Domestic wastewater treatment with household-scale constructed wetland system using water fern plant (Azolla pinnata)

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Abstract. The purpose of writing this scientific paper is to analyze more deeply the management of the quality of the aquatic environment, especially regarding the treatment of domestic wastewater on a household scale. Domestic wastewater treatment with a constructed land system using Air Fern (Azolla pinnata) is expected to reduce concentration parameters such as BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), and Ammonia. The growth rate of Air Fern (Azolla pinnata) after acclimatization is quite good so that it can reduce BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand) and Ammonia, which are a source of nutrients for plant growth so that it can be used as a promising material for plant growth. It can be used as a promising material for plant growth domestic wastewater treatment.

The analysis was carried out using the blended concept, a combination of virtual, online, and laboratory/field activities (offline/outside the network) while still paying attention to health protocols. The priority of this literature study research is to provide input for the government in the form of alternative solutions for managing the quality of the aquatic environment, especially regarding domestic wastewater treatment on a household scale. In addition, this research also supports the international Sustainable Development Goals (SDGs) program: Goal 6: Access to Clean Water and Sanitation” in point 3, namely "Improving water quality by reducing pollution, eliminating waste disposal, and minimizing the disposal of chemicals and hazardous materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally”. This research can contribute to appropriate technology in environmental biotechnology, namely wastewater treatment with a system that has simple technology, low cost, energy-saving and is environmentally friendly, which can create a level of hygiene and comfort for the community and maintain environmental sustainability future.

1. Introduction

The volume of domestic wastewater increases by 5 million m³ per year, with an average content increase of 50% [1]. The increase in the volume of domestic wastewater is not matched by the escalation of the receiving waterbody, both in terms of capacity and quality, which causes the amount of wastewater entering the water body to exceed its capacity and carrying capacity.

The amount of domestic wastewater is waste resulting from domestic activities, including housing (households), buildings, trade, offices, and similar facilities. Untreated wastewater is one of the causes of water ecosystem pollution because of the pollutants contained in wastewater. The domestic quality exceeds the quality standard and is not following the Minister of Environment and Forestry Regulation of the Republic of Indonesia No. P.68/Menlhk/Setjen/Kum.1/8/2016 concerning Domestic Wastewater Quality Standards.
This increase in the amount of domestic wastewater, if not appropriately managed, will cause various diseases and environmental damage because domestic wastewater contains materials both organic and inorganic pollutants which, if in large quantities, will have an impact on the quality of surface water and groundwater [2].

After knowing the characteristics of domestic wastewater, which contain much organic matter, an alternative biological waste treatment system can be used as the leading choice. With concentrations of contaminants that are not too high, the treatment system can be implemented with simple and practical technology in its maintenance. On this basis, a wastewater treatment system (WWTP) is needed that is simple, easy to operate, and inexpensive for its manufacturing and operational costs. One alternative to the wastewater treatment system is the Constructed Wetlands System, which uses aquatic plants as phytoremediants to remove pollutants in wastewater.

Constructed wetlands are divided into the surface flow (Surface Flow) and subsurface flow (Sub Surface Flow). However, knowing that the type of surface flow (Surface Flow) can increase the mosquito population around the WWTP location, then the subsurface flow (Sub Surface Flow) is more suitable for domestic wastewater treatment systems in Indonesia.

2. Methodology

2.1. Research method

The research method used is a blended concept, a combination of virtual, online, and laboratory/field activities (offline/outside the network) while still paying attention to health protocols.

The equipment used in this research are:
1. 2 units of containers which are domestic wastewater treatment reactors (grey water) made of glass with size: pxlxt= 90 cm x 30 cm x 50 cm
2. 1 Unit of wastewater container size: volume = 30 litres
3. Sample bottle
4. Faucet Stop, Speed Control / Dimmer, Timer Outlet
5. Aquarium Pump 1 liter/second capacity, 2” pipe 2 rods

The materials used include:
1. The *Azolla pinnata* water fern is purchased online with a plant age of around two weeks in the form of seeds
2. Domestic wastewater comes from the Wastewater Treatment Plant (WWTP) Campus A Trisakti University
3. Gravel planting media size 15 cm, sand planting media size 10 cm
**Preliminary Stage:** Obtain laboratory test results regarding the quality characteristics of domestic wastewater (greywater) originating from the Wastewater Treatment Plant (WWTP) Campus A of Trisakti University and compare it with the Decree of the Minister of Environment and Forestry of the Republic of Indonesia No. P.68/Menhk/Setjen/Kum.1/8/2016 concerning Domestic Wastewater Quality Standards.

**Research Stage:** Obtaining the percentage (%) of the concentration removal parameters of BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand) and Ammonia in domestic wastewater in a Constructed Wetland System using the Air Fern (Azolla pinnata) plant.

**Analysis Stage:** Get the calculation results regarding the optimal time needed to remove BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand) and Ammonia.

2.2. **Data collection**
The quality of wastewater can be determined by testing water samples with methods following SNI 06-6989.2-2004 for COD, SNI 6989.72-2009 for BOD and SNI 6989.3-2019 for TSS, which is shown in table 1.
Table 1. Water quality parameter analysis method.

| Parameter | Unit | Method |
|-----------|------|--------|
| COD       | mg/L | Reflux |
| BOD       | mg/L | Winkler|
| Ammonia   | mg/L | Spectrofotometer |

\[
\text{COD} = \frac{(A-B) \times N \times F \times 1000}{V_{sample}}
\]

\[
\begin{align*}
\text{DO}_0 &= \frac{1000 \times A_0 \times N \times 8 \times F}{2.98} \\
\text{DO}_5 &= \frac{1000 \times A_5 \times N \times 8 \times F}{2.98}
\end{align*}
\]

2.3. Data analysis method

1. **Debit Calculation**
   Determine the flow rate using the following formula:
   \[
   Q = \frac{V}{t}
   \]
   where: \(Q\) = Flow rate (m/day); \(V\) = Volume (L/sec)

2. **Removal Efficiency**
   According to [3], the calculation of the efficiency of the removal of wastewater is as follows:
   \[
   \text{Efficiency (\%)} = \frac{C_{in} - C_{out}}{C_{in}} \times 100
   \]
   where: \(C_{in}\): Domestic wastewater parameter values before treatment;
   \(C_{out}\): Domestic wastewater parameter values after treatment.

3. **Determining Hydraulic Residence Time**
   Hydraulic residence time is done by calculating the detention time (Td) = 
   \[
   T_d = \frac{V}{Q}
   \]
   where: \(Q\) = Flow rate (m/day), \(V\) = Volume of constructed wetland (m³), \(T\) = Time required (days)

4. **Calculating The Relative Growth Rate**
   The growth rate is calculated using the formula for the relative growth rate of plants:
   \[
   \text{RGR} = \frac{W_2 - W_1}{T_2 - T_1}
   \]
   where:
   \(\text{RGR}\): Relative growth rate (grams/day); \(W_1\): Initial weight (grams); \(W_2\): Weight on day - i (gram);
   \(T_1\): Initial observation time; \(T_2\): Observation time on day - i

5. **Calculating Plant Density (ind/m²)**
   The plant density of Azolla pinnata was calculated using the formula:
   \[
   D = \frac{n}{A}
   \]
   where: \(D\) = Density (ind/m²); \(n\) = Number of individuals; \(A\) = Sampling area (m²);

6. **Mass Allowance Rate**
   Calculation of the mass removal rate using the formula:
   \[
   R = q(C_{in} - C_{out})
   \]
   where: \(R\) = mass removal rate (g/m²/sec); \(q\)=hydraulic loading rate (m/day)

3. Result and discussion

3.1. **Domestic wastewater characteristics**
   Before treatment, wastewater has the following characteristics:

   Table 2. Domestic wastewater initial characteristics.

| No | Parameter | Unit | The Quality of the Wastewater | Quality Standard |
|----|-----------|------|-------------------------------|-----------------|
| 1. | BOD       | mg/L | 67                            | 30              |
| 2. | COD       | mg/L | 185                           | 100             |
| 3. | Ammonia   | mg/L | 16.1                          | 10              |

3.2. **Laboratory wastewater analysis**
   The graph below depicts the examination of BOD parameters in wastewater from day to day.
Figure 2. The value of BOD in wastewater.
The graph below depicts the examination of COD parameters in wastewater from day to day.

Figure 3. The value of COD in wastewater.
The graph below depicts the examination of ammonia parameters in wastewater from day to day.

Figure 4. The value of ammonia in wastewater.
3.3. Removal efficiency of each parameter with plant

| No  | Parameter | Removal Efficiency |
|-----|-----------|--------------------|
| 1.  | BOD       | 32.83%             |
| 2.  | COD       | 29.72%             |
| 3.  | Ammonia   | 18.01%             |

The highest removal efficiency is found in the BOD parameter, while the lowest is found in the Ammonia parameter, as shown in table 2. The effectiveness of the allowance is calculated using day 0 as the starting point for the computation. The amount of organic matter in the constructed wetland determines whether the allowance is high or low.

During ten days of domestic wastewater treatment for parameter values of BOD, COD and Ammonia are still not complying with the Quality Standards, so it needs to be treated again with a detention time of more than ten days, but the constructed wetland is effectively used as domestic wastewater treatment on a household scale.

4. Conclusion
The constructed wetland has removal efficiency for BOD 32.83%, COD 29.72% and Ammonia 18.01%. This research can contribute to appropriate technology in environmental biotechnology, namely wastewater treatment with a system that has simple technology, low cost, energy-saving and is environmentally friendly, which can create a level of hygiene and comfort for the community and maintain environmental sustainability future.

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