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Plant-based coagulants for water treatment

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Abstract. The use of coagulants that are derived from natural material has significantly increased over the last decades due to the safety and cost-effectiveness use of such coagulants. Therefore, the current study aims to use a plant-based coagulant namely Moringa Oleifera seeds to remove the water turbidity. During the experimental work, samples of water of 250 nephelometric turbidity units (NTU) were mixed with various amounts of Moringa Oleifera seeds in the laboratory at room temperature (20 ± 1 ºC) for 90 minutes. Every 10 minutes, 5.0 ml samples were collected using a plastic container and filtered to be checked using a spectrophotometer for the removal of turbidity. Besides, the impact of mixing time, dose of Moringa Oleifera, and pH on the removal of the turbidity was investigated. The outcome showed that the turbidity of the treated water decreases with the increase in the dosage of Moringa Oleifera and the mixing time. However, it was noticed that the removal efficiency of the turbidity decreases when the pH value is more than 7. The removal of the water turbidity of 92% was achieved using 8 g/l of Moringa Oleifera for 80 minutes.

1. Introduction

Many nations around the world suffer from serious potable water scarcity for many reasons including the lack of resources and financial support [1-3]. Besides, the growing population and industrial sectors have led to the discharge of growing pollution loads to freshwater bodies and making the purification process increasingly expensive [4, 5]. Researchers, [6, 7], have reported that about 1.2 billion person does not have access to freshwater, and more than 6 million individual dies due to polluted water-related diseases each year. Other scholars [8-11] confirms that millions of cubic meters of polluted water are yearly discharged into the water bodies (surface or groundwater bodies) due to industrial growth. For instance, Abdulhadi *et al.* [12] stated that the textile industry daily consumes large quantities of freshwater and discharges the majority of this water as extremely contaminated to water bodies. On average, the textile industry consumes about 0.2 cubic meters of freshwater to produce 1.0 kg of fabric. The petroleum industry is the main producer of highly polluted wastewater nearly about 1.6 times of the produced oil. Researchers reported that more than 33.6 million barrels of heavily polluted water are disposed to water bodies to produce only 84 million barrels of oil. It is expected that the demand for oil industry products will more than 100 million barrel per day which will lead to generating huge quantities of heavily polluted water with various contaminants including dyes, phenols, and nutrients [13-16].

Turbidity is one of the most common water pollutants due to soil erosion, runoff, or the presence of elevated numbers of microorganisms [17-20]. It significantly spoils the water appearance, negatively affects fish production, damages the water quality, and could cause several diseases such as nausea [21-24]. Thus, 1.0 nephelometric turbidity unit (NTU) is set by the world health organization as the maximum turbidity level for drinking purposes. To achieve this limitation, many biological, chemical, and physical methods were employed to minimize the turbidity of the water.

Biological approaches employ microorganisms to remove the pollutants from water. Such approaches are effective in the removal of organic components of the water turbidity, nonetheless, their efficiency is less in the removal of inorganic matter-related turbidity. Therefore, researchers normally couple the biological methods with other treatment methods to remove the turbidity. For instance, the granular activated carbon method and the moving-bed biofilm method are combined to remove turbidity from the leachate of landfills, where about 90% of the turbidity and 70% of the colours were removed from the leachate samples [25-29]. The combination of the aerated filter method and an anoxic filter bed was found efficient to decrease the turbidity to about 94% of the turbidity from the textile industry wastewater [12, 30]. Researchers showed that the biological methods are efficient in removing turbidity from water. However, such methods face several limitations including treatment duration, space requirements, and pollution loads [31-33].

Physical methods such as sand filter and screening remove pollutants from water without changing the chemical composition of pollutants [34-37]. For example, a crumb rubber filter was used to remove turbidity from the water where about 47.8% of the turbidity was removed using a grain size of 2 to 4 mm, and discharge of 24.4 m^3/h. The literature indicated that slow sand filters could remove turbidity from water by a percentage of more than 85%. on the other hand, some researchers coupled poly-aluminum-chloride coagulation with rapid sand filtration to remove turbidity and achieved 80.0 % removal of the turbidity. However, physical methods either have low cost and removal efficiency or have high cost and good removal efficiency [38-40].

Chemical methods employ chemical additives to group the fine particles in large flocs in which are removed by sedimentation or floatation [39, 41]. For example, a number of researchers, [17, 19, 39] used many coagulants (such as poly-aluminum chloride and poly-titanium chloride) to minimize the turbidity from 7.0 NTU to 1.2 NTU. A 5 mg/l of poly-aluminum ferric chloride is used to remove 86% of colour and 100% of turbidity at a pH of 7.5. polymeric zinc-iron-phosphate is also used to reduce the turbidity from about 9 NTU to less than 1.0 NTU in 15 minutes [42-44]. However, the industrial coagulants could cause negative effects on humans and the environment such as Alzheimer's disease and some types of cancer. Thus, researchers currently focus on the use of natural coagulants such as cactus opuntia and watermelon seeds to remove turbidity from water [12, 17, 45]. The need for cost-effective coagulants for water treatment because the poor countries are subjected to a significant increase in water demand nowadays because of global warming [46-48], which also increases water pollution in those countries [49-51]. Additionally, the coagulation process is favourable nowadays because the sludge of water and wastewater treatments could be used as a cementitious material [52-55], or in other construction materials [56, 57].

Moringa oleifera seeds (MOSs), Fig.1, are Moringaceae tree seeds, which have been successfully used as a natural coagulant to remove pollutants from water, such as heavy metals [17]. Researchers stated that MOSs are extensively used in water treatment due to their fullness with acids that have great coagulant and anti-microbial properties. For instance, the MOSs were used to remove heavy metals such as lead and copper from wastewater where a removal efficiency of more than 70% was achieved [17]. The MOSs was also used as a powder to remove organic contaminants where about 65% of the organic content was removed after 180 minutes of treatment. Other scholars used the seeds to eliminate biological pollutants from water and achieved 40% removal efficiency after 1.5-hour contact time.

Accordingly, efficient, and safe water treatment methods are required to meet the future demand for potable water. Currently, the researcher's attention is the use of natural to remove pollutants from water and wastewater. Thus, the current research is designed to use the MOSs as a natural coagulant to eliminate the turbidity of the water.

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2. Methodology

2.1. Materials

The Department of Civil Engineering, Liverpool John Moores University provided the seeds. According to Alenazi, *et al.,* [17], the seeds have to be dried for 48 hours at an oven temperature of 40° and crashed and sieved at mesh 0.42 mm to be used in experiments. Following this, after drying the seeds, the exterior of the seeds was removed by hand, while the interior was ground using a food processor. The resultant was passed through a 0.42 mm mesh sieve and kept in a vessel to be employed in the turbidity removal trials.

2.2. Solution

Alenazi, *et al.,* [17] stated artificial turbid water can be prepared by mixing 5 liters of deionized water and 50 grams of kaolin at 20 revolutions per minute for 60 minutes. The turbid water used in this study was prepared according to Alenazi, *et al.,* [17] method and kept for one day to hydrate the kaolin. The turbidity of the prepared synthetic water was 250 NTU.

2.3. Batch experiments

The turbidity removal efficiency of the MOSs was examined by conducting batch tests on the prepared synthetic water samples. As recommended by Alenazi, *et al.,* [17], the tests were conducted by adding a dose of MOSs powder to 1 liter of the prepared turbid water of 250 NTU and mixed for a maximum of 90 minutes at a speed of 40 revaluations per minute. The impacts of the mixing time, the pH level, and the dose of the MOSs powder were examined by applying several mixing times ranged from 10 to 90 minutes, pH level varied between 4 and 9, and MOSs doses varied between 4 to 12 g/l. The pH level was controlled using HCL and NaOH and measured using Hannah portable pH meter.

The turbidity removal efficiency was calculated by collecting 5 ml samples every 10 minutes. Whatman filter paper number 5 was used to filter the samples for the turbidity elimination test and the removal of the turbidity was calculated using the spectrophotometer and the calibration curve. According to Hashim *et al.,* [58], the following equation can be used to calculate the removal efficiency.

$$\text{Turbidity removal efficiency (\%)} = \frac{A_1 - A_2}{A_1} \times 100 \quad (1)$$

Where A_1 represents the primary turbidity level of 250 NTU, while A_2 represents the closing level of the turbidity.

3. Results and discussion

3.1. Influence of the pH

The turbidity removal efficiency can be affected by the concentration of the hydrogen ions (pH level) of the water as it impacts the concentration of ions in the water and cationic acids in the MOSs powder. The influence of pH on the removal efficiency of turbidity has been investigated by treating 1000 ml of water samples using 250 NTU initial turbidity level for 30 minutes at pH values ranged from 4 to 9. Figure 1 provides a graphic presentation on the impact of pH on the removal efficiency of the water turbidity. When the water becomes alkaline (the pH more than 7), the removal efficiency decreases with the increase in water pH level due to the presence of hydroxyl ions. It can be also seen that the best removal efficiency of turbidity was stable at the middle pH level range between 4 and 7. This performance in turbidity removal at the middle pH level is attributed to the existence of hydrogen ions which increased the absorption ability of MOSs powder. Accordingly, a pH level of 7 has been selected to identify the impact of the MOSs dose and contact time.

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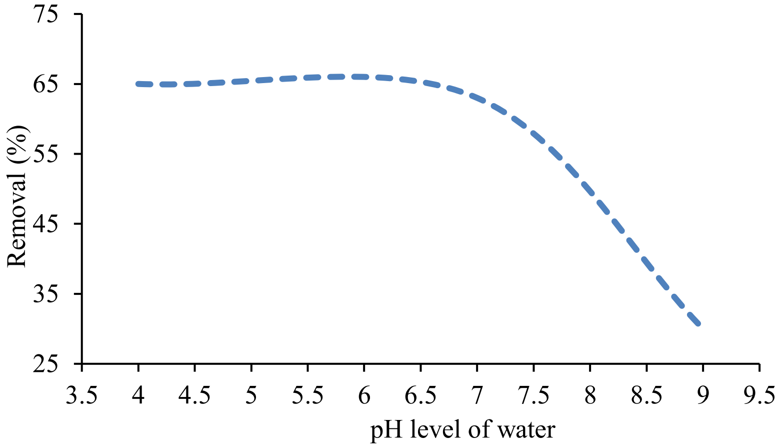

Figure 1. Impact of pH on the removal of water turbidity.

3.2. The influence of the MOSs dose

The dosage of MOSs strangely influences the removal of the turbidity of the water as it makes the most of the surface area available for turbidity adsorption. Accordingly, the impacts of the MOSs on the elimination of turbidity from the water were considered by treating the same sample size (1000 ml) of water for the same duration (30 minutes) and the decided pH level of 7. The initial turbidity was selected to be 250 NTU and the doses of MOSs were 4, 6, 8,10, and 12 g/l at every 5 minutes.

Figure 2 highlighted that the increase in the MOSs dose rises the removal of the turbidity of the water. This confirms that the more the MOSs powder dose the more the available space to adsorb turbidity which significantly enhances the removal efficiency. After 8 g/l dose of MOSs, the removal efficiency stabled on 75% removal; accordingly, a dose of 8 g/l of the MOSs has been used to examines the impact of mixing time on the removal efficiency of the turbidity of the water.

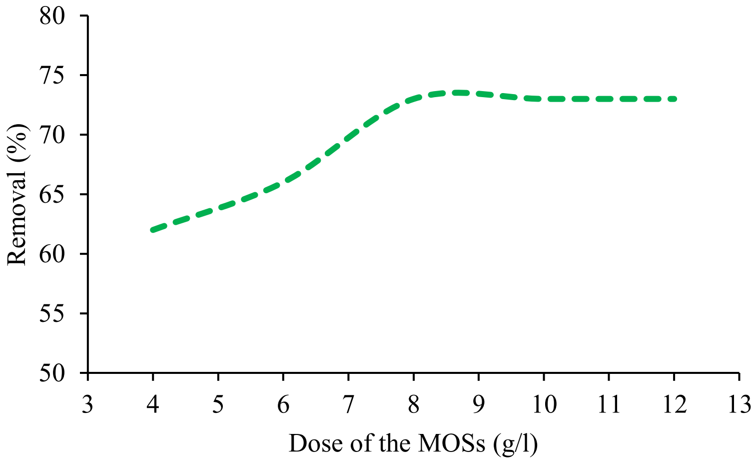

Figure 2. The impact of MOSs dose on the removal efficiency of the turbidity of the water.

3.3. The influence of the mixing time

Time plays a vital role in any water treatment activity such as adsorption. The time allows longer contact between the pollutants of the water and the adsorbent. Thus, the influence of treatment duration on the removal of turbidity has been analyzed by treating samples that have a sample size of 1000 ml, initial turbidity of 250 NTU, the pH level of 7 for 90 minutes using a MOSs dose of 8 g/l. The outcome showed in Figure 3 highlighted that the removal of turbidity has steeply increased to reach about 90% after 50 minutes of contact time. Accordingly, a dose of 8 g/l of the MOSs was able to remove 92% of the turbidity of water with a pH level of 7 after 90 minutes.

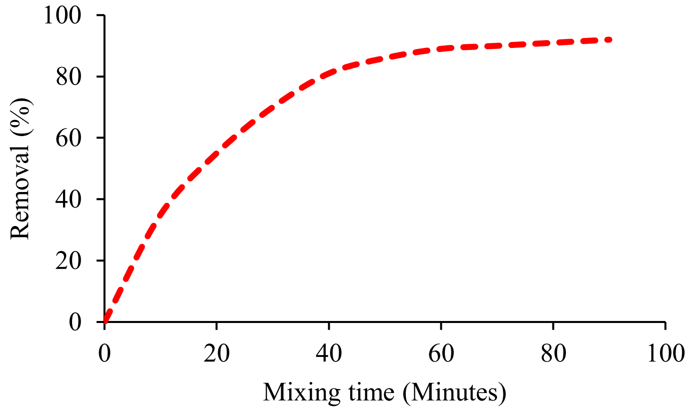

Figure 3. The impact of the treatment duration on the removal of turbidity.

3.4. Evaluating the performance of the MOSs as a coagulant

Scholars such as [17], and [39] applied various types of chemical coagulants to remove the turbidity from the water. According to [17], the removal efficiency of the turbidity from water and wastewater using chemical coagulants ranged between 86 and 100%. Accordingly, the MOSs powder (a natural coagulant) adopted in this research achieved a comparable outcome of 92% removal efficiency for the turbidity of the water. Therefore, it can be said that the negative impacts of chemical coagulants can be minimized by using eco-friendly natural coagulants such as MOSs.

4. Conclusions

The current study investigated the use of natural coagulants namely *Moringa oleifera* seeds for the removal of the turbidity from water. According to the outcome of this experimental study, it can be said that the *Moringa oleifera* seeds can be considered as an acceptable substitute to the chemical coagulants for the removal of the turbidity pollution from water as it was able to remove 92% of the turbidity. A higher dose of MOSs and longer contact time provide better removal of the turbidity pollution from water. Additionally, the removal efficiency of the MOSs is influenced by the pH value of the treated water, which can be improved by maintaining the pH level below 7. The MOSs can be considered as an eco-friendly coagulant as the chemical management for the MOSs is not required and have no impact on human health.

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