

# Heavy metal contamination of the Lami coastal environment, Fiji

Philomena Gangaiya<sup>1\*</sup>, Jioji Tabudravu<sup>1</sup>, Robin South<sup>2</sup> and Subramaniam Sotheeswaran<sup>1</sup>

<sup>1</sup>Department of Chemistry, School of Pure and Applied Sciences,  
The University of the South Pacific, Suva, Fiji

<sup>2</sup>Marine Studies Programme, The University of the South Pacific, Suva, Fiji

**Abstract:** Contamination of the coastal environment of small island countries is of concern because people's livelihoods in these countries are intimately linked to the resources of the coastal zone. The Lami estuary in Fiji is located downstream of an industrial area and is used extensively for fishing and other recreational activities. Sediment samples from twenty-nine sites within the area were analysed for copper, lead and zinc to determine whether the area is contaminated with heavy metals. Within the estuary, significant enrichment is evident, with heavy metal concentrations exceeding some of those from other known contaminated sites in the country. Although copper contamination appears to be restricted to a few sites within the estuary, contamination with lead and zinc seems to be spreading to areas further away from the shore. Metal distribution patterns clearly indicate adjacent factories to be the main source of contamination. The results show that contrary to popular belief, highly contaminated sites do exist in the relatively pristine coastal environments of island countries like Fiji.

**Keywords:** Heavy metals, coastal, contamination, enrichment factor, sediment, Fiji

## 1 Introduction

Environmental contamination from heavy metals is of concern because they exhibit behaviour consistent with those of persistent toxic chemicals. Unlike many organic contaminants that lose toxicity with biodegradation, metals can not be degraded further and their toxic effects can be long lasting (Clark, 1992). And whilst their concentrations in biota can increase through bioaccumulation, heavy metals are also known to have toxic effects at very low concentrations (Davey *et al.*, 1973).

Sediments play a useful role in the assessment of heavy metal contamination (Forstner & Wittmann, 1981). This is because in unperturbed environments, heavy metals are preferentially transferred from the dissolved to the particulate phase and as a result metal concentrations in sediments are generally much higher than in the overlying water and therefore more easily detected (Bryan & Langston, 1992). The advantage of using sediments then is that the analytical problems associated with the detection of low but significant amounts of metals in water do not have to be addressed. Also, continuous monitoring of water is not necessary as sediment concentrations indicate contamination loads over longer periods of time (Forstner, 1989).

The Lami estuary is about 4 km from the port of Suva, the capital of Fiji. Within about a km west of the estuary is the Bay of Islands, an area of immense natural beauty which has great potential for tourism related developments. The site already has a hotel and many yachts visiting Suva anchor in the area. The people of Suva also use the coastal stretch around this area for recreational purposes and for subsistence fishing (Naidu *et al.*, 1991). Whilst there are many additional ways in which people can benefit from the resources in the area, possible

contamination from various land-based sources is a matter of concern. Existing data, although limited, suggest contamination is prevalent in other parts of the surrounding coastal environment (Naidu & Morrison, 1994) but no such data exists for the Lami estuary. The presence of various metal-based factories in this area and the poor state of waste management in the country suggest contamination of the coastal area could be occurring. This paper reports results of investigations into whether contamination is occurring and if so, the extent to which the environment is affected.

The Lami estuary lies on the south-eastern side of the main island of Fiji (Figure 1) and upstream are several factories, some of which are involved in paint manufacture, battery recycling and zinc galvanising. The estuary drains into Suva harbour along which another industrial area and an open rubbish dump are also located. These areas are however physically well separated from the Lami estuary.

## 2 Materials and Methods

The twenty-nine sites selected for sediment sampling are shown in Figure 2. They included one from the upper reaches of the Lami river (Site 1), several sites close to the factories (Sites 2 to 8) and a number along the shoreline (Sites 9 to 18 except 12) and the inter-tidal area (Sites 19 to 29 and 12). Salinity measurements showed that Site 1 was beyond the tidal reach and hence it was considered to be a potentially clean site, which was not affected by any discharges from the industrial area. Site 18, located in the contaminated foreshore area of the open rubbish dump mentioned above, was included for comparison against the Lami sites.

Sediment samples were collected using a plastic scoop into acid-washed plastic bags and transported to the laboratory where the fractions less than 75  $\mu\text{m}$  were separated for analysis. Five samplings over a period of one year at approximately two-month intervals were carried out. For assessment of contamination, the method of (Manuwadi & Chaiyong, 1983) was used in which heavy metals extracted by molar nitric acid is assumed to represent the amount that has been acquired through contamination. In this method, about a gram of sediment is mixed with 10  $\text{cm}^3$

molar nitric acid and heated to 150  $^{\circ}\text{C}$  for 10 minutes. A further 10  $\text{cm}^3$  of molar nitric acid is added and heated after which the mixture is filtered and the filtrate analysed for metals. Copper, lead and zinc concentrations were determined using flame atomic absorption spectrometry. Standard operating procedures for the analysis of metals were used. A reference material for marine sediments (BCSS-1) which is certified for total metal content was analysed for total metals and the reliability of the instrumental technique was verified.

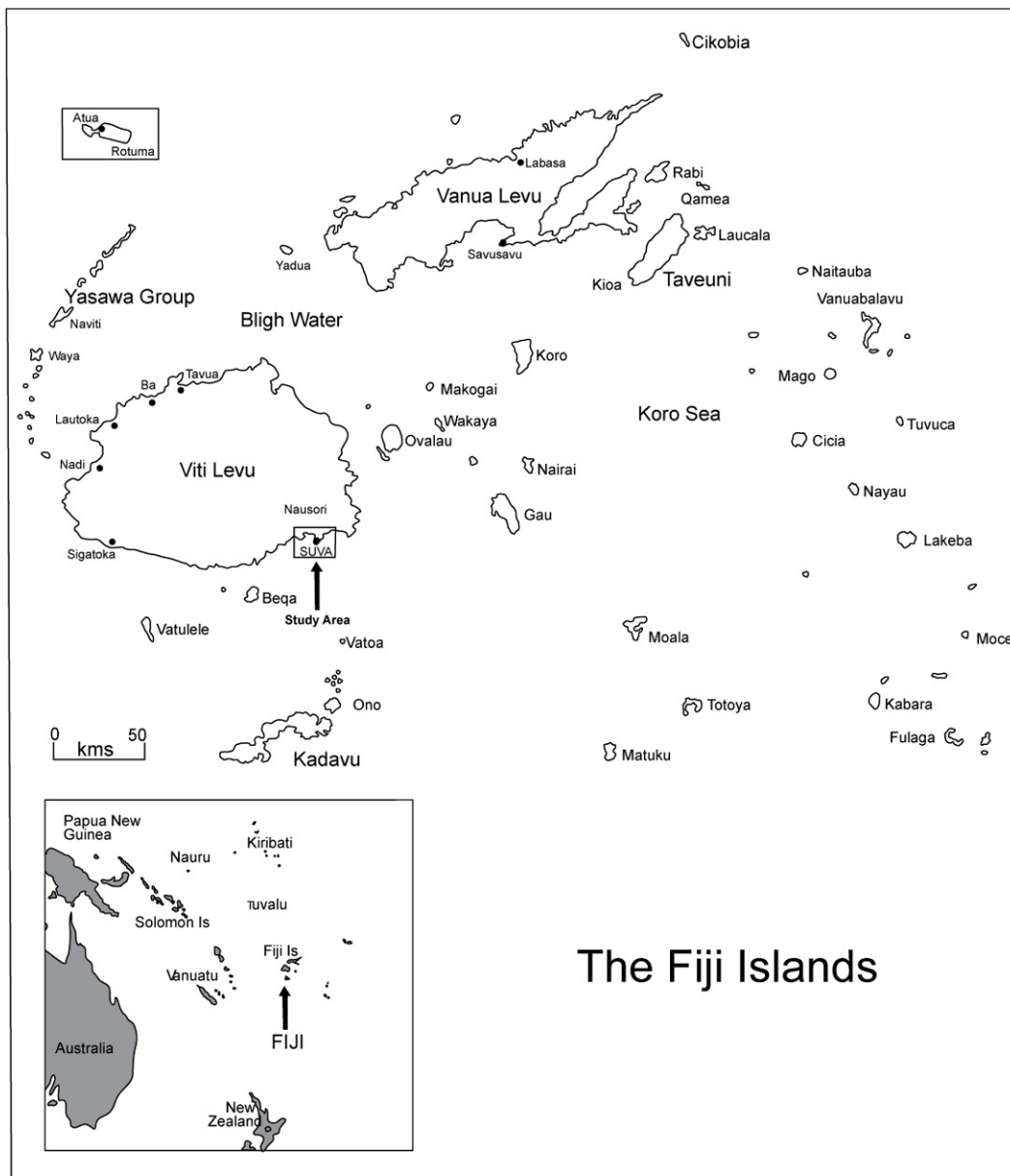


Figure 1. Map of Fiji showing study area.

Fig 1

### 3 Results and Discussion

The results of the analysis of the certified reference material are given in Table 1 along with the certified values. Good agreement with certified values was obtained for all three metals.

Table 2 gives the means and coefficients of variation of heavy metal concentrations in sediments obtained over the

sampling period. The coefficients of variation are quite large at some sites, particularly at sites closer to the factories and the river mouth when compared to sites further out from the shore. This is not unexpected since, in an estuarine environment, sediments are usually continually being reworked (Grumagalz *et al*, 1989) and if heavy metal inputs are also sporadic, then variations are

inevitable. In spite of the variation the data clearly show significant differences between sites, particularly when

compared to Site 1.

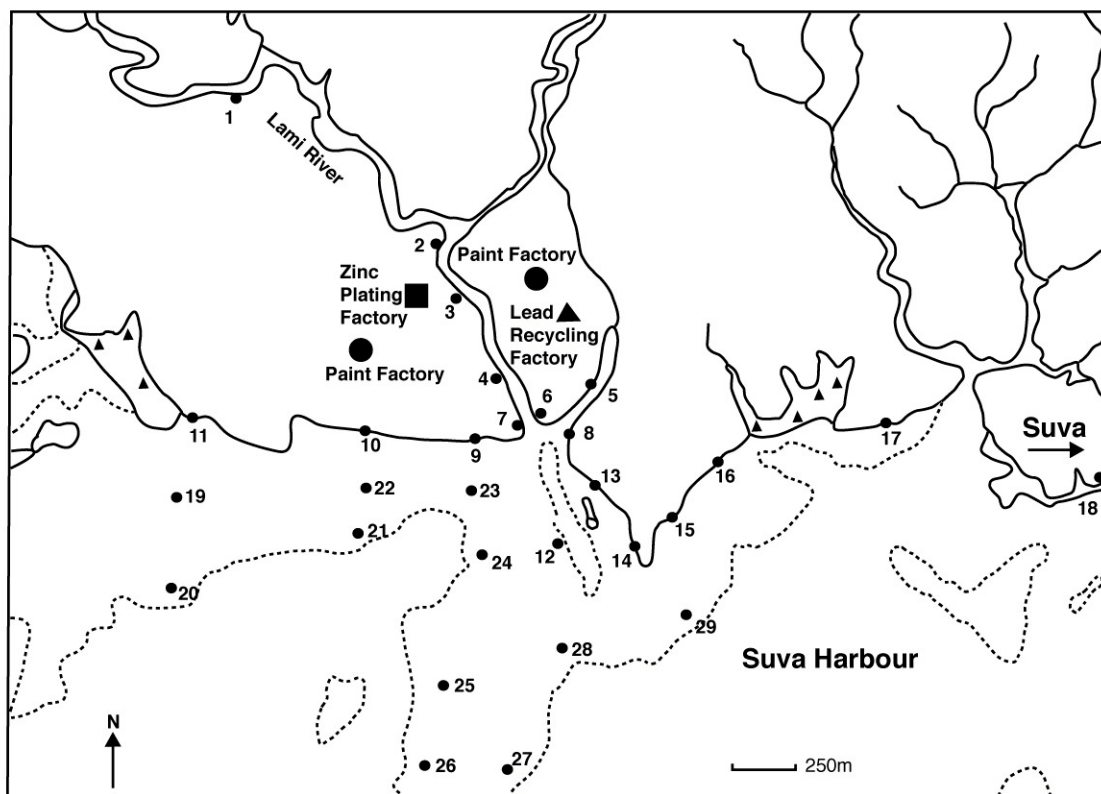


Fig 2

Figure 2. Location of sampling sites.

Table 1. Metal concentrations (mg/kg) in the certified reference material (BCSS-!).

Metal	Copper	Lead	Zinc
Experimental value	20.2 ± 1.2	19.8 ± 3.2	115 ± 5.6
Certified value	18.5 ± 2.7	22.7 ± 3.4	119 ± 12

The high values around Sites 2 to 8 suggest contamination could be a key factor in explaining the results obtained. For determining the degree of contamination at a site, an enrichment factor for the site was determined, which was calculated as ratio of the metal concentration at the site to that at Site 1. Since Site 1 is considered to be free of contamination, a ratio significantly greater than 1 at another site indicates contamination. The method used here for calculating the enrichment factor would strictly only be valid if the metal binding capacity of sediments in the rest of the study area is the same as at Site 1. This would ensure that differences in enrichment factor are not due to differential preferences for heavy metals. All other factors being the same, sediment constituents and their individual binding capacities determine metal binding capacity of whole sediments (Helmke *et al*, 1977). Sediments containing a lot of terrigenous material, for example, could have greater capacity to bind metals than marine-derived sediments because of the presence in the former of minerals such as iron and aluminium oxides and hydroxides which bind metals strongly (Bryan & Langston, 1992). Although no measurements on sediment

composition were made, visual observations indicated significant amounts of terrigenous material at all sites. Also, materials of terrigenous origin usually constitute the finer fractions of sediments (Salomons & Forstner, 1984), and since in this study only the < 75 µm fraction was used, the fractions analysed could quite possibly be very similar in composition and binding capacities. This method of calculating the enrichment factor is therefore not inappropriate. Even if significant differences in composition existed, this approach can still be valid so long as the metal binding capacity at other sites did not exceed that at Site 1. This in most probability was the case as the lack of marine influence at Site 1 suggests this site had the highest amount of terrigenous material and therefore also the highest metal binding capacity. Under these circumstances, using Site 1 as a reference point could result in an underestimate, but never an overestimate, of the extent of contamination at other sites. Consequently, an enrichment factor significantly greater than 1 indicates a strong possibility that contamination has occurred.

**Table 2.** Heavy metal concentrations in sediments ( $\mu\text{g/g}$  dry weight) in the Lami estuary.

Site	Copper		Lead		Zinc	
	mean	c.o.v. (%)	mean	c.o.v (%)	mean	c.o.v (%)
1	29	12	4.2	36	52	6
2	32	34	5.5	82	123	35
3	51	45	455	46	77	40
4	57	49	53	76	514	42
5	1980	39	516	23	460	45
6	58	4	71	36	242	10
7	63	19	103	27	396	18
8	36	17	27	48	169	14
9	21	19	24	38	155	24
10	26	35	60	33	204	25
11	16	19	18	67	128	2
12	22	23	14	43	155	9
13	26	23	25	24	210	14
14	24	29	28	36	282	26
15	28	32	32	31	233	24
16	24	21	25	48	192	20
17	24	46	37	43	198	29
18	200	3	305	2	267	4
19	9	3	10	3	92	5
20	5	20	12	9	55	11
21	9	6	9	3	99	8
22	14	5	12	3	116	3
23	9	12	7	1	103	13
24	8	6	8	1	101	8
25	12	3	13	1	101	3
26	17	5	7	4	138	12
27	9	1	7	1	254	1
28	17	10	12	8	87	8
29	20	2	12	5	82	9

c.o.v. coefficient of variation

The spatial distributions of enrichment factors are given in Figure 3, which show significant enrichment at sites closer to the factories. Some enrichment factors within this area are considerably higher than the value obtained for Site 18, previously thought to be one of the most contaminated sites in the area. The pattern of distribution of enrichment factors clearly indicates the source of contamination to be land-based and implicates the factories in the adjacent area to be the most likely source. The status of waste management in Fiji is very poor mainly because of the lack of sufficient deterrence against improper disposal practices (Watling & Chape, 1992). Factories often discharge wastes virtually untreated into the nearest waterway. Clearly, results such as those obtained in this study show that the impact on the environment can no longer be ignored and reinforce the need for action to improve the management of wastes.

Of concern also is the extent to which the contamination has spread. For copper, enrichment factors are greater than 1 at only a few sites close to the factories, with all other sites showing no indication of enrichment. Contamination from copper therefore appears to be restricted to a small area within the estuary. The distribution of enrichment factors for zinc and lead, however, indicate that contamination may be spreading further out into the coastal environment. At Sites 26 and

27, which are more than a kilometre from the river mouth, enrichment factors of 2 or greater were obtained. Zinc is known to be relatively mobile but the spread of lead is surprising, as it is considered to be relatively immobile, like copper (Sposito, 1984). The reason for this could be that the chemical form in which lead is being released perhaps prevents its immediate removal by the sediment phase and allows it to be carried further out from the shore in the dissolved state.

Table 3 gives heavy metal concentrations obtained for the Lami estuary in comparison to other known contaminated sections of the coastal stretch of Suva harbour. The data for other sites represent total metal concentrations whilst Lami estuary data represent molar nitric acid extractable metals. These include sites from within and the immediate environs of the open rubbish dump and beside a battery factory in another nearby industrial area. The dumping of used batteries in the foreshore area at the second site explains the extremely high values for lead. The method used for determining heavy metal content at the other two locations involved complete dissolution of sediments using a mixture of nitric, hydrochloric and hydrofluoric acids and as such the data represent the total metal content of sediments.

**Table 3.** Comparison of heavy metal concentrations ( $\mu\text{g/g}$  dry weight) with other known contaminated sites in Fiji.

Location	Copper	Lead	Zinc	Reference
Lami estuary	5 – 1980	4 – 516	52 – 514	This study
Lami rubbish dump	59 – 306	19 – 272	88 – 487	Naidu & Morrison (1994)
Battery factory	64 – 1151	0.2 – 27%	250 - 1063	Naidu & Morrison (1994)

The results of this study represent that portion of heavy metals that could be extracted with molar nitric acid – the total amounts in these sediments could obviously be more. Although the data given in Table 2 are not directly comparable, the values nevertheless confirm Lami estuary to be another significant contaminated site within the Suva harbour area that deserves attention.

## 4 Conclusions

Copper, lead and zinc concentrations in sediments at certain sites within the Lami estuary are higher than in other areas along Suva harbour previously considered to be highly contaminated. Although this study was not concerned with assessing the impact of contamination on the area's living resources, the high concentrations detected and the apparent spread of contamination to areas further afield could be causing harmful effects. Efforts towards site remediation must include a thorough assessment of waste management practices of industries located upstream of the estuary.

## 5 Acknowledgement

This project was supported, in part, by the Canada-South Pacific Ocean Development Programme (C-SPOD), through the provision of a postgraduate scholarship to J.N. Tabuadravu.

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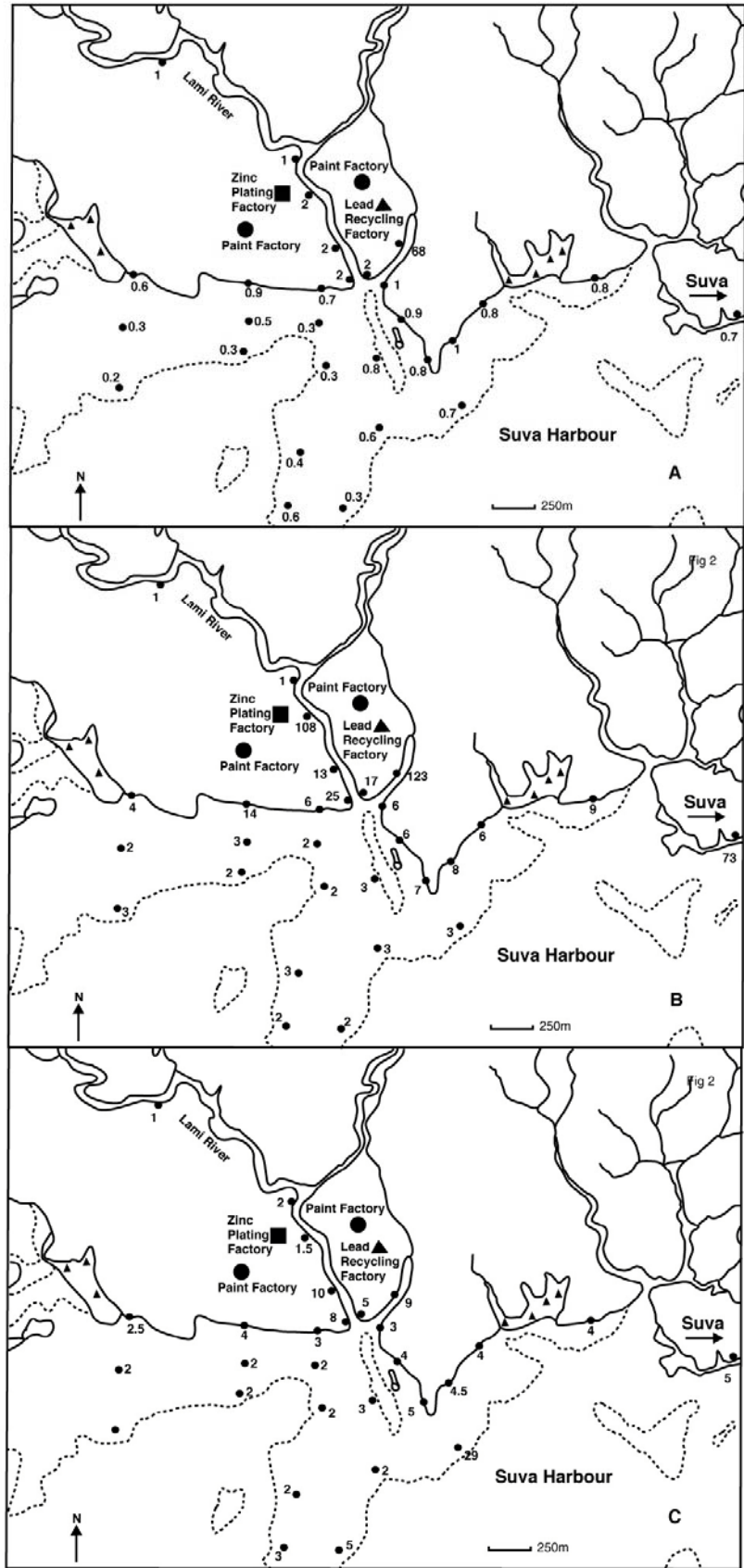


Fig 3

Figure 3. Distribution of enrichment factors (A) copper, (B) lead and (C) zinc.