Biological Processes Involved in Two Wetland Plants and Their Associated Bacteria for the Treatment of Municipal Wastewaters

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Abstract

Shortage of clean water for drinking, household usage, agriculture, farming, etc, is an environmental issue all over the world. Using constructed wetlands to clean-up and recycle wastewater are becoming important, especially in developing countries. Municipal, agricultural and industrial wastewaters are the three main types of wastewaters, their characteristics are different and therefore the clean-up methods are also different.

The feasibility of using sub-surface horizontal flow constructed wetlands to treat municipal wastewater was investigated by using 10-day and 5-day hydraulic retention time (HRT) and different types of treatments (with and without Typha latifolia). Better performance in the planted treatments was obtained in both HRT treatments. Nutrients were better removed in treatments with plants (DOC 68 % and 72%; NH4-N 92 % and 95%; TKN 65 % and 62 %; PO4-P 79 % and 72%; TP 67 % and 52 % for 10-day HRT and 5-day HRT treatments). In the unplanted treatments, negative values were achieved in the removal of phosphate (P) in wastewater and the presence of plants could further polish the wastewater, with a decrease of P.

Using a hydroponic study, the root exudates released under two different nutrient conditions with T. latifolia and Vetiver zizanioides were investigated. High amounts of DOC and low molecular weight (LMW) organic acids were detected in the treatment with both T. latifolia and V. zizanioides. Oxalic and malic acids were the predominant organic acids under nutrient-deficient conditions. In nutrient-sufficient conditions, oxalic acid was detected in high concentration and other types of LMW organic acids only existed in low amounts or undetectable. It demonstrated that the release of tartaric and formic acids in plant roots is greatly affected by the nutritional status in the surrounding environment.

The interaction between phenanthrene (PHE) degradation, bacteria and LMW organic acids were studied. T. latifolia and V. zizanioides could degrade PHE efficiently with or without the inoculation of Pseudomonas frederiksbergensis (ATCC BAA-257), and the degradation was most effective with both plant species. The concentrations of PHE declined from an initial 200 mg kg⁻¹ to less than 52 mg kg⁻¹ in all treatments with plant
cultivation. At the end of the experimental period, PHE was undetectable in combined plant cultivation with bacteria. The presence of bacteria and release of root exudates in plant roots further enhanced the degradation of PHE. Large amounts of monovalent organic acids of citric and malic acids released by plant roots were subsequently used by bacteria growth. The presence of LMW organic acids promoted the degradation of PHE passively by increasing the density and activity of bacteria in the rhizosphere.

Municipal and artificial wastewaters were fed into microcosms planted with Kandelia candel and T. latifolia; and the effects of wastewaters and HRT on radical oxygen loss (ROL) were investigated. Colorimetric method using Ti$^{3+}$-citrate was used to quantify the rates of oxygen ($O_2$) loss from plant roots. The range of $O_2$ loss of K. candel was 266–496 $\mu$mol $O_2$ plant$^{-1}$ d$^{-1}$ and 425-2119 $\mu$mol $O_2$ plant$^{-1}$ d$^{-1}$ for T. latifolia under different conditions. The level of $O_2$ was higher in treatments with shorter HRT, which created a condition similar to flooding, leading to a more oxygenated rhizosphere environment. High concentrations of nutrients, especially NH$_4$-N, DOC, PO$_4$-P and TP were removed from the treatments. Removals of DOC, NH$_4$-N, NO$_3$-N and TKN were significantly correlated with the root dried weight. It showed that the increase in root biomass could increase the removal efficiencies of NH$_4$-N and TKN.

LMW organic acids were involved in the plant detoxification process, used as an nutrient extractant and proton donor. Among the eight types of LMW organic acids detected in the present study, oxalic acid was the most dominant LMW organic acids detected in Pb and Zn treatments. The release of organic acids was suppressed by Pb and Zn for T. latifolia, and only oxalic acid was detected. For V. zizanioides, tartaric, formic and citric acids under Zn condition and citric acid under Pb condition were not detected. A mild antioxidative response in T. latifolia when grown in Pb condition was detected; lipid peroxidation, superoxide dismutase (SOD), peroxidase (POD) and glutathione reductase (GR) were increased with increasing Pb concentration. The release of LMW organic acids and ROL by plant roots could detoxify the heavy metals and organic pollutants.
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