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Evaluating the Efficiency of Tragacanth Coagulant Aid in Removing Colloidal Materials and Suspended Solids Creating Turbidity from Karun River Water

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ABSTRACT

Introduction: Colloidal materials and suspended solids cause turbidity in water. To remove turbidity, clarification method is used that includes processes of coagulation, flocculation, and sedimentation. Due to the long duration of coagulation process, coagulant aids are applied. Despite the favorable efficiency of synthetic polyelectrolytes as a coagulant aid, due to their harmful effects on human health, in this process, natural organic polymers are used instead.

Materials and Methods: In this research, the use of tragacanth as a natural organic coagulant aid was studied instead of synthetic polymers in water turbidity removal along with alum and poly aluminum chloride. To compare the experiments with natural conditions, Karun River water was analyzed. To complete these studies, the effects of several factors such as tragacanth concentration, the concentration of alum and poly aluminum chloride, and pH changes in average and low turbidity were investigated. Optimum pH for turbidity removal was determined by jar testing.

Results: The results showed that the best pH to remove turbidity was from 5.5 to 7, with the efficiency of 97.3%. At pH = 6 and at the concentration of 30 mg/L, poly ammonium chloride had maximum efficiency (90%). Using tragacanth with concentrations of 1 and 4 mg/L along with alum at a concentration of 40 mg/L leads to turbidity removal of 81.75%.

Conclusion: Using 2 and 4 mg/L of tragacanth, a significant removal efficiency is achieved in low and average turbidity. pH = 7 leads to the most efficient use of tragacanth coagulant aid.

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Introduction

The purpose of water purification is to supply water free from microbiological and chemical pollutants. The water using in houses should be acceptable with regard to aesthetics, turbidity, color, smell, and taste. Therefore, turbidity must be removed due to aesthetic issues, as well as disruptions in water disinfection [1]. Almost all substances are partially soluble in water. This solubility depends on temperature, pressure, pH, chemical potential, and relative concentration of other substances in water. These factors are so interrelated in nature that solubility of a substance in water can be hardly predicted. In fact, water is one of the most renowned solvents. Specifically, polar substances are soluble in water to a large extent. Therefore, they do not exist in nature purely [2].

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The reason of turbidity is colloidal materials or suspended solids. To remove turbidity, clarification method is used that includes processes of coagulation, flocculation, and sedimentation. In practice, coagulation and chemicals addition to water prepare small particles which stick together and form larger particles due to the neutralization of electric charges. Neutralization removes repulsive force between small particles [3]. Different coagulants and coagulant aids are used during the process of coagulation. Coagulants include substances that are used for destabilizing particles and pasting them together. Normally, metal salts such as aluminum sulfate, alum, ferric sulfate, ferrous sulfate, ferric chloride, and poly aluminum chloride are considered as coagulants and compounds such as sodium aluminate, bentonite, sodium silicate, active silica, and a variety of cationic, anionic, and nonionic polyelectrolytes coagulant aids are used in water treatment to remove turbidity [4].

Despite the favorable efficiency of synthetic polyelectrolyte as a coagulant aid, due to their harmful effects on human health, in this process, natural organic polymers are used. In this research, using tragacanth as a natural organic coagulant aid instead of synthetic polymers in water turbidity removal along with alum and poly aluminum chloride is studied. This study aimed to determine the best dose of tragacanth as a coagulant aid in removing turbidity from the water of Karun River, as well as determining the optimum pH, the alkalinity and estimated sludge volume caused by coagulation process.

Shrubs and herbaceous plants live from one to several years and include over 200 species. They generally grow in the steppe and mountainous areas of Iran and often thorny.

Tragacanth is a gum that is taken from the stem of Astragalus. This gum flows spontaneously or commonly by splitting astragalus stem and dries after a short time. Tragacanth includes 10-15% water, 3-4% minerals, and 3% starch. It is an odorless substance, 60-70% of which does not dissolve in water. By absorbing moisture, tragacanth turns into a sticky glaze with tangible starch particles in it [5].

In the study of Bina et al. turbidity removal in optimum dose of alum and coagulant aid is more than 94% in all cases [6]. In another study by Goudarzi the following results were obtained:

1. Starch is highly efficient in removing turbidity from water.

2. Starch can considerably reduce the amount of other coagulants, such as aluminum sulfate and ferric chloride.

3. Optimum flocculation and sedimentation time are respectively 25 and 10 minutes, in optimum temperature from 15 to 20 °C 7.

Bina et al. concluded that:

1. The extract of moringaoleifera seed at optimum concentration of 10-30 mg/L and optimum pH of 6-8 can remove 55%, 89%, 97%, and 98% of the above turbidity, respectively.

2. At optimum concentration of 20-30 mg/L and optimum pH of 8 poly aluminium chloride can remove 89%, 95%, 98%, and 99% of the above turbidity, respectively 8.

In a study by Takdastan et al. the turbidity removal efficiency and coliforms were 94% and 98%, respectively that is comparable to alum alone which was 89%. In average turbidity, using 100NTU with 4 mg/L of starch and 8 mg/L alum, the removal efficiency of turbidity and coliform were 98.9% and 99%, respectively while it was 97.2% with alum alone [9]. In high turbidity, using 1170 NTU with 30 mg/L of starch, the removal efficiency was 91.82% compared to 98.24% with alum alone [9].Mandloi et al. studied the efficiency of moringaoleifera seed of corn and chitosan that is used in direct filtration of Bilawalilake [10]. The average reduction in the most likely number (MPN) obtained by moringaoleifera seed of corn and chitosan was 35%, 97%, 95.4%, and 87.1%, respectively while it was 7.7% with alum alone [10]. In a study by Katayon et al. the turbidity removal efficiency of 3-day moringaoleifera stock solution was 73.6% for average turbidity, 86.6% for high turbidity, and 92.3% for very high turbidity [11, 12].

Takdastan et al. stated that the most optimum efficiency of poly aluminum chloride in removing turbidity and microbial parameters occurs when pH=8, quick mixing speed=120 rpm, and optimum dose of poly aluminum chloride=10 with 30 rpm [13]. In another study by Mirzaie et al. at the dose of 10 ppm and 10 ml of injected sludge, turbidity removal with poly aluminum chloride was 98.31%. Furthermore, at the dose of 30 ppm and 4 ml of injected sludge, maximum turbidity removal was 98.92% [14].

Materials and Methods

Sample preparation: Since it is not practical to maintain the water sample containing natural turbidity in the laboratory due to instability, in order to remove interfering factors, samples were prepared on a daily basis before the experiment. All experiments were performed in Water and Wastewater Chemistry Laboratory of Health Faculty in Ahvaz University of Medical Sciences. At first, raw water samples were taken from the pipes connected directly to the river with natural turbidity on which the experiment was performed. The tragacanth used in this study was collected from the grocery stores all around the city. Using Taguchi method, the number of samples was determined as 50.

Chemicals and equipment: Jar tests were performed by Jar device manufactured by Philips and Bride. HACH 2100A turbidimeter was used to determine samples turbidity and the amount of pH was measured by pH meter (WTW) 340i. PAC solution, tragacanth extract, and sulfuric acid 0.02 N, and soda 0.02 N were also used in this experiment.

Methods

1. Determining optimum pH and optimum concentration of poly aluminum chloride and tragacanth. First, each beaker was filled with 1000 mL of water sample with certain turbidity measured before the experiment and then the following tests were performed on samples:

1-1 Determining the pH.

1-2 Jar tests on samples of raw water to determine optimum pH in removing natural turbidity from samples (phase 1). In the first phase, water samples with certain turbidity and pH of 5.5, 6, 6.5, 7, 7.5, and 8 were adjusted by sodium hydroxide and sulfuric acid. The purpose of this experiment is to determine the optimal pH in turbidity removal.

2. In this step, using optimum pH and various concentrations of poly aluminum chloride including 0.5, 1.5, 2, 2.5, 3, 4, and 5 mg/L, optimum concentration of poly aluminum chloride was studied at this pH. Then, by applying optimum dose of poly aluminum chloride and optimum pH, optimum concentration of tragacanth coagulant aid was studied at concentrations of 0.5, 1.5, 2, 2.5, 3, 4 and 5.

3. The final turbidity and pH changes of samples were studied after performing Jar tests mentioned above.

4. A sample of tragacanth stock solution was maintained in laboratory environment for 1, 3, 10, and 15 days. Then, the efficiency of these solutions in turbidity removal from water samples was investigated with initial turbidity of 10-25 NTU and pH = 7. The chart shows the results.

5. In this study, the alkalinity was measured as a new finding. At the beginning of experiment, 100 mL of raw water sample was removed and a few drops of phenolphthalein were added to the sample. Since this reagent caused no color change, methyl orangereagent was also added. Afterwards, it was titrated with sulfuric acid 0.02 N to achieve the color change from yellow to orange. This was also performed on the samples after turbidity removal. Jar tests were performed with Jar device manufactured by Philips and Bride Company. Fast and slow mixing speeds were considered respectively; 100 rpm for 2 minutes, 30 rpm for 10 minutes, 20 rpm for 10 minutes, and 10 rpm for 10 minutes, while sedimentation time was considered 30 minutes. HACH 2100A was used to determine samples turbidity and pH was measured by pH meter. SPSS software was applied to show the changes and comparing the initial data with the final data.

Results

The results of this study, achieved through experiments, are presented by figures and tables below.

Table 1: Turbidity removal at pH = 5.5 and pH = 7

pH Verification	Final turbidity	Turbidity removal (%)
5.5	1.7	96.13
6	1.3	97.04
6.5	1.2	97.27
7	1.5	96.59
7.5	2.5	94.31
8	4.2	90.45

Figure 1(a) shows that the best concentration of aluminum chloride for turbidity removal is 31mg/L. At this concentration and pH, poly aluminum chloride can remove 93% of turbidity.

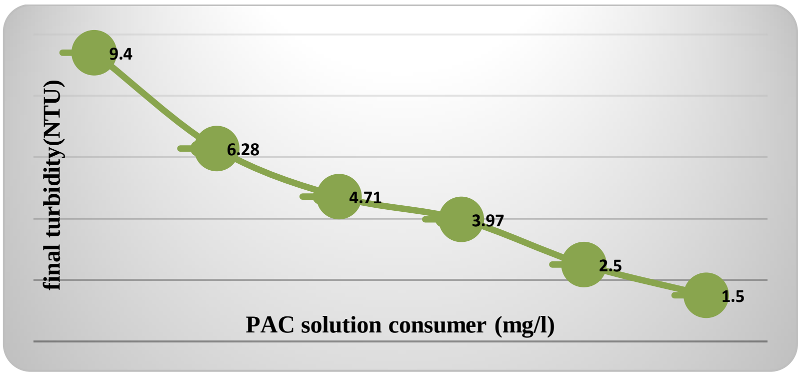

Figure 1(a): The optimum concentration of poly aluminum chloride

Figure 1(b) shows that the most suitable concentration for turbidity removal is poly aluminum chloride coagulant at a concentration of 30 mg/L along with 1.5 mg/L tragacanth coagulant aid in raw water sample with turbidity of 68 NTU.

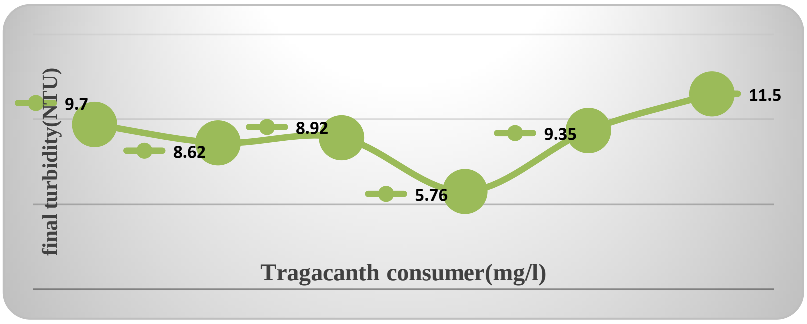

Figure 1(b): Comparing the turbidity removal with initial turbidity, using 30 mg/L of poly aluminum chloride and tragacanth solution at different concentrations, pH = 7, initial turbidity of 68.6 NTU, and alkalinity of 180 mg/Lcaco$_3$.

Figure 2 shows that in average turbidity, using alum coagulants at optimum concentration and tragacanth coagulant aid at concentrations of 1 and 4 mg/L can lead to the highest turbidity removal that is 81.75%.

Moreover, table 2 shows that by increasing turbidity removal, the amount of produced sludge is increased. Besides, adding a coagulant and a coagulant aid does not have a significant impact on initial pH of the raw water.

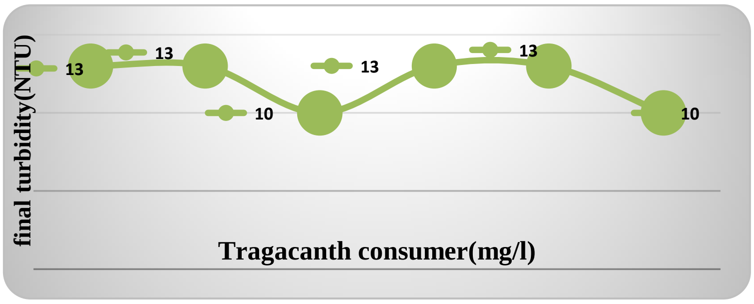

Figure 2: Comparing initial turbidity using tragacanth at the concentration of 40 mg/L, pH = 7.12, and turbidity of 55.9 NTU.

Table 2: Turbidity removal percentage, the amount of produced sludge, and changes in pH of raw water sample with initial turbidity of 55.9 NTU and alumina concentration of 40 mg/L and various tragacanth concentrations.

Consumed tragacanth	Final turbidity	Turbidity removal (%)	Produced sludge	pH verification
0	13.8	75.31	0.2	6.78
0.5	13.5	75.84	2.5	6.82
1	10.2	81.75	3.5	6.83
2	13.2	76.38	4.5	6.85
3	13.8	75.13	1.5	6.85
4	10.5	81.75	2.5	6.86

Figure 3 and table 3 show that low turbidity alum at its optimum concentration (40 mg/L) can remove more turbidity (82.22%) compared to using alum with tragacanth coagulant aid. The volume of produced sludge increases with an increase in coagulant aid. In addition, alkalinity consumption is reduced while the alkalinity of water increases. Adding a coagulant and a coagulant aid did not lead to significant changes in pH.

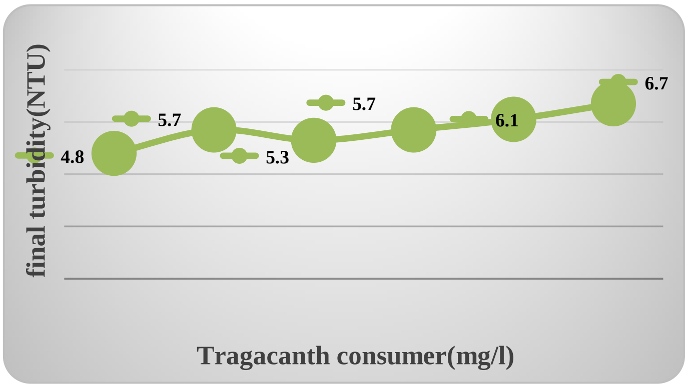

Figure 3: The final turbidity using aluminum sulfate at the concentration of 40 mg/L and various tragacanth concentrations in water samples with initial turbidity of 25 NTU, initial alkalinity of 14.5 mg/L caco$_3$, and initial pH of 7.08.

Table 3: Turbidity removal, the amount of produced sludge, and pH changes, using alum and tragacanth in raw water sample with initial turbidity of 27NTU and pH = 7.08.

Consumed tragacanth	Final turbidity (NTU)	Turbidity removal (%)	Produced sludge (ml)	pH verification	Total alkalinity (mg/L $caco_3$)
0	4.8	82.22	1	6.81	92
1	5.7	78.88	2.5	6.84	112
2	5.3	80.37	4.5	6.86	96
3	5.7	78.88	6.5	6.87	92
4	6.1	77.4	7.5	6.89	95
5	6.7	75.18	9	6.9	105

Discussion

Studies suggest that using poly aluminum chloride at a concentration of 2.5 mg/L, removal percentage is 65.42% in low turbidity; nonetheless, using poly aluminum chloride alone, turbidity removal is 64%. Using poly aluminum chloride at a concentration of 25 mg/L and tragacanth at a concentration of 2 mg/L, removal percentage is 73.29% in turbidity of 23 NTU while by using 25 mg/L of poly aluminum chloride alone, only 52.66% of turbidity is removed. Furthermore, using poly aluminum chloride at a concentration of 30 mg/L and tragacanth at a concentration of 1.5 mg/L, removal percentage is 91.66% in turbidity of 68 NTU (average turbidity) while by using poly aluminum chloride alone, removal percentage is 85.86%. According to the findings on water sample with initial turbidity of 108 NTU, using poly aluminum chloride at a concentration of 23 mg/L and tragacanth at a concentration of 1.5 mg/L, removal percentage is 94.66% in turbidity over 100 NTU, while by using poly aluminum chloride alone, removal percentage is 91.01%. Using alum at an optimum concentration of 40 mg/L and tragacanth at a concentration of 2 mg/L, the removal percentage is 80.37% in raw water sample with initial turbidity of 25 NTU while by using alum alone at a concentration of 40 mg/L, removal percentage is 82.2%. Using alum at a concentration of 40 mg/L and tragacanth at a concentration of 1 and 4 mg/L, the best removal percentage was achieved 81.75% in water sample with initial turbidity of 55.9 NTU (average turbidity) while by using poly alum alone at a concentration of 40 mg/L, removal percentage was 75.31%. These results are in agreement with the findings of the study in Isfahan [8].

The above results indicate that in low turbidity, coagulants and coagulant aids, used to remove turbidity, are less efficient while by increasing turbidity, these substances become more efficient. These results are consistent with the findings of the research conducted in Ahvaz [9]. If the turbidity increases, it can be efficiently removed by increasing the plant coagulant aid and reducing chemical coagulant aid. This finding is in agreement with the studies in India [10, 15- 17].

Optimum pH to be used as a coagulant aid in turbidity removal is 7. In other researches in this area such as those conducted in Isfahan on moringaoleifera with optimum pH of 7 show that plant substances are more efficient in neutral pH [6].

In the research conducted in Isfahan, poly aluminum chloride concentration is 30 mg/L and turbidity removal percentage by using moringaoleifera as a coagulant aid is 99%, while in this study, by using tragacanth, maximum removal percentage is 94.66% [6].The current study shows that poly aluminum chloride as a coagulant along with a coagulant aid is more efficient in turbidity removal than alum and removes up to 91.6% of turbidity in average turbidity. However, alum along with tragacanth coagulant aid removes up to 81.75% of turbidity in average turbidity. These findings are in agreement with those of the research in Isfahan [6, 8].The findings of this study suggest that using tragacanth as a coagulant aid increases the volume of produced sludge. In the water sample where poly aluminum at optimum concentration of 30 mg/L is used alone, the volume of sludge produced is 3 mL, while in the same sample at the same concentration, using tragacanth at a concentration of 0.5 mg/L increases the volume of produced sludge to 6 mL that needs 1 hour for sedimentation. If poly aluminum chloride is used alone, sludge is produced and less time is needed for sedimentation. These results are consistent with those of the study on the effects of poly aluminum in producing sludge in the water of Abadan, conducted by Mahvi and Sheikhi that shows the very low volume of produced sludge [18].

Conclusion

Increasing the amount of coagulant aid can lead to decrease the total alkalinity, after that increased removal efficiency of turbidity. Sluge production is increased when we are using of tragacanth coagulant aid. Another finding of this study is that the plant material is better performed in neutral pH.

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Conflict of interest

We have no competing interests.

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