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Practical Efficiency Comparison of Different Natural Coagulants for Water Turbidity Removal

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Abstract

The expense of water purification is increasing due to the colloidal and suspended molecular load brought on by land scraping and excessive overflow during the rainy season. There are numerous issues with employing manufactured coagulants, and the need for a cost-effective, health safeguard, and natural coagulant is rising. This paper examines the impacts of natural coagulants like; watermelon seeds, okra seeds, cactus, and aloe-vera on reducing water turbidity. The best-performing coagulant among the four coagulants was determined using the coagulation jar test, which also served to calculate the optimal coagulant concentration required to remove 100 nephelometric turbidity units (NTU) of turbidity. The findings of this investigation suggest that aloe-vera can be utilized as a reliable coagulant for turbid water. Subsequent experiments were conducted using the established coagulant to evaluate various variables including coagulant dose, pH, water turbidity, rapid and slow mixing periods, and settling period. By employing aloe-vera, a more significant percentage of turbidity removal may be accomplished when the pH was 6.5, the beginning water turbidity was 500 NTU, the rapid mixing period was equal to 1 minute, the slow mixing period was preferred at 20 minutes, and the settling duration was 25 minutes.

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1. INTRODUCTION

Continuous pollution in the water due to the increase in the discharge of polluted water resulting from population water consumption and the changing characteristics of water resources with climate changes [1-3]. These reasons lead to the necessity of simple, cost-effective, and easily used water purification systems [4-6]. One of the most important water purification steps is coagulation. The process of coagulation is essential because it eliminates not just big or small flakes but also other contaminants such as germs, heavy metals, and other matters that are frequently present in untreated water. The most popular chemicals used to eliminate suspended particles from water during the drinking water purification process are poly aluminum chloride, ferric chloride, and alum [7, 8]. Insoluble flocs are formed because of coagulation between the coagulant applied, the contaminants, and the water's alkalinity. Flocs are clumps of colloidal and dissolved water-borne materials that are suspended in untreated water and are the resultant colloids of the chemicals added to the water. Untreated water contains both inorganic and organic pollutants, including silt, rotting material, alga, bacteria, etc. Coagulation is therefore a crucial step in the process of purifying water. Additionally, coagulants create suspensions in water to collect and lessen the turbidity of the water [9].

Chemical coagulants are less safe, less environmentally friendly, and more hazardous than naturally occurring coagulants [10]. Chemical coagulants remain far behind in green chemistry despite their availability, ease of handling, storage, low cost, etc. because of the large residual quantities of aluminum found in filtered water. Alum and iron salts are the two chemical coagulants most frequently used in water purification. Aluminum has also been associated with neurological disorders like dementia. Alzheimer's disease development has been linked to aluminum particle consumption [11]. Local tissue irritation is the harm caused by aluminum sulfate most frequently. Ingestion, contact with the skin or eyes, or inhalation of dust and mists can all result in the irritating action, which frequently results from alum hydrolysis to create sulfuric acid [12, 13]. Aluminum, a chemical coagulant in high concentrations, lowers the pH of aqueous solutions and can accumulate in food chains [14]. When hazardous sludge is disposed of improperly, it pollutes soil and groundwater. When toxic sludge, such as

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aluminum, iron, etc., accumulates in natural water bodies, aquatic organisms and plant species suffer [15]. So, using natural coagulants effectively is necessary for water purification.

Due to the limitations of chemical coagulants, natural coagulants that are sustainable and eco-friendly in both manufacturing and use are being sought. Cost-effectiveness, renewability, nontoxicity, and biodegradability are the key benefits of natural coagulants. Previous research has already demonstrated the usefulness of natural coagulants in the purification of water [16-18]. Due to their enormous creatures' health, and environmental profits, simultaneously they generally address the issues that chemical coagulants frequently cause, natural coagulants have captured the interest of scientific researchers nowadays. Different sources, including plant tissues, animal tissues, or bacteria [19], create or extract natural coagulants (non-plant-based and plant-based). Today, several potent coagulants with plant origins are being discovered. Moringa oleifera [20], Dolichos lablab (Hyacinth bean) [21], Hibiscus sabdariffa (Roselle seeds) [22], and Nirmali seeds [23] are the most popular varieties. These substances are easy to degrade naturally and be suitable for human consumption [24].

The objective of this research was to discover an inexpensive natural coagulant that could eliminate or reduce water turbidity to the allowable drinking water limits. Based on the outcomes of the jar tests, the study also made improvements to the variables that influence the coagulant process, such as mixing period (rapid and slow mixing) pH, coagulant dosage, settling time, and turbidity concentration.

2. MATERIALS AND METHOD

2-1 Sample preparation

Clayey dirt was dissolved in unchlorinated tap water (tap water was left overnight to ensure chlorine was released) in the laboratory to produce the high turbidity water that was utilized in the study. This experiment's clayey soil was taken from a college campus. 30 g of the obtained clay was dissolved in one liter of unchlorinated tap water. For an hour, the soil solution was agitated to establish a constant dispersion of clay particles. To achieve thorough hydration, the suspended clay was left for at least 24 hours to have sufficient time for settlement. The supernatant suspension of previously manufactured synthetic turbid water was utilized to make a 500 NTU stock solution. The stock solution was diluted with unchlorinated tap water to obtain 10 different suspension solutions with a turbidity of 10 NTU to 100 NTU with 10 NTU.

2-2 Process of coagulant preparation

The four natural and eco-friendly coagulants utilized in this study were watermelon seeds, okra seeds, cactus, and aloe-vera. The selected coagulants were gathered from the neighborhood's residential regions and local fields in Sohag, Egypt. Separated watermelon seeds were sun-dried for six days to get rid of any moisture before being heated in a hot air oven for an hour at 60℃. After that, a grinder was used to grind the oven-dried seeds. The dried ground watermelon seeds had been sieved through Sieve No. 40 (opening 0.425 mm), and the passed materials were used as a watermelon seeds coagulant. Okra seeds were dried for two days in an oven at 50℃. The dried seeds were dried in an oven and then pulverized in a grinder. The ground seeds were passed through Sieve No. 40 (opening 0.425 mm), and the substance that went through served as a coagulant. To create the cactus coagulant, fresh opuntia (cactus) was cut into 1 cm wide strips and baked at 60℃ for a full day. The oven was used to dry Opuntia species (cactus) and then ground them using a grinder. The grinding substance that passed through Sieve No. 40 (opening 0.425 mm), was used for the coagulation study. The aloe-vera was defused and dried in an oven for three days at 60℃ to remove the oil. After drying, a fine powder was obtained by blending the peels. The ground substances were passed from Sieve No. 40 (opening 0.425 mm), and the passed ground seeds were used as a coagulant.

2-3 Coagulation experiments method

The most efficient of the four natural coagulants was determined via a jar coagulation test. Following standard practice, the jar coagulation test was run, beginning with a concentration of 10 NTU. Six beakers (500 ml each) of synthetic turbid unchlorinated tap water with an NTU of 10 were filled with the original coagulant (watermelon seeds, okra seeds, cactus, or aloe-vera) in concentrations ranging from 0.1 to 0.6 g with 0.1 g intervals with concentrations of 0.2 mg/l to 1.2 mg/l [25]. The contents of a 500 ml beaker were violently shaken at 100 rpm for 120 seconds, then gently mixed for 20 minutes at 35 rpm to promote flock formation. The flocculated fluids were not touched for 30 minutes to simulate settling. The floc amount was determined by measuring the settled particles in a measuring jar. The process was the same for the other coagulation experiments.

The best natural coagulant was used to examine the effect of coagulant dose, pH, initial concentration of turbidity rapid mixing period, slow mixing period, and settling period. To find the best coagulant dose of the most efficient coagulant [26], several jar tests with 200 NTU have been performed with different coagulant doses of 4, 8, 12, 16, and 20 mg/l. The turbidity meter has been used to measure the turbidity to calculate the turbidity removal. Using a 200 NTU synthetic turbid solution, a jar experiment was performed to examine the effects of pH on the elimination of turbidity. The ideal dosage from the prior experiment was used. With intervals of 2 for pH values ranging from 2 to 12, the corresponding residual turbidity of the coagulant was determined using the same jar test method. The influence of initial turbidity on turbidity removal has been examined by using different initial water turbidity of 25 NTU, 100 NTU, 200 NTU, 400 NTU, and 500 NTU at optimal pH and ideal dosage. A rapid mix period has been examined between 60 and 300 seconds with 30 seconds intervals at optimal pH and ideal dosage within 200 NTU synthetic turbid solution. A slow mix period has been examined between 10 and 35 minutes with 5 minutes intervals at optimal pH and ideal dosage within 200 NTU synthetic turbid solution. The influence of settling time on turbidity removal has been tested between 5 and 35 minutes with 5 minutes intervals with jar test with the optimal value of other variables. All tests have been repeated twice at least, and the mean and standard deviation were computed and plotted.

3. RESULTS AND DISCUSSIONS

Figure 1 plots the amount of each coagulant's floc settles at various doses after being measured using a measuring flask. The figure shows that the settled floc was different depending on the coagulant types. The highest settled floc was 1.6 ml, 0.95 ml, 0.6 ml, and 0.5 ml for aloe-vera, Cactus, Watermelon, and Okra, respectively at a dose between 0.6 and 0.8 mg/l. Hence aloe-vera was chosen as a good coagulant for the subsequent jar experiments. The following results discussion for all upcoming data has been obtained by using aloe-vera as a coagulant for testing the other parameters.

For the different coagulant dosages of 4, 8, 12, 16, and 20 mg/l, the equivalent turbidity removal of coagulants was calculated and shown in Figure 2. It has been noticed that 89–93% of the turbidity was eliminated when a coagulant dosage of 8 mg/l was used. The lower aloe-vera concentration was not sufficient for the flocculation process, which leads to high turbidity in the solution. The increment of the coagulant dose was associated with the deflocculation of the settled flocs, indicating that a higher concentration of aloe-vera increases the turbidity by itself or by disturbing the created and settled flocs.

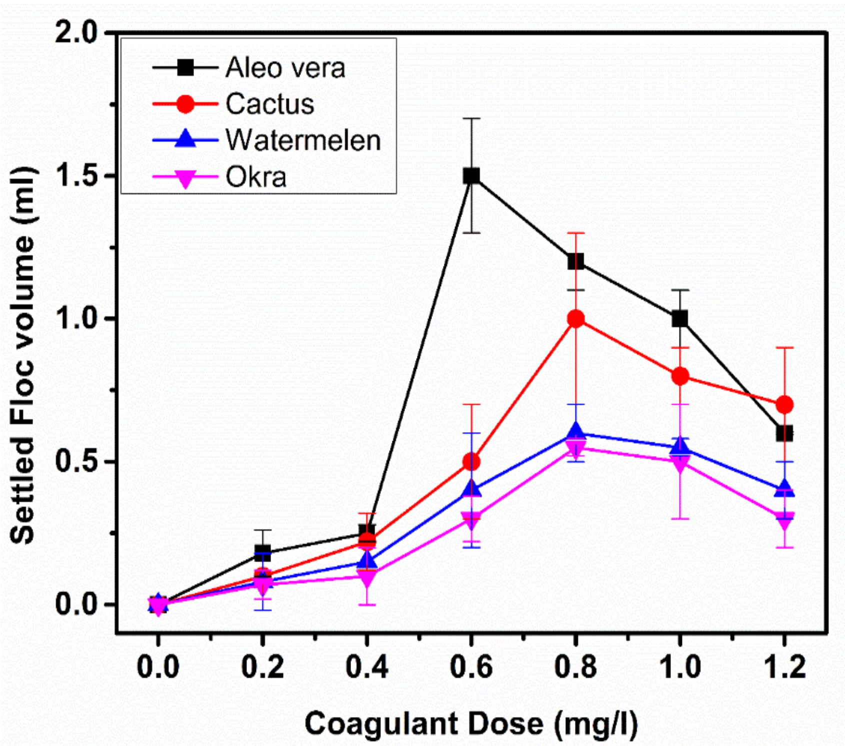


Fig. 1. Settled floc volume at various doses of different natural coagulants.

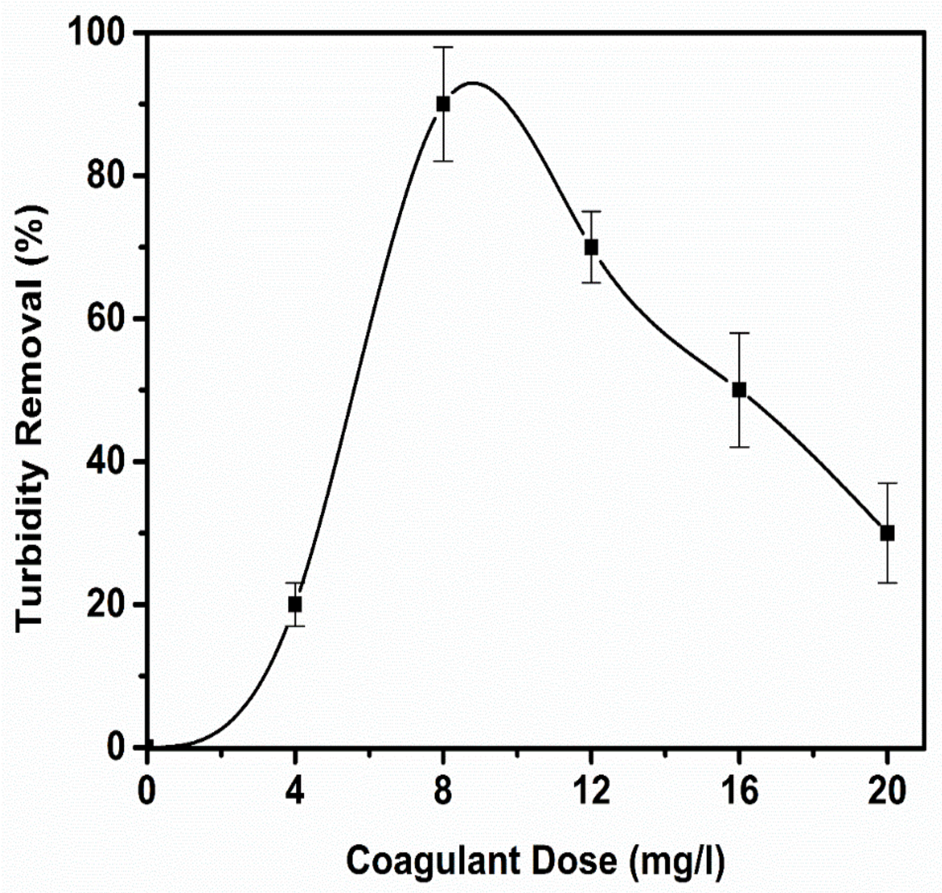


Fig. 2. Effect of coagulant (Aleo-vera) dose on turbidity removal.

Figure 3 presents the variation in turbidity removal percent at various pH settings. As can be seen in the figure, turbidity was eliminated to a maximum percentage of 93 percent when pH was kept at 6.5. Despite the fact that pH modifications do affect the whole removal's final turbidity, A lack of noticeable changes in turbidity removal with pH changes. It suggests that there is no need to use the coagulant at a pH other than neutral.

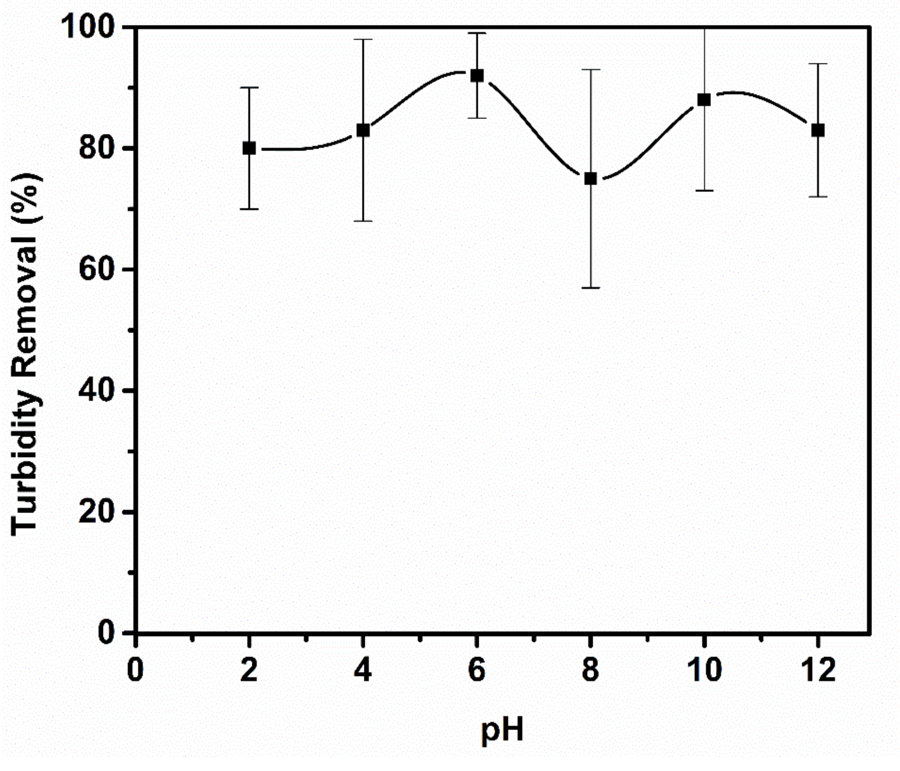
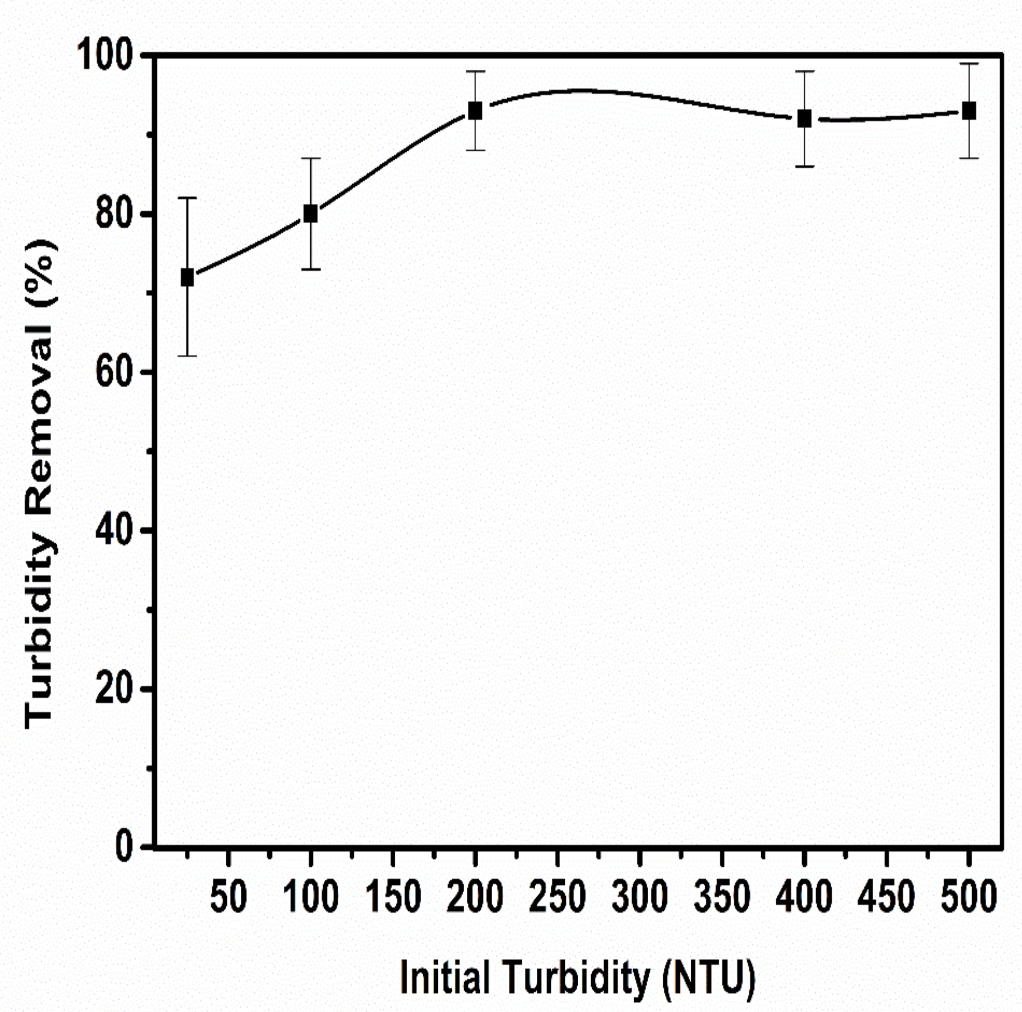


Fig. 3. Influence of water pH on turbidity removal.

According to Figure 4, the relationship between initial turbid concentration and percent of turbidity removal has been plotted. The highest percent of turbidity removal was 93% attained for the beginning turbid concentration of 200 NTU. The turbidity removal percentage has been increased with increasing the initial turbidity of the water from 25 NTU to 200 NTU. The larger rise in initial turbidity beyond 200 NTU, therefore, has no discernible impact on turbidity reduction. This can bring us back to the initial low turbidity where there wasn't enough turbidity to produce a floc with enough weight to easily precipitate.

Fig. 4.



Influence of water initial turbidity on turbidity removal.

Figure 5 displays the turbidity removal percentage as a function of the rapid mixing period. According to the figure, the percentage of turbidity that is eliminated climbs with the rapid mixing period, peaking at 93 percent at 60 seconds. When the rapid mixing period is increased past sixty seconds, Deflocculation of the settle floc occurs, which lowers the amount of removed turbidity.

As indicated in Figure 6, The percentage of turbidity elimination for each slow mixing interval was calculated and displayed. It depicts how the amount of turbidity reduced changes with the amount of mixing period. With each minute of gradual mixing, the elimination percentage rises, peaking at 93% percent after 20 minutes. The fraction of turbidity eliminated decreases as the slow mixing period surpasses 20 minutes due to the floc deflocculating.

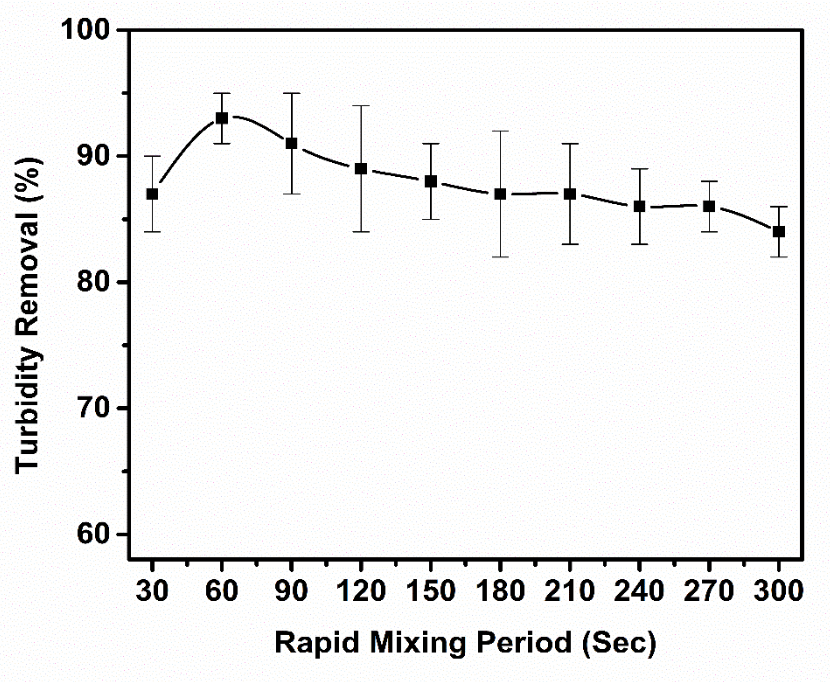


Fig. 5. Effect of Rapid mixing period on turbidity removal.

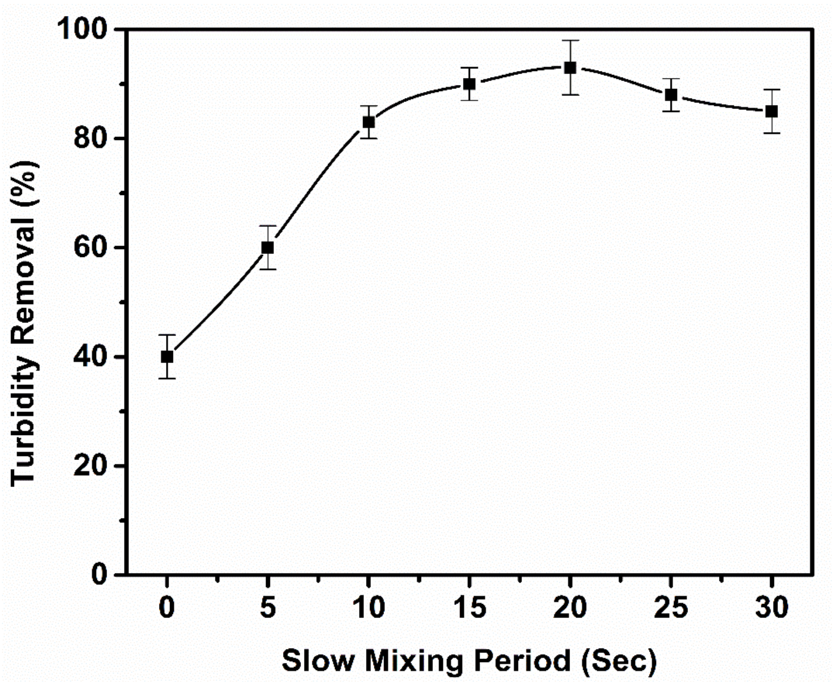


Fig. 6. Effect of slow mixing period on turbidity removal.

Figure 7 plots the computed turbidity removal percentage against the settlement time. Figure 7 shows how, as settling time increases, more turbidity is reduced, reaching a maximum of 93% percent. When the settling duration was 25 minutes, the highest removal was attained. Beyond 25 minutes, the settling period increments do not demonstrate any improvement in turbidity reduction.

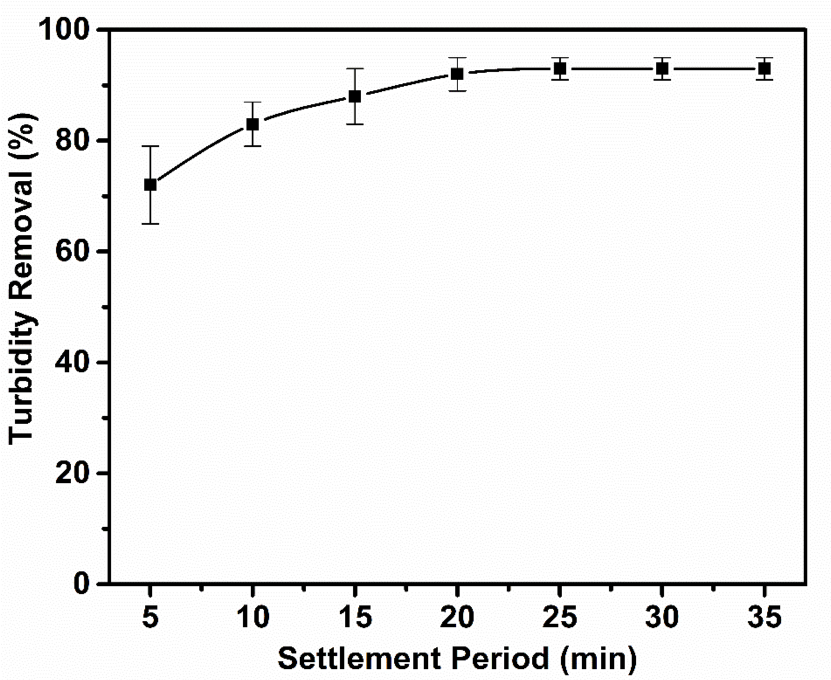


Fig. 7. Effect of settlement period on turbidity removal

4. CONCLUSION

Out of the four coagulants (okra Seeds, watermelon seeds, aloe-vera, and cactus) used in this investigation, aloe-vera is a more potent coagulant than the others. The impact of variables such as coagulant dose, initial turbidity, slow mixing period, rapid mixing period, pH, and settling period on the percentage of turbidity eliminated by the coagulation process was more studied in optimization studies. The maximum amount of turbidity could be eliminated when the dose of coagulant is 8 mg/l, the pH is maintained at 6.5, the initial water turbidity is 200 NTU, and the slow mixing period, the rapid mixing period, and the settlement period are 20 minutes, 60 seconds, and 25 minutes.

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