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Effect of Media on Constructed Wetlands Performance with *Equisetum hyemale*

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Abstract: The objective of this study is to find the effect of the media on constructed wetlands capacity with *Equisetum hyemale* to remove chemical oxygen demand (COD) and phosphate (PO_4^{3-}) in laundry wastewater. Four reactors of constructed wetlands made of the plastic container were used. Three units of reactors used different media that had different diameter media for each, which were sand (SM), expanded clay (CM) and gravel (GM) while the fourth reactor was used without using the media as a control. The environmental parameters and performance of constructed wetlands were monitored every day until the fifth day of the experiment. The results showed that there was a difference of COD and PO_4^{3-} removal capacity between the control reactor and the reactors with media. The best performance was seen in SM, CM, and GM reactors. COD and PO_4^{3-} removal efficiency in SM reactor was up to 96.06% and 97.07%; in CM reactor was up to 86.32% and 95.69%; and GM reactor was up to 84.36% and 77.23%. These results showed that the constructed wetlands performance with *Equisetum hyemale* was affected by the presence of media.

Key words: Constructed wetlands, sand media, gravel media, expanded clay media.

Introduction

Laundry wastewater is one of the wastewater types produced in a few areas because of the population inclining rate in recent years. The laundry wastewater produced from commercial activities has potential pollute the inlet water source, for example,: the eutrophication process is the source of bad odour (Shao et al., 2014). Laundry wastewater contains various pollutants such as linear alkyl-benzene sulphonate (LAS), phosphate, chemical oxygen demand, nitrogen, heavy metals, volatile organic acid, and total suspended solids (Braga and Varesche, 2014). The presence of these contaminants signals urgent treatment to decontaminate laundry wastewater.

There are many technologies that can be used to treat laundry wastewater such AS coagulation-flocculation, electro-coagulation, adsorption and photolysis (Ramcharan and Bissessur, 2017; Sumisha et al., 2015; Terechova et al., 2014). Laundry wastewater treatments need a more advanced technology and expensive operational cost. However, laundry business is micro small and medium enterprises do not profit enough to conduct treatments of wastewater in general. One of the alternatives that can be conducted is using a constructed wetlands method. Constructed wetlands

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are proven to treat wastewaters from domestical to industrial range (Shao et al., 2014; Wu et al., 2015).

A few advantages of constructed wetlands is that it could be applied to various types of waste water and has a low-demand energy usage, it is also low-cost and easy operational process, and does not necessarily need additional chemical substances (Wu et al., 2015). In this research, *Equisetum hyemale* was used as the plant sample in the constructed wetlands reactors because of its fast-growing nature and high tolerance towards the environment. Besides this plant, the important factor which affects the constructed wetlands capacity is the substrate or plantation media (Vymazal and Kröpfelová, 2008; Wu et al., 2015). In general, constructed wetlands uses gravel media as the plant substrate, as researched by Akratos and Tsihrintzis (2007) in their pilot-scale experiment which showed that the constructed wetlands using gravel as media and *Pragmites australis* and *Typha latifola* plants could reduce the BOD contents and orthophosphate up to 89% and 60%, respectively. Based on those references, there is a need to investigate and find an alternative media that have the potential to be utilised in enhancing the constructed wetlands capacity to treat wastewater. This research was conducted with an objective to determine the COD and phosphate (PO_4^{3-}) contents removal capacity using media that have different particle sizes such as sand, expanded clay and gravel in constructed wetlands with *Equisetum hyemale* plant for treating laundry wastewater.

Materials and Methods

Constructed Wetlands Reactors

The four constructed wetlands reactors in rectangular shape were made of plastic with an overall volume of 99 L. The dimensions of rectangular reactors in terms of length, width, and depth were 0.63 m, 0.41 m and 0.38 m, respectively. Each reactor was labelled according to the media that was put into, for example, sand media (SM), expanded clay (CM), gravel media (GM) and without media (NM). The media used were divided into three layers. The first layer was 5 cm of gravel as the holding media. The second layer was 5 cm of sands as the filtration media. Third layer was 15 cm of the variation media of SM/CM/GM as the main media. The media's particle diameter used in this study was 0.4-2 mm for sand, 8-16 mm for expanded clay and gravel 20-30 mm for gravel. The outlet of the reactor was located on the part of the container which contains the holding media. Three reactors of SM, CM and GM were planted with *Equisetum hyemale* and arranged in eight groups' altogether. Each group consists of 20 stems of *Equisetum hyemale* with an average height of 100-120 cm.

Experimental Study

An experimental study in this research was conducted by using the batch system. In total, three reactors for analysing the media's effect on removal performance, and one reactor without media for control measurement were used. The reactors with media were equipped with *Equisetum hyemale,* that is, 160 stems equalled 600 stems/m^2 in density. Reactors were placed inside a greenhouse in Department of Biology, Universitas Airlangga under natural condition. The research was conducted in the dry season which was in June 2019. Laundry wastewater used in this research work was collected from a commercial laundry business.

Acclimatisation for the *Equisetum hyemale* plants in the constructed wetlands was done by using tap water for 7 days (Wahyudianto et al., 2019). After the process finished, the tap water was drained out from the reactors and replaced with laundry wastewater. Laundry wastewater was poured into each reactor prepared with the height of the water up to 23 cm from the reactor's base. The laundry wastewater was analysed to get the initial characteristic or measurement before the treatment. The sample was stored into glass bottles and kept at a temperature of 4^oC before being analysed (Ramprasad et al., 2017).

Analysis of pH, DO and the temperature was done every day right after taking a sample. Parameters analysis in the water sample was pH, DO, temperature, COD and PO_4^{3-}. pH analysis used pH meter (Senz Transinstrument). DO and temperature analysis used multi probe oxygen meter (Lutron, Taiwan). COD analysis used close reflux dichromate titrimetric method, and PO_4^{3-} analysis used stannous chloride method (APHA, 2005) with spectrophotometer instrument (Boeco, Germany). For other environment factors, such as room temperature and humidity, analysis was performed using portable thermo-hygrometer (Krisbow, China) and light intensity analysis used lux meter (Dekko).

Results and Discussion

The laundry waste water collected from commercial laundry activities has initial COD and PO_4^{3-} contents measured amounts of 613 and 6.11 mg/L, respectively. The measurement of the other parameters like pH

with initial value approximately ranged in 7-8, waste water temperature was up to 28°C, and DO was 5.2-6.8 mg/L. External environments condition monitored was air temperature which was measured 31.8-32.4°C in average, humidity in the range of 68-74% and light intensity in the range of 2,000-6,000 lux in range. Those conditions were suitable enough of environment for the *Equisetum hyemale* to grow in the constructed wetlands reactors.

Effect of Media on COD Removal

COD concentration removal results are described in Figure 1. The results showed that the COD concentration from first day to fifth day decreased gradually. The highest result to reduce COD concentration was the outcome from sand media (SM), which could reduce the COD value from 613 to 146 mg/L on first day with removal efficiency was 76.18%. The reduction in COD concentration in the control reactor without media (NM) had the smallest result, with the COD final concentration was approximately 480 mg/L and the removal efficiency was 21.75% on first day. The lowest COD concentration resulted on the fifth day which showed that SM, CM, and GM reactors were capable to reduce the amount to 24, 84 and 96 mg/L, respectively. The longer detention time used for the wastewater in constructed wetlands reactors could increase the COD removal efficiency (Akratos and Tsihrintzis, 2007; Merino-Solís et al., 2015). This is because the degradation process of organic matter by microorganism in the constructed wetlands reactors were higher along with the waste water detention time in the reactors.

The highest performance was shown by SM, which had COD removal efficiency up to 76.18-96.09% with effluent concentration of 24-146 mg/L, compared to CM and GM reactors. In previous research works, it has been stated that using gravel and bio-char could reduce the COD content in range between 78.07 and 81.47% (Gupta et al., 2016). The COD removal process in constructed wetlands was occurred because of removal process in terms of physical, chemical and biological changes taking place in the reactors. Removal efficiency in SM was higher compared to those of CM and GM because of the difference in the particle the particle size of media in SM, which smaller particle size than CM and GM. The research works of Akratos and Tsihrintzis (2007) proved that gravel's medium size and fine gravel showed a different result in reducing BOD and COD contents.

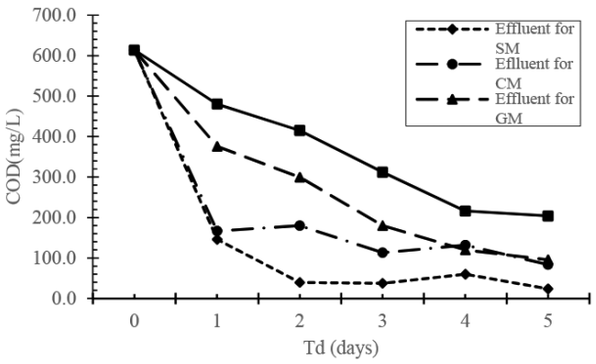

Figure 1: COD concentration in constructed wetlands with *Equisetum hyemale.*

Effect of Media on Phosphate Removal (PO_4^{3-})

Phospate (PO_4^{3-}) concentration removal results are described in Figure 2. PO_4^{3-} concentration started to decrease on the first day of observation for the three reactors of SM, CM and GM. SM reactor could reduce PO_4^{3-} concentration to 1.15 mg/L or equal to 81.08% in removal efficiency on first day whereas the CM reactor was able to reduce PO_4^{3-} concentration to 0.94 mg/L or equal to 84.52% in removal efficiency on first day, and GM reactor was capable to reduce PO_4^{3-} concentration to 1.43 mg/L or equal to 76.54% in removal efficiency. The PO_4^{3-} concentration reduction process in the control reactor without media (NM) also occurred, however, not as much as the three constructed wetlands reactors with media, which was up to 5.30 mg/L or equal to 13.24% in removal efficiency.

The PO_4^{3-} concentration removal process was continuously taking place in SM, CM and GM reactors until the fifth day while the PO_4^{3-} concentration in NM reactor was tended to not have significant reduction results until the fifth day. Removal efficiency of SM, CM and GM on the fifth day was 96.89%, 95.69% and 77.23%, respectively. Referring to the research work by Gupta et al. (2016), gravel media and bio-char could decrease PO_4^{3-} content up to 67.7%. In the full scale constructed wetlands in Yazd's wastewater treatment plant, they were only capable to reduce PO_4^{3-} content for 35.20% (Farzadkia et al., 2015). Whereas other's research stated that constructed wetlands were able to reduce the total phosphate (TP) content up to 72.7 and 90.4% (Jóźwiakowski et al., 2018; Shao et al., 2014).

The common processes that occurred in PO_4^{3-} content removal were precipitation, plant-microbial uptake and adsorption by media (Trang et al., 2010; Vymazal and Kröpfelová, 2008; Wahyudianto et al., 2019). Plant uptake is one of the processes that happens in PO_4^{3-} removal, in which plants use the phosphorus

content to enhance the nutrient content and are able to deposit phosphorus to the stems or roots of *Equisetum hyemale* (Wahyudianto et al., 2019). Media that has a big adsorption capacity could reduce high amount of PO_4^{3-} content (Jóźwiakowski et al., 2018). SM reactor had the highest removal efficiency compared to CM and GM reactors. The reason was because SM reactor had the smallest particle size; so it potentially has a bigger adsorption capacity. Besides this factor, the sand used as media could possibly have iron and/or calcium content that helped to decrease the PO_4^{3-} content (Trang et al., 2010). These results were also shown in CM reactor with a smaller diameter size and porosity that could lead to reduced PO_4^{3-} content better than GM reactor, as described in Figure 2. Therefore, media's size, porosity and media's composition could affect the constructed wetlands capacity with *Equisetum hyemale*.

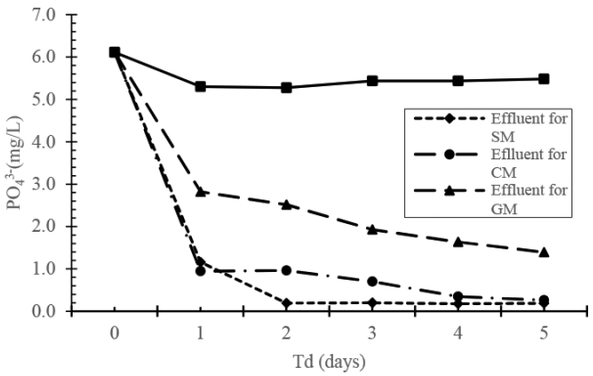

Figure 2: PO_4^{3-} concentration in constructed wetlands with *Equisetum hyemale.*

Conclusions

The results of this research shows the media effect on COD and PO_4^{3-} removal in laundry wastewater using constructed wetlands with *Equisetum hyemale*. Removal of COD and PO_4^{3-} on the first day showed COD and PO_4^{3-} reductions in the outlet of constructed wetlands. COD and PO_4^{3-} qualities were better with detention time of wastewater treatment until the fifth day. The highest COD and PO_4^{3-} concentration removal was in SM reactor, which shows its removal efficiency was up to 96.06% and 97.07% whereas for CM reactor, it was up 86.32% and 95.69% and in GM reactor was up to 84.36% and 77.23%. These results showed that the constructed wetlands performance with *Equisetum hyemale* was affected by the media.

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