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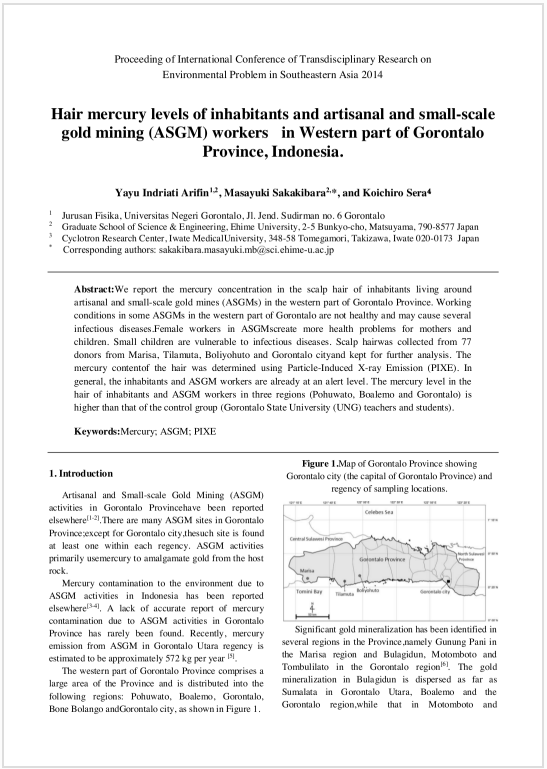

Proceeding of International Conference of Transdisciplinary Research on Environmental Problem in Southeastern Asia 2014

Hair mercury levels of inhabitants and artisanal and small-scale gold mining (ASGM) workers in Western part of Gorontalo Province, Indonesia.

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Abstract: We report the mercury concentration in the scalp hair of inhabitants living around artisanal and small-scale gold mines (ASGMs) in the western part of Gorontalo Province. Working conditions in some ASGMs in the western part of Gorontalo are not healthy and may cause several infectious diseases.Female workers in ASGMscreate more health problems for mothers and children. Small children are vulnerable to infectious diseases. Scalp hairwas collected from 77 donors from Marisa, Tilamuta, Boliyohuto and Gorontalo cityand kept for further analysis. The mercury contentof the hair was determined using Particle-Induced X-ray Emission (PIXE). In general, the inhabitants and ASGM workers are already at an alert level. The mercury level in the hair of inhabitants and ASGM workers in three regions (Pohuwato, Boalemo and Gorontalo) is higher than that of the control group (Gorontalo State University (UNG) teachers and students).

Keywords: Mercury; ASGM; PIXE

1. Introduction

Artisanal and Small-scale Gold Mining (ASGM) activities in Gorontalo Provincehave been reported elsewhere[1-2].There are many ASGM sites in Gorontalo Province;except for Gorontalo city,thesuch site is found at least one within each regency. ASGM activities primarily usemercury to amalgamate gold from the host rock.

Mercury contamination to the environment due to ASGM activities in Indonesia has been reported elsewhere[3-4]. A lack of accurate report of mercury contamination due to ASGM activities in Gorontalo Province has rarely been found. Recently, mercury emission from ASGM in Gorontalo Utara regency is estimated to be approximately 572 kg per year [5].

The western part of Gorontalo Province comprises a large area of the Province and is distributed into the following regions: Pohuwato, Boalemo, Gorontalo, Bone Bolango andGorontalo city, as shown in Figure 1.

Figure 1. Map of Gorontalo Province showing Gorontalo city (the capital of Gorontalo Province) and regency of sampling locations.

Significant gold mineralization has been identified in several regions in the Province,namely Gunung Pani in the Marisa region and Bulagidun, Motomboto and Tombulilato in the Gorontalo region[6]. The gold mineralization in Bulagidun is dispersed as far as Sumalata in Gorontalo Utara, Boalemo and the Gorontalo region,while that in Motomboto and

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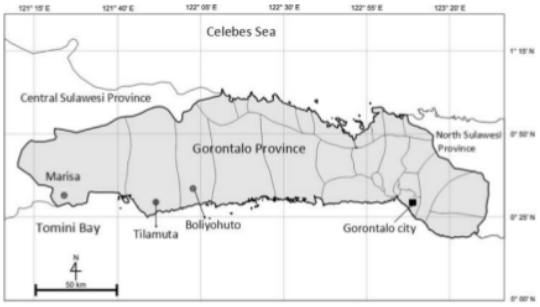


Significant gold mineralization has been identified in several regions in the Province,namely Gunung Pani in the Marisa region and Bulagidun, Motomboto and Tombulilato in the Gorontalo region[6]. The gold mineralization in Bulagidun is dispersed as far as Sumalata in Gorontalo Utara, Boalemo and the Gorontalo region,while that in Motomboto and

Tombulilato is concentrated only in the Bone Bolango region.

The Gunung Pani (Figure 2), Bulagidun, Tombulilato and Motomboto gold-mining sitesare being explored by gold-mining companies. ASGM activity by local people is considered interference and sometimes creates conflicts. ASGM activities are illegal,but the local government does not stop them due to widespread corruption.

Figure 2.ASGM inGunung Pani of Marisa of Gorontalo Province.Location of ore holes indicated by orange sheet on steep slopes (a) and processing site showing trommols (b)

The living conditions of ASGM workers in the western part of Gorontalo Province are similar to those of other ASGMs in the north. The presence of female workers(Figure 3a) and their child(ren) (Figure 3b) living in the mining processing site causes health and social problems such aspoverty and the potential spread of infectious diseases.Many ASGM do not haveclean water facilities. Children areconsidered vulnerableto mercury contamination from ASGMand also to other environmental problems [7].

Figure 3.ASGM working conditions in Gunung Pani of Marisa of Gorontalo Province.(a) Female workers crushing the ore in ASGM processing site and (b) achild living in the ASGM processing site.

The ASGM sites in the western part of Gorontalo Province are mainly inprotected forests. For example, theTombulilato and Motomboto sites are inside Bogani Nani Wartabone National Park. ASGM in Boalemo and Gorontalo regency threatenendangered species (Anoa, Babi Rusa and Tarsius Spectrum and 35 endemic birds) living in Nantu Forest[8-9].

There is no ASGM in Gorontalo city, but many gold shops and the Bone River may be act as sources of mercury contamination. Contamination of mercury due to gold shops has been reported [10]. The Bone River is the main public water source of Gorontalo city and has been contaminated by mercury [11].

Biological monitoring is intended to detect changes occurring in the human body as a result of industrial environments. Human hair as a biological sample has some advantage such as easy to collect, easy to store and it has a longer recording capacity of contamination compared to other biological samples

The mercury concentration in hair sampleswas used to characterize the risk of higher mercury concentration to the health status by comparison it with reference values published by the German Human Biomonitoring (HBM) Commission in 1999 (Human –Biomonitoring Commission of the Federal Environmental Agency Berlin, 1999)[11]. HBM divides the risk category related to mercury in hair into the following 3 levels: below HBM I (normal) for 0 -1 ppm; between HBM I and HBM II (alert) for 1- 5 ppm; and Over HBM II (high) for > 5 ppm.

Here, we report the hair mercury contamination of inhabitants and ASGM workers in the western part of Gorontalo Province. These data can be addedtohe reports from other region to provide a complete picture of ASGM mediated mercury concentration.

2. Experimental Section

2.1 Location

We visited two ASGM sites (Gunung Pani of Marisa in the Pohuwato region and Bilato in the Gorontalo region)to sample scalp hairfrom ASGM workers and inhabitants. We also visited the city of Tilamuta, the capital of the Boalemo region, to obtain scalp hairfrom people living in areas far from ASGM sites. We also took samples from Universitas Negeri Gorontalo students.

2.1 Hair Sampling

Human scalp hair samples were taken from77 participatingASGM minersand inhabitants aged8 to 75 years old. The distribution of participants according to sex, location and occupationis summarized in Table 1. Approximately 10-20 strands of hair were cut close to the skin from the right backside of the head (mastoidal region of the temporal bone) and then labeled and stored in plastic bags[12].

Table 1. Hair Mercury donors distributionsaccording to sex, occupation of several mining sites in western part of Gorontalo Province.

Site (population)	Sex		Miner	Non
	M	F		
UNG (41)	1	40	0	41
Marisa (6)	5	1	6	0
Boliyohuto (17)	7	10	4	13
Tilamuta (13)	2	11	0	13

Figure 4. The researcher wascutting several strands of scalp hairsin mastodidal region of the temporal boneof miner of ASGM.

2.2 Analytical Procedure

Elemental analysis of each sample was performed by **Particle Induced X-ray Emission (PIXE)** in theCyclotron Research Center, Iwate Medical University, Japan. The precision and accuracy of this method have been reported elsewhere[14-16]. Hair samples were washed with Milli-Q water and shaken in an ultrasonic bath for 1 minute. Theywere dried by wipingwith a tissue. The dried hair samples were then washed in acetone for 5 minutes with stirring, washed again using Milli-Q water, wiped well with a tissue and dried at room temperature.The hair samples (approximately 7 strands) were stuck on a target holder. A 2.9 MeV-proton beam hit the target after passing through a beam collimator of graphite with a diameter of 6 mm. X-rays with energy higher than that of the K-Kα line were detected with a Si(Li) detector (25.4μm-thick Be window; 6μm in active diameter) with a 300μm-thick Mylar absorber. To measureX-rays lower than K-Ka, a Si(Li) detector (80 mm Be; 4 mm in active diameter), which has a large detection efficiency for low energy X-rayswas used. A description of the data-acquisition system and the measuring conditions has been reported previously [14]. Typical beam current and integrated beam charge were 100nA and 40mC, respectively. The procedure for the standard-free method for untreated hair is almost same as that reported in previous studies [14].

2.3. Statistical Analysis

Statistical analysis was used to calculate the mean, standard deviation (SD) and ranges. TheArithmetic mean (AM) and thegeometrical mean (GM) were

calculatedusing equations (1) and (2), respectively. The two means are used topresentthe hair mercury data.

$$AM = \sum_{i=1}^{N} x_i \quad (1)$$

$$GM = \prod_{i=1}^{N} x_i \,; x_i \neq 0. \quad (2)$$

Spearman correlation between variables and analysis of variance were performed using Origin (Originlab.inc) software for Windows. A p value less than 0.05 was considered statistically significant.

3. Results and Discussion

3.1. Hair Mercury concentration

Table 2. Hair Mercury level distributions according to HBM.

Site (population)	< HBMI	HBM I <<= HBM II	> HBM II
UNG (41)	10	24	7
Marisa (6)	0	1	5
Paguyaman (17)	0	6	11
Tilamuta (13)	0	4	9

The hair mercury distribution based on HBM is shown in Table 2. In the UNG group, 10 people (24.4%) have a normal amount of hair mercury, 24 people (58.5 %) are at the alert level, and 7 people (17.1 %) have a high level of mercury.Only the UNG groupexhibited people with normal amount of hair mercury. In contrast, subjects from Marisa, Boliyohuto and Tilamuta were mostly classified as having a high levelof contamination with some at the alert level.

3.2. Statistical Analysis

The distribution of mercury concentration from 77 scalp-hair samples from four groups (UNG, Tilamuta, Boliyohuto and Marisa) are shown in Figure 5.The UNG, Tilamuta and Marisa samples were normally distributed at a significance level of 0.05. The data from the Boliyohuto samples are not normally distributed.

The statistical analysis of the mercury concentration in the scalp hair of inhabitants in ASGM areas is shown in Table 3.

Samples were distributed into fourgroups according to their living area. The UNG group is composed of teachers and students at Universitas Negeri Gorontalo. The UNG group is the control group because they do not interact with mining sites directly. The Marisa and Tilamuta groups represent ASGM miners and inhabitants, respectively. The Tilamuta group is a mixture of inhabitants and ASGM miners. The environmental conditions experienced by those in the Marisa, Boliyohuto and Tilamuta groups were different in terms of amount of mercury used per year and geographical conditionsbut thegeometrical means of the Marisa, Boliyohuto and Tilamuta groups were similar. More interestingly, they are not significantly different from each other.Only the UNG group has arithmetic means which is significantly different from the others.

Figure 5. Distribution of Hair mercury content of western part of Gorontalo Province.

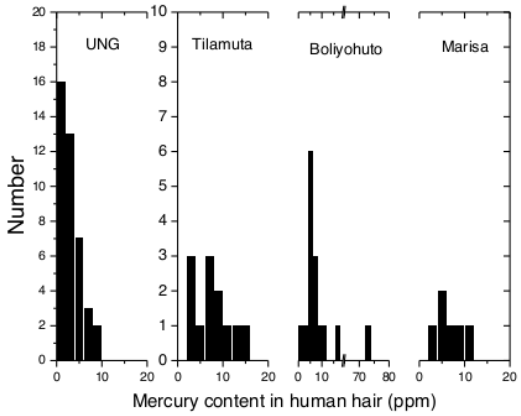


Table 3. Hair Mercury concentration of inhabitants of several mining sites in western part of Gorontalo Province.

Site (population)	Mean		Min	Max
	AM	GM		
UNG (41)	2.90	-	0.00	8.90
Marisa (6)	7.57	6.42	3.77	10.94
Boliyohuto (17)	10.26	6.21	1.27	73.80
Tilamuta (13)	6.78	6.55	1.02	14.44

3.3. Discussions

The Tilamuta group should be discussed in terms of gender, asthe majority of hair donors from Tilamuta are female. Table 4 shows the distribution of hair mercury levelsof the Tilamuta inhabitants according to sex. Many femaleshave long hair, which allows the collection of a long history of mercury contaminationcompared to males. There is a significant difference in the mean(arithmetic and geometric) of hair mercury between groups of male and female.

Table 4. Hair Mercury level distributionsaccording to Gender for Tilamuta inhabitants.

	Male	Female
Number	2	11
Normal	0	0
Alert level	1	3
High level	1	8
Mean (Arithmetic)	5.48	7.95
Mean (Geometric)	4.72	6.97

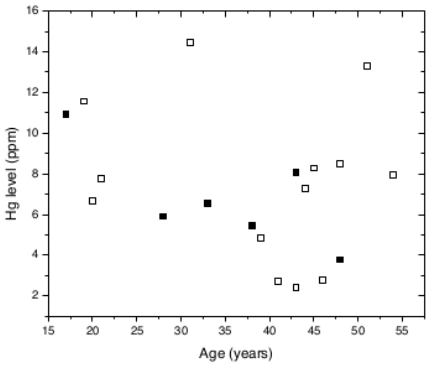
Two male inhabitants from Tilamuta were not miners; the teacher had a lower level of hair mercury compared to the unemployed male. The hair of the unemployed male had a mercury level of 8.27 ppm, which is close to that of the housewives. This result is expected given thatthe unemployed male primarily remains in and around Tilamuta and consumes food and water from Tilamuta. The male teacher was less contaminated by the Tilamuta environment conditions because of his activities allows him to avoid mercury contamination from ASGM of Tilamuta.

The highest hair mercury level (73.8 ppm) was found in young (30 years old) housewives from Boliyohuto. This hair mercury level is far above average (10.13 and 6.10 ppm AM and GM, respectively) and cannot be explained in terms of duration of living only. Further interviews and medical tests are needed to determine the cause of this abnormality. Some possible sources of contamination are food and drinking water,but other sources such as face white cream (containing mercury) cannot be ignored.

According to HBM,a hair mercury concentration above 1 ppm is at the alert level. All of inhabitants of Marisa, Paguyaman and Tilamuta are at the alert level. The UNG group alsoexhibits an average at the alert level, although some students showno mercury in their hair.

There is a question of whether hair mercury levels are age dependent.To answer that question, we plotted the hair mercury levels of Marisa and Tilamuta groups representing ASGM workers and non-ASGM workers (Figure 6). There was no clear relationship between hair mercury and age in Tilamuta inhabitants. While decreasing mercury levelswith increasing age of Marisa miners should be carefully discussed.No significant correlation found between the hair mercury levels of the UNG, Tilamuta and Boliyohuto groups. Thesignificant and negative (-0.16) correlation was found between mercury level and work as a miner needs to be replicated.

Figure 6. Relation between hair mercury level and age of Marisa ASGM workers (closed symbols) and Tilamuta inhabitants (Open symbols).



4. Conclusions

The concentration of mercury in the scalp hair of inhabitants in western part of Gorontalo Province is already at the alert level according to HBM. There was a significant difference between the hair mercury concentration of people who lived around ASGMs and the control group (UNG teachers and students).

Acknowledgments

The authors wish to thank the regents of Pohuwato, Boalemo, Gorontalo, Gorontalo City and its officers, the owners of mining plants for allowing us to conduct interviews and take photographs. The Author (YIA) would like thanks to Japanese Government for providing a Monbusho Scholarship for graduate studies in Ehime University.

The authors declare no conflict of interest.

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