Urban medical geology of mercury pollution on traditional gold smelting in Makassar City, Indonesia

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ABSTRACT

Introduction

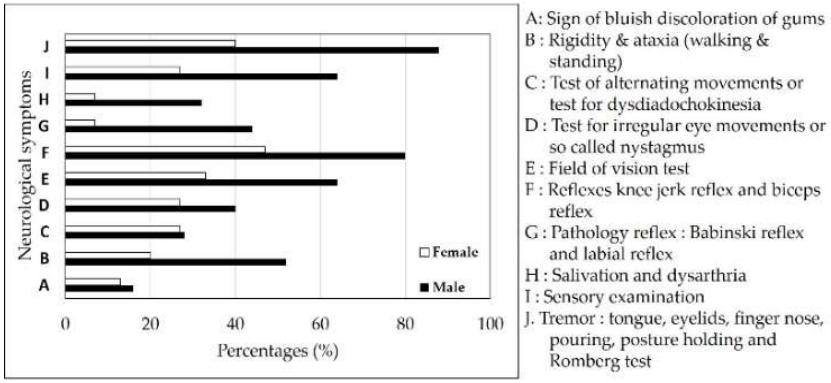
Medical geology is a scientific field which corresponds between natural geological factors and health problem in human, animal, and plants (Komatina 2010). The concept of an urban medical geology perspective is an effect on anthropogenic sources in urban pollution and human health problems. In Makassar, South Sulawesi, Indonesia traditional gold smelting has been run as private enterprises over the last 40 years, with fabricating gold bars to produce gold jewelry as the core business activities. Stages of making gold jewelry include smelting, burning, and panning using mercury (Hg). Therefore, a potential source of mercury exposure and health problems is released in the smelters during their works. This research aims to assess mercury pollution on traditional gold smelters in Makassar City, Indonesia.

Material and Method

Human scalp hair samples were taken from 105 gold smelters comprised of 54 males and 51 females. The control group consists of 16 males and 16 females. Elemental analysis of the scalp hair samples was performed by particle-induced X-ray emission (PIXE). Through a comparison of mercury levels to the reference values published by the German Human Biomonitoring (HBM) Commission (Schulz et al. 2007) toxicological evaluation was examined. To study the neurological symptoms suffered from mercury pollution, a standardized examination (Bose-O'Reilly et al. 2010) was performed and examined by medical doctors.

Results and Discussion

Traditional gold smelters in Makassar City, Indonesia can be categorized into two groups: goldsmith who designs and manufactures jewelry, and urban artisanal gold miner (UAGM) who recovers fine gold particles incorporated in the waste from goldsmith work. The result shows that the mean mercury level of goldsmith and UAGM workers are 11.1, 16.3µg/g, respectively. Comparing to the control group and reference value of HBM, the mean mercury level of goldsmith and UAGM workers can be considered as a high level. The majority of the gold smelters suffer symptoms of tremor in the tongue, eyelids, finger nose, pouring, and posture holdings. The Romberg test of these symptoms is reaching 88% of samples, followed by unstable rigidity, lack of vision field, slow reflexes, and weak sensory with range 60–67% of the samples (Fig.1). Male smelters experience more symptoms than female smelters. It is probably because male smelters are engaged more actively in the work than female smelters.



And also, it is important to consider that the lifestyle of gold smelters probably affects their health.

Fig.1. Neurological assessment of traditional gold smelters.

References

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1. Introduction

Medical geology is the science that examines the relationships between natural geological factors and human health problems. With weathering, rocks break down to form the soils on which crops and animals are raised. Much of the dust and some of the gases contained in the atmosphere are of geological origin, and soil and water support the crops and animals that constitute the food chain. Therefore, human health is linked directly to geology through the food chain and inhalation. The clearest example of this relationship is when geological materials contain too little (deficiency) or excessive (toxicity) trace elements, which can influence human health. Such deficiencies or toxicities can arise from natural or anthropogenic activities [1-2].

The mercury in the urban environment comes from various sources, including occupational and industrial activities, fuel combustion, and waste incineration. Urban populations are exposed directly through the inhalation of mercury vapor, or indirectly via the soil, fish, and edible plants. People living in gold mining towns experience high inorganic mercury levels when mercury vapor is emitted during the burning of amalgam as well as gold dorè in gold shops [3-5]. These activities occur in Makassar, Indonesia, where a group of urban people established an artisanal waste recycling industry, in which they use mercury to recover the fine gold particles contained in the waste from goldsmiths' activities. Here, it is designate this process 'urban artisanal gold mining' (UAGM) because it is similar to the artisanal and small-scale gold mining (ASGM) that occurs in gold mining areas

The traditional gold smelters in Makassar can be categorized into two groups: goldsmiths and urban artisanal gold mining (UAGM) workers. The goldsmith's design and manufacture gold jewelry, while the UAGM workers recover the fine gold particles incorporated in the waste generated during the goldsmiths' work. Except for the ore excavation stage, the recovery process in UAGM is similar to the gold extraction stage in ASGM, but rather than excavating gold deposits or secondary ores, the UAGM workers collect the waste from the goldsmiths and then apply a waste recovery process in the urban core of Makassar. The amalgamation method is applied during this recovery process to separate incorporated gold particles. Mercury that has been used is released from the pond or trommel into the drainage system of the building, from where it flows to the main city drains. Doré, the gold that results from the amalgamation process, usually still contains about 2%–5% mercury [3]. Therefore, when a goldsmith refines the gold doré by burning it, he or she is directly exposed to mercury vapor. Moreover, the smelting operation is carried out in small buildings with insufficient ventilation, and there is no use of retorts or any type of condenser to capture the mercury fumes. Furthermore, approximately, 85% of the gold smelters have been worked for more than 5 years [6]. In other words, they have used mercury for a prolonged time, thereby potentially have health-related mercury intoxication problems. Therefore, the health of the gold smelters was assessed by evaluating a number of neurological symptoms indicating mercury intoxication. Traditional gold smelting may occur in many urban areas of Indonesia, yet there were no official reports of these activities.

2. Material and Method

Human scalp hair samples were taken from 105 gold smelters comprised of 54 males and 51 females. The control group consists of 16 males and 16 females. Elemental analysis of the scalp hair samples was performed by particle-induced X-ray emission (PIXE) [7-8]. Through a comparison of mercury levels to the reference values published by the German Human Biomonitoring (HBM) Commission [9], the toxicological evaluation was examined. To study the neurological symptoms suffered from mercury

pollution, a standardized examination [10] was performed and examined by medical doctors.

3. Results and Discussion

3.1. Distribution of Income of Traditional Gold Worker Based on Age

During our interviews, we found that owners of traditional gold smelting who were aged 60–65 years were first-generation gold smelters, whereas owners aged 30–55 years were second-generation workers continuing the business after their parents or elders retired. The income of the owner can reach US$ 595/month (US$ 20/day), while skilled and un-skilled workers earn about US$ 372/month (US$ 12/day) and US$ 180/month (US$ 6/day), respectively. Figures 4 (a) and (b) show that both goldsmith and UAGM workers who earn more than US$ 180–370/month were mainly 25–40 years old. Goldsmiths and UAGM workers have average incomes of US$ 290/month (US$ 10/day) and US$ 220/month (US$ 7/day), respectively. Their income is slightly higher than the income of ASGM workers in Kalimantan, who earn about US$ 74–223/month [11].

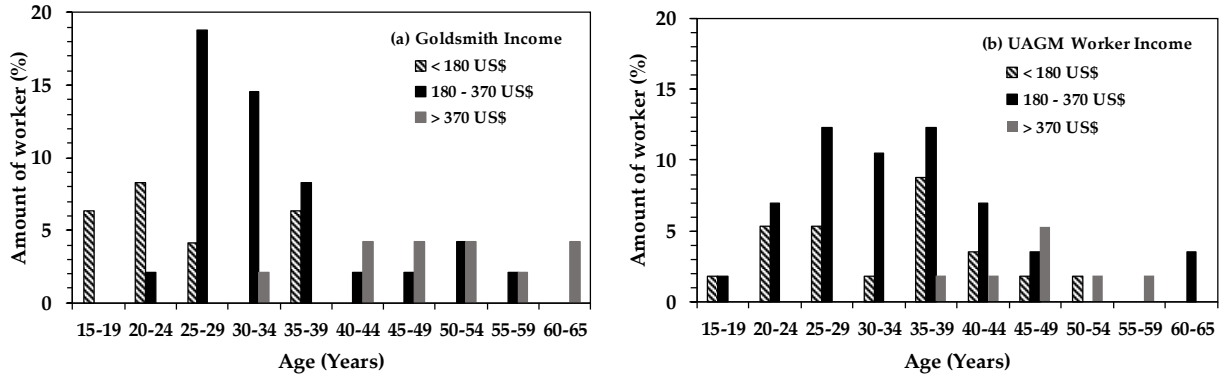

Figure 1. Distribution of income based on the age of traditional gold smelters, (a) goldsmith, and (b) UAGM worker.

3.2. Mercury Exposure of The Traditional Gold Smelters

The activity of goldsmith and UAGM workers causing exposure to mercury is different. The goldsmith might be exposed to mercury by smelting gold doré, while the UAGM worker by amalgamation and burning out the amalgam. To determine mercury level, the head hair of the gold smelter was used as biomonitoring for quantifying total mercury concentration. The benefit of using hair is a simple, integrative, and noninvasive sample for estimating long-term average exposure [11–13].

The average total mercury concentration in the hair of the UAGM workers was 16.3 µg/g ranged from 2.5 to 93.8 µg/g and was higher than the average in the hair of goldsmiths which was 11.1 µg/g ranged from 2.7 to 101 µg/g (Table 1). However, the difference between the mercury concentrations in the hair of UAGM workers and goldsmiths was not statistically significant (t-test, P-value= 0.2). The average mercury level in the hair sampled from urban inhabitants was 2.1 µg/g, which is considerably lower and significantly different (t-test, P-value <0.01) from that of both goldsmiths and UAGM workers. This indicates that both groups of gold smelters are exposed to mercury from their occupation or activities, such as smelting amalgam and doré. Comparison with the threshold limits for mercury of the Human Biomonitoring Commission of the German Federal Environmental Agency shows that the mercury level in the hair of both gold smelters fell within the alert to high-level category. The average

total mercury concentration in the hair of a traditional gold smelter in Makassar was somewhat similar to that reported for hair mercury levels of mining workers engaged in excavation and smelting gold ore. The average total mercury concentrations in hair of smelting workers in Talawaan and Galangan were 13.14 and 17.09 µg/g, respectively, but ranged from 1 to 240 µg/g [11-15]. This finding is unpredicted because the traditional gold smelting is very small-scale manufacturing, process, and production.

Table 1. Total mercury concentration in the hair of traditional gold smelters

	Total mercury concentration in the hair (µg/g)			Mercury level*
	mean (SD)	Min.	Max.	
Goldsmith	11.1 (15.7)	2.7	101.0	Alert – High
UAGM worker	16.3 (22.7)	2.5	93.8	Alert – High
Control group	2.1 (1.4)	0.0	5.4	Normal – Alert

* Based on threshold limit of The Human Bio Monitoring (HBM) Commission of the German Federal Environment Agency [9].

3.5. Neurological Assessment

Mercury exposure is known to have potentially damaging neurological effects on human health. Mercury affects the human body by various mechanisms, such as interrupting microtubule formation; changing the intracellular calcium balance and membrane potential; altering cell membrane integrity; disturbing or inhibiting enzymes, inducing oxidative stress; inhibition of protein and DNA synthesis; and disturbing immune functions [16-17].

Among the sample of the traditional gold smelter, there were 35 gold smelters (or 33%) who agreed to take part in the neurological assessment. They were 26–60 years old and have been working for a minimum of 5 years with elevated mercury concentration in their head hair ranged 2.8–93.8 µg/g as have been observed. The results showed various neurological disturbances, as shown in Figure 2. The most prevalent symptoms among the gold smelter were tremor in the tongue, eyelid, finger nose, pouring, posture holding and Romberg test reaching 80–87% occurrences in samples, whereas 40%–70% had positive findings for a lack of field of vision, slow knee jerk and bicep reflexes, sensory disturbance, unbalanced rigidity, and ataxia. This finding agrees with the health assessment of ASGM workers in Sulawesi and Kalimantan. It was reported that tremor and ataxia were the most common symptoms, where total mercury concentrations of 1.0–224.6 µg/g and 1.2–239.0 µg/g, respectively [10-11,17].

4. Conclusions

In terms of socio-demographics, the urban people engaged in traditional gold smelting are males and females of working age (25–60 years) and with a low level of education. As they can earn a relatively high income, the traditional gold smelting activities continue to exist. Mercury released into the environment during the traditional gold smelting process raises the risks of mercury exposure and health problems for both the gold smelters and the inhabitants

of Makassar. Traditional gold smelters experience a high level of mercury exposure, and numerous neurological symptoms such as tremors, lack vision, slow reflexes, sensory disturbances, unbalanced rigidity, and ataxia, were observed in this group. The number of findings positive for mercury intoxication was not correlated with the mercury concentration in hair but was reasonably correlated with the working years of the gold smelters.

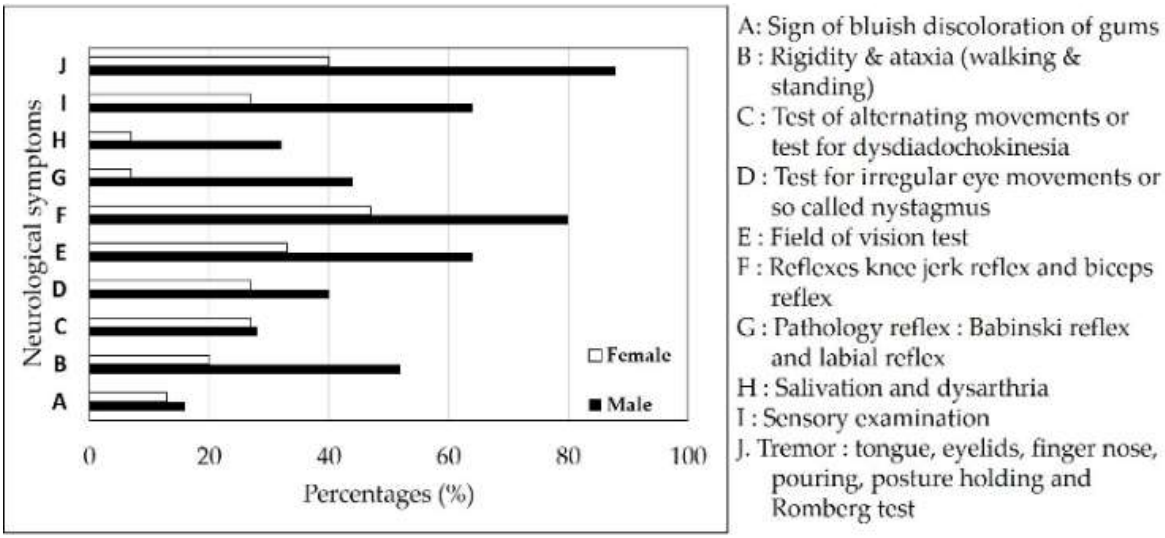

Figure.2. Neurological assessment of traditional gold smelters

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