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Seafood wastewater treatment in constructed wetland: Tropical case

Prapa Sohsalam [a], Andrew Joseph Englande [b], Suntud Sirianuntapiboon [a,*]

[a] Department of Environmental Technology, School of Energy Environment and Materials, King Mongkut's University of Technology Thonburi (KMUTT), Bangkok 10140, Thailand

[b] Department of Environmental Health Sciences, Tulane University School of Public Health and Tropical Medicine, 1440 Canal Street, Suite 2133, New Orleans, LA 70112-2715, USA

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Abstract

A series of investigations were conducted to evaluate the feasibility of using constructed wetlands to remove pollutants from seafood processing wastewater. Six emergent plant species; *Cyperus involucratus*, *Canna siamensis*, *Heliconia* spp., *Hymenocallis littoralis*, *Typha augustifolia* and *Thalia deabata* J. Fraser were planted in surface flow wetland. They were fed with seafood wastewater that was 50% diluted with treated seafood wastewater from an aerated lagoon. All macrophytes were found to meet satisfying treatment efficiency (standard criteria for discharged wastewater) at 5 days hydraulic retention time (HRT). While *C. involucratus*, *T. deabata* and *T. augustifolia* met acceptable treatment efficacy at 3 days HRT. Nutrient uptake rate of these species was observed in the range of 1.43–2.30 g Nitrogen/m^2 day and 0.17–0.29 g Phosphorus/m^2 day, respectively at 3 days HRT. The highest treatment performances were found at 5 days HRT. Average removal efficiencies were 91–99% for BOD_5, 52–90% for SS, 72–92% for TN and 72–77% for TP. Plant growth and nitrogen assimilation were experienced to be most satisfactory for *C. involucratus*, *T. deabata* and *T. augustifolia*. Lower HRTs affected contaminant removal efficiency for all species. *C. involucratus*, *T. deabata* and *T. augustifolia* can remove all contaminants efficiently even at the lowest hydraulic retention time (1 day).

Keywords: Constructed wetland; Seafood wastewater; Nutrient assimilation; Wastewater emergent plant; Nutrient removal

1. Introduction

Seafood processing wastewater contains highly concentrated pollutants, including suspended solids, organics and nutrients. These may deteriorate the quality of the aquatic environments into which they are discharged (Sirianuntapiboon and Nimnu, 1999). To avoid this impact, treatment of seafood processing wastewater before discharge has been proposed. A candidate method of treatment is constructed wetland. Wetlands have significant merits of low capital and operating costs compare with conventional system as activated sludge, aerated lagoon system and so on (Hammer et al., 1993; Cronk, 1996; Kadlec and Knight, 1996; Hill and Sobesy, 1998; Humenik et al., 1999; Neralla et al., 2000; Szogy et al., 2000). And the growth of non-food crops in a closed hydroponic system, using wastewater as nutrient solution, could solve in an ecologically acceptable way the wastewater problem and in the meantime produce biofuels, or other products useful for industry (Mavrogianopoulos et al., 2002). Constructed wetlands have been widely used in treating different types of contaminant found in domestic sewage, storm water, various industrial wastewaters, agricultural runoff, acid mine drainage and landfill leachate (Green and Martin, 1996; Vrhovsek et al., 1996; Higgins et al., 1993; Karathanasis and Thompson, 1995; Bernard and Lauve, 1995). Natural treatment systems have been shown to have a significant capacity for both wastewater treatment and resource recovery (Hofmann, 1996; Ciria et al., 2005; Reed et al., 1988). The wetland system was usually applied as the tertiary treatment due to the high solids

* Corresponding author. Tel.: +662 4708602; fax: +662 4708660.
E-mail address: suntud.sir@kmutt.ac.th (S. Sirianuntapiboon).

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content and organic matter concentration of the raw wastewater (Kadlec and Knight, 1996). Typical upper range of BOD_5 loading rates for design is 67.25 kg/ha d and 44.84 kg/ha d for subsurface flow wetland and surface flow wetlands, respectively (Metcalf & Eddy, 1991). This requires more hydraulic detention times and also was land. These conventional systems as facultative ponds and aerated lagoons are commonly used in the seafood processing industry (Sirianuntapiboon and Nimnu, 1999). One potential solution may be to use a constructed wetland system worked as a part of an integrated sustainable management system. In considering this treatment alternative an important issue arises as to what and how the constructed wetland can perform under heavy loading, to which available information is very limited. Another issue related to the performance of constructed wetland systems under heavy contaminant loadings is the effects of plant species. In Thailand, the most frequently used of wetland emergent plants are cattail (*Typha latifilia*), bulrush (*Scirpus lacustris*) and reed (*Phragmites australis*) (Brix, 1993) for domestic, but the other species may be more efficient under site specific conditions.

This research aimed to reduce the pretreatment unit by using the additional design as settling zone at inlet zone to reduce suspended solid before discharge wastewater into wetland system. Surface flow constructed wetland was selected due to the higher hydraulic loading rate than subsurface flow wetland (Kadlec and Knight, 1996; Metcalf & Eddy, 1991; Reed et al., 1995). A microcosm surface flow wetland, built in central Thailand (Bangkok), was tested for it capability of assimilating pretreated seafood wastewater under various loading conditions. Experiments were conducted in three phases. Each phase was controlled at a particular hydraulic retention time (HRT). The specific objectives of this study are: (i) to examine the wetland performance during operations at the three HRT (5, 3 and 1 day); and, (ii) to compare the performance of six emergent plant species for treating seafood wastewater and (iii) to apply a small wetland for seafood wastewater for saving power cost.

2. Methods

2.1. Study site

The surface flow constructed wetland (SFCW) system employed was located in King Mongkut's University of Technology Thonburi (KMUTT), Bangkok. The wetland cell was 0.6 m deep, 2.0 m long and 0.5 m wide. The empty-bed volume of the wetland cell was approximately 0.6 m^3. The inner wall of the concrete cell was painted with waterproofing paint to prevent leakage. This microcosm was filled with gravel, having a diameter of 1.34–1.55 cm. A pump transferred the influent wastewater from a storage tank to the wetland cell and the exceed flow was recirculated back to storage tank for homogeneous mixing. Upon entering the microcosm, the wastewater flowed down through the permeable brick into the treatment zone. A transparent roof covered the system to prevent rainfall interference. The wetland cell was divided into a settling zone and treatment zones. In the settling zone, an empty gap was partitioned with an acrylic plate (0.5 m wide $\times$ 0.35 m deep $\times$ 4 mm thick) on top of a 0.15 m permeable brick to allow for total suspended solids separation. This also prevented short circuiting of flow.

2.2. Experiment design

The experiment was observed the pollutants removal performance of seven plant species and three Hydraulic Retention Times (HRTs). The plant treatment had seven levels; no plant and six monocultures (*Cyperus involucratus*, *Canna siamensis*, *Heliconia* spp., *Hymenocallis littoralis*, *Typha augustifolia* and *Thalia deabata* J. Fraser). The HRT had three levels; 5 days, 3 days and 1 day. Three HRT of this study were conducted over a period of 90 days.

2.3. Wetland operations

Rhizomatous cuttings of each species from the field were collected. Each microcosm was planted with 22 cutting (approximately 20 cm in length) of each species in monocultured microcosm. The microcosms were monitored three times per week, and invasive seedlings detected were immediately removed.

Each microcosm was fed with wastewater for two three times weekly at start up step. The water level in the microcosm was kept at the constant of 10 cm higher than the level of gravel surface. Then, the systems were continuously fed at the flow rates of 79.0, 131.7 and 395.0 l/day under 5, 3 and 1 days HRT, respectively. Wastewater addition began in November 2002, at which the time the plants were well established. Prior to discharge into the wetland, raw seafood wastewater was 50% diluted with the treated wastewater from the existing three-stage facility at seafood factory including solid separation, facultative pond (with hydraulic retention time, HRT, of 14 days), and aerated lagoon (HRT of 6 h). The mixed wastewater was used as the influent of each microcosm.

2.4. Sample and data analysis

2.4.1. Water sampling

One hundred milliliters of water samples were taken twice a week from influent and outflow end of the wetland cell. Sampling was usually performed at around 10 a.m. on each sampling date. The samples were analyzed for Dissolved oxygen (DO), Oxidation Reduction Potential (ORP), both was determined in the field. Other measurements were performed from field samples which were immediately transferred to the laboratory. Suspended solids (SS), biochemical oxygen demand (BOD_5), ammonia nitrogen (AN), nitrate nitrogen (nitrate N, NO_3^-–N), Total