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Uptake of polycyclic aromatic hydrocarbons (PAHs) in salt marsh plants *Spartina alterniflora* grown in contaminated sediments

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Abstract

Polycyclic aromatic hydrocarbon (PAH) concentrations were measured in *Spartina alterniflora* plants grown in pots of contaminated sediment, plants grown in native sediment at a marsh contaminated with up to 900 μg/g total PAHs, and from plants grown in uncontaminated control sediment. The roots and leaves of the plants were separated, cleaned, and analyzed for PAHs. PAH compounds were detected at up to 43 μg/g dry weight in the root tissue of plants grown in pots of contaminated soil. PAH compounds were detected at up to 0.2 μg/g in the leaves of plants grown in pots of contaminated soil. Concentrations less than 0.004 μg/g were detected in the leaves of plants grown at a reference site. Root concentration factor (RCF) values ranged from 0.009 to 0.97 in the potted plants, and from 0.004 to 0.31 at the contaminated marsh site. Stem concentration factor (SCF) values ranged from 0.00004 to 0.03 in the potted plants and 0.0002 to 0.04 at the contaminated marsh. No correlation was found between the RCF value and PAH compound or chemical properties such as $\log K_{OW}$. SCF values were higher for the lighter PAHs in the potted plants, but not in the plants collected from the contaminated marsh. PAH concentrations in the roots of the potted plants are strongly correlated with soil concentrations, but there is less correlation for the roots grown in natural sediments. Additional plants were grown directly in PAH-contaminated water and analyzed for alkylated PAH homologs. No difference was found in leaf PAH concentrations between plants grown in contaminated water and control plants.

Keywords: Polycyclic aromatic hydrocarbons; Plant uptake; Translocation; Contaminated sediments; Wetlands

1. Introduction

Polycyclic aromatic hydrocarbons (PAHs) are present in many coastal and salt marsh sediments (EPA, 2001). Sources include oil spills, urban runoff, and coal gasification byproducts. PAHs are organic compounds composed of two or more fused benzene rings. They are present in crude oil, and are among the most hazardous components in oil spills (Irwin et al., 1997). PAHs are also formed by incomplete combustion of organic material, including wood. Salt marshes are important habitat for many sensitive species, including amphibians, nesting birds, and juvenile fish. Some salt marsh grasses are eaten by invertebrates, grazing insects, and fish during the growing season. Most of the grasses

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die, and are degraded by microorganisms to become an organic layer on the marsh surface. This organic material is an important source of food for organisms such as snails, amphipods, and shrimp which form the base of the coastal food chain (Mitsch and Gosselink, 2000).

PAH uptake in upland plants has been measured (EPRI, 1993; Bakker et al., 2000; Wennrich et al., 2002). The amount of uptake varies significantly and appears to be a function of many factors, including plant species, initial soil concentrations and microbial population (Ryan et al., 1988; Kapustka, 2004). Several studies have demonstrated that vegetables grown in garden plots contaminated with PAHs may uptake PAHs (Samsoe-Petersen et al., 2002; Wennrich et al., 2002). Laboratory experiments of PAH uptake in plants grown in spiked soil, or directly in contaminated water, also show that uptake occurs (Maillacheruvu and Safaai, 2002; Gao and Zhu, 2004). Several mechanisms may be responsible for the transfer of organic contaminants from soil to plant tissue, including uptake in the transpiration stream, volatilization and subsequent re-deposition on leaves, and sorption from direct contact with soil particles (Ryan et al., 1988; Fryer and Collins, 2003; Wild et al., 2004). Uptake in the transpiration stream is difficult to measure, and is usually inferred by eliminating other mechanisms in the experimental design, or by comparison with controls. Atmospheric deposition has been identified as a pathway in many studies (Kipopoulou et al., 1999; Peck and Hornbuckle, 2003). In this study, PAH uptake in salt marsh plants was evaluated. *Spartina alterniflora*, a common salt marsh plant in the northeastern United States, was grown in PAH-contaminated estuarine sediment. Plants were grown in pots of contaminated sediment, and were also harvested from a PAH-contaminated marsh. Plant physiology parameters were assessed, and PAH concentrations in roots and leaves were analyzed by gas chromatograph/mass spectrometry (GC/MS).

2. Methods

2.1. Experimental design

S. alterniflora plants were sampled under five conditions: (1) native plants at a contaminated field site; (2) native plants at an uncontaminated field site; (3) transplanted plants grown in pots of contaminated sediment; (4) transplanted plants grown in pots of uncontaminated sediment; and (5) bare root plants grown in contaminated water in the absence of sediment.

The sediments from the contaminated field site differed from the control sediments in several ways; in addition to the PAHs, the contaminated sediments contain elevated levels of chromium, and are coarser grained. The organic content is similar at the two sites (10–13 g/kg).

2.2. Plant and soil collection

2.2.1. Cocheco river field site

In the summer of 2003, samples were collected in a PAH-contaminated marsh along the Cocheco river in Dover, New Hampshire. Up to 900 μg/g total PAHs were detected in the marsh sediment. Soil, root, and leaf tissue were collected, processed, and analyzed. At each sampling location a 0.25 m^2 area was delineated, and within this area the maximum stem height of each plant was measured. Plants were then clipped to 2 cm above the ground surface, the roots were excavated, and a soil sample was collected from the sediment surrounding the roots. The leaves and roots were cleaned by removing all visible soil, rinsing in water and Alconox, (a low residual detergent designed for laboratory use, consisting primarily of sodium linear alkylaryl sulfonate, phosphates and carbonates), and wiping with a cloth to remove remaining soil. The leaf and root samples were then rinsed twice in deionized water, and sealed in glass sample jars. The jars were kept frozen until analyzed.

2.2.2. Winnicut field site

A small riverine tidal marsh on the Winnicut river, in Stratham, New Hampshire was selected as a reference field site. The Winnicut is a small river with limited upstream industrial development. Samples were collected from a small tidal marsh dominated by *S. alterniflora* and *Phragmites australis*. The soil for the reference potted plants was collected from a mud embankment adjacent to the marsh. The samples were collected and cleaned as described for the Cocheco field site.

2.2.3. Potted plants in PAH-contaminated soil

S. alterniflora plants were grown outdoors in PAH-contaminated estuarine sediments collected from the Cocheco river. The sediment was placed in 1-gallon plastic pots, over a layer of gravel. Bare-root *S. alterniflora* plants, supplied by a local wetland plant nursery, were transplanted into each pot in June, 2003. The pots were placed in groups of six in plastic tubs, and covered with a PVC frame and netting to prevent contact with wildlife. Water was maintained in the tubs at a depth of about 10 cm.

The plants were harvested in early September, 2003. All of the plants from the six pots in each tub were harvested, and composited to form one sample. The aboveground biomass was clipped and weighed, then cleaned, although there was no noticeable sediment present on the leaves. The roots were cleaned as described for the Cocheco samples.