Journal of Green Chemical and Environmental Engineering
e-ISSN 3090-2568
p-ISSN 3109-2233
Research Paper

The Effectiveness of Coagulant Stems and Seeds of Moringa Oleifera in Improving the Quality of Well Water

Rezky Awaliah Rusmah*, Lili Adriani

Department of Chemical Engineering, Faculty of Industrial Technology, Muslim University of Indonesia, Jl. Urip Sumaharjo No.Km 5 Panaikang, Panakukang, Makassar, South Sulawesi 90231, Indonesia

** Corresponding author: Awaliyahrezky@gmail.com (Rezky Awaliah Rusmah)*

Received 25 Jane 2025
Revised 30 July 2025
Accepted 16 Sept 2025

Citation: R. A Rusmah, L. Adriani. (2025). "The Effectiveness of Coagulant Stems and Seeds of Moringa Oleifera in Improving the Quality of Well Water". J. of Green Chemical and Environmental Engineering, Vol. 1, No. 3, 140-154.

doi : 10.63288/jgcee.v1i3.12

Abstract: This study aims to determine the effectiveness of adding moringa seed coagulant, moringa stem coagulant, and a mixture of both in achieving optimal reduction to improve the quality of well water. The study uses the coagulation method. The research procedure begins with the preparation of the coagulants, where the mature moringa seeds and stems are each ground and dried in an oven for one hour. The clarification process of the well water samples is then carried out through coagulation, using 1000 ml of sample with a stirrer at a speed of 10 rpm for 20 minutes. The coagulant dosage variations used were 0.5 g, 1 g, 1.5 g, 2 g, and 3 g. The mixture variations of the coagulants used were in the ratios of 1:1, 1:2, and 2:1. The observed water quality parameters included: Turbidity, TDS (Total Dissolved Solids), TSS (Total Suspended Solids), pH, Nitrite (NO_2), Manganese (Mn), Iron (Fe), and BOD (Biological Oxygen Demand). The results showed that the moringa seed coagulant was more effective than the moringa stem coagulant or the mixture of seed and stem. The best dosage of moringa seed, moringa stem, and their mixture for improving well water quality was found to be 0.5 g per 1000 ml of sample.

Keywords: Coagulant; Moringa Seeds; Moringa Stems; Well Water.

1. Introduction

Access to clean water is vital for human well-being and daily activities. Based on the Regulation of the Minister of Public Works and Public Housing No. 09/PRT/M/2015 concerning the use of air sources, it states that water is all air contained in and/or originating from air sources, both above and below the ground surface [1]. Additionally, the Decree of the Minister of Health No. 1405/Menkes/SK/XI/2002 defines clean water as water used for daily needs that meets health quality standards and is safe for consumption when boiled [2].

Based on the 2020 Riskesdas study [3], the main sources of household water in Indonesia include protected dug wells (27.9%), drilled wells/pumps (22.2%), and piped water (19.5%). In Makassar, well water remains a common source despite contamination risks from domestic waste, industrial discharge, and pesticides. Such contamination may introduce pathogens, heavy metals, and particulates, posing serious health risks [4].

In Makassar, well water remains a vital source of household water, yet it frequently contains elevated concentrations of heavy metals such as iron (Fe) and manganese (Mn), posing significant health risks to both children and adults due to chronic exposure exceeding safe thresholds. Additionally, groundwater in coastal and urban sites shows signs of seawater intrusion, leachate infiltration, and elevated levels of chloride and electrical conductivity intensifying the risk of contamination via domestic and landfill pollutants. These findings underscore the vulnerability of shallow and hand-dug wells in Makassar, underlining the urgent need for effective, low-cost water treatment strategies suitable for local conditions [5].

Coagulation-flocculation is a simple and effective method to treat raw water by removing suspended particles [6]. Although chemical coagulants are commonly used, natural alternatives such as plant-based coagulants are increasingly favored for their eco-friendly and sustainable characteristics [7]. Moringa oleifera is known to contain various bioactive compounds that contribute to its effectiveness as a natural coagulant. In the seeds, the primary active component is a cationic protein known as Moringa oleifera cationic protein, which is water-soluble and responsible for coagulating negatively charged particles in water through charge neutralization and adsorption mechanisms. Moringa seeds also contain rhamnosyloxy benzyl isothiocyanate, tannins, and polyphenols, all of which have been associated with antimicrobial and coagulation properties [8], [9].

A study demonstrated that both seeds and stems of Moringa oleifera, in raw a forms, exhibit effective coagulating properties, with up to 25% turbidity reduction within 90 minutes. The research revealed that although seeds contain higher concentrations of phytochemicals such as flavonoids and oxalates, the stems also possess significant levels of potassium and sulfur elements associated with coagulation. XRF analysis reveals that both stems and seeds contain aluminum content ranging from 3% to 4%, which contributes to their coagulant properties. The stem also contains bioactive compounds and phenolic content that may participate in coagulation mechanisms [10].

The coagulation flocculation process using *Moringa oleifera* leverages cationic proteins and polyphenolic compounds present in its seeds and leaves to effectively destabilize and aggregate suspended particles. According to Alam et al. (2020), extracts from moringa leaves, rich in flavonoids, saponins, and phenolics, significantly improve water quality by reducing turbidity, total dissolved solids (TDS), hardness, fluoride, and *E. coli* counts, representing a sustainable alternative to conventional coagulants [11]. Furthermore, Rai et al. (2022) demonstrated that the positively charged proteins in moringa seed extract, when combined with ultrafiltration, achieve reduction in turbidity 64% and biochemical oxygen demand (BOD) 58% via mechanisms of charge neutralization and bridging [12]. Desta et al. (2021) also reported that moringa seed powder at optimal dosage (0.4 g/500 mL) can reduce turbidity, color, and chemical oxygen demand (COD) up to 99%, supporting its efficacy in wastewater treatment [13].

One study by Manora et al. (2024) reported that Moringa seeds were effective in reducing chemical oxygen demand (COD), biological oxygen demand (BOD), and total suspended solids (TSS) in tofu industrial wastewater, achieving reductions of more than 50% under optimal treatment conditions [14]. Although many studies have demonstrated the effectiveness of moringa seeds in water treatment, the use of moringa stems as a coagulant and its comparison with moringa seeds, especially in the context of poor quality well water, has not been widely studied.

2. Research and Methodology

2.1 Research Equipment and Materials

The materials used in this study included well water samples from Makassar residents, Moringa seed powder, and Moringa stem powder. Other laboratory chemicals and reagents were also used. The main equipment consisted of a mechanical stirrer, beakers, TDS meter, TSS meter, spectrophotometer, pH meter, blender, Erlenmeyer flasks, inductively coupled plasma (ICP) instrument, graduated cylinders, turbidimeter, and burette.

2.2 Research Variable

The independent variables were defined by the type and dosage of Moringa-based coagulants, which included Moringa seed powder (0.5 g, 1 g, 1.5 g, 2 g, and 3 g), Moringa stem powder (0.5 g, 1 g, 1.5 g, 2 g, and 3 g), and mixtures of Moringa seed and stem powders in ratios of 1:1, 2:1, and 1:2.

The dependent variables were defined as water quality parameters, including turbidity, total dissolved solids (TDS), total suspended solids (TSS), pH, nitrite (NO_2), manganese (Mn), iron (Fe), and biological oxygen demand (BOD). The experimental conditions were standardized with a stirring speed of 10 rpm, a stirring time of 20 minutes, and a sedimentation period of 8 hours.

2.3 Research Prosedures

a. Sample and Coagulant Preparation

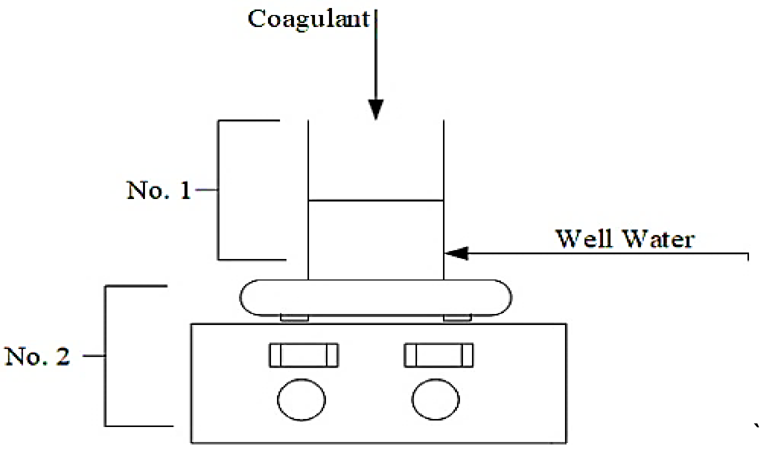

Figure 1. Research Equipment Design
Description :1. Beaker Glass, 2. Stirrer

Coagulant Preparation: Moringa stems and seeds were washed, oven-dried at 105°C for one hour, and then ground into fine powder using a blender. Water Treatment Process: Each 1000 mL sample of well water was treated with the respective coagulant (seed powder, stem powder, or mixtures) in different dosages. The samples were stirred for 20 minutes at 10 rpm, allowed to settle for 8 hours, and the clear supernatant was collected for analysis.

b. Sample Analysis

Water quality parameter analyses were carried out using standardized and calibrated instruments. Turbidity was measured on the supernatant of each sample using a turbidimeter, with readings recorded in Nephelometric Turbidity Units (NTU) after the digital display stabilized.

Total Dissolved Solids (TDS) were determined using a calibrated TDS meter, with measurements taken for each sample at various concentrations and expressed in milligrams per liter (mg/L). Total Suspended Solids (TSS) were analyzed using a TSS meter by inserting the sample into a cuvette, after calibration with a blank, and recording the stabilized value in mg/L.

The pH values of the samples were measured using a digital pH meter, with readings taken once the display stabilized. Nitrite (NO_2) levels were analyzed spectrophotometrically: 50 mL of each sample was transferred into a 200 mL beaker, then 1 mL of sulfanilamide solution was added, shaken, and left to stand for 2-8 minutes, followed by the addition of 1 mL of NED dihydrochloride solution. The mixture was left for 10 minutes before absorbance was measured at 543 nm, within a maximum of 2 hours.

For metal analysis, 1 mL of HNO_3 was added to 100 mL of each water sample, and iron (Fe) and manganese (Mn) concentrations were determined using Inductively Coupled Plasma (ICP) analysis.

BOD analysis is done by titrimetric method. Place the sample in a 300 ml Winkler bottle, aerate if necessary, add nutrient solution, aerate the previously filled Winkler bottle until full, then add 1 ml each of H_2O_2 and $MnSO_4$ reagent. Add, then homogenize, let stand, add 1 ml of H_2SO_4 solution, homogenize again, titrate with sodium thiosulfate solution ($Na_2S_2O_3$) until pale yellow, add 3 drops of starch indicator, titrate with sodium thiosulfate until the solution is clear and record the titration results.

3. Results and Discussion

In the figure of data result, the variable coded as SA refers to the initial sample concentration before the addition of any coagulant. BJ represents the sample concentration after the addition of Moringa seed coagulant, BT denotes the concentration after the addition of Moringa stem coagulant, and BJ-BT indicates the concentration after the addition of a mixed coagulant composed of both Moringa seeds and stems.

3.1 Initial Test Results of Well Water Samples Before Adding Coagulant

Table 1. Initial Test Results Before Adding Coagulant to Well Water

No	Parameter	Maximum Limit (PMK R.I No.2 Th. 2023)	Test Results
A.	**Physics**		
1	Turbidity	< 3 NTU	64.70
2	TDS	< 300 mg/L	223
3	TSS	-	46
B.	**Chemical**		
4	pH	6.5 - 8.5	8.30
5	Nitrite (NO_2)	3 mg/L	0.123
6	Iron (Fe)	0.2 mg/L	0.0448
7	Manganese (Mn)	0.1 mg/L	0.0112
8	BOD	-	7.73

3.2. Test Results of the Effect of Adding Coagulant on Turbidity

Figure 2 shows a graph of the effect of adding moringa coagulant on the turbidity value of well water.

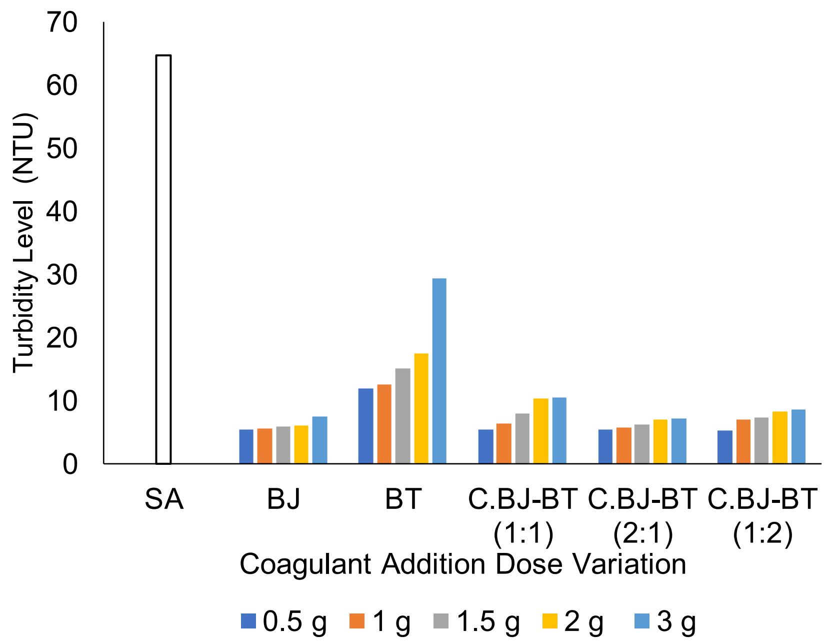

Figure 2. The Effect of Adding Moringa Coagulant on Turbidity Values in Well Water

Turbidity is a key indicator of water quality, reflecting the clarity or cloudiness of water, and is commonly measured using a turbidimeter [10]. In this study, well water samples were treated with various coagulants Moringa seed powder, Moringa stem powder, and a mixture of both at different mass concentrations (0.5 g, 1 g, 1.5 g, 2 g, and 3 g) per 1000 mL of water, and with mixture ratios of 1:1, 1:2, and 2:1. In terms of turbidity reduction, the application of Moringa seed powder resulted in a significant decrease from an initial turbidity of 64.70 NTU to 5.46 NTU at a dose of 0.5 g, achieving a reduction of 91.56%. According Al-Jadabi [9], Moringa oleifera seeds contain water-soluble cationic proteins with strong coagulating properties, enabling them to effectively bind and neutralize suspended contaminants in water. Due to these characteristics, Moringa seed extracts have been widely applied as natural primary coagulants in water treatment processes, demonstrating performance comparable to that of commercial alum [9]. When compared with previous research conducted by Desta et al. (2021), the optimum dose was at a concentration of 0,8 g/L sample [13]. However, this value still exceeds the standard threshold of <3 NTU, indicating the need for further optimization. Interestingly, increasing the coagulant dosage beyond 0.5 g (1-3 g) caused turbidity levels to rise again. This trend aligns with the findings of Khusnaeni et al. (2024), who explained that once the optimal dose is exceeded, excess coagulant may remain unreacted due to charge saturation, contributing to increased turbidity [15].

A similar trend was observed with Moringa stem powder, where turbidity decreased to 11.97 NTU at a dose of 0.5 g, corresponding to an 81.5% reduction. However, this reduction was lower than that achieved by Moringa seeds, likely due to differences in bioactive compound content. Moringa seeds contain a higher concentration of cationic proteins and other bioactive molecules (such as polyelectrolytes and water-soluble lectins), which play a crucial role in destabilizing suspended particles and enhancing coagulation. The stem, while still effective, possesses these compounds in lower amounts, resulting in slightly reduced coagulation performance [10].

Coagulant mixtures of Moringa seeds and stems also demonstrated good performance. The most effective ratio was found to be 1:2 (seed:stem) at a dose of 0.5 g, reducing turbidity from 64.6 NTU to 5.24 NTU (a 91.90% reduction). However, similar to the single-material coagulants, turbidity tended to increase with higher dosages. Interestingly, the 1:2 ratio (with more stem than seed) yielded better results than the 2:1 ratio, which contradicts expectations given the higher bioactive content in seeds. This discrepancy may be attributed to inhomogeneous mixing, which could lead to ineffective distribution of the active compounds. Therefore, further research is necessary to assess the impact of mixing techniques on coagulant effectiveness.

3.3. Test Results of the Effect of Coagulant Addition on TDS (Total Dissolved Solid) Parameters

Figure 3 shows a graph of the effect of adding moringa coagulant on the TDS value of well water.

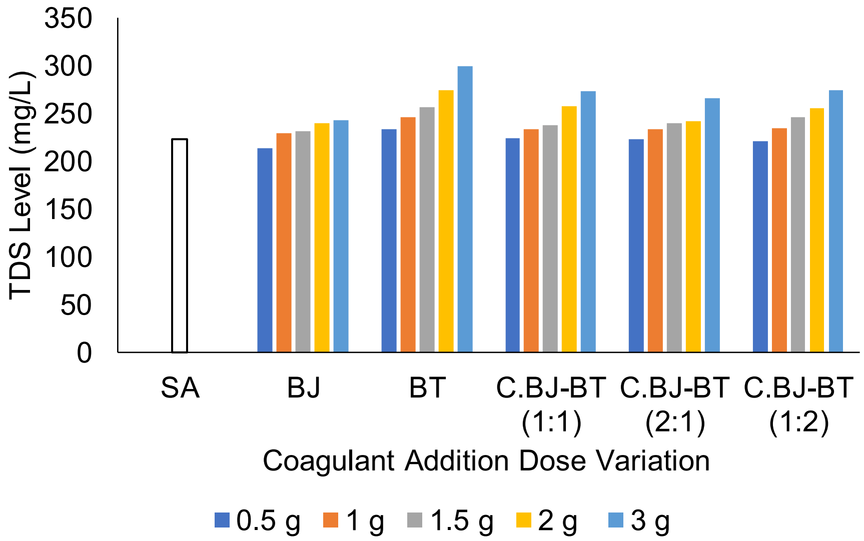

Fig 3. The Effect of Adding Moringa Coagulant on TDS Values in Water

Turbidity in water can also describe the value of TDS in water. The more turbid the waters, the greater the TDS value [16].

In this study, the use of Moringa oleifera seed powder as a natural coagulant at a dose of 0.5 g in 1000 mL of well water resulted in a slight decrease in TDS. However, when the dosage was increased to 1 g, 1.5 g, 2 g, and 3 g, the TDS levels paradoxically increased. This anomaly is likely due to the variation in coagulant particle size, as the powder was not sieved prior to application, thereby impeding effective floc formation and contributing to secondary contamination of the water sample. Similar findings were reported by Pujiastuti et al. (2022), who demonstrated that a particle size of 100 mesh was optimal, resulting in a 60% reduction in TDS [17].

The application of Moringa stem powder as a coagulant also led to an increase in TDS values. Starting from an initial TDS concentration of 214 mg/L, levels increased to 233 mg/L with a 0.5 g dose and continued to rise with higher dosages (1 g to 3 g). Likewise, the combination of seed and stem coagulants in ratios of 1:1, 2:1, and 1:2 resulted in minor TDS reductions, though the changes were not statistically significant.

Among all five treatment groups moringa seeds, stems, and their mixtures no substantial decrease in TDS was observed. The inconsistent floc formation is again attributed to the lack of standardized particle size, which hindered the coagulation mechanism and contributed to residual suspended solids [17]. These results contrast with the findings of Merdana et al. (2020), who reported that TDS reduction occurred due to the presence of positively charged proteins in Moringa seed powder, which bind effectively to negatively charged particles in wastewater. Additionally, their study emphasized that prolonged sedimentation could increase TDS levels, as the van der Waals forces involved in the flocculation process are relatively weak and prone to dissociation over time.

Nevertheless, in the present study, a 60 minutes sedimentation period was still found to be effective in stabilizing TDS values [18].

3.4. Test Results of the Effect of Coagulant Addition on TSS (Total Suspended Solid) Parameters

Figure 4 shows a graph of the effect of adding moringa coagulant on the TSS value of well water.

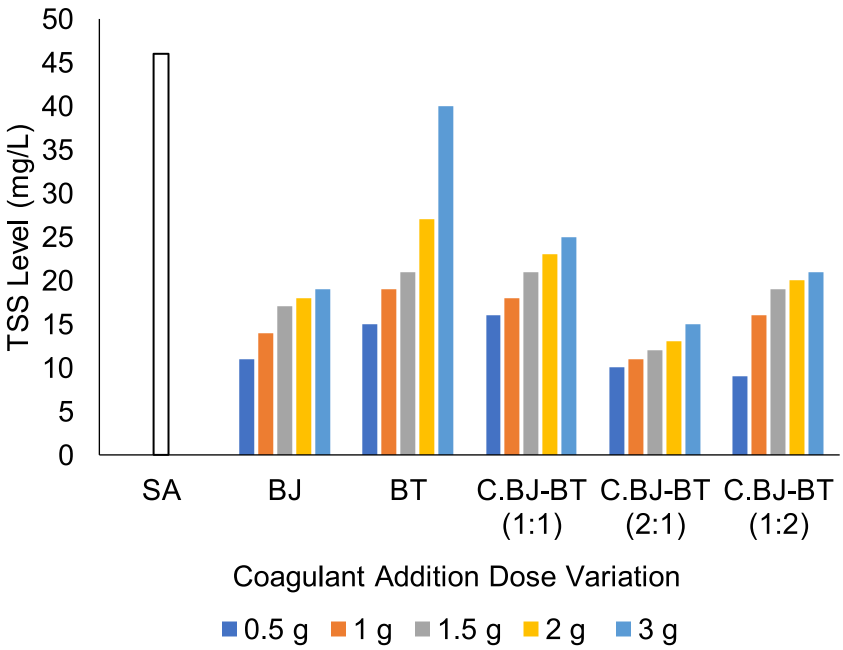

Fig 4. The Effect of Adding Moringa Coagulant on TSS Values in Well Water

Total Suspended Solids (TSS) is one of the key optical parameters used to evaluate water quality, as it provides essential information about the presence of insoluble particulate matter in water [19].

In this study, the addition of Moringa oleifera seed powder as a natural coagulant significantly reduced the TSS value. Initially, the TSS concentration in the raw water sample was 46 mg/L. The most effective reduction occurred at a dose of 0.5 g in 1000 mL of water, resulting in a TSS value of 11 mg/L representing a 76.09% decrease. This reduction is attributed to the presence of bioactive compounds in moringa seeds, particularly cationic proteins and tannins, which act as natural polyelectrolytes. These compounds promote the destabilization and aggregation of suspended particles, forming larger flocs that settle more efficiently. This mechanism is supported by the findings who reported that the tannin-rich content in Moringa oleifera seeds contributes effectively to the coagulation-flocculation process [10], [20]. However, increasing the dosage beyond 0.5 g specifically in the range of 1 g to 3 g to an unexpected rise in TSS levels. This phenomenon aligns with the findings stated that overdosing natural coagulants can destabilize previously formed flocs due to the oversaturation of binding sites and limited interaction space among colloidal particles. As a result, the coagulation-flocculation process becomes suboptimal, and some particles may remain suspended or even re-disperse into the solution, thereby increasing the measured TSS value. Interestingly, although 0.5 g was initially optimal, the highest TSS reduction (94%) was observed at a dose of 1.5 g in some instances, suggesting potential variability in sample responsiveness and the need for further investigation [21].

The application of Moringa oleifera stem powder also showed potential in reducing TSS. At the same initial concentration of 46 mg/L, the TSS level decreased to 15 mg/L when treated with 0.5 g of moringa stem powder, corresponding to a 67.39% reduction. While effective, this result is slightly less significant than the reduction achieved with seed powder. This difference is likely due to the lower content of cationic proteins and coagulating agents in moringa stems compared to seeds, as previously noted [10].

The use of a combined coagulant consisting of Moringa seed powder and Moringa stem powder at ratios of 1:1, 2:1, and 1:2 demonstrated the ability to reduce TSS levels in water. These two natural coagulants possess complementary coagulating properties, thereby enhancing their overall effectiveness in aggregating and settling suspended particles. With an initial TSS concentration of 46 mg/L, the application of the coagulant mixture led to a substantial decrease in TSS. The most optimal reduction was observed at a seed-to-stem ratio of 1:2 with a dosage of 0.5 g per 1000 mL of water, where the TSS value decreased to 9 mg/L, representing a reduction of 80.43%.

3.5. Test Results of the Effect of Coagulant Addition on pH Parameters

Figure 5 shows a graph of the effect of adding moringa coagulant on the pH value of well water.

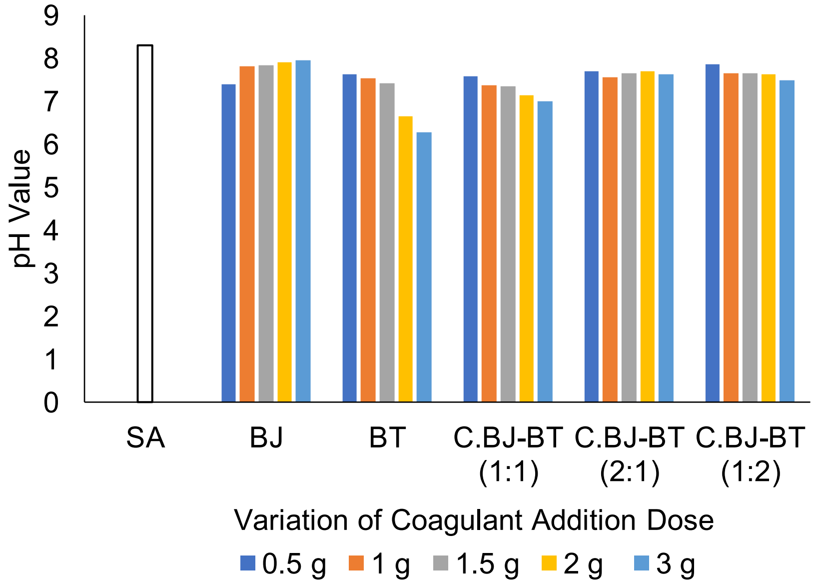

Fig 5. The Effect of Adding Moringa Coagulant on pH Values in Well Water

pH reflects the activity of hydrogen ions in a solution rather than their concentration, and serves as an indicator of a solution's acidity or alkalinity and its intensity [22]. In this study, the application of Moringa oleifera seed powder as a natural coagulant was found to influence the pH of water. The initial pH of the sample, recorded at 8.30, decreased to 7.39 following the addition of 0.5 g of moringa seed powder in 1000 mL of water equivalent to a 10.96% reduction. Interestingly, as the dosage increased (1 g, 1.5 g, 2 g, and 3 g), the pH rose slightly but remained within the neutral range. This phenomenon may indicate that while the initial introduction of coagulant introduces acidic functional groups (carboxyl groups from amino acids), excessive dosage may dilute their impact or introduce buffering effects.

Similarly, the use of Moringa oleifera stem powder also demonstrated the ability to lower the pH of water. The pH of the sample decreased from 8.30 to 7.63 after the addition of 0.5 g of stem powder. Unlike the seed powder, further increases in dosage (up to 3 g) consistently continued to reduce the pH, though values remained within the neutral range, suggesting a more gradual and stable acidifying effect. The combination of moringa seed and stem powders in different ratios (1:1, 2:1, and 1:2) also showed a slight reduction in pH values. However, in all cases, the final pH levels remained within the neutral range (approximately 6.8-7.5), which is generally acceptable for treated water and indicates the absence of strong acidity or alkalinity.

Overall, across all five coagulant variations, pH changes were relatively moderate and did not exceed safe limits. This observation aligns with findings by Aras and Asriani (2021), who stated that the coagulation-flocculation process using seed-based coagulants has only a limited effect on water acidity and conductivity. The reduction in pH is primarily due to the interaction between hydroxide ions in water and the acidic carboxyl groups present in moringa seed proteins, which can lead to the release of hydrogen ions (H^+) in a weakly acidic environment [20].

3.6. Test Results of the Effect of Coagulant Addition on Nitrite Parameters

Figure 6 shows a graph of the effect of adding moringa coagulant on nitrite values in well water.

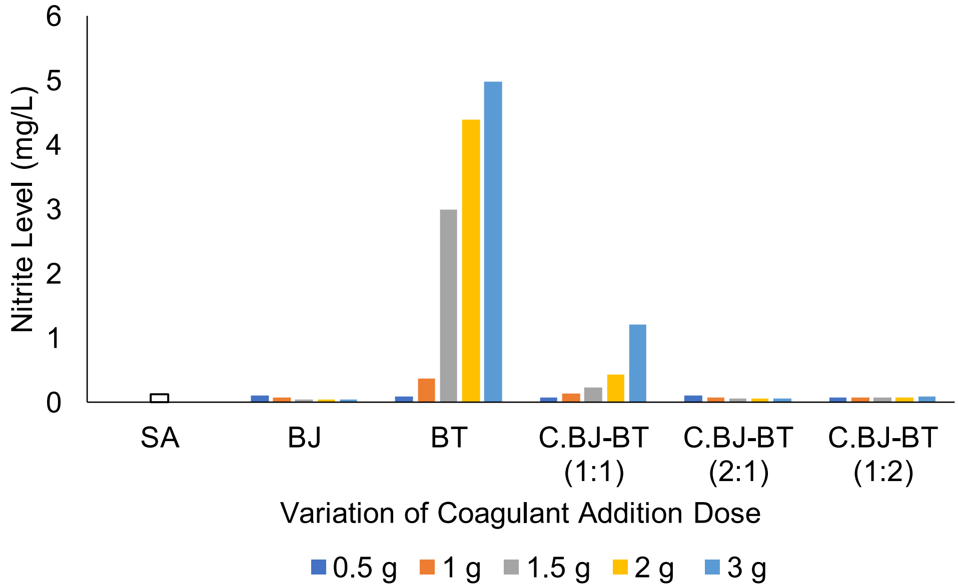

Fig 6. The Effect of Adding Moringa Coagulant on Nitrite Concentration in Well Water

Nitrites (NO_2) are intermediate compounds formed during the nitrification and denitrification processes in the nitrogen cycle. These compounds are considered toxic and are typically found in low concentrations in well water, with a maximum permissible level of 0,3 mg/L based on standard drinking water guidelines [23]. Nitrites interfere with the oxygen-binding capacity of hemoglobin in blood, which may lead to symptoms such as fatigue, dizziness, blurred vision, and drowsiness in humans [24].

The use of Moringa oleifera seed powder as a natural coagulant was found to effectively reduce nitrite concentrations in water samples. In this study, the initial nitrite level was 0.123 mg/L. Upon the addition of 0.5 g of moringa seed powder to 1000 mL of water, the nitrite concentration decreased to 0.103 mg/L, representing a 16.26% reduction. The reduction trend continued with increasing coagulant dosage, indicating a dose-dependent coagulation performance. This effect is attributed to the presence of bioactive, water-soluble proteins in moringa seeds particularly 4-alpha-L-rhamnosyloxy-benzyl-isothiocyanate, a cationic compound that generates positively charged sites capable of binding and neutralizing negatively charged nitrite ions [24].

Similarly, Moringa oleifera stem powder also demonstrated the ability to reduce nitrite levels. At a 0.5 g dose, the nitrite content decreased to 0.094 mg/L. However, further increases in dosage (1 g to 3 g) resulted in a rise in nitrite levels, even exceeding the recommended threshold in some cases. This may be due to the inconsistent particle size of the unsieved moringa stem powder, which could lead to uneven dispersion and ineffective adsorption. Previous research by Abja et al. (2020) supports the idea that the physical characteristics of the coagulant significantly influence its performance, and highlights that activated charcoal derived from moringa biomass may offer improved nitrite removal efficiency [24].

The combination of moringa seed and stem powders at various ratios also showed varying degrees of effectiveness in nitrite reduction. A 1:1 ratio at a 0.5 g dose reduced the nitrite concentration from 0.123 mg/L to 0.069 mg/L (43.90% reduction). However, higher doses resulted in an increase in nitrite levels, possibly due to non-homogeneous mixing and uneven particle sizes from unsieved coagulants. In contrast, the 2:1 seed-to-stem ratio demonstrated a continuous decrease in nitrite levels across doses ranging from 0.5 g to 3 g, indicating sustained adsorption capacity and better performance at higher concentrations. Meanwhile, the 1:2 seed-to-stem ratio also produced a significant decrease of 43.09% at the 0.5 g dose, but subsequent increases in dosage led to a rise in nitrite levels, although still within acceptable quality limits. The results that the presence of phytochemical compounds including tannins, phenols, alkaloids, flavonoids, and oxalates as well as mineral elements such as potassium and aluminum, plays a significant role in the coagulation process and in binding contaminant particles like nitrite [10].

3.7. Test Results of the Effect of Coagulant Addition on Iron (Fe) Parameters

The effect of adding moringa coagulant on iron levels in well water is presented in Table 2.

Table 2. The Effect of Adding Moringa Coagulant on Iron (Fe) Concentration in Well Water

Dose (g)	Fe Concentration (mg/L)				
	BJ	BT	C.BJ-BT (1:1)	C.BJ-BT (2:1)	C.BJ-BT (1:2)
0	0.0448	0.0448	0.0448	0.0448	0.0448
0.5	< 0.0355	< 0.0355	< 0.0355	< 0.0355	< 0.0355
1	< 0.0355	< 0.0355	< 0.0355	< 0.0355	< 0.0355
1.5	< 0.0355	< 0.0355	< 0.0355	< 0.0355	< 0.0355
2	< 0.0355	< 0.0355	< 0.0355	< 0.0355	< 0.0355
3	< 0.0355	< 0.0355	< 0.0355	< 0.0355	< 0.0355

Iron is the second most abundant metal in the Earth's crust, comprising approximately 5%, yet it is rarely found in elemental form due to the tendency of Fe^{2+} and Fe^{3+} ions to readily combine with oxygen, hydroxides, carbonates, and sulfides most commonly occurring as oxides in nature [25].

In this study, the application of Moringa oleifera seed powder demonstrated a significant reduction in dissolved iron (Fe) levels. The initial iron concentration in the sample was 0.0448 mg/L, which decreased to below the method's minimum detection limit (<0.0355 mg/L) after the addition of 0.5 g of moringa seed powder per 1000 mL of water. Further increases in coagulant dose (1–3 g) resulted in consistently undetectable iron concentrations, suggesting saturation of active binding sites, as also reported by Yusniati et al. (2022) [26].

Similarly, moringa stem powder also showed effectiveness in reducing Fe levels, with progressive declines observed across all tested doses (0.5–3 g/L). The combined use of seed and stem powders in varying ratios (1:1, 2:1, and 1:2) further enhanced Fe removal, with higher doses yielding lower iron concentrations. Among all coagulant variations tested, both individual and combined forms of moringa seed and stem were effective in significantly reducing dissolved iron content in well water samples. The findings that biocoagulants derived from Moringa oleifera can form polyelectrolytes capable of binding with metal ions such as Fe, thereby facilitating their removal from water [27]. The coagulation process using *Moringa oleifera* occurs through charge adsorption by protein compounds. This mechanism is further identified the presence of bioactive compounds such as tannins, phenols, alkaloids, flavonoids, and oxalates in moringa seeds, all of which contribute significantly to coagulation activity [10], [28].

3.8. Test Results of the Effect of Coagulant Addition on Manganese (Mn) Parameters

The effectiveness of Moringa oleifera-based coagulants in reducing manganese (Mn) levels in well water is demonstrated in Table 3.

Table 3. The Effect of Adding Moringa Coagulant on Manganese (Mn) Concentration in Well Water

Dose (g)	Mn Concentration (mg/L)				
	BJ	**BT**	**C.BJ-BT (1:1)**	**C.BJ-BT (2:1)**	**C.BJ-BT (1:2)**
0	0.0112	0.0112	0.0112	0.0112	0.0112
0.5	0.0021	< 0.0053	< 0.0053	< 0.0053	< 0.0053
1	< 0.0053	< 0.0053	< 0.0053	< 0.0053	< 0.0053
1.5	< 0.0053	< 0.0053	< 0.0053	< 0.0053	< 0.0053
2	< 0.0053	< 0.0053	< 0.0053	< 0.0053	< 0.0053
3	< 0.0053	< 0.0053	< 0.0053	< 0.0053	< 0.0053

Manganese (Mn) is an essential trace metal required in small quantities for normal physiological functions. However, excessive intake can pose health risks, including potential cardiovascular complications such as heart attacks and vascular damage [29]. In this study, Moringa oleifera seed powder was used as a natural coagulant to reduce manganese content in water. The initial concentration of Mn in the water sample was 0.0112 mg/L. Upon the addition of 0.5 g of moringa seed powder in 1000 mL of water, the manganese concentration decreased to 0.0021 mg/L. With further increases in coagulant dosage (1 g, 1.5 g, 2 g, and 3 g), the manganese levels became undetectable, falling below the minimum detection limit of the analytical method. This phenomenon may be explained by the saturation of binding sites on the coagulant surface, where additional doses beyond the optimal point do not significantly change the outcome [26].

Similarly, Moringa oleifera stem powder also demonstrated effectiveness in reducing manganese levels. From an initial concentration of 0.0112 mg/L, Mn levels dropped to <0.0053 mg/L after treatment with 0.5 g of moringa stem powder, also below the detection threshold. Increased dosages consistently showed a downward trend in Mn concentration, indicating a strong affinity between the bioactive compounds in the stem and the manganese ions.

The combined use of moringa seed and stem powder coagulants, in ratios of 1:1, 2:1, and 1:2 with doses ranging from 0.5 g to 3 g, also proved effective in reducing Mn content in the water samples. All combinations resulted in decreased manganese concentrations, with some measurements falling below the detection limit. These findings demonstrate that both individual and combined moringa-based coagulants possess significant potential for removing manganese from water. The mechanism behind this reduction is attributed to the presence of bioactive polyelectrolytes primarily proteins and polysaccharides in both the seeds and stems of Moringa oleifera. These biopolymers carry functional groups (e.g., carboxyl, hydroxyl, amino) that interact with metal ions such as Mn^{2+} through electrostatic attraction and complexation reactions. The interactions result in the formation of flocs that trap and remove metal ions during the sedimentation process [27].

3.9. Test Results of the Effect of Coagulant Addition on BOD Parameters

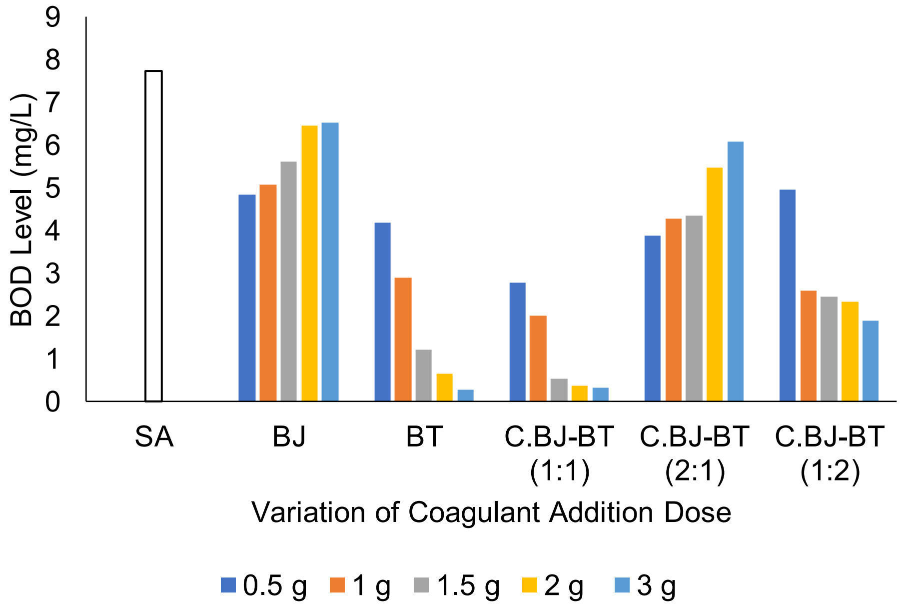

Fig 7. The Effect of Adding Moringa Coagulant on BOD Concentration in Well Water

Figure 7 shows a graph of the effect of adding moringa coagulant on the BOD value in well water. Biochemical Oxygen Demand (BOD_5) refers to the amount of dissolved oxygen required by aerobic microorganisms to biologically decompose organic matter in water over a five-day period. It serves as a key indicator of organic pollution in aquatic environments [30].

In this study, the application of Moringa oleifera seed powder as a natural coagulant demonstrated its potential to reduce BOD levels in well water samples. Initially, the BOD concentration was 7.73 mg/L. After the addition of 0.5 g of moringa seed powder in 1000 mL of water, the BOD value decreased to 4.83 mg/L. However, as the coagulant dosage increased (1 g, 1.5 g, 2 g, and 3 g), the BOD levels rose again. To chemical interactions between organic substances in the raw water and the active components of the coagulant, which can contribute to an increase in measurable BOD. Furthermore, excessive coagulant dosing may lead to an overdose effect, characterized by the formation of large, dense flocs that reduce the effective surface area for interaction with colloidal particles. This limits the coagulation efficiency and may result in residual organic matter remaining in suspension [21].

Similarly, Moringa oleifera stem powder was found to effectively reduce BOD levels. From the same initial value of 7.73 mg/L, BOD decreased to 4.19 mg/L following the addition of 0.5 g of stem powder. Unlike the seed powder, the BOD continued to decline with increasing doses (up to 3 g). This consistent reduction may be due to the lower concentration of organic and protein-based compounds in moringa stems, which leads to minimal contribution to residual BOD. Additionally, that moringa exhibits antimicrobial activity, which may suppress microbial populations responsible for the degradation of organic matter, thereby reducing oxygen demand and resulting in lower BOD values [10].

The combination of moringa seed and stem powder as a mixed coagulant also showed promising results. Various ratios 1:1, 2:1, and 1:2 were tested at different dosages (0.5 g to 3 g). The 1:1 mixture produced a consistent reduction in BOD across all dosages, likely due to the balanced composition of proteins, polysaccharides, and antimicrobial compounds from both plant parts that facilitate effective coagulation and microbial suppression. In the 2:1 mixture (seed: stem), a decrease in BOD was observed at 0.5 g; however, subsequent increases in dosage led to a rise in BOD levels, presumably due to the higher seed content, which may reintroduce additional organic matter or overwhelm the flocculation system. Conversely, the 1:2 mixture (seed: stem) maintained a consistent downward trend in BOD values with increasing dosage, highlighting the beneficial role of the moringa stem in reducing organic load and microbial activity in water samples. Overall, these findings support the role of Moringa oleifera particularly its seeds and stems as effective bioactive and biocoagulant agents in reducing BOD in water treatment applications. Their coagulating performance is influenced by dosage, ratio, and the balance of active compounds, underscoring the importance of optimizing formulation for maximum efficiency.

4. Conclusion

Based on the data obtained from the research results that have been conducted, we can conclude the best dose of adding coagulant of moringa seeds, moringa stems, and a mixture of moringa seeds and stems to improve the quality of well water samples is at a dose of 0.5 g in every 1000 ml of well water sample. Both coagulants of moringa stem and seeds are effective in reducing the concentration of colloidal particles in water. However, moringa seeds show higher effectiveness in reducing the concentration of colloidal particles compared to moringa stem. Moringa seeds and moringa stems are effective for improving the quality of well water. It can be seen in the research data that the turbidity value can be reduced but does not meet the requirements according to the clean water quality standards of the PMK No. 2 Th. 2023; while the parameters TDS, pH, Nitrite, Fe, and Mn are still within the required quality standard range. The BOD and TSS parameters themselves are not required in the PMK No. 2 Th. 2023, but from the research results it can be seen that the BOD and TSS levels in well water samples can be reduced after the addition of coagulants.

Acknowledgement: We would like to thanks to the Chemical Engineering Study Program, Faculty of Industrial Technology, Muslim University of Indonesia and the Public Health Laboratory Center Makassar as the place where the research was carried out.

5. References

[1] V. Amalia, T. Budi Sanjoto, and P. Hardati, “Distribution of Springs and Household Clean Water Needs in Bulu District, Rembang Regency,” International Journal of Research and Review, vol. 10, no. 9, pp. 44-53, Sep. 2023, doi: https://doi.org/10.52403/ijrr.20230906.

[2] Zulhilmi, I. Efendy, D. Syamsul, and Idawati, "Factors Related to the Level of Clean Water Consumption in Households in Peudada District, Bireun Regency” Jurnal Biology Education, vol. 7, no. 2, pp. 110-126, Nov. 2019, doi: https://doi.org/10.32672/jsa.v7i5.1523.

[3] R. Naudita Krisna Setioningrum, L. Sulistyorini, and W. Istining Rahayu, "Description of Clean Water Quality in Domestic Areas in East Java in 2019," Journal of Public Health Sciences, vol. 16, no. 2, pp. 87-94, Sep. 2020, doi: https://doi.org/10.19184/ikesma.v16i2.19045.

[4] T. E. Oladimeji, M. Oyedemi, M. E. Emetere, O. Agboola, J. B. Adeoye, and O. A. Odunlami, “Review on the impact of heavy metals from industrial wastewater effluent and removal technologies,” Heliyon, vol. 10, no. 23, p. e40370, 2024, doi: https://doi.org/10.1016/j.heliyon.2024.e40370.

[5] S. A. Nugroho, W. Wilopo, I. F. A. Lathif, and A. Taufiq, “Seawater Intrusion Assessment based on Geological, Hydrogeological, Cl/Br vs Cl Graphical Analysis, Recharge Area, and

Groundwater Usage in Makassar Coastal Area, South Sulawesi, Indonesia," Journal of Applied Geology, vol. 9, no. 2, p. 109, Mar. 2025, doi: http://dx.doi.org/10.22146/jag.101429.

[6] G. Kooijman, M. K. de Kreuk, C. Houtman, and J. B. van Lier, "Perspectives of coagulation/flocculation for the removal of pharmaceuticals from domestic wastewater: A critical view at experimental procedures," Journal of Water Process Engineering, vol. 34, p. 101161, 2020, doi: https://doi.org/10.1016/j.jwpe.2020.101161.

[7] H. Kristianto, A. Jennifer, A. K. Sugih, and S. Prasetyo, "Potential of Polysaccharides from Fruit Waste as Natural Coagulants in Water and Wastewater Treatment: A Review"," Jurnal Rekayasa Proses, vol. 14, no. 2, p. 108, Dec. 2020, doi: https://doi.org/10.22146/jrekpros.57798.

[8] N. Muthmainna, H. Hafsan, and Y. Hala, "Potential of Moringa Oleifera Lamk. Seeds as Natural Biocoagulants for Well Water," Phylogeny: Journal of Biology Students, vol. 1, no. 1, pp. 7–11, Apr. 2021, doi: https://doi.org/10.24252/filogeni.v1i1.20547.

[9] N. Al-Jadabi, M. Laaouan, S. El Hajjaji, J. Mabrouki, M. Benbouzid, and D. Dhiba, "The Dual Performance of Moringa Oleifera Seeds as Eco-Friendly Natural Coagulant and as an Antimicrobial for Wastewater Treatment: A Review," Sustainability, vol. 15, no. 5, 2023, doi: https://doi.org/10.3390/su15054280.

[10] E. A. Erhuanga, D. J. Arotupin, I. A. Amoo, I. B. Kashim, and T. L. Akinbogun, "Comparative Study of the Physiochemical and Coagulating Properties of Moringa Oleifera (Linn) Seeds and Stem for Use in Water Purification," International Research Journal of Natural Sciences, vol. 10, no. 3, pp. 33–48, 2022, doi: https://doi.org/10.37745/irjns.13/vol10n33348.

[11] M. W. Alam, P. Pandey, F. Khan, B. Souayeh, and M. Farhan, "Study to Investigate the Potential of Combined Extract of Leaves and Seeds of Moringa oleifera in Groundwater Purification," Int J Environ Res Public Health, vol. 17, no. 20, 2020, doi: https://doi.org/10.3390/ijerph17207468.

[12] A. Rai et al., "A Synergistic Effect of Moringa oleifera-Based Coagulant and Ultrafiltration for the Wastewater Treatment Collected from Final ETP," Adsorption Science and Technology, vol. 2022, p.-9, 2022, doi: https://doi.org/10.1155/2022/1285011.

[13] W. M. Desta and M. E. Bote, "Wastewater treatment using a natural coagulant (Moringa oleifera seeds): optimization through response surface methodology," Heliyon, vol. 7, no. 11, p. e08451, 2021, doi: https://doi.org/10.1016/j.heliyon.2021.e08451.

[14] W. Manora, W. Astono, and S. Aphirta, "Efektivitas Biokoagulan Biji Kelor Pada Pengolahan Limbah Cair Tempe (Studi Kasus: Industri Tempe Semanan, Jakarta)," Jurnal Bhuwana, vol. 4, pp. 43-53, Jun. 2024, doi: https://doi.org/10.25105/bhuwana.v4i1.19025.

[15] E. S. Khusnani, M. Marsum, and F. Ma'ruf, "Effectiveness of Moringa Oleifera Seed Powder as a Biocoagulant in Reducing Phosphate Levels in Laundry Wastewater" Buletin Keslingmas, vol. 43, no. 4, pp. 202-210, Dec. 2024, doi: https://doi.org/10.31983/keslingmas.v43i4.12431.

[16] D. R. I. Fariyya, I. Yulianti, and Fianti, "Analysis of Physical Properties of Well Water Quality in Pasuruhan Kidul Kudus Village," Physics Communication, vol. 5, no. 1, pp. 23-26, 2021, doi: https://doi.org/10.15294/physcomm.v5i1.33886.

[17] P. Pujiastuti, Y. M. Wibowo, and Narimo, "Moringa Seed Powder Biocoagulant (Moringa oleifera) for Improving Laboratory Wastewater Quality," Molekul, vol. 17, no. 3, pp. 301-310, Nov. 2022, doi: https://doi.org/10.20884/1.jm.2022.17.3.5461.

[18] I. M. Merdana, I. K. Suada, and I. P. A. S. Putra, "Reducing Total Dissolved Solid of Livestock Wastewater with Moringa Seed Powder," Advances in Tropical Biodiversity and Environmental Sciences, vol. 4, no. 1, p. 1, Feb. 2020, doi: https://doi.org/10.24843/ATBES.2020.v04.i01.p01.

[19] T. Alfiah and J. Caroline, "Total Suspended Solids (TSS) Spatial Distribution of Manganese in Resident Well Impacted by Residential Activity: A Case Study of Medokan Ayu District-Surabaya," Paragraphs Environmental Design, pp. 1-10, Jul. 2023, doi: https://doi.org/10.59260/penvid.2023.01101317.

[20] I. T. Tomasi, C. A. Machado, R. A. R. Boaventura, C. M. S. Botelho, and S. C. R. Santos, "Tannin-based coagulants: Current development and prospects on synthesis and uses," Science of The Total Environment, vol. 822, p. 153454, May 2022, doi: https://doi.org/10.1016/j.scitotenv.2022.153454.

[21] M. Rozan Thabrani and D. Agustian Permadi, "Effectiveness Test of Moringa Seed Powder Utilization as an Alternative Coagulant in Reducing COD, BOD, and TSS in Laundry Wastewater," Jukung Journal of Environmental Engineering, vol. 10, no. 2, pp. 34-48, 2024, doi: https://doi.org/10.20527/jukung.v10i2.20681.

[22] D. Sari, S. Arza, F. Fiona, N. Novita, E. Ega, and B. Darmawan, "Analysis of Carbon Dioxide Content and pH in Water" Journal of Food Security and Agroindustry, vol. 2, no. 2, pp. 44-48, Jun. 2024, doi: https://doi.org/10.58184/jfsa.v2i2.279.

[23] A. Shah, A. Arjunan, A. Baroutaji, and J. Zakharova, "A review of physicochemical and biological contaminants in drinking water and their impacts on human health," Water Science and Engineering, vol. 16, no. 4, pp. 333–344, 2023, doi: https://doi.org/10.1016/j.wse.2023.04.003.

[24] R. Abja, A. H. Mukaromah, and F. A. Wardoyo, "Reducing Nitrite Levels in Water Using Activated Charcoal from Moringa Seeds," Eksergi, vol. 17, no. 1, p. 28, Apr. 2020, doi: https://doi.org/10.31315/e.v17i1.3291.

[25] Y. Khairina Ashar, N. W. Panjaitan, M. Iqbal, and H. Imron, "Iron (Fe) Content in Community Well Water around Mabar Hilir Industrial Area Market 3 Bantenan Medan City in the Perspective of Health and Islamic," Scientific Periodical of Public Health and Coastal Health, vol. 5, no. 5, pp. 294-301, 2023, doi: https://doi.org/10.30829/contagion.v5i1.15042.

[26] K. P. Yusniati, S. Srikandi, and A. Syawaalz, "Effectiveness of Moringa Oleifera Seeds as a Bioadsorbent in Reducing Fe and Mn Concentrations," Nucleus, vol. 3, no. 2, pp. 220-230, Nov. 2022, doi: https://doi.org/10.37010/nuc.v3i2.1122.

[27] D. Fitria, P. S. Komala, and D. Vendela, "The Effect of Flocculation Time on the Coagulation-Flocculation Process Using Moringa Biocoagulant to Remove Iron Content in Well Water," Jurnal Reka Lingkungan, vol. 10, no. 2, pp. 165-174, Jun. 2022, doi: https://doi.org/10.26760/rekalingkungan.v10i2.165-174.

[28] A. Benalia, K. Derbal, Z. Amrouci, O. Baatache, A. Khalfaoui, and A. Pizzi, "Application of Plant-Based Coagulants and Their Mechanisms in Water Treatment: A Review," J Renew Mater, vol. 12, no. 4, pp. 667-698, 2024, doi: https://doi.org/10.32604/jrm.2024.048306.

[29] G. H. Oliveira-Paula, A. C. Martins, B. Ferrer, A. A. Tinkov, A. V. Skalny, and M. Aschner, "The impact of manganese on vascular endothelium," Toxicol Res, pp. 501–517, Oct. 2024, doi: https://doi.org/10.1007/s43188-024-00260-1.

[30] J. A. Aguilar-Torrejón, P. Balderas-Hernández, G. Roa-Morales, C. E. Barrera-Díaz, I. Rodríguez-Torres, and T. Torres-Blancas, "Relationship, importance, and development of analytical techniques: COD, BOD, and, TOC in water—An overview through time," SN Appl Sci, vol. 5, no. 4, Mar. 2023, doi: https://doi.org/10.1007/s42452-023-05318-7.