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Seasonal Variation of Residual Aluminum Concentration in Drinking Water

Abstract- Data for aluminum concentration in Baghdad raw and drinking water have been taken from Baghdad Mayorality for the period of the year (2005-2006) and for six water treatment plants (Al-Karkh, East Tigris, Al-Wathba, Al-Karama, Al-Qadisia and Al-Dora). The available data were analyzed by using statistical programs like (spss, statistica, grapher and excel). Relation with water quality parameters was obtained like relation with pH and temperature. From the study the pH value was found to be ranged between (7.45-7.85) in supplied water for minimum aluminum residual. From the contour plot results show that an equation has been concluded which connect concentration with pH and temperature. Seasonal variation was also studied; maximum concentration found to be in summer season, at Al-Karama and Al-Wathba water treatment plants concentrations were constant during the period of the study. Comparison between water treatment plants was also made, Al-Qadisia and Al-Karkh water treatment plants have the best control conditions, aluminum concentrations were found to be within the Iraqi drinking water quality standards (0.2 mg/l).

Keywords- aluminum concentration, PH value, aluminum residual, Seasonal variation.

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1. Introduction

Aluminum is used in the form of alum (aluminum sulfate) in most surface water treatment plants to help removal of harmful water borne microorganisms and other particles which causing them to (coagulate) into larger particles which are then easily removed, by sedimentation and filtration. This process also removes naturally occurring organic matter present in water, reducing the formation of disinfection by-products [1]. The adult need of aluminum in drinking water quantities, mostly less than 5 % of the total daily intake for an adult. Aluminum concentrations in surface and soil waters may differ considerably, based on physiochemical and geological parameters. Analysis of freshwater samples showed that total aluminum was positively associated with the suspended solids content, as shown by Goenaga et al. [2].

Benefield et al. [3], stated that when a salt of Aluminum is added to water, the formation of aquometal complexes $Al(H_2O)_3+6$ occurs, This leads to the makeup of a different of soluble species consisting mononuclear species (one aluminum ion like $Al(OH)_2^+$, and $Al(OH)_3$, and polynuclear species (various aluminum ions) like $Al_8(OH)_4^{4+}$. In spite of the case that several of these outputs have only one or two positive charges, they are completely effective as

coagulants because they absorb so powerfully onto the surface of most negative colloids. Aluminum sulfate $Al_2(SO_4)_3$, ferric sulfate $Fe_2(SO_4)_3$, ferric chloride $FeCl_3$, and polyalum World Health Organization aluminum chloride are the primary chemicals used for treatment of drinking water. A coagulant aid, powdered activated carbon (PAC), can be used in coagulation cells to reinforce the removal of odors and taste compounds, and strip several organic carbons [4].

In last years, excess attendance has been focused on possible adverse effect of aluminum in drinking water on human health. Several epidemiological studies have reported a slightly increased incidence of dementia in communities where drinking water is high in aluminum and these studies have raised concerns among the media and public. Kidney disease patients who are exposed to high levels of Al^{3+} in dialysis fluids and medicine promote dialysis encephalopathy, a gradual way of senile illustrated through talking and behavioral variation, psychosis, tremble, and spasm [5].

Aluminum has also been joined with dangerous diseases of the nervous system, like Parkinson's disease, Alzheimer, amyotrophic and lateral sclerosis's disease. Ingestion of large amounts of aluminum also reasons anemia, (brittle of soft

bones), glucose intolerance, and cardiac arrest in humans. The effects in humans exposed to low levels of aluminum over a long period (accumulative effect) is not known, but earlier onset or progression of a wide range of diseases of the nervous system is possible [5]. Bioavailability of aluminum is affected by many factors, which contain the low-pH environmental of the stomach, the selective permeability of the stomach lining, the dramatic change in pH and digestive status between the stomach and the duodenum, and the Chemical forms of aluminum [6]. The objective of the study was to note that if there were any aluminum residual after water treatment in the distribution system and this gives a best conception of the basic processes that lead to raised concentrations of aluminum in potable water through the realization of chemistry and transport of aluminum following water treatment, and compare the control availability between water treatment plants. In general, a concentration between 1 and 5 mg/L is desired with addition of an aluminum salt during water treatment [7]. It was recommended that concentration of aluminum should be less than 0.05 mg/L for health purposes and less than 0.2 mg/L has long been recommended for aesthetic purposes and to minimize the turbidity, color, and post precipitation in water apportionment system. AWWA Government Affairs, World Health Organization [8,9] recommended the quantity of aluminum existing in drinking water below 0.2 mg/L. A districts were put for aluminum concentrations in drinking water exceeded 0.01 mg/L in four subsets: 0.02- 0.04 mg/L, 0.05-0.07 mg/L, 0.08-0.11 mg/L, and > 0.11 mg/L were found to have an approximately 50% greater incidence of Alzheimer disease as compared with those in which aluminum concentrations were below 0.01 mg/L.

2. Methods Used for Testing Aluminum concentrations in Water

Data for aluminum concentration in Baghdad raw and drinking water have been taken from Baghdad Mayoralty, there are three major methods used for testing aluminum in water, these are: Atomic Absorption Spectrometric Method; Eriochrome Cyanine R Method; and Catechol Violet Method. Spectrophotometric method was used (C-100) or (C-00) which works on the same idea as for the mentioned methods by using special reagents. Also there is another method used in most water treatment plants by using a standard series method by preparing standard solutions of stock Al and then comparing the colors of the sample and the

standards either directly in the flask or after transferring to 50 ml Nessler cylinders[10].

Principle of Eriochrome Cyanine R Method

Dilute aluminum solutions buffered to a pH of 6 produce with Eriochrome Cyanine R dye a red to pink complex with a maximum absorption at 535nm. The adversity of the developed color affected by the aluminum concentration, reaction time, alkalinity, temperature, pH, and the concentration of other ions in the sample. To compensate for color and turbidity, the aluminum in one part of sample is complexed with EDTA to provide a blank. Involvement by iron and manganese is ejected by adding ascorbic acid. The test for determining residual aluminum was done according to the procedure outlined in the Standard Method [11].

3. Results and Discussion

Data for aluminum concentration in Baghdad raw and drinking water have been taken from Baghdad Mayoralty for the period of the year (2005-2006) and for six water treatment plants (Al-Karkh, East Tigris, Al-Wathba, Al-Karama, Al-Qadisias and Al-Dora). According to the data obtained an evaluation for the water treatment plants were also obtained with the percentage of concentrations exceeding according to the health and aesthetic limits which are (0.1 mg/l) and (0.2 mg/l) respectively. Aluminum concentration in raw water was also measured as a background for the measured aluminum concentration in potable water. The available data were analyzed by using statistical programs like (spss, statistica, grapher and excel).

I. Effect

Figures (1) and (2) appears the relation between aluminum concentration and pH for both raw and supply water respectively. Figures show relation during seasons of the year, for raw water pH ranged between (7.85-8.20) with constant concentration during autumn seasons. Concerning supply water pH ranged between (7.45-7.85) aluminum concentrations exist outside this range and this is in agreement with the curve in Figure (2). PH of Tigris River increased during summer season because of the higher amounts of salts and alkaline compounds content of water, which come from the soil to the river under the effect of temperature rise of the river water.

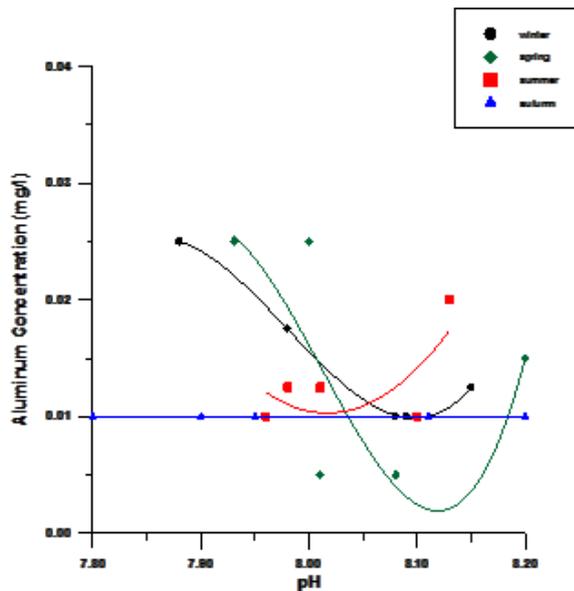


Figure 1: Aluminum –pH Relation for Raw Water

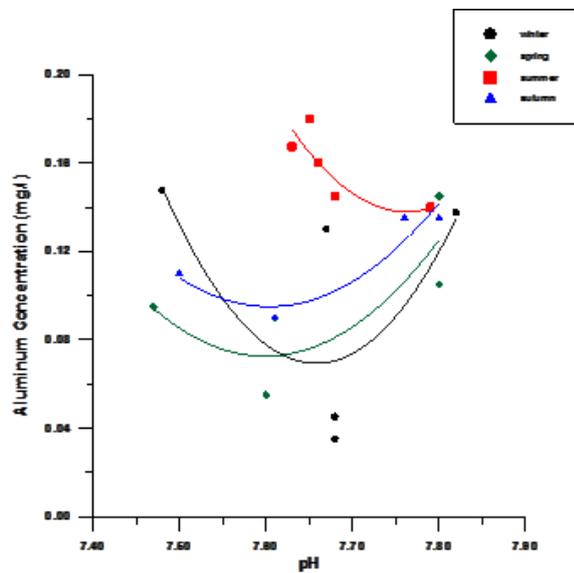


Figure 2: Aluminum –pH Relation for Supply Water

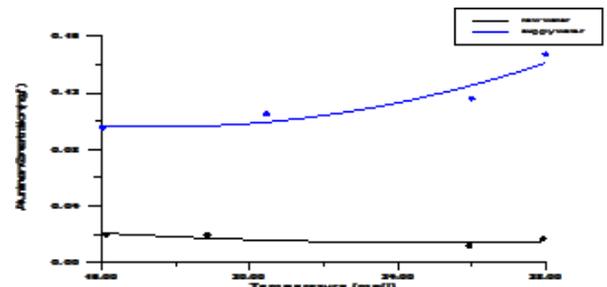


Figure 3: Aluminum –Temperature Relation for Raw and supply Water

II. Concentration - Temperature Relationship:

Figure (3) represents relation of the concentration with temperature, concentrations increased with temperature increasing for supplied water. This is because of the solubility of aluminum particles in high temperature and this is in agreement with the conclusion found by (Casey,1997)[12] which said that temperature has a significant influence on coagulation kinetics.

PH-Temperature-Concentration Relationship

Figure 4 represents 3 dimension contour plots with 3 variables pH, temperature and concentration. An equation has been concluded from this Figure which connects between these variables:

$$Z = -1660.17 + 444.294 * X - 479.25 * Y - 29.296 * X * X + 51.864 * X * Y + 544.95 * Y * Y$$

From Figure it appears that high aluminum concentration found when temperature increased between pH ranges (7.3-7.9).

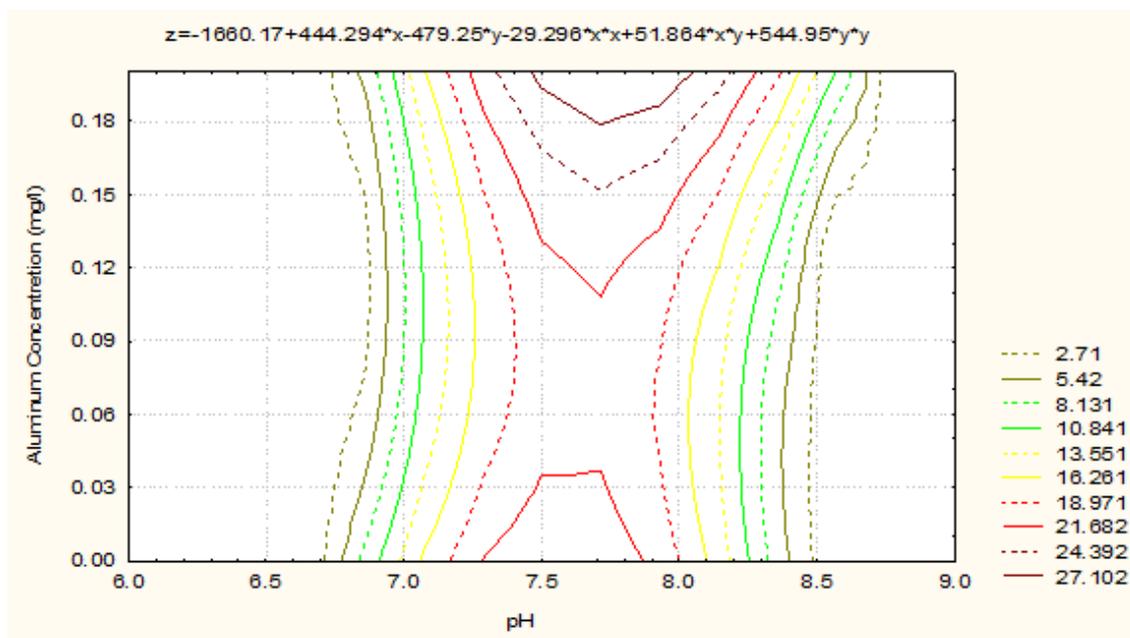


Figure 4: Contour Plot Connecting pH, Temperature and Concentration for Supply Water

It is clear from Figure 5 that this increasing in concentration for supply water because of the treatment process, while concentrations for raw water were almost constant. Seasonal variation effecting on alum dosage which increased in the hot seasons, this is in agreement with conclusion found by [13].

Figure 6 appears that Al-Karama water treatment plant shows the highest raw water aluminum concentration during the year, with almost constant concentration between (East Tigris and

Al-Wathba) water treatment plant and also between (Al-Qadisia and Al-Dora) water treatment plant .

After treatment the concentrations still high between (Al-Wathba and Al-Karama) water treatment plants with an increasing in the concentration in summer season at Al-Karkh water treatment plant, (Figure 7).

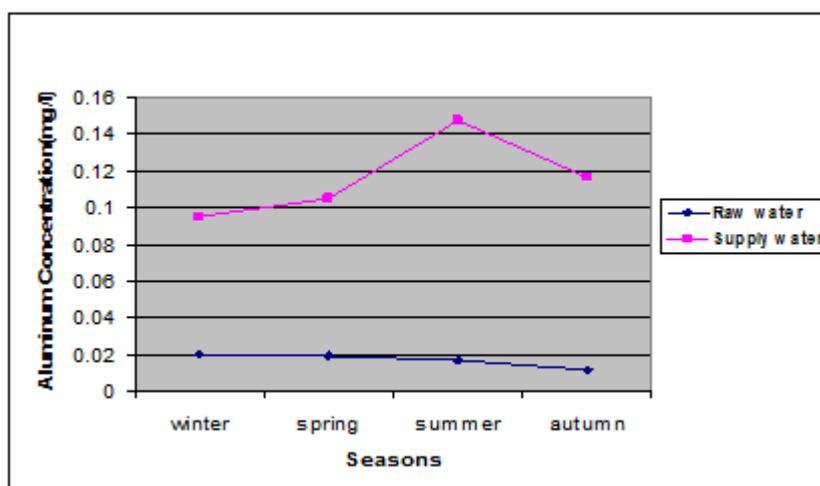


Figure 5: Annual Variation of Aluminum Concentration

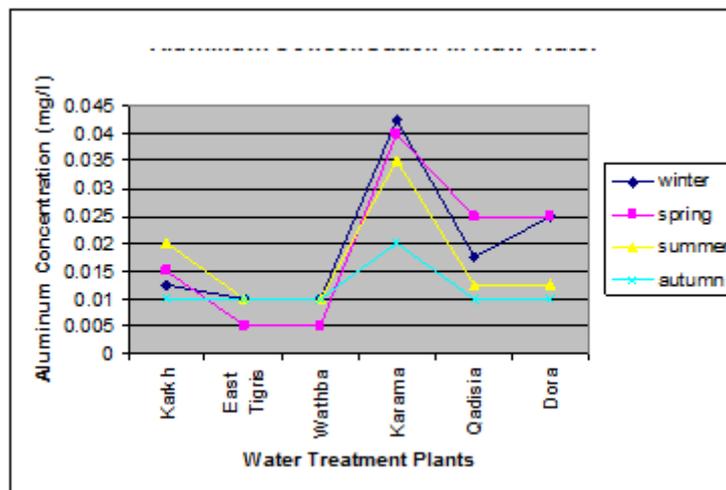


Figure 6: Aluminum Concentration Variation in the Different Water Treatment Plants

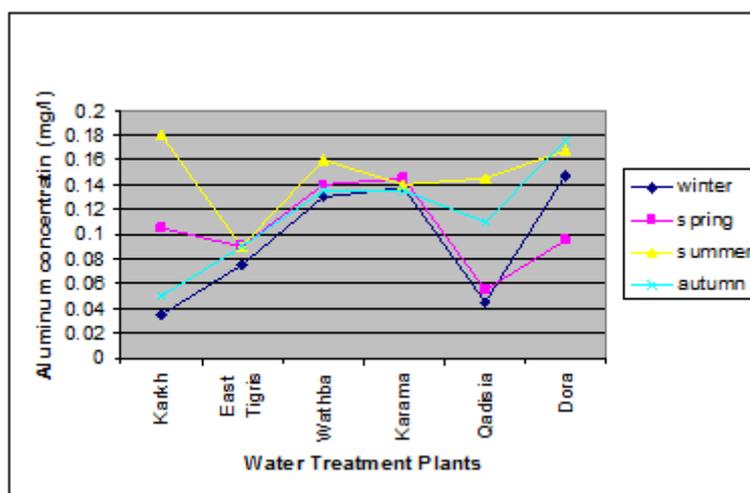


Figure 7: Aluminum Concentration in Drinking Water Supplied from Different Water Treatment Plants

III. Data Analysis

There are several ways to describe data and compare it with each other. Figure 8 represents a boxplot diagram which provides a simple graphical summary of a set of data with a five – number summary. This Figure shows tha most of the water treatment plants were within the international standards on residual aluminum with differences resulting from controlling practice between water treatment plants. It appears that

(Al-Karama) water treatment plant shows the maximum concentrations while (Al-Qadisia,Al-Karkh, and East Tigris) show the lowest concentrations of residual aluminum. This values give an indication of the alum dosing and controlling system at water treatment plants, then water treatment plants were arranged according to the best values on median concentrations of aluminum in finished water as follows:(Qadisia, Karkh, East Tigris, Wathba, Karama, Dora).

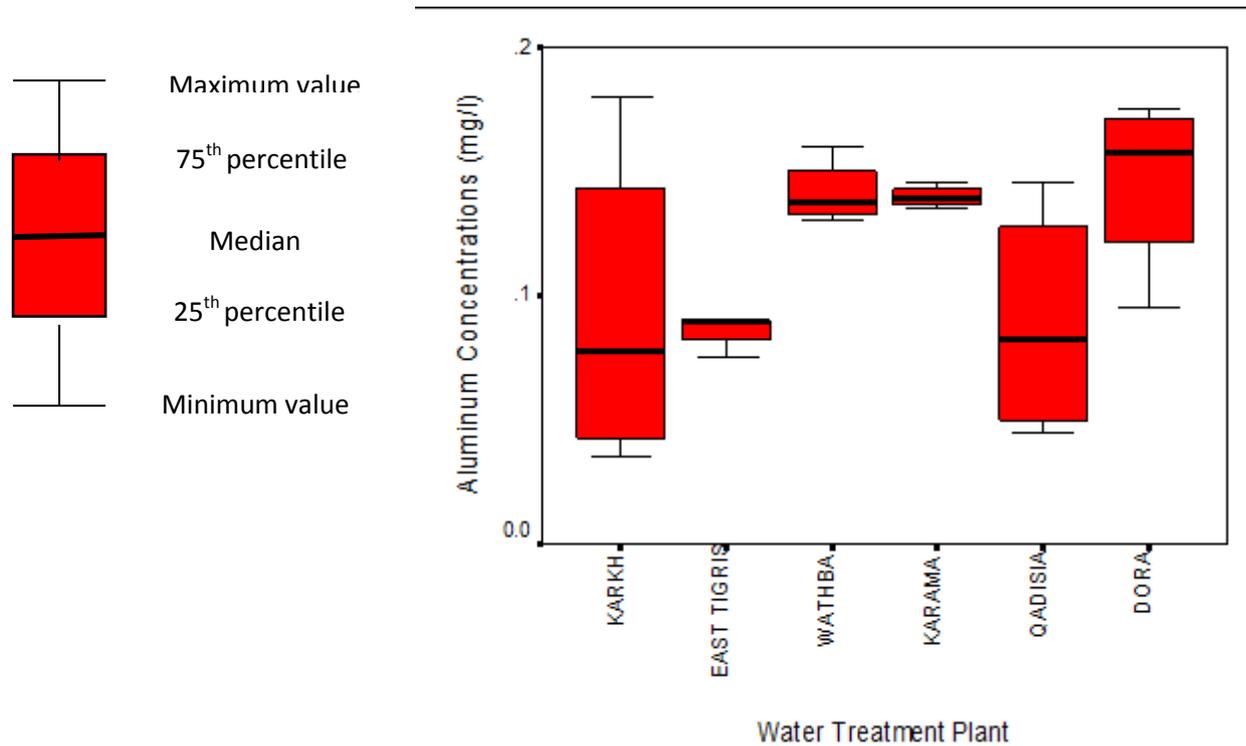


Figure 8: Boxplot Diagram

IV. Percent of Samples of High Concentration:

Percent of samples which exceeded the standards on health and aesthetic limits for each water treatment plant are given in the following Figures which show the relation between residual aluminum concentrations and their cumulative frequency. Samples of water aluminum concentration for Al-Karkh water treatment plant are plotted in Figure 9, (49%) of the samples exceeded the health limit and (8.3%) of the samples exceeded the aesthetic limits. Figure 10 represents East Tigris water treatment plant,

(7.5%) of the samples exceeded the health limit and no exceeding were found for the health limit. Concerning (Al-Wathba and Al-Karama) water treatment plants the concentrations ranged between (0.11-0.18)mg/l as shown in Figures 11 and (12). (43%) of the samples exceeded the health limit at (Al-Qadisia) water treatment plant Figure 13. For (Al-Dora) water treatment plant (70%) of the samples overtake health limit and (31%) of the samples overtake the aesthetic limit as shown in Figure 14.

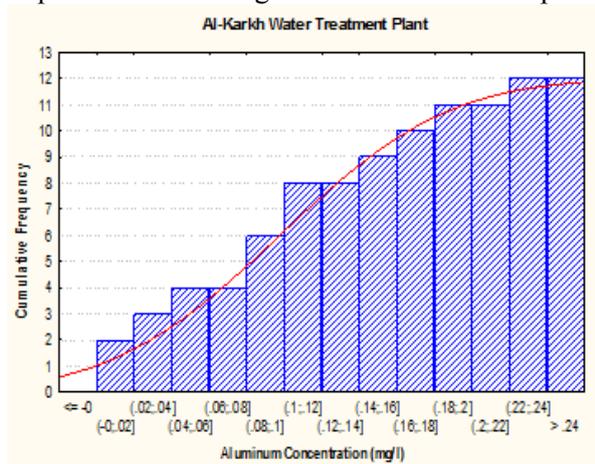


Figure 9: Histogram of Number of Samples of Aluminum Concentration at Al-Karkh Water Treatment Plant

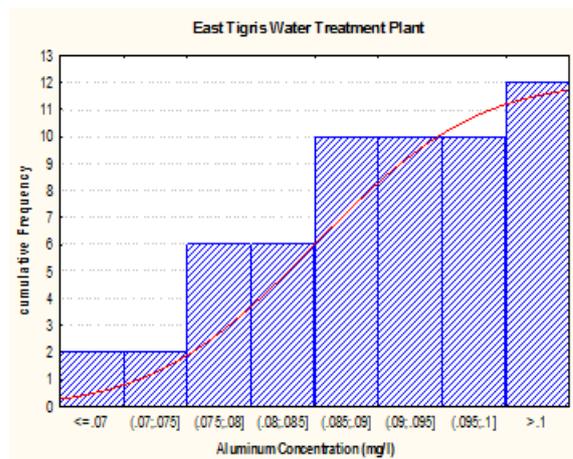


Figure 10: Histogram of Number of Samples of Aluminum Concentration at East Tigris Water Treatment Plant

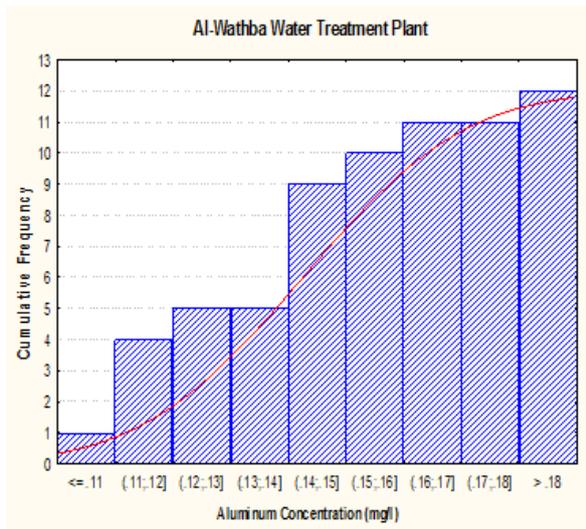


Figure 11: Histogram of Number of Samples of Aluminum Concentration at Al-Wathba Water Treatment Plant

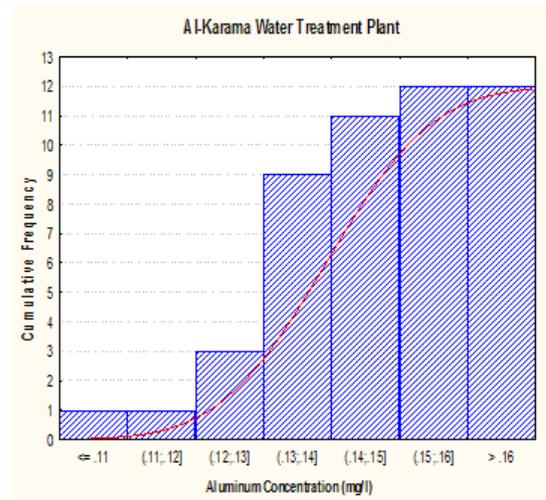


Figure 12: Histogram of Number of Samples of Aluminum Concentration at Al-Karama Water Treatment Plant

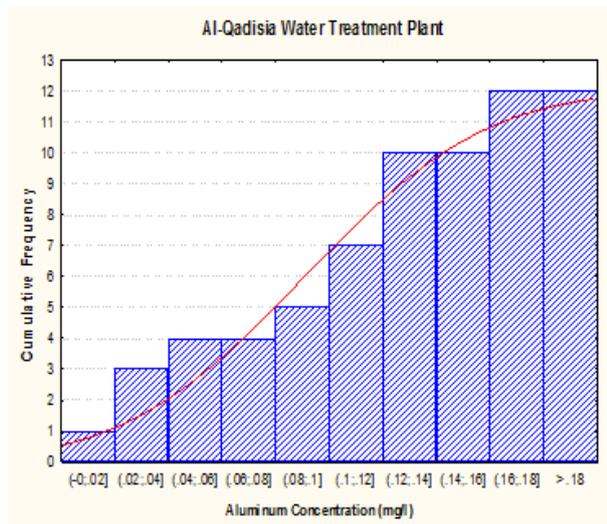


Figure 13: Histogram of Number of Samples of Aluminum Concentration at Al-Qadisia Water Treatment Plant

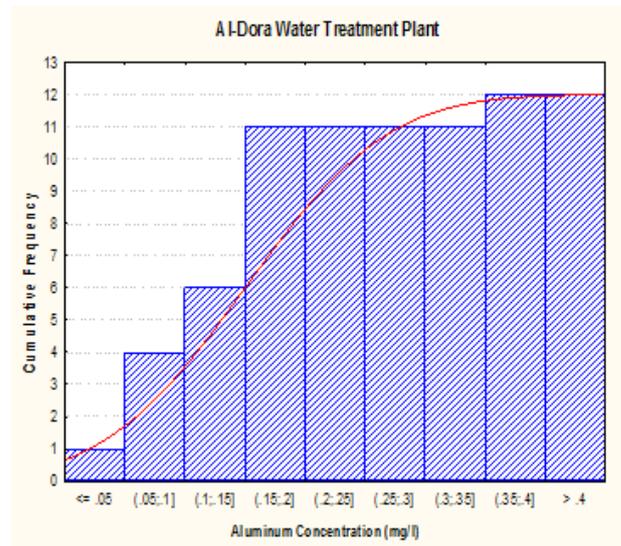


Figure 14: Histogram of Number of Samples of Aluminum Concentration at Al-Dorra Water Treatment Plant

4. Conclusions

1. Alum preparation in water treatment plants is not always under control as indicated by the differences in the efficiency. Al-Karama and Al-Dora water treatment plants show some of high concentrations of the residual aluminum.
2. Alum is not always dosed according to the laboratory experiments. Sometimes alum is dosed randomly according to the estimation of water turbidity, and this result in high concentrations of residual aluminum.
3. For all water treatment plants potable water was within the aesthetic limits (0.2 mg/l) as concerning aluminum, but not all the samples were within the health limits (0.1 mg/l).
4. Aluminum concentration in water is found to be dependent on pH. At pH between (7.45-7.85), residual aluminum decreases because of the deposition of aluminum hydrolyses.
5. Aluminum concentration in water is found to be dependent on temperature and seasonal variation especially in summer season which leads to increase residual aluminum concentration.
6. From three dimensional relation we concluded an equation which relates concentration with pH and temperature.
7. Water treatment plants can be arranged according to the lowest median amounts of residual aluminum as follows (Qadisia, Karkh, East Tigris, Wathba, Karama and Dora).

5. Recommendations

1. Using other alternatives like (FeCl₃) to produce water of the same quality, post-precipitation of alum in pipes could be arrested by using FeCl₃ instead of alum.
2. pH adjustment by using lime or other additives.
3. Making more experiments on alum by using granular activated carbon or powder activated carbon, also using coal-aluminum filters in water treatment plants.
4. Taking into consideration the health limits in the depended standards which must be (0.05-0.1) mg/L.
5. Studying mixing intensity, poor mixing can results in regions of high dosage and uncertain pH so that the coagulation is wasted. Aluminum residuals reduced by increasing intensity of chemical mixing at high pH when the predominant coagulation mode is sweep coagulation.
6. Developing methods of assigning alum dosage based upon the dynamic characteristics of raw water quality entering the plant like (color, turbidity, organic matter, etc...)
7. Modifying the laboratories in water treatment plants, to find the required alum dosage.

8. Making periodic operational courses for the staff working in water treatment plant.

Using small house unit with cation-exchange or reverse osmosis system for alum removal from tap water, as quick solution, especially for the houses near or closed to the treatment plant.

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