Marine polychaetes as biomonitoring tools for total mercury in BTS beach environments

Melise Lemos Nascimento [1,2*], Madson Moreira Nascimento[2,3], Caio Silva Assis Felix [2,3], Natália Matos Menezes[2], Igor Cruz[2], Gisele Olímpio da Rocha[1,2,3], Jaílson Bittencourt de Andrade, [2,3]

[1] *Interdisciplinary Center of Energy and Environment (CIEnAm), Federal University of Bahia (UFBA), Avenida Milton Santos, s/n, Campus Ondina, 40170-115 Salvador, Bahia, Brazil*
[2] *National Institute of Science and Technology in Energy and Environment (INCT), Federal University of Bahia (UFBA), Avenida Milton Santos, s/n, Campus Ondina, 40170-115 Salvador, Bahia, Brazil.*
[3] *Universidade SENAI-CIMATEC, Av. Orlando Gomes, 1845 – Piatã, 41650-010 Salvador, BA, Brazil*
**Corresponding author: Ufba; melise.lemos@gmail.com*

Abstract: Anthropogenic activities such as industrialization, urbanization, mining, and waste disposal release toxic metals into marine ecosystems, posing long-term threats to biodiversity and human health. These contaminants can persist, bioaccumulate in aquatic organisms, and biomagnify along the food web. Biomonitoring, using organisms capable of indicating and quantifying environmental contaminants, is essential for assessing pollution levels and guiding mitigation strategies. Polychaetes—benthic marine worms that inhabit and feed within sediments—are effective biomonitors of toxic metals, as these pollutants are often adsorbed onto sediments and accumulate in their tissues. In this study, polychaetes from the families *Chaetopteridae,* and *Spionidae*/*Eunicidae* were collected in Todos os Santos Bay (BTS), near Salvador, Bahia, Brazil, to monitor mercury contamination in the region.
Keywords: Mercury; Biomonitoring; Marine Contamination.
Abbreviations: Todos os Santos Bay (BTS). Mercury (Hg).

1. Introduction

The potential effects of anthropogenic emissions of toxic metals, along with their long-term consequences for marine ecosystems, have emerged as a key concern in environmental biomonitoring studies [1–2]. Activities such as industrialization, urbanization, municipal waste disposal, urban and agricultural runoff, mining, and sewage discharge are important sources of toxic metal release into marine ecosystems [3]. Biomonitoring studies are essential for assessing pollution levels and identifying potential risks to human health arising from daily exposure to high concentrations of toxic metals [4–5].

Among toxic metals, mercury is considered extremely harmful even at low concentrations due to its ability to bioaccumulate in different organisms [6–7]. Total mercury (THg) occurs in environmental substrates and can contaminate other organisms through dietary intake, accumulating in their tissues and transferring through successive trophic levels via biomagnification [8].

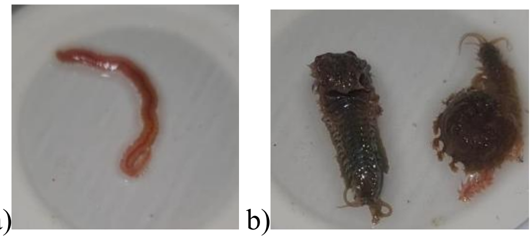
Once introduced into marine environments, mercury can persist for long periods, bioaccumulating in aquatic organisms [9–10]. These processes threaten biodiversity and pose significant risks to human populations that rely on seafood as a dietary staple [11–12]. Understanding the pathways, accumulation patterns, and ecological effects of these contaminants is therefore crucial for developing effective mitigation strategies and guiding environmental policies [13–14].

In this context, the use of organisms—collectively referred to as biota—emerges as an effective approach for providing detailed information on the integrity of aquatic ecosystems [12–13]. According to Markert (2007), bioindicators are species capable of retaining specific contaminants; however, they lack the capacity to bioaccumulate them at levels sufficient for quantification by conventional analytical methods [14]. Thus, bioindicators can only signal the presence of a contaminant in the environment [15]. In contrast, biomonitors are capable of both indicating and quantifying contaminants to which an ecosystem is exposed [16].

Polychaetes are marine worms widely distributed across diverse habitats, including sandy beaches near shallow waters, and exhibit remarkable morphological and ecological diversity [17]. These benthic invertebrates inhabit sediments, where they feed on stored organic matter and contribute to nutrient cycling between sediments and the water column [18]. Contaminants of anthropogenic origin, such as toxic metals, which are often adsorbed onto marine sediments, can accumulate in their tissues [19–21].

A wide range of marine organisms serve as biomonitors for aquatic pollution, including amphibians, fish, mollusks, and sea sponges, as well as microorganisms and crustaceans for monitoring soil and water parameters [22–25]. In this study, polychaetes were collected in the Todos os Santos Bay (BTS) region, near the city of Salvador, Bahia State, Brazil. Specifically, polychaetes from the families Chaetopteridae, Spionidae, and Eunicidae were used as biomonitors of mercury in the BTS region (Figure 1).

Figure 1. Polychaetes samples familys: a) *Chaetopteridae*. b) *Spionidae*/*Eunicidae*.

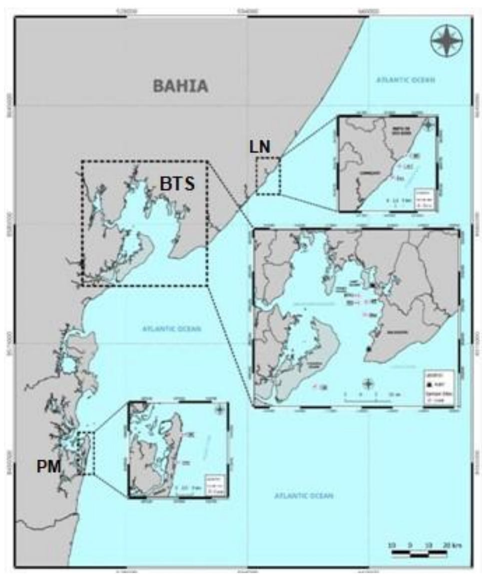
a) b)


2.1. Metodology

2.1.1 Site description and collection of samples

The study was conducted in the BTS region, located between two zones: the North Littoral of Bahia (LN) and the Maraú Peninsula (PM) (Figure 2).

Figure 2. Zones of BTS, LN and PM regions.



Polychaetes were collected from five distinct beaches within Todos os Santos Bay: Aratu (ARA), Itaparica (ITA), Madre de Deus (MD), Paripe (PAR), and Ribeira (RIB).

Table 1. Geographic coordinates of the sampling sites.

	Sites	Lat	Long
Samples	ARA	-12.911	-38.497
	ITA	-12.741	-38.606
	MD	-12.885	-38.675
	PAR	-12.814	-38.488
	RIB	-12.835	-38.476

After verifying the optimal tide conditions (close to zero), approximately 20 individuals were collected from surface sediments at a depth of about 10 cm using aluminum sieves.

2.1.2 Sample preparation

The collected polychaetes were transferred to pre-cleaned glass recipients containing approximately 50 mL of seawater from the same region, placed in a refrigerated thermal box, and transported to the laboratory, where they were stored in a freezer at -20 °C [29]. After that, the samples were freeze dried using an SL-404 lyophilizer (SOLAB, Brazil).

2.1.3 Chemical analysis

Total mercury (THg) determinations in samples from the investigated biota were performed using a DMA-80 Tri Cell Direct Mercury Analyzer (Milestone, Sorisolev (BG), Italy). This methodology was like that used by Menezes et al. (2023) [30]. Each biota was analyzed directly, with approximately 20 to 100 mg of sample placed in nickel sample boats/crucibles. The boats and other metal instruments were previously cleaned in an ultrasonic bath with a 4% Extran solution for 10 minutes, washed with Milli-Q water, dried, and then subjected to a muffle furnace at 700°C for 10 minutes. For mercury determination, three calibration curves were generated, with coefficients of determination (R^2) of 0.9994, 0.9991, and 0.9990, respectively. Calibration was performed using three standard solutions prepared in different volumes, as instructed by the equipment manufacturer, using Table 2 as a reference.

Table 2. Data used to calibrate the Direct Mercury Analyzer DMA-80 Tri Cell instrument (Milestone, Sorisolev (BG), Italy).

Para calibrar para Hg (ng)	Concentração do padrão de Hg
0.5 (low range)	5 µL of 100 PPB
1.0 (low range)	10 µL of 100 PPB
2.0 (low range)	20 µL of 100 PPB
3.0 (low range)	30 µL of 100 PPB
5.0 (Medium range)	50 µL of 100 PPB
10 (Medium range)	100 µL of 100 PPB
20 (Medium range)	20 µL of 1 PPM
50 (High range)	50 µL of 1 PPM
100 (High range)	100 µL of 1 PPM
200 (High range)	200 µL of 1 PPM
500 (High range)	50 µL of 10 PPM
700 (High range)	70 µL of 10 PPM
1000 (High range)	100 µL of 10 PPM

The limits of detection (LOD) and quantification (LOQ) were calculated based on the standard deviation of the blank replicates, using the equations [30]:

$$LOD = 3 \times (SD)/\alpha \quad (1)$$

$$LOQ = 10 \times (\ D)/\alpha \quad (2)$$

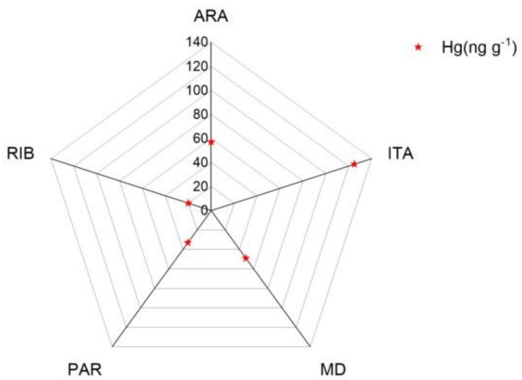
Where α represents the slope of the calibration curve. The values obtained were LOD = 0.004 ng and LOQ = 0.012 ng. The accuracy of the method was evaluated using certified reference materials: marine sediment (MESS-3) and fish protein (DORM-4), both supplied by the National Research Council (NRCC), Canada. The certified values were 0.091 ± 0.009 mg kg^{-1} and 0.410 ± 0.055 mg kg^{-1}, respectively. The results obtained by the DMA method were 0.086 ± 0.003 mg kg^{-1} for marine sediment (95% agreement) and 0.414 ± 0.003 mg kg^{-1} for fish protein (101% recovery).

Intra- and interday precision was assessed by analyzing the certified reference materials. Approximately 40 samples were processed per day, with calibration checks performed every 10 measurements. Intraday precision was estimated with four replicates on the same day, while interday precision was calculated over four consecutive days, with four replicates per day, all performed under the same experimental conditions. The coefficient of variation (CV) found was 1.1% for marine sediment and 2.3% for fish protein (intraday) and 5.6% and 5.3% for sediment and fish protein, respectively (interday) [31-32].

2. Results and discussion

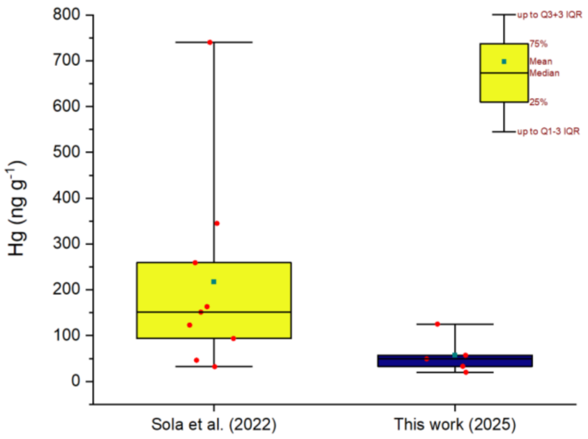
From the results, polychaetes collected at the ITA site exhibited the highest Hg concentration, exceeding 130 ng g^{-1}, which may indicate a stronger influence of anthropogenic sources such as boating activity, fishing, or nearby urban discharge [26]. ARA (Aratu) showed intermediate concentrations (around 60 ng g^{-1}), consistent with its proximity to industrial and port areas, which are known potential contributors of mercury to aquatic ecosystems. PAR (Paripe) and MD (Madre de Deus) presented lower values, between 20 and 40 ng g^{-1}, suggesting reduced contamination compared to ITA and ARA. The lowest concentration was recorded at RIB (Ribeira), near 10 ng g^{-1}, possibly due to less direct exposure to Hg sources or more favorable environmental conditions for mercury dispersion and dilution (Figure 2).

Figure 2. Mean mercury (Hg) concentrations (ng g^{-1}).



Overall, the radar plot illustrates the spatial distribution of mercury concentrations in polychaetes at the five sampled sites, revealing marked spatial variability, particularly at ITA (125 ng g^{-1}), while the other sites displayed values below 60 ng g^{-1}. Such variability may be related to differences in local contamination sources, hydrodynamics, and sediment characteristics influencing the bioavailability and bioaccumulation of Hg in polychaetes.

In the study conducted by Sola *et al.* (2022), eight polychaetes species were collected in BTS, with mean Hg concentrations ranging from 46.1 to 740 ng g^{-1}, indicating a strong potential for Hg bioaccumulation in these organisms.



A comparison between the mercury (Hg) concentrations reported by Sola *et al.* (2022) and those obtained in this study reveals significant differences in both central tendency and dispersion. The Hg levels reported by Sola *et al.* present a notably higher median and a much wider range, with values reaching approximately 740 ng g^{-1}, indicating substantial variability and possibly high contamination in the environment or in the sampled organisms. In contrast, the data from this work show considerably lower median Hg concentrations, with a narrower interquartile range and fewer extreme values, suggesting lower contamination levels.

These marked differences between the two studies may be attributed to several factors, including variations in the polychaetes species analyzed, differences in collection sites, or seasonal variations in sampling. The greater dispersion and higher outliers in the Sola *et al.* (2022) dataset may also reflect localized pollution hotspots or episodic contamination events. Conversely, the data from the present study were more constrained, with lower maximum values than those observed by Sola *et al.* (2022), which may indicate that the studied area was less impacted by Hg contamination.

4. CONCLUSION

Anthropogenic activities such as industrialization, urbanization, mining, and waste disposal release toxic metals into marine ecosystems, posing long-term threats to biodiversity and human health. These contaminants can persist, bioaccumulate in aquatic organisms, and biomagnify along the food web. Biomonitoring, using organisms capable of indicating and quantifying environmental contaminants, is essential for assessing pollution levels and guiding mitigation strategies. Polychaetes—benthic marine worms that inhabit and feed within sediments—are effective biomonitors of toxic metals, as these pollutants are often adsorbed onto sediments and accumulate in their tissues. In this study, polychaetes from the families Chaetopteridae, Spionidae, and Eunicidae were collected in Todos os Santos Bay (BTS), near Salvador, Bahia, Brazil, to monitor mercury contamination in the region.

Although mercury detection in marine ecosystems has been previously reported, continuous monitoring remains of paramount importance. The values reported by Sola et al. were considerably higher, reinforcing the need for frequent biomonitoring to track variations in this toxic metal. Such monitoring enables timely alerts to the competent regulatory authorities and supports the development of public policies aimed at mitigating the deleterious effects of mercury on ecosystems, biota, and human health.

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