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Socioeconomic and Mercury Exposure to The Goldsmiths in Manggala Subdistrict of Urban Artisanal Gold Mining (UAGM) Area in Makassar, South Sulawesi, Indonesia

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Abstract. 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 doré in gold shops. 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. The goldsmith in Manggala is one of UAGM activities to design and manufacture of the unique gold jewelry. Mercury exposure to the goldsmith was happened through gold refining process. The aims of this research are to characterize the socioeconomic and potential mercury exposure to the goldsmith workers. The socioeconomic characterization of goldsmith was obtained by questionnaire survey, in-depth interviews and mercury exposure in hair was analyzed by using Particle-induced X-ray emission (PIXE) from Iwate Medical University. The result showed that the goldsmith workers in Manggala sub district is better than the other gold workers in Makassar in term of income and education. The lower education was graduated from elementary school and the higher education was graduated from the university. The monthly income of goldsmiths are unskilled, skilled and owner, <US\$ 376 (29%), US\$ 376-751 (61%), >751 (11%), respectively. The goldsmiths were exposure by mercury through the refining process in the gold. Therefore, it's found that the average mercury concentration in hair is 6.6 µg/g (min-max: 1.6-47.7 µg/g). The concentration of mercury in human hair of goldsmith is 5.03 µg/g, for indirect exposed and 8.18 µg/g for direct exposed. This result indicate that the level of mercury is seriously problem according to HBM threshold limit. Therefore, mercury exposure from UAGM activities must be prevented before the greater impact on society.

Keywords. Goldsmiths; UAGM; Mercury exposure; Socioeconomic

1. Introduction

More than 50 countries including Indonesia ASGM is as livelihood activity not only in rural but also in the urban area [1]. The ASGM activity is booming in Indonesia when the gold price is increasing



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every years. The people utilize these conditions to looking for a lot of money to fill necessary daily life. The ASGM activity often uses mercury to extract fine gold particles by rudimentary technology, then mercury released and evaporated in the environment during amalgamation and refining process. Heavy metal such as mercury, is a growing cause of environmental pollution worldwide [2]. Mercury can occur in soil naturally or as a result of human activity such as gold mining. Mercury takes three chemical forms in the environment, namely elemental mercury, inorganic mercury and organic mercury or methylmercury. Humans are mainly exposed to organic mercury through consumption of fish, inorganic mercury exposure occurs mostly through the inhalation of mercury vapor. Mercury exposure in urban area is generally from anthropogenic sources such as industrial pollution, transportation, waste incineration, and fossil fuel combustion while ore processing such as artisanal small-scale gold mining (ASGM) was always associated with the source of mercury exposure in rural or mining town.

The UAGM activity have been running as private enterprises over the last 40 years in Makassar South Sulawesi, Indonesia, with business core activities are being the manufacture of gold jewelry. The UAGM in this city refer to two groups of gold processes; goldsmith and gold smelter works, which does gold smelting and processing by rudimentary techniques. The UAGM workers health have been impacted by mercury exposure [3]. Based on the impact of the UAGM activities, this paper purposes are to describe the socio economy and to analysis the mercury concentration of goldsmith in another area of UAGM activity.

2. Data and Method

2.1. Study area

Makassar is in the southern part of Sulawesi and, by population, is the fifth largest city in Indonesia. The majority of the UAGM lives and conducts their smelting activities in the Tallo, Wajo and Manggala sub-districts, shown in Figure 1. The study area is Manggala sub-district.

2.2. Sample collection

Sample collection was conducted in September 2017. The study was approved by the local government of Makassar district and Ethical Committee of our institution. An explanation was given to ensure they know the purpose of the sampling. Then, before the head hair was taken and interview was performed, they signed an informed consent. Human hair sample in this study was collected from goldsmith workers in Manggala sub district. The mercury exposure to goldsmith workers by refining gold particles. The amount sample collected is 30 workers. Two samples were rejected because they were sick when taking their hair.

2.3. Analysis procedures

The goldsmith hair samples were taken to determine mercury concentrations. Approximately 10–20 strands of hair were cut close to the skin from the right back side of the head (mastoid region of the temporal bone) and then labeled and stored in a plastic sample bag [4]. The mercury level associated with the mercury concentrations in hair samples were assessed by comparison with reference values. The reference values obtained from benchmark limit of US EPA [5], and derived in analogy [6] were compared to the toxicology threshold limit established by The Human Bio Monitoring Commission of the German Federal Environment Agency [7,8]. Based on that comparable values, the threshold limits can be divided into three categories: mercury concentrations of 0–1 $\mu\text{g/g}$ are normal, of 1–5 $\mu\text{g/g}$ represent alert level, and of >5 $\mu\text{g/g}$ represent high level risk [6,9].

The human hair samples were washed in an ultrasonic bath using Milli-Q water and acetone for 5 minutes to reduce the contamination such as bacteria, fungi, dust, cosmetics, and possible contaminations. The samples were then dried at room temperature. After that, the human hair samples were analyzed by particle induced X-ray emission (PIXE) spectrometry at the Cyclotron Research Center, Iwate Medical University, Japan.

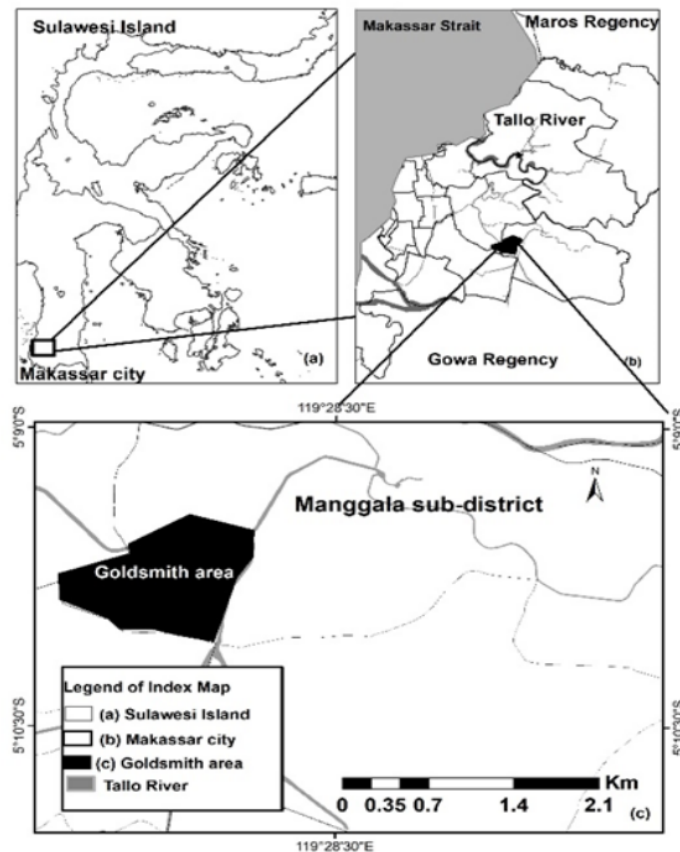


Figure 1. Goldsmith area in Manggala subdistrict (a) Sulawesi Island, (b) Makassar city, (c) Goldsmith area

3. Result and Discussion

The activities of the gold worker in Makassar city have been run over 40 years. Approximately 400 gold workers are doing smelting in the urban area of Makassar at Wajo, Manggala and Tallo sub districts [3]. Urban artisanal gold mining, gold mining-like process using traditional technology was conducted in urban core of Makassar. With the exception of the ore excavation stage, the recovery process in UAGM is similar to the gold extraction stage in ASGM. In principal, the process deals with recovery of fine gold particle incorporated in the goldsmiths' waste, which is included crushing, amalgamation, smelting, refining, forming and decoration [3].

3.1. Socioeconomic

The characteristic of goldsmith in the Manggala sub district is different from the goldsmith in Wajo sub district. The socioeconomic of goldsmith in Manggala sub district is better than the other gold workers in Makassar in term of income and education. Their lifestyle also is better than the others. Commonly, they do not smoke, not drink alcohol, and are doing sport regularly.

The goldsmith in Manggala sub district have unique design of jewelry. The result of in-depth-interviews, we found that the owners of goldsmith, who were aged 55–60 years, were first generation of urban gold workers, while the owners, aged of 27–50 years, were second generation workers

continuing the business after their parents or elders retired. The income of the owner can reach up to US\$ 2000/month (US\$ 83/day), while skilled and un-skilled workers can earn up to US\$ 751/month (US\$ 25/day) and US\$ 375/month (US\$ 13/day), respectively. In Figures 2. It shows that goldsmith in Manggala sub district who earn more than US\$ 375-2000/month were aged between 27–45 years old. Goldsmiths have average incomes of US\$ 600/month (US\$ 20/day). Their income is slightly higher than the income of ASGM workers in Kalimantan, who earn to US\$ 74–223/month [10]. The distribution of income base on the age shows in Figures 2.

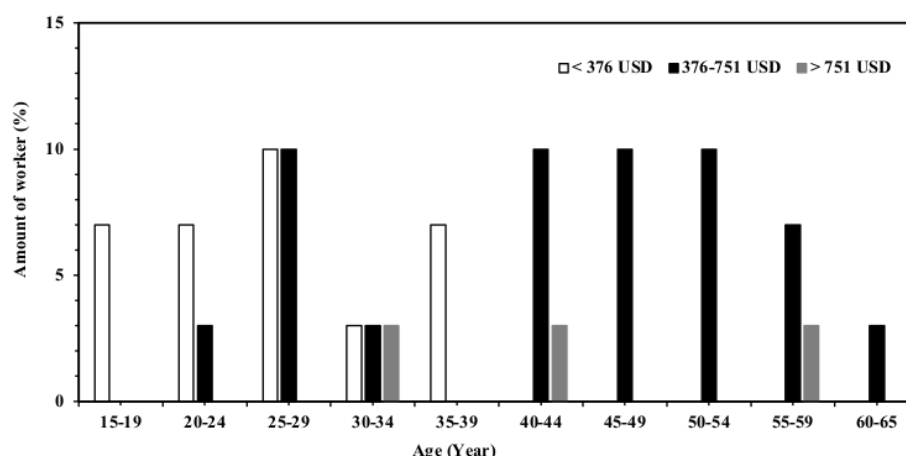


Figure 2. Distribution income of Goldsmith workers base on their age in Manggala subdistrict.

Education will affect the economic level of society [1] [11]. Ability to read and write is a very basic requirement. This ability is close related to education. The educational level of goldsmith workers is better than the others gold workers in UAGM area. This result indicated that education is very important key to change their life.

Majority of goldsmith workers about 64% is senior high school graduated and the lower education about 11% is elementary school graduated. The goldsmith in Manggala sub district may improve their skill by learning by doing. Therefore, workers are classified as un-skilled and skilled according to their ability. As shown in Figures 3, the majority of goldsmith have been working for 20 years. The goldsmith workers should be required to have higher skills because they have to able to produce the gold jewelry manufacturing, design, and decoration processes. The owners hire new workers, mostly their own relatives to run their businesses. The new workers are trained to be skilled workers and become proficient goldsmiths. The workers are explained to this work is between 15-20 years of age and to ensure they are able to master the skills required by the ages of 23–45 years of age. Most of the 23 % un-skilled workers are new workers and are receiving 'on-the-job' training (Figure 3).

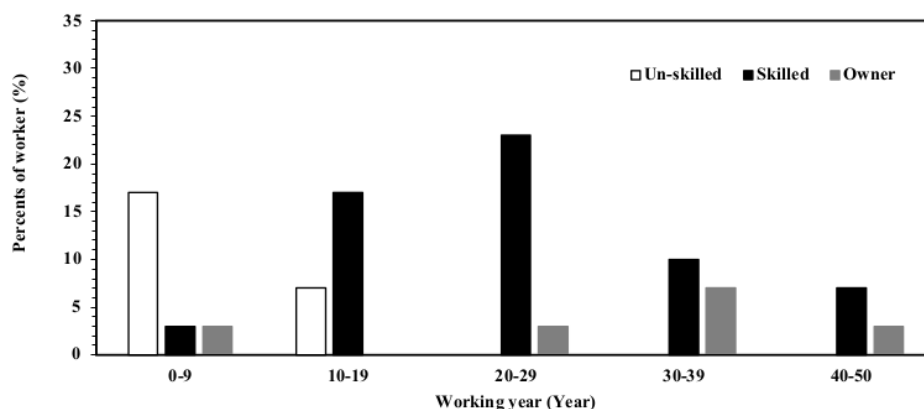


Figure 3. Distribution income of Goldsmith workers base on their age in Manggala subdistrict

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3.2. Mercury Exposure

Mercury exposure during the gold work was probable. The processes which large fraction of mercury released to the environment were refining gold doré, amalgamation and smelting the gold amalgam. Gold amalgam contains 40–50% mercury [12] and gold doré is 2–5 % mercury [13]. It might expose to the environment as well as the gold workers. The amalgam or gold doré when it was burned, the excess mercury was driven off into ambient air of the work site because the work did not use mercury emission controls such as retort, moreover the work sites did not have proper ventilation. The goldsmiths performing refining-alloying the gold doré could be directly exposed to mercury vapor. Likewise, the gold smelters conducting amalgamation and smelting the gold amalgam are potentially directly exposed to mercury vapor, while other workers of handling other jobs such as hammering, bending, cleaning, polishing, collecting the waste, and crushing may be potentially indirectly exposed to mercury. The goldsmith could be exposed to mercury by smelting gold doré, while the gold workers are goldsmith and gold smelter by amalgamation and burning out the amalgam [3]. The head hair of the gold smelter was used to determine mercury level as biomonitoring for quantifying total mercury concentrations. The benefit of using hair are simple, integrative, and noninvasive sample for estimating long-term average exposure [14–17].

The average mercury concentration in hair is $6.6 \mu\text{g/g}$ (min-max: $1.6\text{--}47.7 \mu\text{g/g}$). The concentration of mercury in human hair of goldsmith is $5.03 \mu\text{g/g}$ for indirect exposure and $8.18 \mu\text{g/g}$ for direct exposure. This concentration is the same concentration of UAGM workers [3]. This result indicated that the goldsmith workers were exposed to mercury by refining process for direct exposure and for indirect exposure might be due to mercury evaporation.

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 the gold smith workers are categorized to the alert and high level (Table 1). The average of total mercury concentrations in the hair of a goldsmith in Makassar was somewhat similar to that reported for hair mercury levels of mining workers engaged in excavation and smelting gold ore [9]. This finding is unpredicted because the goldsmith workers is a very small-scale manufacturing, process and productions.

The findings in this study indicate mercury exposure to the gold smelters has reached alert and high level where the adverse health effects are probable. The goldsmith workers, in fact, is a unique informal work and the gold jewelry they produced represents an original product of Makassar.

Table 1. The concentration of mercury in the hair

	The concentration of mercury in hair ($\mu\text{g/g}$)		
	Mean	Min-max	HBM Level
Indirect exposed	5.03	1.6-23.7	Alert level
Direct exposed	8.18	2.2-47.7	High level

4. Conclusions

Commonly ASGM activity is found in countryside and UAGM activity in urban area. Both these activities usually rudimentary technology to extract the gold and also to become as a livelihood.

In term socio economic of goldsmith workers in Manggala sub-district of UAGM area have higher income than compared the others gold workers in ASGM and UAGM area. The concentration of mercury level is alarm-high level, somewhat similar with the others gold worker in UAGM area and also in ASGM area. Because of the gold workers and the miners use mercury in gold extraction process. The effect of mercury exposure is influence of environment and human health problem [18]. Therefore, interventions are essential to reduce it from their occupation, such as introduce retort to capture mercury fume, implement better waste management, and apply recovery process without amalgamation [19]. Health assessment should be to routine medical checkup to prevent of intoxication of mercury

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Conflicts of Interest: The authors declare no conflict of interest.

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