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Assessment of Mercury Accumulation in Dry Deposition, Surface Soil and Rice Grain in Luwuk Gold Mine, Central Sulawesi

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Abstract: Mercury emitted to the atmosphere may pollute different environmental compartments in term of dry and wet fall out deposit. This study aimed to investigate the Total mercury (THg) concentration in dry deposit, surface soil, rice grains and assess its potential risks. Sampling field survey conducted during one period of sample collection. Result shown that Thg concentration in dry deposit were ranged from 1.76-4.00 μg m^{-3} day^{-1}, surface soil were ranged from 85.94-193.33 μg kg^{-1} dw in 0-5 cm depth and 120.64-226.59 μg kg^{-1} dw in 5-10 cm depth and brown rice were in the range of 99.1-181.5 μg kg^{-1} ww and white rive were in the range of 113.1-185.1 μg kg^{-1} ww, respectively. The elevated THg in dry deposit were in St. 4 and 5 had average values with 3.46 μg m^{-3} day^{-1}) while in surface soil (0-5 and 5-10 cm) had averages of 161.64 and 177.89 μg kg^{-1} dw), respectively. Hence in conclusion, THg concentration in dry deposit and surface soil were due to results of ore amalgam processing that correspond to the elevated THg concentration in atmospheric dry deposition.

Key words: Gold mine, THg accumulation, dry deposit, surface soil, rice grains

INTRODUCTION

Elemental Hg is now known to spread very effectively from diverse sources to both terrestrial and aquatic systems. Sediments function as sinks and potential sources of Hg and once contaminated, pose a risk to aquatic life for many years. In terrestrial, the direct vapor of mercury absorption from the air was observed in trees and the uptake of elemental Hg via stomata is controlled by stomata. The length of stoma of rice was in the range of 2.0 and 12 μm while stomata width was in the range of 1-3 μm. Thus, Hg in the form of vapor and also in the form of Hg adsorbed fine particle can be adsorbed directly from the atmosphere. Furthermore, research indicates that the ecological and toxicological effects of Hg strongly depend on the various chemical species present (DMF and BTKL, 2008).

Wet and dry deposition are the only primary mechanisms for transporting this element from the atmosphere to the terrestrial and aquatic systems. Artisanal Gold Mining (AGM) is one such anthropogenic activity that has resulted in the use of an enormous amount of metallic mercury. The mercury used by the miners is usually discharged in an abusive manner into ecosystems (Pfeiffer and Lacerda, 1988; Meech *et al*., 1998). Poor amalgamation practices in rudimentary gold mining are responsible for the emission and abusive discharge of mercury into the ecosystem. Mercury in any form is toxic but the acuteness in toxicity mainly lies in how it is absorbed (lipid solubility and permeability to the blood-brain barrier) and the rate of excretion (Diner and Brenner, 2009). The study aimed to investigate the total mercury concentration in dry deposit, surface soil and its bioaccumulation in rice grain and its potential risks due to the activity surround the Luwuk gold mine and the ore amalgam processing centre. This will assist to understand the Hg bioaccumulation in terrestrial food chain around contaminated site.

MATERIALS AND METHODS

Samples and sampling procedures of dry deposition: To measure the contaminant level of dry deposition, the atmospheric particulates were collected in dry season. In consideration of possible re-suspense of ground contaminant, dry deposit dish sampling set points were located at level of 2.5 m high of above ground. The dish was made of a set of glass container (25×15×10 cm) used to collect Thg particulate from atmosphere (Mallongi *et al*., 2014).

Samples and sampling procedure of surface soil: Surface layer soil (0-10 cm depth) samples were collected around

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the area of Luwuk gold mine. Soil samples were analyzed on a basis of dry weight (dw). Twelve sampling plots were collected from the study area which are located surround the gold mine and the ores amalgam processing centre. At first stage, soil samples were collected individually from the total of three sampling plot at every villages with the wide area of 20 m^2. Each of those samples then divided into two sub samples with three replicates. Then, clean the collected surface soil of wood pieces, pebbles, roots, branch and dust and pass it through a 2 mm mesh sieve to prepare a soil sample (Dennis and Zupko, 1995). After homogenization, we mix an equal weight of each sample to obtain a final composite sample for the mercury analyses. Record the date, location and general condition of the soil samples such as appearance, color, smell impurities (Chapman, 1965; UNEP, 2002).

Samples and sampling procedure of rice grain (*Oriza sativa* sp.): Foodstuffs comprising of rice grain both white and brown were available at the study area. Those samples were collected at the same site as had done for surface soil and dry deposition samples. Those grains were collected in twelve sampling plots in different areas around the sampling tracts. Every station we collected about 2 kg of rice grain on each soil type. Only mature were collected then properly labeled and separately in a sealed plastic bag before transported to laboratory prior to be analyzed.

RESULTS AND DISCUSSION

Dry deposition and surface soil: The magnitude of THg concentration of dry deposit fall out was in St. 4, then followed St. 1 and 5 with 4.00, 2.93 and 2.92 μg m^{-3} day^{-1}, respectively. St. 4 is close distance from the point source, the high level THg generated by the wind blowing direction. At the sample collection days where the windblown to the South (St. 4 and 5) and those areas were in open area. St. 2 with 1.76 and St. 3 with 1.78, however are located far distance from the amalgam open burning central, the concentration of THg values were lower due to the distance site and shaded areas. Furthermore, some Hg pollution to the air come from the open burn of streets gold buyer or gold shop who did open burn which may release Hg into the atmosphere. The Hg release magnitude to the atmosphere is governed primarily by the scale of the open burn of amalgam and the Hg concentration evaporation from the waste.

In the case of Luwuk gold mine area, the main Hg used for amalgamation about 8 h day^{-1} using a 2 shifting system for one group of tromol which may consists of 15-20 tromol each group. Then, many other Hg sources releases from the indivusal or small group miners who do the amalgamation in the open burn areas. Table 1 of THg concentration of dry deposition in luwu gold miner areas and its surrounding is presented in Table 1.

In relation to the THg level in soil, the THg concentration in dry deposit have a linier significant association. Sample station in St. 4 and 5 have a higher THg level of dry deposit which is the same performance with the soil THg level in St. 5 for surface and deeper soil Table 1.

The soil characteristics with consideration at site provided Hg in non-available form that cause less toxic to living organisms.one of the important factor of decreasing soil quality is land use (Boroumand *et al*., 2015). In general, exposure via drinking water and food ingestion have been considered to be major sources of exposure to potentially toxic elements such as Hg, the risk assessment methodologies development for contaminated sites and gold mine workings has highlighted the importance of the inadvertent and deliberate ingestion of soils and dusts (Ferguson *et al*., 1998; Williams *et al*., 1998; Zhang *et al*., 2010).

Rice grains: THg concentrations in brown rice were in the range of 99.1-181.5 μg kg^{-1} ww and white rive were in the range of 113.1-185.1 μg kg^{-1} ww, respectively. It was obvious that THg at the St. 3 that close to pollution sources (ore amalgam processing) was comparatively higher than those in the other sites (Table 2). The highest THg concentrations in the closer the distance the higher THg concentration in rice. Mercury absorbed and impact plants via two main pathways; through the root system from metals entering the soil and via dry arial deposition. In addition, Hg entering the soil can go to a wide variety of species changes as a result of the prevailing edaphic conditions controlling bioavailability.

Table 1: THQ concentration in dry deposit and surface soil in Luwuk gold mine area

		THg concentration		
Stations	Station description	Dry deposition (μg m^{-3} day^{-1})	Surface soil 05cm (μg kg^{-1} dw)	Surface soil 5-10 cm (μg kg^{-1} dw)
St. 1	Upstream about 750 m from river mouth	2.93	85.94	128.64
St. 2	Upstream about 250 m from river mouth	1.76	103.29	120.25
St. 3	At river mouth	1.78	129.94	129.19
St. 4	Downstream about 700 m	4.00	119.11	126.27
St. 5	Away downstream	2.92	193.33	226.59
Standard value		50.00	100.00	100.00

Table 2: THg concentration on rice grain in Luwuk gold mine, Central Sulawesi, Indonesia

Station description	THg in food stuff (μg kg^{-1}dw)			
	Rice grain (*Oriza sativa* L.)			
	Brown	SD	White	SD
St. 1	99.1	0.47	125.6	0.23
St. 2	110.3	0.51	113.1	0.49
St. 3	181.3	0.81	113.9	0.11
St. 4	125.1	0.38	123.5	0.18
St. 5	118.5	0.88	185.1	0.07
Standard	100.0	-	-	-

CONCLUSION

Thg concentration in Luwuk gold mine area and the surround was serious. In the light of the spatial distribution characteristics of THg in the soil, there were two mercury sources: tailing excess and disposal to the ground and the dry deposit due to the open burn of amalgam.

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