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Moringa Seed Powder Biocoagulant (*Moringa oleifera*) for Improving Laboratory Wastewater Quality

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ABSTRACT. The purpose of the study was to examine the ability of 100 mesh size moringa seed powder as a biocoagulant in improving the quality of laboratory wastewater, in terms of parameters: color, TSS, Cu, Fe, COD, $P\text{-}PO_4$, and antibacterial. The variable that changed was the concentration of Moringa seed powder solution of 0 mg/L, 40 mg/L, 80 mg/L, 120 mg/L, and 160 mg/L, with fast stirring of 150 rpm for 15 minutes and slow stirring of 50 rpm for 15 minutes. Analysis of test parameters was carried out using standardized methods of wastewater samples before and after the addition of biocoagulants. Characteristics of 100 mesh Moringa seed powder were that with the SEM-EDX test at 5000x magnification. While with the BET-BJH test it had a surface area of 14.519 m^2/g, a total pore volume of 0.026 cm^2/g, and an average pore size of 7.055. Moringa seed powder could improve the quality of laboratory wastewater and it had good effectiveness. Optimal TSS reduction was at a concentration of 80 % with effectiveness of 81.01 %. The reduction of COD and $P\text{-}PO_4$ at a concentration of 160 % biocoagulants had an effectiveness of 96.36 % and 79.36 %. Whilst the decrease in heavy metal Cu was 67.7 %, Fe was 89.33 % and color was 52.96 % with the addition of 120 % biocoagulants. It had antibacterial properties of E-coli and Bacillus at the addition of 200 mg/L biocoagulant as well.

Keywords: biocoagulants, laboratory wastewater, moringa seeds

INTRODUCTION

Moringa

Moringa is a tropical plant with the family name Moringaceae. It is a plant that is easy to cultivate, to grow and is resistant to hot weather (Yuli, 2018). It does not require special care and generally, it is utilized for hedge plants. Even though planted from seeds, Moringa trees can grow quickly and reach a height of approximately 10 meters (Kurnia, 2019). Moringa leaves are small, oval in shape, and compound in one stalk. Moringa fruit is often called *kelentang* with an elongated triangular in shape (Kurnia, 2019). In Indonesia, the Moringa tree can grow when the climate is hot. In sunny conditions, it can flower, bear fruit, and produce leaves and pods throughout the year. It can be harvested every month (Kurnia, 2019). Moringa is rich in benefits. The leaves and young fruit are used for vegetables and medicine. Moringa as a "Miracle Tree" is a magical tree that contains nutrients and active substances that are efficacious for treatment (Yuli, 2018), beauty, and water purification. The use of dried moringa seeds has not been widely developed.

Nevertheless, researchers have conducted research related to the use of Moringa seeds for water purification. Dried Moringa seeds can improve water quality. Wastewater quality can be elevated by reducing the pollutant content in it through the coagulation process, such as laboratory wastewater. Moringa oleifera seeds contain an active substance (4-Alfa-4- Ramnosiloxy-Benzyllsothiocyanate) which can be used as a natural coagulant in the water purification process (Irmayanti et al., 2019).

Laboratory Wastewater Pollution

Organic and inorganic pollutants in laboratory wastewater can pollute the environment. The pollutant content corresponds to the chemicals used during the experiment. These materials are physical, chemical, and biological materials, which have the chance to pollute the environment. Indicators of polluted environmental water can be observed through changes in water temperature, pH, color, and the formation of deposits, colloids, and dissolved materials (Pujiastuti, 2018).

An educational laboratory is a place where students implement a practicum learning process to develop skills to achieve their competencies. At Setia Budi University, it organizes practicums of various subjects from 3 (three) faculties, namely the Faculty of Engineering, the Faculty of Pharmacy, and the Faculty of Health Sciences. There are 7 (seven) study programs that use educational laboratories for practicums. Those are D3 Chemical Analyst, D3 Health Analyst, D3 Pharmacy, D3 Anafarma, D4 Health Analyst, S1 Pharmacy, and S1 Chemical Engineering. Practicum activities require chemicals and then in the process of implementing learning they produce solid and liquid wastes. Liquid waste is wastewater from practicum activities that is from washing glass utensils before and after practicum use. These lab glass utensils contain the reaction solution and there may also be reagent spills. This lab waste solution is hereinafter referred to as laboratory wastewater. It contains chemicals such as carbohydrates, proteins, fats, and heavy metals. Wastewater from each laboratory is discharged through a sink which is drained to USB WWTP. Currently, the WWTP is not operating due to engine failure. So as the wastewater does not pollute the environment, it is necessary to innovate wastewater treatment before being discharged into the water body.

Environmentally friendly wastewater management has begun to be developed and is in demand by the public. The use of plants and microorganisms began to be expanded to reduce the concentration of pollutants in wastewater. Moringa seeds (Moringa oleifera) can be used for water purification. The ability of Moringa seeds to reduce pollutant parameters can be seen from the percent of effectiveness. Moringa seeds in nano size are potential in the water purification process (Hendrawati, et al., 2016). Moringa seeds as nano biocoagulants can reduce TDS, TSS, and COD parameters up to 70 % at concentration variations between 40 mg/L – 140 mg/L (Wibawarto, et al., 2017) and can reduce dissolved heavy metals (Hendrawati, et al., 2016). It is possible to reduce P-PO_4 and microbiological pollutants as well.

Laboratory Wastewater Coagulation-Flocculation

Coagulation is a process to make small particles (colloids) combine with others to form larger flocs. The coagulation process can be defined as a clotting process through a chemical reaction by mixing a reagent (coagulant) with the solute, forming small flocs (Rahimah, et al., 2016). Coagulants that are often used in the water purification process are synthetic coagulants, such as alum, Fe (III) salt, Poly Aluminum Chloride (PAC), and so on. The final result of the coagulation process with synthetic coagulants still results in pollutants that can contaminate the environment. Currently, many environmentally friendly natural coagulants have been developed such as winged bean seeds, moringa seeds, and so on. The coagulation process is influenced by various factors, including 1) Coagulant dosage. If the coagulant dose is less, then the collision between the particles and the charge neutralization is not perfect. It results in the formation of an unfavorable floc. However, when the coagulant dose is excessive, it will cause the particles to be charged again. Therefore, it will increase the turbidity and color values. 2) Stirring speed. The stirring process is carried out quickly until the collisions between the particles for neutralization are large and perfect. Furthermore, the coagulant distribution can be evenly distributed. 3) Long stirring time. The length of time of stirring can affect the formation of floc. If the stirring is done for too long it can break the floc (Rahimah, et al., 2016).

Previous Studies

Research on the utilization of moringa seeds as a coagulant in water purification has been widely performed. Camacho, et al., (2017) and Hendrawati, et al. (2016) researched the development of biocoagulants from Moringa (Moringa oleifera) seeds for the water purification process. Santos, et al (2016) evaluated the effectiveness of Moringa seeds as a coagulant in surface water for turbidity parameters. Ferreira, et al (2011) investigated Moringa seeds as a coagulant and anti-bacterial. Wibawarto, et al (2017) conducted research on Moringa seeds as biocoagulants in domestic wastewater, on turbidity, TSS, and COD parameters. However, the application to improve the quality of educational laboratory wastewater has not been carried out.

In the study of Tan et al (2016), Moringa oil extracted with ethanol was able to inhibit bacterial growth and reduce the number of heavy metals Cu and Cd (98%), Pb (78.1%), and Fe (100%) in river water. The novelty of this research is that Moringa seed powder 100 mesh with a certain dose can act as a natural biocoagulant properly to improve the quality of educational laboratory wastewater, on the parameters of color, TSS, P-PO4, COD, Cu, Fe, P-PO_4, E-coli and Bacillus.

EXPERIMENTAL SECTION

Materials

Dried moringa seeds, USB laboratory wastewater, KHP, $K_2Cr_2O_7$, concentrated HNO_3, FAS, ferroin indicator. All reagents were obtained from Merck. Instruments: Atomic Absorption Spectrophotometer (Perkin Elmer model 3110), Analytical balance (Ohaus), Erlenmeyer, Burette set, etc.

Sample

1) Moringa seeds (*Moringa oleifera*), 2) USB laboratory wastewater, which is collected at the outlet point of the reservoir.

Research Variables

1) independent variables: particle size of Moringa powder and concentration of Moringa solution as a biocoagulant. 2) Dependent variables: color, TSS, COD, Pb, Fe, Cu, P-PO_4, and microbiology.

Working Procedures

The procedures of this research were: 1) to conduct a representative sampling of laboratory wastewater according to SNI (Indonesian National Standard) 6989.59:2008 at the outlet point of the WWTP reservoir. 2) to conduct field analysis: DO, pH, temperature. 3) to perform laboratory analysis of wastewater before and after coagulation treatment: Color analysis was according to SNI 06.6989.24:2005, and TSS was suitable to SNI 06.6989.27:2005. Meanwhile, COD was appropriate to SNI 6989.73:2009, Pb analysis was in line with SNI 6989.8:2009, Cu analysis was matching to SNI 6989.6:2009 and Fe analysis was agreed with SNI 6989.4:2009. 4) Perform coagulation process in wastewater.

Procedure for preparation of Moringa (Moringa oleifera) seed powder

1) Take the dried moringa fruit from the Moringa oleifera tree (Moringa oleifera) 2) Peel the moringa fruit and take the seeds, 3) Dry the moringa seeds in the sun, 4) Blend the dried moringa seeds and sieved with a 100 mesh sieve, 5) Prepare moringa seed powder that passed 100 mesh for the next analysis: a) characteristic analysis of protein, fat, moisture and ash contents was carried out and SEM analysis was carried out, b). Applied for coagulation of samples.

The procedure for the coagulation process using the jar test method

(Wibawarto, et al., 2017): 1) Prepare 6 beakers with a volume of 1500 ml, 2) Put 1000 ml samples into each beaker, 3) Insert Moringa seed powder coagulant with a concentration 0 mg/L, 40 mg/L, 80 mg/L, 120 mg/L, 150 mg/L. 4) Stir the sample with fast stirring at 150 rpm for 15 minutes or slow stirring at 50 rpm for 15 minutes. 5) Let the floc settle for 30 minutes. 6) Take the filtrate in each beaker to be analyzed according to the specified test parameters.

RESULTS AND DISCUSSION

The inner moringa seeds (cotyledons) and their dried skin were reduced to obtain a size of 100 mesh. Moringa seed powder was then used to improve the quality of USB laboratory wastewater by coagulation. This method is known as a biocoagulant. The color of the powder was light brown because its making process did not separate the skin and the flesh of the fruit. The characterization of moringa seed powder was examined for chemical content, particle size, morphology, and effectiveness of pollutant reduction in USB laboratory wastewater.

Chemical Content of Moringa Seed Powder

Moringa seed powder biocoagulant 100 mesh has chemical characteristics as presented in **Table 1**. Moringa seed powder being studied has a fairly large protein content. 100 grams of Moringa seed powder, contains 28.63 grams of protein or 286,300 ppm. According to Hidayat (2009), Moringa seed skin contains a protein of 15.680 ppm/gram. Protein in moringa seeds without the skin is 147.280 ppm/gram, while the protein in moringa seeds and skin is 73,547 ppm/gram. The high protein content in Moringa seeds will be used as a natural coagulant, which is expected to reduce organic and inorganic pollutants.

Table 1. Chemical characteristics of Moringa seed powder

Parameter	(%)
Ash content	3.69
Water content	7.44
Protein content	28.63

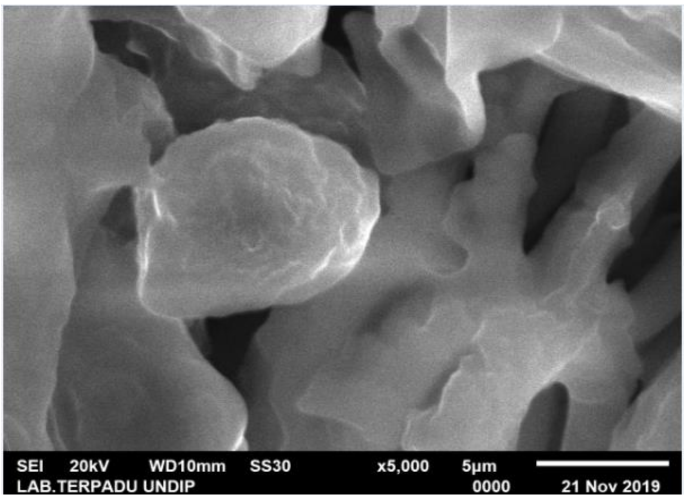

Figure 1. SEM EDX test results

Morphological Characteristics of Moringa Seed Powder.

Moringa seed powder particle size 100 mesh

Based on the results of the Scanning Electron Microscope (SEM) test which was used to see the surface topography and size of the moringa seed powder biocoagulants, the results obtained were scanning electron micrographs in the form of three-dimensional photos. The results of the SEM EDX test with a magnification of 5000 times obtained the results presented in **Figure 1**.

The materials can be included in the type of nanoparticles if they have a size of 1-100 m (Almas, 2016). Based on the SEM EDX test with a magnification of 5000 x, the moringa seed powder biocoagulant passed the 100 mesh because the one used in this research ha d a size of 5 m or 5,000 nm. Therefore, this Moringa seed powder biocoagulant cannot be included in nanoparticles because the particle size is still too large. Advanced chemical or physical processes are needed to make the nanoparticle size.

Characteristics Surface Area of Moringa seed powder biocoagulant

The characterization of Moringa seed powder was also carried out using the Brunauer Emmet Teller (BET) method. The BET test can be used to determine the surface characterization of a material, namely the pore surface area, pore diameter, and pore volume. The results of the BET test on Moringa seed powder are presented in **Table 2** and **Figure 2**. Using the Barret Joyner Hallenda (BJH) method, the pore size calculation is carried out with the assumption that the pore geometry is cylindrical.

Table 2. Characterization of absorption pores of Moringa seed biocoagulants using The BJH method

Pore characterization	Pore size
Specific surface area (m^2/g)	14.519
Total pore volume (cm^3/g)	0.026
Average pore size (Å)	17.035

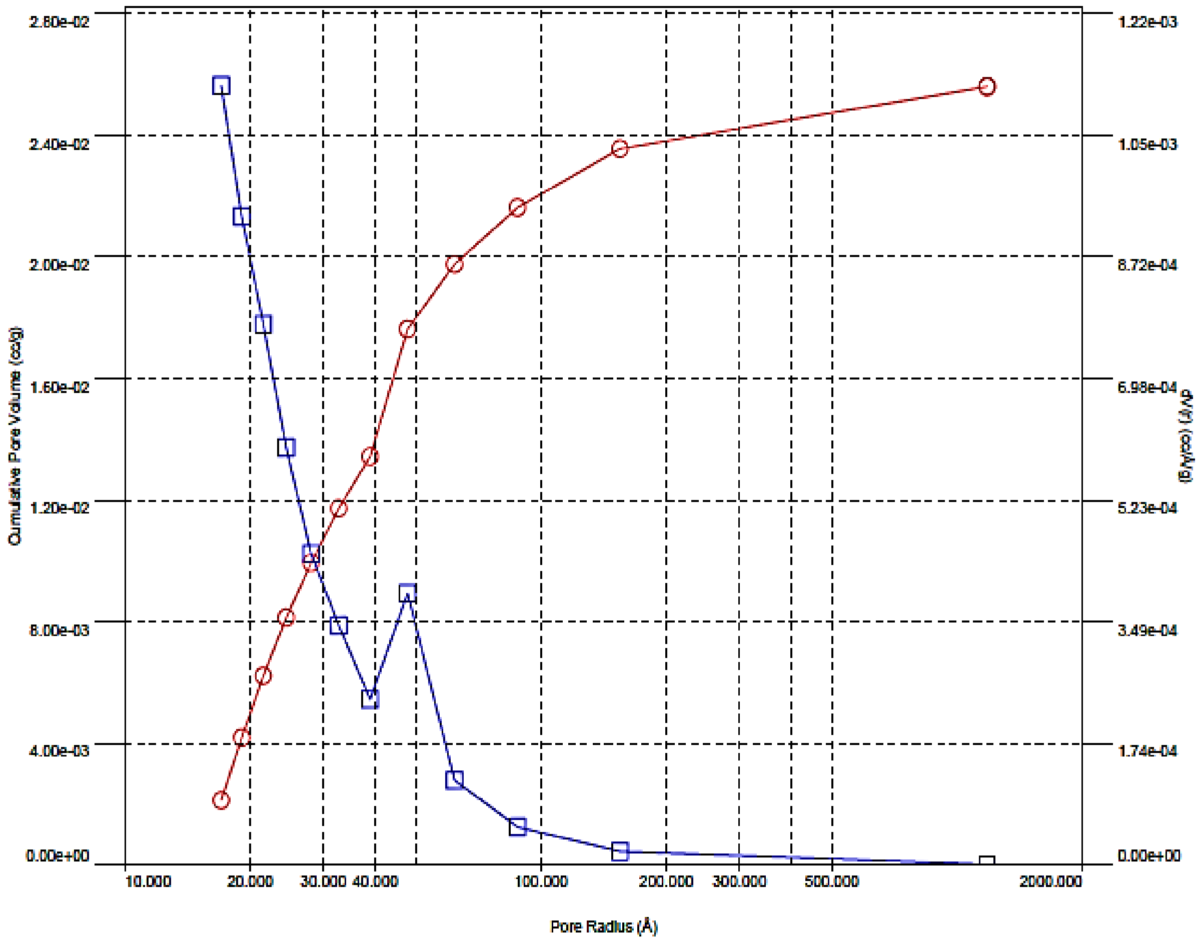

Figure 2. Graph of BJH absorption

The surface area of 100 mesh moringa seed powder is 14.519 m^2/g with an average pore size of 17.035. The size of the surface area of this powder can be classified to be low because this sample did not receive activation treatment. The surface area of the unactivated material will be lower when compared to the activated one, for example in the activated carbon material (Kurniawan et al., 2014). For example, the surface area of activated carbon in a coconut shell that was activated with 3M H_3PO_4 was 386.447 m^2/g (Kurniawan et al., 2014). The low surface area can affect the absorption of Moringa seed powder as a natural coagulant because some of the pores are still closed by other compounds.

The ability of Moringa seeds as biocoagulants to reduce color

The color of the water can be observed visually or measured based on the platinum cobalt scale expressed in Pt-Co units, by comparing the color of the water sample with the standard color. Moringa seed powder biocoagulant 100 mesh can reduce color in educational laboratory wastewater. With the addition of natural coagulant of Moringa seed powder 40, 80, 120, and 160 mg/L, flocculation occurs to form floc after fast stirring at 150 rpm for 15 minutes and slow stirring at 50 rpm for 15 minutes. The floc gets bigger and settles as sediment after being left for 20 minutes, the filtrate is clearer than the initial sample. The results of the color test on the samples before and after the coagulation process are presented in **Table 3**.

The optimal color reduction process with the addition of 120 mg Moringa seed powder into 1L of laboratory wastewater, obtained a color test result of 1.87 Pt-Co with effectiveness of 52.96%. The complete results of laboratory tests are presented in **Figure 3**.

The color parameter measured is the natural color of wastewater that comes from organic compounds, humic acids, and others contained in wastewater. This natural color can be derived using Moringa seed powder, with effectiveness between 23.52 % - 57.96 %. According to Santos, et al (2011), protein in 1 mg/L Moringa oleifera seed extract can reduce humic acids in water. The apparent color of domestic wastewater can be reduced by adding 66 % of Moringa oleifera seed water extract because cationic protein acts as a coagulant capable of multiplying deposits of organic pollutants (Vega, et al, 2021). Decrease in color intensity in water due to the positive charge of a coagulant that can neutralize the negative charge of colloidal particles so that flocs are formed (Irmayanti, et al., 2019).

The ability of Moringa seeds as biocoagulants to reduce TSS

The effectiveness of Moringa seed powder as a natural coagulant in reducing colloidal pollutants suspended in laboratory waste and measured by TSS parameters seems quite good. By varying the concentration of coagulant, different TSS numbers of laboratory waste were obtained. The results of the lab tests are presented in **Table 4**.

Table 3. Color of laboratory waste before and after coagulation

Coagulant concentration (mg/L)	Color (Pt-Co)
0	3.975
40	3.04
80	2.65
120	1.87
160	2.91

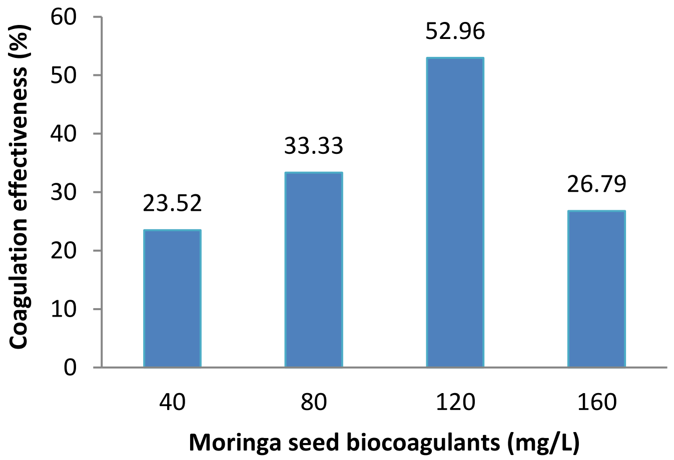

Figure 3. Percentage of effectiveness in reducing color

Table 4. TSS of laboratory waste before and after coagulation

Coagulant concentration (mg/L)	TSS (ppm)	Coagulation effectiveness (%)
0	425.26	-
40	150.10	65
80	80.75	81
120	110.00	74
160	125.50	71

At a concentration of 80 mg/L, it was able to reduce TSS by 81.01%. The complete results of laboratory tests are presented in **Table 4**. In **Table 4** above, it can be seen that Moringa seeds are the most effective in reducing TSS at a concentration of 80 mg/L, which is 81.01%. Meanwhile, at higher concentrations of Moringa seeds, its effectiveness decreased because it was possible that Moringa seeds at higher concentrations could not stabilize negative colloids. This is due to the active substance 4-Alfa-4-Ramnosiloxy-BenzylIsothiocyanate in Moringa seed powder capable of binding colloidal particles suspended in laboratory wastewater samples to form flocs (Ismayanti et al., 2019). Through fast stirring of 150 rpm for 15 minutes and slow stirring of 50 rpm for 15 minutes, the formation of floc will increase so that it can be separated as a precipitate.

The ability of Moringa seeds to reduce COD

Moringa seed powder can reduce organic pollutants in USB laboratory wastewater. it is measured by the COD parameter. The greater the concentration of Moringa seed powder added to laboratory wastewater, the smaller the COD obtained. Lab test results are presented in **Table 5**.

This coagulation process is quite effective in reducing organic pollutants in laboratory wastewater. At a coagulant concentration of 160 mg/L, it was able to reduce the tested organic pollutants through the COD parameter of 96.36%. The percentage of COD reduction effectiveness is presented in **Table 5**.

Laboratory wastewater contains biodegradable and non-biodegradable organic pollutants which are calculated using the COD number approach of 2750.37 ppm. Through the addition of Moringa seed powder, this COD number can be reduced significantly with effectiveness between 58 % to 96 %. The addition of 160 mg of 100 mesh Moringa seed powder into 1L of laboratory wastewater is the most optimal process to reduce organic pollutants in it by 96 %. This is because the protein contained in Moringa seed powder has an amine group (NH_3^+) which acts as a positively charged electrolyte. These positive polyelectrolytes can act as natural coagulants to bind negatively charged non-biodegradable organic pollutant particles in laboratory wastewater so that they are destabilized to form flocs with larger particle sizes and can be deposited. The deposition of these pollutants causes the need for chemical oxygen from the $K_2Cr_2O_7$ reagent which functions as a strong oxidizing agent in the COD analysis process to be less, thus causing the COD number to be small. Research by Desta and Bote (2021) with the addition of 0.6 grams of moringa powder into 500 mL of university wastewater can reduce the COD number by 65.82 %. While in the study of Nonfodji et al. (2020), it was stated that the addition of 320 mg of Moringa oleifera into 1L of hospital wastewater was able to reduce the COD number by 38.36 %, but after being combined with 4.32 mg PAC, Moringa oleifera was able to reduce the COD number by 60.12 %.

The ability of Moringa seed powder to reduce Cu

Heavy metal Cu in USB laboratory wastewater before the coagulation with Moringa seeds was 0.0226 ppm. This means that every 1 liter of USB laboratory wastewater contains Cu heavy metal of 0.0226 mg. After the coagulation with Moringa seed powder 40, 80 and 120 mg/L there was a decrease from 52.65 % to 67.7 %. The greatest decrease occurred in the concentration of moringa seed coagulant 120 mg/L. The complete percentage of Cu reduction is presented in **Figure 4**. The amount of

Table 5. COD of USB laboratory wastewater before and after coagulation.

Coagulant concentration (mg/L)	COD (ppm)	Coagulation effectiveness (%)
0	2750.37	-
40	1150.25	58
80	550.60	80
120	350.20	87
160	100.15	96

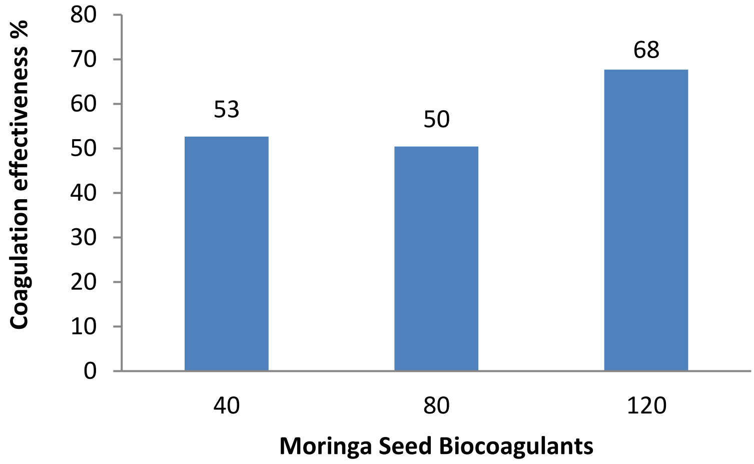

Figure 4. Effectiveness of Cu reduction by Moringa seeds

coagulant of Moringa oleifera seed powder added to wastewater samples affects the formation of flocs by reducing the concentration of heavy metals as pollutants. Jagaba et al. (2021) the addition of 500 mg of moringa oleifera seed powder into a 1L sample of palm oil mill effluent, can reduce Cu by as much as 82.96%. Tan et al. (2017) Moringa oleifera is effective in reducing Cu in river water (98%) and wastewater (90%).

Effectiveness of Fe heavy metal reduction

USB laboratory wastewater contains heavy metal Fe of 0.0073 ppm. After being coagulated with biomoringa powder with various concentrations of 40, 80, and 120 mg/L, the heavy metal content of Fe decreased from 22.66% to 89.33%. The biggest decrease was found in the addition of 80 mg/L Moringa seed biocoagulants. The percentage of the effectiveness of biomoringa powder in reducing heavy metal Fe is presented in **Figure 5**.

Jagaba et al. (2021) the addition of 500 mg of moringa oleifera seed powder into 1L sample of palm oil mill effluent, can reduce Fe metal by as much as 90.41 %. Tan et al. (2017) the addition of Moringa oleifera seed cake can remove all Fe content in river water and wastewater.

The ability of Moringa seed powder to reduce phosphate

Phosphate pollutants are present in wastewater, usually in organic form, as inorganic orthophosphate compounds or complex phosphates. In laboratory wastewater, the phosphate comes from the rest of the student practicum. The USB laboratory wastewater sample contains phosphate as orthophosphate of 0.3352 ppm. After the coagulation process with 100 mesh Moringa seed powder biocoagulant there was a decrease in the content in the wastewater. The data are presented in **Figure 6**.

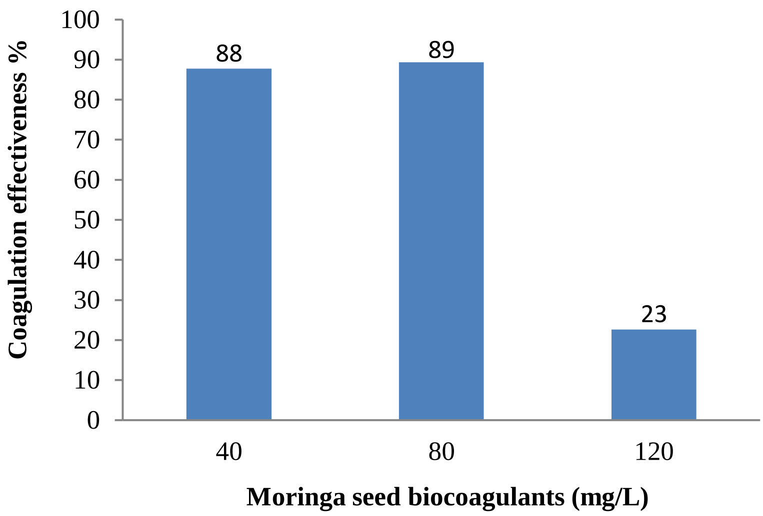

Figure 5. Percentage of effectiveness of Fe heavy metal reduction by Biomoringa

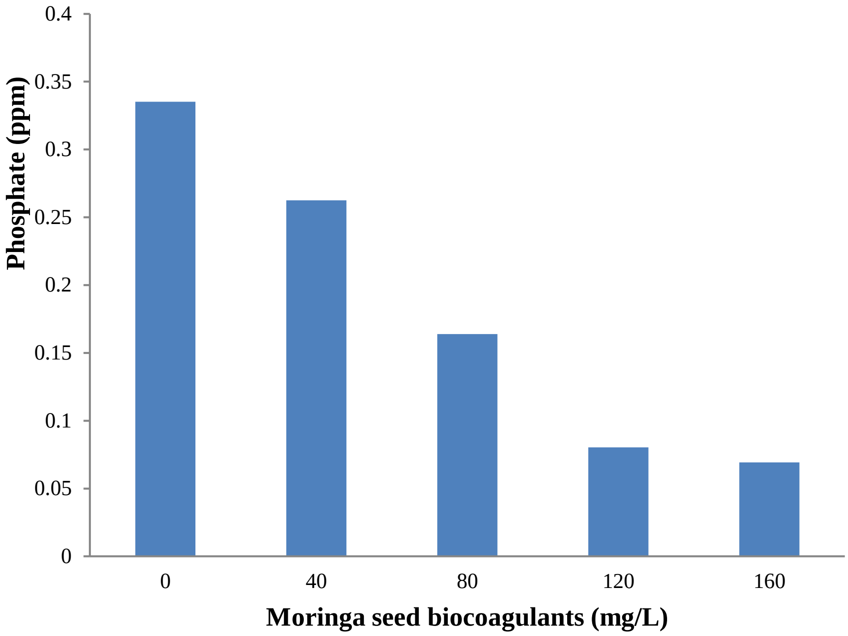

Figure 6. Effectiveness of P-PO_4 reduction by Moringa seeds

Table 6. Anti-bacterial powder of Moringa seed biocoagulants

Bacteria	Concentration	Moringa Seed Powder	
		1	2
E. coli	200 ppm	2.1 cm	2.4 cm
	180 ppm	1.8 cm	1.85 cm
	160 ppm	1.75 cm	1.8 cm
	140 ppm	1.3 cm	1.5 cm
	K (+) Ciprofloxasin 5 μg	3.5 cm	3.5 cm
	K (-) Aquadest Steril	0	0
Bacillus	200 ppm	2.2 cm	2.2 cm
	180 ppm	2.1 cm	2.1 cm
	160 ppm	1.4 cm	1.4 cm
	140 ppm	1.2 cm	1.2 cm
	K (+) Ciprofloxasin 5 μg	4.3 cm	4.3 cm
	K (-) Aquadest Steril	0	0

Moringa oleifera seeds can be used as a natural coagulant which is effective in reducing the phosphorus content of industrial wastewater. The addition of 160 mg of 100 mesh Moringa seed powder into 1L of laboratory wastewater is the most optimal process to reduce phosphate pollutants in it by 79.36 %. Kumar and Kumar, (2021) optimal conditions of 5.8 mL, pH 7, mixing time of 30 minutes, and settling of 30 minutes can achieve a reduction efficiency of 93 %. The use of 475 mg/L of Moringa oleifera Lam presented high efficiency in removing 60% phosphorus in black water (Silva et al., 2021). Moringa seed powder as biocoagulant can reduce phosphate levels at a certain dose. This is due to attractive forces between the –NH3+ group on Moringa seed protein and H2PO4- in wastewater

Moringa seed anti-bacterial powder

100 mesh Moringa seed powder was also tested for antibacterial properties such as *E-coli* and *Bacillus*. The higher the coagulant concentration of Moringa seed biocoagulant powder, the higher the results of laboratory tests obtained for killing *E-coli* and *Bacillus*. The experimental results are presented in **Table 6**.

Based on the experimental results, at a certain concentration, Moringa seed powder can inhibit the growth of bacteria in laboratory wastewater. The sensitivity of Bacillus and E-coli was the same as that of Ciprofloxacin as a positive control. Chemical agents contained in Moringa seed powder will diffuse into the agar medium which can inhibit or kill microbes. The addition of 100-mesh moringa seed powder as much as 140 mg-200 mg per 1 L of wastewater, was able to inhibit the growth of bacillus and E-coli bacteria approaching the positive control of Ciprofloxacin. The larger the dose of Moringa seed powder added, the wider the resistance. The most effective at a concentration of 200 mg/L Moringa seed powder was obtained the diameter (zone) of inhibition of E-coli bacteria around the disk was 2.4 cm and Bacillus was 2.2 cm. This zone of inhibition includes Resistance.

CONCLUSIONS

Characteristics of Moringa seed powder with a size of 100 mesh with SEM-EDX test and 5000x magnification has a particle size of 5 m or 5000 nm. Meanwhile, the BET-BJH test has a surface area of 14.519 m^2/g, a total pore volume of 0.026 cm^2/g, and an average pore size of 17.055. Moringa seed biocoagulants also contain 28.63% protein, 7.44 % moisture, and 3.69 % ash contents.

The biocoagulant can reduce the number of pollutant parameters in laboratory wastewater with a good percentage of effectiveness. Optimization of biocoagulants varies in reducing the number of pollutant parameters. Optimal TSS reduction at a concentration of 80 mg/L with effectiveness of 81.01%. Color reduction at a concentration of 120 mg/L with effectiveness of 52.96 %. The decrease in COD and P-PO_4 at a concentration of 160 mg/L biocoagulants has an effectiveness of 96.36 % and 79.36 %. The decrease in Cu was 67.7 % with the addition of 120 mg/L biocoagulants and 89.33 % Fe decreased with the addition of 80 mg/L biocoagulants. It also has the anti-bacterial power of E-coli and Bacillus with the addition of a biocoagulant of 200 mg/L.

SUGGESTIONS

Further research is needed to reduce the particle size to nano size by chemical or physical activation

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