

INTERTIDAL BEACH SANDS AS MONITORS FOR HEAVY METAL  
POLLUTION IN COASTAL WATER BODIES

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ABSTRACT

Intertidal beach sands were investigated for their use as indicators of metal transport in a contaminated water body, Sepetiba Bay, Rio de Janeiro, Brazil, and are proposed as an alternative and rapid screening method to determine metal pollution status of coastal areas. The results showed that, at least for Cu, Cr, Zn and Pb, beach sands can be included in the existing environmental monitoring programs for heavy metal pollution in water bodies.

INTRODUCTION

Intertidal sediments have been recently proposed as good indicators of the heavy metal pollution status of water bodies due to the ease of collection and analysis (10). Most of the sediments used for this purpose have been fine silt and/or clay (3), due to their higher metal adsorbing and thus accumulating capacity. Sandy sediments, however, have been generally neglected in such studies, because of their large particle size and mineral composition (mostly silicious) which generally prevents high metal accumulation.

Intertidal sands can sometimes contain high levels of heavy metals derived from natural sources, e.g. in placer deposits (1), however, where these natural anomalies are absent, metal contents of sands are basically derived from aqueous solution, either by the adsorption of iron-manganese oxides on the grain surface or by the deposition of suspended particulate matter by tides. Both processes will indeed reflect the overall concentration of metals of the surrounding waters, creating the possibility of using sands as a monitor of the pollution status of the area.

Taking the necessary care in collecting only the superficial layer representing the recently deposited water derived metals as well as avoiding the possible mixture of old depositional horizons, intertidal beach sands may be a rapid screening tool for metal monitoring of water bodies, where collection and filtration of large volumes of water or collection of bottom sediments are difficult.

The present study investigates the use of intertidal beach sands as an indicator and tracer of heavy metals in a polluted water body by comparing their metal content and distribution with those of

suspended particles and bottom sediments already determined for the area.

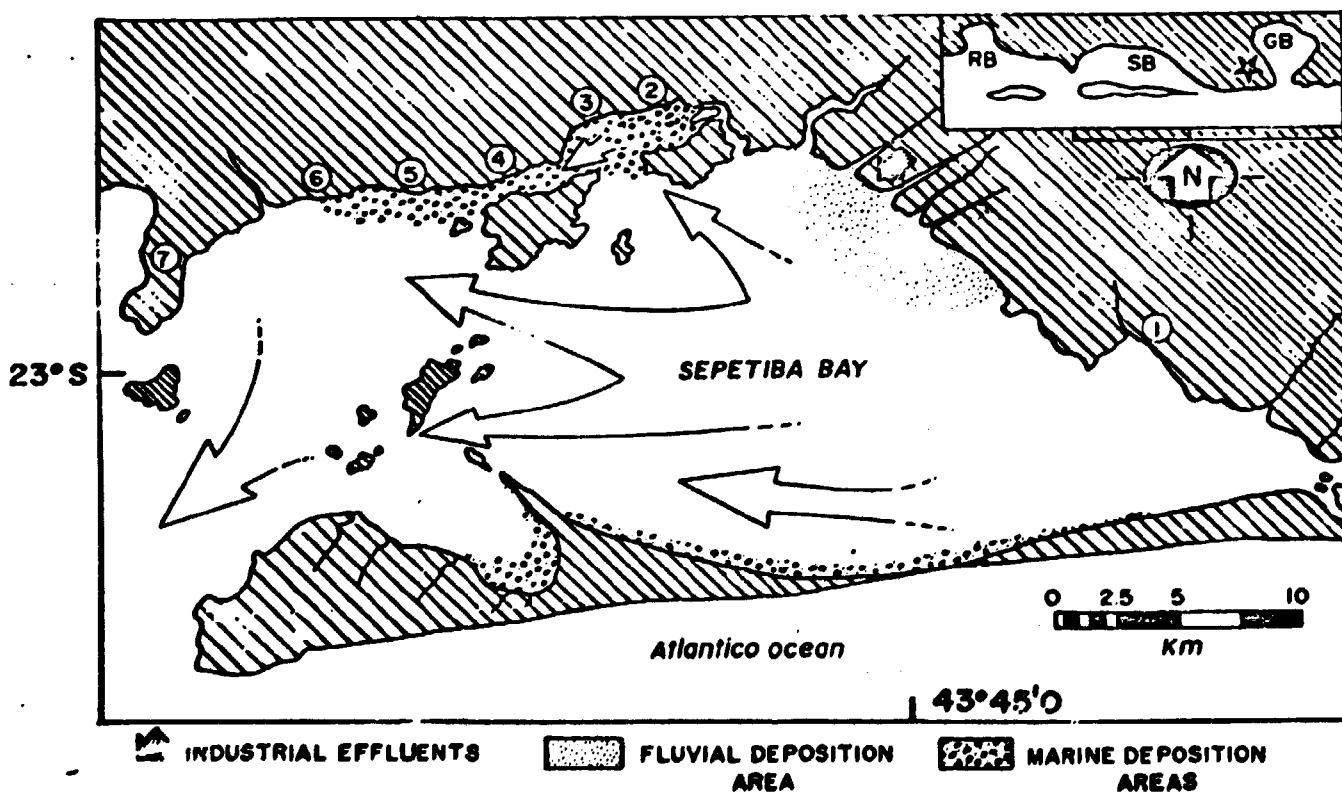
### Study site

The study was carried on in Sepetiba Bay, a semi-enclosed water body, approximately 60 km South of Rio de Janeiro city. The main surface currents follow bottom topography and are controlled by tides (4). They have been reported as responsible for the heavy metal transport associated with suspended particles in the bay (8). Surface currents and depositional areas are presented in Figure 1. Most of the northern coastline of the bay is formed by small sandy beaches separated by rocky points, and at the outlets of rivers one finds small mangrove areas. The south coast of the bay presents a continuous fringe of mangrove and was therefore sampled.

No naturally metal-rich sand deposits are known in the area (Studervart, per. comm.) and therefore the metal content of sands are likely to be derived mainly from a metallurgic industrial park located along the bay's North-Eastern coast, whose effluents are released in the bay through rivers, almost in a single point at the bay's coast. Once reaching the bay they are preferentially transported by suspended particles along the North coast turning it into the most contaminated area of the bay (8).

### MATERIALS AND METHODS

Sands were collected from 7 beaches covering the bay's entire North coast, avoiding the proximity of mangrove areas river deltas and urban centers (Fig.1). Collection was carried out by hand at the intertidal level during two sampling periods



RB- RIBEIRA BAY SB- SEPETIBA BAY GB- GUANABARA BAY ★ - RIO DE JANEIRO CITY

Figure 1 - Studied area indicating sampling points and some local characteristics

(November, 1980 to March, 1981 and March 1982). Only the top 2cm sand layer was collected in order to avoid possible mixture with old stratified layers and to include only the recently deposited material brought in by the tides. Thus metals present in these samples are basically those present in deposited suspended particles and adsorbed on the grain's surface from solution. Due to sampling difficulties normally associated with collecting sands, 10 samples per beach were collected in the first sampling period, covering the entire length of each beach. The low variability (coefficient of variation C.V. < 15%) found among samples of the same beach confirmed the uniformity of metal distribution within a given beach, therefore during the second sampling period only 3 samples per beach were collected. All samples were analyzed individually and the results pooled to represent a mean for each beach.

Sands were sieved through 1.0 mm pore sieves to uniform particle size, dried at 105°C for 24 h, and aliquots of 10 g dried sand were digested with hot 5M HNO<sub>3</sub>, evaporated almost to dryness, redissolved in 0.1M HCl and filtered through Watman 44 filter papers. Diluted acid extractions (0.1M HCl) were also performed in composite samples from each beach. This method was proved to extract metals not incorporated into the lattice structures of the mineral components of the bottom sediments, that is, only the metals more sensitive to the environmental physico-chemical changes were extracted (6). Therefore it was used here to check its usefulness in analysis of sand as an extractant of metals retained on their surfaces and also to confirm the results obtained with the total extraction procedure. The filtrate (30 ml) for both techniques was analyzed in a Varian Technicon Atomic Absorption Spectrophotometer AA-120, and the results expressed in  $\mu\text{g g}^{-1}$  of dried sands.

Granulometric analysis of the samples were also performed in order to quantify the content of particles with mean diameter lower than 63  $\mu\text{m}$ . This fraction was similar and > 0.05% in weight for all beaches, therefore it was not considered as an interferer in the results.

## RESULTS AND DISCUSSION

The diagram in Figure 2 shows mean heavy metal concentrations determined in the two sampling periods. Although quantitative variability between periods was detected, the distribution pattern of all metals remained the same, showing that conditions are quite constant with time.

The highest concentrations for all metals were determined at stations 3, 4 and 5. This area is characterized by a large depositional area of material transported by two of the principal surface currents of the bay (4) which can be seen in Figure 1. This area was also concluded to be the most contaminated area in the bay, thus metal contents in intertidal beach sands seems to reflect the general pattern of distribution of metallic pollutants in the bay (8).

A correlation analysis between pair of metals in all samples presented highly significant coefficients, at levels between 95% and 99% (ranging from 0.834 to 0.986 and from 0.763 to 0.973, for the two sampling periods respectively). This result suggests that the same processes are responsible for the distribution of all metals in the bay. This kind of analysis has been used with success to detect similarity of sources among metals in various environmental studies (3).

Table 1 shows the comparison between metal concentrations in sands as extracted by the two extraction techniques described. The weakly acidic procedure extracted different metal percentages

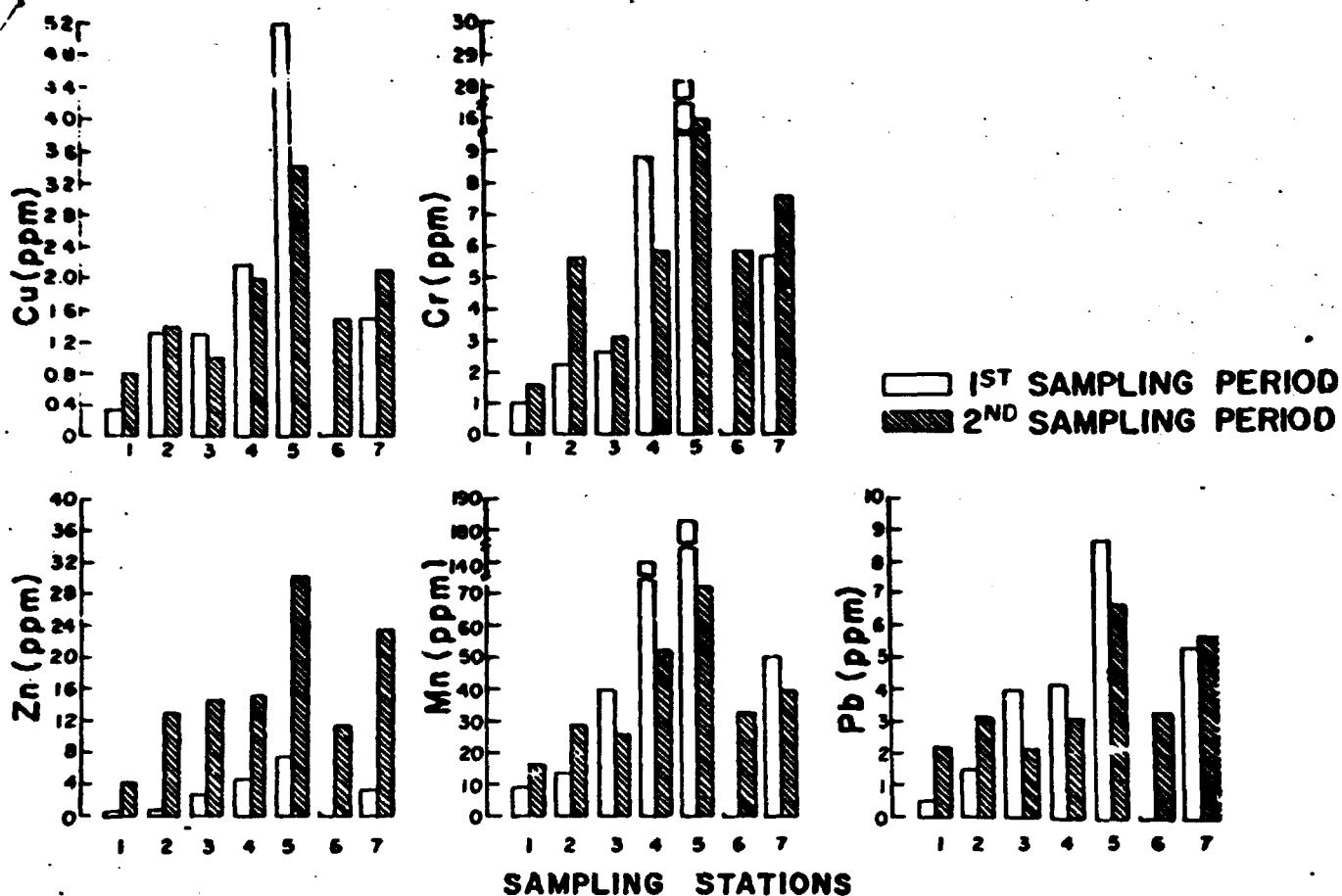


Figure 2 - Diagram of mean heavy metal concentrations at sampling points in two collecting periods.

from the total present in sands depending on the metal. However it did show the same relationship among the different metals as the strong treatment did, confirming its applicability for the study of metal contamination of sands in the same way as it has been used with success for other kinds of sedimentary material (6).

Table 1 - Comparison of metal distribution and concentrations in intertidal beach sands in Sepetiba Bay, Rio de Janeiro as extracted by different acidic treatment

Sample Treatment	Metal Concentrations in $\mu\text{g g}^{-1}$ (Means)*				
	Mn	Zn	Cr	Cu	Pb
Beach Sands Total	85	13	11	2.5	4.8
0.1M-HCl	37	6.7	2.2	0.5	1.6

\* CV (< 15%)

The possibility of using metal concentrations in beach sands as a rapid indicator of the general status of metal pollution in coastal water bodies other than Sepetiba Bay, was evaluated. The mean values of the most contaminated area in Sepetiba Bay (stations 3, 4 and 5), were compared with reported results of metal concentration in beach sands of two similar water bodies in Rio de Janeiro State: the Guanabara Bay, which receives effluents from both industrial and urban sources of the Rio de Janeiro city area (5); and the Ribeira Bay, an unpolluted area approximately 200 km from

Rio de Janeiro city (7). The geographical location of the three areas is presented in Figure 1.

The comparison of the three areas is presented in Table 2. The results reflected the general status of heavy metal contamination of each area. The lowest values are those of the unpolluted Ribeira Bay, with the exception of Pb, which has been reported to be present in anomalously high concentration in the area (7). The value found for the Guanabara Bay, which came from an area of heavy pollution, again reflected the general status of the water body whose principal pollutants are Cr, Cu and Zn (9). For the Sepetiba Bay the results again reflected the overall pollution of the bay whose main contamination has been reported as due to Cr and Zn.

**Table 2** - Comparison of total concentrations in beach sands ( $\mu\text{g g}^{-1}$ ) of distinctively contaminated water bodies of the Rio de Janeiro State\*\*.

	Cu	Cr	Zn	Mn	Pb
Guanabara Bay (6)	15.4	80.9	36.1	67.7	-
Ribeira Bay (7)	2.2	3.5	1.1	-	5.2
Sepetiba Bay* (this study)	2.5	10.7	12.7	85.3	4.8

\* Mean values for the most contaminated stations.

\*\* CV (< 15%)

The data on Mn found in beach sands (pg 2) follows the general pathway showed by the other metals analyzed in Sepetiba Bay. The strong positive correlation ascertained between Mn and other elements might reflect the role of hydrous Mn oxides in the sorption of trace metals from the aqueous solution.

In conclusion, the analysis of metal concentration in beach sands, was able to classify the three water bodies in terms of their general status of contamination. It was even capable of identifying the principal metals involved in each case, thus proving to be a powerful instrument for preliminary surveys of metallic contamination in coastal areas, at least for the metals analyzed in this study. These results may also be important in the settlement of environmental monitoring programs for the nuclear industry, since beach sands can be a significant source of external irradiation to man.

#### ACKNOWLEDGEMENTS

The authors express great thanks to Financiadora de Estudos e Projetos (FINEP); Comissão Nacional de Energia Nuclear (CNEN) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for the financial support and a grant (Proc.No.400229/83) to L.D.L. Thanks are also due to Mr.W. Bastos for help with the analysis and to Miss Z. de Freitas for the typing work.

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