International Journal of Design & Nature and Ecodynamics
Vol. 19, No. 6, December, 2024, pp. 1901-1907
Journal homepage: http://iieta.org/journals/ijdne

Comparative Evaluation of Moringa Oleifera, Vicia Faba, and Abelmoschus Esculentus as Natural Coagulants for Turbidity Removal in Water Treatment

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https://doi.org/10.18280/ijdne.190606

Received: 24 August 2024
Revised: 26 September 2024
Accepted: 15 November 2024
Available online: 27 December 2024

Keywords:
water treatment, neutral coagulants, turbidity removal, Moringa oleifera, Vicia faba, Abelmoschus esculentus

ABSTRACT

This study researched the use of plant-based coagulants instead of chemical coagulants. The research methodology relies on removing turbidity with natural additives. The results of the current study showed the possibility of replacing chemical coagulants with natural ones. The benefit of that in removing turbidity is that they are safer ad lower in cost, water sample was taken from river, the jar test was used to show the percentage of removal. The results showed the possibility of removing turbidity by up to 80% using the Moringa oleifera and Vicia faba plants, at a dose of 100 mg/L, and the sedimentation time was studied, which showed that 50% of the turbidity was removed within the first 5 minutes using natural coagulation. However, the Vicia faba showed better results than Moringa oleifera in the initial sedimentation of turbidity removed, these results could be due to the high percentage of protein found in Vicia faba. The results of treatment using Abelmoschus esculentus plant were promising, where 78% of the turbidity was removed at a dose of 100 mg/L, however it requires a longer sedimentation time. The results of this study are promising results that gives hope to using natural coagulation instead of chemical coagulation which reduces the negative side effects.

1. INTRODUCTION

Turbidity is one of the biggest problems in the water treatment processes. Turbid water contains plankton, colloids, and molecules and is dealt with by the addition of coagulation chemicals in a process called coagulation-flocculation [1-3]. In recent years, there has been an increased interest in natural plant-based coagulants as an alternative to coagulants made from inorganic chemicals. Plant-based coagulants are lower in cost, can be produced abundantly, and are non-toxic [4]. Aluminum sulfate is the most commonly used coagulant internationally, but its utilization can leave behind a residue of aluminum in the water and it brings a variety of health problems because of its bio-accumulative characteristics, causing both the deterioration of the ecosystem and problems for human health. Therefore, natural alternatives must be found to get rid of this metal in treated water [5]. Coagulants play a big role in the purification of natural-water and sludge disposal. However, Coagulants are more commonly used in traditional-treatment processes such as aluminum sulfate. Lately, there has been an increase in interest in creating and utilizing plant-based natural coagulants an example of that is Moringa oleifera due to their natural characteristics in addition to that the absence of heavy metals in their structure [6]. Plants such as carbonized chitosan Moringa is used for removing turbidity from water. Natural materials have proven to be more suitable coagulants for treating synthetically turbid water in wastewater systems [7]. The purpose of the study [8] was to reduce the use of chemical coagulants in water treatment to better the environment and consumer health by using a natural coagulant extracted from the plant Moringa oleifera, alongside aluminum polychloride (PAC) and calcium chloride ($CaCl_2$), for treating spring water with low turbidity between 10 to 30 NTU. However, they find that the isolated Moringa-Oleifera shows poor performance in the treatment of low-turbidity water less than 30 NTU.

Using natural material like Abelmoschus esculentus as coagulation has shown to be cost-effective and environmentally friendly, generating zero waste and providing a more circular approach to waste management in the industry [9]. According to a study [10], the efficiency of turbidity remove by used three plant (Tamarindus indica seeds, Abelmoschus esculentus seeds, and Zea mays husk) as bio coagulant and a bio flocculant an alternative to chemical-coagulants in treating wastewater. The natural treatment was found very effective compared to Aluminum sulfate. In a research paper presented by Bouatay et al. [11], where extracted (Vicia faba) was tested as a coagulant and flocculant for wastewater treatment, and compared it with the flocculation performance of commercial, results showed that the natural product provided good flocculation performance, In addition to its low cost. Reducing the turbidity of river water after heavy rainfall occurs is a challenging part of water treatment plant. Coagulation, flocculation and sedimentation has been agreed upon as a feasible approach in addressing this problem at large scale. However, using chemical flocculants can cause secondary pollution at downstream. For that reason, developing an eco-friendly plant-based flocculants is necessary [12, 13]. Vicia faba was used as an example, where it was investigated as a promising plant-based flocculants for effective removal of turbidity and total suspended solid from river water. It was environmentally friendly and cost-effective approach form turbidity removal from surface water [14, 15]. The research aims to evaluate the effectiveness of natural coagulants such as Moringa oleifera, Vicia faba, and Abelmoschus esculentus in removing water turbidity and to compare their efficiencies. The goal is to identify safer and more cost-effective natural alternatives. The results of the current study showed the possibility of replacing chemical coagulation with natural ones.

2. MATERIAL AND METHODS

The sample (raw water) was taken after heavy rain from Tiger-river. This water is stored and treated for supply uses. The turbidity in the water was measured at 105 NTU. Synthetic turbid water preparing under laboratory conditions: adding 40 mg clay (sifting with a 0.2 mm sieve) to one-liter of distilled water, mixed for one hour using a shaker at a speed of (100) revolutions/minute. Distilled water was added to the turbid water to achieve the desired turbidity (105 NTU). pH ranged between (6-8) [16].

2.1 Preparation of natural coagulants

First step: The Vicia faba plant peels were taken after removing the seeds, washed using distilled water and cut, then drying it completely in the oven at 70°C for 24 hours.

Second step: The Abelmoschus esculentus plant (fruit and leaves) were taken, washed using distilled water and cut, then drying it completely in the oven at 70°C for 24 hours.

Third step: The Moringa oleifera plant seeds cleaned and then dried completely at 70°C for 1 hour.

Fourth step: Each type was ground separately using a grinder, and they were sieved using a 200 mm sieve to obtain fine and homogeneous powder granules [13, 17].

2.2 Jar test operations

Jar test considered as the most widely used experimental method for coagulation-flocculation. A conventional jar test apparatus was used in the experiments to coagulate sample of synthetic turbid water using some coagulants. Consists of (6) beakers with (6) spindle steel paddles. First stape mixed the sample to make sure its homogenously (3) sample were raw water, and (3) water sample were synthetic turbid water, (1) liter for each sample, and measured water sample initial turbidity and pH. Second step coagulants of varying concentrations were added in the beakers, The coagulant was added in six concentrations (5, 10, 20, 40, 80, and 100) mg/L. Jar test procedures were performed at a rotational at several gradual speeds. Mixing the water in the beakers at (100 rpm for 15 minute) for coagulation, and then mixing it at (20 rpm for 10 minutes) to help form the pads (Flocculation). Then leave the mixture to settle for 60 minutes. Then turbidity is measured.

3. RESULT AND DISCUSSION

3.1 Experiment conditions

Synthetic and raw turbid water samples were prepared for jar testing, high turbidity 105 NTU, in addition of three different values of pH (6, 7, and 8) for each sample. Natural coagulants were added in different doses (5, 10, 20, 40, 80, 100 mg/L) for each type of material.

3.2 Sedimentation time

After preforming the Jar experiment test, the sample was left for a period of 60 minutes for sedimentation. The turbidity test was performed for the samples four times during the sedimentation period, the tests were performed at (0, 5, 30, 60 minutes) of the sedimentation period. The results were extracted using the following Eq. (1):

$$\text{Turbidty removal } \% = \frac{\text{turbidity value in any time} - \text{final turbidity value}}{\text{turbidity value in any time}} \times 100 \quad (1)$$

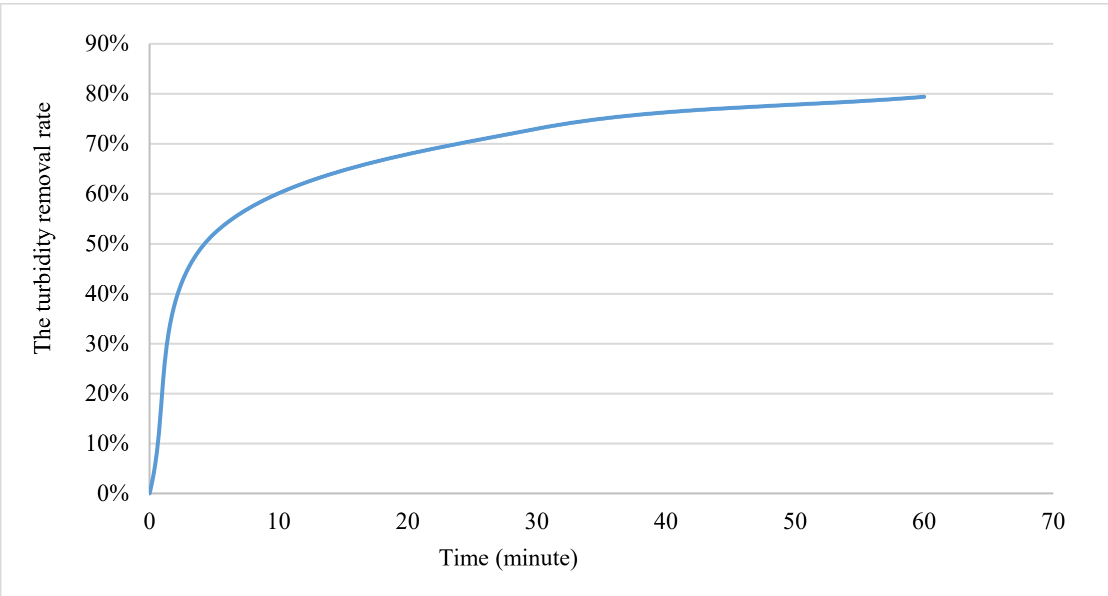


Figure 1. The turbidity removal rate in relation to sedimentation time for samples treating with Moringa oleifera coagulation

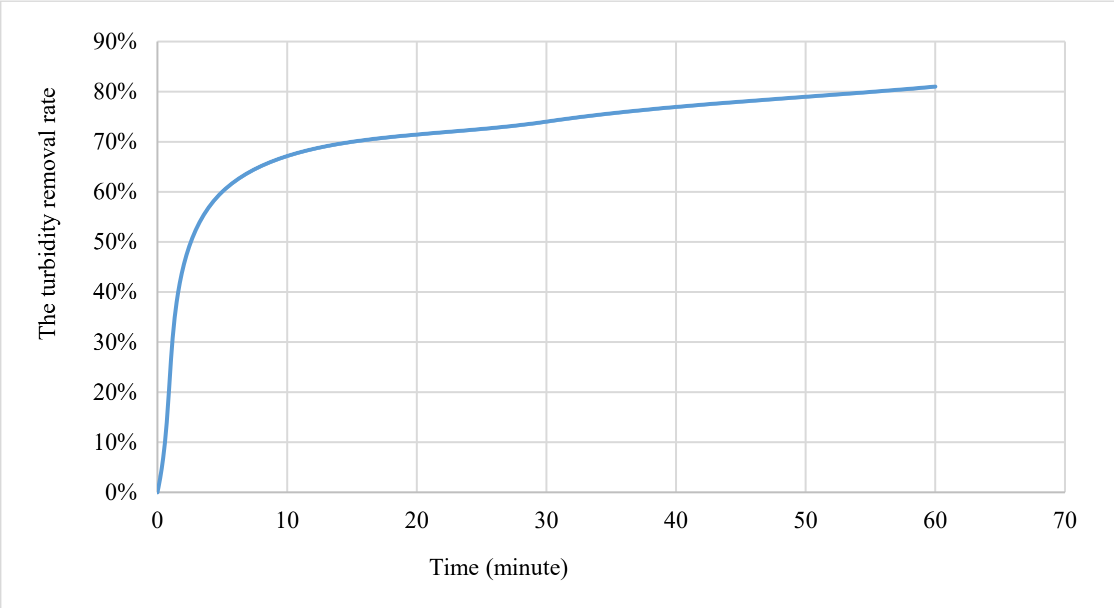


Figure 2. The turbidity removal rate in relation to sedimentation time for samples treating with Vicia faba coagulation

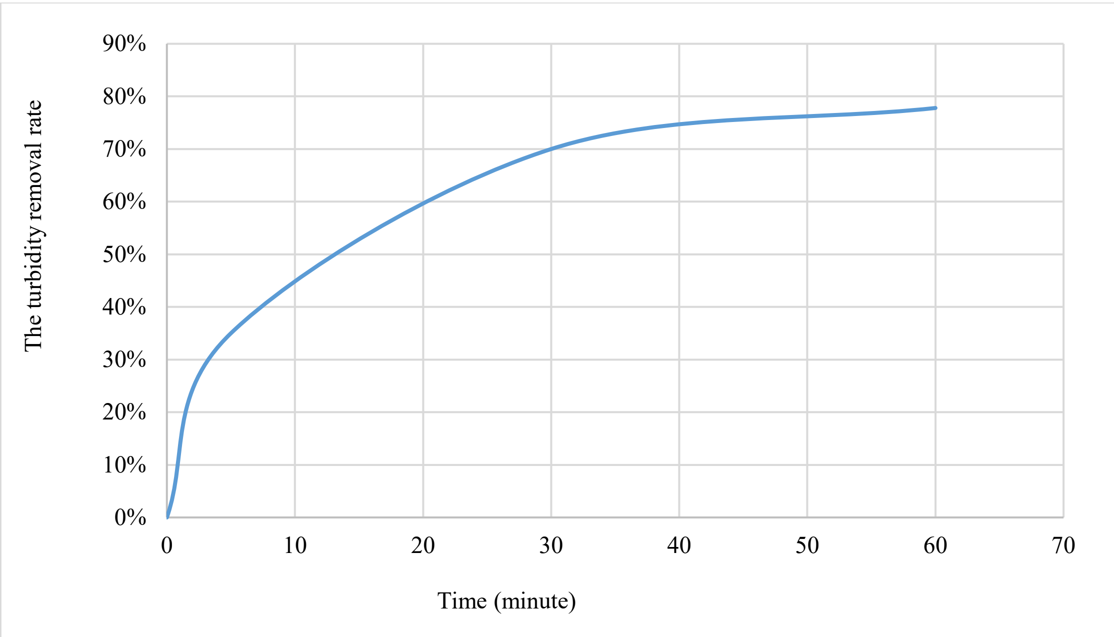


Figure 3. The turbidity removal rate in relation to sedimentation time for samples treating with Abelmoschus esculentus coagulation

According to result, the turbidity removal rate reached 52% of the entire process after 5 minutes of sedimentation as a result of adding Moringa oleifera coagulation in all samples, and reach to 73% turbidity removal rate after 30 minutes, as shown in Figure 1. Based on the result shown in Figure 2, the turbidity removal rate reached 60.2% of the entire process after 5 minutes of sedimentation as a result of adding Vicia faba coagulation in all samples, and reach to 74% turbidity removal rate after 30 min. The results show rapid coagulation-flocculation and sedimentation during the first minute's reach to 52%, 60.2% for Moringa oleifera and Vicia faba respectively, as there is a direct relationship between coagulation and sedimentation and time. As per the result shown in Figure 3, the turbidity removal rate reached 34.9% of the entire process after 5 minutes of sedimentation as a result of adding Abelmoschus esculentus coagulation in all samples, and reached 70% turbidity removal rate after 30 min. The results of treatment using Abelmoschus esculentus showed a low sedimentation rate during the first five minutes of sedimentation compared to other materials used [14, 18, 19]. The high sedimentation rate during the first 5 minutes in Vicia faba and Moringa oleifera compare to Abelmoschus esculentus may be attributed to the protein rate in Vicia faba and Moringa oleifera compared to Abelmoschus esculentus. Where the protein rate of the plants used in the research was measured, and the percentage of protein in Vicia faba was the highest, reaching 30% in the powder after drying and grinding. While the rate of protein in the Moringa oleifera sample reached 28%. As for the Abelmoschus esculentus, its protein content did not exceed 16%, which is the lowest among the plants used in processing. This is consistent with studies [12, 20]. It was demonstrated that the effect of protein on sedimentation and turbidity removal works-by building bridges which work on blocking suspended particles in water.

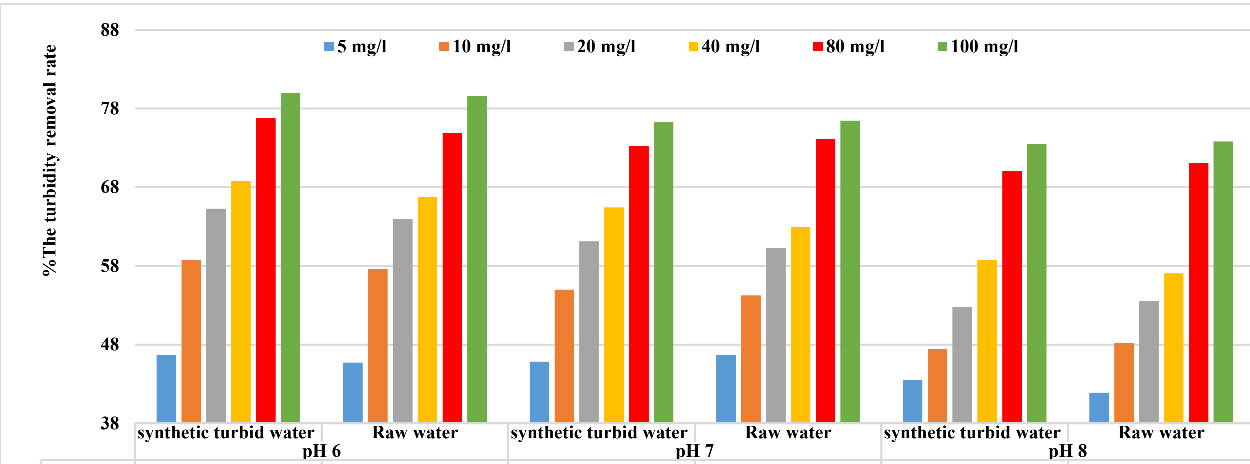
3.3 Turbidity removal results

Results of turbidity removal rates using different doses of natural coagulants: The results were extracted using the following Eq. (2).

$$\text{Turbidty removal }\% = \frac{\text{initial turbidity value} - \text{final turbidity value}}{\text{initial turbidity value}} \times 100 \qquad (2)$$

3.3.1 Using moringa oleifera

Results for the removal of water turbidity using various doses (5, 10, 20, 40, 80, 100 mg/L) of Vicia faba, Moringa oleifera and Abelmoschus esculentus. The jar test operations using three different coagulants were carried out in different value of pH, of synthetic turbid water. Initial turbidity test for raw water was performed at 6 pH, which reduced turbidity levels by a range from 45.7% to 79.6%. then at 7 pH, which also reduced with a range from 46.6% to 76.4%. Lastly at 8 pH, showing the same result a reduce in turbidity levels by a range from 41.9% to 73.8%, corresponding to 5, 10, 20, 40, 80, and 100 mg/L. Likewise, the turbidity removal rate for the synthetic turbidity water turbidity was 105 “NTU”, then put synthetic water under the same condition. After treating it with Moringa oleifera, the test was performed at pH 6, and turbidity removal rate for synthetic turbidity water was reduced with a range from 46.6% to 80%, for dose 5 mg/L to 100 mg/L respectively. then at pH7, which also reduced with a range from 45.8% to 76.3%. Lastly at pH8, which again reduced with a range from 43.5% to 73.5%, corresponding to 5, 10, 20, 40, 80, and 100 mg/L, as shown in Figure 4. From these results, we can rely on natural coagulants to treat water turbidity without the negative effects of chemical coagulants. The study showed a direct relationship between the turbidity removal rate and the concentration of coagulant. The effect of pH is observed in treatment, and this is consistent with studies [6, 9]. The efficiency of the extractions of Moringa oleifera, and other plants, which made them commonly used as (natural coagulants) for the purification of water. The results for turbidity removal using various doses it was promising [16]. One of the most important processes in supply water and wastewater treatment plants is coagulation/flocculation, which rises destabilization of dissolving solids, causing subsequent generation of flocs by using a coagulating agent [5]. Where study [21] provided a use for Moringa oleifera as a coagulant in water purification due to it containing a water-soluble cationic coagulant protein which is capable of reducing turbidity in water.



	synthetic turbid water (pH 6)	Raw water (pH 6)	synthetic turbid water (pH 7)	Raw water (pH 7)	synthetic turbid water (pH 8)	Raw water (pH 8)
5 mg/l	46.6	45.7	45.8	46.6	43.5	41.9
10 mg/l	58.8	57.6	55.0	54.2	47.5	48.2
20 mg/l	65.3	64.0	61.1	60.3	52.7	53.6
40 mg/l	68.8	66.7	65.4	62.9	58.7	57.0
80 mg/l	76.8	74.9	73.2	74.1	70.1	71.0
100 mg/l	80.0	79.6	76.3	76.4	73.5	73.8

Figure 4. The turbidity removal rate using Moringa oleifera coagulation in relation to type of water with different pH

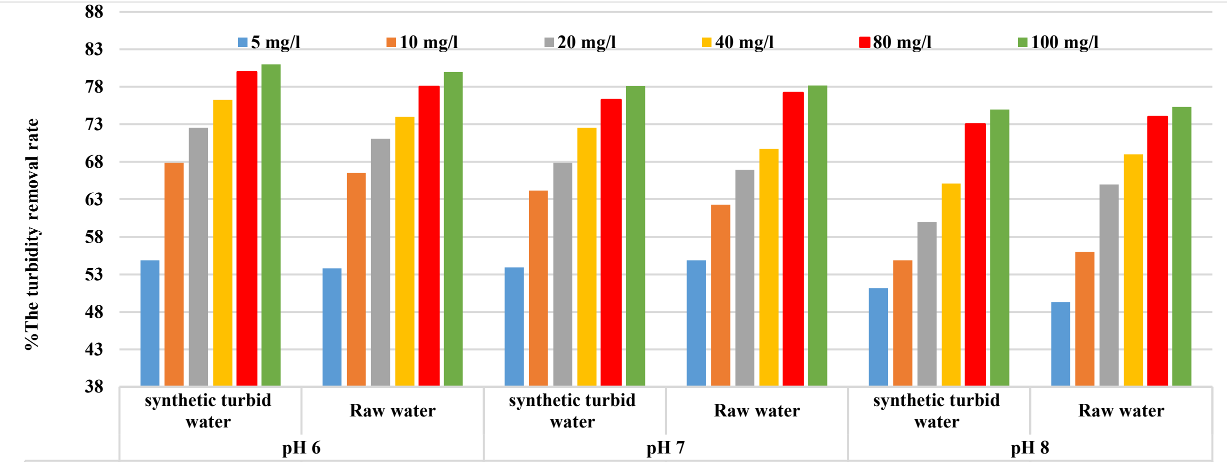
3.3.2 Using Vicia faba

From Figure 5, it appears that there is a higher reduction in turbidity for both types of testing on water synthetic and raw water by using Vicia faba compared to using other materials. The turbidity removal rate for raw water reduced with a range from 53.8% to 80%, at pH 6. At pH 7, it also reduced with a range from 54.9% to 78.2%. Then at pH 8, it reduces with a range from 49.3% to 75.3%, corresponding to 5, 10, 20, 40, 80, and 100 mg/L. Likewise, the rate of turbidity in synthetic water reduced with a range from 54.9% to 81%, at pH 6. Then at 7 pH, it also reduced with range from 53.9% to 78.1%. Lastly at 8 pH, we see a similar result by it reducing with range from 51.2% to 75.3%, corresponding to 5, 10, 20, 40, 80, and 100 mg/L, as shown in Figure 4. The results of treatment by using Vicia faba showed better removal rates than Moringa oleifera, although the treatment context is similar. These results are consistent with study [13].

3.3.3 Using Abelmoschus esculentus

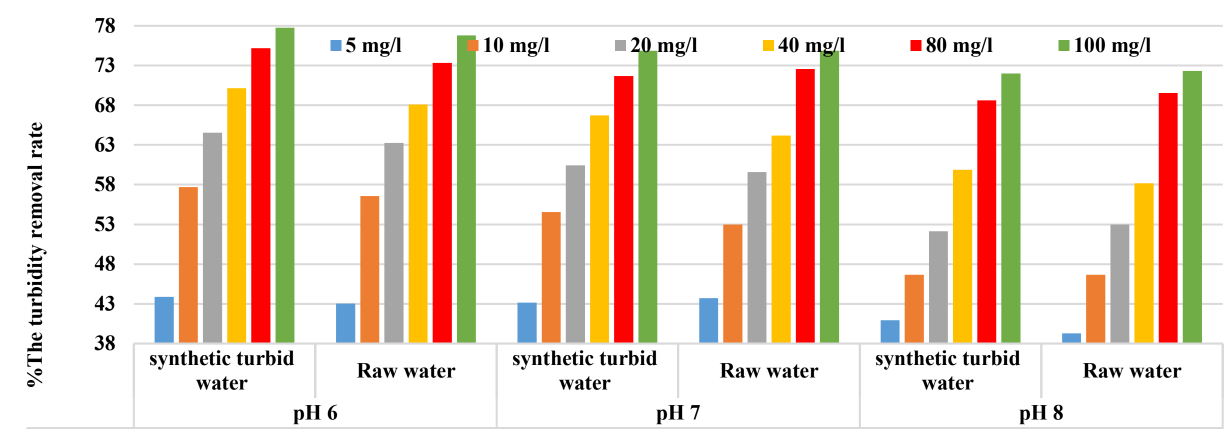
Processing results differed if Abelmoschus esculentus was used as a coagulant as shown in Figure 6, the turbidity removal rate for synthetic water reduced with a range from 43.9% to 77.8%, at pH 6. At pH 7, it showed a reduce with a range from 43% to 74.9%. Then at pH 8, it also reduced with a range from 39.4% to 72.3%, corresponding to 5, 10, 20, 40, 80, and 100 mg/L, as shown in Figure 4. Similarly, the turbidity removal rate for raw water reduced with range from 43% to 76.8%, at pH 6. Then at pH 7, again it reduced with a range from 43.7%

to 74.9%. Lastly at pH 8, it was reduced with range from 39.3% to 72.3%, corresponding to 5, 10, 20, 40, 80, and 100 mg/L. The turbidity removal rates were generally low compared to the other two types, especially in the first stage of sedimentation, where coagulation- flocculation was relatively slower in comparison to Vicia faba and Moringa oleifera. This may be due to the low percentage of protein in the Abelmoschus esculentus, which is an important factor in the formation of coagulation bridges, as the percentage of protein was 16% in the Abelmoschus esculentus sample used in this processing, while Vicia faba and Moringa oleifera contains twice as much protein as Abelmoschus esculentus. Which is consistent with studies [22-27]. This is also consistent with the findings of study [9], which demonstrated that treating water with natural materials is cost-effective and environmentally friendly, generating no waste and promoting a more circular approach to waste management in the industry.



	pH 6 synthetic turbid water	pH 6 Raw water	pH 7 synthetic turbid water	pH 7 Raw water	pH 8 synthetic turbid water	pH 8 Raw water
5 mg/l	54.9	53.8	53.9	54.9	51.2	49.3
10 mg/l	67.9	66.5	64.2	62.3	54.9	56.0
20 mg/l	72.5	71.1	67.9	67.0	60.0	65.0
40 mg/l	76.3	74.0	72.5	69.8	65.1	69.0
80 mg/l	80.0	78.0	76.3	77.2	73.0	74.0
100 mg/l	81.0	80.0	78.1	78.2	75.0	75.3

Figure 5. The turbidity removal rate using Vicia faba coagulation in relation to type of water with different pH



	pH 6 synthetic turbid water	pH 6 Raw water	pH 7 synthetic turbid water	pH 7 Raw water	pH 8 synthetic turbid water	pH 8 Raw water
5 mg/l	43.9	43.0	43.2	43.7	40.9	39.3
10 mg/l	57.7	56.6	54.5	53.0	46.6	46.6
20 mg/l	64.6	63.3	60.4	59.6	52.1	53.0
40 mg/l	70.2	68.1	66.7	64.2	59.9	58.2
80 mg/l	75.2	73.3	71.7	72.6	68.6	69.6
100 mg/l	77.8	76.8	74.9	74.9	72.0	72.3

Figure 6. The turbidity removal rate using Abelmoschus esculentus coagulation in relation to type of water with different pH

4. CONCLUSION

Natural coagulants can be considered a decent solution for treating water turbidity, as they have given good results in water turbidity removal. The results are promising of using natural coagulants and avoiding the adverse effects of chemical coagulants. In addition to recycling these materials and their cheap price. The Vicia faba's peels showed better results than the rest of the options used in the research in terms of rapid initial coagulation and higher removal rates. The results show that the best conditions for natural coagulations that were used in this study with the pH of 6 as the more the pH levels decreases the better the removal rate as for the sedimentation time the optimal time depends on the type of coagulation used overall the relation between sedimentation time and efficiency of removal is a direct relationship, however 40 minutes was the optimal time for high removal result. The study recommends to preform research to find natural alternatives to the chemical ones in order to avoid the negative side-effects.

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