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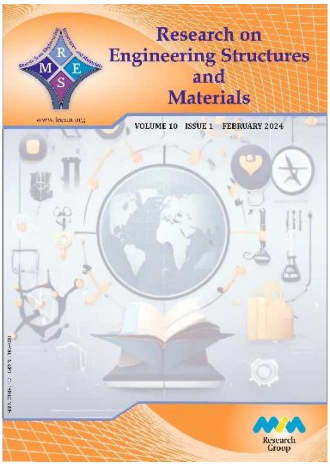

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Research Article

Domestic wastewater reduction using constructed wetlands

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Abstract

Domestic wastewater is household liquid waste that comes from sinks, bathrooms, and wastewater from washing machines. In Johan Pahlawan Sub-district, West Aceh District, the community and government's concern is still low towards achieving environmental health where the coverage of wastewater management has not been optimized. This is shown by people who do not manage wastewater properly. One of the alternative domestic wastewater management technologies is the concept of constructed wetlands with phytoremediation techniques. This study aims to determine the efficiency of reducing wastewater concentrations using phytoremediation with Eichhornia Crassipes plants, Pandanus amaryllifolius plants and Scirpus grossus plants. After the phytoremediation process with the concept of CWs-SF and CWs-SSF, it shows that the use of pandanus has not been effective in reducing contaminant levels in domestic wastewater. While Eichhornia Crassipes and Scirpus grossus plants are much better at reducing wastewater concentrations. The efficiency of reducing BOD values with a contact time of 3 to 9 days can reduce BOD levels by 80%-91%, COD and TSS can reduce the wastewater to 89%-90%, the temperature of the wastewater has been qualified with Eichhornia Crassipes and wlingen plants with 29^{0}C, and the pH of the wastewater has increased to 7.5-8.

1. Introduction

Wastewater is water that has undergone physical, chemical, or biological changes owing to the addition of specific substances. Most daily activities depend on water, so waste is discharged into the channel. Body wastes (feces and urine), hair shampoo, hair, food scraps, fat, laundry detergent, fabric softeners, toilet paper, chemicals, detergent, household cleaners, dirt, and microorganisms (germs) that can harm the environment [1-3]. Domestic wastewater is the liquid or waste produced by households and includes groundwater. Greywater originating from sinks, kitchen sinks, dishwashers, and washing machines can contain soluble contaminants, such as soap, detergents, and dirt. The type of contaminants of greywater detergents, organic and microbial, require distinct treatment processes [4-8].

Approximately 30%–50% of the wastewater dumped into sewers is greywater. It will be easier for sewage treatment plants to use less water if this greywater is recycled and managed separately. Conventional wastewater treatment techniques, such as activated sludge and biological nutrient removal technology or chemical methods, have been used to treat wastewater from other hazardous chemicals. Wastewater disposal creates an uncomfortable environment, and the germs can multiply. Wastewater can cause several problems for humans, the environment, and water. The waste liquid gradually turned

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black and smelled. This condition disrupts the surrounding environment and spreads disease. There have been many studies on greywater characteristics [9,10]

Greywater management issues harm the ecosystem, particularly in residential areas. Environmental issues that frequently arise can affect health and cause the drainage canal to smell badly. Phytoremediation techniques are alternative options for treating wastewater. The use of plants to clean waste is known as phytoremediation. Despite the potential of this method for wastewater reclamation, phytoremediation is only successful in shallow and deep locations, where plant roots may develop and employ plant remediation systems that prevent toxins from seeping into groundwater [11,12]. Phytoremediation is an eco-friendly technology based on plants (aquatic and semiaquatic) and microorganisms in water degraded from the soil, sediment, and aquatic plants [13-15]. One currently used technique that is becoming increasingly important in phytoremediation is the creation of wetlands for wastewater treatment [16,17]. The most advantageous and environmentally friendly method is using aquatic plants to reduce toxins that their roots can absorb, stems and leaves because they are readily available and more effectiveness.

The phytoremediation concept of constructed wetlands is a low-cost and efficient technique for wastewater treatment. In comparison, traditional wastewater treatment and constructed wetlands are simple, require minimal operation and maintenance, and are highly effective in removing pollutants [19-25]. Constructed wetlands are artificial systems built using the natural processes of wetland plants, soils, and microbial assemblages that live there to help treat wastewater. In a more regulated setting, there is more benefit from many activities in natural wetlands, where the CWs concept offers ecological wastewater treatment systems. Chemical, physical, and biological principles determine the cost of constructed wetland treatment processes. These include absorption, microbial biodegradation, desorption, fragmentation, and oxidation [26-27]. The effectiveness of constructed wetlands is affected by the plant species chosen, the substance of the wastewater to get treated, the pace of seedling growth, the amount of biomass produced, and the total quantity of plants in the sewage system [28-31].

The reduction of wastewater content using plant roots through the CWs concept has been performing by several researchers. CWS is highly effective when applied to manage wastewater in small-area housing. This study examined the removal of microorganisms from domestic wastewater of a single household in Kentucky using Typha Latifolia L. cattails or fescue was cultivated in the wetlands with polyculture methods (Festuca Arundinacea Schreb). The vegetated systems demonstrated removal efficiency for BOD (75%) and TSS (88%). Cattail performance can be improved when plants are cut after growth and can reduce BOD and TSS inputs. For all wastewater characteristics, polyculture systems appeared to offer the best and most reliable treatment while being least sensitive to seasonal fluctuations (12).

Several studies on greywater management using phytoremediation techniques with constructed wetlands have been performed, such as using Phragmites Karka as a horizontal subsurface flow for wastewater (sewage) treatment. Before the treatment, the wastewater was dark black and a bad smell. After managing a constructed wetland with Phragmites Karka plants, CWs became clean and odorless. After 96 hours of hydraulic residence times, the concentration of TDS, TSS, nitrate, phosphate, BOD, and COD at 60.37%, 63.19%, 94.69%, 92.95%, 61.47%, and 64.74%. The results show that root zone technology is suitable for managing wastewater and reducing the contamination load on groundwater (19).

Experiments conducted by several researchers to test the effectiveness of pandanus wetlands showed that the value of COD decreased from 70 mg/L to 39.25 mg/L, and phosphate decreased to 1.10 mg/L and 19.42 mg/L. That proves that constructed wetlands with phytoremediation using pandanus plants can reduce the level of wastewater to a safe level when released into the community environment (20).

An experiment to investigate the improvement of removal efficiency using Lotus (Nelumbo nucifera) and Hydrilla Verticillata co-planted with one control unit. The results showed that the system with Lotus plants showed the best removal efficiency for Hydrilla wastewater management. However, this study emphasizes that Lotus and Hydrilla can provide alternative aquatic plant systems for wastewater treatment (21).

In Kuta Padang Village, West Aceh District, the community and government continue to show little care for environmental health, which harms the availability of wastewater management services. Based on EHRA (Environmental Health Risk Assessment) in 2015, 50.46% of the pollution was caused by improper sewerage, where home wastewater was released directly into canals without any treatment. The environment and community health will be affected if this situation persists (Sanitation Working Group, 2015). The current condition identified many households in the Johan Pahlawan Sub-district directly discharging wastewater into the drainage channel, which will increase pollution of water quality and the environment. Based on these conditions, this study aims to determine the efficiency of reducing wastewater content in the form of BOD, COD, TSS, pH, and temperature, using the phytoremediation of *Eichhornia Crassipes, Scirpus Grossus plants*, and *Pandanus Amaryllifolius*. The concept used is the Constructed Wetlands with Surface Flow and sub-surface flow systems. An environmentally sustainable waste management effort of using phytoremediators as green plants can transform pollutants into harmless substances.

2. Materials and Methods

2.1. Research Area and Wastewater Sampling

This research area was in the Kuta Padang Village in Johan Pahlawan District, West Aceh Regency, Aceh Province, Indonesia. Kuta Padang area have around 1.02 km^2. This area is downtown, where field conditions indicate that domestic wastewater is discharged directly into the city's drainage canals. This condition will have an impact on environmental health. This research uses quantitative and experimental description research methods. BOD, COD, TSS, pH, and temperature parameters testing at the Laboratory of the Industrial Research and Standardization Center of Banda Aceh City. The research time starts from February to March 2023. Wastewater collection was carried out for 3 (three) days, namely in the morning at 09.00 WIB and in the afternoon at 17.00 when the activities of using water were at their peak.

Fig. 1. Research area

2.2. Eichhornia Crassipes, Scirpus Grossus Plants, and Pandanus Amaryllifolius

Eichhornia Crassipes is a plant that floats in water and has roots with a height of about 0.4-0.8 meters, no stems, leaves are oval, and the tip is pointing at the base, the base of the stalk is swollen and has fibrous roots. This plant conveniently spreads through water bodies, so it is often referred to as a weed because it has a fast-growing speed. Eichhornia crassipes plants hold great promise for pollutant removal due to their fast growth rate and extensive root system. In addition, this plant can be cultivated and planted for wastewater treatment and water purification (22).

Scirpus Grossus has fibrous roots with white to brown color, triangular stems, and leaves 2 m or more long with a thickness of 10 mm. This plant is an aquatic plant with the common name Wlingen (Indonesia) and can be used to treat domestic wastewater with phytoremediation and wetland systems. Scirpus Grossus can absorb metals with the highest concentrations in the root, stem, and leaf zones (23).

Pandanus (Indonesian) or Pandanus Amaryllifolius i s a plant with fragrant leaves with a height of 1.2 m - 1.5 m, a leaf length of 80 cm, and a width of 60 cm - 90 cm. The leaves are palm frond-shaped, sharp, unserrated. The roots are large and can support the plants when they are tall. Pandanus is one of the plants that can manage domestic wastewater. Some of the research results proved effective in assimilating pollutants contained in domestic greywater. These plants are beginning their use as a medium in natural wastewater management processes (20).

Fig. 2. Eichhornia Crassipes, Scirpus Grossus Plants, and Pandanus Amaryllifolius

2.3. The Variables of This Study

Figure 3 shows the variables in this study, namely the independent variable and the dependent variable. Independent variables consist of Eichhornia crassipes, Scirpus grossus, Pandanus amaryllifolius, and domestic wastewater. The dependent variable consists of BOD, COD, TSS values, Temperature, and pH before and after phytoremediation with the CWs concept.

2.4. Materials and Instruments

Materials and instrument in this study are used:

- Eichhornia Crassipes, Scirpus Grossus plants and Pandanus Amaryllifolius (Fig. 2)
- Acclimatization and the number of plant clumps (Fig. 4)
- Gravel, sand and soil media (Fig. 4)
- tap water, bucket, PVC pipe and etc. (Fig. 4)

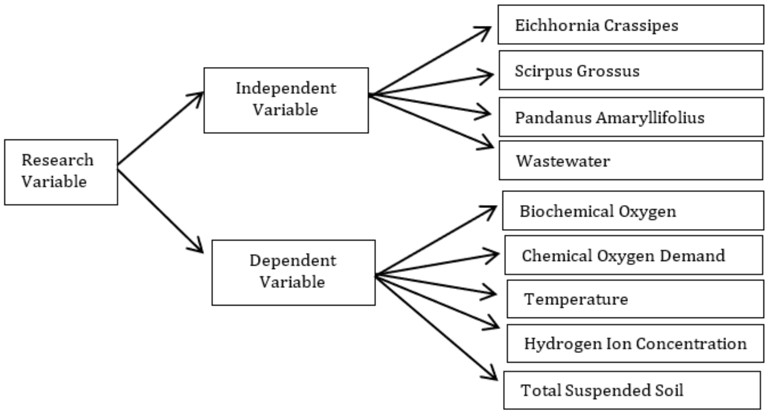

Fig. 3. Research variable of this study

2.5. Reductions Efficiency Pollutant

Reduction efficiency (E, in %) pollutant concentration according to the International Water Association (IWA) proposes an equation to calculate the percentage of pollutant removal using the formula: (24)

$$E = \frac{C_0 - C_1}{C_0} x100\% \tag{1}$$

where: C_0 and C_1 are the average concentrations of influent and effluent.

2.6. Research Procedure

The following is the implementation of the research that consists of several stages:

Step 1: Sampling of wastewater at the research location at Kuta Padang Village. Furthermore, examination of wastewater samples before testing the Constructed Wetlands (CWs) with phytoremediation. The wastewater sample examination includes BOD, COD, TSS, pH, and temperature parameters.

Step 2: Preparation of Constructed Wetlands (CWs) media. Setting up CWs-SF and CWs-SSF, then Prepare filter media using gravel, coral sand, soil, and activated carbon. Gravel and sand sizes have a diameter of 15 mm and 0.25 mm. CWs media each for 3 (three) plants used (Fig. 4).

Step 3: Preparation of aquatic plants and acclimation with 5 clumps/stem each. These plants are allowed to adapt to the media for 7 days.

Step 4: Observation of wastewater samples with a contact time of 1 day and 3 days.

Step 5: Testing wastewater after the phytoremediation process by examining the BOD, COD, temperature, and water pH parameters.

Step 6: Analysis of the efficiency and effectiveness of reducing wastewater content before and after the phytoremediation process.

Fig. 4. Materials, procedures and observations

3. Results

Plant roots have an optimal role in reducing contaminants from domestic wastewater. The physical condition of three plants from the first day to the ninth day of observation was still in good condition.

3.1. Before Phytoremediation with CWs

Wastewater testing at the Baristand laboratory (Industrial Research and Standardization Center) resulted in the parameters tested being BOD, COD, pH, TSS, and Temperature. The Biological Oxygen Demand (BOD) is the amount of oxygen in organisms required to stabilize organic matter into CO_2 and H_2O in the waste. Chemical Oxygen Demand (COD) is the amount of oxygen in mg required to oxidize organic and inorganic materials/substances in one liter of wastewater. COD values are usually higher when compared to BOD values as stable materials in the BOD test can oxidize in the COD test.

Table 1. Wastewater content results before phytoremediation

Parameter	Waste water quality standard requirements	results before phytoremediation			description
		Sample 1	Sample 2	Sample 3	
BOD	30 mg/L	116,36	142,4	151,76	Unqualified
COD	100 mg/L	489,37	500,15	502,96	Unqualified
TSS	30 mg/L	242	246	248	Unqualified
Temperature	27 - 29	30	31	31	Unqualified
pH	6 - 9	7,4	5,8	5,55	Unqualified

Total Suspended Solid (TSS) is the number of suspended solids (mg) in one liter of water. Suspended solids consist of particles that are smaller in weight and size than sediment, insoluble in water, and cannot settle immediately. Suspended solids cause water turbidity, such as fine clay, various types of organic matter, and cells of microorganisms. pH is a measurement of acidity as a parameter of water quality because it can control the chemical reactions that occur and determine the activity of microorganisms in the decomposition of domestic household wastewater. Wastewater Content Results Before Phytoremediation were given in Table 1. Table 1. shows that the wastewater levels of the 3 (three) samples tested for the parameters BOD, COD, TSS, pH, and temperature before phytoremediation have exceeded the wastewater quality standard threshold set by the Minister of Environment Regulation No. 68 of 2016.

3.2. Wastewater Quality Test Results After Phytoremediation with CWs

Based on Table 1, which shows that wastewater at the research site does not meet the requirements of wastewater quality standards, the next step is to test wastewater with the concept of Constructed Wetlands (CWS) with phytoremediation. Constructed wetlands with the surface flow (CWS-SF) are used for Eichhornia Crassipes and with the subsurface flow (CWs-SSF) for Pandanus Amaryllifolius and Scirpus Grossus plants. Before observation, a plant is acclimatization processed for at least 7 (seven) days. The plants used were 5 (five) clumps/stems of uniform size. During the acclimatization process, the three plants were able to live well. The results of wastewater content after the phytoremediation with the concept of CWs will be compared between the initial domestic wastewater concentration and after phytoremediation in each parameter. Table 2, Table 3, and Table 4 below show the test results of wastewater content after phytoremediation with observation times using Eichhornia Crassipes plants, Pandanus, and Wlingen plants.

Table 2. Wastewater content results after phytoremediation with 1-day observation

Parameter	standard	Results after phytoremediation with 1- day observation					
		Eichhornia Crassipes	Reduction (%)	Pandanus Amaryllifolius	Reduction (%)	Scirpus Grossus	Reduction (%)
BOD	30	58.04	57.59	112.3	17.93	42.8	68.7
COD	100	77.21	84.48	252.11	49.32	75.11	84.9
TSS	30	40.97	83.30	102.26	58.32	38.32	84.4
Tempera-ture	27 - 29	29		31		30	
pH	6 - 9	7.33		7.5		7.43	

Table 2. with a contact time of 1 day, shows that Eichhornia Crassipes and Wlingen were better at reducing pollutants from wastewater than the pandanus plant. Phytoremediation using pandanus plants can reduce wastewater content for values BOD, COD, and TSS. Although it can reduce pollutants, the results have not yet complied with wastewater quality requirements. Eichhornia Crassipes and Scirpus Grossus plants can reduce BOD values by 50% - 70%, although the decrease in BOD values with a contact time of 1 day has not been able to meet the requirements of wastewater quality standards. The COD and TSS reduction using Eichhornia Crassipes and Scirpus Grossus plants can reduce contaminants by 80%-85%, and the pH of wastewater has increased above 7. Based on the test, the more effective wastewater management of the CWs concept with phytoremediation techniques is using Wlingen plants.

Figure 3 shows the trend of decreasing wastewater parameters, that the contact time of wastewater with plant roots for one day, showing the parameters have reduced from the results of wastewater testing before phytoremediation. Eichhornia Crassipes and Scirpuss Grossus plants can reduce COD parameters below the maximum limit of 100 mg/L and have complied with the requirements of wastewater quality standards by the Minister of Environment Regulation No. 68 of 2016.

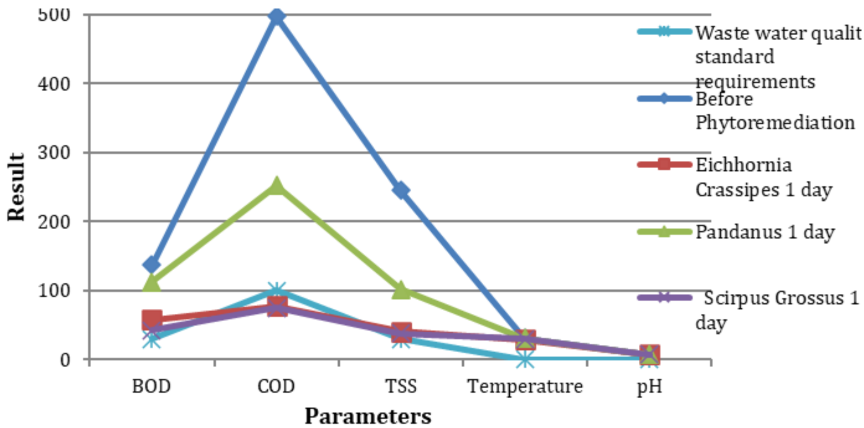

Fig. 5. The trend of wastewater parameter reduction with 1-day contact time

Table 3. Wastewater content results after phytoremediation with 3-day observation

Parameter	standard	Results after phytoremediation with 3- day observation					
		Eichhornia Crassipes	Reduction (%)	Pandanus Amaryllifolius	Reduction (%)	Scirpus Grossus	Reduction (%)
BOD	30	22.25	83.74	106	22.54	26.01	81.0
COD	100	52	89.55	218.05	56.17	53	89.3
TSS	30	28.66	88.32	94.34	61.55	25.09	89.8
Tempera-ture	27 - 29	29		31		29	
pH	6 - 9	8		7.72		7.59	

Table 3. with a contact time of 3 days, shows that Eichhornia Crassipes and Scirpus Grossus (Wlingen) plants are much better at reducing pollutants from wastewater than Pandanus plants. Phytoremediation using pandanus plants can reduce wastewater content for BOD, COD, and TSS values. Although it can reduce pollutants, the results have not yet complied with wastewater quality requirements. With a contact time of 3 days, Eichhornia Crassipes and Wlingen plants can reduce BOD levels by 81%-84%, and the reduced BOD levels have qualified the wastewater quality requirements. The reduction in COD and TSS levels can reduce contaminants to 89%. The temperature is qualified, and the pH of wastewater has increased to 7.5-8. Based on the test, the more effective wastewater management of the CWs concept with phytoremediation techniques is using Eichhornia Crassipes and Wlingen plants.

Figure 4 shows the trend of decreasing wastewater parameters, that the contact time of 3 days with plant roots, showing the parameters can reduce wastewater testing before phytoremediation. Eichhornia Crassipes and Scirpuss Grossus plants can reduce BOD, COD, TSS, pH, and temperature parameters according to wastewater quality standard requirements by the Minister of Environment Regulation No. 68 of 2016.

Table 4 with a contact time of 9 days, shows that Eichhornia Crassipes and Wlingen plants can reduce pollutants from wastewater much better than pandanus plants. Phytoremediation using pandanus plants can reduce wastewater content for BOD, COD, and TSS. Although it can reduce pollutants, the results have not yet complied with wastewater quality requirements. With a contact time of 9 days, Eichhornia Crassipes and Wlingen plants can reduce BOD levels by 80%-91% and have qualified the wastewater quality requirements. The reduction of COD and TSS levels by 89%-90%, the temperature is qualified, and the pH of the wastewater has increased to 7.5-8.

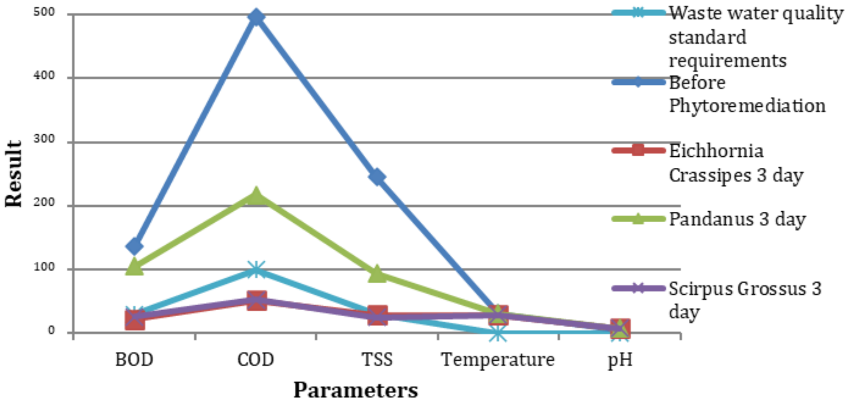

Fig. 6. The trend of wastewater parameter reduction with 3-day contact time

Table 4. Wastewater content results after phytoremediation with 9-day observation

Parameter	standard	Results after phytoremediation with 9- day observation					
		Eichhornia Crassipes	Reduction (%)	Pandanus Amaryllifolius	Reduction (%)	Scirpus Grossus	Reduction (%)
BOD	30	11.65	91.49	101.89	25.54	3.39	97.5
COD	100	49.28	90.09	203.9	59.01	35.68	92.8
TSS	30	26.5	89.20	87	64.54	17.8	92.7
Tempera-ture	27 - 29	29		30		29	
pH	6 - 9	8.08		7.94		7.64	

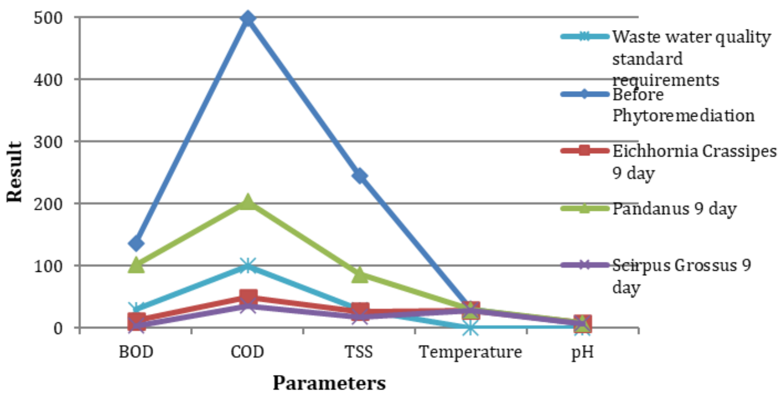

Fig. 7. The trend of wastewater parameter reduction with 9-day contact time

Figure 7 shows the trend of decreasing wastewater parameters with plant roots of 9 days. All parameters can reduce wastewater testing before phytoremediation. Values of BOD, COD, TSS, pH, and temperature parameters are below the maximum limit of 30 mg/L. Wastewater management with the CWs concept using Eichhornia Crassipes and Wlingen plants can reduce wastewater levels, increasing the pH and temperature parameters according to wastewater quality standard requirements by the Minister of Environment Regulation No. 68 of 2016

4. Discussion

The results show that Eichhornia Crassipes and Scirpuss Grossus plants can reduce contaminants in graywater. The decrease in BOD value is due to the nature of the two plants being able to do several things, such as adsorb various organic materials in the form of ions from microorganism decomposition and remove oxygen required by microorganisms for the oxidation process of degrading microorganisms. The more contact time with wastewater, the greater the organic matter in the form of ions can absorbed and affect the decrease in BOD. The more contact time with wastewater, the greater the organic matter in the form of ions can absorbed and affect the decrease in BOD. The results of previous research by (25) using Scirpuss Grossus plants with a contact time of 10 days using 300 grams of Scirpuss Grossus plants TSS before treatment amounted to 57 mg/L to 9.67 mg/L with a percentage decrease of 83.04%, pH before treatment 8.08 to 7.02 with a percentage decrease of 13.12%, BOD before treatment 73.83 mg/L to 30.84 mg/L with a percentage decrease of 58.23%, nitrite before treatment 0.2982 to 0.1541 with a percentage decrease of 48.32%. The results of this study are much more effective and efficient than the research (25), where the results of this study using 300 grams of clumps or 5 Scirpuss Grossus stems with a contact time of 9 days reduced BOD levels to 97.5%, reduced COD parameters 92.8%, TSS dropped by 92.7, lowered pH to 29^0C and increased pH 7.64.

Eichhornia Crassipes plants can reduce contaminants in greywater. The decrease in plants with a contact time of 1 day using 250 grams of water hyacinth plants decreased BOD by 166.40 mg/L to 86.4 mg/L, COD by 264.4 mg/L to 98.13 mg/L, pH by 8.7 to 7.48, and TSS by 346.4 mg/L to 112.4 mg/L (26). The results of this study are much more effective and efficient than the research (26), where the results of this study using 250 grams of clumps or 5 (five) clumps and contact time of 9 days effectiveness reduced BOD levels by 91.49%, COD by 90.02%, TSS by 89.20%, reduced pH to 290C and increased pH by 8.08.

The decrease in COD value is due to microorganisms found in the roots of Eichhornia Crassipes, where this phytoremediation process has an optimal role in the absorbent of organic pollutants. The plant can absorb contaminants through its roots. Microorganisms that grow at the roots of Eichhornia Crassipes plants can effectively reduce COD values because the total microorganisms increase, and microorganisms can adapt to the environment (27). The increase in the pH value of wastewater is due to the photosynthesis process that can utilize the CO_2 concentration in wastewater. Changes in pH value are due to photosynthesis and respiration activities of aquatic plants. Photosynthesis requires carbon dioxide (CO_2), which the autotroph component transforms into monosaccharides. A decrease in CO_2 can increase the pH of the wastewater (28).

Eichhornia Crassipes plants will capture suspended solids in wastewater through the roots system. In the phytoremediation test with a contact time of 9 days, the colors of the leaf edge turned yellow, and the roots of the Eichhornia Crassipes plant seemed to be slimy due to contaminants that have not been absorbed and adhered in the Eichhornia Crassipes roots. This research is in line with another study that the part of the plant that first dies is the leaves. Due to the metabolism of leaf dying, the color of the leaf edges becomes yellowing and withering, and then the leaves dry out. Eichhornia Crassipes then began to grow on the stem of the leaves, and the roots of the plants died off. Roots look slimy on the 10th day due to contaminants or nutrients that have not been absorbed and have not attached to the roots of Eichhornia crassipes. All plants rotted and died on the 14th day. (25)

5. Conclusions

The CWS concept using phytoremediation of Eichhornia Crassipes and Wlingen plants with an observation time of 3-9 days can reduce wastewater quality. There was a decrease in BOD, COD, TSS, and temperature parameters, as well as an increase in pH value and met the requirements of wastewater requirements according to Article 1 Paragraph 2 of the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number 68 of 2016 concerning Domestic Wastewater Quality Standards. With a contact time of 9 days, shows that Eichhornia Crassipes and Scirpuss Grossuss plants can reduce pollutants from wastewater much better than pandanus plants. Phytoremediation using pandanus plants can reduce wastewater content for BOD, COD, and TSS. Although it can reduce pollutants, the results have not yet complied with wastewater quality requirements. Eichhornia Crassipes can reduce BOD levels 91.49%, COD levels 90.09%, TSS levels 89.20%, the temperature is qualified, and the pH of the wastewater has increased to 8.08. Scirpuss Grossuss plants can reduce pollutants for BOD levels 97.5%, COD and TSS levels by 92.8%, the temperature is qualified, and the pH of the wastewater has increased to 7.64. The wastewater content value of the research results using domestic wastewater before and after phytoremediation is much more effective in decreasing compared to previous studies. The efficiency of this pollutant value reduction depends on the difference or number of clumps and the contact time of wastewater with plant roots. With a contact time of 9 days, Eichhornia Crassipes and Scirpuss Grossuss plants can reduce BOD levels by 80%-91% and have qualified the wastewater quality requirements. The reduction of COD and TSS levels by 89%-90%, the temperature is qualified, and the pH of the wastewater has increased to 7.5-8.

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