Using Bentonite Clay as Coagulant Aid for Removing Low to Medium Turbidity Levels

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ABSTRACT: *Alum is a widely used coagulant around the world, but its use of it is associated with some problems, as it increases the aluminum residuals, which have been linked to Alzheimer's disease. Coagulant aids may help with reducing the needed dose of alum. In this paper, many sets of experiments were done to determine the effect of using bentonite clay as a coagulation aid. The experiments were performed under different conditions and on different seasonal circumstances, where many alum and bentonite clay doses were used at low to medium initial turbidity levels. It was found that the addition of a small dose of bentonite clay; 5 mg/L improves the coagulation efficiency between 5 to 7.5 % for the Alum dose 10 mg/L and between 10.6 to 14% for the alum dose 15 mg/L . The coagulation process was also studied by changing both the temperature and the pH value; the best performance of bentonite was when pH is 5 and 6, and when the temperature changed between 10 to 25, the improvement of the removal percentage was about 30 % for the low turbidity and about 9% for the high ones. Finally, the effect of changing the settling time and the mixing speed were also studied. In this regard, it was observed that the best settling time was 90min and the best stirring speed was 200 rpm.*

KEYWORDS: *Alum dose; Bentonite clay; Coagulant; Turbidity.*

INTRODUCTION

Since ancient times, man has been interested in the quality of the water he uses, as it is an essential element of his existence, and this interest has developed in the development of human societies.

In Syria, the main mass of surface water, which is estimated at 70% of the volume of annual resources, is in the rivers shared with neighboring countries, which results in great issues, especially if we take into account the high rates of population growth and the rapid economic development that occurred in the last decade.

Rivers and lakes are among the most important sources of surface water. These water sources are polluted by various sources of pollution, such as leaks from sewage and industrial effluents and the excessive use of pesticides

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and agricultural fertilizers. These pollutants, according to quantity and type, affect the physical and chemical properties and characteristics of water sources and thus lead to deterioration [1].

As mentioned, natural water is polluted by either man or nature, and its components are organic and inorganic dissolved materials. Colloidal impurities in water allow the study of it as heterogeneous phase aggregates. These molecules are very fine units with a crystalline structure. It has very large surface capabilities and therefore a high adsorption capacity. Since the basic process of water purification, coagulation is related to adsorption on the colloidal particles of impurities, so the huge specific surface of these particles plays an important role in this process [2].

Turbidity is one of the most important indicators of water quality, and it refers to the stability of the drinking water purification plants' work [3].

It is an integrated measurement because its high values indicate high values of other parameters of water quality. The impurities that cause turbidity and watercolor are of very small dimensions and therefore it is hard to be deposited. It is negatively charged and could be neutralized by cations that collect them in bigger flocs [4].

The sedimentation by gravity is one of the most widely used methods to reduce the concentration of impurities in water. The impurities that cause turbidity and color have minute sizes, which makes the process of sedimentation very slow, as the diffusion forces overcome the forces of gravity. Here comes the role of the coagulants that are generally used to purify water from suspended substances and to reduce the color of the water, as well as to accelerate the sedimentation of calcium carbonate and magnesium hydroxide during the water softening processes.

As mentioned, the main objective of purification plants is to reduce water turbidity, by means of coagulation and flocculation processes. These processes neutralize the charge of suspended particles that causes turbidity. Coagulants make the fine particles less stable and thus facilitate their incorporation into relatively large flocs that are capable of sedimentation in the later stages. The produced species of the coagulants have large surface areas that can adsorb soluble organic pollutants and trap the colloidal particles. Then, these flocs can be simply separated from the aqueous solution [5].

The process of coagulation is a very complex process and several things intervene in it, including water turbidity, the chemical composition of the water, coagulant quality, coagulant dosage, organic matter, some physical properties such as temperature, pH and mixing conditions [6].

The dosages of coagulants are not the same for different types of water and they are determined by an experimental method using jar test, the optimum dose of the chemical leads to forming flocculants of medium size that are able to be settled in the later process and therefore the residual turbidity is as little as possible [7].

The chemistry of the aluminium ion reaction is complex as this ion has the advantage of reacting with different negative ions, such as hydroxide ions OH-, sulphate SO42- and phosphate PO_4^{3-} forming soluble or insoluble products. These products affect the amount of dose required to reach the desired level of destabilization of the chloroforms. When the alum is added to the water, a series of chemical reactions will occur, starting with its dissolution, then its hydrolysis, and finally its polymerization [8-10].

However, there are many problems associated with the use of alum as a coagulant, including increased values of residual aluminum in treated water, which is a very harmful component in uncontrolled concentrations and is linked to Alzheimer's disease. That is why some coagulation aids are usually used to reduce the necessary dose of alum [11].

Few articles have discussed the use of bentonite as a coagulant aid, *Syafalni, S., et al*, Studied the use of chitosan with bentonite clay as a coagulant, the article recommended an optimal ratio of 30:70 concentration of 1,000 mg/L with 0.15 g of chitosan plus 0.35 g bentonite. The estimated cost of bentonite-chitosan is 10 times higher than that of alum [12].

Hasan M.S., Al-Tamir M.A., in their study, showed that bentonite has been proven to be efficient especially at low turbidity levels of not more than 25 NTU, with a 25 mg/L dose, and with a dose of 30 mg/L for high initial turbidity Level 500 NTU [13].

The results of a study done by *Ahari, M et al*, 2019, showed that the addition of bentonite doses of 20 mg/L can eliminate 96.72% of the turbidity when the raw water turbidity was about 3 NTU [14].

In this research the use of bentonite clay as a coagulant aid was studied, as it is a relatively cheap material and can be substituted for synthetic materials and expensive polymers. Jar tests were used to determine the optimal dose of the bentonite clay as a coagulation aid, in addition, to studying the effect of changing pH, temperature, settling time, and mixing speed on turbidity removal efficiency.

Table 1: Statistical characteristics of water samples

Parameter	Tur- in Mg/L	pH	T ℃
Min	8.89	6.55	8.1
Max	55.35	8.93	21.9
Mean	17.06	7.4	15.5
Std. Deviation	8.2	0.3	2.7

Table 2: The five sets of experiments details.

	Turbidity NTU	Alum dose Mg/L	Bentonite Mg/L	pH	T ºC	Sedimentation Time Min	Rapid mix speed RPM
Set 1	25, 50, 75, 100 ± 3	5,10,15,20,25,30 For 25 &50 10 ,20,30,40,50 For 75 &100	5,10,15	7 ± 0.4	20 ±2	60	150
Set 2	25, 50, 75, 100 ± 3	Optimal	Optimal	6,7,8,9	20 ±2	60	150
Set 3	25, 50, 75, 100 ± 3	Optimal	Optimal	7.5 ± 0.4	10,15, 20 ±3	60	150
Set 4	25, 50, 75, 100 ± 3	Optimal	Optimal	7.5 ± 0.4	20 ± 2	30,60,90	150
Set 5	25, 50, 75, 100 ± 3	Optimal	Optimal	7.5 ± 0.4	20 ± 2	60	100, 150, 200, 250

EXPERIMENTAL SECTION

Raw water samples

The raw water samples were taken from the Asi River, right after entering the water purification plant in Qusayr, Homs. The samples were immediately tested for Turbidity level, pH, and Temperature. When the adjusting of turbidity was needed, synthetic turbidity samples were made by adding the clay taken near the river.

The raw water turbidity levels varied between 8.89 and 55.35 during the time of the study, with some extreme values up to 100 NTU, during rainy seasons, the temperature varied between 8 and 22, and the pH was between 6.5 and 8.9. The statistical characteristics of the water interring the plant during the study are described in Table 1.

Jar Test experiments

A series of chemical experiments has been conducted using jar test experiments, the study focused on many aspects, the difference in the bentonite doses, pH variation, temperature, the best sedimentation time, and the best stirring speed. The next steps describe the way that each experiment had been conducted:

1- First of all, a Jar Test was performed for each initial turbidity level, (25, 50, 75,100 NTU ± 3). The alum dose was changed between 5 and 30 mg/L. the turbidity were actual values as possible and not synthetic samples.

At this part of the experiment, the pH was about 7 ± 0.4, T = 20 ± 2℃.

2- Rapid mixing was carried out at 120 rpm during three-minute intervals in order to homogenize the distribution of coagulant. The slow mixing was done at a speed of 25 rpm during 10 then the small flocs formed in the coagulation were allowed to sediment for 30 min.

3-The second set of experiments was to evaluate the effect of pH differences on each dose. Turbidity values were (25, 50, 75,100NTU ± 3), and the dose the optimal gained from step 1. PH was changed between 6 to 9 for each set of experiments, in order to study the effect of pH on the suitable dose. Then step 2 repeated.

4-The temperature at the time of the study is deferred from one month to another, during the year. Therefore, a set of experiments were studied to determine the optimal dose at each specific temperature.

This collection of experiments was done at different times of the year, the temperature of raw water was (10, 20, 25 ±1), initial turbidity was (25, 50, 75,100NTU ± 3) and the dose and the dose optimal gained from step. Then step 2 was repeated.

5- Settling times were changed between 30, 60, 90, and 120 minutes.

6- Different stirring speeds were studded 100, 150, 200, and 250. Table. 2 summarizes the steps of the experiments.

RESULTS AND DISCUSSIONS

First set of experiments, The turbidity levels studied were 25, 50, 75, and 100 ∓ 3, the alum dose between 5 and 30, and the biotinide dose was 0,5,10,15 .pH was set at about 7 ∓0.4, and the temperature at 20 ∓ 02.

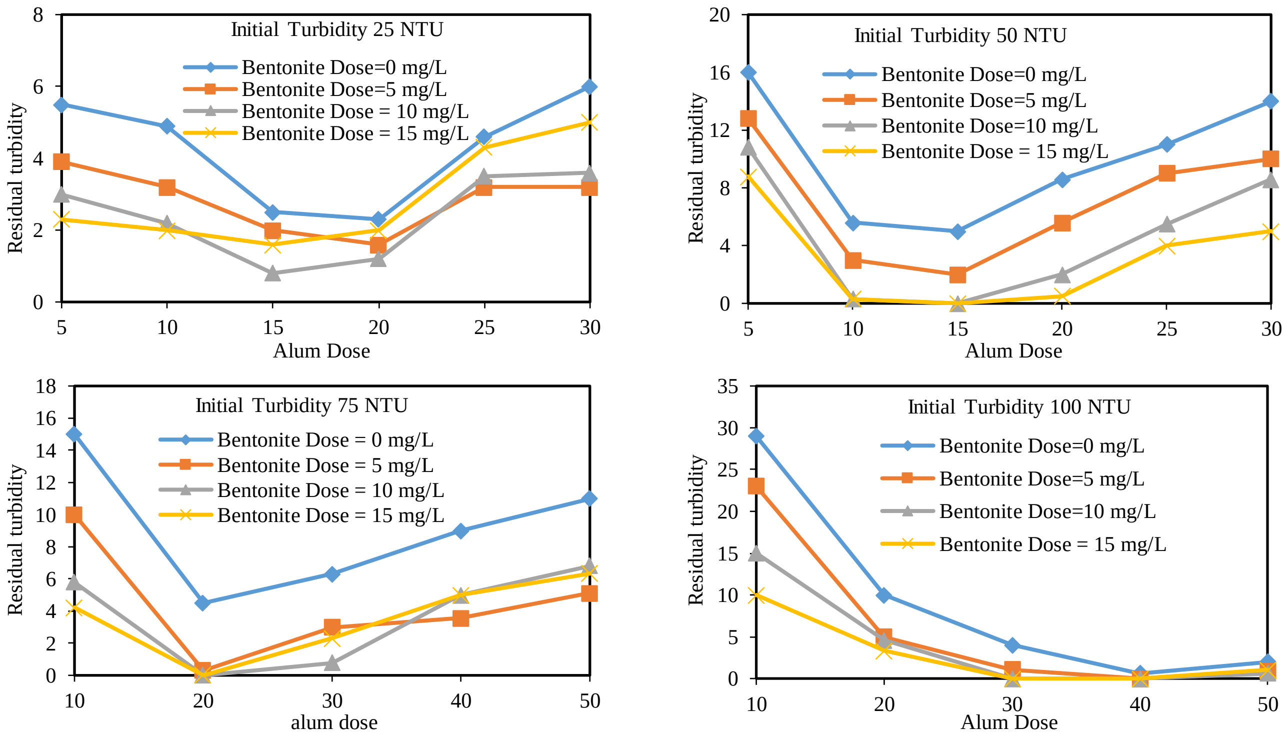

Fig. 1: Residual turbidity for different alum and Bentonite doses and different initial turbidity

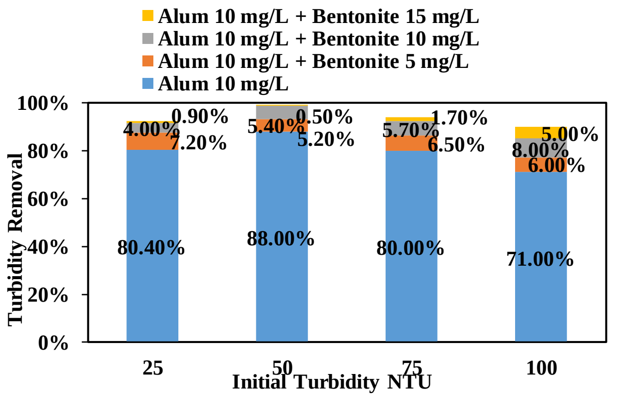

Fig. 2: the improvement of adding different bentonite doses to a 10mg/L from Alum, for different turbidity levels

A breaker of 1000 mL raw water sample was used, after the rapid mix, slow mix, and precipitation. The residual turbidity was measured. The results of the experiments are presented in Fig.1

At the turbidity 25 NTU, the optimal alum dose was 15 mg/L, with an effectivity of removal 90 %. The optimal dose dropped into 5 mg/L of alum when adding a dose of 5 mg/L bentonite. Likewise, the optimal alum dose dropped from 15, 20, and 30 for the initial turbidity 50, 75,100 to 10, 10, 20 mg/L of alum when adding 5 mg/L of bentonite.

The improvement of the effectivity of the turbidity removal, when adding 5, 10, and 15 mg/L from Bentonite clay to a dose of 10 mg/L from alum is presented in Fig. 2.

As it is shown in Fig.2, the removal effectivity of the 10 mg/L of Alum is 80 %, for the initial turbidity 25 NTU. The addition of 5 mg/L from Bentonite clay improves the effectivity of the turbidity removal 7.2%, as the turbidity removal (TR) becomes 87.6 %. It rises to 91.6 % when adding 10 mg/L from Bentonite, and to 92.5 % when adding 15 mg/L from Bentonite.

In the Second set of experiments, Turbidity was set at (25, 50, and 75,100) ∓ 3 NTU, and pH was changed between 5-9, for the optimal doses gained from set 1. Temperature at 20 ∓ 2 . The results are listed in Fig.3.

For initial turbidity 25 NTU, when pH changed from 5 to 9 for the same dose, the effectivity varied from 96.4% to 64%. From 98 to 73.8 when the initial turbidity 50 NTU, from 99 to 80 when for initial turbidity 75 NTU, and from 96.2 to 87 when the initial turbidity 100 NTU. When the pH value of the treated water is increased, the coagulation efficiency becomes less and the residual turbidity is higher.

The third set of experiments was to study the effect of temperature, as temperature changes throughout the days during the months. In this set of experiments, pH,

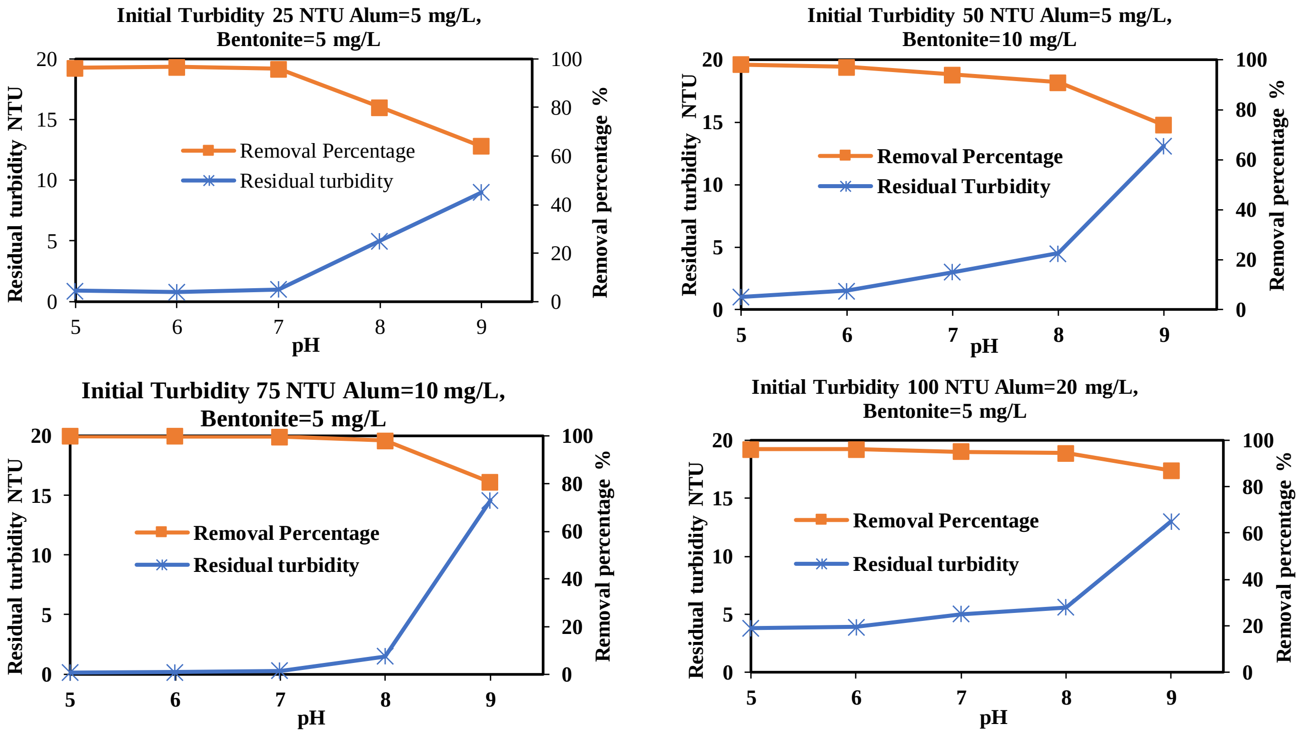

Fig. 3: Residual turbidity for different pH level at different initial turbidity

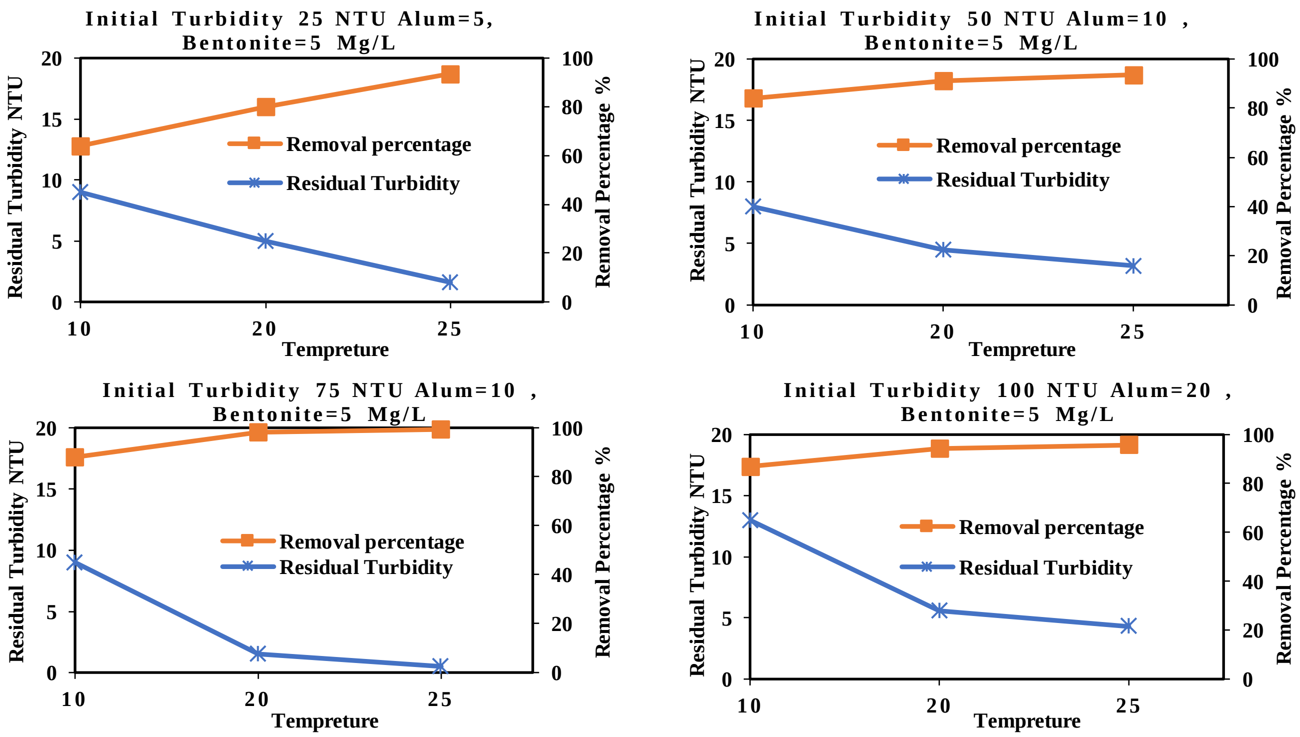

Fig. 4: Residual turbidity for different alum, and Bentonite doses at different temperatures

was constant as possible at the value, 7.5 ± 0.4. The experiments were done at different times of the year, and the temperatures were 10, 15, 20 ±2. The results are described in Fig. 4.

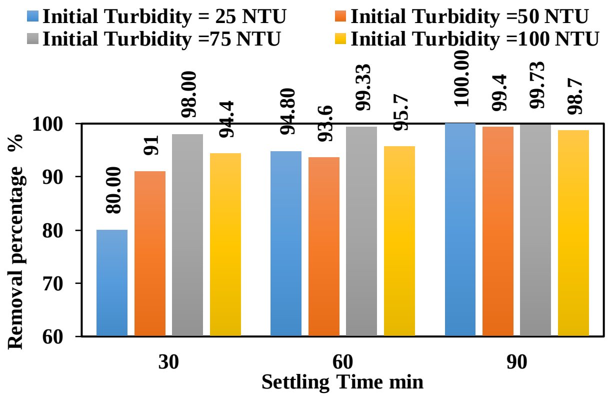

Fig. 5: Turbidity removing percentage for different settling time levels

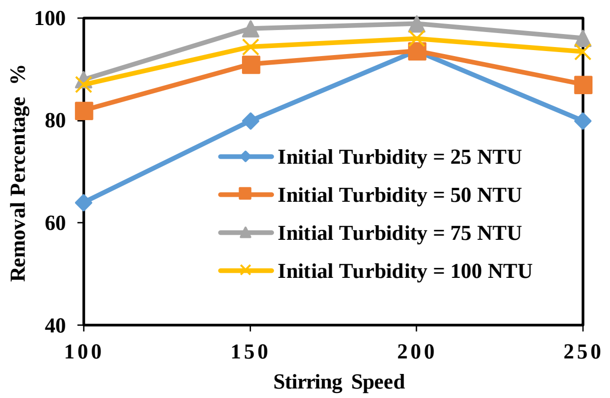

Fig. 6: Turbidity removing percentage for different stirring speeds

Low Turbidity was more affected by the temperature, The Removal percentage of the turbidity raised from 64 to 93 % for the raw water turbidity 25 NTU, and from 87 to 95.6 for the raw water 100 NTU, when the temperature raised from 15 to 20 °C

Higher coagulant dosage, and the addition of flocculation aids, are required at lower temperatures.

The experments were done for a settling time 60 min, two sets of experments were done to detemine the amount of effect that a 30 minute settling time make. It was shown that raising the settling time to 90 minute will raise the effecicy of the removal, but not with a high percentage, as it changed between 2 to about 6 % for the different doses, between 60 and 90 minutes of settling. The results are presented in Fig. 5.

The last set of experiments was conducted to evaluate the proper stirring speed. 4 different speeds were studied, 100, 150, 200, 250 rpm. The results of the experiments are shown if Fig.6.

The best results were obtained when the speed was 200. Raising the mixing speed did not give better results, it reduced the percentage of efficiency. When the stirring speed rose from 100 to 200, the removing percentage rose from 64 % to 94 % for the initial turbidity 25 NTU, the lowest turbidity levels were most affected by the stirring speed. The residual turbidity was raised when the speed was set on 250 rpm.

CONCLUSIONS

This study has successfully proved the effectiveness of the combination of bentonite and alum as a coagulant for drinking water treatment processes. The optimal parameters were determined based on turbidity removing percentages. The aspects studied were the dose of bentonite and alum, the pH effect, the variation of effectivity with the temperature differences, the settling time and the stirring speed. A small amount of bentonite 5 mg/L could improve the efficiency of the alum and reduce the required alum dose. As adding 5 mg/L of bentonite to a 10 mg/L of alum, increases the removal percentage between 5.2 to 7.2 %, for different initial turbidity levels. When initial turbidity was 100 NTU. Adding this amount of bentonite to the doses (10, 20, 30, 40, 50 mg/L) of alum, increases the removal percentage to (77, 95, 98, 100, 99 %) respectively. pH affects the improvement percentage, lower pH levels gave better performance of the Bentonite. And so did the higher temperature levels. The mixing speed affected the results as the best mixing speed was 200 rpm, with a removal percentage of the turbidity between 93.6 to 98.9%.

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