Advanced Science Letters
Vol. 23, 11843–11847, 2017

The Effect of Detention Time and Plant Density to the Effectivity of Constructed Wetland as Wastewater Treatment Innovation in Small Industry of Cassava Chips

Erina Rahmadyanti[1,*], Andre Dwijanto Witjaksono[2], and Ulil Hartono[2]

[1]*Department of Civil Engineering, Universitas Negeri Surabaya, Surabaya 60231, Indonesia*
[2]*Department of Management, Universitas Negeri Surabaya, Surabaya 60231, Indonesia*

The sustainable development issue provides an enormous effect on the survival of small industries, especially in terms of waste treatment which is often discarded without any treatment processes beforehand. Cassava chips industry is one of the small industries which grows due to the availability of excessive raw materials, meanwhile this industry produces the wastewater. This study aims to determine and analyze the effect of plant density and detention time of the effectivity of constructed wetland in treating wastewater produced by small industries of cassava chips. The plants used were *Typha latifollia L* with density of 16, 20 plants, and 24 plants/m^2 and the detention time of 0, 3, 5, 10, and 15 days. The parameter of wastewater pollutants observed were BOD, TSS, NH_3–N, Phosphate, and CN. Conclusions derived from the processing of cassava chips wastewater using sub-surface constructed wetland with *Typha latifollia L* plants was significant effect on the interaction between plant density and the detention time on the effectivity of sub-surface constructed wetland in the designated levels of BOD, TSS, NH_3–N, Phosphate, and CN in the wastewater of cassava chips using *Typha latifollia L*.

Keywords: Cassava Chips, Constructed Wetland, Small Industry, Wastewater.

1. INTRODUCTION

Small and medium enterprises are the backbone of the Indonesian economy. It has role in producing, innovating and creating job opportunities. However, in reality there are many limitations such as knowledge, equipment, and capital come as obstacles.

These limitations cause the majority of small and medium enterprises less or even unaware if their industrial activities pollute the environment. The rapid growth of small and medium enterprises in various economic sectors in Indonesia which has similar characteristics causes the increase of environmental pollution potentials.[1]

This condition becomes an important issue, especially in global trade where SMEs must have good environmental performance in order to compete in global market.[2] Reducing environmental impacts by SMEs does not only mean to win the global trades market but also become a key factor in succeeding greener economy and sustainable development. Therefore, these conditions require better environmental performance of SMEs in controlling pollution by implementing simple and inexpensive technology.[3]

Food and beverage industries are one of the major contributors for Indonesian economic growth, due to the availability of raw materials. One of the raw materials widely used in food and beverage industries is cassava. Cassava is able to be processed into various products such as chips, flour, and starch.[4,5] In producing cassava into various products, water becomes an essential factor used in various stages of production. Therefore, wastewater is resulted as one of the main waste in this industry.[6]

Processing sub-surface constructed wetland method commonly used in wastewater treatment in food industry is biological treatment.[7] This method is difficult to be implemented by SMEs because it requires skilled personnel and high cost. Constructed wetland is a promising method especially for developing and tropical countries, such as Indonesia. Constructed Wetland has been used as green technology in treating various wastewater for decades.[8] Aesthetically, constructed wetland seems like a garden rather than conventional wastewater treatment unit. This system emphasizes the use of local resources which is more environmentally friendly than biological wastewater treatment unit. Constructed wetland has several characteristics namely: (1) natural process; (2) simple construction design; (3) simple operation and maintenance; (4) cost-effectiveness; and (5) local resources.[9,10]

*Author to whom correspondence should be addressed.

 1936-6612/2017/23/11843/005 doi:10.1166/asl.2017.10529

Constructed wetland can be used in primary, secondary and tertiary treatment for domestic wastewater or settlements, agricultural wastewater and industrial wastewater; and usually combined with adequate pre-treatment.[11] In addition, this system is possible to treat in small quantities until large volume of waste water in different levels and types of pollutants.[12] There are previous studies mentioned that constructed wetland has potential in decreasing level of cyanide and other pollutants.[13] The effectiveness of treatment using constructed wetland for domestic wastewater was explained that the use of constructed wetlands with Phragmites karka in Sumedang, Indonesia was able to decrease the content of BOD_5 into 98.94%; COD into 96.76%, PO_4–P into 91.92%, total of nitrogen into 53.71% and more than 98% of *E. coli* bacteria.[14] Another researcher stated that the constructed wetland is able to decrease BOD_5 into 98%, COD into 95–99%, total N into 71–97%, and total P into 97–99%.[15] Other researchers explained that there was a decrease of pollutant parameters of BOD_5 to 87–98%, COD to 59–91%, and SS to 77–99% by implementing constructed wetland.[16]

Based on the various results of the earlier studies, it was concluded that the constructed wetland was an appropriate solution for wastewater treatment. Despite the extensive used of constructed wetland for wastewater treatment, the sustainability in successfully implementing and managing this system still remains a challenge.[10] This study aims to determine and to analyze the effect of plant density and detention time to the affectivity of constructed wetland in wastewater treatment by small industries cassava chips.

2. METHOD

2.1. Plants Used in Constructed Wetlands

Plants used in domestic and industrial wastewater treatment, were cattails *(Typha spp.),* bulrushes *(Scipus spp.),* and reed canarygrass *(Phalaris arundinacea)*.[17] This research used *Typha latifolia L.* due to its availability in Indonesia. *Typha latifolia L.* was planted 7 months in tropical climates before it was used in constructed wetlands.[9] It must be undergone, in order to make *Typha latifolia L.* Be able to adjust from the stress which occurs during the early plantation before it was flowed by wastewater on constructed wetland. In planting, periodical monitoring was needed normally every week in order to oversee the growth, health, pest, and rodents. Other plants which may grow along with *Typha latifolia L.* should be eliminated. *Typha latifolia L.* populations should be controlled according to the variables in this research which were 16 plants/m^2, 20 plants/m^2, and 24 plants/m^2. These actions were taken to prevent overcrowding growth.

2.2. Structure of Constructed Wetland

Constructed wetland made in pilot scale with the surface area $A = 1.4$ m^2, the effective depth $h = 1.0$ m, and an average depth of liquid in a constructed wetland $ho = 0.65$ m. Furthermore *Typha latifolia L.* planted at a density of 16 plants/m^2, 20 plants/m^2, and 24 plants/m^2. Plants planted on the media of bed with a depth of 0.5 m with buds slightly open and the water level set at 5 cm below the bed surface. Constructed wetland units filled with the substrate from the bottom with 0:15 am thickness, the next gravel was 6 mm with 0:46 am thickness, and 0.3–0.5 mm sand-sized layer at the top with 0:09 m thickness of. As part of the construction, before filled by constructed wetland, media covered by impermiable HDPP (High Density Polypropilene) plastic with 1 mm thickness to prevent ground water contamination. Wastewater through perforated *polyvinylchloride* (PVC) pipe was discharged set at 100 m/min.

2.3. Constructed Wetland Operation

Wastewater was taken from the production process of cassava chips stored in refrigerator at the temperature of 3 °C prior to analysis.[18] Analysis was performed immediately after collecting samples. Constructed wetland subsequently was filled by wastewater with varied detention time of 3–15 days to replenish pollutants process from wastewater.[19] In this research, the detention time was set at 0, 3, 5, 10, and 15 days; and the samples were periodically taken at the inlet and outlet constructed wetland. Subsequently the samples were analyzed with the parameters according to standard methods: pH (potentiometric method), chemical oxygen demand (COD; Closed Reflux, Colorimetric Method), biochemical oxygen demand (BOD_5; 5-day BOD test), total suspended solids (TSS; total Solids Dried at 103–105 °C Method), Kjeldahl Nitrogen (TKN; Kjeldahl Method), nitrate (NO_3; nitrate Electrode Method), ammonia (NH_3 Phenate Method), total phosphorus (total P; Manual Digestion and flow Injection Analysis for total Phosphorus), total Chromium (total Cr; Nitric Acid Digestion Followed by the Colorimetric Method), total Cyanide (total Cn; Micro distillation and flow Injection Analysis) and hexavalent chromium (Cr VI; Colorimetric Method).

2.4. Data Analysis

The objectives of this research were to determine the effect of detention time and the plants density to the effectivity of constructed wetland in wastewater treatment in small industry of cassava chips. The variables were grouped into dependent and independent variables. The dependent variables of this research were the levels of pollutants in wastewater in small industry of cassava chips, such as BOD, TSS, NH_3–N, Phosphate and CN. While the independent variables of this research were detention time and plant density. Furthermore, the data was analyzed for its homogeneity and partially effect as well as the interaction between the independent variables and the effectivity of constructed wetland using Multivariate ANOVA (Manova).

3. RESULTS AND DISCUSSION

Cassava is one of the staple food consumed by Indonesian people. Its availability throughout the country makes cassava processed into various types of foods; one of them is cassava chips. Cassava chips production is mostly carried out by small and medium industries. Lack of knowledge creates the wastes which are directly discharged to the environment without any prior treatment. As for the characteristics of the wastewater resulted by cassava chip industry can be seen in Table I.

Table I. Characteristics of liquid waste of cassava chips industry.

No	Parameter	Influen (mg/l)	Efluen (mg/l)
1	BOD	220	163
2	TSS	178	97
3	NH_3–N	56	17
4	Phosphate	20	8
5	CN	7	0.5

Table II. Result of Levene's test for equality of variances.

	F	df1	df2	Sig.
BOD	1.623	14	30	.130
TSS	1.254	14	30	.291
NH_3–N	.816	14	30	.647
Phospate	3.218	14	30	.421
CN	1.471	14	30	.183

Table III. Result of multivariate test on detention time.

Effect	Value	F	Sig.
Intercept			
Pillai's trace	.999	5772.9	.000
Wilks' lambda	.001	5772.9	.000
Hotelling's trace	1110.183	5772.9	.000
Roy's largest root	1110.183	5772.9	.000
Time detention			
Pillai's trace	1.835	4.916	.000
Wilks' lambda	.004	18.832	.000
Hotelling's trace	72.608	88.945	.000
Roy's largest root	70.479	408.77	.000
Plant density			
Pillai's trace	1.161	7.477	.000
Wilks' lambda	.135	8.973	.000
Hotelling's trace	4.230	10.576	.000
Roy's largest root	3.624	19.569	.000
Time detention ∗ Plant density			
Pillai's trace	1.831	2.167	.000
Wilks' lambda	.075	2.358	.000
Hotelling's trace	4.013	2.448	.000
Roy's largest root	2.121	7.953[b]	.000

Those wastewaters were treated using sub-surface constructed wetland as designed in the previous section. Table I shows the significant reduction for all parameters pollutants. The optimal reduction occurred at density of 20 plants/m^2, while the optimum detention time was 10–15 days. Effectivity of sub-surface constructed wetland needs more in depth study, especially related to the role of plants and detention time in reduction process in the level of various pollutants.

An initial stages to determine the role of detention time and plant density on the effectivity of sub-surface constructed wetland was to find whether the data obtained had been homogenized, hence it can be well-generalized. Homogeneity of variance test was conducted to determine the homogeneity of dependent variables, namely BOD, TSS, NH_3–N, Phosphate and CN which were hypothesized as:

H_1: Matrix variance/covariance in each dependent variable is different (heterogeneous).

H_0: Matrix variance/covariance in each dependent variable is same (homogenous).

If the value of the significance of Levene's Test >0.05 H_0 were accepted, however, if the value of the significance of Levene's Test ≤ 0.05, H_1 were accepted. The results of data processing for the homogeneity of variance test showed in Table II.

Based on the results showed in Table II, it can be concluded that the significance of Levene's Test >0.05 for all of the dependent variable. It means that H_0 was accepted; this indicated that the variance of the dependent variable had homogeneous variance or covariance, so the data can be further analyzed. Furthermore, the analysis of the effect of variable partial detention time on the effectivity of constructed wetland were:

H_1: Variable of detention time has significant effect on the levels of BOD, TSS, NH_3–N, phosphate, and CN for any detention time.

H_0: Variable detention time has no significant effect on the levels of BOD, TSS, NH_3–N, phosphate, and CN for any detention time.

Based on multivariate test, Table III shows that the value of Pillai's Trace, Wilks' lambda, Hotelling's Trace, and Roy's Largest Root on detention time had significance value of 0.000 or >0.05. It means that H_1 was accepted or can be concluded that independent variable of detention time had significant impact on the decreasing levels of BOD, TSS, NH_3–N, Phosphate, and CN for any detention time. The research showed that the effectivity of constructed wetland in the lower levels of BOD, TSS, NH_3–N, Phosphate, and CN was strongly influenced by the detention time. This result was in line with the prior research was done[20, 21] which found that the submersion time is the most important factor in the efficiency of the pollutant reduction process. The longer submersion time of the water in constructed wetland, the more reduction could be taken. These conditions rose to possibilities of biological, physical and chemical interaction become more optimal. These were also carried out to determine the partial effect of plant density variable on the effectivity of constructed wetland.

H_1: Variable of detention time has significant effect on the levels of BOD, TSS, NH_3–N, phosphate, and CN for any detention time.

H_0: Variable detention time has no significant effect on the levels of BOD, TSS, NH_3–N, phosphate, and CN for any detention time.

Based on multivariate test, Table IV shows that the value of Pillai's Trace, Wilks' lambda, Hotelling's Trace, and Roy's Largest Root on the density of the plants had a significant value of 0.000 or >0.05. This means that H_1 was accepted or can be concluded that the independent variable density of the plants had significant effect in decreasing levels of BOD, TSS, NH_3–N, Phosphate, and CN for each plant density. Significant effect of plant density in reducing the levels of pollutant in the constructed

Table IV. Result of multivariate test on density of plant.

Effect	Value	F	Sig.
Intercept			
Pillai's trace	.999	5772.950[a]	.000
Wilks' lambda	.001	5772.950[a]	.000
Hotelling's trace	1110.183	5772.950[a]	.000
Roy's largest root	1110.183	5772.950[a]	.000
Time detention			
Pillai's trace	1.835	4.916	.000
Wilks' lambda	.004	18.832	.000
Hotelling's trace	72.608	88.945	.000
Roy's largest root	70.479	408.778[b]	.000
Plant density			
Pillai's trace	1.161	7.477	.000
Wilks' lambda	.135	8.973[a]	.000
Hotelling's trace	4.230	10.576	.000
Roy's largest root	3.624	19.569[b]	.000
Time detention ∗ Plant density			
Pillai's trace	1.831	2.167	.000
Wilks' lambda	.075	2.358	.000
Hotelling's trace	4.013	2.448	.000
Roy's largest root	2.121	7.953[b]	.000

Table V. Result of multivariate test on interaction between detention time and density of plant.

Effect	Value	F	Sig.
Intercept			
Pillai's trace	.999	5772.950[a]	.000
Wilks' lambda	.001	5772.950[a]	.000
Hotelling's trace	1110.183	5772.950[a]	.000
Roy's largest root	1110.183	5772.950[a]	.000
Time detention			
Pillai's trace	1.835	4.916	.000
Wilks' lambda	.004	18.832	.000
Hotelling's trace	72.608	88.945	.000
Roy's largest root	70.479	408.778[b]	.000
Plant density			
Pillai's trace	1.161	7.477	.000
Wilks' lambda	.135	8.973[a]	.000
Hotelling's trace	4.230	10.576	.000
Roy's largest root	3.624	19.569[b]	.000
Time detention * Plant density			
Pillai's trace	1.831	2.167	.000
Wilks' lambda	.075	2.358	.000
Hotelling's trace	4.013	2.448	.000
Roy's largest root	2.121	7.953[b]	.000

wetland was increased. It can be caused by the capacity of the plant (*Typha latifolia L.*) release oxygen to the roots. The availability of oxygen supports the growth of aerobic bacteria that consumes and outlines the pollutants. *Typha latifolia L.* could further boost the growth of bacteria through the provision of surface area and nutrient. This condition also occurred in previous researches, which benzene showed significant decrease through P karka ability in providing surface area and nutrients to the exudates root; in addition, the potential reduction in benzene was through the absorption of pollutans.[22–24] Higher redox potential was found higher in the root zone of the sub-surface flow wetland rather than in uncultivated area.[25] This was due to the presence of microorganisms in the rhizosphere which conducts aerobic respiration. Furthermore, the oxygen release in the root zone affected the type of microorganisms live in the rhizosphere. The next test was the effect of the interaction between the independent variables, detention time and plant density on the dependent variable levels of BOD, TSS, NH_3–N, Phosphate, and CN. This was undertaken to determine the effect of variable interactions detention time and plant density on the effectiveness of constructed wetland.

H_1: There was significant effect on the interaction between variables of detention time and plant density to the level of BOD, TSS, NH_3–N, phosphate, and CN.

H_0: There was no significant effect on the interaction between variables of detention time and plant density to the level of BOD, TSS, NH_3–N, phosphate, and CN.

The test result is seen on Table V showed by the grey area.

Based on multivariate test, Table V shows that the value of Pillai's Trace, Wilks' lambda, Hotelling's Trace, and Roy's Largest Root on the interaction between detention time and the density of the plants has a significant value of 0.000 or >0.05. This means that H_1 was accepted or can be concluded that there was significant interaction effect between variables of detention time and plant density on levels of BOD, TSS, NH_3–N, phosphate, and CN.

Based on these results, it can be concluded that the function of wetland in this research was used as an independent wastewater treatment unit, although the pre-processing stage to reduce solids content and dissolved material were also important. Interactions between plant density and detention time on the constructed wetland in the research had a significant impact on the content of the decreasing wastewater pollutant in small industry of cassava chips, especially on parameters BOD, TSS, NH_3–N, phosphate, and CN. It was aligned[26] which described that the interaction between plants, water, soil, and microorganisms play an important role in the concept of constructed wetland. The strength of this interaction determined the reliability of the constructed wetland as media of technology to treat various pollutants to become environmentally friendly. The changes were due to various processes that occur in it, such as sedimentation, precipitation, adsorption, asimiliasi plant and microbial activity.[27]

4. CONCLUSIONS

Conclusions derived from the processing of cassava chips wastewater using sub-surface constructed wetland with *Typha plants latifollia L.* was plant that reduced level of BOD, TSS, NH_3–N, Phosphate, and CN when it was planted in the density of 20 plants/m^2 (the largest space) and with detention time of 10–15 days. The test of the plant density and detention time to the reduction of BOD, TSS, NH_3–N, Phosphate, and CN in the wastewater of cassava chips shows:

1. The density of the plants separately had significant impact on the effectivity of sub-surface constructed wetland in the designated levels of BOD, TSS, NH_3–N, Phosphate, and CN in the wastewater of cassava chips using *Typha latifollia L.*
2. Time detention separately had significant effect on the effectivity of sub-surface constructed wetland in the designated levels of BOD, TSS, NH_3–N, Phosphate, and CN in the wastewater of cassava chips using *Typha latifollia L.*
3. There was significant interaction effect between plant density and detention time on the effectivity of sub-surface constructed wetland in the designated levels of BOD, TSS, NH_3–N, Phosphate, and CN in the wastewater of cassava chips using *Typha latifollia L.*

Acknowledgments: The researcher would like to thank to the Ministry of Research, Technology, and Higher Education for funding this research through the Outline of Indonesian Economic Development Acceleration and Expansion Masterplan at 2016 with work order number 001.27/UN38.11-P/LT/2016.

References and Notes

1. J. Redmond, E. A. Walker, and C. Wang, *Journal of Environmental Management* 2, 275 **(2008)**.
2. K. Charmondusit, S. Phatarachaisakul, and P. Prasertpong, *Clean Technology Environmental Policy* 16, 935 **(2014)**.
3. S. I. Abou-Elela, Pollution prevention and waste management in Egyptian industry, *EPCOWM Conference*, Tunisia **(2002)**.
4. A. P. Cardoso, E. Mirione, M. Ernesto, and F. Massaza, *Journal of Food Composition Analysis* 451 **(2005)**.
5. J. A. V. Famurewa and P. O. Emuekele, *African Journal of Food Science and Technology* 5, 75 **(2014)**.
6. D. A. Okunade and K. O. Adekalu, *European International Journal of Science and Technology* 2, 75 **(2013)**.
7. D. Mulkerrins, O. Eamon, B. LawLee, P. Barten, and A. Dobson, *Bioresource Technology* 91, 207 **(2004)**.
8. E. A. Korkusuz, Manual of practice on constructed wetlands for wastewater treatment and reuse in Mediterranean countries, Report, MED-REUNET II support programme (EC Project No:INCO-CT-2003-502453), AGBAR FOUNDATION, Spain, http://med-reunet.org// **(2005)**.

9. N. Tanaka, W. J. Ng, and K. B. S. N. Jinadasa, Wetlands for tropical applications: Wastewater treatment by constructed wetlands, Imperial College Press, London **(2011)**.
10. H. Wu, J. Zhang, H. H. Ngo, W. Guo, Z. Hu, S. Liang, J. Fan, and H. Liu, *Bioresource Technology* 175, 594 **(2015)**.
11. R. H. Kadlec, R. L. Knight, J. Vymazal, H. Brix, P. Cooper, and Haberl, Constructed wetlands for pollution control. R. Processes, performance, design and operation, IWA Specialist Group on the Use of Macrophytes in Water Pollution Control, IWA Scientific and Technical Report No. 8, IWA Publishing, London **(2000)**.
12. C. H. Sim, The use of constructed wetlands for wastewater treatment, Wetland International, Malaysia **(2003)**.
13. R. H. Kadlec and S. Wallace, Treatment wetlands, Second edn., CRC Press, Boca Raton, FL, United States **(2009)**.
14. D. Kurniadie and C. Kunze, *Journal Applied Botany* 74, 87 **(2000)**.
15. G. Geller, *Water Science Tecnology* 35, 157 **(1997)**.
16. J. Vymazal, R. H. Kadlec, and H. Brix, *Water Science Technology* 32, 357 **(1995)**.
17. J. Vymazal, *Ecologo. Eng.* 25, 478 **(2005)**.
18. C. S. C. Calheiros, A. O. S. S. Rangel, and P. M. L. Castro, *Water Research* 41, 1790 **(2007)**.
19. R. Kincanon and S. McAnally, *Ecology Model* 174, 309 **(2004)**.
20. C. S. Akratos, J. N. E. Papaspyros, and V. A. Tsihrintzis, *Chemical Engineering* 143, 96 **(2008)**.
21. P. D. Sindilariu, A. Brinker, and R. Reiter, *Ecological Engineering* 35, 711 **(2009)**.
22. J. Vymazal, *Ecol. Eng.* 61, 582 **(2013)**.
23. J. Vymazal, *Eco. Eng.* 73, 724 **(2014)**.
24. J. F. Kyambadde, L. Kansiime, G. Gumaelius, and Dalhammar, *Water Res.* 38, 475 **(2004)**.
25. C. C. Tanner, *Wat. Sci. Tech.* 44, 9 **(2001)**.
26. Wetlands International-Malaysia Office, The use of constructed wetlands for wastewater treatment, Selangor, Online at: http://www.wetlands.org/WatchRead/Currentpublications/tabid/56/Article **(2013)**.
27. I. Brutch, J. Fritsche, D. Banninger, U. Alewell, M. Sendelov, H. Hurliman, R. Hasselbach, and C. Alewell, *Bioresource Technology* 102, 937 **(2011)**.

Received: 30 August 2016. Accepted: 30 May 2017.