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Performance of Horizontal Subsurface Flow Constructed Wetland in Domestic Wastewater Treatment Using Different Media

Elizabet Matolisi[1], Nurhayati Damiri[1,2*], Momon Sodik Imanudin[3], Hamzah Hasyim[4]

[1] Study Program of Environmental Science, Sriwijaya University, Jl. Raya Palembang-Prabumulih Km. 32, North Indralaya, Ogan Ilir, 30662, South Sumatera, Indonesia

[2] Departmentof Pest and Disease, Faculty of Agriculture, Sriwijaya Universitas, Jl. Raya Palembang-Prabumulih Km. 32, Indralaya, Ogan Ilir, 30662, South Sumatra, Indonesian

[3] Department of Soil Science, Faculty of Agriculture, Sriwijaya University, Jl. Raya Palembang-Prabumulih Km. 32, Indralaya, Ogan Ilir, 30662, South Sumatra, Indonesian

[4] Faculty of Public Health, Sriwijaya University, Indralaya, Indonesia

* Corresponding author's e-mail: nurhayati@fp.unsri.ac.id

ABSTRACT

Water and land pollution is a major environmental problem. One treatment system that is suitable for use in many parts of the world is wastewater treatment from artificial wetlands. The sample source came from the Aur River, Palembang City. The vegetation used consists of water spinach, water hyacinth and lotus. This research aims to determine the influence of constracted wetlands (CW); know the differences in length of treatment; determine the differences in the effectiveness of kale, water hyacinth and lotus vegetation, and calculate the percentage reduction in concentration after treatment. The results of the research showed that the results of the analysis of the influence before and after the CW intervention on three vegetation on the parameters BOD, COD, DO, oil and fat, detergent, ammonia, and total coliform obtained the same P value, namely 0.000, meaning there was a significant influence on concentration before and after CW intervention was carried out. The results of the analysis of differences in concentration in the three vegetation groups in week -1, week -2, week -3 and week -4 on the parameters BOD, COD, DO, oil and fat, detergent and ammonia obtained the same P value, namely 0.000 (< 0.05) means that there is a significant difference in concentration after the CW intervention, while the total coliform in the three vegetation groups was found to be kale vegetation 0.979 (> 0.05), water hyacinth vegetation 0.972 (> 0.05) and lotus vegetation 0.971 (> 0, 05) means there is no significant difference in concentration. The results of the analysis of kale, water hyacinth and lotus vegetation of the horizontal CW type showed that the P value of BOD, COD and DO was the same, namely 0.000, (< 0.05) meaning there was a difference, while the parameters oil and fat = 0.888, detergent = 0.945 , ammonia = 0.902 and total coliform = 0.977 (> 0.05) meaning there is no difference. Apart from that, there was also a decrease in concentration before and after the constracted wetlands intervention. Each vegetation group. In water spinach vegetation, it is between 86.36–562.50%, water hyacinth is between 91.30–737.50%, and lotus is between 91.30–737.50%.

Keywords: artificial wetlands, constracted wetlands, CW horizontal, vegetation, contaminants, pollutants.

INTRODUCTION

Polluted water and land are major environmental problems (Khare & Lal, 2017). Today, water is a major vulnerability throughout the world. As in the Middle East, wastewater originating from industry and cities amounts to 23 billion m^3 every year, while only 6.96% of waste is reused (Elmeligy et al., 2023). Water pollution is a problem in developing countries, including Indonesia. As society grows, so does the amount of household and industrial waste (Huynh et al., 2021), especially in densely populated areas, such as Palembang City. The culture of building houses on the banks of rivers. The existence of these houses creates sanitation problems because household activity waste is discharged directly into the river without waste treatment (Oktriyedi et al., 2022). One treatment system that is suitable for use in many parts of the world is artificial wetland wastewater treatment (Anil et al., 2023). Artificial wetlands have been widely implemented on both small and large scales. These wetlands are very effective in reducing pollutants (Arliyani et al., 2021). This artificial wetland is a nature-based wastewater treatment technology that is very easy to build, operate and environmentally friendly (Bedu-Addo et al., 2023). This artificial wetland is very effective in reducing pollutants to a greater extent with vegetation than without vegetation (Zhu et al., 2018). There are three main types of artificial wetlands, namely water surface artificial wetlands, vertical subsurface flow, and horizontal subsurface flow artificial wetlands (Hassan et al., 2021). Artificial wetland media that can be used include bagasse, marble chips, iron powder, sylhet sand, soil, rice husks, cocopeat, bricks, stones, clay, gravel, sand, sawdust, coal, etc. (Parde et al., 2021).

Constracted wetlands (CW) was carried out by Mburu et al. (2013) but only carried out measurements on the parameters COD, BOD_5, TSS, and SO_4^{2-} -S using the horizontally fed subsurface-flow constructed wetland (HSFCWs) type and only used gravel as the substrate. They revealed the successful performance of wetlands in reducing COD, BOD_5, TSS, and SO_4^{2-}-S concentrations (Mburu et al., 2013). There are several differences between the current study and previous studies, namely: more parameters such as: BOD, COD, DO, ammonia (Oktriyedi et al., 2021) oil and fat, detergent, and total coliform parameters; different substrate materials, such as: a mixture of gravel and sand, charcoal, rice husks, mud; and using vegetation, such as: water spinach, water hyacinth and lotus. This research aims to determine the influence of constracted wetlands; know the differences in length of treatment; determine the differences in the effectiveness of kale, water hyacinth and lotus vegetation, and calculate the percentage reduction in concentration after treatment.

METHODS AND MATERIALS

Study area

The sample source came from the Aur River, Palembang City. Samples were taken at 3 stations, namely station 1 in the upstream section (ordinate point -2.998377, 104.771467), station 2 in the middle (ordinate point -2.995815, 104.768369) and station 3 in the downstream section (ordinate point -2.991283, 104.766674).

Constructed wetland unit

Laboratory scale constracted wetlands are carried out in all boxes. The box measures 100 cm top length, 70 cm bottom length, 40 cm height and 40 cm width. The box is given a plastic base so that it does not leak when holding waste water. Apart from that, there is an inlet

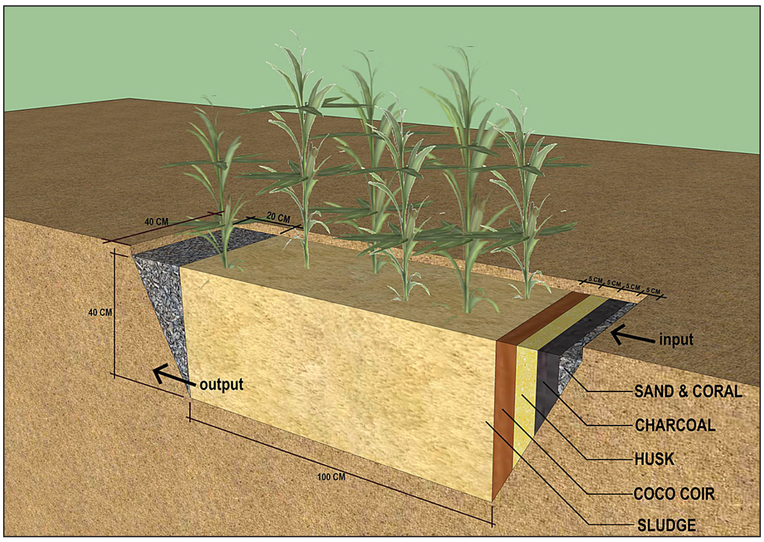

Figure 1. Constracted wetlands desing

pipe to enter the waste water and an outlet pipe to remove the waste water from the constructed wetlands. Constracted wetlands box models were designed based on EPA and CPCB design manuals. The wetland model design is in accordance with Darcy's law (Sudarsan et al., 2015). Darcy's law is one that is commonly used to investigate water flow through horizontal layers of sand that will be used for water infiltration (Fiorillo et al., 2022). The materials used for each layer are a mixture of gravel and sand, charcoal, rice husks, coconut fiber, mud and vegetation (Swarnakar et al., 2022). Wastewater flows below the top surface around the roots of vegetation. Wastewater flows horizontally through the underlying substrate where it comes into contact with a mixture of facultative microbes. Wetlands constructed below the ground surface increase the potential for removing wastewater pollution (Swarnakar et al., 2022). Constracted wetlands in the horizontal type, the first layer is ½ split stone measuring 20–30 mm and mixed with sand measuring ± 0.4 mm with a thickness of 5 cm. the second layer is charcoal measuring 20–50 mm and 5 cm thick. The third layer is rice husk 5 cm thick. The fourth layer is coconut fiber 5 cm thick. The fifth layer is mud 60 cm thick and vegetation is planted. The last layer of material that is added is split stone ½ measuring 20–30 mm and mixed with sand measuring ± 0.4 mm, 20 cm thick (Murniati & Muljadi, 2013). Each layer is given a wooden board border that has been perforated. Sand is used as the main substrate material. Gravel is used in the inlet and outlet zones to distribute influent wastewater evenly and collect treated wastewater (Tan et al., 2020). More details are shown in Figure 1.

Wetland vegetation

Wetland plants require optimal environmental conditions to grow well and work optimally (Thalla et al., 2019).

Spinach

Water spinach (*Ipomoea aquatica* Forsskal) is characterized by hollow stems, arrowhead-shaped leaves that are about 15 cm long and 2 cm wide, grows up to 3 cm and floats in polluted waters (Lin et al., 2012). Water spinach has been successfully used for heavy metal adsorption, organic pollution adsorption, cadmium and carotenoid phytoextraction, and cultivation wastewater treatment (Zhang et al., 2014).

Water hyacinth

Water hyacinth grows and develops very quickly in freshwater environments (El-Chaghaby et al., 2022) and is vegetation that has a high ability to absorb phosphorus and nitrate from the water column (Varasteh et al., 2021). Apart from that, water hyacinth can also absorb carbon dioxide and release oxygen. as well as removing suspended substances from water bodies (Wang, 2021).

Lotus

Lotus (*N. Nucifera*) contributes to eliminating pollutants. Lotus has leaves, stems and rhizomes for bacteria to attach to and grow (Abd Rasid et al., 2019). Lotus roots can reduce nitrogen and phosphorus content and inhibit the growth of Microcystis aeruginosa (Yang et al., 2022).

Operational and analytical procedures

The horizontal subsurface flow artificial wetland was observed for 4 weeks. All wastewater samples were taken manually. Treatment was carried out on 3 vegetation groups, namely water spinach, water hyacinth and lotus vegetation. Each group consists of 6 samples. All wastewater and treated samples were analyzed according to the standard method for water and wastewater examination (Thalla et al., 2019). Data from the intervention were compared with waste water quality standards and water classifications set by the government (Governor of South Sumatra, 2005) especially regarding effluent to determine the effectiveness of CWs (Rahmadyanti & Audina, 2020).

Determination of contaminant removal

Parameters are analyzed on the inlet and outlet systems. The percentage of contaminant reduction from the measurement results is calculated. The formula used to calculate contaminant reduction is in the equation below (Vazquez et al., 2023):

$$\%R = \frac{CE - CS}{CE} \times 100 \quad (1)$$

where: R – removal, CE – entrance concentration, CS – exit concentration.

Statistical analysis

Statistical analysis uses the dependent t test and anova test with a significance level of 5%. Data analysis was carried out using SPSS 25.

RESULTS AND DISCUSSION

Treatment was carried out on 3 vegetation, namely water hyacinth vegetation, water hyacinth vegetation, and lotus vegetation. Each group consists of 6 samples. So the total treatment was 18 units. The treatment process can be seen in Figure 2. Before being added to waste water, the media and vegetation were prepared for 1 week. After one week, the roots and stems of the vegetation have grown and developed. The first three days, the leaves on all vegetation looked yellowish and the stems looked black. Starting from the fourth day to the seventh day, the leaves begin to turn green and the diameter of the leaves and stems

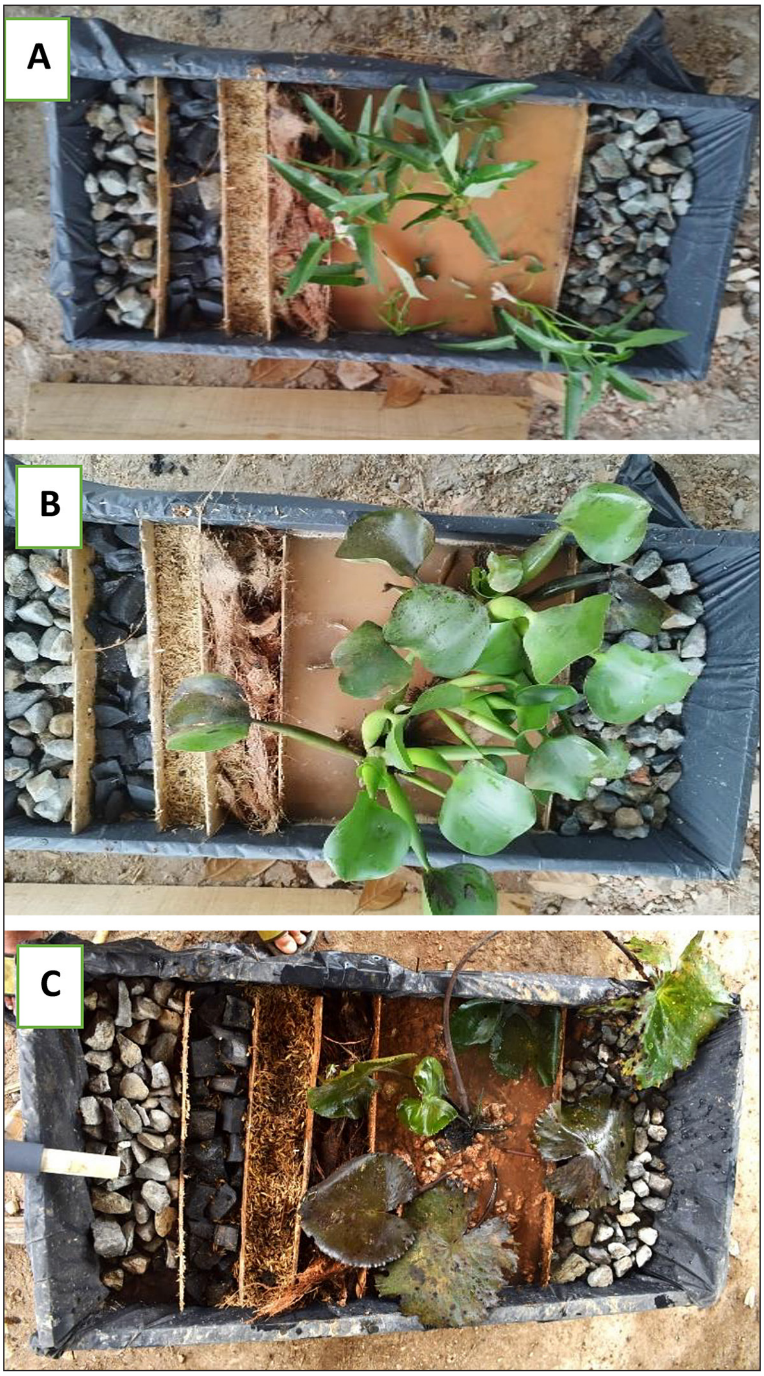

Figure 2. Constracted wetlands (a) spinach vegetation; (b) water hyacinth vegetation; (c) lotus vegetation

is visible, but the stems still appear black. Leaf and stem development began to return to normal during the second week of observation. In the third week, you can see that the diameter of the leaves and stems has reached its maximum until the color of the leaves on each vegetation is completely green. Furthermore, in the fourth week of observation, the color of the vegetation leaves appeared bright green, the diameter of the leaves was getting bigger, the diameter of the leaves and stems were growing. The water already looks clear. The results of the analysis consist of the influence of constracted wetlands; differences in length of treatment; differences in the effectiveness of spinach, water hyacinth and lotus vegetation, and calculating the percentage reduction in concentration after treatment.

Effect of CW on concentration before and after intervention

In the concentration effect test before and after the CW intervention, 3 vegetation was carried out on the parameters BOD, COD, DO, oil and fat, detergent, ammonia, and total coliform. The results are presented in Table 1. The measurement results for BOD, COD, DO and ammonia after the intervention decreased to below the quality standard in all vegetation, while oils and fats, detergents and total coliforms experienced a decrease but were still above the quality standard. Quality standards refer to South Sumatra Governor Regulation No. 17 of 2005 (Governor of South Sumatra, 2005). The results of the analysis of the influence before and after the CW intervention on the three vegetation on the parameters BOD, COD, DO, Oil and fat, detergent, ammonia, and total coliform obtained the same P value, namely 0.000, meaning there is a significant influence of concentration before and after CW intervention. Constracted wetlands is a technology that has the potential to produce bioelectricity and wastewater treatment. Factors that influence performance include the materials used, vegetation, configuration design, and process form (Guadarrama-Pérez et al., 2019). Constracted wetlands can reduce the quality of polluted water even with high waste concentrations and excessive use of solid/organic materials (Ergaieg et al., 2021). In the constracted wetlands process, organic nitrogen is converted into nitrate (NO_3^-) under aerobic and anaerobic conditions, while ammonia nitrogen (NH_3-N) is removed through hydrophyte absorption, evaporation, nitrification, and denitrification (Bedu-Addo et al., 2023). This system is categorized as a nature-based water treatment system that uses natural processes and components (El-meligy et al., 2023). Constracted wetlands are also a cost-effective and environmentally friendly technology for remediation of soil and wastewater contaminated with toxic substances (Khare & Lal, 2017), besides increasing biodiversity and improving the landscape, environment and local ecosystem (Huynh et al., 2021). The roots of the vegetation used can hold the ecosystem in water and increase the conversion of natural wetlands due to agriculture and urban development. Apart from that, it functions as a flood control center and produces food and fiber (Anil et al., 2023).

Constracted wetlands can be concluded as a technology that can be used in the waste water management process which is economical and environmentally friendly. It is also proven that the proposed HFCW is a viable option for primary and secondary wastewater treatment. Oxygen dynamics in HFCW are regulated by wetland vegetation, and influent pre-aeration has little influence on treatment performance (Tan et al., 2020). This technology is very suitable for application in slum areas and housing complexes. Apart from that, this technology is also cost-effective so it is possible to apply it anywhere. In the future, no one will dispose of untreated domestic wastewater into freshwater resources due to its low maintenance requirements, ease of operation, and good large-quantity pollutant removal performance (Polepaka et al., 2021).

Comparison of concentrations based on length of treatment

In the comparative test of the concentration parameters of BOD, COD, DO, oil and fat, detergent, ammonia, and total coliform week -1, week -2, week -3 and week -4 on 3 vegetation. The results are obtained in Table 2. Based on Table 2, The results of observations on BOD, COD, DO and ammonia decreased to below the quality standard in the week-4 in all vegetation, while oils and fats, detergents and total coliforms experienced a decrease but were still above the quality standard in the week-4 of observation. Quality standards refer to South Sumatra Governor Regulation No. 17 of 2005 (Governor of South Sumatra, 2005). The results of the analysis of differences in concentration in the three vegetation groups in week -1, week -2, week -3

Table 1. Effect of concentration of several parameters before and after CW intervention on water spinach, water hyacinth and lotus vegetation

Vegetation	Parameter	Units	Std	Variables	Mean	n	SD ±	SE	P Value
Spinach	BOD	mg/L	3	Before	35.167	6	0.983	0.401	0.000
				After	3.000	6	0.000	0.000	
	COD	mg/L	25	Before	148.833	6	8.400	3.429	0.000
				After	20.333	6	0.516	0.211	
	DO	mg/L	4	Before	0.753	6	0.042	0.017	0.000
				After	5.333	6	0.516	0.211	
	Oil and fat	mg/L	0.017	Before	14.333	6	1.366	0.558	0.000
				After	0.683	6	0.041	0.017	
	Detergent	mg/L	0.003	Before	2.500	6	0.548	0.224	0.000
				After	0.217	6	0.010	0.004	
	Ammonia	mg/L	0.5	Before	7.969	6	0.026	0.011	0.000
				After	0.466	6	0.043	0.018	
	Total Coliform	Total/100	5×10^3	Before	5.3×10^6	6	1.2×10^4	4.9×10^3	0.000
				After	2.2×10^4	6	2×10^4	8×10^3	
Water hyacinth	BOD	mg/L	3	Before	35.167	6	0.983	0.401	0.000
				After	2.000	6	0.000	0.000	
	COD	mg/L	25	Before	148.833	6	8.400	3.429	0.000
				After	6.000	6	0.000	0.000	
	DO	mg/L	4	Before	0.753	6	0.042	0.017	0.000
				After	6.667	6	0.516	0.211	
	Oil and fat	mg/L	0.017	Before	14.333	6	1.366	0.558	0.000
				After	0.683	6	0.041	0.017	
	Detergent	mg/L	0.003	Before	2.333	6	0.516	0.211	0.000
				After	0.217	6	0.010	0.004	
	Ammonia	mg/L	0.5	Before	7.969	6	0.026	0.011	0.000
				After	0.437	6	0.042	0.017	
	Total Coliform	Total/100	5×10^3	Before	5.3×10^6	6	2.1×10^4	4.9×10^3	0.000
				After	2.1×10^4	6	1.8×10^4	7.4×10^3	
Lotus	BOD	mg/L	3	Before	35.167	6	0.983	0.401	0.000
				After	2.000	6	0.000	0.000	
	COD	mg/L	25	Before	148.833	6	8.400	3.429	0.000
				After	6.000	6	0.000	0.000	
	DO	mg/L	4	Before	0.753	6	0.042	0.017	0.000
				After	6.667	6	0.516	0.211	
	Oil and fat	mg/L	0.017	Before	14.333	6	1.366	0.558	0.000
				After	0.683	6	0.041	0.017	
	Detergent	mg/L	0.003	Before	2.333	6	0.516	0.211	0.000
				After	0.217	6	0.010	0.004	
	Ammonia	mg/L	0.5	Before	7.969	6	0.026	0.011	0.000
				After	0.437	6	0.042	0.017	
	Total Coliform	Total/100	5×10^3	Before	5.3×10^6	6	1.2×10^4	4.9×10^3	0.000
				After	2.1×10^4	6	2×10^4	7.4×10^3	

Note: std – standar quality, n – number of samples, SD ± – maximum and minimum standard deviation, SE – standard error.

and week -4 on the parameters BOD, COD, DO, oil and fat, detergent and ammonia obtained the same P value, namely 0.000 (< 0.05) meaning that there was a significant difference in concentration in week -1, week -2, week -3 and week -4 after the CW intervention, while the total coliform in the three vegetation groups was obtained for water spinach vegetation of 0.979 (> 0.05), water hyacinth vegetation 0.972 (> 0.05) and lotus vegetation 0.971 (> 0.05) meaning there was no significant difference in concentration at week -1, week -2, week -3 and week -4 after the CW intervention. Apart from that, it was also found that in week -4 this technology could reduce the concentration of BOD, COD, DO, oil and fat, detergent and Ammonia parameters below the quality standard. Wetlands constructed below the ground surface increase the potential for removing polluted water (Swarnakar et al., 2022) Nitrogen declines in as little as three or four days, with longer periods allowing for greater declines (Merino-Solís et al., 2015). Retention influences the process of reducing waste levels. Artificial wetland systems reduce organic matter concentrations. This occurs due to the mechanisms of microorganisms and plant activity. The oxidation process occurs through aerobic bacteria that grow around the plant's rhizosphere (Wasita et al., 2019). In general, the NH_4^+-N removal percentage increased with hydraulic retention time. Organic matter experienced the largest decrease on day 7 in all CW. Polyculture showed better concentration reduction efficiency compared to monoculture or control without vegetation. NH_4^+-N removal reached 98.7% within 5 days (Zhu et al., 2018).

Table 2. Differences in concentrations of several parameters in week -1 to week -4 in water spinach, water water hyacinth and lotus vegetation

Vegetation	Parameter	Units	Std	Variables	Mean	n	SD ±	SE	P Value
Spinach	BOD	mg/L	3	Week -1	6	8.667	0.516	0.211	0.000
				Week -2	6	6.833	0.753	0.307	
				Week -3	6	5.000	0.894	0.365	
				Week -4	6	3.000	0.000	0.000	
				Total	24	5.875	2.232	0.456	
	COD	mg/L	25	Week -1	6	108.500	2.950	1.204	0.000
				Week -2	6	59.333	3.077	1.256	
				Week -3	6	39.667	1.033	0.422	
				Week -4	6	20.333	0.516	0.211	
				Total	24	56.958	33.566	6.852	
	DO	mg/L	4	Week -1	6	1.910	0.020	0.008	0.000
				Week -2	6	2.543	0.128	0.052	
				Week -3	6	3.217	0.248	0.101	
				Week -4	6	5.333	0.516	0.211	
				Total	24	3.251	1.344	0.274	
	Oil and fat	mg/L	0.017	Week -1	6	299.667	10.033	4.096	0.000
				Week -2	6	148.333	7.367	3.007	
				Week -3	6	53.333	5.538	2.261	
				Week -4	6	14.333	1.366	0.558	
				Total	24	128.917	112.518	22.968	
	Detergent	mg/L	0003	Week -1	6	84.833	8.134	3.321	0.000
				Week -2	6	34.500	7.662	3.128	
				Week -3	6	7.000	2.757	1.125	
				Week -4	6	2.500	0.548	0.224	
				Total	24	32.208	33.892	6.918	
	Ammonia	mg/L	0.5	Week -1	6	5.894	0.108	0.044	0.000
				Week -2	6	3.335	0.191	0.078	
				Week -3	6	1.128	0.044	0.018	
				Week -4	6	0.466	0.043	0.018	
				Total	24	2.706	2.174	0.444	
	Total Coliform	Total/100	$5 \cdot 10^3$	Week -1	6	$2.7 \cdot 10^4$	$2.1 \cdot 10^4$	$8.6 \cdot 10^3$	0.979
				Week -2	6	$2.5 \cdot 10^4$	$2.1 \cdot 10^4$	$8.5 \cdot 10^3$	
				Week -3	6	$2.3 \cdot 10^4$	$2 \cdot 10^4$	$8.3 \cdot 10^3$	
				Week -4	6	$2.1 \cdot 10^4$	$2 \cdot 10^4$	$8 \cdot 10^3$	
				Total	24	$2.4 \cdot 10^4$	$1.9 \cdot 10^4$	$3.9 \cdot 10^3$	

Table 2. Cont.

Water hyacinth	BOD	mg/L	3	Week -1	6	4.000	0.000	0.000	0.000
				Week -2	6	2.333	0.516	0.211	
				Week -3	6	2.000	0.000	0.000	
				Week -4	6	2.000	0.000	0.000	
				Total	24	2.583	0.881	0.180	
	COD	mg/L	25	Week -1	6	6.333	0.516	0.211	0.206
				Week -2	6	6.333	0.516	0.211	
				Week -3	6	6.000	0.000	0.000	
				Week -4	6	6.000	0.000	0.000	
				Total	24	6.167	0.381	0.078	
	DO	mg/L	4	Week -1	6	4.340	0.278	0.114	0.000
				Week -2	6	5.633	0.493	0.201	
				Week -3	6	6.000	0.000	0.000	
				Week -4	6	6.667	0.516	0.211	
				Total	24	5.660	0.936	0.191	
	Oil and fat	mg/L	0.017	Week -1	6	283.833	11.286	4.607	0.000
				Week -2	6	132.667	7.711	3.148	
				Week -3	6	35.667	5.465	2.231	
				Week -4	6	14.333	1.366	0.558	
				Total	24	116.625	108.847	22.218	
	Detergent	mg/L	0.003	Week -1	6	79.167	8.612	3.516	0.000
				Week -2	6	32.167	5.269	2.151	
				Week -3	6	6.000	2.683	1.095	
				Week -4	6	2.333	0.516	0.211	
				Total	24	29.917	31.711	6.473	
	Ammonia	mg/L	0.5	Week -1	6	5.372	0.109	0.044	0.000
				Week -2	6	3.078	0.125	0.051	
				Week -3	6	0.954	0.180	0.074	
				Week -4	6	0.437	0.042	0.017	
				Total	24	2.460	1.996	0.407	
	Total Coliform	Total/100	$5 \cdot 10^3$	Week -1	6	$2.6 \cdot 10^4$	$2.1 \cdot 10^4$	$8.4 \cdot 10^3$	0.972
				Week -2	6	$2.4 \cdot 10^4$	$2 \cdot 10^4$	$8.1 \cdot 10^3$	
				Week -3	6	$2.2 \cdot 10^4$	$1.9 \cdot 10^4$	$7.6 \cdot 10^3$	
				Week -4	6	$2.1 \cdot 10^4$	$1.8 \cdot 10^4$	$7.4 \cdot 10^3$	
				Total	24	$2.3 \cdot 10^4$	$1.8 \cdot 10^4$	$3.7 \cdot 10^3$	

Comparison of CW vegetation types to concentrations

In the comparative analysis of the concentration parameters of BOD, COD, DO, oil and fat, detergent, ammonia, and total coliform, spinach, water hyacinth and lotus vegetation in the horizontal CW type. The results are presented in Table 3. Based on Table 3, The results of observations on BOD, COD, DO and ammonia decreased to below the quality standard in water hyacinth vegetation, while oil and fat, detergent and total coliforms were relatively the same in all vegetation. Quality standards refer to South Sumatra Governor Regulation No. 17 of 2005 (Governor of South Sumatra, 2005). The results of the analysis of kale, water hyacinth and lotus vegetation of the horizontal CW type show that the P value of BOD, COD and DO is the same, namely 0.000, (< 0.05) meaning that there are differences in the concentration of the parameters BOD, COD, DO, kale vegetation, water hyacinth and lotus vegetation, while the parameters oil and fat = 0.888, detergent = 0.945, ammonia = 0.902 and total coliform = 0.977 (> 0.05) meaning there is no difference in the concentration of the parameters oil and fat, detergent, ammonia, and total coliforms of kale, water hyacinth and lotus vegetation.

Some plants are capable of not only removing contaminants but converting safe side contaminants. This occurs due to degradation caused by the release of certain enzymes, root exudates, and the buildup of organic carbon in the soil. Rhizofiltration is a process where dissolved heavy metals are transferred from water to the roots and leaves of plants (Hassan et al., 2021). Microbiology in roots is an activity of biological degradation mechanisms. Plant roots increase the density and activity of microbes provided by the root surface for microbial growth (Wasita et

Table 2. Cont.

Lotus	BOD	mg/L	3	Week -1	6	10.000	0.894	0.365	0.000
				Week -2	6	7.833	0.983	0.401	
				Week -3	6	5.667	0.817	0.333	
				Week -4	6	4.000	0.000	0.000	
				Total	24	6.875	2.419	0.494	
	COD	mg/L	25	Week -1	6	102.000	2.098	0.856	0.000
				Week -2	6	55.833	1.472	0.601	
				Week -3	6	45.333	1.366	0.558	
				Week -4	6	20.833	0.983	0.401	
				Total	24	56.000	30.106	6.145	
	DO	mg/L	4	Week -1	6	2.052	0.163	0.066	0.000
				Week -2	6	2.683	0.232	0.095	
				Week -3	6	3.750	0.259	0.106	
				Week -4	6	5.247	0.245	0.100	
				Total	24	3.433	1.254	0.256	
	Oil and fat	mg/L	0.017	Week -1	6	302.500	11.167	4.559	0.000
				Week -2	6	152.167	7.574	3.092	
				Week -3	6	55.667	5.465	2.231	
				Week -4	6	14.833	1.602	0.654	
				Total	24	131.292	113.300	23.127	
	Detergent	mg/L	0.003	Week -1	6	86.000	8.672	3.540	0.000
				Week -2	6	36.167	8.864	3.619	
				Week -3	6	7.500	3.619	1.478	
				Week -4	6	2.500	0.548	0.224	
				Total	24	33.042	34.410	7.024	
	Ammonia	mg/L	0.5	Week -1	6	5.876	0.118	0.048	0.000
				Week -2	6	3.321	0.185	0.075	
				Week -3	6	1.124	0.047	0.019	
				Week -4	6	0.458	0.044	0.018	
				Total	24	2.695	2.169	0.443	
	Total Coliform	Total/100	$5 \cdot 10^3$	Week -1	6	$2.6 \cdot 10^4$	$2.1 \cdot 10^4$	$8.5 \cdot 10^3$	0. 971
				Week -2	6	$2.5 \cdot 10^4$	$2 \cdot 10^4$	$8.3 \cdot 10^3$	
				Week -3	6	$2.3 \cdot 10^4$	$1.9 \cdot 10^4$	$7.9 \cdot 10^3$	
				Week -4	6	$2.1 \cdot 10^4$	$1.8 \cdot 10^4$	$7.4 \cdot 10^3$	
				Total	24	$2.4 \cdot 10^4$	$1.8 \cdot 10^4$	$3.8 \cdot 10^3$	

Note: std – standar quality, n – number of samples, SD ± – maximum and minimum standard deviation, SE – standard error.

al., 2019). Water spinach is one of the plants that has the ability to accumulate Pb and Cr metals in high concentrations (Suherman et al., 2021). Water hyacinth also has the potential and is recommended for reducing high Fe concentrations (Hassan et al., 2021). In addition, lotus is also the best candidate for processing runoff fertilizer in a natural environment. The thermo-osmotic gas transport mechanism found in N. nucifera also provides sufficient O_2 gas to buried rhizomes, thereby improving water quality in the ecosystem (Abd Rasid et al., 2019).

Pollutant removal percentage

To find out what percentage reduction in concentration in the parameters BOD, COD, DO, oil and fat, detergent, ammonia, and total coliforms of spinach, water hyacinth and lotus vegetation, the results are shown in Table 4. Based on Table 4, it was found that the concentration decreased before and after the constracted wetlands intervention. Each vegetation group. In water spinach vegetation, it is between 86.36–562.50%, water hyacinth is between 91.30–737.50%, and lotus is between 91.30–737.50%. CW is effective in reducing concentrations of pollutants such as BOD, COD, DO, Oils and Fats, Detergents, and Ammonium, besides that it has also been proven to be efficient in eliminating fecal indicator bacteria, with total coliform removal rates and (Justino et al., 2023).

The author believes that Constracted Wetlands are quite effective in reducing the concentration of domestic waste, especially in the parameters of BOD, COD, DO, ammonia, with treatment for 4 weeks (30 days) in the Water hyacinth vegetation. Meanwhile, the oil and fat,

Table 3. Differences in parameter concentrations in water spinach, water hyacinth and lotus vegetation after treatment

Parameter	Units	Std	Variable	n	Mean	SD ±	SE	P Value
BOD	mg/L	3	Spinach	24	5.875	2.232	0.456	0.000
			Water hyacinth	24	2.583	0.881	0.180	
			Lotus	24	6.875	2.419	0.494	
			Total	72	5.111	2.678	0.316	
COD	mg/L	25	Spinach	24	56.958	33.566	6.852	0.000
			Water hyacinth	24	6.167	0.381	0.078	
			Lotus	24	56.000	30.106	6.145	
			Total	72	39.708	35.060	4.132	
DO	mg/L	4	Spinach	24	3.251	1.344	0.274	0.000
			Water hyacinth	24	5.660	0.936	0.191	
			Lotus	24	3.433	1.254	0.256	
			Total	72	4.115	1.611	0.190	
Oil and fat	mg/L	0.017	Spinach	24	128.917	112.518	22.968	0.888
			Water hyacinth	24	116.625	108.847	22.218	
			Lotus	24	131.292	113.300	23.127	
			Total	72	125.611	110.180	12.985	
Detergent	mg/L	0.003	Spinach	24	32.208	33.892	6.918	0.945
			Water hyacinth	24	29.917	31.711	6.473	
			Lotus	24	33.042	34.410	7.024	
			Total	72	31.722	32.912	3.879	
Ammonia	mg/L	0.5	Spinach	24	2.706	2.174	0.444	0.902
			Water hyacinth	24	2.460	1.996	0.407	
			Lotus	24	2.695	2.169	0.443	
			Total	72	2.620	2.088	0.246	
Total Coliform	Total/100	$5 \cdot 10^3$	Spinach	24	$2.4 \cdot 10^4$	$1.9 \cdot 10^4$	$3.9 \cdot 10^3$	0.977
			Water hyacinth	24	$2.3 \cdot 10^4$	$1.8 \cdot 10^4$	$3.7 \cdot 10^3$	
			Lotus	24	$2.4 \cdot 10^4$	$1.8 \cdot 10^4$	$3.8 \cdot 10^3$	
			Total	72	$2.4 \cdot 10^4$	$1.8 \cdot 10^4$	$2.1 \cdot 10^3$	

Note: std – standar quality, n – number of samples, SD± – max and min standard deviation, SE – standard error.

Table 4. Calculation results of the percentage of pollutant removal on the concentration parameters of spinach, water hyacinth and lotus vegetation

Vegetasi	Parameter	Consetration before (a)	Consetration after (b)	c (a-b)	c/a x 100 (%)
Spinach	BOD	35.2	3.0	32.2	91.48
	COD	148.8	20.3	128.5	86.36
	DO	0.8	5.3	4.5	562.50
	Oil and fat	14.3	0.6	13.7	95.80
	Detergent	2.5	0.2	2.3	92.00
	Ammonia	8	0.5	7.5	93.75
	Total Coliform	$5.3 \cdot 10^6$	$2.2 \cdot 10^4$	$5.1 \cdot 10^5$	95.85
Water hyacinth	BOD	35.2	2.0	33.2	94.32
	COD	148.8	6	142.8	95.97
	DO	0.8	6.7	5.9	737.50
	Oil and fat	14.3	0.7	13.6	95.10
	Detergent	2.3	0.2	2.1	91.30
	Ammonia	8	0.4	7.6	95.00
	Total Coliform	$5.3 \cdot 10^6$	$2.1 \cdot 10^4$	$5.1 \cdot 10^5$	96.04

Table 4. Cont.

Lotus	BOD	35.7	2.0	33.7	94.40
	COD	148.8	6	142.8	95.97
	DO	0.8	6.7	5.9	737.50
	Oil and fat	14.3	0.7	13.6	95.10
	Detergent	2.3	0.2	2.1	91.30
	Ammonia	8	0.4	7.6	95.00
	Total Coliform	$5.3 \cdot 10^6$	$2.1 \cdot 10^4$	$5.1 \cdot 10^5$	96.04

detergent and total coliform parameter has decreased but is not yet optimal because it is still above the quality standard. So, the oil and fat, detergent and total coliform can increase the treatment time. Specifically for the total coliform, special treatment is required, such as the media to be used must be washed clean so that it is not contaminated with coliforms in the environment of the media itself.

CONCLUSION

The results of this research are that the results of measurements of BOD, COD, DO and ammonia after the intervention have decreased to below the quality standard in all vegetation, while oil and fat, detergent and total coliform have decreased but are still above the quality standard. Apart from that, it is known that there is an influence of constracted wetlands on the parameters BOD, COD, DO, oil and fat, detergent, ammonia, and total coliform. There were group differences at week -1, week -2, week -3 and week -4 in all types of vegetation, while in the three vegetation groups there were no differences in total coliforms. Based on the results of the treatment period, it is known that in the 4th week this technology was able to reduce the concentration of BOD, COD, DO, oil and fat, detergent and ammonia parameters below quality standards. There are differences in the concentrations of BOD, COD, DO parameters in spinach, water hyacinth and lotus plants, while there are no differences in the parameters of oil and fat, detergent, ammonia, total coliform in spinach, water hyacinth and lotus plants. Additionally, constracted wetland interventions are also effective in reducing wastewater. In water spinach vegetation, it is between 86.36–562.50%, water hyacinth is between 91.30–737.50%, and lotus is between 91.30–737.50%.

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