Introduction

For more than two decades, artisanal and small-scale gold mining (ASGM) has been operated in Indonesia, spread widely across 31 provinces.¹ In West Java Province, ASGM is found in Bogor, Cianjur, and Sukabumi Regencies. Commonly, ASGM in Indonesia uses mercury (Hg) in gold ore processing.² Mercury is released into the environment during and after this process, and potentially spreads to all environment media, such as air, water, and soil. Studies have found that Hg contamination occurs in water, air, sediments, soil, biotas such as mammals and birds, fishes, rice, vegetables and trees, and miners, processors or other nearby inhabitants to ASGM.³⁻⁶ Uncontrolled Hg application occurs due to the low technical knowledge of the miners, which makes ASGM the second most significant source of Hg pollution, after coal burning, in Indonesia.⁴⁻¹⁸

Elemental Hg and Hg compounds are known to be toxic and can bioaccumulate and be transported long distances. Methyl Hg is formed by oxidation of anaerobic bacteria in sediments and water. It is highly toxic and accumulates in the food chain.⁹ Determination of Hg exposure in the body can be done through the measurement of levels in the body tissues, such as hair, nails and urine which are known as biomarkers.¹⁹,²⁰ Mercury exposure over a long period of time can trigger health problems in humans, and become highly toxic. Chronic mercury poisoning often occurs in humans who live around ASGM.²¹,²²

In the Sukabumi mine, which has been in operation for more than ten years, miners apply Hg in a ball mill gold ore processor.²³ However, data and information regarding Hg contamination on the environment and in humans at this site are scant. The present study aimed to trace Hg exposure in humans and investigate socioeconomic factors related to Hg exposure in the Sukabumi area. The research findings will be valuable for local and national governments for
proposing Hg phase-out in ASGM as part of the National Action plan of Indonesia under the ratification of the Minamata Convention.\textsuperscript{24}

**Methods**

The present study was carried out during February-May 2019 in purposively selected sites in Sukabumi Regency, namely Cicadas village and Sukarame village in the Cisolok sub-district and Kertajaya village in the Simpenan sub-district (Figure 1). These locations were chosen because some of the inhabitants in the villages worked as miners or gold ore processors.\textsuperscript{9} All gold mining sites were located in the state forest area, while the gold grinding processors were located in the settlement areas, within 1 to 5 km from the mining sites.

**Data collection procedure**

The present study employed a purposive survey method for data collection. Data were gathered through a combination of the quantitative method using structured questionnaires and the qualitative method employing in-depth interviews. A convenience sample of respondents were selected based on their involvement in ASGM or ASGM-related jobs as well as distance from their homes to the ASGM site. All respondents worked in ASGM or ASGM-related jobs, although some worked only occasionally and further identified as ‘housewives’. Subjects consisted of miners and non-miners, such as women involved with gold ore processing, for a total of 71 respondents. Socioeconomic characteristics examined in the survey included age, family size, education level, distance to the location of mining and processing mill, income level, and years living in the village. Additional questions were posed to miners and processors, covering mining processes and gold ore processing procedures, working hours, the use of Hg in the process of ball mill processing, gold ore production, and respondents’ history of mining activities. Furthermore, the present study also assessed respondents’ knowledge and attitudes towards the use of Hg in gold ore processing and impact on the environment.

Hair samples were collected from all 71 respondents. Total mercury (T-Hg) determinations were carried out using a Mercury Analyzer NIC MA-3000 at the Research and Development Center for Environmental Quality and Laboratory in Serpong, Banten Province. The analysis method for T-Hg determination was done using the combustion system, described in the United States Environmental Protection Agency’s (USEPA) International Standard 7473.\textsuperscript{25} The accuracy of the analytical method was checked by employing the recovery of Standard Reference Material issued by National Institute of Standards and Technology (SRM NIST 1641d) (the value was 99.9%, recovery of

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### Abbreviations

| Abbreviation | Description |
|--------------|-------------|
| ASGM         | Artisanal and small-scale gold mining |
| FAO          | Food and Agriculture Organization |
| IDR          | Indonesian Rupiah |
| T-Hg         | Total mercury |
| USD          | United States Dollars |

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**Figure 1 — Map of research location**
samples spiked with Hg standard was 91.5% to 109.2%) and the blank sample method.24 A blank sample was prepared by using a weight of reagent water at the specified weight in the preparation method and then carried through appropriate steps of the analytical process. The result of the blank method was lower than the minimum detection limit (MDL = 0.3 mg/g).

**Ethics approval**

This study was approved by the Ministry of Environment and Forestry of the Republic of Indonesia. The study purpose and protocols were explained, and informed consent was obtained from all respondents prior to interviews and hair sampling.

**Data analyses**

The collected data were analyzed using descriptive and statistical analysis. Respondents’ socioeconomic background was tabulated and descriptively presented. Respondents’ level of knowledge, perception, and attitude toward Hg application in gold ore processing was evaluated using the Likert scoring system. Mercury exposure was measured based on the value of T-Hg in the respondents’ hair and then analyzed by comparing those values to the human biomonitoring standard.27 This study also examined the effect of socioeconomic factors in Hg exposure in humans using statistical analysis employing the linear regression model.

**Results**

Table 1 presents the socioeconomic characteristics of the respondents in the present study. A total of 71 respondents were included in the analysis, with the majority (87.33%) between 20 and 51 years old, locally considered to be of working age. Men worked at the mining site, digging, and transporting materials into the processing facility. Women worked in gold ore grinding facilities, breaking down materials before they are placed on the ball mill.

The majority of respondents attended primary school. Most of the respondents worked as farmers and miners. Some of the residents also work in tea or rubber plantations.28 The majority of the subjects lived on a monthly income range of Indonesian Rupiah (IDR) 500,000-1,000,000 (USD 34.03- USD 68.09). Compared to the Food and Agriculture Organization (FAO) standard, the majority were living below the poverty line.29 Poverty has also been documented at other ASGM communities, such as Sumbawa, where ASGM has not boosted the residents’ income.30 Most of the respondents stated that the mining site was located 0.5 km-1.5 km from their residence and the ball mill processing was located in the backyard or beside their houses.

Figure 2 shows the settlements and a ball mill facility in the study area.

The present study evaluated the perception and knowledge of respondents towards Hg usage and the potential of Hg residue to contaminate neighborhoods near AGSM activities. On a total of ten questions, respondents’ answers were scored on a 5-point Likert scale (strongly disagree, disagree, unsure, agree, and strongly agree) and the results are presented in Table 2.

As seen in Table 2, most of the respondents in the research area indicated that they are aware of the dangers of using Hg in the gold amalgamation process. They also agreed with the statement that Hg is very harmful to human health. Most respondents agreed with the statement that Hg pollution in the air, soil, and water can pose a risk to human health. Related to the handling of Hg pollution, most respondents agreed with the statement that the handling of Hg pollution is crucial. Most of the subjects suggested limiting Hg usage in the gold ore process or phasing it out. This is in line with the government decision to reduce or phase out Hg in ASGM in Indonesia by 2030, as stated in Presidential Decree Number 21/201931 supporting non-mercury gold processing technologies.31 The respondents also agreed with the statement that ASGM facilities should be located outside of settlement areas to minimize their contact with Hg. They believe that the process of Hg reduction or phase-out in ASGM should be done by the community in collaboration with local governments, but they were unsure if the process would be a success if performed without assistance. They were also unsure about available alternative sources of income. They also pointed to the need for alternative occupations providing a higher income than ASGM.

Hair is a preferred biomarker because of its simple collection technique, storage, and analysis.32 The results of T-Hg in the respondents’ hair samples is presented in Table 3. Hair Hg levels from three ASGM communities ranged from 0.71 to 24 ppm and averaged 4.34 ppm.

The present study found a significant difference between Hg in hair of males and females (P = 0.02, P < 0.05), as presented in Figure 3. The average Hg content was higher in females.

The classification of the risk level of T-Hg found in human hair is displayed in Table 4. The level of Hg content in respondents’ hair in the research area can be classified into
### Table 1 — Socioeconomic Characteristics of Respondents

| Criteria                        | Classification                  | Number | %    |
|---------------------------------|---------------------------------|--------|------|
| Village                         | Sukarama                        | 29     | 40.85|
|                                 | Cicadas                         | 31     | 43.66|
|                                 | Kertajaya                       | 11     | 15.49|
| Age (years)                     | 20-27                           | 13     | 18.31|
|                                 | 28-35                           | 19     | 26.76|
|                                 | 36-43                           | 14     | 19.72|
|                                 | 44-51                           | 16     | 22.54|
|                                 | 52-59                           | 5      | 7.04 |
|                                 | 60-67                           | 2      | 2.82 |
|                                 | 68-75                           | 2      | 2.82 |
| Gender                          | Male                            | 38     | 53.52|
|                                 | Female                          | 33     | 46.48|
| Number of family members        | 1                               | 1      | 1.41 |
|                                 | 2                               | 6      | 8.45 |
|                                 | 3                               | 25     | 35.21|
|                                 | 4                               | 25     | 35.21|
|                                 | 5                               | 10     | 14.08|
|                                 | 6                               | 4      | 5.63 |
| Education level                 | Primary School                  | 50     | 70.42|
|                                 | Junior High School              | 6      | 8.45 |
|                                 | Senior High School              | 12     | 16.90|
|                                 | Bachelor/University              | 1      | 1.41 |
|                                 | N/A                             | 2      | 2.82 |
| Primary occupation              | Civil servant                   | 2      | 2.82 |
|                                 | Miner                           | 21     | 29.58|
|                                 | Farmer                          | 24     | 33.80|
|                                 | Private                         | 11     | 15.49|
|                                 | Housewife                       | 13     | 18.31|
| Income (IDR/month) = x          | x ≤ 500,000 (USD 34.03)         | 14     | 19.72|
|                                 | 500,000 (USD 34.03) < x ≤ 1,000,000 (USD 68.09) | 22 | 30.99|
|                                 | 1,000,000 (USD 68.09) < x ≤ 2,000,000 (USD 136.17) | 21 | 29.58|
|                                 | 2,000,000 (USD 136.17) < x ≤ 3,000,000 (USD 204.18) | 8 | 11.27|
|                                 | x > 3,000,000 (USD 204.18)      | 4      | 5.63 |
|                                 | N/A                             | 2      | 2.82 |
| Water source                    | River                           | 1      | 1.41 |
|                                 | Well                            | 22     | 30.99|
|                                 | Spring water                    | 37     | 52.11|
|                                 | Tap water                       | 11     | 15.49|
| Food sources                    | Traditional market              | 28     | 39.44|
|                                 | Home garden                     | 2      | 2.82 |
|                                 | Kiosk                           | 41     | 57.75|
| Distance of respondents’        | ≤ 3 m                           | 34     | 47.89|
| housing to ball mill            | > 3-5 m                         | 17     | 23.94|
|                                 | > 5-10 m                        | 9      | 12.68|
|                                 | > 10-20 m                       | 4      | 5.63 |
|                                 | > 20-50 m                       | 4      | 5.63 |
|                                 | > 50 m                          | 3      | 4.23 |
| The distance of respondents’    | ≤ 1 km                          | 18     | 25.35|
| housing to mine                 | > 1-2 km                        | 35     | 49.30|
|                                 | > 2-5 km                        | 14     | 19.72|
|                                 | > 5 km                          | 4      | 5.63 |

Abbreviation: USD, United States dollar
Figure 2 — Gold ball mill in Lebak Nangka sub-village, Sukarame sub-district, Sukabumi Regency. (a) Settlement (b) Ball mill facility

Table 2 — Respondents’ Perception and Knowledge of Mercury Usage in ASGM

| Statement                                                                 | Score | Criteria | Percentage (%) |
|--------------------------------------------------------------------------|-------|----------|----------------|
| The use of mercury is very harmful to the health of gold miners and the surrounding community | 66.76 | Agree    | 46.91          |
| Mercury pollution in the air, soil, and water can interfere with human health and the environment | 68.17 | Agree    | 48.15          |
| The handling of mercury pollution in the environment is crucial           | 69.01 | Agree    | 40.74          |
| The use of mercury in gold processing should be limited or reduced       | 63.38 | Agree    | 38.27          |
| Gold processing should be done without mercury                           | 62.25 | Agree    | 50.62          |
| Ball mill gold ore processing should be located far away from settlements| 68.17 | Agree    | 45.68          |
| The community should reduce mercury use                                  | 58.87 | Unsure   | 35.80          |
| Reducing mercury pollution should involve communities and local governments| 69.30 | Agree    | 41.98          |
| Alternative sources of income replacing ASGM are available              | 59.72 | Unsure   | 44.44          |
| Alternative livelihood should provide higher incomes                     | 60.56 | Agree    | 43.21          |

Remarks, range value for criteria: 0-20 (strongly disagree); 21-40 (disagree); 41-60 (unsure); 61-80 (agree); 81-100 (strongly agree).
Table 3 — Mercury Content in Hair Samples

| Group   | No. | Age (year) | Hg range (ppm) | Hg average ± SD (ppm) |
|---------|-----|------------|----------------|-----------------------|
| Males   | 48  | 23-70      | 0.71-18        | 3.27±2.89             |
| Females | 33  | 22-60      | 1.5-24         | 5.91±4.69             |
| Children| 4   | 2.5 - 10   | 0.96-8.1       | 5.34                  |

Figure 3 — Box plot representing the concentration of T-Hg in hair of male and female respondents, outliers (o), and extremes (*).

Table 4 — Classification of Mercury Content in Hair

| Toxicology threshold limit | Category      | Number of samples |
|----------------------------|---------------|-------------------|
| <1 µg Hg/g hair            | Normal        | Men: 2  Women: 0  |
| 1-<5 µg Hg/g hair          | Alert level   | Men: 28 Women: 16 |
| ≥5 µg Hg/g hair            | High level    | Men: 8 Women: 17  |

*Human biomonitoring categories 27,31,34
the alert and high-level categories in terms of human biomonitoring classification. Only three males had Hg content at a normal level. Mercury content in females were classified in the alert and high levels. Possible explanations for these results were analyzed using explanatory variables such as socioeconomic characteristics.

Table 5 presents the result of the multiple linear regression, and the tested independent factors affecting T-Hg contamination in respondents’ hair. The factors predicted to affect the levels of mercury in hair (Y) included age (X1), number of family members (X2), education level (X3), income level (X4), length of stay at the location (X5), distance from the respondent’s house to the mining sites (X6), distance of the respondent’s house to the ball mill location (X7), and perception (X8). The regression model’s ability to predict the effect of social-economic factors affecting Hg levels in hair is qualified by $P$-value < 0.001 and $R^2$ = 0.36. The regression model selected in the analysis was a robust regression model to eliminate the problem of possible homoscedasticity.

| Variables                  | Coefficient (SE) | $P$-value |
|----------------------------|------------------|-----------|
| Age (X1)                   | -0.082 (0.056)   | 0.15      |
| Number of family members (X2) | -0.060 (0.251)   | 0.81      |
| Education (X3)             | -1.188 (0.459)   | <0.01     |
| Income (X4)                | 0.000 (0.000)    | 0.27      |
| Length of stay (X5)        | -0.008 (0.043)   | 0.86      |
| Distance to mining site (X6)| -0.001 (0.000)   | <0.01     |
| Distance to ball mill (X7) | 0.100 (0.009)    | <0.01     |
| Knowledge (X8)             | 0.063 (0.070)    | 0.38      |

Table 5 — Multiple Linear Regression Results

Discussion

There are several gold ore processing locations in Cicadas Village, although there is no gold mining sites in this area. The villagers received material containing gold ore from the neighboring village, Sukarame. Cicadas villagers process the material containing gold using a ball mill. Based on an interview with village government officials, about 500 households (of a population of 1751 individuals) are involved in ASGM activities in Cicadas.

One of the ball mill owners explained that his business was started around ten years ago, with an initial capital of IDR 50,000,000 (USD 3402.78) He bought the material from miners in Sukarame and the price ranged from IDR 50,000-100,000 (USD 3.4 – 6.8) per sack of ore (±50 kg), depending on the predicted quality and the deal between the ball mill owner and the miners. If the ball mills owners also manage the mining operation, then they can employ up to 50 miners. They share the ore containing gold materials equally.

The leader of Sukarame Village indicated that the ASGM has been present since the 1990s. Many inhabitants perform mining extraction in the state-owned forest and the gold processing in their settlement area. These activities are illegal, and therefore there are no official records of gold miners. Around 35% of the total households are miners. Women are involved in breaking down materials and can process as many as five sacks of material each day. In comparison, men can process seven sacks daily. Mercury is used in ball mill grinding tubes to bind gold ores, with as much as 500 g of Hg used for each ball mill per week. Based on field observation, there are hundreds of ball mills in Sukarame village (Figure 2) which operate 24 hours, seven days a week.

A similar system also applies to Kertajaya Village, which has been in operation since the Dutch colonial
era. The villagers have been working in ASGM for more than 50 years. Based on the information gathered from a ball mill owner, there are approximately 300 households involved in the business. The laborers are paid IDR 7 (approximately USD 0.5) per sack. This job can be done by men and women to obtain additional income.

Mercury usage ranged from 1-4 oz to produce 2.4-4 grams of gold per month on average in Cicadas and Sukarame Villages. Since the total number of ASGM in these villages is 1.3 units, the average use of Hg in gold amalgamation ranged from 260-520 kg/month, which is eventually released as a byproduct into the environment. This is lower than the amounts of Hg used in other areas such as Poboya and Sekotong. 11

In the present study, an elevated Hg level of 24 ppm was found in a 23-year-old woman. This was a result of the addition of Hg in the ball mill. During this process, workers do not wear masks or gloves and thus have direct contact with Hg. Another associated factor is the process of releasing the gold from the amalgamation by burning the gold-mercury compound. 3,16 Local residents are exposed to Hg vapor through inhalation from the amalgam burning that are located on or nearby the settlements.

The results showed that the average Hg content was higher in females than males. However, some factors related to hair Hg concentration were not considered in the present study, including dietary habits and water consumption. In comparison, the total Hg concentrations in hair of people directly exposed to Hg in Bombana, Southeast Sulawesi ranged from 3.29 to 81.44 ppm. 33 Meanwhile, in North Gorontalo Regency, the highest Hg level of 17.9 ppm was found in the miner group. 34

The education level of respondents had significant effects (p < 0.01) on hair Hg content. Respondents with higher education tended to have lower Hg levels. The distance between the house and the mine hole showed a negative relationship, thus the farther from the mine, the lower the T-Hg in hair. Different results were found for the distance of the house to the ball mills. The results showed a positive relationship, thus the closer to the ball mill, the lower the T-Hg in hair. The distance of the ball mills from the inhabitants’ residence ranged from 1-150 meters, which suggests that the T-Hg in hair does not come from ball mills, but from mercury-gold amalgam burning activities. Mercury burning is mostly carried out in gold collectors’ houses which are located within the same area as the ball mills. This phenomenon is possibly related to the Hg released into the air through the combustion chamber during the gold purification process.

Other studies in Indonesia also found hair Hg contamination. In Gorontalo Utara Regency, Gorontalo Province, the hair Hg levels of ASGM miners ranged from 7.1-17.9 ppm. 34 The mean hair Hg levels of miners and non-miners in Sekotong ASGM were 2.77±1.68 ppm and 2.37±1.82 ppm, respectively, and the highest level of Hg in hair of miners was 12.93 ppm. 37 Another study reported that mercury content in hair sampled in an ASGM community in Cisitu, Banten province reached as high as 25 ppm. 21

Mercury exposure to humans can originate from skin lightening products, dental amalgam filling, consumption of Hg-contaminated fish, vegetables, rice, and drinking water. 16,39-46 People who live and work at or near ASGM areas are vulnerable to health issues caused by Hg vapor inhalation such as neurological, digestive, and immune system disorders. 47 Some symptoms of mercury intoxication are sleeping troubles, tremors, numbness, and headaches. 22 Inorganic Hg accumulates in the kidneys and induces kidney damage. 42

A limitation of the present study was the lack of examination of Hg intoxication symptoms experienced by participants. However, few adults and children in the research with high T-Hg levels showed neurological symptoms. This could be related to Hg contamination in this area, as suggested by a previous study. 48

A reduction or phase-out of mercury application in ASGM is necessary based on the results of the community evaluation. 49 However, government support for these measures is crucial, as has been proposed in Nigeria, especially in providing new employment alternatives that could replace gold mining activities. 50,51 As these villages are located near the state forest, the government could introduce a social forestry management system as an alternate source of income based on economic and ecological feasibility. 12-54

Conclusions

The present study found that inhabitants living around ASGM had elevated hair Hg content, with the majority classified in alert and high levels. Women had higher Hg content than men. Factors affecting the level of Hg content in hair included education level and distance of the mining site and ball mills to settlements. The respondents were familiar with steps to minimize the health effects of ASGM and agreed to relocate ball mills away from their residences. This research recommends
several actions: providing alternative livelihoods that create higher income than gold mining; developing social forestry programs; conducting further health examinations on those with high Hg levels; and increasing public knowledge of the dangers of Hg on the environment and public health.

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References

1. Rahmayani A, Montrado 1818-1858: Dinamika kota tambang emas. Patanjala [Internet]. 2015 Jun [cited 2020 Oct 9];7(2):345-60. Available from: http://doi.org/10.30959/patanjala.v7i2.105

2. Siahaan BC, Utami SR, Handayanto E. Fitoremediasi tanah tercemar merkuri (Hg) limbah tailing tambang emas menggunakan Lindernia crustacea, Digitaria radicosa, dan Cyperus rotundus serta pengaruhnya terhadap pertumbuhan dan produksi tanaman jagung. J Tanah Sumberd Lahan [Internet]. 2014 [cited 2020 Oct 9];12(2):35-51. Available from: https://jtsl ub.ac.id/index.php/jtsl/article/view/111

3. Gafur NA, Sakakibara M, Sano S, Sera K. A case study of heavy metal pollution in water of Bone River by Artisanal Small-Scale Gold Mine Activities in Eastern Part of Gorontalo, Indonesia. Water [Internet]. 2018 [cited 2020 Oct 9];10(11):Article 1507 [10 p.]. Available from: https://doi.org/10.3390/w10111507

4. Green CS, Lewis PJ, Wozniak JR, Drewnick PE, Thies ML. A comparison of factors affecting the small-scale distribution of mercury from artisanal small-scale gold mining in a Zimbabwean stream system. Sci Total Environ [Internet]. 2019 Jan 10 [cited 2020 Oct 9];647:400-10. Available from: https://doi.org/10.1016/j.scitotenv.2018.07.418 Subscription required to view.

5. Sumantiri A, Laelasari E, Junita NR, Nasrudiant N. Logam Merkuri pada Pekerja Penambangan Emas Tampak Izin. Kesmas Naul Public Heal J. 2014;8(8):398-403.

6. Zaharani F, Salami IRS. Kandungan Merkuri Pada Urin Dan Rambut Sebagai Indikasi Paparan Merkuri Terhadap Pekerja Tambahan Emas Tampak Izn (Peti) Di Desa Pasar Terusan Kecamatan Muara Bulian Kabupaten Batanghari – Jambi. J Teh Lingkung [Internet]. 2015 Oct [cited 2020 Oct 12];21(2):686-79. Indonesian. Available from: http://dx.doi.org/10.5614%2Fjtl.2015.21.2.7

7. Indirati Arifin Y, Sakakibara M, Sera K. Heavy metals concentrations in scalp hairs of ASGM miners and inhabitants of the Gorontalo Utara regency. (IOP Conference Series: Earth and Environmental Science; vol. 71).

8. Basu N, Clarke E, Green A, Calys-Tagoe B, Chan L, Dzodzomenyo M, et al. Integrated Assessment of Artisanal and Small-Scale Gold Mining in Ghana: Part 1: Human Health Review. Int J Environ Res Public Health [Internet]. 2020 May 13 [cited 2020 Oct 12];17(5):5143-76. Available from: https://doi.org/10.3390/ijerph1705143

9. Niane B, Guédron S, Feder F, Shirazi FH, Chan Getriana A, Achmadi UF, Leometa CH. Behavioral mercury exposure of people in artisanal and small-scale gold mining site area at lebaksitu village, Indonesia. J Health Pollut [Internet]. 2019 Mar [cited 2020 Oct 12];12(8):1584 [15 p.]. Available from: https://doi.org/10.3390/ijerph12081584

10. Martinez G, McCord SA, Driscoll CT. Mercury contamination in riverine sediments and fish associated with artisanal and small-scale gold mining in Madre de Dios, Peru. Int J Environ Res Public Health [Internet]. 2018 Jul 26 [cited 2020 Oct 12];15(8):Article 1584 [15 p.]. Available from: https://doi.org/10.3390/ijerph15081584

11. Junaidi M, Krisnayanti BD, Juharfa, Anderson C. Risk of mercury exposure from fish consumption at artisanal small-scale gold mining areas in West Nusa Tenggara, Indonesia. J Health Pollut [Internet]. 2019 Mar [cited 2020 Oct 12];12(8):190302 [10 p.]. Available from: https://doi.org/10.5692/2156-9614.9.21.190302

12. Prasetya H, Sakakibara M, Omori K, Laird JS, Sera K, Kurniawan IA. Mangifera indica as a bioindicator of mercury atmospheric contamination in an ASGM area in north gorontalo regency, Indonesia. Geosciences [Internet]. 2018 [cited 2020 Oct 12];8(1):Article 31 [9 p.]. Available from: https://doi.org/10.3390/geosciences8010031

13. Mostafazadeh B, Kiani A, Mohamadi E, Shaki F, Shirazi FH. Mercury exposure of gold mining workers in the northwest of Iran. Pak J Pharm Sci. 2013 Nov;26(6):1267-70. [Cited 2020 Oct 20]. Available from: https://remote-lib.ui.ac.id/2117/ehost/pdfview/pdfview?vid=1&sid=bff1c6bf8-ceed-49f6-9a0f-6b3e932841b4%40sessionmgr101. Subscription required to view

14. Getriana A, Achmadi UF, Leometa CH. Behavioral mercury exposure of people in artisanal and small-scale gold mining site area at lebaksitu village, Indonesia. Indian J Public Health Res Dev [Internet]. 2018 Jun 1 [cited 2020 Oct 12];9(5):433-
20. Pérez R, Suelves T, Molina Y, Corpas-Burgos F, Yusá Y. Biomonitoring of mercury in hair of children living in the Valencian Region (Spain). Exposure and risk assessment. Chemosphere [Internet]. 2019 Feb [cited 2020 Oct 12];217:558-66. Available from: https://doi.org/10.1016/j.chemosphere.2018.11.017 Subscription required to view.

21. Krisnayanti BD. ASGM status in West Nusa Tenggara Province, Indonesia. J Degraded Min Lands Manag [Internet]. 2018 Jan [cited 2020 Oct 12];5(2):1077-84. Available from: https://doi.org/10.15243/jdmlm.2018.052.1077

22. Bose-O'Reilly S, Schierl R, Nowak D, Siebert U, William JF, Owi FT, et al. A preliminary study on health effects in villagers exposed to mercury in a small-scale artisanal gold mining area in Indonesia. Environ Res [Internet]. 2016;149:274–81. Available from: http://dx.doi.org/10.1016/j.envres.2016.04.022

23. Widodo. Pencemaran air raksa (Hg) sebagai dampak pengolahan bijih emas di Sungai Tenggara Province, Indonesia. Pros Farm [Internet]. 2015 Aug [cited 2020 Oct 12];18(8):771-87. Available from: https://doi.org/10.1016/j.prosfarm.2015.06.022

24. Pemerintah Republik Indonesia. Peraturan Presiden No 21 Tahun 2019 tentang Rencana Aksi Nasional Pengurangan dan Penghapusan Merkuri. 2019[cited 2020 Oct 20]. Available from https://www.hukumonline.com/pusatdata/detail/556dcdcf02c42d/node/8511a58b1b845f/2019-perpres-no-21-tahun-2019-rencana-asli-nasional-pengurangan-dan-penghapusan-merkuri

25. United States Environmental Protection Agency. Method 7473 (SW-846): Mercury in Solids and Solutions by Thermal Decomposition, Amalgamation, and Atomic Absorption Spectrophotometry. Revision 0. Washington, DC.; 1998. [accessed 2020 Oct 20]. Available from: https://www.epa.gov/esaam/epa-method-7473-sw-846-mercury-solids-and-solutions-thermal-decomposition-amalgamation-and

26. Magnusson B, Ornemark U. The Fitness for Purpose of Analytical Methods. Eurachem Guide. 2014[accessed 2020 Oct 20]. Available from: https://www.eurachem.org/images/stories/Guides/pdf/ MG_guide_2nd_ed_EN.pdf

27. Schulz C, Angerer J, Ewers U, Kolososa-Gehrung M. The German human biomonitoring commission. Int J Hyg Environ Health [Internet]. 2007 May 22 [cited 2020 Oct 12];210(3-4):373-82. Available from: https://doi.org/10.1016/j.ijeh.2007.01.035 Subscription required to view.

28. Nugrahani S, Kota Sukabumi: dari distrik menjadi Gemeente (1815-1914). Patanjila [Internet]. 2017 Sep [cited 2020 Oct 12];9(3):423-38. Indonesian. Available from: http://dx.doi.org/10.5695/ptnjlanja.v9i33

29. Chen S, Ravallion M. Absolute poverty measures for the developing world, 1981-2004. Proc Natl Acad Sci U S A. 2007;104(43):16757–62. [cited 2020 Oct 20]. Available from: https://www.pnas.org/content/pnas/104/43/16757.full.pdf

30. Ibrahim, Baiquni M, Ritoñardoyo S, Setiadi. Characteristics of Poverty in Rural Communities of Gold Mining District Area West Sumbawa. Mimbar Health [Internet]. 2016 Sep [cited 2020 Oct 12];21(4):986-1006. Available from: https://doi.org/10.3390/toxics5010007

31. Islam MS, Ahmed MK, Habibullah-Al-Mamun M. Determination of heavy metals in fish and vegetables in Bangladesh and health implications. Hum Ecol Risk Assess [Internet]. 2015 [cited 2020 Oct 12];21(4):986-1006. Available from: https://doi.org/10.1080/10807039.2014.950172 Subscription required to view.

32. Wang X, Sato T, Xing R, Tao S. Health risks of heavy metals to the general public in Tianjin, China via consumption of vegetables and fish. Sci Total Environ [Internet]. 2005 Nov 1 [cited 2020 Oct 12];350(1-3):28-37. Available from: https://doi.org/10.1016/j.scitotenv.2004.09.044 Subscription required to view.

33. Ikem A, Egibor NO. Assessment of trace elements in canned fishes (mackerel, tuna, salmon, sardines and herrings) marketed in Georgia and Alabama (United States of America). J Food Compos Anal [Internet]. 2005 Dec [cited 2020 Oct 12];18(8):771-87. Available from: https://doi.org/10.1016/j.jfca.2004.11.002 Subscription required to view.

34. Purwanto N. Uji Sitotoksik Ekstrak Biji Salak (Salacca Zalacca (Gaert) Voss) Dengan Menggunakan Metode Brine Shrimp Leathality Test (BSLT). Pros Farm [Internet]. 2015 Aug [cited 2020 Oct 12];1;2(2):616-22. Indonesian. Available from: http://karyailmiah.unisba.ac.id/index.php/farmasi/article/view/2143

35. Islam MS, Ahmed MK, Habibullah-Al-Mamun M. Determination of heavy metals in fish and vegetables in Bangladesh and health implications. Hum Ecol Risk Assess [Internet]. 2015 [cited 2020 Oct 12];21(4):986-1006. Available from: https://doi.org/10.1080/10807039.2014.950172 Subscription required to view.
to view.

42. Park J-D, Zheng W. Human exposure and health effects of inorganic and elemental mercury. J Prev Med Public Health [Internet]. 2012 Nov [cited 2020 Oct 12];45(6):344-52. Available from: https://doi.org/10.3961/jpmph.2012.45.6.344

43. Mackert Jr JR, Berglund A. Mercury exposure from dental amalgam fillings: absorbed dose and the potential for adverse health effects. Crit Rev Oral Biol Med. 1997;8(4):410–36. [Cited 2020 Oct 20]. Available from: https://journals.sagepub.com/doi/abs/10.1177/10454411970080040401

44. Zhang H, Feng X, Larsen T, Qu G, Vogt RD. In inland China, rice, rather than fish, is the major pathway for methylmercury exposure. Environ Health Perspect. 2010 Sep [Internet];118(9):1183-8. Available from: https://doi.org/10.1289/ehp.1001915

45. Alinejad A, Farsani SF, Bahmani Z, Barafrashtehpour M, Sarsangi V, Khodadadi R, et al. Evaluation of heavy metals level (arsenic, nickel, mercury and lead) effecting on health in drinking water resource of Kohgiluyeh county using geographic information system (GIS). Int J Med Res Sci [Internet]. 2016 [cited 2020 Oct 12];5(8):233-41. Available from: https://www.jimrshs.com/abstract/evaluation-of-heavy-metals-level-arsenic-nickel-mercury-and-lead-effecting-on-health-in-drinking-water-resource-of-kohgi-8399.html

46. Riaz A, Khan S, Muhammad S, Shah MT. Mercury Contamination in Water and Sediments and the Associated Health Risk: A Case Study of Artisanal Gold mining. Mine Water Environ [Internet]. 2019 [cited 2020 Oct 12];38:847-54. Available from: https://doi.org/10.1007/s10230-019-00613-5 Subscription required to view.

47. World Health Organization. Exposure to mercury: a major public health concern. WHO, Public Heal Environ. 2007;

48. Ronchetti R, Zuurbier M, Jansen M, Koppe JG, Farah Ahmed U, Ceccatelli S, et al. Children's health and mercury exposure. Acta Paediatr Suppl [Internet]. 2006 Oct [cited 2020 Oct 12];95(453):36-44. Available from: https://doi.org/10.1080/0035250600886157 Subscription required to view.

49. Spiegel SJ, Agrawal S, Mikha D, Vitamerry K, Le Billon P, Veiga M, et al. Phasing Out Mercury? Ecological Economics and Indonesia’s Small-Scale Gold Mining Sector. Ecol Econ [Internet]. 2018 Feb [cited 2020 Oct 12];144:1-11. Available from: https://doi.org/10.1016/j.ecolecon.2017.07.025

50. Salati LK, Mireku-Gyimah D, Eshun PA. Evaluation of Stakeholders’ Roles in the Management of Artisanal and Small-Scale Gold Mining in Anka, Zamfara State, Nigeria. Dev Ctry Stud [Internet]. 2014 [cited 2020 Oct 12];4(19):150-61. Available from: https://www.iiste.org/Journals/index.php/DCS/article/view/16603

51. Salati LK, Eshun PA. An integrated management model for artisanal and small-scale gold mining in Northern Nigeria. Int J Adv Res [Internet]. 2016 Dec [cited 2020 Oct 12];4(12):23 p. Available from: http://www.ijor.org/journals/IJOAR/papers/AN-INTEGRATED-MANAGEMENT-MODEL-FOR-ARTISANAL-AND-SMALL-SCALE-GOLD-MINING-IN-NORTHERN-NIGERIA.pdf

52. Iswandi RM, Baco L, Yunus L, Alwi LO. Kelayakan finansial pengembangan usaha tani dalam suatu wilayah lingkar tambang emas di Kabupaten Bombana, Provinsi Sulawesi Tenggara. J Agro Econ [Internet]. 2017 May [cited 2020 Oct 12];35(1):67-76. Indonesian. Available from: http://dx.doi.org/10.21082/jeac.v35n1.2017.67-75

53. Ma’mun SR. Pertambangan emas dan sistem penghidupan petani: studi dampak penambangan emas di Bombana, Sulawesi Tenggara. J Sosiol Pedesaan. 2016 Dec:274-80. Indonesian.

54. Espejo JC, Messinger M, Román-Dañojetnya F, Ascorra C, Fernandez LE, Silman M. Deforestation and forest degradation due to gold mining in the Peruvian Amazon: A 34-year perspective. Remote Sens [Internet]. 2018 [cited 2020 Oct 12];10(12):Article 1903 [17 p.]. Available from: https://doi.org/10.3390/rs10121903

55. Haranja et al