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Application of Vetiver (*Vetiveria zizanioides*) on Phytoremediation of Carwash Wastewater

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ABSTRACT

Carwash wastewater (CW) contains potentially harmful compounds. Due to water scarcity, its reuse is indispensable. Phytoremediation is one of methods to eliminate pollutants by using plants, such as vetiver grass. This study observed the growth characteristic of vetiver in CW and its capacity in pollutant removal. Treatment with two factors and three replicates was done: Media for vetiver growth was tap water (TW) without carwash wastewater (M_0), mixture of 50% tap water + 50% carwash wastewater (M_1), and 100% of carwash wastewater without tap water (M_2). Media grown without and with vetiver was of V_0 and V_1 respectively. Individual stem of vetiver was planted hydroponically in a chamber. Plant growth was observed once a week. At the harvesting (day 70), root, stem and leaf of the vetiver were collected separately Results showed that vetiver has a capacity to adapt, survive and growing in CW media. Plant generation achieved 70.1-81.8%, 60.6-75.8%, and 71.7-78.5% for stem, leaf and root respectively. Within 70 days, the pollutant that covered of 78.5 and 57.9% N, 83.5 and 69.0% P, 76.0 and 65.3% COD, 68.6 and 64.8% BOD, 81.3 and 59.5% detergent, 98.6 and 95.8% phenol, 73.3 and 61.5% Pb, and 88.5 and 82.8% Zn could be removed by vetiver, i.e. in growth media M_1 and M_2, respectively.

Keywords: Carwash wastewater, phytoremediation, pollutant removal, vetiver grass

INTRODUCTION

The use of industrial wastewater in agriculture is common practice in order to provide a reliable source of water for irrigation and to add valuable nutrients and organic matters to soil. In developed countries, where environmental standards are applied, wastewater is treated firstly before using for irrigation. On the other

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hand, in some developing countries, such as Indonesia, untreated wastewater is widely used for irrigation and watering of agriculture lands This is one of the most significant sources of environmental pollution that directly affect human health via crops and soil. Untreated wastewater either industrial wastewater or domestic wastewater contains toxic compounds. Degradation of water quality can pose serious threats due to high population growth and rapid urbanisation. In addition, the urban areas commonly lack wastewater and solid waste treatment facilities (Bomh et al., 2011; Sharma, Agrawala, & Marshall, 2007).

Bandung city, a capital of West Java Province of Indonesia is an urban area with high population growth and rapid urbanisation. Its population density increased from 14,491 to 14,687 p.km^{-2} of which the highest is West Java province. Pollution is with its economic growth which is showed by the vehicle belonging number. The vehicle density increased from 5,323 to 6,618 units.km^{-2}. During 2011 to 2014, the increase of vehicles in Bandung city was much higher than its population as of was 22.93 and 1.3% respectively. The increase in vehicle numbers is followed by the increase in carwash unit establishment. Wastewater is generated directly from carwash unit services directly.

Approximately, 40 L unit^{-1} of water is required for carwash unit service (Zaneti, Etchepare, & Rubio, 2012) whereas in Europe 60-70L unit^{-1} (Boussu, Kindts, Vandecasteele, & Bruggen, 2007). Carwash unit involves the use of detergents, petrol, kerosene and diesel for cleaning. Therefore, carwash wastewater contains potentially harmful compounds and serious damage might result to environment. The discharging of carwash wastewater (CW) directly to watercourses would lead to environmental degradation (Boussu et al., 2007; Zaneti et al., 2012). High level of lead should be considered especially in urban areas with high level of traffic (Paz-Alberto, Sigua, Baui, & Jacqueline, 2007).

Treatment and reuse of wastewater was important due to the increasing of water scarcity (Finley, Barrington, & Lyew, 2009; Jhamaria & Yadav, 2014). By a careful management, the positive aspects of wastewater for irrigation can be achieved (World Health Organization [WHO], 2006). Phytoremediation is an alternative method that uses plants to clean up a contaminated area. Plant species for remediation must be adapted and tolerant to a high concentration of metals. A different plant species shows a different capacity to uptake nutrient and remove the contaminant substances. The selection of appropriate plant as phytoremediator for contaminated area is important Vetiver grass *(Vetiveria zizanioides* L) is an ideal plant species for pollutant removal (Truong & Director, 2006).

The previous study investigated vetiver that can grow in diesel contaminated soil (Nisa & Rashid, 2015). Vetiver system is mainly recommended for wastewater treatment in hydroponic system (Akbarzadeh, Jamshidi, & Vakhshouri, 2015). The use of vetiver grass in phytoremediation may be cost effective and could be environmentally friendly. Nevertheless, the practical phytoremediation tool for carwash wastewater treatment has not well understood yet. This study was carried out to observe the growth characteristic of vetiver in carwash wastewater and its capacity to remove the existing of pollutant substances.

MATERIALS AND METHODS

Date and Place of Experiment

The study was conducted for 70 days in the field laboratory of Indonesian Institute of Science in Bandung, Indonesia. The position of the place is at 847m ASL (Above Sea Level) with latitude of 06°52'57.5" SL, and longitude of 107°36'39.8" EL. The ambient temperature (T) was recorded in the range of 21-30°C, Relative Humidity (Rh) was 78-87%, and the length of daylight was 38-57%.

Carwash Wastewater (CW), Plant Chamber, and Vetiver Grass used in Study

Wastewater was obtained from outlet pipe of the carwash service unit in Bandung city. It was collected in a 20L-plastic container. Carwash wastewater used during the experiment was from the same carwash service and taken only once. Carwash wastewater parameter specifically are BOD, COD, detergent, phenols (aromatics), phosphates, nitrate, nitrite, ammonia, lead and other minerals, suspended solid and dissolved solid. Prior to use for experiment, CW was filtered using 60-mesh sieve to remove the existence of plastics, papers, rubbers, cigarette etc. The filtered CW was then stocked in plastic container. Glass aquarium of 24 cm length, 20 cm width, and 25 cm height was used for vetiver grass chamber. One side of the aquarium wall was scaled and marked which showed the relation between the heights of liquid surface with volume of media. Each aquarium was completed with aerator (SPA 26). Vetiver grass was placed in media carwash wastewater diluted with tap water at ratio 3:1 (v/v) or equivalent with 25% concentration of the native carwash wastewater. Individual stems of vetiver were separated from its bundle. Individual stems of vetiver with 4-8 pieces of leaf were selected for experiment. Figure 1 shows the stem bundles, individual stems, and hydroponic cultivation of vetiver.

Experiment

In this study, concentration of carwash waste water in growth media (M) and vetiver grass planted in growth media (V) varied. The growth media was without vetiver (V_0) as control. The concentration of carwash wastewater for growth media was 0% of which tap water without carwash wastewater (M_0), mixture of 50% tap water + 50% carwash wastewater (M_1), and 100% of carwash wastewater without tap water (M_2), and with vetiver grass (V_1) respectively. The treatment was carried out with three replications

Aquarium for each treatment was filled with 10 L of growth media (±80% of capacity) and was pumped into the plant

(a) (b) (c)

Figure 1. (a) Stem bundles; (b) individual stems; and (c) hydroponic cultivation of vetiver in media CW

chambers under continuous mixing. From six units of glass aquarium of medium M_0; M_1; and M_2 was then divided into two groups, three units for planted with vetiver grass (V_1) and three units without planted with vetiver (V_0) as a control. Each aquarium consisted of two baskets (B). For treatment V_1, growth media was planted hydroponically with eight individual stems of vetiver grass. Therefore, each aquarium consists of 16 individual stems and in total 48 pieces of individual stems for each treatment. Table 1 presents composition of tap water and carwash wastewater used in study.

Table 1
Composition of tap water (TW) and carwash wastewater (CW) in this study

Parameter	Unit	TW	CW
pH	-	7.29	7.14
BOD_5	$mg. L^{-1}$	15.9	398
COD	$mg. L^{-1}$	28.22	812
Total N	$mg. L^{-1}$	0.08	16.11
Nitrite ($N\text{-}NO_2$)	$mg. L^{-1}$	0.00	1.27
Nitrate ($N\text{-}NO_3$)	$mg. L^{-1}$	0.08	3.76
Ammonia ($N\text{-}NH_3$)	$mg. L^{-1}$	0.00	11.08
Phosphate (PO_4)	$mg. L^{-1}$	0.24	12.10
Detergent	$mg. L^{-1}$	1.98	10.29
Phenol	$mg. L^{-1}$	0.00	0.12
Lead (Pb)	$mg. L^{-1}$	0.02	0.13

Growth Characteristic

Growth characteristic of vetiver is indicated by its vegetative reproduction, i.e. stem, leaf and root. Three individual stems from each basket were selected randomly as sample for observation (Table 2); they were observed once a week. The number of leaves was calculated and the leaf length was measured using a ruler.

Stem number consisted of initial and new stem generation. At day 70, the whole roots, stems, and leaves were harvested and collected separately. All vetiver roots were cut and sprayed with water, drained, and their root length measured. The root-shoot ratio was calculated by dividing the dry weight of shoot by the dry weight of roots. Dry matter of root and leaf was determined gravimetrically oven-dried at 105^{o}C until; constant weight was achieved.

Table 2
Growth Media, Replication, Baskets, and Individual Stems Planted in Study

Growth media (M)	Replication/ Aquarium (A)	Basket (B)	Code of individual stems of vetiver plant in study*							
M_0	A_1	B_1	**1**	2	3	**4**	5	6	7	**8**
		B_2	**9**	10	11	12	13	14	**15**	**16**
	A_2	B_1	**17**	18	**19**	20	21	22	**23**	24
		B_2	25	**26**	27	28	29	**30**	**31**	32
	A_3	B_1	33	34	**35**	**36**	37	38	39	**40**
		B_2	41	**42**	43	44	**45**	**46**	47	48
M_1	A_1	B_1	1	**2**	3	**4**	5	**6**	7	8
		B_2	**9**	10	11	12	**13**	14	15	**16**
	A_2	B_1	17	18	**19**	20	21	**22**	**23**	24
		B_2	25	26	**27**	**28**	29	30	31	**32**
	A_3	B_1	33	34	**35**	36	37	38	**39**	**40**
		B_2	41	**42**	43	44	**45**	46	**47**	48
M_2	A_1	B_1	**1**	2	**3**	4	5	6	**7**	8
		B_2	**9**	**10**	11	**12**	13	14	15	16
	A_2	B_1	17	**18**	19	**20**	21	22	**23**	24
		B_2	**25**	26	27	28	29	**30**	31	**32**
	A_3	B_1	33	34	**35**	**36**	37	**38**	39	40
		B_2	41	**42**	**43**	44	45	**46**	47	48

Note: Bold and shade of individual stems are randomised selected as samples for observation

Tensile Strength of Vetiver Root

For tensile strength test, as much as 60 of vetiver root of each growth media with L ≥ 50cm were used as specimen. The roots were carefully checked for possible damage before tensile strength test. The diameter of vetiver root was measured in three different positions to obtain a representative value (Mattia, Bischetti, & Gentile, 2005). Tensile Strength measurement was carried out based on ASTM D2101-79 using Universal Testing Machine (Orientec. Model UCT-5T). Tensile strength (T_R) was calculated using Equation 1 below.

$$T_R = Fmax/\pi.(D/2)^2 \quad (1)$$

where:

T_R = Tensile strength (Mpa)

F_{max} = The maximum registered load (N)

D = Average diameter of root (mm)

Pollutant Removal of Carwash Wastewater

To evaluate the pollutant removal capacity, the growth media were analysed before and after planted with vetiver grass. The analysis was carried out at Water Quality Laboratory, Faculty of Civil and Environment Engineering, Bandung Institute of Technology, which covered of total N, P, COD, BOD, detergent, phenol, lead, and zinc.

RESULT AND DISCUSSION

Growth Characteristic of Vetiver Plant in Carwash Wastewater Media

Response of plant to growth media is reflected by its capacity to adapt, survive, and then generate new stem, leaf, and root. Vetiver can be integrated as wastewater treatment due to the capability of plant in removal of water contaminants (Gupta, Roy, & Mahindrakar, 2012).

Data showed (Figure 2.) the stem generation of vetiver tended to decrease by the addition of carwash wastewater, both at concentration 50% and 100%. At the first two weeks after planting, the stem grew slowly. This period reflected the adaptation phase of vetiver with carwash wastewater as growth media. Afterwards, vetiver showed a capacity to survive and started to generate the new stems. In this study, stem number of vetiver increased linearly with the growth period (Figure 2). Initially, stem number was 1.78±0.19 (M_0); 1.89±0.10 (M_1); and 1.67±0.10 (M_2). It was then increased to 8.56±0.20; 7.00±0.19; and 6.00±0.33 for M_0; M_1; and M_2 respectively. In average, the number of stem at harvesting increased to 4.81 (M_0); 3.70 (M_1); and 3.59 times (M_2) from its initial stage. Stem generation of vetiver in growth media carwash wastewater achieved 81.8% for M_1 and 70.1% for M_2 if compared to control (M_0).

Leaf is the other principal organ of plants, in which photosynthesis and transpiration occurs. Photosynthesis is a sensitised, photochemical, and oxidation-reduction reaction (Meyer & Cusanovich, 2003). The sensitiser is chlorophyll, which captures

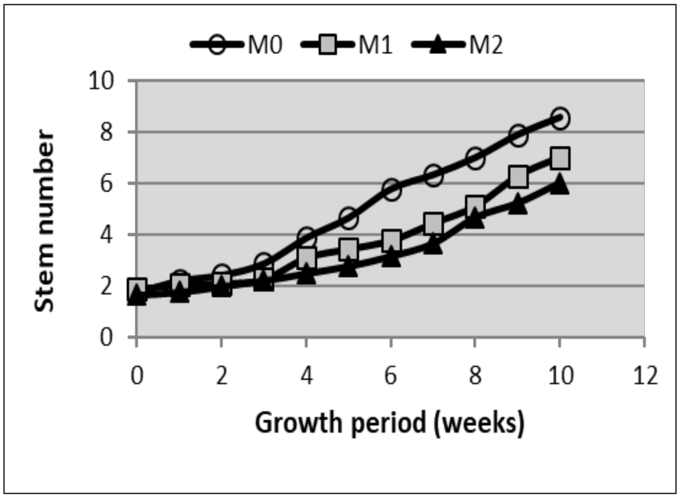

Figure 2. Stem number of vetiver in media with varying concentration of carwash wastewater

light and has functions in transformation of radiant into chemical energy. The main reaction of photosynthesis is fixing of atmospheric carbon dioxide and releasing oxygen to the atmosphere (Equation 2).

$$n\,(CO_2) + 2n\,(H_2O) \xrightarrow[\text{Radiant energy}]{\text{Plant}} (CH_2O)\,n + n\,(O_2) + n\,(H_2O) + n\,(119.6)\ \text{Cal}$$

At the initially, vetiver leaf in this study tend to dry and then fall down. It was not a causal for plant dies due to resistant characteristic. The new leaf was produced slowly in early of cultivation and increased at the 5th weeks after. This condition indicated that vetiver has a capability to grow in media of carwash wastewater, although it needs of several weeks for adaptation.

In this study, the fresh leaf number of vetiver decreased until the first three weeks after cultivation in media CW. After this period, leaf number increased linearly with the plant ages. Initially, the leaf number of vetiver in media M_0; M_1; and M_2 was 7.67±1.15; 7.33±1.15 (M_1); and 6.66±0.58, respectively. Then it increased significantly to 33±2.83 (M_0); 27±2.90 (M_1); and 20±3.03 (M_2) after 70 days of cultivation. Compared to its initial stage, the leaf number of vetiver in all of treatment increased, linear with the plant ages, i.e. 4.30; 3.68; and 3.00 times, for M_0; M_1; and M_2, respectively. Leaf generation of vetiver achieved 81.82% in M_1 and 60.61% in M_2 compared M_0. The leaf generation within ten weeks of cultivation is shown in Figure 3. The study result is in line with previous studies that the maximum leaf number of vetiver planted in diesel contaminated soil was 24 pieces (Darajeh et al., 2014).

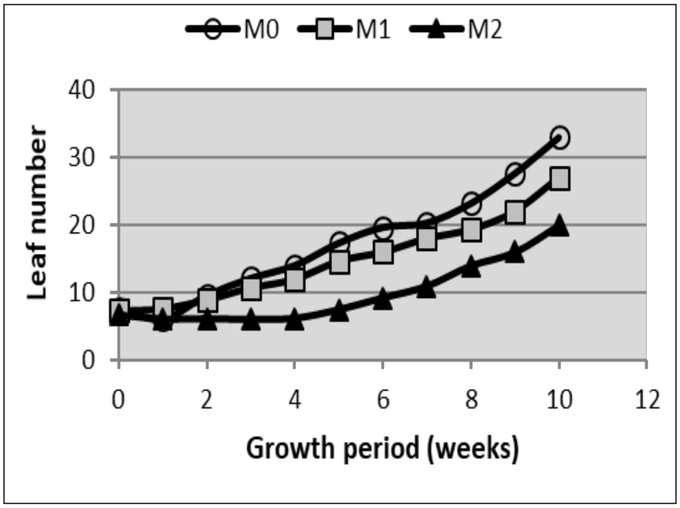

Figure 3. Leaf number of vetiver in media with varying concentration of carwash wastewater

Table 3 shows the vetiver leaf distributed in various length classes. In control media, the leaf length was distributed in all categories, from L< 10 to L ≥ 90 cm. Meanwhile, the vetiver leaf in M_1 and M_2 was dominated by leaf with L ≤3 0 cm at 68.5 and 82.4% respectively. Vetiver leaf with L > 60 cm has not been generated in M_1 and M_2 during 70 days of cultivation. As a result, the leaf area of vetiver in M_1 and M_2 was slightly lower than M_0. Vetiver with higher leaf area resulted in higher photosynthesis rate and vegetative growth rate.

Table 3
Leaf length distribution of vetiver at harvesting time (%)

Leaf length class	Leaf length distribution (%)		
(cm)	M_0	M_1	M_2
L ≤ 10	25,8	36,4	48,3
10 < L ≤ 20	22,2	19,1	20,8
20 < L ≤ 30	17,7	13,0	13,3
30 < L ≤ 40	10,6	15,4	9,2
40 < L ≤ 50	10,6	8,0	7,5
50 < L ≤ 60	6,1	7,4	0,8
60 < L ≤ 70	3,5	0,6	0,0
70 < L ≤ 80	1,5	0,0	0,0
80 < L ≤ 90	0,5	0,0	0,0
≥ 90	1,5	0,0	0,0
Total	100,0	100,0	100,0

Similar findings were reported previously (Nisa & Rashid, 2015). The maximum leaf length of vetiver which was planted in high concentration of palm oil mill effluent (POME) was 42.2 cm whereas in low of POME concentration was 70.2cm . The number of vetiver leaf media in low concentration of POME was 3.18 times higher than in high POME (Darajeh et al., 2014). However, it was reported the vetiver shoot length decreased ± 37% when planted in diesel contaminated soil

In the current study, the initial root number of vetiver was 13-21 with the average of 16.8 pieces, and the root length was in range of 1.5-69.9cm, Table 4 shows root number of vetiver at harvesting time was in the range of 37-45; 27-37; and 23-34 pieces in M_0, M_1, and M_2 respectively. The average root number of vetiver decreased with addition of carwash wastewater in growth media, i.e. from 41.8±3.1 in M_0 to 32.8±3.7 in M_1 and 30.0±2.4 in M_2. The root generation achieved 78% in media with 50% CW (M_1) and 72% in media with 100% CW (M_2). Nevertheless, vetiver has a capability to survive in media of carwash wastewater and generate new organs as well as roots

Roots in vetiver is its most important part. Besides quantitative parameter of root, qualitative characteristics such as nutrient uptake capacity should be considered. This characteristic is strongly related to the root length than the root weight. The root length determines the capacity of plant to obtain water and nutrients for growth (Darajeh et al., 2014; Gupta et al., 2012; Paz-Alberto et al., 2007). In fact, roots of herbaceous species may reach up to 10m in height. Nevertheless, phytoremediation is more effective in 50-100cm depth (Cameselle, Chirakkara, & Reddy, 2013). In this study, the highest total root length was achieved when the vetiver used tap water as growth media at 1,373 cm in average. On the other hand, root length in M_1 and M_2 was 861 and 553 cm respectively.

Table 5 presents the root length distribution of vetiver at harvesting time. The generation of vetiver root with L≤50cm

Table 4
The root number and root length of vetiver at harvesting time

Root growth / Treatment	M_0	M_1	M_2
Root number (per piece) per plant)			
• Range	37-45	27-37	27-34
• Average	41.8±3.1	32.8±3.7	30.0±2.4
Total root length per plant (cm)			
• Range (cm)	1,204-1,670	603-1.019	440-848
• Average (cm)	1,373±187	861±162	553±155
Individual root length			
• Range (cm)	2.6-92.4	1.4-73.0	1.3-64.5
• Average (cm)	32.7±20.5	26.2±19.0	18.7±14,9

Table 5
Root length distribution of vetiver at harvesting time (%)

Root length class	Root length distribution (%)		
(cm)	M_0	M_1	M_2
$L \leq 10$	11,6	24,9	38,3
$10 < L \leq 20$	20,7	17,3	27,8
$20 < L \leq 30$	19,5	19,3	11,7
$30 < L \leq 40$	19,5	16,8	10,0
$40 < L \leq 50$	10,0	9,1	6,7
$50 < L \leq 60$	8,0	5,6	3,9
$60 < L \leq 70$	4,0	4,6	1,7
$70 < L \leq 80$	2,8	2,5	-
$80 < L \leq 90$	3,6	-	-
≥ 90	0,4	-	-
Total	100,0	100,0	100,0

in media 100% CW (M_2) was 94.4%, higher than M_1 and M_0. In other words, root with length of 50-100 cm was only 5.6% in M_2, lower than in M_1 (12.7%) and M_0 (18.7%). There was no root with length ≥70cm was produced by vetiver when using 100% CW media. This data indicates that utilisation of CW as cultivated media would decrease the growth rate of vetiver root. In spite of that, vetiver has a capability to survive and adapt to media CW. Similar study reported that the maximum root length of vetiver in remediation of media with high concentration of palm oil mill effluent (POME) was 47.5 cm. Meanwhile, the maximum root length of vetiver in low concentration of POME was higher, i.e. 70.3 cm with 24 pieces (Darajeh et al., 2014). Another research found that the average root length of vetiver in medium of diesel contaminated soil decreased compared with uncontaminated soil, i.e. 12.6 vs 19.6 cm (Nisa & Rashid, 2015).

Root and shoot ratio is affected by environmental conditions to which the plant is exposed. In this study, there is no significant difference in root-shoot ratio among treatments. Approximately, root-shoot ratio of vetiver was 3:7 before treatment and 2.8:7.2 after treatment in CW. Ash content of vetiver leaf and root in harvesting was 9.3 and 5.8% respectively.

Tensile Strength

There is no significant difference in terms of tensile strength among growth media (Table 6). Tensile strength of Vetiver root with diameter 0.71 mm is higher than roots with diameter 0.81 mm, 33.9 and 16.3 MPa respectively. Tensile strength of root decreased with increase in diameter (Mattia et al., 2005; Teerawattanasuk, Maneecharoen, Bergado, Voottipruex, & Lam, 2015). Tensile strength of vetiver with root diameter 0.74±0.047 mm was 28.007±8.252MPa. This result is consistent

Table 6
Tensile strength of vetiver in different roots

Root diameter class	Diameter (mm)	Sectional area (mm^2)	Tensile strength (MPa)
1	0.810	0.520	16.300
2	0.722	0.416	28.123
3	0.716	0.409	33.688
4	0.710	0.398	33.917
Average	**0.740**	**0.436**	**28.007**
Dev. Std	**0.047**	**0.057**	**8.252**

with earlier research that found tensile strength of vetiver root varied between 22.55-33.83 MPa for diameter of 0.25-2.90 mm (Teerawattanasuk et al., 2015). Tensile strength obtained in the experiment is useful in the phytoremediation with continuous wastewater. Water storm in the system should be calculated not to exceed the tensile strength of the roots.

Pollutant Removal of CW by Vetiver

Plants need essential nutrient for their growth, both macro nutrients such as C, H, O, N, P, K, S, Mg, Ca, and Fe, and micro elements, such as Cu, Zn, B, Mn, and Mo. The root cells have a capacity in selection intake of ions for growth, both of cation and anion, counting of C, H, O, N and P. On the other hand, the root zone of plant is specifically interesting due to its capacity to absorb and store the contaminant. Therefore, high absorbing potential of roots is desirable, mainly in absorption of toxic substances of polluted water.

Generally, the growth rate of vetiver is affected by the pH level of growth media. Plant growth is poor when the active acidity is too high (pH too low). The previous research reported that pH level of domestic effluent changed from 7.26 to 5.98 after treated with vetiver (Truong & Director, 2006). Similar pattern was showed in this study which pH level of CW decreased after treated with vetiver grass for 70 days, i.e. from 7.02 to 6.04 in $M_1$and from 7.86 to 6.33 in M_2. This level complied with the effluent standard in Indonesia, which must be in the range of 6-9. Table 7 presented the pollutant removal in CW. The removal of total N was of 78.5% in $M_1$and 57.9% in M_2. Meanwhile, the elimination of P substances by vetiver was 83.5% for M_1 and 69.0% for M_2. The capacity of vetiver in removal in high concentration of CW was lower than in low concentration and it was reflected also in the growth rate of vetiver in growth medium. The plant growth rate and hydraulic retention time influenced the reduction of contaminants (Gupta et al., 2012).

It was noticed that the objective of biological treatment of wastewater, including of phytoremediation is to remove or reduce the pollutant compounds, including N and P (Jhamaria & Yadav, 2014). It also successfully demonstrated the vetiver

Table 7
Pollutant removal of cw by vetiver

Parameter	Unit	Initial		At harvesting		Removal (%)	
		M_1	M_2	M_1	M_2	M_1	M_2
Nitrite (NO_3)	mg. L^{-1}	0.64	1.27	0.15	0.39	76.4	69.3
Nitrate (NO_2)	mg. L^{-1}	2.05	3.76	0.54	1.53	73.7	59.3
Ammonia (NH_3)	mg. L^{-1}	5.54	11.08	1.08	4.86	80.5	56.1
Total N	mg. L^{-1}	8.23	16.11	1.77	6.78	78.5	57.9
Total P (PO_4)	mg. L^{-1}	6.17	12.10	1.02	3.75	83.5	69.0
C O D	mg. L^{-1}	420	812	101	282	76.0	65.3
B O D	mg. L^{-1}	207	398	65	140	68.6	64.8
Detergent	mg. L^{-1}	6.14	10.29	1.15	4.17	81.3	59.5
Phenol	mg. L^{-1}	0.07	0.12	0.00	0.01	98.6	95.8
Lead (Pb)	mg. L^{-1}	0.08	0.13	0.02	0.05	73.3	61.5
Zink (Zn)	mg. L^{-1}	0.26	0.29	0.03	0.05	88.5	82.8

was capable to remove the N and P from contaminated soil and water, was of 60 and 59-85%, respectively (Truong & Director, 2006). COD removal of carwash wastewater by vetiver achieved 76 and 65.3% in M_1 and M_2, respectively. The BOD removal was not significantly different, between 68.6 and 64.8%. As comparison, the removal efficiency of COD and BOD_5 in natural form of local soil with municipal landfill leachate was 47.7 – 97.9% of COD and 48-99% BOD_5 respectively (Pazoki, Abdoli, Karbassi, Mehrdadi, & Yaghmaeian, 2014). In water passing through the floating wetland system, the median of COD was reduced to 66%, BOD 52%, and total P 65% (Stefani, Tocchetto, Salvato, & Borin, 2011).

In this study, the removal of detergent was 91.3 and 59.5%; phenol was 98.6 and 95.8% in M_1 and for M_2 respectively. Another study found although plant growth was reduced in presence of phenol vetiver adapted to phenol without any decline in potential for phenol remediation. Almost all the phenol was removed at the end of 4 days when concentration was 50-100mg.L^{-1} (Singh, Melo, Eapen, & D'Souza, 2008). Lead (Pb) has been used as an additive in gasoline and resulted in substantial increase in Pb levels in the area adjacent to highways. The present of Pb in fuels also contributes to air pollution, especially in urban areas. In plant, the toxic symptoms of Pb include inhabitation of seed germination and growth rate. The proper system is required to remove or reduce the lead content in the environment. It was reported that vetiver grass can be used to phyto-remediate soil and water in urban areas with various contaminants, such as public parks.

The previous research carried out by Antiochia, Campanella, Ghezzi and Movassaghi (2007) found that vetiver plant could take up large amount of Pb and Zn, both in shoots and roots. The Pb uptake by shoots is higher than 0.1% (dry weight) from the 4th day and about 3 times by roots. The Zn uptake was even higher, i.e. 0.38% (dry weight) in shoots and 0.61% in roots after 8 days irrigated daily with solutions of 621ppm Pb and 653ppm Zn. Another study investigated that vetiver grass is most tolerant and registered the highest rate of Pb absorption, i.e. 10.15±2.81mg.kg^{-1} (Paz-Alberto et al., 2007). In this study, the removal of Pb by vetiver was 73.3% in M_1 and 61.5% in M_2. This result is higher than the previously found that phytoremediation coefficient of lead by vetiver was 32% (Chantachon et al., 2004). It concluded that vetiver was a good hyper accumulator for Pb and Zn, which was concentrated more in roots than in shoots (Antiochia et al., 2007; Chantachon et al., 2004; Roongtanakiat, Tangruangkiat, & Meesat, 2007).

CONCLUSION

Vetiver has a capability to survive, adapt and generate new organs in carwash wastewater. The first three weeks of cultivation is a sensitive stage in growth, but afterward, it starts to grow normally. Nevertheless, the growth rate of vetiver decreased with the increase in carwash wastewater concentration in growth media. Within 70 days, the pollutant substance in media carwash wastewater 50% and 100% could be removed by vetiver, i.e. 78.5 and 57.9% N, 83.5 and 69.0% P, 76.0 and 65.3% COD, 68.6 and 64.8% BOD, 81.3 and 59.5% detergent, 98.6 and 95.8% phenol, 73.3 and 61.5% Pb and 88.5 and 82.8 % Zn respectively.

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