A Simple Technology for the Remediation of Waste Water Discharge from Tapioca Factories

E. R. Indrayatie[1), E. Handayanto[2), W.H. Utomo [2)

[1)Lambung Mangkurat University, Banjarmasin, Indonesia

[2)International Research Centre for Management of Degraded and Mining Land; Brawijaya University, Malang, Indonesia

Extended abstract

Indonesia has known as one of the largest cassava producers in the words, and therefore cassava plays an important role in the Indonesian society and economy. In the past, cassava is an important food crop, mainly for the poor rural and urban sectors of the population. However, the use of cassava as a food is now declining, and in the other hand its use for industry is becoming more and more important. The tapioca industry in Indonesia, especially in Java, is mostly small to medium scale industries. Such factories play an important role in the rural community; however, these small and often simple industries create very serious environmental problems. The cassava factories generate a large volume solid and liquid waste, and due to its high cost and technology, these small to medium scale tapioca did not have efficient wastewater treatment and mostly directly drain their liquid waste into rivers. Therefore, a simple and low cost waste water treatment technology would be very helpful.

Experiments were carried out to explore the potential use of Vetiver (*Vetivera zizanoides* L.) to remediate wastewater discharged from tapioca factory. The first experiment done to study the ability of Vetiver to improve the quality of waste water discharge from Tapioca factoriy, and the second experiment was carried out to test the resulted remediation for agricultural purpose.

The experimental results showed that Vetiver not only tolerance and grew well in medium contain wastewater discharged from tapioca factory, it also very effective for improving tapioca wastewater quality. The efficacy was influenced by the remediation system (wetland or hydroponics) and the density of the plants at the start of the remediation. Vetiver remediation was more efficient in a wetland system relative to a hydroponic system. To achieve the standard quality mandated by the East Java Province, Indonesia, with the initial wastewater of BOD 3,600 mg/L, COD 3,840 mg/L and Cyanide content 4.2 mg/L, the required plant density for 30 days remediation was $\geq$ 65 g dry biomass/1256 cm^2.

The resulted waste water remediation was safe for agricultural purpose, both for growing maize and fish culture.

Keywords: organic waste, vetiver, phytoremediation, cyanide, aquaculture

Introduction

In the past, mostly cassava in Indonesia was grown for human food. However, since 2007 the use of cassava as a food is declining and this now accounts for only 53% of total production (*versus* 64% in 2002). Its use for the production of starch, modified starch, sorbitol, and fuel-ethanol is becoming more and more important (CBS, 2007). The most common cassava industry in Indonesia are tapioca factories, and mostly small-to medium-scale industries. Wargiono and Suyamto (2006) reported that from 423 tapioca factories in Indonesia, 340 factories can be categorized as small to medium scale industries, and 299 of these factories are operated in Java. This is a good, because it increasing the use of cassava and farmer's income, either both through employment and the creation of value-added products. However, these small and often simple industries create environmental problems because most of these tapioca factories lack of the infrastructure for efficient waste water treatment and directly drain their liquid waste into rivers.

Hien et al. (1999) calculated that in order to produce 1 ton of starch, a tapioca processing factory discharges about 12 m^3 of waste water with a pH of 4.5 – 5.0, and containing a COD of 11,000-13,500 mg/L and total suspended solids (TSS) of 4,200-7,600 mg/L. Mai et al. (2004) reported that the concentration of cyanide in the waste water of a large-scale tapioca factory in Vietnam could be as high as 19 – 28 mg/L.

The acidic nature of the tapioca waste water can harm aquatic organisms and interfere with normal ecosystem function in the receiving stream. Suspended solids present in the waste water are primarily organic in nature, they decompose easily and thus deoxygenate the water. Similarly, the high BOD of the waste water can also cause rapid depletion of the oxygen content in the receiving water body and promote the growth of nuisance organisms (eutrophication). In addition, cassava is a plant containing cyanide compounds which is well-known as a metabolic inhibitor.

Toxicity problems in the Brantas River, one of the most important rivers in East Java, due to waste water from tapioca factories have been reported since 1996, and continuously occur every year, especially during the dry season (Ecoton, 2003; Rohimah, 2009). Serious environmental problems associated with the discharge of tapioca waste water have also been reported in many other countries such as India (Padmaja et al., 1990) and Thailand (Rajbhandari and Annachhatre, 2004).

The simplest system to treat waste water from a tapioca factory is the open pond system where solid materials settle and the organic compounds degrade naturally by means of chemical or microbial pathways (Rajbhandari and Annachhatre, 2004). However, this system needs a large area of land (Hasanuddin et al., 2008), and often yields poor degradation. The application of chemical substances to treat waste water is not recommended because of the price and environmental risk associated with such treatments. It seems that the more appropriate technology for waste water management of small- to medium-scale tapioca companies is the use of phytoremediation. This technique is relatively simple, cheap, possesses a relatively low risk, and has been proven to work very well for both metal and organic compounds (Alkorta and Garbisu, 2001; Cunningham and Ow, 1996; Smith, and Raskinet al., 1998; Trap and Karlson, 2001).

The application of phytoremediation for waste water remediation has been discussed extensively by Schröder et al. (2007). Bindu et al. (2008) used taro (*Colocasia esculenta)* to remove pollutants from domestic waste water. The potential of water hyacinths (*Eichhornia crassipes*) for tapioca factory waste water management has been studied by Jauhari, Wurjanto and Setyono (2002). Truong et al. (2008) extensively studied the use of vetiver grass (*Vetivera zizanioides* L.) for waste water management and reported good potential for the use of this species owing to the ability of vetiver grass to tolerate toxic conditions, and to grow very fast with a high yield of biomass. Indrayatie *et al.* (2011) had shown the effectiveness of vetiver for remediation of tapioca waste water factory.

The study reported her was to develop a simple technology in employing vetiver grass for remediation of waste water generated by the tapioca industry. The end result of this work is to clean waste water to meet the standard mandated by the government. In addition, to ensure the resulting remediation, it was also tested for fish culture.

2. Materials and methods

Experimental Procedure

Two experiments were conducted in a glass house at Brawijaya University, Malang, Indonesia. The first study aimed to explore the potential of vetiver phytoremediation for tapioca factory waste water, and the second experiment tested the resulting waste water remediation for fish culture and maize growing.

The technology developed in this studied was directed to obtain the suitable growth medium and the time (plant ages) when the remediation can reach the maximum results. Two growth media were used, i.e. (1) wetland systems, and (2) hydroponics (solution); and the time of starting (plant ages) when remediation was started are: 15, 30, 45, 60, and 75 days of age after planting. These 10 treatmenst combinations were arranged in Complete Randomized Design, with 4 replications. As the control, Vetiver was grown in wetland and hydroponic systems using de-ionized water

Planting materials (with a plant height of 30cm and root length of 5cm) of Vetiver were planted on 15 kg of wetland and/or in a 15 liters hydroponic system in a plastic pot of 35.0 liters capacity. The wastewater was applied to the system for 60 days, and the wastewater quality was measured periodically at 4, 8, 15, 30, 45, and 60 days after remediation. The height of inundated water was maintained by adding wastewater or de-ionized water every 7 days. The wastewater used for this purpose was diluted so that it had the same characteristics as the experimental treatments at the time of wastewater addition.

On harvest, the plants were measured for biomass, cyanide concentration in plant tissue, and Index of Tolerance (TI). Wastewater was measured for pH, BOD, COD, Cyanide, and dissolved oxygen (DO)

In the second study, the experiments were set up for the utilization of the resulted remediation for maize growing and fish cultures. The result of the first experiment show that the best remediation occurred with 75 days old vetiver at 30 days remediation time; this remediate wastewater was used for fish culture and maize growing. In addition, as the control, the experiments also used the factory treated wastewater, as well as the factory fresh wastewater for fish culture and maize growing. The characteristics of this wastewater are given in Table 1.

Table 1.The characteristics of wastewater and soil used for the experiment

Experimental materials	pH	BOD mg L^{-1}	COD mg L^{-1}	Cyanide mg L^{-1}	DO mg L^{-1}
Soil	6.7	-	-	-	-
Fresh waste water	3.6	7,760	10,240	6.24	undetected
Factory treated waste water (first study)	4.6	3,600	3,840	4.20	undetected
Factory treated waste water (second study)	4.9	3,400	3,840	4.28	undetected
Vetiver treated waste water	7.3	185	266	0.62	5.2

Maize was grown on 10 kg soil in a plastic pot of 15 L capacity, The treatments were (1) fresh tapioca factory wastewater (FW), (2) factory treated wastewater: watered with factory treated wastewater (TTW), (3) factory remediated wastewater: watered with remediated wastewater (TRW), and (4) remediated waste water, watered with remediated wastewater (RW), and (5) de-ionized water as the control (C). The maize crops were fertilized with 90kg N/ha, 50kg P/ha, and 50kg K/ha and grown for 45 days. Measurements were taken for total dry biomass and cyanide content.

The fish culture experiment was done in a glass aquarium of 5l. The treatments were (1) Factory fresh wastewater (FW), (2) Factory treated wastewater (TW), (3) Vetiver remediated wastewater (RW), (4) Vetiver remediated wastewater + spring water (1:1) (RWS), and (5) spring water (SW). Ten freshwater fish of *Barbonymus gonionofus* species with 5 – 7 cm length were put into these aquariums, and grown for 30 days. The measured parameters were the number of dead fish and the fish weight.

Laboratory Analysis

Wastewater analysis was done by American standard methods (APHA, 1992). COD was oxidized with $K_2Cr_2O_7$ and cyanide with silver nitrate ($AgNO_3$) standard titrations. The pH was measured with a pH-meter (Jenway 3305). Nitrogen was extracted with Nestler reagent, and Phosphorus with Ammonium molybdinate and both of them were determined with a spectrophotometer (Vitatron). Total Potassium was extracted by wet acid digestion, and the concentration was read with AAS (Shimatzu).

3. Results and Discussion

The result presented in Table 2 shows that the result of vetiver remediation of was depended on the system by which remediation executed, and it was influenced by plant ages at the start of remediation. The model of wetland system (W) was more effective compared to the hydrophonic system. This is a reasonable phenomenon because in a soil system there are many organisms which act as decomposers of the organic compounds in the wastewater, so the decomposition of these compounds will be faster than that in the hydroponic system.

Table 2. The affect of the remediation system and plant age (biomass) at time of planting on the quality of tapioca factory waste water quality after 60 days of remediation

Vetiver at the start of remediation		Solution concentration (mg/L)							
Ages (days)	Dry biomass (g/pot)	BOD		COD		DO		CN	
		W	H	W	H	W	H	W	H
Control/no plant		445 g	618 h	470 e	688 f	1.10 a	0.96 a	1.46 cd	2.60 e
7	5.1	165 c	413 f	199 b	450 e	2.42 b	1.06 a	0.99 bc	2.08 de
15	9.4	85 b	375 f	100 b	390 c	3.04 b	0.98 a	0.63ab	1.61 cd
30	11.5	30 a	325 e	34 a	350 c	3.48 c	1.24 a	0.62 ab	1.45 cd
45	22.6	36 a	270 d	30 a	298 c	5.98 cd	2.36 b	0.28 ab	1.51 cd
75	37.4	6 a	265 d	24 a	320 c	6.40 d	2.46 b	0.26 a	1.40 cd

3).Means followed by the same letters for each characteristic measurement are not significantly different (p= 0.05 . The time variable was the age, and thus biomass, of plants at day 0 of the remediation period. W is the model wetland system. H is the hydroponic system.

Using the “purification, η” term which was defined as the percentage of the removed pollutant by the plant as done by Lin *et al.* (2002), it can be seen that with the wetland model, the utilization of 45 days old vetiver at the start of remediation had resulted of purification of BOD, COD and HCN for more than 90 % (Table 3). This indicated that the quality of waste water had nearly the same with the quality of fresh water.

Table 3. The effect of the remediation system and plant age (biomass) at time of planting on the purification (η) of tapioca factory waste water after 60 days of remediation

etiver at the start of remediation		η (%)					
ges (days)	Dry biomass (g/pot)	BOD		COD		CN	
		W	H	W	H	W	H
ontrol/no plant		86.87 ab	81.77 a	87.76 a	82.60 a	65.23 bc	38.09 a
	5.1	95.13 b	87.82 ab	94.81 b	88.28 a	76.42 bcd	50.47 ab
5	9.4	97.49 cd	88.94 ab	97.39 b	89.84 a	85.00 cd	61.66 ab
0	11.5	99.11 cd	90.41 bc	99.11 b	90.88 a	85.23 cd	65.47 bc
5	22.6	99.00 d	92.50 bcd	99.21 b	92.23 b	93.33 d	64.04 bc
5	37.4	99.82 d	92.18 bcd	99.37 b	91.67 ab	93.80 d	66.67 bc

3).Means followed by the same letters for each characteristic are not significantly different ($p = 0.05$). All experimental units had a remediation period of 60 days. The time variable was the age, and thus biomass, of plants at day 0 of the remediation period. W is the model wetland system. H is the hydroponic system.

The purity of the remediated waste water increased with the increasing age and biomass of the vetiver plants used at the start of the remediation. This is likely due to the fact that as the plants grow older, their root and top biomass will develop, and hence their nutrient absorption and photosynthesis rates will increase; older plants at the start of the remediation period had a greater starting biomass (Tables 2 and 3) and thus greater degradation potential. Furthermore, in older plants, with increasing root biomass, there will be an increase in surface area for biological processes that occur at the root-soil interface. These processes assist in the decomposition of organic compounds in the waste water.

The data in Table 2 show that at the end of the 60 day remediation period, the cyanide concentration was still higher that the required standard (more than 0.06 mg/L). To determine the remediation period required to attain the quality standard for cyanide concentration, a further experiment investigating the cyanide concentration in solution as a function of biomass at different remediation periods was conducted using the wetland system. The waste water for this experiment had an initial BOD concentration of 3,600 mg/L; COD concentration of 3,840 mg/L and cyanide concentration of 4.2 mg/L. Remediation was performed using initial vetiver biomass values of 0 (control); 5.1 g/pot; 9.4 g/pot; 17.7 g/pot; 35.1 g/pot; and 51.4 g/pot) for up to 60 days. Measurement was performed for two replicates and the results (Table 4) show that within a 60 day remediation period, the prescribed cyanide quality standard could only be obtained using initial vetiver biomass values of 35.1 g/pot and 51.4 g/pot.

Table 4. The cyanide concentration in tapioca factory waste water as a function of varying initial vetiver biomass and the length of the remediation period (up to 60 days) for a model wetland system (Experiment 3).

	Cyanide concentration in waste water (mg/L)					
Remediation period (days)	Vetiver biomass at the start of the remediation period (g/pot)					
	0	5.1	9.4	17.7	35.1	51.4
0	4.22	4.22	4.22	4.22	4.22	4.22
7	3.64	3.54	3.21	3.23	2.98	2.04
15	3.06	2.96	2.34	1.76	1.45	0.76
30	2.22	1.95	1.62	1.25	0.86	0.36
45	1.94	1.21	0.97	0.84	0.33	0.26
60	1.46	1.15	0.83	0.36	0.24	0.26

Values are the mean of two replicates

Utilization of remediated wastewater

The maize planted on the medium watered with fresh tapioca wastewater did not germinate (Table 5). Maize grown on the treatment of factory treated wastewater, either then watered with the same wastewater (TTW) or watered with Vetiver remediated wastewater (TRW) and the other two treatments (in the Vetiver remediate wastewater, RW, and in de-ionized water, C) grew quite well. The highest total biomass of maize (24.67g)/plant) was obtained by the maize planted in factory treated wastewater, and this is significantly different from the other treatments. This is not surprise, because this wastewater still contains a lot of plant nutrients, while the nutrients in the Vetiver remediated wastewater had been used by the Vetiver. The total dry biomass of maize planted in factory wastewater and watered with Vetiver remediated wastewater (TRW) treatment is not significantly different from that planted in the Vetiver remediated wastewater treatment, and the de-inonized treatment (C).

Table 5.The effect of remediated tapioca wastewater on the total maize biomass and cyanide content at 45 days old.

Treatment	total biomass g/plant	plant-CN mg/kg	Soil-CN mg/kg
Fresh wastewater, FW	0	0	3.40 c
Factory treated wastewater, TW	24.67 c	1.80 b	2.25 b
TW, then watered with RW	20.76 ab	0.80 a	0.22 a
Vetiver remediate wastewater, RW	17.24 a	0.76 a	0.12 a
De-ionized water, C	19.45 ab	0.60 a	0.04 a

Means followed by the same letters, in each column are not significantly different (p=0.05

The results in Table 6 also show that the high biomass of maize planted in the medium watered with factory treated wastewater was followed by the high cyanide content in its tissue. Therefore, if the maize biomass is used for animal feeds, then this phenomenon should be taken into a consideration. The cyanide content of soil watered with fresh wastewater and factory treated waste water was still quite high, i.e. 3.4 mg/kg and 2.2 mg/kg respectively.

The results of the utilization of remediated waste water on fish culture are presented in Table 6. Soon after the fish were put into the fresh waste water (FW), all of these fish were dead. This was due to either high cyanide content of the medium, or because of no DO due to high BOD and COD. Until 30 days, the cyanide content in this medium was still high (3.4mg/l). The same occurred for factory treated wastewater.

Table 6.The utilization of Vetiver remediate tapioca industrial wastewater for freshwater fish culture

Treatment	No of dead fish at					fish weight At 30 days
	0 days	2 days	7 days	15 days	30 days	g/fish
Fresh wastewater, FW	10	-	-	-	-	-
Factory treated wastewater, TW	5	2	3	-	-	-
Vetiver remediate wastewater, RW	0	0	0	0	2	24.6
RW + Spring water (1:1), RWS	0	0	0	1	2	24.5
Spring water, C	0	0	0	0	3	25.4

The results in Table 7 also show that the number of deaths and the fish weight grown in this medium was not different from that grown in spring water. This result indicated that the remediated tapioca industrial wastewater was safe for the culture of *Barbonymus gonionofus* freshwater fish.

REFERENCES

Alkorta, I and Garbisu, C. 2001. Phytoremediation of organic contaminants in soils. Bioresources Technology 79 (3) : 273 - 278

APHA, 1992. Standard Methods for the Examination of Water and Wastewater, Section 5210, 18th ed., American Public Health Association Water Works

Association, American Water Environment Federation, Washington, DC, pp. 5.1–5.6.

Balagopalan, C & Rajalakshmy, L. (1998). Cyanogen accumulation in environmental during processing of cassava for starch and sago. *Water, air and soil pollution* 102, 407-413.

Bindu, T., Sylas, V.P., Mahes M. , Rakesh, P.S. and Ramasamy, E.V. 2008. Pollutant removal from domestic wastewater with Taro (*Colocasia esculenta*) planted in a subsurface flow system. Ecological Engineering 33 (1): 68-82

Chavalparit, O. and Ongwandee, M. 2009. Clean technology for the tapioca starch industry in Thailand. Journal of Cleaner Production 17 : 115 - 110

Central Bureau of Statistics (CBS). 2007. Statistik Indonesia 2005/06. Jakarta, Indonesia

Cunningham, S.D. and Ow, D.W. 1996. Promises and Prospects of Phytoremediation. Plant Physiol 110 : 715 – 719.

Ecoton. 2003. Water, 2 millions of Surabaya population shortage of water (In Indonesian) www.ecoton.or.id/index.php?awal=161. Retrieved via Internet Explorer Ver. 6, 15 October 2009

Hasanuddin, U. 2008.Handbook Wastewater of Post Harvest Technology of Agro-. Industry. Lampung University, Lampung, Indonesia.

Hien, P. G., Oanh L.T.K., Viet, N.T. & Lettinga, G. (1999), Closed Wastewater System in the Tapioca Industry in Vietnam, *Wat. Sci. Tech.* 39(5), 89-96.

Jauhari, I, Wurjanto and Setyono. P. 2003. The use of water hyacinth ((*Eichhornia crassipes*) to decrease pollutant from wastewater of tapioca industry (*in Indonesian*). Enviro 2 (1) : 26 – 34.

Lin, Z.Q., de Souza, M., Pickering, I. J. and Terry, N. 2002. Evaluation of the Macroalga, Muskgrass, for the Phytoremediation of Selenium-Contaminated Agricultural Drainage Water by Microcosms . J Environ Qual 31: 2104-2110

Mai, H.N.P., Duong, H.T., Trang T.T.T. and Viet, N.T. (2004), UASB Treatment of Tapioca Processing Wastewater In South Vietnam. *In proceedings: International Conference on "10th World Congress – Anaerobic Digestion 2004"* 29th Aug. to 2nd Sep, 2004 Montreal, Canada, Vol 4, pp. 2420-2424.

Malik, A. 2007. Environmental challenge *vis a vis* opportunity: The case of water hyacinth. Environmental International 33 (1): 122 – 138.

Padmaja, G., Balgopalan, C., Kurup, G.T., Moorthy, S.N. and Nanda, S.K., 1990. Cassava processing, marketing and utilization in India. In: *"Cassava breading,* *agronomy and utilization research in Asia", Proceeding of the Third Regional Workshop, Malang, Indonesia, October 1990*, Centro International de Agriculture Tropical (CIAT), pp. 327–338

Pemprov Jatim. 2000. Regulation of East Java government No. 5/2000 : the control of water pollution in East Java (*in Indonesian)* . Government of East Java, Surabaya. Indonesia.

Rajbhandari, B.K. and Annachhatre, A. P. 2004. Anaerobic ponds treatment of starch wastewater: case study in Thailand. Bioresources Technology 95 (2)_ : 145-153

Rohimah, 2009. The problems of garbage (In Indonesian). Indoskripsi. www.oneindoskripsi.com/mode/7578. Retrieved via Internet Explorer Ver. 6, 15 October 2009

Salt,D.E., Smith, R.D. and Raskin, I.1998. Phytoremediation. Annu. Rev. Plant Physiol. Plant Mol. Biol. 49:643–68

Shi, G. and Cai, Q. 2009. Cadmium tolerance and accumulation in eight potential energy crops. Biotechnology Advanced 27 (5) : 555-561

Trapp, S. and Ulrich Karlson, U. 2001. Aspects of Phytoremediation of Organic Pollutants. J. Soils & Sediments 1 : 1 - 7.

Truong, P.N. and Hart, B. 2001. Vetiver system for wastewater treatment. Tech. Bull. No 2001/2. Pacific Rim Vetiver Network. Royal Development Project Board, Bangkok, Tailand.

Truong, O., Van, T.T. and Pinners, E. 2008. Vetiver System Application, Technical Reference Manual. The Vetiver Network International, Bangkok, Thailand.

Wargiono, J. and Suyamto 2006. The Potential, Constraint and Opprtunity of Cassava Development for Bioethanol Industry (Indonessian). Workshop The Development of Cassava for Agroindustry and Food Security. Research Institute for Legume and Tuber Crops. Malang, Indonesia.

Wilkins, D.A. 1978. The measurement of tolerance to edaphic factors by means of root growth. New Phytol 80 :. 623–