Environmental Research ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

A preliminary study on health effects in villagers exposed to mercury in a small-scale artisanal gold mining area in Indonesia

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A R T I C L E I N F O

Article history:
Received 23 September 2015
Received in revised form
8 February 2016
Accepted 5 April 2016

Keywords:
Mercury
Rice
Artisanal small-scale gold mining
Intoxication
Indonesia

A B S T R A C T

Cisitu is a small-scale gold mining village in Indonesia. Mercury (Hg) is used to extract gold from ore, heavily polluting air, soil, fish and rice paddy fields with Hg. Rice in Cisitu is burdened with mercury. The main staple food of the inhabitants of Cisitu is this polluted rice. Villagers were concerned that the severe diseases they observed in the community might be related to their mining activities, including high mercury exposure. Case report of the medical examinations and the mercury levels in urine and hair of 18 people with neurological symptoms. Typical signs and symptoms of chronic mercury intoxication were found (excessive salivation, sleep disturbances, tremor, ataxia, dysdiadochokinesia, pathological coordination tests, gray to bluish discoloration of the oral cavity and proteinuria). Mercury levels in urine were increased in eight patients (>7 μg Hg/L urine). All 18 people had increased hair levels (>1 μg Hg/g hair). 15 patients exhibited several, and sometimes numerous, symptoms in addition to having moderately to highly elevated levels of mercury in their specimens. These patients were classified as intoxicated. The situation in Cisitu is special, with rice paddy fields being irrigated with mercury-contaminated water and villagers consuming only local food, especially mercury-contaminated rice. Severe neurological symptoms and increased levels of mercury in urine and hair support are possibly caused by exposure to inorganic mercury in air, and the consumption of mercury-contaminated fish and rice. The mercury exposure needs to be reduced and treatment provided. Further research is needed to test the hypothesis that mercury-contaminated rice from small-scale gold mining areas might cause mercury intoxication.

1. Introduction

Artisanal and small-scale gold mining (ASGM) practices identified in more than 800 Indonesian hotspots provide livelihood to more than 2 million miners and their communities, produce more than 100 t of gold per year (Ismawati, 2011) and about 57.5% of national mercury emissions (Dewi and Ismawati, 2012).

Cisitu is a small village in a remote area within the Gunung Halimun-Salak National Park, which is located in Banten Province, a western part of Java in Indonesia. Approximately 7000

Abbreviations: AAS, Atomic Absorption Spectrometry; ADI, Acceptable daily intake; AMAN, Aliansi Masyarakat Adat Nusantara (Indigenous Peoples of the Archipelago Alliance); ASGM, Artisanal small-scale gold mining; CGGM, Community Green Gold Mining; CI, Confidence interval; CV-AAS, Cold Vapour-Atomic Absorption Spectrometry; FAO, Food and Agriculture Organization of the United Nations; HBM, Human biomonitoring value; HG, Mercury; Hg^{+}, Hg^{2+}, Inorganic mercury salts; Hg°, Elemental liquid mercury; MeHg, Methyl-mercury; NGO, Non-governmental organization; PTWI, Provisional tolerable weekly intake; RfD, Reference dose; US-EPA, United States Environmental Protection Agency; WHO, World Health Organization

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http://dx.doi.org/10.1016/j.envres.2016.04.007
0013-9351/

indigenous people, called *Kasepuhan Adat Cisitu*, live in 2 hamlets and work as rice farmers. Cisitu has no health service facilities. The water running from the hills is used to irrigate the paddy fields and supply the fish ponds. Houses are located between the paddy fields and fish ponds. Traditionally only locally grown rice is consumed.

In recent years, increased gold prices have attracted many small-scale gold-mining operations to the Lebak Regency. In 2003–2004, following several years of conflict with a state-owned gold mining company, the Cisitu people and migrant miners reopened an old gold mining site within the territory of the tribe. During its peak time, gold mining provided an opportunity to earn quick money for up to 10,000 people (Ismawati and Zaki, 2014).

Thousands of miners dig in deep shafts about 3–4 h away from the village centre to obtain the gold containing ore. Stone crushers, often directly located next to houses, mill rocks to a fine powder, which when mixed with liquid mercury, produces a fine sludge in form of amalgam. When the amalgam is smelted to extract the gold, toxic mercury vapours are released. Muddy water tainted by unprotected mercury-contaminated tailings has been released into local water ways that are draining into rice paddy fields and fish ponds. Burning amalgam releases mercury vapours and contaminates the air. The vapours are washed out by rain and eventually deposited locally into the soil and water/ponds (Ismawati and Zaki, 2014).

Elemental liquid mercury (Hg°) becomes highly toxic when vaporized and absorbed by the lungs. In ASGM areas the main source of exposure is usually the inhalation of elemental mercury vapour from processing especially smelting amalgams. Elemental mercury can be oxidized into inorganic mercury salts (Hg^{+}, Hg^{2+}), or methylated in the aquatic food chain by microorganisms to methyl-mercury (MeHg), accumulating in fish (Drasch et al., 2004). Ingestion of methyl-mercury containing fish is the most common route of mercury exposure worldwide. Results from mercury mining areas indicate that mercury can penetrate rice (Horvat et al., 2003). Mercury in rice is partly methyl-mercury and becomes as such bioavailable in rice (Feng et al., 2008; Li et al., 2010; Rothenberg et al., 2014). Methyl-mercury can be ingested by eating contaminated rice and fish. The exposure of the villagers in Cisitu consists of inorganic mercury vapour from the processing units plus methyl-mercury from contaminated fish and rice.

Mercury can be measured in human specimens. Acute exposure to inorganic mercury can be well measured in urine. Chronic exposure to methyl-mercury is usually analysed as total mercury in hair samples. Speciation of mercury is used to measure the levels of methyl-mercury in hair samples (Berlin et al., 2015; Horvat and Hintelmann, 2007).

Exposure to mercury can cause serious health effects (Berlin et al., 2015; Clarkson et al., 2003). There are a number of publications available that address the issue of Hg as a health hazard in ASGM. Recently a good review article was published (Kristensen et al., 2013). This detailed article summarizes the results from 26 studies, showing that the exposure with inorganic Hg vapour is high, and that toxic effects have to be considered. Another review article came to the conclusion that miners and their families are exposed with mercury vapour and methyl-mercury contaminated fish in ASGM areas, resulting in increased levels of mercury in human specimens (Gibb and O'Leary, 2014). In our own studies we mainly observed neurological symptoms such as ataxia, tremor and dysdiadochokinesia due to mercury vapour exposure, (Bose-O'Reilly et al., 2010a, 2010b; Drasch et al., 2001; Steckling et al., 2011, 2014).

The residents of Cisitu noticed that an increasing number of individuals were severely diseased, leading many to question whether it could be related to high levels of mercury exposure in the community.

2. Material and methods

2.1. Environmental assessment

BaliFokus – a non-governmental organization – in collaboration with the Indigenous Peoples of the Archipelago Alliance (AMAN) have conducted environmental monitoring activities in Cisitu since 2012, especially related to the impact of mercury use.

A portable mercury air analyser (Lumex RA915+) indicated the average concentration of 9.91 mg/m3 (maximum 55.8 mg/m3 or >50 times higher than the World Health Organization (WHO) guideline value of 1 mg/m3). Mercury in water taken from several ponds revealed mercury concentrations below 0.13 μg/L, as a report of the Bandung Institute of Technology shows (Manik, 2014). This values are low compared to the guideline level for drinking water of 6 μg/L from WHO (World Health Organization, 2011). From the same ponds, sediment samples were also taken and showed high concentration of mercury 2400 μg/kg to 21,450 μg/kg (Aprianne, 2014). Mercury in soil around the village ranges from 0.3 mg/kg to 146 mg/kg (Aprianne, 2014). The United Kingdom recommendation for elemental mercury in soil in residential areas is 1 mg/kg of soil (dry weight) (Environment Agency, 2009).

The levels of mercury in fish samples from the Cisitu fish ponds ranged from 0.1 mg/kg to 1.3 mg/kg (see Table 1), using an Atomic Absorption Spectrometry (AAS) method based on the SNI 01-2354.6-2006 procedure(Manik, 2014), in two out of six samples exceeding the maximum quantity for human consumption, which is 0.5 mg/kg for non-predatory fish (Food and Agriculture Organization of the United Nations (FAO) and World Health Organizaion (WHO), 2012).

Stored rice was analysed using the Cold Vapour-Atomic Absorption Spectrometry (CV-AAS) method with a mercury analyser MA-2000-NIC (see Table 2). For food the recommended levels are below 100 ng/g (FAO/WHO Codex alimentarius (Food and Agriculture Organization of the United Nations (FAO) and World Health Organizaion (WHO), 2012)). Mercury rice levels were up to ten-fold higher than the guideline level. The mercury concentrations were found to increase over time as mining activities in Cisitu increased.

Table 1
Mercury intake from fish in Cisitu. Total Hg in fish samples (Manik, 2014).

No.	Hg in fish (mg/kg)	Average body weight (kg)	Assumed fish consumption (kg/capita/week)	Mercury ingested from fish consumption (μg/kg body weight per week)	Total mercury ingested from fish consumption based on JECFA PTWI standard (4 μg/kg body weight per week or 0.57 μg/kg body weight per day)
1	0.13	55	0.67	4.6	0.57
2	1.3			49	
3	0.19			6.9	
4	0.30			11	
5	0.21			7.9	
6	0.63			23	

Please cite this article as: Bose-O'Reilly, S., et al., A preliminary study on health effects in villagers exposed to mercury in a small-scale artisanal gold mining area in Indonesia. Environ. Res. (2016), http://dx.doi.org/10.1016/j.envres.2016.04.007