iCon-ITSD The 2 International Conference on Industrial Technology for Sustainable Development
In Conjunction with
SemNas PTI Seminar Nasional Perkembangan Teknologi Industri II
Fakultas Teknologi Industri, Universitas Muslim Indonesia
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Mercury Pollution in The Aquatic System Near of Urban Artisanal Gold Mining (UAGM) Activity in Makassar, South Sulawesi, Indonesia

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Abstract— The Urban Artisanal Gold Mining (UAGM) in Makassar, South Sulawesi, Indonesia, has been run by a number of goldsmiths with gold jewelry manufacture as its core activity. The urban artisanal gold mining process has been existing and also using mercury in the process of gold production. The amalgamation, smelting, and refining are the processes in which Hg may release into the environment. This research aimed to assess Hg environmental pollution in the Tello river near the UAGM area. In UAGM workers use drainage or canal to discharge waste from their tailing reservoirs or some of them directly discharge to drainage. The results showed that the Hg concentration in the drainage sediment was found very high in the spot C3 and C7, reaching 627 and 79 µg/g, respectively. On the other drainage spots, mercury concentration average 16 µg/g (0–30.5 µg/g). On the other hand, the canal sediments in the inside UAGM site showed an elevated concentration of heavy metals due to contaminant enrichment. This is because the discharged wastes taken from the goldsmith's area were already contaminated by heavy metals. This was because burning goldsmith's wastes were commonly conducted in an open space using kerosene, gasoline, or firewood as a fuel. The aquatic system such as rivers, fishponds, and beaches have been polluted by heavy metals. This is due to heavy metals in the tailing of UAGM flow and contaminates the river and fishpond around it.

Keywords— Concentrations heavy metals pollution; Sediments; Tallo River; UAGM

I. INTRODUCTION

The contribution of mercury to environmental pollution worldwide has grown in proportion to its use in artisanal and small-scale gold mining (ASGM). The ASGM often uses simple mercury-based technologies to extract gold, and mercury is released and evaporated during the amalgamation and burning processes. Metallic mercury from amalgamation tailings spreads with low dispersion and concentrated in soils and sediments near the mining areas. Mercury vapor is dispersed by the wind over an extensive area, then deposited by dry and wet processes, and eventually become bioavailable. Once released into the environment, mercury may be oxidized into compounds through complex chemical and physical transformations, and it biomagnifies in food webs. This issue has been attracting an increasing level of concern because mercury is a highly toxic pollutant and exposure to even small amounts can cause serious health problems in humans [1,2].

Mercury exposure in the urban area 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.

A large quantity of elemental mercury has been used for the extraction of gold ores and released to the environment using the smelting and refining process. It is estimated that annually, between 800 and 1000 tons of mercury have been released from artisanal and small-scale gold mining (ASGM) to the environment. As a result, mercury was exposed to the atmosphere as gases, aerosols, and particles, and they were subsequently precipitated, and bioaccumulated in the soil, lakes and rivers, and living organisms in the food chain.

The ASGM in Indonesia is increasing that has been exposed to the environment and human health[3]. In general, gold mining is conducted in the countryside, however the

UAGM similar to the ASGM process conducting in an urban area. The effect of the UAGM process has been exposed to gold workers suffering from neurological sympthoms[4]. The potential problem due to UAGM activities not only the gold workers but also the environment. Therefore, this study aims to determine environmental pollution in the river near UAGM activities.

II. METHODOLOGY

A. Material

The location of UAGM is in Makassar city, shown in Figure 1. We took sediment samples in the tailing reservoir, the drainage system, Tallo riverbank, pondfish, and also beaches. That is because elemental mercury from the UAGM site is discharged to the tailing reservoir then flowing through the drainage system until reaches the tributary of the Tallo river. On both sides of the river are fishponds. There are 27 sediment samples for chemical analyses.

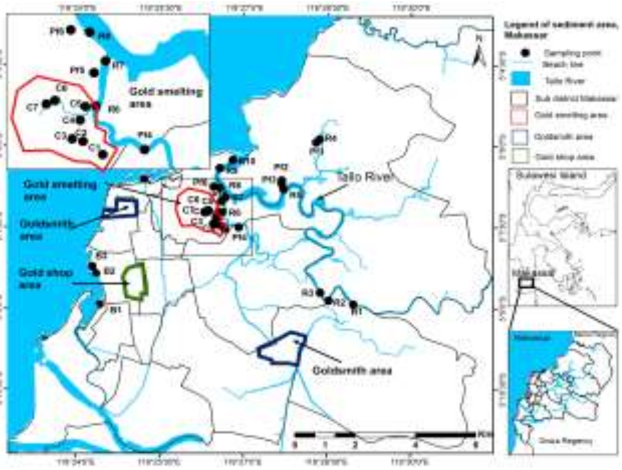

Figure 1. Location of spot samples in the UAGM area.

B. Method

The sample was well dried up in 120°C for 2 hours and was crushed by the planetary micro mill with three-step crushing, step one used level third speed with five minutes, step two used level fifth speed with three minutes, and step 3 used level ninth speed with three minutes. After crushing and the sample becomes homogenous, then 50 mg of it was taken. Pd-Carbon 10 mg was added as an internal standard element (Pd weight is 10000 ppm). Pd-Carbon made by Wako (167-07541 Palladium Carbon abt.5 % (Pd)). By using an agate mortar powder sample was mix with Pd-Carbon for 10 minutes. A small mixed powder was picked up by pincer (tweezers) and then put on the film. About 3 µl of Collodion solution (Collodion: ethanol = 1: 9) was dropped on the powder and then spread it until become very thin and flat as it can be used for pipette tip. The powder sample is analyzed by PIXE analysis.

III. RESULTS

The tailing of UAGM flow into the drainage system, and ultimately into a tributary of the Tallo River, before entering its downstream waterways. The spots of the sediment samples we sign by symbol P is the Pondfish, R is the river and C is canal or drainage. Two tailing reservoirs were sampled their sediment, and six spots in the drainage system were taken their sediments to mercury concentration measurement. The results showed that all of them contained mercury elements. The highest was found in the C3 and C7 spots as mercury concentration reached 627 and 79 µg/g, while mercury concentration in the other spots averaged 16 µg/g (7–30.5 µg/g) as can be seen in Figure 2. C3 and C7 spots are of the gold smelting process that is undertaken outside of the house.

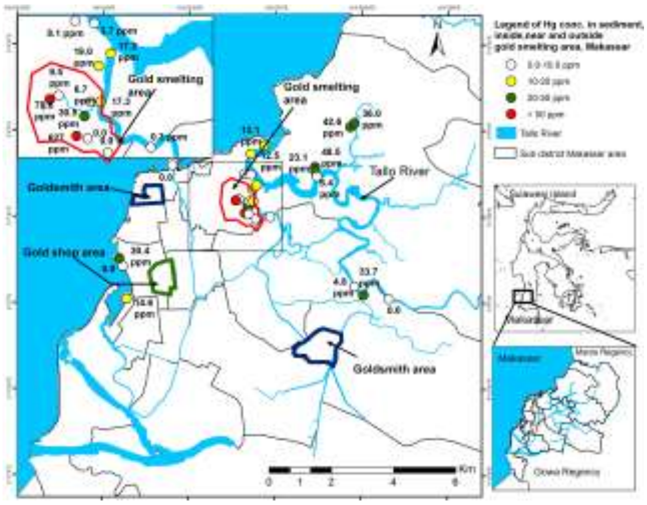

Figure 2. Hg Concentration base on the spot sampling

We observed they use mercury in the gold process such as amalgamation and smelting. Approximately, they used 100–300 kg mercury in a year.

Mercury concentration is also concentrated in the aquatic system i.e.: river, fishponds, and the beach also exhibited mercury elements in their sediments within an average of 15, 24, and 14 µg/g, respectively, shown in table 1. The mercury concentration in the aquatic system all of the spot near the UAGM proses are the high level according to the threshold limit by WHO/ICPS [5].

IV. DISCUSSION

A very small-scale gold mining was conducted traditionally in a high populated area. A similar process to the ASGM in the mining site drives us to name it "urban artisanal gold mining". There are about 400 urban gold workers working in the urban mining site with six to eight workers in every site. Due to the small scope, some gold workers can handle three to four stages in goldwork. Therefore, classifying the gold workers based on every task on the goldwork was rather difficult. They were grouped into two groups: 1 goldsmith and gold smelter; and 2; direct and indirect exposed group.

The goldsmith work generates solid and liquid wastes that contained fine gold particles such as used clay bowls, dust containing gold chips, wastewater, acid solvents, cleaning towels, and tailings sediment. These wastes were collected in separate tanks and were retained for further recovery processes. The gold smelter conducted crushing, amalgamation in panning or tromelling, and smelting process utilizing traditional tools and techniques. A UAGM spends approximately 37–300 kg per year liquid mercury for amalgamation. To obtain gold amalgam from rotating trommel, the excess mercury was squeezed through the fabric and maybe re-used 2–3 times before finally being discharged. The used mercury was released into the drainage system of the building, from where it flowed to the main drains. The gold amalgam was smelted by burning using torch flame in an open clay bowl. Thermal decomposition of the gold amalgam resulted in mercury evaporated leaving the gold doré in the clay bowl.

In UAGM workers use drainage or canal to discharge waste from their tailing reservoirs or some of them directly discharge to drainage. The mercury concentration into the drainage sediment was found very high in the spot C3 and C7. On the other drainage spots, mercury concentration average 16 μg/g (0–30.5 μg/g) Figure 2. On the other hand, the canal sediments in the inside UAGM site showed an elevated concentration of mercury due to contaminant enrichment. This is because the discharged wastes taken from the goldsmith's area were already contaminated by mercury[6]. This was because burning goldsmith's wastes were commonly conducted in an open space using mercury, kerosene, gasoline, or firewood as a fuel.

Table 1. Mercury (Hg) concentration in the Sediment of Aquatic system near of UAGM Activities

No	Spot sampling	Hg(μg/g)
1	B1 (Beach 1)	14.6
2	B2 (Beach 2)	0
3	B3 (Beach 3)	30.4
4	C1 (Canal 1)	0
5	C2 (Canal 2)	0
6	C3 (Canal 3)	627
7	C4 (Canal 4)	30.5
8	C5 (Canal 5)	6.70
9	C6 (Canal 6)	9.50
10	C7 (Canal 7)	78.6
11	C8 (Canal 8)	0
12	Pf1 (Pondfish 1)	42.6
13	Pf2 (Pondfish 2)	48.5
14	Pf3 (Pondfish 3)	23.1
15	Pf4 (Pondfish 4)	0.30
16	Pf5 (Pondfish 5)	19.0
17	Pf6 (Pondfish 6)	8.10
18	R1 (River 1)	0
19	R2 (River 2)	33.7
20	R3 (River 3)	4.80
21	R4 (River 4)	36.0
22	R5 (River 5)	6.40
23	R6 (River 6)	17.3
24	R7 (River 7)	17.2
25	R8 (River 8)	3.70
26	R9 (River 9)	12.5
27	R10 (River 10)	13.1

Mercury toxicity in the urban area comes from the uagm and the other source of emissions such as industrials and power plant combustion. We consider 2 pathways of mercury exposure before reaching humans and the environment: Firstly through atmospheric emission, and secondly through direct discharge. The urban artisanal gold mining process has been existing and also using mercury in the process of gold production[4]. Amalgamation, smelting, and refining are the processes in which mercury may release into the environment[3,7–9][10,11]. Based on the study, gaseous elemental mercury is predominant of the atmospheric mercury and easy to travel long distances in the atmosphere [5]. Then it transforms into divalent mercury after undergoing oxidation. Divalent mercury is easily settled in the local environment[5][12]. The inorganic mercury is converted to MeHg in the aquatic system of the city[6-7]

Elemental mercury in these aquatic systems can be transformed into its most dangerous form, methylmercury, which then readily enters the food chain[15]. These results demonstrate that mercury is present within the environment, especially inside and near the UAGM site. Therefore, it investigated the exposure of the gold workers to mercury and assessed their health problems arising from mercury poisoning[4].

V. Conclusion

The aquatic system receives water from the tailing of UAGM that is why elevated mercury level in the sediment of river and pond fish. Some sediments were taken from the power plant and the industrial area also show elevated mercury level. The highest level of mercury in sediment found the spot close to the UAGM activities.

Acknowledgment

The authors would like to thank the Universitas Muslim Indonesia and South Sulawesi of Indonesia government that has permitted to conduct research. I would like also to thank Japan government for supporting this research by (conducted as a part of) feasibility study "Social Acceptance of Regional Innovation for Reducing High Impact Environmental Pollution", Research Institute for Humanity and Nature (RIHN) and JSPS KAKENHI Grant Number 16H02706 to M. Sakakibara and also Koichiro Sera for his laboratory in Cyclotron Research Center, Iwate Medical University, Japan.

REFERENCES

[1] Zahir F, Rizwi S J, Haq S K and Khan R H 2005 Low dose mercury toxicity and human health *Environ. Toxicol. Pharmacol.* **20** 351–60

[2] Gibb H and O'Leary K G 2014 Mercury exposure and health impacts among individuals in the artisanal and small-scale gold mining community: A comprehensive review *Environ. Health Perspect.* **122** 667–72

[3] IPEN 2013 Mercury Hotspots in Indonesia ASGM sites : Poboya and Sekotong in Indonesia 1–8

[4] Abbas H, Sakakibara M, Sera K and Arma L 2017 Mercury Exposure and Health Problems in Urban Artisanal Gold Mining (UAGM) in Makassar, South Sulawesi, Indonesia *Geosciences* **7** 44

[5] World Health Organization (WHO) 2007 Preventing Disease Through Healthy Environments Exposure to Mercury : A Major Public Health Concern.

[6] Gul N, Khan S, Khan A, and Ahmad S S 2015 Mercury health effects among the workers extracting gold from carpets and dusted clays through amalgamation and roasting processes *Environ. Sci. Pollut. Res.* **22** 17965–74

[7] Arifin Y, Sakakibara M and Sera K 2015 Impacts of Artisanal and Small-Scale Gold Mining (ASGM) on Environment and Human Health of Gorontalo Utara Regency, Gorontalo Province, Indonesia *Geosciences* **5** 160–76

[8] Krisnayanti BD and Asmara M D 2016 Analysis of Artisanal Small-scale Gold Mining Sector in West Sumbawa Regency, Indonesia **6**

[9] Krisnayanti BD, Anderson C W N, Utomo W H, Feng X B, Handayanto E, Mudarisna N, Ikram H and Khususiah 2012 Assessment of environmental mercury discharge at a four-year-old artisanal gold mining area on Lombok Island, Indonesia *J. Environ. Monit.* **14** 2598–607

[10] Nakazawa K, Nagafuchi O, Kawakami T, Inoue T, Yokota K, Serikawa Y, Cyio B, and Elvince R 2016 Human health risk assessment of mercury vapor around the artisanal small-scale gold mining area, Palu city, Central Sulawesi, Indonesia *Ecotoxicol. Environ. Saf.* **124** 155–62

[11] Li P, Feng X B, Qiu G L, Shang L H and Li Z G 2009 Mercury pollution in Asia: A review of the contaminated sites *J. Hazard. Mater.* **168** 591–601

[12] Park J-D and Zheng W 2012 Human exposure and health effects of inorganic and elemental mercury *J. Prev. Med. Public Heal.* **45** 344–52

[13] UNEP 2013 Global Mercury Assessment 2013: Sources, Emissions, Releases, and Environmental Transport

[14] Azimi S and Moghaddam M S 2013 Effect of Mercury Pollution on the Urban Environment and Human Health **1** 12–20

[15] Castilhos Z C, Rodrigues-Filho S, Rodrigues A P C, Villas-Bôas R C, Siegel S, Veiga M M and Beinhoff C 2006 Mercury contamination in fish from gold mining areas in Indonesia and human health risk assessment *Sci. Total Environ.* **368** 320–5