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Removal of Turbidity from the River Water using *Tamarindus indica* and *Litchi chinensis* Seeds as Natural Coagulant

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Abstract: The present study was conducted to assess the efficacy of powder extracted from mature-dried *Tamarindus indica* and *Litchi chinensis* seeds for the turbidity reduction of polluted river water. Efficiency of *Tamarindus indica* and *Litchi chinensis* in removal of turbidity was compared with a synthetic coagulant Polyaluminiumchloride(PAC). The jar test experiment was performed to treat sample water using seed extracts along with PAC in laboratory condition. Polyacrylamide (PAM) was used as a model coagulant to aid the coagulation process. Water samples were analyzed before and after treatment with target coagulants. *Tamarindus indica* achieved maximum 91.16% turbidity reduction aided with0.5% PAM. Likewise, *Litchi chinensis* showed 91.82% turbidity reduction aided with 0.2% PAM, whereas PAC showed maximum 96.20% turbidity reduction aided with 0.5% PAM. The overall results revealed that both of the seed extract has impressive coagulation capacity in compare to the PAC. After treatment with natural seed extracts there was no significant changes in the other water quality parameters; pH, TDS, EC and COD. It can be stated that the present study will be a pathway to examine the kinetics of coagulation and mechanism of reactions by using natural seed extracts as coagulant.

Keywords: Seed Extract, Water Treatment, TDS, COD, PAC and PAM

1. Introduction

Synthetic coagulants like aluminium salts are most commonly used in water purification all over the world [1]. Due to the environmental concerns many authors put their doubt towards the application of aluminium salts [2,3]. The alternatives like ferric salts along with synthetic polymers are now getting popularity. But their cost and unclear environmental consequences are the main obstacles to their usage. In recent years finding natural sources of coagulant are getteing priority. Both mineral and vegetable origin of the natural coagulant have been simultaneously observed. Since recently there has been more interest in the subject of natural coagulant especially for the treatment of water and wastewater in developing countries [4].

Bangladesh is a tropical country and in her very dynamic

stage of economic development. *Tamarindus indica,* and *Litchi chinensis* grows aboundantly in Bangladesh. *Tamarindus indica* is a leguminous tree in the family of fabaceae indigenous to tropical Africa. The genus *Tamarindus* is a monotypic taxon, having only a single species. It is used as traditional medicine in India, Africa, Pakistan, Bangladesh, Nigeria, and most of the tropical countries [5]. Likely, *Litchi chinensis* is also tropical and subtropical fruit tree native to the Guangdongand Fujian provinces of China, and now cultivated in many parts of the world. Natural plant extracts has been used as water purifying agent for many years, such as Shulz and Okun together with Sanghi et al. reported that seeds of the nirmali tree (*Strychnos potatorum*) were used to clarify turbid river water 4,000 years ago in India [6, 7]. Most of these extracts are derived from the seeds, leaves, pieces of bark or sap, roots and fruit extracts of trees and plants [8]. A study was conducted to evaluate the potentiality of natural seeds on the turbidity removal of surface water by using *Tamarindus indica*, *Litchi chinensis and Dolichos lablab* seed [9]. But it was necessary to compare the efficiency of natural seeds to commercial chemical coagulant.

Water is one of the fundamental requirements of life and any undesired addition of chemical substances leads to its contamination and makes it unfit for human utility [10]. The removal of colloidal and suspended particles present in water would be extremely beneficial as it would assuage the majority of problems associated with turbidity. Most particulate matter can not settle by gravity and their sizes are so small that they pass through the pores of most common filtration media [11]. Conventionally, the enmeshment and removal of the colloids in water could be achieved by coagulation. For many developing countries, this treatment process is not feasible because of the high costs involved and the difficulty in assessing chemical coagulants including alum. Moreover, recent studies have pointed out the health threats arising from the consumption of residual aluminium present in water, such as Alzheimers disease and neurodegenerative illness [12]. Subsequently, large non-biodegradable sludge volumes are produced comprising of residual aluminum sulphate requires treatment facilities to prevent further contamination into the environment [13]. It is evident that the use of extracts from plant species possessing both coagulating and antimicrobial properties which are safe for human health [14]. To over come chemical coagulant problems it can be a suitable solution to increase the use of natural coagulants for water treatment. In this context, an experiment was conducted to compare the efficacy of seed extracts of *Tamarindus indica* and *Litchi chinensis* to that of the polyaluminiumchloride (PAC), regarding both treatment efficiency and influence on water quality and to optimize the usage of coagulant aid to reduce the cost and residual effect of synthetic chemicals.

2. Materials and Methods

2.1. Preparation of Sample Water

The sample water used throughout the study was collected from the Bangshi River, located near the Dhaka city. Water was collected during winter season. The raw water was stored in the plastic bottle in the laboratory of Bangladesh Council of Scientific and Industrial Research (BCSIR), Bangladesh.

2.2. Stock Solution of Poly-Aluminium Chloride (PAC)

Poly-aluminiumchloride (PAC) was used in this study was supplied by Department of Environmental sciences, Jahangirnagar University, Savar, Dhaka. 1% solution of PAC (1g of PAC in 100ml water) in deionized water was prepared. Then the desired concentrations were used for the experiment.

2.3. Stock Solution of Poly Acrylamide (PAM)

Poly-acrylamide (PAM) was supplied by Department of Environmental sciences, Jahangirnagar University, Savar, Dhaka. Three different percentage of stock solution of PAM were prepared (0.2%, 0.5% and 1.0%) for the study.

2.4. Preparation of Seed Powder

Locally available dry *Tamarindus indica* seeds were obtained from the local market of Mohammadpur, Dhaka. And *Litchi chinensis* seeds were also collected from local market during summer season. The seeds were dried in sunlight and kept in room temperature. Then the seeds were oven dried and grounded to fine powder using a mortar and then kitchen blender to make it of approximate size of 0.005mm to make soluble in water of active ingredients of the seeds (Figure1). Then the powder was stored in the BCSIR laboratory for use in the experiment.

2.5. Preparation of the Seed Extract

Dried seed powder from *Tamarindus indica* and *Litchi chinensis* were used to prepare the seed extract. 1.0g of powder was added to 100ml of de-ionized water and then stirred for 15min using a magnetic stirrer. Then the solution was allowed to stand without disturbance for 15min for settling. After that seed extract was separated into another beaker. Fresh solutions were prepared daily to avoid aging effect.

Figure 1. *Litchi chinensis (A) and Tamarindus indica (B) seed powder*

2.6. Jar Test Operations

Experiment was carried out in the laboratory of Bangladesh Council of Scientific and Industrial Research (BCSIR). The treatment was performed with varying concentrations of Tamarindus indica and *Litchi chinensis* seed powder. Each treatment was conducted on the response of turbidity, pH, electric conductivity, total dissolved solids and COD. First the samples were analysed to measure turbidity, along with other parameters. The experiment was carried out in a jar test operations [15]. The jar test was used to determine turbidity for each coagulants used with sample water. In conventional filtration water treatment plants, the jar test was most commonly used to optimize the removal of turbidity from the treated water. It was carried out as a batch test. Before operating the jar test the samples were mixed homogenously. Then the dry seed powder was measured by digital balance. Coagulants of desired concentrations were added in the beakers. The whole procedures in the jar test were conducted in different rotating speed. For reproducibility, the study was triplicate and represented as avarage. Add 3 drops of coagulant aid (PAM) in the beaker. Then the beakers were agitated at various mixing time and speed, which consist of rapid mixing for 15 min and slow mixing for 12-15 min using magnetic stirrer for mixing the sample with coagulant. The flocculated suspensions were allowed to stand without disturbance for 30min to be settled. Finally, sample was taken using a pipette from the middle of supernatant for turbidity, pH, TDS, EC and COD measurements.

So, the coagulation-flocculation process consists of three distinct steps. First, the coagulant was added to the raw water and a rapid high intensity mixing was initiated. Second, the suspension was slowly stirred to increase contact between coagulating particles and to facilitate the development of large flocks. Third, mixing was terminated and the flocks were allowed to precipitate.

2.7. Water Quality Analysis

The desired water quality parameters pH, turbidity, EC, TDS and COD were measured by using the instruments and technique follow by our previous work [9].

3. Results and Discussion

3.1. Characterization of Sample Water

The sample water for this study was collected from the Bangshi river near Dhaka city. The sample water was analyzed for water quality parameters pH, turbidity, conductivity, TDS, and COD (Table1).

Table 1. *Characterization of the sample water*

Initial parameter	DO	pH	TDS	EC	Turbidity	COD
Unit	mg/L		mg/L	µs/cm	NTU	mg/L
Sample	0.77	7.48	494	994	26.5	250
WHO Standard	-	6.5-8.5	<1000	-	5	-
EnvironmentalConservation Rules (ECR), Department of Environment	>6	6.5-8.5	1000	-	4NTU	4

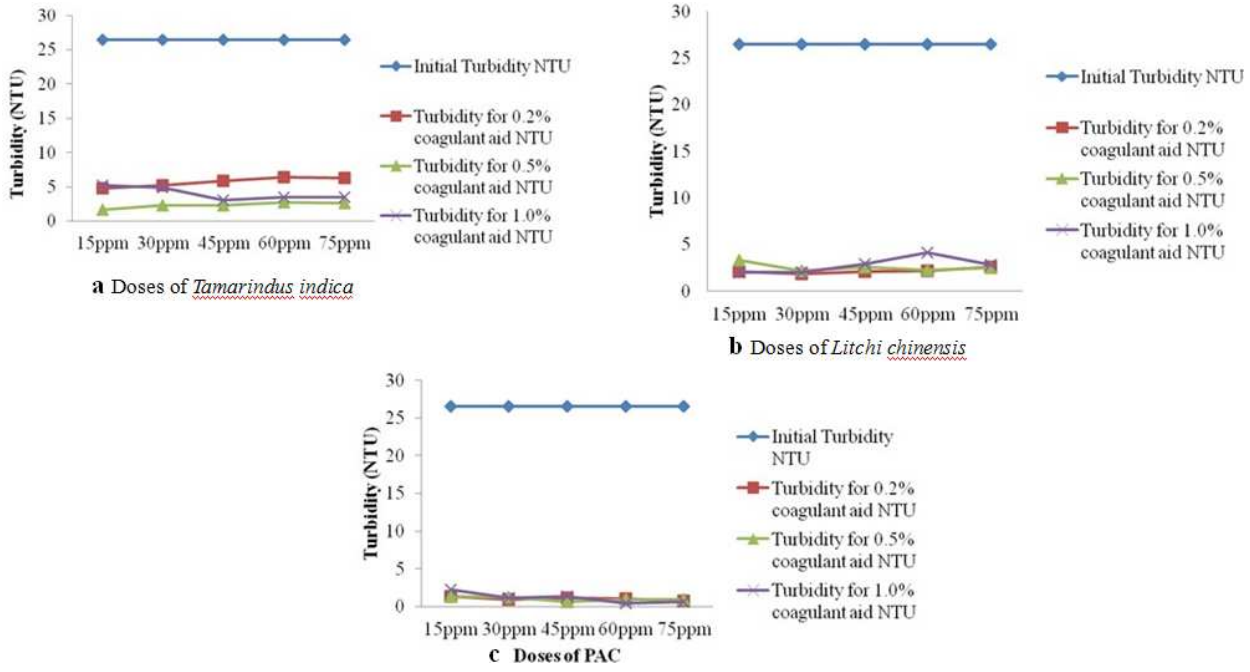

Figure 2. *Effects of Tamarindus indica (a), Litchi chinensis (b) and PAC (c) on the removal of turbidity from sample water.*

3.2. Effect of Seed Extracts on Turbidity

Results for the removal of turbidity using various doses of *Tamarindus indica* are shown in Figure 2a. The seed extracts from *Tamarindus indica* was dosed at 15, 30, 45, 60 and 75ppm along with three different doses (0.2, 0.5 and 1.0%) of the PAM. After using 0.2% PAM as a coagulant aid, turbidity was reduced from 26.5 NTU to 4.79, 5.22, 5.87, 6.36 and 6.27 NTU corresponding to 15, 30, 45, 60 and 75 ppm doses of *Tamarindus indica*, respectively. For 0.5% PAM, turbidity was reduced to 1.69, 2.31, 2.32, 2.78 and 2.59 NTU corresponding to same dosed concentrations of *Tamarindus indica*. And for 1.0% PAM, turbidity was reduced to 5.21, 4.94, 3.08, 3.54 and 3.46 NTU corresponding to 15, 30, 45, 60 and 75 ppm doses of *Tamarindus indica*, respectively. The results obtained by using *Tamarindus indica* at every dose comply with the Bangladesh drinking water standard and WHO guidelines [16, 17].

The best removal was obtained by using 15 ppm of seed solution aided with 0.5% PAM and it was 93.62% from the initial value of turbidity (26.5 NTU). Results of using *Litchi chinensis* are shown in figure 2b. Likeas Tamarindus indica, three different percentages of the coagulant aid were used. Using of 0.2% PAM, turbidity was reduced from the initial turbidity (26.5 NTU) of sample water to 2.07, 1.90, 2.07, 2.16 and 2.63 NTU corresponding to the 15, 30, 45, 60 and 75 ppm doses of *Litchi chinensis*, respectively. For the use of 0.5% PAM, turbidity was reduced from the same initial turbidity value to 3.34, 2.19, 2.58, 2.27 and 2.52 NTU corresponding to 15, 30, 45, 60 and 75 ppm doses of *Litchi chinensis*, respectively. And in case of use of 1.0% PAM, turbidity was reduced to 1.99, 2.02, 2.95, 3.15 and 2.88 NTU corresponding to same doses as 0.1% and 0.5% of *Litchi chinensis*, respectively. By using *Litchi chinensis* maximum average turbidity reduction (91.82%) was obtained for 0.1% dose of PAM along with the seed extracts dose, when the initial turbidity was 26.5 NTU. A similar result was obtained by using *Litchi chinensis*, when the initial turbidity was 90.3 NTU [9]. To compare the results of natural coagulants with synthetic chemical coagulant, PAC was used as chemical coagulant. The result of using PAC for the removal of turbidity is presented in Figure 2c. Under the same experimental conditions using 0.2% PAM, turbidity was reduced to 1.37, 0.92, 1.18, 1.08 and 0.68 NTU corresponding to 15, 30, 45, 60 and 75 ppm doses of PAC, respectively with an initial turbidity of 26.5 NTU and for 0.5% PAM, turbidity was reduced to 1.34, 1.27, 0.60, 0.89 and 0.93 NTU corresponding to 15, 30, 45, 60 and 75 ppm doses of PAC, respectively. Moreover, for 1.0% PAM ,turbidity was reduced to 2.25, 1.14, 1.30, 0.80 and 0.61 NTU corresponding to same doses of PAC. PAC is a widely used commercial coagulant for water/wastewater treatment in Bangladesh. It has been used to clarify the raw water that is difficult to treat [18, 19]. Turbidity removal by using PAC was found for 0.2%, 0.5% and 1.0% PAM, the average turbidity reduction was 96.05%, 96.20% and 95.57% respectively. It was found that in maximum cases optimum dose of PAC were 75mg/l. A previous study using alum showed turbidity reduction occurred from 110 NTU to 8-12 NTU [20]. So, it can be speculated that in comparison with the commercial coagulant PAC, *Tamarindus indica* (91.16%) and *Litchichinensis* (91.82%) seeds extract showed a very good comparable results in terms of the removal of turbidity from surface water having 26.5 NTU of initial turbidity. A similar performance was studied by another author using *M. oleifera* a 96% reduction in turbidity was found with initial 49 NTU trubidity content [15].

3.3. Water Quality Parameters after Coagulation

Total Dissolved Solids (TDS), Electric Conductivity (EC), pH and Chemical Oxygen Demand (COD) were measured before and after using natural and synthetic chemical coagulants for coagulation-flocculation process.

3.3.1. pH

The use of seed extracts and PAC might have effect on the pH of the treated water. The results of the effects are shown in figure 3. After using 0.2% PAM along with natural seed extracts and PAC, pH varied within the range of 7.10-7.81 (Figure3d). Consequently for 0.5% and 1.0% use of PAM showed almost similar range of pH change 6.53-8.25 and 7.2-8.13 respectively (Figure3e-f).

The change of pH after coagulation treatment was found within the permissible limit for drinking as well as domestic water quality set by the WHO and DoE. It was observed that the change of pH was random but not in any extreme level either acidic or basic.

3.3.2. TDS

The changes of TDS after treatment with *Tamarindus indica*, *Litchi chinensis* and PAC are shown in figure 4. Initial TDS of sample water was 494mg/l. Using 0.2% PAM (Figure 4g) the TDS were slightly reduced from its initial concentration. In case of desired doses of *Tamarindus indica* showed reduction of TDS to 487mg/l, 480mg/l, 474mg/l, 464mg/l and 465mg/l, for *Litchi chinensis* TDS were reduced to 490mg/l, 484mg/l, 476mg/l, 470mg/l and 462mg/l and for PAC, the TDS reduction of treated water were 495mg/l, 500mg/l, 492mg/l, 488mg/l and 482mg/l from the initial concentration of TDS (494mg/l). In case of 0.5% PAM (figure 4h) along with *Tamarindus indica* seed extracts the TDS contents were reduced to 491mg/l, 487mg/l, 490mg/l, 472mg/l and 468mg/l. However, for *Litchi chinensis* seed extracts TDS were 497mg/l, 488mg/l, 480mg/l, 471mg/l and 461mg/l and for PAC, TDS were 492mg/l, 491mg/l, 483mg/l, 485mg/l and 482mg/l. The changes of TDS for 1.0% PAM are shown in figure 4i. Use of 1.0% PAM in coagulation the value of the TDS after treatment, for *Tamarindus indica* were found 494mg/l, 489mg/l, 487mg/l, 474mg/l and 474mg/l, for *Litchi chinensis* the values were 496mg/l, 487mg/l, 485mg/l,

486mg/l and 486mg/l and for PAC the values of the TDS were 496mg/l, 494mg/l, 491mg/l, 486mg/l and 486mg/l. It was clear that after treatment there were no significant changes in TDS of the treated water and valueswere within the acceptable range for the use of domestic purposes according to WHO guideline. Hence, the coagulation process has only very little or no effect on the concentration of TDS of the sample water.

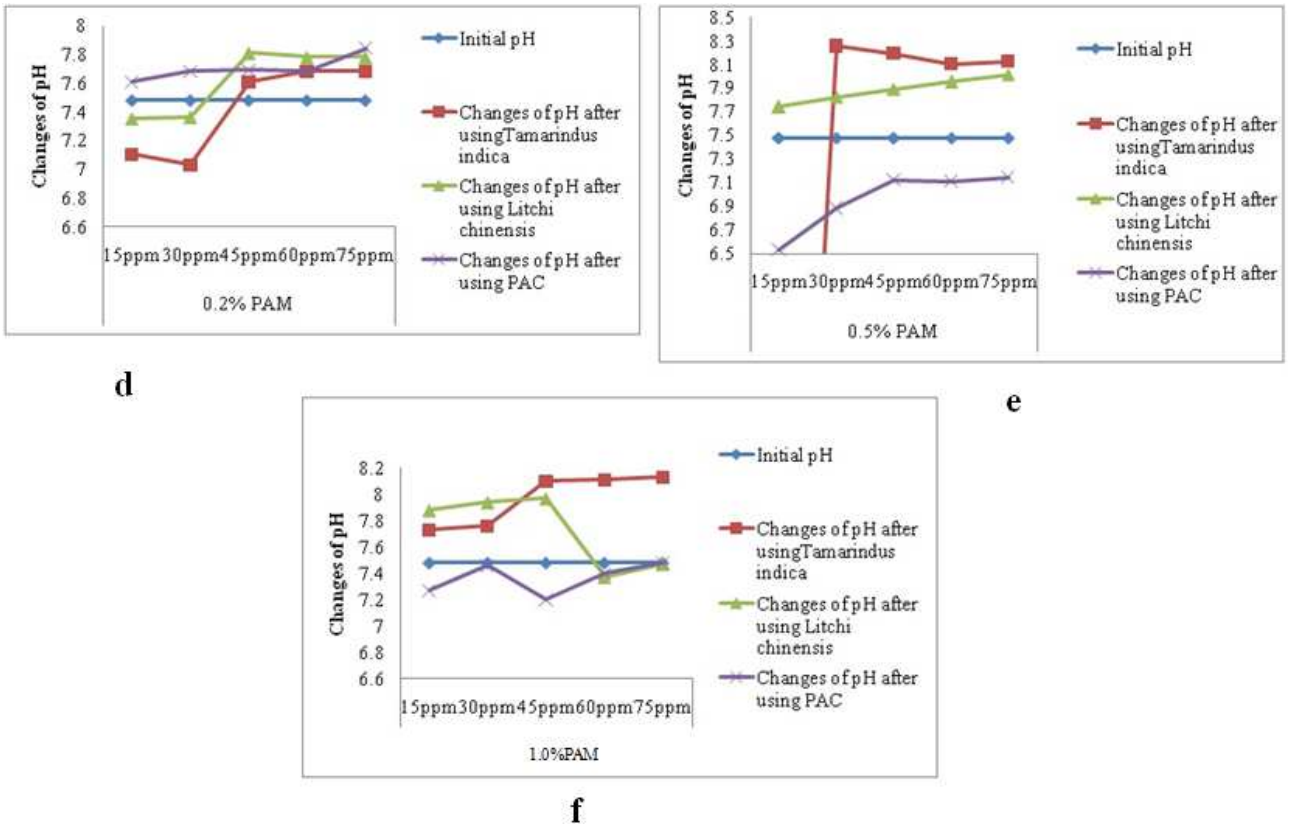

Figure 3. *After coagulation with seed extracts and PAC the pH changes for 0.2% (d), 0.5% (e) and 1.0% (f) of treated sample water.*

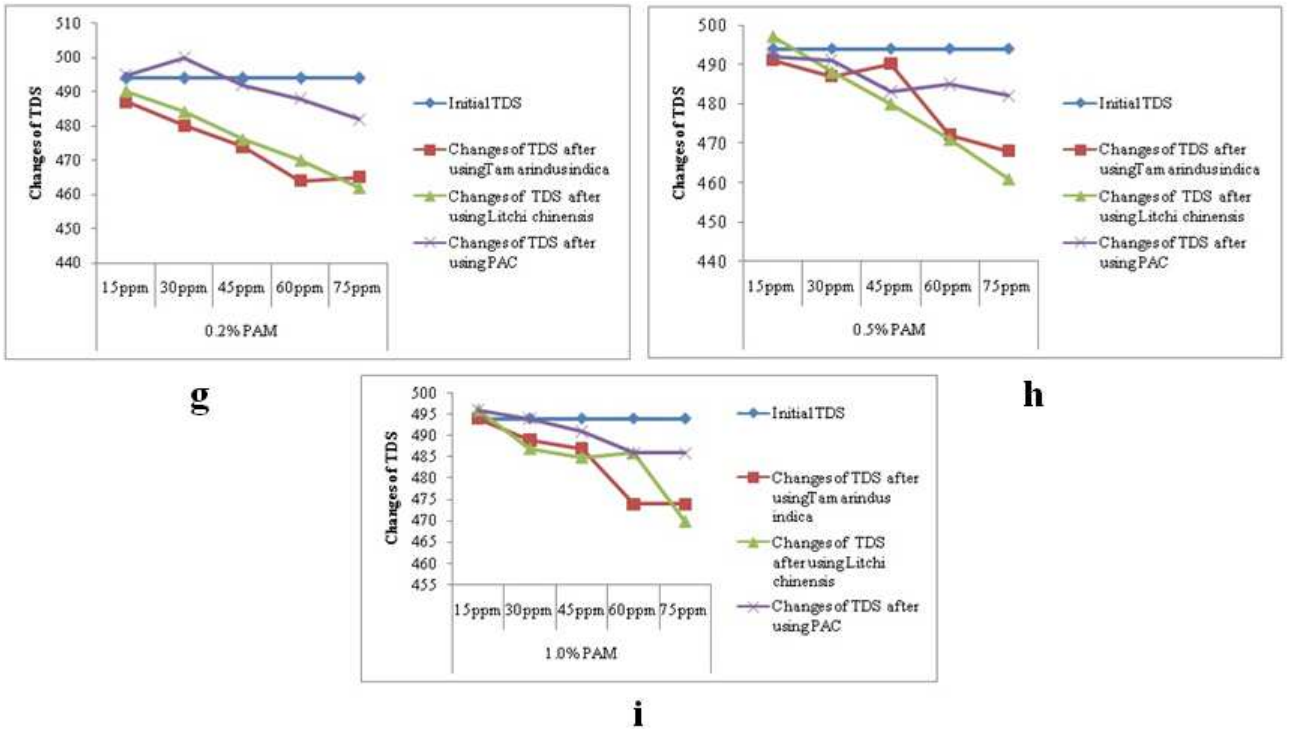

Figure 4. *After coagulation with seed extracts and PAC the TDS changes for 0.2% (g), 0.5% (h) and 1.0% (i) of treated sample water.*

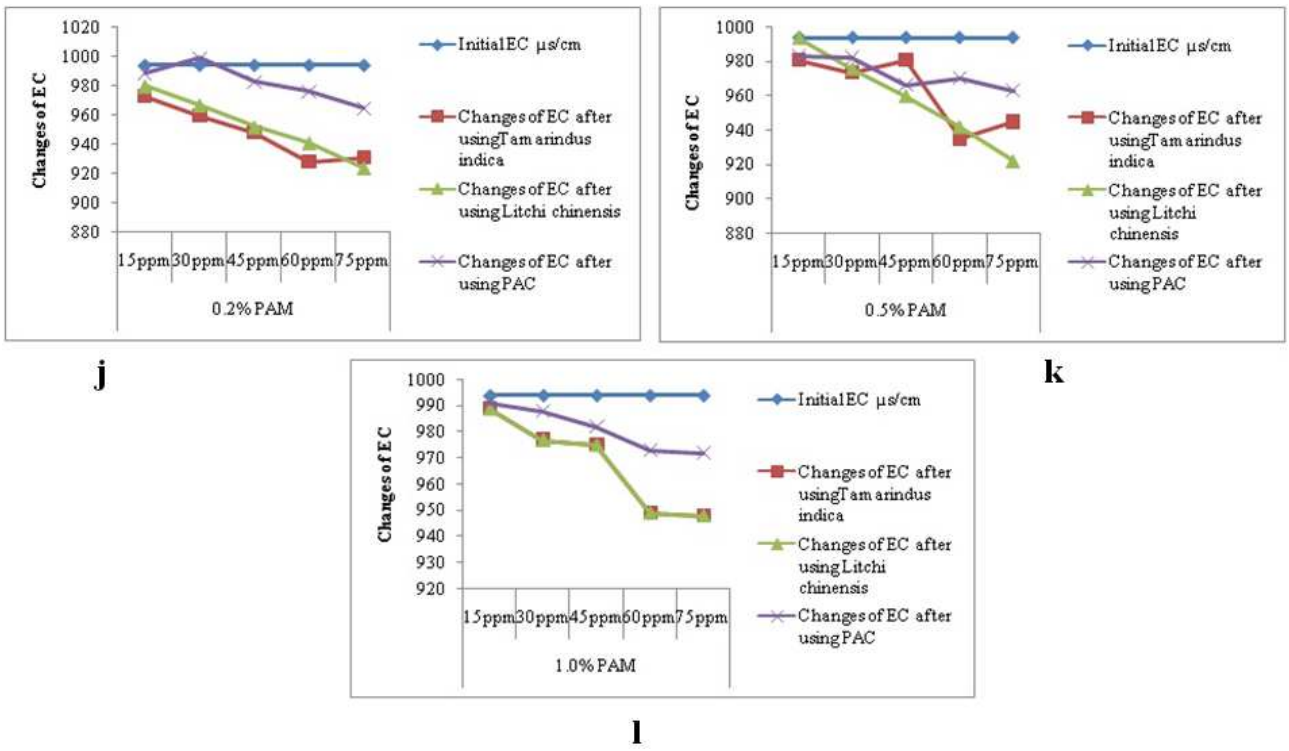

Figure 5. *Changes of EC (µs/cm) of sample water after treatment with natural coagulant and synthetic coagulant aided with 0.2% (j), 0.5% (k) and 1.0% (l) of PAM.*

3.3.3. EC

Initial EC of the sample water was 994µs/cm. EC was also reduced slightly from the initial value. The doses were used for the treatment are 15ppm, 30 ppm, 45 ppm, 60 ppm and 75 ppm. The changes of EC after coagulation are shown in figure 5. When 0.2% PAM (figure5j) was used in coagulation the values of the EC after coagulation for *Tamarindus indica* were found 973µs/cm, 960µs/cm, 948µs/cm, 928µs/cm and 931µs/c min response to corresponding desired dose. For *Litchi chinensis* the values of the EC were obtained 980µs/cm (15ppm), 967µs/cm (30ppm), 952µs/cm (45ppm), 941µs/cm (60 ppm), and 924µs/cm (75ppm).

And for PAC the values of the EC were 989µs/cm, 999µs/cm, 983µs/cm, 976µs/cm and 965µs/cm in response to the same applied coagulant dose. Figure 5k shows that when 0.5% coagulant aid was used incoagulation the values of the EC after coagulation with *Tamarindus indica* were 981µs/cm, 974µs/cm, 981µs/cm, 945µs/cm and 935µs/cm for the respective dose. Likely, for *Litchi chinensis* the values of the EC were 994µs/cm, 976µs/cm, 960µs/cm, 942µs/cm and 922µs/cm. And for PAC the values of the EC were 983µs/cm, 982µs/cm, 966µs/cm, 970µs/cm and 963µs/cm.

Figure 5l shows that when 1.0% coagulant aid was used the values of the EC after coagulation with *Tamarindus indica* were 989µs/cm, 977µs/cm, 975µs/cm, 949µs/cm and 948µs/cm in response of desired dose. For *Litchi chinensis* the values of the EC were 992µs/cm, 974µs/cm, 969µs/cm, 973µs/cm and 941µs/cm, and for PAC the values of the EC were 991µs/cm, 988µs/cm, 982µs/cm, 973µs/cm and 972µs/cm. From the obtained results it can besummerised that the natural coagulant has very little effect on the EC content of treated water.

3.3.4. COD

The COD concentrations were changed after the coagulation treatment of water. It was reduced from the initial concentration (250mg/l). Figure 6(m-o) showed the changes of COD for 0.2%, 0.5% and 1.0 PAM. The doses were used for the treatment were15ppm, 30ppm, 45ppm, 60ppm and 75ppm. Using 0.2% PAM the concentration of COD after coagulation with *Tamarindus indica* were found 50mg/l, 50mg/l, 50mg/l, 100mg/l and 25mg/l in respect of predesired dose. In case of *Litchi chinensis* the values of the COD were 250mg/l, 25mg/l, 200mg/l, 25mg/l and 25mg/l. And for PAC the values of the COD were 50mg/l, 25mg/l, 50mg/l, 100mg/l and 50mg/l. When 0.5% PAM was used the values of COD using *Tamarindus indica* were reduced to 50mg/l, 50mg/l, 25mg/l, 200mg/l and100mg/l and for *Litchi chinensis* the values of the COD were 50mg/l, 25mg/l, 100mg/l, 50mg/l and 25mg/l. In case of PAC the values of the COD were 200mg/l, 100mg/l, 25mg/l, 50mg/l and 50mg/l. When 1.0% PAM was used with *Tamarindus indica* in coagulation, the COD concentrations were reduced to 25mg/l, 100mg/l, 25mg/l, 250mg/l and 25mg/l. For 1% PAM and *Litchi chinensis* the COD values were found 50mg/l, 150mg/l, 150mg/l, 250mg/l and 50mg/l. And for 1% PAM and PAC the COD were reduced to 150mg/l, 100mg/l, 25mg/l, 50mg/l and 50mg/l. From the results it can be concluded that in every treatment there was a significant

effect of COD content of the sample water. The treatment process significantly able to remove COD from water.

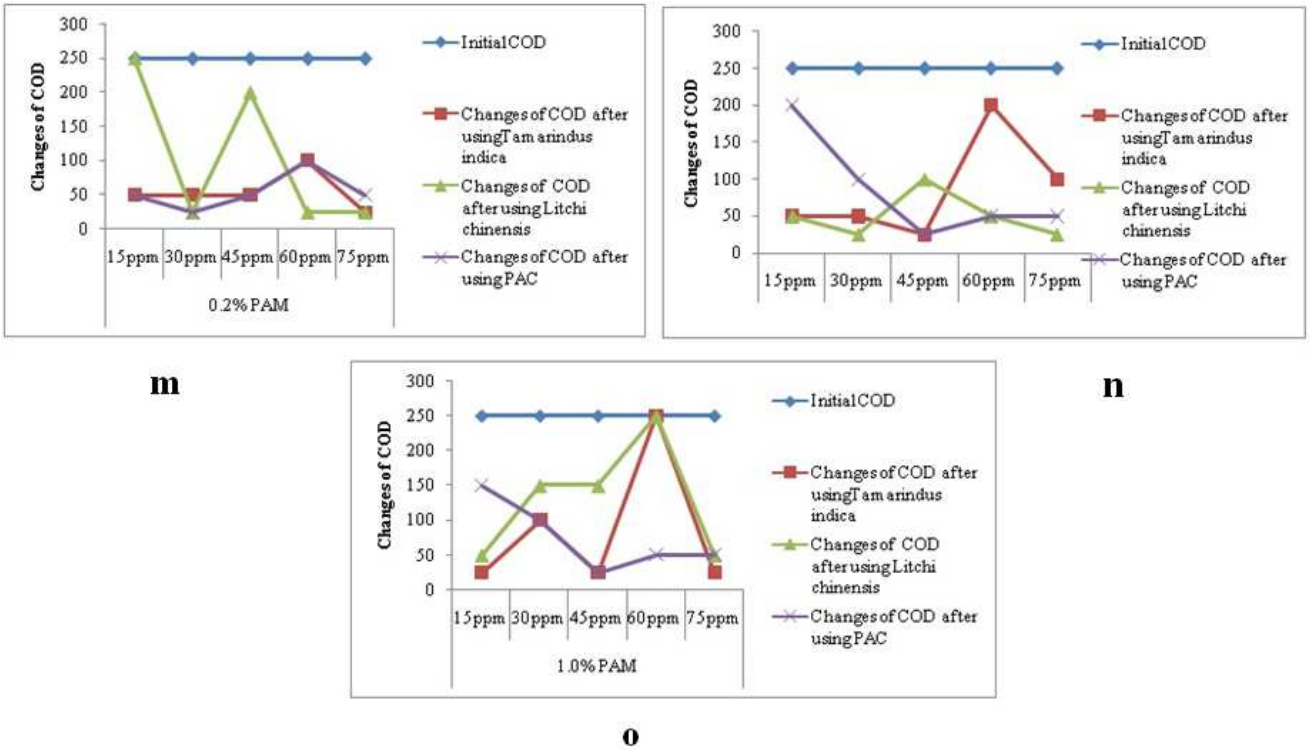

Figure 6. *Changes of COD (mg/l) of sample water after treatment with natural coagulant and synthetic coagulant aided with 0.2% (m), 0.5% (n) and 1.0% (o)*

4. Conclusion

The results obtained from the treatment with *Tamarindus indica* and *Litchi chinensis* were impressive and comparable with synthetic commercial coagulant. The findings of the present study comfirmed that the seed of *Tamarindus indica* and *Litchi chinensis* contains coagulating potentials of removing turbidity as like conventional coagulants. Their turbidity removal capacity was significantly similar to PAC, a renowned chemical coagulant. Since usages of 0.2% PAM showed better removal efficiency than 1.0% PAM usage, it should be optimized during usage which could lead to reduce the cost of the chemicals and its consequences towards environment. *Tamarindus indica* and *Litchi chinensis* were not significantly effective to reduce TDS and EC, though pH was increased from the initial value after coagulation. The COD content of the sample was significantly reduced after coagulation with natural coagulants. *Tamarindus indica* and *Litchi chinensis* seeds were collected locally at low cost. The extractions of seeds were performed by tap water as this seems to be a cheaper, most practical and more efficient method than the conventional synthetic chemicals. The natural coagulant is biodegradable, environmental friendly and non-toxic. A further advantage was that the produced sludge is biodegradable because it contains organic matter. It can be reused as a fertilizer. So, it can be concluded that *Tamarindus indica* and *Litchi chinensis* has coagulating properties which, can be used as an alternative to the chemical coagulant in the treatment of turbidity of surface water.

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