Domestic Wastewater Disinfection Planning for Constructed Wetland Treatment Effluent

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Abstract

Excessive water consumption to meet water needs has changed aquatic water quality and quantity. Focus on domestic wastewater treatment via built wetlands. Disinfection protects humans against disease-causing viruses, bacteria, and protozoan parasites in wastewater. This study planned the disinfection of artificial wetland wastewater to fulfill microbiological criteria. From the examined data, each unit's design criteria and disinfection effectiveness for the created wetland outlet in the WWTP unit will be discussed. The created wetland must process 8696 cfu/100mL of fecal coliform. Despite good processing efficiency, 94% of fecal coliforms do not fulfill quality criteria. WWTP's wetland emits 8.011 mg/L of Ammonia. 90% chlorine costs Rp. 35,000/kg on the market. Total disinfection costs are rough Rp. 1,018,210.73. Water quality, lamp output power, and exposure distance affect lamp intensity. The lamp's electric power controls the beam's intensity; the more power, the more emission. The emitted power isn't equal to the lamp's electric power. According to the state electricity provider, families with a 900VA power limit will pay Rp. 1,352/kWh in July-September 2021. Nine 30-W bulbs irradiate bacteria. The lights will run for 24 hours non-stop. Hence the monthly electricity usage is 194.4 kWh or Rp 262.829.00.

Keywords: *Domestic Wastewater, Constructed Wetland, Desinfection*

I. INTRODUCTION

The need for water for domestic activities has become an everyday water use in big cities [1]–[4] in addition to water for industry. Water needs, such as in developing countries, are expected to continue to grow along with population and industrial growth [5]–[7]. Excessive use of water to meet the water supply has caused changes in the physical and chemical characteristics of aquatic water quality and quantity [8]–[10], and direct and indirect biological changes that ultimately lead to changes in water balance. Another consequence of the excessive use of water is related to the decline in the quality of the water that has been used, and this is another problem that triggers the occurrence of water scarcity [11].

The application of wastewater treatment with constructed wetlands is a reasonably dominant choice compared to other water treatment options [12], [13]. This is because treating domestic wastewater with constructed wetlands looks environmentally friendly [14]. This is an added value in its choice that minimizes negative opinions from the wastewater treatment unit. In addition, the use of plants can add to the green value of a building, so this combination of added values is actually what is needed.

The concept of domestic wastewater treatment with constructed wetlands is the main focus that can be developed further [15]. Still, it is necessary to consider further related to the biological risks in wastewater. Fecal coliform content and total coliform are other problems that must be resolved [16], [17]. Although disinfection can be a combination of treating domestic sewage with constructed wetlands [18]–[20], combining the two allows for producing effluent that can meet the quality standards set. The next stage of its implementation is designing the right design to become a wastewater treatment unit. Other influences are still very dependent on the right design. The selection of plants with high accumulator properties that can adapt well to a polluted environment will be excellent.

Disinfection is a human barrier against exposure to disease-causing pathogenic microorganisms in wastewater, including viruses, bacteria, and protozoan parasites [21], [22]. Therefore, this study was conducted to plan the effluent water's disinfection from constructed wetlands to meet the quality standards for microorganisms.

II. MATERIAL AND METHOD

Data collection is carried out to collect data needed in planning. Two sources of data are used namely primary and secondary data. The data required includes measuring the characteristics of the wastewater carried out by the sampling method, namely the Integrated sample method from the WWTP in the study area where the study area of this research is in the South Jakarta area.

From the data that has been analyzed, a discussion of each unit will be carried out related to the design criteria and the effectiveness of the disinfectant for the outlet of the constructed wetland planning in the WWTP unit [23]. The discussion was conducted to determine the suitability of the design criteria with the dimensional planning of the WWTP units.

Conclusions are obtained from the discussion results that answer the planning objectives. At the same time, the suggestions contain things that can still be done better and can be developed further.

III. RESULTS AND DISCUSSIONS

Calculating the mass balance can determine the wastewater load before and after passing through the WWTP unit. The loading is done by multiplying the discharge with the parameter concentration in the wastewater. For example, in WWTP location calculation, it is known that the incoming discharge and concentration:

1) Q in = 12.48 m^3/day
2) Fecal Coliform inlet (Ce) = 10.090 cfu/100 mL

Elimination of fecal coliform in subsurface flow artificial swamp systems can be calculated using the equation from US EPA [24] and the following:

$$Ce = Co / (1 + HRT\ Kp))^n \quad (1)$$

Where :

Ce = Concentration of fecal coliform effluent (cfu/100ml)
Co = Concentration of fecal coliform influent (cfu/100ml)
HRT = Hydraulic Retention Time (days) = 1.14 day
Kp = Fecal coliform removal rate constant = 2.6 x 1.19^{T-20}
n = Number of Wetland series = 1

The complete mass balance based on the calculation of equation 1 can be depicted in Figure 1. And the final result of the fecal coliform processing load that must be processed with the constructed wetland is 8696 cfu/100mL.

Although the processing efficiency is already excellent, around 94% of the total existing fecal coliforms have not met the quality standards of PermenLHK No. 68/2016 concerning Domestic Wastewater Quality Standards. This is because microorganisms are removed from various levels during the deposition process, the addition of chemicals, and filtration. To remain safe for human consumption, the water that has undergone several treatment stages must be disinfected first. Usually, most water treatment plants use disinfection in the form of chlorine gas or chlorine. But in this plan, the disinfection used is fine salt. Why use fine salt in its use is very environmentally friendly even though, in terms of price, it is less economical than chlorine gas or chlorine.

This is because the value of fecal coliform that enters the constructed wetland system is already too high. Generally, the average fecal coliform removal performance is 98.1% using a constructed wetland, so the amount of BOD processed in the DKI Jakarta Environmental Agency Dormitory is less than the existing average [25]. Therefore, the total coliform

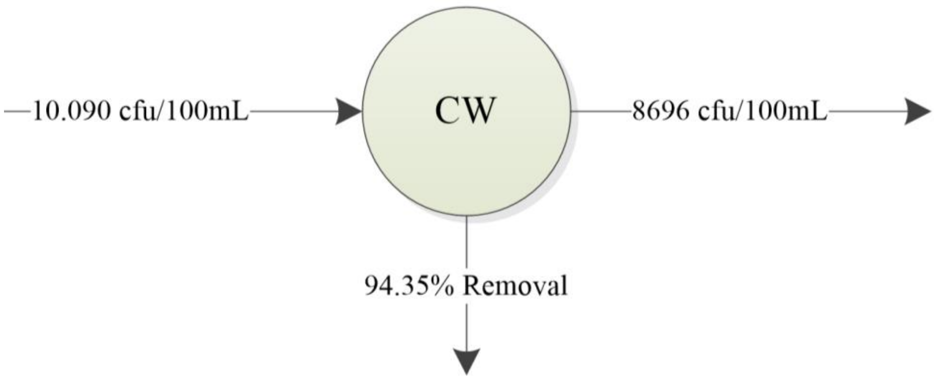

Figure 1. Mass Balance of Constructed Wetland Treatment Based on Field Survey

Table 1. Calculation of the Limiting Reagent to Determine the Chlorination Turning Point

	NH_3	HOCL	N_2	H2O	HCL
COEF	2	3	1	3	3
Mass	8.011	3.000	-	-	-
Mol	4.712×10^{-4}	5.714×10^{-5}	-	-	-
React	3.810×10^{-5}	5.714×10^{-5}	1.905×10^{-5}	5.714×10^{-5}	5.714×10^{-5}
Remainder	4.331×10^{-4}	0	1.905×10^{-5}	5.714×10^{-5}	5.714×10^{-5}

Table 2. Mole Equation of Chlorine Dissolution Reaction

	Ca(OCl)2	H2O	HOCL	CaO
COEF	1	1	2	1
Mass gr	3.444×10^{-3}	2.529×10^{-3}		
Mol	2.409×10^{-5}	2.409×10^{-5}	4.817×10^{-5}	2.409×10^{-5}

value that does not meet the applicable rules is 3000 cfu/100mL, so disinfection is needed. The standard disinfection process uses chlorine from chlorine/$Ca(ClO)_2$ or chlorination. Chlorination is given by providing chlorine solution into the wastewater to be treated. The reaction for making a chlorine solution can be seen in Eq 1 and 2.

$$Ca(ClO)_2 + H_2O \rightarrow 2HOCl + CaO \quad (2)$$

$$3HOCL + 2NH_3 \rightarrow N_2 + 3H_2O + 3HCL \quad (3)$$

However, before the Cl in the chlorine performs disinfection, the chlorine will react with NH3 to form monochloroamine until it reaches the turning point. Based on the technical guidebook for wastewater treatment from the Ministry of Health of the Republic of Indonesia (2011), the chlorination turning point value occurs when the ratio between NH_3 and Cl is between 7.5:1 and 11:1. After the Cl content has reached the turning point, the new chlorine will function to disinfect with residual chlorine.

The amount of Ammonia that comes out of the wetland at WWTP is 8.011 mg/L. Through equation 3, the moles of NH_3 are 4.712×10^{-4}. The value of HOCL needed to reach the NH_3:Cl ratio of 9.25:1 was carried out by iterating the HOCl mass as the limiting reaction. In Table 1, the administration of 3 mg/L of HOCl every second resulted in the value of the ratio of Cl to HCl and Ammonia of 7.793.

After iterations were carried out from 1 mg/L to 7 mgL, the relationship between HOCl mass administration and the NH3:Cl ratio. The mass value of HOCl given to achieve the ratio of Ammonia and Cl 9.37 is about 2.529 mg/l. The required chlorine requirement to reach the desired value can be found using the mole equation of reaction equartion 2.

Chlorine requirement = (0.5 cl mg/ls x 10^{-3} gr/mg + 3.444 x 10^{-3} Cl gr/ls) x 100% $Ca(ClO)_2$/49.65% Cl = 7.944 x 10-1 gr/ls (4)

The reaction's mass value of chlorine needed for disinfection was 7.944 x 10^{-3} gr/l/s. Therefore, the amount of Ca(ClO)2 used to reduce the number of fecal coliforms in a month is 26,183 kg/month.

Chlorine requirement (per month) = 7.944x10^{-1} gr/ls x 1 kg/10^3gr x 10^{-3}l/1 m^3 x 3600 sec/hours x 24 hours/day x 30 day/month x 12.715 m^3/day (5)

Chlorine requirement (per month) = 26.183 kg/month (6)

The price of chlorine which is generally sold in the market is Rp. 35,000/kg with 90% chlorine content. Then the total cost needed to disinfect is Rp. 1,018,210.73 or around Rp. 1,020,000. In addition to using chlorination, exposure to UV light is one way to reduce the levels of microorganisms in wastewater treatment. Ultraviolet radiation is electromagnetic radiation with an optimum disinfection wavelength of 254 nm, which can damage the ability of organisms to duplicate and cause damage to RNA and DNA [26], [27]. The ultraviolet dose is obtained by multiplying the lamp's intensity by the time, as in equation 7.

$$\text{UV Dosage} = \text{Intensity } (mW/cm^2) \times \text{time (s)} \quad (7)$$

The lamp's intensity is influenced by three main factors: water quality, lamp output power, and exposure distance. Water quality is a factor that is considered because the radiation of light waves in water differs from that in air. Radiation in water will not run smoothly because the particles in it can cause light to be reflected, diffracted, and fluorescent. UV transmission values in wastewater generally range from

50-80%, with a sufficient intensity of killing pathogens of 40 mW/cm^2 [27], [28]. The irradiation distance affects the intensity received at a certain distance. The UV intensity value of distance X based on the Department of Environmental Conservation Wastewater Management [29] is expressed in the following equation 8:

$$I = I_0 \ x \ \varepsilon^{-\alpha x} \quad (8)$$

Where:

I = Intensity at point X (mW/cm^2)
I_0 = Initial intensity (mW/cm^2)
α = Absorbance coefficient (Wastewater Transmission 60%; 0.51/cm)
x = distance (cm)

The electric power of the lamp also determines the intensity of the beam. The greater the electric power, the greater the emission value. However, the intensity of the emitted power is not the same as the electric power of the lamp. The power of the emitted UV lamp is obtained from the experimental results by measuring it with a UV meter. Based on research conducted by Lawal et al. [30] regarding the measurement of 254 nm UV lamp output, the ultraviolet value emitted by the lamp is only 36% of the lamp's power usage. So for a 30-watt lamp, the UV value emitted is 10.8 W/m2 or 1.08 mW/cm2.

The UV lamps are arranged horizontally with a geometric arrangement, the distance between the lamps is 15 cm, and the distance to the wall is 5 cm, so the channel cross-sectional area is 0.1606 m^2. The UV light intensity received at each point will not be the same, so a calculation with equation 8 is needed to determine the smallest amount of light intensity at the farthest point from the ultraviolet lamp. In Figure 2, the most distant point with the lowest intensity is the corner of the disinfection channel. The intensity at that point is obtained from lamps 1, 2, 3, 4, and 7. The other lights can be ignored because the intensity of light received at that point is very small and can be ignored.

Based on the circular of the state electricity company regarding the adjustment of electricity tariffs for July-September 2021, the cost per kWh of electricity usage by households with a power limit of 900VA is Rp. 1,352/kWh. The lamps irradiate microorganisms are nine units with a power of 30 W each. The use of lights will last 24 hours non-stop, so the total monthly electricity usage is 194.4 kWh or Rp 262.829.00.

According to Adeyemo et. al [28], UV can inactivate microorganisms up to 99% at this dose. So that with the number of microorganisms that come out of the artificial swamp system as much as 8969.72 cfu/100 ml, it will be reduced to 89.69 cfu/100 mL and meet the total coliform quality standard in PermenLHK No 68/2016. In addition, using this UV lamp will also make it easier for users because it does not require more expertise to check UV lamps. Due to the superiority of disinfection treatment with UV, which is easier and cheaper than chlorine (chlorine), this process will be applied to every location of domestic wastewater treatment in the Jakarta Environmental Agency Dormitory.

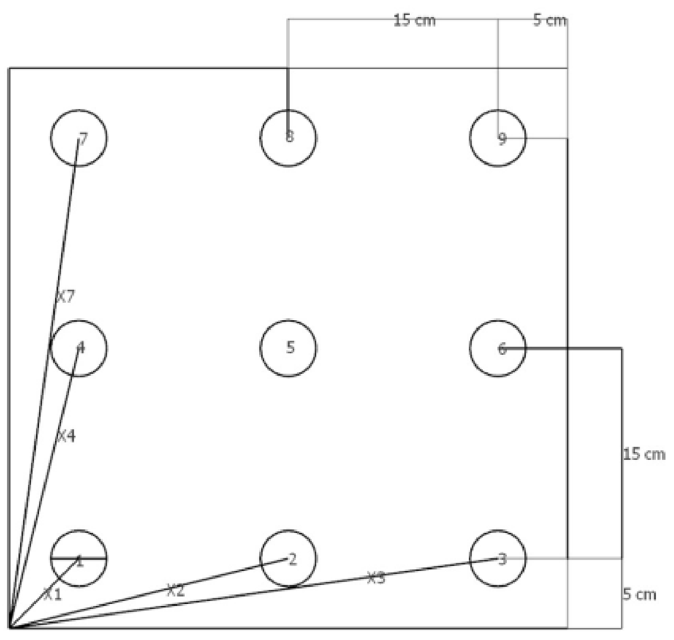

Figure 2. UV Lamp Arrangement for Disinfection

IV. Conclusions

The newly formed wetland needs to be able to eliminate 8696 cfu/100mL of fecal coliform. Despite the high efficiency with which they were processed, 94% of the fecal coliforms did not meet the quality criteria. The wetland at the WWTP releases 8.011 mg/L of Ammonia into the air. One kilogram of 90% chlorine on the market can set you back Rp. 35,000. The total expenditures for disinfection come to approximately Rp 1,018,210.73. The light intensity can be affected by water quality, lamp output power, and exposure distance. The beam's intensity is determined by the amount of electric power supplied to the lamp; the more power, the more significant emission. The power emitted from the lamp is not the same as the electric power that the lamp produces. Families with a power limit of 900 VA are expected to spend Rp. 1,352/kWh in the months of July-September 2021, as stated by the state electricity provider. Radiation from nine bulbs of 30 W is applied to the bacterium. The lights will be on continuously for a full day. As a result, the average monthly power consumption is 194.4 kWh, equating to Rp 262.829.00.

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