Characteristics Of Physical And Chemical Properties Of Soil After Gold Processing (Case Study Of Unlicensed Gold Mining In The DistrictSumbawa Regency, Indonesia)

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Abstract.

The purpose of this study was to analyze the physical and chemical characteristics of the soil used for unlicensed gold processing in West Sumbawa Regency. This research was carried out in Kuang Village, Taliwang District, West Sumbawa Regency in September 2023. The criteria for soil sampling location is that the activity of the spindle has been inactive for 5 years, using mercury as a material for gold extraction and is in the home environment. This study was conducted by quantitative descriptive method or direct observation in the field and soil analysis in the Laboratory of soil chemistry and Biology, Faculty of Agriculture, University of Mataram. Furthermore, soil sampling was carried out using purposive sampling method or based on purpose with consideration of potential pollution. Based on the results, it can be seen that the physical characteristics of soil including clay with volume weight, specific gravity and porosity are quite dense soil with poor infiltration, while the chemical characteristics of soil include low fertility of both C-organic, CEC, soil pH, N and P soil. The concentration of Hg found in soil ranges from 1.42-15.83 ppm. In this case, mercury contaminated soil needs to be remediated using environmentally friendly materials, cheap and the availability of many in nature. Efforts that can be done is the use of green technology using phytoremediator plants and soil improvement materials, namely biochar. Therefore, it is necessary to conduct further research aimed at reducing the availability and mobility of mercury in the soil.

Keywords: *Mercury (Hg), former gold processing, physical and chemical properties of soil and polluted soil.*

I. INTRODUCTION

One of the potential districts in terms of Natural Resources in West Nusa Tenggara province is West Sumbawa Regency. The high potential comes from various aspects such as the Rea watershed as an ecotourism area as well as a source of water for the agriculture, fisheries and livestock sectors (Efendi & Fatmalia, 2021). However, one of the factors that have a positive impact on the economic growth of the community is the mining sector. According to BPS NTB data (2019), it was recorded that the potential amount of gold excavation in West Sumbawa Regency was 13,907,237 tons. This potential causes high illegal or unlicensed mining activities that use gold processing methods that are not environmentally friendly. This is also in line with the results of the monitoring of DLHK NTB, (2018) that there were 16,247 units of unlicensed gold processing activities (crates) spread throughout the sub-districts in West Sumbawa Regency. This number will continue to grow as the profits obtained due to overexploitation increase. In addition, crate activities generally do not follow proper sops (operational standards of implementation) in exploring, processing and managing tailings waste, causing negative impacts on the environment and living things (Qishlaqi & Moore, 2007).PETI activities are increasingly massive effect on the decline in soil fertility and aesthetic value of the environment. Several studies have reported that the condition of the former mining soil causes the dominant soil texture of sand, damaged soil structure, organic matter and nutrient levels tend to be low-very low and the ability to retain nutrients and low water (Henrianto et al., 2019).

In addition, soil biological activity is also disrupted due to unwise disposal of tailings waste. This causes the soil fertility rate of the topsoil to be low. According to Mirdat et al., (2013), that environmental damage due to gold mining causes the soil to become polluted because it exceeds the ability to digest waste. One of the sources of problems from the crate activity is using liquid mercury (Hg) which is harmful to the environment as a gold extractor. This is because it can bind gold from gold ore that has been milled, thus forming amalgam. Amalgam that has been exhausted is extracted using mercury, generally dumped into the ground or surrounding locations (Ruslan & Khairuddin, 2011). According to Sumarjono, (2020) the amalgam method in the gold extraction process uses relatively low operating costs compared to other

methods (Soil washing, cyanidation, froth flotation), but with a higher level of risk to the environment.Mercury is a heavy metal that is toxic to humans even at low concentrations (Lyu et al., 2019).

According to WHO, (2017); Wang et al., (2012) Mercury is included in one of the lists of heavy metals listed in pollutants harmful to the environment and human health. Toxic forms of mercury in nature due to chemical reactions and interactions with microbes, namely methylmercury or dimethyl Mercury (Inbaraj et al., 2009). In addition, in research (Bobby & Desmi 2002), reported that HG elements are bioaccumulated and biomagnified, so it has the potential to accumulate through the food chain. If the compound enters the human body, especially through the medium of water, it causes poisoning, causing damage to organs, disability to death as happened to the victims of Minamata (Fashola et al., 2016; Perryman et al., 2020). From the above problems, gold processing activities cause the emergence of non-productive land after processing. This can certainly harm farmers and life on the ground due to Mercury (Hg) pollution in the long term. In re-managing the land from the case requires intensive attention and a long process for remediation or conservation activities. Therefore, it is necessary to conduct preliminary research before taking any further measures. The purpose of this study was to determine the impact of former gold processing without permission on the physical and chemical characteristics of soil in West Sumbawa Regency.

II. METHODS

This research was carried out at the site of the former unlicensed gold mine processing (PETI) of Kuang Village, Taliwang District, West Sumbawa Regency in September 2023. The criteria for soil sampling location is that the activity of the spindle has been inactive for 5 years, using mercury as a material for gold extraction and is in the home environment.

Fig 1. Soil Sampling Location Point
(Source: Research Team Merkuri UNRAM)

The tools used in the research are Global Positioning System (GPS), sample ring, soil drill, hoe, roll meter, ruler, sack, stationery, plastic, rubber and documentation tool. The materials used are contaminated soil samples, plastic bags, rubber, label paper, markers and other chemicals for the analysis of chemical and physical properties of the soil. This study was conducted by quantitative descriptive method or direct observation in the field and analysis in the Laboratory of soil chemistry and Biology, Faculty of Agriculture, University of Mataram. Furthermore, soil sampling using purposive sampling method or based on the purpose and consideration of potential HG pollution in the soil. Contaminated soil sampling was carried out at 13 points around the former gold processing with a depth based on three (3) categories of layers, namely Layer 1= 0-10 cm; layer 2= 10-25 cm; and Layer 3= 25-50 cm as presented in Figure 1.Data from laboratory analysis of physical and chemical properties of soil compared with soil chemical fertility criteria based on the technical handbook of soil Research Institute, 2009.

III. RESULT AND DISCUSSION

The research site is located in Gegubuk Hamlet, Kuang Village, Taliwang District, West Sumbawa Regency (Figure 1.) The coordinate point of the research site is located at 1160 50'32" BT and 80 45'21" LS. In general, HG contaminated soil sampling sites are included in alluvial soils which according to the USDA soil taxonomy System (1975) are categorized as equivalent to entisol or inceptisol soils (Akbar, 2023). The most dominant vegetation types at the site of the former gold processing are Cyprus kynglia weeds, babandotan, other ground cover grasses and trees.HG polluted soil conditions become one of the limiting factors for plant growth and solubility of Hg in the soil. This is because the soil becomes one of the main components of an ecosystem that is integrated between one component and another. According to (Ibe et al., 2014), states that soil constituents consist of several components such as soil, water, air, organic matter, minerals and soil organisms. The component affects the presence of Hg in the soil, in particular, the physical and chemical properties of the soil. In this case, soil conditions can determine the degree of mobility or the degree of its solubility and desorption adsorbs Hg in the soil.

Physical characteristics of soil

The physical properties of soil observed in this study include soil texture, soil color, volume weight (BV), specific gravity (BJ) and soil porosity presented in Table 1.

Soil Texture

In Table 1. the above shows that the results of the analysis of the physical properties of the land used for unlicensed gold processing (Crate) have a low level of soil fertility. It can be seen from the texture of the soil belonging to the category of clay (Loam) with the highest percentage fraction of sand as much as 41%, and followed by dust fraction of 39% and 18% Clay. The higher proportion of sand fractions tends to have a low water binding ability because sandy soils have a large space between particles (Andayono & Palinto, 2023).

Table1. Results of laboratory analysis of soil physical properties

Parameter	Lap. 1	Lap. 2	Lap. 3
Soil texture			
- Sand (%)	41		
- Dust (%)	39		
- Clay (%)	18		
	Clay		
Ground Color			
Hue	10YR	7.5YR	7.5YR
Value	6	5	6
Chroma	2	3	2
	Light brownish gray	*Brown*	*Pinkish gray*
BV (g/cm^{-3})	1.29	1.17	1.21
BJ (g/cm^{-3})	2.10	2.14	2.82
Porositas (%)	40	45	57

Description: Wipe: Lining

Source: Technical Book Of Land Research Institute, 2009

In this case, this type of soil can easily pass water into the soil surface along with heavy metals that are leached into the lower layers and settle in the waters and mix with soil sediments. The relationship between texture and the availability of Hg in the soil is found in a low percentage of clay fraction negatively correlated with the mobility of Hg. This condition causes the mobility of Hg to increase, due to the lack of role of soil as an adsorbent. In line with (Qu et al., 2019), that Clay and dust fractions with smaller grain sizes than sand play a role in adsorbing mercury higher.

Soil volume weight

In addition, the parameters of volume weight and soil density at the research site are related to soil pore space. Volume weight describes the ratio of soil mass to the volume of soil particles including the volume of soil pores. The value of the volume weight (BV) of the layer (0-10 cm) to (26-50) decreases as the depth of the soil increases. This indicates that there is soil compaction due to community activities. High volume weight value in Layer 1 (Table 1), the presence of soil compaction and the number of soil pores, both

micro and macro, is reduced, or denser, causing plant rooting to make it difficult to take nutrients and water in the soil and small soil porosity. According to Rosyidah & Wirosoedarmo, (2013) states that the soil compaction caused by the intensification of Population Activities that affect the level of tillage. The form of activity of the population in the settlement in the form of tillage, traffic and landfill. The BV value of layer 0-10 is higher than the layer below due to low levels of C-organic soil and low total pore space. In line with what was revealed by (Hurum, 2023) that the high value of BV is caused by low levels of soil organic matter.

Soil type weight

Unlike the case with the value of soil specific gravity (BJ) which of course the deeper the soil layer, the higher it is. Soil specific gravity indicates the overall level of density of solid soil particles filling the pore space per soil layer. The value of soil specific gravity at the research site also increased significantly from layer (0-10 cm) to layer (11-25) and (26-50) with a value of 2.10 g/cm-3, 2.14 g/cm-3, and 2.82 g/cm-3. This indicates that the deeper the soil layer, the higher the mineral content of the soil. In line with the opinion of Rosyidah & Wirosoedarmo, (2013), that the deeper a layer of soil with a specific gravity value approaching 2.6-2.9 g/cm-3, indicating the presence of silicate minerals in high soil. Therefore, population activity factors that affect the value of BV and BJ, other factors also determine the physical characteristics of the soil, one of which is the parent material of the soil.

Soil porosity

Then the soil porosity parameter (%) describes the percentage of total soil pores occupied by water and air in micro and macro pores. The value of soil porosity in HG polluted soil tends to increase along with the depth of the soil. This shows that layers 1 and 2 have a lot of pore space between soil particles, especially in the sand dominant soil texture is quite large, so the water storage capacity is low and the ability to pass water is high. This is in line with (Hurum et al., 2023), that the type of soil with a high percentage of sand fraction has many macro pores filled with air (porous), so that water (drainage) and air (aeration) are easier to circulate. Related to the availability of mercury in the soil where if the porosity value is high, then the HG level in the soil becomes low. This is because Mercury will be carried away by the flow of water through the leaching process.

Chemical characteristics of soil

The physical characteristics of HG polluted soil affect the chemical properties of the soil. In the cultivation of plants, the soil serves as a growing medium and meet the needs of nutrients, water and air for plants. The main requirement for a good planting medium is that it contains enough nutrients needed by the plant so that it can grow well until harvest. The chemical properties of soil observed in this study include nutrient levels of nitrogen, phosphorus, pH, c-organic, CEC and HG soil presented in Table 2.

Table 2. Results of laboratory analysis of soil chemical properties

Parameters	Lap. 1	Lap. 2	Lap. 3
Nitrogen (%)	0.38 (S)		
Phosfor (%	3.22 (SR)		
pH	6.80 (N)	5.76 (AM)	7.06 (N)
C-Organik (%)	0.72 (SR)	0.75 (SR)	0.62 (SR)
KTK (me/100g)	7.21 (R)	8.94 (R)	5.62 (R)
HG soil	15.83 (Tc)	10.84 (Tc)	1.42 (Tc)

Description: Lap= layer; N=neutral; AM=slightly sour; SR=very low; R=Low; s=medium; TC=polluted (quality standards HG 0.3-0.5 ppm Land);

Source: Technical Guide soil Research Institute, 2009.

Soil pH

One indicator of nutrient availability is soil pH. In Table 4. the results of the analysis of the chemical properties of the soil at the research site where the average pH value is in a rather sour condition of pH 6.54, so that the levels of H + ions are higher than OH - (Ningsih et al., 2016). If you look at the pH value in Layer 1 to Layer 3, there is a tendency for the pH value to vary along with the depth of the soil layer. According to (Aryanti & Hera, 2019), the decrease in soil pH due to unwise disposal of waste (tailings) from the amalgamation process and still containing heavy metals is a negative impact of gold mining activities. Therefore, the value of C-organic is directly proportional to the chemical properties of the soil such as pH, CEC and nutrient levels, especially nitrogen in the soil.

Total Nitrogen

The pH value that tends to be neutral describes the availability of nutrients for plants. In Table 2. visible levels of N total of 0.38% berharkat medium. The medium value of nitrogen is influenced by soil pH ranging from 6-6.5 and there is a contribution from plant residues on the surface in the form of grass weeds. One of the sources of Nitrogen in the soil is organic matter that has been decomposed by microbes both from plant tissues (primary) and animals (secondary) (Purwanto, 2012). During plant growth, the forms of Nitrogen absorbed by plants are NH4+ and No3 - and are needed a lot in the vegetative phase.

P-available land

The second essential nutrient after nitrogen is phosphorus. Phosphorus levels in the soil is very low at 3.22 ppm even at neutral pH conditions. This is because the top layer at the research site is a landfill soil from the remaining waste logs during the amalgamation process, so it also affects the availability of P. According to (Nursyamsi & Setyorini, 2009), nutrient management P is not only influenced by soil pH, but many other factors, among others: 1). Amount and type of minerals; 2), soil organic matter; 3). Cations and anions; 4. Degree of saturation P; 5). Time and temperature; 6). Inundation. Soil organic matter content in the research site is very low and low, so it is directly proportional to the availability of P in the soil.

C-organic soil

Other components of soil chemical properties that play an important role in the availability of nutrient sources, water holding capacity, and aggregate stability are organic matter and are measured from soil C-Organics. Can be seen in Table 4. that C-organic content is quite varied from Layer 1, 2 and 3 as much as 0.72%, 0.75% and 0.62% is very low. In layers 1, 2 and 3 have very low value due to the presence of residual deposits of the amalgamation process that are dumped into the ground, thus affecting the low physical and chemical properties of other soils such as C-organic, CEC soil, and nutrients. In line with the opinion of Conesa et al., (2005), that gold mining activities cause a negative impact on soil fertility decline and increase pollution of heavy metals that are harmful to the environment. In addition, the C-organic content in each type and soil layer varies, so that qualitative analysis can be done using soil color indicators. From the observation of the color composition of the soil at the research site from Layer 1 to 3 is 10YR 6/2, 7.5 YR 5/3 and 7.5 YR 6/2. This indicates that the color of the soil is quite light along with the depth of the soil and is related to the characteristics of the physical and chemical properties of the soil. In line with the opinion (Muna et al., 2020), that the brighter the color of the soil describes the lower the soil C-organic content.

Soil cation exchange capacity

Furthermore, the cation exchange capacity of the previous soil is influenced by the presence of clay fraction and soil organic matter. In Table 4. Obtained CEC values at Layer 1, 2 and 3 are 7.21 me/100g, 8.49 me/100g and 5.62 me / 100g low value. High levels of CEC in Layer 2 is influenced by high C-organic in Layer 2. In line with according to (Rohim et al., 2023), that the ability of soil to bind cations by soil Colloids and CEC values is largely determined by organic matter, so that low C-organic levels are directly proportional to CEC values. The relationship with the availability of heavy metals mercury in the soil that HG mobility will be high in the dominant soil texture of sand, C-organic and CEC levels are low. This is because the negative charge of the soil that functions in the adsorption of heavy metal ions, especially Mercury, is reduced and the role of organic matter as a metal chelator is reduced (Khasanah et al., 2021). Because of this, the availability of heavy metals mercury is high in the soil.

Land Hg

The total amount of Hg in the soil at the research site is classified as polluted because it has exceeded the soil quality standards, especially Hg, which is 0.3-0.5 ppm. In Table 4. Visible levels of mercury in layers 1, 2 and 3 are 15.83 ppm, 10.84 ppm and 1.42 ppm. The high concentration of mercury in Layer 1 is due to the low C-organic and CEC soils and the dominant soil texture of sand. The deeper the soil layer, the mercury levels are reduced because one of the functions of the soil is to filter dissolved heavy metal substances. In line with Stone et al. (2019), that there are 4 functions of land that are an assessment or interpretation of soil quality, among others: 1). Support of soil activity and biodiversity; 2). Water from the soil; 3. As a filter, buffer, degrader, immobilizer, detoxifier of toxic substances or heavy metals; 4). Storage and recycling of nutrients. In addition, the concentration of mercury is also high because it exceeds the Environmental Quality Standard for heavy metal mercury (Hg) which is 0.5 ppm (Mirdat et al., 2013). This causes the soil conditions are polluted and toxic, especially in plants that grow on the surface of the soil (Sun et al., 2019; Zhu et al., 2018). The availability of heavy metals in the soil is also in one or more forms according to the following conditions: 1). In exchangeable form (inorganic form); 2). In an insoluble form in the form of a precipitate; 3). In dissolved Form; 4). As a component of soil minerals (Wang et al., 2019; Shaheen & Iqbal, 2018; Zhang et al., 2018).

Correlation Matrix

To describe the relationship between soil properties with Mercury metal in different layers has been analyzed using pearson correlation analysis (Table 3).

Table 3. Value of Pearson correlation coefficients (r) between physical, chemical and heavy metal properties of soil in different soil layers

Variable	BJ	BV	Porositas	Hg	pH	KTK
C-organik	-0.627	-0.103	-0.446	0.640	-0.615	0.691**
KTK	-0.739*	-0.136	-0.534	0.594	-0.899**	
pH	0.604	0.428	0.269	-0.361		
Hg	-0.937**	0.248	-0.902**			
Porositas	0.836**	-0.560				
BV	-0.067					

Description: significant correlation at the level of 5% (*),
significant correlation at the level of 1% (* *)

Based on the table shows that there are quantitative differences based on each variable tested. From the analysis, the existence of a real positive correlation can be seen in the parameters of soil CEC with C-organic (0.691*) and negative correlation with pH (0.899**), BJ (0.789*) and porosity percentage with BJ (0.863**) negative correlation was found. The relationship between Mercury metal and soil properties also obtained an average of negative real correlation on porosity (0.902**) and BJ (0.937). In addition, the correlation is weak to sufficient and positive seen in the parameters of BV (0.248), C-organic (0.640) and CEC (0.594). In Table 3 it shows the same results as the research of Mohan et al. (2014), that the negative correlation between HG with pH and sand but positively correlated with other parameters. In general, the adsorption capacity of mercury by the soil will decrease when the pH is also getting lower due to the exchange of H+ ions with Hg ions dissolved in the soil solution. In line with the opinion of Mohan et al. (2014), that at low soil pH, Mercury metal will accumulate in sediments, thus affecting its mobility and bioavailability in soil and soil solutions. Other reports also mention that at high pH, Mercury adsorption is more intense where most of the mercury is strongly bound by organic materials in sediments than inorganic components (Gabriel & Williamson, 2004; Jackson et al., 1980).

This is because alkaline cations can replace weakly bound Mercury during acidic conditions. In addition to soil pH, C-organic also showed a positive correlation although not significant at real levels of 5% and 1%. This is because the role of C-organic is very important in influencing the availability of Hg in the soil. In line with the report of Hesterberg et al. (2001), that organic materials are closely related to thiol (-SH) groups containing sulfur, causing strong affinity of HG to organic materials and the potential to form HGs (insoluble in water or precipitate in sediments). The distribution and binding mechanism of heavy metals mercury in the soil is highly dependent on physical properties (soil type and origin) and soil chemistry

pH, redox potential, water availability and others (Khan et al., 2015; Roca, 2015). Furthermore, other parameters with the same results are also supported by the results of research Linhares et al. (2019), on agroforestry land management, irrigation (rice fields) and home plantation after 10 years in Brazil. Therefore, the higher the soil organic matter, the lower the availability of Hg in the soil because it is strongly bound by functional groups and organic acids derived from the characteristics of each organic material.

IV. CONCLUSION

Based on the results of research that has been carried out it can be concluded that the soil texture including clay with porosity values including poor, average BV value of 1.22 g/cm-3 and BJ of 2.35 g/cm-3 and soil color tends to be rather bright (light brownish gray, brown pinkish gray. In addition, the pH of the soil includes relatively sour with low nutrient levels and very low for N and P. In addition, the value of C-organic and CEC including very low and low, causing the concentration of Hg in the soil is high and polluted is 1.42-15.83 ppm.In this case, soil contaminated with Mercury metal needs to be remediated using environmentally friendly materials and reduce the loss of nutrients and soil microorganisms. One of them is the utilization of green technology using phytoremediator plants and soil improvement materials, namely biochar. Therefore, it is necessary to conduct further research aimed at reducing the availability and mobility of mercury in the soil.

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