Jurnal Kesehatan Lingkungan
Journal of Environmental Health
Journal Home Page: https://e-journal.unair.ac.id/JKL
Vol. 15 No. 2
DOI: 10.20473/jkl.v15i2.2023.99-108
ISSN: 1829 - 7285 | E-ISSN: 2040 - 881X
LITERATURE REVIEW Open Access

THE EXISTENCE OF ARTISANAL SMALL-SCALE GOLD MINING IN INDONESIA, THE IMPACT OF PUBLIC HEALTH AND ENVIRONMENTAL SUSTAINABILITY : A NARRATIVE REVIEW

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Article Info

Submitted	: 15 January 2023
In reviewed	: 3 February 2023
Accepted	: 20 March 2023
Available Online	: 30 April 2023

Keywords : *ASGM, Environmental damage, Health impact, Safety miner, Toxic substance*

Published by *Faculty of Public Health Universitas Airlangga*

Abstract

Introduction: *This study reviewed the negative impacts of artisanal small-scale gold mining (ASGM). This paper presents an examination of ASGM's impact on health, with the scope of discussion covering human diseases and disorders, toxic substances, public and miners' safety, environmental damage, socioeconomic conditions. This study contributes mitigation recommendations for ASGM in Indonesia. This research subject is important because there has not been an ASGM study that has reviewed these aspects in Indonesia.* ***Discussion:*** *Chronic diseases, acute diseases, infectious diseases, and disabilities can threaten local communities' health and survival. Toxic heavy metals such as mercury, cadmium, arsenic, and lead are difficult to avoid in ASGM, since they have a high level of use. Other pollutants generated by ASGM are noise and silicia dust. ASGM has caused accidents with a total of 36 minor injuries, an estimated 57 serious injuries, and 11 deaths. ASGM also causes water, soil, and air pollution; it is a threat to the geology of world heritage sites. ASGM has been proven to improve the community's economy in several parts of Indonesia.* ***Conclusion:*** *ASGM has proven to have a significant impact on public health, environmental sustainability, and the socioeconomic state of Indonesian society. In general, the lack of ASGM legitimization in Indonesia is an enabling factor for these impacts.*

INTRODUCTION

Artisanal Small-Scale Gold Mining (ASGM) has experienced growth and development globally. This is in line with the increasing price and scarcity of minerals, as well as an increase in miners. In 2017, there were 40.5 million ASGM miners, compared to only 30 million in 2014 (1). Indonesia is a country with large amounts of metal content. It is a recognized gold producer with total production reaching 130 tons in December 2020 (2–3). ASGM does have a big role in supporting a country's economy. ASGM is defined as gold mining activities that are owned or carried out by individuals or local communities (4–5). In general, ASGM miners operate without having a license or certificate that supports environmental health sustainability. For example, mining activities are carried out in protected forest areas, conservation areas, and even some areas near settlements. As a result, these activities can have an impact on the environment and local communities (5).

The gold mining and extraction process requires at least four steps. The first step is the process of extracting gold ore at a predetermined location, which can be in the form of soil, rock, and surrounding tributaries. The excavation process can be carried out directly or on

Cite this as :
Fikri E, Firmansyah YW, Afifiah AS, Fauzi M . The Existence of Artisanal Small-Scale Gold Mining in Indonesia, The Impact of Public Health and Environmental Sustainability : A Narrative Review. *Jurnal Kesehatan Lingkungan*. 2023;15(2):99–108. https://doi.org/10.20473/jkl.v15i1.2023.99-108

former industrial mine excavations (6). In the second step, gold ore is processed and concentrated using the gravity method. Then, mercury compounds are added to form a gold-mercury amalgamation. In the third step, the amalgam is burned to remove mercury through the evaporation process. In the last step, the combustion result is a gold alloy with a high purity level, which will continue to the refinement process (7). The mining process produces waste from burning gold ore with the addition of heavy metal (mercury) and liquid (in the form of leachate from the sale of the amalgam). In addition to the mercury used in ASGM, cyanide is also still found and used in gold mining activities. Cyanide is used in the cyanidation process. The gold extraction method is also very dangerous for public and environmental health. In addition to these, chemicals such as thiocyanate, thiourea, and thiosulfate are also used (7). The type of chemical used in ASGM is the mine owner's responsibility. Usually, the mine owner will choose cheap chemicals that can still provide the effectiveness and efficiency of gold extraction. This is intended to minimize production costs and get the maximum possible profit. The mine owner's ignorance of the dangers posed by these chemicals is another driving factor for the emergence of public health problems and environmental damage. The Indonesian government has not identified the limitations of safe chemical alternatives in ASGM. The use of mercury and other toxic substances has indeed been banned by the Indonesian government through the Regulation of the President of the Republic of Indonesia number 21 of 2019 and Regulation of the Indonesian Ministry of Environment and Forestry number 81 of 2019.

Such gold refining processes harm public health and the environment. In addition to mercury, other heavy metals such as lead, cyanide, arsenic, cadmium, and cobalt are also commonly used. The amalgam's evaporation process is a contamination source for toxic materials that are harmful to public health. These materials can cause damage to the nerves, kidneys, digestion, and immunology (8). In addition, miners often neglect the use of personal protective equipment during the mining process. As a result, miners can have work accidents, such as falling from a height, resulting in serious injuries, lacerations, and amputations (6). It is estimated that there are 10–18 million ASGM miners worldwide, a third to half of whom are women and children (specifically 5 million child miners) (5,9). This can happen because children have a smaller body size than adults, making it possible for them to enter small gold mining pits. These conditions can allow for hazards that threaten these children's safety and health. In 2020, 592 deaths due to ASGM were reported (10). This study focused on reviewing the negative impacts of ASGM. This paper presents an examination of ASGM's impact on health, with the scope of discussion covering human diseases and disorders, toxic substances, public and miners' safety, environmental damage, and socioeconomic conditions. This study contributes mitigation recommendations for ASGM in Indonesia. This research subject is important because there has not been an ASGM study that has reviewed these aspects in Indonesia.

DISCUSSION

This study is a review with a narrative approach. A narrative review was used to identify the dangers posed by ASGM to human diseases and disorders, toxic substances, public and miners' safety, environmental damage, and socioeconomic conditions. In this study, there were no research questions or hypotheses; this study's output of results will serve as a reference for further research. The data used were sourced from articles published in the SCOPUS and Google Scholar. The selected articles contained the keywords artisanal small-scale gold mining, environment, health, and safety of miners. The inclusion criteria for the articles were those published between 2018 and 2022; those that had themes related to ASGM; those that mentioned hazards to public health and environmental damage; those that could be downloaded in full; and those that did not use the review method. Narrative reviews do not have specific requirements or protocols for the article screening process (11); therefore, Figure 1 below shows this study's article screening process,

From the article screening process, a total of 36 articles were obtained to be used as review material. The articles met the specified inclusion criteria. A total of 17 articles were used to review the human diseases and disorders aspect. A total of four articles were used to review the toxic substances aspect. A total of four articles were used to review the public and miners' safety aspect. A total of eight articles were used to review the environmental damage aspect. A total of five articles were used to review the economic and social aspects. The findings from the article review are presented in Table 1 below.

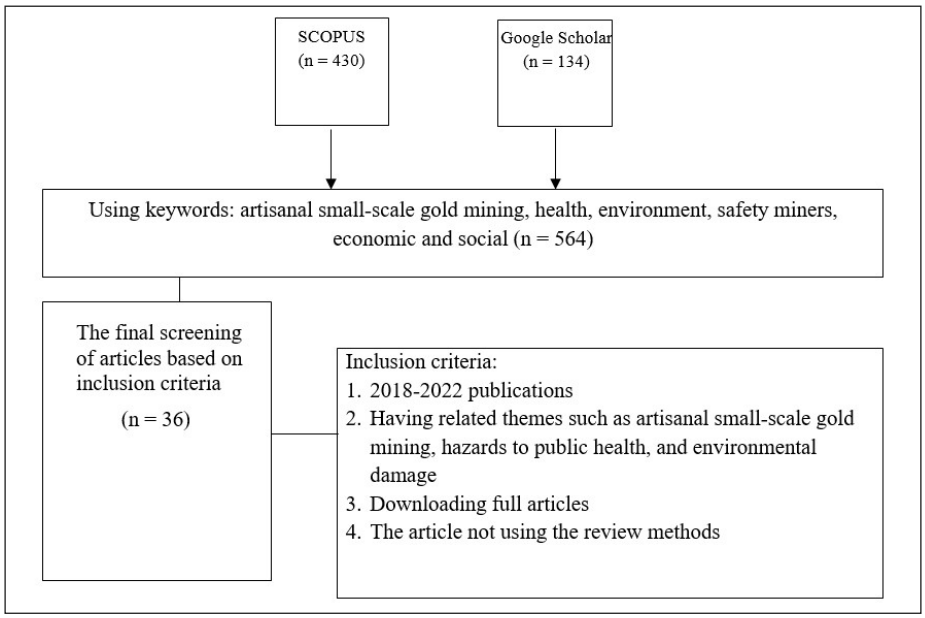

Figure 1. Article Screening Flowchart 2018-2022 from Online Databases

Table 1. Results of Reviewed Aspects of Articles Published between 2018-2022

Aspects Reviewed	Study Finding	Reference
Disease and disorder in human	1. Malaria is most reported infectious disease in Venezuela, Brazil, French Guiana, and Sudan because of artisanal small-scale gold mining. Brazil has also reported other diseases such as hantavirus and yellow fever. Meanwhile, French Guiana reported another disease, namely measles.	(12–19)
	2. Noise pollution from the use of tools for artisanal small-scale gold mining that exceeds the threshold value can cause hypertension, hearing loss, social effects, and even disability.	(20–22)
	3. Some artisanal small-scale gold mining in Indonesia harms public health. For example, the outbreak of chronic and acute diseases. In Indonesia, illegal artisanal small-scale gold mining in the North Lebong Sub-district, Lebong Regency, Bengkulu Province led to impaired lung function, coughing, and tuberculosis in the community. Artisanal small-scale gold mining in Merangin, Sarolangun, Bungo, and Tebo, Jambi Province affected pregnant women and children around the location, thereby suffering from impaired child development and permanent disability.	(23–28)
Toxic substances	1. Studies show 15% of artisanal small-scale gold mining worldwide produces 40% mercury pollution. Apart from being a toxic material for humans, mercury is also a toxic material for ecology. As reported in a study, mercury was identified with a concentration of 1.4 g/g in the leaves of plants growing around the mine. Plants around artisanal small-scale gold mining in Rarowatu and Rarowatu Utara Bombana Districts were contaminated with mercury with a concentration of 9.9 ± 14 g/g d.w.	(28–29)
	2. Other toxic metals used in artisanal small-scale gold mining are cadmium, arsenic, and lead. Cadmium, arsenic, and lead help in gold exploration geochemistry and produce gold with a good level of purity.	(30)
	3. Silica dust was discovered during the crushing process of artisanal small-scale gold mining for hard rock.	(31)
Public and mining safety	1. The Indonesian Ministry of Energy and Mineral Resources reported a total of 36 minor injuries, an estimated 57 serious injuries, and 11 deaths in Indonesia in 2021. Work accident data on artisanal small-scale gold mining reported in 2021 showed 25 miners who suffered injuries and 25 work-related accidents.	(2, 32)
	2. Psychosocial hazards also threaten the safety of the public and miners. Psychosocial threats such as prostitution, criminalization, violence, substance abuse, and the displacement of indigenous peoples. These threats certainly affect the quality of life of the public and miners.	(33–34)
Environmental Damage	1. Water pollution is one of the environmental damages caused by artisanal small-scale gold mining. In Indonesia, several rivers such as the Sekonyer river basin, Central Kalimantan; Kayeli Bay, Kayeli Bay Sub-district, Buru Regency, Maluku Province; and the Batanghari River, Dharmasraya Regency, West Sumatra were contaminated with mercury. High concentrations of mercury in water, sediment and aquatic life are the impacts of artisanal small-scale gold mining.	(35–37)
	2. Artisanal small-scale gold mining resulted in the loss of 3,900 hectares of land in Madre de Dios, Peru. This incident happened because of the conversion of land use into mining. The world heritage sites along the Marupa and Kahayan rivers, Central Kalimantan, is also threatened by artisanal small-scale gold mining.	(21,38–40)
	3. The emission of mercury in the air which is also the cause of air pollution is classified into three forms: gaseous elements, reactive gases, and particulates.	(41)
Economic and social aspects	1. Artisanal small-scale gold mining in West Nusa Tenggara (Sekotong Island, Lombok) and East Nusa Tenggara (Taliwang-Sumbawa), was proven to contribute to improving the community's economy. The mining in North Lebong Sub-district, Lebong Regency, Bengkulu Province did not have a socio-economic impact on the community, and so did Sulawesi.	(42–43)
	2. The existence of artisanal small-scale gold mining has two impacts in various locations, such as in North Lebong District, Lebong Regency, and Bengkulu Province. The positive impact of the mining is to increase economic welfare for miners, while the negative impact is the threats to public health and environmental health.	(22)
	3. Artisanal small-scale gold mining in Pongkor, West Java, did not yet have regulations regarding the labor system.	(44)

Human Diseases and Disorders

Based on the article review results, ASGM locations were found to have poor access to basic sanitation and health services such as vaccination facilities and disease surveillance. Based on eight articles, malaria was most commonly reported in Venezuela, Brazil, French Guiana, and Sudan (12–19). Studies in Guyana showed that 94% of malaria cases occurred in major gold mining areas. These areas have small, isolated populations, high malaria densities, and minimal resources. These cases can be detected with active surveillance efforts and diagnosis (12). Studies in Brazil and French Guiana explain that 32.7% (6,390 cases) of malaria cases occurred in rural areas. One of the rural areas was the gold miner area along the river. The parasites detected in Brazil and French Guiana were *Plasmodium falciparum* (67.8%) and *Plasmodium vivax* (27.8%); *Plasmodium malariae* was also detected, but the amount found was not significant (0.2%). Slow diagnosis and treatment were contributing factors to the spike in cases in Brazil and French Guiana (17). Other diseases reported included hantavirus, yellow fever, leishmaniasis, and measles (14–17). Residents who live around ASGM sites typically do not get vaccinated, especially the children who are a group susceptible to infectious diseases. Even though children have received basic immunizations, a study says that exposure to mercury and malnourishment can cause a decrease in the body's immune system (18–19). Malaria, hantavirus, yellow fever, leishmaniasis, and measles emergence in several countries is a warning for Indonesia to be prepared, especially for areas of Indonesia used for ASGM. There is a need for regular active disease surveillance and early diagnosis for gold mine workers and communities living in mining areas as a form of disease prevention and control.

Noise pollution comes from the use of engines and diesel. The use of machinery such as dredges and excavators for gold mining generates a certain level of noise. Noise due to the use of equipment that is not operated properly in ASGM often exceeds the permissible quality standards. As a result, miners and the surrounding community will experience hearing problems, decreased productivity, cognitive issues, chronic stress, and social problems (20–21). In addition, high noise levels can cause hypertension, sleep disturbances, and behavioral changes (22).

In Indonesia, illegal ASGM in North Lebong, Lebong Regency, Bengkulu has health effects on the surrounding community in the form of impaired lung function, coughing, and tuberculosis (23). These diseases can occur due to air pollutants, such as silica dust and airborne particles caused by the gold-making process. ASGM in Merangin, Sarolangun, Bungo, and Tebo, Jambi affect surrounding pregnant women and children's health, causing impaired child development and permanent disability (24). Heavy metal usage is a contributing factor to impaired child development and permanent disability. The threat of chronic and acute disease also lurks in gold miners. Chronic diseases that may occur as a result of ASGM include impaired liver function, decreased leukocytes, partial or total limb paralysis, numbness, impaired balance (Parkison's disease), depression, emotional fluctuations, memory decline, and so on. Meanwhile, acute diseases that can occur include acute poisoning, diarrhea, upper respiratory tract infections, eye diseases, vertigo, and Multisystem Inflammatory Syndrome in Children (MIS-C) (25–28).

Toxic Substances

Mercury is one of the toxic materials often used in ASGM processes. Of the total 15% supply of global ASGM in 2018, it produced 40% of mercury pollution (28). The United Nations reported Indonesia as the third-largest mercury producer in the world after China and India. The use of mercury for mining processes has been restricted and prohibited based on the Minamata Convention on Mercury. The Indonesian Ministry of Environment and Forestry has ratified the convention, which is contained in the Republic of Indonesia Regulation number 21 of 2019 and Regulation of the Indonesian Ministry of Environment and Forestry number 81 of 2019. Mercury is classified as transition metal. The mercury exposure pathway is through amalgam vapor and leachate, which is emptied into rivers and contaminates fish (methylmercury). The highest mercury toxicity can interfere with the nervous system and the reproductive system. When pregnant women are exposed to mercury, it can cause impaired fetal growth and development, spontaneous abortion, premature birth, low birth weight, and congenital malformations anomalies (45–47).

Mercury concentrations in the form of gaseous elements were identified around the gold mining area of Central Sulawesi, Indonesia with an average of 9,172 ng/m^3 per 24 hours. This concentration exceeds the threshold set by the World Health Organization (WHO), which is 1,000 ng/m^3. In Mangkahui Village, Palu City, mercury is a pollutant that causes indoor and outdoor air pollution. The mercury concentration in Palu City's indoor air has reached 450 ng/m^3, while the mercury concentration in the outdoor air has reached 2,250 ng/m^3 (48). Meanwhile, at Site A in the village of Mangkahui, the

mercury concentration has reached 196 ng/m^3 indoors and 103 ng/m^3 outdoors. At Site B, the indoor mercury concentration was 238 ng/m^3 and in the outdoor air, it reached 279 ng/m^3. Apart from being a toxic material to humans, mercury is also toxic to ecology. As reported in a study, mercury was identified with a concentration of 1.4 g/g in the leaves of plants growing around the mine. Plants around ASGM sites in Rarowatu and Rarowatu Utara Bombana Districts were contaminated with mercury with a concentration of 9.9 ± 14 g/g d.w. (29). This value is categorized as high-level ecotoxicology (i.e., the value exceeds 3 g/g). These plants are also used as raw materials for animal feed. Mercury-contaminated plants will experience bioaccumulation and biomagnification of their toxicity when fed to animals.

Other toxic metals used in ASGM are cadmium, arsenic, and lead. Cadmium, arsenic, and lead help in gold exploration geochemistry, later producing gold with a good purity level (30). These metals have toxic properties. For example, lead can cause anemia, stomach pain, encephalopathy, and even death. Metal arsenic is a carcinogenic substance which can cause respiratory, skin, and cardiovascular diseases. Meanwhile, cadmium exposure can impair kidney functions, the immune system, the cardiovascular system, and bones (45, 49–52).

Silica dust in ASGM has also been found in values above the quality standard. Silica dust is present due to the crushing process of hard rock during ASGM. Silica dust in high concentrations will result in respiratory disorders and cause diseases such as silicosis, tuberculosis, and lung cancer (31).

Public and Miners' Safety

In 2020, 592 deaths caused by ASGM were reported globally. Meanwhile, in Indonesia, the Ministry of Energy and Mineral Resources reported a total of 36 minor injuries, an estimated 57 serious injuries, and 11 deaths in 2021 (32). The number of cases is the accumulation of legal and non-illegal gold mining. The Indonesian Ministry of Energy and Mineral Resources does not report specific minor injuries, serious injuries, and deaths from ASGM. Work accident data in ASGM were reported in 2021; a total of 25 miners suffered injuries and another 25 had work-related accidents. The data were obtained from a review article. The article did not fit into the reviewed articles' inclusion criteria and did not include where the data were obtained from; it only stated that the data were obtained from online news (2).

Psychosocial hazards also threaten public and miners' safety. Psychosocial threats include prostitution, criminalization, violence, substance abuse, and the displacement of indigenous peoples (34). These threats certainly affect the public and miners' quality of life (33). Psychosocial threats also contribute to increased morbidity and mortality among the public and miners. Lack of awareness and occupational safety and health regulation enforcement in ASGM is a contributing factor to psychosocial threats.

The psychosocial threats that occur cannot be separated from the applicable regulations. Currently, top-down regulations are enforced, which means that lower-level gold mining activities are not monitored or covered by the regulations. Top-down regulations lead to a lack of availability, financing, health insurance, and health services (promotive, preventive, and curative). The absence of financial, social, and formal employment contracts also threatens the welfare of small-scale gold mining establishments' owners or workers (53).

Environmental Damage

Apart from humans, the biotic (animals, plants, and other organisms) and abiotic (soil, water, and air) environments are also affected by ASGM. In Indonesia, illegal ASGM causes damage to agricultural land. This happens because of clogged irrigation channels in rice fields, causing them to become breeding grounds for mosquitoes, pollute rivers and aquatic biota, and change soil structure. In the Sekonyer river basin, Central Kalimantan, the mercury concentration in water and sediment exceeds the quality standard. This is due to illegal ASGM which has been operating since 1990 (35). Besides being found in sediment and water, mercury has also been found in some shrimp and fish in amounts that exceed the Environmental Protection Agency (EPA) requirements (35). In Kayeli Bay, Buru Regency, Maluku, mercury concentrations in the bay were found to exceed the quality standard. Due to the bioaccumulation process, mercury was also found in the leaves and rhizomes of the seagrass *Enhalus acoroides* (36). In the Batanghari River, Dharmasraya Regency, West Sumatra, ASGM along the river has caused ecosystem damage and threatened the survival of aquatic biota; high turbidity levels have caused the river water to no longer be consumable (37). In the Cikaniki River, Bogor, West Java, the mercury concentration in the water reached 0.4–9.4 g/L. The highest concentrations were found in watersheds adjacent to ASGM sites. Hg(0) was found to be the form of mercury with the highest concentration, while Methyl Mercury (MeHg) was identified in lower concentrations. This shows that ASGM does not produce Methyl Mercury (MeHg) waste, but produces mercury waste in the form of Hg(0) (54). ASGM has proven to threaten the environment's resilience and sustainability.

Damage to the Indonesian aquatic environment in the form of water pollution, irrigation dams, and land and agriculture damage has occurred due to ASGM. Access to clean water has also been disrupted; people living around the mine have difficulty accessing clean water. On the other hand, mining activities are the people's livelihood (55–56).

Soil pollution can also occur due to ASGM. In Madre de Dios, Peru, ASGM resulted in the loss of 3,900 hectares of land (38). This happened because the land was converted for mining activities. Deforestation is a possible cause of the El Niño Southern Oscillation climate phenomenon (ENSO) in the Amazon; there are fluctuations in rainfall due to these activities. ENSO is one of the climate phenomena that can also cause climate change. Fluctuations in the Amazon cause flooding. This is because the Amazon is a rainforest. Besides having an impact on residents around the Amazon, flooding can also disrupt mining activities (21). In Indonesia, the geology of world heritage sites along the Marupa and Kahayan Rivers in Central Kalimantan is threatened by ASGM. Indonesia's unique biodiversity and geology are threatened with damage to forests, watersheds, and mountains (39). This is because ASGM owners and miners often disturb protected places such as national parks (40). It is projected that ASGM produces 57.5% of mercury pollution in the air, 15.5% in water, and 14% in soil or sediment (57). In addition to the mercury residue found in aquatic biota, pesticide residues have also been found in plants and animals around the mine. Mercury residue was identified in forests and paddy fields in concentrations of 0.07–16.7 and 0.4–24.9 g/g, respectively. Meanwhile, MeHg was identified in lowland soil in concentrations of 0.07–2 g/kg and 0.07-56.3 g/kg. People who eat plants, animals, or fish contaminated with mercury will undergo bioaccumulation and biomagnification, causing the highest mercury residue to exist in humans and affecting their health.

Mercury emission in the air, which is also a cause of air pollution, is classified into three forms: mercury in the form of gaseous elements, mercury in the form of reactive gases, and mercury in the form of particulates (41). Gaseous mercury from ASGM is the highest source of mercury pollution in the air. Gaseous mercury has high kinetics, meaning it can travel very long distances in the air and residue can be found in the treetops and forest leaves (58). As reported by the United Nations Environment Program (UNEP) in 2018, globally mercury emissions released into the air reached 838 tons. East and Southeast Asian countries contributed greatly to the release of mercury emissions in the air (214 tons) (28). Indonesia was included in this group of countries, specifically the Central Sulawesi region (48).

Economic and Social Impact

As reported by the United Nations Development Program (UNDP), as many as 300,000 miners in Indonesia depend on ASGM (59). ASGM owners can produce up to 70% gold at prices above international standards. Due to this, people in rural areas consider ASGM a way out of poverty (60). ASGM miners mostly consist of farmers and fishermen that work part-time to supplement their income. Some communities rely on ASGM as their main source of livelihood. ASGM in West Nusa Tenggara (Sekotong Island, Lombok) and East Nusa Tenggara (Taliwang-Sumbawa) has been proven to contribute to improving the community's economy (42). This is isnversely proportional to ASGM in the North Lebong Sub-district, Lebong Regency, Bengkulu, where the mines do not have a socioeconomic impact on the community (22). ASGM in Sulawesi does not have a long or large economic impact on the community (43).

ASGM has two impacts in North Lebong, Lebong Regency, Bengkulu. The positive impact is increased economic welfare for miners, while the negative impact is the threat to public and environmental health (22). Even though the mines in the area have a positive impact, the residents living around the location do not receive compensation or benefits. Instead, the residents experience the negative impact of environmental damage. ASGM's benefits are directly proportional to environmental damage, social vulnerability, and injustice (social security disruption and corruption) (44). ASGM must have an operating license to anticipate its impacts, including the provision of profit-sharing for residents living around the mine (22). The community's economy in the Dharmasraya Regency, West Sumatra has proven to have improved dramatically, especially for mining owners. Mining facilities cause social inequality; the rich will get richer by getting continuous profits, while the poor will get poorer because of these activities' various impacts (37).

Human resource management in illegal ASGM varies and has no (subjective) standards. For example, ASGM in Pongkor, West Java, does not yet have regulations regarding the labor system (44). Based on ethnographic research conducted in Pongkor, West Java, all artisanal small-scale gold mining operations have been illegal over the past 25 years. Local gold development occurs dynamically and is closely tied to the surrounding communities' lives. Gold production is closely aligned with fluctuating socio-natural factors, local geology, the global financial crisis, and technological innovation demands. In addition, the ASGM wage

system does not refer to the regulations that should be set by the Indonesian Ministry of Manpower. In Pongkor gold mining, labor in the extractive section is paid using ore wages, while labor in the downstream section is paid monetarily. The division of gold ore and money to labor certainly fluctuates based on the mining results. Miners have the possibility of not being paid if they do not get anything from the mining process. However, if they produce good results, they can get paid up to one million rupiah per week or five million rupiah per day. The absence of a labor system gives workers huge losses, such as not getting health insurance, employment insurance, and proportional workload.

ACKNOWLEDGMENTS

The authors thank the Ministry of Health Polytechnic Department Bandung, Universitas Sebelas Maret, Politeknik Industri Furnitur dan Pengolahan Kayu, and Institut Teknologi Bandung for supporting this study.

CONCLUSION

ASGM can impact miners or the surrounding community's health. Chronic, acute, and infectious diseases and disabilities can threaten local communities' survival and health. This can happen due to the absence of health facilities, thus hindering optimal promotive, preventive, curative, and rehabilitative efforts. The use of toxic materials such as metals or heavy metals is difficult to avoid in ASGM. This is especially true for mercury, which has a high level of use. These toxic materials can have an impact on public and environmental health around the mine. Depending on the use of heavy metals in the mining process, miners do not use personal protective equipment, which is caused by the absence of compensation or profit-sharing with the community. ASGM has caused accidents with a total of 36 minor injuries, an estimated 57 serious injuries, and 11 deaths. This is because illegal mining does not require a health safety license or supervision. ASGM also causes environmental damage. Water, soil, and air pollution threaten the geology of world heritage sites. This can happen due to lack of environmental maintenance. For example, there is no budget for repairs or maintenance of environmental sustainability. ASGM has been proven to improve the community's economy in several parts of Indonesia, but it is also directly proportional to health risks, environmental damage, and social vulnerability. This happens because there is no profit sharing between the mine owner and the affected community.

The Indonesian government should supervise ASGM, especially when it comes to the existence and operation of occupational safety and health systems or procedures. In addition to ensuring mine owners compliance in providing access to healthcare for their workers, the government needs to facilitate and develop a management system, especially in sectoral participation. The government must reduce the crime rate at or around the mine. They should establish multisectoral collaboration in the equity of health facilities. In addition, the government needs to ratify these mines legitimacy to maintain public health and environmental sustainability to protect vulnerable groups. The government must enforce and discipline international conventions, such as the Basel Convention, the Stockholm Convention, and the Minamata Convention on Mercury. The government must adopt the International Labour Organization (ILO) regulations. The government must facilitate miners and mine owners in integrating access to health. The government should increase marketing to allow local ASGM production to enter and compete in the international market.

ASGM owners have a responsibility to create a safe and secure working environment for their workers. Miners must use personal protective equipment and comply with work safety and environmental sustainability procedures. Mine owners must carry out corporate social responsibility.

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