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Performance of Natural Mixed in Comparation to Plug Flow Sub Surface Constructed Wetlands Using Vetiver Grass (*Zizanioides*) in Sun Exposure Area (Case Study at Malang, Indonesia)

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ABSTRACT

Household wastewater treatments are badly needed in Indonesia, since 60% the quality of surface water has been contaminated by domestic wastewaters. Constructed wetland (cw) is one of the simple and cheap waste water treatment plants that using natural waterplants to reduce concentration of pollutants in domestic wastewater. This study was conducted using two types of cws which were semi completely mixed (natural mixed) and plug flow in continuous and batch condition(s). The sub-surface flow (SSF) cws used gravel as their media planting and Vetiveria zizanioides as their waterplant. The purpose of this experiment is to study the performance of these cws in terms of reduction of BOD, Total-N and Ortho-Phosphate and TSS at various hydraulic retention times (HRTs) which were 12, 24, 36 and 48 hours. T-test was applied to analyze the comparation of performance of both cws. The results show that there was no significant difference in reducing BOD and TSS in both reactors at various HRTs, but total-N and ortho-Phosphat were differ signifantly. The best performance of BOD reducing happened using continuous flow. The average value of BOD reducing was 83%. The Total-N and TSS performance in natural mixed reactor better than plug flow reactor with average reduction 91% (Total-N) and 73% (TSS) using batch flow.

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INTRODUCTION

The population growth and the unavailability of wastewater treatment installation will increase the rivers' pollution in Indonesia. One of the biggest contributors to the pollution of the Brantas river in East Java, Indonesia is domestic waste, which reaches 60%-70% of the total pollutant (Ismuyanto, 2010; Kurniadie 2012).

The domestic waste-processing technology commonly used in housing is a septic tank, which is only used to treat the black water from toilet.

Grey water has not been treated by any means of treatment and has been channeled into rivers. The general quality of grey water can be characterized by low contents of nutrients (nitrogen and phosphorus) and low microbiological contamination (indicator organisms and pathogens). Grey water can be treated effectively by constructed wetland and is a good quality source to be reused for various purposes. However, if grey water is not treated and discharged in the environment it can cause serious problems, with regard its nutrient content.

The volume of grey water ranges 66% of household wastewater (Metcalf & Eddy, 1991; Balho & Wach in Kurniadie, 2011). In general, grey water containing detergent, fat and food particles (Almeida, 2013). The limitations of the house yard to provide grey water treatment plant caused the sewage to be discharged directly into sewers and finally to the river (Suswati, 2012). Consequently, this increased the pollution load of rivers to dangerous levels (Yusuf, 2008; Masrevaniah, 2006). Constructed wetland (cw) in this case is a simple and usefull wastewater treatment as an alternative solution of the problem (Wibisono and Masrevaniah, 2008), because cw could be built at the narrow area.

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Constructed Wetland:

Constructed wetland can be named as a Water Plant Garden (Wibisono and Masrevaniah, 2008) also called the Wastewater Treatment Garden (Irawanto, 2010) utilizes the roots of aquatic plants, media and various bacteria to reduce pollutant in domestic wastewater. Therefore, planned wastewater treatment should be designed using plants that are tolerate to sun exposure.

Constructed Wetland has been widely proven in many countries to significantly reduce the levels of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Nitrogen (N), Phosphorous (P), e-coli bacteria, nutrients and heavy metals (Sarafraz,S *et al*., 2009; Dhokikah, 2006). In this research cw used to treat grey water, and the parameter were pH, BOD, total-N, Orthophosphate and TSS. This technology is one option that is appropriate to resolve the issue of the domestic wastewater in Indonesia. Therefore, efforts are needed to treat the wastewater prior to discharge into the surface water. This effort is not limited to a pilot project but can be applied individually or communally housing (Arfiati, 2009). This technology is effective, cheap and easy to maintain (Dallas, 2005; Chang, 2012; Crites and Tchobanoglous, 1998), and can be applied in large scale/communal or small scale/individual.

This study used a cw-type Horizontal Sub-Surface Flow (HSSF) using *Vetiveria zizanioides* and gravel as media of planting. The advantages of this method compared to the other method such as the Free Water Surface (FWS) it only needs a narrow area, is odorless, and does not become a breeding ground for mosquitoes. The horizontal flow system of cw is the appropriate technology to reduce BOD and COD, but to the nutrient decrease is only 30-50% (Kurniadie and Chr. Kunze, 2008). The purpose of using the plant is to provide oxygen in the root zone and to increase the area of biological growth (Crites and Tchobanoglous, 1998), as well as absorbing pollutants. The choice of plant was depend on its performance to reduced the pollutant.

Vetiveria zizanioides:

Vetiveria zizanioides is a type of grass that has many benefits for ecological purposes such as phytoremediation of land and water, rehabilitation of mined land, slope erosion control, retaining of coastal erosion, slope stabilization, etc (Wijayakusuma, 2007). As an ecological plant it has advantages due to its unique root system. This plant has hairy root that goes very deep into the ground (the record for the longest *Vetiver* root was 5.2 meters found in Doi Tung, Thailand). This plant has a very wide adaptation growth, and can grow well in unfavorable environments including heavy land such as: (1) acidic, containing manganese and aluminum; (2) high-salinity and containing a lot of sodium; (3) containing heavy metals such as Al, Cd, Co, Cr, Pb, Hg, Ni, Se, and Zn, including leachate, septic tanks, pesticides and chemical fertilizers (Wijayakusuma, 2007; Raude *et al*., 2009; Simon, 2007; Danh, 2009). This plant has the ability to absorb heavy metals from the soil through their roots. The material is converted and transported throughout the body without causing harm growth.

The purposes of this study are: 1) treatment grey water using cw technology in order to be safely discharged into water bodies and 2) obtain optimum results of treated domestic wastewater using cw in sun exposed locations.

MATERIALS AND METHODS

The research instruments used were:

No	Instruments	Description
1	Pre-treatment	Two chambers (0.5 & 0.75 m^3); peristaltic pumps; grease trap of cleaning interval 4 times/month.
2	Surface area	Horizontal sub-surface flow constructed wetland (HSSF CW) glass reactors; length = 0.9m, width = 0.45m, depth = 0.45m
3	Peristaltic pump	One pump to distribute grey water to the splitter tube. peristaltic pump for each of reactors that suck grey water from splitter tube and distribute to the reactors.
4	Inlet	Slotted pipe for grey water distribution, inlet depth = 0.43 m
5	Treatment volume	Fine gravel (Ø 8mm – 2.5 mm); initial porosity = 40%; with an average wetted depth of 0.41 m
6	Outlet	Outlet depth = 0.41 m; variable effluent outlet height
7	Other design considerations	bottom slope of 1-2%; gravel media
8	Plants	Vetiver grass (*Vetiveria zizanioides*)
9	Retention time	12 hours, 24 hours, 36 hours and 48 hours

The arrangement of research instruments used natural mixed and plug flow reactors with the flow pattern as shown follows :

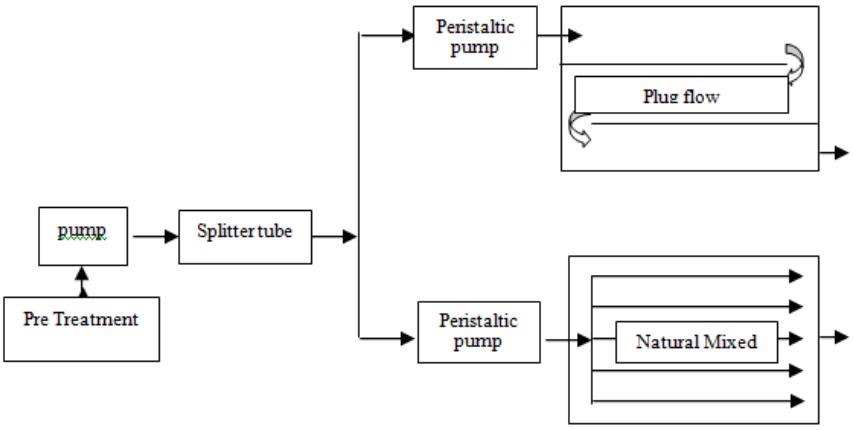

Fig. 1: Schematic diagram of research flow chart.

The type of cw applied was Sub Surface Horizontal Flow (HSSF) at a house hold. The discharge was regulated by peristaltic pump in according to the Hydraulic Residence Time (HRT). The Hydraulic Residence Times were 12 hours, 24 hours, 36 hours and 48 hours. The flow types respectively were continuous flow and batch.

The step of the study with a continuous flow is according to the above schematic diagram. Samples were taken at the starting point inlet, middle and outlet according to the residence time. The samples for measurement of BOD_5, were stored in the incubator with the temperature range about 19,7^oC - 20,3^oC. The step of the study with batch flow was by draining the grey water into the reactor to full. Then the samples were taken at the inlet, and at the outlet point after the HRT was met.

Plants that used were *Vetiveria zizanioides* with the consideration that it has many uses and tolerate to the sun exposed location. The distance between clumps of plants were 10 cm (Hidayah, 2011). The planting media used gravel with the diameter of 0.8-2.5 cm.

The results of the measurement of (HSSF) cw's performance will be compared to some Domestic Wastewater Standards as shown in the following table:

Table 1: Domestic waste water quality standard.

Parameter	Maximum consentration	Data Resource
• pH	• 6-9	• Domestic Wastewater Quality Standard of Indonesia (2003)
• BOD	• 30mg/l	• Domestic Wastewater Quality Standard of Indonesia (2003)
• Total-N	• 20 – 85 mg/l	• *Benefield & Randall, 1980*
• P-Organic • P-inorganic	• 1 – 5 mg/l • 3 – 10 mg/l	• *Metcalf & Eddy, 1979* • *Metcalf & Eddy, 1979*
• TSS	• 100 mg/l	• Domestic Wastewater Quality Standard of Indonesia (2003)

Source: *Peraturan Pemerintah Republik Indonesia No.82 Tahun 2001; Kep. Men. LH. No. 112 of 2003,* and Metcalf & Eddy, 1979; Benefield & Randall 1980

RESULT AND DISCUSSION

The performance of cw using *Vetiveria zizanioides* plant to remove household waste water parameters would present as follows:

Temperature:

Waste water temperature at the inlet ranged between 23.5^oC - 26.4^oC, and the average temperature was 26.26^oC. The temperature at the outlet point ranged between 24.3^oC - 27.8^oC, and the average temperature was 25.28^oC. These conditions showed that the wastewater temperature was in the normal range, which is 25°C ± 3°C. In the normal water temperature (22 - 25°C) is allow for the survival of aquatic biota normally in the water (Sugiharto, 2003).

The acidity (pH):

The degree of wastewater's acidity at the inlet point ranged about 6.9 - 8.2, with an average of 7.3. At the outlet point, the degree of acidity ranged between 6.9 -7.5. In this case the degree of acidity at the inlet and outlet points were in the normal pH range.

The pH value on a Continuous and Batch flow in the Plug flow Reactor:

All of the acidity measurement shown in the figure bellow:

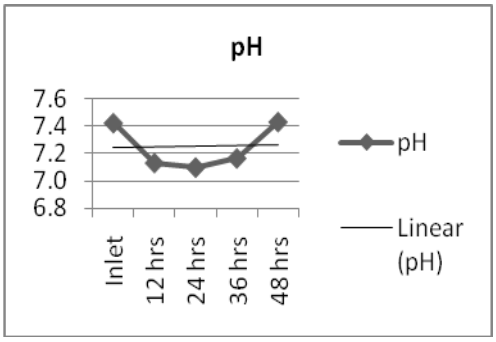

Fig. 2: The acidity value on continuous flow the Plug flow reactor.

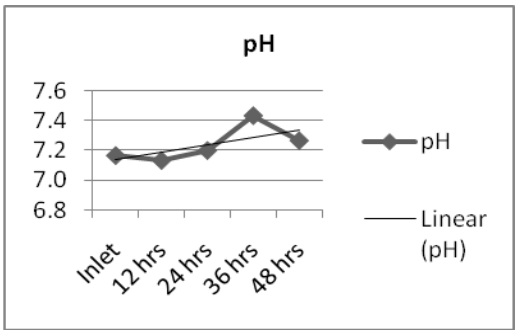

Fig. 3: The acidity value on batch flow the Plug flow reactor.

The pH value of acidity in the plug flow reactor in the both types of flow about 7.2-7.4 in the inlet and 7.1-7.4 in the outlet. The pH value shows the normal condition.

The pH value on a Continuous and Batch flow in the Natural Mixed Reactor:

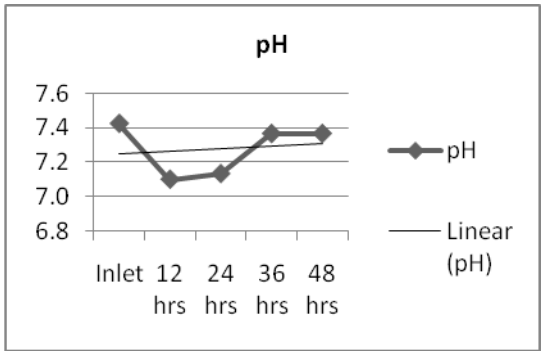

Fig. 4: The acidity value in the Natural Mixed reactor with continuous flow.

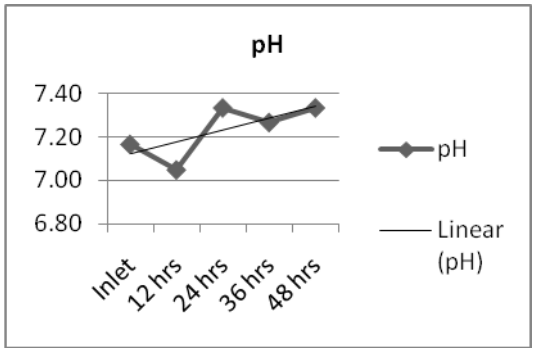

Fig. 5: The acidity value in the Natural Mixed reactor with batch flow.

Trend of the pH measurement in the inlet and outlet points have shown the increase, approximately 0.54 – 3.79% in the HRT 12 – 48 hours. The pH value in the inlet about 7.2-7.4, and in the outlet about 7 -7.4. The increase of pH value occurred by supply oxygen from the plant. In the aerator system could increasing pH value 2.5 – 5.5% (Middlebrooks and M.A. Al-Layla, 2001). Using plant can replace the aerator function.

BOD Reduction:

The result of BOD measurement in this study showed that BOD maximum in the inlet was 46.25 mg/L and the average of BOD value in the tank as a source of waste water was 28.95 mg/l. It mean the condition was better than Indonesian Domestic Waste Water Quality Standard (30 mg/l). BOD values were measured based on residence time, flow pattern and reactor shapes as presented in the following figure.

BOD value using a Continuous and Batch Flow in the Plug flow Reactor:

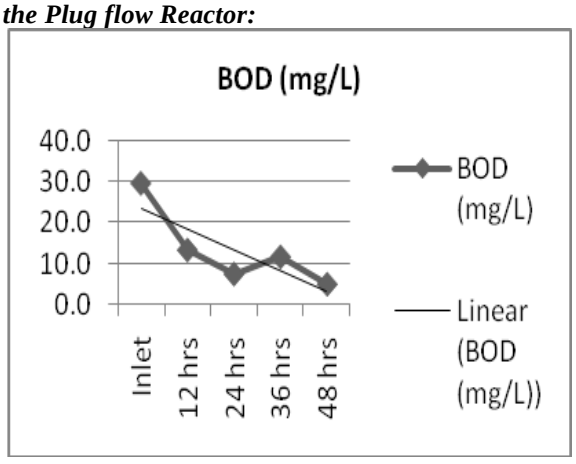

Fig. 6: BOD value using a Continuous Flow in the Plug flow Reactor.

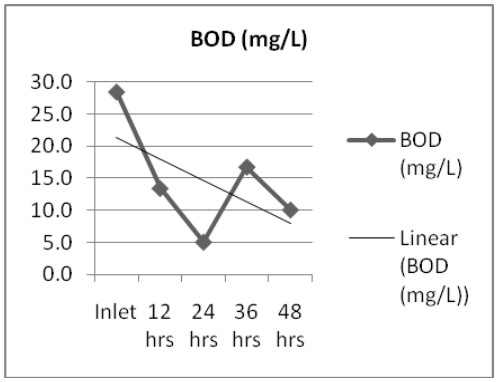

Fig. 7: BOD value using Batch Flow in the Plug flow Reactor

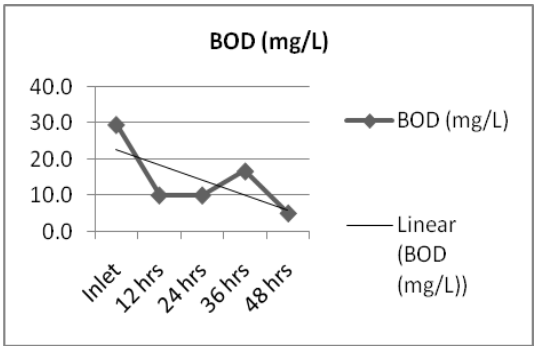

Fig. 8: BOD Value with a Continuous Flow in the Natural Mixed Reactor

There were occurred a decrease of the BOD average values, in the measurement. In the plug flow reactor using continuous flow, the average of BOD value in the inlet was 29.6 mg/l, and in the outlet was 5- 13.3 mg/l. The average of decrease was 24.8 mg/l or 83%. The highest of decrease occurred at a residence time of 48 hours.

The average of the batch flow in the plug flow reactor in the inlet was 28.3 mg/l, and in the outlet was 5-16.7 mg/l. The average of decrease was 18.3 mg/l or 65%. The lowest BOD values occurred at a residence time of 24 hours.

The statistic analysis result of the waste water treatment with continuous and batch flow patterns in plug flow reactor shows there is no significant differences. The level of significant differences is α 0.819 > 0.05.

Based on the mean value of BOD, that is no significant differences, because there is little differences of mean value. The mean value of continuous flow was 13.28 mg/l, and the batch flow was 14.66 mg/l. In the overall, the continuous flow performance is better than batch flow to decreasing BOD value in the plug flow reactor.

BOD value using Continuous and Batch Flow in the Natural Mixed Reactor:

The decrease of BOD value using continuous and batch flow in the natural mixed reactor is presented in the following graph.

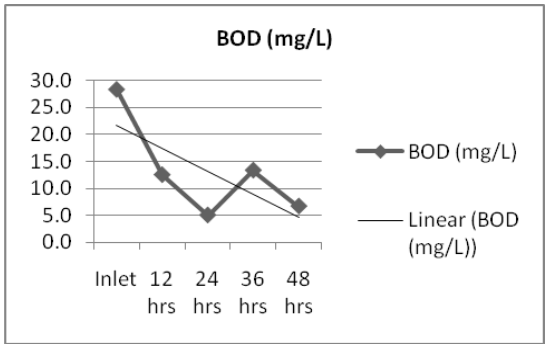

Fig. 9: BOD value in the Batch flow in the Natural Mixed reactor

The performance of cw using continuous and batch flow patterns in the natural mixed reactor can be known by statistic analysis. The mean value of batch flow in the inlet was 28.3mg//l, and outlet 5-13.3 mg/l. The average of BOD decreased was 21.7 mg/l or 76%. The BOD value of continuous flow in the inlet was 29.6 mg/l and outlet 5 -16.7 mg/l. The decrease of BOD in the Natural Mixed Reactor using continuous flow was 24.6 mg/l or 83%. Based on the mean values, it shows that the performance of continuous flow was better than batch flow. It is possible, because there was occurred the water turbulence using continuous flow that increased the DO value. The over all of the result, BOD value in the inlet point was the highest. But all of the result was lower standard of Indonesian Domestic Wastewater Quality Standard (30 mg/l). This condition indicate that waste water quality is safe to drain to the river, and the cw make this condition more safe. It is showed that using plant can decreasing BOD value than without plant (Suswati, 2012).

Total-N:

Based on the criteria for domestic wastewater, total-N concentrations range around 20-85 ppm (Benefield & Randall, 1980). In this study the results of Total-N measurement of waste water sources taken from the first tank as the inlet maximum was 18.74 ppm, and the average of Total-N in the inlet was 12.16 ppm. The concentration of Nitrate-Nitrogen > 0.2 ppm resulted in *eutrophication*.

Total-N using Continuous and Batch Flow in the Plug flow Reactor:

The average of total-N in the inlet point was 5.58 mg/l. The range of total-N in the outlet in the plug flow reactor was 1.12- 4.46 mg/l. The percentage of the decrease in the ability of total-N

content was 38% in average using continuous flow. Even though, total-N increased in HRT of 24 and 36 hours. Over all there was a decreasing trend of total-N. In the batch flow, the average of the decrease in ability of total-N content was 80%. Total-N in the average at the inlet point using batch flow in the plug flow reactor was 11.38 mg/l.

The performance of cw to removing total-N using continuous and batch flow system is shown in the following figure:

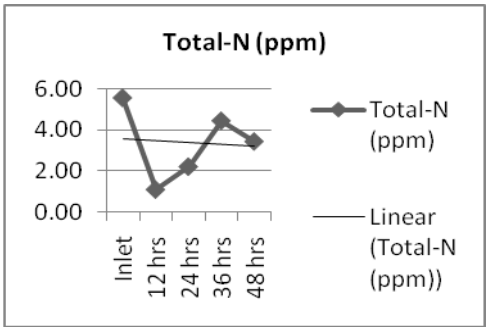

Fig. 10: Total-N using the continuous flow in the plug flow reactor.

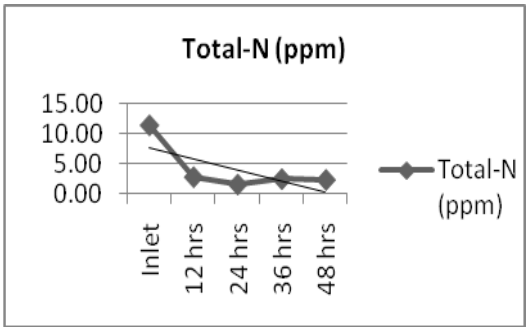

Fig. 11: Total-N using batch flow in the plug flow reactor.

Based on the statistic analysis, the result showed that there were significant differences with the α 0.009 < 0.05. The performance of CW using batch flow pattern was better than continuous flow in the plug flow reactor. The mean value of reducing total-N in the batch flow was 80% higher than the continuous flow which was 38%.

Total-N using Continuous and Batch Flow in the Natural Mixed Reactor:

The concentrations of total-N using continuous flow in the natural mixed reactor ranged between 2.37-5.91 mg/l. The ability of the reactors in lowering the levels of total-N was 70.63%. It happens at residence time of 12 hours.

Total-N content in the average at the inlet point using batch flow was 12.16 mg/l in the natural mixed reactor. This shows that the quality of waste water is still below the reference standard. The lowest concentrations in the outlet occurred at the residence time of 36-48 hours which is17.06 mg/l using the continuous flow in natural mixed reactor. The highest percentage of total-N reduction was 100% at a residence time of 36-48 hours. The average of lowest concentration of the outlet point was 1.12 mg/l, which was at residence time of 48 hours with a reduction ability of 100%.

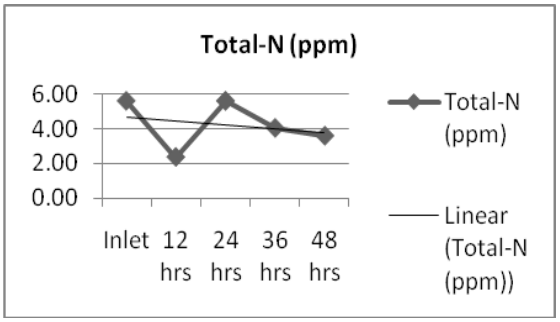

Fig. 12: Total-N using continuous flow in the Natural Mixed reactor.

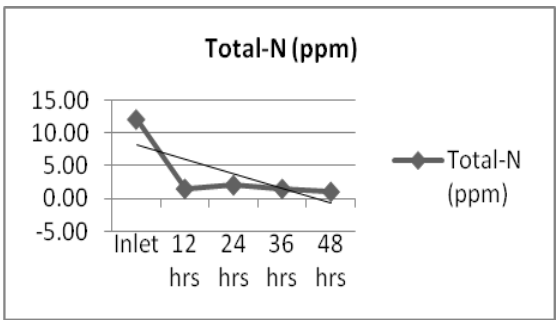

Fig. 13: Total-N using batch flow in the Natural Mixed reactor.

The percentage value of total-N reducing in batch flow was 91% and continuous flow was 36%. This result is better than Schierup's opinion (1990) in Kurniadie (2008), who states that the percentage of the decrease of total-N ranges from 30% -50% (Kurniadie and Chr. Kunze, 2008) using batch flow. Based on statistic analysis, the performance of cw with the natural mixed reactor, using continuous and batch flows, shows significant differences in both of reactor types. The α value was 0.009 < 0.05. The application of batch flow gave better result than continuous flow. This is shown by the mean value.

Overall of total-N reducing shows that batch flow is better than continuous flow because there was longer contact between root and water in the batch flow than in continuous flow. Nitrogen is required for the formation or growth of vegetative parts, such as leaves, stems, roots, but too much of it can inhibit flowering and fruiting in plants. Nitrogen also plays a role in the process of plant growth and increased the chlorophyll content of plants (Syekhfani, 2012). *Vetiver z.* that is used in this cw has no flowers and seeds. These plants grow as vegetative, so to meet

the needs of nutrients the roots and the leaves will absorb nitrogen.

Orthophosphate:

The forms of inorganic phosphate in the water are orthophosphate and polyphosphate. All polyphosphate experience hydrolysis to orthophosphate. This change would be accelerated in the waste which contained bacteria (Effendi,H. 2003). The measurements of phosphate in this study were done in the orthophosphate form, because in this form the plant will absorb phosphate. So to assess the performance of the plant and not measure the performance of the bacteria, the parameter used is orthophosphate. The mechanisms of the decrease in P are through absorption, rain, biological transformation and uptake by plants in a small percentage (Sarafraz S. *et al*., 2009).

Orthophosphate Value using the Continuous and Batch Flow in Plug flow Reactor:

The highest orthophosphate's consentration in the inlet was 1.3725 ppm. The lowest average of orthophosphate's consentration using the continuous flow in the outlet is 0.35 ppm occurred at a residence time of 48 hours. And the lowest average of batch flow was 0.51 ppm occurred at a residence time of 36 hours. In the outlet of HRT 48 hours was 0.58 ppm. All of the orthoposphate measurements were below inorganic phosphate concentration (3-10 mg/l, Metcalf and Eddy, 1991). But there was a slight increase of orthophosphate in the batch flow. The condition is shown by the figure below:

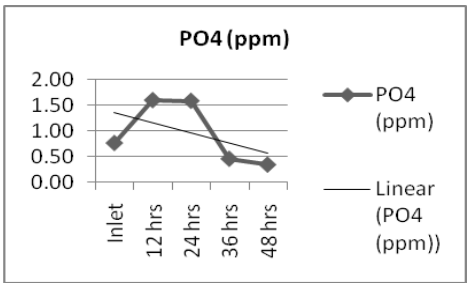

Fig. 14: Orthophosphate using a continuous flow in the plug flow reactor.

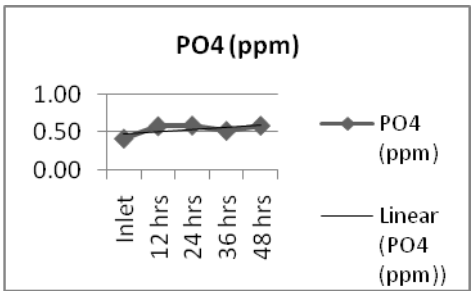

Fig. 15: Orthophosphate using batch flow in the plug flow reactor.

There occurred 54% decrease of PO_4 in the continues flow and 41% increase of PO_4 using batch flow in the plug flow reactor type. Based on statistic analysis, there were no significant differences in cw performance using both continuos flow and batch flow in the plug flow reactor. The α value from the analysis for all residence time 12 – 48 hours was 0.729>0.05. There were no significant differences, because there was low PO_4 consentration (about 0,35 – 1,6 ppm), its mean lower than the standard of P-inorganic (3-10 ppm).

Orthophosphate Value using the Continuous and Batch Flow in the Natural Mixed Reactor:

The performance of cw using continuous and batch flow in the Natural Mixed is as follows:

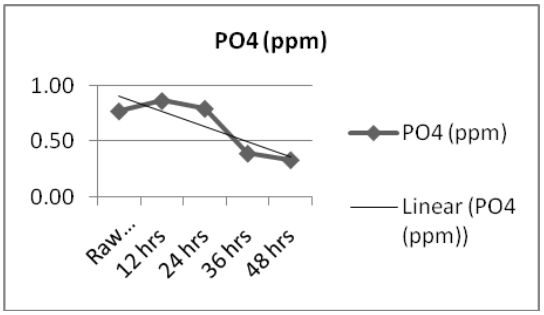

Fig. 16: Orthophosphate in a continuous flow in the Natural Mixed reactor

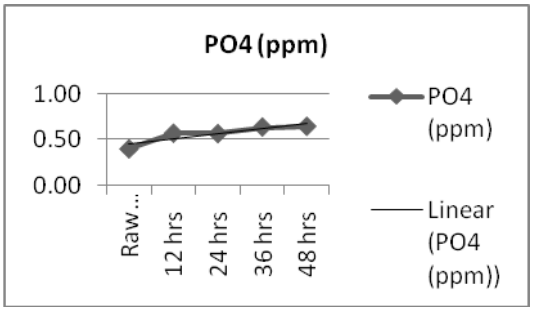

Fig. 17: Orthophosphate with Batch flow in the Natural Mixed reactor.

The decrease of orthophosphate occured with continuous flow in the natural mixed reactor as shown in figure 16. The percentage of the reduction of PO_4 was 57%. The result of the measurement shows an increase (62%) of PO_4 using batch flow in the natural mixed reactor type.

Absorption by plants at the Sub Surface Flow cw type is generally less than 10%. This is because of the limited contact between water absorption and waste water areas (Crites R. et. all., 2006). In the media without Fe, Al or Ca, reduction of phosphorus will be running slowly (D. Ragsdale in Holba, M et. al., 2012). This study showed no reduction in orthophosphate until HRT of 48 hours using batch flow. But overall, the results of orthophosphate were

still below the content of P-inorganic (3-10 mg/l). Phosphorus will be absorbed by plant that has seed or flowers to improve the quality of seeds or fruit. In this case, *V.zizanioides* does not reproduce by seed, therefore does not require a lot of phosphorus (Syekhfani, 2012). This caused a decrease of orthophosphate in cw which only uses *V.zizanioides* plants, because this plant has no seeds and flowers.

Based on statistic analysis, there were no significant differences of cw performance in the natural mixed reactor using continuous and batch flows. The α value was 0.945 > 0.05.

Total Suspended Solid (TSS):

Total Suspended Solid is one of domestic wastewater parameter in Indonesia. This parameter shows turbidity of water. In this case, concentration of TSS was 133-339 mg/l in the inlet. And in the outlet was 86-444 mg/l. In the maximum TSS was higher than Indonesian Domestic Wastewater Standard (100 mg/l).

Total Suspended Solid using the Continuous and Batch Flow in Plug flow Reactor:

The highest Total Suspended Solid in the plug flow reactor was 353 mg/l in the inlet, and the highest TSS in the outlet was 190 mg/l using the batch flow at the HRT 12 hours, and at HRT 48 hours was 148 mg/l using continuous flow and 122 mg/l using batch flow. It is higher than Indonesian Domestic Wastewater Standard. The condition is shown by the figure below:

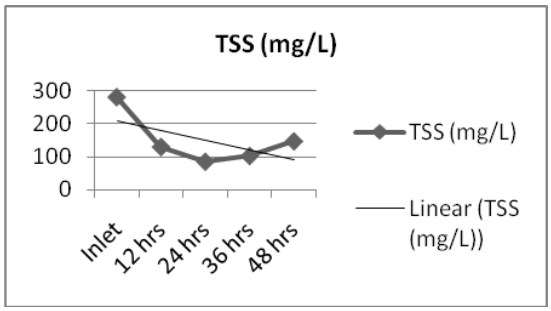

Fig. 17: TSS using continuous flow in the Plug Flow reactor.

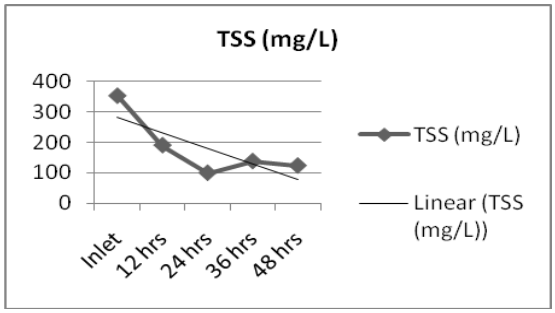

Fig. 18: TTS using batch flow in the Plug Flow reactor.

There occurred 47% reduce of TSS in the continues flow and 65% reduce of TSS using batch flow in the plug flow reactor type. Based on statistic analysis, there were no significant differences in cw performance using both continuos flow and batch flow in the plug flow reactor. There was no significant differences with the α value from the analysis for all residence time 12 – 48 hours was 0.445>0.05. Based on compare mean showed that batch flow had better than continuous flow, because there was not occurred turbulence in the water flow

Total Suspended Solid using Continuous and Batch Flow in the Natural Mixed Reactor:

The performance of cw using continuous and batch flow in the Natural Mixed is as follows:

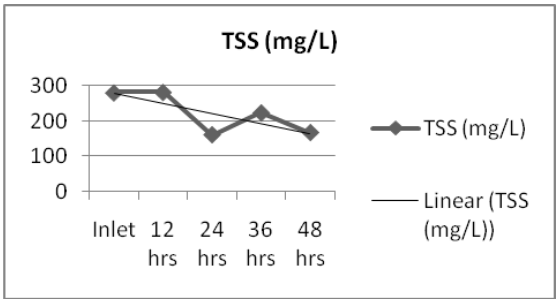

Fig. 19: TSS using continuous flow in the Natural Mixed reactor.

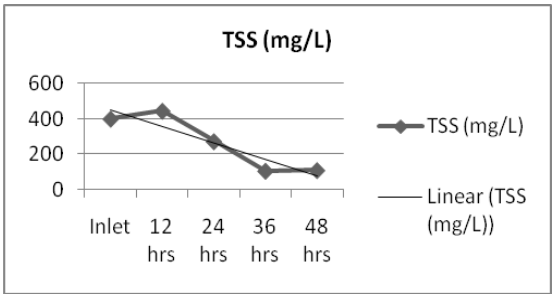

Fig. 20: TSS using Batch flow in the Natural Mixed reactor.

The trend of TSS was decrease both using continuous and batch flow in the natural mixed reactor as shown in figure 19 and 20. The concentration TSS in the outlet 48 hours was 167 mg/L using continuous flow and 107 mg/l using batch flow. It is mean higher than Indonesian Domestic Wastewater Standard (100 mg/l). The percentage of the reduction of TSS using continuous flow was 41%, and using batch flow was 73%.

Based on statistic analysis, there were no significant differences of cw performance in the natural mixed reactor using continuous and batch flows. The α value was 0.796> 0.05. Based on compare mean showed that batch flow had better

than continuous flow, because there was not occurred turbulence in the water flow.

Conclusion and Recommendation:

Constructed wetland using *V. zizanioides* plants in the natural mixed and plug flow type-reactors using continuous and batch flows in reducing pollution parameters can be described as follows:

1.a. In both types of reactors and type of flows (continuous and batch), temperature and pH parameters remained within the normal range. Both for the values at the inlet and outlet points.

b. In the case of reducing BOD's value it is shown that plug flow reactor has better performance compared with natural mixed reactor. The highest BOD value in the measurement results is 16.7 mg/l at the outlet, which is lower than the Indonesian Wastewater Quality Standard Group I (30 mg/ l).

c. The performance of cw in reducing BOD value, shows that the cw using continuous flow has better performance in the both of reactor's type. The BOD reducing mean value in the both of reactor's type using continuous flow was 83%.

d. Total-N in the wastewater sources (taken from the first accommodate tank) was < 20 ppm. The highest concentration of total-N in the waste water tank was 18.74 ppm. The biggest decline in total-N, occurred in a natural mixed reactor with batch flow, was 1.12 mg/l at HRT of 48 hours. The average percentage of the decline is 91% occurred in the natural mixed reactor with batch flow. The batch flow had better performance than continuous flow.

e. In this study Orthophosphate's concentration increased. The highest increase (62%) occurred in Natural mixed reactor using batch flow at HRT of 48 hours. The result of orthophosphate measurement was still below the content of P-inorganic (3 mg/l). But the cw using *V. zizanioides* couldn't remove orthophosphate. because these plants do not reproduce by seeds.

f. In this study, TSS concentration was decreased. But over all measurement showed that the value was higher than Indonesian Domestic Wastewater Standard. The performance of cw was better using batch flow than continuous flow in both reactor types.

2. In general it can be concluded that for parameters BOD, total-N and Orthophosphate in natural mixed reactors provide better performance than in plug flow reactor. According to the type of flow, the batch flow has better performance than continuous flow for reducing BOD value and removing total-N.

Recommendations:

1. Constructed wetland using *V. Zizanioides* plants demonstrated the ability to lower the values of BOD and total-N. However, more efforts are needed to reduce Orthophosphate and TSS which is one of the causes of eutrophication and turbidity.

2. The performance of CW with a HRT of up to 48 hours already fulfilled quality standard. For households with 5 family members that are assumed to produce waste discharge of 600 l/day, an area of 1.2 m^2 is needed. Further research needs to be done at locations that only have small yard in the house property.

3**.** To increase the performance of CW, combined plants usage is needed to remove the water pollutant.

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