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SELECTION OF AMMONIA AND TSS REMOVAL IN EFFLUENT WATER FROM DURI KOSAMBI IPLT USING ANALYTIC HIERARCHY PROCESS (AHP)

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ABSTRACT

The ammonia and total suspended solids (TSS) content in the wastewater of IPLT Duri Kosambi Jakarta City still does not meet the standard. It requires further processing that needs to be applied. The three treatments that are used as alternatives are GAC Adsorption, Zeolite Adsorption, and Built-Up Wetlands. The purpose of this study is to analyze the best alternative suitable for use as advanced processing in IPLT Duri Kosambi with analysis of decision-making analysis. Analysis decision-making is carried out using the analytical hierarchy process (AHP) using four criteria: construction costs, TSS removal efficiency, ammonia removal efficiency, and Human Resources (HR) requirements. The highest scores of the GAC Adsorption, Zeolite Adsorption, and Constructed Wetland alternatives were 0.41; 0.30l, and 0.28. So that the GAC unit is the unit selected based on the criteria set in the AHP criteria.

1. INTRODUCTION

Fecal sludge is waste material resulting from the decomposition of human feces in a septic tank. Fecal sludge, as domestic waste from human waste, has a very high concentration of pollutants. Further processing is needed not to pollute the environment (Direktorat Jenderal Cipta Karya Kementrian PUPR, 2017). One of the fecal sludge management units is located at Duri Kosambi IPLT (Instalasi Pengolahan Limbah Tinja/Faecal Sludge Treatment Plant), West Jakarta. Processing at Duri Kosambi IPLT uses two systems: a conventional system and a mechanical system. The basic concept of conventional systems is to utilize microorganisms to set aside environmental parameters, whereas mechanical systems use physical and chemical processes to separate environmental parameters. The conventional system is maintained because of the low operating costs and relatively easy maintenance. The conventional system consists of a receiving and manual filtering unit, aeration pond unit, anaerobic pond unit, facultative pond unit, maturation pond unit, and final pond unit.

The effluent resulting from wastewater treatment from fecal sludge 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 (Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia, 2016). However, the quality TSS and ammonia NH_3 of the effluent did not meet the quality standards. The effluent concentrations for TSS and Ammonia-N parameters were 54 mg/L and 41.16 mg/L, respectively (Fazhar & Febrina, 2016). This value still does not meet regulation (Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia, 2016).

Ammonia-N is corrosive and irritative, these gas can interfere with breathing such as coughing, shortness of breath, breath sounds, and others (Justiani, 2021). The high TSS can cause physical changes including the addition of solids both organic and inorganic into the water, thereby increasing turbidity which in turn will inhibit the penetration of sunlight into water bodies. Reduced penetration of sunlight and high levels of Ammonia-N will affect the photosynthesis process carried out by phytoplankton and other aquatic plants so that it will not directly affect the health of the surrounding community (Afifah et al., 2020; Fadhilah et al., 2020; Suryawan et al., 2021).

This study aims to choose the right further processing at Duri Kosambi IPLT by decision-making analysis. The method used in decision-making analysis is the AHP (Analytical Hierarchy Process) method. AHP is a decision support method developed by Saaty (1990, 2004). This decision support model will describe a complex multi-factor or multi-criteria problem into a hierarchy. AHP is used as a method for selecting alternatives to other methods for the following reason's hierarchical structure, because of the chosen criteria, reaches the deepest sub-criteria, and considering validity as the criteria.

2. METHOD

This study uses data from a literature review to support the process of selecting the best alternative in proper processing at Duri Kosambi IPLT. Three alternatives will be analyzed so that one unit is selected to treat sludge waste at the Duri Kosambi IPLT. The three alternatives are constructed wetland, zeolite adsorption, and granular activated carbon's (GAC) adsorption. Three alternatives will be selected for the best alternatives. Data analysis in this study was analyzed using the Analytical Hierarchy Process (AHP) method. AHP is a general theory of measurement used to find the ratio scale, either from discrete or continuous paired comparisons. AHP describes a complex multi-factor or multi-criteria problem into a hierarchy. Hierarchy is defined as a representation of a complex problem in a multi-level structure where the first level is the goal, followed by the level of factors, criteria, sub-criteria, and so on down to the last level of the alternative. With a hierarchy, a complex problem can be broken down into groups which are then arranged into a hierarchical form so that the problem will appear more structured and systematic.

The criteria used in the AHP analysis are construction cost, TSS removal efficiency, ammonia removal efficiency, and HR needs. AHP method users must be consistent when comparing between pairs of objects so that the best solution is produced.

Construction Costs

One of the criteria that are used as a limitation on the selection of alternatives is construction costs. Construction costs are problem faced by Duri Kosambi IPLT. The limited cost in budgeting for the construction of a new unit is a challenge to treat wastewater efficiently at an affordable cost. Duri Kosambi IPLT, a regional company managed by PD PAL Jaya to treat fecal wastewater, does not have full authority to plan the budget. The cost construction calculation is done by budget plan analysis. Weighting is done by giving the highest weight from Thomas L. Saaty[9)] for the alternative that has the highest price.

TSS Removal Efficiency

TSS removal in wastewater content is a criterion for limiting the problem because it is one of the environmental parameters that have not been fulfilled in Duri Kosambi IPLT processing. It is necessary to remove the highest TSS levels in the three selected alternatives to meet environmental quality standards. The highest weighting for the TSS Removal Efficiency is that which has an allowance efficiency that is close to 100%.

Ammonia Removal Efficiency

Ammonia is one of the environmental parameters that need to be considered. In Kosambi IPLT, the level of ammonia in the effluent is still above the quality standard, so it is necessary to evaluate these parameters and make ammonia removal efficiency the limiting criterion. The selection of alternative units needs to consider the percentage of ammonia removal. The highest score for the Ammonia Removal Efficiency is that which has an allowance efficiency that is close to 100%.

Human resources (HR)

In each planned processing alternative, it has a different level of operating difficulty. Human resources (HR) or processing unit operators must know or experience operating the unit following the functional unit operating conditions. The operator's understanding of a qualified processing unit will help support a more efficient processing process. Competent and reliable operators can solve the problems of operating units in the field later. Duri Kosambi IPLT has several operators who are quite competent and experienced in handling existing units. However, this will be different when operators are faced with the new processing technology that will be provided later. The more sophisticated the processing technology is, the more complex the components in the unit that need attention. The unit implementation manual will assist in increasing operator understanding of the new unit that will be implemented later. However, if troubleshooting occurs beyond the basic knowledge of the processing occurs, the operator will be faced with ignorance of how to handle it. The selection of the best alternative for this criterion is based on a review in which the relevant technology has been applied.

Each predetermined criterion must be known its weight. This aims to determine the level of importance of the existing criteria. The first step is to make pairwise comparisons by comparing each of the existing criteria. Suppose against a hierarchical sub-system with criteria C and a number of n alternatives under it. If A is an n x n matrix, then the nonzero vector x in Rn is called the Eigen Vector of A if Ax is the multiple of scalar λ, namely:

$$Ax = \lambda x \tag{1}$$

In order for λ to be an eigenvalue, there must be a non-zero solution to this equation. However, The equation above will have a non-zero solution if and only if:

$$\det(\lambda I - A)x = 0 \tag{2}$$

3. RESULT AND DISCUSSION

Figure 1 shows the hierarchical structure of the problem to be investigated with weighting criteria, namely construction costs, TSS removal efficiency, ammonia removal efficiency, and HR requirements. Whereas in this study, there are three alternatives of advanced wastewater treatment: GAC adsorption, zeolite adsorption, and constructed wetland.

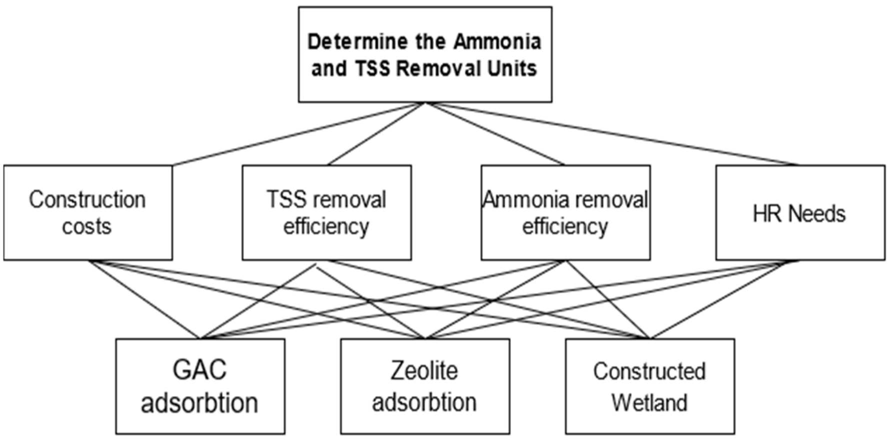

Figure 1 Hierarchical Structure AHP of Ammonia and TSS Removal Unit

After forming a hierarchy of criteria and alternatives for wastewater treatment, the weighting of the criteria is carried out in determining the selected alternative. The results of the pairwise matrix calculation between the criteria can be seen in Table 1.

Table 1. Construction costs Inter-Criteria weights, TSS removal efficiency, ammonia removal efficiency, and HR requirements

Criteria	Construction costs	TSS removal efficiency	Ammonia removal efficiency	HR Needs
Construction costs	1	5	3	7
TSS removal efficiency	0.2	1	0.2	5
Ammonia removal efficiency	0.33	5	1	7
HR Needs	0.14	0.20	0.14	1
Total	1.68	11.20	4.34	20.00

Table 2 Normalization Criteria Matrix

Criteria	Construction costs	TSS removal efficiency	Ammonia removal efficiency	HR Needs	Average
Construction costs	0.60	0.45	0.69	0.35	0.52
TSS removal efficiency	0.12	0.09	0.05	0.25	0.13
Ammonia removal efficiency	0.20	0.45	0.23	0.35	0.31
HR Needs	0.09	0.02	0.03	0.05	0.05
Total	1	1	1	1	

Table 3. Results of the Value Analysis of Each Criteria Against the Alternative

Alternative	Construction costs	TSS removal efficiency	Ammonia removal efficiency	HR Needs
GAC Adsorption	Rp 680,338,775	80% (Hatt et al., 2013)	70% (Horan et al., 1997)V	There is an ultra-filtration system similar to the RSF Activated Carbon system; easy access to media if O&M is carried out; fast clogging, so it needs backwash.
Zeolite Adsorption	Rp 1,878,813,776	84% (Suyata & Irmanto, 2016)	87% (Esmaeilzadeh et al., 2020)	There is no system similar to the zeolite.
Constructed Wetland	Rp 1,092,260,048	89.4% (Dotro et al., 2017)	71.25% (Apritama et al., 2020)	A similar system is currently in the planning stage at IPLT so that IPLT operations commonly understand it.

The determination of this weight shows that the HR requirement and TSS removal efficiency criteria are higher than the ammonia removal efficiency and construction cost. The next step is to calculate the criteria eigenvalues. Eigen criteria (equation 1 and equation 2) are calculated by normalizing the matrix and summing the average value for each row, referred to as the criteria eigenvalues. The results of the normalization of the alternative selection criteria can be seen in Table 2.

The calculation of the value for the construction cost is carried out based on the dimensions of the units required along with the bill of quantity. Zeolite adsorption construction costs tend to be more expensive with other alternatives. The highest TSS removal efficiency was constructed wetland, while ammonia removal was greater in zeolite adsorption. HR requirements for zeolite adsorption operation are more difficult because there is no further application for zeolite. The results of the calculation of each criterion for the alternative can be seen in Table 3.

Evaluation of alternatives by defining the comparison matrix between alternatives by giving weight to the criteria shown in Table 4. The matrix normalization is carried out, and the average value for each row is calculated after this, referred to as the alternative eigenvalues. The same is done for all criteria. After all the alternative eigenvalues are obtained, the matrix multiplication is carried out between the alternative eigenvalues and the criteria eigenvalues. The GAC alternative scoring is the selected wastewater unit with score 0.41 (Table 5).

Table 4. Criteria Eigen Value (Green) and Alternative Eigen Value (Blue)

Alternative	Construction costs	TSS removal efficiency	Ammonia removal efficiency	HR Needs	Criteria Eigen Value
GAC Adsorption	0.70	0.11	0.08	0.28	0.52
Zeolite Adsorption	0.07	0.26	0.75	0.07	0.13
Constructed Wetland	0.23	0.63	0.17	0.64	0.31

Based on AHP calculations, further processing is suitable for application in adsorbs with activated carbon. Activated carbon is material in amorphous carbon (not having regular lattice), mostly of free carbon and good adsorbs. Carbon adsorption is used to remove organic and inorganic compounds, which are quite difficult to overcome, such as suspended solids, organometallic compounds, chlorine, and other compounds that cannot be removed by conventional secondary processing (Hatt et al., 2013).

In general, activated carbon comes in two forms: Powdered Activated Carbon (PAC) and Granular Activated Carbon (GAC). Activated carbon can be used in wastewater treatment for TSS and NH_3 removal applications (Erabee et al., 2018; Nayl et al., 2017; Oladimeji et al., 2021). However, column GAC is the most used method because treated wastewater is absorbed through the column until the GAC is saturated with contaminant (Qasim & Zhu, 2018).

Table 5. Final Score for Each Alternative

Alternative	Score
GAC Adsorption	0.41
Zeolite Adsorption	0.30
Constructed Wetland	0.28

Activated carbon can reduce organic pollutants, including organic materials susceptible to biodegradation processes. It was found that activated carbon could remove ammonia ranging from 20.04% to 94.30% in leachate for 60 minutes of treatment time (Abdul Halim et al., 2017)..Besides, activated carbon can also remove total suspended solids (TSS) that still do not meet quality standards.

TSS that has not been removed properly can cause turbidity in the water. Granular activated carbon can remove TSS with minimum removal of 80% (Hatt et al., 2013). With the addition of an activated carbon filter in the form of Granular Activated Carbon (GAC) in IPLT, Duri Kosambi can help reduce the ammonia and TSS content so that the resulting effluent is following predetermined quality standards.

The ammonia and TSS removal unit's design to improve the quality of effluent at the Duri Kosambi IPLT is a granular activated carbon reactor. The granular activated carbon reactor will be located in the final existing pond at IPLT. Several previous theories and studies will support the choice of ammonia and TSS removal technology as a reference for unit design. 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 (Cecen & Aktas, 2012). GAC is used as a tertiary treatment method in a wastewater treatment plant with the adsorption removal mechanism. In tertiary treatment, GAC will function to adsorb organic molecules that are not excluded in biological treatment. GAC in wastewater treatment plants is used to meet the quality standards of waste disposal in water bodies. Allowance using GAC needs to be preceded by pre-treatment, namely lime precipitation followed by rapid filtration (Hatt et al., 2013).

The GAC continuous flow system generally consists of a carbon adsorber, fresh and spent carbon storage, a carbon transport system, and carbon regeneration. Carbon adsorbers or 'filter' layers are an arrangement of iron columns or rectangular tanks which consist of a collection of carbon (Hatt et al., 2013). Some of the main reactor configurations for the GAC adsorption system are fixed-bed, expanded-bed, and fluidized-bed (Dao et al., 2020; Davoodi et al., 2021; Gawande et al., 2017; Igwegbe et al., 2020; Jafari et al., 2019).

In operation, this layer provides a process for filtration and adsorption of passed wastewater, removing pollutants in wastewater using an expanded layer and a fluidized-bed layer (Hatt et al., 2013). In an expanded layer system, wastewater will be flowed at the bottom of the layer and expand to flow towards the top layer (upward flow). Meanwhile, the moving-bed layer is a wastewater drainage system at the contactor where the activated carbon layer that is used is continuously replaced and minimizes the formation of head loss in the system. In designing an activated carbon adsorption system, several important factors need to be considered, namely the characteristics of activated carbon, operating conditions (discharge and contact time), and mode of operation. GAC filters can be designed in an up-flow or down-flow system arranged in series or parallel in one or more vessels. The main parameters in the operation characterization and measurement of the GAC column are the empty-bed contact time (EBCT), the hydraulic loading rate, carbon depth, and the number of contactors units (Hatt et al., 2013).

4. CONCLUSION

The alternative selection analysis based on the AHP method uses the criteria of Construction costs, TSS removal efficiency, Ammonia removal efficiency, HR Needs weighing 1.68, 11.2, 4.34, and 20, respectively. The GAC Adsorption alternative is the chosen alternative that has the greatest weight compared to Zeolite Adsorption and Constructed Wetland. So that GAC Adsorption needs to be considered in further processing at Duri Kosambi IPLT.

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