Surface Water Treatment Using Tamarind Seed as Coagulants via Coagulation Process

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Abstract. The potential of natural coagulants is highly sought nowadays as the use of commercial coagulants, aluminum sulfate (alum) affect the environment negatively. An alternative coagulant is needed. In this study, the effectiveness of natural coagulant, the tamarind seed extract is being evaluated as a coagulant to measure the highest percentage removal of turbidity and chemical oxygen demand (COD) in the surface water. The surface water sample taken from the Sungai Perlis located in Kangar, Perlis. The sample were analysed using Jar Test Experimental works with rapid mixing speed of 120 rpm in 1 minutes, slow mixing speed of 30 rpm in 20 minutes and settling time of 1 hour. The tamarind seed is being extracted using distilled water and 1 M of sodium chloride (NaCl). Seed extract from distilled water effectively removes 99.2% of turbidity and 77.2% of COD with optimum coagulant dosage of 30 mg/L and optimal pH 5.0. While, the seed extracts from 1 M of NaCl can remove 99.4% of turbidity and 73.8% of COD with the optimum coagulant dosage of 30 mg/L and optimal pH 3.0. Hence, this study demonstrates the potentials of the seed extract of tamarind seeds using distilled water in treating the surface water.

1. Introduction

In the past few past decades, the quality of the water is declining sharply because of the anthropogenic activities mainly in the industrial field. In Malaysia, there are two major causes of the polluted surface water which are the land development for industry and natural resources activity. The polluted surface water from the industrial came from the new development of the textile, foods, beverages and healthcare industries that has been increasing in this past few year. The agriculture area came from the development of the new agricultural activities and logging area. The waste produced from those area is not being treated and being released in the river causing the deterioration of the quality of the surface water [1]. Those activities mentioned above causing the soil erosion to seep in the surface water like rivers and lakes contributing to the rise of the organic, inorganic matter and river sedimentation problem. It contributes to the increasing of the turbidity of the water itself. Furthermore, the eutrophication phenomenon that was also a result from the human activities has also severely affected the quality of the water [2] and risking the human health. The river sedimentations promote the repository of the heavy metals and the buildup of those elements may reach a certain threshold of toxicity to aquatic life and eventually to the food chain systems [3].

There are several techniques that can be used to treat the polluted surface water especially river. One of them is the coagulation technology that requires coagulants. The conventional coagulant such as acrylamide has strong neurotoxic and carcinogenic effects [4]. Besides, the other conventional coagulants like iron salts, they need a meticulous process controls are needed as the excessive iron
residual in the treated water will lead to the highly visible rust or bloodcolored stains [5] caused by the hydrolysis of iron salts. The solution to these problems is by using the natural coagulants instead of the conventional coagulants. Nowadays, the natural or the plant-based coagulant has been widely used and practiced all around the world. In this study, tamarind seeds are being used as the natural coagulants to replace the conventional coagulants (chemical). It is safe, eco-friendly and generally free from toxic [6],[7]. In addition, it can also produce smaller sludge volume of up to five times lower and a higher nutritional sludge value [8]. Hence, the tamarind seeds are selected as the natural coagulants replacing the conventional coagulants, alum to treat the polluted surface water.

In this study, two different extraction solutions were used which are distilled water and sodium chloride (NaCl) to extract the active component of the tamarind seeds. The used of seed extract is more appealing as it will produce smaller sludge compared to the used of the seeds itself. However, the previous researcher combines the use of extract tamarind seeds with the coagulant aid such as polyacrylamide (PAM) [9]. Furthermore, there is also a study that used NaCl as extraction solution, but the effectiveness is being questioned as synthetic turbid water is used instead of the river water. As mentioned above, the potential of seeds extract of tamarind seeds is not being explored thoroughly. Hence, this study will focus more on the ability of the seed extracts of tamarind seeds without coagulant aid to remove turbidity and COD on surface water (river water) using distilled water and NaCl.

2. Material and Method

2.1. Preparation of coagulants
In this experiment, tamarind seeds were used as the natural coagulants. The tamarind seeds were collected from the kitchen waste in municipal area. The whole seeds were grounded to fine powder using a laboratory mill. All the grounded materials were sieved through 750 μm sieve and the fraction with particle sizes less than 750 μm was used in experiments. Fifty grams of prepared powder was suspended in 1 L of distilled water and 1.0 M NaCl and the suspension was stirred using a magnetic stirrer for 10 minutes to extract the coagulation active components. The components were filtered through a filter paper. The filtered solutions called the crude extracts were prepared prior to the jar test experiment is run.

2.2. Sampling of river water
The water samples were collected under turbulent condition because of the rainy day. The samples were collected manually from the bridge of Sg. Perlis. Grab sampling technique was used to collect the water sample. After that, the samples were filled inside an empty plastic bottle of 1.5 L. The bottles were labeled using a sticker. The river is located at Kangar, Perlis. Sg. Perlis is recorded as a slightly polluted river with a WQI of class III by the DOE [10].

2.3. Jar test
The coagulation activity of each seed extract was determined by the jar test. The apparatus consists of six batch reactors, each jar equipped with a paddle mixer. The sample of surface water were filled up in each beaker and mixed at constant room temperature. Different doses of seed extracts were added into the beakers and run the jar test for 1 minute at 120 rpm. The mixing speed was reduced to 30 rpm and kept for 20 minutes. Then the suspensions were left for sedimentation. After 1 hour of sedimentation, clarified samples were collected from the top of the beaker and the samples were analyzed.

3. Results and Discussions
The observed spectra for dried tamarind seed are illustrated in Figure 1 showed a range of frequency between 400 cm\(^{-1}\) and 4000 cm\(^{-1}\). The broad absorption band at 3349.17 cm\(^{-1}\) indicates the presence of -OH functional group [11]. These can prove the theoretical chemical structure of tamarind seeds consists of polysaccharide polymers of glucose, xylose and galactose. These structures are known to be responsible for the presence of -OH functional group in tamarind seeds[12]. The spectrum of carboxylic
acid is represented by two absorption band. The first band is at the peak of 1438.45 cm\(^{-1}\) with a C-O stretching vibration and the second band is 1645.38 cm\(^{-1}\) with C=O stretching vibration \[13\]. A sharp band occurs at the peak of 2926.01 cm\(^{-1}\) is because of the C-H stretching vibrations. The peak at 1051.05 cm\(^{-1}\) is represented by the C-O-C stretching vibrations. These functional groups contain properties that can induce the process of coagulation for tamarind seeds.

Zetasizer is used to measure the zeta potential of a molecules especially the surface charge of the polymer molecules. It can be used to confirm and determine the mechanism used for the coagulant in the coagulation process. In this study, the surface charge for tamarind seeds is discovered to be in negative charge, -26.9 mV. Hence, proved the theory where the tamarind seeds are an anionic polysaccharide \[14\]. The coagulation mechanism for anionic polyelectrolyte could be credited from the interlinking between particles lead to the bridging mechanism. The bridging between molecules happened when the anionic polymers attached to the adsorption sites of the surface water molecules. The formed bridge will be intertwined together with another bridge that formed on the adjacent sides. The size will continue to increase until the sites for the intermolecular of the polymers is fully occupied \[15\]. Hence, it can help to reduce the contaminants in the contaminated water such as turbidity and COD. Figure 2 shows the zeta potential analysis of the tamarind seeds.
The OFAT analysis was applied to study the effect of pH on coagulation process using two extraction solution, distilled water and 1M of NaCl. In this study, the optimum coagulant dosage, 30mg/L was used throughout the experiment. Based on Figure 3, it shows the highest percentage removal using distilled water for turbidity is 99.7% at pH 2.0. Higher pH value (alkaline condition) will decrease the ability of the coagulant dosage to remove turbidity. This is because, the nature of the coagulant itself is negative surface charge so, efficient turbidity removal can only occur when the opposite surface charge are present to allow the binding between molecules. Since, lower pH solution (acidic condition) can provide positive surface charge, the better removal occur in lower pH solution [16]. Besides, there was also a possibility that the turbidity being removed due to the settlement of the heavy particles not because of the charge of the tamarind seeds. This is because the sampling of the water was taken during a rainy day. The same theory applied to the removal of COD since the highest removal occur at 77.22% at pH 5.0.

The results for the turbidity removal and COD removal using NaCl as extraction solvents on the tamarind seeds are shown in the Figure 4. The highest removal efficiency for turbidity is 99.4% at pH 3.0. In contrast, the highest removals of COD occur at alkaline condition of pH8 with 84.5%. The results
may be affected by the imbalance of the charge introduce to the sample since the NaCl solvents can leads to salting out effect. The salting out effect may occur at pH 8 that increase the amount of positive net charge on the solution [17].

Figure 4. Percentage of turbidity and COD removal against pH (NaCl).

The effect of dosage on the seed extract of distilled water is shown in Figure 5. The percentage removal for turbidity showed fluctuate trend before reaching the highest percentage removal of 84.9% at dosage of 30 mg/L. After that, the graph continues to show a declining pattern. This could be explained based on the amount of dosage applied on. Before reaching the highest percentage removal, the dosage used is not enough to remove all the contaminants and lead to incomplete coagulation process. The coagulant dosage needs to be added until it reached the optimum dosage. However, further increased of the coagulant dosage can cause the overcrowding of coagulants. This phenomenon can limit the amount of adsorption sites available for particle bridging.

On the other hand, the percentage removal of COD from seed extract of distilled water showed a reversal result. The amount of dosage required to remove COD is higher compared to turbidity. From the graph, the higher coagulant dosage can remove COD more than 50% while, the lower coagulant dosage can remove COD in the average of 30% only. Based on the Figure 5, the highest percentage removal of COD is 62.3% at 0 mg/L coagulant dosage while, the lowest percentage removal of COD is 29.8% at 30 mg/L coagulant dosage. The COD in the jar test of 0 mg/L may experience error reading due to the longer time of keeping in the chiller.

Figure 5. Percentage of turbidity and COD removal against T.indica extraction dosage (distilled water)
Figure 6 show the effect of dosage in seed extract of tamarind seeds using 1M of NaCl on the percentage removal of turbidity and COD. The percentage removals of turbidity show a consistent increasing trend and achieved highest percentage removal of 85.4% at extraction dosage of 30 mg/L. Further increasing of the dosage resulted in the decreasing trends of the turbidity removal. As discussed earlier, the overdosing phenomenon is responsible for the decreasing trends. For COD removal, the highest percentage removals occur at dosage of 20 mg/L, with 71.7%. It gives a contrast result when compared to the used of distilled water. It could be due to the salting out effect takes places when higher dosage is used to remove COD.

![Figure 6. Percentage of turbidity and COD removal against T. indica extraction dosage (NaCl)](image)

4. Conclusions
In this study, the treatment of surface water using tamarind seeds as coagulant was successfully conducted. Two extraction solutions used to extract the active component in the tamarind seeds that can induce the performance of the coagulant itself. When distilled water is used as the extraction solution, 99.2% and 77.2% are achieved for the percentage removal of turbidity and COD respectively. The optimum condition achieved is at coagulant dosage at 30 mg/L and pH 5.0. In comparison, the used of NaCl at optimum dosage of 30 mg/L and optimum pH of 3.0 gives 99.4% and 73.8% for the highest percentage removal achieved for both turbidity and COD. The removal efficiency for extraction solutions, distilled water and 1M of NaCl solution was almost similar. This scenario proved that tamarind seeds can be used to replace the commercial coagulant, alum in the water treatment industry in the future. Hence, tamarind seeds using distilled water as solvent can be proposed as the effective natural coagulant that are safe to be used without causing serious health effect to the environment. Throughout the study, the polyelectrolyte ion and polysaccharide present inside the tamarind seeds had been recognized and confirmed as one of the many factors that contributed to the efficiency of the natural tamarind seeds as the coagulant. The performances are almost as efficient as the commercial coagulants.

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