Gold production in rural areas of Bogor Regency and its hidden hazards implication

Ir. Yuyun Ismawati, MSc[1) 4)*], *Email:* Yuyun.Ismawati@lrz.uni-muenchen.de

dr. Lelitasari, MKK[2)**], *Email:* lelita4life@gmail.com

Sonia Buftheim, SSi[3)], *Email:* sonia@balifokus.asia

[1)] PhD candidate, Center for International Health, Ludwig-Maximilians-Universität München;

[2)] 4Life OHS Services, Indonesia;

[3)] BaliFokus Foundation, Indonesia.

**Corresponding author*

***Presenter*

Abstract: *Artisanal and small-scale gold mining in developing country have similarities in the process. In Indonesia, more than 850 hotspots identified in 27 provinces and provide livelihood to more than 1 million people. Almost all of them use mercury in the process to extract gold. In Pangkal Jaya Village, a small village in Pongkor area, Bogor Regency, West Java Province, Indonesia, a set of ball-mills used to make the process of gold extraction and operates as a home industry activity runs by the whole family members. Most ball-mills unit are located around the houses and located next to the kitchen and areas where children also seen playing and mothers hold the babies. The average results of measurements of mercury vapour in the air was 4,154 nanogram/m3 or four times higher than the safe level recommended by the WHO and US Department of Health and Human Services. The average results of the Total Mercury in rice samples was 143 ppb, almost three times higher than the safe level recommended by the government of Indonesia. Several community members and children had already shown severe symptoms of mercury intoxication.*

Keywords: *mercury; ASGM; neurotoxic; mercury pollution.*

1. Introduction

Mercury is of global concern. In October 2013, 128 countries agreed to adopt the Minamata Convention on Mercury to protect human health from mercury exposure. UNEP (2013) has identified Artisanal and small-scale Gold Mining (ASGM) sector as one of the largest single source of mercury emissions from intentional use, contributed to 37% of the global mercury emissions and releases. Indonesia is the third largest country in Asia that contributed the largest mercury pollution.

In Indonesia, more than 850 hotspots identified in 27 provinces and provide livelihood to more than 1 million people (Ismawati, 2011). Almost all of them use mercury in the process to extract gold. About 57% of mercury emissions in Indonesia came from ASGM sector (Dewi, K., 2012).

Pangkal Jaya Village, is a small village with 2000 households located in a well-known gold mining area called Pongkor, in Bogor Regency, West Java Province, Indonesia. In Pongkor area, there is a state-owned mining company, PT. Aneka Tambang, that has been operated in the area since 1994. Ever since that, many illegal small-scale gold miners, called *gurandil*, also operated in the areas. Initially it was mainly came from the communities around Pongkor but eventually, many miners and migrant workers tried their luck in Pongkor areas (Syafrul, H., 2003). Recently, Police forces eradicated the *gurandil* operation due to a corruption case.

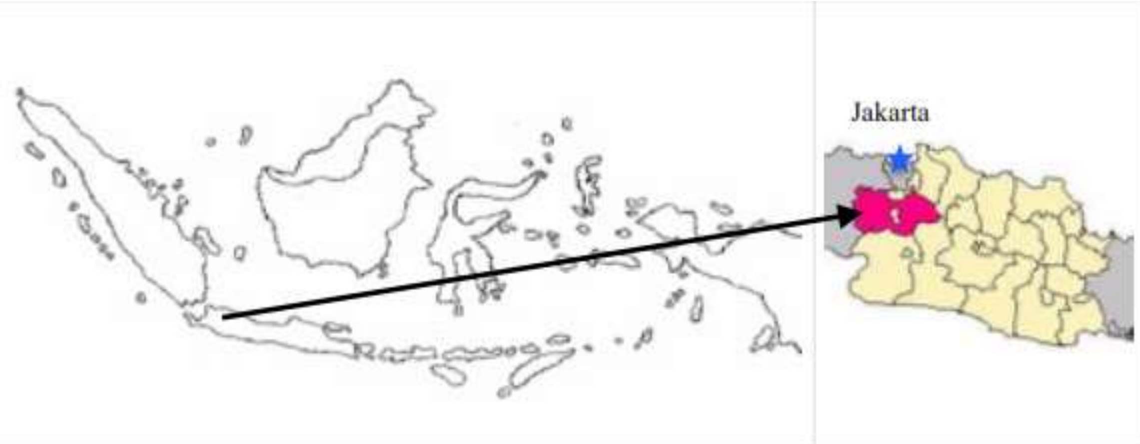


Figure 1. Map of Indonesia and the study location at Bogor Regency

The existence of the ball-mills use as one of gold processing methods in the Pangkal Jaya Village has been lasted for more than 15 years. The ores containing gold minerals would be crushed and the milled inside a set of ball-mills unit mixed with water and mercury for 4-5 hours per batch. As most of the ball-mills unit are installed or set-up around or between houses and within the residential areas, that provide flexibility and convenient to be operated as "home industry" industry activities, the process are being conducted in 24 hours a day, 7 days a week. Some ball-mills are located next to the kitchen where the ladies cook to prepare the food for the whole families. In the vicinity of the ball-mills children also seen playing and mothers hold the babies.

The amalgam burning process to get gold that releases mercury vapour into the air also can be conducted any time at their convenient. The amalgam will be burned in a clay pot, added with a dash of borax salt to clean the dirt, and for security reasons, sometimes it is being burned near the house or in the kitchen area. This pattern also found in other ASGM hotspots in Indonesia, such as in Central Java, Sulawesi, Kalimantan, Lombok, etc.

The ball-mill process also generated mercury-contaminated processed water and tailings that is discarded and dumped around the working areas. In the last 10 years, it became a common practice that the discarded tailings or soils are being used for the foundation of their houses or their warehouses. The remaining processed water contaminated with mercury were being discharged to the near by rice field. During the observation, around several houses, shallow water wells also dug and utilised to meet their daily needs.

Depending on the duration of exposure, route and concentration, mercury exposure have been linked with a variety of health problems, such as kidney and bone disease, and developmental and behavioural disorders (WHO, 2010).

People who work with heavy metals such as mercury are at particularly high risk. Children are more susceptible than adults to poisoning from such sources. Poisoning can be chronic (building over a long time period) or acute (when exposure to a particularly high level of a toxin causes sudden health effects).

Bose-O'Reilly et.al. (2010) stated that acute or chronic mercury exposure can cause adverse effects during any period of development. There is no known safe level of exposure for mercury. Ideally, neither children nor adults should have any mercury in their bodies because it provides no physiological benefit. Prenatal and postnatal mercury exposures occur frequently in many different ways (Grandjean, 2014).

Experts and various studies stated that is a neurotoxin, persistent, teratogenic and even

in low dose could affect the vulnerable groups, such as offsprings, babies, delayed development in children, and potentially leave a life-time suffering as learned from Minamata (Harada, M. et.al. (1998); Counter S.A, et.al. (2004); Rothenberg, S. et.al. (2010); Gibb, H. et.al. (2014)).Mercury presented in various forms or species. Figure 2 below, shows mercury speciation and its solubility characteristic.

Figure 2. Mercury speciation

CH_3 CH_3Hg	⟷	CH_3Hg	⟷	Hg^{++}	⟷	Hg
Dimethyl Mercury		Methyl Mercury		Mercury Ions		Elemental (atomic) Mercury
Lipid soluble		*Lipid soluble*		*Water soluble*		*Liquid metal/lipid soluble gas*

The study aim to see the hidden hazards of the small-scale gold production activity that involve mercury as an informal sector or "home industry" and its implication as a preliminary survey. The study will be focus on identifying the potential hazard from mercury emissions during the gold extraction process in residential setting.

2. Materials and method

2.1. Materials

The results presented in this study are derived from a brief observation that was conducted in September 2015 at Pangkal Jaya Village, Sub-District Nanggu, Bogor Regency, West Java Province, approximately 85 km from Jakarta.

The study team consisted of an integrated survey by multi-experts, consisted of chemist, environmental engineer, a paediatrician, an occupational health specialist and a general practitioner medical doctor. The survey considered as a preliminary environmental health assessment. The study population consisted of 12 respondents, representing ball-mills rental unit operator, owners of ball-mills unit, non-gold related worker, and children between 7 months old until 16 years old. The inclusion criteria in the selection of these respondents are:

- for adults: already lived at least 12 months as a resident of Pangkal Jaya Village;
- for children: parents admitted that their children have some health problems or uncommon diseases;
- agreed to participate in the survey.

The team measured the mercury vapour in air around the residential areas where gold processing are taking place and a spot that formerly functioned as a ball-mills unit. Additionally, some rice samples were also collected from the study area. Some rice samples are hulled and some samples are already de-hulled or polished.

2.2. Method

2.2.1. Mercury vapour measurement

The real-time mercury vapour emission measurement was conducted using a portable mercury vapour analyser (Lumex Model RA-915+, St. Petersburg, Russia) in 12 sampling points correlated with the respondents' living environment. A neutral sampling location with mercury vapour <20 nanogram/m3 has been chosen as the ambient background concentration. The limit of detection for the ambient air sampling is 2 nanogram/m3.

The Portable Mercury Analyser works on the principle of Zeeman atomic absorption spectrometry with high frequency modulation of light polarisation (ZAAS-HFM, differential Zeeman Atomic Absorption Spectrometry using High Frequency Modulation of light polarisation). This equipment is designed to measure the concentration of mercury vapour in the air, including ambient air, natural gas, and industrial emissions.

Measurements were conducted with direct readings in the field, where the Portable Mercury Analyser performs direct reading of mercury concentrations in the indoor air and displayed the reading every 10 seconds. After the reading for three times 10 seconds, the screen will display the results of the average concentration of mercury in the air at the time of monitoring.

2.2.2. Total mercury measurement in rice samples

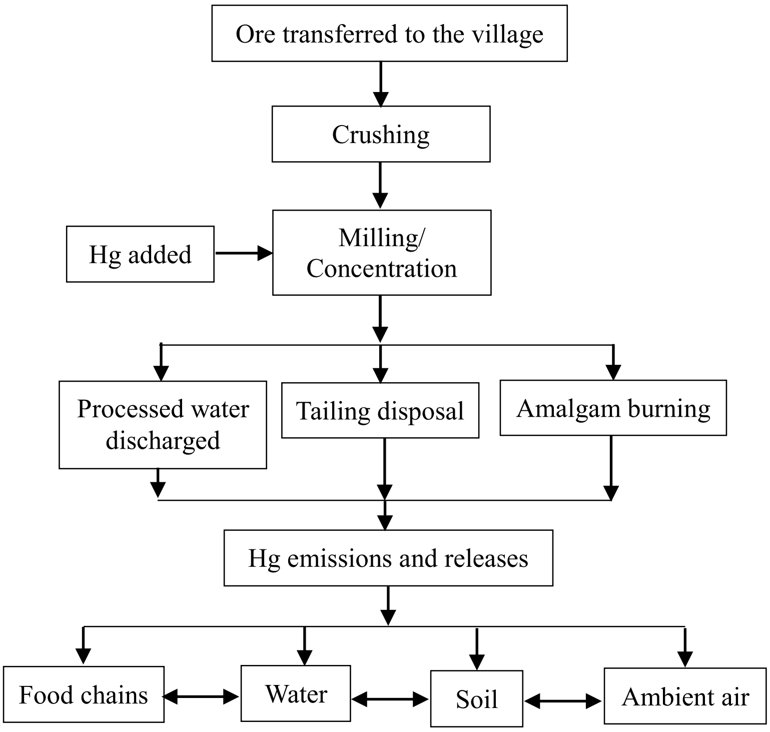
Rice grain was dehulled (JLGJ4.5, China) and polished (Pearlest Grain Polisher, Kett Electric Lab, Tokyo, Japan), then ground to a powder (Capresso Grinder, USA). Instruments for polishing and grinding were cleaned with ethanol after each sample to prevent carry-over.

Rice THg concentrations were analysed with a portable Hg vapour analyser (Lumex, Model RA-915+/PYRO-915+, St. Petersburg, Russia) using thermal decomposition, amalgamation and atomic absorption spectrophotometry, and no pre-digestion steps were required (EPA 7473) (USEPA, 2007).

3. Results and Discussions

Observation in the field shows the flow of gold processing activity in Pangkal Jaya as provided in Figure 3 below.

Figure 3. Gold processing activity in Pangkal Jaya



Almost all of the populations in Pangkal Jaya, in any ways, work or involve in gold processing activities. Since the gold processing business practiced and accepted as 'a home-industry' activity, many women involved in business activities and in almost every step of the process from crushing to amalgam burning (when the husband is not available). Most ball-mills units are located between houses, in the front yard, back yard or besides every house. Every family, at least owned minimum 4 ball-mills.

Mercury use in the milling process between 100 gram to 500 gram per batch per unit ball-mill or *gelundung*. The amalgam burning activity takes place around the house, mostly at the side or the backyard, where children, babies and women also playing and wondering around.

There are several ball-mills unit that are operated as a rental space. It means, the operation of the ball-mills would be more intensive and frequent than the individual family's ball-mills. The family ball-mills unit operates only when the head of the family decided to get some gold and buy some sacks of ore. Every family could have gold yield between 2-5 grams per week.

The team also observed the local customs of sitting on the floor. Some houses have tiles floors, some only have cement floors. In the last 10 years, it became a common practice for to build a new house with foundation construction made of mercury-contaminated tailings.

3.1. Mercury vapour measurement results

At each mercury vapour sampling point, complementary data recording such as air temperature, air humidity and wind speed also observed.

Table 1. Mercury vapour in Pangkal Jaya Village

Sampling number	Sampling locations	Mercury vapour (nanogram/m^3)	Remarks
PJL-01	House A	3110 ± 23.00	Space between the ball-mills unit and the main house.
PJL-02	Ball-mills unit of House A	49220 ± 19.00	Ball-mills in operation.
PJL-03	Rice field at the backyard of House A	150 ± 28.00	Below the ball-mills unit, open space, near a ground water well.
PJL-04	At the terrace of House R	330 ± 21.00	Right in the middle of the frontyard terrace.
PJL-07	1 m from an active ball-mills unit (in operation) around House R	11410 ± 22.00	West side of the house. R is a 2 years old girl with frequent seizures and delayed development.
PJL-06	7 meter away from an active ball-mills unit (in operation) around House R	23940 ± 34.00	West side of the house
PJL-05	10 meter away from the ball-mills around House R	2320 ± 24.00	West side of the house.
PJL-08	Front yard of House S	4030 ± 3.00	Former location of a ball-mills unit. Hg-contaminated tailing was used as the foundation.
PJL-09	Front side of the living room of House S	5620 ± 3.00	Near a ball-mills unit. S is a 16 years old girl with delayed development and mentally retarded.
PJL-10	Front side of House I	17310 ± 28.00	Near an active ball-mills unit (in operation).
PJL-11	Front yard of House H	50380 ± 19.00	15 meters from an active rental ball-mills unit (in operation). Mercury was being poured into the ball-mills.
PJL-12	Living room of House H	2050 ± 3.00	One year old house. The foundation of the house was built using the mercury-contaminated tailings.

3.2. Total mercury in rice results

Total Mercury concentration in several rice samples taken from the study area has the average value 143 ng/g with 101 ng/g minimum value and 200 ng/g maximum value.

QA/QC for rice THg includes analysis of standard reference materials and analysis of replicates. Recovery for NIST Apple leaves recovery averaged 102% (n=2) and recovery for TORT-2 averaged 98.3% (n=2), while relative percent difference between duplicates averaged 9.76% (n=6).

The tolerable limit value of Total Mercury in rice set by WHO-FAO Joint Committee is 30 ppb. While the Indonesian's tolerable limit as set by the Decree of the Directorate General of Food and Drugs Surveillance *(Direktur Jenderal Pengawasan Obat dan Makanan)* No.03725/B/SK/VII/89 dan SNI 01-2729.1-2006 is 50 ppb.

3.3. Suspected mercury intoxication children and adult

During the survey, the team observed several children and adult that showed several symptoms that might correlate to mercury intoxication. Table 2 provides the list of children and adult with several symptoms of mercury intoxication.

Table 2. Children and adult with mercury intoxication symptoms in Pangkal Jaya

Respondent	Age	Location	Observed health conditions	Remarks
PJB-S-001-R	2 y.o	Perempeng Hamlet	Delayed development, experiencing frequent seizures during her sleep (3-4 times), cannot walk, hyper-salivation, blisters in her skulls	The parents owned and operate 18 ball-mill units, operated as a rental place. Gold processing unit using mercury and cyanide.
PJB-S-002-Rz	3.5 y.o	Perempeng Hamlet	Lip and cleft palate (cheiloschisis)	Never been operated.
PJB-S-003-S	16 y.o	Ciketug Hamlet	Mentally retarded, cerebral palsy, uncontrollable emotion	When she was 1 y.o, she got severe seizures, coma and then started to have frequent seizures and delayed development.
PJB-S-004-PR	7 m.o	Ciketug Hamlet	Muscular dysthrophy	Foundation of the house from hg-contaminated tailings.
PJB-S-005-F	7 m.o	Ciketug Hamlet	Uneven (asymmetrical) head shape (deformational plagiocephaly/ positional plagiocephaly)	Playing ground is a former ball-mills unit.
PJB-S-006-AS	13 y.o	Ciketug Hamlet	Lump on the right side of the neck.	Undergoing a TB treatment, diagnosed at the local hospital. Uncle of R, S and F.
PJB-S-007-H	27	Ciketug Hamlet	Mild tremor	Ball-mills operator for 1 year.

Some mothers admitted that during their pregnancy, they stayed more at that home and sometimes helped their husbands taking care of the ball-mills operation. Almost every house in the Pangkal Jaya Village, has at least one sick family member, children or adult with health problems.

3.4. Discussions

The results of measurements of mercury vapour about 15 meters from the active ball-mills unit showed the maximum value of 50,380 nanogram/m3, far exceeding the threshold value and safe reference set by the WHO that is <1,000 nanogram/m3. The average mercury vapour concentration in the village was 4,150 nanogram/m3.

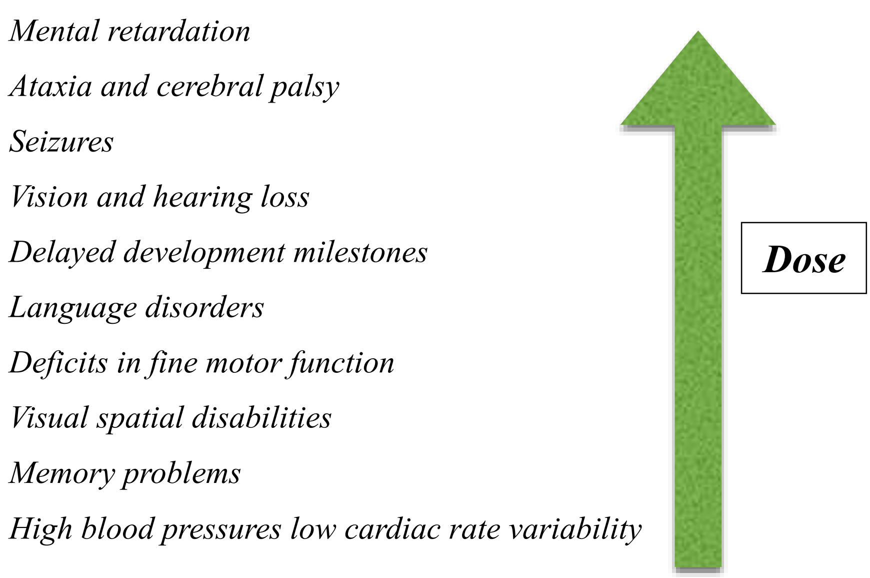
According to the direction provided by the US Department of Health and Human Services (2012) for actions to be taken based on indoor mercury concentrations measured are presented in Table 3.

Table 3. Action benchmarks for indoor mercury concentration

Hg indoor concentration (nanogram/m3)	Recommended action	Remarks
< 1,000	Safe	WHO, US Department of Health and Human Services
1,000 - 10,000	Prepare for evacuation	US Department of Health and Human Services
> 10,000	Evacuate/isolate	US Department of Health and Human Services
25,000	Treshold Limit Value	Appendix of Circular Letter of the Minister of Labour No. SE-01/MOM/1997 about the Threshold Limit Values for Chemical Factors *(Lampiran Surat Edaran Menteri Tenaga Kerja No. SE-01/MENAKER/1997 Tentang Nilai Ambang Batas Faktor Kimia)*

Boese-O'Reilly (2008) stated mercury is a serious health hazard for children in gold mining areas. He also stated (2010) that acute or chronic mercury exposure can cause adverse effects during any period of children's development. Mercury exposures though inhalation to foetus, babies and children could affect Central Nervous System (CNS), kidney, lung, and acrodynia. Exposures through ingestion of fish or rice contaminated with mercury could affect CNS and cardiovascular system. The high degrees of fat solubility of the mercury vapour as well as direct effect on cerebral blood vessels altering permeability contributes to the ease with which mercury can affect the nervous system (Vroom, et.al. 1972).

Figure 4. Effects of prenatal exposures (Boese-O'Reilly, e.al., 2010)



Mercury vapour will be redeposited to the ground, washed out by the rain and deposited in rice fields, rivers, fish ponds, agriculture land, roofs, etc. The average result of rice samples analysed showed that rice THg from Pangkal Jaya is almost three times higher than the safe level recommended by the Indonesian Food and Drug Surveillance Agency.

However, Rothenberg (2014) reviewed mercury in rice from 41 countries, representing polluted sites and non-polluted sites. The Total Mercury (THg) concentration values of from several polluted sites ranged from 2.3 to 510 ng/g. The review reported that in the high mercury concentration areas of Wanshan, China, where rice THg and MethylMercury (MeHg) are highly elevated, there are no cases of mercury poisoning.

Meanwhile, a study by Velasquez et al. (2010) reported that only 51–59% of mercury used in amalgamation processes is recovered when miners squeeze the excess of mercury from the amalgam, approximately 29% of the mercury was lost when burned, and 15% was lost in the tailings.

4. Conclusions

Looking at the situation and condition of Pangkal Jaya Village, there is a high possibility of mercury intoxication through inhalation. To protect the vulnerable group, the safe level reference of mercury vapour established by the Ministry of Labour in 1998 need to be reviewed.

Further research is needed to determine the distribution of the sources of the mercury exposures, measures to identify early symptoms of mercury intoxications among the population, identify mercury-contaminated areas and its concentration as well as the rice paddy system. Most importantly, there is a need to raise the awareness within the community of Pangkor in general about the harmful effect of mercury. Safer alternatives need to be introduced, prohibition the use of mercury and gold processing activities as 'home industry' need to be promoted as part of the formalisation of the sector. Clean up and remediation of contaminated soils also need to be advocated.

Acknowledgement

This project is partly funded by the US Department of State Grant No. S-LMAQM-11-GR-1251 awarded to BaliFokus Foundation and the Pilot Grant from the Jewish Community Federation and the Goldman Environmental Foundation. The authors wish to thank Alexis Donohue for assistance in analysing the rice samples.

References

Boese-O'Reilly S, Beate Lettmeier, Raffaella Matteucci Gothe, Christian Beinhoff, Uwe Siebert, Gustav Drasch. 2008. Mercury as a serious health hazard for children in gold mining areas. Environmental Research 107 (2008) 89–9. doi:10.1016/j.envres.2008.01.0097

Boese-O'Reilly S, McCarty KM, Steckling N, Lettmeier B. 2010. Mercury exposure and children's health. Curr Probl Pediatr Adolesc Health Care 40:186–215

Counter, A, S. and Leo H. Buchanan. 2004. Mercury exposure in children: a review. Toxicology and Applied Pharmacology 198 (2004) 209– 230. doi:10.1016/j.taap.2003.11.032

Dewi, Kania. 2012. Mercury emissions and releases in Indonesia. BaliFokus Foundation.

Ismawati, Yuyun. 2011. Opening the Pandora's Box of Poboya: The social and environmental production of suffering in Central Sulawesi, Indonesia. Master dissertation. School of Geography and the Environment, University of Oxford.

Grandjean, Philippe. 2013. Only one chance. University of Oxford Press. ISBN: 9780199985388

Gibb H, O'Leary KG. 2014. Mercury exposure and health impacts among individuals in the artisanal and small-scale gold mining community: a comprehensive review. Environ Health Perspect 122:667–672; http://dx.doi.org/10.1289/ehp.1307864

Harada M, J. Nakanishi,, S. Konuma, K. Ohno, T. Kimura, H. Yamaguchi, K. Tsuruta, T. Kizaki,

T. Ookawara, and H. Ohno. 1998. The Present Mercury Contents of Scalp Hair and Clinical Symptoms in Inhabitants of the Minamata Area. ENVIRONMENTAL RESEARCH, SECTION A 77, 160‹164 (1998). ARTICLE NO. ER983837

Rothenberg Sarah, Windham-Myers Lisa Marie, Creswell Joel E. 2014. Rice methylmercury exposure and mitigation: A comprehensive review. Environmental Research133 (2014) 407–423. http://dx.doi.org/10.1016/j.envres.2014.03.001 0013-9351/& 2014. Elsevier Inc.

Syafrul, Halimah. 2003. Pencemaran merkuri dan strategi penanganan Penambangan Emas Tanpa Izin (PETI) di Pongkor, Jawa Barat. University of Indonesia. Jakarta.

Velasquez P, Veiga M, Hall K. 2010. Mercury balance in amalgamation in artisanal and small-scale gold mining: identifying strategies for reducing environmental pollution in Portovelo-Zaruma, Ecuador. J Clean Prod 18:226–232

Vroom, Fred. Q, Greer, Melvin. 1972. Mercury vapour Intoxication. Division of Neurology, University of Florida, College of Medicine. Brain (1972) 95, 305-318.

WHO. EXPOSURE TO MERCURY: A MAJOR PUBLIC HEALTH CONCERN.

Zahir Farhana, Shamim J. Rizwi, Soghra K. Haqb, Rizwan H. Khanb. 2005. Low dose mercury toxicity and human health. Environmental Toxicology and Pharmacology 20 (2005) 351–360. doi:10.1016/j.etap.2005.03.007.