AFRIKA FOCUS — Volume 21, Nr. 1, 2008 — pp. 103-116

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Environmental and human health risks of mercury released from artisanal gold mining in Tanzania

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Public defence: 25 January 2008

Artisanal gold mining is one of the major sources of mercury (Hg) contamination in Tanzania. Whilst the gold extraction process (known as amalgamation) is a simple technology, it is potentially very harmful to the environment and can contaminate air, soil, rivers and lakes with mercury. High levels of environmental mercury can cause harm to organisms living in the various environmental compartments. Also the health of the miners and other people living within the contaminated areas may be adversely affected through inhalation of mercury vapour, direct contact with mercury, through eating Hg contaminated fish and other food items, or through ingesting Hg contaminated water. The Mugusu mine, which is privately owned by the Chipaka family, is one of the active artisanal gold mines in Geita district, Tanzania. The current status of mercury use, environmental contamination and the potential risks of Hg to humans and the environment at the Mugusu mine are not well understood.

This doctoral study aimed at using the Mugusu mine as a model to asses the risks of Hg use in artisanal gold mining in Tanzania. In this thesis, the current status of mercury use and environmental contamination at the Mugusu mine was established. The knowledge and perception of miners about the possible effects of mercury to the environment and human health were explored using structured questionnaires and focus group discussions. Based on chemical analysis and ecotoxicity testing the possible ecological effects to the aquatic ecosystem of wastes released from artisanal mining was studied. The potential health risk to humans was assessed by estimating mercury exposure of women residing in a fishing village near the Mugusu mine through fish consumption. Concentrations of mercury in muscle and liver tissues of free grazing cattle and scavenging domestic fowl in gold mining centres were determined and used to assess the potential contribution of this exposure route to the Hg intake. Additionally, a total diet study approach was used to estimate the dietary mercury intake of people living and working in the Mugusu village. Finally, through head hair monitoring we established the current exposure of mercury to artisanal gold miners at the Mugusu mine.

Results from the present study show that use of mercury in gold mining contaminates nearby water resources and soils. Analysis of water and sediment samples collected from the river Mabubi which drains the Mugusu mine demonstrated that Hg concentrations in sediment and water decreased towards the river mouth. The highest concentrations of Hg in sediment (2.3 $\mu g\ g^{-1}$ dw) were

measured three kilometres downstream of the mine.

As in previous studies in the Lake Victoria goldfields, we showed that the distribution of Hg in river sediments away from the mine is relatively restricted. Probably Fe-rich laterites and seasonal swamps act as natural barriers restricting the movement of Hg downstream into Lake Victoria.

In the ecotoxicity assessment, sediments collected up to six kilometres downstream of the Mugusu mine significantly reduced survival and growth of the African catfish (*Clarias gariepinus*). The calculated 5 day-LC50 value (larval survival) was 1.75 µg Hg g^{-1} dw (95% CL of 0.72 – 2.53), the 5 day-NOEC for hatching was >2.3 µg Hg g^{-1} dw and that for larval survival and growth was 0.23 µg Hg g^{-1} dw. These results were in agreement with results obtained from laboratory toxicity evaluations using mercury spiked artificial sediments and the benthic invertebrate *Chironomus riparius*. In this experiment, mercury affected life characteristics of *C. riparius* at concentrations lower than the levels of mercury which have been measured in different artisanal gold mining impacted watersheds in Tanzania. The chemical analysis and the ecotoxicity results from this study indicate that sediments downstream of the Mugusu mine and probably in other artisanal gold mining impacted watersheds in Tanzania pose a risk to aquatic fauna.

Results from the fish consumption survey indicate that, because of high fish intake (144 g/day), the weekly MeHg intake in the studied village (4.0 µg/kg bwt/day) was above the Provisional Tolerable Weekly Intake (PTWI) recommended by WHO/FAO for protection of the unborn child and young children (1.6 µg/kg bwt/week). On the other hand, the total diet study showed that daily Hg dietary intake for people living and working within the Mugusu mining village exceeded the provisional tolerable daily intake recommended by WHO/FAO for protecting unborn children (15.5 µg/day) by a factor of two. However, the contribution to overall Hg exposure of meat obtained from cattle and domestic fowl reared in the mining villages was low. Also, chemical analysis of Hg in head hair collected from people working and living in the Mugusu mining village indicated low exposure. The mean concentration (1.55 ± 1.2 µg g^{-1} dw) was lower than the warning limit (10 µg Hg g^{-1} dw) established by WHO for pregnant women. Compared with studies performed ten years ago, the mercury concentrations in the hair of miners at the Mugusu mine have slightly increased.

In conclusion, this doctoral study has demonstrated that, artisanal gold mining at the Mugusu mine causes contamination of all of the environmental compartments, which leads to increased risks to the environment and to humans. It is therefore recommended that more efforts are made (1) to reduce the use of Hg in gold mining and (2) to educate the miners and surrounding communities on the effects of Hg on the environment and human health.