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Design of combination biofilter and subsurface constructed wetland-multilayer filtration with vertical flow type using *Vetiveria zizanioides* (akar wangi)

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Abstract. As environmental regulation has become stricter in recent years, there is an increasing concern about the issue of wastewater treatment in urban areas. Senior High School as center of student activity has a potential source to generated domestic wastewater from toilet, bathroom and canteen. Canteen wastewater contains high-organic content that to be treated before discharged. Based on previous research the subsurface constructed wetland-multilayer filtration with vertical flow is an attractive alternative to provide efficient treatment of canteen wastewater. The effluent concentration complied with regulation according to [9]. Due to limited land, addition of preliminary treatment such as the presence of biofilter was found to improve the performance. The aim of this study was to design combination biofilter and subsurface constructed wetland-multilayer filtration with vertical flow type using *vetiveria zizanioides* (akar wangi) treating canteen wastewater. *Vetiveria zizanioides* (akar wangi) is used because from previous research, subsurface constructed wetland-multilayer filtration (SCW-MLF) with vertical flow type using *vetiveria zizanioides* (akar wangi) can be an alternative canteen wastewater treatment that is uncomplicated in technology, low cost in operational and have a beautiful landscape view, besides no odors or insects were presented during the operation.

Keywords: biofilter, constructed wetland, domestic wastewater

1. Introduction

In Jakarta, there are more than 176 Senior High School and Vocational School, but most of them do not have a wastewater treatment plant (WWTP), so wastewater generated directly discharged into receiving water bodies. Wastewater generated by the schools not only wastewater from toilets or bathrooms but also from the canteen/cafeteria. Canteen wastewater contains high-organic content that have to be treated before being discharged. Constructed wetland is planned or controlled system which has been designed and constructed using natural processes that involve vegetation, media, and microorganisms to treat wastewater [1], [2], [3]. Constructed Wetlands are widely used as advanced treatment of wastewater, in various countries to treat domestic and non-domestic wastewater, but not for canteen wastewater treatment that containing high concentrations of organic compound. Some researches in constructed wetlands conducted to process wastewater containing low concentrations of heavy metals and do not use multilayer filtration. Vertical wetlands treated domestic wastewater achieved 99% COD removal [4], [5], [6]. Therefore, this study was carried out to design combination of biofilter and subsurface constructed wetland multilayer filtration (SCW-MLF) vertical flow treated



high-organic wastewater. This treatment unit expected to be a canteen wastewater treatment alternative which is simple since it does not require complicated technology. It is cheaper in terms of cost of manufacture and operation as well as maintenance, and more natural [7], [8]. *Vetiveria zizanioides* can reduce dissolved P by 99% after three weeks and 74% N dissolved after five weeks. Due to limited land, addition of preliminary treatment such as the presence of biofilter was found to improve the performance.

2. Research Method

This study was carried out by implementing step by step data analysis of the quantity and quality of wastewater from the school canteen of Senior High School, West Jakarta, to design and determine the unit treatment. The data related to the quantity and quality of wastewater is obtained from domestic processing activities of the canteen, and are used as the basic design the unit of biofilter and vertical-flow subsurface constructed wetland multilayers filtration with Akar Wangi (*Vetiveria zizanioides*)

2.1. Data of wastewater quantity

Data related to the quantity of domestic wastewater from canteen of Senior High School, West Jakarta, are obtained from the direct measurement of the flow rates of wastewater collected in the collecting tank. This measurement is conducted during the school periods started from 7 a.m. to 4 p.m. (with 9 hours duration) for 5 days (weekdays) in order to calculate the daily waste flow rates started from Monday to Friday. The results of the measurement indicate that the wastewater flow rates are typically varied, as observed from both daily and hourly measurement of wastewater flow rates within the same day. The highest rate of daily measurement was 3,459 m³/day.

2.2. Data of wastewater quality

The data related to the wastewater quality from the canteen of Senior High School, West Jakarta, is conducted by laboratory analysis using the sample of the wastewater taken from school canteen's wastewater outlet in order to investigate the characteristics of wastewater. Table 1 below presents information related to the results of laboratory analysis of the wastewater.

Table 1. Canteen wastewater quality analysis.

No	Parameter	Unit	Range of Concentration	Dom WW Standard
1	pH	-	6.8 – 7.4	6-9
2	COD	mg/L	665.6 – 3200	100
3	BOD	mg/L	208.1 – 1,208.1	30
4	Total Nitrogen	mg/L	3.1 – 26.6	-
5	Total Fosfat	mg/L	1.8 – 51.8	-
6	Oil and Fat	mg/L	8 – 146.8	5

2.3. Effluent standard

Quality effluent standard used is the effluent standard based on regulation of Ministry of Environment and Forestry's Standard for Domestic Wastewater Nr. P.68/2016 [9].

3. Results and Discussion

The units of wastewater treatment of school canteen, consist of wastewater reservoir, an aeration tank, and a vertical flow type constructed wetland multilayers filtration unit with vetiver grass, precisely located on the west side of school. This location was selected as the area is next to the school canteen, so the researcher to place and conduct treatment phase easily.

3.1. The basic design

The design of the building dimension of the whole units is based on the selected design criteria, with the help of key and empirical formulas in the planning of a vertical flow type of subsurface constructed wetland multilayers filtration unit. The dimensions are explained as follows:

1. The construction of aeration tanks and influent pipes are calculated using design criteria.
2. The construction of the vertical flow type of subsurface constructed wetland multilayers filtration unit with vetiver grass is calculated based on design criteria with the organic loading rate Kg BOD/Ha/Day.
3. The height of media and the diameter of gravel, the mixture of soil and sand as multilayer filtration are based on design criteria.
4. The pipes of wastewater distribution are calculated based on design criteria (volume) in accordance with closed/pressurized hydraulic formulas.
5. The pipes of wastewater are calculated based on the design criteria and pump formula.

3.2. *The calculation of wastewater treatment plants*

The following presents the results of treatment unit calculation for the treatment of wastewater of the school which is conducted in sequences started from preliminary treatment that consist of the collecting tank (aeration tank), and biofilter. And wastewater flow in vertical flow type subsurface constructed wetland multilayers filtration unit.

3.2.1. *Dimensions of preliminary treatment unit*

The collecting tank is not only useful for collecting wastewater removed from the canteen and then flowed through biofilter, but also for sedimentation of the suspended solids, garbage, oil and fat. The collecting tank equipped with an aerator as oxygen supply as part of biological treatment, but the supply from the aerator is also expected as water flotation which is able to remove the oil and fat in the wastewater so they will not be emulsified.

3.2.2. *The Dimensions of vertical-flow subsurface constructed wetland multilayers filtration unit*

This unit is designed to optimally remove the parameters of pH, COD, BOD, total nitrogen, total phosphate and oil and fat contained in domestic wastewater. The following presents dimensions of the unit and its equipment.

The Calculation is based on the results of calculation of BOD surface loading 309,78 - 850,73 kgBOD / Ha / Day [10]

Given that:

$$\text{BOD surface loading} = 600 \text{ kg/Ha/Day}$$

$$\text{BOD loading (kg/day)} = 0.644 \text{ kg/day}$$

$$\text{Efficiency Removal at Biofilter } 30\%, \text{ thus BOD loading} = 0.45 \text{ kg/day}$$

Dimension of *Constructed Wetland*

$$1 \text{ Ha} = 600 \text{ kg/day}$$

$$\text{With BOD concentration at } 0.45 \text{ kg/day, so that the total wetland area (X) is } 600 \text{ kg/Ha/day} = 0.45 \text{ kg/day/X (Ha)}$$

$$\begin{aligned} X \text{ (Ha)} &= \frac{0.45 \text{ kg/day}}{600 \text{ kg/Ha/day}} \\ &= 0.000751 \text{ Ha} = 7,51 \text{ m}^2 \\ &\cong 8,1 \text{ m}^2 \text{ (10\%)} \end{aligned}$$

The total area of IPAL should be equal to or bigger than the result of calculation to meet the safety standard.

Table 2. Multifiltration layer thickness and the total depth of the reactor.

No	Layers	Filter Types	Thickness design criteria	Thickness Selected	Diameter
1.	Space of distribution pipelines and plants	-	-	35 cm	-
2.	Surface	90% soil 10% quartz sand	0 – 30 cm	20 cm	-
3.	Second layer	Compost	0 – 40 cm	30 cm	0.03 cm
4.	Third layer	Silica sand	0 – 70 cm	20 cm	0.03 cm
5.	Forth layer	Gravel	0 – 40 cm	30 cm	1 – 2 cm
6.	Collecting systems	-	-	15 cm	3 – 5 cm
Total depth of reactor				150 cm	-

Table 3. Design of unit system of domestic wastewater treatment.

No	Unit	Unit	Shape	Capacity	Dimension	Remarks
1.	Collection Piping	1	Cilinder	-	-	-
2.	Collection Tank	1	rectangular	0,6 m ³	P = 1 m L = 1 m T = 0.6 m	-
3.	Aerator	1	Oval	-	-	-
4.	Sewage pumps	1	Oval	-	-	Submersible
5.	Biofilter	1	rectangular	1,4 m ³	P = 1 m L = 1 m T = 1,4 m	-
6.	Equalization Tank	1	rectangular	2,1 m ³	P = 1,5 m L = 1 m T = 1,4 m	-
7.	Constructed Wetland	1	rectangular	3,459 m ³ /day	P = 8,1 m L = 1 m T = 1,5 m	-
8.	Distribution Piping	3	PVC	3,459 m ³ /day	½ inchi	-

The available are to build the unit in this study is very limited compared to the volume of the wastewater resulted from the canteen activities and high influent concentrations, with a total area at 11.5 m² for the treatment unit and 8.1 m² for the vertical flow type of the subsurface constructed wetland multilayers filtration unit with *vertiveria zizanioides*. Therefore, the vertical flow type is considered as an effective alternative to be implemented in the limited area since it requires shorter retention time compared to the horizontal flow type. Meanwhile, the use of filtration media consisting of 3 types with 3 layers in certain thickness standard is expected to maximize the treatment as it provides optimum retention time. Moreover, using the vertical flow type of constructed wetland multilayers filtration with vetiver grass and the subsurface flow is considered safer especially related to environmental health condition, because it will prevent the vector breeding in wastewater, considering the characteristics of wastewater in the canteen and its location which is close to the people's activities. The retention time (td) of wastewater in this unit is calculated based on the porosity of each filter obtained from the experimental results in the field, with the assumption that the wastewater is 20 cm below the surface of compost layer. The calculation of wastewater retention time in the vertical flow type constructed wetland multilayers filtration unit.

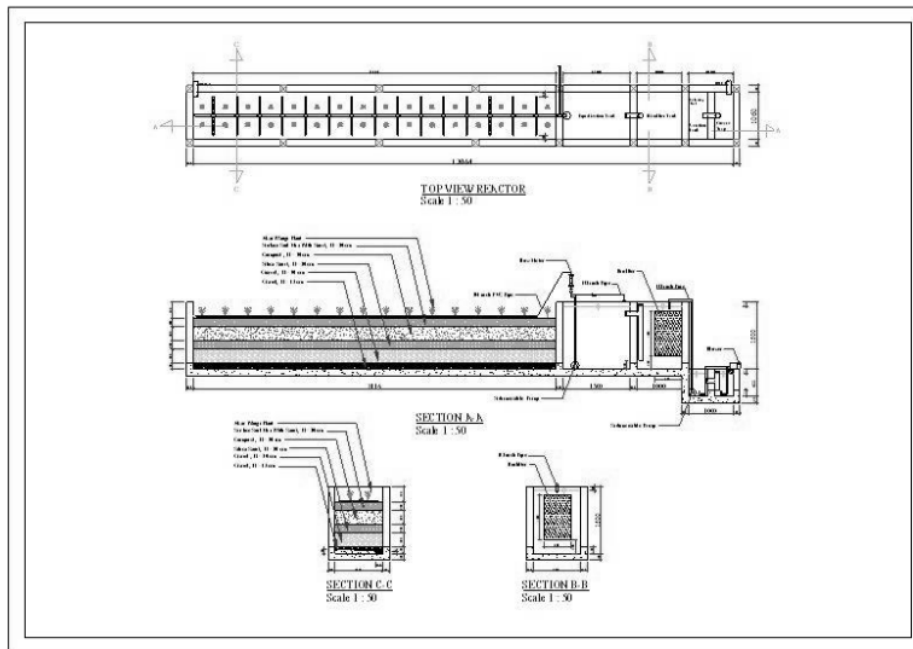


Figure 1. The design of domestic wastewater treatment from canteen of senior high school West Jakarta.

3.3. The distribution piping

The distribution pipes supply water from the pump in the aerator tank to the vertical flow type constructed wetland multilayers filtration with vetiver grass and multilayers filtration unit. The criteria of the pipe are presented as follows.

- a. Pipes with $\frac{3}{4}$ inch diameter is used as the connector of the pump to the distribution pipes with the length of the pipes is 1.5 meters.
- b. Tee with $\frac{3}{4} \times \frac{1}{2}$ inch

Pipe with $\frac{1}{2}$ inch diameter is used as a distribution pipe to the vertical flow type constructed wetland multilayers filtration unit with vetiver grass and multilayers filtration unit with size about 8 meter.

4. Conclusion

The design of domestic wastewater treatment from canteen of Senior High School West Jakarta using a combination biofilter and vertical-flow subsurface constructed wetland multilayers filtration with vetiver grass, with the collection tank and aeration tank in the prior stage of the preliminary treatment, has domestic wastewater removal rates at 3,459 L/day in area of 11.5 m².

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