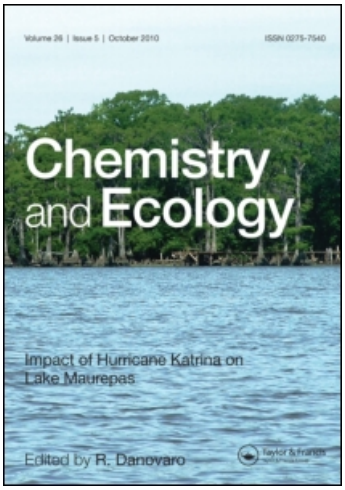

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HEAVY METALS IN SEDIMENTS AND OYSTERS FROM BLUEFIELDS BAY, NICARAGUA

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The distribution of trace metals (Co, Cu, Fe, Mn, Ni, Pb and Zn) was investigated during a year (1994–95) in surface and core sediment samples and in the oyster (*Crassotrea rhizophorae*) from Bluefields Bay, Nicaragua. The aim was to assess the arthropogenic impact of potential pollutant sources, mainly Bluefields City, since domestic waste waters are discharged directly or by infiltration to the bay. Lyophilised samples were submitted to different acid digestion methods and analysed by flame atomic absorption spectrophotometry. The results showed highest contents for copper, lead and zinc near Bluefields City, with an increase in the affected area in the rainy season that is generated by greater city run off. Metal contents in oysters do not show the same distribution pattern than in sediments and were similar to those from other areas without reflecting pollution levels.

Keywords: Bluefields Bay; Nicaragua; heavy metals; sediments; oysters

INTRODUCTION

The evaluation of the environmental quality of several ecosystems in some countries of the Caribbean Region has been promoted by the UNEP Regional Project "Planning and Environmental Management of Heavily Contaminated Bays and Coastal Areas in the Wider

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Caribbean". The Nicaragua's case study selected for this Project was the Bluefields Bay, because of the intense erosion and sedimentation processes that have been affecting this area during the last few years as well as the scarcity of existing information on the arthropogenic problems that have occurred (IRENA, 1983).

Bluefields Bay is located at the Atlantic coast of Nicaragua, with a semi-closed shape with two areas affected. The aim of the research undertaken in this bay was to evaluate the distribution of heavy metals in sediments and organisms to assess the arthropogenic impact of potential pollutant sources, mainly from Bluefields City, since domestic waste waters are discharged directly or by infiltration to the bay.

MATERIALS AND METHODS

Figure 1 shows the sampling network. Sediment samples were collected in three sampling campaigns: the first one in November 1994 (only 7 stations in the north lobe) and two others in 1995, one during the dry season (April) and the other during the rainy one (November). Two core sediment samples were collected in November 1995, in a reference zone (Station 17) and near Bluefields City (Station 11). In the port area (less than 300 m of the shoreline), an extensive survey made measurements in 8 surface and 3 core sediment samples.

Surface sediments were obtained with a Van Veen dredge and core sediment with a plastic gravity corer. For the core sediment samples, the first 14 cm were sectioned each in 2 cm intervals, while the remaining were in 4 cm intervals, obtaining 13 sub-samples.

Oyster, *Crassostrea rhizophorae*, was chosen taking into account that it is distributed throughout the bay with a special feature since the main habitat is the bottom sediment and not the mangrove roots. Organisms were collected in April and November, 1995, in 3 and 7, nursery areas.

All samples were lyophilised; for sediments, the fraction $< 63\,\mu m$ was separated by nylon sieves, except those from the port area. Surface and core sediment samples in the bay were digested with nitric acid/hydrochloric acid (McKown *et al.*, 1978) and metals bioavailability was evaluated with hydrochloric acid (0.5 N) (Chester and Voutsinou, 1981). Only sediments obtained in the port area were submitted to a

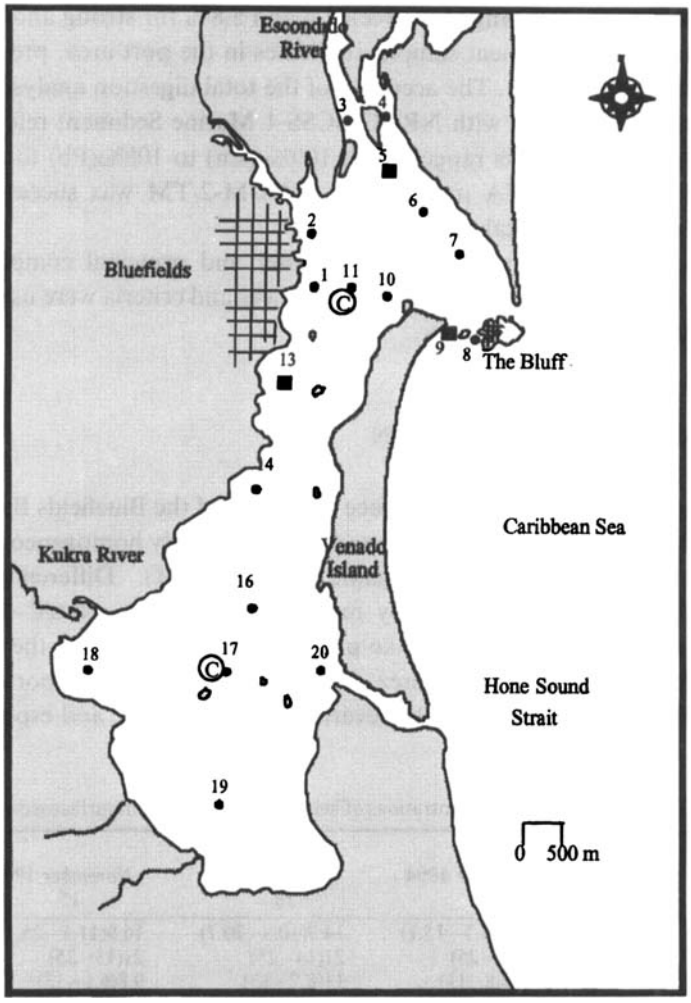

FIGURE 1 Sampling network at Bluefields Bay; © core sampled in November 1995; ■ only sampled in April 1995.

total digestion with concentrated mixed acids ($HF/HNO_3/HCl$). Organic matter (OM) was calculated using the ignition loss at 550°C after 3 hours. Soft tissues of organisms were digested with nitric acid/hydrochloric acid. Digested solutions were analysed by flame atomic absorption spectrophotometry (Pye Unicam SP-9) with deuterium background correction.

Precision ($n = 3$) ranged between 1.6 and 5.8% for strong and weak digestions. For sediment sample duplicates in the port area, precision was better than 7.3%. The accuracy of the total digestion analysis was satisfactorily verified with NRCC BCSS-1 Marine Sediment reference material; mean results ranged from 100‰ (Zn) to 108‰(Pb) to mean certified values; IAEA mussel tissue MA-M-2/TM was successfully analysed for biological material.

Uni- and multivariate methods (cluster and principal component analysis) as well as different pollution indices and criteria were used for the interpretation of results.

RESULTS AND DISCUSSION

Contents of heavy metals in surface sediments of the Bluefields Bay are reported in Table I. The distributions were relatively homogeneous for iron, cobalt, nickel and organic matter (OM). Differences in distribution pattern showed by manganese could be related to the high salinity variations that take place between the dry and the rainy seasons (Rodríguez and Alvarez, 1996), as was previously reported by Middleton and Grant (1990). Nevertheless, for copper, and especially

TABLE I Bluefields Bay: concentrations of heavy metals ($\mu g \cdot g^{-1}$) in surface sediments

	$\bar{X}$ (*range*)		
	November 1994	*April* 1995	*November* 1995
n	7	18	15
OM	12.7(11.1–15.1)	14.3(10.3–20.7)	16.9(11.1–25.7)
Co	21(16–25)	21(14–25)	21(13–25)
BCo	9.3(7.8–11)	11(8.7–13)	9.8(6.1–13)
Cu	56(38–65)	54(38–79)	53(40–68)
BCu	22(12–34)	20(15–36)	22(14–48)
Fe	6.06(4.95–7.06)	6.33(5.03–7.89)	5.96(5.01–7.10)
BFe	1.21(1.00–1.34)	1.29(0.99–1.72)	1.27(1.06–2.04)
Mn	769(577–956)	670(427–981)	826(402–1707)
BMn	484(295–740)	431(165–804)	610(175–1524)
Ni	16(13–18)	19(12–25)	14(9.7–18)
BNi	< 5.0	< 5.0	< 5.0
Pb	20(13–35)	18(7.7–31)	19(5.9–61)
BPb	15(6.6–25)	16(6.7–31)	16(5.0–58)
Zn	102(72–139)	111(82–151)	117(92–219)
BZn	48(31–89)	57(35–112)	65(40–172)

Fe in %; B means bioavailable fraction in these metals.

zinc and lead, the highest contents were found near to Bluefields City as the result of the negative influence of the urban waste waters. In the dry season, this situation is only shown by Station 1, but in November, when storm rains happened during the rainy season, the city run off intensified and caused an increase in the affected area, including Station 2.

Concerning the bioavailable concentrations (Tab. II), ranges and mean of percent of bioavailability for each element, were similar between the two climatic seasons and patterns obtained were closed to those of the strong digestion with high correlations between both contents ($p < 0.001$, except copper and iron). For copper, lead and zinc, the maximum was found again in the Stations 1 and 2, evidencing in these areas their arthropogenic origins brought for the city waste water. In this polluted area, the levels of copper, lead and zinc can be a threat to marine organisms due to their chance for provoking adverse biological effects, according to the criteria of Long *et al.* (1995).

The results obtained during this year, in spite of the difference in the number and location of the stations, showed only little variation, which could be explained by one of the following reasons:

(a) the ecosystem receives and assimilates a relatively constant load of heavy metals in a practically uniform way during the time
(b) the time elapsed between samplings was not enough to detect changes
(c) a combination of both factors.

The core samples for Stations 11 and 17 showed a generally uniform distribution of metals throughout the sedimentary columns (Fig. 2), which is reflected in Table III by the low enrichment factors and arthropogenic percentages of contribution (Donard, 1983). If this

TABLE II Bioavailability of heavy metals in surface sediments (in %)

	$\bar{X}$ (*range*)	
	April 1995	*November* 1995
Co	53(44–61)	48(43–52)
Cu	38(25–26)	40(28–70)
Fe	21(13–26)	22(18–35)
Mn	62(26–85)	68(44–99)
Pb	89(74–100)	84(60–100)
Zn	51(38–76)	54(40–88)

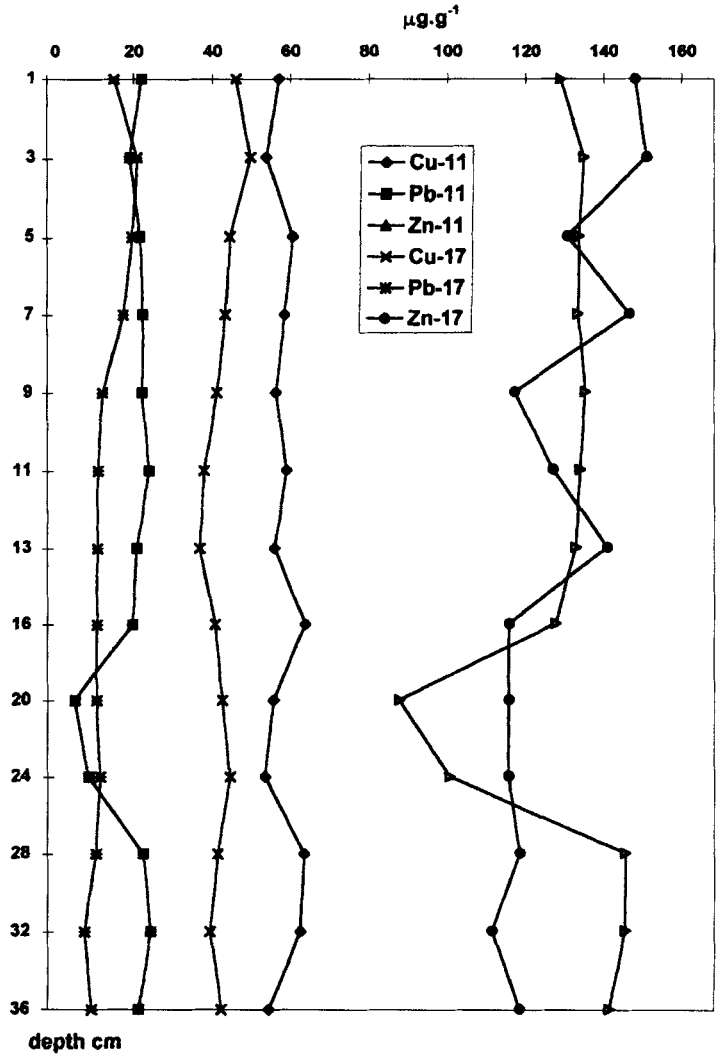

FIGURE 2 Concentration profiles of heavy metals ($\mu g \cdot g^{-1}$) in depth core samples from Bluefields Bay. Metals were found in 2 samples (Stations 11 and 17).

distribution is caused by a chronic pollution during years or has a natural behaviour, especially in Station 11 considering its distance from the city, is not easy to elucidate without data for sedimentation rates. Table IV showed results in the port area, where negative

TABLE III Enrichment factors (E.F.) and % of arthropogenic contribution (A.C.) in the sediment core samples

	E.F.		*A.C.*	
	site 11	*site* 17	*site* 11	*site* 17
Co	0.92–1.08	0.89–1.14	–8/7	–12/12
Cu	0.96–1.16	0.86–1.13	–4/14	–17/12
Fe	0.93–1.04	0.95–1.07	–7/4	–5/6
Mn	0.86–1.05	0.71–1.06	–16/5	–41/5
Ni	1.00–1.10	0.85–1.45	0/9	–17/31
Pb	0.27–1.10	0.83–1.89	–267/9	–21/47
Zn	0.62–1.03	0.94–1.26	–60/3	–6/21

TABLE IV Heavy metals concentration ($\mu g \cdot g^{-1}$) in the port area

	surface samples	*core samples*
n	8	3
Cu	77–134	59–88
Pb	39–244	5.4–49
Zn	284–790	70–957

influence of Bluefields City is reflected only in the 10–20 upper cm of sediments, with enrichment factors up to 4 (Pb) and 22(Zn). This fact allows assuming as natural, the metal levels in core samples from Stations 11 and 17. With respect to different Cuban bays studied using the same methodology (González, 1991, 1996; Hernández and González, 1993; González and Ramírez, 1995; González *et al.*, 1997), this emphasised the similar or higher contents of cobalt, manganese and iron in Bluefields. The absence of pollutant sources for these elements and the fact that they are generally characteriztic of the lithogenic fraction, permit us to consider the contents as representative of the natural levels for the area. For copper, zinc and lead, excepting more impacted stations, especially Stations 1 and 2, Blueflelds concentrations were similar to those in non-polluted sites in Cuba.

No correlations were found ($p < 0.05$) among zinc, manganese, copper and iron; however, principal component analysis showed a different pattern for zinc. Histograms, dendrograms, principal component analysis as such as an urban-industrial pollution index (González and Ramírez, 1995) for both digestions, showed Stations 1 and 2 have a different behaviour due to their higher pollution level

TABLE V Concentrations of heavy metals ($\mu g \cdot g^{-1}$ d.w.) in *Crassostrea rhizophorae*

	$\bar{X}$ (*range*)	
	April 1995	*November* 1995
Cu	343(269–430)	478(325–592)
Fe	901(652–1143)	560(243–686)
Mn	68(54–90)	33(15–61)
Ni	< 2.5	< 2.5–6.1
Pb	< 2.5–3.6	< 2.5
Zn	1701(1246–1978)	1758(1410–2216)

than the other stations. Stations 17, 18 and 19 have the lowest metal contents. They are placed in the southwest zone of the bay, characterised by low depths and limited exchange of water and are the most remote from the potential pollutants sources, all features permit us to consider them as a reference for the study zone.

Oysters: zinc, iron and copper showed greater concentrations than other elements (Tab. V). Similar results for bivalves and zinc contents for this species and *C. corteziensis* were previously reported (Villanueva *et al.*, 1988; Osuna-López *et al.*, 1990; Campos, 1991; Herńndez and González, 1993). Commonly the maximum concentrations of zinc in marine biota appear in filtering organisms, such as oysters (Eisler, 1981). Metal contents in oysters do not show the same distribution pattern than in sediments. Remoteness to the city and/or intrinsic factors other than pollution might be the explanation. Thus, oyster, *Crassostrea rhizophorae*, does not reflect pollution levels.

CONCLUSIONS

Heavy metal levels in sediments and oysters from Bluefields Bay, can be considered this area as relatively unaltered by metal pollution, except the surrounding area to Bluefields City on account of the city waste waters.

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