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Planning of Granular Activated Carbon Unit to Remove Ammonia and TSS at IPLT X, Kota Jakarta

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ABSTRACT. Fecal **s**ludge can be treated by conventional treatment, such as pond stabilization which is commonly used to reduce organic concentrations. However, nutrients such as NH3 are still widely measured in the effluent. One of the sewerage treatments in Jakarta, for example, experienced this condition. This study aims to design an appropriate technology to increase the efficiency of nutrient ammonia and total suspended solid (TSS) removal at Duri X IPLT. The unit added in the selected effluent treatment is Granular Activated Carbon (GAC). Design considerations are the characteristics of activated carbon, operating conditions (discharge and contact time), and operating mode (fixed-, expanded-, or fluidized-bed, pumped, or gravity flow). The Carbon Usage Rate for removing ammonia and TSS is 1.384 g/L and 0.378 g/L, respectively. Maintenance is required so that the granular activated carbon (GAC) unit can continue operating and functioning properly. Blockages in carbon transport pipes can occur in many pipes. This can occur due to a too-small pipe, a short bend radius of the pipe, a lack of speed, and a lack of cleaning of the pipe. The eroded pipe is also a common problem that often occurs in unlined mild steel and fiberglass reinforced plastic (FRP), usually in sharp bends.

1. INTRODUCTION

Sludge is a waste material resulting from the decomposition process of human feces in a septic tank. Fecal sludge as domestic waste sourced from human waste has a very high concentration of pollutants so further processing is needed not to pollute the environment [1]–[3]. The basic concept of conventional systems is to utilize microorganisms to separate environmental parameters, while mechanical systems use physical and chemical processes to separate environmental parameters [4], [5]. Conventional systems are maintained because of low operating costs and relatively easy to maintain [6], [7]. The conventional system consists of a manual receiving and filtering unit, an aeration pond unit, an anaerobic pond unit, a facultative pond unit 1 and 2, a maturation pond unit, and a final pond unit [8]–[10].

In practice, the treatment of sewage sludge several times encountered problems in operations and the quality of the treated water. In its process, IPLT X does not yet have a standard reference regarding the basic technical matters that need to be considered in its processing, such as the blueprint for the treatment unit, the residence time of treated water, the work system of each treatment unit, and the detailed flow of the wastewater treatment process. Sludge discharge is very volatile in one week. Based on field observations, in the operation of the reception unit, it is often found that the process flow does not run following applicable regulations. In addition, problems in treated water are often encountered in the results of laboratory tests which are carried out every 2 (two) weeks. The effluent resulting from wastewater treatment from sewage treatment should meet the quality standards stipulated in the Regulation of the Minister of Environment and Forestry Number 68 of 2016 concerning Domestic Wastewater Quality Standards. However, the quality of the effluent does not meet the quality standards, especially in the TSS and ammonia NH_3 parameters. Based on the effluent quality test data in the processing period from May to September, it was found that the ammonia (NH_3) content was 23.84 mg/L. The ammonia (NH_3) content in this effluent has exceeded the quality standard threshold of 10 mg/L. In addition, the results of testing the TSS content in the final pond found that the TSS content was 70.30 mg/L. This value has exceeded the standard threshold of

30 mg/L. The excess ammonia (NH_3) and TSS found in the effluent quality test led to algae blooms in facultative pond 2 in IPLT X.

Sewerage treatment, which is supposed to reduce the amount of organic entering the water body, becomes a pollutant contributor to the water body [11]. The high organic content in water bodies certainly impacts the environment, with both positive and negative impacts. The shellfish farmers can feel the positive side of the estuary/beach. The growth of cultured shellfish is so good because it gets abundant food. Meanwhile, the opposing side impacts the environment by increasing nutrients in rivers and being carried to the sea causing a phytoplankton explosion. River body inputs with organic pollutant levels that have exceeded the quality standard will trigger diatom blooms [12]–[14]. Ammonia content that still does not meet quality standards can also cause negative impacts on the surrounding environment, especially organisms in marine areas . If dissolved ammonia is excessive in the waters, it will cause poisoning for almost all aquatic organisms [15]. Toxins accumulating in fish and shellfish will cause poisoning in humans who consume them. In addition, ammonia also causes disturbances in fish respiration because it can damage fish gill tissue so that the ammonia content is absorbed into the fish's blood [16]. The death of fish also proves this theory in the final pond of Duri Kosambi IPLT. Therefore, we need a design technology that can process the parameters of ammonia and TSS in the effluent following the established quality standards. This study aims to design an appropriate technology to increase the efficiency of ammonia removal in IPLT X.

An activated carbon reactor is the design of the ammonia and TSS removal unit used in IPLT X to enhance the effluent quality. The IPLT's current final pond will house the activated carbon reactor. The decision to use ammonia and TSS removal technology as a guide for unit design will be supported by a number of hypotheses and earlier studies. Granular activated carbon is the sort of activated carbon used, according to prior studies (GAC). GAC regeneration is a desirable alternative given the relatively high cost of activated carbon; nevertheless, regeneration is not always economically viable due to the high cost of regeneration facilities/services [17]. In these situations, which often include low GAC utilization rates, the used GAC is thrown away in a landfill. Therefore, it is vitally desirable to develop regeneration technology that is less expensive. Thermal, chemical, or biological processes can be used to replenish the adsorption capability of used granular activated carbon. One drawback of thermal reactivation, which is almost exclusively used, is the high energy cost of heating the GAC to about 800 °C [18]; is the transfer of contaminants to the air phase; and is the extremely high cost for small facilities [19].

2. METHOD

The main problem in the sewage treatment system at IPLT X is that the removal of ammonia (NH3) in the treatment process of IPLT X has not been maximized. This is based on the results of laboratory tests which show that the ammonia level in the final pond exceeds the quality standard set by the Ministry of Environment and Forestry. So this study will plan to add a system that can improve sewage treatment in IPLT X. Some of the recommendations we put forward are based on considerations of data in the field, the possibility of access to be able to realize it, and the funds needed.

The study framework used in the design is described in several stages. First, this study is based on the descriptive analysis method. This method is an explanation/description of the current phenomena accompanied by the literature that supports the theories being worked on. Second is the determination of ideas or ideals, by adjusting the information developed in IPLT X. Third, the data analysis was carried out qualitatively using a descriptive method that discussed collecting, processing, analyzing, and presenting a group of data. These steps include comparative objects, site locations to obtain data, and comparisons related to the design object. Early research did not conduct experiments because there was no testing, but the emphasis was on a particular design context.

3. RESULT AND DISCUSSION

The design of the ammonia and TSS removal unit used to improve the quality of the effluent in IPLT X is an activated carbon reactor. The activated carbon reactor will be placed in the existing final pond at the IPLT. Several theories and previous research will support the selection of ammonia and TSS removal technology as a reference for unit design. According to previous research, the type of activated carbon used is granular activated carbon (GAC). In wastewater treatment technology, activated carbon is often used to remove the content of Natural Organic Matter (NOM) and Synthetic Organic Compounds (SOCs) in domestic wastewater and industrial wastewater [20], [21]. GAC is used as a tertiary treatment method in a wastewater treatment plant with an adsorption removal mechanism. In tertiary treatment, GAC will function to adsorb organic molecules that are not left out in biological treatment. The use of GAC in wastewater treatment plants is used to meet the quality standards of wastewater discharge in water bodies. GAC allowance needs to be preceded by pre-treatment, namely lime precipitation followed by rapid filtration [20], [21]. GAC is a type of activated carbon with a diameter greater than 0.1 mm and uses pressure in its operation or by gravity [22].

GAC continuous flow systems generally consist of a carbon adsorber, fresh and spent carbon storage, a carbon transport system, and carbon regeneration. The carbon adsorbent or 'filter' layer is an arrangement of iron columns or rectangular tanks with carbon pools [20]. Some of the main reactor configurations for the GAC adsorption system, namely:

1. Fixed-bed layer,
2. Expanded-bed,
3. Fluidized-bed

In operation, this layer serves to provide a filtration and adsorption process for the wastewater that is passed. In the removal of pollutants in wastewater using an expanded layer (expanded-bed) and a fluidized layer (fluidized-bed) [21]. In an expanded-bed system, wastewater will flow at the bottom of the coating, and the expanded flow will flow towards the top of the layer (upward-flow). At the same time, the moving-bed is a wastewater drainage system in the contactor where the activated carbon layer used is continuously replaced and minimizes the formation of headloss in the system. In detail, the parameter data for processing stimuli in thorn can be seen in Table 1.

In this design, two GAC reactors are designed, each with a diameter of 1.74 meters and a height of 5.73 meters. The GAC reactor was able to remove the parameters of ammonia by 64.05% [23] to 8.57 mg/L [8] and TSS by 80% [24] to 14.06 mg/L [8]. Therefore, with the addition of the GAC unit, the amount of carbon needed to treat wastewater is at least 1.384 g/L of the total wastewater to remove ammonia. Meanwhile, TSS requires at least 0.378 g/L (Table 1).

Table 1. GAC Unit Design Data in IPLT X

No	Parameters			Value
1	Carbon Usage Rate (CUR)	$\frac{m_{GAC}}{Qt}$ [25]	NH_3	1.384 g/L
			TSS	0,378 g/L
2	Filter Cross-sectional Area (A)	Planning Data		1.19 m^2
3	Filter Diameter			1.74 m
4	Filter Depth			2.92 m
5	Mass of GAC in Filter			1526 kg
6	Treated Water Volume		NH_3	1.103×10^6 L
			TSS	4.037×10^6 L
7	Bed life		NH_3	5.5 day
			TSS	20.2 day
8	Velocity (vs)	$v_s = \left(\frac{4 \times g(\rho_s - \rho) \times d}{3 \times 0,55838 \times \rho}\right)^{1/2}$ [26]		0.231 m/s
9	Reynold Nurmber (R)	$R = \frac{\Psi \text{ d } v_a}{\nu}$ [26]		1.16
10	Cd	$C_d = \frac{24}{R} + \frac{3}{\sqrt{R}} + 0,34$ [26]		23.815
11	Headloss Backwash (HL)	$h_{Le} = \frac{f_g}{A \times \rho \times g}$ [26]		0.6947 m
12	Headloss filtration (hLe)	$H_L = 1,067 \frac{C_d L v_a^2}{\Psi \text{ d } \varepsilon^4 g}$ [26]		0.171 m

Where:

1. m (gram) GAC = mass of GAC in the filtration column
2. Qt = Volume treated to breakthrough (m^3)
3. ρ = density of water, (kg/m^3)
4. ρs = density of activated carbon, (kg/m^3)
5. g = gravitational force, (m/s^2)
6. d = diameter of activated carbon, (m)
7. Ψ = roundness factor
8. va = Approach velocity, (m/s)
9. V = kinematic viscosity, (m^2/s)
10. fg = Gravity force on expanded filter, (m^2/s)
11. A = filter cross-sectional area, (m^2)
12. L = diameter or cross-sectional width of the filter reactor, (m)
13. Cd = drag coefficient
14. ε = Medium porosity

In designing an activated carbon adsorption system, several important factors need to be considered, namely the characteristics of the activated carbon, operating conditions (discharge and contact time), and operating mode (fixed-, expanded-, or fluidized-bed, pumped or gravity flow). GAC filters can be designed with upflow or downflow systems arranged in series or parallel in one or more vessels. The main parameters in characterizing the operation and measuring the GAC column are the empty bed contact time (EBCT), the hydraulic loading rate (HLR), carbon depth, and the number of contactor units [20]. HLR equals target particle settling rate by calculating the HLR as Q/Area [26], [27]. So from Table 1, the Q equal to V x A with 0.382 m^3/second, and HLR is 0.32 m/second or 19.2 m/hours. The increased recycling flow rate, which would make it easier for organic compounds to bind to GAC surfaces while the HLRs were 7.3 - 31.8 m/hours at high HLR can improved organic removal [28].

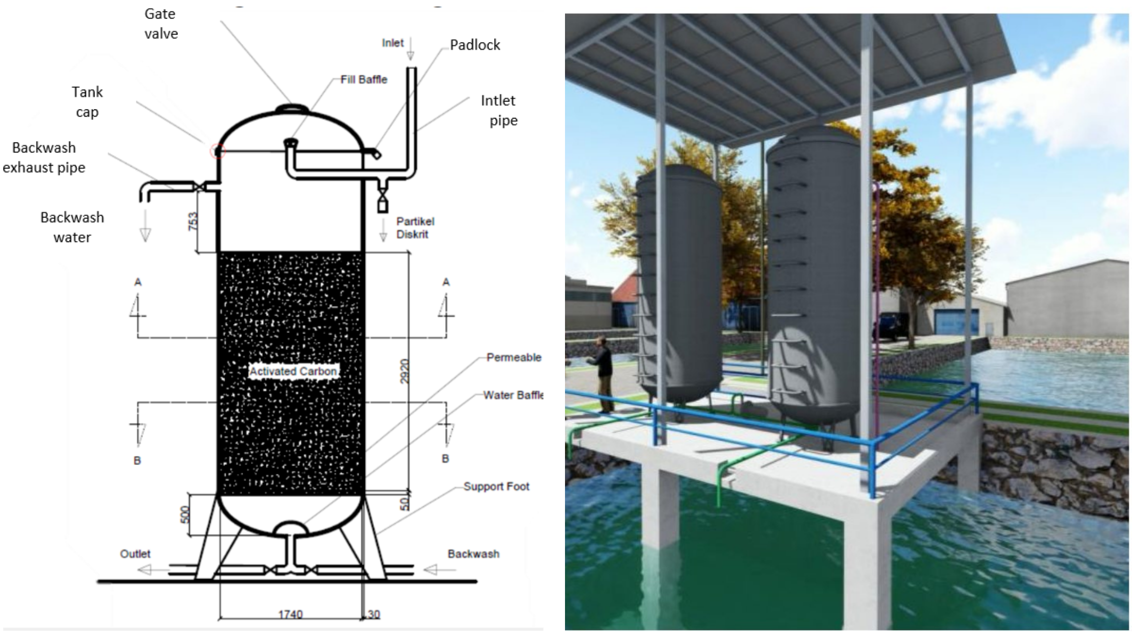

Figure 1. GAC design details in IPLT X

Maintenance is required so that the GAC unit can continue operating and functioning properly. The components of the GAC system that need to be controlled include carbon contractors (vessels), backwash systems, carbon transportation systems (pipes), unit generation, and instrument and control systems [29].

Blockages in carbon transport pipes can occur in many pipes. This can occur due to a too-small pipe, a short bend radius of the pipe, a lack of speed, and a lack of cleaning. The eroded pipe is also a common problem in pipes made of unlined mild steel and fiberglass reinforced plastic (FRP), usually in sharp bends. Solutions that can be given include using a larger pipe (recommendation for a pipe with a minimum diameter of 2 inches), using a thinner carbon, using a long radius pipe, and adequate pipe cleaning to prevent clogging problems. In addition, replacing pipes with glass, rubber-lined steel, or pipes-coated pipes can be a solution for pipe erosion.

The problem of clogging generally occurs during backwash and at the nozzle. This can occur due to the transfer of carbon and solids during the backwash process to the underdrain so that it closes the nozzle hole. The addition of a filter will reduce the potential for media transfer to the underdrain. In addition, backwashing after adding carbon can remove dirt from the media and reduce clogging. The backwash is required when one of the following three conditions occurs:

1) Headloss along the filter reaches the maximum design level or beyond the limit range of 2.4– 3 m
2) Filter turbidity reaches the highest limit
3) Some of them reach their maximum time limit usually it reaches a range of 3-4 days

The water flow in the backwash process will be entered at the bottom of the bed (layer) through the underdrain system and will continue to run continuously until the washing water is clean. The temperature rise during backwash is kept from exceeding 2% to prevent a reduction in bed expansion.

The regeneration system is one of the reasons for the loss of carbon from the system, this is due to the unit regeneration operation error. Setting the temperature and time in the regeneration unit can prevent excessive carbon loss. The provision of a carbon storage tube is required so that the system of unit regeneration continues to run. Carbon regeneration methods can be categorized into four groups based on the mechanisms and agents involved in the regeneration process: thermal, chemical, microbiological, and vacuum. Among the four categories, the chemical regeneration method is more attractive in financing because it does not require a large amount of energy. Chemically regenerated activated carbon will undergo a desorption process of adsorbate through the decomposition of the adsorbed species using chemicals such as acids to restore the adsorption capacity of activated carbon and increase the pores of the activated carbon through hot water washing. The advantage of using this regeneration method is that the processing process can be carried out quickly without friction against the carbon [30]. The chemical regeneration method will involve several components, namely water and hydrogen chloride (HCl). However, in this project we recommend a chemical regeneration process on carbon using 0.005 M HCL with a contact time of 360 minutes at 10 mL of HCL solution for every 1 gram of dry mass of activated carbon. The selection of these conditions takes into account the optimum and most effective conditions for the pro chemical regeneration test at a regeneration rate of 1 mL/minute. In the research of [30], it is stated that a chemical regeneration process on used carbon is sufficient to remove some adsorbed contaminants of concern such as heavy metals attached to the surface of the pores of the used activated carbon. so that more MB absorbs carbon and indicates that the regeneration efficiency is high. [30]. Parameter control is significant because the displayed results must be accurate.

4. CONCLUSION

In this design, two GAC reactors are designed, each with a diameter of 1.74 meters and a height of 5.73 meters. With the addition of the GAC unit, the amount of carbon needed to treat wastewater is at least 1.384 g/L of the total wastewater to remove ammonia. As for TSS, it requires at least 0.378 g/L. Therefore, with the addition of the GAC reactor, wastewater treatment at IPLT X can meet the quality standards set out in the Regulation of the Minister of Environment and Forestry Number 68 of 2016 concerning Domestic Wastewater Quality Standards.

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