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Model of Hospital Waste Processing Equipment to Remove Heavy Metal Pb

Model Alat Pengolah Limbah Rumah Sakit Untuk Menurunkan Logam Berat Pb

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ABSTRAK

Rumah sakit merupakan fasilitas pelayanan kesehatan yang menghasilkan limbah berupa padat, cair, dan gas. Limbah cair yang dihasilkan dari aktivitas rumah sakit mengandung bahan berbahaya dan beracun, sehingga perlu dilakukan pengolahan sebelum dibuang ke badan air. Penelitian ini bertujuan untuk menurunkan kadar Pb dengan metode kuasi eksperimen yaitu menggunakan arang biji alpukat dan arang bambu. Pengambilan sampel menggunakan metode grab sampling, yaitu sebanyak 50 liter. Arang biji alpukat dan arang bambu memiliki kemampuan penyerapan yang baik, sehingga mampu menurunkan kadar Pb limbah cair rumah sakit. Hasil penelitian menunjukkan bahwa terdapat penurunan kadar Pb sebesar 0,007 mg/L yang artinya tidak melebihi baku mutu yang ditetapkan oleh Peraturan Menteri Lingkungan Hidup dan Kehutanan No. 6 Tahun 2021 yaitu maksimum sebesar 0,01 mg/L. Penurunan kadar Pb rata-rata tertinggi yaitu pada campuran arang biji alpukat dan arang bambu sebesar 39.27%.

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ABSTRACT

Hospitals are healthcare facilities that produce solid, liquid, and gas waste. Liquid waste produced from hospital activities contains hazardous and toxic materials, so it needs to be treated before being discharged into water bodies. This study aims to remove Pb levels using the experimental quartz method, namely using avocado seed charcoal and bamboo charcoal. Sampling was conducted using the grab sampling method, with a total of 50 liters collected. Avocado seed charcoal and bamboo charcoal have good adsorption capabilities, so they can remove Pb levels in hospital liquid waste. The method of this research is quasi-experimental. The results of the study showed that there was a decrease in Pb levels of 0.007 mg/L, which means that it does not exceed the quality standards set by the Regulation of the Minister of Environment and Forestry No. 6 of 2021, which is a maximum of 0.01 mg/L. The highest average reduction in Pb levels was in the mixture of avocado seed charcoal and bamboo charcoal at 39.27%.

1. INTRODUCTION

1.1 Background

Hospitals, in their operations, generate waste in the form of solid, liquid, and gaseous waste. One type of waste that significantly impacts environmental quality is liquid waste (Syafi W, 2016). Liquid waste from all hospital activities, including domestic liquid waste and liquid waste from clinical activities, must be treated before being discharged into water bodies through liquid waste treatment units. The results and quality of liquid waste treatment are closely related to the liquid waste management process. Proper liquid waste management is essential to support effluent quality so that it does not exceed the quality standards set by the government and does not cause pollution to the surrounding environment (Rosalita, 2021).

Hospital waste also ranges from various organic materials, hazardous materials, radioactive materials, and even pathogenic bacteria and microbes. One of the diseases caused by hospital liquid waste is nosocomial infection (Rahmat B, 2018). There is a need for balanced hospital management and liquid waste management so that the hospital environment is more secure and can prevent the occurrence of cross-contamination (nosocomial). Most of these diseases will enter the soil and generally enter wells that are sources of water consumption.

These waste products consist of organic and inorganic compounds that can cause water pollution, resulting in a decline in water quality. One type of inorganic waste is the heavy metal lead (Pb). The Pb content in hospital liquid waste is related to the presence of iodinated contrast agents used for radiography, certain drugs and metabolites, and those containing organohalogen elements, the use of disinfectants, detergents, and chlorinated solvents, and other substances from laboratories (Novita, Y., & Purnomo, 2021). Pb can be found in hospital liquid waste in various forms, including dissolved, precipitated, or fine particles (Wardalia, 2016).

Heavy metals such as Hg, Cu, Cd, and Pb are dangerous because they are biomagnified, meaning they can accumulate and remain in the tissues of organisms for long periods as accumulated toxins. Excessive lead concentrations in water can adversely affect human health, causing conditions such as anemia, damage to the blood formation system, kidney damage, high blood pressure, and reproductive system damage. They can also damage the nervous system, leading to mental retardation or even blindness if accumulated over the long term (Ardillah Y, 2016).

The quality standards for treated liquid waste have been established in the Regulation of the Minister of Environment and Forestry No. 6 of 2021 concerning Procedures and Requirements for the Management of Hazardous and Toxic Waste. The quality standard for Pb in liquid waste is 0.01 mg/L (Permen LHK, 2021). Lead can get into the soil, air, water, and even the food we eat. Even a small amount of lead in liquid waste can accumulate, especially in water and soil. This can lead to bioaccumulation and biomagnification in the food chain, which can expose humans when they eat or breathe (Simatupang, 2024). Therefore, hospital wastewater containing Pb requires better treatment to reduce or stop the problems caused by Pb pollution.

Treatment of liquid waste in the case of Pb can be done by adsorption using an adsorbent in the form of bamboo charcoal, which can affect the effectiveness of Pb metal absorption (Pinalia, 2017). Preventing lead contamination in hospital waste requires treatment, including filtration processes using avocado seed charcoal and bamboo charcoal.

Avocado seed charcoal undergoes electrocoagulation and adsorption processes in hospital waste treatment. Avocado seed adsorbents are known to have better and simpler adsorption capabilities than silica. Avocado seeds have a water content of 12.67%, ash content of 2.78%, mineral content of 0.54% higher than other fruit seeds (Alsuhendra, 2007). Avocado seed waste is one alternative material that can be reused to produce activated carbon. Avocado seeds contain organic compounds in the form of amylose (43.4%) and amylopectin (37.7%). The amylose and amylopectin content in avocado seeds can be converted into a starch content of 80.1%, where the high starch content is proportional to the high carbon content in a substance (Setiawan, 2020).

Bamboo charcoal is a porous material with excellent adsorption properties (Kanagalakshmi, 2016). Activated charcoal made from bamboo has holes that are considered mesopores, and its surface area is 1,329 m^2/g. Because bamboo charcoal has a good pore structure and a large surface area, it is good at soaking up heavy metal ions (Manurung et al., 2019). Using clay biosorbents and bamboo charcoal can help lower the amount of lead in liquid waste from the batik industry (Tamyiz M, 2019). How bamboo charcoal is activated affects how well it can soak up substances. Research has shown that activated bamboo charcoal is good at soaking up Pb, but bamboo charcoal that is not activated does not work as well (Widayatno T, 2017).

The quality standards for treated liquid waste have been established in the Regulation of the Minister of Environment and Forestry No. 6 of 2021 concerning Procedures and Requirements for the Management of Hazardous and Toxic Waste. The quality standard for Pb in liquid waste is 0.01 mg/L (Permen LHK, 2021). Therefore, liquid waste containing Pb needs to be treated using a combination of bamboo charcoal and avocado seed charcoal. To remove Pb levels more efficiently, a good model of equipment is required. This study, titled "Model of Hospital Waste Treatment Equipment to Remove Heavy Metal Pb," is an

alternative method for treating hospital waste to remove Pb levels.

1.2 Research Objectives

The objectives of this research are: (a) to determine the effect of the hospital liquid waste treatment tool model in removing Pb levels; (b) to determine the average Pb remove after being treated using avocado seed charcoal, bamboo charcoal and their mixture; (c) to obtain the best tool model in removing Pb levels.

2. METHOD

2.1 Location and Time of Research

This research was conducted from March to November 2024 at the Waste Bank, Sembada, Jetis, Donokerto, Sleman.

2.2 Research Method

The method used in this study is the quasi-experimental method. The quasi-experimental method is a research method used to test the causal relationship between variables, but without randomizing subjects into groups. The population of this study is hospital liquid waste in the form of grab sampling of 50 liters.

Table 1. Research design (pre-test & post-test group)

Pre Test	Treatment	Post Test
O_1	X_1	$O_{1'}$
O_2	X_2	$O_{2'}$
O_3	X_3	$O_{3'}$

Description:

O_1 = Bamboo Charcoal

O_2 = Avocado Seeds

O_3 = Combination of avocado seeds and bamboo charcoal

X_1 = Measurement of Pb in bamboo charcoal

X_2 = Measurement of Pb in avocado seeds

X_3 = Measurement of Pb in combination of avocado seeds and bamboo charcoal

The data obtained were tabulated using a dummy table. The data obtained were tested for normality using Kolmogorov Smirnov. If the data were normally distributed, they were followed by a multivariate ANOVA test with a significance level of 95% ($\alpha = 0.05$).

Next, the retention time of waste can be calculated using the following formula:

$$d = \frac{Vs}{Wt}$$

Description:

Vs = Filter volume

Wt = Waste retention time in the filter

Q = Flow rate

In this research, the waste retention time in the filter was set at 1 hour so that the flow rate of the liquid waste to be filtered using avocado seed charcoal, bamboo charcoal, and a mixture of both could be calculated.

$$Q = \frac{Vs}{Wt}$$

$$Q = \frac{30\ cm\ x\ 30\ cm\ x\ 15\ cm}{1\ hour}$$

$$Q = \frac{13.500}{60\ minutes}$$

Q = 225 cm^3/minute (225.000 mL/s)

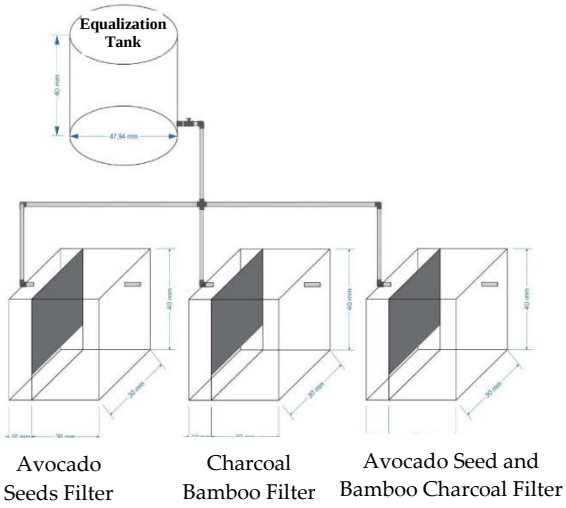

Figure 1. Tool Model Design

3. RESULTS AND DISCUSSION

3.1 Results of Pb Level Measurements

The treatment of hospital liquid waste using avocado seed charcoal, bamboo charcoal, and a mixture of both is presented in Table 2 as shown below. Table 2 shows that the highest percentage decrease in Pb (difference between pre-test and post-test) was in Tank 1 (avocado seed charcoal filter) in repetition 9, while the lowest was in Tank 2 (bamboo charcoal filter) in repetition 1.

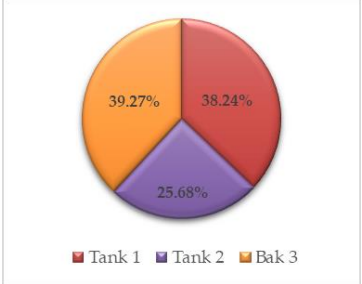

Figure 2. Average Percentage Decrease in Pb Levels

The average percentage decrease in Pb levels can be seen in Figure 1, with the highest decrease in Pb occurring in Tank 3 (a combination of avocado seed charcoal and bamboo charcoal), while the lowest decrease in Pb occurred in Tank 2 (bamboo charcoal filter).

Table 2. Reduction in Pb Levels After Treatment

Repetition	Pre-test (ppm)	Tank 1 (ppm)	Tank 2 (ppm)	Tank 3 (ppm)	Difference					
					Tank 1		Tank 2		Tank 3	
					AMOUNT	%	AMOUNT	%	AMOUNT	%
1	0.0071	0.0048	0.0056	0.0045	0.0023	32.39	0.0015	21.13	0.0026	36.62
2	0.0070	0.0049	0.0055	0.0042	0.0021	30.00	0.0015	21.43	0.0028	40.00
3	0.0072	0.0046	0.0052	0.0051	0.0026	36.11	0.002	27.78	0.0021	29.17
4	0.0070	0.0038	0.0055	0.0044	0.0032	45.71	0.0015	21.43	0.0026	37.14
5	0.0073	0.0057	0.0055	0.0044	0.0016	21.92	0.0018	24.66	0.0029	39.73
6	0.0068	0.0049	0.0052	0.0033	0.0019	27.94	0.0016	23.53	0.0035	51.47
7	0.0071	0.0038	0.0053	0.0052	0.0033	46.48	0.0018	25.35	0.0019	26.76
8	0.0072	0.0039	0.0055	0.0043	0.0033	45.83	0.0017	23.61	0.0029	40.28
9	0.0090	0.0038	0.0052	0.0043	0.0052	57.78	0.0038	42.22	0.0047	52.22
AMOUNT	0.066	0.040	0.049	0.040	0.026	344.17	0.017	231.13	0.026	353.39
AVG	**0.007**	**0.004**	**0.005**	**0.004**	**0.003**	**38.24**	**0.002**	**25.68**	**0.003**	**39.27**

3.2 Data Analysis Results

The results of descriptive statistical analysis can be seen in Table 3 as followed.

Table 3. Descriptive Statistical Test Results

Processing Model	Repetition	Mean (%)
Tank 1 (Avocado Seeds)	9	38.24
Tank 2 (Bamboo Charcoal)	9	25.68
Tank 3 (a combination of avocado seed charcoal and bamboo charcoal)	9	39.27

Based on Table 3, the highest average percentage decrease in Pb levels was 39.27% in the model using a mixture of avocado seed charcoal and bamboo charcoal (Tank 3), while the lowest average percentage was 25.68% in the model using bamboo charcoal (Tank 2).

Table 4. Results of ANOVA Statistical Test

	Sum of squares	df	Mean square	F	Sig
Between groups	1029.769	2	514.885	6.255	0.007
Within groups	1975.450	24	82.310		
Total	3005.219	26			

Table 4 shows that there is an effect of Pb reduction in the hospital liquid waste treatment model using avocado seed charcoal, bamboo charcoal, and a combination of both on Pb reduction ($\alpha \leq 0.05$).

3.3 Discussion

Hospital liquid waste comes from domestic waste such as bathrooms, kitchens, and clinical waste such as treatment rooms, radiology, laboratories, and others. Some of these liquid waste sources have the potential for pollution, one of which is lead (Pb). Hospital liquid waste needs to be treated so that when it is discharged into water bodies, it does not pollute the environment.

In this research, processing was carried out using a model of avocado seed charcoal, bamboo charcoal, and a mixture of both. Statistical test results showed a decrease in Pb ($\alpha \leq 0.05$). The highest decrease in Pb levels was achieved using a combination of processing models (avocado seed charcoal and bamboo charcoal) at 39.27% and an average difference in Pb levels of 0.003 ppm.

Based on the quality standards for treated liquid waste, which have been established in Regulation of the Minister of Environment and Forestry No. 6 of 2021 concerning Procedures and Requirements for the Management of Hazardous and Toxic Waste. The quality standard for Pb in liquid waste is 0.01 mg/L (Permen LHK, 2021). This can be considered safe for the environment as it does not exceed the quality standard.

Although the results of pre-measurements or measurements taken before adsorption were found to be within quality standards, the presence of lead (Pb) remains dangerous because lead (Pb) is a heavy metal that can accumulate in the environment and accumulate in the human body through absorption, bioavailability, bioconcentration, and biomagnification, which disrupt the nervous system, skeletal system, reproductive system, hematopoietic system, kidneys, and cardiovascular system (Collin MS, 2022).

This study found that there was a decrease in Pb levels after treatment with avocado seed charcoal, bamboo charcoal, and a mixture of both. Then, statistical testing showed that there was a decrease in Pb levels in the treatment models using avocado seed charcoal, bamboo charcoal, and a mixture of both. This proves the adsorbent function, which can adsorb Pb levels in hospital liquid waste.

Avocado fruit has soft, bumpy skin that can be dark green to brownish purple, depending on the avocado type. Usually, the avocado seed is thrown away, or used only to grow new plants. But some businesses are using avocado seeds to make them more valuable. Avocado seeds can be used to soak up heavy metals like lead. Avocado seeds have natural substances that can be used to make activated carbon.

Avocado seed waste is one alternative material that can be reused to produce activated carbon. Avocado seeds contain organic compounds in the form of amylose (43.4%) and amylopectin (37.7%). These amylose and amylopectin are converted into starch content, and a high starch content indicates a high carbon content. Avocado seed adsorbents are known to have better and simpler adsorption capabilities compared to silica. Liquid waste treatment using a combination of activated carbon adsorption from avocado seeds after electrocoagulation has been proven to enhance the efficiency of removing Pb(II) metal (Setiawan, 2020).

Bamboo charcoal is a good material to use as an adsorbent because it has good adsorption power. The following are the reasons for using bamboo charcoal as an adsorbent (Pinalia, 2017):

1. It has special micropores.
2. It has special biological characteristics.
3. High density and good pore structure.
4. The surface area is greater than that of charcoal, which is 300 m^2/gram, while charcoal is 30 m^2/gram.

The following is the liquid waste treatment process used to remove Pb levels in this research:

a. Avocado Seeds

First, separate the avocado seeds from the skin and cut them. Next, wash them thoroughly and dry them. This process aims to clean the avocado seeds from contamination by unwanted elements and substances during the process of separating the avocado seeds from the fruit skin (Rahmat A, 2021). After drying, the avocado seeds are ground into powder. Then, hospital liquid waste is adsorbed using avocado seed charcoal to remove the concentration of Pb.

b. Bamboo Charcoal

In this process, bamboo charcoal is dried first. The drying process is conducted to maximize adsorption. After that, hospital liquid waste is adsorbed by bamboo charcoal to remove Pb concentration.

The combination of bamboo charcoal and avocado seeds can produce adsorbents with complementary physical and chemical characteristics. Bamboo charcoal is superior in physical structure with the presence of micropores so that it can adsorb physically, while avocado seeds enrich the chemical side with organic compounds contained in avocado seeds so that they can adsorb chemically. This increases the capacity and efficiency of pb absorption to the maximum. So, in accordance with this research it is proven that the mixed processing tool model (Avocado Seed Charcoal and Bamboo Charcoal) is the best tool model in removing Pb levels.

4. CONCLUSION

The study demonstrated that the hospital liquid waste treatment model utilizing avocado seed charcoal and bamboo charcoal effectively reduced lead (Pb) concentrations in wastewater. The results indicate a significant influence of the treatment model on Pb level reduction, with the highest removal efficiency achieved through a mixed treatment approach combining both avocado seed and bamboo charcoal. This mixed treatment model yielded an average Pb reduction of 39.27%, confirming its superior performance compared to single-material treatments. Therefore, the combined use of avocado seed and bamboo charcoal is recommended as the most effective model for reducing Pb contamination in hospital liquid waste.

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