Effect of Optimum Alum Dosage On Improvement of Some Physical and Chemical Water Properties

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Abstract

In the recent years, the water amount of Euphrates River decrease to the low levels which has led to increase the concentration of pollutants in it. In the city of Karbala, potable water is treated by purification plants that involves coagulation, flocculation, sedimentation, filtration ,and sterilization units whereupon pumping to ground tanks and then to a network or directly to the network. In process of coagulation alum substance is commonly used as coagulant in water treatment plant in Iraq. In the present study the alum was evaluated in water purification process with increase in the pollutants concentration using the jar test for samples taken from Al-Husseiniyia river. It was found that high removal ratios of turbidity reached to 96% by optimum dose amount of 10 mg/L, and the pH value of 7 with the optimum speed and time of flocculation 25 revolution per minute and 20 minutes respectively. The study was done to show the effect of removing turbidity in the optimum condition on the improving of the some physicals and chemicals water properties such as reducing the concentration of total dissolved solids, electrical conductivity, calcium and magnesium hardness. It was found that optimum alum dosage (remove turbidity in optimum conditions) does not reduce the concentration of total dissolved solids or electrical conductivity (ratio of removal non-existent), but their effect on the removal of calcium and magnesium hardness levels is very **low.**

الخلاصة

في السنوات الأخيرة انخفضت كمية مياه نهر الفرات إلى مستويات متدنية مما أدى إلى زيادة تركيز الملوثات فيه. ففي مدينة كربلاء تعالج هذه المياه في محطات تصفية تتضمن عملية تخثير وتلبيد وترسيب وعملية ترشيح وتعقيم ومن ثم الضخ إلى خزانات أرضية ومن ثم إلى الشبكة أو الى الشبكة مباشرة. تستعمل مادة الشب في عملية التخثير وهي مادة شائعة الاستعمال في محطات التصفية في العراق. في الدراسة الحالية تم تقييم مادة الشب في عملية تصفية المياه مع الزيادة الحاصلة في تركيز المواد الملوثة باستعمال فحص الجرة لعينات أخذت من نهر الحسينية. تم الحصول على نسب إزالة عالية للعكرة وصلت إلى 96% بجرعة شب مثالية مقدارها 10 ملغم/لتر, وقيمة الرقم الهيدروجيني 7 وسرعة وزمن التلبيد مثالي25 دورة لكل دقيقة , 20 دقيقة على التوالي. وتم دراسة تأثير إزالةالعكرة في الظروف المثالية على تحسين بعض خصائص الماء الفيزيائية والكيميائية مثلتقليل تركيز المواد الصلبة الذائبة الكلية والتوصيل الكهربائي وعسرة الكالسيوم والمغنيسيوم, فوجد ان جرعة الشب المثالية (إزالةالعكرة في الظروف المثالية) لا تقلل تراكيز المواد الصلبة الذائبة الكلية أو التوصيل الكهربائي (نسب الإزالة معدومة), أما تأثيرها على إزالة عسرة الكالسيوم والمغنيسيوم كانت بمستويات قليلة جداً.

Introduction

Producing water with lower turbidity may be a treatment objective because it is compliance with water quality regulations, and would be removal of particulate contaminants and improve water properties [Logsdon, 1987].

The agglomeration (coagulation-flocculation) process in water treatment is the most important step in contaminants removal. This process, which is induced by the addition and dispersion of chemicals, destabilizes particles in solution by neutralizing there surface charge[Drikas et al., 2001].The most commonly used coagulants in the drinking water industry are aluminum or iron salt[Exall and Vanloon, 2000]. Approximately (60 – 98)% of coliform bacteria, (65 – 99)% of viruses, and (60 – 90)% of giardia will be removed from the water along with organic matter and heavy metals[Cheremisinoff, 2002].Koohestanian and et al. studied the influence of PH, temperature, coagulant ,and coagulant aid dosage on the coagulation process. They found that (85-98)% reduction of turbidity from raw water can be achieved by using the optimum coagulant dosage (8 mg/L, ferric chloride/ 10 mg/L, alum) in the optimum PH range (9.2, ferric chloride/ 8.5, alum) in the optimum temperature (20˚C, ferric chloride/24˚C, alum)[Koohestanian et al., 2008].

One of the physical characteristics of potable water that should meet the standards is turbidity. In some cases this standards is a low as 1 nephlometric turbidity unit (NTU) and in some other cases are as high as 5 NTU as maximum permissible [Iraqi Central Organization for Standardization and Quality Control, 2001]. Al-Hussaniyia evaluated the water quality at Hilla city by studying the reliability of turbidity and hardness for Hilla water treatment plant that used alum as coagulant. The removal of turbidity was more effective from hardness removal [Al-Hussainiyia, 2004].

If adding coagulant chemical is essential, so is maintaining the proper chemical control of coagulation. The efficacy of inorganic coagulants especially alum, depends on the PH of the water. Aluminum salts are most effective as coagulants when PH range is from 4.0 to 7.0 [Steel, 1981] or from 5.5 to 8 [Cheremisinoff, 2002]. Chemical dose is important, both for inorganic coagulants and for polymers. Inadequate doses result in inadequate particle destabilization and coagulation [Logsdon, 1987].The usual dose for coagulant as alum is 10 to 30 mg/L for water [Cheremisinoff, 2002].

Probably the most common approach to coagulant chemistry evaluation is jar test. Jar test necessary to establish optimum coagulant dosage and PH condition [Qasim et al., 2009]. For turbid waters, jar test results can be based on the turbidity of settled water. For low turbidity waters perhaps, 5 NTU or low, changes in raw waters turbidity may not be sufficient to indicate clearly the optimum chemical doses. Jar tests can be used to develop preliminary estimates of flocculation time and energy requirements. [Logsdon, 1987].

The flocculation process is an important step in the removal of suspended, colloidal, and in some cases dissolved material from water. The purpose of the flocculation process is to promote, by mixing, the growth of particle aggregates of such size and density that effective phase separation occurs in subsequent unit process in the treatment system. The process consists, in general, of an initial or rapid mixing step in which the coagulant is dispersed or particle agglomeration (flocculation) begins, followed by a period of less intense agitation (a slow-mix or flocculation period) to promote the formation of larger and more settleable flocs [Villegas and Letterman, 1976].

The most important factor for coagulation process is a proper dosage of coagulant, with or without a coagulant aid. The choice of coagulant is, of course, also an important consideration. Even though a wide variety of polymers and polyelectrolytes are available now, aluminum sulfate (alum) is still one of most effective, economical, and foolproof coagulants and is extensively used in the water treatment field. Alum coagulation and flocculation can, however, be affected by many factors such as salt concentration, PH, temperature, nature of colloids, size of turbidity particles, mixing, and alum concentration [Kawamura, 1976].

Research Objectives

The objective of this study is to evaluate the efficiency of alum on improving some of the physical and chemical water properties through optimum turbidity removed. And to state the effect of optimum turbidity removal on some physical and chemical water properties. This was done by using jar test instrument.

Another objective of research was to evaluate the efficacy of alum as coagulant to improve some of physical and chemical water properties when raw water turbidity has low or high levels.

This work was conducted to optimize alum dose, PH flocculation time, and flocculation rate using jar test. Major objectives of this study are stated in order to determine the optimum alum dose using turbidity as performance and to study the effective of optimum alum dosage on improving drinking water properties.

Materials and methods

The performance of coagulation-flocculation in improving some of the physical and chemical water properties was studied by using typical jar-test (type JLT6-VELP scientific, Germany) procedures. Each series of experiments was designed to achieve the optimum removal of turbidity by optimizing the coagulant dosage, taking into account PH, flocculation time, and mixing speed.

The jar tests were performed using six-bladed paddles. Water samples were placed in 1 liter beakers and stirred for 2 minutes at 100 rev/min, after which sufficient 1.0N hydrogen chloride (HCL) or 1.0N sodium hydroxide (NaOH) was added for PH adjustment when necessary along with the coagulant. Then the samples were flash-mixed at 100 rev/min. The stirring rate was then reduced to the desired speed, and after flocculation for the desired time, it was set to zero. After 30 minute of settling, the supernate was analyzed for turbidity, electrical conductivity (EC), total dissolved solid (TDS), calcium hardness (Ca^{++}), and magnesium hardness (Mg^{++}) .

Two series of coagulation experiments were performed by using alum as coagulant. Each series of experiments were performed with Al-Hussainyia river water at Karbala governorate with two different raw water properties. The experiments of two different river water properties made at 20-30 $^{\circ}$C, the first one had turbidity 19.15 NTU, PH of 8.79, EC of 1105 μs/cm, TDS of 553 mg/L, and calcium and magnesium hardness was 220 mg/L and 270 mg/L as $CaCO_3$ respectively. The other one had turbidity 146 NTU, a PH of 8.7, EC of 949 μs/cm, TDS of 476 mg/L, and calcium and magnesium hardness was 187 mg/L and 245 mg/L as $CaCO_3$ respectively. The two different raw water quality characteristics are summarized in table 1.

Table 1. Raw Water Quality Characteristics

Parameter	Sample 1	Sample 2
	concentration	concentration
Turbidity (NTU)	19.15	146
PH	8.79	8.7
EC (μs/cm)	1105	949
TDS (mg/L)	553	476
Calcium Hardness(mg/L)	220	187
Magnesium Hardness(mg/L)	270	245

The stock solution of coagulant, which is used in the jar tests, has 100mg alum solution per 1 liter alum-water solution, was prepared by adding 5.7 mg (eq. wt=molecular weight/eq. No) of alum to 1 liter distilled water, and then add specified amount of alum stock solution to each of six 1 L jars. This amount was determined by using the dilution equation (N1 * V1=N2 * V2). For example to obtain 10 mg/L of alum solution as coagulant in 1 liter jar, a100 ml of alum stock solution should be added.

The instruments were used for tests was turbidity bench meter (model 2100N, Hach company, Germany),PH bench meter (HI 213, Hanna company),electrical conductivity and total dissolved solid bench meter (HI 2300, Hanna company)and multi-parameter bench photometer for calcium and magnesium hardness measuring (model C99).

Results and Discussion

The laboratory experiments were performed to evaluate the removal of TDS, EC, and Ca and Mg hardness by chemical coagulation at optimum conditions for turbidity removal. To define the condition for optimum turbidity removal each water sample was subjected to four experimental series: (1) optimization of coagulant flocculation dose; (2) Optimization of PH at the Optimum coagulant dose; (3) optimization of flocculation time at a constant flocculation speed of 25 rpm; and (4) optimization of flocculation speed at a constant time of 20 min.

The coagulant (alum) was tested with two different raw water properties that collected from point located at south of Al-Hussainyia river. Two series of coagulation experiments were performed by using alum as a coagulant. Figures 1 to 4 show the results of these experimental series. Experimental series 1 were performed with raw water turbidity of 19.15 NTU, TDS of553, EC of1105 µs/cm, Ca and Mg hardness of 270 mg/L and 220 mg/L respectively. As shown in figures 1 and 2, the optimum removal of turbidity occurred with a dosage of 10 mg/L alum as aluminum oxide ($Al2O3$)/L at PH approximately 7. Figure 3 shows that with a flocculation speed of 25 rpm, turbidity removal between (60 to 96) percent were achieved with mixing time of 20 and 50 min. Figure 4 shows that with a flocculation time of 20 min all mixing rates between 25 and 50 rpm gave turbidity removals of (60 to 96) percent.

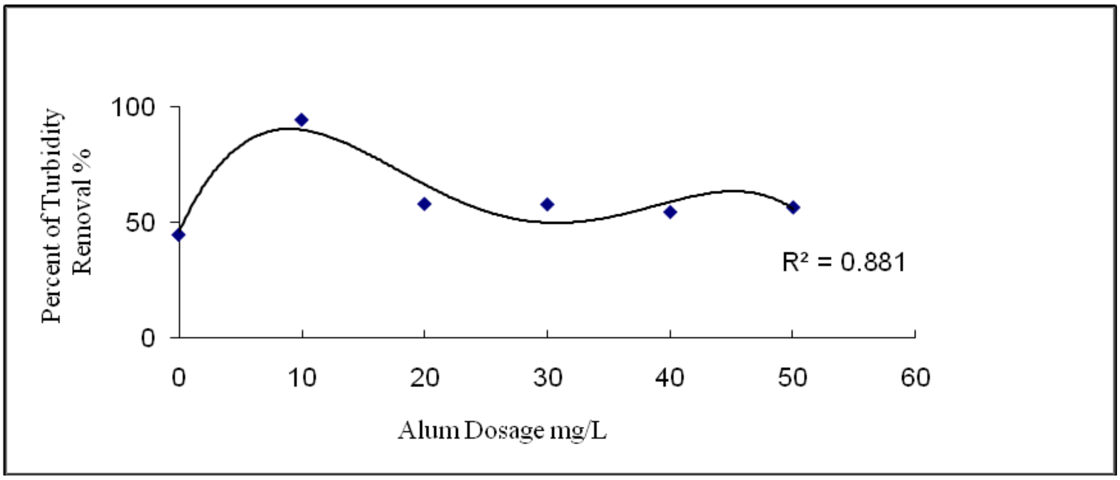

Fig.(1) Optimum alum dosage for removal of turbidity with PH=7 ,flocculation time of 20 min and flocculation speed of 25 rpm

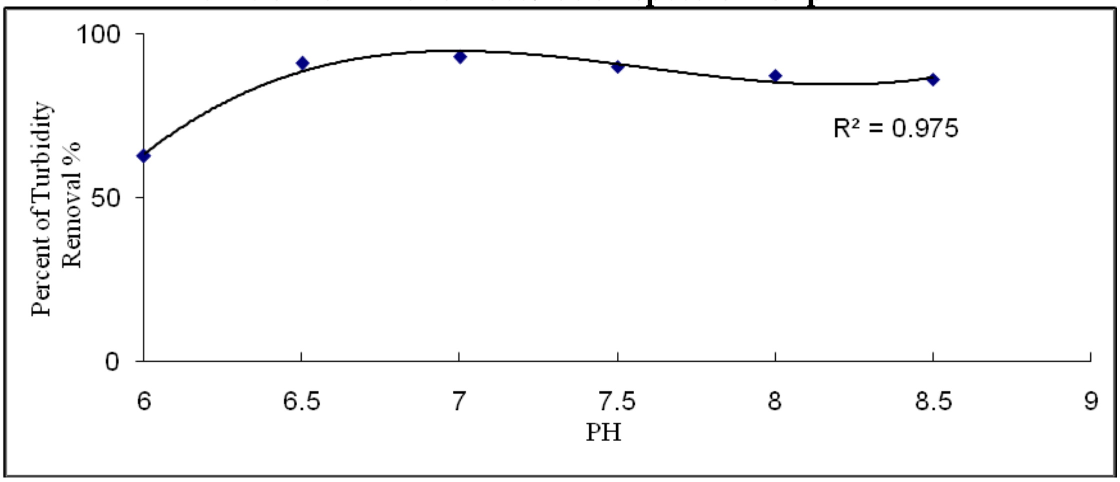

Fig.(2) Optimum PH for removal of turbidity using 10 mg/L alum dose, flocculation time of 20 min and flocculation rate of 25 rpm

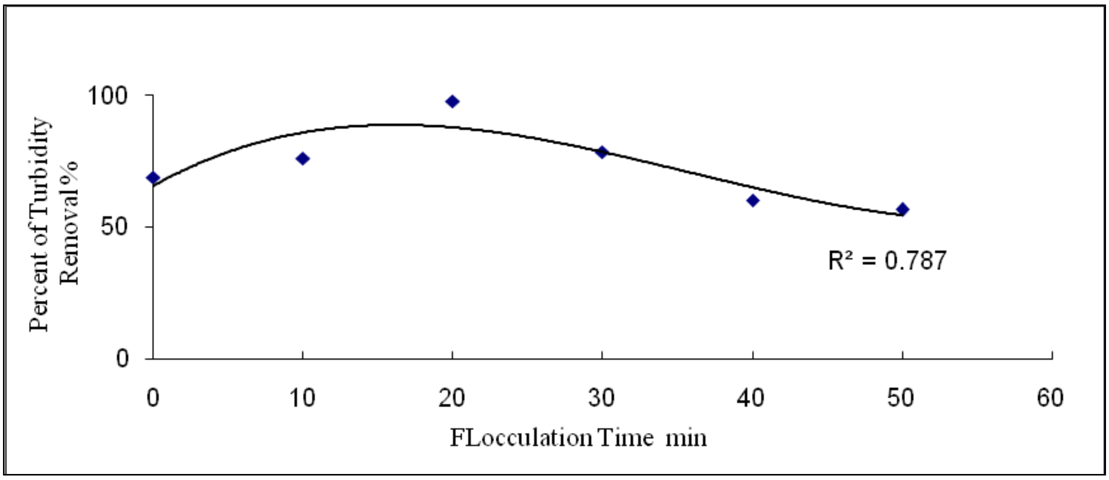

Fig.(3) Optimization of flocculation time for removal of turbidity using 10 mg/L alum dose at PH 7 and a flocculation rate of 25 rpm

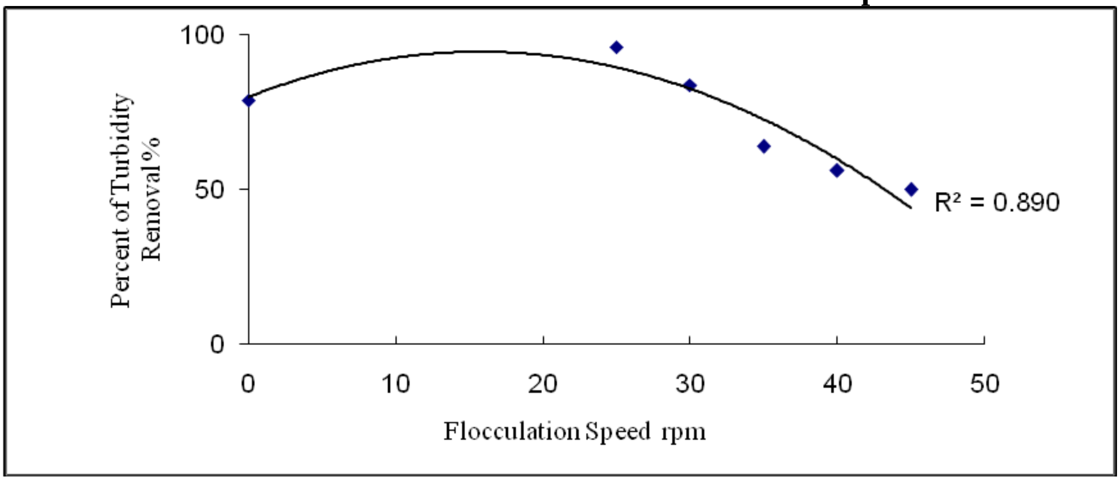

Fig.(4) Optimization of flocculation speed for removal of turbidity using 10 mg/L alum dose at PH 7 and a flocculation time of 20 min

Experimental series 2 was performed with raw water turbidity of 146 NTU, TDS of 476 mg/L, EC of 949 μs/cm, and Ca and Mg hardness of 245 mg/L and 187 mg/L respectively. The results of series 2 were essentially the same as in series 1 as shown in figures 5, 6, 7, and 8. The percent of optimum turbidity removal appears slightly larger than in the first series. The optimization of flocculation time (fig.(7)) for second experimental series gave a removal of turbidity of (70 to 98) percent with flocculation time (20 – 50) min. The optimization of mixing speed indicated an (65 to 98) percent removal of turbidity with a mixing speeds of (25 – 50) rpm.

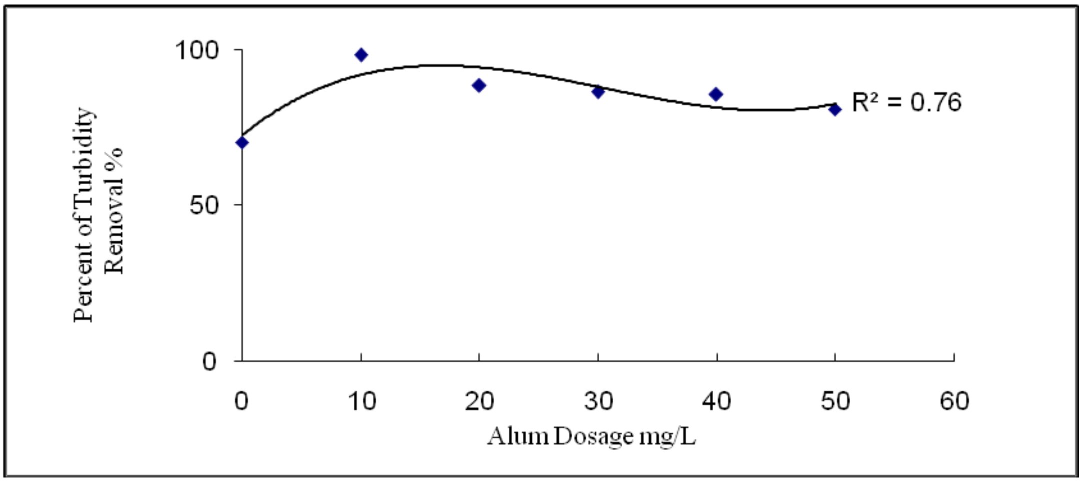

Fig.(5) Optimum alum dosage for removal of turbidity with PH=7 ,flocculation time of 20 min and flocculation speed of 25 rpm

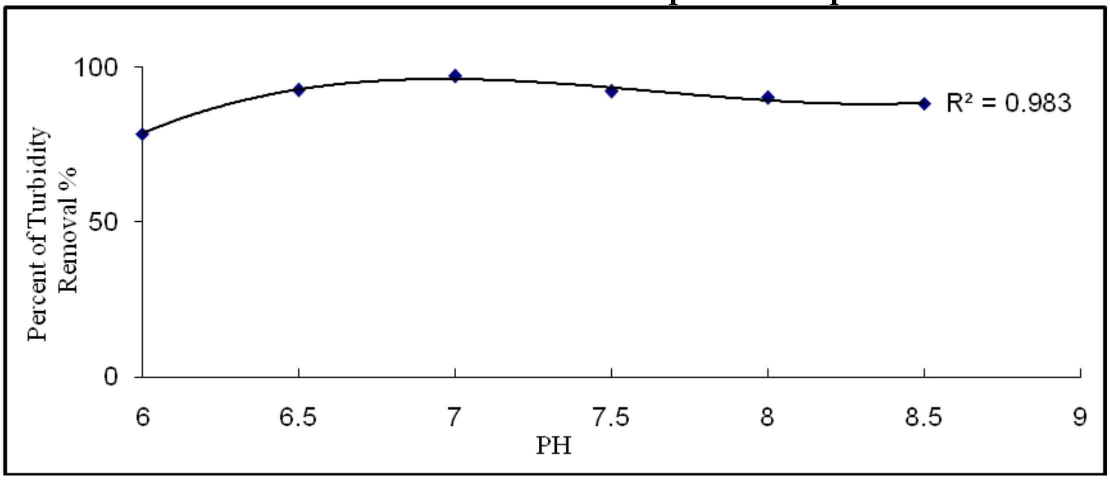

Fig.(6) Optimum PH for removal of turbidity using 10 mg/L alum dose, flocculation time of 20 min and flocculation rate of 25 rpm

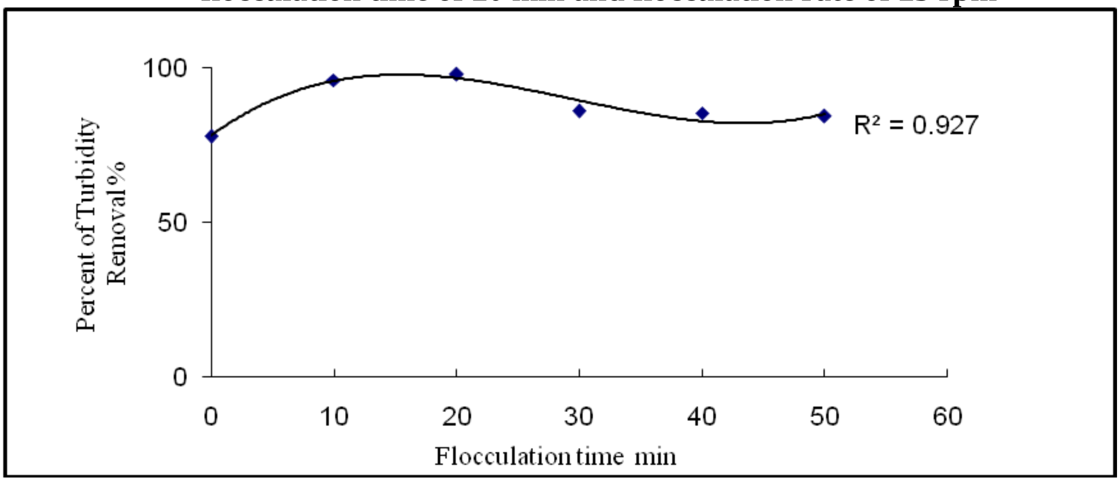

Fig.(7) Optimization of flocculation time for removal of turbidity using 10 mg/L alum dose at PH 7 and a flocculation rate of 25 rpm

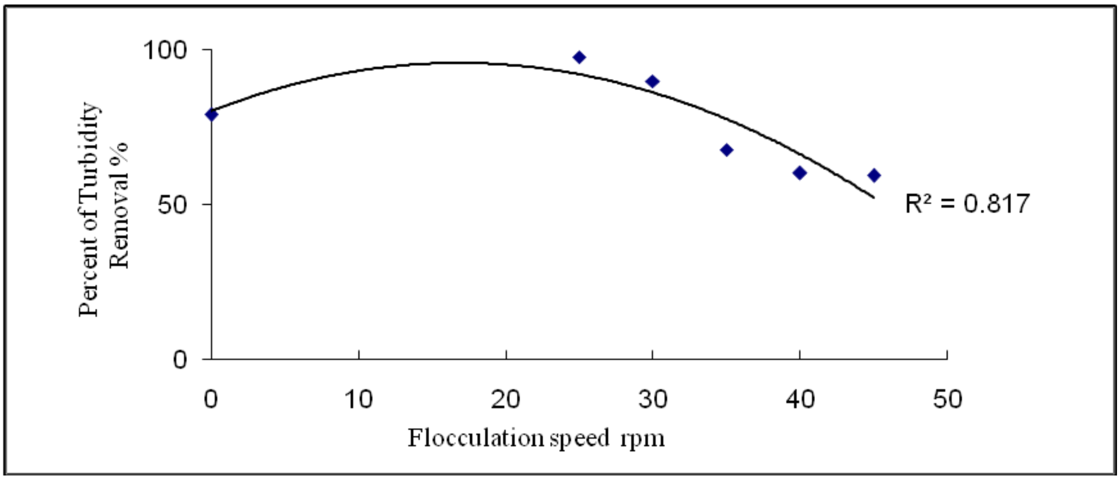

Fig.(8) Optimization of flocculation speed for removal of turbidity using 10 mg/L alum dose at PH 7 and a flocculation time of 20 min

Since the emphasis was on removing the TDS, EC , and Ca and Mg hardness at optimum conditions for removing turbidity, as shown in figures 9,10,11, and 12 for experimental series 1 and 2. These figures show that the effect of optimum turbidity removal percent using alum as a coagulant on the TDS, EC was null but the level of these properties increases about initial level. While the effect of the optimum turbidity removal on Ca and Mg hardness was too low.

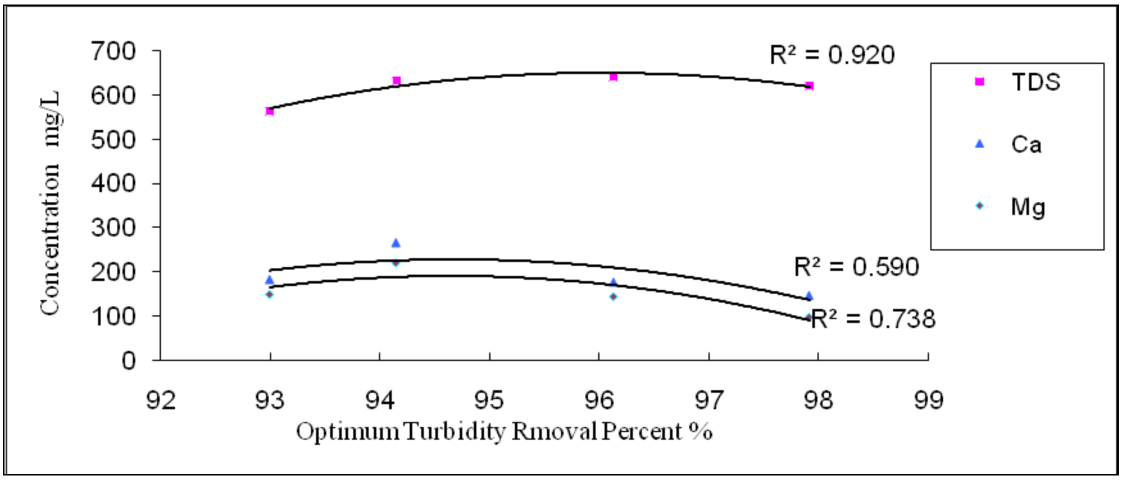

Fig.(9) Relationship between optimum turbidity removal and some physical and chemical properties

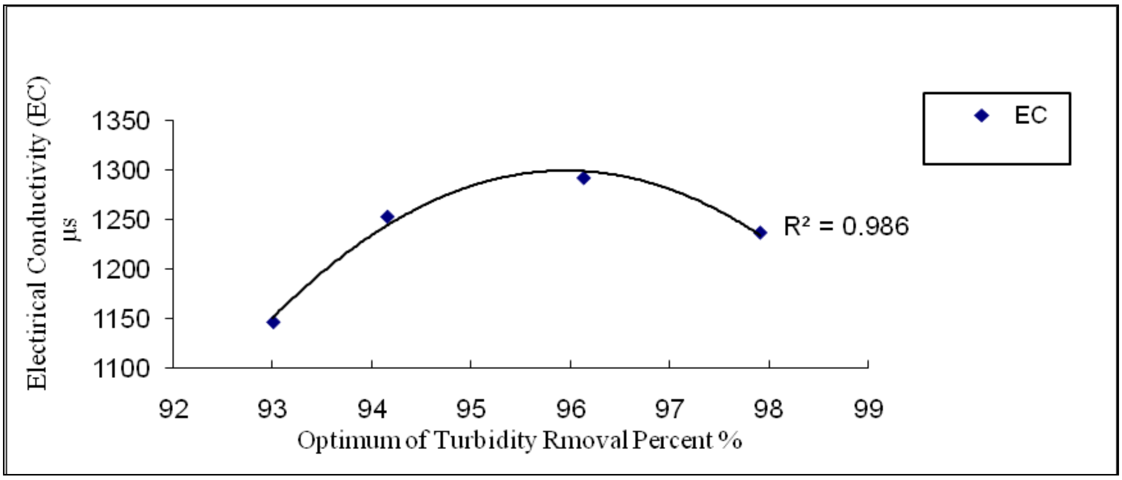

Fig.(10) Relationship between optimum turbidity removal and electrical conductivity

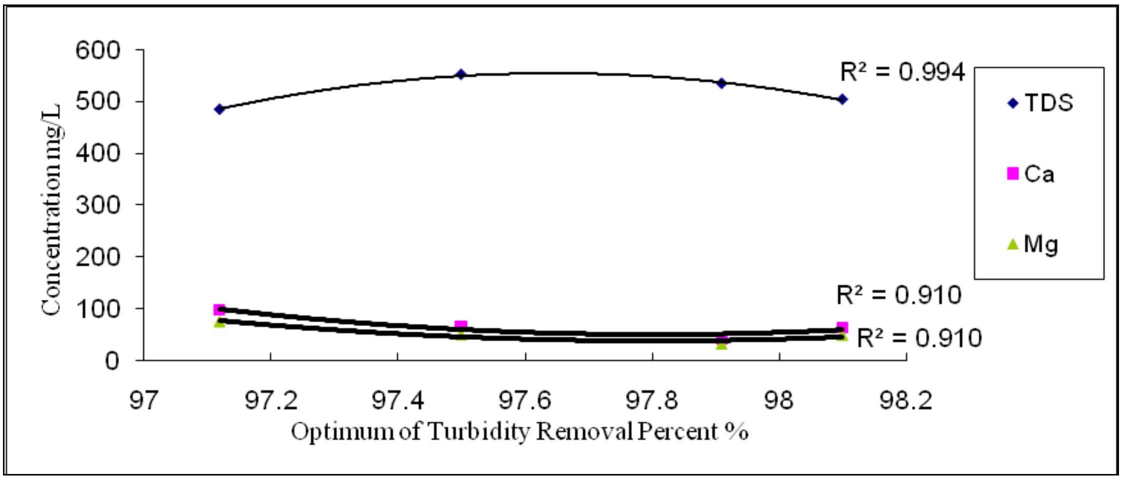

Fig.(11) Relationship between optimum turbidity removal and some physical and chemical properties

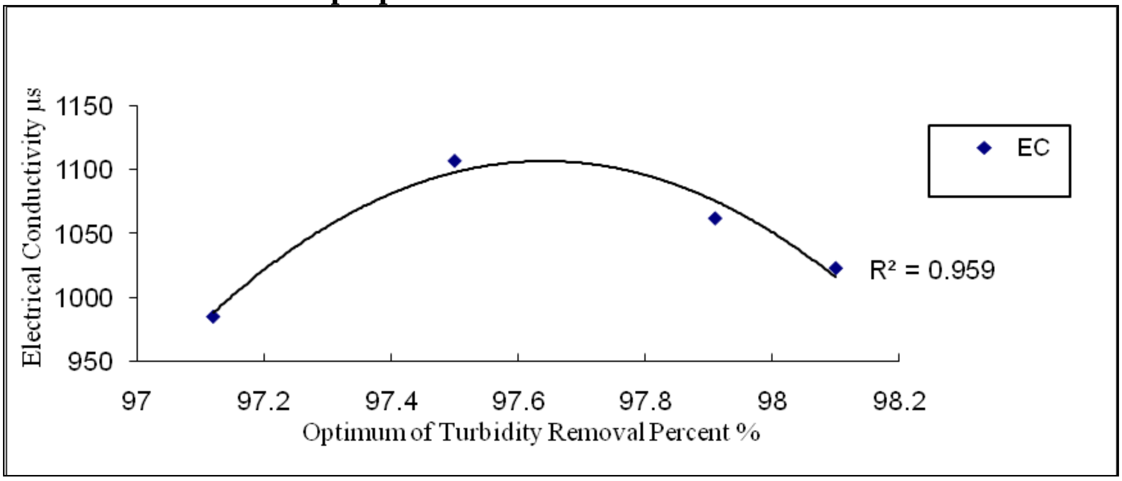

Fig.(12) Relationship between optimum turbidity removal and electrical conductivity

Conclusions

The objective of this study was to ascertain the expected improvement of some physical and chemical water properties when coagulation – flocculation process is used. Since coagulation – flocculation, using alum, is designed for optimum removal of turbidity by using Jar-test instrument.

From the analysis of the results for this study, the following conclusions may be drawn:

1- The results of this research indicate that the Jar-test is applicable to optimize coagulant dose depend on turbidity removal. Outputs from this tests have similar shape for turbidity – coagulant dosage curves. The shape and position of the output curve indicates that the effects of imposed conditions like PH, coagulant dose, flocculation speed, flocculation time, and water properties.
2- It's found that the effect of optimum alum dosage was not effective in removal TDS and EC of water properties and slightly was more effective for Ca and Mg hardness, but not for high level.
3- Optimum alum dose is effective for low and high raw water turbidity and the efficiency of turbidity removal increase with increasing turbidity of raw water.
4- When optimum turbidity removal percent occurs, the percent of removal of EC, TDS, and Ca and Mg hardness is low or not visible to change water taste.
5- When alum is used as a coagulant, it is un effective for improving drinking water properties without used coagulant aids or more efficient coagulant.

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