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Pollution of mercury and cyanide soils and plants in surrounding in the Artisanal and Small-Scale Gold Mining (ASGM) at Sekotong District, West Lombok, West Nusa Tenggara

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ABSTRACT

The Artisanal and small-scale gold mining (ASGM) activities at Sekotong District, NTB have a negative impact on the environment. This study aims to determine the content of mercury and cyanide in soil and plants around gold mining. The research method used is descriptive explorative. The research sample was taken purposively at 4 locations and sample analysis at the Chemical Laboratory of Universitas Brawijaya. The results showed that the Hg and HCN content in surface soil ranged from 2.90-26.94 and 63.93-104.08 mg/Kg, Hg and HCN in soil with a depth of 30 cm ranging from 3.48-53.86 and 66.59-106.55 mg/Kg . The Hg and HCN content in plants ranges from 1.23-8.15 and 18.41-52.85 mg/Kg. Referring to the standards set by WHO and the rules of Health the Republic Indonesia 2016, soil and plants have polluted and have a negative impact on other living things.

Conflict of interest: The authors declare that they have no conflicts of interest.

Introduction

Based on a survey by the International Labour Organization (ILO) and Mining, Minerals, and Sustainable Development (MMSD)[1], an estimated 13 million people worldwide from 30 developing countries are directly involved in gold mining. People's gold mining or in a foreign language called Artisanal and Small-Scale Mining (ASGM) accounts for around 50% of world mining[1]. Indonesia has many mountains and rich in natural resources such as mineral resources. Gold is one of the mineral resources found in Indonesia. Indonesia is known as one of the major gold producers in the world[2]. According to Lamare, there are 90 gold producing countries and Indonesia has ranked 8th in the world with official gold ownership of 73.1 tons[3].

In Indonesia, community mining is regulated in Mineral and Coal Law (Law No. 4/2009). The Government of Indonesia issued Government Regulation No. 22/2010 concerning Mining Areas. The regulation revealed that mining must obtain community mining areas (WPR). The authority to grant community mining areas in regional government is regulated by the district. In the last 5 years the number of gold mining has doubled. In 2010, there were around 900 hotspots with 250,000 miners, including women and children[4]. Indonesia is one of the main locations for community gold mining activities[5]. One of the people's gold mining locations is located at Sekotong District, West Lombok Regency, West Nusa Tenggara Province. Since early 2008 mining activities have been carried out by local people without permission[6]. Ulfa stated that 50% of 42,000 Sekotong residents carried out activities related to gold mining and processing[7].

It is estimated that mercury used in 2011 reached 1.15 tons per day[8]. The process of gold processing begins with crushed gold-filled rock into 1-2 cm and then processed through the amalgamation process using logs with a length of 55-60 cm and a diameter of 30 cm with 3-5 iron bars in the spindle as a grinder. Amalgamation gold processing is done by mixing ore with mercury to form amalgam (Au-Hg alloy metal) with water media. Each spindle can accommodate 2-3 kg of gold ore for 3-4 hours. In each amalgamation process about 250-500 grams of Hg are added to the spindle to a fine grain of less than 0.5 mm. According to the results of observations carried out on 30 July 2018, in addition to mercury some chemicals used in the amalgamation and cyanidation processes such as carbon, potassium, and cyanide.

A small portion of mercury evaporates and spreads into the air, others are discharged into the environment along with tailings, in rivers, the sea, and agricultural land. Mercury is then absorbed by fish and then consumed by humans so that it leads to fatal. It is known that mercury is the most toxic metal that is harmful to human health. In addition, tailings also contain some heavy metals which can be toxic to agricultural crops[2].

From the results of research on environmental conditions resulting from gold mining at Sekotong experienced high mercury and cyanide contamination. The results of the analysis of the mercury content of the people's gold mining waste in January 2016 showed the mercury content in the waste collection basin of 4.04-29.88 ppm[7]. The results of another study showed that the mercury content in the soil varied from 25 to 40 ppm[2]. The mercury content in rice, corn and rice grown on tailings disposal is around 0.20 ppm. The results of other studies explained the average mercury content at Sekotong Barat Lombok gold mine reached 8363.64 ppm[8]. This figure is much higher than the WHO standard 0.001 ppm[9,10] or the Indonesian standard 0.005 ppm based regulation of the Minister of Health of the Republic of Indonesia[11]. The purpose of this study was to analyse the content of mercury and cyanide in soils and plants at Sekotong District gold mining.

Method

This research is an export descriptive study that aims to obtain information related to mercury and cyanide pollution in soils and plants at Sekotong Lombok Barat West Nusa Tenggara community mining area. The research sample was taken in January 2019 and the analysis was carried out at the UB Laboratory of Chemistry by using the Atomic Absorption Spectrophotometry (AAS) and Argentometry methods. Samples were taken at 4 locations, the soil and plant sampling points in the following Table 1.

Table 1. The soil and plant sampling points

Location	Village	Sample Point	Coordinate	
			Latitude	Longitude
Sekotong Central	Telaga Lebur	1	S 08°47.101'	E 116°02.423'
		2	S 08°47.081'	E 116°02.423'
Sekotong West	Lendang Re I	1	S 08°45.671'	E 116°02.262'
		2	S 08°45.672'	E 116°02.266'
Pelangan	Tembowong 1	1	S 08°45.623'	E 116°02.279'
		2	S 08°45.617'	E 116°02.286'
Pelangan	Tembowong 2	1	S 08°48.606'	E 115°56.484'
		2	S 08°48.594'	E 115°56.488'

How to take soil and plant samples by purposive sampling with stratified random so that the quality of the sample is more representative. Sampling based on; (1) determine the centre of the location of the land affected by pollutants, (2) the land is divided into 2 division line, (3) draw a perpendicular line in the middle of the division line, (4) choose a sampling location in each quadrant, (5) each quadrant area of sampling with various depths, (6) depth of 0-30 cm to determine the quality of topsoil or area of plant root activity while 30-100 cm to find out chemicals in the soil due to leakage/spillage of a waste, (7) samples soil and plants are put on plastic samples and given information using label paper[12].

Data analysis was performed by comparing the maximum concentrations of mercury and cyanide in soils and plants. Based on the Regulation of the Minister of Health of the Republic of Indonesia Number 57 Year 2016, the threshold level of mercury allowed on the ground is 0.005 mg/L and plants are 0.001 mg/L. Whereas the standard threshold for plant cyanide is 0.5 mg/L and in soils 0.8 mg/L according to WHO[10].

Results and Discussion

The results of the analysis of mercury and cyanide content in soil and plants in Tables 2 and 3 are as follows.

Table 2. Results of analysis of mercury and cyanide content in soil

Land Code	**Hg ±SD mg/Kg**	**HCN±SD mg/Kg**
ST P	26.94±0.18	95.60±0.50
ST K	3.48±0.18	106.55±0.58
P1 P	7.98±0.16	63.93±0.01
P2 P	7.89±0.12	104.08±0.08
P1 K	42.32±0.34	89.67±0.01
P2 K	8.65±0.1	66.59±0.01
SB P	2.90±0.00	98.50±0.02
SB K	53.86±0.31	104.92±0.08

Description information of the land code: Sekotong Tengah Surface (ST P), Sekotong Tengah Depth 30 cm (ST K), Pelangan 1 Surface (PI P), Pelangan 1 Depth 30 cm (P1 K), Pelangan 2 Surface (P2 P), Pelangan 2 Depth 30 cm (P2 K), Sekotong Barat Surface (SB P), and Sekotong Barat Depth 30 cm (SB K).

Table 3. Results of Analysis of Cyanide and Mercury Content in Plants

Plant	**Hg±SD mg/Kg**	**HCN±SD mg/Kg**
Eleusine indica L	0	45.50
Musa paradisiaca L	0	37.24
Manihot esculenta C	1.83±0.00	52.85
Sesbania grandiflora L	3.82±0.00	31.15
Capsicum sp L	8.15±0.20	40.39
Rhizophora apiculate L	3.07±0.00	46.52
Mangifera indica L	1.86±0.00	24.61
Oryza sativa L	1.23±0.00	18.41

Analysis of Mercury and Cyanide Pollution in Soil

The results of the analysis of the mercury and cyanide contents, which are listed in Table 2, stated that the land in the people's gold mining area of the Sekotong District of West Lombok is polluted due to the levels of pollutants of mercury and cyanide. In soil samples exceeding the WHO standard threshold which is 0.001 ppm or the Indonesian standard 0.005 ppm (Regulation of the Minister of Health of the Republic of Indonesia)[11] for mercury and cyanide threshold in the soil 0.8 mg / l according to WHO[10].

Land is a place of life for various living things, including for plants to grow, to store and purify water, and to maintain the earth's atmosphere. The existence of gold mining activities adjacent to agricultural areas such as at Sekotong has the potential to reduce the quality of land, especially paddy land, because mining waste is accommodated in paddy fields or discharged into rivers/water bodies, while the river is a source of irrigation water for paddy fields in these areas, especially in the dry season. Waste processing tailings from the separation of gold ore (amalgamation) which are dumped on agricultural land, so that the land becomes polluted and unproductive[13].Waste that comes out of the engine was detected to contain up to 62.27 ppm Hg in the liquid and 598.14 ppm Hg in the sediment. Inevitably, several rivers and rice fields around the area were also affected[14]. Pollution of heavy metals in paddy soils is suspected to be accumulated into plants. If the plant parts are consumed by animals or humans, it will gradually cause health problems for those who consume them[15].

The concentration of mercury (Hg) in harmless soil is 0.005 ppm[16], while Mirdat states that normal conditions in the soil are in the range of 0.01-0.3 ppm, while the critical range is 0.3-0 .5 ppm[17]. The concentration of mercury (Hg) will be greater in the dry season[18] and usually accumulates 75 cm above the ground so that it is easily absorbed by plants[19]. Mercury and cyanide content that exceeds the Environmental Quality Standards can cause harm to humans, including brain damage, disability, to death[20].

Analysis of mercury and cyanide pollution in plants

Analysis of mercury and cyanide content in plants around the gold processing site, leaf samples were taken from 8 plant species, namely rice (*Oryza sativa* L.), cassava (*Manihot esculenta* C.), bananas (*Musa paradisiaca* Linnaeus), chillies (*Capsicum* sp L .), turi (*Sesbania grandiflora* L.), mango (*Mangifera indica* L.), mangrove (*Rhizophora apiculate* L.), and grass bones (*Eleusine indica* L.). This plant was chosen based on the distribution of plants that always exist in each research sample collection location, with a view to knowing the effects of mercury and cyanide pollution. The selected plants have the closest distance to the location of the gold processing activity.

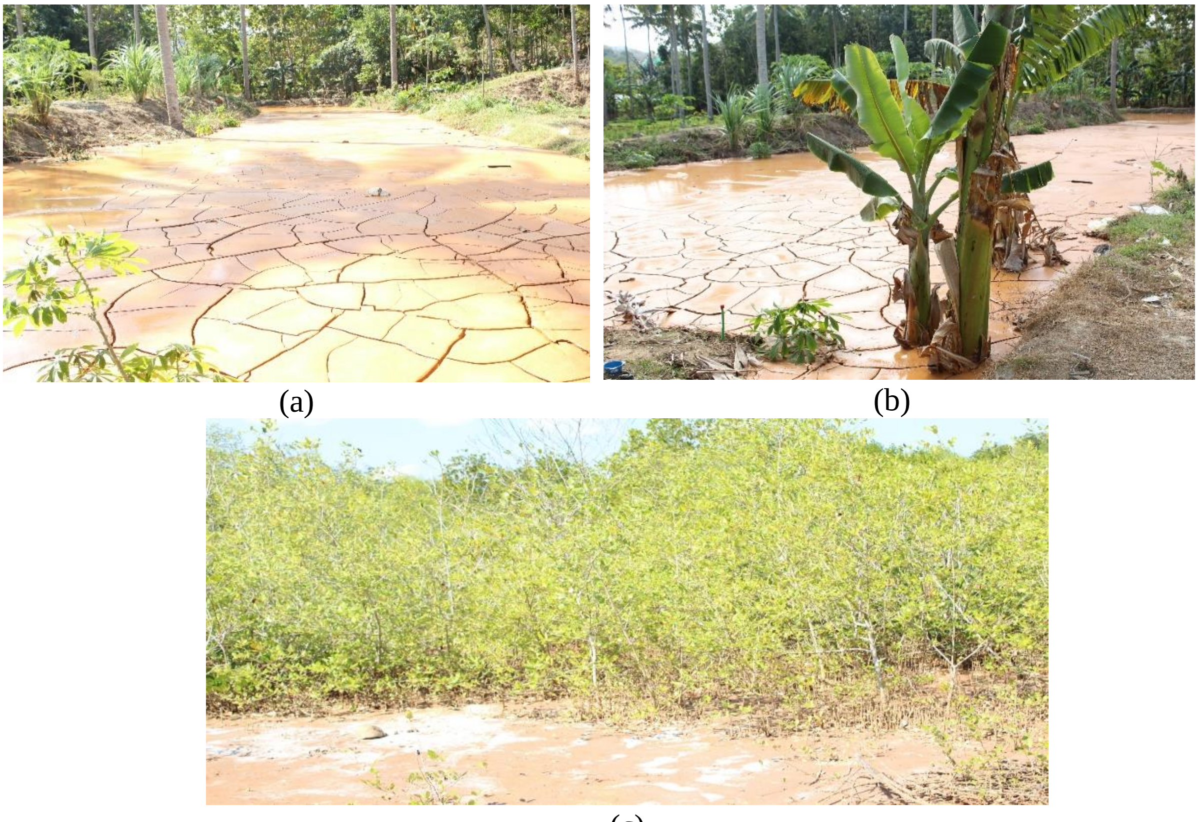
From the results of the analysis of the mercury and cyanide content listed in Table 3, it was stated that some plants in the people's gold mining area Sekotong Lombok Barat District were contaminated with mercury and cyanide waste in plants exceeding the standard threshold determined by the Health of the Republic of Indonesia Number 57 of 2016, the threshold level mercury in plants 0.001 mg/L. Whereas the cyanide threshold standard in plants is 0.5 mg/L and according to WHO[10]. This means that plants in the region cannot be consumed by surrounding living things because they contain high pollutants.

Absorption and accumulation of heavy metals by plants can be divided into three processes, (1) metal absorption by roots, (2) metal translocation from roots to other plant parts, and (3) localization of certain metal cells so as not to inhibit metabolism[21]. Mercury-contaminated environments produce different responses in the physiological adaptability of plants. Plants that grow in the PETI area, show a tendency to accumulate Hg and CN in very high levels in the roots[22].

Cyanide is a strong and fast-acting asphyxia that prevents tissue oxygen utilization by inhibiting the cell's respiratory enzyme, cytochrome oxidase. Inhaling or swallowing cyanide produces a reaction in a few seconds and death within a few minutes[23]. The level of cyanide contamination in the soil when exposed to light will turn into free cyanide which is very toxic and volatile. Compounds containing cyanide ions are poisons that work quickly, which mainly disrupt the process of cellular respiration, which results in a number of diseases, even death[24]. Free cyanide and cyanide complex, including HCN and CN^- are the most reactive and toxic substances of all industrial pollutants[25].

Plants as producers that occupy the first food chain. This means that plants have an important role for the life of other living things. If a plant is declared exposed to heavy metals mercury and cyanide and then consumed by humans and animals, then the heavy metal will accumulate in the human body and the animal and then will have a negative impact on human and animal health. Another problem arising from mining activities is high soil pH, which is 7.9. This figure shows that the soil in the study area is basic. High soil pH will cause immobilization of the elements so that plants cannot grow properly. High soil pH also causes changes in plant metabolism which in turn can cause a decrease in crop yields[26].

Mercury is the most toxic heavy metal to soil biota both animals and plants, but plants can survive in extreme environmental conditions including the content of mercury[27]. Mercury (Hg) can enter the plant through the roots and transported by xylem vessels, then accumulated in all parts of the plant starting from the roots, stems and leaves[28]. The presence of mercury in plants can inhibit germination[29,30], root lengthening and plant growth[31]. Mercury poisoning (Hg) can inhibit the process of mitosis, reduced cell wall component synthesis and alter photosynthetic activity[32]. The activity of mercury (Hg) in plants is by reducing the elements of manganese, potassium, magnesium, and iron in the roots and root tips so that it interferes with growth[30], this is because the plant parts which are the gathering place for mercury elements are the roots and leaves[33]. Cyanide when exposed to light in an environment will turn into free cyanide which is very toxic and volatile.



(a) (b)

(c)

Fig 1. Soil conditions in January 2019 (a), Plants conditions in January 2019 (b), Tailings damage the mangrove ecosystem, January 2019 (c).

Conclusion

People's gold mining activities at Sekotong District of West Lombok, West Nusa Tenggara have a negative impact on the environment. The use of mercury (Hg) and cyanide (CN) in the gold extraction process can cause pollution in soil and plants. The results showed the Hg content on the surface of the surface made it easy from 2.90-26.94 mg/Kg, the Hg in the soil depth of 30 cm reached 3.48-53.86. HCN content in the soil surface is 63.93-104.08 mg/Kg, HCN in the soil depth of 30 cm reaches 66.59-106.55 mg/Kg. The content of mercury and cyanide in rice (Oryza sativa), cassava (Manihot esculenta), banana (Musa paradisiaca), chili (capsicum sp), turi (Sesbania grandiflora), mango (Mangifera indica), mangrove (Rhizophora apiculata), and grass (Eleusine indica). The Hg content in these plants ranges from 1.23-8.15 mg/Kg, HCN content ranges from 18.41 to 52.85. Referring to the standards set by WHO and Republic of Indonesia Health Number 57 of 2016, the soil and plants have been polluted and have a negative impact on the making of other lives.

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Author contributions

All authors contributed to the study's conception and design. Material preparation, data collection and analysis were performed by All Author. The first draft of the manuscript was written by Third and Fourth author, all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.