Heavy metal contamination of shallow marine sediments from submarine tailings disposal and artisanal gold mining, North Sulawesi, Indonesia

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Shallow marine sediments in the Buyat-Ratototok district of North Sulawesi, Indonesia, are affected by heavy metals from two principle sources: submarine dumping of tailings from an industrial gold mine, and small-scale gold mining using mercury amalgamation. Marine sediment samples were collected with a Petit Ponar grab sampler in June 2002 and August 2004. Natural sediments in the region consist of siliciclastic sands and muds, and mixed carbonate-clastic sands and muds adjacent to fringing coral reefs. Whole-sediment heavy metal concentrations and sequential extractions were determined by ICP-MS; total Hg was measured using cold-vapour AAS. Mine tailings collected in June 2002 contained > 660 ppm As, > 550 ppm Sb, and 5.8 ppm Hg. High concentrations of these metals in other siliciclastic sediments in Buyat Bay indicate contamination by tailings, except for primarily fluvial sediments dominated by Fe, Ti, Co, Cr, and Cu, and Zn, and generally < 50 ppm As. Reef sediments collected in < 40m water depth outside Buyat Bay contained 30-40 ppm As, with nearly identical metals ratios to the mine tailings. Modified Tessier sequential extraction of mine tailings showed that 30% of As was soluble in dilute acetic acid, hence exchangeable and probably biologically available, while less than 50% was lithogenic. Arsenic in fluvially-derived sediments and sediments affected by artisanal gold mining was 75- 80% lithogenic. Antimony in tailings and tailings contaminated sediments was > 90% lithogenic. Electron microprobe study of mine tailings suggests that most As, Sb, and Hg in the tailings are contained in < 2 μm ground-mass, probably amorphous Mn- and Fe-oxides and oxyhydroxides. Sequential extraction data suggest that submarine tailings disposal introduces large fluxes of exchangeable As in shallow marine environments. Further study by the Indonesian government indicates that heavy metals from the tailings enters the food chain via benthic invertebrates, and that some of the nektobenthic fish species are unsafe for consumption by local human populations. Highest sediment Hg concentrations were observed in marine muds below the watersheds affected by small-scale mining using mercury amalgamation; this mercury also enters the food chain, and may pose a health threat.

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