A Mathematical Model to Determination of Alum Amount Added for the Purpose of Coagulation in Water Purification Plants

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Abstract-*Chemicals are used to increase the settling velocity for suspended deposition colloids which are not settled in sedimentation tanks in water purification plants . For this purpose, the alum is used in wide spread across the water purification projects in Iraq. This research contains studying the factors that effect on alum amount added by conducting laboratory tests of water samples from Euphrates river at the purification plant in AL-Musayyab city over ten years (with monthly rate). It was noted that the amount added depends heavily on the turbidity of water entering the purification plant, in addition to water temperature and its pH. The results of laboratory tests have been approved, which included the measurement of the turbidity, pH, temperature, and the value of alum added. Since this method is applicable in all water purification plants. The results during the period of ten years are accredited, and subjected to multi -regression analysis. A mathematical model was conducted to calculate the alum dose, which must be added depending on the raw water turbidity, temperature, and pH. This model also has been examined by using data of another years and gave satisfactory results to be up to 91% each. This model compensates the use of the Jar-test of raw water to determine the amount of alum that must be added and sufficient by measuring the turbidity, temperature, and pH of the raw water only, and then calculating the value of the required dose of alum.*

Keywords*- Alum Dose, Coagulation, Turbidity, pH*

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1. Introduction

The raw water enters purification plants in Iraq having high levels of suspended solids, of them may be removed by sedimentation process, using sedimentation tanks, which holds the process of removal by gravity reaction. This process called natural sedimentation [1]. The remain part which contains colloid particles are not settled by this action because of the low values of settling velocities or when their density be less than the density of water. So that the chemicals, in a process called coagulation are used which contains collecting of the fine particles with each other and convert it into particles with a density exceeding the water density, this makes it available for settling. This process is called chemical sedimentation [1]. The process of chemical sedimentation contains two stage, the first process involves feeding chemicals added for this purpose in the form of powder or liquid, and mix quickly to ensure uniform solution . The second stage contains slow mixing for the purpose of flocculent formation, which attract the colloidal particles through flocculation and then sedimentation process.

The coagulation chemicals are different types such as aluminum sulfate (alum), ferric, ferrous sulfate, and electrolytic materials like the poly- electrolytes. Alum is widely used in Iraq due to the locally available and easily used. However, polypropylene electrolytes have been used as assistant factor for alum to increase the efficiency of coagulation process, especially at higher concentrations of turbidity of raw water [2]. The method used to assess the required dose of alum added to the water entering the purification water plants, is the use of a Jar-Test experiment which requires the addition of six different doses and choose the best depending on highest one in settling the particles, This experiment may be repeated more than one time to get the dose which arrive good settling case [2]. This research proposal a new method to determine the dose of alum required for coagulation in water purification plants, depending on the factors affecting the dose by knowing the properties of the raw water entering these plants.

2. Factors Affecting the Coagulation Process

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A coagulation process is affected by a number of factors , including the amount and properties of colloids particles, temperature, pH value, and the velocity of coagulation. A number of researchers had studied in this field, the properties of water and the influence on each other and thus on the dose of chemical additive for the purposes of coagulation. WHO [3,4] gave standard specifications for drinking water , which showed that the best limits for pH which gives the best coagulation are between (6.5 - 8. 5). While AL- Hashimi et al. [1] studied the effect of alum dose on pH, also studied the relationship between the turbidity of water and the suspended solids on one hand and measuring the electrical conductivity of the water and TDS materials on the other hand. They found empirical relationships linking these variables, as follows:

$$pH= 8.723/DA^{0.05} \quad (1)$$

$$SS=2.2TR \quad (2)$$

$$Ds= 1.3\ Ec^{0.91} \quad (3)$$

Where:
pH = Hydrogen number
DA= Alum dose (ppm)
SS = Suspended solid
Concentration (ppm)
TR= Water turbidity (NTU)
Ds = Concentration of dissolved solids(ppm)
Ec = Electrical conductivity (Micron/cm)

AL-Layla et al. [5] studied the effect of coagulation and sedimentation time on the efficiency of turbidity removal in water using ethylene alum and polyelectrolytes and created the following relationship:

$$R= -8.895 \log(F)-1.135 \log(S)+15.22554 \quad (4)$$

Where: R=Final or residual turbidity
F=Coagulation time
S=Sedimentation time

Kim [6] studied coagulation and settling with alternatives in the water treatment in Nepal , this study include travelled a team of MIT master of engineering students to Kathmandu , Nepal to investigate the effectiveness of three potential potable water treatment processes (coagulation, filtration, and disinfection) by using them separately and in combination. The paper focuses on the coagulation study as applied to point - of - use (POU) household water treatment for use in rural areas of Nepal and to centralized water treatment plants in Kathmandu, which currently use coagulation as one unit process . They used Jar – test experiments on locally available alum from Nepal for the purpose of coagulation and settling experiments, to determine a dosage and mixing regime that would yield optimum removal of turbidity . These doses were found to be (40.0 , 30 and 20 mg/lit) for Nepal alum, U.S. alum and U.S.$FeCl_3$ respectively. The optimum dosage was then applied to POU treatment in the form of manual coagulation (coagulation by hand) in order to qualify its effectiveness.

Holger et al. [2] modeled alum dose of southern Australian surface waters by using an artificial neural network models. They found that the performance of the models be very good , with correlation (R) values ranging from (0.9 - 0.98) for the process models predicting treated water turbidity, color and ultraviolet absorbance at a wave length of (254nm) .

Li et al. [7] studied the behavior of coagulation of coagulants with different basic –ties that were examined through Jar-tests and hydrolyzed Al (III) speciation distribution characterization in the coagulation process. The results showed that the coagulation efficiency of Al coagulants positively correlated with the content of Al in the coagulation process rather than in the initial coagulants. Aluminum chloride ($AlCl_2$) was more effective than poly-aluminum chloride in removing turbidity and dissolved organic matter because $AlCl_2$ could not only generate Al species but also function as a pH control agent in the coagulation process.

Marco [8] evaluated the coagulation process in treatment of municipal wastewater based on organic materials and suspended solids removal efficiency. They took (24) samples from four wastewater treatment plants , and made a series of jar test using pH range between (4-10). They obtained highest COD removal (80%) at pH range (6-8).

Hamilton et al. [9] applied alum dose to Okaro Lake to evaluate its suitability for reducing bloom frequency. Before dosing, pH exceeded (8) in but was for optimal flocculation (6-8) below (4m) depth after dosing, there was no significant change in water clarity.

Robert [10] showed that the first factor affecting alum dose came across discusses labeling of aluminum content in injected dextrose. They found that when kidney function was impaired Aluminum might reach toxic levels with prolonged administration. The research also indicates that patients with impaired kidney function, including premature neonates system and bone toxicity (this toxic dose would be 10-

20 micrograms and for an adult it would be about 350 micrograms).

3. Laboratory Works

Monthly samples were taken from the Euphrates river in the town of AL-Musayyabv , near the water purification intake , during a period of ten years began from year 2004. The following laboratory tests for the models of water were conducted:

1- Temperature
2- pH
3- Turbidity using turbidity meter
4- Suspended solids using a microfiltration
5- Alum dose, which must be added using a Jar test

The Jar-test experiment included adding different doses of alum ranged between (5-140) mg/L depending on the turbidity of water that range between (35–4000) NTU. This experiment also included fast mixing for one minute and then slow mixing for (30) minutes, with (20) minutes as a settling time. At the end of each experiment, the final turbidity was measured after each dosage selected to determine the best ones, as illustrates in Figure1.

4. Results and Discussion

Figure 2 shows the values of water turbidity of Euphrates river, which are ranged between (35-4000) NTU during the period of study include taking monthly models from Euphrates river .This figure illustrates that the high values of turbidity occurs at the periods of high rates of flow while the values be about (35-220) NTU at the remaining period of the year. Results also show that the average of temperature ranged between (15 – 30 ^{0}c), Figure 3, while pH values were ranged between (7.6-8.2), Figure 4. The results also show that the concentration of suspended solids is equivalent to almost twice the values of water turbidity. This conclusion also was proved from other researchers [1]. So that the turbidity values has been taken as a measure of the concentration of suspended solids. The influence of factors of water turbidity, temperature, and pH on the added dose of alum (measured from Jar-test experiments) is studied by plotting the relationship between the values of turbidity and the added dose of alum, in Figure 5 which shows that the dose depends mainly on the values of turbidity that increased with the increasing of turbidity especially at high turbidities. Figure 6 shows the relationship between the values of temperature degrees and alum dose added for different values of pH and turbidity which shows that the alum dose increase with the increasing of temperature degree. Figure7 shows the effect of pH on the alum dose for different temperature degrees and turbidities, this figure shows that the alum dose increase with the increasing of pH, but this increasing is limited due to the limit change in the values of this factor

5. Mathematical Model

The results of laboratory tests which are (alum dose added, water turbidity, pH, and temperature) were analyzed using a multi - regression analysis to differentiate the following relationship:

$$AD= 33.6+0.037TR - 0.466T - 1.06pH \quad (5)$$

Where:
AD= Added alum dose (mg/lit)
TR= Water turbidity (NTU)
pH= Hydrogen number
T= Temperature degree (^{0}C)

This formula was tested by applying it on different samples and comparing the results with those obtained from Jar-test experiments and give good correlation reach to (0.97) as shown in Figure 6.

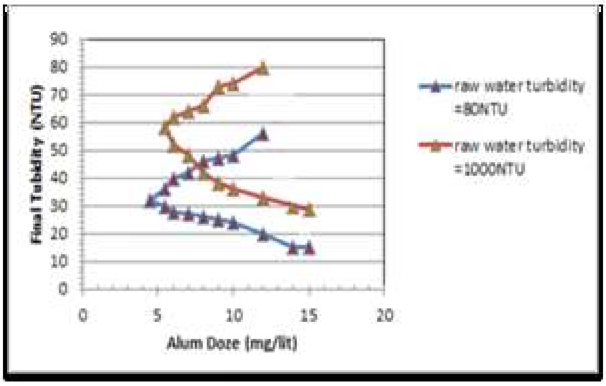

Figure 1: The Final Turbidity Versus Alum Dose

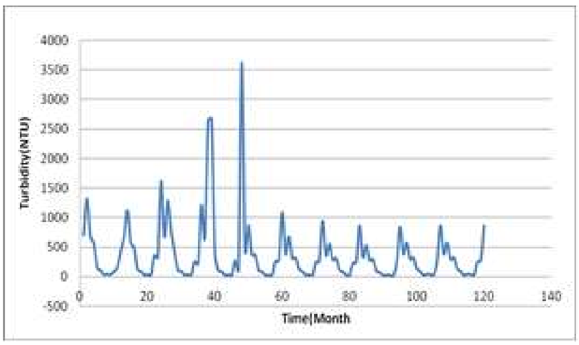

Figure 2: Turbidity of Euphrates River

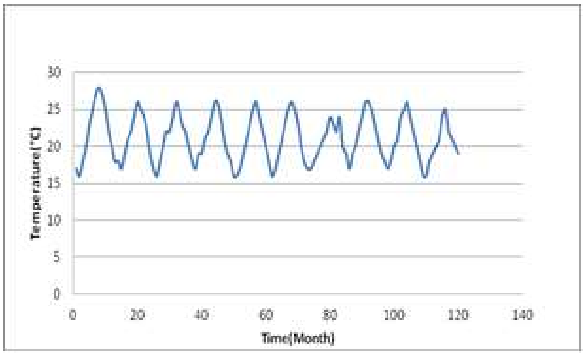

Figure 3: Temperature Degrees of Euphrates River

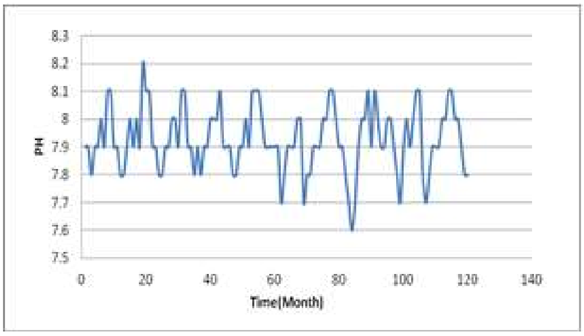

Figure4: PH of Euphrates River

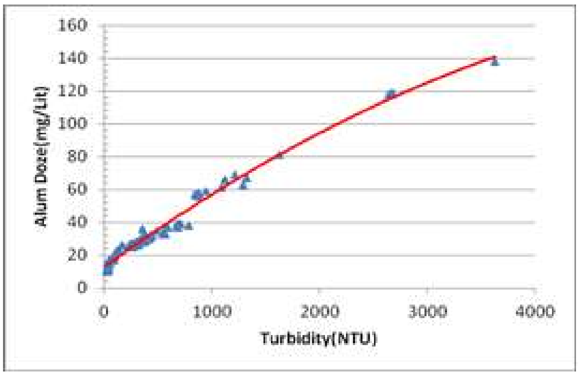

Figure 5: The Relation between Alum Doze and Turbidity

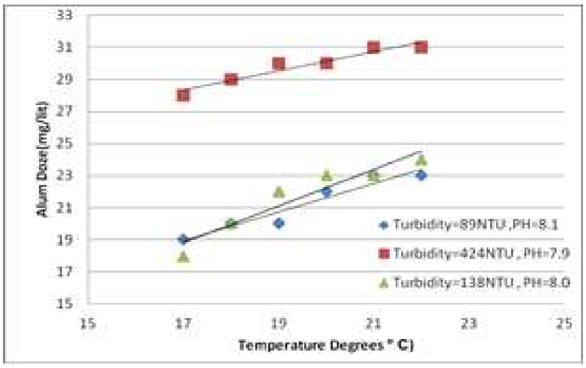

Figure 6: The Relation between Alum Doze and Temperature Degrees for different values of Turbidity and PH

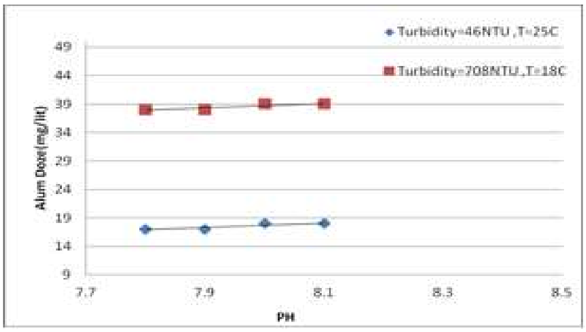

Figure 7: The Relation between Alum Doze and PH for different values of Turbidity and Temperature degrees

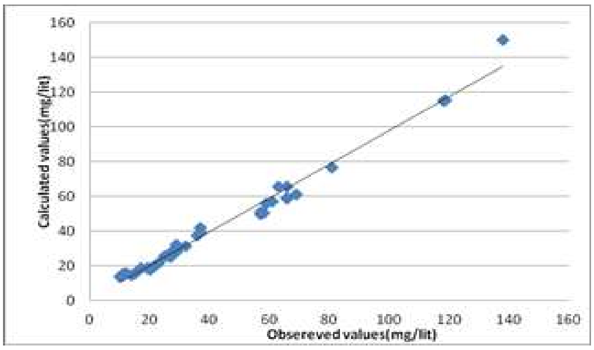

Figure 8: The Calculated Versus Observed Alum Doze

6. Conclusions

1- The alum dose varies mainly with thevariation of the turbidity and it increases with Increasing of turbidity values, but the increasing rate will be decrease.

2-The alum dose increase with the increasing of temperature degrees and its pH , and this increment can be clear at low ranges of turbidity and small at high ranges of turbidity ,but remains limited impact at the border of these two factors change in the water of Euphrates river.

3- Adoption of a mathematical model (Equation 5) to determine the dose of alum which must be added without resorting to an examination of the experience of the Jar-test.

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