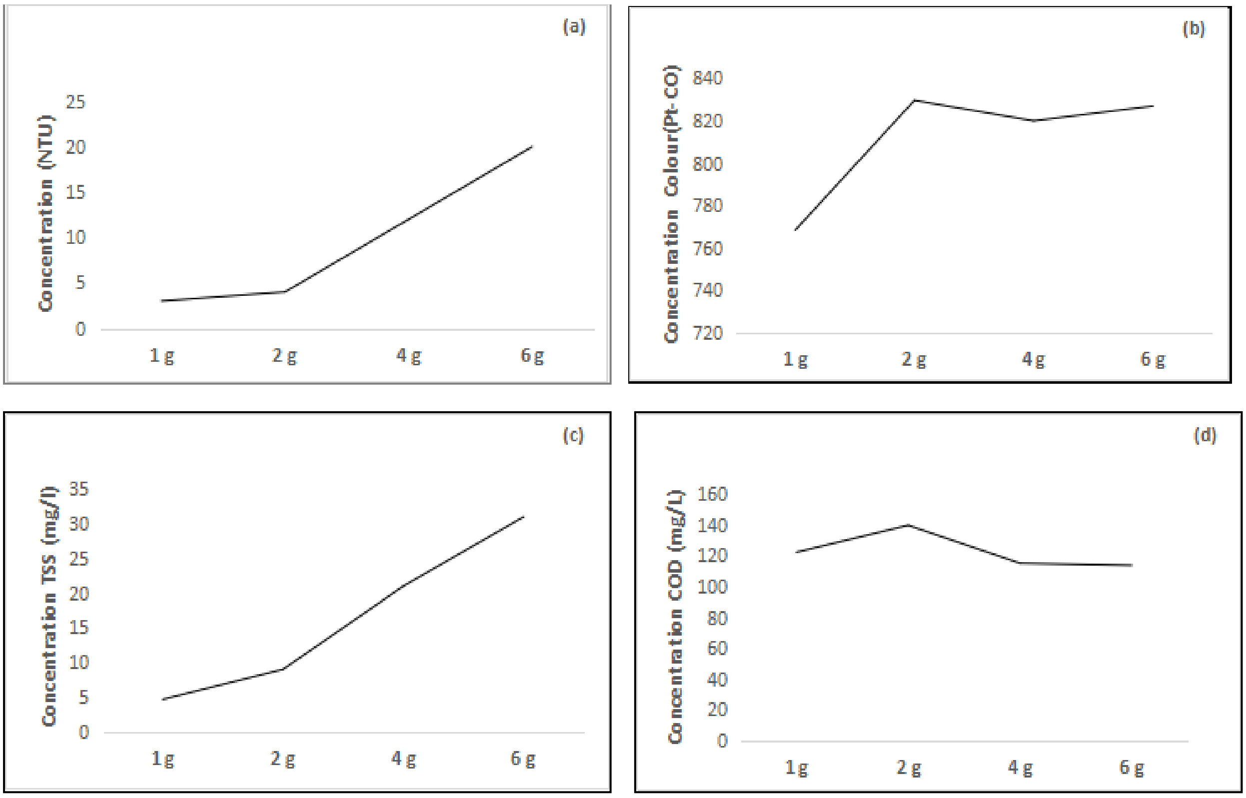

Fig. 3: Variation of adsorbent dosage on the leachate of (a) turbidity (b) colour (c) total suspended solid and (d) chemical oxygen demand

Actually at the Jeram Sanitary Landfill, receives 95% of domestic waste and 5% others, which is domestic or household waste, commercial waste, light industrial waste, market waste, street or public cleaning waste, construction waste and condemned food waste [8]. Heavy metal available due to the function of characteristics of leachate for example flow rate, value of pH, moisture, soil wastes, landfill chemical and biological activities and age of the landfill. Thus, the leachate composition is different depending to the site specification characteristic [6]. Fig. 4, 5 and 6 shown the result from the ICP-OES analyzer of the concentration of heavy metal that detected in sample leachate.The analysis of concentration of heavy metal in leachate varied with raw sample, retention time, different pH value and dosage. There is five heavy metal are detected found in the raw leachate and treated leachate which is Al, Fe, K, Mg and Na.

For the raw leachate (Fig. 4), the order of concentration of the heavy metal were Al > Na > K > Mg > Fe from higher concentration to lowest concentration. Al was the dominant metal in the raw leachate (498.93 ppm) while Fe was the minor (0.44 ppm). This explains the Al from the raw leachate might come from a wide range of source which is from household waste, electronic and from plant tissues ashes [8].

E. Elemental study of heavy metal

But for little amount of Fe, it can explain that the present of the dumpling of stell scrap in the Jeram Landfill in very small amount. So it shows that the Jeram Landfill is follow standard discharge amount for Fe concentration. Meanwhile K and Na constituents are consider as major of cations present in the raw leachate. According to the [7] K and Na is specifically not influence by microbiological activities within the landfill site. But these ions acts in plant physiology and mostly come from vegetable residues and domestic waste. The increase the K in the ground water may should be implied to the leachate pollution. Commonly, source of K comes from leaching fertilizer, weathering and erosion then maybe cause to the exposure of drinking water supply to human being.

For the retention time analysis, the biochar (1 gram) were immersed into the diluted leachate and leaves for 24 and 48 hours. The purpose of this study to determine the capability of the surface area of the biochar to adsorb any heavy metal, organic or inorganic chemical from the leachate. According to the result obtains Fig. 4 indicates that the order concentration of the heavy metal Al > Na > K > Mg > Fe. From the data shows that the concentration of heavy metal were decreases as the retention time increases. Therefore the output from the retention time, shows the capabilities of the nical.

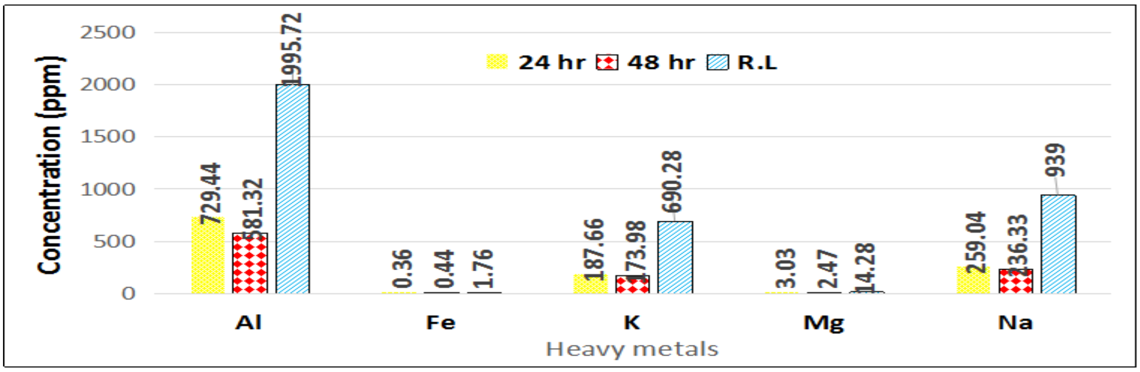

Fig. 4: Effect on retention time (24 and 48 hours) on the leachate of heavy metals

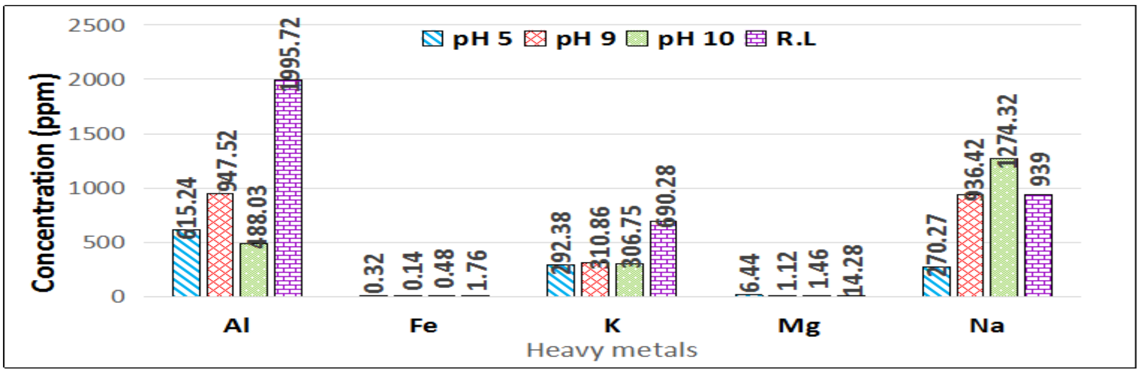

Fig. 5: Effect on variation pH value (pH 5, pH 9, pH 10) on the leachate of heavy metal

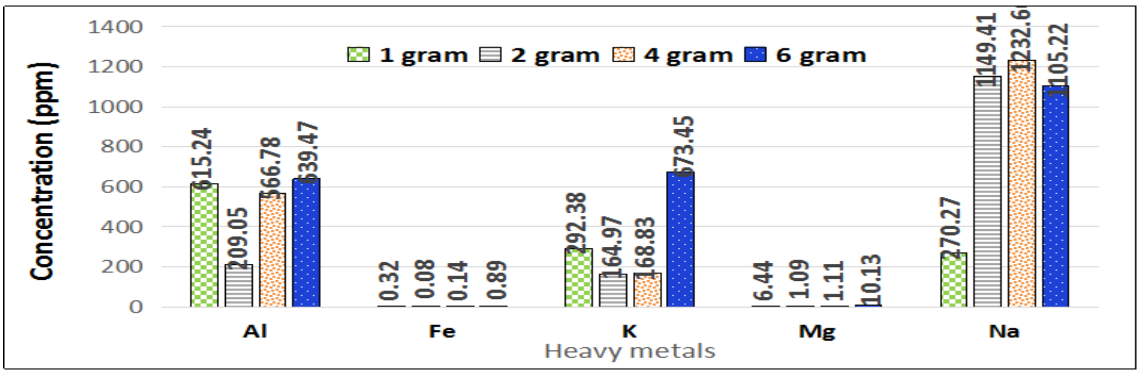

Fig. 6: Effect on variation adsorbent dosage (1g, 2g, 4g, and 6g) on the leachate of heavy metal.

The analysis of heavy metal to the variant value of pH, shown the different concentration of heavy metal for every value of pH. As stated in [8] solution pH is a major operational indicator influence the level of ionization and solubility of metal ions, surface charge and concentration of work surface ions of solid adsorbent appear in the solution. By referring to the Fig. 5, for acidic medium of leachate, pH 5 were selected to study the capabilities of biochar to adsorb the metal. At this acidic medium, the solution is acts as an electron acceptor, so the metal ions species is poorly attached to the binding site of biochar. Resulting to the lower adsorption uptake to the metal ions due to present high of hydrogen ions.

Meanwhile for the alkaline medium the solution of pH 9 and 10 shows the different result for the adsorption uptake of the metal ions. Generally at this medium OH- ions is competing with metal ions for adsorption site of biochar [6]. By referring to the graph, the best adsorptive uptake of metal ions was noted at pH 10, due to the reduction of heavy metal concentration in the leachate after treated.

By referring to the Fig. 6, the order of dosage biochar, indicate that the 2g>1g>4g>6g of capabilities of adsorption uptake of metal. The result is illustrated the concentration of remaining heavy metal in the leachate after treated by the biochar.The hypothesis that suggest that by raising the amount of dosage would be increase the present of surface area and exchangeable binding sites from biochar. But from this preliminary studies, the biochar dosage of 4g/500 ml and 6g/500 ml shows a reduction of adsorption uptake of metal. According to the [8] this condition due to the overlapping of adsorption sites of the biochar, consequences of overcrowding of adsorbent particles of 4g/500 ml and 6g/500 ml. As a conclusion, the increase in the adsorbent of the biochar, may cover the binding site from metal ions to reacts cause reduction the metal ions removal per unit of adsorbent.

IV. CONCLUSION

Overall of this study, shown that the gaharu waste have potential for the production of the valuable adsorbent in order to treat leachate, as long as there any improvement and value added of the property and characterization to the gaharu waste. As a conclusion, the finding from the performance water quality test and heavy metals adsorption at alkaline solution of pH 10 and at range 1-2 gram dosage of bio-char indicated that the optimum condition to adsorption process. This results was revealed for removing contaminants in the leachate. This is because bio-char is not only excellent in adsorption ability but also their environmental and economic benefits. In addition, according to the [9] properties of high calorific value, concentrated carbon content, excellent grindability, porosity and species homogeneity of bio-char, revealed the ability to be used as absorbent. But due to the small pore surface area structure of bio-char causes small amout uptake of contaminants compound in the leachate. So for the further study, the recommendation regarding to activated the carbon of the bio-char. This is because the current average pore size gaharu bio-char is only 4.64 Å, this is the essential property finding the fraction of the molecules in order to access the pore of the adsorbent.

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