Marine Pollution Bulletin 109 (2016) 435–445

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Ecological risk evaluation of sediment metals in a tropical Euthrophic Bay, Guanabara Bay, Southeast Atlantic

Ilene Matanó Abreu [a,d], Renato Campello Cordeiro [a], Abílio Soares-Gomes [b,*], Denis Moledo S. Abessa [c], Luciane Alves Maranho [c], Ricardo Erthal Santelli [e]

[a] Departamento de Geoquímica, Universidade Federal Fluminense, Niterói, RJ 24020-150, Brazil
[b] Departamento de Biologia Marinha, Universidade Federal Fluminense, Niterói, RJ 24020-150, Brazil
[c] Universidade Estadual Paulista Júlio de Mesquita Filho, Campus Experimental do Litoral Paulista - CLP, São Vicente, SP 11330-900, Brazil
[d] Departamento de Oceanografia, Universidade Federal da Bahia, Salvador, BA 40170-110, Brazil
[e] Departamento de Química Analítica, Universidade Federal do Rio de Janeiro, Ilha do Fundão, RJ 21941-909, Brazil

ARTICLE INFO

Article history:
Received 22 January 2016
Received in revised form 11 May 2016
Accepted 14 May 2016
Available online 11 June 2016

Keywords:
Geo-accumulation index
Enrichment factor
Heavy metals
Southeast Atlantic
Brazil

ABSTRACT

Surface sediments were collected from Guanabara Bay, at 14 stations distributed in five sectors, over three sampling campaigns. Analyses of metals, grain size fractions and total organic carbon analyses were performed. The geo-accumulation index and the enrichment factor were estimated to assess contamination status based on background values. Additionally, the sediment quality guidelines were applied to evaluate the adverse biological effects. Results show that there was no seasonal variation in sediment quality based on any methodology, and all methods utilized showed that NW sector and HRJ sector were the worst affected and that the NE sector had the best conditions. The sediments of GB are polluted mainly by Cr, Pb and Zn. According to ΣSEM/AVS, these metals are not available to the biota, although toxicity tests dispute this. Among the various methods employed, those using background values for the area seem to best reflect the local historical contamination.

1. Introduction

Sediments act as a sink for pollutants of diverse sources that can be re-released to overlying water via natural or anthropogenic processes, potentially having adverse outcomes for ecosystems (Adams et al., 1992; Essien et al., 2009). Geochemical study of sediments is crucial to obtain information regarding the potential risk pollutants represent to aquatic organisms (Maia et al., 2006), becoming a primary issue for the management of aquatic ecosystems.

Trace metals are dangerous pollutants in the environment due to their potential toxicity, persistence and bioaccumulation. Metals generated by anthropogenic activities cause more environmental pollution than naturally-occurring ones because they are discharged in greater amounts into the environment. Trace metal contamination has become a serious problem in marine ecosystems throughout the world. Such metals enter ecosystems through industrial, agricultural and urban effluents (Feng et al., 2012). The main factors affecting the concentrations of metals in sediments include, grain size; the presence of oxides and hydroxides of Fe, Al and Mn; the presence of organic matter, with which they can form organometallic compounds; and co-occurrence of clay minerals, which form clay-pollutant complexes that can be remobilized by erosion events (Maia et al., 2006).

In this context, Guanabara Bay (GB), located in the littoral region of Rio de Janeiro, Brazil, is a heavily polluted environment that represents one of the most important embayments of the Brazilian coastline, with a high ecological value and socio-economic relevance. Many stakeholders share the bay's environment with fishing, tourism, industries, harbors, wharfs, marinas, domestic and industrial landfills, mariculture, oil refineries, shantytowns and sewage outfalls all occurring (Maranho et al., 2009). Burgeoning urban occupation and industrial development have increased the quantity of contaminants being discharged into GB and its tributaries, which are responsible for 85% of contaminant input into the bay (Kfouri et al., 2005). Thus, large amounts of solid waste, organic matter, trace metals, organic pollutants and hydrocarbons are introduced into the bay and may potentially accumulate in the sediments.

GB has been extensively studied regarding its environmental quality (Carreira et al., 2002; Xavier de Brito et al., 2002; Azevedo et al., 2004; Baptista-Neto et al., 2006; Silva et al., 2007; Vieira et al., 2007; Mendes et al., 2007; Maranho et al., 2009, 2010; Soares-Gomes et al., 2010; Soares-Gomes et al., 2016), but a multi- and inter-disciplinary approach is still lacking. Considering the ecological and socioeconomic importance of the bay, our study is the first attempt to make an evaluation risk analysis of the bay, searching for an integrative diagnosis of its sediment quality by applying several indexes of sediment quality.

* Corresponding author at: Departamento de Biologia Marina, Universidade Federal Fluminense, P.O. Box 100.644, Niterói, RJ, 24001-970, Brazil.
E-mail address: abiliosg@id.uff.br (A. Soares-Gomes).

http://dx.doi.org/10.1016/j.marpolbul.2016.05.030
0025-326X/

2. Study area

GB is a 384 km^2 eutrophic coastal bay located in Southeast Brazil. The rivers and channels that discharge into the bay cross greatly urbanized areas, receiving all kinds of effluents (Faria and Sanchez, 2001; Fonseca et al., 2014; Borges et al., 2014). Its drainage basin receives polluted effluents from about 6000 industries, 2 airports, 2 commercial harbors and 15 oil terminals located in its vicinity (Kjerfve et al., 1997). Furthermore, there are inputs of untreated domestic sewage from diffuse sources. Mostly, those inputs come from the rivers of the vast watershed (about 45 rivers and innumerable streams), six of which are responsible for 85% of the total runoff (Kjerfve et al., 2001). At river influx points, internal estuaries are formed and deltas are present, which are occupied by mangrove ecosystems at the mouths of the main rivers, mainly in the northeast portion of the bay (Silva et al., 2015). Trace metals, petroleum hydrocarbons, pesticides and other toxic chemical compounds enter the bay daily, especially at its inner area, accumulating in the sediments (Xavier de Brito et al., 2002; Ventura et al., 2002; Baptista-Neto et al., 2006; Silva et al., 2007).

The water quality of the bay exhibits considerable variability, both spatially and temporally, governed by hydrology, pollutant hotspots and rainfall (Kjerfve et al., 1997). Tides and winds control circulation, allowing water inflow from the ocean through the lower water layers. According to Kjerfve et al. (2001), the worst water quality is indicated by average faecal coliform counts higher than 1000 mL^{-1} and by the average chlorophyll concentration exceeding 130 μg L^{-1} in the inner bay, the most critical zone, in response to high nutrient loading. Dissolved oxygen concentration reaches 300% of saturation in the daytime due to phytoplankton blooms, but can drop below 1 mL L^{-1} in the lower water layers (Wagener et al., 1988, 1990). Concentrations range from anoxia to 7.26 mL L^{-1} for the more restricted water circulation in the inner bay area (Paranhos et al., 2001; Pereira Neto et al., 2004).

The sedimentation rate in GB has increased over the last 50 yrs from 0.19 cm y^{-1} to 0.86–2.20 cm y^{-1} (Lima, 1996; Godoy et al., 1998), and the flux of organic matter in the last 100 yrs changed from 4.2 mol C m^{-2} y^{-1} to 41.7 mol C m^{-2} y^{-1} for some areas of GB (Carreira et al., 2002). Those increments in particle settling have promoted an increase in the organic loads of GB's sediments, favoring anoxic conditions and accumulation of pollutants.

Sediments are not evenly distributed, with mud predominating at the inner bay areas and fine sand near the mouth (Baptista-Neto et al., 2006). Soft-bottom macrobenthos studies have revealed three main sectors in GB: inner, intermediary and outer. Within those sectors, an increasing gradient of biodiversity is observed, ranging from the azoic and impoverished inner sector to a well-structured community in terms of species composition and abundance in the outer sector (Soares-Gomes et al., 2012; Santi et al., 2006; Santi and Tavares, 2009; Mendes et al., 2007).

3. Material and methods

3.1. Sampling design

For this work, GB was compartmentalized according to the main sources of contamination, resulting in five sectors. Sector 1 is located in the northwestern zone of GB, between Governor's Island and the city of Duque de Caxias (Fig. 1), and receives a contaminant load primarily from industrial and urban loads sources. Sector 2 is a transition zone between the northwestern and northeastern zones, which shows the widest variability. Sector 3, located in the northeastern zone, is semi-enclosed and exhibits better environmental conditions due to the preservation of mangrove swamps and possesses lower heavy metal concentrations. Sector 4 is located in Jurujuba Sound, Niterói, and is considered one of the most polluted sites (Baptista-Neto et al., 2000;

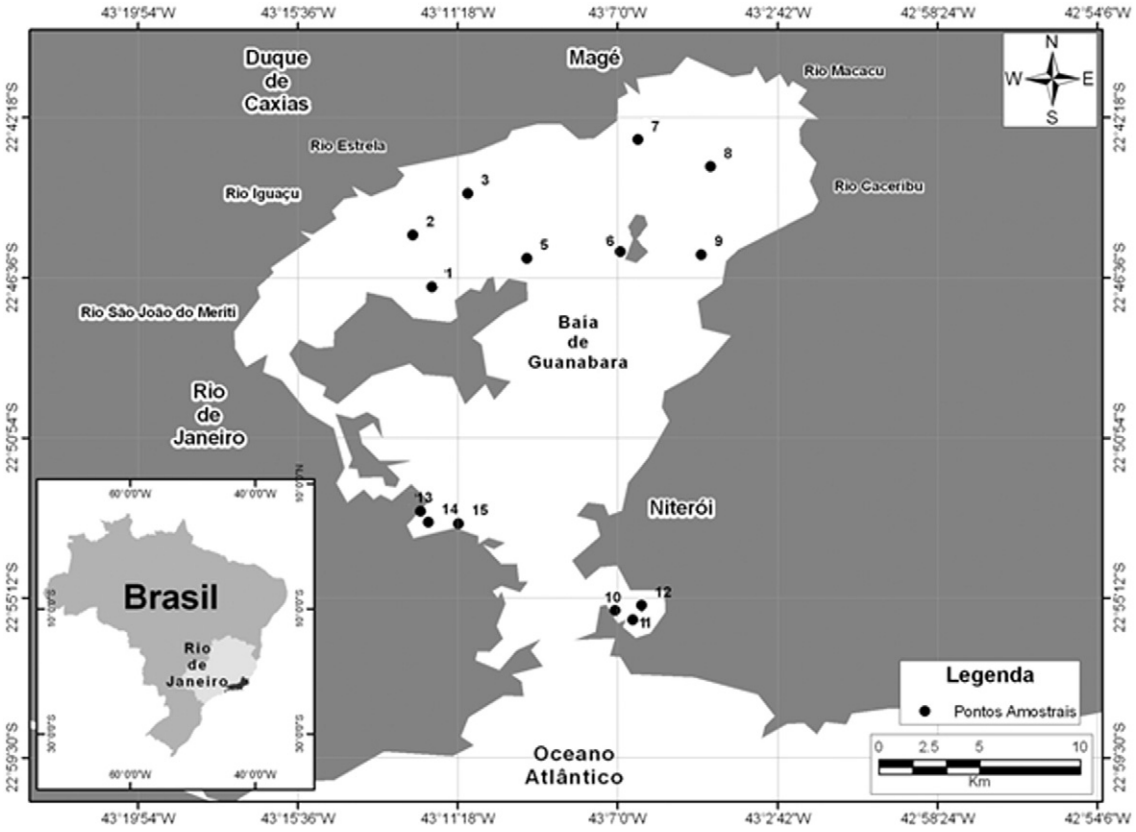

Fig. 1. Location map of the study area and sampling sites (Sector 1: 1, 2 and 3; Sector 2: 5 and 6; Sector 3: 7, 8 and 9; Sector 4: 10, 11 and 12; Sector 5: 13, 14 and 15).