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Gary R. W. Denton [a], Michael S. Trianni [b], Brian G. Bearden [c], Peter C. Houk [d] & John A. Starmer [d]

[a] Water and Environmental Research Institute (WERI) of the Western Pacific, UOG Station, University of Guam, Mangilao, Guam, USA

[b] Saipan Department of Lands and Natural Resources, Division of Fish and Wildlife, Saipan, USA

[c] Saipan Division of Environmental Quality, Saipan, USA

[d] Pacific Marine Resources Institute, Saipan, USA

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IMPACT OF A MEDICAL WASTE INCINERATOR ON MERCURY LEVELS IN LAGOON FISH FROM A SMALL TROPICAL ISLAND IN THE WESTERN PACIFIC

Gary R. W. Denton[1], Michael S. Trianni[2], Brian G. Bearden[3], Peter C. Houk[4], John A. Starmer[4]

[1]Water and Environmental Research Institute (WERI) of the Western Pacific, UOG Station, University of Guam, Mangilao, Guam, USA
[2]Saipan Department of Lands and Natural Resources, Division of Fish and Wildlife, Saipan, USA
[3]Saipan Division of Environmental Quality, Saipan, USA
[4]Pacific Marine Resources Institute, Saipan, USA

In 2004–2005, several species of marine fish were collected for mercury (Hg) analysis from Saipan Lagoon, Saipan, Commonwealth of the Northern Mariana Islands. Relatively high concentrations were found in representatives from the Hafa Adai Beach area located some distance from known sources of Hg contamination. A follow-up investigation aimed at identifying additional land-based sources of Hg in the area was launched in early 2007. The study identified a medical waste incinerator as the primary source of Hg enrichment. The incinerator was operational for about 20 years before it was closed down by the U.S. Environmental Protection Agency (EPA) in January 2006, for multiple violations of the Clean Air Act. Stormwater runoff from this facility entered a drainage network that discharged into the ocean at the southern end of Hafa Adai Beach, about 1 km away. At the time of this investigation storm drain sediments at the coast were only marginally enriched with mercury although values some 50x above background were detected in drainage deposits a few meters down-gradient of the incinerator site. Mercury concentrations in fish from the Hafa Adai Beach area were also significantly lower than those determined in similar species 3 yr earlier. The implications of the data are briefly discussed.

Saipan (15°18′0.93″ N, 145°75′59.97″ E) is the second most densely populated island in Micronesia and is located approximately 200 km north of Guam in the Mariana Archipelago. The island is about 20 km long, 9 km wide, and covers an area of approximately 115 km^2. While the eastern side of Saipan is composed primarily of rugged rocky cliffs, a barrier coral reef system on the western side creates a large lagoon that extends almost the entire length of the island. This stretch of shallow water is locally referred to as Saipan Lagoon and contains large expanses of patch reef interspersed with sand and rubble. This in turn provides for a diversity of shallow-water habitats that harbor rich assemblages of flora and fauna (Doty and Marsh 1977; Amesbury et al. 1979). Aside from Saipan Lagoon's ecological significance, it also supports a variety of recreational activities, and local residents traditionally harvest many of its fisheries resources at a subsistence level.

In 2004–2005, more than 300 popular food fish (65 different species) were collected for mercury (Hg) analysis from 9 sites within this region (Figure 1). While values in fish axial muscle were quantitatively elevated in representatives from around the municipal dump (site 6), concentrations were generally higher

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Address correspondence to Dr. Gary R. W. Denton, Water & Environmental Research Institute of the Western Pacific, University of Guam, Mangilao, GU 96923, USA. E-mail: gdenton@uguam.uog.edu

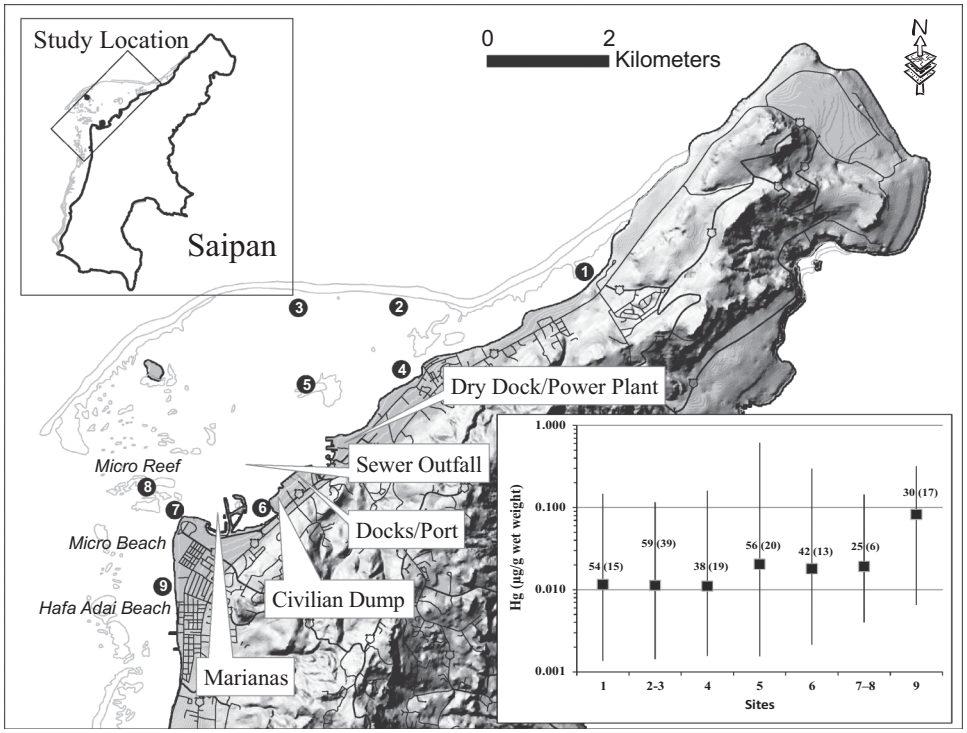

FIGURE 1. Portion of a 1:25,000 U.S. Geological Survey (USGS) topographical map of Saipan showing fish sampling sites 1–9 in the northern half of Saipan Lagoon. Bottom inset shows geometric means and ranges of mercury concentrations determined in fish from each site. Numerical values are total numbers of fish (and species) analyzed from each site. Potential sources of mercury pollution known to exist at the time of the investigation are also shown.

in specimens taken some distance to the south at site 9 (Denton et al. 2010). This particular stretch of Saipan coastline is known as Hafa Adai Beach and, together with Micro Beach immediately to the north, is a popular fishing, relaxation, and recreational area for tourists and local residents alike. The relatively high Hg values found in fish here were of interest, considering the aesthetic beauty of the area and the relatively large distance separating it from obvious pollution sources. In early 2007, a follow-up investigation searched for additional land-based sources of Hg in the area. The principle findings of this study are discussed herein.

MATERIALS AND METHODS

Coral sands were collected for Hg analysis at approximately 100 m intervals along the beach between Hafa Adai Beach and the small boat marinas further north (Figure 1). Sediments and soil samples were also collected from surface water drainage pathways to the coast. All samples were scooped directly into acid-washed, polyethylene vials using a clean, stainless-steel trowel. After air-drying at 30°C, they were sieved through a 1-mm nylon screen prior to refluxing in hot nitric acid for 3 h. Upon cooling, the digests were analyzed for total Hg by flameless atomic absorption spectroscopy (AAS) using the syringe technique (Stainton 1971). All Hg calibration standards (5–20 ng/L) were made up in 10% nitric acid containing 0.05% potassium dichromate as a preservative (Feldman 1974).

Two types of fish with restricted foraging ranges (*Lethrinus harak* and *Myripristis* spp.) were captured from the Hafa Adai Beach area for comparative analysis with samples collected in the earlier survey. Samples were also collected from sites further north and south within the lagoon. Following dissection,

TABLE 1. Total Mercury Levels in Fish from Saipan Lagoon before and after Closure of the Commonwealth Health Center Incinerator

Location	N	Fork Length (cm)			Hg (μg/g wet weight)			% of Catch with Hg Values š0.088 μg/g Wet Weight[1]
		Range	Median	Mean	Range	Median	Mean	
2004–5 Survey (fish collected approximately 1–1.5 years before incinerator ceased operating)[2]:								
Lethrinus harak								
Hafa Adai Beach	10	16.7–24.4	22	21.6	0.062–0.212	0.157	0.144	70
Micro Beach	1	13.9	13.9	13.9	0.144	0.144	0.144	100
Control Sites (4)	9	12.5–22.0	18.5	17.5	0.029–0.146	0.064	0.072	33
Myripristis spp.								
Hafa Adai Beach, 2005	14	12.7–16.5	13.9	14.2	0.070–0.207	0.151	0.147	86
Control Sites (3)	32	8.8–14.2	11.9	11.7	0.009–0.060	0.019	0.020	0
2007 Survey (fish collected approximately 1.5–2 years after incinerator ceased operating):								
Lethrinus harak								
Hafa Adai Beach, 2007	10	14.5–23.7	17.2	18.0	0.029–0.154	0.063	0.067	10
Micro Beach	15	15.2–27.5	21.9	21.9	0.057–1.185	0.127	0.216	80
Micro Reef	5	20.8–25.5	22.7	22.6	0.083–0.327	0.215	0.201	80
Control Sites (4)	33	10.0–26.8	20.4	19.7	0.028–0.138	0.053	0.062	15
Myripristis spp.								
Hafa Adai Beach, 2007	26	9.7–21.0	16.3	16.0	0.017–0.170	0.102	0.095	62
Micro Beach	30	10.8–22.2	14.5	15.4	0.023–0.191	0.087	0.096	47
Micro Reef	21	7.6–16.3	14.7	13.5	0.026–0.423	0.063	0.097	48
Control Sites (6)	201	9.8–17.5	12.3	12.6	0.008–0.124	0.031	0.038	3

[1]USEPA (2000) recommended maximum for methyl mercury in fish consumed by the general population on an unlimited (daily), basis assuming a standard 8-ozmeal size (227 g), an adult body weight of 70 kg, and an empirically derived chronic reference dose (safe level) for methyl mercury of 3×10^{-4} mg/kg bodyweight/day.

[2]In the 2004–5 survey, only *Lharak* was taken of Micro Beach and neither fish types were collected from Micro Reef.

approximately 1 g of wet axial muscle tissue was digested with 10 ml of 2:1 concentrated nitric and sulfuric acids and analyzed by flameless AAS as previously described. Mean recoveries of total Hg from a standard reference material (RM 50: albacore tuna) were greater than 95%.

RESULTS AND DISCUSSION

Total Hg levels found in beach sand samples rarely exceeded 6 ng/g dry weight. Such values are typical of clean, bioclastic sediments (Denton et al. 2001). Watershed soils collected further inland were more geologically enriched with Hg and yielded levels of 30–60 ng/g. Mercury concentrations in uncontaminated soils typically range from 10 to 60 ng/g (Fergusson 1990). Three storm drains discharge into the ocean along this section of coastline: two to the north of Hafa Adai Beach and one immediately to the south. Discharge plumes from all three generally move northward and/or seaward toward Micro Reef (Figure 1). Sedimentary Hg levels at the mouths of the two northerly drains were unremarkable at 4 ng/g and 10 ng/g. In contrast, the third storm drain to the south yielded 33 ng/g on average. Increasingly higher concentrations were found in deposits further upstream in this particular drainage basin, with levels peaking at 200 ng/g at the entrance of the Commonwealth Health Center, Saipan's only public hospital. Sediment from a small drainage ditch inside the hospital grounds yielded values above 1000 ng/g near the site of a recently dismantled incinerator. The incinerator was used for the destruction of medical waste from the hospital and other medical clinics on island. It was operational for about 20 years before the U.S. Environmental Protection Agency (EPA) shut it down in January 2006 for multiple violations of the Clean Air Act (U.S. EPA 2005).

Mercury values in fish examined during the current investigation are summarized in Table 1 along with the 2004–2005 data. A comparison between the two data sets suggests available Hg levels declined in both fish types from the Hafa Adai Beach area since the incinerator closed down. However, levels were generally higher than in equivalent-sized fish from control sites further north and south. This was not entirely unexpected, considering the biological half-life of Hg in chronically exposed fish (i.e., greater than 90 d) is in the order of several months to years (Trudel and Rasmussen 1997).

Levels of Hg found in fish from nonpolluted environments generally range between 0.001 and 0.1 μg/g wet weight (Holden 1973), although higher concentrations might occur in long-lived, predatory species like sharks, marlin, and tuna (Denton and Burdon-Jones 1986). While none of the fish analyzed were excessively high in Hg, 53% of all specimens removed from Hafa Adai Beach, Micro Beach, and Micro Reef yielded values above the 0.088 μg/g wet weight benchmark for unrestricted consumption (U.S. EPA 1997), compared with only 4% from control sites (Table 1). For those who prefer fishing these areas, then, larger fish, especially carnivorous types like *L. harak* with restricted foraging ranges, should perhaps be consumed no more than thrice per week as a precautionary measure for now.

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