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Urban rivers as conveyors of hydrocarbons to sediments of estuarine areas: Source characterization, flow rates and mass accumulation

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HIGHLIGHTS

- 6 river and 2 channels deliver 3 t hydrocarbons year^{-1} into Guanabara Bay.
- PCA/MLR allowed identification and quantification of all hydrocarbon sources.
- Annual mass sedimentation of PAH in the receiving area was estimated as 10 t.

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ABSTRACT

Aliphatic (n-C_{12}–n-C_{40}, unresolved complex mixture, resolved peaks) and aromatic hydrocarbons (46 PAH) were investigated in suspended particulate matter (SPM) sampled over eleven months in six of the major rivers and two channels of the Guanabara Bay Basin. PAH flow rates of the most contaminated rivers, the contribution to the PAH sediment load of the receiving bay, and the main sources of hydrocarbons were determined. PAH (38) ranged from 28 ng L^{-1} to 11,514 ng L^{-1}. Hydrocarbon typology and statistical evaluation demonstrated contribution of distinct sources in different regions and allowed quantification of these contributions. Total flow rate for the five major rivers amounts to 3 t year^{-1} and responds for 30% of the total PAH annual input into the northern area of the Guanabara Bay. For the first time PAH mass deposited in the bay sediments has been estimated and shall serve as base for decision making and source abatement.

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1. Introduction

The fast industrial development, principally in the second half of the 20th century, the unprecedented population growth, soil occupation, and urbanization are the major causes of the increasing release of contaminants in the environment.

Among the contaminants that pose high risk to the health of humans and animals are the polycyclic aromatic hydrocarbons (PAH) because of the potential action as carcinogenic and mutagenic substances (USEPA, 1998) as well as endocrine disrupters (Clemons et al., 1998). Hydrocarbons are widely distributed in all the environmental compartments and emission of those derived from anthropogenic activities has been increasing due to the growth of the vehicular fleet and mobility based on internal combustion motors in general. This is especially true in developing nations, in addition to the increasing importance of oil and gas exploration in these areas.

Among the major routes of PAH introduction into the marine environment are the oil spills (Gabardo et al., 2001; Neff et al., 2003) the atmospheric deposition of residues from biomass and fuel incomplete combustion (Lammel et al., 2013; Zhang and Tao, 2009) in addition to urban drainage (Hwang and Foster, 2006).

Because of hydrophobicity PAH easily associated to organic particulate matter present in aqueous media and are then transferred to sediments causing contamination of vast areas of a hydrographic basin. Recently, some studies report estimates for the export of PAH from different hydrographic basins in Asia (Guo et al., 2011; Zhang et al., 2012), however estimates based on frequent and continuous observations are rare.

A number of reports on hydrocarbon contamination in Brazilian coastal regions can be found that also address the issue of source assignment. Due to the high risk of contamination from activities related to the

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oil industry and to the intense anthropic occupation of the hydrographic basin, Guanabara Bay in Rio de Janeiro has been subject of studies targeting the determination of PAH in sediments (Mauad et al., 2013; Silva et al., 2007a; Wagener et al., 2012). However there are no estimates of inputs derived from the network of rivers crisscrossing the bay's hydrographic basin housing the highest population density among the coastal systems in Brazil.

The present work aimed to understand the relevance and the typology of the riverine hydrocarbon input derived from densely populated and industrialized areas taking as a model the Guanabara Bay hydrographic basin in Rio de Janeiro.

2. Study area

Guanabara Bay actual area is of 348 km^2, with an average depth of 6 m reaching 30 m in the central channel (Godoy et al., 1998; JICA, 1994). The hydrographic basin houses about 10 million inhabitants (IBGE, 2010) and 11,000 industrial installations. At the bay rim there are several potential hydrocarbon sources such as two refineries, two major harbors, 16 oil terminals and 32 ship yards (PDRH-BG, 2003).

The bay receives inputs from an extensive drainage network providing on the average 350 m^3 s^{-1} of fresh water. Most of the fresh water input occurs in the inner areas in the NE bay region (PDRH-BG, 2003). Among the 45 rivers and channels flowing into the bay the Caceribu (CB), Guapimirim (GM), Iguaçu (IG), São João de Meriti (SJM), and Irajá (IR) rivers and the Cunha (CC) and Mangue (CM) channels provide 70% of the fresh water discharge into the bay (Rocha Filho, 2000).

The NW region is the most important source of sediment load and the water input is very variable with peak flow rates during the summer (Amador, 1997). Except for the Guapimirim River, most rivers of higher flow rates are heavily polluted.

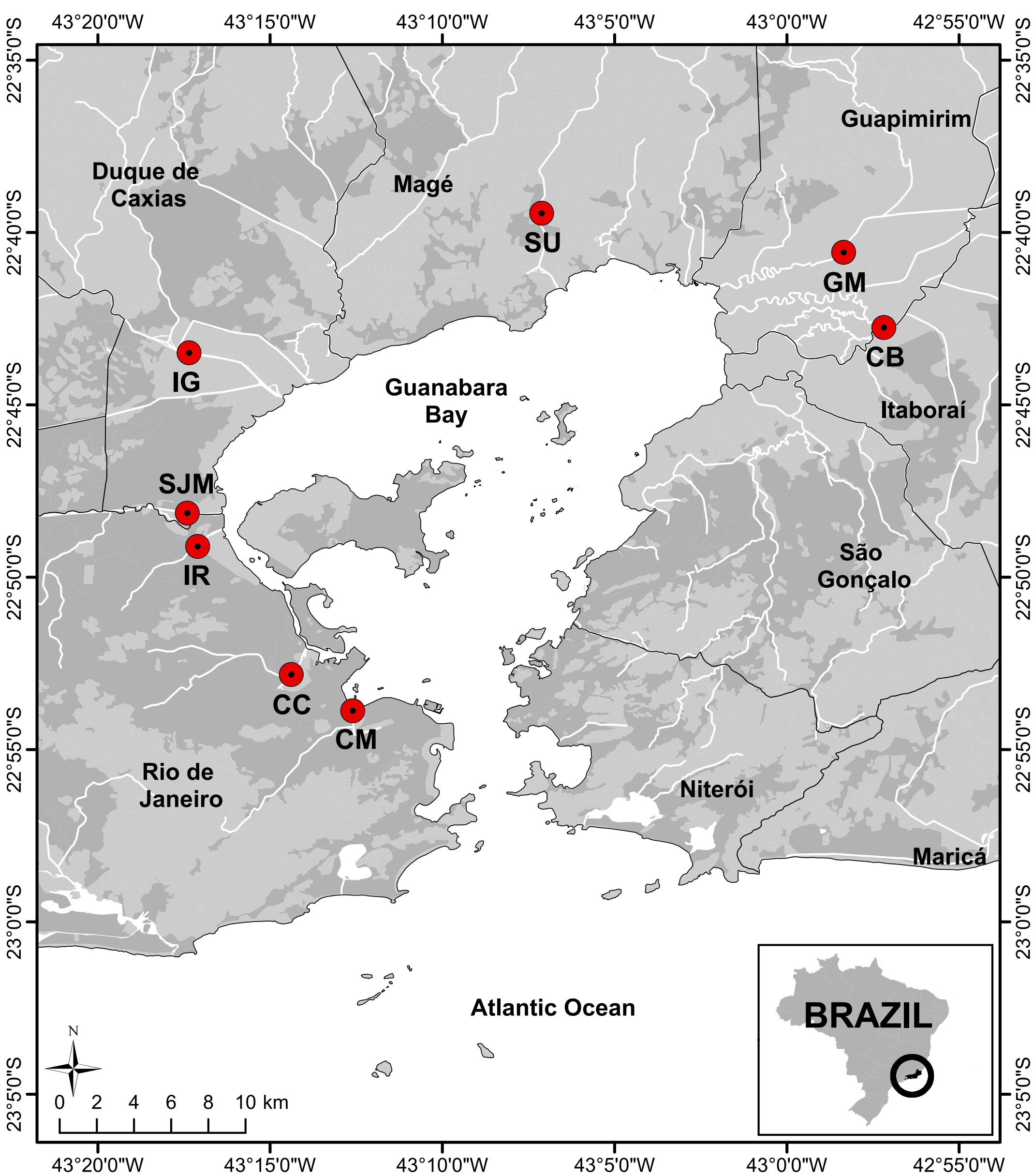

Fig. 1. Map of Guanabara Bay highlighting the sampling stations: Caceribu River (CB) (22° 42′ 45.5″ S; 42° 57′ 10.8″ W), Guapimirim River (GM) (22° 40′ 34.0″ S; 42° 58′ 20.8″ W), Suruí River (SU) (22° 39′ 25.7″ S; 43° 07′ 07.0″ W), Iguaçu River (IG) (22° 43′ 28.6″ S; 43° 17′ 20.6″), São João de Meriti River (SJM) (22° 48′ 07.8″ S; 43° 17′ 24.4″ W), Irajá River (IR) (22° 49′ 06.2″ S; 43° 17′ 06.3″ W), Cunha Channel (CC) (22° 50′ 46.8″ S; 43° 14′ 28.8″ W) and Mangue Channel (CM) (22° 53′ 52.5″ S; 43° 12′ 35.6″ W).

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