The Use of Moringa Seeds and Potassium Alum to Improve the Quality of Well Water into Drinking Water

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Abstract*. Water is a basic need of living things that is very important to maintain its quality so that it does not cause problems. The method that can be used to improve water quality is to carry out the coagulation method using moringa seed coagulant (Moringa oleifera) and potassium alum which has been proven to be able to improve the quality of water. Both coagulants can reduce the following parameters, Turbidity by reducing TDS measured using a digital TDS meter (±0.1 ppm accuracy) with measurement procedures in accordance with APHA 2510 standards, neutralizing pH measured using a pH meter with measurements in accordance with SNI 6989.11-2004 standards, reducing dissolved metal content (Fe and Ni), where Fe is measured using the Atomic Absorption Spectrophotometry (AAS) method based on the SNI 6989.84-2019 standard, while Ni is tested using UV Spectrophotometry in accordance with the APHA 2018 section 4500-NO3B standard, and color is tested spectrophotometrically in accordance with the SNI 6989. 80.2011, and reduce microorganisms contained therein, such as E. coli bacteria which was tested using membrane filtration techniques in accordance with APHA 2017 standard section 9222-J. The results of this study indicate that both coagulants can reduce the TDS parameter value by 5.13%, turbidity by 100%, iron content by 90%, E. coli by 100%, color by up to 90%, and pH by 22.22% in the water sample which is below the maximum limit or in accordance with drinking water quality standards while the nitrate parameter was successfully reduced by 53.8% but was not yet below the maximum level. The optimum coagulant concentration (moringa seed and potassium alum) to improve the quality of well water into drinking water is 2.5 ppm (ppm: mg coagulant/L water sample) with an optimum residence time of 4 weeks.*

Keywords*: Coagulation–flocculation, Drinking water quality, Moringa oleifera seed, Potassium alum, Well water treatment*

1. Introduction

Water is a basic need that cannot be separated from human life and has an important role in supporting the survival of living things. Therefore, water resources must be maintained in order to provide benefits for living things on earth (Aslamiah, Yulianti & Jannah, 2013). The quality of water that is suitable for consumption can be seen based on chemical, biological, and physical properties. These three parameters are water quality standards that absolutely must be met to be suitable for consumption so that it is not harmful to health (Harahap, Sirait & Lubis, 2023). These health hazards are caused by the presence of harmful pathogens and toxic chemicals in the water consumed. So, it is very important to ensure the So, it is very important to ensure the appropriateness of the water to be consumed(Harahap, Sirait & Lubis, 2023). So that water that is suitable for consumption can also be used in various activities as life support (Sutapa, 2009).

One way that can be done to ensure the feasibility of water which aims to improve the quality of the water so that it is suitable for consumption is by coagulation. Coagulation is the process of precipitating contaminants or water contaminants using both chemical and biological coagulants (Aprilianti & Wahyudin, 2020). Some materials that are often found in everyday life that can be utilized as coagulants are moringa seeds and potassium alum. Moringa plants are plants that are widely used for their leaves but moringa seeds are rarely utilized and often become waste, while potassium alum is a salt group chemical compound that is often used to clean turbid water and the price is very cheap (Saina, Lukman & Elyanovianti, 2024). These two things are one of the reasons for using moringa seeds and potassium alum to improve water quality to make it suitable for consumption (Mursitaningrum, Fricilia & Adhani, 2024).

Moringa seed (Moringa oleifera) is a natural coagulant material that has great potential in water treatment due to its positively charged protein content (Ekoputri et al., 2024). These proteins act as active cationic compounds capable of interacting with negatively charged colloidal particles in water (Tsoutsa et al., 2024). This interaction produces flocs, which are particle aggregates that facilitate the process of settling and removing water turbidity. In addition, Moringa seeds also contain natural polyelectrolytes that neutralize the charge of particles, making the process of separating impurities more efficient (Khettad et al., 2021).

Moringa seeds also act as an effective coagulant due to the active substance 4-alpha-4-rhamnosyloxy-benzyl- isothiocyanate contained in moringa seeds (Rustiah & Andriani, 2018). The active substance is able to adsorb wastewater particles. By changing the size to a very small size, the active substance derived from moringa seeds will be more and more because the surface area of moringa seeds has a wider contact area. Moringa seeds can be used as one of the locally available alternative natural coagulants. The moringa seeds used are left until they are ripe or old on the tree then harvested after drying with a moisture content of approximately equal to 10%. According to research reported that moringa seed flour is a natural material that can clean wastewater relatively as effective as cleaning using chemicals (Bangun et al., 2013).

Chemical coagulants such as alum ($Al_2(SO_4)_3$) have long been used in water treatment due to their ability to work in a variety of water conditions (Irmayana, Hadisantoso & Isnaini, 2017) Its mechanism of action involves a hydrolysis reaction that produces aluminum hydroxide (Muthmainna, Hafsan & Hala, 2021). This aluminum hydroxide acts as a flocculating agent, where suspended particles in water combine to form large flocs that settle easily. With this mechanism, potassium alum is able to significantly reduce turbidity and other small particles that are difficult to filter (Saputra, 2024). In addition to having high effectiveness, potassium alum is also easy to find on the market, so it is often the first choice for large-scale water treatment, such as in drinking water treatment plants and industrial waste (Dulanlebit, Sunarti & Male, 2020).

The purpose of this study was to evaluate the effectiveness of moringa seeds (Moringa oleifera) and potassium alum as coagulants in improving well water quality to meet potable water standards. This study also aims to determine the effect of variations in coagulant concentration and retention time on changes in various water quality parameters, such as TDS, turbidity, nitrate content, iron (Fe) content, pH, color, and the number of E. coli and total coliforms. Furthermore, this study was conducted to determine the optimal dosage and retention time for each coagulant, while comparing the performance of natural and chemical coagulants to obtain recommendations for more effective, economical, and environmentally friendly coagulants for community well water treatment.

2. Material and Methods

2.1. Tools and Materials

The materials used in the implementation of this research are dried moringa seeds and potassium alum as coagulants, well water sourced on campus 1 UPNVY as sample water, and distilled water. The equipment used are grinder, food dryer, 80 mesh sieve, automatic stirrer, 250ml erlenmeyer, stirrer, dropper pipette, analytical scales, filter paper, glass funnel, 50ml and 100ml measuring cups, TDS (Total Dissolved Solids) meter which also contains EC (Electrical Conductivity) meter in it to measure TDS and conductivity of sample water, pH meter, turbidity meter, 5000ml sample gallon, and 500ml sample bottle.

2.2. Procedure

2.2.1 Pretreatment

The pretreatment step begins with moringan seed crushing and drying. Moringa seeds are pulverized with a blender orgrinder to turn moringa seeds into fine powder. The fine powder is dried using a dryer at 70°C until it reaches a constant weight which indicates the release of water bonds contained in moringa seeds, so that moringa seed compounds become more stable. After the weight of moringa seeds is constant, sieving is then carried out using a sieve shaker with a size of 80 mesh to homogenize the size of moringa seeds. Furthur potassium alum pulverization and sieving is carries out. Aluminum potassium sulfate or potassium alum is ground until smooth to dry using a dryer at 70°C and then sieved with an 80 mesh sieve shaker to get a uniform potassium alum particle size.

2.2.2 Coagulation

A certain amount of water was put into an erlenmeyer and added coagulants (moringa seed powder; potassium alum) with a certain mass to produce concentrations of 0 ppm; 0.5 ppm; 1 ppm; 1.5 ppm; 2 ppm; and 2.5 ppm. The coagulant is then dissolved in water through stirring using a hand mixer until all coagulant particles are dissolved. The coagulant solution was then filtered with filter paper, The filtrate was put into a gallon and 4000 ml of water was added and then homogenized between the coagulant solution and water.

2.2.3 Settling

Gallons containing water and coagulant were precipitated for 2 hours and then sampled each sample water for testing pH, conductivity, TDS, E-coli, total coliform, nitrate levels, and dissolved iron levels. Further testing is carried out periodically for 2 weeks to see if there is a change in the quality of the sample water that has been added to the coagulant.

2.2.4 Sample Testing

Testing of direct parameters was carried out at the Separation and Material Technology Laboratory of UPN "Veteran" Yogyakarta, while indirect parameters were tested at he Center for Environmental Health and Disease Control (B/BTKLPP), located on Jalan Imogiri Timur. Tests on direct parameters included TDS, measured using a digital TDS meter (±0.1 ppm accuracy) with measurement procedures in accordance with APHA 2510 standards, pH analyzed using a pH meter with measurement procedures in accordance with SNI 6989.11-2004, and turbidity measured using a turbidity meter with the USEPA Method 180.1 standard. Testing for the indirect parameter Fe was conducted using the Atomic Absorption Spectrophotometry (AAS) method based on the SNI 6989.84-2019 standard, the color parameter was tested spectrophotometrically in accordance with the SNI 6989.80.2011, the nitrate parameter was tested using UV Spectrophotometry in accordance with the APHA 2018 section 4500-NO3B standard, and the biological parameter of E-coli was tested using membrane filtration techniques in accordance with the APHA 2017 section 9222-J standard.

3. Results

3.1. Preliminary Test

In this study, preliminary tests were carried out to identify potential problems or methodologies and determine the optimal parameters of this study. In addition, the preliminary test was intended to reducing the risk of errors during the research so as to increase the time efficiency and accuracy of the research conducted The following presents preliminary test data on the samples to be tested.

Table 1. Preliminary Test Result of Water Samples

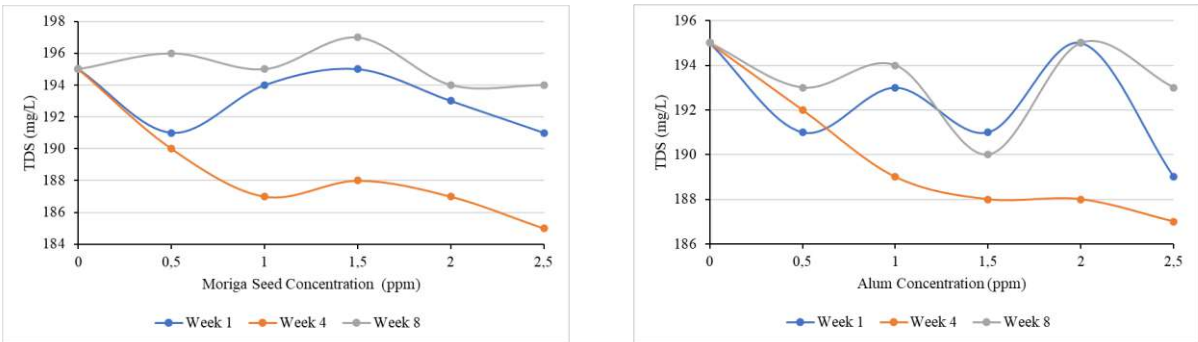
Parameters	Unit	Maximum Level	Test Results	Test Method
Amount of solute (TDS)	mg/L	<300	195	IK/BBTKLPP/3-K/Pj-C-39
Temperature	°C	suhu udara ±3	26.5	SNI 06-6989.23-2005
Turbidity	**NTU**	**<3**	**10,4**	SNI 06-6989.25-2005
Color	**TCU**	**10**	**20**	SNI 6989.80.2011
Smell	-	tidak berbau	tak berbau	In House Methode
pH	**-**	**6.5 – 8.5**	**9**	SNI 06-6989.11-2019
Nitrate (As dissolved NO_3)	**mg/L**	**20**	**64.85**	APHA 2017, Section 4500-NO_3B
Nitrite (As dissolved NO_2)	mg/L	3	0.0886	SNI 06-6989.9-2004
Chromium Valence 6 (Cr^{6+}) (dissolved)*	mg/L	0.01	<0.0066	APHA 2017, Section 3500 B Cr
Dissolved iron (Fe)*	**mg/L**	**0.2**	**0.2**	SNI 6989.84-2019
Dissolved Manganese(Mn)*	mg/L	0.1	0.046	SNI 6989.84-2019
Residual Chlor (dissolved)	mg/L	0.2 – 0.5	<0.03	IK/BBTKLPP/3-K/Pj-C.44
Arsenic (As) (dissolved)	mg/L	0.01	<0,005	IK/BBTKLPP/3-K/Pj-C.38
Cadmium (Cd)(dissolved)*	mg/L	0.003	<0,0009	SNI 06-6989.38-2005
Dissolved lead (Pb)*	mg/L	0.01	<0.0011	SNI 6989.46-2005

Parameters	Unit	Maximum Level	Test Results	Test Method
Dissolved aluminum (Al)*	mg/L	0.2	<0.0086	APHA 2017, Section 3120 B
Flouride (F)*	mg/L	1.5	<0.0110	SNI 06-6989.29-2005
Total Coliform	**CFU/100 ml**	**0**	**30**	APHA 2017 section 9222-J
Escherichia coli	**CFU/100 ml**	**0**	**30**	APHA 2017 section 9222-J

Source: Data displayed form Laboratory Test Result of the Center Ministry of Public Health.

3.2. Parameter Test Result

3.2.1 TDS Test Result



(a) (b)

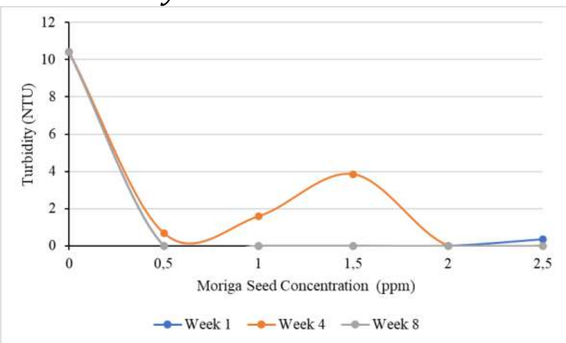
FIGURE 1. Test result of TDS. a)TDS test result of moringa seed coagulant. b)TDS test result of potassium alum coagulant.

The reduction of Total Dissolved Solids (TDS) observed in both Moringa seed and potassium alum treatments indicates that both coagulants were capable of facilitating the removal of dissolved ionic and molecular species through coagulation-flocculation mechanisms. Although the initial TDS value of the raw well water was already below the maximum limit for drinking water (<300 mg/L), a further decrease at 2.5 ppm demonstrates that the application of coagulants can enhance water clarity and stability even under low-salinity conditions. This finding is consistent with previous research, which reported that Moringa seed flour was able to reduce TDS by up to 15–20% in groundwater treatment (Harahap, Sirait & Lubis, 2023).

In week 4, the graph shows that the TDS value tends to decrease as the concentration increases until it reaches the lowest point at a concentration of 2.5 ppm. This value is still far below the maximum limit of TDS in drinking water which is <300 mg/L, in accordance with water quality standards. This decrease in TDS indicates that the treatment at this concentration is effective in reducing solutes in water.

The slight fluctuations in TDS values, particularly at week 8, may be attributed to the re-dissolution of mineral ions after prolonged storage or disturbance of the sediment layer during sampling. Similar trends have been reported in previous studies, which observed that natural coagulants tend to exhibit reduced stability over time due to the degradation of active organic compounds (Sutapa, 2009). In contrast, potassium alum showed slightly higher fluctuations compared to Moringa seed, likely due to the increase in sulfate ions released during potassium alum hydrolysis, as also documented in (Aprilianti & Wahyudin, 2020).

3.2.2 Turbidity Test Result



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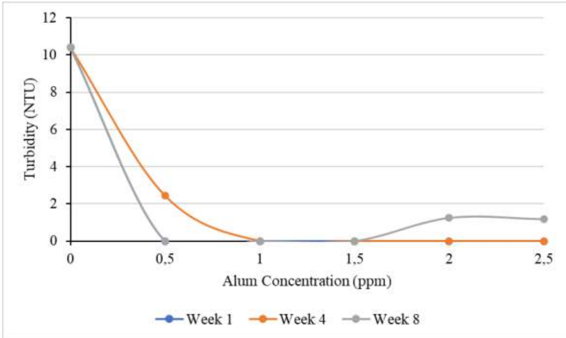


(b)

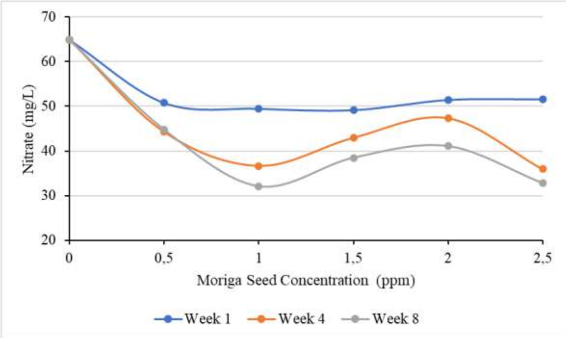
FIGURE 2. Test result of turbidity. a)Turbidity test result of moringa seed coagulant. b)Turbidity test result of potassium alum coagulant.

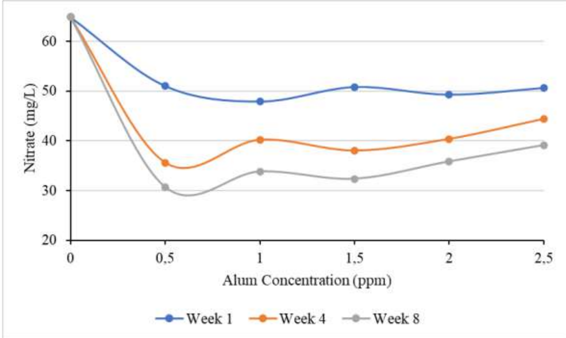
The significant reduction in turbidity from 10.4 NTU to 0 NTU at concentrations of 0.5–2.5 ppm indicates that both Moringa seed and potassium alum were highly effective in removing suspended colloidal particles from the well water. The rapid decrease observed as early as week 1 suggests that coagulation and flocculation occurred almost immediately after coagulant addition. This observation is consistent with the established coagulation mechanism, where positively charged coagulant molecules neutralize negatively charged colloids and promote floc formation (Saina, Lukman & Elyanovianti, 2024).

Interestingly, a slight increase in turbidity at 1.5 ppm for Moringa seed and at 2–2.5 ppm for potassium alum indicates a possible overdosing effect, where excess coagulant molecules may have caused restabilization of colloids or fragmentation of previously formed flocs. Similar phenomena have been reported in previous studies (Mursitaningrum, Fricilia & Adhani, 2024), which emphasized that excessive coagulant dosage can reverse the charge neutralization effect, leading to partial dispersion rather than sedimentation. Despite this fluctuation, all turbidity values remained within the acceptable limit of <3 NTU, confirming that the treatment was effective across all tested concentrations.

When comparing performance over time, week 4 exhibited the most optimal reduction, suggesting that a moderate residence time enhances floc stability. However, a slight increase in turbidity at week 8 indicates possible degradation of organic coagulant components, particularly in Moringa-based treatments. This agrees with previous observations (Ekoputri et al., 2024), which reported that natural coagulants tend to lose flocculating strength after prolonged storage due to microbial activity and oxidation. Nevertheless, the ability to achieve complete turbidity removal at relatively low doses and moderate contact times demonstrates that both coagulants are suitable for household-scale water treatment applications.

3.2.3 Nitrate Test Result





(a) (b)

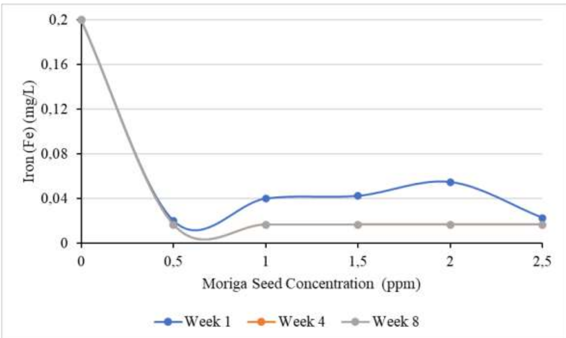
FIGURE 3. Test result of nitrate. a)Nitrate test result of moringa seed coagulant. b)Nitrate test result of potassium alum coagulant.

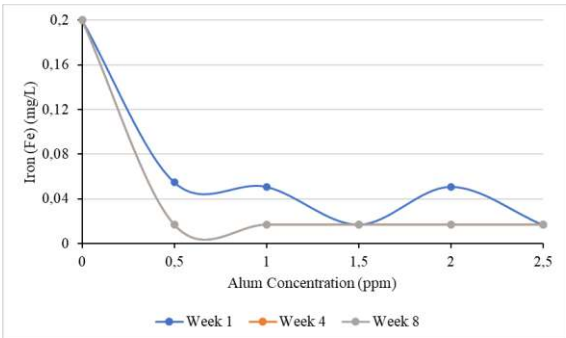
Although nitrate removal was not as optimal as other parameters, with the concentration decreasing only up to 53.85% from the initial value of 66.85 mg/L, the consistent downward trend across increasing coagulant dosages confirms that both Moringa seed and potassium alum possess partial denitrification or adsorption capabilities. The most significant decline was observed at concentrations between 0.5–1 ppm, suggesting that nitrate removal is likely governed more by ion exchange or adsorption mechanisms rather than coagulation alone. This pattern is consistent with previous findings (Tsoutsa et al., 2024), which reported that natural coagulants tend to be more effective in removing charged ions at lower doses, whereas excessive dosages may compete for active sites and consequently reduce performance.

The relatively lower efficiency compared to turbidity and Fe removal can be attributed to the high solubility and mobility of nitrate ions, which are less susceptible to classical coagulation-flocculation processes. Unlike suspended solids or metal ions that easily bind to protein functional groups, nitrate requires specific binding affinity to amine or hydroxyl groups to form stable complexes. Moringa seed contains bioactive compounds such as 4-α-L-rhamnosyloxy-benzyl isothiocyanate, which may play a minor role in nitrate sequestration, but its concentration may not be sufficient to completely neutralize dissolved anions. A similar limitation has been documented in previous studies (Khettad et al., 2021), which reported that nitrate reduction using Moringa seed extract was significantly lower compared to phosphate or Fe removal.

Furthermore, potassium alum exhibited comparable nitrate reduction performance, likely through coprecipitation

3.2.4 Iron Fe





(a) (b)

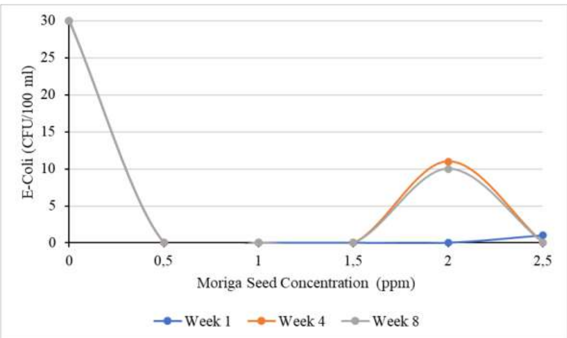
FIGURE 4. Test result of iron. a)Iron test result of moringa seed coagulant. b)Iron test result of potassium alum coagulant.

The reduction of dissolved iron (Fe) from the initial concentration of 0.2 mg/L to 0 mg/L by week 4 demonstrates that both Moringa seed and potassium alum were highly effective in eliminating metal contaminants through adsorption and coprecipitation mechanisms. The absence of fluctuation in Fe levels at weeks 4 and 8 for both coagulants indicates that once metal ions were bound to the coagulant matrix, they remained stably immobilized without redissolution. T This finding is consistent with previous results (Bangun et al., 2013), which reported that Moringa seed powder could reduce Fe concentration by more than 85% in well water treatment, attributing the efficiency to the presence of amino and carboxyl functional groups capable of forming coordination bonds with metal cations.

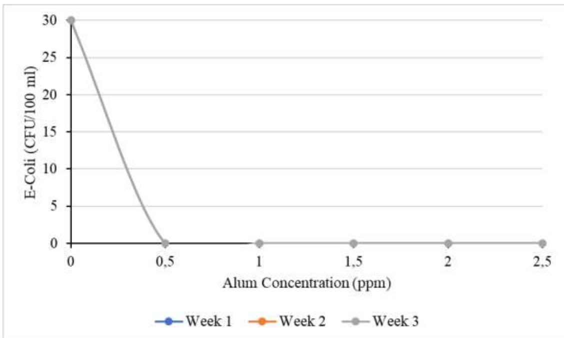
The proteinaceous nature of Moringa seed, which contains cationic polypeptides, facilitates metal chelation through ion exchange, allowing Fe^{2+} or Fe^{3+} ions to be adsorbed onto the surface of macromolecular chains. This mechanism aligns with previous explanations (Irmayana, Hadisantoso & Isnaini, 2017), which highlighted that bio-coagulants act simultaneously as adsorbents and charge neutralizers. In the case of potassium alum, the hydrolysis of $Al_2(SO_4)_3$ produces gelatinous aluminum hydroxide flocs with a high surface area and positive charge, enabling effective scavenging of metal ions through coprecipitation. Similar behavior was observed by Irmayana et al. (2017), who confirmed that potassium alum could reduce Fe and Mn concentrations in textile wastewater to below detection limits.

The decline to complete Fe removal by week 4 indicates that residence time plays a crucial role in enhancing metal-binding efficiency. While initial fluctuations in week 1 suggest that equilibrium between sorption and desorption phases had not yet been fully achieved, the stabilization observed in subsequent weeks confirms that both coagulants possess long-term retention capacity. However, it is noteworthy that Moringa seed achieved similar results without introducing additional sulfate ions to the treated water, highlighting its superiority as a greener alternative compared to potassium alum.

3.2.5 E-Coli Test Result



(a)



(b)

FIGURE 5. Test result of E-Coli. a)E-Coli test result of moringa seed coagulant. b)E-Coli test result of potassium alum coagulant.

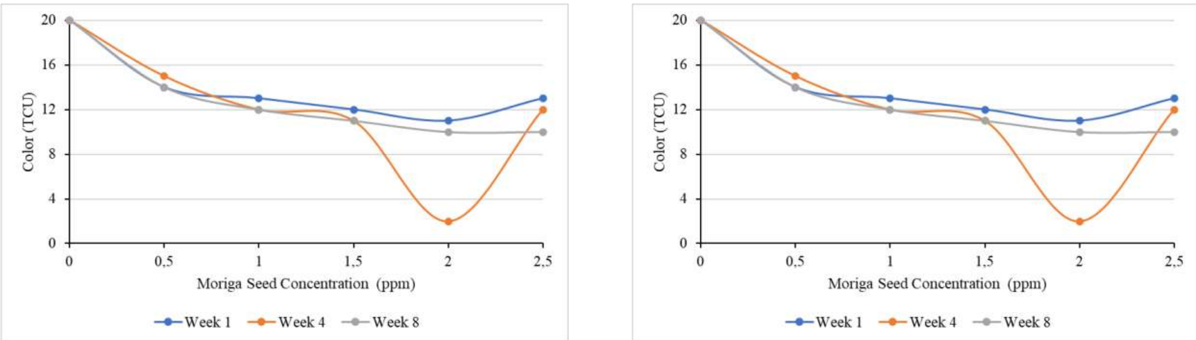
The complete elimination of *Escherichia coli* (E-Coli) from an initial concentration of 30 CFU/100 mL to 0 CFU/100 mL at coagulant dosages as low as 0.5 ppm demonstrates that both Moringa seed and potassium alum possess strong antimicrobial or bio-aggregation properties. This rapid reduction within the first week suggests that coagulation does not only act through physical sedimentation but may also involve biochemical inhibition or entrapment of microbial cells within flocs. Similar results have been reported in previous studies (Muthmainna, Hafsan & Hala, 2021), which observed that Moringa seed extract was able to reduce coliform bacteria to undetectable levels within a few hours of treatment.

The antimicrobial effect of Moringa seed is attributed to the presence of bioactive compounds such as isothiocyanates and phenolic derivatives, which have been reported to disrupt bacterial cell membranes and inhibit enzymatic activity (Saputra, 2024). These compounds likely act synergistically with the cationic proteins that neutralize the negatively charged surfaces of bacterial cells, leading to aggregation and subsequent sedimentation. This dual mechanism of bacteriostatic activity and coagulative removal enhances the overall disinfection performance of Moringa seed beyond mere physical separation.

In the case of potassium alum, bacterial removal is likely achieved through charge neutralization, where microbial cells are captured and precipitated alongside inorganic flocs. However, unlike Moringa-based treatments, potassium alum-treated samples exhibited more stable bacterial suppression over prolonged storage, as indicated by the absence of fluctuations across weeks 1 to 8. This stability may be related to the residual acidity induced by potassium alum hydrolysis, which creates an unfavorable environment for bacterial regrowth. Similar observations have been reported in previous studies (Dulanlebit, Sunarti & Male, 2020), which found that potassium alum-treated wastewater maintained sterility longer than samples treated with bio-coagulants.

The slight fluctuation in E-Coli levels in Moringa-treated water at certain concentrations during weeks 4 and 8 suggests the possibility of bacterial regrowth when organic residues from the coagulant serve as nutrient sources. This limitation has also been noted in previous studies [16], which recommended post-treatment storage under controlled conditions to prevent microbial rebound when using natural coagulants.

3.2.6 Water Color Test Result



(a) (b)

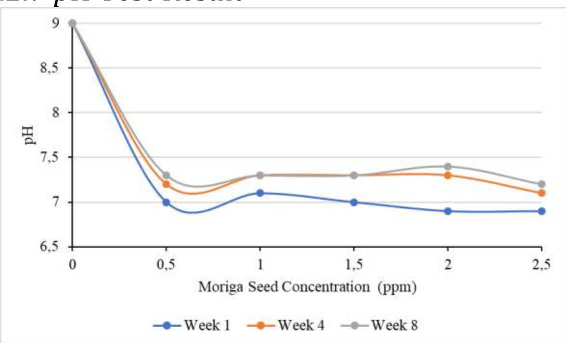
FIGURE 6. Test result of water color. a)Water color test result of moringa seed coagulant. b)Water color test result of potassium alum coagulant.

The reduction of water color from an initial value of 20 TCU to as low as 2–8 TCU demonstrates that both Moringa seed and potassium alum exhibit strong decolorization capabilities. The most notable decrease occurred at concentrations of 2–2.5 ppm, particularly in week 4, indicating that color removal is closely associated with both coagulant dosage and residence time. Since water color is typically caused by dissolved organic matter, humic substances, or metal complexes, the observed reduction suggests that both coagulants were able to effectively adsorb or precipitate chromophoric compounds. This observation is consistent with previous findings [17], which reported that Moringa seed powder reduced color intensity in groundwater by up to 80%, primarily through adsorption and entrapment mechanisms.

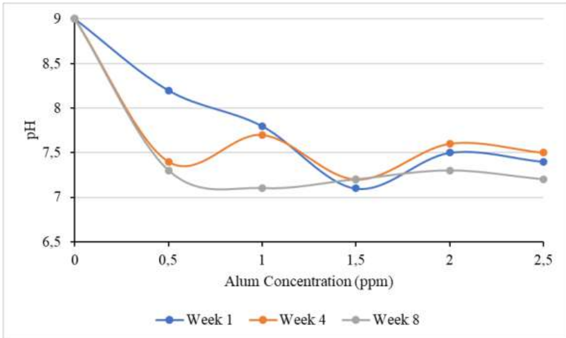
The temporary increase in color observed at higher concentrations in Moringa-treated samples may be attributed to the release of natural pigments or residual organic compounds from the seed material itself, particularly when overdosing occurs. Similar trends have been reported in previous studies [18], which noted that excessive Moringa dosage can contribute to marginal increases in organic load, leading to slight discoloration if not followed by adequate sedimentation. In contrast, potassium alum treatment exhibited less fluctuation, likely due to its inorganic nature and more stable floc formation.

The superior performance at week 4 further suggests that moderate contact time allows sufficient interaction between coagulant molecules and color-causing compounds. However, the slight increase in color at week 8 indicates possible re-solubilization of weakly bound organic molecules or degradation of flocs over extended storage. This aligns with previous observations [19], which emphasized that natural coagulants require optimized settling time to prevent post-treatment leaching of organic residues.

3.2.7 pH Test Result



(a)



(b)

FIGURE 7. Test result of pH. a)pH test result of moringa seed coagulant. b)pH test result of potassium alum coagulant.

The acidity or pH allowed in drinking water ranges from 6.5-8.5. In the preliminary test results, it is known that the acidity of the sample water is at 9, which indicates that the sample water does not meet the drinking water quality standards. Therefore, treatment of sample water is carried out to reduce the acidity of the sample water to meet drinking water quality standards.

From the research that has been conducted, the data shows that the addition of coagulants, both moringa seed coagulant and potassium alum, is proven effective in helping to reduce the acidity of water to comply with drinking water quality standards, which are between 6.5-8.5. All samples with the addition of coagulants, both in the observation results of weeks 1, 4, and 8, experienced a decrease in acidity levels that were in accordance with the quality of drinking water standards. Thus, the optimum residence time and concentration in week 1 with a concentration of 2.5 ppm.

4. Conclusion

The addition of coagulants can improve the quality of well water into drinking water through the coagulation-flocculation process to meet the standard parameters of drinking water standards. The parameters of TDS, turbidity, iron content, E-coli, color, and pH in the sample water have been below the maximum limit for both moringa seed coagulant and potassium alum but the nitrate parameter has not been below the maximum level. The optimum concentration to improve the quality of well water into drinking water is 2.5 ppm with an optimum residence time of 4 weeks. The higher the concentration of coagulant, the more water quality will be, but if the concentration is excessive, there will be an overdose of coagulant so that it will actually reduce water quality. Meanwhile, too long a residence time will cause degradation of the coagulant and a decrease in its effectiveness. Moringa seed coagulant and potassium alum have fairly identical results in improving the quality of the parameters Moringa seed coagulant provides an alternative choice of natural coagulant that is environmentally friendly and more economical.

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