Mercury and Cyanide Pollution on the Aquatic Organism in Sekotong People Gold Mining

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Abstract. This study aimed to determine the pollution of mercury and cyanide in gold mining conducted by Sekotong people. Samples of this research were water and the aquatic organism around people gold mining consisting of Acetes indicus, Perna viridis, Polymesoda expansa, Plotosus canius, Scylla serrata, Tegillarca granosa, Moolgarda seheli, and Crassostrea gigas.

The content of mercury in the samples can be known using Atomic Absorption Spectrophotometry (ASS). In the same way, in order to know the content of cyanide in the samples can be obtained using Ultraviolet-Visible (UV-Vis) Spectrophotometry. The results showed that Sekotong people's gold mining has been contaminated with mercury and cyanide in aquatic and animal environments exceeding the specified threshold value with the highest level of mercury 48.91 ppm and cyanide 90.22 ppm.

1. Introduction

Indonesia is a country with abundant gold resources [1]. There are 90 countries conducting gold mining activities, but of 75% of the world's gold, production only produced by 20 countries. Indonesia is ranked in the top eight with gold production of 73.1 tons, with around 3000 tons of gold reserves [2]. Gold production in Indonesia produced through several sectors including large-scale, medium-scale, and small-scale mining. Small scale mining or called in Indonesia with smallholder gold mining produces about 15-20% gold [3].

Sekotong people's gold mining is one of the small-scale mining points of 900 community gold mining points in Indonesia [4]. A total of 187 mining points has been started since 2001 [5]. Small-scale mining is mining that is carried out by a person, a group, or a family cooperatively with little or no suitable mining mechanism as done in large-scale mining [6]. Geologically, the Sekotong region has the potential to form metal deposits such as gold and base metals, and there are also indications of well-developed mineralisation and relatively even distribution [7] with metal reserves of around 1,686,462 tons with gold potential reaching thousands of tons and silver around three times that amount [8].

The Sekotong region was once explored by large scale mining companies including PT. Newmont Nusa Tenggara from 1986 to 2004 and PT. Indotan from 2004 to 2006 [9]. After the issuance of the West Nusa Tenggara Province, Regional Regulation on Spatial Planning (RTRW) Number 11 of 2006 article 38 paragraph 2 states that the Lombok Island Development Area (SWP) is directed only to mining C class excavated materials [10] which is PT. Indotan stopped his exploration activities. One of the reasons for this mining is done by the community because economically, the income generated is very high. The average income of the community is Rp 4,136,667/month/person [11]. Unlicensed Gold Mining Activity (PETI) which has been going on since 2008 [12,13].
Environmental pollution can be defined as the accumulation and adverse effects of contaminants or pollutants on human health and welfare, and the environment [14]. Pollutants are defined as any substances that are put into the environment that adversely affect the use of resources [15]. Environmental pollution is the entry or inclusion of living things, substances, energy, and/or other components into the environment by human activities so that they exceed the established environmental quality standards [16]. Mining activities carried out by the people are known to use mercury (Hg) and cyanide (CN) which are heavy metals and hazardous compounds if not appropriately managed [17, 18, 19, 20, 21].

Field observations on Sunday, January 21, 2018, showed that the community used simple and inexpensive techniques in gold processing without regard to environmental safety aspects due to pollution of the resulting waste. Gold processing uses amalgamation and cyanidation techniques. The amalgamation technique is a technique used by 10-12 million people's gold mining around the world [22]. This technique is done by mixing rocks with Hg in water media using small gold trommel/spindles to form an amalgam. This tool has a length of 55-60 cm with a diameter of 30 cm, and in it, there are 3-5 iron rods that are useful for crushing stones. Each log is at least able to accommodate 3-5 kg of rock that has been destroyed. This process usually takes between 3-4 hours, and each process is used from 250 to 500 g Hg. The results of the spindle are then filtered and squeezed with a cloth to separate the amalgam from the pulp. Gold separated from the curing process (evaporation of Hg) at very high temperatures, which are around 400°C while the rest of the mining process is discharged directly in the environment. The next technique is the cyanidation technique using a big gold trommel/barrel with a diameter of 1.5 m and a height of 7 meters.

In 2009 the number of spindles found in gold mining in Sekotong District was 1268. In 2011 the number increased by 4630 while the cask was 140 [13]. The cause of Hg pollution is due to the disposal of gold processing tailings into the environment [23]. Further impacts in the form of a decrease in the quality of soil and water will indirectly affect other organisms and end in humans [12]. The mining process is still ongoing until now, and no preventive efforts have been made. Based on these conditions, it is deemed necessary to determine the pollution of mercury and cyanide in Sekotong people gold mining.

2. Method
2.1 Experimental Design
This research is a quantitative descriptive study that aims to find out information related to Hg and HCN pollution in Sekotong people's gold mining. The research data was collected at Sekotong people's gold mining. Observations and analyses were carried out at the Chemical Laboratory of Brawijaya University.

2.2 Population and Samples
2.2.1 Population
The population of this study are as many as six locations, including: Sekotong Tengah village (Telaga Lebur hamlet), Cendi Manik village (Sayong Daye hamlet), Sekotong Barat village (Lendang Re 1 hamlet), Sekotong Barat village (Lendang Re 2 hamlet), Sekotong Barat village (Labuan Petung hamlet), and Pelangan Village (Tembowong hamlet).
2.2.2 Water Samples
A sampling of water is done by using purposive sampling with consideration of the location of gold processing activities. The number of samples taken at eight points.

Table 1. Coordinates of water sampling points

| No | Village          | Hamlet   | Sample Point | Latitude   | Longitude  |
|----|-----------------|----------|--------------|------------|------------|
| 1  | Sekotong Tengah | Telaga Lebur | 1 | S 08°47.101’ | E 116°02.423’ |
|    |                 |          | 2 | S 08°47.081’ | E 116°02.423’ |
|    |                 |          | 3 | S 08°47.073’ | E 116°02.416’ |
|    |                 |          | 4 | S 08°47.071’ | E 116°02.400’ |
| 2  | Pelangan        | Tembowong | 5 | S 08°48.606’ | E 115°56.484’ |
|    |                 |          | 6 | S 08°48.594’ | E 115°56.488’ |
| 3  | Sekotong Barat  | Lendang Re I | 7 | S 08°45.671’ | E 116°02.262’ |
|    |                 |          | 8 | S 08°45.672’ | E 116°02.266’ |

2.2.3 Animal Samples
A sampling of animals is done by using purposive sampling with consideration of the location of gold processing activities that dispose of waste into the sea. Samples were taken in Sekotong Barat village by considering the distance of taking 100-100 m from the coast. The locations for sampling animals are as follows.
Table 2. Coordinating points for sampling animals

| No | Village       | Sample Point | Coordinate        |
|----|---------------|--------------|-------------------|
|    |               |              | Latitude          | Longitude         |
| 1  | 1             | 1            | S 08°45.558'      | E 116°02.445'    |
| 2  | 2             | 2            | S 08°45.522'      | E 116°02.429'    |
| 3  | 3             | 3            | S 08°45.476'      | E 116°02.407'    |
| 4  | 4             | 4            | S 08°45.423'      | E 116°02.416'    |
| 5  | 5             | 5            | S 08°45.382'      | E 116°02.423'    |
| 6  | 6             | 6            | S 08°45.296'      | E 116°02.389'    |
| 7  | 7             | 7            | S 08°45.272'      | E 116°02.381'    |
| 8  | 8             | 8            | S 08°45.254'      | E 116°02.347'    |
|    | Total         | 8            |                   |                   |

Figure 3. Gold processing

2.3 Tools and Materials
Tools and materials used in this study include 100 ml sample bottles (High Density Polyethylene, (HDPE), impermeable), funnels, measuring cups, ice boxes, and Global Positioning System (GPS), tweezers, Atomic Absorption Spectrophotometry (AAS), Ultraviolet-Visible (UV-Vis) Spectrophotometry, 100 ml water/sample, 100 g animals/samples, tissue, cooler, label paper, and stationery.

2.4 Procedures
2.4.1 Sampling
The stages of water sampling are as follows: (1) water samples are taken in reservoirs at a depth of 0.8 d (times depth) provided that the sample points are taken in the centre of the reservoir with the aim of knowing the average level of pollution; (2) Water samples are taken and placed in 100 ml sample bottles; (3) water samples are stored in an icebox at 0°C ≤ 6°C. The stages of animal sampling are as follows: (1) animal samples are taken at predetermined coordinates; (2) animal samples are taken as much as 100 g and put into sample bottles; (3) samples were stored in an icebox at 0°C ≤ 6°C [24, 25, 26].

2.4.2 Sample Observation
Sample observations were carried out with Hg observation guidelines namely SNI 6989.78: 2011 [27], HCN namely SNI 6989.77: 2011 [28], and animal identification sheet [29].
2.5 Assessment
Data analysis was performed by comparing the levels of Hg and HCN in water and animals with the threshold set by WHO, regulation of the ministry of health of the Republic of Indonesia, and regulation of the ministry of environment of the Republic of Indonesia [30, 31, 32, 33].

3. Results and Discussions
3.1 Hg and HCN levels in water
The levels of Hg and HCN in water are carried out at three different locations, namely in the disposal ponds, the sea, and wells.

3.1.1 Drainage Ponds
Analysis of Hg levels in the drainage pond showed that the lowest to highest concentration was 0 to 3.35 ppm. While the analysis of HCN levels in the disposal ponds showed that the lowest to the highest concentration of 5.31 to 13.27 ppm.

| Points | Concentration (ppm) | Information | HCN Information | Information |
|--------|---------------------|-------------|----------------|-------------|
| 1      | 0.80 ± 0.00         | Polluted    | 7.43 ± 0.00    | Polluted    |
| 2      | 0.40 ± 0.00         | Polluted    | 10.08 ± 0.00   | Polluted    |
| 3      | 1.45 ± 0.07         | Polluted    | 11.15 ± 0.00   | Polluted    |
| 4      | 0.70 ± 0.00         | Polluted    | 6.90 ± 0.00    | Polluted    |
| 5      | 1.20 ± 0.00         | Polluted    | 6.16 ± 0.00    | Polluted    |
| 6      | 0.00 ± 0.00         | -           | 5.31 ± 0.00    | Polluted    |
| 7      | 3.35 ± 0.07         | Polluted    | 13.27 ± 0.00   | Polluted    |
| 8      | 0.90 ± 0.00         | Polluted    | 12.21 ± 0.00   | Polluted    |

3.1.2 The Seawater
Analysis of Hg and HCN levels was also carried out in seawater, which has a distance of ± 1 km from the disposal pond.

| Points | Concentration (ppm) | Information | CN Information | Information |
|--------|---------------------|-------------|----------------|-------------|
| 1      | 0.00 ± 0.00         | -           | 6.37 ± 0.00    | Polluted    |
| 2      | 1.57 ± 0.00         | Polluted    | 6.90 ± 0.00    | Polluted    |

3.1.3 Well Water
Analysis of Hg and HCN levels was also carried out in well water within ± 10 m from the holding pond.

| Points | Concentration (ppm) | Information | CN Information | Information |
|--------|---------------------|-------------|----------------|-------------|
| 1      | 0.30 ± 0.00         | Polluted    | 5.31 ± 0.00    | Polluted    |
| 2      | 2.18 ± 0.00         | Polluted    | 9.02 ± 0.00    | Polluted    |

3.2 Hg and HCN levels in animals
Analysis of Hg levels in animals showed that the lowest to highest concentration was 0 to 48.91 ppm.
Table 6. Hg Levels in Animals

| No | Species             | Hg on bone/shell (ppm) | Hg on meat (ppm) | Information |
|----|---------------------|------------------------|-----------------|-------------|
| 1  | Acetes indicus      | 5.28 ± 0.19            | 0.00 ± 0.00     | Polluted    |
| 2  | Perna viridis       | 6.72 ± 0.17            | 0.00 ± 0.00     | Polluted    |
| 3  | Polymesoda expansa  | 6.37 ± 0.10            | 0.00 ± 0.00     | Polluted    |
| 4  | Plotosus canius     | 48.91 ± 0.49           | 1.36 ± 0.00     | Polluted    |
| 5  | Scylla serrata      | 5.45 ± 0.10            | 23.43 ± 0.66    | Polluted    |
| 6  | Tegillarca granosa  | 9.99 ± 0.13            | 20.37 ± 0.36    | Polluted    |
| 7  | Moolgarda seheli    | 43.91 ± 0.49           | 0.00 ± 0.00     | Polluted    |
| 8  | Crassostrea gigas   | 7.41 ± 0.10            | 0.00 ± 0.00     | Polluted    |
| 9  | Menippe mercenaria  | 9.73 ± 0.12            | 17.49 ± 0.25    | Polluted    |
| 10 | Strombus canarium   | 5.45 ± 0.10            | 11.84 ± 0.29    | Polluted    |

Analysis of HCN levels in animals showed that the lowest to highest concentration was 8.84 to 90.22 ppm.

Table 7. HCN Levels in Animals

| No | Species            | HCN on bone/shell (ppm) | HCN on meat (ppm) | Information |
|----|--------------------|-------------------------|-------------------|-------------|
| 1  | Acetes indicus     | 18.88 ± 0.01            | 56.51 ± 0.02      | Polluted    |
| 2  | Perna viridis      | 14.15 ± 0.00            | 50.20 ± 0.02      | Polluted    |
| 3  | Polymesoda expansa | 8.84 ± 0.00             | 64.00             | Polluted    |
| 4  | Plotosus canius    | 17.66                   | 25.43 ± 0.00      | Polluted    |
| 5  | Scylla serrata     | 22.99 ± 0.00            | 18.21 ± 0.01      | Polluted    |
| 6  | Tegillarca granosa | 17.68 ± 0.00            | 90.22             | Polluted    |
| 7  | Moolgarda seheli   | 30.21 ± 0.01            | 51.14 ± 0.02      | Polluted    |
| 8  | Crassostrea gigas  | 20.16 ± 0.00            | 79.40             | Polluted    |
| 9  | Menippe mercenaria | 28.30 ± 0.00            | 22.67 ± 0.01      | Polluted    |
| 10 | Strombus canarium  | 15.91 ± 0.00            | 34.01 ± 0.00      | Polluted    |

Sekotong people's gold mining is known to have experienced Hg and CN pollutions with levels exceeding the threshold value set by WHO [30, 31], Regulation of the Ministry of Health of the Republic of Indonesia Number 57 of 2016 [32], and Regulation of the Ministry of Environment of the Republic of Indonesia Number 5 of 2014 [33]. Hg and CN pollution in Sekotong people's gold mining is known to have polluted the aquatic environment around the mining site, animals, to humans with very high and dangerous levels. Surely this is a hazardous condition because it is known that heavy metal Hg is a heavy metal that is very toxic and dangerous [17, 18, 19], quickly accumulated [34], can cause digestive disorders, kidney and central nervous system [18] as well as cyanide [20, 21, 35]. Hg is a heavy metal that is very easy to accumulate in the environment, settles in the bottom waters [19, 36], can easily evaporate and pollute the air [37]. This is evidenced by a large number of Hg-contaminated species, especially species that live in the waters, that Hg can easily contaminate aquatic organisms until they accumulate in the human body and enter the blood circulation [38]. Likewise, CN is known to pollute the environment through air, soil, water, and food [30, 39]. CN can settle in waters, contaminate the surrounding environment, and endanger human health [40]. The results showed that the aquatic environment, animals, to humans are known to have experienced Hg and CN pollution, which is very high and certainly very dangerous for the environment.

4. Conclusion
Sekotong people's gold mining has been contaminated with Hg and CN in aquatic and animal environments exceeding the specified threshold value. We also recommend that more in-depth research
is needed to find solutions to reduce the impact of Hg and CN pollution due to the Sekotong people's gold mining activities.

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