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Original Research Paper

Capability of Vetiver Grass (*Vetiveria zizanioides* (L.) Nash) on Wastewater Treatment from Fermented Rice Noodle

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ABSTRACT

Fermented rice noodle industry can generate a large volume of undesirable liquid waste into the environment. This study was conducted to investigate the ability of Vetiver grass (*Vetiveria zizaniodes* (L.) Nash) and sedge (*Cyperus corymbosus* Rottb.) to treat wastewater from fermented rice noodle industry. Vetiver grass and sedge were cultured into flooding condition and used for treated wastewater (TWW) and untreated wastewater (UWW) in experiment. The results found that vetiver grass and sedge could grow well in TWW; whereas, the growth vetiver grass and sedge in UWW was slow because the vetiver grass and sedge were non-tolerant to high COD concentration of UWW in the long period of this experiment. Moreover, UWW also could decrease wastewater treatment efficiency of vetiver grass and sedge. Unlike, TWW could increase wastewater treatment efficiency in both vetiver grass and sedge leading to long period of treatment experiment. The results also found that wastewater treatment capability in both vetiver grass and sedge declined as treatment experimental period increased; however, vetiver grass performance was more stable than sedge. To achieve the water quality standard of Pollution Control Department, wastewater could be remediated up to 56 days using vetiver grass planted in soil filter system.

INTRODUCTION

Noodle products have been recognized as favourite food in many countries. Fermented rice noodle is one of noodle products which is widely consumed in Thailand. Thus, fermented rice noodle industry is rapidly expanding into rural and urban areas of Thailand, and comprises mostly small to medium-scale industries. These small and often household industries create environmental problems through the generation and discharge of large volumes of solid and liquid wastes into the environment. Many small to medium-scale fermented rice noodle factories normally lack of infrastructure for efficient wastewater treatment and directly drain their wastewaters into waterways (Siripattanakul-Ratpukdi 2012). Although wastewater from fermented rice noodle factories does not contain high toxic contaminating substances, their wastewater can still cause environmental problems owing to its low pH and high concentration of complex organic compounds (Bunnag et al. 2010, Siripattanakul et al. 2010, Ratanapongleka et al. 2010). The complex organic compounds contain mainly fermented starch and some inorganic compounds. Moreover, fermented starch in complex organic compound seems to be a critical problem because it can increase biochemical oxygen demand (BOD) and chemical oxygen demand (COD) in this wastewater (Sirianuntapiboon & Yommee 2006, Siripattanakul et al. 2010).

These figures indicate that the wastewater is highly biodegradable and will result in excessive environmental damage. Suspended solids (expressed in terms of fermented starch) present in the wastewater can settle into rivers. Thus, they decompose easily and can cause rapid depletion of oxygen content in the receiving water bodies and promote eutrophication. In addition, wastewater from fermented rice noodle factory is a source of undesirable smell and directly affects sanitation (Bunnag et al. 2010, Ratanapongleka et al. 2010). Chiemchaisric et al. (2007) found that fermented rice noodle factory wastewater was discharged from ten small-scale factories in Bangkok, and surrounding provinces of Thailand contaminated with complex compound as the main constituent and varied in a range 2.7-5.4 m^3/ton of the product. Environmental problems associated with the discharge of fermented rice noodle wastewater have also been reported in many areas in Thailand.

Several physical and chemical methods may successfully remove high concentration of complex organic compound but could be very expensive because of high chemical usage, costly infrastructure and high operating expenses. Moreover, accumulation of concentrated sludge becomes a new disposal problem. Biological wastewater treatment technologies in most cases give the highest degree of confidence from and engineering and economic practicability point of view (Martin 1991). Phytoremediation is one of the biological wastewater treatment technologies which is relatively simple, low cost, environmental friendly, consumes less energy, and has been proven to work very well for both metals and organic compounds. It seems that the more appropriate technology for wastewater management of small to medium-scale fermented rice noodle industries is phytoremediation. Plant species used for phytoremediation should have a high uptake of pollutants, grow well in polluted water and be easily controlled in quantitatively propagated dispersion. Vetiver grass (*Vetiveria zizanioides*) was found to be an efficient species for wastewater management. Although vetiver grass is not hyperaccumulator species but it will often remove a higher volume of pollutants from a contaminated medium (Truong et al. 2008). Therefore, vetiver grass has also been successfully used in the field of environmental protection (Truong & Hart 2001).

The aim of this study is to examine the fermented rice noodle factory wastewater treatment using vetiver grass in soil filter system. The analysis took into account the COD removal from fermented rice noodle factory wastewater and increase of wastewater treatment period. Our findings can be used as an alternative technique for wastewater treatment from noodle industries.

MATERIALS AND METHODS

Wastewater sample preparation: The fermented rice noodle factory wastewater was obtained from a small factory in Pathumthani, Thailand. Preparation of this wastewater was divided into untreated wastewater (UWW) and treated wastewater (TWW). In addition, all of the wastewater samples were preserved at 4°C prior to use.

Emergent plants preparation: Emergent plants, vetiver grass (*Vetiveria zizaniodes* (L.) Nash) and sedge, (*Cyperus corymbosus* Rottb.) were pruned to 20 cm height before cultivation. Afterwards, emergent plants were planted with a density of 1 rhizome per soil filter container and watered by irrigation water until they were acclimatized.

Wastewater treatment: After plant acclimation, all soil filter containers were fed with fermented rice noodle factory wastewater. The soil filter system consists of cylindrical plastic container with a cross-sectional area of 1,520.0 cm^2 filled with media. Each soil filter container is fitted with plastic valve at the base for collection of effluent (Fig. 1). Media consisted of 5 cm of gravel layer filled at the bottom of each unit followed by 3 cm of sand layer and finally with 20 cm of sandy clay loam soil (mixture of paddy soil and sand in ratio 1:3) layer for emergent plant support. In the treatment cycle, wastewater was maintained at 10-12 cm above the ground surface for flooding cycle at 5 days. Afterwards, it was drained out and the experimental containers were allowed to air-dry for drying cycle of 2 days (Klomjek & Nitisoravut 2005). The hydraulic loading rates (HLR) were in the range of 20-25 litres/flooding cycle. Further, three unplanted units were also set as control experiment. During experiments, weeds were thoroughly removed from the soil filter containers. Wastewater treatment capabilities of emergent plants were based on COD removal from fermented rice noodle factory wastewater and increase of wastewater treatment period. The wastewater samples were analysed for pH, COD, and salinity according to the standard methods (APHA 2005).

Table 1: Pre-experimentation properties of fermented rice noodle factory wastewater.

Parameter	UWW	TWW[a]	Industrial effluent std.[b]
pH	3.9±0.2	8.0±0.1	5.5-9.0
Salinity (mg/L)	3,870±226.67	3,176.67±31.11	≤ 5,000
COD (mg/L)	3,410.48±172.81	988.93±124.89	≤ 400

[a] TWW was obtained from previous study (Pratum et al. 2014)
[b] Pollution Control Department (2014)

Statistical analysis method: Each experiment was repeated at least 3 times. The pre-experimentation properties of wastewater in the experiments were statistically analysed for their mean and standard deviation (X±SD). Meanwhile, the percentage of COD removal was compared using one-way analysis of variance (ANOVA) at the 95% confidence level. Further, Duncan's multiple range test was used to differentiate mean value, with significance defined at $p <$ 0.05.

RESULTS AND DISCUSSION

The fermented rice noodle factory wastewater quality: The fermented rice noodle factory wastewater quality before plant cultivation was investigated. UWW was obtained from the fermented rice noodle factory which has directly drain wastewater without treatment (Fig. 2). Meanwhile, TWW was obtained from primary biological treatment using potential isolated bacteria. The potential isolated bacterial strain can reduce the wastewater strength of fermented rice noodle wastewater along with the recovery of biomass (Pratum et al. 2014).

The pH value of TWW was within the limits of industrial effluent standards, except UWW, which had a pH of 3.9 ± 0.2. Further, salinity values of TWW and UWW were within the limits of industrial effluent standards. In addition, the content of COD in the two samples of wastewater was very much higher than the industrial effluent standards, especially UWW, which has the highest content of COD at 3,410.48 ± 172.81 mg/L. A large amount of fermented starch

Table 2: The wastewater treatment performance of emergent plants.

Wastewater type	Emergent plants	Parameters[a] pH	Salinity (mg/L)	COD removal (%)
TWW	Vetiver grass	7.0 ± 0.0	5,350.00 ± 75.00	87.81 ± 0.78
	Sedge	6.9 ± 0.0	5,181.25 ± 181.25	85.74 ± 0.75
	Control/no plant	7.3 ± 0.1	4,050.00 ± 291.67	54.53 ± 4.14
UWW	Vetiver grass	7.0 ± 0.1	2,812.50 ± 37.50	90.94 ± 0.59
	Sedge	7.0 ± 0.1	3,250.00 ± 150.00	89.40 ± 0.56
	Control/no plant	7.1 ± 0.1	5,800.44 ± 405.41	72.05 ± 1.13

[a] Mean values during 8 weeks of experiment period are reported for all variables and SD.

and pith residue is responsible for the COD in UWW (Table 1).

It is obvious that all the fermented rice noodle factory wastewater samples used in this study were contaminated with organic pollutants, especially fermented starch. Thus, they decompose easily and can cause rapid depletion of the oxygen content in the receiving water bodies. In addition, wastewater from fermented rice noodle factory is a source of undesirable smell and directly affects sanitation (Bunnag et al. 2010, Ratanapongleka et al. 2010). When discharged to lakes and rivers the high organic pollutants in the fermented rice noodle factory wastewater is a big concern relative to water quality. These wastewaters definitely require treatment before discharging them into the waterways.

Wastewater treatment experiments: Table 2 summarizes the wastewater treatment performance of emergent plants operated in container with flooding condition of 5 days and air-drying condition of 2 days.

The flooding conditions play an important role in wastewater treatment, which had aerobic biodegrade process in root zone and anaerobic biodegradation process in soil matrix. Air-drying conditions were used for protection of soil matrix clogging (Nemade et al. 2009, Christen et al. 2010). This clogging layer could impede wastewater filtration through soil matrix (Quanrud et al. 1996). All the emergent plants studied in this work were able to improve the quality of TWW more than UWW. In addition, UWW could decrease efficiency of treatment experiment period. Unlike, TWW could increase efficiency of treatment leading to long period of treatment experiment. Whereas control/no plant unit found that very low efficiency of treatment experiment period which has 4 weeks in TWW and 3 weeks in UWW.

The pH values of the treated water complied with the Pollution Control Department (PCD) regulatory rules, pH 5.5-9.0, for drainage to environment. This demonstrates the soil capacity to neutralize and buffer the wastewater pH, during flooding cycle. Even during periods when the pH of UWW was quite acidic, pH of 3.9 ± 0.2, the pH of the treated water was close to neutral (7.0). This may have been due to clay fixation of the organic acids. The salinity of TWW averaged 3,176.67 ± 31.11 mg/L, while that of the drainage averaged 5,350.00 ± 75.00 mg/L in vetiver grass and 5,181.25 ± 181.25 mg/L in sedge, respectively. Both the values were higher than the maximum PCD limit for drainage to environment of ≤ 5,000 mg/L. Vetiver grass resulted in a 7% increase in the salinity of the treated water. Meanwhile, sedge resulted in a 3.6% increase in the salinity of TWW. The high salinity of the treated water places restrictions on its reuse, however, dilution with stormwater or non saline water is possible to reduce the salinity before reuse. The average reduction in COD concentration ranged from 90.94% to 54.53%. In comparison with the control units, the units with emergent plants provided better performance. Whereas, one-way ANOVA study showed the highest efficiency of COD removal at planted units ($p < 0.05$). This result showed difference for COD removal between planted and unplanted units due to soil microbes playing a prominent role for COD removal whereas emergent plants gave mere oxygen supply and a support medium for microbial degradation to occur (Lim et al. 2001).

After finish of experiment, appearance of emergent plants growth could indicate that the complex organic compounds, especially fermented starch, played an important role in attenuating in both vetiver grass and sedge growth. Emergent plants grown in TWW had the best growth due to less content of fermented starch (expressed in term of COD), while the worst growth was found in UWW (Fig. 3). Emergent plants showed injury symptoms from the combination effect of high COD concentration and flood conditions. Vetiver grass appeared dwarfed, wrinkled, dry, yellowish and less tillering. Whereas, sedge appeared dry, yellowish and less tillering.

Influence of Wastewater Type on Treatment Capability

Treated wastewater samples: In TWW section, the experiments were conducted to compare long term between vetiver grass and sedge. It was observed that the treatment efficiencies in both vetiver grass and sedge declined as the

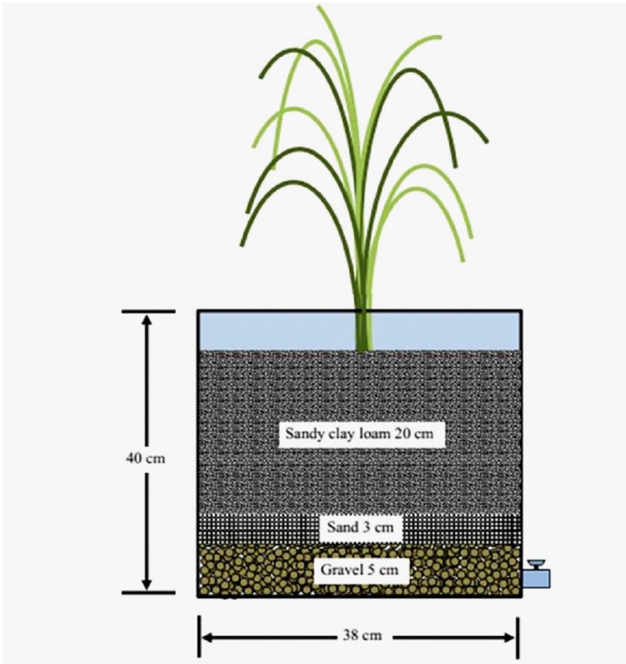

Fig. 1: Schematic diagram of a media layer in the soil filter container.

Fig. 2: Untreated wastewater discharge of fermented rice noodle factory at study field.

number of treatment cycles increased; however, vetiver grass performance was more stable than sedge. Whereas control experiment with no plant, found that low efficiency of treating wastewater (Fig. 4).

In the 1st to 8th treatment cycles, vetiver grass provided better COD removal efficiencies than sedge. Whereas COD value of sedge at 8th treatment cycle exceeded the limit of industrial effluent standard at 400 mg/L. The efficiency of COD removal in both vetiver grass and sedge was decreased following the period of treatment cycles. Meanwhile, the maximum COD value within the limit of industrial effluent standard by vetiver grass and sedge of 400.80 ± 14.07 mg/L in 8th treatment cycle and 320.63 ± 19.44 mg/L in 7th treatment cycle, respectively, were obviously different. From this result, vetiver grass was shown to be the most effective emergent plant for COD removal. This could be from vetiver grass root assisting increase in soil porosity and a loss of bending strength with low leaching of wastewater. Turnover of root mass of emergent plants creates macropores in a soil matrix allowing for greater percolation of water, thus increasing effluent/plant interactions (Sim 2003). The active zone for wastewater treatment is the root zone. This is where physicochemical and biological processes take place that are induced by the interaction of emergent plants, microbial, the soil matrix and pollutants (Stottmeister et al. 2003).

***Untreated wastewater samples*:** In UWW section, the trends of COD removal by vetiver grass and sedge were similar to the experiment in TWW sample (Fig. 5).

In the 1st to 5th treatment cycles, vetiver grass provided better COD removal efficiencies than sedge. The efficiency of COD removal in both vetiver grass and sedge was decreased following the period of treatment cycles. Meanwhile, the maximum COD value within the limit of industrial effluent standard by vetiver grass and sedge of 271.70 ± 0.04 mg/L and 373.63 ± 22.65 mg/L in 5th treatment cycle were obviously different. The high organic load (expressed in term of COD) in UWW is a big concern relative to COD removal of vetiver grass and sedge. This result indicated that high COD concentration in UWW could be inhibiting wastewater treatment process of emergent plants and microbial in the root zone. Moreover, vetiver grass and sedge are not tolerant to high COD concentration of UWW in the long period of this experiment. Nevertheless, vetiver grass was shown to be the most effective emergent plant, even at record high level of COD in UWW.

CONCLUSIONS

Treated wastewater (TWW) condition and untreated wastewater (UWW) condition of fermented rice noodle factory wastewater was used for treatment capability testing by emergent plants namely vetiver grass, *Vetiveria zizaniodes* (L.) Nash, and sedge, *Cyperus corymbosus* Rottb., in bath experiments. High level of COD in UWW can affect emergent plant growth and cause low removal efficiency. Emergent plants grown in TWW had the best growth, while emergent plants grown in UWW, high COD concentration had the worst growth. Therefore, TWW has good potential for emergent plants growth and the wastewater treatment capability. Wastewater treatment capability of emergent plants was observed that the efficiencies in both vetiver grass and sedge declined as number of treatment cy-

Fig. 3: Effect of wastewater type on emergent plants growth; A= Emergent plants were planted in UWW, B = Emergent plants were planted in TWW.

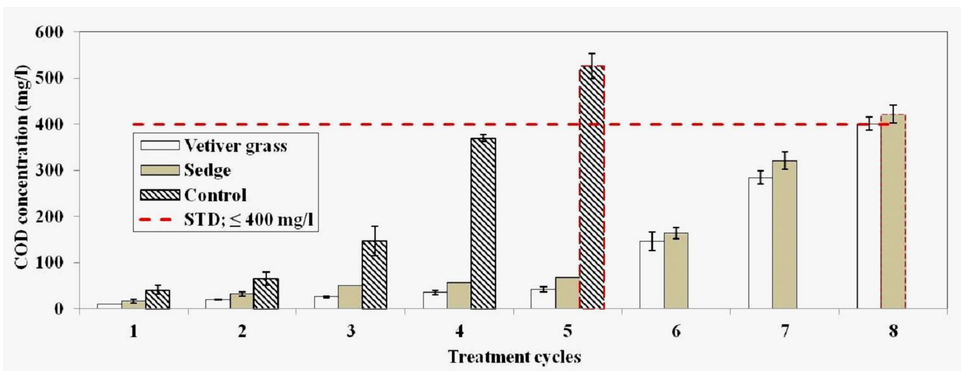

Fig. 4: COD removal (mg/L) of vetiver grass and sedge in TWW.

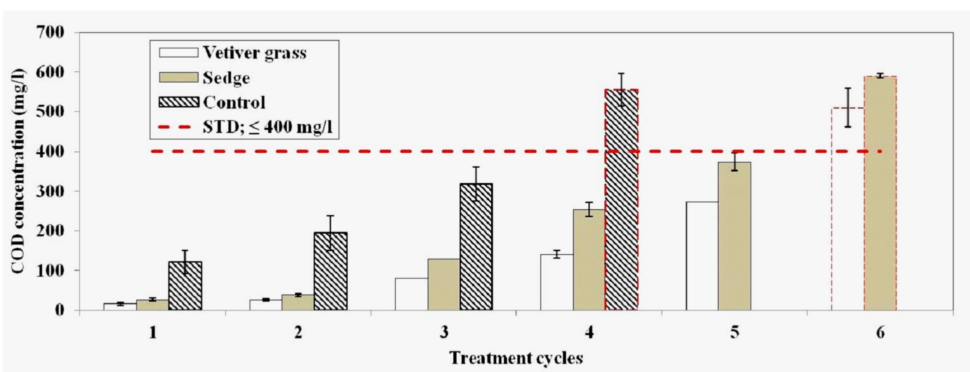

Fig. 5: COD removal of vetiver grass and sedge in UWW.

cles increased; however, vetiver grass performance was more stable than sedge. Moreover, vetiver grass was shown to be the most effective emergent plant for COD removal and also assist in increasing treatment period. This result showed that vetiver grass technology is an appropriate system for fermented rice noodle factory wastewater remediation. To achieve the water quality standard mandated by Pollution Control Department (PCD), wastewater with initial parameter of COD 988.93 ± 124.89 mg/L can be remediated up to 56 days (7 treatment cycles) using vetiver grass planted in soil filter container. In practice, concept of vetiver grass in soil filter system could be applied for other starch processing industries also.

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