

DOCTORAL THESIS

Enhanced bioremediation of waterlogged soil contaminated with phenanthrene and pyrene using wetland plant and PAH-degrading bacteria

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**Enhanced Bioremediation of Waterlogged Soil
Contaminated with Phenanthrene and Pyrene Using
Wetland Plant and PAH-degrading Bacteria**

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**A thesis submitted in partial fulfillment of the requirements
for the degree of
Doctor of Philosophy**

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Abstract

The present study aims to investigate the interactions of PAH-degrading bacteria (*Acinetobacter* sp.) and higher plant (*Oryza sativa* L.) on enhancing bioremediation of PAH-contaminated waterlogged soil.

The growth of *Oryza sativa* was adversely affected by 200+200 mg kg⁻¹ phenanthrene (PHE) and pyrene (PYR), with significant decreases of chlorophyll content and shoot and root biomass. *Oryza sativa* was able to regulate the elevation of superoxide dismutase (SOD) activities and water-soluble protein (WSP) content to counteract the intracellular overproduction of reactive oxygen species (ROS) under PAH stress. *Acinetobacter* sp. alleviated the toxic effects caused by PAHs on rice growth, and even stimulated the growth of rice by increasing its chlorophyll content and biomass. Addition of *Oryza sativa* root exudates or extracts stimulated the growth of *Acinetobacter* sp. substantially on the mixtures of PHE and PYR in both liquid cultures and waterlogged soil, which may be beneficial to maintaining *Acinetobacter* sp. population during the remediation process.

In soil microcosms containing *Oryza sativa* and *Acinetobacter* sp., interactions between *Oryza sativa* and *Acinetobacter* sp. greatly accelerated the dissipation of PYR from waterlogged soil, when compared with microcosms containing *Oryza sativa* or *Acinetobacter* sp. alone. In addition to stimulating microbial degradation of PAHs, *Oryza sativa* would also enhance PAH dissipation

through elevating peroxidase activities in soil. Root exudates contributed to the formation of dissipation gradients of PHE and PYR along vertical directions of roots, with the highest dissipation in the rhizosphere and near rhizosphere zone. Dissolved organic carbon (DOC) was one of the major factors affecting PAHs dissipation rates of soil in rhizosphere and near rhizosphere zone. In addition to providing a favorable rhizosphere environment for PAH degradation, *Oryza sativa* roots accumulated PHE and PYR through adsorption and absorption. Using a sequential extraction method, it was found that PAHs were more easily absorbed into the interior rice roots than being adsorbed on root surface. Butanol-extractable PHE and PYR in rhizospheric soil were significantly ($p < 0.05$) correlated with their corresponding concentrations in rice roots, indicating the feasibility of using butanol-extractable PAHs for estimating availability of PAHs.

The present results indicated that there is a potential for developing a plant-assisted bioremediation system containing PAH-degrading bacteria and wetland plant to clean up PAHs-contaminated waterlogged soil.

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