Comparison of Wetlands and Phytoremediation Methods as Treatment Media for Hospital Wastewater

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Abstract. Every day, Jember Klinik hospital generates wastewater from its various health service that becomes one of the contributing factors to water pollution. This wastewater may contain hazardous chemical compounds that have the potential to cause diseases in the surrounding community. Therefore, this research aims to analyze the condition of hospital wastewater treatment at Jember Klinik Hospital using the wastewater treatment methods (wetlands and phytoremediation) to assess how well papyrus plants can minimize the wastewater content. In this research using the wetland and phytoremediation methods, three treatment time variables were applied, namely 1, 2, and 3 days. The initial values of the TSS (Total Suspended Solids), BOD (Biochemical Oxygen Demand), and COD (Chemical Oxygen Demand) before testing were 102 Mg/L, 104 Mg/L, and 184 Mg/L, respectively. In the study using the wetlands method, during the 3-day process, there was a reduction in TSS, BOD, and COD to 0 Mg/L, 25 Mg/L, and 32 Mg/L, respectively. On the other hand, using the phytoremediation method, the reduction in TSS, BOD, and COD was to 9 Mg/L, 28 Mg/L, and 43 Mg/L, respectively. Based on the results of the wetlands and phytoremediation treatment processes above, it can be concluded that the wetlands method is more effective in treating wastewater compared to the phytoremediation method

Keywords: Cyperus Papyrus, Wetlands, Phytoremediation, Wastewater.

1 Introduction

The Earth's surface is made up of 71% water [1], which is why when viewed from space, it appears blue. 97.61% of the water on Earth is saline and found in the oceans, while approximately 2.39% is freshwater. Out of the total freshwater, 1.75% exists as snow and ice, 0.72% is groundwater, and 0.001% is surface water (rivers and lakes), along with being present in the biosphere and atmosphere. Knowing the uniqueness of water and the limited amount of freshwater on Earth, it is mandatory for us to preserve water from various types of waste and pollutants caused by various human activities, including those in the industrial, agricultural, office, and healthcare sectors.

According to the World Health Organization [2], a hospital or healthcare facility is an entity that provides short-term and long-term healthcare services, including observation, diagnostics, therapeutics, and rehabilitation for the sick, injured, and women in

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childbirth. Hospitals are individual healthcare facilities that provide inpatient and outpatient care [3]. Therefore, quality service is a necessity and must be fulfilled by a hospital. One effort to improve the quality of service to the community is to enhance the hospital's performance in a professional and independent manner [4]. With various healthcare facilities such as clinics, operating rooms, delivery rooms, emergency departments, morgues, as well as supporting public facilities such as cafeterias and green spaces, the amount of wastewater generated from these activities is estimated to be significant. This is a cause for concern if the hospital is not equipped with a wastewater treatment system, as the wastewater can pollute the surrounding environment. With proper wastewater management systems, the discharge of wastewater does not have negative impacts on the community and the environment. Therefore, awareness of wastewater treatment is crucial in order to preserve the water environment and prevent pollution. The quality parameters of liquid waste that are important to know are suspended solids, dissolved solids, biochemical oxygen requirements (BOD), chemical oxygen requirements (COD), coliform organisms, pH, dissolved oxygen (DO), requirements chlorine, nutrients, heavy metals, and other parameters [5].

There are various methods that can be used to process hospital waste. For hospital wastewater treatment with large capacity, generally using so-called wastewater treatment technology Activated Sludge Process, but for small capacities this method is not enough economical because the operating costs are quite large, operational control is more difficult [6]. Another wastewater treatment method is the Anaerobic-Aerobic Biofilter System as carried out by Sari (2015) [7]. From the results of these observations, it can be concluded that the best results obtained in this study were at a flow rate of 500 ml/minute with a concentration of 50% dilution with a BOD analysis of 22.40 mg/l, COD of 56.24 mg/l, and TSS of 12.71 mg/l. These values are in accordance with the liquid waste quality standards stipulated in South Sumatra Governor Regulation No. 18 of 2005.

Wetlands have quite high economic value and maintenance is very easy and cheap, but does not reduce performance compared to other methods. Another advantage of wetlands is that they can be operated 24 hours a day as long as the dimensions of the wetlands area can accommodate the amount of wastewater being managed. The community of plant types used in wetlands does not require special maintenance, the plants are also very easy to obtain, most of which are shrubs.

In this research, hospital waste from Jember Klinik Hospital will be carried out using the wetlands method and phytoremediation method. These methods has quite high economic value and is very easy and cheap to maintain, but does not reduce performance compared to other methods. Another advantage of wetlands is that they can be operated 24 hours a day as long as the dimensions of the wetlands area can accommodate the amount of wastewater being managed. The community of plant types used in these methods does not require special maintenance, the plants are also very easy to obtain, most of which are shrubs.

2 Literature Review

2.1 Wastewater

According to the Minister of Environment and Forestry of the Republic of Indonesia Regulation No. 5 of 2014 on Wastewater Quality Standards, wastewater refers to the residue of a business or activity in liquid form [8]. Wastewater or effluent is the leftover water from processes that are discharged from households, industries, and other public places. Wastewater is liquid waste originating from households, industries, and other public places, usually containing substances or materials that can endanger human life and disturb environmental sustainability [9] such as: Arsen (As), Cadnium (Cd), Crom (Cr), Plumbum (Pb), Cuprum (Cu), and Zinc (Zn) [10].

2.2 Hospitals

According to the World Health Organization (WHO) in Pangarepan et al (2018), hospitals are integral parts of social and health organizations that function as providers of comprehensive healthcare, disease treatment (curative), and disease prevention (preventive) to the community [11]. Hospitals are also training centers for healthcare professionals and medical research centers. Based on Law No. 44 of 2009 concerning hospitals, a hospital is defined as a healthcare institution that provides comprehensive individual healthcare services, including inpatient, outpatient, and emergency care [12].

2.3 Cyperus Papyrus

In principle, all types of plants can be used as wastewater treatment media because naturally, various plants have the ability to absorb various substances in water for growth nutrients. The aquatic plant Cyperus papyrus is chosen as a planting medium because it has been extensively researched, yielding excellent results.
Muhammad et al. in 2020 [13] conducted a study titled "The Effect of Water Star Grass (Cyperus Papyrus) and Water Bamboo (Equisetum Hyemale) in Treating Domestic Wastewater," which showed that Water Star Grass (Cyperus papyrus) could remove 97.14% of BOD5 content, while the efficiency of COD removal was 95.43%. Water Bamboo (Equisetum hyemale) could remove 90.34% of BOD5 and had an efficiency of 89.67% for COD removal. Considering the ability of these two plant species to absorb pollutants in domestic wastewater, Water Star Grass (Cyperus papyrus) showed superior pollutant absorption compared to Water Bamboo (Equisetum hyemale). Another study conducted in 2021 by Galuh D Senki et al. [14], titled "Wastewater Treatment Analysis of Soybean Industry Using Wetlands System," also utilized Cyperus papyrus in a constructed wetland. The study resulted in BOD decreasing from 1195 mg/L to 31.8 mg/L, COD decreasing from 2883 mg/L to 64.4 mg/L, and TDS decreasing from 1033 to 393.

2.4 Phytoremediation

Yuliana Herman Welhelmus Djo et al. in 2017 conducted a study titled "Phytoremediation Using Water Hyacinth (Eichhornia crassipes) to Reduce COD and Cu and Cr Content in Laboratory Analytical Wastewater of Udayana University." The study showed a decrease in COD and heavy metal content (Cu and Cr), presumably due to biological activities that oxidize organic and inorganic compounds in wastewater. The initial concentrations of COD, Cu, and Cr before treatment were 47.04, 0.375, and 2.58 mg/L, respectively, and after treatment for 14 days, they decreased to 26.34, 0.111, and 0.72 mg/L. The effectiveness of COD, Cu, and Cr reduction was 42.36%, 68.73%, and 42.40%, respectively. The absorption capacity of water hyacinth for COD, Cu, and Cr was 0.1232, 0.0016, and 0.0051 mg/g of water hyacinth [15].
Baroroh et al (2018) stated that using Pistia stratiotes in phytoremediation could reduce Cu heavy metal concentrations by 94% at 2 ppm and 90% at 5 ppm. However, Pistia stratiotes experienced damage in the form of chlorosis and necrosis at both concentrations. On the other hand, using Salvinia molesta in phytoremediation could reduce Cu heavy metal by 96% at 2 ppm and 95% at 5 ppm without damaging the plants. Phytoremediation treatments could also affect the pH value of water and soil. Post-phytoremediation water application did not significantly affect the growth and yield of Brassica rapa plants. Brassica rapa plants were also able to accumulate Cu heavy metal in their roots and shoots. The Cu heavy metal content in the roots and shoots of Brassica rapa exceeded the threshold limit for Cu in vegetables. Brassica rapa experienced leaf damage [16].

2.5 Wetlands

Wetlands are transitional areas between land and water. Natural wetlands include marshes, wet grasslands, tidal flats, floodplains, and wetlands along river channels [17]. In 2020, Siswoyo Eko et al. utilized a Free Water Surface (FWS) reactor with a batch system, employing water hyacinth (Eichhornia crassipes) in a wetland media. They studied the effect of different concentrations of tapioca industrial wastewater (ranging from 20%, 40%, 60%, 80%, and 100%) on parameters like BOD (Biological Oxygen Demand), COD (Chemical Oxygen Demand), TSS (Total Suspended Solids), and cyanide over a period of 10 days. Sampling was done on days 0, 2, 4, 6, 8, and 10. The research findings demonstrated that the wetland was capable of reducing BOD, COD, TSS, and cyanide levels by 97.9%, 84.4%, 45.6%, and 99.9%, respectively. These results indicate that wetlands constructed with water hyacinth have excellent potential in reducing pollutants in tapioca industrial wastewater. Thus, wetlands can be considered as an alternative solution to address environmental pollution issues caused by wastewater disposal in Indonesia [18].

3 Methodology

The research method employed in this study consists of a series of stages. The stages that need to be carried out are outlined in the flowchart in Fig.1. The flowchart illustrates the detailed steps, which are explained as follows:

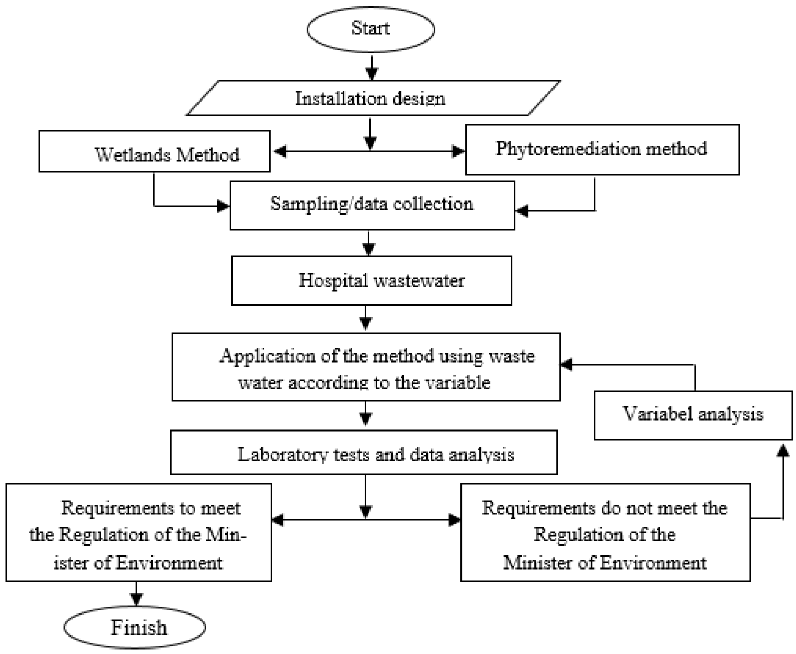

Fig. 1. Research Flowchart

Initial Stage. In this study, wastewater is continuously flowed into a wastewater treatment installation using a complete treatment system method which consists primer, secondary, and tertiary treatment. This process aims to reduce the concentration of water pollutants that exceed the standard quality limits using wetlands and phytoremediation, resulting in high-quality wastewater. The research design to be conducted is as follows:

1. Field survey to observe the study location.
2. Sampling in the study area, followed by laboratory testing to determine the content of substances in the wastewater.
3. Based on the laboratory test results, design a wastewater treatment installation.
4. Conduct an experiment using the designed wastewater treatment installation.
5. From the wastewater treatment installation experiment, obtain samples to be tested in the laboratory to determine the level of reduction in pollutant content present in the wastewater.
6. From the results of laboratory tests carried out in this research, it can be concluded how far the pollutant content elements can be reduced and whether they comply

with the requirements of the 2014 Waste Water Quality Standards for Hospital Activities.

Design Stage. In this study, a wastewater treatment installation system is planned, which includes a storage tank, filtration tank, and control tank as shown in Figure 2 for wetlands method and Figure 3 for phytoremediation method. The effectiveness of these method will then be tested at the Water Quality Laboratory to determine the concentration of harmful substances in the wastewater. Parameters considered in the water quality testing include standard requirements for wastewater quality based on the requirements of the 2014 Waste Water Quality Standards for Hospital Activities as shown in table 1 below.

Tabel 1. Waste water quality standards for hospital activities

No	Parameter	Requirements
1	Temperature	< 30^{o}C
2	TSS	< 30 Mg/L
3	pH	< 6 – 9
4	PO_4	< 2 Mg/L
5	BOD	< 30 Mg/L
6	COD	< 80 Mg/L

The following is the proposed model of the wastewater treatment installation system to be studied. Figure 2 for wetlands method and Figure 3 for phytoremediation method.

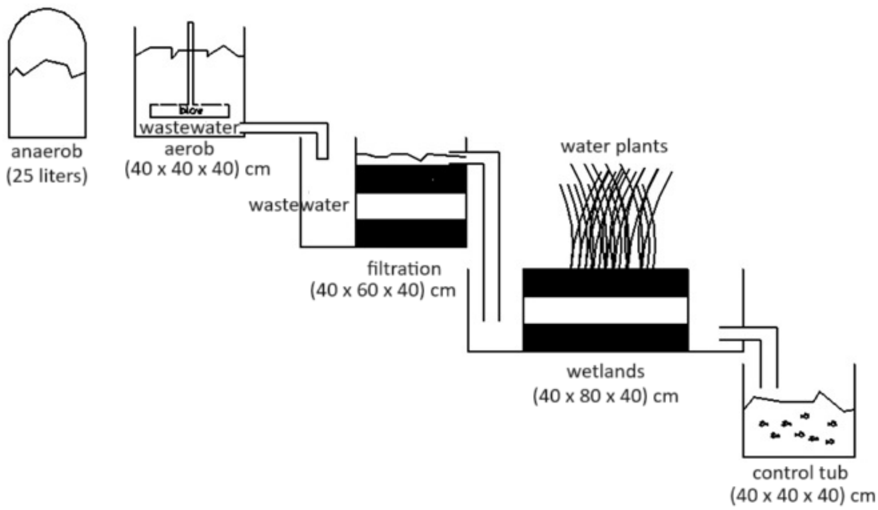

Fig. 2. The design of the wetlands method

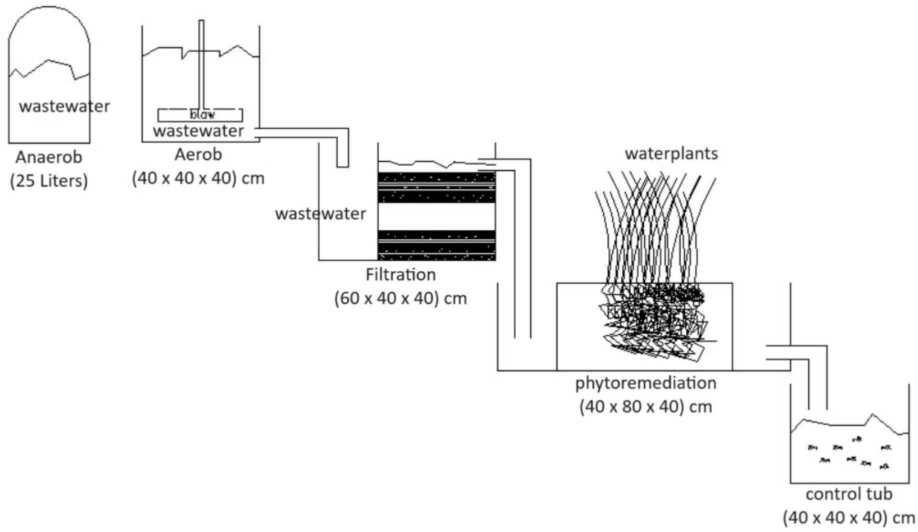

Fig.3. The design of the phytoremediation method

Advanced Stage
Wastewater Treatment Process using the Wetlands Method. The arrangement of the wastewater treatment installation using the wetlands method consists of an anaerobic process followed by an aerobic process, and finally, the main process, which is the wetlands process. The samples taken and tested in the laboratory are the wastewater outputs from the final process, after going through a series of wetlands processes with varying durations of 1, 2, and 3 days.

Wastewater Treatment Process using the Phytoremediation Method. In the arrangement of the wastewater treatment installation using the phytoremediation method, it is similar to the wetlands method, except that the wetlands process is replaced with the phytoremediation process. After undergoing anaerobic, aerobic, and filtration processes, the wastewater is directed into the phytoremediation process for a duration of 1, 2, and 3 days. The phytoremediation process only involves the use of papyrus plants as the medium, without additional media like in the wetlands process. The samples taken and tested in the laboratory are the wastewater that has gone through the final series of processes, specifically in the phytoremediation method.

4 Result and Discussion

In the research conducted using the wetlands and phytoremediation methods, treatments were carried out for 3 (three) different time variables, namely 1, 2, and 3 days. Table 2 shows the temperature, TSS, pH, PO4, BOD and COD values of wastewater before treatment using the wetlands and phytoremediation methods. This is the result wastewater treatment at RSU Jember Klinik which is carried out using the ultraviolet light method. The results in table 2 show that the TSS, BOD and COD values before treatment using the wetlands and phytoremediation methods were respectively 102 Mg/L, 104 Mg/L and 184 Mg/L. This value does not meet water quality standards because it exceeds the maximum standard limits that have been set, namely 30 for TSS, 30 Mg/L for BOD, and 80 for COD. Another disadvantage of this ultraviolet light method is that it can only be used when sufficient sunlight is shining.

Tabel 2. The initial water sample quality before testing was evaluated

No	Parameter	Unit	Value	Requirements	Evidence
1	Temperature	^{o}C	26,23	$30^{o}C$	Meet
2	TSS	Mg/L	102	30	Not meet
3	pH	-	6,51	6 – 9	Meet
4	PO_4	Mg/L	0,806	2	Meet
5	BOD	Mg/L	104	30	Not meet
6	COD	Mg/L	184	80	Not meet

In the variable 1 process, the wetlands method uses a processing time of 1 (one) day which is then accommodated in the control tank. The results of this process is shown in Table 3.

Table 3. Result of wetlands method uses a processing time of 1 (one) day

No	Parameter	Unit	Value	Requirements	Evidence
1	Temperature	^{o}C	26,55	$30^{o}C$	Meet
2	TSS	Mg/L	0	30	Meet
3	pH	-	7,42	6 – 9	Meet
4	PO_4	Mg/L	0,558	2	Meet
5	BOD	Mg/L	40	30	Not meet
6	COD	Mg/L	67	80	Not meet

These results show that the wetlands method produces parameters that meet water quality standards, namely for temperature, TSS, pH, and PO_4, and COD with values respectively 26.55°C, 0 Mg/L, 7.42 Mg/L, 0.558 Mg /L, and 67 Mg/L but does not meet the BOD parameter of 40 Mg/L while the maximum water quality standard demand is 30 mg/L.

In the variable 2 process, the wetlands method uses a processing time of 2 (two) days which is then accommodated in the control tank. The results of this process is shown in Table 4.

Table 4. Result of wetlands method uses a processing time of 2 (two) day

No	Parameter	Unit	Value	Requirements	Evidence
1	Temperature	^{o}C	26,49	$30^{o}C$	Meet
2	TSS	Mg/L	1	30	Meet
3	pH	-	7,03	6 – 9	Meet
4	PO_4	Mg/L	0,372	2	Meet
5	BOD	Mg/L	36	30	Not meet
6	COD	Mg/L	40	80	Meet

The results of the process analysis over a period of 2 days resulted in a significant decrease, including from the initial process of 1 day between PO_4, BOD and COD, which on the first day resulted in PO_4 being 0.558 Mg/L on the second day to 0.372 Mg/L, BOD on the first day 40 Mg/L to 36 Mg/L in the second day, and COD on the first day

was found to be 67 Mg/L to 40 Mg/L in the second day. However, BOD does not meet the requirements below 30 Mg/L.
In the variable 3 process, the wetlands method uses a processing time of 3 (three) days which is then accommodated in the control tank, the results of which are shown in table 5.

Table 5. Result of wetlands method uses a processing time of 3 (three) day

No	Parameter	Unit	Value	Requirements	Evidence
1	Temperature	^oC	26,56	30^oC	Meet
2	TSS	Mg/L	0	30	Meet
3	pH	-	7,26	6 – 9	Meet
4	PO_4	Mg/L	0,310	2	Meet
5	BOD	Mg/L	25	30	Meet
6	COD	Mg/L	32	80	Meet

In the 3 day period analysis, maximum results were obtained in reducing waste water with temperature, TSS, pH, PO4, BOD and COD which met the waste water quality standard requirements, including temperature is 26.56^oC, TSS 0 Mg/L, pH is 7.26, PO_4 is 0.310 Mg/L, BOD is 25 Mg/L and COD is 32 Mg/L.
After the wetlands process has been completed and laboratory tests and data analysis have been carried out, the process continues using the phytoremediation method. The results of variable 1 water quality testing using a processing time of 1 (one) day on the phytoremediation method is shown in Table 6 below. In the phytoremediation process, waste water from the same hospital is used with the same collection time at the same time as the wetlands process.

Table 6. Result of variable 1 water quality testing using a processing time of 1 (one) day on the phytoremediation method

No	Parameter	Unit	Value	Requirements	Evidence
1	Temperature	^oC	27,20	30^oC	Meet
2	TSS	Mg/L	2	30	Meet
3	pH	-	7,67	6 – 9	Meet
4	PO_4	Mg/L	9,502	2	Not meet
5	BOD	Mg/L	42	30	Not meet
6	COD	Mg/L	67	80	Meet

The results of the analysis of the phytoremediation process within 1 day showed that the results of temperature, TSS, pH and COD passed waste water quality standards. The remaining PO_4 and BOD did not pass with respective values of PO_4 is 9.502 Mg/L from the requirement of below 2 Mg/L, and BOD 42 Mg/L from the requirement of below 30 Mg/L. The results from this process are higher than the results from the wetlands method during 2 days process.
Table 7 below shows the results of the phytoremediation method carried out for 2 days. In the treatment period of 2 days, the PO_4 and BOD figures were reduced from the previous day, but these figures still did not meet the requirements for waste water quality standards. PO_4 produces a value of 7.24 Mg/L and BOD produces 35 Mg/L. These results are higher than the results of the wetlands method during 2 days process.

Table 7. The results of variable 2 water quality testing using a processing time of 2 (two) days on the phytoremediation method

No	Parameter	Unit	Value	Requirements	Evidence
1	Temperature	^oC	27,18	30^oC	Meet
2	TSS	Mg/L	0	30	Meet
3	pH	-	7,72	6 – 9	Meet
4	PO_4	Mg/L	7,24	2	Not meet
5	BOD	Mg/L	35	30	Not meet
6	COD	Mg/L	52	80	meet

Based on table 8, the phytoremediation method over a period of 3 days show that the overall results were quite good but did not meet waste water quality standards, including a temperature of 27.25°C which should be below 30°C, TSS 9 Mg/L which should be below 30 Mg/L, pH 7.26 from what should be below 6 - 9, PO_4 8.145 Mg/L from what should be below 2 Mg/L, BOD 28 Mg/L from what should be below 30 Mg/L and COD 43 Mg/L from which should be below 80 Mg/L. In this case, it was stated that during the 3 day process the phytremediation method could not fully meet the waste water requirements. These results also show higher parameter values than the wetlands method during 3 days process.

Table 8. The results of variable 3 water quality testing using a processing time of 3 (three) days on the phytoremediation method

No	Parameter	Unit	Value	Requirements	Evidence
1	Suhu	^oC	27,25	30^oC	Meet
2	TSS	Mg/L	9	30	Meet
3	pH	-	7,26	6 – 9	Meet
4	PO_4	Mg/L	8,145	2	Not meet
5	BOD	Mg/L	28	30	Meet
6	COD	Mg/L	43	80	Meet

5 Conclusion

Based on the results of the tests that have been carried out, most of the temperature, TSS, pH, PO_4, BOD and COD values produced from the wetlands method are lower than those from the phytoremediation method. This shows that the wetlands method can be the best method that can be applied and used to reduce wastewater pollution compared to the phytoremediation method. Apart from that, the test results also show that the wetlands method is able to overall reduce wastewater pollutants over a period of 3 days, while the phytoremediation method still leaves PO_4 which does not meet the wastewater requirements.

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