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EFFICIENCY WITH *CONSTRUCTED WETLANDS* SYSTEM USING WATER FERNS (*Azolla microphylla*) TO TREAT LAUNDRY WASTEWATER

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Abstract

This research aims to analyze the efficiency of processing liquid waste from the laundry industry using the Free Water Surface Constructed Wetland (FWS) system with Azolla microphylla plants. The research method used is experimental research by manipulating independent variables and controlling other relevant variables, as well as observing the effect on the dependent variable. Laundry waste samples were taken from Berkah Laundry, Puri Gading, Bekasi. The results showed that the biomass of Azolla microphylla plants increased significantly from day 0 to day 12, with a growth rate between 0.0289 – 0.0477 grams/day and plant density between 185.19 ind/m2 – 277.78 ind/m2. The influent BOD concentration of laundry liquid waste during the acclimatization stage ranged from 5.89 – 10.54 mg/L, while the effluent BOD ranged from 4.35 – 6.98 mg/L, with the highest efficiency reaching 33.8%. The constructed wetland system with Azolla microphylla plants has proven to be effective in reducing pollutant content in liquid waste, with a BOD removal efficiency of 11.1% - 17.7% and COD of 14.5% - 39%. The conclusion of this research is that the use of artificial wetlands with Azolla microphylla plants can be an effective and environmentally friendly alternative solution for processing liquid waste from the laundry industry. The implications of this research show the potential for applying constructed wetland technology in the clothes washing industry to reduce the negative impact of waste on the environment.

Keywords: Constructed Wetland, Azolla microphylla, Waste Management, BOD, COD, Laundry Industry

Introduction

From year to year, the population increases quite significantly, especially in big cities. It is recorded that the population of Bekasi City in 2020 is estimated to be 2.56 million people (Statistics, 2022). This number will continue to increase along with the high rate of population growth and urbanization in Bekasi City. As the population increases, people's need for goods and services will also increase. With increasing working hours and activities carried out in big cities, people are no longer able to meet their household needs independently. Washing clothes and other household items (laundry) is one of the businesses operating in the service sector that is mushrooming in several big cities in Indonesia, especially in Bekasi City.

The existence of the laundry business industry and other sectors which provide side effects in the form of waste produced from these sectors in the form of solid, gas and liquid waste (Meiliasari, 2016). The increasing number of clothes washing industries in Bekasi City are opening as a result of the increasing amount of waste water produced by the clothes washing industry (Azahra, Sutrisno, & Wardhana, 2015). The increase in the amount of waste caused by washing clothes produced has a direct impact on the

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environment if it is not managed and processed properly because this laundry waste can pollute water bodies (Meiliasari, 2016). The laundry industry produces liquid waste from detergents which causes problems if it is discharged directly into water bodies. Apart from that, the detergent content is excessive, and if it is thrown into the water without special treatment, it will ultimately be very dangerous for aquatic life and its surroundings (Dessy & Ika, 2019). This occurs due to the high concentration of detergent waste containing toxic materials, and the long decomposition process.

*Constructed wetlands*is an artificial wetland that is engineered or formed to be a cost-effective alternative water quality treatment or improvement technique. This technique is a wastewater treatment method that is widely used in developed countries (Zahra, 2015). The effectiveness of artificial wetlands in degrading pollutants in wastewater is influenced by the type of plants and filter media used.

Various types of liquid waste processing have been discovered, one of which is biological technology that utilizes associated plants to reduce environmental pollutants in water, soil and air caused by heavy metals or organic materials, namely phytoremediation (Hilal & Rohmah, 2018). The Azolla microphylla plant is better known as the water fern, and this plant often grows in swamp areas where it has green leaves and floats in the water. According to (Salafiyah, 2016) in Stowell (2016) the waste processing system using Azolla as a biofilter is the main organism that plays a role in the process of decomposing organic substances and nutrients in wastewater.

In research conducted by (Erwin & Lanang, 2019) with Vertical Flow Sub-Surface Flow Constructed Wetland using Cattail plants (Typha sp) and Kana plants (Canna sp) there is an allowance for the pH parameter value every week, then for the BOD parameter there is a percentage of effective removal of 76.31%, an effective COD allowance of 67 .41%, and the effective removal of Phosphate was 57.53%. Other research conducted by(Damayanti, 2022)with Free Water Surface in Azolla microphylla plants there is a BOD removal of 11.9% - 17.7%, and COD of 5.26% - 8.45%.

One alternative treatment for processing laundry wastewater is with Constructed Wetlands (artificial wetlands). Artificial wetlands are a form of natural processing which is a concept of environmentally based natural wetlands because in principle, using aquatic plants in wastewater treatment, processing and operation is easy and does not require large costs. Research on reducing wastewater pollution with constructed wetlands has been carried out by many researchers using various types of plants, one of which is using the water fern (*Azolla microphylla*). This plant has a root system that can absorb organic material, especially in waste water.

The purpose of this research is to obtain an overview of the processing of liquid waste from the laundry industry using constructed wetlands with Azolla microphylla plants. In this research, the aim is to analyze the efficiency of processing laundry industrial waste with artificial wetlands using the Azolla microphylla plant.

Research Methods

This type of research is experimental research for processing liquid laundry waste where laundry waste is included in the category of domestic wastewater (greywater) originating from the laundry business, Berkah Laundry, Puri Gading, Bekasi using Free Water Surface Constructed Wetland (FWS). Experimental research is a research method carried out for certain influences on others under controlled conditions. In this experimental research, it is a type of quantitative research where the researcher manipulates one or more independent variables, controls other relevant variables, and observes the effect of the manipulation on The dependent variable and the data used are in the form of numbers processed using statistical methods

The types of data obtained in this research are primary data and secondary data. The primary data obtained in this research are the characteristics of laundry wastewater and the efficiency of constructed wetlands in reducing BOD and COD removal. And the secondary data used in this research is data from the laundry industry, and the literature used.

This research began with sampling liquid laundry waste at UMKM Berkah Laundry, Bekasi to determine the initial condition of the existing samples. This laundry waste comes from used washing water. Samples were taken from the laundry disposal which flows through the water used to wash clothes using a hose. The sample will be collected using a container in the form of a jerry can which has previously been homogenized by rinsing the sample in accordance with SNI 6989.59:2008. This is done so that there are no more substances in the jerry can that will affect the quality of the sample. Furthermore, for data processing analysis, sampling was carried out on laundry waste that would enter the constructed wetland (influent) which was poured from jerry cans into a collection tank and then flowed using a Luckiness 2518 pump and a hose with a diameter of 2 cm.

Results and Discussion

Acclimatization Process

The acclimatization process aims to ensure that the plants and microorganisms in the reactor can adapt to waste water and to prevent shock loading in the artificial wetland. The retention time used was 3 days. This process is carried out by gradually diluting the waste water influent with a mixture of clean water. In the processing process using the Free Water Surface artificial wetland system for waste water from Berkah Laundry Laundry, Bekasi. The artificial wetland reactor was placed in the yard of the house, Puri Gading Bekasi. The position of the artificial wetland reactor is placed after the holding tank. Figure 1 shows the location of the artificial wetland reactor and the position of the storage tank.

Figure 1. Reactor *Constructed Wetlands*
Source: Author, 2024

The waste water is taken and placed in a holding tank which is then flowed to the reactor tank with a detention time of 3 days. The processing operating system uses a reactor tank with a continuous flow system. The removal of pollutant concentrations can be seen from the physical condition of the waste water in the influent and effluent detention for 3 days, the water looks gray while in the effluent detention for 3 days it looks clear, slightly brownish in color, this occurs due to the use of sand and gravel as filter media in the constructed reactor. wetlands.

In processing laundry wastewater, an acclimatization process is required. The acclimatization stage is a stage of adjusting the microorganisms that will be used to degrade wastewater and in this research a free water surface flow system is used. The main aim of acclimatization is to ensure that plants do not experience sudden loading (shock loading), this is done so that plants can absorb pollutants, especially in removing various types of waste water. The acclimatization stages are carried out in stages and the Azolla microphylla plants are around 2 weeks old. In this research, the acclimatization process will be carried out by going through several stages where each stage will be carried out with a hydraulic residence time of 3 days each.

In the acclimatization process, phasing is carried out in the percentage of waste water and clean water. Initial composition with a mixture of 25% waste water and 75% clean water for 2 days, on the 3rd day with a mixture of 50% waste water and 50% clean water for 2 days, on the 5th day with a mixture of 75% waste water and 25% clean water for 4 days, on the 9th day with a mixture of 100% waste water for 4 days and the next stage (running) with 100% waste water for 21 days at the artificial wetland operation stage. The following is the growth biomass of the Azolla microphylla plant as measured using an analytical balance.

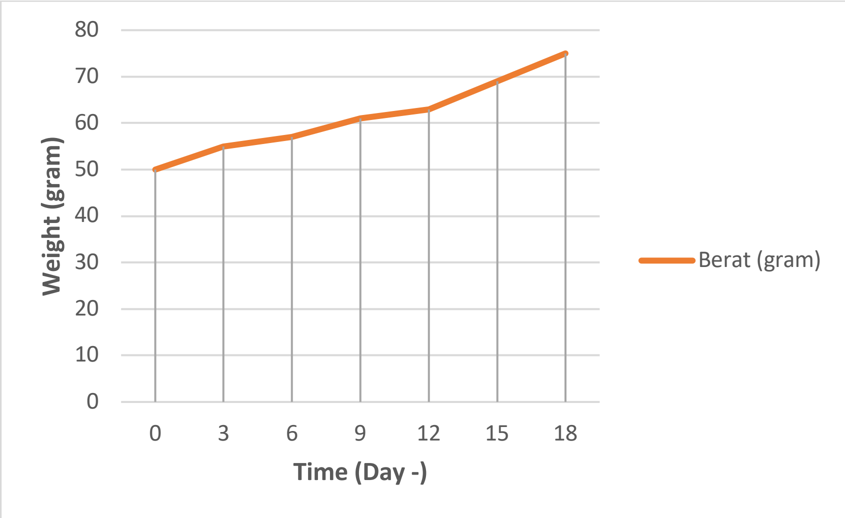


Figure 2. Plant Biomass*Azolla microphylla*
Source: Author Data, 2024

Based on the biomass of the Azolla microphylla plant, it experienced an increase from day 0 to day 12. The growth of Azolla microphylla increased on the 2nd day, increasing to 5 grams, and on the 12th day increasing to 6 grams. The growth of Azolla microphylla plants increases every day. During the acclimatization process, monitoring of the effect of waste water on plants is carried out, and this increase indicates that Azolla microphylla is experiencing fairly good growth and is able to adapt to the pollutant load from the waste water, with its rapid growth being supported by the presence of nutrients. height in the Azolla microphylla planting medium. Research conducted by (Nurmalinda, 2018) in acclimatizing Azolla microphylla plants with leachate waste, on day 0 the plant weight was 120 grams, and on day 12 the plant weight was 150 grams. This indicates that Azolla microphylla is experiencing fairly good growth and is able to adapt to the pollutant load from the wastewater. This fast growth is supported by the high levels of nutrients in the Azolla microphylla planting medium (El-Rahimi, Hasri, & Surdina, 2018).

Plant growth rate is carried out with the aim of finding out how fast the Azolla microphylla plant grows during acclimatization by observing plant density. Plant growth rate was calculated from day 0 to day 12 using an analytical balance. The following are the results of observations through calculations of the growth rate of Azolla microphylla plants, using equation (3.6).

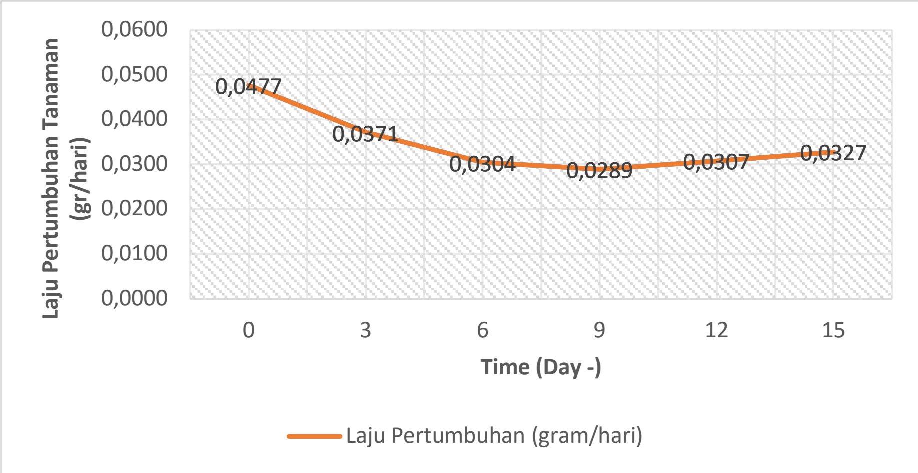


Figure 3. Plant Growth Rate*Azolla microphylla*
Source: Author Data, 2024

Based on the results of these data, it can be seen that the growth rate of Azolla microphylla plants ranges from 0.0289 – 0.0477 grams/day. On the 6th day there was the lowest growth rate, this indicates that there are contaminants in the cells of the water fern (*Azolla microphylla*) which are closely related to enzymes that catalyze chemical reactions in plant cells and can disrupt the growth rate of the plant. This is caused by palisade tissue, and a plant epidermis which causes the plant to lack a nutrient (Ryan, 2021). The availability of nutrients contained in plants is able to increase plant growth, therefore these nutrients play a very important role in the photosynthesis process which will ultimately influence the results of the Relative Growth Rate, this is closely related to plant biomass (Estuningsih & Tanzerina, 2021).

The rate of plant growth is greatly influenced by plant biomass, and the higher the plant biomass, the lower the rate of plant decline. This is caused by intraspecific competition, both from sunlight and space. The more the plant growth rate decreases, the higher the chance of the plant dying, thus disrupting the reduction in wastewater concentration (El-Rahimi, Hasri, & Surdina, 2016). According to research conducted by (Damayanti, 2022). The growth rate of Azolla microphylla plants in constructed wetlands is greatly influenced by water quality, light intensity, temperature and plant density.

Apart from the rate of plant growth, you can also see the density of Azolla microphylla plants which refers to the mass or weight of plants found in a certain area of constructed wetland. Plant density is very important because optimal density can increase the efficiency of waste processing. Plant density can be measured by plant biomass. Azolla microphylla per unit area, with the right plant density, can reduce the concentration of pollutant parameters because this can help in the decomposition process of organic matter in water. The density of Azolla microphylla plants in the constructed wetland can be seen in the following picture, using equation (3.7).

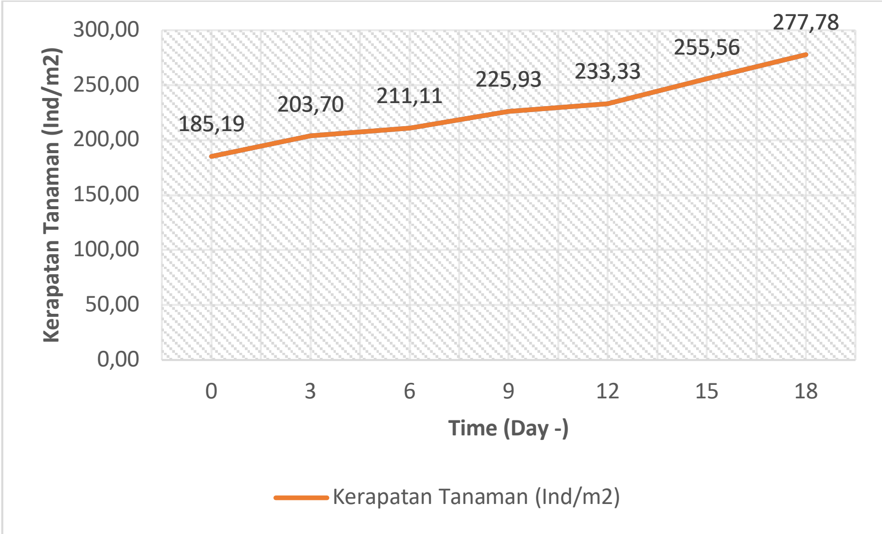


Figure 4. Plant Density*Azolla microphylla (Ind/m2)*
Source: Author Data, 2024

Based on the plant density above, it can be seen that the density of Azolla microphylla plants ranges between 185.19 ind/m2 – 277.78 ind/m2. The density of Azolla microphylla plants is increasing day by day and can be seen in Figure 3. According to research conducted by (Andrio & Azmi, 2016), the higher the plant density value, the better the plants will develop, thereby increasing the efficiency of waste water removal. The density of Azolla microphylla plants varies according to environmental conditions such as temperature, light intensity, nutrients that can influence growth. One factor that can increase plant density is the planting time used in constructed wetlands. Plant growth in constructed wetland reactors is also influenced by the organic load factor, where a high organic load will increase the density of plant biomass. As the age of the plant increases, the absorption by the plant will increase until within a certain time it will reach a maximum limit and will decrease again (Damayanti, 2022).

In the initial stages of operating a wastewater treatment system, especially constructed wetlands in the acclimatization stage have an important role in determining the long-term efficiency of the system. One of the parameters used to measure the effectiveness of the treatment process is Biochemical Oxygen Demand (BOD), which describes the amount of oxygen required by microorganisms to decompose organic matter in wastewater. The results of this analysis show that in the acclimatization stage the removal efficiency can be seen:

Table 1. Concentration and Efficiency of BOD Removal at Acclimatization Stage

Days to-	Date	Water Composition		BOD (mg/L)		Elimination Efficiency (%)
		Laundry Water	Clean water	Influent	Effluent	
1	March 04, 2024	25%	75%	7.34	6.25	14.9%
2	March 08, 2024	50%	50%	9.57	6.87	28.2%
3	March 13, 2024	75%	25%	5.89	4.35	26.1%
4	March 20, 2024	100%	0%	10.54	6.98	33.8%

Based on table 1, the influent BOD concentration in stages one to stage four ranges between 5.89 – 10.54 mg/L. The influent value obtained fluctuates because the number of people washing in the laundry varies quite a bit every day. So the effluent obtained also fluctuates and ranges between 4.35 – 6.98 mg/L. At the 4th day stage, the highest removal efficiency was obtained, namely 33.8%. According to research conducted (Koordaryani, Muttaqien, Qomariyah, & Sobriyah, 2017), at the acclimatization stage the concentration of wastewater influent pollutants increases or experiences an increase along with the increase in the percentage of wastewater concentration. The higher the influent BOD concentration, the higher the BOD removal efficiency. This is caused by the increasing number of microorganisms as a source of energy for metabolism, so that microorganisms will be more active in degrading pollutants in the form of BOD in waste water (Badzlin, 2018).

There was a change in influent and effluent results which decreased on the 3rd day to become low, and then increased again on the 4th day, this was caused by several factors that influenced the water treatment system in constructed wetlands. In this case, it could be caused by the biological processing system, because microorganisms need time to adapt to new conditions or changes in pollutants, which are currently in an adjustment or fluctuation phase which causes decomposition efficiency to temporarily decrease.

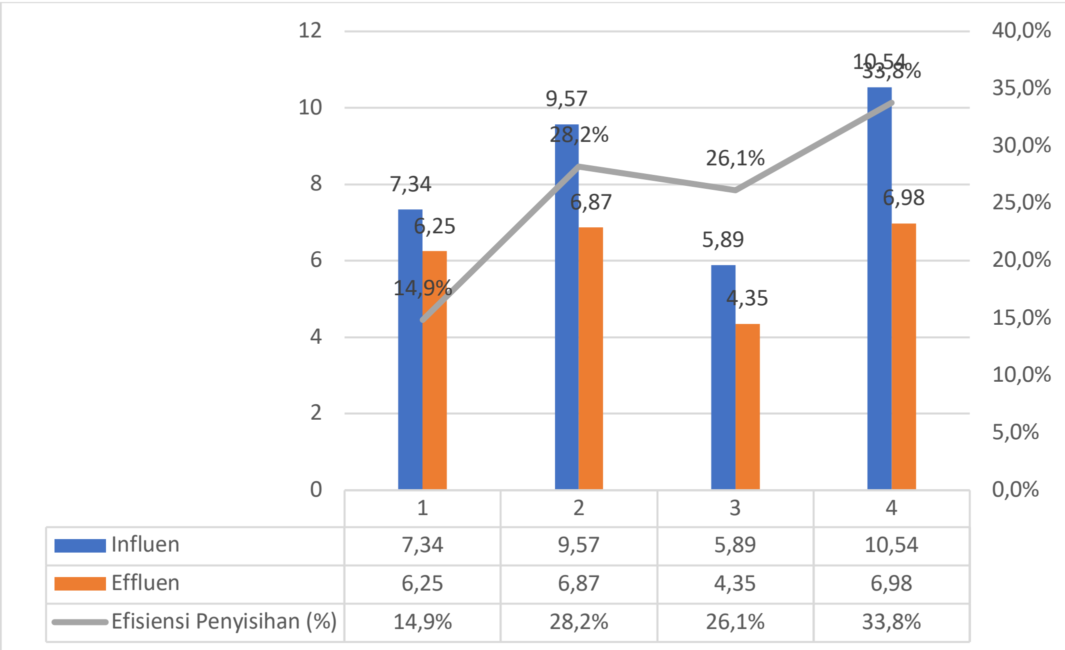


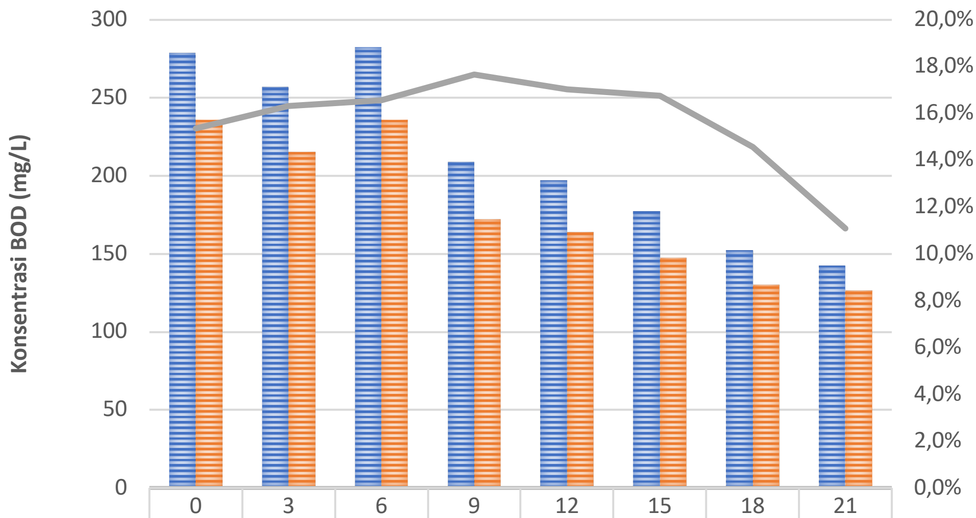
Figure 5. Acclimatization Stage BOD Testing Graph
Source: Author Data, 2024

Removal of BOD Concentration on the Free Water Surface

Based on the data, it can be seen that the Biological Oxygen Demand (BOD) concentration value in Figure 5 can be seen that the highest inlet BOD concentration was 282.7 mg/L on day 6, and the lowest BOD outlet concentration was 126.7 mg/L on 21st day. According to (Damayanti, 2022) Biological Oxygen Demand (BOD) content means that a significant decrease in BOD can be caused by the filtration process. The use of gravel and silica sand media is very effective in the process of precipitating dissolved particles in waste water, where there are sections of gravel cavities which allow for a sedimentation process which causes the treated waste water to become clearer. Gravel media is a good medium for breeding microorganisms in breaking down polluting organic materials.

In the reactor, there is a decrease in the efficiency of Biological Oxygen Demand (BOD), this is due to the presence of Azolla microphylla plants covering the surface of the wastewater being processed in the constructed wetland. These organics must be degraded by fewer microorganisms. The less organic material that has been degraded by microbes, the higher the oxygen content in wastewater. Dissolved oxygen in treated wastewater will increase due to the oxygen supply that comes from the photosynthesis process carried out by the Azolla microphylla plant (Wulandari & Anwari, 2020). There was a decrease after being given treatment, according to (Ghofar, Haeruddin, & Ningrum, 2020) can be caused by factors that influence the concentration of BOD contained in water, namely: type of water, water temperature, degree of acidity (pH), and overall water condition. Research conducted by (Ghofar, Haeruddin, & Ningrum, 2020).

According to research conducted by (Bintara, Ibrahim, & Wahyu, 2020), in treating industrial wastewater with water hyacinth plants for 21 days with a plant weight of 1 kg, it can reduce the BOD concentration of wastewater by 4001.8 mg/L to 154.42 mg/L with a percentage of 96.1%, and with a plant weight of 1 .5 can reduce the BOD concentration to 123.49 mg/L and a plant weight of 2 kg can reduce the BOD concentration to 118.08 mg/L with a percentage of 97%. It can be concluded that the detention time can influence the level of efficiency of BOD reduction, apart from that there is the activity of microorganisms with plants attached to the roots which produce oxygen which will be used in breaking down complex organic materials into simple ones which are reabsorbed by the plant through the roots. This shows that the more plants there are in the constructed wetland, the lower the BOD concentration in wastewater. Based on the data from measurements of these test parameters, the concentration allowance for BOD parameters in free water surface artificial wetlands can be seen in the following figure:



	0	3	6	9	12	15	18	21
Inlet	278,7	257,3	282,7	208,9	197,3	177,3	152,4	142,5
Outlet	235,9	215,3	235,9	172	163,7	147,6	130,2	126,7
%	15,4%	16,3%	16,6%	17,7%	17,0%	16,8%	14,6%	11,1%

Figure 6. BOD Concentration Removal Efficiency
Source: Author Data, 2024

Based on the analysis results in Figure 6, it can be seen that the highest inlet BOD concentration was 282.7 mg/L, and the lowest inlet BOD concentration was 142.5 mg/L. Then the results of the analysis of the highest BOD outlet concentration were 235.9 mg/L and the lowest BOD was 126.7 mg/L. According to research conducted by (Anwari, Nusantara, & Wulandari, 2019), the concentration contained in BOD before the treatment was carried out was 377 mg/L and after the treatment the results were 22 mg/L with a detention time of 9 days.

The significant reduction in BOD is caused by the filtration process in the media, where the sand and gravel media are very influential and effective in the process of settling dissolved particles in waste water, where there are gravel cavities that allow the sedimentation process to occur which causes the treated waste water to become clearer. . The use of gravel media is a good medium for breeding microorganisms in breaking down polluting organic materials (Damayanti, 2022).

Removal of COD Concentrations on the Free Water Surface

The Chemichel Oxygen Demand (COD) parameter measures indirectly all organic compounds in water expressed in milligrams per liter (mg/L). This parameter shows the amount of oxygen required for the chemical oxidation of organic compounds and to produce CO2 and water (Amany, 2021). The following are the COD influent and effluent concentrations, as well as their removal efficiency after processing in the reactor:

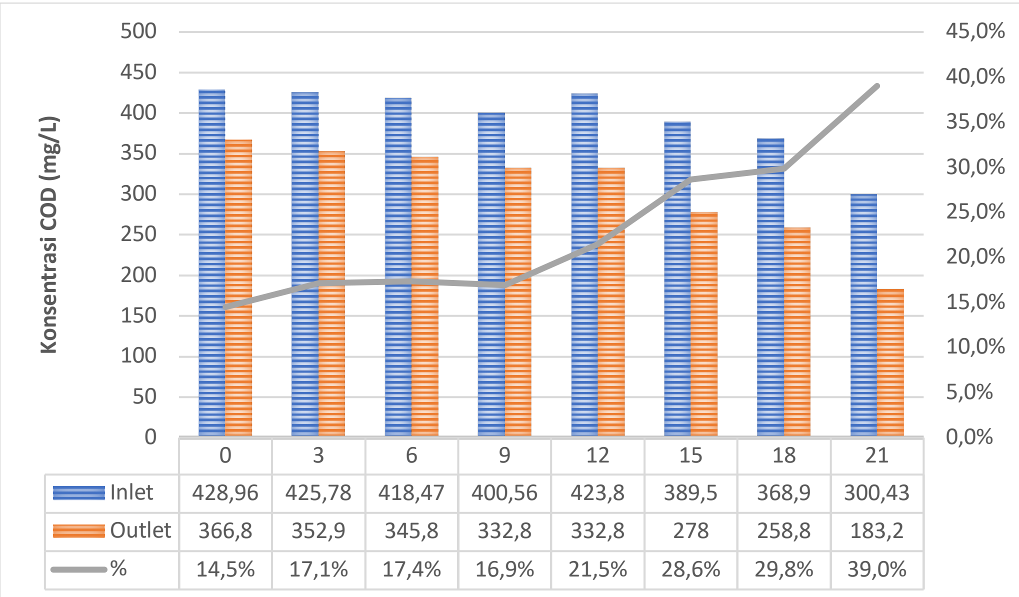


Figure 7. COD Removal Concentration Efficiency

Source: Author Data, 2024

Based on the data shown in Figure 7, the Chemical Oxygen Demand (COD) concentration value can be seen that the highest COD inlet concentration was 428.96 mg/L on day 0, and the lowest COD outlet concentration was 183.2 mg/L on day 0. 21st. The inlet COD concentration on the 12th day increased, then on the 15th day it decreased again, according to the statement (Damayanti, 2022)In this case, the rise and fall of COD concentration is also influenced by the presence of plants in the waste water. The plants will carry out the process of photosynthesis and produce oxygen so that the plants supply the oxygen needed which is used to decompose the organic material in the waste water.

The organic material is then converted by microorganisms into simple compounds, the degradation is carried out by microbes in absorbing nutrients. This is in line with research conducted by (Firmanda & Kasman, 2022), the removal of COD concentration during 9 days experienced fluctuations in efficiency of 65%, 59%, and 65% which occurred on days 5, 6, and 7. This was because there were remnants of roots and leaves from Pistia stratiotes which were slightly wilted, resulting in turbidity, in addition to the loss of organic compounds contained in the media due to eroding by waste water in the constructed wetland.

Conclusion

From the results of the research and analysis that has been carried out, it can be concluded that: (1) Azolla microphylla plant biomass increased significantly from day 0 to day 12, this shows good plant adaptation to the wastewater environment. Where the growth rate influences plant biomass ranging from 0.0289 – 0.0477 grams/day, and has an Azolla microphylla plant density of 185.19 ind/m2 – 277.78 ind/m2. The influent BOD concentration of laundry liquid waste in the acclimatization stage ranges from 5.89 – 10.54 mg/L, effluent BOD ranges from 4.35 – 6.98 mg/L with the highest efficiency reaching 33.8%. (2) *Constructed wetland free water surface*with Azolla microphylla plants is effective in reducing pollutant content in Berkah Laundry liquid wastewater with BOD removal efficiency of 11.1% - 17.7%, COD of 14.5% - 39%.

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