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Impact of a coastal dump in a tropical lagoon on trace metal concentrations in surrounding marine biota: A case study from Saipan, Commonwealth of the Northern Mariana Islands (CNMI)

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Solid waste disposal facilities (dumps/landfills) have long been known as sites of potential environmental problems, unless they are very well managed (Lisk, 1991). This is particularly true if such facilities are located near water bodies. In the Pacific Islands, many past urban solid waste disposal sites were situated on the coast and, in most cases, were little more than open dumps (Morrison and Munro, 1999). These operations usually were ineffectively managed, with minimal control on the materials dumped and no impervious lining or leachate control (SPREP, 2006). The Puerto Rico Dump in Saipan, CNMI, is one such example and served as the island's primary waste disposal site for over 50 years before its closure in February, 2003. This 8 ha site sits directly on the coast at the southern end of Tanapag Lagoon, a typical high-island barrier reef lagoon bordering the western shore of Saipan (Fig. 1) and is rumoured to contain a plethora of toxic chemicals of both military and civilian origin (Ogden Environmental and Energy Services, 1994). Trace metal enrichment of subtidal sediments from around the base of the dump has previously been identified (Denton et al., 2001, 2006). The preliminary study described herein examines the metal status of dominant ecological representatives collected close to the dump and other known or suspected sources of trace element contamination in the lagoon including two marinas, a sea port (Port of Saipan) and dry dock area, and a power plant.

Biota and surface sediments were collected from 12 intertidal sites in Tanapag Lagoon (Fig. 1) over a two week period in June 2003. Site details and sediment characteristics are summarized in Table 1. Biota samples were collected on either low or falling tides. Preference was given to species with known or suspected bioindicator potential as well as those traditionally harvested for food by local residents. Any size effects were minimized by selecting similar sized representatives for analysis from each site. A complete list of organisms taken for analysis, together with their respective collection sites are shown in Table 2. Not all species were available at all sites. Juvenile fish were captured in shallow water (<1 m depth) using a cast net and immediately placed in chilled containers. In the laboratory, axial muscle was taken for analysis from pooled samples of from one to six fish depending upon the species and size of individuals caught. All other biotic representatives and surface sediments were collected and processed as previously described along with all analytical methods and QA/QC protocols (Denton and Morrison, 2008). Metal recoveries from standard reference materials (soil, orchard leaves and albacore tuna) were within satisfactory limits.

The sediment metals concentrations are summarized in Table 3. Levels of copper, lead, and zinc in sediment from the base of the dump (Site 2) were at least two orders of magnitude higher than the lowest values determined elsewhere in the lagoon, while values for silver, cadmium, chromium, mercury and nickel were at least one order of magnitude higher. Relatively high concentrations of copper, zinc and lead were determined in sediment from Seaplane Ramps (Site 4) and lead enrichment was apparent at CUC Beach (Site 5). The generally lower metal concentrations in sediments from the northern half of the lagoon reflect less extensive

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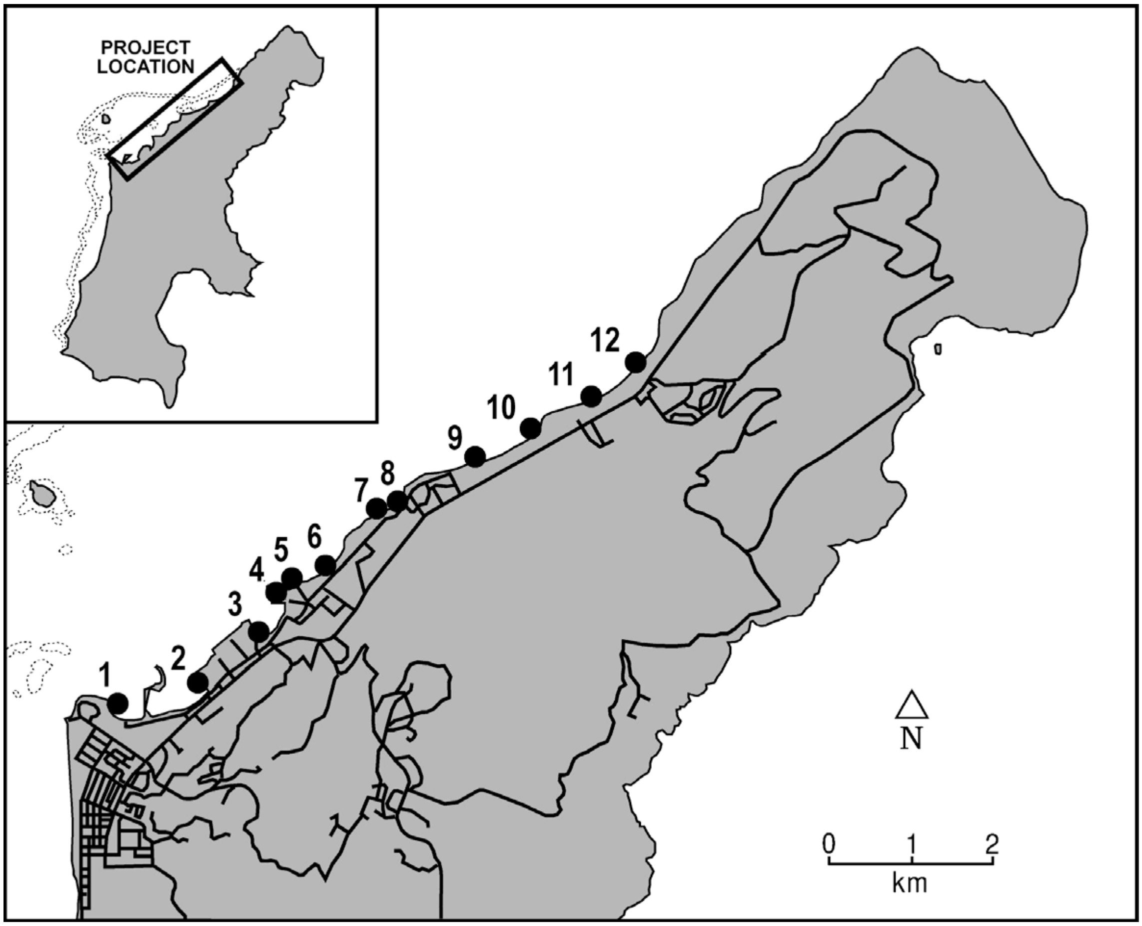

Fig. 1. Biota and sediment sampling site locations in Tanapag Lagoon, Saipan.

anthropogenic activity in this area. The comparatively high mercury value found in sediment from the mouth of Saddok Dogas (Site 8), a small stream that feeds into a relatively remote part of the lagoon, was unexpected. A possible connection with past military activities further upstream remains to be examined. Sedimentary arsenic concentrations were low throughout the study area with most samples yielding values of <3 μg/g. Such low levels are typical of uncontaminated marine sediments in this part of the world (Denton et al., 2005a, 2006; Denton and Morrison, 2008). Significant positive correlations (coefficients all >0.8) were found between sediment concentrations of most metals with the notable exception of arsenic which showed no strong relationship to any other element studied. Particularly strong relationships (coefficients all >0.9) were found between cadmium, chromium, copper, nickel, lead and zinc, while mercury was less well correlated with these elements.

The biota data are presented in Tables 4–8 and were evaluated by comparative assessments with similar and related species from elsewhere. Of particular importance here was the information available for identical species of algae, seagrass, seacucumbers and bivalves from a relatively clean bay off the eastern coast of central Guam, ~120 nautical miles SSW of Saipan (Denton and Morrison, 2008).

Biotic silver concentrations were close to or below analytical detection limits in most species with the notable exception of *Quidnipagus palatum* from Site 2 (Table 7). This species appears to be particularly sensitive to changes in the ambient availability of silver and clearly highlights the mild enrichment noted in the surrounding sediment. No unusual arsenic concentrations were found in any of the organisms analysed in this study. There was also no compelling evidence to suggest a significant net increase in cadmium concentrations had occurred in biotic components near the dump despite the significant enrichment noted in sediment at the base of this facility.

Chromium levels in algae and seagrass from uncontaminated waters usually range between 1 and 3 μg/g (Denton et al., 1980; Denton and Burdon-Jones, 1986) and concentrations found in specimens from Tanapag Lagoon are in agreement with this (Tables 4 and 5). While seacucumbers clearly compartmentalized chromium in their hemal tissue (Table 6), there was no obvious relationship between levels accumulated and those in surrounding sediments. Chromium concentrations in marine molluscs normally lie between 0.5 and 3.0 μg/g (Eisler, 1981). Values recorded in Tanapag Lagoon (Table 7) ranged from less than 1 μg/g in *Ctenna bella* from Micro Beach (Site 1), to over 10 μg/g in *Asaphia violascens* and *Q. palatum* near the dump (Site 2). Levels in the latter species were at least an order of magnitude higher than in their Guam counterparts (Denton and Morrison, 2008). These data provide additional evidence of light to moderate chromium enrichment near the dump and highlight the bioindicator potential of both species for this element.

Marine plants normally contain copper levels of less than 10 μg/g except near polluting sources where values in excess of 50 μg/g are not uncommon (Moore, 1991). Copper concentrations recorded in seaweeds and seagrass during the present investigation were almost always less than 10 μg/g. The notable exceptions were at Seaplane Ramps (Site 4) were levels ranged from 25 to 30 μg/g in algae and approached 50 μg/g in seagrass (Tables 4 and 5). These data infer elevated levels of dissolved copper exist in the water column