Study of mercury contamination in the environment as an impact of Artisanal gold mines activities at North Halmahera Indonesia

C Chamid1,*, B Sulistijo2, H Hindersah1 and Y Asyiawati1
1 Department Urban and Regional Planning, Faculty of Engineering UNISBA, Bandung, Indonesia
2 Mining Engineering Department ITB, Bandung, Indonesia

*chusharini@yahoo.com

Abstract. North Halmahera is part of Halmahera Island in East Indonesia which has natural resources that can be used for capital development of the island, such is gold deposit. An environmental destruction has occurred in surrounding areas of artisanal gold mines, one of them is mercury contamination. This is a descriptive analysis study in order to find out has mercury contamination occurred in the study area. The study was conducted by measuring mercury concentration directly in the atmosphere and soil by using mercury vapor analyzer, and collected river and marine water which analyzed in laboratory. The average measured mercury vapor in the atmosphere was 2.071,8 mg/L, and in soil was 12,568.4 mg/L, while the EPA threshold limit of mercury vapor concentration is 300 mg/L. All mercury concentration in river water were lower than 0.009 mg/L below the threshold limit of Water Quality Class II PPRI No.82/2001 which is 0.002 mg/L. The measurements were also below the threshold limit for water marine of KepMen LH No 51/2004 of 0.001 mg/L. It is find out that mercury vapor has contaminated the atmosphere of the study area of Malifut and Kao Teluk sub districts.

1. Introduction
Mercury is emitted naturally from volcanoes, and earth crust. It is anthropogenic emitted as a pollutant from many sources, such as coal fired power plants, gold mines, agriculture, medical, and etc. Mercury is still used in thermometers, blood-pressure cuffs, batteries, light bulbs, paints and in agriculture as fungicide. Therefore, mercury exposure on human currently comes from many sources. Today, mercury exposure to population majorly comes from fish consumption, dental amalgam, vaccines [1] and cosmetics such as face whitening cream, and mascara. One of mercury characteristic is its ability to bio-accumulate in living organisms, then a higher organism in the food chain will has more mercury which will end in human via consumption of contaminated fish [2-3]. Due to mercury is a toxic substance, it will affect human body, especially the central nerve system in human’s brain as a chronic effect of mercury exposure [1].

Mercury pollution at North Halmahera mostly occurs due to activities of artisanal gold mining. Artisanal gold mining mines primary and secondary gold deposit, but mostly it mines secondary gold deposit because it is much easier than primary deposit. At North Halmahera, the artisanal gold mining mines primary deposit by making vertical shaft opening at Anggrek Village. Gold miners re-process gold tailing produced from previous gold processing, or they continue to apply cyanidation process after
 amalgamation. Amalgamation tailing is traded among communities because gold can still be recovered from the amalgamation tailing. Mercury is used in artisanal gold mine activities for separating gold from its impurities in amalgamation process. Improper application of mercury during gold processing induces mercury pollution in the environment, such as air, land and water.

As gold processing waste contained mercury is discharged into the surrounding environment, then it’s health effects will affect not only miners but also the whole families and surrounding communities, as well as communities who live far from the mine areas because eating contaminated fish from river. Metallic mercury in riverbed can be converted to become methyl mercury by micro-organism before being eaten by larger invertebrates and higher up in the food chain which will end in human via consumption of fish [2,3]. Methyl mercury is more toxic than metallic mercury because it can pass through the brain barrier caused destruction at the human’s central nerve system [1].

A major source of mercury vapor contamination from gold processing is amalgam burning in order to obtain gold and silver. Mostly artisanal miners burn the amalgam in open cast instead of retort then the mercury vapor release directly into the atmosphere and then drops onto soil nearby. Moreover, miners burn amalgam in their house or next to their house in where the whole family is in this area. Mercury vapor inhaled is absorbed in the lungs. Mercury vapor can cause acute pneumonitis, renal failure, and neurological dysfunction, meanwhile chronic effects of inhaled mercury vapor can cause neurological impairment, memory lost, renal failure, anorexia and tremors [4].

Due to artisanal of gold mines at North Halmahera have operated many years, it is predicted mercury contamination has occurred in the surrounding environment. Therefore, it is important to measure mercury concentration in river and marine water, mercury vapor in the atmosphere, and in soil. This study will find out how far mercury contamination has occurred at North Halmahera due to artisanal gold mines activities.

1.1. Study locations
North Halmahera district has gold natural resources which is mined as big scale mines, as well as artisanal mines. It spans an area of approximately 3,896.09 km² or 12.18 % of the province of North Maluku. The region consists of 17 sub-districts, 196 villages and approximately 183.596 people. The local communities consist of the traditional landowners and a number of migrant populations. These migrants are both government transmigration people, itinerant and voluntary migrants from around the country and locally within Maluku (Bugis, Banjar, and Javanese). The traditional land owners and migrants have traditionally worked as farmers.

There are two sub-districts at North Halmahera as locations of artisanal gold mines, those are Malifut and Kao Teluk. This research was conducted at these two sub-districts. There are several villages in the study area, such as Tabanoma, Dumdum, Beringin, Tabobo, Bukit Tinggi etc. Most of artisanal miners live at Beringin village in which all mine transactions, such as mine equipment supply as well as gold transaction are conducted.

2. Methodology
This is a descriptive analysis study in order to find out has mercury contamination occurred in the study area. The study was conducted by measuring mercury vapor concentration directly in the study area by using equipment of mercury vapor analyzer. Measured mercury vapor were in the atmosphere and in soil. Water samples of river and marine were collected then analyzed in laboratory by using Atomic Absorption Spectroscopy (AAS). Results of mercury vapor measurements will be compared with EPA mercury vapor threshold limit, and threshold limit of mercury concentration in river water used is Water Class II of PPRI No.82/2001. The measurements had been conducted at Kobok and Beringin villages, and at an area in where miners do gold processing by using amalgamation method. There were 52 measurements mercury concentration in the environment. Those were 12, 18 and 22 measurements mercury concentration in water, in the atmosphere, and in soil respectively.
3. Results and discussion

3.1. Results of the research

3.1.1. Mercury measurements in river water. There were 12 measurements mercury concentrations in River. The threshold limit used in this study was Water Class II in PPRI No.82/2001 that is 0.002 mg/L. Meanwhile, all measurements findings of mercury concentrations in river were below than 0.009 mg/L. So all the findings were below the threshold limit. Figure 1 shows locations and result of mercury measurements in river water.

3.1.2. Mercury vapor measurements in the atmosphere. There were 18 samplings to measure mercury vapor concentration in the atmosphere. Sampling locations were at villages of Beringin, Tabobo, Tabonama, and Malifut in where gold processing was conducted. The threshold limit of mercury vapor concentration used was based on EPA standard for inhalation reference concentration of elemental mercury. The EPA threshold limit used for mercury vapor inhalation is 300 ng/m3. Measurements were conducted from March 4th to 9th 2017, findings can be seen in table 1.

Figure 1. Location of mercury measurements of river water.
3.1.3. Mercury vapor measurements in soil. Mercury vapor measurements were also conducted in soil in which mercury vapor was trapped in soil. There were 22 measurements of mercury vapor in soil conducted at Beringin, Tabobo, Tabonama and Malifud villages in which gold processing was still conducted (see table 2). The threshold limit of mercury vapor used in soil gas was the same with mercury vapor in the atmosphere. The measurements were also conducted from March 4th to 9th 2017.

Table 2. Mercury vapor concentrations in soil gas.

| No. | Sampling Locations | Date     | Concentrations (ng/m³) | EPA Threshold Limit (ng/m³) |
|-----|-------------------|----------|------------------------|-----------------------------|
| 1   | Beringin          | 04/03/2017 | 4,083.493             |                             |
| 2   | Beringin          | 04/03/2017 | 4,689.577              |                             |
| 3   | Beringin          | 04/03/2017 | 22.869                 |                             |
| 4   | Beringin          | 04/03/2017 | 9,726.284              |                             |
| 5   | Beringin          | 04/03/2017 | 8,734.241              |                             |
| 6   | Beringin          | 04/03/2017 | 234.488                |                             |
| 7   | Malifut           | 09/03/2017 | 16,520.859             |                             |
| 8   | Malifut           | 09/03/2017 | 50,848.569             |                             |
| 9   | Malifut           | 09/03/2017 | 494.068                | Above the equipment limit   |
| 10  | Malifut           | 09/03/2017 | 26,625.944             |                             |
| 11  | Malifut           | 09/03/2017 | 12,553.906             |                             |
| 12  | Tabobo            | 05/03/2017 | 757.823                |                             |
| 13  | Tabonama          | 08/03/2017 | 2,005.122              |                             |
| 14  | Tabanama          | 08/03/2017 | 2,343.980              |                             |
| 15  | Tabanama          | 08/03/2017 | 39,716.186             |                             |
| 16  | Tabanama          | 08/03/2017 | 4,101.372              |                             |
| 17  | Tabanama          | 08/03/2017 | 42,641.696             |                             |
| 18  | Malifut           | 09/03/2017 | 1,388.270              |                             |
| 19  | Malifut           | 09/03/2017 | 3,984.149              |                             |
| 20  | Malifut           | 09/03/2017 | 835.788                |                             |
| 21  | Malifut           | 09/03/2017 | 1,719.792              |                             |
| 22  | Muara             | 09/03/2017 | 757.823                |                             |

3.2. Discussion

3.2.1. Mercury concentration in river water. M-01 sample represents water quality before it reach into Kobok River. While M-09 represents water quality which is influenced from settlement at Kobok area. The water quality M-01 and M-09 were still below the threshold limit of water class II PP No 82/2001.
which is 0.002 mg/L. M-11 and M-04 represent an estuarine water at southern part of the area and M-06 represents an estuarine water at northern part of the area. Both mercury concentrations in water estuarine were below the threshold limit for water marine of KepMen LH No 51/2004 (Mercury=0.001 mg/L). M-07, M-08 represent water quality from a cyanidation plant. The feed for cyanidation process is obtained from tailing of amalgamation process. Therefore, at the area of cyanidation plant also contained mercury vapor that had been deposited on surface soil. An overflow from temporary pond has discharged into a nearby river which eventually will flow into Kao Bay. The findings of mercury concentration in these samples were below the threshold limits. Other measurements of mercury concentration in river water indicate the mercury concentration were below the threshold limit of water class II PP No 82/2001 which is 0.002 mg/L due to the all measurement results of mercury concentration in river water were less than 0.009 mg/L.

3.2.2. Mercury vapor concentration in the atmosphere and in soil. From 18 samplings of mercury measurements in the atmosphere, the maximum value was 22.362.2 mg/L, the minimum value was 123.2 mg/L, and the average was 2.071,8 mg/L. There were 22 samplings of mercury vapor concentration in soil. The maximum value of measurements was cannot be detected with the analyser equipment used, it was over the maximum value that can be read with this equipment, the minimum value was 22.9 mg/L and the average value was 12,568.4 mg/L. While, the EPA threshold limit used was 300 mg/L.

It indicates a very high mercury vapor concentration in the study area which is induced by burning amalgam in open cast which is conducted by artisanal gold mines. Besides burning amalgam, another source of mercury vapor pollution was burning carbon from cyanidation process because the feed used was a tailing of amalgamation which still contains high mercury. Mercury vapor pollution in the study area can be reduced if mercury retort is used while amalgam is burning to obtain gold and silver. Retort mercury is a close system then mercury vapor produced during amalgam burning can be formed again into mercury liquid. Study using mercury retort instead of open cast [5] during amalgam burning can reduce 98% mercury release into the atmosphere.

4. Conclusions
Mercury vapor contamination has occurred at the study area of Malifut and Kao Teluk sub districts. The average measured mercury vapor in the atmosphere was 2.071,8 mg/L, and in soil was 12,568.4 mg/L, while the EPA threshold limit of mercury vapor concentration is 300 mg/L. Then mercury vapor concentration is much higher than the threshold limit of EPA.

Mercury concentration in river water do not indicate mercury contamination in river water. All the measured mercury concentration in river water were lower than 0.009mg/L below the threshold limit of Water Quality Class II (PPRI No.82/2001 which is 0.002 mg/L. the mercury concentrations in water estuarine were also below the threshold limit for water marine of KepMen LH No 51/2004 of 0.001 mg/L.

References
[1] Clarkson T W, Magos L, and Myers G J 2003 The toxicology of mercury—current exposures and clinical manifestations New England Journal of Medicine 349(18) 1731-1737
[2] Langford N J and Ferner R E 1999 Review Toxicity of Mercury Jurnal Human Hypertension 13 651-656
[3] USEPA 2006 Mercury Transport and Fate Through a Watershed Synthesis Report of Research
[4] Rimjhim J, Kumar S S, Uma A, Saurabh K and Neha S 2013 Mercury toxicity and its management International Research Journal of Pharmacy 4(8) 38-41
[5] Chusharini 2000 Pengembangan Retort Merkuri Tepat Guna untuk Pertambangan Emas Rakyat The 2000 FTUI Seminar Quality in Research