MTJ

Mining Technology Journal
Vol.(1), No.(2), 2022
E-ISSN: 2460 - 8386
http://jurnal.upnyk.ac.id/index.php/mtj

Phytoremediation Agent of Mercury Waste on Indonesian Small-Scale Gold Mine Using Hyacinth

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ARTICLE INFO

Keywords:
environmental, hyacinth, small-scale gold mine, wastewater

ABSTRACT

Amalgamation is the common method to process and purified gold in a tube in small-scale mine worldwide, especially in Indonesia. The method uses mercury (Hg) to bind gold metals, which pollutes the environment. Therefore, this reviewed paper aims (i) to assess the environmental impact of small-scale gold mine in Indonesia and (ii) to evaluate the used hyacinth to ameliorate the deterioration on surface water quality. Hyacinths potentially reduce Hg levels in gold mining wastewater. Hyacinths are proved to absorb heavy metal in mercurial wastewater of gold mining. The addition of 500 gr/L hyacinth to mercurial wastewater would decrease 79.7% of Hg concentration. The more hyacinths, the more Hg levels will be absorbed.

INTRODUCTION

Indonesia's geological map shows that the distribution of potential gold reserves in Indonesia is evenly distributed throughout all provinces, making Indonesia in the seventh position of the world's largest gold producer [1]. Indonesia has 2,600 tons of gold reserves or 5% of the world's total gold reserves of 50,300 tons of gold with national gold production in 2021 of 90,000,000 kg [2]. This record is up compared to the previous 86,000,000 kg for 2020. This production is the amount of figures from contract of work companies (KK) and Mining Business Permits (IUP) recorded in the mineral and coal mining sub-sector. The small-scale gold mining sector contributes 17-20% of world gold production [1].

Gold is one of the precious metals most widely used by humans as jewelry, foreign exchange reserves, and can also be used for investment. As the age of gold grows, the need for gold will increase, gold that has a high economic value will encourage humans to develop methods for extracting gold. Gold mining activities can indeed increase people's income, however, gold mining can also be detrimental if in its implementation without being followed by the process of processing waste products correct processing of gold [3]

Small-scale gold mining is a gold mining activity carried out by individual miners and small

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businesses with limited capital investment and production [3]. Small-scale gold mining activities generally operate illegally and exploit marginal gold reserves located in remote areas with hard-to-reach access such as in protected forests and even in conservation areas [3]. Gold ore processing carried out by small-scale gold mining generally uses mercury to separate the gold content from other minerals. A study conducted by UNEP in 2013 showed that mercury released from small-scale gold mining activities reached 727 tons or about 37% of global emissions [4].

According to the Decree of the Minister of Environment No. 202 of 2004 concerning wastewater quality standards for businesses and or activities of mining gold and ore and or copper explained that the maximum Hg content environmental quality standard is 0.005 ppm [5]. Mercury that is wasted into the environment will undergo bioaccumulation and biomagnification in the food chain, generally forming methyl mercury which is very dangerous for living things besides that environmental recovery caused by mercury is economically very expensive.

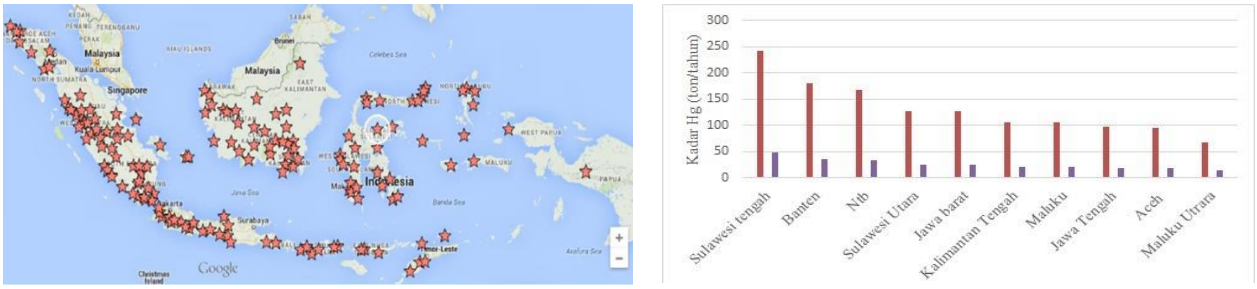
METHODOLOGY

Compaction and Consolidation

To examine the mercury content, as conducted by shelga, et al. is by making control variables and free of them. The control variables used are wastewater containing mercury that is not added with hyacinths, for the variable of free wastewater that hyacinths are added weighing 300 gr / L, 400 gr / L, and 500 gr / L, respectively, wastewater that is not added with hyacinths is marked with a sample K. For addition with hyacinths 300 gr / L is marked with sample X1, the addition of hyacinths of 400 gr/L is marked with sample X2, and the addition of hyacinths of 500 gr/L is marked with sample X3. The number of samples taken was 24 samples. The step of this experiment is quite easy, namely after preparing the sample, then it is enough to just let it sit for 9 days, after that just check the Hg level using spectrophotometry on each sample. In the experiments that have been carried out, that the results of each sample treatment X1, X2, and X3 have different results of decreases In the difference in mercury (Hg) reduction that occurs between groups indicates that there is an influence or relationship between the weight of hyacinths or without the addition of hyacinths.

RESULT

Distribution Of Locations Of Six Small-Scale Gold Mines In Indonesia



(a) (b)

Figure 1. (a) (a) Locations of small-scale gold mining activities in Indonesia (Source: Ministry of energy and mineral resources, 2016). (b) Data showing mercury usages (red) and emissions (purple) in 10 most affected provinces by the use of mercury in small-scale gold mining

Small-scale gold mining activities are found in almost all provinces in Indonesia. The activities are spread across 197 regencies or cities throughout the country. Most of the gold processing process being conducted in the industry is amalgamation using mercury. The distribution of small-scale gold mining sites could be observed in Figure 1 (a), which took place in major cities and regions. Based on the 2019 BCRC - SEA Minamata Initial Assessment document, data obtained from the 10 highest provinces of mercury use in small-scale gold mining in Indonesia Figure 1 (b).

Impact of Mercury Use on The Environment

Mercury (Hg) is widely used to extract gold from its ores, both before and after the cyanidation process is used. When Mercury is mixed with the ore, it will form an amalgam with gold or silver. To obtain gold and silver, the amalgam must be burned to evaporate its mercury. Traditional gold miners use mercury to capture and separate the grains of gold from the grains of the rock. These Hg deposits are filtered using cloth to obtain the remaining gold. The filtered precipitate is then kneaded by hand. Mercury-containing mining debris water is allowed to simply flow into rivers or into other waters [5]. Mercury produced from small-scale gold mining waste will enter the aquatic environment and undergo deposition, dilution, dispersion, then be absorbed by living organisms in the water [6]. The ilustration on mercury cycle in the environment is provided in **Figure 2**.

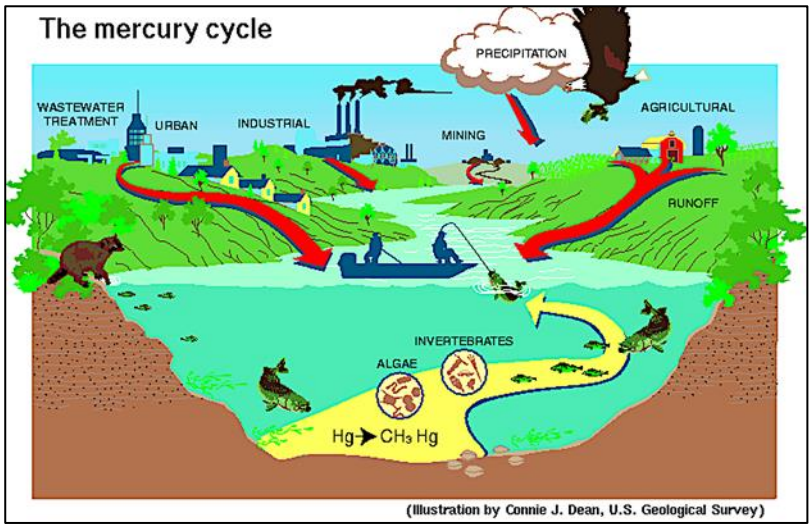


Figure 2. Ilustration on Mercury Cycle in the Environment (Source: U.S *Geological Survey)*

Mercury is persistent in bioaccumulation and biomagnification in the food chain, generally forming methyl mercury in addition to that it is also a transboundary pollutant due to its volatile nature (*volatile*) in room temperature. The impact of wastewater disposal from gold mining using mercury is very dangerous. The following is the impact of wastewater disposal used for gold mining using mercury in terms of several aspects including impacts on health ; socioeconomic; and socio-ecological aspects. In the process of washing gold using mercury, so that gold and dirt can separate, many miners do not use personal protective equipment so that direct contact occurs. In addition to direct contact, it can also have an impact on the surrounding environment. If gold washing activities using mercury are carried out periodically, it will allow accumulation in the miner's body which gives rise to various types of chronic and acute diseases. The health effects that arise depend on the part and duration of the heavy metal bonded in the human body. If viewed from the socioeconomic aspect, it can be possible to decrease the income of people engaged in agriculture, due to the decline in the quality of the land used, the increase in labor costs due to labor scarcity in the agricultural sector. On the socio-ecological aspect, namely the occurrence of environmental pollution. The gold processing process is in the yards of houses and gardens, allowing the occurrence of mercury pollution to the environment, especially if the tailings storage pond is not handled with well. In addition, the fencing process is simply carried out around the house, it can cause environmental pollution by the mercury vapor it causes [7].

Phytoremediation

Phytoremediation is a technology that utilizes plants to purify, remove, or reduce pollutants in the soil or water. One ofthe effective plant hiper-akmuulators as a phytoremediation of heavy metals is hyacinth (*Eichornia crassipes*). Hyacinth is a type of aquatic plant that can absorb and accumulate heavy metals, can absorb heavy metals because of heavy metals that accumulate in a short time. Various previous studies have shown the benefits of hyacinths, for example, in a study that explained that as many as 9 hyacinth stems consisting of one type of plant in contact with wastewater for 9 days, resulted in a decrease in Hg levels which were originally 0.22 ppm (control samples) decreased to 0.0037 ppm [8].

Hyacinth plants have a physiology of the root system of fibers with a length ranging from 10-300 cm. The arrangement of long roots in hyacinths serves to absorb heavy metals in waters at a certain depth. The high accumulation of metal elements absorbed by hyacinths occurs in the root part when compared with the stems and leaves. This is because at the root there is a phytocellular compound that functions to bind metal elements so that the phytoremediation mechanism that occurs is rhizofiltration [9]. Phytocrasformation is the change of toxic compounds into simpler compounds such as carbon dioxide, water and methane as a non-toxic form of material. Plants will remodel organic matter by using water as their fuel [10]. Based on the mechanism of plants in remediating heavy metals and other polluting organic compounds, it can be divided into several processes, namely:

a. Phytoexstration includes the absorption of contaminants carried out by the roots and will be translocated or accumulated polluting compounds to other plant parts such as leaves and headers. Rizofiltration is the ability of plant roots to absorb, precipitate and accumulate heavy metals and other compounds from waste streams with the aim of cleaning the surrounding environment.
b. Phytodegradation is an attempt to change or metabolize contaminants in tissues. Dehalogenase is one example in this mechanism where it overhauls oxygenase-depleted compounds or halogens in an overhaul of aromatic compounds.
c. Phytostabilization is a phenomenon of stabilizing polluted soils by producing certain chemical compounds.
d. Phytocollatilization is a phenomenon of plants absorbing contaminants and then releasing them into the atmosphere through the leaves.

Data Analysis

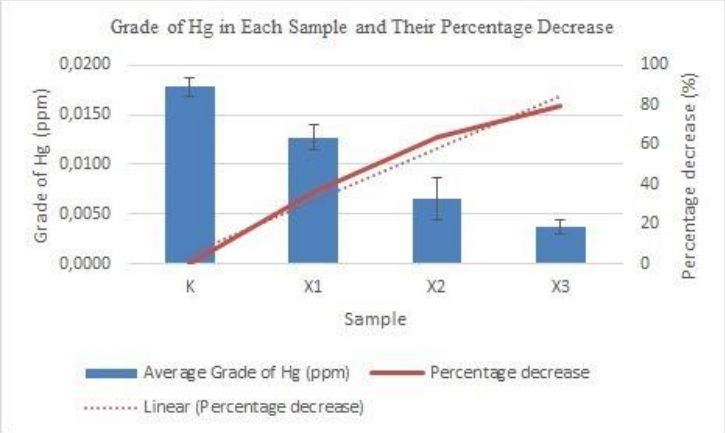


Figure 4. Hg levels in each sample and their percentage decrease

Based on the experimental data obtained, the more weight the hyacinth, the greater the percent decrease. The most effective treatment was obtained in sample X3, where the sample used was mercury wastewater which had been added with hyacinth weighing 500 gr / L and allowed to stand for 9 days . From this, mercury levels, which were originally 0.0178 ppm, were reduced to 0.0036 ppm. Where this 0.0036 ppm has met the environmental quality standards that have been set by according to the Decree of the Minister of Environment No. 202 of 2004. The experimental data can be seen in figure 4.

Hyacinth or latin name (*Eichornia crassipes*) physiologically has an important role in overcoming pollutants of waters, because it can survive by forming clumps. If the more or heavier the hyacinth, automatic evaporation will occur frequently, the more frequent evaporation occurs it is this that can speed up the process of salt transportation salts and metals from root to leaf. This is also what causes when added with hyacinth weighing 500 gr / L, it produces the most percent decrease in mercury, which reaches 79.7%.

The mechanism of this experiment is that it begins with small-scale folk gold mining using amalgamation. The amalgamation method is the process of binding gold metal from the ore using mercury (Hg) in a tube called a amalgamator. An amalgamator, in addition to functioning as a place for the amalgamation process also plays a role in reducing the size of gold ore from coarse to fine-grained (80 - 200 mesh) with a scouring medium in the form of iron ingots. The amalgamator can be rotated by the driving force of river water through a pinwheel or electric power (dynamo). The result of this process is in the form of wet amalgam and tailings. Wet amalgam is then accommodated in a place, like a reservoir which is then panned for the separation of mercury with amalgam. The obtained amalgam is processed through burning (bombing) to obtain a gold-silver metal fusion (bullion). Furthermore, the separation between gold metal (Au) from silver metal (Ag) is carried out using a solution of silver nitrate. Water from the results of this treatment, do not immediately discharge into the river water, but are separated first in the reservoir that has been provided, from this reservoir is later hyacinth added. After that, only then can the water from the reservoir be discharged into the river.

In the absorption process, of course hyacinths are also influenced by other factors, such as temperature, pH and time, To obtain effective results, a good temperature is around 25oC – 30oC. Then a good pH is in the range of 7 – 7.5. If the pH is too low or too high, then the growth of hyacinths will be inhibited, so later absorption will also be maximized. For the time factor, a good time for the hyacinth absorption process is about 5-9 days, only then can wastewater be discharged into the river.

CONCLUSION

Mercury undergoes bioaccumulation and biomagnification within the food chain, generally forming methyl mercury in addition to that mercury is persistent and as a *transboundary pollutant* due to its volatile properties (*volatile*) at room temperature. Phytoremediation is a technology that utilizes plants to purify, remove, or reduce pollutants in the soil or water. One of the hyperaccumulator plants that is effective as a phytoremediation of heavy metals is hyacinth (*Eichornia crassipes*). Hyacinths were proven to be able to absorb wastewater from mercury gold mining, so that the water becomes clearer. The addition of hyacinth weighing 500 gr / L to mercury wastewater is the most appropriate step, because it gets the highest percentage of decrease, which is 79.7% The heavier or more hyacinths, the more mercury levels will be absorbed. Community of gold miners who are still mining gold in a home industry are suggested to treat their wastewater using hyacinths to absorb the mercury, thus mercury gold mining will become relatively safer. Considering the temperature and pH factors, the hyacinths take roughly 5-9 days to react with the mercury before the wastewater can be discharged into the river.

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