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Commentary

Influence of illegal gold mining on mercury levels in fish of North Sulawesi's Minahasa Peninsula, (Indonesia)

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"Capsule": *Fish exposed to run-off from illegal gold mines in Indonesia have very high levels of mercury and pose a risk to human consumers.*

Abstract

North Sulawesi's Minahasa Peninsula currently is experiencing intense illegal gold mining activity. It has been estimated that 200 t of mercury are used annually in Indonesia in the recovery of gold from the illegal mines. To date no study has assessed the environmental impact of this illegal activity on the nearby aquatic biota. To address this concern, we compared tissue mercury levels from several sites, including a reference site and a site near an illegal mine. Fish from the region of the illegal mine contained 30 times the mercury content of fish at the reference site. Moreover, whole fish tissue levels were four times those recommended by the World Health Organization for consumption restrictions and often two-fold higher than recommended for total restriction on fish consumption. The environmental and human health implications of these levels are of grave concern; citizen education programmes are required to alert indigenous peoples of the risks associated with mercury exposure and fish consumption guidelines put into place. A more comprehensive effort to identify major sources and effects are required. Such information can be used to determine the correct course of action that needs to be taken to close existing illegal mines and prevent future illegal mining activities.

Keywords: Mercury; Illegal mines; Human health; Fish consumption

1. Introduction

Driven by the world demand for gold, within the past 4 years there has been a rapid expansion of illegal gold mining activities in regions of eastern Indonesia such as North Sulawesi's Minahasa Peninsula. The Manado-based environmental group, Yayasan Bina Cipta AquaTech has reported active mining in more than 100 illegal mines spread over five or six different sites within this region. The illegal mines or "trommels" (derived from the Dutch term for barrel) are crude mills that use mercury to remove gold from the host rock. Once the gold is extracted, the waste rocks or tailings, which include excess mercury, are placed into the large barrels. The barrels are disposed of by simply burying them along side of the mining site typically within walking distance of the river. Mercury then enters the aquatic system during the gold extraction process or through the leaching of waste from the barrels.

Despite the obvious impact the illegal mining activity could have on the receiving environment, no study to date has assessed the impact on the associated biota. As trommels occur in rivers that also are used for domestic purposes such as fishponds, of most concern are mercury levels in fish taken directly from the mining region for human consumption. The objective of this study was to assess the impact of illegal gold mining activities on whole fish tissue mercury levels. To meet this objective we compared fish tissue levels from: (1) a reference site; (2) an estuarine region downstream from an illegal gold mine; (3) a region within close proximity to an illegal mine; and (4) a local supermarket. We found that concentrations of mercury in fish tissue from the region of the illegal mine exceeded levels recommended by the World Health Organization (WHO) for total consumption restriction (WHO, 1991). The aim of this

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preliminary study is to document that this serious problem exists, and to strongly recommend that actions be taken to ameliorate mercury impacts on aquatic biota and humans in the region. Specific recommendations are provided in the closing section of this commentary.

2. Materials and methods

2.1. Study site

The study site was located within the Minahasa Peninsula, North Sulawesi (Fig. 1). This region has seen a rapid expansion of illegal mining activities within the past four years. Within this region three sites were sampled for representative fish species: (1) the Taanawangko River, Tanawangko Village, Minahasa, a reference site with no known history of illegal mining; (2) the Talawaan River, Talawaan Village, Minahasa, the site of an active illegal gold mine; and (3) downstream from an illegal gold mine on the Talawaan River, near Tanawangko Village, Manado. For a further comparison, fresh fish were purchased from the local supermarket in Manado.

2.2. Fish species

Species and length of fish sampled from each of the study sites are presented in Table 1. All sampled species are of economic importance and are a major protein source for local inhabitants. The fish include a variety of feeding habits, including omnivores and carnivores.

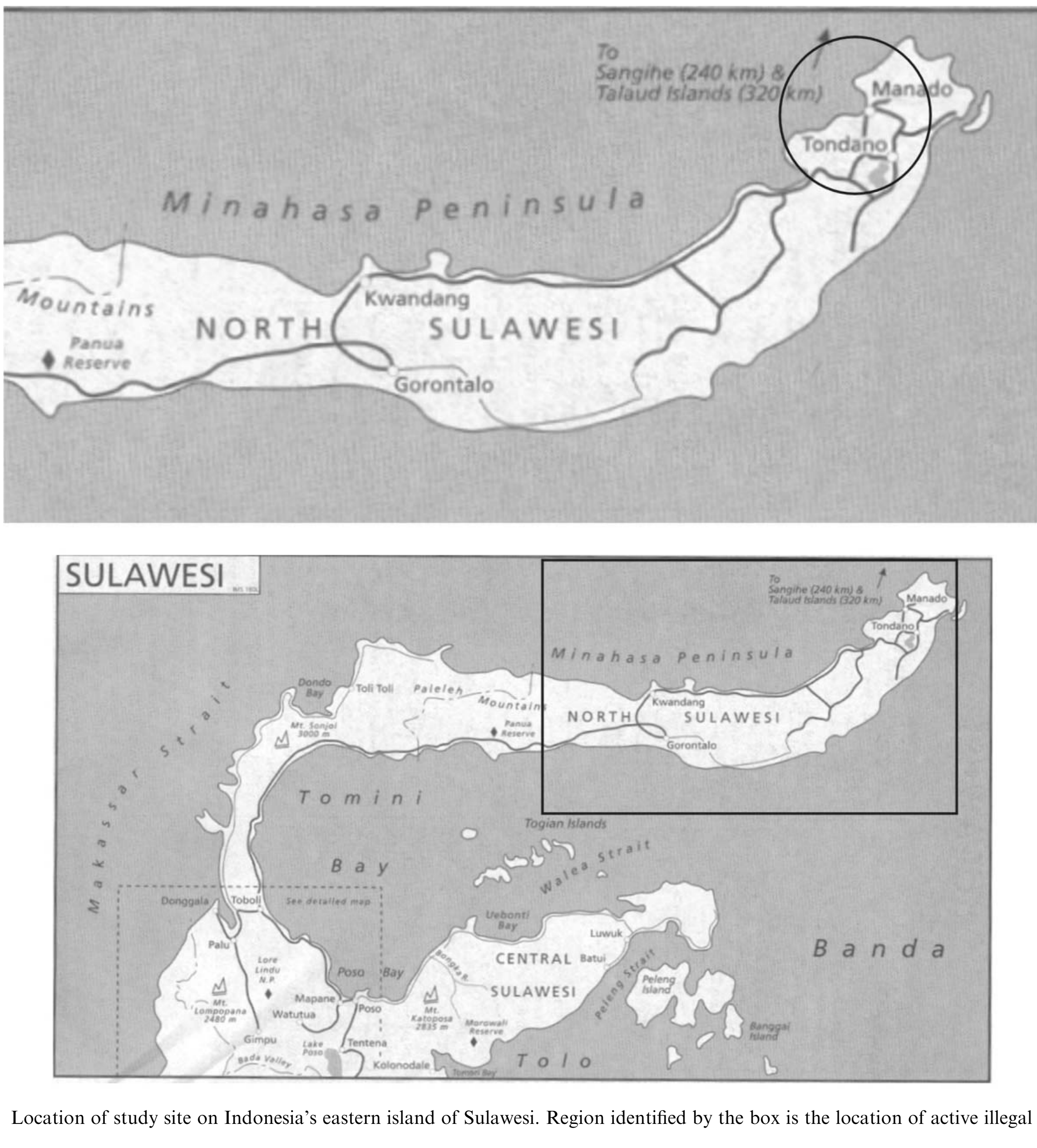

Fig. 1. Location of study site on Indonesia's eastern island of Sulawesi. Region identified by the box is the location of active illegal mining.

Table 1
Species and total length (cm) of fish sampled at the three field sites plus purchased at the supermarket (Manado)[a]

Location	Species					
	Osteochilus mossambicus	*Liza* spp.	*Caranx* spp.	*Upeneus* spp.	*C. carpio*	*Upeneus* spp.
Reference	19.3±0.76	18.1±1.6	–	–	–	–
Supermarket	22/23	–	–	–	23/23	–
Estuary	–	15.3±0.76	19.1±7.7	14/12	–	–
Goldmine	14.8 ±2.09	–	–	–	27/21	10/18

[a] Values are means±S.D. of $n=3$–6, except where $n=2$, where only ranges of the two replicate measures are provided. Fish length did not differ either among site or fish species ($P>0.05$, one-way ANOVA).

2.3. Mercury analysis

A total of 30 fish were sampled in the field by seine net from three locations. Collected fish were sacrificed, dried to a constant weight (at 60°C), and bagged in plastic zip lock bags for courier from North Sulawesi, Indonesia to Simon Fraser University, Burnaby, BC. On arrival at the university, whole fish were thoroughly homogenized in a blender and a subsample of tissue (approximately 1.0 g) digested using a nitric-hydrogen peroxide digestion procedure (US-EPA method 200.3). Analysis was performed using Cold Vapour Atomic Absorption Spectrophotometry (CANTEST LTD., Burnaby, BC, Canada). Mercury detection limits were 0.01 μg g^{-1} dry weight.

2.4. Statistical analysis

Only those sample sites were $n>3$ fish were included for statistical analysis. For all other sites the range of replicated measures has been given. To meet the assumptions of the ANOVA (data normality and variances independent of the mean) fish tissue mercury concentrations were log transformed. One-way ANOVA with fish length as the factor indicated that length was not significantly different among species of fish or sampling locations ($P>0.05$). Moreover, fish tissue mercury concentration was not dependent on fish length within the size range of fish sampled. Therefore, no correction for fish length was made for a subsequent one-way ANOVA with sampling site as the main factor (where $n>3$). Where significant differences occurred, a Tukey's Multiple Range test was applied to identify the significant differences ($\alpha=0.05$). Statistical analysis was performed through SAS (Statistical Analysis System Institute Inc. Cary NC, USA, 1999).

3. Results and discussion

Total fish mercury content was dependent on site. All fish sampled within the region of the gold mine contained high mercury levels. Notably, *Osteochilus mossambicus* (carp, an omnivore) contained almost 30 times the amount of whole tissue mercury as compared to the same species sampled from the reference site (Table 2, Fig. 2). Moreover, whole fish tissue levels sampled from the region of illegal mining were four times the levels recommended by the World Health Organization for consumption restrictions and often twice the levels recommended for total consumption restriction (WHO, 1991). *Caranx* spp. (jack, carnivores) sampled within the estuary downstream of the mining activity also contained significantly greater amounts of whole tissue mercury as compared to fish sampled from the reference site. In contrast to *O. mossambicus* and *Caranx* spp., *Liza* spp. (mullet, an omnivore) sampled from the estuary contained the same amounts of whole tissue mercury as compared to reference fish (Table 2). It is important to note that WHO guidelines are for tissue methylmercury, not total mercury as measured in the current study. However, Bloom (1992) has shown that the chemical form of mercury in fish and marine invertebrate tissue primarily is methylmercury. Hence, we assume that the total mercury measured is an adequate surrogate for the toxic form.

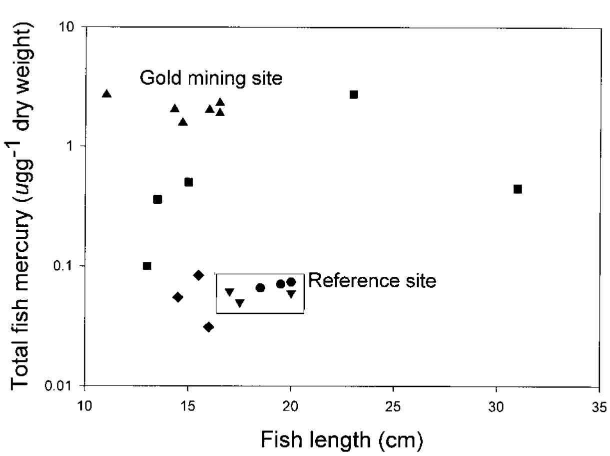

Fig. 2. Whole fish tissue mercury concentrations for each of the sampling sites versus fish length. ▲: *Ostochilus mossambicus* sampled from the mining site; ■: *Caranx* spp. sampled from the estuary downstream from the mine site; ◆: *Liza* spp. from the estuary downstream from the mine site; ● and ▼: *Liza* spp. and *O. mossambicus* sampled from the reference site.

Table 2
Average mercury concentration in whole fish ($n = 3$–6) sampled from three sites in North Sulawesi's Minahasa Peninsula plus purchased at the supermarket in Manando[a]

Location	Species					
	Osteochilus mossambicus	*Liza* spp.	*Caranx* spp	*Upeneus* spp	*C. carpio*	*Osteochilus* spp.
Reference	0.07± 0.004c	0.057±0.006c	–	–	–	–
Supermarket	0.019/0.019	–	–	–	0.03/0.04	–
Estuary	–	0.06±0.026c	0.83±10.7b	1.33/0.3	–	–
Goldmine	2.08± 0.38a	–	–	–	0.61/1.04	1.56/1.94

[a] Values are means±S.D. except where $n = 2$ then only ranges of the replicate values are provided. Values that are significantly different are denoted by a letter (Tukey's $\alpha = 0.05$).

O. mossambicus is most commonly found (as in the current study) in the warm weedy pools of sluggish freshwater streams, canals and ponds. These conditions are highly conducive to the microbial methylation of inorganic mercury to its bioavailable form, methyl mercury (e.g. Korthals and Winfrey, 1987, Mason and Fitzgerald, 1990). Moreover, *O. mossambicus* tends to stay within one region with little movement either upstream, towards the mouth of the river (the estuary) or the coastal waters. By contrast, *Liza* spp. is found in the saline shallow coastal waters and is not confined to slow moving warm waters of rivers and streams. It may be these different life history characteristics that contribute to observed differences in tissue mercury levels.

Adult *Caranx* spp., like *Liza* spp., also inhabits mostly coastal and oceanic waters associated with reefs. However, juveniles are encountered in estuaries (Paxton et al., 1989) and they were sampled in the current study, rather than the reef associated adult. The life history of a fish may be an important consideration in assessing exposure to the mercury generated by the illegal mines. In the case of *Caranx* spp., juvenile stages may be more vulnerable as compared to adults. Indeed, the basic biology of tropical fishes and how this biology affects exposure and bioaccumulation of contaminants such as mercury is little understood.

That fish sampled from a region heavily impacted by illegal mining activities contained significant amounts of tissue mercury is not surprising. Of grave concern, however, are the actual tissue levels. Determined whole fish tissue mercury values in some cases exceeded values recommend by the World Health Organization for a total consumption restriction. It is imperative that immediate action is taken to prevent further contamination of this region by illegal mining activities.

3.1. Recommendations

As the mining activity is illegal, it would follow that the local authorities would have some responsibility to enforce closure of the mines. However, despite its illegal nature, the mining activity still persists. Immediate action in regards to alerting the local inhabitants as to health risks posed by the consumption of fish caught within regions of illegal mining activity is required. A more comprehensive effort to identify major sources and effects should be undertaken. Such information may help local citizens, those most affected by the illegal activities to push the local government into action to stop existing illegal mining practices and to prevent further mines from becoming established.

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