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Original Research Article

The Performance of Household-Scale Horizontal Flow Constructed Wetland (HFCW) Unit for Treating Greywater

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Abstract

Horizontal flow constructed wetland (HFCW) is a method mimicking natural processes in which plantations are used to treat wastewater. This method demonstrates superior efficacy in the removal of organic pollutants and total nitrogen. Furthermore, it offers the advantage of reduced operational and maintenance expenses. This research employs a household-scale HFCW unit, utilizing water hyacinths (*Eichornia crassipes*) to treat greywater from a single house. The study aims to assess the HFCW unit's performance in treating greywater at a household scale, with effluent quality compared against Minister of Environment and Forestry Regulation (Regulation Number 68/2016 on Domestic Wastewater Quality Standard) using testing methods in accordance with the Indonesian National Standards (SNI). The results indicate that the HFCW unit removal efficiencies after two days retention time are: BOD_5 (74%-93%), COD (47%-80%), TSS (55%-97%), oil and grease (50%-94%), and ammonia (46%-99%). After three days, the unit generally demonstrates improved performance, which are: BOD_5 (67%-96%), COD (57%-91%), TSS (51%-97%), oil and grease (11%-99%), and ammonia (35%-99%). Overall, the effluent quality meets government standards for both two- and three-days retention time, establishing the HFCW unit as an effective household-scale greywater treatment solution.

Keywords: Constructed wetland; water hyacinth; greywater; household scale; detention time

1. Introduction

Domestic wastewater according to the Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia Number 04/PRT/M/2017 concerning the Implementation of Domestic Wastewater Management Systems is defined as wastewater originating from businesses and/or residential activities, restaurants, offices, commerce, apartments, and dormitories. Domestic wastewater comes from 60-80% of the clean water we use and is divided based on the source into blackwater and greywater. Presentation of the blackwater processing uses individual septic tanks in urban areas 74.86% and in rural areas 51.92% (Central Bureau of Statistics, 2020). Meanwhile, around 51-53% of the greywater produced is discharged into water bodies without processing (Ministry of Health, 2018). In fact, the quantity of greywater is four times higher than the quantity of blackwater and both require processing to meet quality standards so that it is safe to discharge into the environment (Gunasekara and Dissanayaka, 2022).

Blackwater and greywater processing is experiencing gaps due to the government having established a blackwater treatment system in the Minister of Public Works and Public Housing Regulation Number 04/PRT/M/2017 concerning Implementation of Domestic Wastewater Management Systems and Indonesian National Standards Number 2398:2017 concerning Procedures for Planning Septic Tanks with Treatment. However, so far greywater does not have specific references for the technology that can be used. Therefore, this is a significant research gap that needs to be filled. Especially those that can be applied on a household scale so that they can be a complement to blackwater treatment using septic tanks. This is supported by the statement in the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number 68 of 2016 concerning Domestic Wastewater Quality Standards Article 3 Paragraph 1, that every business and/or activity that produces domestic wastewater is obliged to process the domestic wastewater it produces (Minister of Environment and Forestry, 2016). The greywater processing process can be carried out physically, biologically and chemically (Adany, 2017). There are several greywater processing methods that are commonly used according to the literature, namely filtration, coagulation, photocatalysis, membrane bioreactors, adsorption, and constructed wetland (CW) (Noman et al., 2019; Perdana et al., 2020).

The CW method is a treatment system designed to carry out natural processes contained in wetland substrates, vegetation, and microbial collections in treating wastewater. The CW processing systems are classified into free water surface flow (FWSF) and subsurface water flow (SWF) (Vymazal and Kröpfelová, 2008). The SWF system is said to be an appropriate CW alternative for treating wastewater because it does not have direct contact between the wastewater and the soil base. From a public health perspective, this system is safer because there is no opportunity for pests to breed (Patel and Dharaiya, 2013). The type of SWF is classified based on the direction of flow into horizontal flow CW (HFCW) and vertical flow CW (VFCW) (Oteng-Peprah et al., 2018). The HFCW type has been proven to be an effective wetland configuration for eliminating biological oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solids (TSS) and nitrate compared to VFCW (UN-HABITAT, 2008; Gunasekara and Dissanayaka, 2022). Research shows that HFCW can remove TSS, COD, BOD_5 contained in greywater by 85%, 89% and 88% respectively (Collivignarelli et al., 2020).

The CW method can use aquatic plants in the form of Hydrilla (*Hydrilla verticillata*), umbrella grass (*Cyperus alternifolius*), cattail (*Typha angustifolia*) and water hyacinth (*Eichornia crassipes*). Based on previous research, water hyacinth has the best effectiveness in remediating greywater compared to Hydrilla and Umbrella grass on the parameters BOD_5, COD, and TSS with efficiencies of 77-85%, 77-82%, and 78-86% (Kalsum et al., 2014). Another study comparing water hyacinth, cimmon reed (*Phragmites australis*), and scabies weed (*Commelina cyanea*), showed that Water Hyacinth outperformed the other two aquatic plants in overall wastewater treatment efficiency. This superiority is attributed to water hyacinth's ability to optimize oxygenation conditions, accelerating aerobic decomposition processes for organic matter and nutrients. Water Hyacinth exhibited excellent nutrient removal capabilities, including pH, Nitrite, Nitrate, Sulfate, BOD_5, and COD (Ajibade and Adewumi, 2017).

However, CW built with dimensions of 1.2 m^2 and 3 m^2 are not easy to implement on a household scale in Indonesia which generally does not have a large enough page (Qomariyah et al., 2017; Hoffmann et al., 2011). Therefore, it is necessary to design an experimental greywater treatment unit using CW with a small size so that it can be applied in Indonesian households in general. Thus, this study aims to assess the effectiveness and efficiency of synthetic greywater treatment using an HFCW unit with smaller designs to make it applicable for households in Indonesia.

2. Methods

This research is conducted in the form of experimental research or experiments. The study was carried out in the Pertamina University Laboratory located at Teuku Nyak Arief Street, Simprug, South Grogol, RT.7/RW.8, Kebayoran Lama, South Jakarta, Special Capital Region of Jakarta, Indonesia.

2.1 Synthetic Greywater

The wastewater used in this research is synthetic greywater. The selection and composition of materials used in the creation of synthetic greywater are based on references from previous research. The primary reference literature utilized in this study is from research conducted and the materials will be adjusted according to the most commonly used product brands in Indonesia (Pazare and Waghmare, 2018). The specific product brands to be used are detailed in Table 1.

Table 1. The use of the synthetic greywater material brands.

Synthetic Greywater Materials	Product Brands	References
Washing Powder	Rinso	(Top Brand Index, 2023)
Coconut Oil	Bimoli	
Dish Washing	Sunlight	
Body Wash	Lifeboy	
Handwash	Dettol	(Batubara et al., 2020)

The creation of synthetic greywater begins with weighing the necessary materials. After weighing, 0.16 g of washing powder, 0.16 g of dishwashing detergent, 0.16 g of handwash, and 0.16 g of body wash are individually dissolved in 10 mL of tap water in a 50 mL glass beaker and stirred using a magnetic stirrer for 4 minutes. Meanwhile, 0.1 g of coconut oil is directly dissolved in 10 mL of tap water in a 1 L glass beaker to prevent oil loss. Subsequently, all the components are combined in the 1 L glass beaker. The 50 mL glass beaker is rinsed with tap water, totaling 950 mL, and the rinsing water is mixed with the dissolved materials in the 1 L glass beaker. The mixture of all the components and 1 L of water (50 mL + 950 mL) is stirred again using a magnetic stirrer for 10 minutes (Berger, 2012). In this study, the quantity of synthetic greywater production is adjusted according to the capacity of the influent tank used, which is 60 L. Therefore, the composition of the weighed synthetic greywater materials is adjusted to meet the requirement of 60 L. Additionally, because the influent tank can only accommodate 60 L of synthetic greywater, a fresh supply of synthetic greywater is provided every day. Hence, during the 10 days synthetic greywater running process, synthetic greywater is produced 10 times.

2.2 Sampling Procedure and Greywater Quality Testing

The testing of greywater quality aims to determine the characteristics of both influent and effluent greywater for each parameter. These parameters include pH, BOD_5, COD, TSS, oil and grease, and ammonia, referring to the Minister of Environment and Forestry Regulation No. 68 of 2016 regarding Domestic Wastewater Quality Standards. Before testing, greywater sampling is conducted using the composite sampling method. The sampling process can be seen in Figure 1. The procedures for greywater sampling and quality testing adhere to established standard methods and previous research. References for greywater sampling and testing methods can be found in Table 2.

Table 2. Reference for Sampling Methods and Greywater Quality Testing

Information	Method	Reference
Sampling Greywater	Composite Sampling	Indonesian National Standard No. 6989.59:2008
pH	Using a pH Meter Tester	Indonesian National Standard No. 6989.11:2019
COD	Titrimetry	Indonesian National Standard No. 6989.73:2009
TSS	Gravimetry	Indonesian National Standard No. 06-6989.3:2004
Oil & Grease	Gravimetry	Indonesian National Standard No. 06-6989.10:2004
Ammonia	Fenat Spectrophotometer	Indonesian National Standard No. 06-6989.30-2005

2.3 Construction of Horizontal Flow Constructed Wetland Reactor

The reactor used is a container box made of copolymer plastic with dimensions of 73 cm in length, 41 cm in width, 32 cm in height, and a 1% slope (Gauss, 2008). These dimensions were designed based on previous research criteria and were adjusted according to the availability of container boxes in the market. The reactor is divided into three areas: the inlet area, processing area, and outlet area, which are separated by acrylic dividers. The inlet and outlet areas are filled with gravel with a diameter of 10-20 mm, while the processing area contains silica sand with a mesh size of 6/8, which has been sieved and planted with water hyacinth. These three areas are connected through small holes in the acrylic dividers. There are 30 small holes with a distance of 1 cm between them and a diameter of 1 cm (Khoirunnisa, 2022).

The media's adsorption capacity depends on the detention time of wastewater, where a sufficient detention time allows for contact between microorganisms and the wastewater (Suprihatin, 2014). According to findings from Nema's study (2021), it was indicated that the most effective detention times were observed on the 2 and 3 days from 5 days detention time. Hence, this investigation will compare these two detention durations. The influent treatment using HFCW will be conducted in two different reactors to vary the detention time, namely, for 2 days and 3 days (Khoirunnisa, 2022; Putra, 2018). The HFCW reactors desain can be seen in Figure 1 and Figure 2.

Figure 1. Greywater sampling process

2.4 Acclimatization

Acclimatization is carried out so that aquatic plants can adapt to the new media and environmental conditions, enabling them to maximize their pollutant absorption capacity (Alwi, 2022). The acclimatization process lasts for 7 days (Novita et al., 2022; Imron et al., 2019; Simamora, 2018). During acclimatization, water hyacinth is placed in a wetland reactor filled with fresh water and is left exposed to direct sunlight (Imron et al., 2019; Novita et al., 2022). Therefore, HFCW reactor needs to be positioned in an area with sufficient access to direct sunlight and should not be exposed to rainwater (Novita et al., 2022).

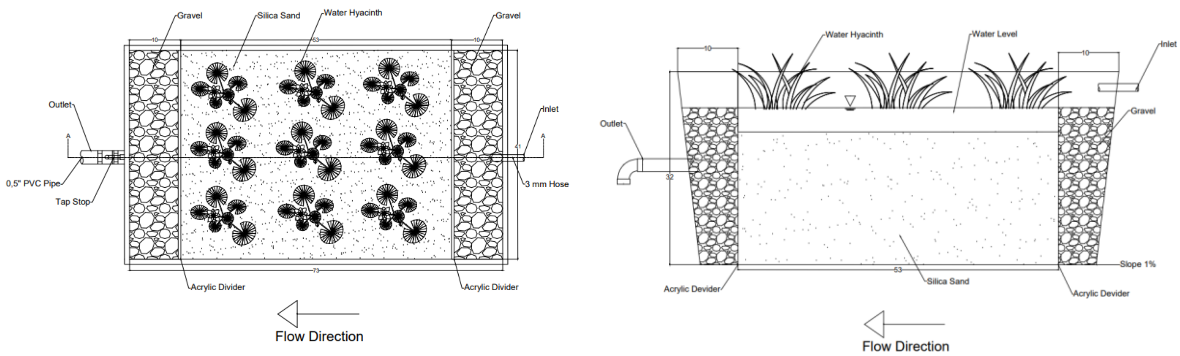


Figure 2. Top and front view of the hfcw design

2.5 Data Analysis Method

The data obtained will be analyzed to assess the efficiency of greywater treatment using the HFCW method. The calculation of treatment efficiency aims to determine the extent to which pollutants in wastewater have been reduced. This efficiency can be calculated by subtracting the concentration of influent (Co) from the concentration of effluent (Ci) in mg/L. To calculate the treatment efficiency, equation (1) can be utilized (Romadhonah and Arif, 2020).

$$E\ (\%) = \frac{C_o - C_i}{C_o} \tag{1}$$

3. Result and Discussion

The influent treatment using HFCW will be conducted in two different reactors to vary the detention time with sampling over a period of 10 days. The first reactor will have a detention time of 2 days, while the second reactor will have a detention time of 3 days (Khoirunnisa, 2022; Putra, 2018). Both reactors will receive greywater from the influent tank using a peristaltic pump with flow rates and speeds adjusted based on the 2-day and 3-day detention times. Subsequently, the greywater will flow horizontally through the inlet zone containing gravel, the treatment zone containing silica sand and water hyacinth, and the outlet zone, which also contains gravel. The HFCW reactor is equipped with pipes and valves to direct the greywater towards the effluent tank. The HFCW reactor setup can be observed in Figure 3.

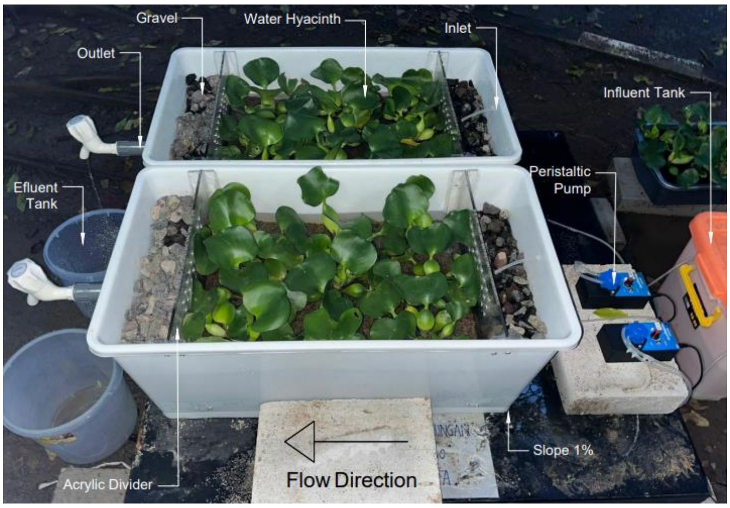


Figure 3. The HFCW reactor

3.1. Quality of Synthetic Greywater Influent

The characteristics of the synthetic greywater influent quality based on the conducted experiments can be seen in Table 3.

Table 3. The use of the synthetic greywater material brands

Parameter	Experiments			Average	Quality Standards*
	I	II	III		
pH	9.37	9.23	9	9.2	6-9
BOD (mg/L)	55	154	61	90	30
COD (mg/L)	238.48	358.79	257.31	284.86	100
TSS (mg/L)	32	53.33	29.33	38.22	30
Oil and Grease (mg/L)	1.6	7.58	6.64	5.27	5
Ammonia (mg/L)	0.217	0.53	0.351	0.37	10

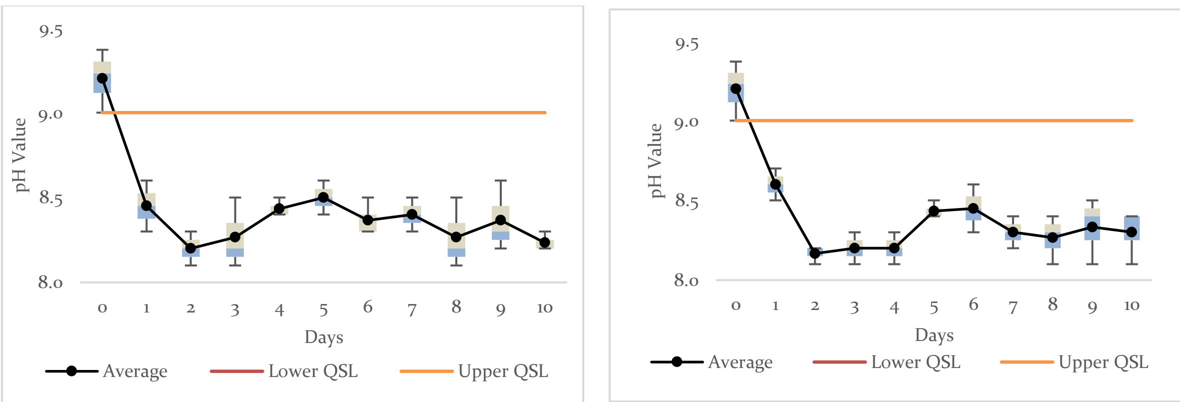
Source: (Minister of Environment and Forestry, 2016)

3.2 Reduction of Synthetic Greywater

3.2.1 Acidity Level/pH

The pH parameter was tested using a pH meter over a period of 10 days. The decrease in pH values at detention times of 2 days and 3 days can be observed in Figures 4. The decrease in pH values complies with the allowed quality standards limit (QSL) according to Minister of Environment and Forestry Regulation Number 68 of 2016, which is between 6 and 9. The high pH values of the wastewater can be easily adjusted to neutral as it passes through the water hyacinth system. This adjustment is due to the carbon dioxide (CO_2) equilibrium influenced by photosynthesis (algal respiration). Changes in pH along the water hyacinth system affect electrostatic interactions between algal particles and root surfaces, as well as sedimentation processes. If the algal particle surface and the water hyacinth root surface have different charges, they will attract each other, and the particles will be adsorbed by the roots, there by aiding the water purification process. Figure 4 illustrates a significant decrease in pH on the first and second days, which is caused by the absorption of large amounts of sparingly soluble nutrients by the water hyacinth root surfaces, acidifying the root zone by releasing H^+ in exchange for cations and releasing organic acids and CO_2 (Ajibade and Adewumi, 2017). The gradual and stable increase in pH from day three onward suggests an increase in sedimentation during the initial stages of the water hyacinth system (days one and two), as the roots operate at maximum capacity. Meanwhile, adsorption processes dominate during subsequent treatment stages (from day three onward) (Kim et al., 2004).

More specifically, the decrease in pH values is a result of the photosynthesis process. The pH value is closely related to the amount of CO_2 in water. The higher the CO_2 content in greywater, the lower the resulting pH value. In the HFCW system, water hyacinth utilizes CO_2 in the process of photosynthesis, which is then converted into monosaccharides. This process leads to an increased demand for CO_2 in greywater and a decrease in pH. CO_2 is absorbed during the photosynthesis process, leading to an increase in pH. On the other hand, in aquatic ecosystems, the respiration process carried out by all organisms and the decomposition of organic and inorganic matter by bacteria produce CO_2 in greywater. The interplay of these processes results in a pH value within the neutral range (Hartanti et al., 2014)(Hariyanti, 2016).



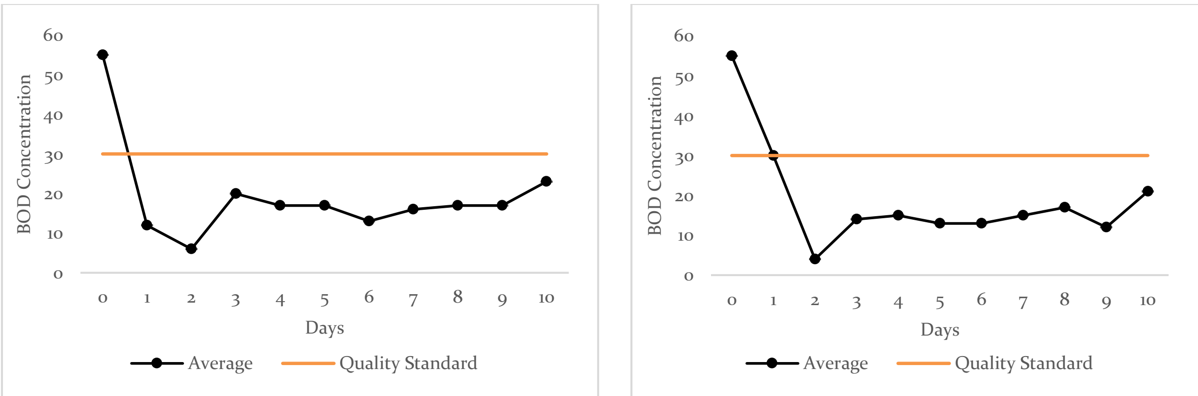
a) b)

Figure 4. Reducing pH value in HFCW a) DT 2 & b) DT 3

3.2.2 Biochemical Oxygen Demand (BOD_5)

The BOD_5 concentration in influent wastewater is 90 mg/L, thus failing to meet the established standards. After undergoing treatment using HFCW with detention times of 2 and 3 days, there is a decrease in BOD_5 concentration, as depicted in Figure 5. The most significant reduction at a detention time of 2 days occurred on the second day at 6 mg/L, while at a detention time of 3 days, it occurred on the second day at 4 mg/L. The decrease in BOD_5 concentration in the HFCW system can occur through two removal processes: physical and biological. Physical removal occurs due to the sedimentation process, which involves gravitational settling, causing coarse organic compounds in BOD_5 to accumulate on the surface of the media (Abou-Elela, 2017). This process is influenced by the gravel media in the inlet and outlet areas, which help settle and capture particulate materials contained in BOD_5 (Hidayah et al., 2018). Meanwhile, biological removal happens due to the activity of microorganisms on the roots of water hyacinth within the reactor (Kholisah and Pramitasari, 2018). The collaboration between water hyacinth and microorganisms is crucial in reducing organic content. The photosynthesis process of water hyacinth produces oxygen required by microorganisms to decompose organic matter and increase the dissolved oxygen content in water. Additionally, organic substances in domestic wastewater are absorbed by water hyacinth roots through interactions between water hyacinth molecules and organic substances in wastewater (Rahmawati and Warsito, 2020). Synergy between water hyacinth and microorganisms within the roots reduces BOD_5 content through the decomposition of organic and inorganic contaminants during phytoremediation. Reduction in BOD_5 also occurs through phytodegradation, where organic compounds in water are decomposed by microorganisms and then absorbed through water hyacinth roots, dispersed throughout the plant (Putriarti et al., 2021).

Meanwhile, the overall efficiency of BOD_5 concentration removal in HFCW with detention times of 2 days and 3 days can be seen in Figure 6. The overall efficiency of BOD_5 concentration removal in HFCW with a detention time of 2 days ranges from approximately 74-93%, while with a detention time of 3 days, it ranges from approximately 67-96%, as illustrated in Figure 8. This is in line with previous studies by Ibrahim (2020) indicating that treatment using constructed wetlands with water hyacinth as the medium achieved an overall efficiency of BOD_5 of 96-97%. The longer the detention time between wastewater and treatment using constructed wetlands with water hyacinth plants as the medium, the greater the reduction in BOD_5 levels in the wastewater (Ibrahim et al., 2020).



a) b)

Figure 5. Reducing BOD_5 concentration in HFCW a) DT 2 & b) DT 3

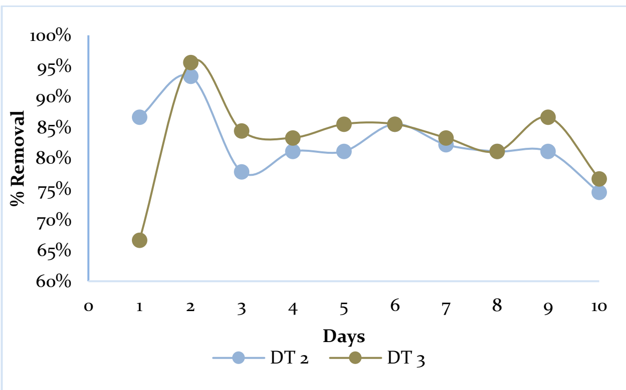


Figure 6. Efficiency of BOD_5 Removal in HFCW

3.2.3 Chemical Oxygen Demand (COD)

The concentration of COD in influent greywater is 284.86 mg/L, failing to meet the established standards. Following treatment using HFCW with detention times of 2 and 3 days, a decrease in COD concentration is observed, as depicted in Figure 7. The significant reduction in COD concentration during the growth period is attributed to fully developed plant roots and the filtration capacity of the roots, which precipitate dissolved solids and enhance the absorption of dissolved nutrients (Ghaly et al., 2005). In more detail, the decrease in COD concentration in greywater can be attributed to the water hyacinth's ability to assimilate organic matter, the root's capability to provide sufficient dissolved oxygen, and the leaf's role in photosynthesis, accelerating the decomposition of organic material (Hidayah et al., 2018). The oxygen produced by the water hyacinth root system acts as a catalyst for microbial metabolism. Moreover, previously decomposed organic matter is further broken down by microorganisms into simpler compounds that can be utilized by water hyacinth as a nutrient source. Additionally, the reduction in COD concentration can also be caused by physical processes within the media, such as gravel and silica sand, which function as absorbents, leading to sedimentation and filtration processes (Picauly, 2022). These findings are consistent with another research, demonstrating the effectiveness of gravel in precipitating dissolved particles in wastewater. The gaps within the gravel facilitate sedimentation processes, resulting in clearer wastewater. Gravel also provides a conducive environment for microbial growth, aiding in the breakdown of organic matter (Lestari et al., 2013).

Meanwhile, the overall efficiency of COD concentration removal in HFCW with detention times of 2 and 3 days is depicted in Figure 8. The overall efficiency of COD concentration removal in HFCW with a detention time of 2 days ranges from approximately 47-80%, while with a detention time of 3 days, it ranges from approximately 57-91%, as illustrated in Figure 8. The higher efficiency of COD concentration removal in HFCW with a detention time of 3 days is attributed to the longer contact time. This finding is consistent with Suprihatin's study (2014), indicating that the adsorption capacity of the media depends on the detention time of wastewater, where sufficient detention time allows for better contact between microorganisms and wastewater, resulting in improved removal efficiency (Erlita et al., 2022).

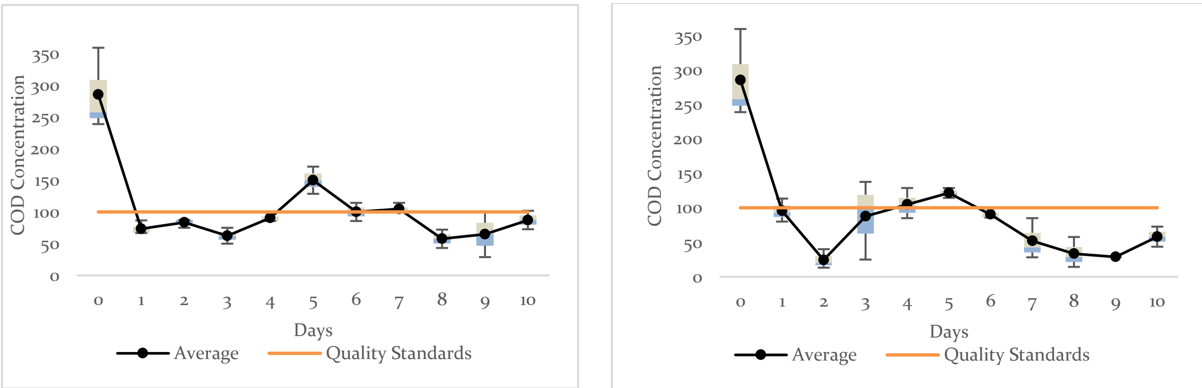


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Figure 7. Reducing COD concentration in HFCW a) DT 2 & b) DT 3

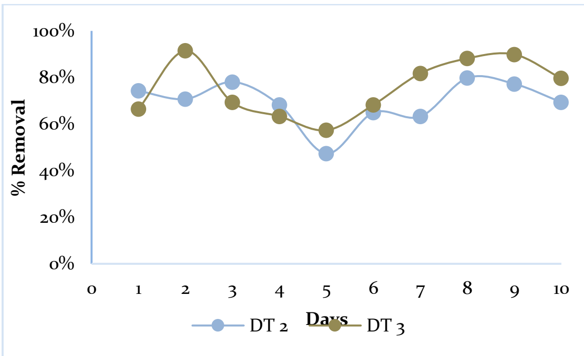


Figure 8. Efficiency of COD removal in HFCW

3.2.4 Total Suspended Solid (TSS)

Suspended solids are particles that cause water turbidity, remain undissolved, and cannot directly settle, comprising particles whose size and weight are smaller than sediments (Novita et al., 2020). The concentration of TSS in influent greywater is 38.22 mg/L, failing to meet the established standards. Following treatment using HFCW with detention times of 2 and 3 days, a decrease in TSS concentration is observed, as depicted in Figure 9. The decrease in TSS concentration occurs due to the combined performance of the media (gravel and silica sand), water hyacinth, and microorganisms in the processes of sedimentation, filtration, and adsorption (USEPA, 2000) (Hadi and Pungut, 2022). Sedimentation and filtration processes take place in the media and water hyacinth roots. The influent greywater entering through the inlet and outlet zones containing gravel, as well as the processing zone containing silica sand and fibrous water hyacinth roots, causes TSS content to be filtered, settled, and trapped in the media pores. Additionally, an adsorption process occurs on the water hyacinth roots where contaminants are attracted and accumulated around the roots, which are later decomposed by microorganisms (Picauly, 2022).

Overall, the efficiency of TSS concentration removal in HFCW with a detention time of 2 days ranges from approximately 55-97%, while with a detention time of 3 days, it ranges from approximately 63-97%, as illustrated in Figure 10. The overall percentage efficiency for the best TSS concentration removal occurs at a detention time of 3 days. This finding is consistent with research indicating that longer detention times lead to better absorption processes (Suprihatin, 2014). However, as observed in Figure 10, the overall efficiency in TSS concentration removal tends to be unstable. This instability may be attributed to media filter clogging by both suspended solids and organic matter. Therefore, maintenance steps are necessary both before the wastewater enters the reactor, such as through sedimentation processes, and after filtration processes, such as filter media cleaning (Ilmannafian et al., 2020).

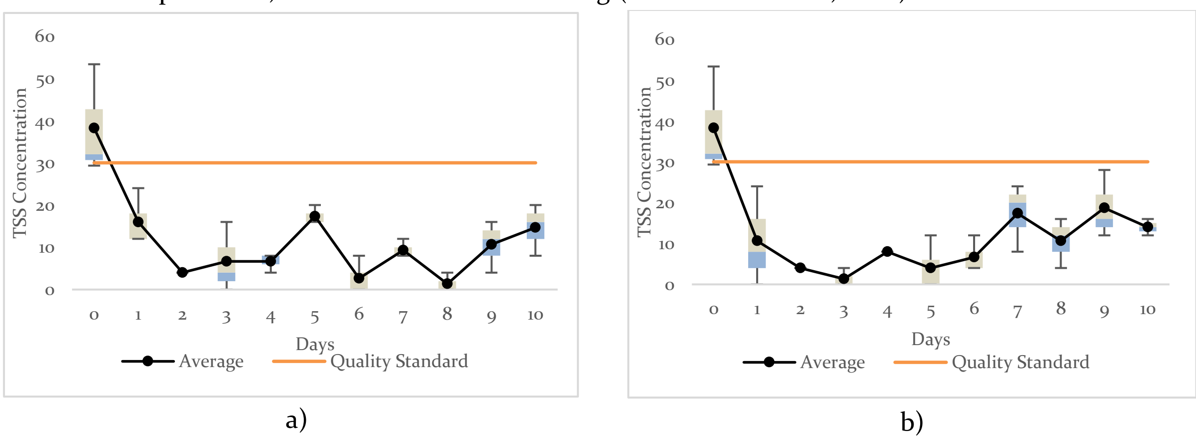


Figure 9. Reducing TSS concentration in HFCW a) DT 2 & b) DT 3

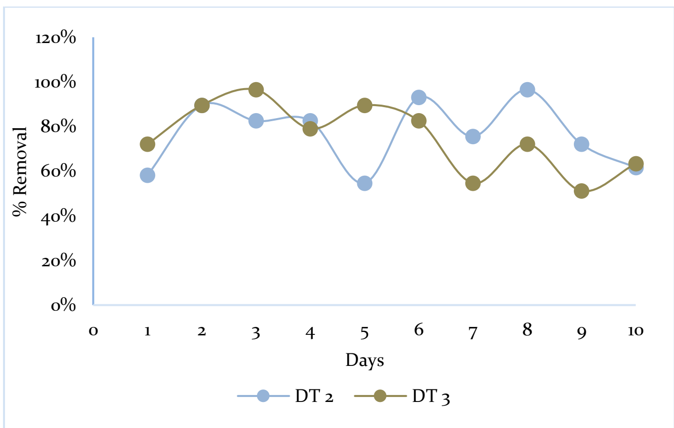


Figure 10. Efficiency of TSS removal in HFCW

3.2.5 Oil and Grease

The concentration of oil and grease in the influent greywater exceeds the quality standard, which is 5.27 mg/L. Following treatment using HFCW with detention times of 2 and 3 days, a decrease in oil and grease concentration is observed, and it has met the quality standard, as depicted in Figure 11. The reduction of oil and grease concentration in the HFCW system occurs due to several processes. When influent is introduced, there is interaction between greywater and the leaves and roots of water hyacinth, causing oil and grease particles to adhere to the leaves and roots. Additionally, the roots and tissues of water hyacinth create an environment conducive to the growth of decomposer microorganisms. These microorganisms are responsible for breaking down oil and grease into simpler compounds. The reduction in oil and grease concentration is also influenced by the mechanisms of phytoaccumulation and rhizodegradation, which can draw and degrade contaminants around the roots of water hyacinth (Putra, 2018). The overall efficiency of oil and grease concentration removal in HFCW with a detention time of 2 days ranges approximately from 50-94%, while with a detention time of 3 days, it ranges approximately from 11-100%, as illustrated in Figure 12. Fluctuations in the reduction of oil and grease concentration are also caused by the fact that initially, the contaminants are present on the surface of greywater and then accumulate in the influent tank when the greywater has been depleted. This results in an unstable level of contaminants entering the HFCW, and there are periods where the oil and grease content may increase (Perdana et al., 2020).

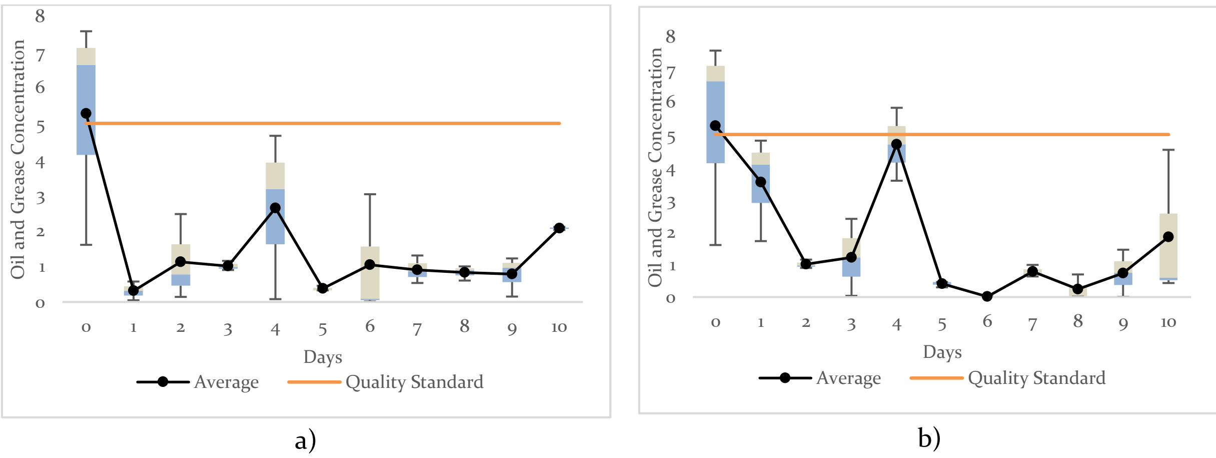


Figure 11. Reducing oil & grease concentration in HFCW a) DT 2 & b) DT 3

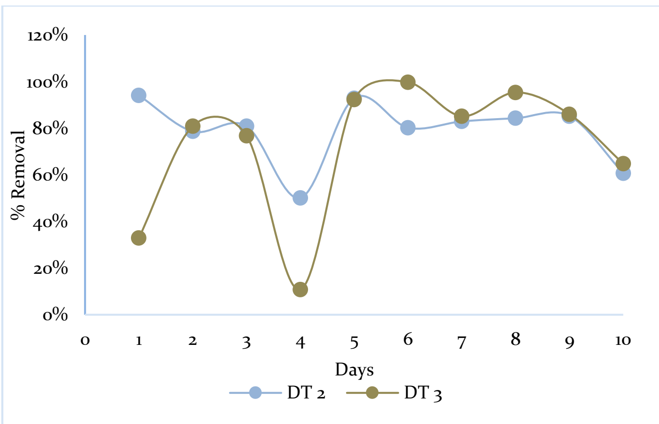
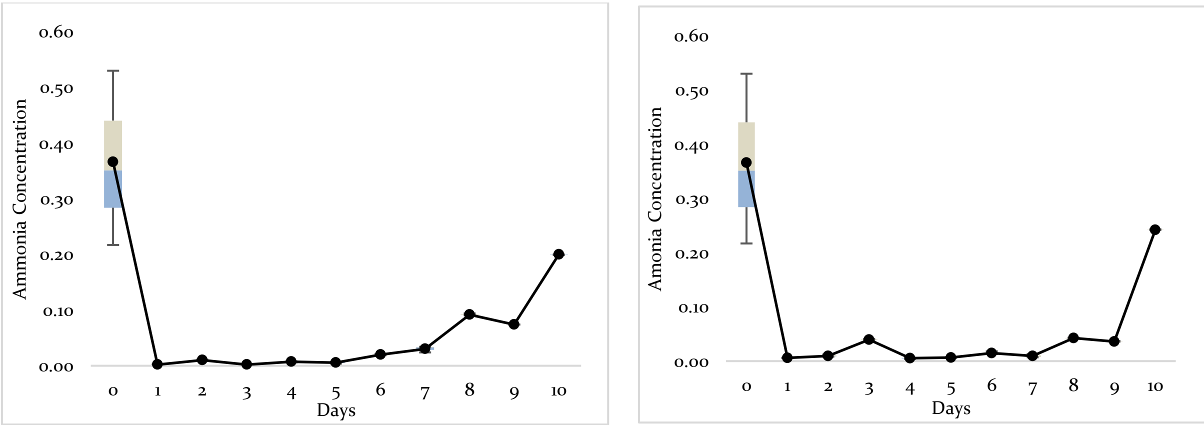


Figure 12. Efficiency of oil & grease removal in HFCW

3.2.6 Ammonia

Ammonia in surface waters primarily originates from domestic waste, particularly human excretions like urine and feces, as well as through the biochemical oxidation of organic matter by microorganisms (Romadhony and Sutrisno, 2017). However, the synthetic greywater utilized in this study lacks materials containing urine and feces, resulting in relatively low ammonia levels. The ammonia concentration in the influent, at 0.217 mg/L, meets the defined quality standards. On the first day, with detention times of 2 and 3 days, there was a noticeable decrease in ammonia concentration, as depicted in Figure 13. This ammonia reduction can occur in wastewater through ammonia volatilization, ammonification, immobilization as nitrogen compounds by microorganisms, and plant root activity (Ratnawati and Talarima, 2017). Microorganisms actively decompose organic material adhering to the surface of water hyacinth roots. Before decomposition, organic matter is filtered by water hyacinth roots, facilitating microbial decomposition (Prastiwi, 2015). These microorganisms, including Nitrosomonas and Nitrobacter, convert ammonia into nitrite and subsequently into nitrate, serving as a growth source for water hyacinth (Hastuti, 2011). Furthermore, water hyacinth roots supply oxygen through the rhizosphere, supporting aerobic growth and reducing ammonia concentration in treatment systems (Romadhony, 2013).

The overall efficiency of ammonia concentration removal in HFCW with a detention time of 2 days ranges approximately from 46-99%, while with a detention time of 3 days, it ranges approximately from 35-99%, as illustrated in Figure 14. There was a decrease in efficiency on the tenth day, observed for both detention times of 2 and 3 days. This decrease is likely attributable to the non-absorption of ammonia by plants due to plant death and decomposition, resulting in ammonification. Organic matter in wastewater decomposes with microbial assistance, thereby generating new ammonia sources (Maddusa, 2018). Nonetheless, despite this increase, the ammonia concentration remains within quality standards.



a) b)

Figure 13. Reducing ammonia concentration in HFCW a) DT 2 & b) DT 3

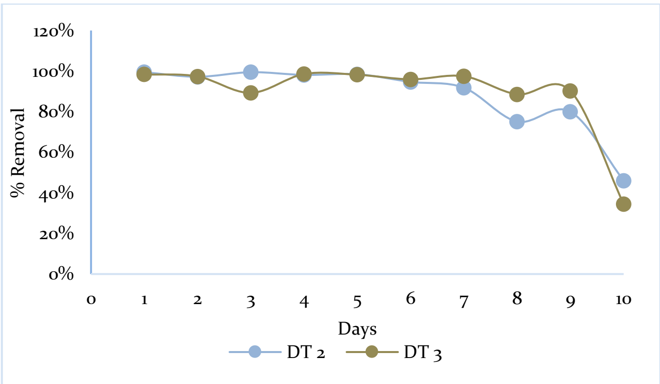


Figure 14. Efficiency of ammonia removal in HFCW

4. Conclusion

The efficiency of the HFCW unit's performance in a 2-day detention time for each parameter ranges from BOD_5 74.44%-93.33%, COD 47.34%-79.76%, TSS 54.65%-96.51%, oil and grease 50.10%-84.12%, and ammonia 46.04%-99.46%. Meanwhile, the efficiency of the HFCW unit's performance at a 3-day detention time for each parameter falls within the range of BOD_5 66.67%-95.56%, COD 57.37%-91.42%, TSS 51.16%-96.51%, oil and grease 10.81%-99.75%, and ammonia 34.50%-98.56%. The effluent quality for parameters such as pH, BOD_5, TSS, oil & grease, and ammonia has met the standards set by the Minister of Environment and Forestry Regulation Number 68 of 2016 regarding Domestic Wastewater Quality Standards. However, concerning COD, the effluent quality did not meet the standards on the 5th and 7th days.

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