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Jurnal Biota Vol. 9 No. 2 (2023) https://doi.org/10.19109/Biota.v9i216664

Research Article

The Potential of *Moringa oleifera* Extract Waste as Fe Adsorbent in South Sumatra, Indonesia

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Received: 02/04/2023	Revised: 26/05/2023	Accepted: 29/05/2023

ABSTRACT

The issue of environmental pollution has become a concern, especially for the government, since the establishment of Law No. 4 of 1982. This is because the effects of pollution can be toxic and even fatal for living beings, particularly humans. One of the pollutants in the environment generated from mining industry waste is heavy metal Fe. In light of these problems, a study was conducted to investigate the effectiveness of sawdust and Moringa twigs as by-products in adsorbing heavy metal iron (Fe) in the liquid waste of the gold mining industry. This research is classified as pure experimental research. The research reveals that the mean percentage reduction in the heavy metal iron (Fe) content in the gold mining industry wastewater, after treatment with the addition of Moringa leaf powder, is 9.6%. On the other hand, treatment with the addition of Moringa stem powder achieves a reduction of 92%. This significant difference is attributed to the bioactive compound rhamnosyloxy-benzyl isothiocyanate present in Moringa. This compound has the ability to adsorb and neutralize sludge and metal particles found in the waste suspension, along with dirt particles in the water. Consequently, Moringa shows potential as a natural coagulant for water purification purposes.

Key words: *Adsorption; Moringa Oleifera; Waste; Water.*

Introduction

Human activities that exploit Natural Resources (SDA) can lead to environmental pollution, especially in the mining industry because the mining industry economy has high economic value (Gavgani et al., 2021). Natural resources owned by the Indonesian State are very abundant (Amrulloh et al., 2021). One of Indonesia's natural resources is well-known in various regions in Indonesia both on a large scale such as the Gasbeg Mine (Freeport) in Papua and small-scale gold mining (ASGM) such as in Lebak, Banten (Aspinall, 2001).

Gold is a precious metal that has high selling power and usefulness (Amorim et al., 2023). Gold mining is traditionally one of the community's livelihood activities which is carried out independently that can improve their economy (Putra et al., 2017). The gold processing process begins with rock excavation, processing and disposal of waste (Sumual, 2009).

Sukamenang Village, Musi Rawas Utara Regency, is one of the areas in South Sumatra that has unlicensed gold miners (PETI). Nearly 70% of the local population's economic resources come from mining and processing gold ore which are carried out independently on a household scale. Meanwhile, what is the concern of this mining is the liquid waste generated from the leaching of the gold ore. The remainder of the gold ore processing is liquid waste which is only collected in a simple shelter and then flows into river water.

In general, the liquid waste resulting from washing gold ore will contain heavy metals iron (Fe), copper (Mn), lead (Pb) and zinc (Zn). The negative impact that may arise from the mining process is the emergence of acid mine drainage due to a reaction between the smell of acid and air or water. Acid Mine Drainage is water formed at mining sites with a low pH value (pH <4) and has high dissolved metals, such as ferrous metal (Fe), aluminum (Al), manganese (Mg), cadmium (Cd) (Amrulloh et al., 2021), copper (Cu), lead (Pb), zinc (Zn), arsenic (Ar) and mercury (Hg) (Vaghetti et al., 2009).

In the preliminary test carried out, iron (Fe) has the highest concentration of liquid waste generated from the gold ore mining process in Sukamenang Village, Musi Rawas Regency, which is 23.2 mg / L. Iron is a metal that comes from a lot of iron ore used for everyday human life. In the periodic table, iron has the symbol Fe and atomic number 26. Iron also has a high economic value. Iron has been found since ancient times and it is not known who the real discoverer of this element is. Iron and the fourth element are widely earthed and are the most important metals in industry. Pure iron is somewhat soft and chewy. Therefore, in industry, iron is always combined with steel (Mandasari & Purnomo, 2016).

In the soil, Fe (iron) can undergo oxidation and reduction processes (Permanasari et al., 2010). The element of Fe can enter the water through the soil so that a biological reaction will occur by the bacteria anaerobically and turn into divalent (ferrous ion) (Hartini, 2012; Purwoto & Nugroho, 2013). Meanwhile, the Fe metal in the soil will be absorbed by plant roots in the form of ferric ions (Fe3 +) and ferrous ions (Fe2 +), and absorbed in the form of chelate compounds (Sembiring et al., 2016). When the ferrous ion reacts with water, the Fe3 + ion will be reduced to Fe2 + ion then reduced again to Fe3 + ion occurs and if this happens excessively, the Fe2 + ion formed will then accumulate in the soil so that it exceeds the quality standard value, the plant will become a target. subsequent toxic effects (Setiawan & Subiandono, 2015).

When the waste enters the aquatic ecosystem such as river and sea water, the sea becomes a place for pollutants to collect which is carried by the flow of water. Heavy metals that enter the waters will experience deposition, dilution and dispersion and then accumulate in organisms that live in these waters. The easiest bioindicator that can be identified is fish. If the heavy metals have entered the body of the fish, through the process of the food chain the fish will be eaten by humans and heavy metals will also enter the human body and accumulate (Setiawan & Subiandono, 2015; Vaghetti et al., 2009).

Iron (Fe) is an essential metal which in a certain amount is needed by living organisms, but if the concentration exceeds the specified quality standard, it can have a toxic effect and cause health problems for humans such as poisoning (vomiting), intestinal damage, premature aging and sudden death, arthritis, birth defects, bleeding gums, cancer, kidney cirrhosis, constipation, diabetes, diarrhea, dizziness, fatigue, hepatitis, hypertension, insomnia (Mandasari & Purnomo, 2016).

From the above explanation, it can be seen that the toxic effects that can be caused by iron (Fe) pollution from mining waste, especially for areas surrounded by mining and gold ore washing industries, are not properly controlled. Therefore it is considered important to find a solution in order to reduce the rate of Fe contamination in the environment and living things. Several methods have been developed, especially to find ways to remove heavy iron with adsorption techniques (Mandasari & Purnomo, 2016), and there have even been many studies that have succeeded in adsorbing Fe, including using zeolitalam (Alfanaar et al., 2022), chitosan -bentonite (Permanasari et al., 2010), and nano particles of CoFe2O4 (Nurdila et al., 2015).

Adsorbents derived from inorganic compounds can provide a good and fast effect, but there are still drawbacks, namely high costs and side effects even though they are small. Meanwhile, if you can use adsorbents from natural materials, the resulting performance is just as good and the cost is more affordable and safer than adsorbents based on inorganic compounds (Bello et al., 2017).

Explanation it is evident that the control of toxic effects caused by iron (Fe) pollution from mining waste, particularly in areas surrounded by mining and gold ore washing industries, is inadequate. Therefore, it is crucial to find a solution to reduce the contamination rate of Fe in the environment and living organisms. Numerous methods have been developed, primarily focusing on adsorption techniques to remove heavy iron (Mandasari & Purnomo, 2016). Several studies have successfully adsorbed Fe using different approaches, including the use of zeolitalam (Alfanaar et al., 2022), chitosan-bentonite (Permanasari et al., 2010), and CoFe2O4 nanoparticles (Nurdila et al., 2015). While adsorbents derived from inorganic compounds offer effective and rapid results, they have drawbacks such as high costs and potential side effects, albeit minimal. On the other hand, utilizing adsorbents from natural materials can yield comparable performance, with more affordable and safer costs compared to inorganic-based adsorbents (Bello et al., 2017). One plant believed to have the potential as an adsorbent for heavy metal Fe is moringa. Moringa possesses a beneficial property for water purification due to its *rhamnossyloxy-benzyl-isothiocyanate* compound, which carries a positive charge and enables the absorption of wastewater particles. With this in mind, the present research aims to assess the efficacy of chlorine powder derived from *Moringa oleifera* (leaf powder and twigs) as a coagulant in the wastewater treatment process of gold ore preparation, specifically focusing on the iron (Fe) parameter.

Materials and Methods

The Moringa oleifera extract waste used for preparation is a collection from the Botanical Laboratory of Universitas Isalam Negeri Raden Fatah Palembang. The simplicia process refers to the method described by (Fatiqin et al., 2021a; Fatiqin et al., 2021b), while the extraction process refers to the method outlined by Amrulloh et al (2021) and Das et al (2018), Moringa leaf powder and stems, totaling 10 grams, were dissolved in 90 ml of distilled water. The mixture was then heated to 60 °C for 20 minutes with stirring until all the Moringa sample powder was evenly mixed. After cooling, it was filtered using Whatman filter paper, and the resulting filtrate was used as stock for Fe adsorption.

Analysis of heavy metal content

To analyze the heavy metal iron (Fe) levels in the wastewater, we followed a comprehensive sampling and analysis procedure in accordance with the Indonesian National Standard (SNI 6989.59: 2008). The sampling procedure involved collecting wastewater samples from various locations within the gold mining industry to ensure a representative sample. Strict precautions were taken during the sampling process to prevent any potential contamination.

For the analysis, we employed the Atomic Absorption Spectrophotometer (AAS) according to the specifications of SNI 6989.59: 2008. This method allowed us to determine the content of heavy metal iron (Fe) in the wastewater samples accurately. The AAS measured the absorbance of Fe at a specific wavelength, enabling us to quantify its concentration. Calibration curves were constructed using known Fe standards to ensure precise and reliable measurements. Each sample was analyzed in triplicate to account for measurement precision and obtain dependable results.

To investigate the effectiveness of sawdust and Moringa twigs as potential adsorbents for reducing heavy metal iron (Fe) in the wastewater, we treated the liquid waste samples with different combinations. Sample A1 involved mixing 100 mL of the liquid waste sample with 3 grams of Moringa leaf powder, followed by stirring for a designated period to facilitate adsorption. After the adsorption process, the sample was filtered to separate the liquid phase from the adsorbent. Similar steps were followed for Sample A2 and Sample A3, except with varying amounts of Moringa leaf powder (5 grams and 8 grams, respectively). For Sample B1, B2, and B3, we treated 100 mL of the liquid waste sample with 3 grams, 5 grams, and 8 grams of sawdust, respectively. These samples were stirred and filtered after the designated adsorption time.

The experimental results were obtained by analyzing the adsorption of Fe using the extract of Moringa Oleifera in Musi Rawas Regency, South Sumatra. This analysis was performed using the Atomic Absorption Spectrophotometer (AAS) in accordance with the Indonesian National Standard SNI 6989.4:2009. The absorbance readings obtained from the AAS measurements were utilized to determine the concentration of Fe in each treated sample. These results provide valuable insights into the potential of utilizing natural adsorbents for reducing heavy metal pollution in the gold mining industry.

Results and Discussion

From the results of laboratory tests, it is known that the levels of heavy metal iron (Fe) in the liquid waste of the gold mining industry which have been added with Moringa leaf powder and Moringa stem powder, show a decrease in Fe levels when compared to the treatment without the addition of Moringa leaf powder and Moringa stem powder. The decrease in Fe levels can be seen in Figure 1.

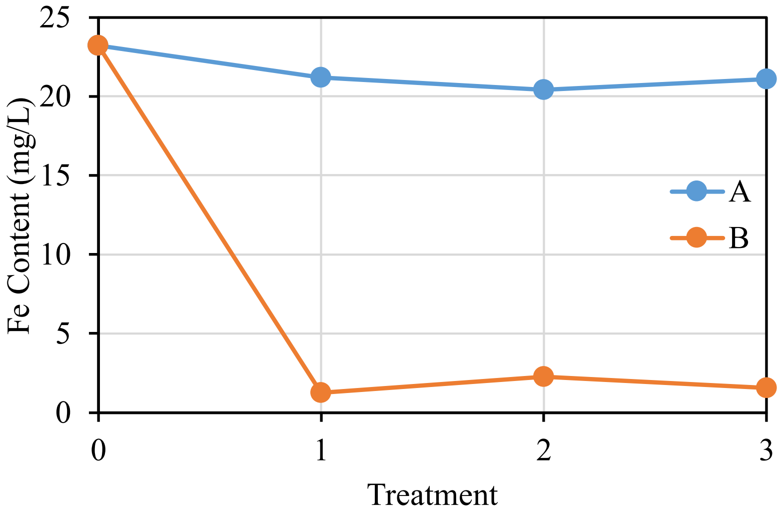

Figure 1. Fe content after addition of Moringa leaf powder treatment (A) and addition of Moringa stem powder (B).

The highest reduction in Fe content was the addition of 3 grams of Moringa stem powder, namely 1.27 mg / L. Whereas for the addition of 5 grams of Moringa leaf powder, it was 20.4 mg / L. This shows that the use of moringa stem powder is much more effective in reducing Fe content in the tested waste.

From the results of laboratory tests, it is known that the ratio of the average percentage reduction in iron (Fe) levels between group A and Group B can be seen in Table 1.

Table 1. Comparison of the percentage reduction in content Fe.

Treatment	Decrease Percentage Comparison Heavy Metal Concentration Iron (Fe) Treatment Group (%)			
	1	2	3	Average ± SD
A (Moringa leaf powder)	8	12	9	9.6 ± 1,70
B (Moringa stem powder)	94	90	93	92 ± 2.08

Table 1, it can be seen that moringa stems have a greater adsorption power than moringa leaves, which is 92% and the most effective concentration of moringa stem powder to absorb iron by weight is at a concentration of 3 g or B1.

Discussion

The results showed that Moringa stem powder exhibited a higher adsorption capacity compared to Moringa leaf powder, with an average of 92%. The most effective concentration was observed with the addition of 3 grams of Moringa twig and tree powder, resulting in a 94% decrease in Fe content compared to untreated controls. The significant decrease in Fe content in this treatment sample indicates that Moringa stem powder has a greater ability to adsorb heavy metal iron (Fe). This finding confirms the potential of Moringa stem powder, a byproduct of the extraction process, in the adsorption of heavy metal iron (Fe).

The leaf powder of Moringa leaves and stems can assist in the adsorption process of heavy metal iron (Fe) in industrial waste, which can pose risks to human life. The removal of heavy metals has been accomplished through various alternative methods, one of which is the adsorption process. Adsorption involves the attachment of liquid molecules to a solid surface. Numerous substances can be utilized as adsorbents for this process (Pratiwi & Prinajati, 2018). In addition, chemical precipitation filtration processes, ion exchange, adsorption and membrane systems can also be carried out to treat dye and metal waste (Darjito et al., 2014). The adsorption method has several advantages including relatively simple processing, and relatively high efficiency, effectiveness and does not have a negative impact on the environment (Hossain et al., 2012).

Moringa stem powder and moringa leaf powder are capable of reducing Fe levels in waste due to the presence of *rhamnossyloxy-benzyl-isothiocyanate* compounds in moringa. These compounds have a positive charge, allowing them to adsorb particles in wastewater. Amorim et al (2023), stated that moringa stem has a high cellulose content. Cellulose serves as an adsorbent due to the carboxyl and hydroxyl groups that can bind metal ions. The polar nature of cellulose, attributed to the -OH group, enables it to absorb more polar substances compared to less polar ones. The decrease in heavy metal concentrations can also be attributed to the activity of biofloculant amino acids. These amino acids have the ability to adsorb and form bonds between wastewater and biofloculant particles, leading to the formation of stable bonds. According to Gassenschmidt et al., (1995), moringa's coagulant extract contains proteins with high levels of amino acids, including glutamine, arginine, and proline. These proteins, with a molecular weight of 3 kDa as measured by SDS-PAGE (or equivalent to 3000 gr/mol), act as active components in the coagulation process.

The polymer's binding of colloid particles occurs when the polymer molecules attach to the particles on one side. The unbound part of the polymer chain can then bind to other chains that have already bound to colloid particles, forming a chemical bridge. The more bonds that are formed, the more colloid particles are joined together. This aggregation results in the formation of larger clumps or flocs that can settle down. However, if a free chain fails to bind with another chain, it may cover the entire surface of the colloid particle it is attached to. This prevents further binding and can lead to the colloid particles returning to a stable state. The addition of an excessive amount of coagulant can disrupt floc formation. In this case, the excess polymer molecules will cover the entire surface of the colloid particles, leaving no space for the end chains to attach and hindering the flocculation process. As a consequence, the colloid particles may remain stable or be unable to combine with other particles due to their similar charges (Larry D & Joseph, 1982). This observation aligns with the research findings, where the addition of 3 grams of Moringa stem powder demonstrated the highest reduction in Fe content, measured at 1.27 mg/L, compared to the addition of 5 and 8 grams of Moringa stem powder.

Previous studies have indicated that the presence of bioactive compounds, such as rhamnosyloxy-benzyl isothiocyanate, in moringa seeds enables the adsorption and neutralization of mud and metal particles present in suspended waste, along with dirt particles found in water. This characteristic highlights the potential of moringa seeds as a natural coagulant for water purification (Bello et al., 2017). The research conducted by Gavgani et al., (2021), revealed that the addition of Moringa seed powder was effective in treating tofu liquid waste, leading to the elimination of BOD5, COD, TSS, and a decrease in pH. Specifically, the addition of 2.5 grams of Moringa seeds resulted in the removal of 88.37% of BOD5, 79.39% of COD, 81.36% of TSS, and a pH decrease of 6.7%.

Heavy metals are a major problem for the environment, especially those from industrial waste. The decline in environmental quality at this time can be said to be included in the category of worrying, but sometimes this condition is not a major concern for some groups of society because it is considered not dangerous and they have not felt the effect directly. But without them realizing it has happened with the decline in water quality, high air pollution and many degenerative diseases at this time which are caused by harmful chemicals that accumulate in the bodies of living things.

The impact of heavy metal toxicity to the environment involves contamination of soil, groundwater, sediment, natural water and air. Metal contamination can affect human health through several routes of exposure. There are three main routes: inhalation, diet, and skin contact or through manual handling of pollutants. Heavy metals can severely inhibit or interfere with the degradation and reduction of organic matter. Soil is polluted by excessive sediment or accumulation of toxic metals and metalloids released by many dangerous human activities (Vaghetti et al., 2009).

Heavy metal contamination in the environment (soil, water and air) can pose risks and toxicological problems that are harmful to humans and animals. The natural environment becomes highly contaminated due to direct or indirect exposure to heavy metals in drinking water and natural water supplies and this results in reduced productivity and soil fertility, air quality and food quality (Amorim et al., 2023).

Iron (Fe) is a form of heavy metal that is actually needed for human life but if it exceeds the threshold it will cause poisoning for the human body itself. Industries can contribute waste which contains a lot of heavy metals, one of which is Fe. Industrial waste containing heavy metal compounds, Fe is not only toxic to plants but also to animals and humans because of the nature of the metal which can easily accumulate so that it can settle in the body.

Iron is needed by the human body in the formation of hemoglobin. Even though iron (Fe) is needed by the human body, but in large doses it can damage the intestinal wall, iron dust can also accumulate in the alveoli and can cause reduced lung function. It is also irritating to the skin and eyes. This is because the skin's pH is 6-8 while Fe3 + is difficult to dissolve at this pH so that Fe3 + can irritate the skin, while Fe3 + is easily dissolved in low pH (around 5) (Amorim et al., 2023).

The normal value of iron (Fe) in an adult human body is 40 -50 mg Fe / Kg body weight (40-50 mg / L), most of which is stored in erythocytes that bind to hemoglobin and if it exceeds the value it can cause health problems for humans depend on which part of the iron is bound in the body and the amount. Iron (Fe) can inhibit or damage the work of the enzyme so that if the enzyme is disrupted, the body's metabolism will be disrupted because enzymes have an important role in the body's metabolic processes, namely as a catalyst or which helps the body's biochemical processes so that the body can give negative responses such as allergies, are mutagens, teratogens, or carcinogens for humans (Widowati, 2008).

In primary hemochromathesis, iron is absorbed and stored in excessive amounts in the body. Ferritin is in a saturated state of iron so that the excess of this mineral will be stored in a complex form with another mineral, namely hemosiderin. The result is liver sirosi and damage to the pancreas, leading to diabetes. Secondary hemochromatics occurs due to repeated transfusions. In this state iron enters the body as hemoglobin from the transfused blood and this excess iron is not secreted.

Moringa contains several phytochemical compounds in the form of steroids, flavonoids, alkaloids, phenols, and tannins (Amrulloh et al (2021). Several types of steroid compounds are used in medicine, including estrogen is a type of sex hormone steroid used for contraception as an ovulation inhibitor, progestin is a synthetic steroid used to prevent miscarriage and pregnancy tests, glucocorticoids as anti-inflammatory, allergy, fever, leukemia, and hypertension (Mutiara et al., 2012). Tannins have activity as antibiotics. The working principle of tannins as antibiotics is by forming complexes with extracellular enzymes produced by pathogens or by interfering with the metabolic processes of these pathogens. Condensed tannins have antioxidant activity and can protect the skin from damage caused by ultraviolet radiation (Fatiqin et al., 2021a).

Moringa leaves are very often used by Indonesians for food, traditional medicine, and traditional ritual materials. One of the uses of leaves for the treatment of jaundice is by drinking finely ground Moringa leaves, added with coconut water, filtered, and added with honey (Amorim et al., 2023). It is known that Moringa leaves contain vitamin A, calcium and iron compared to other foods (Mutiara et al., 2012). Besides the root leaves are also often used for goiter, cholesterol, coughs, fever, gout, diabetes and thrush. While the stems are used for animal feed, colic pain medication, coughs and fever, the fruit is usually cut and the seeds can be used as a stomachache medicine (Bahriyah et al., 2015).

The cultivation of moringa (*Moringa oleifera* L.) is an international program that is being promoted. There are many terms for the Moringa tree, including The Miracle Tree, Tree for Life, and Amazing Tree. The term arises because all parts of the Moringa tree can be used, starting from leaves, fruit, seeds, flowers, bark, to roots (Purwati, 2019). Moringa leaves are very often used by Indonesians for food, traditional medicine, and traditional ritual materials. One of the uses of leaves for the treatment of jaundice is by drinking finely ground Moringa leaves, added with coconut water, filtered, and added with honey (Amorim et al., 2023). It is known that Moringa leaves contain vitamin A, calcium and iron compared to other foods (Mutiara et al., 2012). Besides the root leaves are also often used for goiter, cholesterol, coughs, fever, gout, diabetes and thrush. While the stalks are used for animal feed, colic, cough and fever, the fruit is usually in the vegetables and the seeds can be used as an upset stomach (Bahriyah et al., 2015).

Conclusion

The addition of powdered moringa stems and leaves to liquid waste from the gold mining industry has the ability to reduce the levels of heavy metal iron (Fe). In the treatment with Moringa leaf powder (group A), the results were as follows: A1 (3 gr) had a concentration of 26.2 mg/l, A2 (5 gr) had a concentration of 20.4 mg/l, and A3 (8 gr) had a concentration of 21.1 mg/l. In the treatment with Moringa stem powder (group B), the results were: B1 (3 gr) had a concentration of 1.27 mg/l, B2 (5 gr) had a concentration of 2.28 mg/l, and B3 (8 gr) had a concentration of 1.55 mg/l. On average, the percentage reduction in heavy metal Fe content in the liquid waste of the gold mining industry after treatment with Moringa leaf powder was 9.6%, whereas the treatment with Moringa stem powder showed a much higher reduction at 92%. This indicates that Moringa stem powder is more effective than Moringa leaf powder as an adsorbent for heavy metal iron (Fe) in the wastewater of the gold mining industry. The most effective concentration was found to be 3 grams of Moringa stem powder in 500 ml of the sample, resulting in a 94% reduction in Fe levels.

Acknowledgment

This research received funding from the Institute for Research and Community Service (LP2M) of the Universitas Islam Negeri (UIN) Raden Fatah Palembang No: 0685 for the fiscal year 2020.

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