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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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ABSTRACT

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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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	

2.2. Study population

During the environmental assessment the inhabitants of Cisitu complained to the scientist, that they would suffer from severe health problems. Due to the lack of health facilities in Cisitu, BaliFokus formed a medical team of two Indonesian doctors (J. F. W., F. T. O.) from the Medicuss Foundation and one international expert (S.B.) to examine villagers requiring a medical assessment (explorative medical examinations of subjects). Examinations were strictly conducted on a volunteer basis. The study took place 15th to 18th of October 2014.

In 2012, at the General Assembly of AMAN (Aliansi Masyarakat Adat Nusantara or Indigenous Peoples of the Archipelago Alliance), a community leader representative of Kasepuhan Adat Cisitu expressed their commitment to develop a Community Green Gold Mining (CGGM) program and welcomed any cooperation to implement the program. In 2013, BaliFokus signed a cooperation agreement with AMAN to conduct a collaborative study with the community of Cisitu focusing on environmental monitoring and the health impact of mercury. In February 2014, the leader of the Cisitu communities invited BaliFokus to conduct health assessments and determine for themselves whether they were at risk from exposure to Hg contamination and to assess potential health impacts from Hg exposure, especially in women and children. In October 2014, BaliFokus invited an expert for mercury intoxication from Germany (S.B) and two Indonesian medical doctors as part of the research team.

All participants signed an informed consent form, including photo and video documentation. The local ethical committee and the local health authorities approved the study.

In Cisitu, the medical team visited the patients in their homes, or the volunteers came to the open clinic at the village community centre. Due to budget and resource constraints, not all villagers in need of medical examination were evaluated. The physicians examined 140 individuals exhibiting varied symptoms and diseases For 18 patients with neurological symptoms, a more extensive follow-up evaluation was performed including: detailed medical history, basic health data, and a neurological examination.

2.3. Clinical assessment

Prior to study commencement, health data from several ASGM projects had been reassessed to identify the essential indicators of an individual with chronic mercury intoxication, resulting in a diagnostic algorithm for chronic mercury intoxication (Doering, 2014). The ten indicators (classified into one of four categories) used in this study to identify individuals suspected of chronic mercury intoxication were:

- Anamnestic symptoms: Excessive salivation, tremor, sleep disturbances;
- Clinical symptoms: Ataxia of gait, disturbed coordination (dysdiadochokinesia), finger to nose tremor; gray or bluish discoloration of the oral cavity;
- Proteinuria; and
- Pencil tapping test and match box test to assess coordination.

The number of positive tests were summed to calculate a medical score (maximum of ten points) (Doering, 2014). Other causes of neurological symptoms like a previous stroke episode, brain injuries, Parkinson disease, etc., were recorded for each individual as possible confounders.

2.4. Laboratory assessment

Human specimens were collected to evaluate the mercury

Table 2
Mercury intake from rice in Cisitu. Total Hg in rice samples.

#	Rice characterization	Hg in rice (µg/kg)	Average body weight (kg)	Rice consumption (g/d)	Hg digested from rice consumption (µg/kg body weight /day)	ADI of mercury from rice based on US EPA IRIS standard (µg/kg body weight/day)	Total mercury ingested from rice based on JECFA PTWI standard (1–4 µg/kg bw/week)
1	White rice AO from Pasir Katimus (10 km from the centre of the village), 2 years old	1186	55	280	6.03	0.10	Between 0.14 (µg/kg body weight/day) for adults and 0.57 (µg/kg body weight/day) for children
2	Brown rice AO with husk, 4 years old	585			2.97		
3	Brown rice AO without husk (K), 4 years old	220			1.12		
4	Brown rice AO with husk, 5 years old	208			1.06		
5	Brown rice AO without husk (K), 5 years old	100			0.51		
6	White rice AO with husk, 5 years old	130			0.66		
7	White rice AO without husk (K), 5 years old	89			0.45		
8	Brown rice AO with husk, 10 years old	149			0.76		
9	Brown rice AO without husks (K), 10 years old	68			0.35		
10	Sirih Kuning rice AO with husk, 11 years	412			2.09		
11	Sirih Kuning rice AO without husk (K), 11 years	174			0.88		

content of each sample. A spontaneous urine sample (10 ml) was collected using a closed vessel. Samples were cooled immediately after and were kept cooled at 4 °C until they were analysed in the laboratory a few weeks later. A hair strand was cut, if possible from the occipital area directly over the skull, collected, and stored in a plastic bag.

The urine sample was analysed following 6 h of UV-photolysis (MAUV 2X, Maassen, Germany). The Hg-concentration was determined by Cold-Vapour Atomic Absorption Spectrometry (CV-AAS) using a Mercury Lab Analyser 254, and a Vapour Monitor VM-3000 (Mercury Instruments, Karlsfeld, Germany). Tin chloride ($SnCl_2$) was applied for the reduction of total mercury. All urine samples were above the detection limit (LOD) for total Hg (0.10 μg/L). Variation coefficient between replicates was 5–9%. Control urine from Recipe (Germany) ClinCheck1 (Hg 2.31 μg/l, found 2.49 ± 0.17 μg/l) was analysed together with the samples. The laboratory participates twice a year successfully in an external quality control scheme.

Hair samples (approx. 50 mg) were digested with 2 ml HNO_3 (65% suprapure, Merck) over 8 h at 50 °C. After cooling, the samples were filled with ultrapure water (up to 10 ml). An aliquot of 0.1 ml was analysed utilizing the same procedure as described for the urine samples. The LOD was 0.1 μg/g and variation coefficient between replicates was 15%, mainly caused by inhomogeneity of hair subsamples. For quality control, hair reference material BCR 397 (Hg 12.3 μg/g, found 10.0 ± 2.7), and GBW 9101 (Hg 2.16 μg/g, found: 2.29 ± 0.16) was analysed together with the samples.

2.5. Exposure limit values

The German Human-Biomonitoring Commission published widely accepted exposure limit values for mercury levels in urine and blood, i. e., Human-Biomonitoring (HBM) values (Schulz et al., 2007), and are comparable with other countries such as the U.S. (Caldwell et al., 2009). Mercury levels below HBM I are considered safe, mercury levels between HBM I and HBM II are considered alert levels, and mercury levels classified above HBM II level are considered action levels (see Table 3) (Schulz et al., 2012). For hair samples, ordinal HBM values do not exist. However, Trasande and colleagues (Trasande et al., 2005) have used a value of 1 μg/g as lower benchmark value, based on the results from studies conducted in the Seychelles (Davidson et al., 1998). Using the HBM blood exposure limit values and applying the stable ratio between blood and hair of 1:250 to 1:300, 5 μg/g can be considered as a reasonable4 alert level (see Table 3) (Berlin et al., 2015; Drasch et al., 2001).

2.6. Intoxication

An algorithm to define chronic mercury intoxication was used (see Table 4) (Drasch et al., 2001).

If typical signs and symptoms are established and the levels of mercury in human specimens are elevated intoxication can be clinically diagnosed. This algorithm has been reassessed (Doering, 2014). The algorithm was used in this study to determine an individual's intoxication status (see Table 5).

2.7. Statistical analysis

For clinical symptoms as well as for hair and urine examinations, absolute and relative frequencies were calculated. 95% exact binomial confidence intervals (95%CI) using the Clopper-Pearson method are given for the main results (Brown et al., 2001).

Table 3
Exposure limit values for mercury in urine and blood (Schulz et al., 2012).

	Hg-urine (μg/L)	Hg-blood (μg/L)	Hg-hair (μg/g)	
Below HBM I	≤ 7	≤ 5	≤ 1[a]	Low level
Between HBM I to HMB II	> 7– ≤ 25	> 5– ≤ 15	> 1– ≤ 5[a]	Alert level
Over HBM II	> 25	> 15	> 5[a]	High level

Green = safe level, yellow = alert level, red = action level.
[a] Derived values for hair (Drasch et al., 2001).

3. Results

3.1. Clinical assessment

Eighteen patients were carefully assessed (detailed medical history, basic health data, neurological examination, see Table 5). Pathological findings ranged from 13.3% (2 individuals) for proteinuria to more than 70% for sleep disturbances, subjective tremor, finger-to-nose tremor, ataxia of gait and dysdiadochokinesia. Table 6 summarizes the frequencies and 95%CIs for the pathological findings.

Mercury can cause additional signs and symptoms. Some of them such as paresthesia, numbness or headache were additionally observed in a few patients. Moreover, several patients had very severe neurological symptoms (esp. # 3, 5, 12, 14, 15, 16).

3.2. Video recording

The most prominent symptoms were recorded on video. For example, three patients presented with dysdiadochokinesia (patient #14, 15, 16), and severe tremor was found in two patients (#14, 16). These patients additionally had severe ataxia of gait test and coordination problems (see video). Mercury levels were elevated in all three patients.

Supplementary material related to this article can be found online at http://dx.doi.org/10.1016/j.envres.2016.04.007.

3.3. Laboratory results

The results from the mercury analysis of the urine and hair specimens are given in Table 6. Comparing the results with the exposure limit values from Table 3 shows that with respect to urine examination results, ten individuals had concentrations below the alert level of 7 μg/L (55.6%, 95%CI: 30.8–78.5%), five were within the range of the alert area between 7 μg/L and 25 μg/L (27.8%, 95%CI: 9.7–53.5%), and three were above the action level of 25 μg/L (16.7%, 95%CI: 3.6–41.4%) with a maximum of 86 μg/L.

Regarding the mercury hair analyses, all individuals exceeded the alert level of 1 μg/g (100%, 95%CI: 81.5–100%), with 13 individuals being within the range of the alert area between 1 μg/g and 5 μg/g (72.2%, 95%CI: 46.5–90.3%), and five individuals with concentrations above the action level of 5 μg/g (27.8%, 95%CI: 9.7–53.5%) with a maximum of 25 μg/g.

3.4. Intoxication

Using the chronic mercury intoxication algorithm (Doering, 2014), which combines the clinical results with the mercury levels found in the urine and hair samples, three individuals showed only a few symptoms and/or low mercury levels in their specimens. Consequently, these individuals were not classified as intoxicated. However, 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 subsequently classified as intoxicated.

Table 4
Decision algorithm for chronic mercury intoxication (Doering, 2014; Drasch et al., 2001).

Urine level μg Hg/L urine	OR	Hair level μg Hg/g hair	Exposure limit values (HBM)	AND	Medical Score Sum	Decision
< 7		< 1	Normal level (< HBM I)		0–10	No intoxication
7–25		1–5	Alert level (HBM I-II)		6–10	Intoxication
> 25		> 5	Action Level (> HBM II)		3–10	

4. Discussion

This study found that 15 out of 18 (83%) examined individuals were intoxicated, showing both the typical mercury-related symptoms such as ataxia, tremor and coordination problems, as well as having elevated levels of mercury in the urine and hair samples.

Only 8 of 18 mercury values in the urine samples were above the exposure limit values, where in prior studies performed in ASGM areas, urine levels were considerably higher (Baeuml et al., 2011). Conversely, and unlike prior studies (Baeuml et al., 2011), all hair sampled from villagers of Cisitu, indicated mercury levels above the exposure threshold. Miners working with mercury during the ball-milling, panning or burning the amalgam are exposed to elemental mercury which is transformed to inorganic mercury in the body. Subsequently, miners generally showed in former studies high levels of inorganic mercury in urine and not very high levels of total mercury in hair (Baeuml et al., 2011; Bose-O'Reilly et al., 2010a, 2010b). Inorganic mercury exposure leads to increased mercury levels especially in urine, and to a lesser extent in the hair. Meanwhile, methyl-mercury exposure is captured fairly well in hair but to a lesser extent in urine samples. The results from the Cisitu villagers indicate that there might be a notable exposure to methyl-mercury. What is the most likely source of this methyl-mercury exposure?

According to our knowledge of the existing literature no methyl-mercury related intoxication was observed in any ASGM area so far. What might be plausible exposure pathways for methyl-mercury in Cisitu? Elemental mercury discharge from the ball-mills and precipitation of mercury vapour potentially pollute the soil, including rice paddy fields, with inorganic mercury. These inorganic mercury forms might be transformed into methyl-mercury by microorganisms in the muddy waters and/or absorbed by the roots of the rice plant and could be finally transformed to methyl-mercury to be found in the grain (Feng et al., 2008). The villagers eat this polluted rice and might absorb especially methyl-mercury. The mercury contaminated fish from the ponds in Cisitu are eaten and contributed to the mercury burden of the inhabitants. The mercury levels found in the urine and hair, coupled with the typical symptoms, lead to the result, that 15 out of 18 villagers have chronic mercury intoxication. It is a hypothesis that this chronic mercury intoxication is not only caused by inhaling elemental mercury vapour, but as well from the mercury exposure from fish and rice, which might be dominantly methyl-mercury.

The mercury levels in the rice grown in Cisitu are elevated, compared with literature results (Feng et al., 2008; Li et al., 2010; Meng et al., 2014; Rothenberg et al., 2014). The villagers of Cisitu are autonomous, consuming their own locally grown rice, three-times a day, every day. The staple food of the villagers does not consist of a combination of local products and food from a supermarket - it is only "home-grown" food. The patients in Cisitu suffer from the symptoms of chronic mercury intoxication which might be partly due to the consumption of locally contaminated food (rice, fish). To our knowledge this is the first time that mercury intoxication in an ASGM area - that may be related to the pollution of local rice and fish – has been observed.

There are several limitations that restrict the generalizing conclusion of our findings. As mentioned above, low number of cases, potential other differential diagnoses, and confounders, such as age, are limiting factors. Another theoretical explanation would be that the indigenous population in Cisitu might be genetically homogenous where some gene variation may be related to higher mercury levels in their body (Engstrom et al., 2013). To overcome these restrictions, and to confirm our results, a comprehensive and well-funded study that examines all affected individuals of Cisitu, is urgently needed. This study could also ascertain underlying prevalence rates of neurological diseases from Cisitu and comparing them with prevalence rates in control areas.

4.1. Daily intake of mercury

Data from the Indonesian's Ministry of Agriculture showed that the rice consumption in 2013 was 102 kg per capita per year (Indonesian's Ministry of Agriculture, 2013). Assuming the average body weight of an inhabitant from Cisitu is 55 kg, and applying the levels of mercury in rice found in Cisitu (see Table 2), the average uptake of mercury is estimated to be between 0.35 and 6.0 μg/kg body weight per day. In comparison, the US-EPA guidelines state that the acceptable daily intake (ADI) or reference dose (RfD) that is allowed to enter the body with no harmful effect is 0.1 μg/kg body weight/day (US-EPA, 2001). For methyl-mercury, the recommended provisional tolerable weekly intake (PTWI) (Joint FAO/WHO Expert Committee on Food Additives, 2004) is 1–4 μg/kg body weight/ week – equal to 0.14–0.57 μg/kg body weight/day). This estimated uptake from mercury contaminated rice from Cisitu is 3–60 times higher than the US-EPA RfD or 0.6–43 times higher than the PTWI (see Table 2).

The Ministry of Marine Affairs and Fisheries data showed that national fish consumption by the Indonesians in 2013 were 35 kg per capita per year or about 0.67 kg fish per capita per week (Ministry of Marine Affairs and Fisheries, 2014). If we assume the average body weight of the Cisitu people is 55 kg, the mercury ingested through fish consumption by Cisitu people ranging between 8 and 86 times higher than the provisional tolerable weekly intake (PTWI) (Joint FAO/WHO Expert Committee on Food Additives, 2004) set by the JECFA as shown in Table 1.

4.2. Limitations

One major limitation is that only 18 patients were neurologically examined. Due to budget and time constraints it was not possible to exhaustively examine all villagers in need of evaluation. With a larger number of cases, the findings in this study may become more valid. This study is a case report study and not an epidemiological study. Furthermore, the selection of participants was not at random and no control group was available. Two patients (#1, #3) were older relative to the other participants, subsequently, several of their neurological symptoms may be more related to age rather than to mercury. There were no medical facilities in the village, and the patients were only clinically examined. It cannot be excluded that subjecting patients to additional blood tests, EEG, computer-tomography of the brain, or other techniques might have revealed additional differential diagnoses. The number of fish samples was low (i.e., six), and additional fish samples are needed. Speciation of samples to differentiate between inorganic and methyl-mercury was financially not

Table 5
Patients data, results of the medical examination, laboratory results.

#	Gender	Age	Job, exposure factors	Symptoms	Hg-urine µg/L	Hg-hair µg/g	Intoxication	Video
1	Male	60	Rice farmer, house located near the mercury bubble pond	Tremor, ataxia, dysdiadochokinesia, excessive salivation, accidental paralysis since one year	1.9	2.12	**Yes**	
2	Female	65	Rice farmer, house located near the mercury bubble pond	Moderate ataxia, moderate dysdiadochokinesia, tremor, coordination problems, sleep disturbances, paresis – right foot in the last 2 years	4.4	2.55	**Yes**	
3	Male	70	Rice farmer	Severe ataxia, severe tremor since 2–3 years, dysdiadochokinesia, sleep disturbances	4.0	2.59	**Yes**	
4	Female	53	Rice farmer	Since an accident not able to move 3 years ago, subjective tremor, sleep disturbances, digestive problems	3.8	1.44	No	
5	Male	82	Rice farmer	Severe tremor, unable to walk, sleep disturbances, paresthesia – hand, feet, getting worse in the last 5 months	2.9	7.06	**Yes**	
6	Female	37	Rice farmer	Ataxia, dysdiadochokinesia, subjective tremor, sleep disturbances, polyneuropathy for 7 years	1.6	5.55	**Yes**	
7	Female	40	Rice farmer	Symptomatic tremor, sleep disturbances, coordination problems in the last 3–4 months	47.7	4.54	**Yes**	
8	Female	40	Rice farmer	Tremor	20.3	11.02	**Yes**	
9	Male	50	Rice farmer	Ataxia, tremor, dysdiadochokinesia, coordination problems, sleep disturbances, excessive salivation, paresthesia – fingers, tuberculosis	3.5	1.56	**Yes**	
10	Female	40	Mercury vendor	Coordination problems, excessive salivation, sleep disturbances, gray to bluish discoloration oral cavity, edema	7.9	3.95	No	
11	Male	55	Miner, smelting amalgams, had worked in gold mining and processing for 35 years	Moderate dysdiadochokinesia, ataxia, tremor, coordination problems, excessive salivation, gray to bluish discoloration oral cavity	7.5	2.60	**Yes**	
12	Male	43	Miner, smelting amalgams, already worked in gold mining and processing since 13 years old (30 years)	Severe ataxia, moderate tremor, coordination problems, dysdiadochokinesia, excessive salivation, sleep disturbances, gray to bluish discoloration oral cavity,	85.8	24.96	**Yes**	
13	Female	46	Rice farmer	Ataxia, tremor, dysdiadochokinesia, coordination problems, distal numbness, proteinuria	14.5	5.50	**Yes**	
14	Female	60	Rice farmer	Most severe tremor in the last 7 years, severe ataxia, severe dysdiadochokinesia, severe coordination problems, excessive salivation, sleep disturbances, gray to bluish discoloration oral cavity	4.5	1.55	**Yes**	Mrs. O.
15	Female	38	Rice farmer	Severe tremor, moderate dysdiadochokinesia, ataxia, coordination problems, sleep disturbances, nausea, paresthesia – extremities	25.2	2.54	**Yes**	Mrs. P.
16	Male	35	Rice farmer	Most severe coordination problem, severe ataxia, tremor, gray to bluish discoloration oral cavity, dysarthria, nausea, loss of sensation – extremities, proteinuria – getting worse in the last 2 years	3.1	1.52	**Yes**	Mr. T
17	Male	50	Panning with mercury,-working intensively with mercury in 1999–2002	Moderate ataxia, dysdiadochokinesia, tremor, coordination problems, excessive salivation, sleep disturbances, high blood pressure	13.6	3.13	**Yes**	
18	Female	23	Rice farmer	Coordination problems, sleep disturbances	2.8	2.94	No	

Table 6
Frequency and confidence intervals of pathological findings; Medical score sum points: 0–2 low score sum; 3–5 medium score sum; 6–10 high score sum.

Sign	Absolute frequency (%)	95% confidence interval (%)	Score point if pathologic finding or positive result
Excessive salivation	7/18 (38.9)	17.3–64.3	1
Sleep disturbances	13/18 (72.2)	46.5–90.3	1
Subjective tremor	13/18 (72.2)	46.5–90.3	1
Ataxia of gait	13/18 (72.2)	46.5–90.3	1
Finger-to-nose tremor	12/17 (70.6)	44.0–89.7	1
Dysdiadochokinesia	12/16 (75.0)	47.6–92.7	1
Gray to bluish discoloration of the oral cavity	5/18 (27.8)	9.7–53.5	1
Proteinuria	2/15 (13.3)	1.7–40.5	1
Pencil tapping test	8/14 (57.1)	28.9–82.3	1
Matchbox test	8/14 (57.1)	28.9–82.3	1
Maximum medical score			10

possible to perform to distinguish between exposure pathways of inorganic and methyl-mercury.

5. Conclusion

Further research is needed to test the hypothesis that mercury-contaminated rice from small-scale gold mining areas might cause mercury intoxication. A well-designed environmental epidemiological study is required. Additional environmental samples, such as soil, water, air, fish and especially rice need to be analysed. Speciation of specimens is needed to distinguish between the impact of inhaling elemental mercury vapour and in-digesting methyl-mercury burdened fish and rice.

If the results confirm the previous high readings, efforts to control and limit ongoing mercury exposure will be a major undertaking. Furthermore, medical treatment of existing patients with confirmed mercury intoxication will need to be considered, necessitating medical infrastructure in Cisitu.

The village of Cisitu may not be unique – rice farming is a dominant form of agriculture in Indonesia and in other parts of Asia. ASGM activities also take place alongside farming in some areas. If our findings are confirmed, other high-risk areas of Indonesia and elsewhere should be identified. It may be necessary to test the mercury content in seeds from those areas prior to planting or consuming the rice. Furthermore, mercury use in gold mining processing activity should be stopped and remediation of contaminated soil and ponds need to be done. These measures should be considered in order to help prevent and reduce the environmental and health burdens in Cisitu as well as those in settings similar to Cisitu.

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