Aluminum Concentrations in Baghdad Water Supplies During 2004

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Abstract

Alum represents the most coagulant used for water treatment .It is used due to its low cost and efficiency. However, there are many disadvantages, mainly some effects due to aluminum accumulation with time in human mind causing Alzheimer's disease.

In this work, Samples of water were collected and tested for residual aluminum concentration as a fieldwork investigation in the distribution system of Baghdad City. Samples of raw water were also taken from the intake of water treatment plants located along Tigris River in Baghdad (Al-Karkh, East Tigris, Al-Karama, Al-Wathba, Al-Dora, Al-Wahda and Al-Rasheed), then samples of tap water were taken from some regions which the project supply and comparing it with the Iraqi standards. Samples collection were continued for four months (February, April, May, July) –2004 . The results indicated that aluminum concentrations decreased with increasing distance from water treatment plants due to the precipitation of aluminum hydroxides on pipes wall, results had showed that most samples were within standards except Al-Rasheed water treatment plant which showed that 70% of samples exceeded the health limit (0.1 mg/L) and 30% of samples exceeded the aesthetic limits (0.2 mg/L) at the beginning of the water treatment plant .While in other water treatment plants percents were as follows: 35% of the samples exceeded health limits and did not exceeded the aesthetic limit in Al-Karkh water treatment plant ,45% of samples exceeded the health limit and 10% of samples exceeded the aesthetic limit in East Tigris water treatment plant, 33% of samples exceeded the health limit and in other points there were no samples exceeded the aesthetic limit in Al-Karama water treatment plant .Percent of samples which exceeded the health limit was 35% and there were no samples exceeded aesthetic limit in Al-Wathba water treatment plant .While that in Al-Dora and Al-Wahda water treatment plants shows that no samples out of the range for both health and aesthetic limits

تراكيز الالمنيوم في شبكات ماء شرب بغداد لسنة 2004

الخلاصـــة

يعد الشب المختر المعتمد في معالجة المياه في جميع محطات تصفية الماء في العراق . ويتم استخدامه لكونه رخيص الثمن ولكفاءته في ترسيب العوالق لكن هناك اضرار صحية ايضـا تترتب نتيجة هذا الاستخدام في حالة استخدامه بصورة عشوائية او عند عـدم مراعـاة الجـرع المناسبة المطلوبة للمعالجة, ومن اهم هذه الاضرار هو مرض الزهايمرالذي تسببه التراكيز العالية للالمنيوم حيث ان معدن الالمنيوم يدخل في تركيب الشب والذي يتراكم بمرور الزمن في الدماغ.

تمت دراسة تراكيز الالمنيوم في شبكات توزيع مياه الشرب في مدينة بغداد . ولمعرفة ذلك تم أخذ نماذج موقعية لمناطق من شبكات توزيع محطات تصفية الماء .

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تم فحص نماذج للماء الخام الداخل الى مشاريع تصفية الماء في بغداد وهي(الكرخ, شرق دجلة,الكرامة ,الوثبة,الدورة,الوحدة ,الرشيد) ثم اخذت نماذج لمياه الشرب من مناطق تغذيها المحطات , استمر جمع النماذج اربعة اشهر(شباط,نيسان,ايار,تموز) لسنة 2004 وهذا تضمن الجو الحار والبارد.

اشارت نتائج الدراسة الى ان تركيز الالمنيوم المتبقي يقل بزيادة المسافة عن محطة تصفية الماء وذلك نتيجة للترسب الذي يحصل لهيدروكسيدات الالمنيوم على جدار الانابيب الناقلة .

تم اجراء مقارنة لتراكيز الالمنيوم في الماء الخام وماء الشرب ووجد ان الزيادة بهذه التراكيز تأتي بعد اضافة الشب عند التصفية كما تم اجراء مقارنة بين مواصفات الناحية الجمالية والصحية العراقية ,ووجد ان مشروع الرشيد اظهر اعلى التراكيز لنسب الالمنيوم المتبقي,70% من النماذج تجاوزت الحدود الصحية (0.1 ملغم/لتر)المسموحة و 30% من النماذج تجاوزت الحدود الجمالية (0.2 ملغم/لتر)المسموحة لمياه الشرب في بداية المشروع.بينما كانت النتائج لباقي المحطات كالاتي : 35 % من النماذج تجاوزت الحدود الصحية ولم تتجاوز النماذج الحدود الجمالية في محطة الكرخ , 45 % من النماذج تجاوزت الحدود الصحية و10% من النماذج تجاوزت الحدود الجمالية في محطة شرق دجلة , 33 % من النماذج تجاوزت الحدود الصحية ولم توجد تجاوزات في الحدود الجمالية لمحطة الكرامة. نسبة النماذج التي تجاوزت الحدود الصحية كانت 35 % وايضا لم توجد تجاوزات في الحدود الجمالية في محطة الوثبة.بينما اظهرت النتائج التابعة لمحطتي الدورة والوحدة عدم تجاوز للحدود الصحية والجمالية.

Introduction

The primary chemicals used to treat drinking water are Aluminum sulfate $Al_2(SO_4)_3.14H_2O$ (alum) , ferric chloride $FeCl_3$, ferric sulfate $Fe_2(SO_4)_3$ and polyaluminum chloride. Most water treatment plants use aluminum in the form of alum to help removal of particles. Powdered activated carbon (PAC), a coagulant aid, can be used in coagulation cells to enhance the removal of taste and odors compounds, and remove some organic carbon.

In recent years, increased attention has been focused on possible adverse effect of aluminum in drinking water on human health like:Kidney disease,Dementia , and Alzheimer's disease.(Internet 4)

Miller (1984), in his survey concluded that when alum is used in the coagulation process there is 40 to 50% chance that the concentration of Aluminum will increase above raw water values.

Shahin (1985), confirms that the total Aluminum concentration in finished water was usually well above that of raw water.

Qureshi (1985),concluded that reducing the pH with acid was effective in reducing the aluminum residuals, but post treatment pH adjustment with lime to stabilize the water increased its hardness.

Driscoll (1987) stated that pH adjustment was the most commonly reported strategy used to minimize residual aluminum.

Driscoll and Letterman (1988), in their results showed that approximately 11% of the aluminum input (raw water and alum) was not retained during treatment, and this residual Aluminum was conservatively transported throughout the distribution system.

Collins et al. (1985), stated that the use of coal-aluminum granular media filters successfully reduce turbidity in low-alkalinity raw waters to less than

1 NTU, without a coagulation step or external coagulant aids.

Dempsey et al. (1985), reported that polyaluminum chloride is an unconventional coagulant that is produced by partial hydrolysis of aluminum chloride and is thought to consist of stable cationic polymers of aluminum

Qureshi (1985), suggested that the most promising means of reducing aluminum residuals is to replace part of the aluminum dosage with ferric chloride.

Shahin (1985),stated that sedimentation and filteration units showed a total aluminum removal of 85% and 95% respectively when the plant operated at optimum conditions.

Letterman (1988) and Berube'(2002), Survey results suggested that effective removal of particulate matter minimizes residual aluminum levels, especially when raw water contains elevated concentration of total aluminum which may results to high treated water turbidity.

In a study of the black alum by Ismail,(1996) the results of this study had shown that the use of powder activated carbon (PAC) is a powerful coagulant aid which acted as adsorber and a weighting agent. The results also indicated that the use of PAC reduces the required alum dose significantly at all turbidity levels, it also reduces the volume of sludge.

Other studies showed that treatment by cation-exchange resin, reverse osmosis, and electrodialysis is the most effective process for the removal of aluminum in water (90-100% efficiency), whereas processes involving aeration and stripping, anion-exchange resin and chemical oxidation/ disinfection are poor (0-20% efficiency). Lime softening and coagulation coupled with sedimentation and filteration are moderately effective methods (0-70% efficiency). (Internet- Srinivasan et al.,1999)

Al-Marshidi (2000), found that the residual aluminum can be reduced by using either bentonite or porcelanite.

The speciation of aluminum in the treated water depends on pH, temperature of the water during treatment, the type of organic and inorganic ligands in raw water, and the amount of coagulant employed.

Letterman (1973) and Amirtharajah (1982), illustrated numerous hydrolysis intermediates as formed prior to precipitation of aluminum hydroxide [$Al(OH)_3$ (s)]. When Al salts are dissolved in water, the metal ion Al^{+3} hydrates to form an aquometal ion $Al(H_2O)^{3+}_6$. This ion reacts to form several hydrolysis species like monomeric and dimeric hydroxo complexes and possibly polymers.

McGhee (1991), described this complex process as follows:

1) Dissolution:

$$Al_2(SO_4)_3 \rightarrow 2Al(H_2O)^{+3}_6 + 3SO^{-2}_4$$

2) Hydrolysis:

$$Al(H_2O)^{+3}_6 + H_2O \rightarrow Al(H_2O)_5OH^{+2} + H^+$$

$$Al(H_2O)_5OH^{+2} + H_2O \rightarrow Al(H_2O)_4(OH)^{+1}_2 + H^+$$

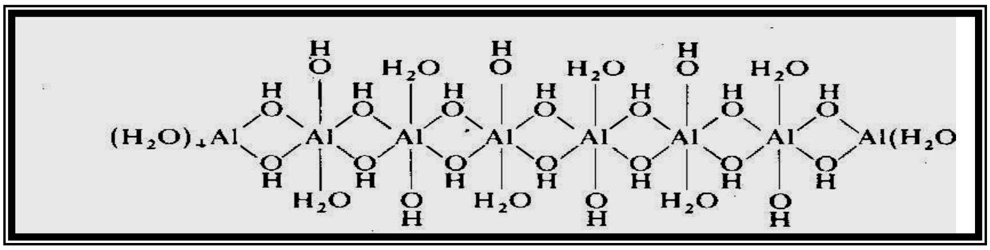
$$Al(H_2O)_4(OH)^{+1}_2 + H_2O \rightarrow Al(H_2O)_3(OH)_3 + H^+$$

$$Al(H_2O)_3(OH)_3 + H_2O \rightarrow Al(H_2O)_2(OH)^-_4 + H^+$$

3) Polymerization: The products of the hydrolysis combine to form a variety of molecules including: McGhee (1991)

$Al_6(OH)^{+3}_{15}$, $Al_7(OH)^{+4}_{17}$, $Al_8(OH)^{+4}_{20}$, $Al_{13}(OH)^{+5}_{34}$

McGhee (1991), illustrated the molecular structure for the form $Al_8(OH)^{+4}_{20}$ as follows :-



Hydrolysis of iron salts is somewhat different than that of aluminum, but results in the formation of similar polymeric species.

Three major categories define the various aluminum fractions in water represented in figure 1.

Casey (1997), mentioned that the principal ion species remaining in solution are considered to be: Al^{3+} , $Al(OH)^{2+}$, $Al_7(OH)^{4+}_{17}$, $Al_{13}(OH)^{5+}_{34}$, $Al(OH)^{4-}$, $Al_2(OH)^{24+}$

Field Work

Seven water treatment plants were studied in order to determine the amount of residual aluminum in their distribution system over a period of four months(February, April, May, July) –2004. These are Al-Karkh, East Tigris, Al-Karama, Al-Wathba, Al-Dora, Al-Wahda, and Al-Rasheed water treatment plants. About 76 samples of tap water and 24 samples of raw water were tested over the study period, samples of tap water were taken randomly from points nearest to the water treatment plant and faraway from it along the supply pipe as shown in Fig(2), to determine the variation of aluminum concentration along pipes.

Three points where taken along the distribution pipe of (Al-Karkh,Al-Wahda and Al-Rasheed) water treatment plants, and four points for (East Tigris) water treatment plant due to the large distances which the projects are supply.

Two points had taken from (Al-Karama, Al-Wathba and Al-Dora) water treatment plants due to the small distances which the projects are supply.

Samples collection repeated four times for each point , taking in the consideration temperature changing along the year.

Distances between sampling points were calculated according to the layout of the distribution system which is taken from (Baghdad Mayoralty).

Samples were collected in plastic containers. Each test needs about (100 ml) of water. Samples of water were tested on the same day without any additional preservation chemicals.

The method used in this study is the (Eriochrome Cyanine R Method), samples were tested in the Ministry of Environment laboratories by using a computerized spectrophotometer which has a wave length of 535nm .

pH and Temperature also tested directly in the site. Figure 2 shows seven water treatment plants in Baghdad and their regions of the study.

Results:

1.Concentration-Distance Relationship:

The main effect which may be studied is the relation between residual aluminum concentration and distance in order to determine the amount of residual aluminum in distribution system.

Figures (3,4,5 and 6) show (East Tigris, Al-Karama, Al-Wathba, and Al-Rasheed) water treatment plants respectively with confidence limit 95%. There was a wide variation between mean and confidence limit at the beginning of the water treatment plant and this variation decreasing gradually in the farthest point of the distribution system. This may be because of the high dose added in the water treatment plant.

Figures (7,8 and 9) show (Al-Karkh, Al-Dora and Al-Wahda) water treatment plant respectively, there is a little variation between the mean and the confidence limit at the beginning of the project which ensures a good control, while there is a wide variation at the end of the distribution system due to dispersion.

Concentration-pH-Temperature Relationship:

Figure 9, represents the effect of the variables pH and temperature of water on the concentration of aluminum. From this figure, it appears that high concentrations of residual aluminum exist at high pH and high temperature.

That is during warm seasons, there is an increase in the amounts of dissolved aluminum, which leads to an increase in the amount of residual aluminum. This is in agreement with the findings reported by Driscoll and Letterman (1988) and Casey (1997).

Figure (11 a, b, c) , shows high percentages of samples which exceeded the health and aesthetic limits for Al-Rasheed water treatment plant . For the first station (x=0),70% of samples exceeded health limits and 30% of samples exceeded aesthetic limits. At the second station (x=0.7 km),percents of samples was 60% for health limit and 13% for aesthetic limits . Finally at the third station (x=3.7 km), 3% of samples exceeded health limits.

Data Analysis:

Figure 12 shows a pictorial summary of residual aluminum concentrations in Baghdad water distribution system through contour plot. This figure shows regions of with high concentrations and regions with loe concentrations .From this figure , it appears that regions in the northern west and southern east show the highest concentrations while regions in the center show the lowest concentrations.

There are several ways to describe the data and compare it with each other; figure 13 represents a box and whisker plot (sometimes called boxplot) which provides a simple graphical summary of a set of data with a five –number summary.

This figure shows that most of the water treatment plants were within the international standards on residual aluminum with differences resulting from controlling practice between water treatment plants.

Maximum concentrations are found to be between (0.065-0.3)mg/l.The75th percentile gives concentrations between (0.046-0.171)mg/l.The median concentrations ranged between (0.023-0.1)mg/l. The 25th percentile ranged between (0.001-0.041)mg/l.The minimum concentrations ranged between (0-0.02)mg/l.

Driscoll (1987) reported aluminum concentrations values for 17 utilities in the US. He stated that the highest values in these utilities ranged between 0.24 to 1.3 mg/l , while minimum aluminum concentration ranged between 0.01 to 0.045 mg/l .It appears that aluminum concentration levels in Baghdad potable water are much lower than those reported by Driscoll (1987).

From above concentrations we could also conclude that the average adult probably takes in about 0.0168 to 0.303 mg of aluminum each day from drinking water if we assume that the average consumption for drinking is 2.5 l/day , while some researches (Internet 4) found that the average adult probably takes 9 to 14 mg of aluminum each day from all exposure roads.

Table (1) shows a summary of the readings of the boxplot diagram. It appears that Al-Rasheed water treatment plant shows the maximum concentrations for the (maximum,75th prcentile,median,25th percentile, and minimum)values , while Al-Dora water treatment plant shows the best values of residual aluminum. These values give an indication of the aluminum dosing and controlling system in the water treatment plant. Then water treatment plant can be arranged according to the best values for the median concentrations of aluminum of finished water as follows: Dora, East Tigris ,Karama, Wathba, Karkh, Wahda, and Rasheed.

Conclusions:

Based on the results obtained from this study, the following conclusions are drawn:

1. Alum preparation in water treatment plants is not always under control as indicated by the differences in the efficiency. Al-Rasheed water treatment plant shows some of high concentrations of the residual aluminum.

[2]. For all water treatment plants potable water was within the aesthetic limits concerning aluminum concentration, but not all the samples were within the health limits.

Residual aluminum concentrations decreased with increasing distance from water treatment plant. This means that there is deposition of aluminum hydrolysis on the pipe walls; therefore, the distribution system may have reduction in its pipe diameter.

[3]. Aluminum concentration in water is found to be dependent on pH ,this is in agreement with Casey (1997). At pH between (7.4-7.8), residual aluminum decreases because of the deposition of aluminum hydrolyses

[4]. Residual aluminum concentration in finished water supplies increased with increasing water temperature, and this is in agreement with Driscoll and Letterman (1988) and Casey (1997).

5. Water treatment plants can be arranged according to the lowest median amounts of residual aluminum as follows Al-Dora, East Tigris,Al-Karama, Al-Wathba,Al-Karkh,Al-Wahda and Al-Rasheed.

6. Regions in the northern west (Al-Karkh and East Tigris) and southern east (Al-Wahda and Al-Rasheed) show the highest concentrations of aluminum.

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Table (1) , Summary of boxplot readings

Water treatment plant	Maximum concentration mg/l	75th percentile mg/l	Median mg/l	25th percentile mg/l	Minimum Concentration mg/l
Karkh	0.124	0.11	0.05	0.026	0.001
East Tigres	0.125	0.08	0.041	0.019	0.012
Karama	0.077	0.068	0.043	0.02	0.009
Wathba	0.078	0.075	0.046	0.018	0
Dora	0.065	0.046	0.023	0.001	0
Wahda	0.08	0.07	0.052	0.031	0.005
Rasheed	0.3	0.171	0.1	0.041	0.02

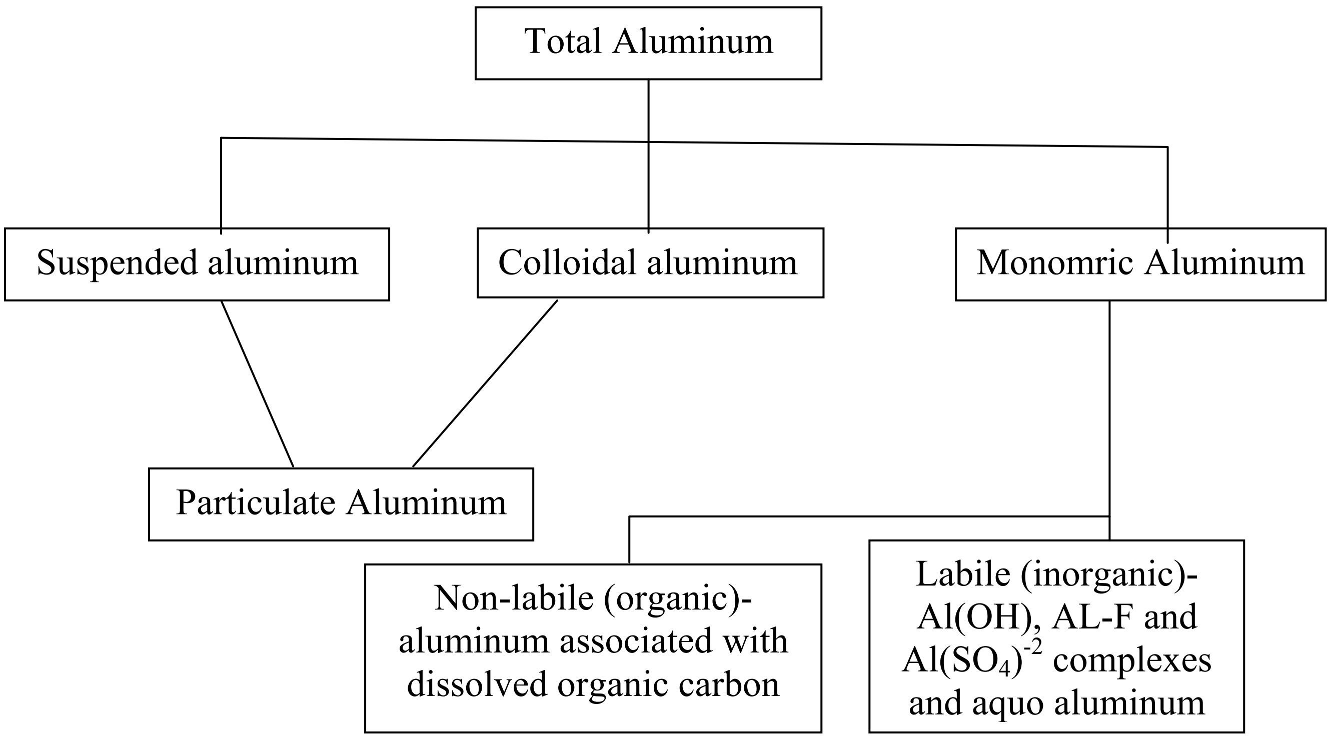


Figure 1 , The various Fractions of Aluminum in Water
(Source: Internet- Srinivasan et al.,1999)

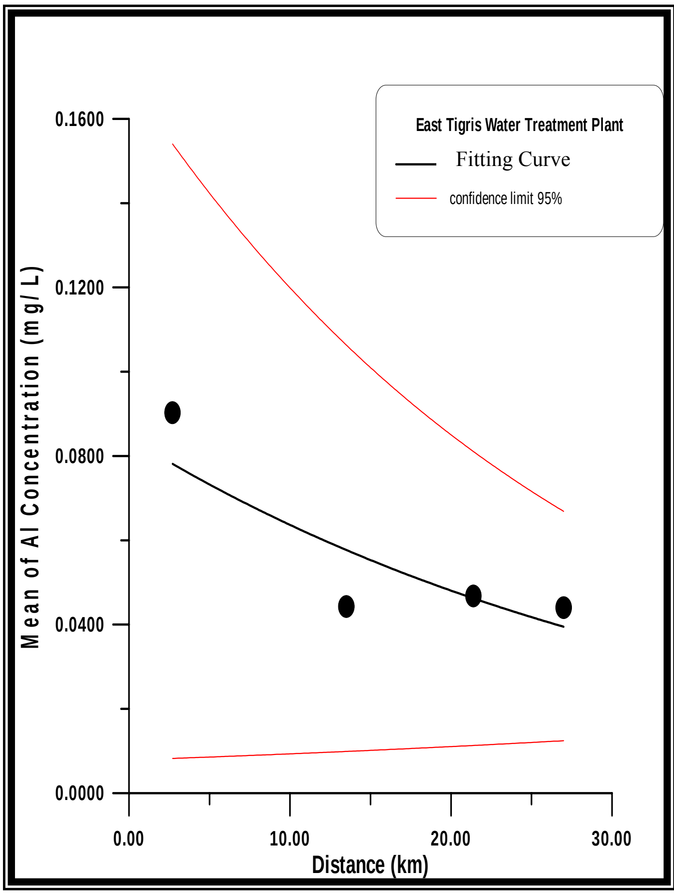


Figure 3, Relation between mean of Al concentration and distance for East Tigris water treatment plant

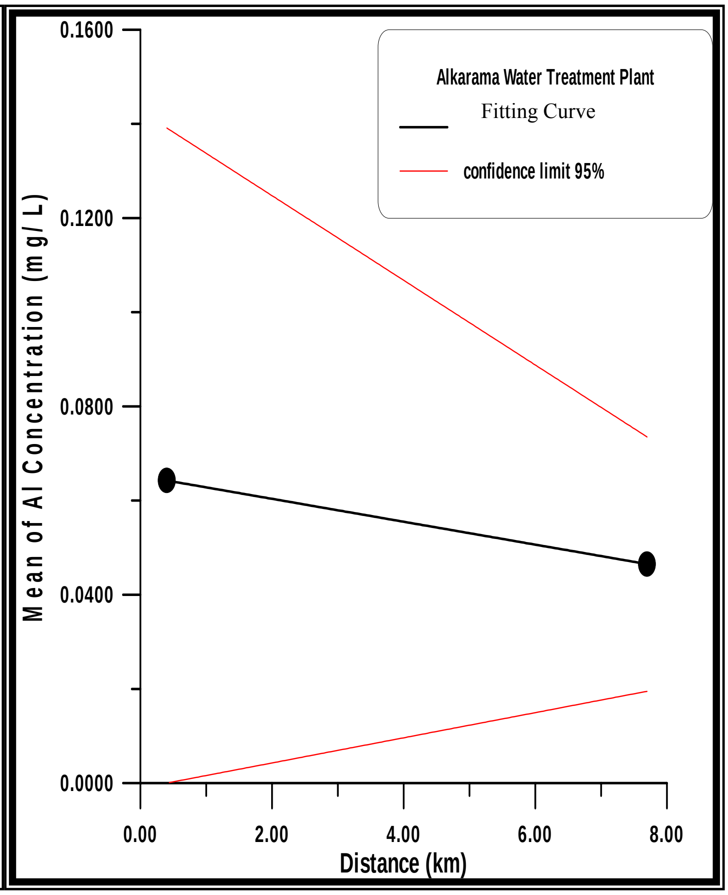


Figure 4,Relation between mean of Al concentration and distance for Al-Karama water treatment plant

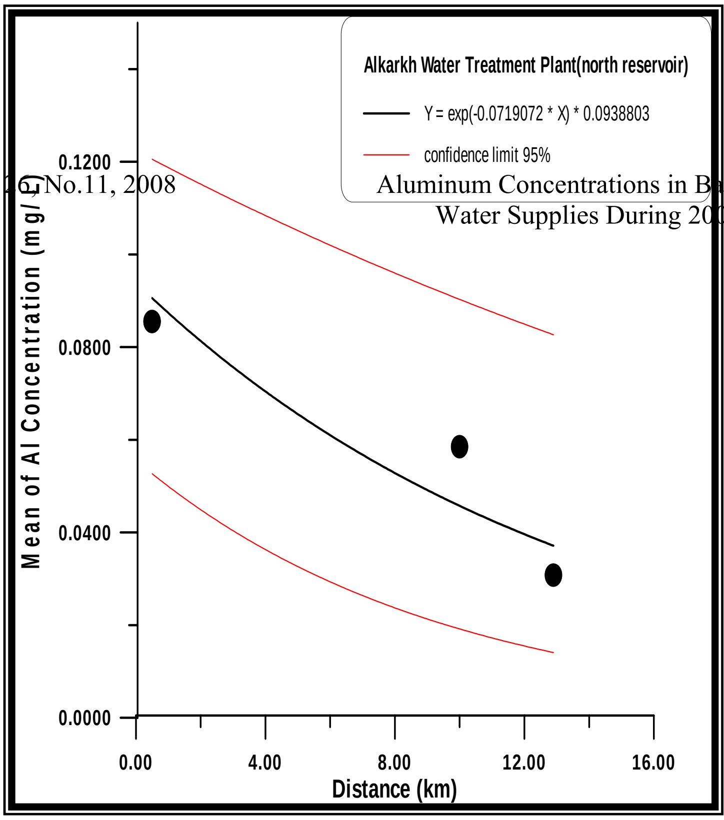


Figure (7),Relation between mean of Al concentration and distance for Al-Karkh water treatment plant

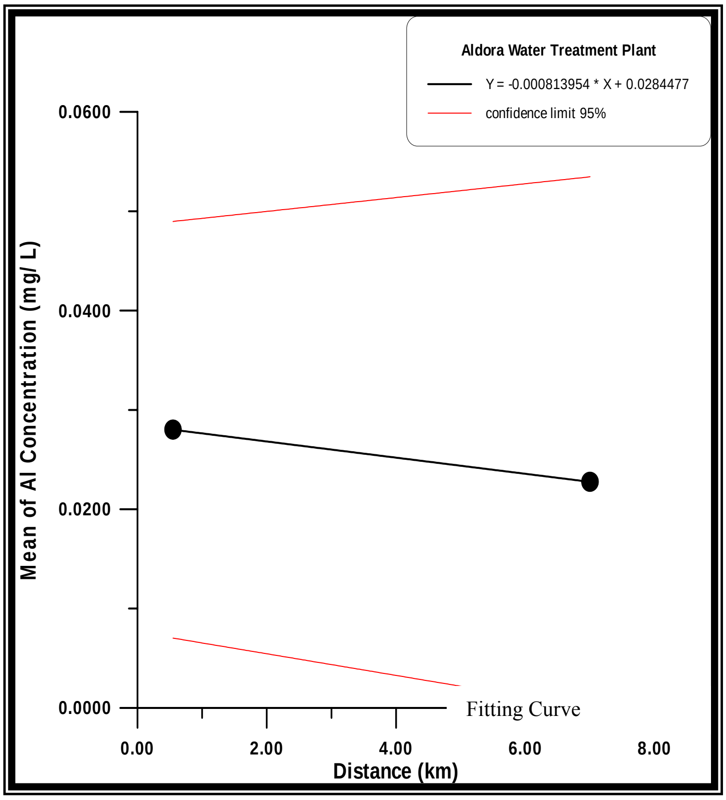
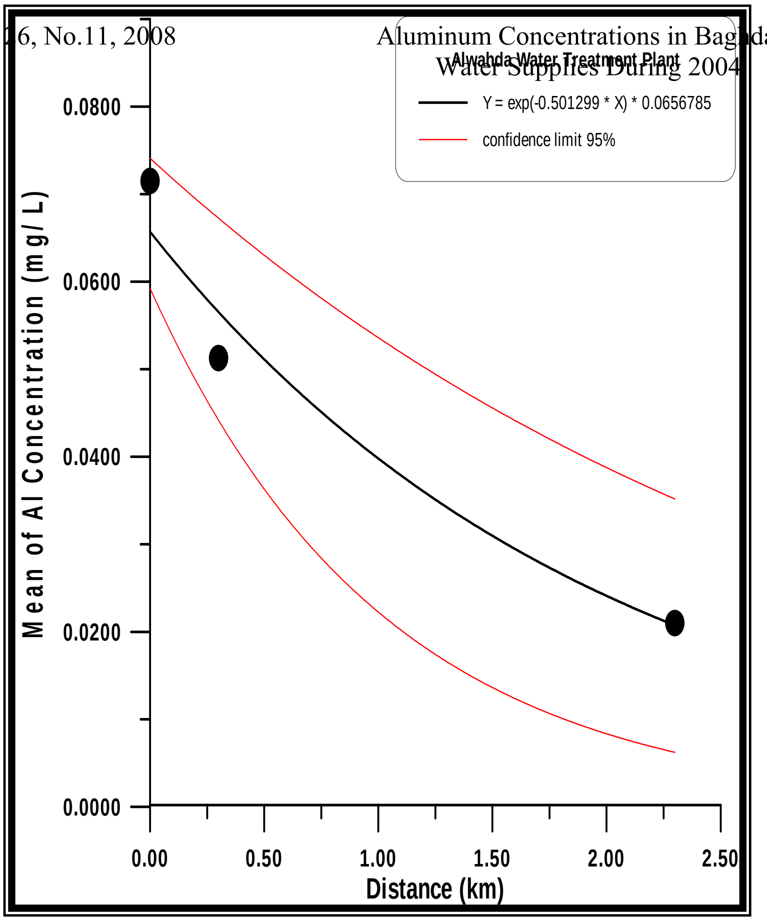
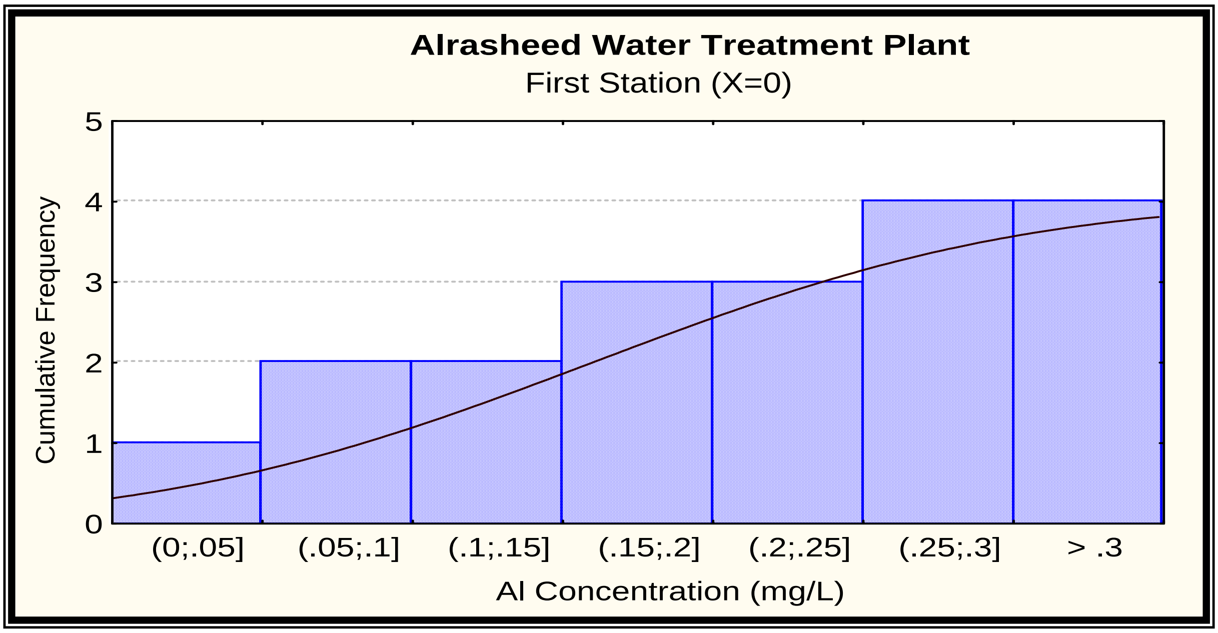


Figure (8),Relation between mean of Al concentration and distance for Al-Dora water treatment plant



Figure(9),Relation between mean of Al concentration and distance for Al-Wahda water treatment plant



Figure(10), Contour Plot connecting pH, temperature, and aluminum concentration

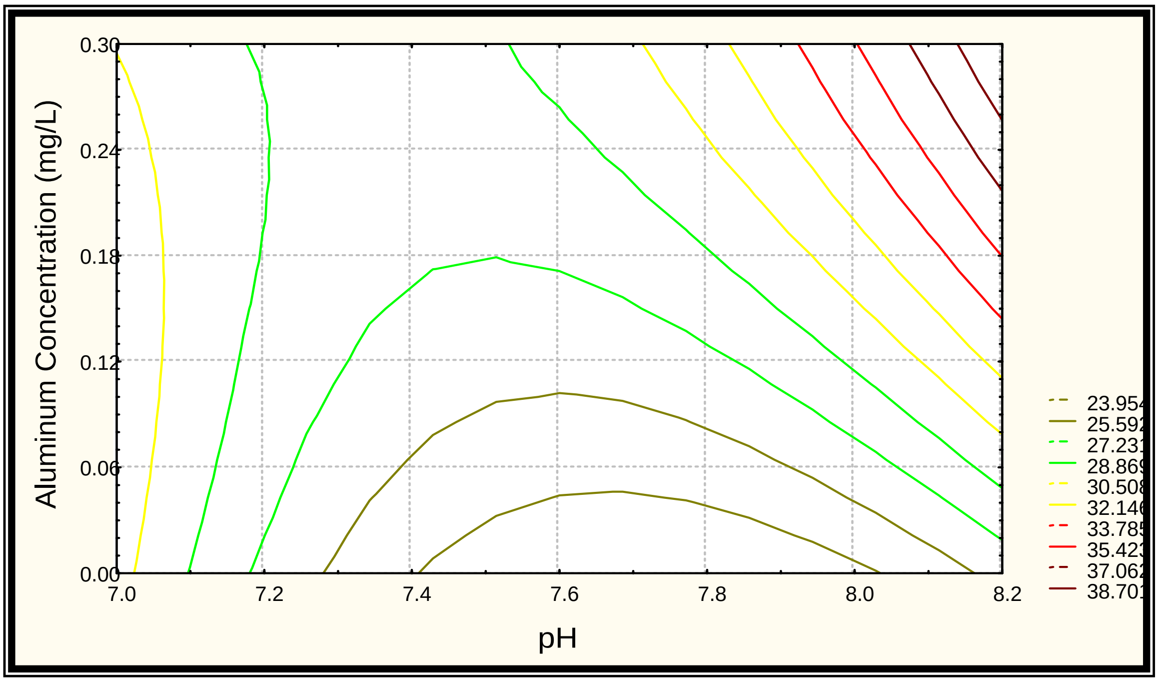


Figure (11 a), Histogram of number of samples for aluminum concentration in Al-Rasheed camp

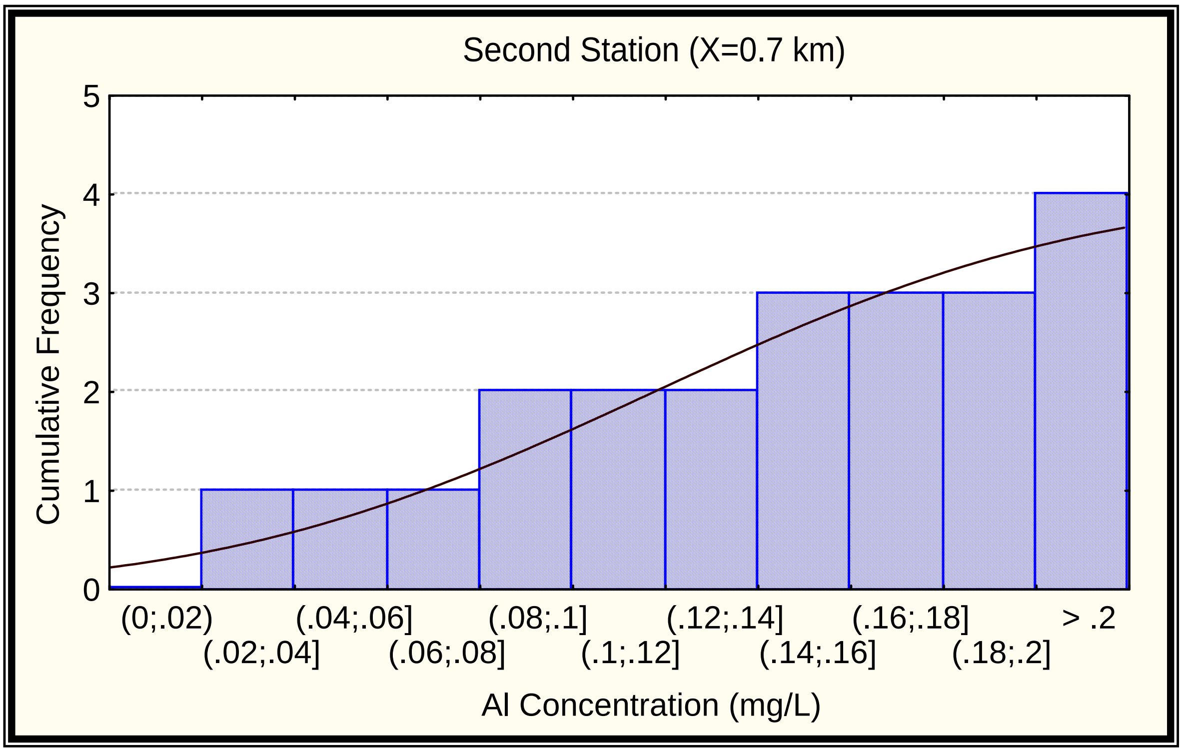


Figure (11 b), Histogram of number of samples for aluminum concentration in Hay Al-Sindbad

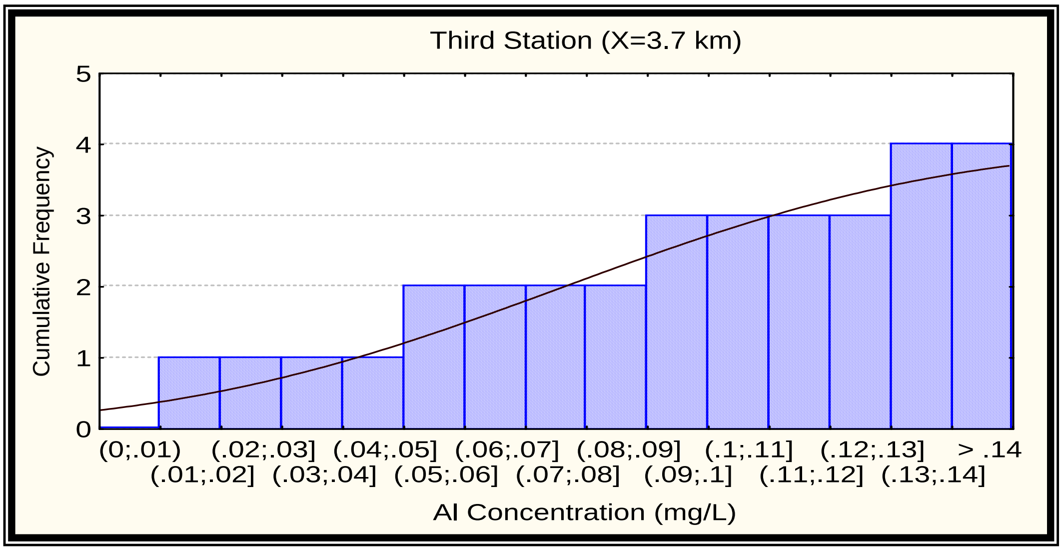
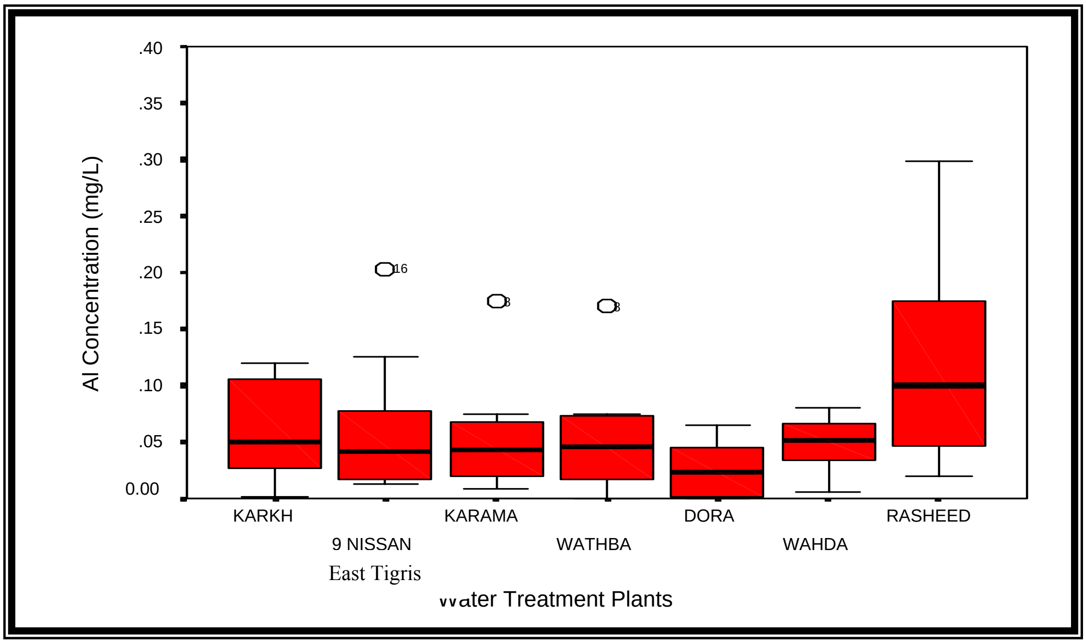
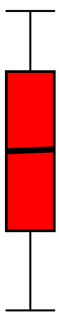


Figure (11 c), Histogram of number of samples for aluminum concentration in Hay Al-Zafrania





Maximum value

75th percentile

Median

25th percentile

Figure 2,Existing Water Treatment Plants and Regions of The Study of Baghdad City

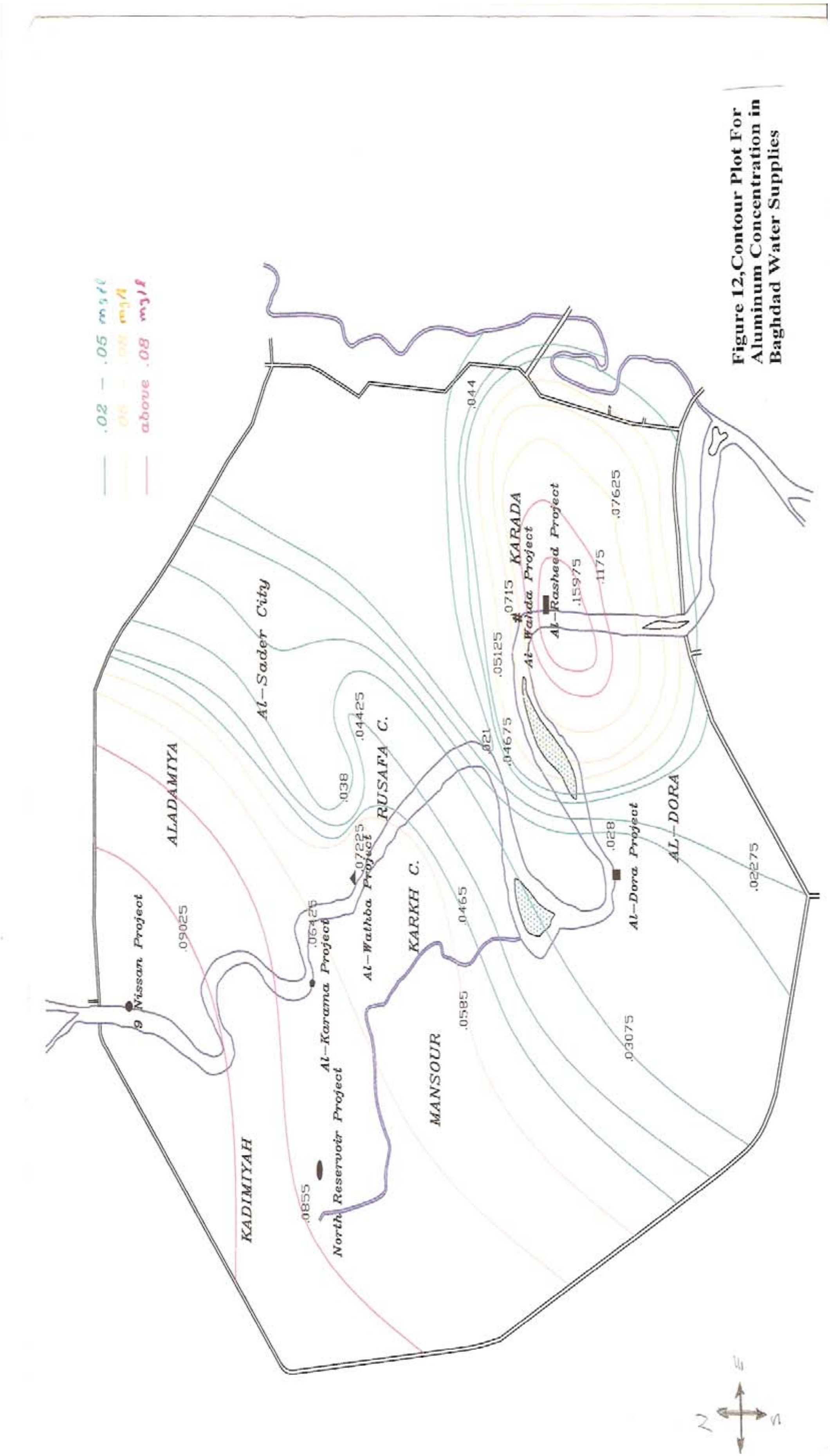
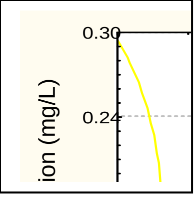


Figure 12,Contour Plot For Aluminum Concentration in Baghdad Water Supplies


0.30
0.24
ion (mg/L)