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Evaluate the Efficiencies of Reduction Techniques on Biological Oxygen Demand and Total Suspended Solid of Domestic Waste by Comparative Performance Index Method

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ABSTRACT

Population growth and limitations of domestic wastewater treatment plant causes pollution of surface water, especially river water. Application of constructed wetlands, biofilter, wastewater garden, and activated sludge to treat domestic wastewater was conducted to know the effectiveness in reducing of Biological Oxygen Demand (BOD) and Total Suspended Solid (TSS). Comparative Performance Index (CPI) method had been used to find out the best technology that could be implemented for reduction efficiency of BOD and TSS from domestic wastewater. The results showed that constructed wetlands are the most effective technologies and applicable to the reduction of BOD and TSS, followed by wastewater garden, biofilter and activated sludge. Effectiveness of constructed wetlands performance was evaluated which indicated good mean reduction efficiency: BOD (50 – 76%) and TSS (53 – 78%).

Keywords*: *comparative performance index, constructed wetlands, wastewater, BOD

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1. Introduction

Water pollution has become a crucial issue in many countries and got the attention of researchers worldwide (Huang and Morimoto, 2002). Scarcity and difficulty getting clean water and decent life become a problem that began to appear in many places and increasingly implicated from year to year, not least in Indonesia. Indonesian territory has 6% of the world's water supply, or about 21% of water supply Asia-Pacific (KLH, 2005), but the tendency of water consumption rises exponentially while the availability of clean water is declining rapidly due to the nature of damage and contamination (KLH, 2009). Most of the water quality of rivers in Indonesia has been polluted domestic waste and industrial waste as a result of the increasing population and industrial development. Results of water quality monitoring on 33 rivers in 30 provinces in 2007 showed that more than 50% of water samples taken for parameter DO is only 29% that meets the DO value in accordance with the criteria of water quality class 1, whereas the parameters BOD is only 25%, COD28%, phenol 18%, 29% fecal coliform and total coliform 40% (KLH, 2008).

Source of water pollution is mainly caused by anthropogenic activities and triggered a quadratic by population growth (Al-Jlil, 2009). In urban areas, pollution of rivers and other water bodies is mainly due to the domestic sector and nearly 80% of the water supply used by households returned as wastewater (Sunaryo et al., 2007; Sinha et al., 2008). Domestic waste containing organic materials and hazardous chemicals, thereby increasing the biological oxygen demand (BOD) and total suspended solids (TSS). Increase the amount of domestic wastewater is not matched by an increase in the receiving water bodies both from the aspect of capacity and quality, causing the amount of waste water that goes into the water body can exceed the carrying capacity and assimilative capacity. These conditions resulted in the waters become contaminated with levels of increasingly severe.

Pollution control measures need to be done in order to harm the ecological, economic and public health can be minimized. Pollution control efforts can be done either by doing the content of BOD and TSS reduction of domestic waste which is the largest source of the pollution load of the river. Several technologies have been developed to reduce BOD and TSS from waste water both domestic waste and industrial waste, using physical processes, chemistry, biology and combinations thereof (Hidayat, et al., 2010), but there is no evaluation of which technology is most effectively developed to reduce both parameters.

The use of constructed wetlands, biofilters, activated sludge and wastewater garden is an alternative technology to reduce BOD and TSS from domestic waste, but the level of application of these technologies may differ due to differences in operating costs, efficiency, ease of management and operation, ability reduction, and other factors. Therefore, it is necessary to determine priority reduction technology of BOD and TSS using Composite Performance Index techniques for obtaning the most effective and efficient technologies based on defined criteria.

2. Materials and Methods

2.1. Method of Collecting Data

The method used in this research is quantitative descriptive analysis using primary data and secondary data. Primary data on BOD and TSS reduction technology of domestic waste obtained through expert interviews. The case studies and the literature used to obtain secondary data from relevant agencies or literature, especially the results of studies with similar cases. Alternative technologies BOD and TSS reduction of domestic waste processing technologies includes a variety of chemistry, physics, biology or a combination thereof is determined based on the source of the literature and experts. Alternative reduction technology that has been identified was the Constructed Wetlands, Biofilter, Wastewater Garden, and Activated Sludge.

Expert determination is done by purposive sampling based on criteria conformance expertise with the field being studied. Respondents expert should meet at least one of the following criteria:

a. Formal education for master's or doctoral in environmental science;
b. Have experience or competence according to the field being studied;
c. Practitioners in the field under study;
d. Have high credibility and are willing to be interviewed related to the field being studied.

2.2. Analysis Method

Determination of BOD and TSS reduction technology of domestic waste was developed to determine the choice of the most effective reduction technology. Decision-making technique used is the technique of comparative performance index (CPI). The CPI is a composite index that can be used to determine the assessment or ranking of alternatives (i) based on several criteria (j) (Marimin, 2005). Engineering equations used in the CPI are:

$$A_{ij} = X_{ij}\,(min) \times 100 / X_{ij}\,(min)$$

$$A_{(i+1.j)} = (X_{(I+1.j)})/ X_{ij}\,(min) \times 100$$

$$I_{ij} = A_{ij} \times P_j$$

$$I_i = \sum_{j=1}^{n} (I_{ij})$$

Description:

A_{ij} : value alternative to i on the criteria to j
$X_{ij\ (min)}$: value alternative to i on the minimum entry criteria to j
$A_{(i+1.j)}$: value alternative to i + 1 on the criteria to j
$X_{(i+1.j)}$: value alternative to i + 1 on the initial criteria to j
P_j : importance weight criteria to j
I_{ij} : alternative indexes to-i;
I_i : composite index alternative criteria to i
i : 1, 2, 3,…, n;
j : 1, 2, 3,…, m

The criteria used for the assessment of alternatives are: (1) The efficiency of separation; (2) Investment costs; (3) The product side; (4) Operational costs; and (5) Ease of operation. The separation efficiency was evaluated using an ordinal scale (5 = very efficient, 4 = efficient, 3 = fairly efficient, 2 = less efficient, 1 = inefficient).

Table 1. Matrix of alternative reduction technology on assessment results

Alternative	Criteria				
	(1)	(2)	(3)	(4)	(5)
Biofilter	5	5	60	4	2
Constructed Wetlands	5	3	30	2	4
Wastewater Garden	3	1	40	2	5
Activated Sludge	5	4	90	5	2
Weighting Criteria	**0.30**	**0.20**	**0.15**	**0.25**	**0.1**

Description: (1) Efficiency; (2) Investment Costs; (3) Byproducks; (4) Operating Costs, (5) Ease of Operation

The investment costs are the amount of procurement cost reduction technology until ready to operate. Evaluation of the cost of investment using an ordinal scale (5 = very high, 4 = high, 3 = moderate, 2 = low, 1 = very low). By products (kg/day) was calculated from the amount of sludge or other by-products formed as a side effect of the application of technology. Operational costs were evaluated using an ordinal scale (5 = very high, 4 = high, 3 = moderate, 2 = low, 1 = very poor), the ease of operation were also evaluated using an ordinal scale (5 = very easy, 4 = easy, 3 = fairly easy, 2 = hard, 1 = very difficult).

3. Results and Discussion

3.1. Assessment Criteria

Surface water quality degradation caused by the entry of pollutants coming from domestic waste, industrial waste, livestock waste and agricultural waste. According Ismuyanto (2010) in Suswati et al. (2013), 60-70% of the river water pollution comes from domestic waste. Therefore, domestic wastewater treatment is very important to do before the wastewater is discharged into water bodies to reduce the pollution load of surface water.

Selection of BOD and TSS reduction technology of domestic waste is intended to determine the order of priority of viable technology used in the processing of domestic wastewater in order to meet the Minister of Environment Decree No. 112 of 2003. The Decree requires levels of BOD and TSS in domestic wastewater will discharged or released into surface water is a maximum of 100 mg/L. There are four processing technology that is used to reduce levels of BOD and TSS from wastewater, i.e. biofilters, constructed wetlands, wastewater garden, and activated sludge. The fourth of these technologies have different criteria in terms of separation efficiency, the cost of construction/investment, undesirable side products, operating costs, and ease of operation. The fourth criterion reduction technology assessment is done through expert judgment and literature study. The average value of the results of expert assessment of the four alternative domestic wastewater treatment technology to reduce levels of BOD and TSS is based on the five criteria set out in Table 1. Based on alternative assessment matrix (Table 1), the transformation is then performed using the criteria of positive trends and negative trends and the results are presented in Table 2.

Table 2. Matrix of transformation of the CPI technique

Alternative Technology	Criteria (1)	(2)	(3)	(4)	(5)	Value
Biofilter	167	20	50	50	100	84.1
Constructed Wetlands	167	33.3	100	100	200	116.8
Wastewater Garden	100	100	75	100	250	111.3
Activated Sludge	167	25	33.3	40	100	80.1
Weighting Criteria	**0.30**	**0.20**	**0.15**	**0.25**	**0.10**	

Based on the analysis using a composite index above, shows that the Constructed Wetlands with alternative value occupies 116.8 to rank one as a domestic wastewater treatment technology is based on five criteria are evaluated, followed by a wastewater garden, biofilter, and the final ranking is activated sludge.

3.2. Constructed Wetlands

One alternative domestic wastewater treatment exciting to offer is utilization of artificial wetlands or contructed wetland. Constructed Wetlands are one of the waste treatment system engineering designed and built with the involvement of aquatic plants, soil or other media, and the collection of associated microbes

(Xu et al., 2006). Utilization of artificial ecosystem is based on a concept in which the natural processes that occur in nature are filtering and cleaning the water when the water is flowing through rivers, lakes, swamps and wetlands so that the water quality can be improved. This system has a base with layers or channels filled with sand or media (stone, gravel, sand, soil). Channel or bowl coated barrier is impermeable to water to prevent seepage of wastewater. Native vegetation allowed to grow at the base. Artificial wet-lands technology has been proven as an efficient technology for wastewater treatment with several advantages, namely low operational costs, maintenance and easy operation, requiring no electricity, and can function as a park (Kadlec and Wallace, 2009; Kivaisi, 2001, Mustafa, 2013). This system has been studied and used extensively in countries subtropical climates such as Australia (Greenway, 2005), Canada (Cameron et al., 2003), Czech Republic (Vymazal, 2007), the Nether-lands, United States (Kadlec et al., 2010) and in tropical countries such as Malaysia (Chong et al., 2009).

Artificial wetland systems can improve the quality of water polluted by domestic waste, agricultural waste, industrial waste (Kivaisi, 2001). The system is based on the removal or reduction of pollutants whether physical, chemical and biological. (Ran et al., 2004). Application of wastewater treatment with constructed wetland system is able to reduce BOD (50 - 76%) and TSS (53 – 78%), but is only able to reduce TDS by 14.94%. The investment costs of technology procurement constructed wetlands form the cover layer and filling are moderate, but require large tracts of land where land requirement is 120 m^2 per 50 families. Byproducts produced constructed wetlands are also relatively small in the form of mud and rubble plant about 30 kg / day for each area.

3.3. Wastewater Garden

Wastewater garden is one of the techniques utilized to reduce the burden of waste by various types of plants that have a good ability to absorb nutrients material contained in the waste. At the same time oxygen and microbes contained in the wastewater garden system to eliminate harmful bacteria that cause disease are found in the untreated wastewater. Efficiency of wastewater garden techniques actually quite moderate, but this technique is superior to the aspects of the investment cost and ease of operation. This is supported by the results of the study Nelson et al. (2006) who showed that the technique of wastewater garden is able to reduce of COD only (65-75%), BOD (87.9%), total P (76.4%), total N (79.0%), and TSS (44.4%).

The investment cost of technology procure-ment wastewater garden until ready to operate around 25 million rupiah which is much cheaper than the biofilter and activated sludge technology, each of which requires an investment cost amounts to about 500 and 400 million rupiah. Byproduct of wastewater garden generated is also relatively small in the form of mud and plant debris remains of about 40 kg / day for each area.

Biofilter

Biofiltration is a pollution control technique using living material to capture and process biological degradation of pollutants. This technology is one technology that is widely used for domestic wastewater treatment that is reliable and easy maintenance. This is according to the opinion Uhl (2000), Juhna and Melin (2006) which states that the technique of biofilter is very effective to degrade organic materials, able to reduce the presence of microorganisms that cause disease, and requires relatively low maintenance costs. Biofiter technique uses microorganisms (bacteria and fungi) to separate or breakdown contaminants of organic material so as to reduce the concentration of BOD, COD and TSS more than 90%. According to USEPA (1998) and Said (2009), among other advantages of the technique biofilter (1) filter medium that is used hold up to 20 years, (2) resistant to fluctuations in the amount of wastewater and the concentration fluctuations, (3) the operational and maintenance easy and simple , (4) energy consumption (electricity for the blower) lower, (5) resistance to flow and concentration fluctuations, (6) can be applied to a variety of wastewater treatment both domestic sewage and industrial wastes, and (7) can be designed for small-scale and large scale. Furthermore, USEPA (1998) stated that the biofilter technology is able to reduce of BOD up to 95-96%, TSS 97-98%, 97-98% of $N\text{-}NH_4$, and total nitrogen 59-65%. Based on the expert judgment, the application of biofilter technology for pollution control are considered the most efficient and operational phases are easy even for the procurement of these technologies require highest investment costs compared to the three other alternatives.

Activated sludge

Activated sludge is one of the water pollution control techniques with the principles of aerobic treatment of organic material which oxidizes into CO_2 and H_2O (Klopping et al., 1995). According Herlambang & Wahjono (1999), activated sludge is a complex ecosystem composed of bacteria, protozoa, viruses, and other organisms. The term of activated sludge used for a biological suspension or highly active microbial mass to degrade the organic materials dissolved. Degradation of organic matter by activated sludge is done by utilizing the ability of microbes to degrade complex organic materials into stable compounds and can reduce the BOD (biochemical oxygen demand) and COD (chemical oxygen demand) of approximately 70-95% of waste. The success of the activated sludge wastewater treatment within certain limits is determined by the ability of bacteria to form a flock. According Sulistyanto (2003), activated sludge is also able to metabolize and breakdown polluting substances in waste.

4. Conclusion

Domestic waste has a content of high BOD and TSS. This waste is becoming a major contributor to pollution of the river water. BOD and TSS reduction in the burden of domestic waste can be done by using constructed wetlands, a biofilter, wastewater garden, and activated sludge. Constructed wetlands are a green technology that is a top priority to reduce levels of BOD and TSS in domestic wastewater, followed by wastewater garden, biofilter, and the last priority is the activated sludge.

Wastewater treatment process with techniques constructed wetlands has several advantages such as operation and maintenance easy and inexpensive, does not require electrical energy, investment costs moderate, sludge produced relatively few, suitably used for wastewater with BOD load is high, and can reduce solids suspended (TSS) well.

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