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Research paper

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

**Keywords**
Artificial Wetlands, Constracted Wetlands, CW horizontal, vegetation, contaminants, pollutants

**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; 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%.

**Explanation letter**
Dear
Prof. Gabriel Borowski
editor in chief of Journal of Ecological Engineering

My co-authors and I were pleased to receive your response on December 6, 2023 inviting us to revise and resubmit our manuscript. Therefore, we would like to submit the attached revised paper, Performance of Wetland-Made Horizontal Subsurface Flow in Domestic Wastewater Treatment Using Different Media, Manuscript #JEENG-05036-2023-01, for reconsideration for publication in the Journal of Ecological Engineering.
We thank you and the reviewers for your time and effort in reviewing our manuscript. The input provided was very valuable in improving the content and presentation of this paper. We have revised our manuscript based on the reviewers' comments. These changes are in the table below:
All authors have read and approved the revised manuscript. We hope our resubmission is now worthy of inclusion in the Journal of Ecological Engineering and we look forward to your feedback.

Kindest regards

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Explanation letter.docx

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

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**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; 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%.

Key words: Artificial Wetlands, Constracted Wetlands, CW horizontal, vegetation, contaminants, pollutants

## INTRODUCTION

Polluted water and land are major environmental problems (Khare & P. 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

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in many parts of the world is Artificial Wetland (CW) wastewater treatment (A 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, coco-peat, bricks, stones, clay, gravel, sand, sawdust, coal, etc. (Parde et al., 2021).

Contracted Wetlands 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 Contracted Wetlands (CWs) 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 pipe to enter the waste water and an outlet pipe to remove the waste water from the Constructed Wetlands. Contracted Wetlands (CWs) 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).

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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 (CWs) 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 in Figure 1 below:

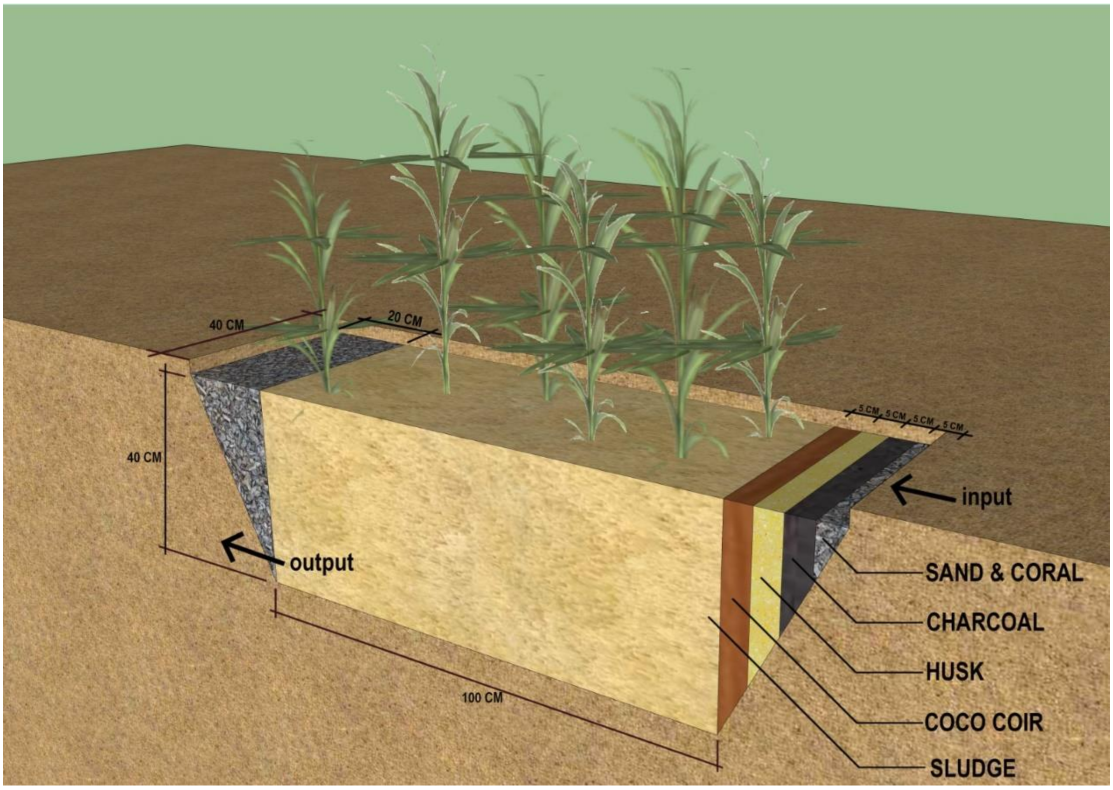


**Figure 1 Contracted Wetlands Desing**

**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).

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### 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):

$$\%R = \frac{CE - CS}{CE} X100$$

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 1 below:

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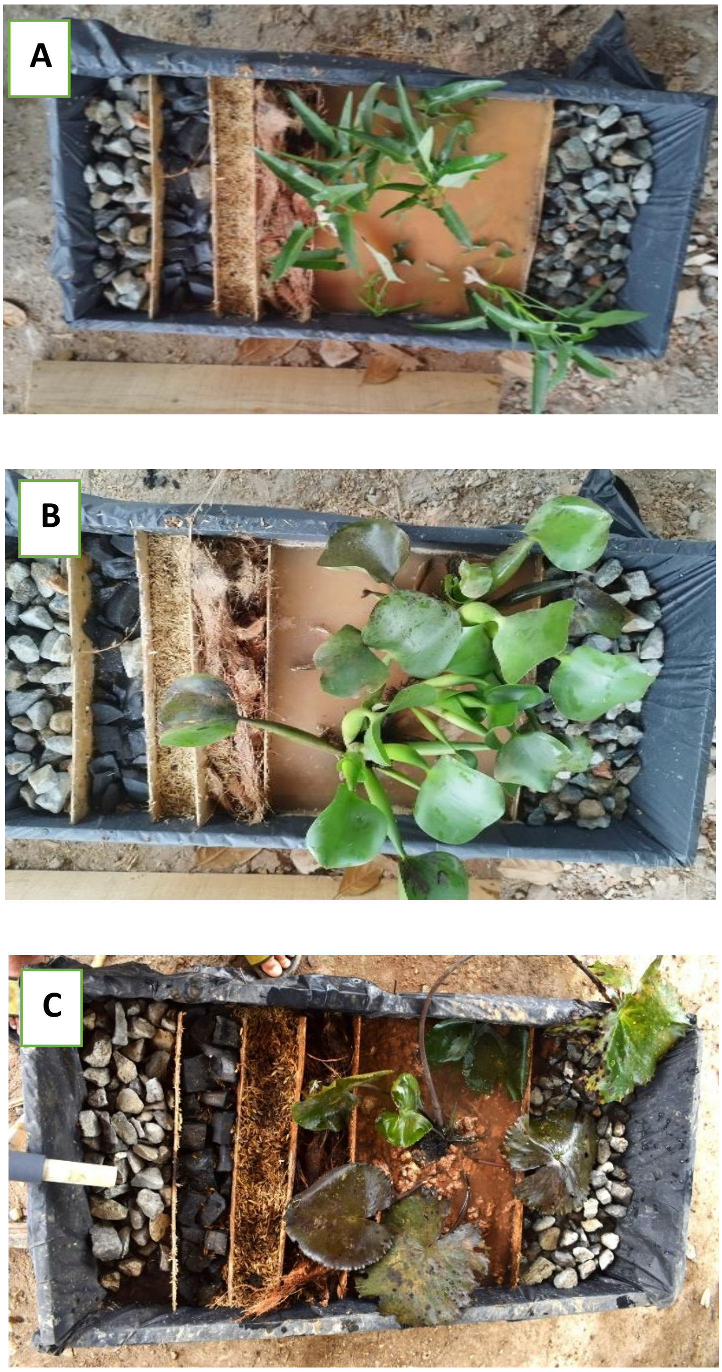


**Figure 2 Constracted Wetlands A. Spinach vegetation; B Water Hyacinth Vegetation; C Lotus Vegetation**

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 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

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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 obtained in table 1 are as follows:

**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 | $5 \times 10^3$ | Before | $5,3 \times 10^6$ | 6 | $1,2 \times 10^4$ | $4,9 \times 10^3$ | 0,000 |
| | | | | After | $2,2 \times 10^4$ | 6 | $2 \times 10^4$ | $8 \times 10^3$ | |
| 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 | $5 \times 10^3$ | Before | $5,3 \times 10^6$ | 6 | $2,1 \times 10^4$ | $4,9 \times 10^3$ | 0,000 |
| | | | | After | $2,1 \times 10^4$ | 6 | $1,8 \times 10^4$ | $7,4 \times 10^3$ | |
| 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 |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 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 x $10^3$ | Before | 5,3 x $10^6$ | 6 | 1,2 x $10^4$ | 4,9 x $10^3$ | 0,000 |
| | | | After | 2,1 x $10^4$ | 6 | 2 x $10^4$ | 7,4 x $10^3$ | |

note:
std = Standar quality
n = number of samples
SD ± = maximum and minimum standard deviation
SE = Standard error

Based on 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 (Elmeligy 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 & P. 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 (A 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 obtained in table 2 are as follows:

**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 | | | Week -1 | 6 | 8,667 | 0,516 | 0,211 | 0,000 |
| | | | | Week -2 | 6 | 6,833 | 0,753 | 0,307 | |
| | | mg/L | 3 | 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 | | | Week -1 | 6 | 108,500 | 2,950 | 1,204 | 0,000 |
| | | | | Week -2 | 6 | 59,333 | 3,077 | 1,256 | |
| | | mg/L | 25 | 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 | | | Week -1 | 6 | 1,910 | 0,020 | 0,008 | 0,000 |
| | | | | Week -2 | 6 | 2,543 | 0,128 | 0,052 | |
| | | mg/L | 4 | 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 | | | Week -1 | 6 | 299,667 | 10,033 | 4,096 | 0,000 |
| | | | 0,017 | Week -2 | 6 | 148,333 | 7,367 | 3,007 | |
| | | mg/L | | 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 | | | Week -1 | 6 | 84,833 | 8,134 | 3,321 | 0,000 |
| | | | 0,003 | Week -2 | 6 | 34,500 | 7,662 | 3,128 | |
| | | mg/L | | 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 | | | Week -1 | 6 | 5,894 | 0,108 | 0,044 | 0,000 |
| | | | | Week -2 | 6 | 3,335 | 0,191 | 0,078 | |
| | | mg/L | 0,5 | 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 | | | Week -1 | 6 | 2,7 x $10^4$ | 2,1 x $10^4$ | 8,6 x $10^3$ | 0,979 |
| | | | | Week -2 | 6 | 2,5 x $10^4$ | 2,1 x $10^4$ | 8,5 x $10^3$ | |
| | | Total/100 | 5 x $10^3$ | Week -3 | 6 | 2,3 x $10^4$ | 2 x $10^4$ | 8,3 x $10^3$ | |
| | | | | Week -4 | 6 | 2,1 x $10^4$ | 2 x $10^4$ | 8 x $10^3$ | |
| | | | | Total | 24 | 2,4 x $10^4$ | 1,9 x $10^4$ | 3,9 x $10^3$ | |
| Water hyacinth | BOD | | | Week -1 | 6 | 4,000 | 0,000 | 0,000 | 0,000 |
| | | | | Week -2 | 6 | 2,333 | 0,516 | 0,211 | |
| | | mg/L | 3 | 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 | | | Week -1 | 6 | 6,333 | 0,516 | 0,211 | 0, 206 |
| | | | | Week -2 | 6 | 6,333 | 0,516 | 0,211 | |
| | | mg/L | 25 | 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 | |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 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 | | | Week -1 | 6 | 283,833 | 11,286 | 4,607 | 0,000 |
| | | | | Week -2 | 6 | 132,667 | 7,711 | 3,148 | |
| | | mg/L | 0,017 | 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 | | | Week -1 | 6 | 79,167 | 8,612 | 3,516 | 0,000 |
| | | | | Week -2 | 6 | 32,167 | 5,269 | 2,151 | |
| | | mg/L | 0,003 | 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 | | | Week -1 | 6 | 5,372 | 0,109 | 0,044 | 0,000 |
| | | | | Week -2 | 6 | 3,078 | 0,125 | 0,051 | |
| | | mg/L | 0,5 | 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 | | | Week -1 | 6 | 2,6 x $10^4$ | 2,1 x $10^4$ | 8,4 x $10^3$ | 0, 972 |
| | Coliform | | | Week -2 | 6 | 2,4 x $10^4$ | 2 x $10^4$ | 8,1 x $10^3$ | |
| | | Total/100 | 5 x $10^3$ | Week -3 | 6 | 2,2 x $10^4$ | 1,9 x $10^4$ | 7,6 x $10^3$ | |
| | | | | Week -4 | 6 | 2,1 x $10^4$ | 1,8 x $10^4$ | 7,4 x $10^3$ | |
| | | | | Total | 24 | 2,3 x $10^4$ | 1,8 x $10^4$ | 3,7 x $10^3$ | |
| Lotus | BOD | | | Week -1 | 6 | 10,000 | 0,894 | 0,365 | 0,000 |
| | | | | Week -2 | 6 | 7,833 | 0,983 | 0,401 | |
| | | mg/L | 3 | 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 | | | Week -1 | 6 | 102,000 | 2,098 | 0,856 | 0, 000 |
| | | | | Week -2 | 6 | 55,833 | 1,472 | 0,601 | |
| | | mg/L | 25 | 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 | | | Week -1 | 6 | 2,052 | 0,163 | 0,066 | 0,000 |
| | | | | Week -2 | 6 | 2,683 | 0,232 | 0,095 | |
| | | mg/L | 4 | 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 | | | Week -1 | 6 | 302,500 | 11,167 | 4,559 | 0,000 |
| | | | | Week -2 | 6 | 152,167 | 7,574 | 3,092 | |
| | | mg/L | 0,017 | 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 | | | Week -1 | 6 | 86,000 | 8,672 | 3,540 | 0,000 |
| | | | | Week -2 | 6 | 36,167 | 8,864 | 3,619 | |
| | | mg/L | 0,003 | 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 | | | Week -1 | 6 | 5,876 | 0,118 | 0,048 | 0,000 |
| | | | | Week -2 | 6 | 3,321 | 0,185 | 0,075 | |
| | | mg/L | 0,5 | 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 | | | Week -1 | 6 | 2,6 x $10^4$ | 2,1 x $10^4$ | 8,5 x $10^3$ | 0, 971 |
| | Coliform | | | Week -2 | 6 | 2,5 x $10^4$ | 2 x $10^4$ | 8,3 x $10^3$ | |
| | | Total/100 | 5 x $10^3$ | Week -3 | 6 | 2,3 x $10^4$ | 1,9 x $10^4$ | 7,9 x $10^3$ | |
| | | | | Week -4 | 6 | 2,1 x $10^4$ | 1,8 x $10^4$ | 7,4 x $10^3$ | |
| | | | | Total | 24 | 2,4 x $10^4$ | 1,8 x $10^4$ | 3,8 x $10^3$ | |

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note:
std = Standar quality
n = number of samples
SD ± = maximum and minimum standard deviation
SE = Standard error

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 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).

## 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 obtained in table 3 are as follows:

**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 | |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 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 x $10^3$ | Spinach | 24 | 2,4 x $10^4$ | 1,9 x $10^4$ | 3,9 x $10^3$ | 0,977 |
| | | | Water hyacinth | 24 | 2,3 x $10^4$ | 1,8 x $10^4$ | 3,7 x $10^3$ | |
| | | | Lotus | 24 | 2,4 x $10^4$ | 1,8 x $10^4$ | 3,8 x $10^3$ | |
| | | | Total | 72 | 2,4 x $10^4$ | 1,8 x $10^4$ | 2,1 x $10^3$ | |

note:
std = Standar quality
n = number of samples
SD ± = maximum and minimum standard deviation
SE = Standard error

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 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).

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## 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, as follows:

**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 | $5,3 \times 10^6$ | $2,2 \times 10^4$ | $5,1 \times 10^5$ | 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 | $5,3 \times 10^6$ | $2,1 \times 10^4$ | $5,1 \times 10^5$ | 96,04 |
| 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 | $5,3 \times 10^6$ | $2,1 \times 10^4$ | $5,1 \times 10^5$ | 96,04 |

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, 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 Contracted 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, Contracted 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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**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 | $5 \times 10^3$ | Before | $5,3 \times 10^6$ | 6 | $1,2 \times 10^4$ | $4,9 \times 10^3$ | 0,000 |
| | | | | After | $2,2 \times 10^4$ | 6 | $2 \times 10^4$ | $8 \times 10^3$ | |
| 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 | $5 \times 10^3$ | Before | $5,3 \times 10^6$ | 6 | $2,1 \times 10^4$ | $4,9 \times 10^3$ | 0,000 |
| | | | | After | $2,1 \times 10^4$ | 6 | $1,8 \times 10^4$ | $7,4 \times 10^3$ | |
| 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 | $5 \times 10^3$ | Before | $5,3 \times 10^6$ | 6 | $1,2 \times 10^4$ | $4,9 \times 10^3$ | 0,000 |
| | | | | After | $2,1 \times 10^4$ | 6 | $2 \times 10^4$ | $7,4 \times 10^3$ | |

note:
std = Standar quality
n = number of samples
SD ± = maximum and minimum standard deviation
SE = Standard error

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**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 | | | Week -1 | 6 | 8,667 | 0,516 | 0,211 | 0,000 |
| | | | | Week -2 | 6 | 6,833 | 0,753 | 0,307 | |
| | | mg/L | 3 | 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 | | | Week -1 | 6 | 108,500 | 2,950 | 1,204 | 0,000 |
| | | | | Week -2 | 6 | 59,333 | 3,077 | 1,256 | |
| | | mg/L | 25 | 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 | | | Week -1 | 6 | 1,910 | 0,020 | 0,008 | 0,000 |
| | | | | Week -2 | 6 | 2,543 | 0,128 | 0,052 | |
| | | mg/L | 4 | 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 | | | Week -1 | 6 | 299,667 | 10,033 | 4,096 | 0,000 |
| | | | 0,017 | Week -2 | 6 | 148,333 | 7,367 | 3,007 | |
| | | mg/L | | 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 | | | Week -1 | 6 | 84,833 | 8,134 | 3,321 | 0,000 |
| | | | 0,003 | Week -2 | 6 | 34,500 | 7,662 | 3,128 | |
| | | mg/L | | 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 | | | Week -1 | 6 | 5,894 | 0,108 | 0,044 | 0,000 |
| | | | | Week -2 | 6 | 3,335 | 0,191 | 0,078 | |
| | | mg/L | 0,5 | 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 | | | Week -1 | 6 | $2,7 \times 10^4$ | $2,1 \times 10^4$ | $8,6 \times 10^3$ | 0,979 |
| | | | | Week -2 | 6 | $2,5 \times 10^4$ | $2,1 \times 10^4$ | $8,5 \times 10^3$ | |
| | | Total/100 | $5 \times 10^3$ | Week -3 | 6 | $2,3 \times 10^4$ | $2 \times 10^4$ | $8,3 \times 10^3$ | |
| | | | | Week -4 | 6 | $2,1 \times 10^4$ | $2 \times 10^4$ | $8 \times 10^3$ | |
| | | | | Total | 24 | $2,4 \times 10^4$ | $1,9 \times 10^4$ | $3,9 \times 10^3$ | |
| Water hyacinth | BOD | | | Week -1 | 6 | 4,000 | 0,000 | 0,000 | 0,000 |
| | | | | Week -2 | 6 | 2,333 | 0,516 | 0,211 | |
| | | mg/L | 3 | 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 | | | Week -1 | 6 | 6,333 | 0,516 | 0,211 | 0, 206 |
| | | | | Week -2 | 6 | 6,333 | 0,516 | 0,211 | |
| | | mg/L | 25 | 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 | | | Week -1 | 6 | 4,340 | 0,278 | 0,114 | 0,000 |
| | | | | Week -2 | 6 | 5,633 | 0,493 | 0,201 | |
| | | mg/L | 4 | 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 | | | Week -1 | 6 | 283,833 | 11,286 | 4,607 | 0,000 |
| | | mg/L | 0,017 | 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 | |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Total | 24 | 116,625 | 108,847 | 22,218 | |
| | Detergent | | | Week -1 | 6 | 79,167 | 8,612 | 3,516 | 0,000 |
| | | | | Week -2 | 6 | 32,167 | 5,269 | 2,151 | |
| | | mg/L | 0,003 | 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 | | | Week -1 | 6 | 5,372 | 0,109 | 0,044 | 0,000 |
| | | | | Week -2 | 6 | 3,078 | 0,125 | 0,051 | |
| | | mg/L | 0,5 | 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 | | | Week -1 | 6 | $2,6 \times 10^4$ | $2,1 \times 10^4$ | $8,4 \times 10^3$ | 0, 972 |
| | | | | Week -2 | 6 | $2,4 \times 10^4$ | $2 \times 10^4$ | $8,1 \times 10^3$ | |
| | | Total/100 | $5 \times 10^3$ | Week -3 | 6 | $2,2 \times 10^4$ | $1,9 \times 10^4$ | $7,6 \times 10^3$ | |
| | | | | Week -4 | 6 | $2,1 \times 10^4$ | $1,8 \times 10^4$ | $7,4 \times 10^3$ | |
| | | | | Total | 24 | $2,3 \times 10^4$ | $1,8 \times 10^4$ | $3,7 \times 10^3$ | |
| Lotus | BOD | | | Week -1 | 6 | 10,000 | 0,894 | 0,365 | 0,000 |
| | | | | Week -2 | 6 | 7,833 | 0,983 | 0,401 | |
| | | mg/L | 3 | 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 | | | Week -1 | 6 | 102,000 | 2,098 | 0,856 | 0, 000 |
| | | | | Week -2 | 6 | 55,833 | 1,472 | 0,601 | |
| | | mg/L | 25 | 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 | | | Week -1 | 6 | 2,052 | 0,163 | 0,066 | 0,000 |
| | | | | Week -2 | 6 | 2,683 | 0,232 | 0,095 | |
| | | mg/L | 4 | 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 | | | Week -1 | 6 | 302,500 | 11,167 | 4,559 | 0,000 |
| | | | | Week -2 | 6 | 152,167 | 7,574 | 3,092 | |
| | | mg/L | 0,017 | 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 | | | Week -1 | 6 | 86,000 | 8,672 | 3,540 | 0,000 |
| | | | | Week -2 | 6 | 36,167 | 8,864 | 3,619 | |
| | | mg/L | 0,003 | 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 | | | Week -1 | 6 | 5,876 | 0,118 | 0,048 | 0,000 |
| | | | | Week -2 | 6 | 3,321 | 0,185 | 0,075 | |
| | | mg/L | 0,5 | 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 | | | Week -1 | 6 | $2,6 \times 10^4$ | $2,1 \times 10^4$ | $8,5 \times 10^3$ | 0, 971 |
| | | | | Week -2 | 6 | $2,5 \times 10^4$ | $2 \times 10^4$ | $8,3 \times 10^3$ | |
| | | Total/100 | $5 \times 10^3$ | Week -3 | 6 | $2,3 \times 10^4$ | $1,9 \times 10^4$ | $7,9 \times 10^3$ | |
| | | | | Week -4 | 6 | $2,1 \times 10^4$ | $1,8 \times 10^4$ | $7,4 \times 10^3$ | |
| | | | | Total | 24 | $2,4 \times 10^4$ | $1,8 \times 10^4$ | $3,8 \times 10^3$ | |

note:
std = Standar quality
n = number of samples
SD ± = maximum and minimum standard deviation
SE = Standard error

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**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 | $5 \times 10^3$ | Spinach | 24 | $2,4 \times 10^4$ | $1,9 \times 10^4$ | $3,9 \times 10^3$ | 0,977 |
| | | | Water hyacinth | 24 | $2,3 \times 10^4$ | $1,8 \times 10^4$ | $3,7 \times 10^3$ | |
| | | | Lotus | 24 | $2,4 \times 10^4$ | $1,8 \times 10^4$ | $3,8 \times 10^3$ | |
| | | | Total | 72 | $2,4 \times 10^4$ | $1,8 \times 10^4$ | $2,1 \times 10^3$ | |

note:
std = Standar quality
n = number of samples
SD ± = maximum and minimum standard deviation
SE = Standard error

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**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 | $5,3 \times 10^{6}$ | $2,2 \times 10^{4}$ | $5,1 \times 10^{5}$ | 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 | $5,3 \times 10^{6}$ | $2,1 \times 10^{4}$ | $5,1 \times 10^{5}$ | 96,04 |
| 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 | $5,3 \times 10^{6}$ | $2,1 \times 10^{4}$ | $5,1 \times 10^{5}$ | 96,04 |

**Figure 1**

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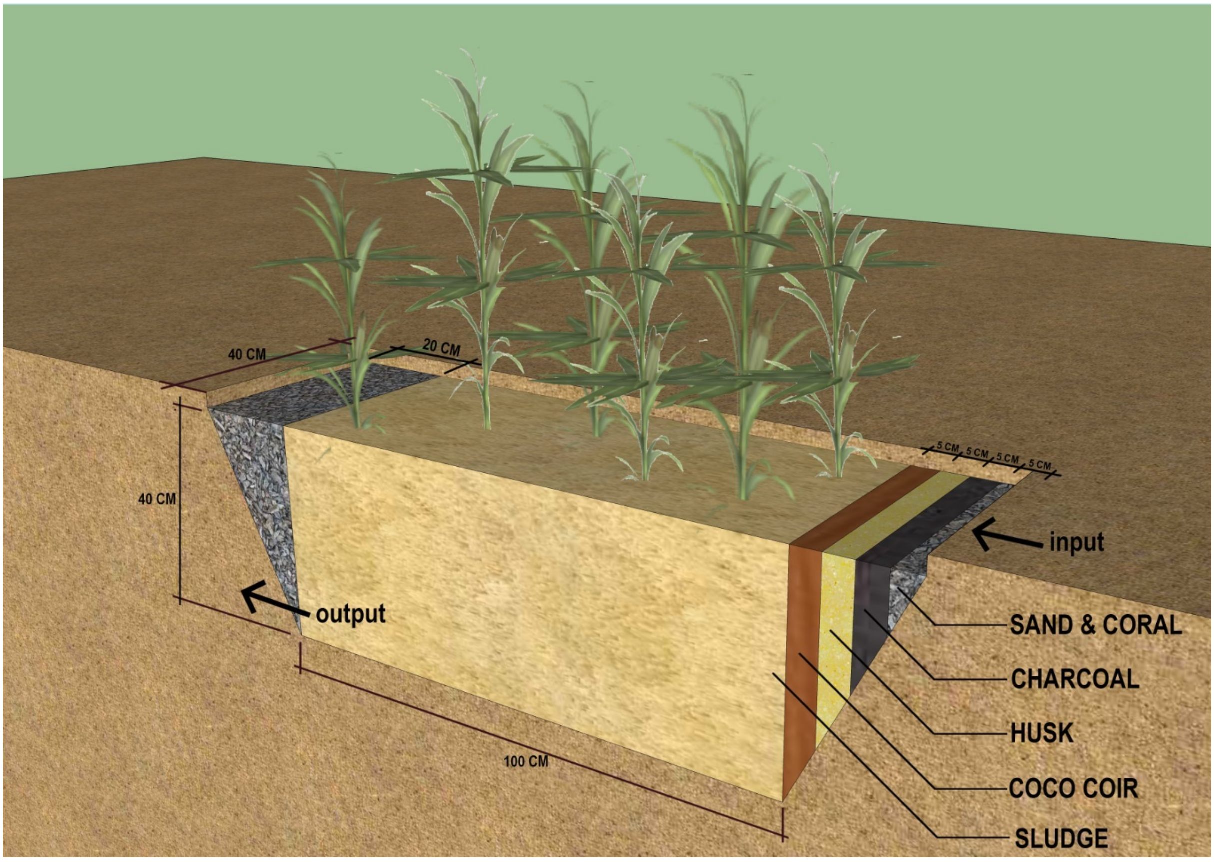


Contracted Wetlands Desing

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Constracted Wetlands Spinach vegetation

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Constracted Wetlands Water Hyacinth Vegetation

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Constracted Wetlands Lotus Vegetation

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