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Polycyclic aromatic hydrocarbons (PAHs) in surface sediment and oysters (*Crassostrea rhizophorae*) from mangrove of Guadeloupe: Levels, bioavailability, and effects

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ABSTRACT

Surface sediment and oysters (*Crassostrea rhizophorae*) from the coastlines of Guadeloupe were analysed for polycyclic aromatic hydrocarbons (PAHs) using GC/MS. Biomarkers of oxidative stress were used to assess the response of these oysters to hydrocarbons exposure. The total concentration of PAHs in the sediment ranged from 49 to 1065 ng/g dw, while concentrations in oyster ranged from 66 to 961 ng/g dw. Molecular indices based on isomeric PAHs ratios characterize the pollution sources and show that most of the contaminations in sediment originate from pyrolytic inputs. Bioaccumulation factors (BAFs) have been related to isomeric ratio calculated for oysters in order to refine PAHs sources. The variations of BAFs observed in the different compounds resulted from different uptake pathways in the mangrove oysters according to the type of inputs. Response of biomarkers showed inhibition of catalase and an increase of lipid peroxidation at the station where PAHs concentrations were the highest. Taken together, data obtained point to the relevance of considering environmental conditions as factors influencing biomarker responses in environmental monitoring programs. These data also indicate the need for regular environmental follow-up studies in Guadeloupe.

1. Introduction

Mangrove is an ecosystem that develops both in estuaries and along the coastlines in tropical and subtropical regions. Owing to its intrinsic features (abundance of detritus, high primary productivity, anoxic/reduced conditions, high levels of organic matter and fineness of sediments), mangrove is a preferential trap for contaminants such as polycyclic aromatic hydrocarbons (PAHs) from anthropogenic inputs (Bernard et al., 1996). As elevated concentrations of PAHs have been recorded in estuarine and mangrove ecosystems (Tam et al., 2001; Páez-Osuna et al., 2002; Cavalcante et al., 2009; Domínguez et al., 2010), monitoring these exceptional ecosystems is a priority.

PAHs are ubiquitous persistent environmental contaminants, present in complex mixtures and mainly introduced into the environment *via* natural processes and/or anthropogenic activities (Neff, 1979; McElory et al., 1989). Due to their toxic, mutagenic and carcinogenic characteristics, a number of them have been identified as priority pollutants by the United States Environmental Protection Agency (USEPA) (IARC, 2007). Thus their sources and distributions in the environment have to be particularly monitored. Previous studies have shown that each source is characterized by a specific molecular pattern (Neff, 1979) and that the simultaneous consideration of several molecular indices is necessary to assess the origin of the compounds (Budzinski et al., 1997; Yunker et al., 2002; Oros and Ross, 2005). In addition, these different origins as well as other parameters such as physicochemical features of the compound, characteristics of the sediment and the organisms considered (Baumard et al., 1999a) are likely to influence the bioavailability and distribution of PAHs in the sediment. Then, in order to assess their fate, the bioavailability of hydrocarbons absorbed by the sediment can be estimated by calculating bioaccumulation factors (BAF) (Baumard et al., 1998a) and related to their origin.

In tropical coastal environments, mangrove oysters *Crassostrea rhizophorae* have been regarded as useful sentinels for chemical pollution studies in mangrove environment (Valdez Domingos et al., 2007). Recently, the simultaneous use of integrated measurement of contaminant levels and biomarker responses in bivalves has been extensively used in pollution monitoring and impact assessment in marine environments. Even if measurement of the induction of cytochrome P450 and its components is a fairly well established method for detection of exposure to organic pollutants like PAHs (Livingstone et al., 1995), induction of antioxidant enzymes in bivalve

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molluscs in response to pollutant mediated oxyradical production has also been often proposed as a possible biomarker of organic pollution in aquatic environments (Niyogi et al., 2001; Van der Oost et al., 2003). When these antioxidant enzymes are unable to cope with the production of oxyradicals, an oxidative stress occurs (Livingstone et al., 1990) that is responsible for protein degradation, lipid peroxidation (LPO) and DNA damage (Marnett, 1999). LPO is considered a very important consequence of oxidative stress by which tissue damage occurs, leading to impaired cellular function and alteration in physicochemical properties of cell membranes (Barata et al., 2005; Zanette et al., 2006). Catalase (CAT) which breaks the hydrogen peroxide (H_2O_2) down to water (H_2O) and oxygen (O_2) is one the enzymes involved in the antioxidant defense systems. LPO and CAT are widely used as biomarkers of exposure to contaminants, notably for PAHs.

In Guadeloupe, a French West Indies (FWI) island, mangrove spreads over 3000 ha. The importance of this hot spot of biodiversity is such as a part of this island, is a natural UNESCO Biosphere Reserve. Nevertheless, during the past decades, industrialisation and urbanisation have proceeded rapidly in Guadeloupe exposing coastal ecosystems notably to PAHs contamination. In the Caribbean area, especially in the FWI islands, very few studies are carried out on PAHs contamination and their effects on mangrove ecosystems.

The present paper is a first overview dealing with the PAHs contamination of surface sediments and oysters from the main sites sheltering mangrove ecosystems of Guadeloupe, including the use of biochemical biomarkers.

Surface sediment and oyster (*Crassostrea rhizophorae*) concentrations associated with biomarkers responses (CAT and LPO) are assessed in order to evaluate the condition of natural populations of these benthic invertebrates living in the mangrove and by extension, to track potential effects on human health, if oysters are consumed. Moreover, contamination patterns and diagnostic ratios are analysed for the identification of possible sources of the contamination.

2. Materials and methods

2.1. Study area and sampling sites

Guadeloupe is an archipelago located in the Lesser Antilles (16°15N, 61°35W). The wet tropical climate of the island is characterized by a dry season (December to April) and a rainy season (July to November). In the Lesser Antilles, the surface circulation is submitted to the regime flows of Guyanes and North-Equatorial (Pujos et al., 1992). However, this circulation is very complex in Guadeloupe, because of the indented morphology of the island and the presence of two bays: the Grand Cul-de-Sac Marin and the Petit Cul-de-Sac Marin (Assor, 1988). Due to an area of 1708 km^2 and a population of 458,000 inhabitants, most of the activities of the island are concentrated on the coastlines. The economy is mainly based on tourism and agriculture (banana and sugar cane). The island is devoid of fossil energy then hydrocarbons are imported and stocked in the industrial zone before their distribution.

The study was carried out on the coastlines of Guadeloupe (Fig. 1). A total of ten sampling stations were selected according to the location of the main streams

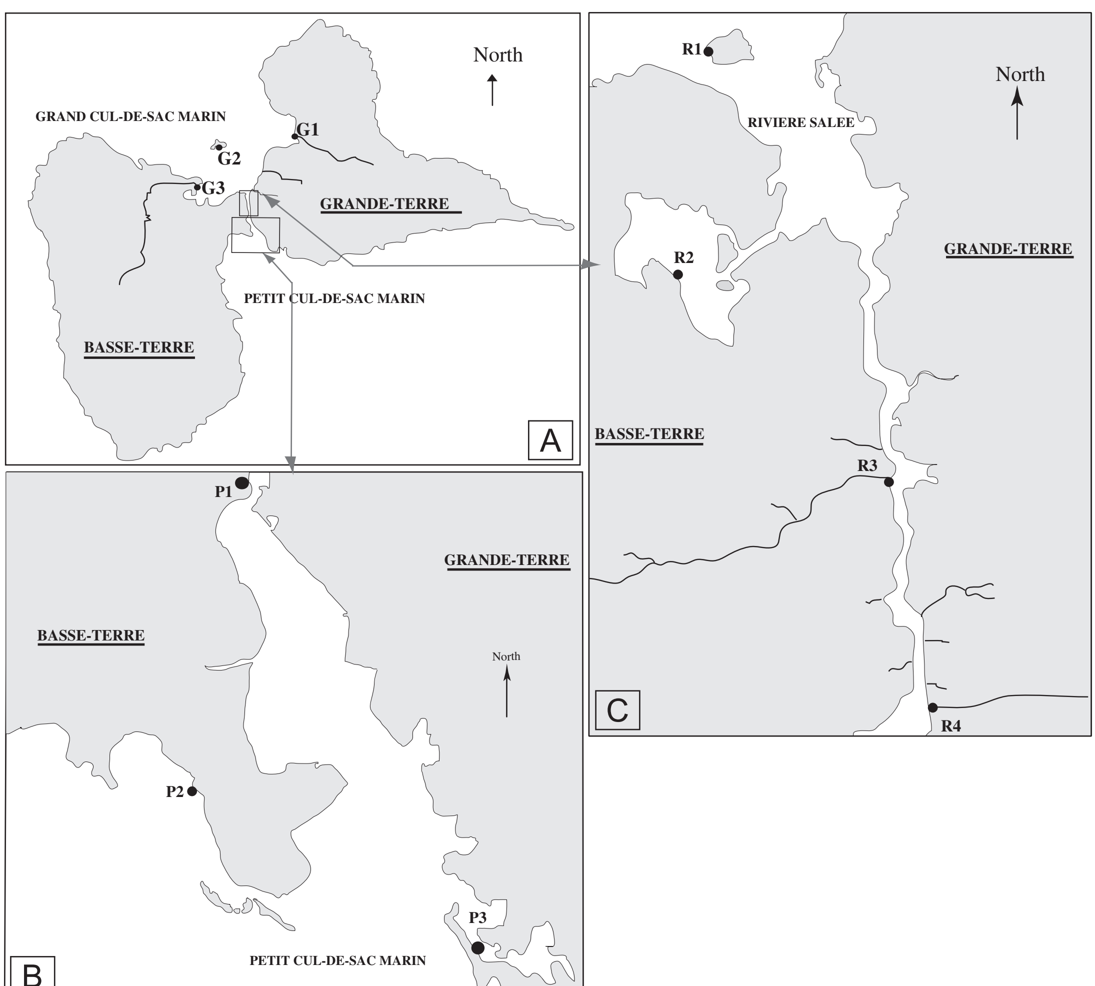

Fig. 1. Map of Guadeloupe Island (**A**) showing location of sampling stations in (**A**) the Grand Cul-de-Sac Marin (G1, G2, G3), (**B**) the Petit Cul-de-Sac Marin (P1, P2, P3) and (**C**) the Rivière Salée (R1, R2, R3, R4).