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Assessment of heavy metal contamination in sub-tropical riverine sediments using geoaccumulation index

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Abstract

Heavy metal determination in surface sediment allows pollutant assessment when the detection in the water column is not possible. Geoaccumulation Index (Igeo) and the Sediment Quality Guidelines (SQGs) were used to quantitatively evaluate the degree of heavy metal contamination in fluvial sediments. Both of these methods had already been used by several authors and the generated indexes allowed a good comparison parameter. In the present study, heavy metal in sediments (Mn, Zn, Cd, Cr, Cu, Pb and Ni) were analyzed in 14 sampling points, distributed in the upper watercourse of Subaé river, Feira de Santana – BA, in two field campaigns in order to compare dry and wet seasons. The quantification of heavy metal contents was measured by flame atomic absorption spectrometer. The heavy metal levels in the sampling points were low when compared to the global reference values for world sediments. Cadmium concentrations were always below the detection limit of the used spectrometer, and the relative abundance of the studied metals was the following: Mn>Zn>Pb>Cu>Cr>Ni. The variation range of each element concentrations was: Mn 69.3 and 266 mg Kg⁻¹; Zn 30.7 and 426 mg Kg⁻¹; Pb 6.00 and 63.6 mg Kg⁻¹; Cu 4.26 and 66.2 mg Kg⁻¹; Cr 3.24 and 52.9 mg Kg⁻¹; Ni 1.96 and 24.7 mg Kg⁻¹. These results are indicating low contamination risk to biota, despite of the fact that some points presented moderate risk of toxicity. The Igeo ranged from unpolluted (Zn, Mn, Cr, and Ni) to slightly polluted (Pb and Cu) in the assessed sediments. The different approaches to geochemical information treatment allow a wide and coherent debate about the environmental risk of heavy metals from anthropogenic diffuse sources.

Keywords: Igeo; heavy metals, sediments

INTRODUCTION

The increasing urban development brings, besides the benefits, the emergence of ecological problems. According to Oliveira (2010), the unbridled rise of industrialization and irregular urban occupation cause changes in terrestrial and marine ecosystems, due to the discharge of undesirable compounds in the environment. This originates a degradation scenario, causing negative impacts that probably enhance community health at risk. The presence of higher levels of several pollutants with different physical-chemical characteristics had already being proved to cause serious environmental problems (Costa *et al.*, 2008).

Considering this problem, environmental studies are required to determine contaminants in the environment. As sediment plays an important role in aquatic ecosystems, due to its capacity of accumulating and remobilizing polluting substances, like heavy metals, many studies have used sediments as indicators of contamination in these environments. Sediment chemical analysis can be the interpretation key of the events that occur over time in the waterbody (Esteves, 1998; Ribeiro, 2002).

The literature shows some discrepancies among researchers in relation to the acceptable concentrations in the sediment and soil compartments. There is not a common consensus about the acceptable maximum limits, since this is information

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originated from different lithological environments. Therefore, sometimes a chemical element concentration found in an area may be considered natural for an environment and for another could be considered high, showing that it is very important to consider its location characteristics (Matschullat *et al.*, 2000).

To reduce those problems, indexes were created as analysis parameters, in which it is considered the chemical element concentrations in the shale (sedimentary rock) and the contents found in surface sediments. Some indexes stand out as analysis parameter when related to chemical element contents in sediments, for example: Enrichment Factor (EF), Contamination Factor (CF), and Geoaccumulation Index (Igeo) (Aprile & Bouvy, 2008; Mortatti *et al.*, 2012).

The main objectives of this research are; (1) determinate the heavy metals distribution in sediments from the upper course of Subaé River, to assess the impact of the industrial and urban activities in this environment; (2) evaluate the status of heavy metals contamination using of different types of indexes.

MATERIALS AND METHODS

Sampling points were selected by the systemic analysis and using georeferencing techniques. The same sampling points were used in the water quality monitoring study developed by the research group where this project is

inserted. Points with proximity of anthropogenic activities and accessibility were considered.

Study area

The Hydrographic Basin of the Subaé River is located in the Reconcavo North of Bahia State, covering an area of 655 Km². The main watercourse of this basin, the Subaé River, has its source in the urban perimeter of Feira de Santana city and during many years has been affected by untreated wastewater originated from enterprises installed along the river course. The degradation condition is visible from its source and it worsens all the way through the watercourse (Vilas Boas, 2006).

The geological formation of the municipality is characterized by the presence of a plateau formed by very porous and permeable sand-clay sediments responsible for the accumulation and transmission of subterranean water, creating sources and lagoons that lay on the crystalline basement (Lima, 2009).

The sampling points were located in the upper watercourse of the Hydrographic Basin of the Subaé River, in the limits of the municipality of Feira de Santana – BA. The three sampling areas are represented in figure 1, which correspond to Subaé lagoons to the north and south of BR 324 (LSU), Salgada lagoon (LSA) and the source located in Pedro Suzart Avenue (NPS).

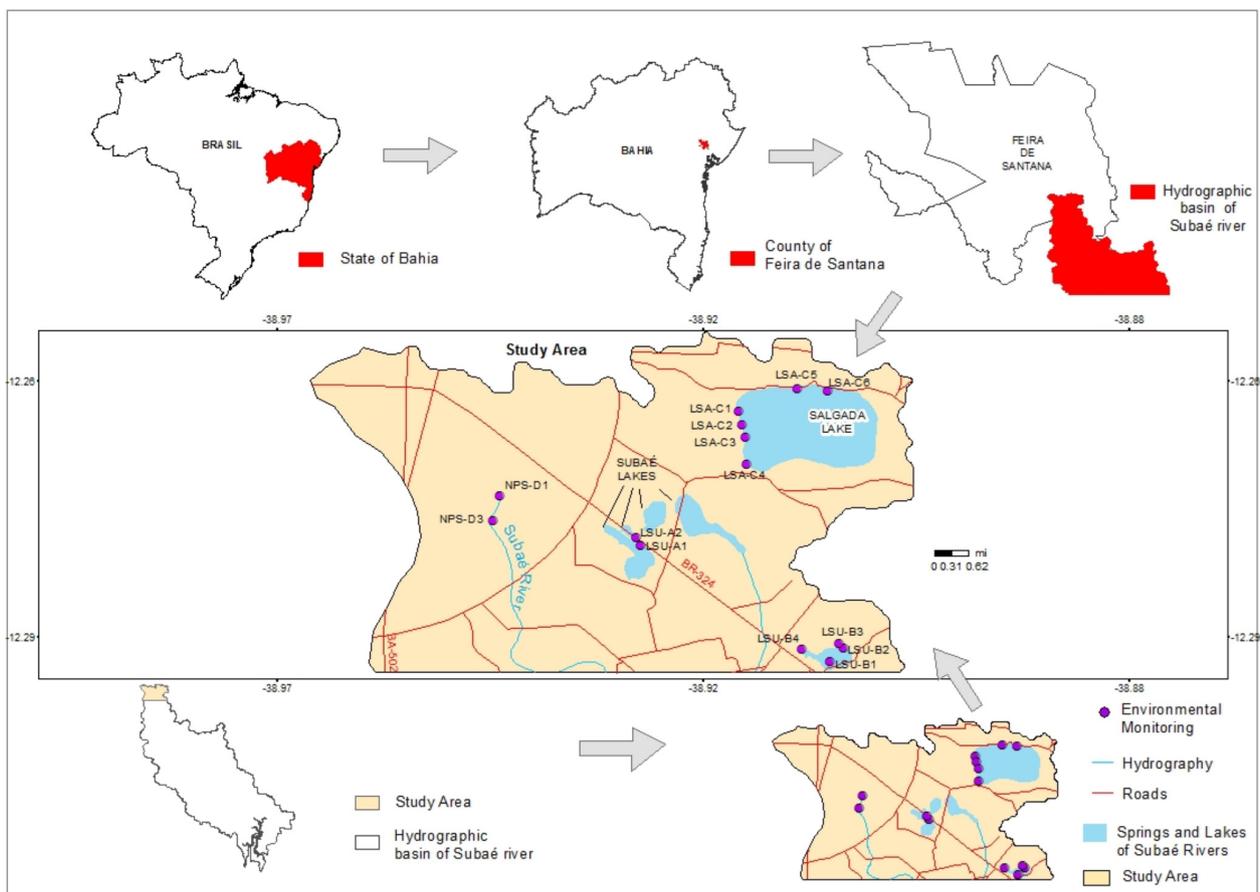


Figure 1. Localization map of Subaé River sources, Feira de Santana - Bahia. Source: Adorno, 2013.

According to Franca-Rocha (1998) *apud* Cruz (2013), the sources of Subaé River are confined aquifer type, with the exception of NPS source, that was identified by remote sensing as a source without initial water accumulation and with permanent flow.

Sampling

Two field campaigns were performed for sediment sampling, the first was in May 2011 and the second, in May 2012, in order to compare the wet and dry seasons. The 14 sediment samples, with around 250 g, were collected using a plastic shovel. The samples were identified and cold stored in a refrigerator of the Environmental Geochemistry lab (PPGM-UEFS).

Sample preparation

The samples were dried for 12 hours at 60°C and then ground and sieved in a 63 mesh stainless steel sieve, respectively. After sieving, approximately 1 g from each sediment sample was weighed in a digital scale (precision 0.0001).

The sediment digestion from the first field campaign was performed in an Anton Paar microwave oven, model Multiwave 3000. The samples were analyzed in analytical triplicates, placed in a Teflon vase, adding 9 mL of HCL and 3 mL of HNO₃, and then heating to approximately 190°C for 30 minutes.

After digestion, each sample was filtered and filled up to 50 mL with ultra pure water in a volumetric flask.

Analytical procedures

The metals were quantified by flame atomic absorption spectrophotometer (FAAS), Varian brand (Model: HG-3000). The heavy metals quantified were: Cd, Cr, Cu, Mn, Ni, Pb, and Zn. Calibration curves were obtained through standards prepared with the same extractor of each fraction, to avoid possible mistakes. Table 1 shows the detection limits (DL) of the technique.

Data Treatment

Freshwater Sediment Quality Guidelines (SQGs) adopted by NOAA (mg Kg⁻¹) was used as evaluation criteria to analyze the probability of deleterious effects on biota exposed to contaminants (Silvério *et al.*, 2006), since the Brazilian environmental legislation still lacks criteria to evaluate the sediment quality.

SQGs showed in the Table 2 were based on databases of effects and non-effects levels, i.e. threshold effects level

Table 1. Detection limits of flame atomic absorption spectrophotometer.

	Mn	Pb	Cu	Ni	Zn	Cr	Cd
DL	0.002	0.006	0.002	0.004	0.008	0.005	0.009

DL= Detection limit

(TEL), probable effects level (PEL), and severe effects level (SEL), which are numerical guideline values of individual concentrations of inorganic (metals and non-metals) and organic (a large number of different compounds) contaminants. These values were statistically defined based on the chemical concentration values of these contaminants in sediments associated to the results of toxicity tests with a large number of organisms (Mozeto, 2008; Saraiva, 2009).

For heavy metals pollution degree in sediment, the Geoaccumulation Index (Igeo) was determined as followed (Muller, 1979):

$$I_{geo} = \log_2 [C_n / 1.5 C_b]$$

Where: C_n is the metal concentration in sediment (mg Kg⁻¹), C_b is the base concentration (mg Kg⁻¹), in other words, the metal background value based on the average shale composition and 1.5 is a correction factor to background data variables due to lithogenic effects (Cruz, 2013).

Müller's Geoaccumulation Index (Table 3) is an assessment modeling used to analyze the sediment contamination intensity. This index establishes the relation among the metal contents found in the analyzed area and an equivalent reference value to the world average shale for metals associated with clay which allows the calculation of the contamination level of different areas (Cruz, 2013).

RESULTS AND DISCUSSION

Determination of heavy metal concentrations

Fine-grained fractions (< 63 µm) of surface sediments were analyzed. Table 4 and table 5 show the heavy metal concentrations found in sediments in the sampled points in the two field campaigns.

Table 2 - TEL, PEL, and SEL guidelines used by the NOAA (mg Kg⁻¹)

Effect level	Cd	Cr	Cu	Mn	Ni	Pb	Zn
TEL	1	37	36	-	18	35	123
PEL	4	90	197	-	36	91	315
SEL	10	110	110	1100	75	250	820

TEL (threshold effect level): No toxic effect is observed on the organisms.

PEL (probable effects level): sediment contamination level that can be tolerated by most of the organisms.

SEL (severe effect levels): level in which can be expected disturbances in the sediment-dwelling communities.

Table 3. Intensity scale of the Geoaccumulation index

Pollution intensity	Accumulation in soil (Igeo)	Igeo class
Very heavily polluted	>5	6
Heavily to very heavily polluted	4-5	5
Heavily polluted	3-4	4
Moderated to heavily polluted	2-3	3
Moderately polluted	1-2	2
Slightly to moderately polluted	0-1	1
Practically unpolluted	<0	0

Cadmium concentration, from all analyzed sediments, were always below the detection limit of the equipment ($0.0009 \text{ mg Kg}^{-1}$). Metal abundance in a descending order was: $\text{Mn} > \text{Zn} > \text{Pb} > \text{Cu} > \text{Cr} > \text{Ni}$. Manganese was the more abundant element in surface sediments from the analyzed ones. Probably because Mn is trapped in the solid phase of the sediment, compounding the group of majority elements (Fe, Al, Ca, Mn). It is also considered good geochemical support due to its capacity to scavenge others heavy metals by mechanisms like precipitation and adsorption, mainly in oxides and hydroxides forms (Forstner & Wittmann, 1981; Wetzel, 1983; Esteves, 1998).

Mn concentrations ranged from 69.33 to 266.09 mg Kg^{-1} (Table 4). There was an increase of Mn concentration in seven of the fourteen points sampled in the second field campaign.

Despite Mn contamination in aquatic ecosystems has different anthropic sources, environments with higher concentrations are areas affected by urbanization and disordered occupation (LSU A1). Probably, domestic sewage wastes are sources of Mn to those environments.

Zn concentrations ranged from 30.73 to 426.00 mg Kg^{-1} (Table 4). There was an increase in Zn concentration in the second field campaign in twelve of the fourteen sampled points; there was a reduction only in the NPS D1 and NPS D3 points, which showed higher concentrations in the first field campaign. The increase of Zn mobility (sediment-water) occurred in conditions of high oxidation and in acid medium (Reimann & Caritat, 1998).

The increase of Zn concentrations present in most of the points is probably indicating anthropogenic contribution.

Table 4. Average, and standard deviation, heavy metal levels (mg Kg^{-1}) in surface sediments from Subaé River, first field campaign (May 2011).

	Mn	Pb	Cu	Ni	Zn	Cr
LSAC1	70.87 ± 3.1	34.81 ± 1.9	39.97 ± 1.3	20.62 ± 1.5	49.20 ± 2.9	28.92 ± 3.8
LSA C2	93.58 ± 1.7	35.98 ± 1.9	28.26 ± 1.0	14.54 ± 0.6	30.73 ± 2.5	16.39 ± 0.9
LSA C3	69.33 ± 3.1	44 ± 2.0	31.73 ± 2.0	18.8 ± 0.4	56 ± 5.3	27.13 ± 1.3
LSA C4	107.67 ± 2.0	41.61 ± 0.3	33.77 ± 3.0	24.50 ± 0.4	50.88 ± 4.5	29.06 ± 1.1
LSA C5	105.81 ± 7.4	21.57 ± 2.0	< 0.002	2.61 ± 1.1	< 0.008	3.24 ± 1.5
LSA C6	100.94 ± 6.7	38.83 ± 0.2	35.37 ± 1.1	14.70 ± 2.9	94.41 ± 6.3	14.63 ± 1.3
LSU A1	200.58 ± 6.2	25.61 ± 3.1	66.24 ± 0.04	12.74 ± 1.3	105.59 ± 3.4	19.29 ± 6.1
LSU A2	175.56 ± 5.6	34.05 ± 2.1	25.84 ± 0.7	24.70 ± 1.1	71.44 ± 6.3	52.87 ± 2.3
LSU B1	144.47 ± 3.3	33.96 ± 0.2	4.26 ± 0.1	13.32 ± 1.1	45.96 ± 4.3	19.78 ± 2.3
LSU B2	115.58 ± 5.8	21.95 ± 2.1	20.75 ± 0.9	11.04 ± 1.4	64.52 ± 9.7	15.37 ± 2.3
LSU B3	96.60 ± 7.4	16.47 ± 2.5	15.22 ± 4.7	1.99 ± 0.3	42.81 ± 8.4	< 0.005
LSU B4	124.6 ± 8.1	24 ± 3.5	11.13 ± 1.9	3.73 ± 1.9	42 ± 8.1	< 0.005
NPS D1	123.9 ± 7.2	34.72 ± 0.6	54.36 ± 8.5	7.73 ± 1.9	426.85 ± 14.0	< 0.005
NPS D3	113.02 ± 3.3	63.57 ± 1.3	56.32 ± 2.4	12.60 ± 1.1	408 ± 11.3	< 0.005

Table 5. Average, and standard deviation, heavy metal levels (mg Kg^{-1}) in surface sediments from Subaé River, second field campaign (May 2012).

	Mn	Pb	Cu	Ni	Zn	Cr
LSA C1	119.3 ± 2.54	28.00 ± 0.11	44.94 ± 3.89	12.67 ± 1.20	53.03 ± 10.2	9.88 ± 1.52
LSA C2	95.16 ± 6.26	27.27 ± 2.47	42.53 ± 9.43	9.97 ± 1.96	116.2 ± 37.6	5.50 ± 1.59
LSA C3	79.40 ± 6.87	32.50 ± 1.88	25.93 ± 3.86	7.80 ± 0.15	59.14 ± 3.15	17.19 ± 2.41
LSA C4	266.1 ± 9.62	32.01 ± 2.20	33.47 ± 0.69	15.34 ± 1.21	69.13 ± 0.83	35.19 ± 5.73
LSA C5	122.0 ± 12.74	33.39 ± 2.50	33.12 ± 4.03	7.85 ± 2.71	114.9 ± 17.2	37.94 ± 29.35
LSA C6	127.47 ± 9.59	33.26 ± 2.52	26.50 ± 5.59	5.32 ± 1.13	96.4 ± 8.52	5.46 ± 1.47
LSU A1	160.7 ± 8.93	37.54 ± 3.24	63.35 ± 3.20	7.24 ± 1.10	133.1 ± 2.79	16.23 ± 1.17
LSUA2	146.7 ± 13.98	33.00 ± 1.60	35.42 ± 6.99	8.0 ± 0.05	105.1 ± 24.6	7.70 ± 1.60
LSU B1	130.3 ± 7.25	26.03 ± 3.94	14.15 ± 1.16	4.00 ± 1.99	50.73 ± 1.14	13.19 ± 9.24
LSU B2	89.1 ± 8.03	6 ± 5.66	21.15 ± 6.28	4.02 ± 2.02	89.37 ± 4.77	< 0.005
LSU B3	96.21 ± 3.94	30.56 ± 3.86	28.01 ± 4.29	5.97 ± 1.94	77.8 ± 10.19	14.20 ± 4.71
LSU B4	118.44 ± 9.61	19.31 ± 1.15	24.06 ± 16.33	5.99 ± 0.06	47.70 ± 2.41	2.22 ± 3.84
NPS D1	135.77 ± 8.81	46.78 ± 6.02	45.65 ± 5.80	5.86 ± 0.14	148.3 ± 15.2	14.27 ± 4.21
NPS D3	108.14 ± 10.9	27.51 ± 0.23	16.65 ± 1.57	1.96 ± 0.02	64.25 ± 8.6	< 0.005

Since Zn is present in some common daily use products like deodorants and shampoos and these became domestic sewage components, and then when these wastes are discharged untreated, contribute to metal concentration increase (Boyd & Massaut, 1999).

Ni concentrations ranged from 1.96 to 24.70 mg Kg⁻¹ (Table 4). There was an increase in Ni concentration in three of the fourteen points analyzed in the second field campaign. According to Trindade (2012), the presence of Zn in high concentrations may inhibit the Ni adsorption in sediments, due to competitive adsorption. That would explain the low Ni concentrations found in sediments, mainly in points where the higher Zn values in the sediment were detected.

The study areas probably suffer influence from one or more activities in which Ni is included. But since several activities around the study areas can be influencing the presence of Ni, there is no a specific area that are exposed in a more intensive way.

Cu concentrations ranged from 4.26 to 66.24 mg Kg⁻¹ (Table 4). There was an increase in Cu concentration in nine of the fourteen points analyzed in the second field campaign. According to Pedrozo & Lima (2001), one of the Cu anthropogenic sources are human and animal sewage that can be one of the causes for the presence of Cu in that point.

Pb concentrations ranged from 6.00 to 63.57 mg Kg⁻¹ (Table 4 and 5). There was an increase in Pb concentration in four of the fourteen points analyzed. The increase in Pb concentration may originate from an enrichment source like domestic sewage. According to Paoliello & Chasin (2001), domestic waste is one of Pb emission sources, along with superficial and urban drainage and atmospheric deposition are significant indirect Pb sources found in aquatic environments.

High concentrations of this element in other sampling points of the river source area indicate two possibilities, the area is naturally enriched by that metal, or the Pb emission sources next to the river sources analyzed affect as a whole. Contamination by Pb is irreversible, which generates an accumulative process, even when small amounts are added to the environment (Paoliello & Chasin, 2001). Cr concentrations ranged from 3.24 to 52.87 mg Kg⁻¹ (Table 4 and 5). There was an increase in five of the fourteen points analyzed in the second field campaign.

Poleto (2007) and Mortatti *et al.* (2012) highlight that river stretches that flow through urban areas have a greater potential polluter of the sediment, due to the additional presence of pollutants from untreated sewage releases and intense vehicular traffic. Lacerda (1997) mention that high contents of organic matter and low oxygenation seem to be the factors that control the metal accumulation in the sediment, because it alters the adsorption capacity and maintain the sediment in reduced state.

In urban areas, the vehicle flow in impermeable areas tends to concentrate the metals that must be transported by the drainage system during the rain events, polluting the nearby waterbodies through the surface drainage, one of the

primary sources of sediment contamination. Those factors in conjunction create an increase in metal concentration in the sampled points (Dias, 1999).

Sediment quality

Cu when compared to the Sediment Quality Guidelines (TEL, PEL, and SEL) in the first campaign showed concentrations below the TEL limits, with the exception of LSA C1, LSU A1, NPS D1, and NPS D3, which surpassed the limits, but remaining below the PEL. In the second campaign, the point corresponding to LSA C2 remained above the TEL limit and there was a metal concentration decreasing in point NPS D3, remaining below the TEL. According to evaluation criteria, the chance that Cu values cause some effects on biota is low (Figure 2).

Cu is an essential element and required in low concentrations for all biota. Concentrations above the tolerated level cause harmful effects which can be sub-lethal (changes in biochemical and physiological functions) and lethal (damages reach high proportions and cause risk of death) (Rand, 1995; Oliveira, 2003).

Cr values in the two field campaigns were below the TEL limit for all the points, except the point LSU A2 which exceeded the TEL limit but remained below the PEL limit. The probability of Cr values cause deleterious effects to the biota would be low according to the evaluation criteria (Figure 3).

Cr (III) is an essential element for animals and humans and, despite the presence in all the plants, there is no evidence that it is essential to them. However, Cr (VI), besides not being essential, is more toxic, even in low concentrations. Exposition effects to high Cr levels include decrease of organism body size and growth rate, and also influence the reproduction and offspring survival rate in aquatic organisms (Masutti, 2004).

Mn concentrations presented well below the SEL recommended limit, there is no TEL and PEL reference values for this element. Although its concentrations are relatively high if compared to the concentrations found for the other

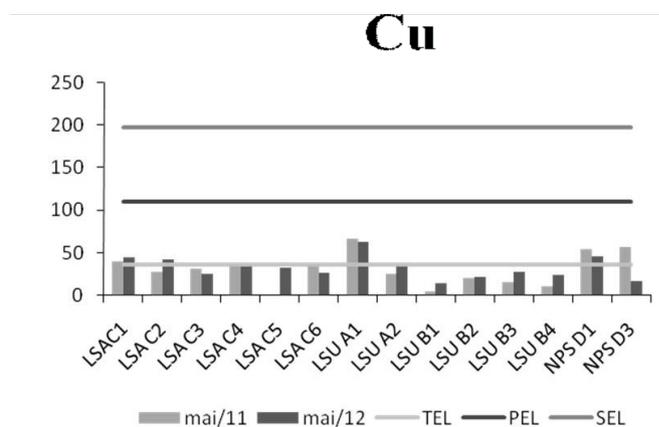


Figure 2. Cu concentrations compared to the guideline values of NOAA (mg Kg⁻¹).

analyzed metals, those values cannot be directly related to a possible concentration able to causing deleterious effects, mainly, related to toxicity to biota. Since manganese is one of the most abundant elements in the Earth's crust, it is normal to encounter high concentrations in sediments (Figure 4).

Most of the sampled points presented Ni concentration values within the TEL limits. According to the evaluation criteria, the chances that the Ni concentrations found cause any effects on biota is low, but monitoring those areas is necessary because Ni, despite of being an essential metal, in high concentrations can cause heart and other tissue degeneration and be also be carcinogenic in animals (Figure 5) (Favaro *et al.*, 2007).

Pb concentrations presented values above TEL for the points LSA C3, LSA C4, LSA C6, LSU A1, NPS D1, and NPS D3. There was an increasing concentration of Pb in four points in the second field campaign. According to the evaluation criteria, the chance that the Pb values found cause any effects on biota would be minimum, but based on Pb concentrations obtained in the points NPS D3 and NPS D1,

an upward trend can be observed in the concentration of this metal mainly in the Pedro Suzart source (Figure 6).

Pb is a nonessential toxic element which accumulates in the organism and practically affects all organs and systems, and also, an important aspect of the toxic effects of Pb is the reversibility of the induced biochemical and functional modifications. Knowing the toxic power of Pb, this area must be monitored with the aim to mapping this metal concentration and distribution in time and space.

Zn presented higher concentrations than PEL limit in two points of the first field campaign (NPS D1 and NPS D3), and there was a reduction of those concentrations in the second field campaign. This fact may be related to the pavement and drainage works developed in that place at the moment of the second field campaign, which stirred up the sediment of the place, bringing up deeper sediment layers. According to the evaluation criteria, concentrations with values above PEL may cause moderated risks to the biota (Figure 7).

Zn is an essential element for the metabolism of most organisms, however, when plants and animals are exposed to concentrations considered toxic, the normal growth and metabolism of plant species can be affected.

According to Poletto (2007) the contaminated bottom sediments in lake represent risk to the aquatic ecosystem,

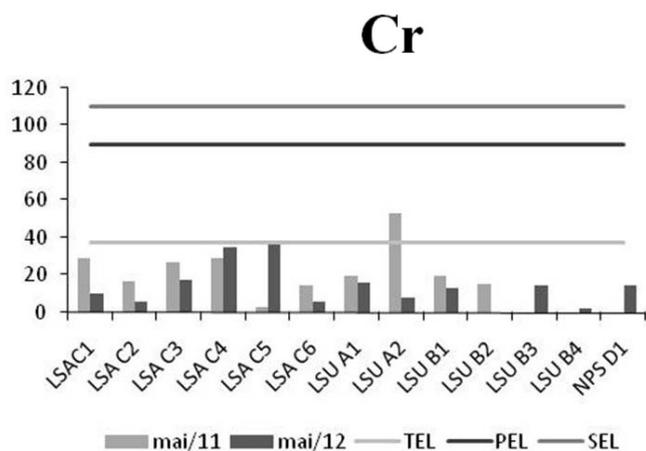


Figure 3. Cr concentrations compared to the guideline of NOAA (mg Kg⁻¹).

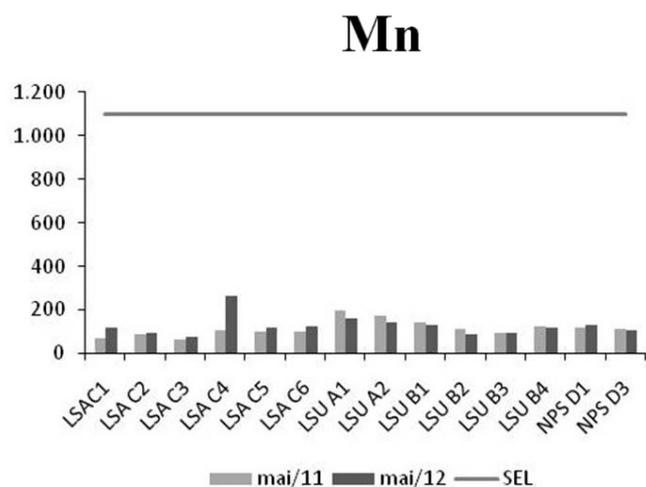


Figure 4. Mn concentrations compared to the guideline of NOAA (mg Kg⁻¹).

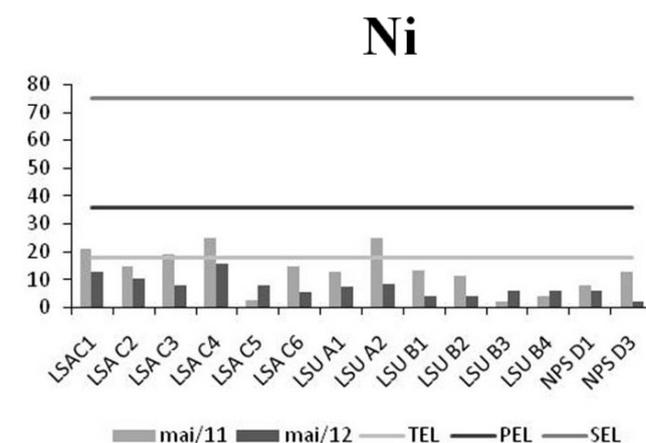


Figure 5. Ni concentrations compared to the guidelines of NOAA (mg Kg⁻¹).

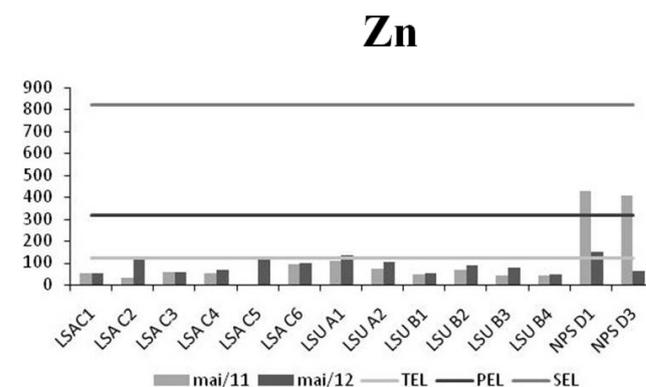


Figure 6. Pb concentrations compared to the guidelines of NOAA (mg Kg⁻¹).

Pb

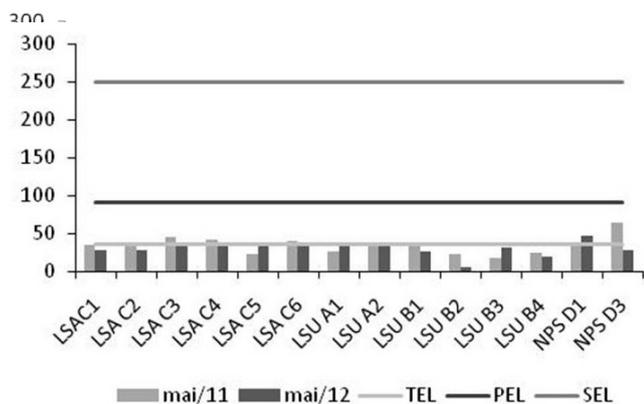


Figure 7. Zn concentrations compared to the guidelines of NOAA (mg Kg⁻¹).

because it is used as habitat for benthic and epibenthic organisms, directly affecting them and indirectly affecting non-aquatic consumers (humans and all wild organisms).

Risks to biota can be inferred as low when considering the criteria used as parameter to establish if heavy metal concentrations found in sediments of Subaé river sources are harmful. But, these values cannot predict the dynamic of the pollutants associated to sediments within aquatic ecosystems, neither the possible effects that the variations of concentration within the established limits may cause, in other words, the concentrations near to lower limits will produce different effects compared to concentrations near to upper limits.

Establishing permanent monitoring plans is necessary in order to verify responses of the biota to the presence of those

elements. Also, the continuous study in this area is necessary to the contaminant levels do not increase over the years and damage the biota and all the aquatic system.

Geoaccumulation index

The pollution categories of surface sediments of Subaé River sources were determined by the Geoaccumulation index calculation. The Geoaccumulation Index (I_{geo}) of the metals Cr, Cu, Mn, Ni, Pb, Zn found in the surface sediment of the two field campaign are presented in table 6.

Cu was not detected in point LSA C5 and Cr was not detected in points LSU B3 and B4 and in the points corresponding to Pedro Suzart source (NPS D1 and D3), in the first field campaign and in the second field campaign, Cr was not detected in points LSU B2 and NPS D3 and, therefore, there are no categories determined for those points. The values indicate that the quantified Pb and Cu contents, in the two field campaigns, in most of the points fit into the I_{geo} 1 category (values between 0 and 1) which corresponds to a slightly to moderately polluted sediment. For Zn, the points corresponding to Pedro Suzart source in the first field campaign were in the I_{geo} 1 category, but with the improvement in the sewage system and the works developed in the place, the Geoaccumulation Index in those points moved to the category I_{geo} 0. All values found for Mn, Ni, and Cr in the two field campaigns are in the category I_{geo} 0.

Concerning I_{geo}, the Subaé River sources are slightly to moderately polluted by Cu and Pb. These data serve as a warning to these points do not become heavily polluted, causing environmental damages to the study area and to the entire Subaé river watercourse.

Table 6. Metal Geoaccumulation index of the surface sediment of Subaé River sources, Feira de Santana- BA.

	Mn		Pb		Cu		Ni		Zn		Cr	
	may/11	may/12										
LSA C1	0	0	1	1	1	1	0	0	0	0	0	0
LSA C2	0	0	1	1	1	1	0	0	0	0	0	0
LSA C3	0	0	1	1	1	1	0	0	0	0	0	0
LSA C4	0	0	1	1	1	1	0	0	0	0	0	0
LSA C5	0	0	1	1	1	1	0	0	0	0	0	0
LSA C6	0	0	1	1	1	1	0	0	0	0	0	0
LSU A1	0	0	1	1	1	1	0	0	0	0	0	0
LSU A2	0	0	1	1	1	1	0	0	0	0	0	0
LSU B1	0	0	1	1	0	1	0	0	0	0	0	0
LSU B2	0	0	1	1	1	1	0	0	0	0	0	0
LSU B3	0	0	1	1	1	1	0	0	0	0	0	0
LSU B4	0	0	1	1	1	1	0	0	0	0	0	0
NPS D1	0	0	1	1	1	1	0	0	1	0	0	0
NPS D3	0	0	1	1	1	1	0	0	1	0	0	0

Legend:

0	1-2
Not polluted	Slightly to moderately polluted

FINAL CONSIDERATIONS

Presence of heavy metals such as Cr, Zn, Mn, Ni, Cu, and Pb were observed in the sediments of the sources in all the study areas. Higher heavy metal concentrations in sediments were recorded in points where there are evidences of organic load discharge and domestic effluents, as in the case of the Subaé lagoon and the Pedro Suzart avenue source.

The results found in that research show that heavy metal levels in the sampled points are low compared to the global reference values defined for the world sediments by Muller (1979) and by the Sediment Quality Guidelines. Regarding the contamination risk to biota, it is worth mentioning that some points presented slight risk of toxicity and the harmful effects caused by the analyzed elements show the need for establish permanent monitoring plans, in order to verify the biota behavior at the presence of those elements.

The heavy metal concentrations (Cr, Cu, Mn, Ni, Pb, Zn) present in the sediment, may be related to natural sources and the anthropogenic contributions caused mainly by the use of the water for industrial and residential waste, grounding for opening of access roads, construction of roadsides as well as the increase of the human occupation rate in the area.

Despite of the lack of vegetal coverage, combined with the excessive urbanization in the sampled areas, the sampled area did not present signals of serious contamination, but the metal contents recorded serve as a warning, because it is unknown the frequency and quantity these metals are thrown into the study area.

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