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Research Article

The effectiveness of constructed wetland method in greywater treatment using Purun danau (*Lepironia articulata*) plant

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Abstract. The use of clean water around the world continues to increase along with the increase in population and is increasing when the whole world is hit by the COVID-19 pandemic. Therefore, research is carried out to treat greywater waste effectively in a simple and inexpensive way. The method used in this study is a single method, namely filtration (a mixture of soil and sand, activated char- coal and gravel), *Lepironia articulata* and a combination of the two methods, namely constructed wetland subsurface vertical flow. The results of this study showed a decrease in BOD and COD levels reaching 97%, 88% phosphate, 18% pH and 95% MBAS in the constructed wetland. This is due to the synergistic interaction between plants, media and microorganisms in removing pollutants effectively. This research needs to be developed further and explore the capabilities of each constructed wetland element, especially the *Lepironia articulata*.

Keywords: Constructed wetland, *Lepironia articulata*, Greywater

1. Introduction

The inadequate domestic waste management take important contribution in the decrease of clean water supply in Indonesia. This is proven by pollution in the river which is dominated by household domestic waste (Sugiester *et al*., 2021). This pollution is increasing when the whole world is facing COVID-19 pandemic. The increase in population and the occurrence of the COVID-19 pandemic have contributed greatly to the increase in the amount of domestic wastewater in Indonesia. The poor management of household domestic wastewater in Indonesia results in the waste entering the environment without undergoing treatment, causing pollution that causes various health problems.

The liquid waste produce originating from household activities except urine and feces is called greywater. The source of greywater comes from household activities such as washing clothes or dishes, bathroom activities (Ridderstolpe, 2008) or from the sink in the toilet (Risks, Considerations and Capacity, 2014). The characteristics of greywater generally consist of nitrogen, phosphorus, potassium, heavy metals and pathogenic microorganisms which come from the use of detergents, fats and other ingredients (Maliga, Asdak and Winata, 2021).

There are several types of domestic wastewater treatment including the filtration method (Mashadi et al., 2018), rotating biological contactors (RBC) which utilize microorganisms with biofilms as growth media (Suherman et al., 2020), sequencing batch reactor (SBR) which is the development of activated sludge using aerobically suspended microorganisms (Alfiah and Sinatria, 2013), a membrane bioreactor (MBR) that combines an activated sludge process with a filtration membrane (Aditia, 2020), reuse as fertilizer and upflow anaerobic sludge blanket (UASB) which treating greywater with the help of aerobic bacteria to form suspended flocs under the reactor (Rochim, Fariha and Abadi, 2017).

Constructed wetlands by utilizing *Lepironia articulata* plants are a method for treating simple greywater waste at a lower cost and easier (UN-HABITAT, 2008). Constructed wetland is a combination of filtration and phytoremediation methods. Where the filtration media and the plants used work synergistically to treat greywater waste. Constructed wetlands by utilizing *Lepironia articulata* plants are able to absorb heavy metals such as As, Cd, Cr, Fe, Mn, and Pb (H.A.M, Idris and Abdullah, 2016). The use of *Lepironia articulata* plants in constructed wetlands is because these plants are capable of being Pb hyperbioaccumulators in the environment (Sidek, 2015).

In research of Alateeqi et al., 2023, show that constructed wetlands is able to use Ageratum conyzoides plants with soil and gravel media arranged diagonally to reduce blockages. In this study (Yasmin H.A.M et al., 2016) using constructed wetlands utilizing *Lepironia articulata* and *Scripus grossus* as a method of processing water into drinking water. In addition, in research (Mohamed et al., 2015) the use of *Lepironia articulata* in constructed wetlands for processing greywater wastewater is inconsistent. Greywater gets pre-treatment using sand and gravel arranged vertically. In this study (Wurochekke et al., 2014) using constructed wetlands and growing media in two different reactors. Greywater gets pre- treated using gravel, activated charcoal and sand. Research from Malaysia (Al-Ajalin et al., 2020) used constructed wetlands utilizing *Lepironia articulata* and *Scripus grossus* with different planting medium depths. Before processing the greywater effluent in the constructed wetland, pre-treatment is carried out, namely on gravel media and sand media in different reactors. This study aims to carry out greywater treatment using the constructed wetland method utilizing *Lepironia articulata* which are expected to be able to reduce BOD, COD, phosphate and surfactants concentrations.

2.Methods

2.1. Reactor Preparation

The reactor used was made of glass with a volume of 50 cm x 50 cm x 30 cm with a thickness of 5 mm as much as 2 pieces. The study was conducted for 10 days and was carried out alternately. In the constructed wetland treatment reactor and *Lepironia articulata* treatment reactor without media, *Lepironia articulata* will be used with the assumed root density and number of stem blades being the same. The *Lepironia articulata* used comes from Central Kalimantan and has been acclimatized to a neutral pH for eight months, since May 2022.

The type of constructed wetland used is free water surface. The choice of this type is because the *Lepironia articulata* plant is an emergent plant or a plant that sticks out from the water. The planting medium used in the constructed wetland is a filter media consisting of a mixture of soil and sand up to a height of 10 cm, 8 cm of activated charcoal and 2-3 cm of gravel. The greywater waste storage tanks used have a capacity of up to 21 liters with branched pipes to channel the waste to each reactor. The reservoir is placed on a reservoir support with a height of about 60 cm.

2.2. Sample preparation

Sampling processes conducted at one of the houses in the housing area of Semarang City. Sampling was carried out at night because the population of the location is dominated by workers, so the activities that produce the most greywater waste are at night after work. Greywater waste taken about 90 liters. The waste that has been taken is poured into the reactor storage tank as much as 21 liters and given an aerator. The rest of the sample is stored in the refrigerator for backup. Greywater waste will undergo treatment for five days. Where the sample will be taken on day 1, day 3 and day 5 from each treatment reactor. Greywater waste samples that have been treated will be put into the cooling machine

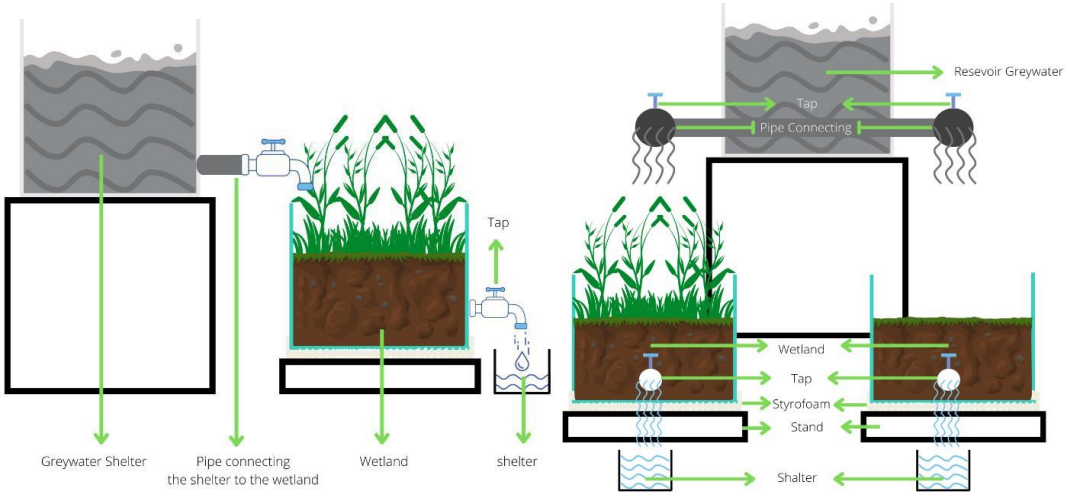

Figure 1. Constructed Wetland Reactor (a) Front and (b) Side View

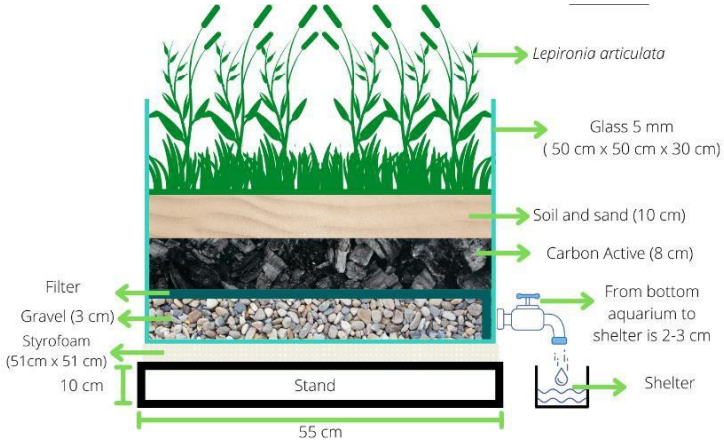

Figure 3. Constructed Wetland Reactor Side View

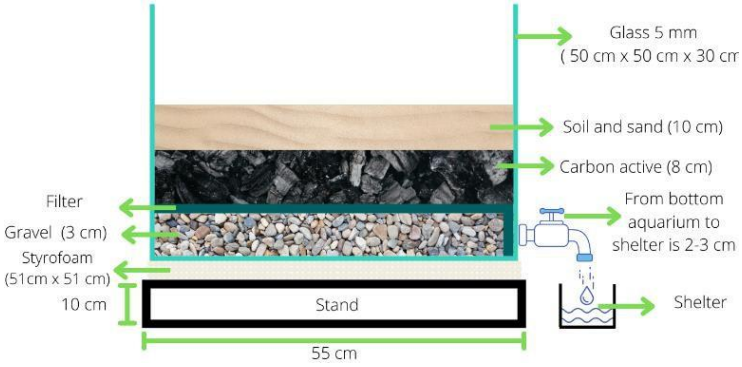

Figure 4. Filtration reactor

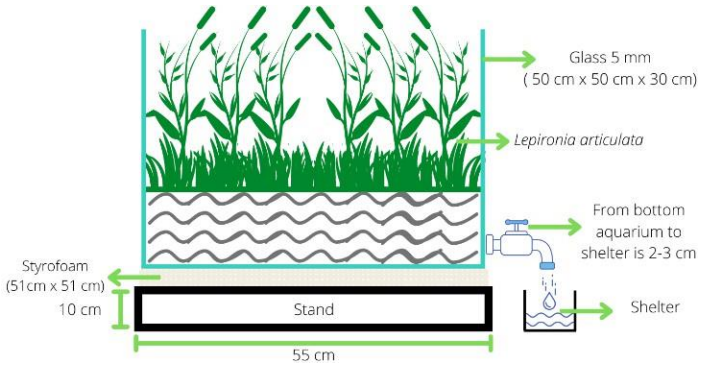

Figure 5. Phytoremediation reactor

2.3. Sample analysis

Sample analysis was carried out at the Diponegoro University Environmental Engineering Laboratory. BOD content analysis followed SNI 6989.72:2009, COD analysis followed SNI 6989.2:2019, phosphate level analysis followed APHA 4500-P B,C: 2017, surfactant content analysis followed SNI 06- 6989.51-2005 using the Merck Spectro quant Prove 100 spectrophotometer. For analysis pH values follow SNI 6989.11-2004 using a pH meter Ohaus Starter 300.

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3. Result and Discussion

3.1. Greywater Characteristic Test

From the results of the analysis that has been carried out, the characteristics of the greywater waste obtained are shown by Table 1. In Table 1, the levels of BOD, COD, phosphate, surfactants and pH values in greywater waste have exceeded the quality standards of Central Java Regional Regulation No. 5 of 2012.

Table 1. Initial Characterization of Greywater

Characterization			Quality Standards
Parameter	Unit	Measurement	
BOD	mg/L	400,4	100
COD	mg/L	953,33	100
Fosfat	mg/L	5,521	2
pH	-	9,36	6-9
MBAS	mg/L	18,165	5

Based on table 1. Shows that almost all parameters are exceed the quality standards for household wastewater quality. Greywater is water produced by all household activities exclude toilets, which may contain organic and inorganic materials (Ghaly, A.E., et.al., 2021), so the parameters for measuring the quality of greywater in this study are BOD, COD, phosphate, pH and MBAS is a representation of pollution due to household activities. Furthermore, to comply by the quality standards for household wastewater, it is necessary to carry out a waste treatment process to reduce the concentration of COD, BOD, phosphate, pH and MBAS.

3.2. BOD Concentration of Greywater After Treatment

In this research, the greywater is processed using phytoremediation, filtration and combining the two (constructed wetland). In the phytoremediation process, aquatic plants function as agents that can increase oxygen in water for the decomposition process by bacteria thereby reducing Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Turbidity in waste water (V. Alireza, H., et al., 2014). Meanwhile, the filtration process will work physically and chemically, where adsorption and interaction processes occur between pollutants and the filtration media. While, for the constructed wetland, the combination of two processes is expected increase the effectiveness in greywater treatment.

Based on Figure 6, BOD levels in all reactors have decreased. Where the most significant decrease occurred in the constructed wetland reactor. The decrease in BOD levels on the first day in the constructed wetland reactor, filtration media reactor and Lepironia articulata reactor respectively were 347.9 mg/L, 45.24 mg/L and 366.63 mg/L. The decrease in BOD levels on the third day in the constructed wetland, filtration media reactor and Lepironia articulata reactor respectively were 53.03 mg/L, 33.96 mg/L, 369.25 mg/L. The decrease in BOD levels on the fifth day in the constructed wetland, filtration media reactor and Lepironia articulata reactor respectively were 11.2 mg/L, 28.32 mg/L and 331.63 mg/L.

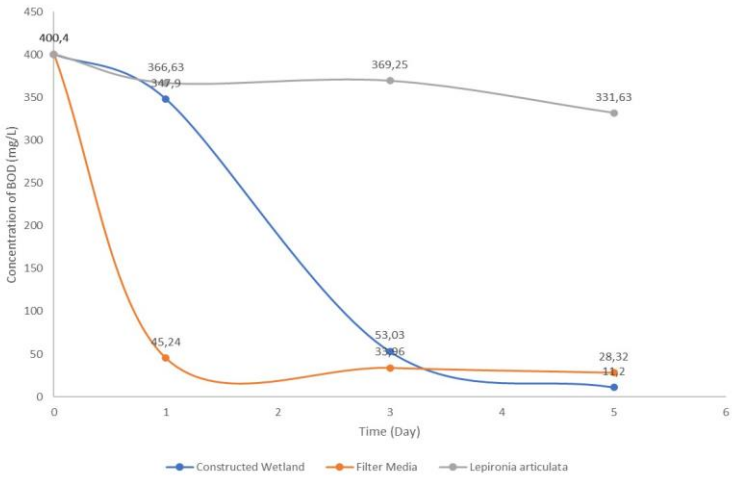

Figure 6. The Decrease of Greywater BOD concentration after treatment

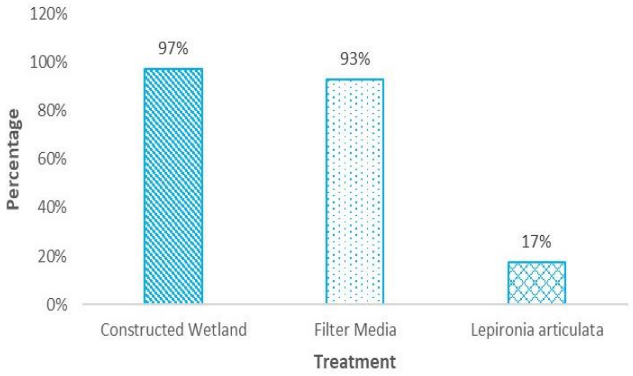

Figure 7. The Percentage of BOD Concentration decrease after treatment

Based on Figure 7, menunjukkan terjadinya penurunan yang signifikan terjadi pada greywater dengan perlakuan constructed wetland dengan besarnya penurunan sekitar 97%. The decrease in BOD levels in greywater waste occurs due to microbial activity not only as a result of the presence of plants but also the presence of filtration media which provides a growing medium for microorganisms in the water. The addition of plants in constructed wetlands creates interaction between plants, media and microor- ganisms in removing pollutants effectively (Al-Ajalin et al., 2020). Microorganisms play an important role in the elimination of organic materials which in the decomposition process require oxygen (Khiatuddin, 2010).

3.3. The Decrease of Greywater COD Concentration

Constructed wetland are engineered systems built for waste treatment using natural waste processes of soil, substrate, plants and microorganisms with a synergistic combination of physical,chemical and biological functions (Wu, H., et.al., 2015). Moreover, in this process, water depth has become an important variable in term of decreasing COD in gtey water since intensity of light and oxygen influencing biochemical reactions that are responsible for removing pollutants through redox effects. Beside, the rate of COD will affect the dissolved oxygen rate in constructed wetland (Song, H.L., et.al., 2009). Based on Figure 8, COD levels in all reactors have decreased. Where the most significant decrease occurred in the constructed wetland reactor. The decrease in COD levels on the first day in the constructed wetland reactor, filtration media reactor and *Lepironia articulata* reactor respectively were 930 mg/L, 433,33 mg/L and 923,33 mg/L. The decrease in COD levels on the third day in the constructed wetland reactor, filtration media reactor and *Lepironia articulata* reactor respectively were 143.33 mg/L, 293.33 mg/L and 946.67 mg/L. The reduction in COD levels on the fifth day in the constructed wetland reactor, filtration media reactor and *Lepironia articulata* reactor were 26.67 mg/L, 156.67 mg/L and 933.33 mg/L, respectively.

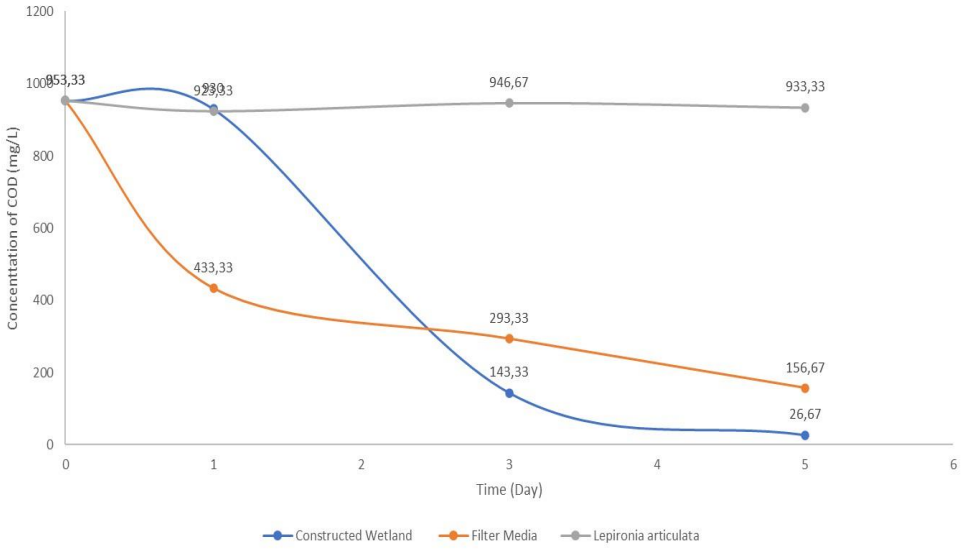

Figure 8 The Decrease of Greywater COD concentration after treatment

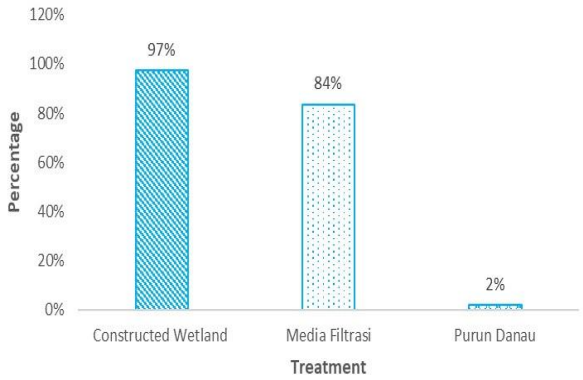

Figure 9. The Percentage of Decrease Greywater COD Concentration after Treatment

Based on Figure 9, the reduction in greywater COD levels up to the fifth day in the constructed wetland reactor was 97% (211.98 mg/L/day), the filtration media reactor was 84% (138.20 mg/L/day) and 2% in *Lepironia articulata* (1.5251 mg/L/Day). The high reduction in COD in constructed wetlands occurs due to good cooperation between microorganisms in removing organic materials biologically and filtration media which removes inorganic materials. This will reduce the oxygen concentration needed in the oxidation process of organic and inorganic materials in greywater.

3.3. The Decrease of Greywater Phosphate Concentration

Phosphorus (P) overloading in fresh water systems has a detrimental effect by increasing the speed of eutrophication. Senyawa yang mengandung Phosporus didalam grewywater adalah Phosphate. Salah satu metode menyisihkan senyawa kimia yang mengandung logam, seperti halnya phosphate adalah dengan memanfaatkan tanaman yang mampu mengubah bahan kimia dengan memamnfaatkan enzim di dalam tanaman. (Chapman K and Boucher,J.,2020).

Based on Figure 10, the phosphate levels in all reactors have decreased. Where the most significant decrease ocurred in the constructed wetland reactor. The decrease in phosphate levels on the first day in the constructed wetland reactor, filtration media reactor and *Lepironia articulata* reactor were 0.624 mg/L, 0.688 mg/L and 4.583 mg/L respectively. The decrease in phosphate levels on the third day in the constructed wetland reactor, filtration media reactor and *Lepironia articulata* reactor were 0.015 mg/L, 3.276 mg/L and 3.682 mg/L respectively. The reduction of phosphate levels on the fifth day in the con- structed wetland reactor, the filtration media reactor and the *Lepironia articulata* reactor were 0.65 mg/L, 3.149 mg/L and 2.921 mg/L

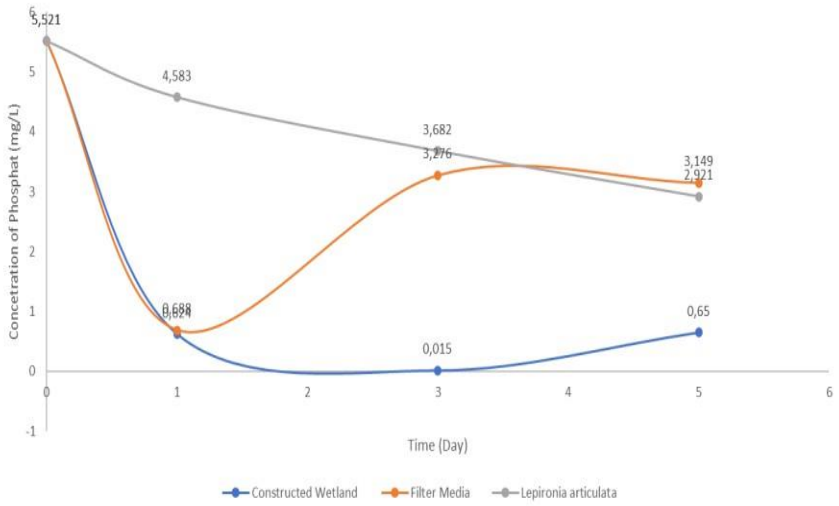

Figure 10. The Decrease of Phosphate concentration in Greywater after treatment

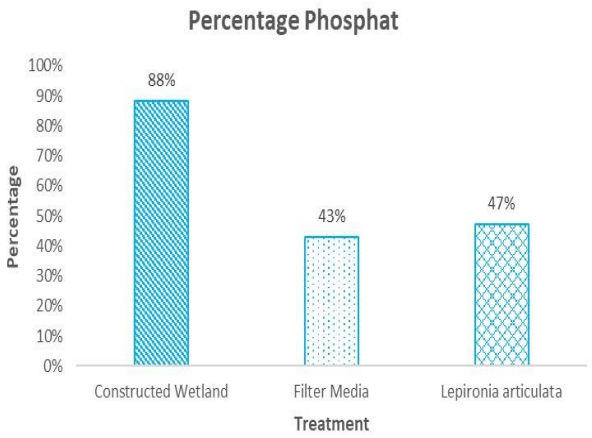

Figure 11. The Percentage of Decrease Greywater Phosphate Concentration

Based on Figure 11, the reduction in greywater phosphate significantly is occurred in reactor with constructed wetland design about 88%. Meanwhile, in the removal of phosphate, it appears that reactors using the phytoremediation method have a slightly greater reduction in phosphate when compared to reactors using the filtration method. This decrease is due to the fact that phosphate in greywater waste is utilized by *Lepironia articulata* in the process of growth in cells and metabolic activity by absorption through plant roots (Al-Ajalin et al., 2020). Careful choice of plant varieties in proses constructed wetland and phytoremediation should be given much emphasis since plant delivery of O2 and C substances, greater absorption of toxins, particularly evolving toxins,like heavy metals . In conjunction, constructed wetland materials should be produced and utilized a media that has excellent adsorption potential and is advantageous for removing techniques (Rahman,Md.,E.,et.al.,2020).

3.4. The Decrease of Greywater pH Concentration

Since changes in pH can change the concentration and form of toxic chemicals in water, it is important to measure pH in determining wastewater quality. Water pH also affects the survival of various aquatic organisms. The high and low pH of waste water is greatly influenced by the type of pollutants in it, because water that is free from pollutants is in the range of 7 (neutral).

Based on Figure 12, the pH value in all reactors has decreased. Where the most significant decrease occurred in the constructed wetland reactor. The decrease in pH value on the first day in the constructed wetland reactor, filtration media reactor and *Lepironia articulata* reactor respectively were 7.6, 7.75 and 8.49. The decrease in pH value on the third day in the constructed wetland reactor, filtration media reactor and *Lepironia articulata* reactor were 7.87, 8.09 and 8.49 respectively. The decrease in pH value on the fifth day in the constructed wetland reactor, filtration media reactor and *Lepironia articulata* reactor were 7.65, 7.89 and 8.49.

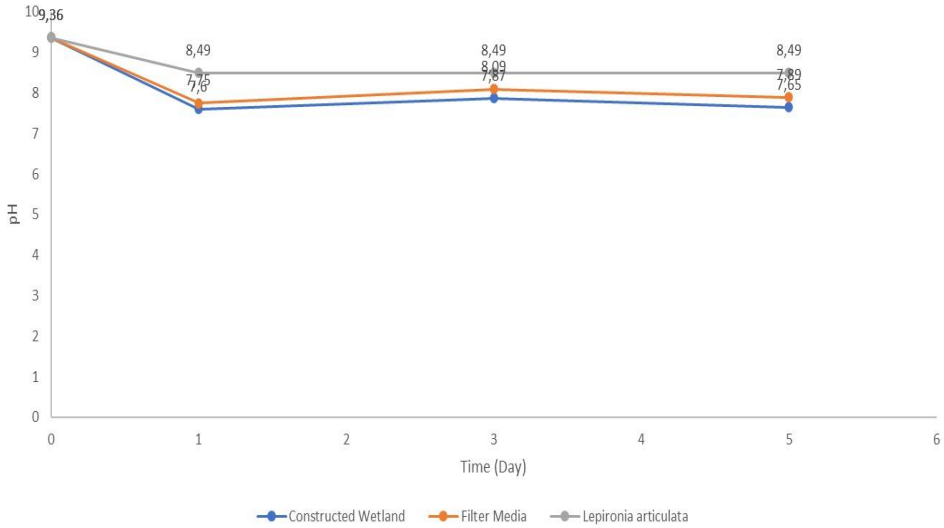

Figure 12. The Change of pH Value of Greywater after treatment

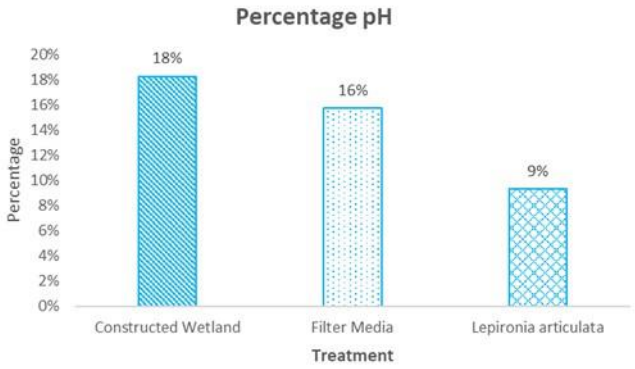

Figure 13. The percentage of pH Value of Greywater after treatment

Based on Figure 13, the decrease in pH value in the greywater until the fifth day of the constructed wetland reactor was 18%, the filtration media reactor was 16% and *Lepironia articulata* was 9%. The decrease in the pH value is due to the presence of organic matter that has not been completely decomposed so that it still releases organic acids (Ferry Yunianti, Yulia Ningrum and Ariani, 2020). In addition, the presence of gravel in the constructed wetland used may contain silica-containing quartz rocks. Silica is able to bind organic materials from surfactants, fats or carbohydrates in greywater so that it can lower the pH (Darwito, Sa'diyah and Radityas, 2019). In another similar study, constructed wetlands using *Lepironia articulata* were able to increase the pH from 4.9 to 6.8 (Wurochekke et al., 2014).

3.5. The Decrease of Greywater MBAS Concentration

Greywater is liquid waste which contains ingredients from washing activities so it can be ensured that it contains detergents and surfactants. To determine detergent or surfactant levels, one of the most methods is used namely MBAS (Methylen Blue Active Surfactant). The results of this research show the high effectiveness of constructed wetlands in reducing MBAS, this can be seen from the results in Fig.15 where a reduction in MBAS of around 95% occurred. As with phosphate reduction, the results of this research also show the excellent ability of *Lepironia articulate* to remove detergents and surfactants, even more than the filtration method. This shows that *Lepironia articulates* an important role in reducing metals, surfactants and detergents when compared to filtration media, so that in the constructed wetland concept, this role is also better with the cooperation of filtration media.

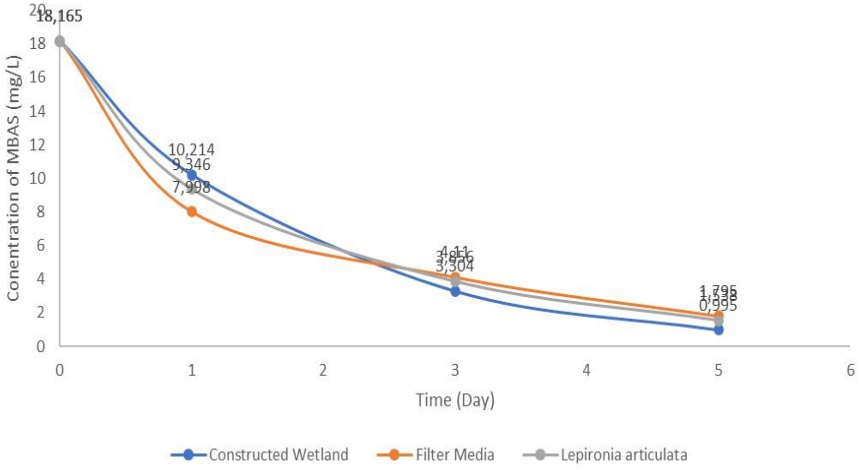

Figure 14. The Decrease of Greywater MBAS Concentration after treatment

Based on Figure 15, the reduction in the level of MBAS greywater until the fifth day in the con- structed wetland reactor was 95% (0.2453 mg/L/day), the filtration media reactor was 90% (0.2022 mg/L/day) and the *Lepironia articulata* reactor was 92%. (0.1327 mg/L/Day). The decrease in MBAS levels in constructed wetlands is due to the presence of bacteria in the soil or plant roots so that surfactants are processed into a source of energy and carbon in the metabolism of these bacteria. Surfactants are utilized to become complex molecules which will undergo decomposition to become simple compounds (Sulistiyawati, 2018).

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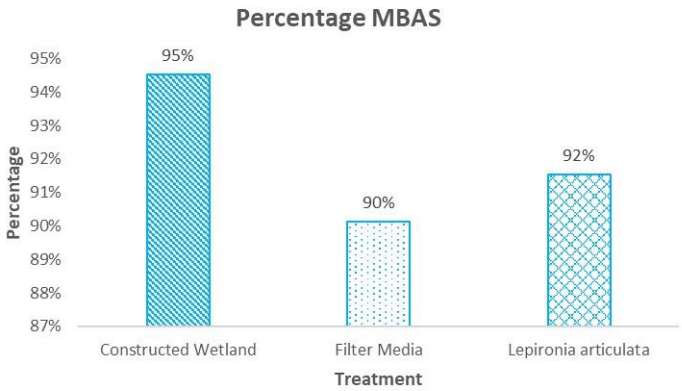

Figure 15. The Percentage of Greywater MBAS Concentration

4. Conclusions

This study shows an improvement in the quality of greywater after using constructed wetlands. This study shows that the constructed wetland is able to significantly reduce levels of BOD, COD, phosphate, pH and MBAS. The reduction results obtained were 97% for BOD and COD, 88% phosphate, 18% pH and 95% MBAS. From the results of research using a single method, filtration and phytoremediation using the Lepironia articulata plant, it provides evidence of the ability of each method to set aside different parameters. Filtration in this study was able to reduce COD, BOD and pH concentrations better when compared to the phytoremediation method, this shows that the ability of the Lepironia articulata plant is less effective in reducing COD, BOD and pH. On the other hand, the single method of phytoremediation using the Lepironia articulata plant showed excellent ability to reduce phosphate and MBAS concentrations. Finally, from this research it can be concluded that in the constructed wetland method, the combination of both filtration and phytoremediation methods is able to increase the effectiveness of each single method. Furthermore, more in-depth research needs to be carried out to see the composition of the metals and organic materials in the greywere so that we can find out how much influence the inorganic materials have on the COD concentration.

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