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Distribution patterns of polycyclic aromatic hydrocarbons (PAHs) in the sediments and fish at Mai Po Marshes Nature Reserve, Hong Kong

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abstract

Sediment samples were collected monthly from eight shrimp shallow ponds (local name gei wais) from July 2003 to January 2004, and from mangrove swamps and inter-tidal mudflats in July and November 2003, respectively. Fish samples (tilapia) were also collected. Polycyclic aromatic hydrocarbons (PAHs) were analyzed by gas chromatography and mass spectrometry (GC/MS). The results indicated that under wet season wet deposition and suspended particulates brought in by nearby rivers, such as the Peal River, served as an important source of PAHs entering Mai Po Marshes. Total organic matter in the sediments showed significant correlations ($p<0.01$) with PAHs in the sediments, mainly due to the mechanism that organic matter such as humic substances increased PAH persistence by binding and occluding PAHs. Except for naphthalene, biota-sediment accumulation factors (BSAF) of the PAHs in tilapia were below 1.7, which may be caused by biotransformation and the lower uptake in fish. In addition, aqueous route dominated accumulation of non-biodegradable PAHs in tilapia because higher levels were detected in larger fish than in smaller ones. A general trend was observed that BSAFs declined with the increase of K_{ow} values, which suggested that bioavailability of low K_{ow} isomers was high due to higher gill transfer efficiencies (aqueous uptake) in fish but enhanced biotransformation and decreased gut assimilation (dietary uptake) resulted in decreased accumulation of more hydrophobic PAHs (high K_{ow}). Lastly, viscera appeared to be a promising tissue for biomonitoring, as it contained much higher concentrations than the muscle (3.5 magnitudes), and the levels in the muscle were significantly correlated with those in the viscera ($r^2 = 0.938$, $p<0.0001$).

1. Introduction

Mai Po Marshes Nature Reserve, locating at the northwestern corner of the New Territories of Hong Kong, is the largest remaining coastal wetland in Hong Kong (381 ha). Because of its biodiversity and productivity, it is a valuable wildlife habitat and wintering ground for migrating birds (Young, 2004). An area of 1500 ha of wetland around Mai Po and Inner Deep Bay Wetland was listed as a Wetland of International Importance (Ramsar Site) under the Ramsar Convention in 1995. Mai Po Marshes is in the vicinity of the Inner Deep Bay, which is located on the eastern side of the Pearl River Estuary,

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while the area is fed by Shenzhen River at the north and also Kam Tin River at the south of the shrimp ponds (gei wais) (Fig. 1). Due to the rapid industrial and commercial developments surrounding this area, Mai Po is facing increasing threats and pressures from both landward and seaward sides (Young and Melville, 1993; Young, 2004).

Polycyclic aromatic hydrocarbons (PAHs) originate mainly from incomplete combustion of fossil fuels and organic materials as well as petroleum. Due to their hydrophobic nature, PAHs in the aquatic environment rapidly bind with particles and deposited sediments become their primary reservoirs (Latimer and Zheng, 2003). PAHs may pose toxicity in fish and birds (Payne et al., 2003; Albers, 2003), by interfering with cellular membrane function and the associated enzyme systems (Neff, 1985), and metabolites of PAHs may bind to proteins and DNA which causes biochemical disruptions and cell damage in animals (Varanasi et al., 1989; Eisler, 2000). In addition, the carcinogenicity of PAHs can be increased by exposure to ultraviolet radiation, and 11 out of the 16 PAHs listed by the US Environmental Protection Agency as priority pollutants were photomutagenic (Yan et al., 2004). It was suggested that levels of PAHs commonly found in many aquatic environments are an important risk factor for various health aspects of fish (Payne et al., 2003), such as adverse histopathologic and immunological responses in tilapia (Hart et al., 1998; Holladay et al., 1998). At Mai Po Marshes, PAHs were detected in the sediments across the wetland (Lam and Lam, 2001; Wong et al., 2005). PAHs found in the mangrove sediments appeared to originate from petrogenic (oil spill and leakage from boats and ships) and pyrolytic (discharge from municipal and industrial wastewater and runoff) inputs (Tam et al., 2001; Zheng et al., 2002). This indicated that local sources rather than long-range air transportation were responsible for PAH contamination of Mai Po Marshes.

However, in-depth seasonal dynamics of PAHs in the sediments associated with the aquatic environmental changes have not been investigated at Mai Po Marshes, though distinct spatial distribution and seasonal change patterns of the biogeochemical processes within Mai Po were reported (Liang and Wong, 2003, 2004). Further, although levels of PAHs in biota were documented previously (Lam and Lam, 2001; Wong et al., 2005), bioavailability of PAHs in fish from the sediments, especially through the examination of biota-sediment accumulation factors (BSAF), is not available. Therefore, the main aim of the present study is to identify major environmental factors in mediating PAH levels in the sediments as well as bioaccumulation patterns in fish at Mai Po Marshes. The information will greatly enhance our understanding of the environmental behavior of PAHs at Mai Po Marshes, which is essential for the monitoring and management.

2. Materials and methods

During July 2003–January 2004, sediment samples (top 10 cm of the surface sediments) were collected monthly (using a

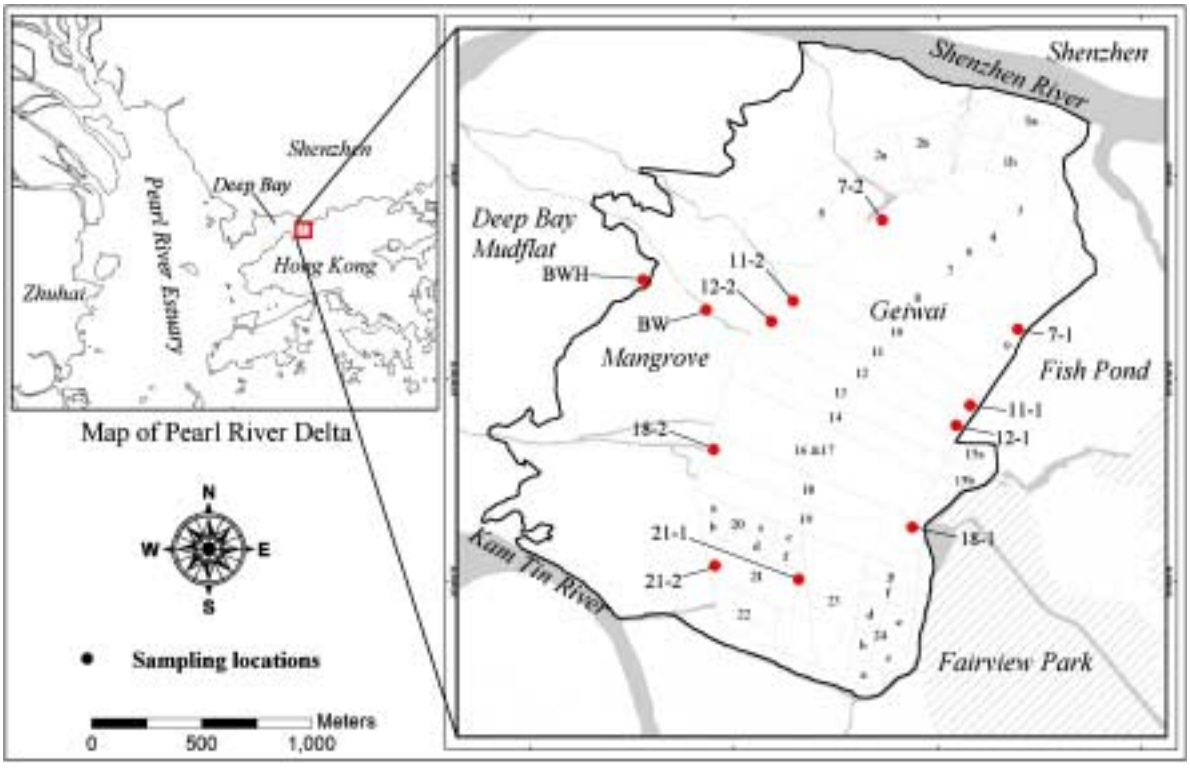

Fig. 1 – Sampling sites in Mai Po Marshes Nature Reserver.