The use of Moringa Oleifera Seed Powder as Coagulant to Improve the Quality of Wastewater and Ground Water

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Abstract. Wastewater and ground water treatment are mostly using Polyaluminum Chloride (PAC), a synthetic coagulant, which possess health risk and require expensive cost. This research was carried out to observe the effect of Moringa oleifera seed as natural coagulant to replace synthetic coagulant. M. oleifera reduced 98.6% turbidity of wastewater, 10.8 % of its conductivity, 11.7% of its BOD and removed its metal contents (Cd, Cr, Mn). When applied to ground water, M. oleifera removed the turbidity of ground water as much as 97.5%, while reduced the conductivity and BOD of ground water 53.4 % and 18%, respectively. The use of M. oleifera also reduced total number of coliform. The advantage of using M. oleifera is that it does not reduce pH as PAC, hence does not require further treatment to adjust pH of the treated water.

1. Introduction

Water is an important resource for life. Entire living organisms on earth need water for life. However, water can be problematic if it is not available in the right conditions. Water is used by human for various purposes, therefore the cleanliness of water consumed is very important since water is known to affect the health. Today, the quality of water becomes a major problem that needs serious attention. Good quality water has become an expensive item, because many water sources has been polluted by waste coming from the various human activities. This leads to declining quantity of water sources that could not meet the ever growing need.

In the provision of clean drinking water, besides the quantity and continuity, the quality must meet the applied standards. The ideal water should have some characteristics such as clear, colorless, tasteless, odorless, pathogen-free, harmful chemical-free and non-corrosive. Water is also expected not to leave sediment in all distribution organs. This standard was set to prevent the occurrence and the spread of waterborne diseases.

To achieve this standard, there is one common technique applied in water treatment process, which is coagulation-flocculation. Coagulation is the process of coagulating colloidal particles due to the addition of synthetic materials to neutralize charged particles thus forming a precipitate due to the force of gravity. Coagulant can be synthetic materials such as ferrous sulfate (Fe(SO₄)), aluminum sulfate or alum (Al₂(SO₄)₃), and Poly Aluminum Chloride (PAC) (Al₃(OH)₂Cl)₁₀.
Coagulation is one of the most common ways to reduce the pollutant contents in the water body that are present as turbidity, color and organic matters. Coagulation is also used to reduce the metal ion content in water. Separation of these colloids can be done by the addition of synthetic coagulant or biocoagulant followed by slow agitation (flocculation) that causes coagulation of colloidal particles so they can be separated by sedimentation [1].

The common methods of water purification using synthetic materials such as aluminum sulfate (alum) and calcium hypochlorite are not efficient, because these materials are imported and thus make the water cost becomes relatively expensive in most economically developed countries and is not affordable for most rural population. Therefore, some people try to get the water source from dams, mining, small streams, rivers, and lakes. Water from these sources is usually turbid and contaminated with microorganisms that may cause various diseases.

Several findings from previous research in Postnote (2002) demonstrated the use of synthetic materials for water purification can be severely hazardous to health if something goes wrong in their treatment during processing [2]. The report considered the high level of aluminum in the brain is a risk factor causing Alzheimer's disease. Other studies have raised doubt about the feasibility of inserting aluminum into the environment by the use of aluminum sulfate as a coagulant continuously in the water treatment process. However, Davis (2006) found no conclusive evidence about the correlation between aluminum and Alzheimer's disease [3].

Besides synthetic chemicals, there are natural ingredients that can be derived from tropical plants which can be used as coagulants, including moringa seeds (*Moringa oleifera*). The use of natural ingredients from local indigenous plants to clear muddy water is not a new idea [4]. From existing reports, there were allegations that the powder of Moringa seeds has antimicrobial properties. Previous research found that Moringa is not toxic [5] and recommended for use as a coagulant in developing countries. Various studies have been conducted and showed that moringa seeds are effective as biocoagulant to improve physico-chemical properties of contaminated water. *M. oleifera* functions as coagulant trough adsorption and neutralization mechanisms [6]. *Moringa oleifera* is potential as organic pollutant absorber in simulation solution [7]. *M. oleifera* is reported able to eliminate the turbidity and dissolved organic matters of river water [8]. Damayanti *et al.* (2011) made a membrane consisted of *M. oleifera*, PAC and zeolite for palm oil effluent treatment [9].

Indonesia is rich in biodiversity, and moringa tree can grow well, easy to find and easy to cultivate in various regions. Therefore it is not difficult to use Moringa seeds as a natural coagulant or biocoagulant for water clarifying process. The use of natural coagulants in water treatment process is expected to provide more advantages than the use of synthetic materials because they are natural and reported as safe to be consumed. The cost of using natural coagulants will be less expensive than that of alum. Effectiveness of natural coagulant for water purification will be tested also in the wastewater treatment process. Therefore, research should be conducted to find out the effectiveness of moringa seed in improving water quality. Water quality parameters that need to be investigated are including turbidity, electrical conductivity, pH and temperature, metal absorbing capability, and ability to decrease microbial content.

2. Methods

2.1. Sample Collection

Wastewater samples were taken from a textile industry in Karawang. Wastewater sampling was conducted in March, April and May 20??, where the company is in normal production period. Wastewater samples were taken from the equalization basin. Groundwater samples were taken from a well in Pamulang. Analysis was conducted at the Research Laboratory, Center for Integrated Laboratory, Syarif Hidayatullah State Islamic University Jakarta.

2.2. Materials and equipment

Materials used in this study were the test substance (sample) and chemicals. Wastewater test material was taken from a textile industry in Karawang and ground water was taken from the
Pamulang, *Moringa oleifera* seeds were taken in March 20??, in Pasawahan, Purwakarta. The chemicals used were Poly Aluminum Chloride (PAC) brand Kuriflock concentration of 100 mg/L, Single Strength Lactose Broth (Merck), Double Strength Lactose Broth (Merck), oxygen-alkali iodide azide reagent Sodium Iodide (NaI) as an oxidant, sodium thiosulfate (Na$_2$S$_2$O$_3$) 0.025 N (Merck), sulfuric acid (H$_2$SO$_4$) 6 N (Merck), manganese sulfate (MnSO$_4$) 4 M (Merck), and starch indicator.

The instruments used were pH meter (Myron L ARH1), digital thermometer, portable conductometer (Myron L ARH1), portable turbidity meter (HANNA Instrument), Atomic Adsorption Spectrophotometer (Perkin Elmer), magnetic stirrer (Cymarec*2), cuvet, durham tube and glasswares.

![Research Flowchart](image)

**Figure 1.** Research Flowchart

### 3. Results and Discussion

In the wastewater and groundwater treatment process using *M. oleifera* as coagulant, the optimum dose required to treat the wastewater and ground water is different. This can be seen in Table 1, a dose of 100 mg/L gave the best result for the wastewater as the treated water showed the lowest value of turbidity, closest pH value to 7, and the lowest value of conductivity. While the ground water needed 80 mg/L of coagulant. This showed that the optimum dose of *M. oleifera* as coagulant was influenced by the level of the initial turbidity of the water to be processed. The optimum dose to treat water with initial turbidity around 300 FTU (wastewater) is 100 mg/L or higher. The lower the initial turbidity, the lower the optimum dose. Excessive coagulant addition will not cause turbidity to disappear until the lower limit. Determination of optimum dose can be done by the lab-scale Jar Test method.
Table 1. Effect of coagulant addition to the tested parameters of the sample

| Tested Parameter | Wastewater | Ground Water |
|------------------|------------|--------------|
|                  | Control    | PAC (100 mg/L) | PAC (100 mg/L) | Control |
|                  |            | M. oleifera (80 mg/L) | M. oleifera (80 mg/L) |            |
| Temperature (°C) | 28.27      | 28.66         | 28.83         | 28.40     | 28.90     | 28.90     | 29.00     |
| Turbidity (FTU)  | 85.79      | 32.19 (89.6% reduction) | 6.75 (97.9% reduction) | 4.913 (98.6% reduction) | 49.92 (89.4% reduction) | 5.44 (97.5% reduction) | 6 (97.4% reduction) |
| pH               | 5.10       | 4.83          | 5.67          | 6.20      | 6.96      | 5.21      | 7.38      | 7.42      |
| Conductivity (µS)| 1109.70    | 1906.30       | 1052.50       | 1004.65 (10.8% reduction) | 227       | 238.70 (53.4% reduction) | 219       | 216.35    |

3.1. The effect coagulant addition to water temperature

The addition of powdered moringa seed (M. oleifera) and the PAC as a coagulant in wastewater treatment processes and water purification did not significantly affect the temperature. The initial temperature of the wastewater samples was 28.27 °C and the highest temperature after the addition of coagulant was 29 °C. While the initial temperature of ground water sample was 28.40 °C and the highest temperature after coagulant addition was 29.00 °C. The use of coagulant in water treatment process did not drastically change the temperature. Temperature of each sample was still in the normal temperature range for water.

3.2. The effect of the use of M. oleifera to water turbidity

Table 1 shows that the optimum concentration of M. oleifera coagulant to reduce wastewater turbidity was 100 mg/L, while the ground water only need 80 mg/L of Moringa oleifera, which reduced 97.9% and 97.5% turbidity, respectively. M. oleifera coagulant has better coagulation capability to reduce water turbidity compared with PAC at concentration of 100 mg/L that was able to reduce turbidity by 89.6% in wastewater and 89.4% in ground water.

The highest turbidity value in wastewater after coagulation process using M. oleifera was 6.75 FTU and the lowest turbidity value was 4.913 FTU. Meanwhile, the highest turbidity value in ground water after coagulation process using M. oleifera was 5.44 FTU and the lowest was 6 FTU. When M. oleifera concentration exceeded the optimum dosage, turbidity raised up because all colloids have been neutralized and precipitated with an optimum dosage, so the excess coagulants will cause turbidity in water as they did not interact with oppositely charged colloidal particles.

Turbidity in the water is caused by suspended solids, both organic and inorganic substances. Inorganic substances include crack of rock, sand, mud, and dissolved metals. Organic matters originating from domestic and industrial waste could serve as good environment for bacteria to grow. Besides microorganisms, algae and plankton can also cause cloudiness in the water.

When the coagulant was added to the sample and followed by rapid stirring, the resulting cationic protein from M. oleifera was distributed to all parts of the liquid and then interacted with the negatively charged particles that caused dispersed turbidity. Such interactions disturb the force that stabilize the particles, so that it can bind to small particulates to form precipitate. This process is called
coagulation. An additional advantage in this case is, that all the mud that comes from grain coagulation *M. oleifera* is biodegradable and is an organic material. Unlike alum, coagulation activity is strongly influenced by the natural alkalinity of the water itself. So it is necessary to add material, such as lime, to increase alkalinity or pH of the water that will be coagulated using alum. As a result, the sludge that is produced through this process has a larger volume than the one produced by the coagulant *M. oleifera* seeds.

### 3.3. The effect of *M. oleifera* usage to water pH

The degree of acidity (pH) is one of the most important factors affecting the coagulation process. When the coagulation process is not carried out at optimum pH range, it could lead to failure of the floc formation and poor quality of water produced. The optimum pH for each coagulant is different. Specific coagulant will not work optimally in more acidic or more alkaline environment than the optimum pH value. Based on the analysis, the optimum pH obtained using *M. oleifera* biocoagulant is at pH 6-8. At this value, amino acids ionize to produce carboxylate ion and proton, proton charge attracts electrons (colloids) to form neutral group and then produce floc [10].

Recommended pH range for water by WHO (2006) is between 6.0 and 8.0 [11]. The treatment was performed in the range of 4.83 to 7.42 which increased by increasing the coagulant dosage. The pH of 100 mL of distilled water increased from 7.6 to 8.28 mg after the addition of *M. oleifera* powder. This can be explained by the fact that the solution becomes more alkaline due to the ability of *M. oleifera* as a coagulant lies in the presence of cationic water-soluble protein found in its skin and seeds. This causes the acceptance of protons in water by the alkaline amino acids present in *M. oleifera* protein that results in the release of hydroxyl groups which make the solution becomes alkaline [12].

In the sample that used the PAC as coagulant, the pH will be more acidic with the addition of coagulant dosage. During water treatment process, alum produces acid which in turn lower the pH. Increased acidity may occur due to the aluminum trivalent cation that act as Lewis acid and accept lone electron pairs [4] In the synthetic coagulant (PAC), a decrease of pH was caused by the presence of free hydrogen ions (H\(^+\)) generated from the hydrolysis reaction, which is when the coagulant reacts with water. Generally, the higher the amount of coagulant, the higher the decrease of pH.

### 3.4. The Effect of *M. oleifera* Usage on Conductivity

Conductivity in water is vary widely. The solubility of minerals in different geographic regions also varies. There is no standard value but high level of conductivity is not allowed in drinking water for consumers [12]. Table 1 shows that the optimum dosage of *M. oleifera* to decrease conductivity was at 100 mg/L. At this concentration, *M. oleifera* reduced 10.8% conductivity of wastewater and 53% conductivity of ground water. Compared with the initial conductivity, the addition of a coagulant in wastewater and ground water made the conductivity value down to 1109.70 μS/cm and 227 μS/cm, respectively. The decline of conductivity value was affected by the initial conductivity value. Initial low conductivity value decline larger than the higher initial conductivity value. However, the excess use of *M. oleifera* beyond optimum dosage made conductivity value rise again due to the presence of unbound ions.

Table 1 shows increasing conductivity value with the addition of coagulant PAC, from 1109.7 μS/cm to 1906.3 μS/cm. Whereas initial conductivity in the control of ground water was 227 μS/cm and after the addition of PAC was 238.6 μS/cm. High conductivity value was determined by the presence of mineral ions and dissolved inorganic compounds. The addition of coagulant *M. oleifera* may result in the dispersion of some mineral ions and inorganic compounds into a floc which will then be precipitated and separated from the solution. This caused the reduction of electrical conductivity.

The addition of coagulant PAC increased the conductivity of water due to the reaction of water with acidic or alkaline metals. Water can also react with salt which will cause the rise of conductivity value. Another reason is the inorganic compounds that dissociate in water, which contribute to water’s ability to conduct very large electric current. Conductivity or electrical conductivity of water depends on the concentration of ions in water. In the coagulation process,
moringa seeds give little effect on the degree of acidity and conductivity. *M. oleifera* seed solution reacted as positively charged natural polymer coagulant.

### 3.5. The Effect of *M. oleifera* Usage in Metal Level

There have been many efforts conducted by scientists to reduce the concentration of dissolved metals in the environment. One of them is coagulation process. The observed metals in this study were Cd, Cr, and Mn. Cd and Cr metals components of dying agents used in textile industries, while Mn are found in the groundwater. Determination of metal content in this study was carried out by using Atomic Absorption Spectroscopy. The result can be seen in Table 2.

**Table 2.** The effect of coagulant addition on the metal level

| Tested Parameter | Wastewater | Ground Water |
|------------------|------------|--------------|
|                  | Control    | **PAC** (100 mg/L) | **M. oleifera** (80 mg/L) | Control | **PAC** (100 mg/L) | **M. oleifera** (80 mg/L) |
| Mn (mg/L)        | 6          | 0.092         | -                        | -       | 0.594             | -                        |
|                  | 6          | 0.024         | -                        | -       | 0.092             | -                        |
| Cd (mg/L)        | 6          | -             | -                        | -       | 0.092             | -                        |
| Cr (mg/L)        | 6          | -             | -                        | -       | 0.092             | -                        |

Tabel 2 shows that the addition of coagulants can reduce the level of metals in wastewater significantly. The addition of *M. oleifera* coagulant decreased the Cd metal content from 6 ppm to undetectable, whereas PAC coagulant decreased the Cd content from 6 ppm to 0.024 ppm (99% reduction). Cr content was decreased from 6 ppm to undetectable with the addition of *Moringa oleifera* and PAC. The addition of *Moringa oleifera* lowered the Mn content from 6 ppm to undetectable, whereas the addition of PAC lowered the Mn content from 6 ppm to 0.092 ppm (98% reduction). The presence of dissolved Cd and Cr metals was not detected in tested ground water. Dissolved Mn amount in ground water is 0.594 mg/L. After the addition of *M. oleifera* coagulant, it became undetectable. Meanwhile, Mn level decreased to 0.265 after the addition of PAC (55.4% reduction).

This study proved that the coagulant may reduce level of metals in the wastewater. This could be due to the addition of a coagulant that will form flocs and pull those metals into the flocs. Chemical wastewater treatment is usually performed to remove particles that are not easily precipitated (colloidal), including heavy metals. With the addition of coagulant, removal of such materials in principle takes place through changes in the properties of these materials, which can be precipitated from not easily deposited (coagulation-flocculation), either with or without oxidation-reduction reactions, and also takes place as a result of the oxidation reaction. Decreased levels of these metals may also occur because of *Moringa* amphoteric protein binds to the oppositely charged metal ions-binding compounds, which causes the metal ions to precipitate. Alkaline pH generated by the addition of *Moringa* also allows the positively charged metal ions to precipitate as insoluble metal hydroxides due to the release of OH groups of *M. oleifera*. This is supported by the fact that in the treatment without coagulant, to precipitate the metal is done by applying a solution of alkali (eg. lime) to form hydroxide precipitate of the metals. Precipitated metal will be more stable if the pH of water is above 10.5. This of course is not effective in the treatment of wastewater and ground water because it will require additional process to lower the pH value.
3.6. The Effect M. oleifera usage on Total Coliform

More than 80% of diseases in tropical areas are caused by the use of unclean water. The presence of coliform in surface water, such as ground water, comes from poor sanitation [13], while the presence of microbes in the wastewater comes from biological treatment of wastewater treatment processes. This process involves decomposing bacteria to decompose organic compounds in wastewater. The use of water for consumption without prior treatment can cause serious illness that spread through the water (serious water-borne disease).

Processing the water by coagulation using M. oleifera as natural coagulant showed that the treatment with M. oleifera provided additional advantage of reduced total microbes (Table 3). M. oleifera treatment reduced e-coli values by 80% in wastewater treatment. While the use of M. oleifera in ground water treatment reduced microbial content by 45%.

With proper mixing, the moving particles will enlarge and form flocs that tend to fall to the bottom of the vessel due to gravity. This confirms the effectiveness of Moringa as coagulant for the purification of dirty water. Furthermore, the decrease in total coliform number was also affected by alkaline condition generated by Moringa. Most microorganisms grow well at pH 6.0-8.0, but some of them can grow well at pH 3 (acidophiles) and at pH 10.5 (alkaliphiles). Coliform bacteria are facultative anaerobic microorganisms that can grow in aerobic environments and in fermentation condition that produces lactic acid. Therefore these bacteria can still grow at low pH environment, coliform bacteria can still grow, but they can not survive alkaline pH [14]. The addition of Moringa as coagulant affect the increase in pH which in turn stop them from growing.

M. oleifera seeds also have bactericidal activity, which have been proved by Oluduro and Aderiye (2007) in their research. Bacterial species S. faecalys and P. aerugenosa which were cultured in water, stop growing back after M. oleifera seeds were added. When the seeds of M. oleifera are crushed and dissolved into the water, protein produces a positive charge that acts like a magnet and attracts dominant negatively charged particles such as clay, silk, and other toxic particles. This is in accordance with the invention of Schwarz (2000) that the flocculation process removes about 90-99% of bacteria that are usually attached to solid particles, so the bacteria will be aggregated together to form flocs and can be removed from the water [19].This suggests that bacteria in water were not only inactivated in a dormant state, but also were killed. M. oleifera removes both gram negative and gram positive bacteria [20-21].

Table 3. The effect coagulant addition on total coliform, DO and BOD of Wastewater and ground water.

| Tested Parameter | Wastewater | Ground Water |
|------------------|------------|--------------|
|                  | Control    | PAC (100 mg/L) | M. oleifera (100 mg/L) | Control | PAC (100 mg/L) | M. oleifera (100 mg/L) |
| Total Coliform (MPN/100ml) | >1100 | 1100 | 210 (80% reduction) | 28 | 20 | 11 (45% reduction) |
| DO (mg/L) | 14 | 12.4 | 11.2 | 10.8 | 10 | 8.4 |
| BOD (mg/L) | 6.8 | 6.3 | 6 | 6.4 | 6.2 | 5.2 |

3.7. The Effect of M. oleifera Usage on Dissolved Oxygen

Contaminants in industrial wastewater of textiles consist of organic and inorganic materials that are dissolved or dispersed in water and coarse solids, like the residue of the fiber and yarn. Textile dyes from organic or inorganic compounds can also cause an increase in the BOD. Solute removal originated from textile dyes in wastewater will reduce its BOD.

Table 3 shows that the addition of coagulant can affect the decline of dissolved oxygen in wastewater and groundwater. The addition of 100 mg/L M. oleifera in control wastewater reduced
20% DO from 14 mg/L to 11.2 mg/L. The addition of PAC decreased the DO content by 11.5%. In groundwater, *M. oleifera* lowered 22% DO value from 10.8 mg/L to 8.4 mg/L. PAC only decreased 8% of DO value. The level of biological oxygen demand (BOD) also declined 11.7% from 6.8 mg/L to 6 mg/L in the control wastewater after the addition of *M. oleifera*. Meanwhile, PAC decreased the BOD level by 7%. The addition of *M. oleifera* as coagulant into ground water decreased 18% of BOD level from 6.4 mg/L to 5.2 mg/L, whereas the addition of PAC was only able to decrease the BOD level by 3%. The addition of coagulant decreased the DO level due to the increase in inorganic (PAC) and organic (*M. oleifera*) substances which cause increased oxygen needs to oxidize these substances.

3.8. General Discussion

In the wastewater and groundwater treatment process using *M. oleifera* as coagulant, the optimum dose required to treat the wastewater and ground water is different. This can be seen in Table 1, a dose of 100 mg/L gave the best result for the wastewater as the treated water showed the lowest value of turbidity, closest pH value to 7, and the lowest value of conductivity; while the ground water needed 80 mg/L of coagulant. This showed that the optimum dose of *M. oleifera* as coagulant was influenced by the level of the initial turbidity of the water to be processed. The optimum dose to treat water with initial turbidity around 300 FTU (wastewater) is 100 mg/L or higher. The lower the initial turbidity, the lower the optimum dose. Excessive coagulant addition will not cause turbidity disappear until the lower limit. Determination of optimum dose can be done by the lab-scale Jar Test method.

Compared with Indonesian regulation number KEP-51/MENLH/10/1995 on Standard Quality of Liquid Waste for Industrial Activities, the result achieved by this research is safe to be use. The standard quality for pH ranges from 6.0 to 9.0. The pH score after the addition of coagulant were 6.2 and 7.38. The standard quality of BOD is 60 mg/L, while the coagulation process gave 5.2 mg/L and 6.2 mg/L. Maximum levels of Cr, Cd, and Mn permitted in the industrial waste are 0.5 mg/L, 2 mg/L, and 2 mg L, respectively, whereas the result of using *M. oleifera* treatment was undetected.

Several scientific studies suggested that *Moringa* seeds could serve as coagulant because it contains low molecular weight water soluble protein [15-16]. Protein will be positively charged when dissolved in water [17]. Protein will act as positively charged synthetic materials [18] and can be used as synthetic polymer coagulant. Therefore, *Moringa* can be called as a coagulant. Since this coagulant is derived from plants and without any synthetic process, it is also called natural coagulant or biocoagulant. The most likely mechanism that occurs in the coagulation process is the adsorption and neutralization of the voltage or adsorption and bonding between unstable particles. It is difficult to determine which mechanism that occurs because both mechanisms may occur simultaneously. But, the most common mechanisms of coagulation that involves *Moringa* seeds are the adsorption and voltage neutralization [19]. When *Moringa* seeds that have been processed (powder) were poured into the dirty water, the protein in the seeds will bind the negatively charged particulates that cause turbidity, such as clay, bacteria, dust, and others. Thus, the particulates are collected and agglomerated into larger molecules, which will settle to the bottom, then it will be easy to separate the water and contaminant.

4. Conclusion

*Moringa oleifera* was proven to be able to be used for textile wastewater treatment and purification of groundwater. *M. oleifera* can be used in the coagulation process because it has properties as a natural coagulant. Our result suggested that *M. oleifera* is effective at the concentration of 80 to 100 mg/L as a coagulant to treat wastewater from textile industry and ground water. *M. oleifera* optimum coagulant dose is also influenced by the initial state of the sample to be coagulated. The heavier the burden of pollution, the higher the optimum dose that is needed.
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