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Application of *Equisetum hyemale* in Constructed Wetland: Influence of Wastewater Dilution and Contact Time

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ABSTRACT

In the present study, the systematic approach to evaluate potency of *Equisetum hyemale* in constructed wetland, bio-degradation and adsorption of TSS, COD, phosphate, and LAS were described. The overall objective of the study was to determine the ability of *Equisetum hyemale* to remove pollutants in laundry waste water in several percentage of dilution and contact time. This research used 4 groups of *Equisetum hyemale* in each reactor. *Equisetum hyemale* was planted in the richest nutrient of soil. The laundry waste water was contacted in batch system. The *Equisetum hyemale* removed TSS, COD, Phosphate, LAS until 90% in variation of waste water dilution after 2 days of contact. *Equisetum hyemale* showed best performance in 100% of laundry waste water. It was observed that 4 days of contact time were optimal for removing pollutants in laundry waste water. The *Equisetum hyemale* removed TSS, COD, Phosphate, LAS up to 90% in variation of contact time.

Keywords: constructed wetlands, *Equisetum hyemale*, batch system

INTRODUCTION

Wastewater is an environmental issue which has always been the focus of the environmental management. It could not be separated from the urban development which is rapidly increasing especially in the developing countries. Along with the increasing of population, unavoidable environmental consequences occur. One of the many threats for the environment is from the laundry activities, which could come from both domestic and commercial laundries. In general, the laundry procedure uses detergents as a material to clean clothes and fabrics. The procedures generate the wastewater which contains phosphate, surfactant, grease, *total suspended solid*, organic material contents [Sawadogo *et al.*, 2014]. High concentration of nitrogen and phosphate parameters in the water source causes eutrophication and unwanted odor [Shao, *et al.*, 2014]. The surfactant content can increase the bacteria population while linear alkyl benzene sulfonate (LAS) that is found

in laundry waste water can become a carcinogenic substance [Sumisha *et al.*, 2015].

The effort to decrease the laundry waste impact is by conducting the laundry wastewater treatment. The Laundry wastewater treatment methods that can be performed involve coagulation, flocculation, adsorption, filtration, oxidation, biological treatment [Sumisa *et al.*, 2015; Kim *et al.*, 2005]. One of the biological treatments that can be used for laundry wastewater treatment is constructed wetlands (CWs). CWs is a treatment plant that has some benefits, including ease of application, low energy use, and low operational costs [Wu *et al.*, 2015; Timotewos *et al.*, 2017]. These factors show that CWs can be applied in densely populated and even in the developing areas.

The treatment process in CWs is not fixated only on biological treatment such as pollutant absorption by plants or microorganism. In CWs, other treatment processes occur as well, for example sedimentation, filtration, adsorption, precipi-

tation [Wu *et al.*, 2014; Wu *et al.*, 2015]. These processes can increase the pollutant elimination that occurs in the CWs unit. The use of CWs for waste water treatment can be affected by a few factors, which include plants species, hydraulic retention time, medium type, temperature, dissolved oxygen, and loading rate [Gosh and Gopal, 2010; Meng *et al.*, 2014; Liu *et al.*, 2016].

On the basis of these factors, in this research the plant used for laundry wastewater treatment was *Equisetum hymale* which has the ability to grow fast and well (Australian Weed Management, 2003). Aside from that this research aimed at measuring the pollutant removal efficiency in laundry waste water with dilution and detention time in CWs unit.

MATERIALS AND METHODS

The laundry wastewater was collected from commercial laundry at Jl. Sutorejo, Surabaya City, Indonesia. The volume of laundry wastewater was 20L. The characteristics of wastewater were described in Table 1.

The batch experiments reactors used 40 L pots with the length, width, and height of 80cm, 20 cm, and 25 cm respectively. The composition of media in the reactor consisted of 3 cm gravel (ϕ 20 mm), 3 cm sand (ϕ 0.4–2 mm), and 15 cm of soil and 4 group of *Equisetum hymale* as shown in Figure 1. Each reactor had 4 variations with 2 replications.

The implementation of laundry wastewater treatment was conducted in 2+stage experiments. The first stage was treating the laundry waste water with dilution variation. The laundry wastewater was diluted with 100%, 80%, 60%, 40%, and 20% concentration. The diluted wastewater then was inserted in CWs reactor by a batch system in 2 days of contact time and then the samples were collected to analyze the TSS, COD, phosphate, and LAS parameters. The results obtained from the first stage were subjected to ANOVA to determine the concentration that would be used in the second stage.

Table 1. Characteristic of Laundry Wastewater

| Parameter | Unit | Concentration |
|-----------|------|---------------|
| TSS | mg/l | 641.00 |
| COD | mg/l | 876.92 |
| Phosphate | mg/l | 10.42 |
| MBAS | mg/l | 47.54 |

The implementation of the second stage was conducted with contact-time variation. Time contact was arranged as 1, 2, 3, 4, and 5 days. The laundry wastewater was inserted into CWs reactor correspond to the variation planned by the batch system. The samples were collected corresponding to the detention time variation and were analyzed for the TSS, COD, phosphate and anionic surfactant parameters value. The results obtained from the parameters analysis were subjected to ANOVA to find the optimum time in laundry wastewater treatment by CWs.

The water quality analysis was conducted for the TSS, COD, Phosphate, LAS parameters. Each parameter was analyzed corresponding to the following procedures [APHA, 2005]:

- Gravimetric analysis – to determine the TSS value, dried at 103–105 °C (2540 D),
- Titrimetric analysis with closed reflux – to determine the COD value (5220 C),
- Stannous Chloride analysis – to determine the phosphate value (4500-P D),
- Anionic surfactant as MBAS – to determine the LAS value (5540 C).

The calculation of the pollutant removal efficiency was conducted by comparing the initial concentration value (C_d) and final concentration (C_o) corresponding to the following equation [Dębska *et al.*, 2015]:

$$\%removal = \left(1 - \frac{C_o}{C_d}\right) \times 100\% \quad (1)$$

RESULT AND DISCUSSION

Influence of waste water dilution

The results of removal efficiency for TSS, COD, phosphate and LAS parameters using *Equisetum hymale* with wastewater variation in CWs were presented in Figure 2. These results showed that the TSS removal efficiency was between 34–93%. COD was between 74–95%, phosphate was between 29–90%, and LAS was between 95–99%. The results proved the ideal performance of CWs unit.

The TSS removal efficiency in the CWs using *Equisetum hymale* ranged between 34–93%. The highest TSS removal was shown with 80% wastewater dilution with the removal efficiency up to 93%. That result correlated with the prior research, where the TSS removal using CWs to

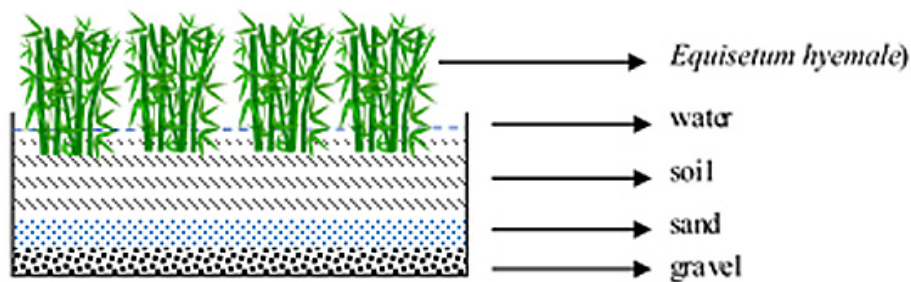


Figure 1. Schematic of reactor

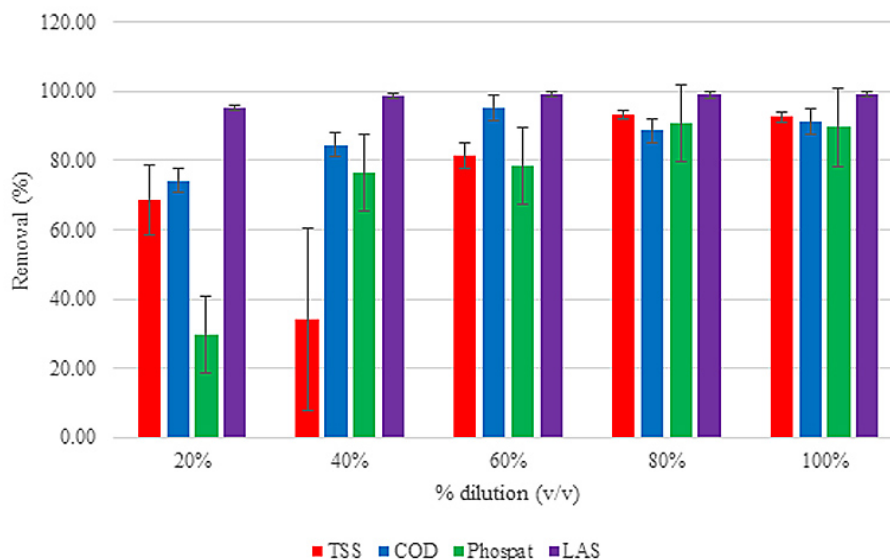


Figure 2. Effect of Dilution on the Efficiency TSS, COD, Phosphates and LAS removal in CWs

treat laundry wastewater was up to 83% [Davison et al., 2005], while in Abdel-Shafy [2009] research for treating grey water could reduce the TSS concentration up to 94%. The CWs using *Equisetum hymale* for TSS removal occurred because the solid particles were trapped into the media, which are soil, sand, and gravels.

The COD removal efficiency in the CWs unit using *Equisetum hymale* ranged between of 74–95%. The highest COD removal was shown with 60% wastewater dilution with the removal efficiency up to 95%, which has no significant change with 100% wastewater dilution. The research by Puchlik [2016] showed that with CWs unit, it could reduce the COD up to 79.3% by using common reed (*Phragmites australis*), while in the Dębska et al. [2015] research, the domestic wastewater treatment using CWs unit could reduce the COD value by up to 94%. The result of laundry wastewater treatment using CWs with *Equisetum hymale* had a little bit higher of removal value than the previous similar studies. The COD removal in CWs happened because of the soil,

sand, and gravel media which caused a filtration mechanism to remove organic matter. Apart from that the media could produce a bio-film which could increase the removal of organic matters.

The phosphate removal in the CWs using *Equisetum hymale* with variation of wastewater dilution ranged between 30–91%, where the phosphate content value was up to 1.14–10.7 mg/l. The highest phosphate removal was shown with 80% wastewater dilution. The removal efficiency result in CWs with *Equisetum hymale* showed a quite high efficiency compared with Dębska et al. [2015] research where they used *common reed*, where the result obtained was up to 86.1–88.4%. The phosphate removal process in CWs happened because of the media adsorption, sedimentation of microorganism activities, and the uptake process by the plants [Luca et al., 2017; Prodanovic et al., 2017].

The Linear Alkyl Sulfonate (LAS) removal in the CWs with *Equisetum hymale* was between 95–99%. The highest removal was shown at 100% concentration of wastewater, where LAS

concentration was 16.96 mg/l. These results showed that *Equisetum hymale* could treat the laundry wastewater directly without dilution. The treatment using CWs with *Equisetum hymale* has higher capability of LAS removal efficiency than exhibited in Pucci et al., [2010] research, where they used *Phragmites australis* and the result obtained was only up to 84%.

On the basis of the efficiency results obtained from TSS, COD, phosphate, and LAS parameters, it could be found that a CWs unit using *Equisetum hymale* has the capability of treating the laundry wastewater with the 100% concentration of waste compounds.

Influence of detention time

This research also was conducted to find the influence of detention time on the removal efficiency of TSS, COD, phosphate, and LAS parameters in the CWs using *Equisetum hymale*. The influence of detention time was conducted with variation of the detention time, which were 1, 2, 3, 4, and 5 days, respectively. The results from the laundry wastewater treatment using the CWs with *Equisetum hymale* by the detention time variation were expressed in Figure 3. The results showed the the removal of TSS parameter ranged between 2.88–12.5%, COD ranged between 53.57–95.12%, phosphate between 95.49–99.32%, and LAS between 99.16–99.76%.

The highest TSS removal by the influence of detention time variable was 12.5% which was obtained in 3 days of detention time. Suspended particles could be removed by the media in CWs using *Equisetum hymale* plants, which were sand

and soil. It was caused by the media, which was one of the important parts as filter.

The COD removal in a CWs using *Equisetum hymale* with variation of detention time had the highest efficiency in 4 days of detention time, reaching 85.12%. The removal of organic matter such as COD in a CWs system could be caused by the filtration mechanism on the media's surface and the microbiology activities which resided in the media [Qin and Chen, 2016]. In Sultana et al., [2015] research it was shown that in 1 day detention time, it could reduce the COD value by up to 91%. Meanwhile, in Merino-Solis et al., [2016] research, they showed that the COD removal efficiency was up to 32% with 2 days of detention time.

The phosphate removal in a CWs unit using *Equisetum hymale* with variation of detention time showed a very high removal efficiency, which was up to 95.49–99.32% and the highest removal was in 4 days of detention time. Detention time has influence on the removal process, which was caused by a few removal mechanisms of CWs. The phosphate removal mechanism could be caused by the media's adsorption, sedimentation, the uptake process by the plants, and micro-organism activities, which all were the processes that occurred for the phosphate removal in a CWs unit [Luca et. al., 2017; Prodanovic et. al., 2017].

The LAS removal efficiency obtained in CWs using *Equisetum hymale* with variation of detention time was 99.16–99.76%. This result showed a very high level of removal. Each variation has the efficiency value that was relatively equal amounting to 99%. This showed that the LAS removal process was optimal in this research. The highest removal was up to 99.76% which occurred in a

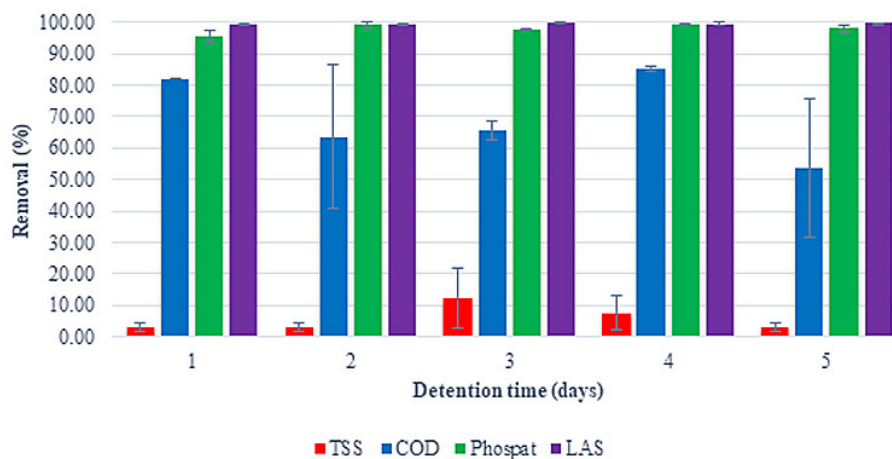


Figure 3. Effect of Detention Time on Efficiency of TSS, COD, Phosphate and LAS removal in CWs

CWs with 5 days detention time. In the research by Thomas *et al.*, [2017], it was mentioned that plants utilization in wastewater treatment could increase the removal efficiency of a CWs unit.

The laundry wastewater treatment with CWs using *Equisetum hymale* had optimal value in 4 days of detention time. This result was based on the efficiency analysis of TSS, COD, phosphate, and LAS parameters.

CONCLUSION

The *Equisetum hyemale* removed TSS, COD, Phosphate, LAS until 90% in variation of wastewater dilution after 2 days of contact. *Equisetum hyemale* showed the best performance in 100% of laundry waste water. The optimal contact time for removal of pollutants in laundry wastewater was 4–5 days. The *Equisetum hyemale* removed TSS, COD, Phosphate, LAS up to 90% in variation of contact time.

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