Impact of WWII and Stormwater Discharges on the Mercury Status of Fish from Saipan Lagoon, Saipan, CNMI

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Abstract. Total mercury levels were examined in emperor fish (*Lethrinus harak* and *L. atkinsoni*) from 14 coastal sites along the entire length of Saipan Lagoon. These carnivorous species are abundant throughout the lagoon and are prized tablefish among local residents. Monitoring their mercury content is therefore important from a public health standpoint. Additionally, both species have relatively restricted foraging ranges; hence they are ideal candidates for delineating areas of mercury enrichment in their immediate environment. As expected, relatively high mercury levels were found in specimens from the most industrialized stretch of coastline in the central region of the lagoon. In one notable instance, however, considerably higher concentrations were encountered in specimens taken from more remotely located waters further south. Surface sediments taken along seaward transects from the coast in this section, supported the fish data and revealed atypical mercury concentration profiles that frequently increased with increased distance offshore. These unusual findings were attributed to the extensive use of mercury in WWII munitions, and to the heavy bombardment of Saipan during the US invasion of the island in 1944. All evidence in support of this contention is presented here.

1. Introduction

Saipan is the largest and most densely populated island of the Commonwealth of the Northern Mariana Island (CNMI). Its economy is primarily tourist-based with visitors to the island largely attracted by the equable climate, sandy beaches, and extensive coral reefs. Of particular importance in this regard is Saipan Lagoon, which extends along the western coastline and occupies a total area of approximately 31 square kilometers. The lagoon harbors a rich diversity of marine life and supports a variety of commercial and recreational activities[1,2].

Pollution monitoring and assessment studies in Saipan Lagoon have largely been confined to the central region, which borders the most industrialized part of the island. Heavy metals were among several recalcitrant chemical groups initially examined in these waters and were subsequently found to be the contaminants of greatest concern in sediments and biota[3-9]. Waters further south in the

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lagoon, although less obviously impacted by anthropogenic activities, are heavily inundated by stormwater runoff from commercial and residential premises, highways, and unpaved roads[10].

In 2002, a preliminary analysis of stormwater discharged at several points along the southern half of Saipan Lagoon revealed surprisingly high levels of mercury[11]. Unlike zinc, copper, and lead, which correlate strongly with traffic densities and are by far the most prevalent priority pollutants found in urban runoff[12], mercury has no known source link to vehicle use and is rarely encountered in stormwater discharges[13]. In USEPA's 5-year National Urban Runoff Program, for example, mercury was found in only 9% of the several hundred samples analyzed[12]. This contrasts sharply with the Saipan study in which mercury was detected 70% of the time. Reported values ranged from 8-150 ng/L and again are remarkable given that detectable levels in runoff seldom exceed 0.01 ng/L[14].

This important study raised the following questions: a) From where was the mercury coming; and b) what impact was it having on local fisheries? Denton and coworkers, who noted an indiscriminate scattering of mercury enrichment in sediments throughout the southern half of Saipan Lagoon, recently proposed a likely answer to the first question[15]. They believed this unusual distribution to be reflective of the widespread use of mercury in WWII munitions, i.e., as mercury switches in projectiles and rockets, and mercury fulminate in primers and detonators of artillery shells and percussion caps of bullets[16,17]. This suggestion is certainly plausible given that the southern beaches of Saipan Lagoon provided tactical access to the island for US troops during WWII, and that Japanese defenses positioned along the shoreline were heavily shelled during this maneuver[18,19].

To what extent the aftermath of this historic battle has impacted local fisheries in these waters has only partially been addressed. In 2004, a fish monitoring program was mounted in the central region of Saipan Lagoon[7]. Primary anthropogenic disturbances in this region include a commercial port (Saipan Harbor), a municipal dump (now closed), a power station, a sewer outfall, and two small-boat marinas. In all, 340 fish representing 67 species from four trophic levels were examined. Total mercury concentrations in two species of emperor fish (*Lethrinus atkinsoni* and *L. harak*) were of particular interest and are summarized here in Figure 1. The relatively high mercury values noted in specimens from high disturbance areas (Zones 3-5) were expected, whereas the elevated levels noted in fish from the most remote site (Zone 7) were not.

A substantial mercury hotspot was subsequently identified in sediments at the northern end of Zone 7 and is believed to be the source of contamination that impacted these fish[15]. The hotspot was located in nearshore waters adjacent to the Gualo Rai Road intersection (Figure 1). It extended seaward from the coast for several hundred meters with levels in excess of 100 ng/g in surface sediments 100 and 250 meters offshore. Lower, but nonetheless significant levels of enrichment, were also noted at the 500 meter mark.

Concerns over the possibility of other mercury hotspots impacting fisheries further south in the lagoon prompted the following investigation to: a) determine mercury levels in soils and sediments from inland drainage pathways channeling runoff into Zone 7 coastal waters; b) perform additional mercury analysis on fish from Zone 7, thereby narrowing the focus area for source detection and delineation; and c) extend the fish monitoring program to the southern end of Saipan Lagoon.

2. Methodology

Surface soil samples were taken for mercury analysis from drainage pathways on the landward side of the main coastal highway (Beach Road) between Gualo Rai Road and Quartermaster Road. The primary objective of this part of the investigation was to identify any landward sources of mercury that could account for the hotspot noted above. Eight stormdrains discharge directly into the ocean along this 3-km stretch of coastline and include many of the stormwater outlets monitored in 2002[11]. Runoff from this area is primarily derived from Beach Road and adjacent properties within 0.5 km of the coast. It is channeled into the stormdrains via a series of swales and culverts. Surface deposits were taken from 29 sampling points along drainage pathways servicing all eight of these drains. The deposits were scooped up in hand-held, pre-cleaned polypropylene vials and deep frozen within three hours of collection. The samples ranged in color and texture from light brown, gravelly sand to darker clay substrates containing varying amounts of organic matter. In the laboratory the thawed samples were dried to constant weight at 40°C and disaggregated by gently kneading between finger and thumb in clean Ziploc bags. Only the fraction that passed through a 1-mm Teflon screen was taken for analysis.

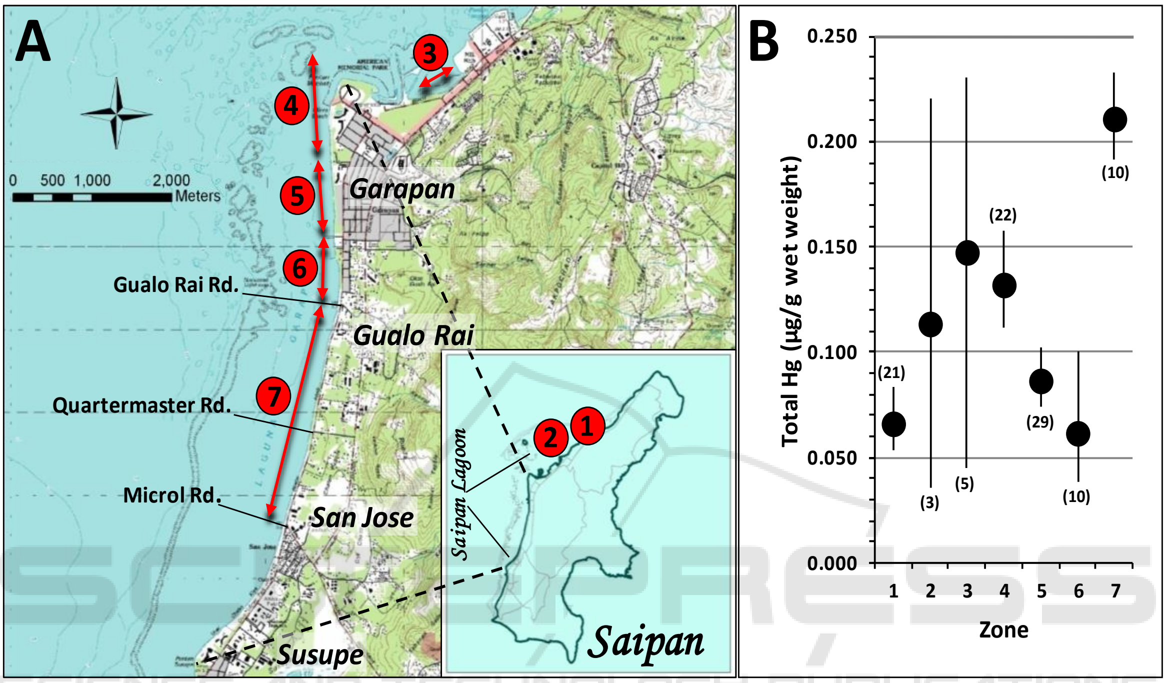

Figure 1. A = Map of Saipan (see insert) showing emperor fish capture zones 1-7; roads adjoining the coastal highway (Beach Road); and the names of coastal villages (*italicized*). B = Graph of geometric mean mercury concentrations in axial muscle of fish from each zone (normalized to a standard 20 cm fork length); whiskers = 95% confidence limits about the mean; numbers in parentheses = sample sizes.

Fish sampling again focused on *L. atkinsoni* and *L. harak,* thereby permitting comparative analysis with the earlier fish data. These two species are among the most common emperor fish in Saipan Lagoon[20,21]. They also have restricted foraging ranges, which makes them ideal for monitoring spatial differences in mercury abundance over relatively short distances. Additionally, they have similar food preferences, growth rates, and mercury affinities, which supports their use in tandem for pollution monitoring and assessment studies such as this one. Both species were therefore opportunistically taken from an additional seven sampling zones between Quartermaster Road and Agingan Point at the southern end of Saipan Lagoon (Figure 2). Being nocturnal feeders, the fish were caught at night by hook and line while they were foraging among nearshore seagrass beds. Captured individuals were placed on ice as soon as possible and transported to the laboratory in insulated containers. Mercury levels were determined in axial muscle taken immediately below the dorsal fin of each fish.

All screened surface deposits and fish axial muscle samples were wet digested in a 2:1 nitric-sulfuric acid mixture at 100°C for 3 hours. Analysis was accomplished by cold vapor Atomic Absorption Spectroscopy using the 'syringe technique' described by Stainton[22]. Calibration standards (5-20 ng/l) were made up in 10% nitric acid containing 0.05% potassium dichromate as a preservative[23]. Approximately 10% of all samples were run in duplicate and were accompanied by appropriate method blanks and matrix spikes. Accuracy and precision estimates were based on mercury recoveries from certified standard reference materials and were within acceptable limits.

3. Results and discussion

Mercury levels in all drainage pathway deposits are summarized in Table 1. Overall, levels were generally low and ranged from 2.45-76.8 ng/g dry weight (average: 17.6 ng/g). Baseline mercury levels in Saipan soils normally hover around 30 ng/g and rarely exceed 50 ng/g[24]. Clean, sandy deposits from adjacent nearshore waters are typically an order of magnitude lower[15]. The only sample to exceed 50 ng/g was retrieved ~100 m inside Pumpkin Street, which runs parallel to a car dealership and auto repair/storage facilities that contribute runoff to stormdrain 6 (Table 1). The evidence obtained suggests no major land-based sources of mercury are currently impacting the lagoon along this stretch of coastline. The results also confirm earlier findings of little more than light mercury enrichment in beach sediments down gradient of stormdrains discharging into Zone 7 within the road boundaries established above[15].

Table 1. Mercury levels (ng/g dry wt.) in drainage pathway deposits.

Stormdrain	Drainage Pathways Examined	Total Hg (ng/g dry wt.) Mean (Range)
(Gualo Rai Road)		
1	4	4.49 (2.36-8.67)
2	3	4.03 (3.76-4.29)
3	3	17.7 (7.98-27.3)
4	4	18.6 (9.20-30.1)
5	3	19.0 (13.3-24.6)
6	4	29.2 (5.01-76.0)
7	3	16.9 (6.92-27.0)
8	5	24.6 (11.9-40.5)
(Quartermaster Road)		

Mercury concentrations in the fish examined are summarized in Figure 2 following log-transformation of the raw data and normalization to a standardized 20-cm fish length. The results are presented together with the earlier data shown in Figure 1. A comparison between the two datasets clearly shows that fish from Zones 8-14 consistently contained lower mean mercury concentrations in their axial muscle when weighed against their northern counterparts. Mercury levels in axial muscle of fish from non-polluted waters typically range between 0.001-0.100 μg/g wet weight, depending upon age and trophic level[25]. All recent fish samples analyzed yielded values well below this upper limit with the exception of one large specimen of *L. harak* (28.0 cm), which contained 0.283 μg/g wet weight of mercury in its axial muscle. This particular fish was caught in waters directly opposite Quartermaster Road (Figure 2). Baseline mercury levels in emperor fish from reference sites in the northern waters of Saipan Lagoon are around 0.050 μg/g wet weight for a standardized 20-cm fish[7]. The results from the current study suggest the equivalent benchmark for fish from the southern half of Saipan Lagoon is about 20% lower. This is indeed good news for Saipan residents, many of whom regularly fish these waters for subsistence purposes. Nevertheless, a cautionary note is warranted for consumers of fish above the 20-cm standardized limit upon which these estimates are predicated. According to USEPA's fish consumption guidelines for the general population, fish with methylmercury concentrations in their muscle tissue of below 0.088 μg/g wet weight may be eaten on an unrestricted basis[26]. In contrast, 8-oz fish meals containing the same concentration as that noted above for the *L. harak* representative examined should not be consumed more than twice a week; and not more than three times a month for women of childbearing age, nursing mothers or sensitive individuals. Mercury in fish occurs predominantly in the highly toxic methylated form and typically accounts for 80-90% of total mercury in axial muscle tissue[27].

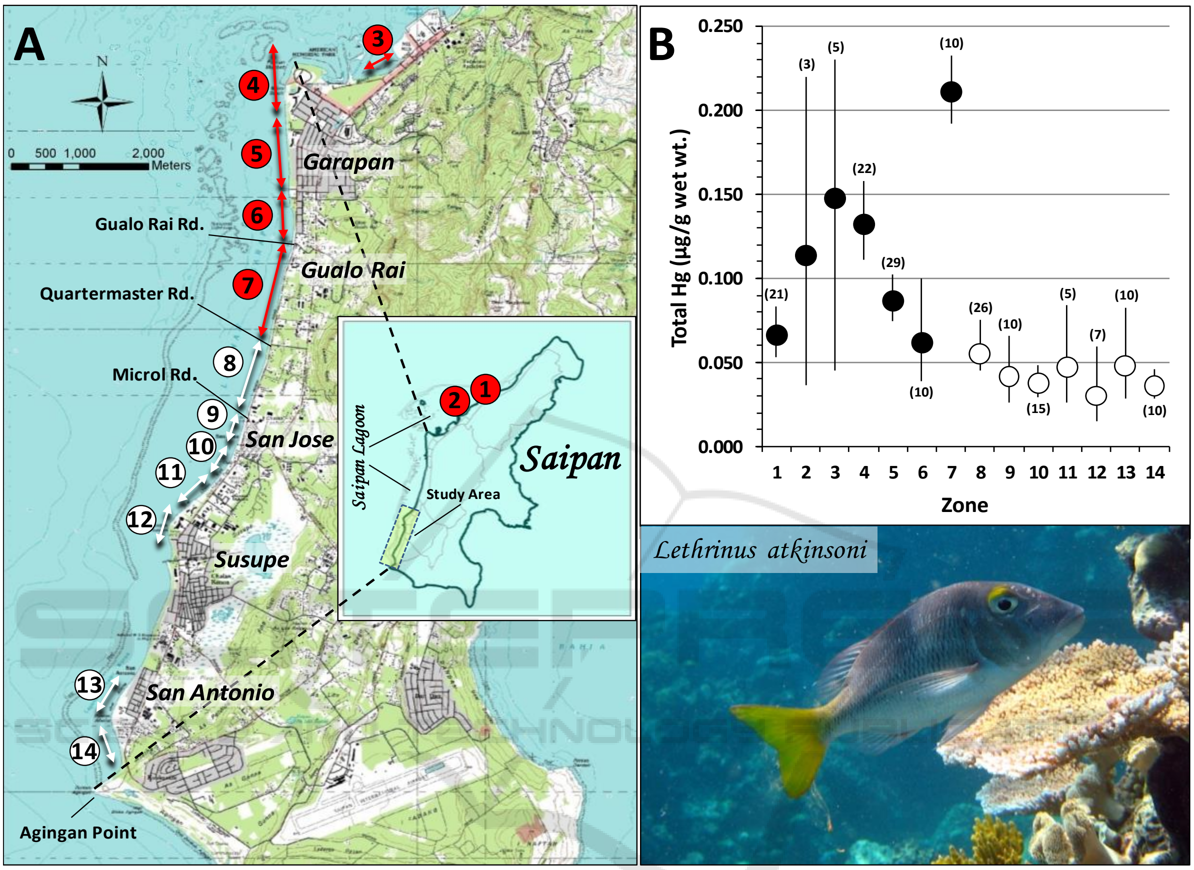

Figure 2. A = Map of Saipan (see insert) showing emperor fishing zones 1-14. Current zone delineation arrows and numerical markers (8-14) are drawn with white backgrounds. B = current data plots are shown as white filled circles. All other pertinent map and chart details remain as described in Figure 1.

4. Conclusions

The collective fish and soil/sediment data gathered during this investigation essentially rules out the possibility of any significant land-based mercury sources entering the lagoon between Gualo Rai Road and Microl Road. We are, therefore, of the opinion that the mercury source impacting emperor fish previously examined from Zone 7, emanates from within the lagoon itself; and is, in all probability, the mercury hotspot identified earlier and presumed to be a residual munitions artifact dating back to WWII[15].

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