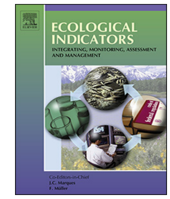
Ecological Indicators 90 (2018) 513–518

Contents lists available at ScienceDirect

Ecological Indicators

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



Original Articles

Chemical and biological indicators of sewage river input to an urban tropical estuary (Guanabara Bay, Brazil)

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ARTICLE INFO

Keywords:
Guanabara Bay
River
Sewage
Contamination
Coprostanol
E. coli

ABSTRACT

Spatial and temporal variations in raw sewage input via river discharge to a tropical bay (Guanabara Bay, Rio de Janeiro, Brazil) were characterized by considering chemical (sterols, $\delta^{13}C$) and biological (*E. coli*) indicators in suspended particles collected during three periods in eight representative rivers that contribute to the bay. Coprostanol concentrations ranged from 0.03 to 206 μg L^{-1}, averaging 21.9 ± 43.4 μg L^{-1}, whereas thermotolerant coliforms counts ranged between 0.4×10^3 and 1.1×10^{12} MPN/100 mL. A close relationship between the most contaminated rivers and human density occupation was determined, revealing the extreme lack of basic sanitation networks in the largest metropolitan region on the coast of Brazil. Coprostanol concentrations of 0.060 μg L^{-1} correspond to the limit established in the national legislation for primary contact water according to microbiological standards (thermotolerant coliforms). Therefore, this criterion based on coprostanol can be used as an additional tool to monitor the quality of the water used for recreation in the region.

1. Introduction

A significant fraction of the world's population lives in coastal zones and depends, directly or indirectly, on environmental services provided by coastal ecosystems. The balance between organic matter production and cycling in aquatic environments is important, among other aspects, in ensuring the ecological balance of these ecosystems, which, in turn, will have significant direct and indirect implications on the Earth's climate (Cai, 2011; Canuel et al., 2012). Thus, there is a growing interest in identifying the role of ecosystems along the river/estuary/coastal-ocean continuum in the global carbon cycle, in a scenario of climate change and anthropogenic impacts (Bauer et al., 2013).

Significant health threat vectors in coastal aquatic environments are the organic matter and contaminant loads due to the release of domestic effluents (e.g., Eganhouse and Sherblom, 2001). The contribution of fecal matter to aquatic environments can be evaluated using molecular indicators (Bianchi and Canuel, 2011). In this approach, coprostanol and other sterols, directly or indirectly linked to the digestive system of warm-blooded animals (i.e. cholesterol, ethylcoprostanol, sitosterol and epicoprostanol, among others) are used to quantify contamination by domestic and manure effluents and, through diagnostic reasons between selected compounds, for source pollution tracing (e.g., Martins et al., 2010; Matić Bujagić et al., 2016; Rada et al., 2016). The advantages in considering fecal sterols are the specificity of these groups of compounds in relation to the fecal material supply, as well as their stability in the environment, particularly under anaerobic conditions (Takada and Eganhouse, 1998). On the other hand, coliform bacteria and streptococci are widely used as biological indicators of fecal contamination due to simplicity and low costs in their determination. These indicators are, in fact, the basis of environmental legislation in several countries regarding the classification of natural waters for recreational use, despite controversies over the efficiency of these organisms in indicating risks to human health by direct contact with contaminated water (Isobe et al., 2004; Noblet et al., 2004).

Guanabara Bay, in SE Brazil, represents a model of a coastal system chronically impacted by anthropic action. Among other environmental changes, a rapid eutrophication process is observed in this bay, due to the release of domestic sewage produced by a population of approximately eight million inhabitants around the Guanabara Bay hydrographic region (Fistarol et al., 2015). Signs of significant changes in the carbon cycle in this bay include, for example, the increase of one order of magnitude in the storage of organic matter in sediment, reaching 42 mol C m^{-2} $year^{-1}$, due to accentuated autochthonous production and raw sewage input (Carreira et al., 2002). In addition, the role of Guanabara Bay as an organic matter sink has recently been confirmed by CO_2 water saturation studies (Cotovicz Jr et al., 2015), which makes the bay an exception to the generally heterotrophic behavior observed in similar systems (Cai, 2011).

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https://doi.org/10.1016/j.ecolind.2018.03.046
Received 20 December 2017; Received in revised form 7 March 2018; Accepted 19 March 2018

In the present study, chemical (fecal sterols, $\delta^{13}C$) and biological (*E. coli*) indicators were evaluated in the suspended particulate matter (SPM) of representative rivers of the Guanabara Bay drainage basin, aiming at (i) identifying spatial and temporal variability in the domestic sewage river input of a densely populated urban region lacking basic sanitation and (ii) comparing the two classes of indicators to evaluate fecal contamination.

2. Material and methods

2.1. Study region and sampling procedures

The hydrographic region of Guanabara Bay (HRGB; 22–23°S and 42–43°W) comprises an area of about 4066 km^2, covering 16 municipalities in the state of Rio de Janeiro, southeastern Brazil. The HRGB covers the largest coastal urban cluster in Brazil, with more than 12 million inhabitants that reside mainly in the metropolitan region of Rio de Janeiro. The drainage network consists of 12 main rivers, responsible for the discharge of 33 $m^3 s^{-1}$ (dry period) to 186 $m^3 s^{-1}$ (rainy season) (Kjerfve et al., 1997). The climate at the HRGB varies from mild subtropical, in the highest parts, to tropical, in the flat parts, characterized by hot (averages ranging from 25 to 27 °C, reaching 34 °C in February) and rainy (150–200 mm) summers, and slightly colder (average around 21 °C) and drier (30–60 mm) winters (Fistarol et al., 2015).

Eight basins of the HRGB (Fig. 1) were evaluated, three in the northeastern sector (Caceribu/CB, Guapimirim/GM and Suruí/SU rivers) and five in the west sector (Iguaçu/IG, São João de Meriti/ME and Irajá/IR rivers, and the Cunha Channel/CC and Mangue Channel/CM). The campaigns were carried out during three periods (Sep/2014, Jan/2015 and April/2015), with 4 L of water being collected at a single station in each river using a 4 L glass amber bottle and a metal support. The bottles were decontaminated in a muffle oven at 450 °C for 8 h and inserted closed in the water, to avoid contamination by oil from the boat.

In the field, sub-sampling of the collection bottle to 50 mL plastic tubes was conducted, in triplicate, for thermotolerant coliform (*E. coli*) determinations, taking care to avoid contamination and maintaining the samples refrigerated when in the field. Accessory data (temperature, dissolved oxygen, pH and salinity) were determined *in situ* with a multi-parameter AKSO probe (model AK88).

In the laboratory, the SPM was retained in glass fiber filters (GF/F type, 142 mm diameter) after vacuum filtration. Total SPM was determined by gravimetry and the filters were lyophilized and stored frozen for the chemical indicator analyses.

2.2. Sterol analyses

The sterols were analyzed following a published method (Rada et al., 2016). Briefly, the filters were extracted by a Thermo Scientific Dionex® ASE 200 Accelerated Solvent Extractor at a 9:1 (v:v) ratio of dichloromethane and methanol using androstanol (5α-androstan-3β-ol)

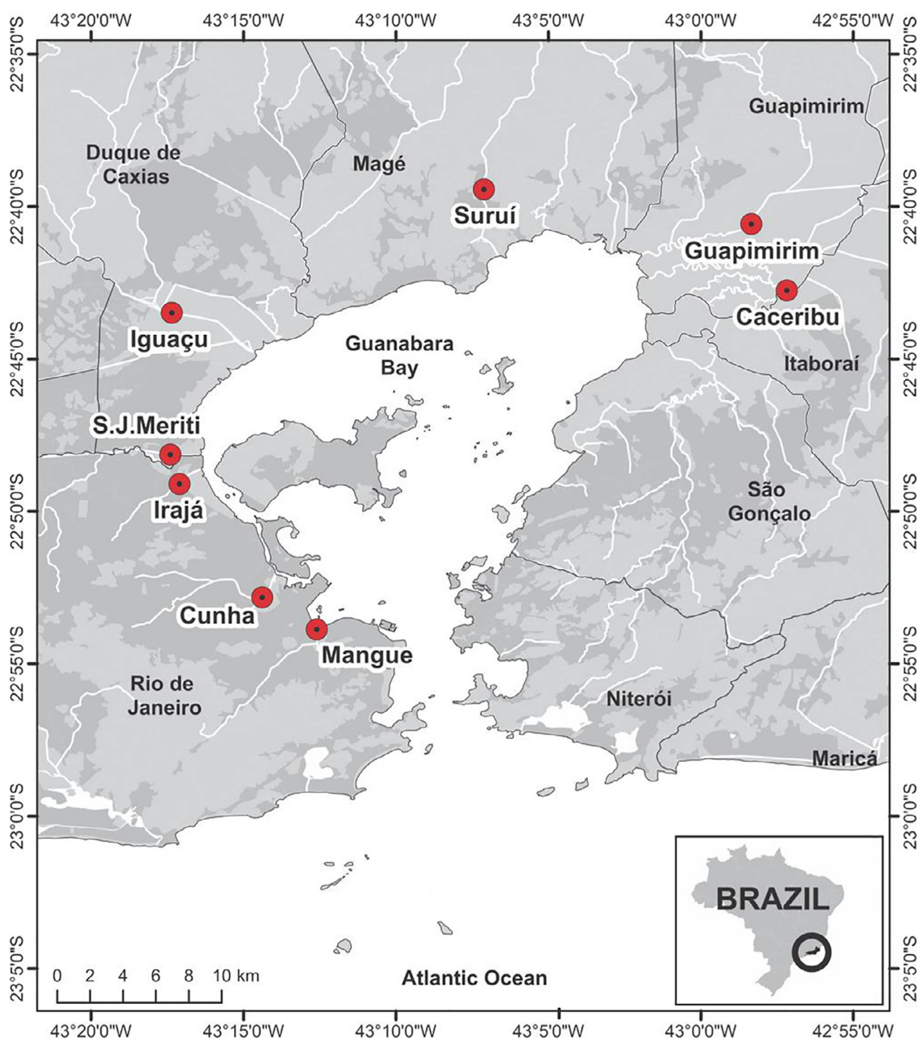

Fig. 1. Overview of the river sampling stations and indication of major cities (human settlements are indicated as darker gray areas) at the hydrographic region of Guanabara Bay.