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Science of the Total Environment 343 (2005) 111–133

Science of the Total Environment
An International Journal for Scientific Research into the Environment and its Relationship with Humankind

www.elsevier.com/locate/scitotenv

Environmental assessment of mercury contamination from the Rwamagasa artisanal gold mining centre, Geita District, Tanzania

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Received 31 March 2004; received in revised form 23 September 2004; accepted 24 September 2004

Abstract

This study presents the results of an environmental assessment of mercury (Hg) contamination in the Rwamagasa artisanal gold mining area, northwest Tanzania, and the potential downstream dispersion along the River Malagarasi to Lake Tanganyika. At the time of sampling, generally low concentrations of Hg (<0.05 mg/kg) occurred in most cultivated soils although higher Hg (0.05–9.2 mg/kg) was recorded in urban soils and vegetable plot soils where these are impacted by Hg-contaminated water and sediment derived from mineral processing activities. Hg in vegetable and grain samples is mostly below the detection limit of 0.004 mg/kg Hg, apart from 0.007 and 0.092 mg/kg Hg in two yam samples and 0.011 to 0.013 mg/kg Hg in three rice samples. The standardized (i.e., standardized to 10 cm length) Hg concentrations in *Clarias* spp. increase from about 0.01 mg Hg/kg for the River Malagarasi delta to 0.07, 0.2, and 1.6 mg/kg, respectively, for the Rwamagasa 'background', moderately and most contaminated sites. For piscivorous (*Lates*, *Brycinus*, and *Hydrocynus* spp.), insectivorous (*Barbus* spp.), and planktivorous (*Haplochromis* spp.) fish species, the 10-cm standardized Hg concentrations increase from about 0.006 mg/kg for the River Malagarasi-Lake Tanganyika area to 0.5 and 3.5 mg/kg, respectively, for the Rwamagasa moderately and most contaminated sites. The low concentrations of Hg in fish from the Malagarasi River delta and Lake Tanganyika indicate that Hg contamination from the Rwamagasa area does not have a readily discernible impact on the biota of Lake Tanganyika. Many of the fish samples from Rwamagasa exceed guidelines for human consumption (0.5 mg/kg) as well as the WHO recommended limit for vulnerable groups (0.2 mg/kg). Tissue total Hg (THg) of all fish collected from the River Malagarasi-Lake Tanganyika subarea is well below these guidelines. Potential human exposure through consumption of 300 g/day of rice grown on Hg-contaminated soils is 5.5 μg/week. Consumption of 250 g Nile perch (*Lates* spp.), 500 g tilapia (*Oreochromis* spp.), and 250 g of catfish (*Clarias* spp.) each week would result in an intake of 65 μg Hg/week for people consuming only fish from the Mara and Mwanza regions of Lake Victoria and 116 μg Hg/week for people in the Rwamagasa area consuming tilapia and Nile perch from Lake Victoria and catfish from mining-impacted streams. This is lower than the Provisional Tolerable Weekly Intake

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doi:10.1016/j.scitotenv.2004.09.042

(PTWI) of 300 μg for Hg in the diet set by the WHO and the FAO. Inadvertent ingestion of soil containing 9 mg Hg/kg at a rate of 80 mg/day would give an additional estimated weekly intake of 5 μg THg, whereas the persistent and purposeful consumption of soil (geophagia) at a rate of 26 g soil/day would produce an additional chemical exposure of 230 μg Hg/day.

Keywords: Africa; Sediment; Water; Soil; Fish; Plants; Human exposure; Drainage sediment

1. Introduction

Artisanal gold mining provides income to some of the world's poorest people, many of whom are women and children, but it is also one of the major sources of mercury (Hg) contamination, especially in developing countries. Whereas the gold extraction process (known as amalgamation) is a simple technology, it is potentially very dangerous and contaminates the air, soil, rivers, and lakes with Hg. The health of the miners and other people living within the area affected by Hg contamination may be negatively affected through inhalation of Hg vapour, direct contact with Hg and through eating fish and other food affected by Hg contamination. The Global Environmental Facility (GEF) of the UN funds a project Removal of Barriers to the Introduction of Cleaner Artisanal Gold Mining and Extraction Technologies (also referred to as the Global Mercury Project (GMP; http://www.unites.uqam.ca/gmf/intranet/gmp/front_page.htm) that is currently being executed by UNIDO in six developing countries (Brazil, Indonesia, Laos, Sudan, Tanzania, and Zimbabwe). This paper presents the results of an environmental assessment in the Rwamagasa (or Rwamagaza) artisanal gold mining area, which was selected by UNIDO as the GMP demonstration site for Tanzania. Primary artisanal workings in the Rwamagasa area are centred on quartz veins in sheared, ferruginous, chlorite mica schists. Grab samples of vein and wall rock grade 6–62 g/t Au (Spinifex 2002 Annual Report). One of the objectives of the current study was to assess the impact of Hg contamination on international waters as well as in the immediate vicinity of the Rwamagasa 'mining hotspot'. Consequently, the field programme was carried out in two subareas: (a) the Rwamagasa 'mining hotspot' subarea and (b) the River Malagarasi–Lake Tanganyika subarea (Fig. 1). Dispersion of Hg from Rwamagasa to Lake Tanganyika is probably relatively unlikely because contaminant Hg will be adsorbed by organic material in the extensive Moyowozi and Njingwe Swamps and flooded grassland area, located from 120 to 350 km downstream of Rwamagasa (Fig. 1). Whereas the swamps will act as a potential biomethylation zone, they will also act as an environmental sink for Hg contamination which is likely to inhibit migration of Hg into the lower reaches of the Malagarasi River and Lake Tanganyika, some 430 km downstream from Rwamagasa. The swamp area was inaccessible within the logistical and budgetary constraints of the current project.

The only legal mining in the Rwamagasa area is carried out within the boundaries of the Primary Mining Licence held by Blue Reef Mines (Fig. 2) where approximately 150 people are involved in mining and mineral processing activities. This is the only site in the Rwamagasa area where primary ore is being mined underground. All other mineral processing activity of any significance is concentrated at the northern margin of Rwamagasa, especially on the land sloping down to the Isingile River (Figs. 2 and 3). In this area, there are about 30 groups of historic and active tailings dumps and about 10 localities where small (200 l) ball mills are operating. The number of people actively involved, at one particular time, in ball milling, sluicing, and amalgamation is probably no more than 300.

Amalgam is burned in a small charcoal fire, which releases Hg to the atmosphere. Retorts are not used. Amalgamation mainly takes place adjacent to amalgamation ponds, which are usually formed of concrete, but sometimes have only wood walls even though environmental legislation dictates that the Hg-contaminated mineral concentrates and tailings should be stored in concrete lined structures. The field programme was carried out during the dry season at which time there was little evidence that large quantities of contaminated tailings were being washed into the Isingile River. However, waste water and tailings from amalgamation 'ponds' were