# Evaluation of Potable Water Quality of AL-Diwaniyah Water Treatment Plants

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## Abstract

The selection of proper treatment is of prime importance in the providing of drinking water. In this study tow WTPs in Diwaniyah were selected to evaluate their water quality in producing potable water according to the Iraqi standards. The two plants had high removal efficiency in turbidity which reached to ( 90 – 95) % and the turbidity of the treated water did not exceed 5 NTU.As for the natural constituents in raw water Ca, Mg and Na, their concentrations decreased in the treated water, but were within the desirable standards. Concentration of Al appeared also, as alum is added in the coagulation process. The final effluent had concentrations of Al ranging 0.01 - 0.02 mg/l. Fe with concentrations of 0.01 -0.2 mg/l appeared also, but Fe salts were not added for treatment. Must therefore follow-up tests of water on an on going basis to determine the cause. The two plants are efficient in bacterial removal as pre and post chlorination is applied. The residual chlorine in the effluent from the plants ranged 2.0 - 2.5 mg/l, which was enough to leave 0.5 mg/l in the distribution system.

## الخلاصة

أختيار طريقة المعالجة ألأفضل تعتبر من اهم الاولويات لانتاج مياه الشرب. في هذه الدراسة تم اختيار محطتين في مدينة الديوانية لتقييم ادائهم لانتاج ماء الشرب بموجب المواصفات العراقية الخاصه بالماء. في المحطتين كانت نسب ازالة العكورة عالية وصلت 90 - 95 % ولم تتعدى عكورة الماء الناتج 5 درجة عكورة. أما العناصر الطبيعية في الماء، الكالسيوم، المغنسيوم والصويوم فقد قلت تراكيزها في الماء المعالج ولكنها كانت ضمن التراكيز المقبول بها . ظهرت تراكيز الألمنيوم حيث يضاف الشب كمادة مخثرة في مرحلة التخثير. بلغت تراكيز الالمنيوم في الناتج النهائي (0.01 - 0.02) ملغ/لتر. ايضا ظهرت تراكيز للحديد بين (0.01 - 0.2 ) ملغ/لتر بالرغم من عدم اضافة املاح الحديد الى المياه المعالجة. لذا يجب متابعة فحوصات المياه بشكل مستمر لتحديد السبب. عملية التعقيم كانت ذات كفاءة عالية لقتل البكتريا الممرضة. تركيزالكلور المتبقي تباين بين 2.0 - 2.5 ملغ/لتر بحيث وصل الى المستهلك بتركيز 0.5 ملغ/لتر.

**Key Words** Potable water, Water quality, Water treatment

## 1. Introduction

To produce water that is safe to drink, pleasant in taste and could be used for various purposes, treatment processes should be selected to remove specific constituents from raw water. Water treatment can be defined as the manipulation of water from various sources to achieve a water quality that meets specified goals or standards (Crittenden et al., 2005). The basis for selecting treatment process alternatives is established by the characteristics of raw water and the finished water quality goals. In Iraq water treatment plants (WTP) are designed to work as conventional processes. Many continuous investigations and studies are attended to improve the performance of water treatment units, especially with the deterioration of the water quality of the raw water. The aim of such work is to provide the consumer with the best quality of drinking water.

Rashid (1989), tested chemically pretreated water from the Tigris River having turbidities ranging from 17-171 NTU, filtered without settling. He noticed that water quality of the filtered water improved when using polymer dose ranging 0.025-0.3 mg/l. Turbidity percentage removal was more than 99%, bacterial removal reached 93% and Aluminum removal was 95%. When using 0.3 mg/l dose of polymer, the filtered water turbidity was less than 5 NTU and Aluminum concentration was less than 0.2 mg/l.

Al-Dulami (1995), studied the quality of supply water from one of the WTPs in Baghdad which is 7-Nessan water project (known today as east of the Tigris project). He measured aluminum concentration in the clarified and filtered water. The experimental tests showed that the removal efficiency of Al was affected by high turbidity, suspended solids concentration, Fe concentration, pH and temperature. These percentages increased as these factors increased and reached 73.9% in the clarifiers and 78.3% in the filters.

In 2000, Abu hamdeh evaluated the eight WTPs in Baghdad city for the period 1998-1999. The plants had high removal for turbidity when it ranged to 91% to 99%, but in the old plants it decreased to 65%. In all the plants, TDS concentration was between 400-1000 mg/l depending on the high concentration in the Tigris River. For disinfection the plants were efficient in coliform and fecal coliform removal, where the removal efficiency ranged 100-92%.

## 2. Study Objectives

The purpose of this study is to evaluate the performance of existing water treatment in the city of Diwaniyah in order to be inferred from the existence of a problem, especially the change in the quality of river water (water entering the treatment plant) because of pollution, according to the Iraqi drinking water specification, 2000.

## 3.Description of the Water treatment Plants in Diwaniyah

Two water treatment plants supply potable water in Diwaniyah city. These plants are constructed on a branch of the Euphrates River known as Shut Diwaniyah, As indicated in the photo program Google Earth Fig(1). The old plant was constructed in the fifties in the center part of the city. It is designed with a capacity of 650 $m^3$/hr. The New plant known as Al-Muwahad is located in the north region of the city. It was constructed in 1980 with a capacity of 4000 $m^3$/hr. This plant was expanded to treat 6000 $m^3$/hr in 2007.The two plants are constructed as conventional water treatment plants, where pre and post chlorination is applied. About 12 kg/hr of chlorine is added for the disinfection process.

## 4.Field observation and Data Collection Method

The water quality data for the raw water (river) and the treated water (potable) from the plants were collected from Diwaniyah water administration authority. These data were collected through three times a month. At the beginning and the middle and the end of the month for the period from January 2006 of September 2008. Samples were examined in the lab in the water in Diwaniyah

## 5.Discussion The Results and Analysis

Turbidity and suspended solids are mainly removed from raw water by the different processes in conventional water treatment plants, by the coagulation/ flocculation and filtration processes. Total dissolved solids are not significantly affected, where some constituents concentration my increase because of the addition of chemicals. Chlorination is added to provide the best disinfection and to produce the recommended residual reaching the consumer through the distribution systems. This discussion will include these aspects.

### 5.1.Turbidity

Turbidity in raw water is caused by suspended solids such as clay, sand, silt, organic and inorganic matter also microorganisms. Turbidity in water will decrease the efficiency of chlorine for disinfection. Here turbidity will protect microorganism from being killed by chlorine (Lechevallier et al.,1981).The average turbidity values for the river (R) ranged between 30 – 40 NTU as shown in Figs.2 and 3 and increased to 70 NTU at the intake of the old plant and more than 60 NTU in the new plant. The turbidity of the treated water (P) from these plants as shown in the figures did not exceed 5 NTU, which is within the Iraqi drinking specification. The plants had high percentage removal for turbidity which reached 90 – 95%.

### 5.2.Aluminum (Al)

Aluminum is found in small concentrations in natural water. One of the most important sources of Al is the disposal of industrial waste and the infiltration of water through different types of soil and rocks (WHO, 1989). The raw water in the location of the plant in this study had no aluminum contain. For the coagulation processes in these plants, aluminum is used in the form $AL_2(SO_4)_3.18H_2O$ which is know as alum. The maximum permissible amount of aluminum in drinking water should not exceed 0.2 mg/l, where it may cause Alzheimer. Also it causes death to patients suffering kidney illness, when consuming high concentrations of aluminum (Tebbutt, 1998). Fig.4 shows that the drinking water (P) from the two plants is within 0.01 - 0.02 mg/l.

### 5.3.Iron (Fe)

Iron is found in rocks, soils and water in a variety of forms and oxidation states. In oxygenated surface waters with pH 5.28, typical concentrations of iron are around 0.05-0.2 mg/l (Crittenden et al.,2005). From the available data there is not any iron in the river water (R). Fig.5 shows that the potable water (P) from the treatment plants contains iron ranging between 0.01-0.2 mg/l with a maximum value of 0.45 mg/l in the new plant and more than 0.3 mg/l in the old. This amount of iron may be to the addition of iron salts as a coagulant for the agglomerate processes. In Iraq the plants use only alum for this process, so the existence of iron concentration in the treated water (P) may be caused by the corrosion of the metal parts in these plants (Tebbutt,1998).A water stability analysis should be calculated to confirm this problem. Also water of low alkalinity contains higher concentration of

Fe(AWWA,1971).As to the Iraqi drinking specification the maximum permissible concentration for iron should not exceed 0.3mg/l.

## 5.4.Sodium (Na)

Sodium in nature is found in rocks and soil. It is transported into water from rocks through weathering and from soil by ion exchange reaction. Industrial wastes often contain high concentrations of sodium as it is the common cation in industrial salts and such wastes are discharged to the river, (Crittenden et al., 2005). In natural waters, sodium is generally present as the free ion $Na^+$. Several complexes and ion pairs may occur including sodium carbonate $Na_2CO_3$, bicarbonate $NaHCO_3$, sulfate $Na_2SO_4$ and chloride Nacl. Sodium salts and ions are highly soluble and tend to remain in solutions (Hem, 1971, Eichenberger, et al., 1982). As shown in Figs.6 and 7 a significant concentration of sodium was measured in the raw water entering the two plants ranging between 60 – 90 mg/l in the intake of the old WTP. In the intake of the new WTP the concentration increased to70–85 mg/l. The concentration of Na decreases downstream from the new plant.

Sodium may be added to the treated water through the chemical utilized for treatment, such as sodium hydroxide or carbonate. This addition may be required for the coagulation process if the alkalinity is not enough for the reaction of alum or to raise the pH which decreases through this reaction (Steel and McGee, 1979). Figs. 6 and 7 show that the concentration of sodium in the treated water (P) ranged in the two plants between 60 – 90 mg/l. A maximum sodium concentration of 130 mg/l was obtained in summer 2007 in the old plant, where in the winter of the same year it reached 120 mg/l in the new plant. The maximum permissible level of Na in drinking water should not exceed 200 mg/l (Iraqi standard, 2000).

## 5.5.Calcium (Ca)

After bicarbonate, calcium is the second most prevalent constituent in most surface waters of the world and is generally among the most prevalent three or four ions in groundwater. Weathering and soil ion exchange reactions are the main sources of calcium in natural waters. Common mineral forms of calcium are calcite, also known as aragonite ($CaCO_3$), gypsum ($CaSO_4.H_2O$), anhydrite ($CaSO_4$) and fluorite ($CaF_2$). Calcium is generally present as the free ion $Ca^{+2}$ in natural waters and adsorbed into soil particles. Calcium concentrations can reach several hundred milligrams per liter in arid regions or under conditions where hydrogen ion activity is higher than under atmospheric equilibrium conditions. Waters with calcium levels between 60 to100 mg/L are generally considered moderately hard to hard as calcium is a primary constituent of water hardness. Calcium is of importance to industry as a component of scale. The precipitation of $CaCO_3$ scale on cast iron and steel pipes helps inhibit metallic corrosion but the same precipitate in boilers and heat exchangers adversely affects heat transfer. Water high in calcium have a nuisance value in wash waters both domestic and industrial, as the alkaline environment causes precipitation of the calcium (scale) on fixtures and soap (Crittenden et al., 2005).

Decreasing concentrations of calcium are noticed in the river (R), where 120 mg/l was found in 2006 and decreased to 90 mg/l in 2008 as shown in Figs.8 and 9. In the potable water (P) from the plants the concentration decreased, ranging between 60 – 80 mg/l. Less amounts of Ca is measured in the potable water indicating the precipitation or the adsorption of this constituent through the treatment processes. The desirable concentration of Ca is 75 mg/l and the maximum permissible is 200 mg/l.

## 5.6.Magnesium (Mg)

Magnesium salts are more soluble than calcium, but they are less abundant in rocks and soil therefore less available for weathering reactions. Also ion exchange reactions in soil and rocks may affect local concentrations of magnesium. Concentrations of magnesium are typically below 10 – 20 mg/l in surface water (AWWA, 1971). Magnesium is also a primary constituent of water hardness, where hardness is the total amount of Ca and Mg. Magnesium concentration in the raw water (R) at the intakes of the two plants increased from 30 mg/l in 2006 to 60 mg/l in 2008 as shown in Fig.10 and 11. Levels of magnesium decreased in the potable water (P) from the two plants ranging between 30 – 50 mg/l, which may be due to precipitation or adsorption through the treatment processes. The levels of Mg are within the desirable limit 50 mg/l and the maximum permissible 150 mg/l.

## 5.7.Alkalinity (Alk)

Alkalinity is a measure of the ability of water to resist changes in pH. Alkalinity in water is due to the presence of weak acid systems that consume hydrogen ions produced by other reactions or produce hydrogen ions when they are needed by other reactions allowing chemical or biological activities to take place within water without changing the pH. The primary source of alkalinity is the carbonate system, although phosphates, silicates, borates, carboxylates, and other weak acid systems can also contribute. In water treatment plants, alkalinity is required in the coagulation process for the reaction of alum; lime, caustic soda and soda ash could be added if the natural alkalinity is not enough for this reaction (Crittenden et al., 2005).

Corrosively of water decreases as the alkalinity increases, where it is necessary to provide a stable pH of the treated water (P) for corrosion control of the metal parts of the water work system (Schock, 1989). Low iron corrosion rates and iron concentrations in the distribution systems have been associated with higher alkalinities (Pisigan and Singley, 1987). A rough comparison of the solubility of Fe in water, having the same pH but with different alkalinity was studied by Eugene Bowers (AWWA, 1971). Decreasing the alkalinity from 500 to50 mg/l as $CaCO_3$ caused an increase in Fe concentration 0.55 to 5.5 mg/l.Figs.12 and 13 shows that the alkalinity of the raw water (R) decreased from 160 mg/l in 2006 to 130 and 140 mg/l. 1n 2007 and 2008. The alkalinity of the treated water (P) from the two plants decreased compared with raw water (R) entering the plants which ranged between 120 – 130 mg/l as shown in these Figs. The consumption of alkalinity by alum in the coagulation process is the cause of this decrease.

## 5.8.Hydrogen Ion Concentration (pH)

pH is a measurement of the acid base properties of a solution. pH is important in water treatment as it directly influences the dosages of chemicals added to reduce hardness and coagulate particles (Crittenden et al., 2005). As shown in Figs.14 and 15. pH of the raw water (R) ranged between 6.5 to 8 at the intake of two plants. The effluent from the water treatment plants (P) decreased depending on the amount of coagulants added for suspended solids removal and the chlorine dose used for disinfection. In the coagulation process $CO_2$ is produced from the reaction of alum with the natural alkalinity of the raw water and causing the decrease in pH. The reaction of chlorine gas added for disinfection will produce free available chlorine in the form OCl and HOCl also this will depress pH. In the two plants the pH was low reaching 6 to 6.6 in 2006 and increased in 2007 to7.5. Where in 2008 it varied between 7 to 8 as shown in the Figs. The Iraqi drinking specification considers pH in the range 6.5 to 8.5.

## 5.9.Residual Chlorine

For the disinfection process pre and post chlorination is the recommended procedure in these plants. This application of chlorine is used when high pollution is expected in the river (Steel and McGee, 1979). Among the recorded data, the results of the bacteriological tests for raw water were missing, so the degree of contamination of the river is hard to be dictated. For potable water (P) from the two plants, all the bacteriological tests gave negative results, indicating high disinfecting efficiency. The tests performed were Total Bacterial Count, Total Coliform and Total Fecal Coliform for the treated water (P) as recommended in the Iraqi specification, 2000. The treated water which is distributed to the consumer has high levels of residual chlorine. As shown in Fig. 16 the residual chlorine ranged between 2.0 - 2.5 mg/l from the two plants in 2006. It decreased to 1.5 mg/l in the beginning of 2007 in the new plant.

A significant increase is noticed in summer 2007 and spring 2008 that reached 3.5 mg/l. This increase may indicate contamination of the river and the incidence of a disease producing organism in the raw water. The importance of residual chlorine is to avoid any contamination in the distribution system that delivers potable water to the consumer. The desirable level is 0.25 to 0.5 mg/l as free or combined available chlorine. From the recorded data for samples taken from tap water at different locations in the distribution system, significant concentrations of residual chlorine were measured. The smallest amount detected was 0.5 mg/l.

## 6. The Conclusions And Recommendations

The main aim of this study is to evaluate the performance of the two water treatment plants in Diwaniyah City was valued. The plants produced treated water according to the Iraqi specification. The main conclusion are :-

1-The two plants had high efficiency in turbidity removal reaching to about ( 90 -95) % and the turbidity of the treated water does not exceed 5 NTU.

2- Alum is added for the coagulation process, where the concentration of Al was between 0.01 -0.02 mg/l in the potable water.

3- Concentration of iron(Fe) which appeared in the statistical analysis of the treated water is reaching to (0.01 - 0.2) mg/l, knowing that no iron salts are added in the treatment processes. The problem of such situation must be solved. It is recommended to make continues sampling for the effluent from each unit in the treatment process to out come the cause of this problem.

4-The concentration of natural constituents in raw water namely Ca, Mg and Na decreased in the treated water, where Ca concentration is within 60 – 80 mg/l, Mg 30 – 50 mg/l and Na 60 – 90 mg/l, which were all with in the permissible limits.

5- The two plants are efficient in bacterial removal where pre and post chlorination is applied. The residual chlorine in the effluent water from the plants is ranged from 2.0 to 2.5 mg/l. This range is satisfy dosage of chlorine of 0.5 in the distribution system. It was also noted that has increased the amount of chlorine residual to 5.3 mg/l in the summer of 2007 and spring 2008.

6- Through research has been inferred the existence of any problem, especially the change in the quality of river water (water entering the plant) because of pollution. Which requires that tests are continuing to water before and after treatment

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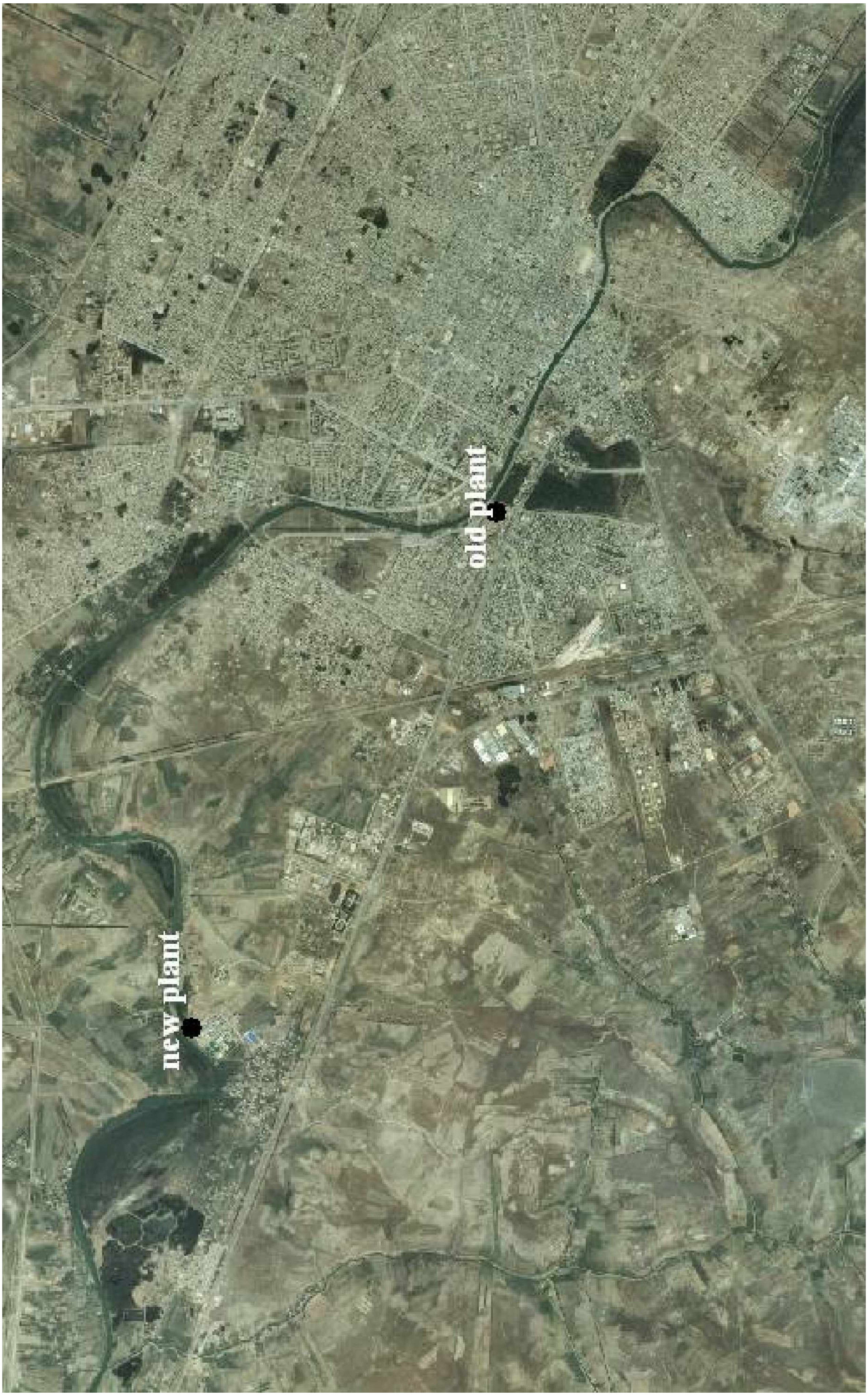
old plant
new plant

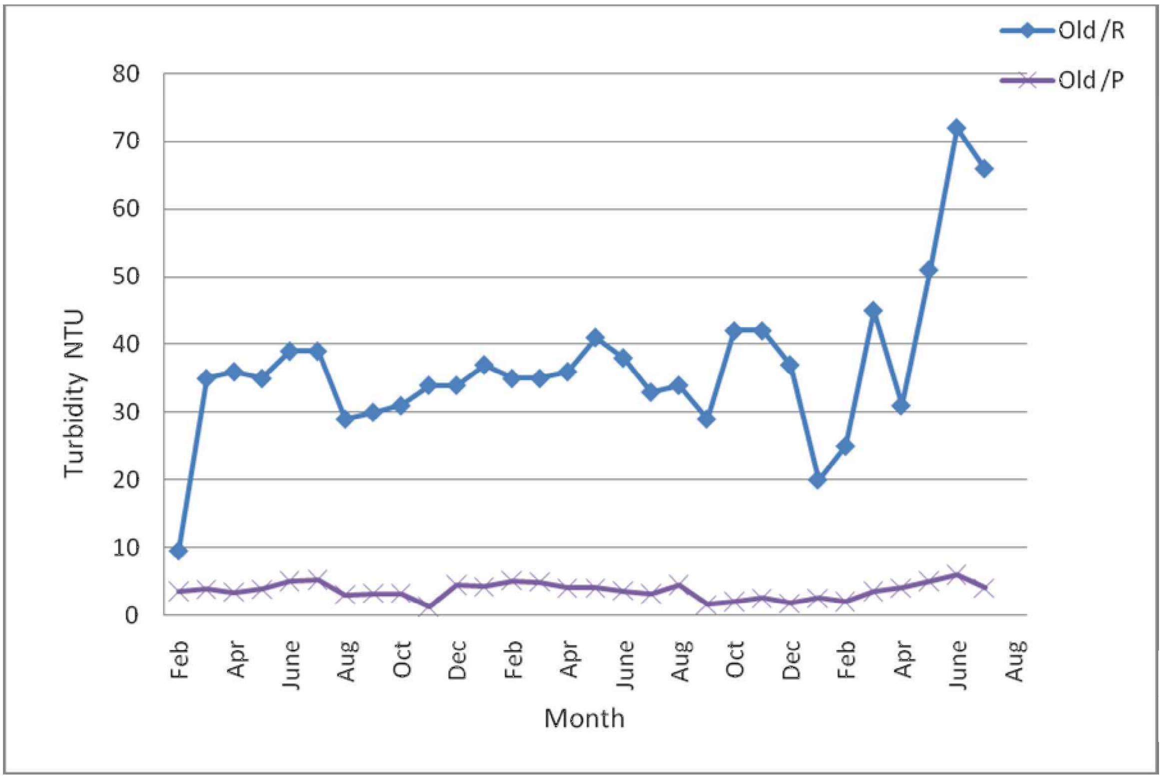

Fig.(2):Variation of Turbidity in Raw & Potable Water at the Old Plant.

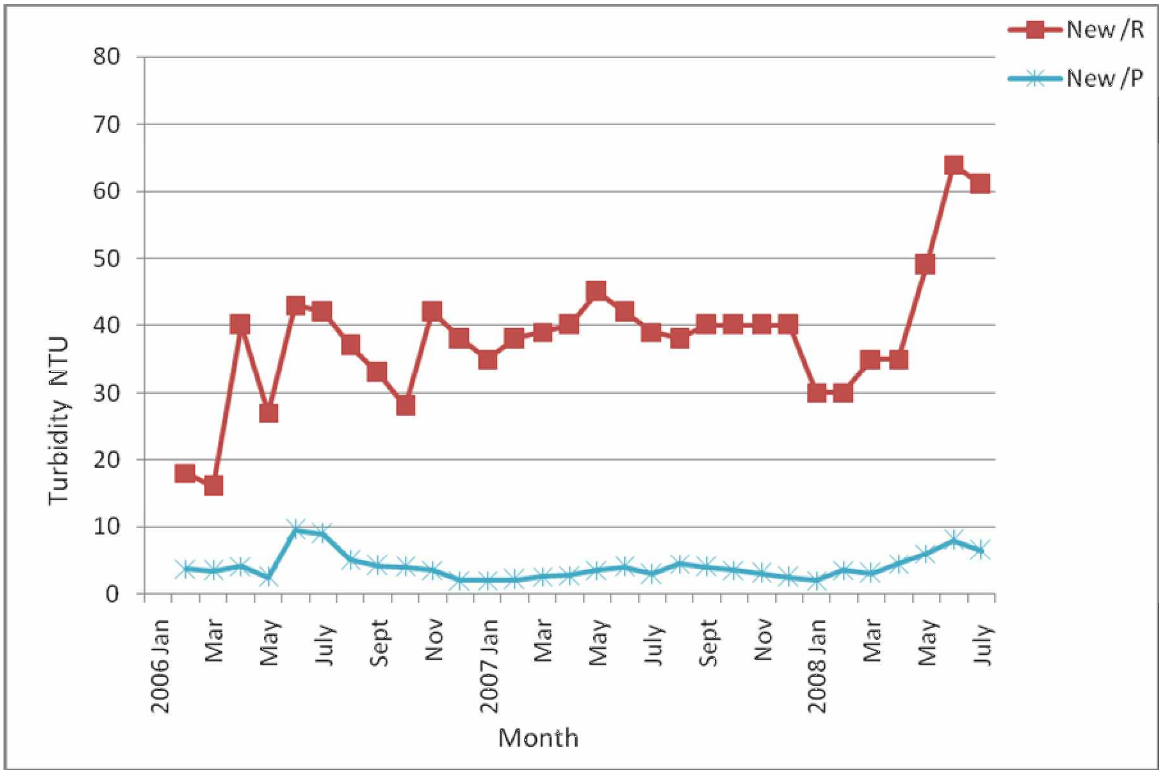

Fig (3): Variation of Turbidity in Raw & Potable Water at the New Plant.

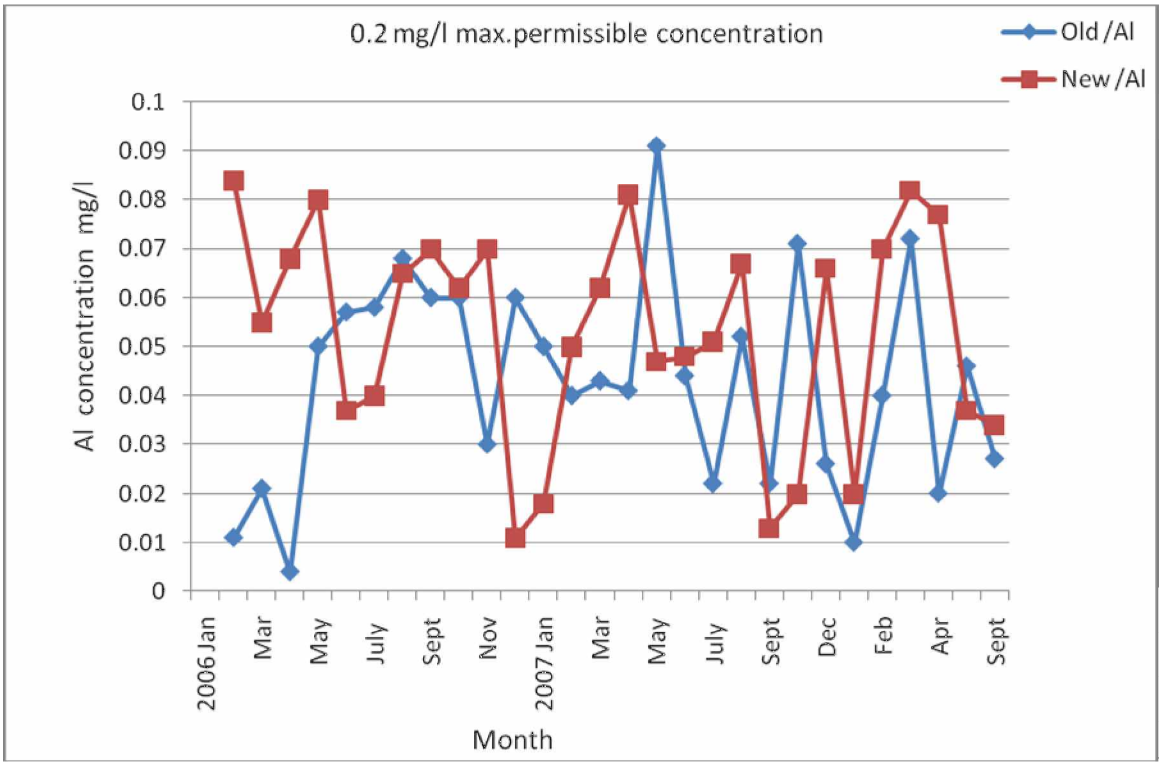

Fig (4): Variation of Aluminum in Potable Water at the Old & New Plants.

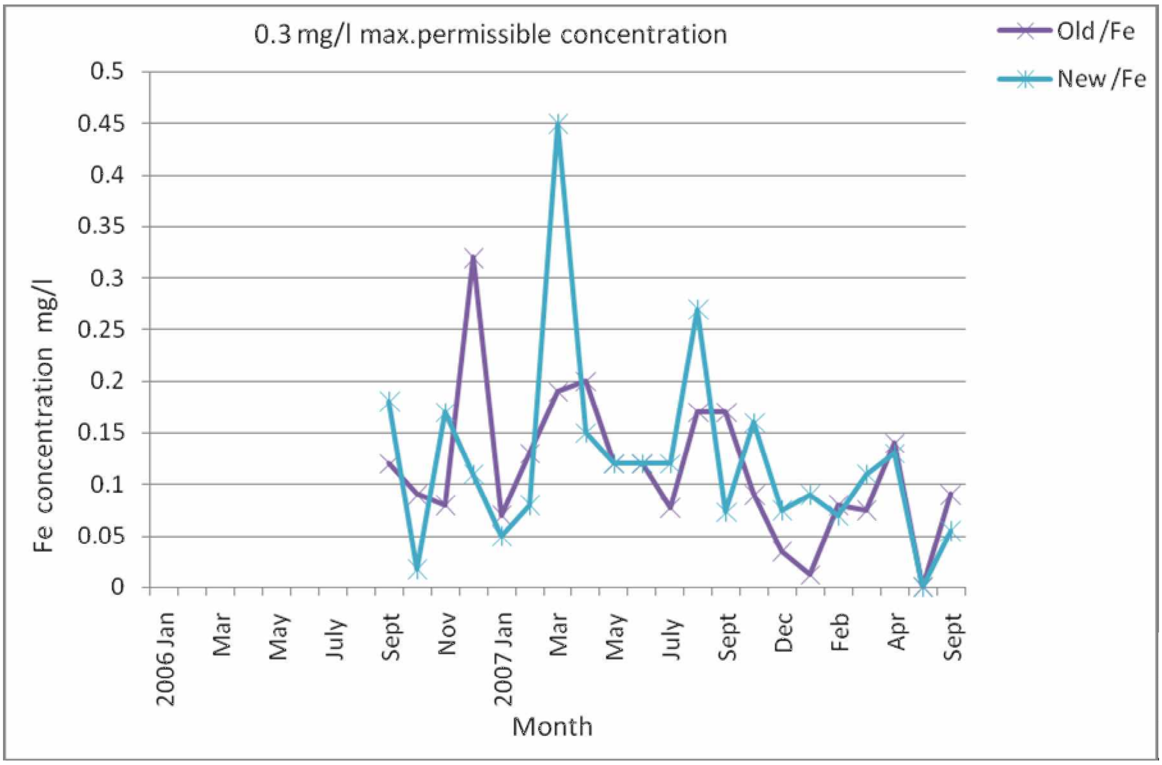

Fig (5): Variation of Iron in Potable Water at the Old & New Plants

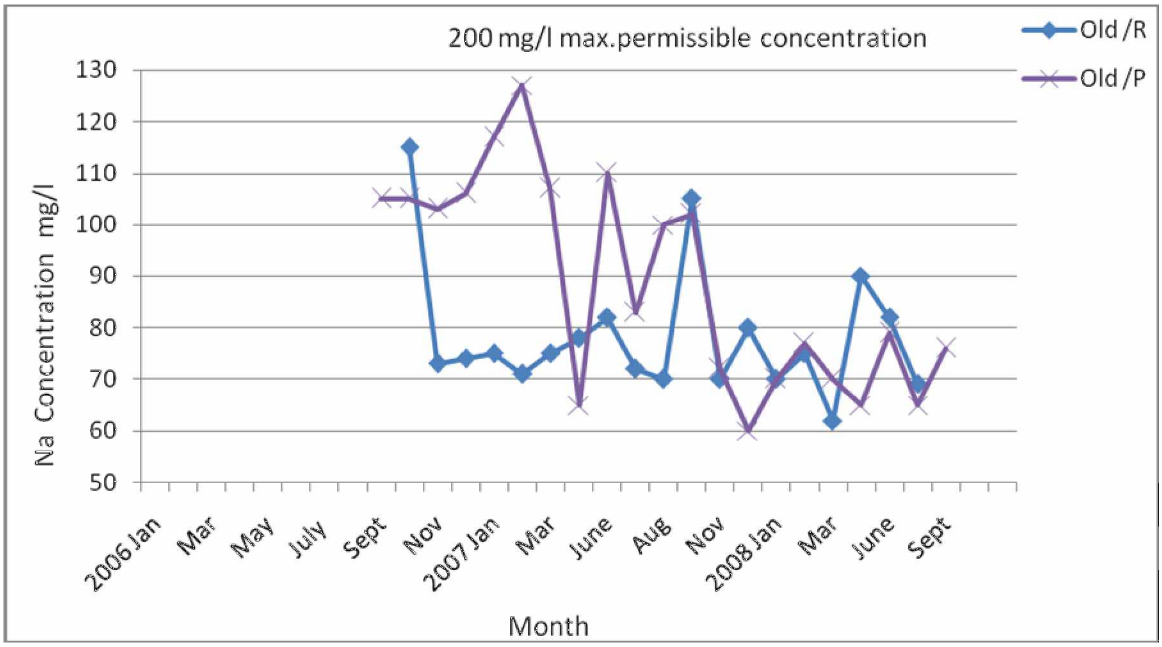

Fig (6): Variation of Sodium in Raw & Potable Water at the Old Plant

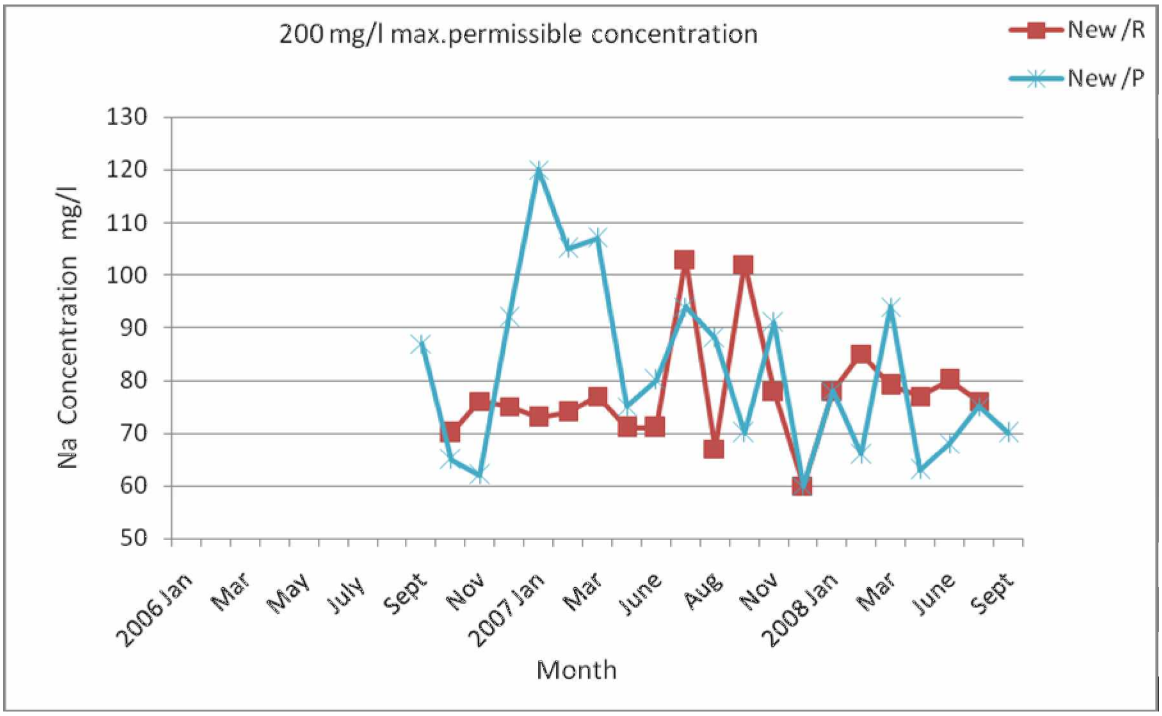

Fig (7): Variation of Sodium in Raw & Potable Water at the New Plant

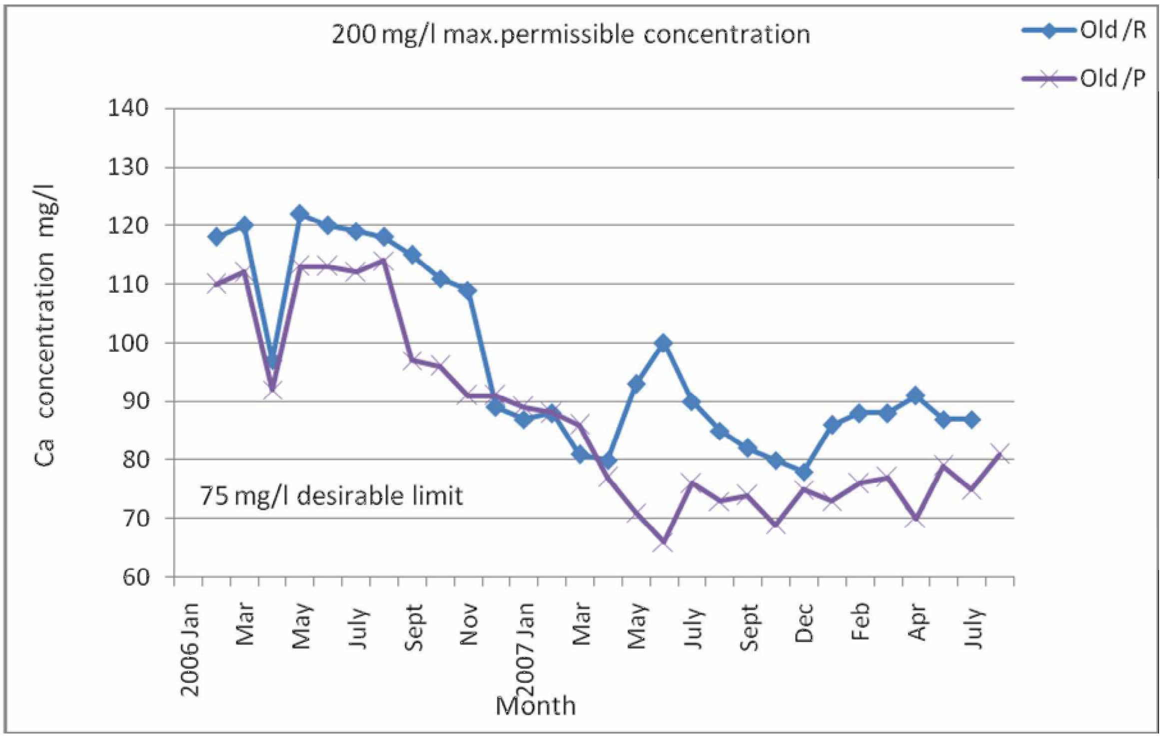

Fig (8): Variation of Calcium in Raw & Potable Water at the Old Plant

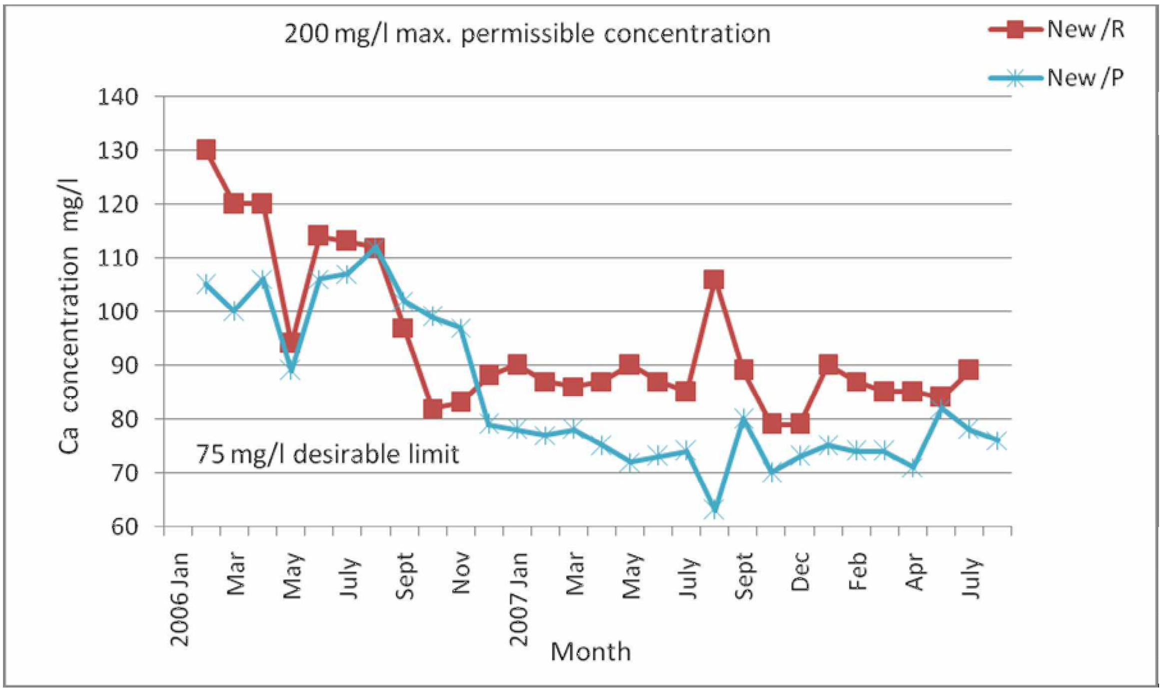

Fig (9): Variation of Calcium in Raw & Potable Water at the New Plant

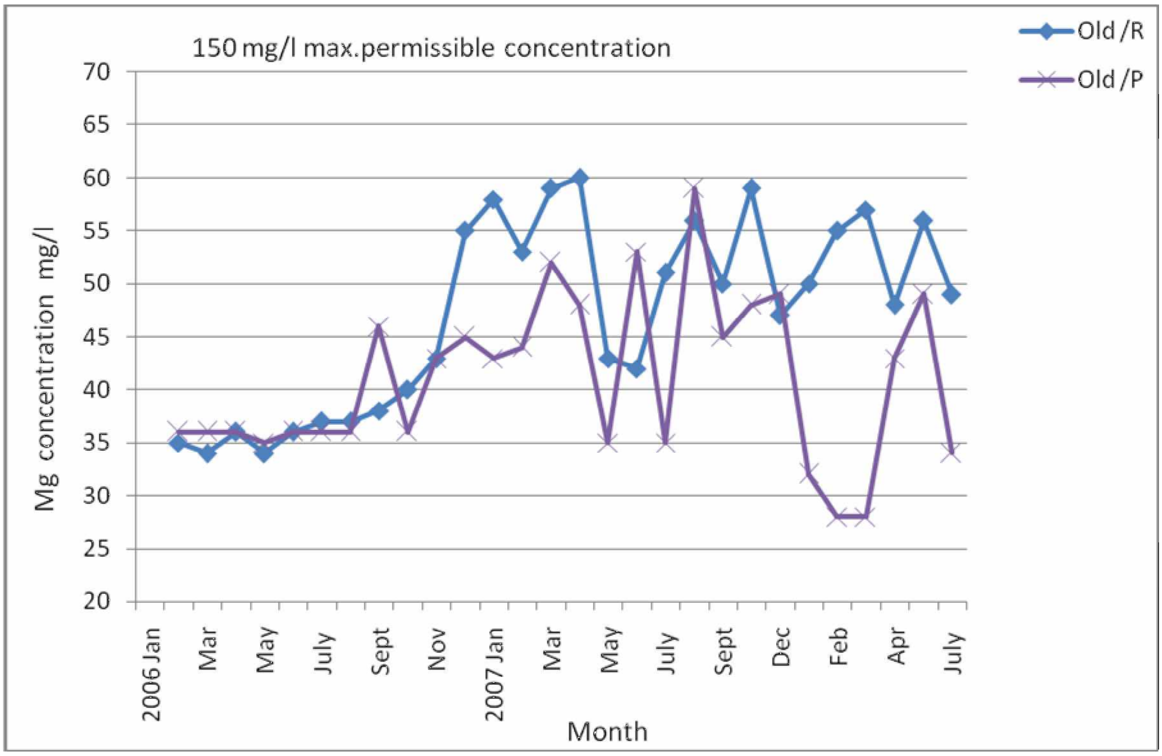

Fig (10): Variation of Magnesium in Raw & Potable Water at the Old Plant

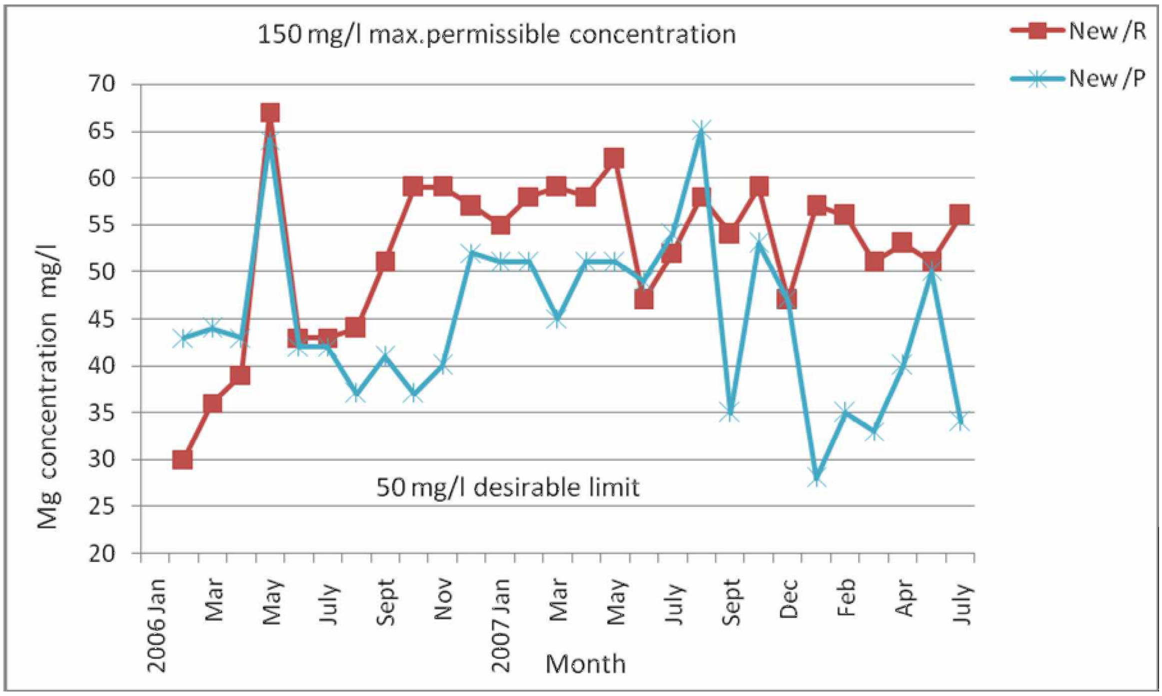

Fig (11): Variation of Magnesium in Raw & Potable Water at the New Plant

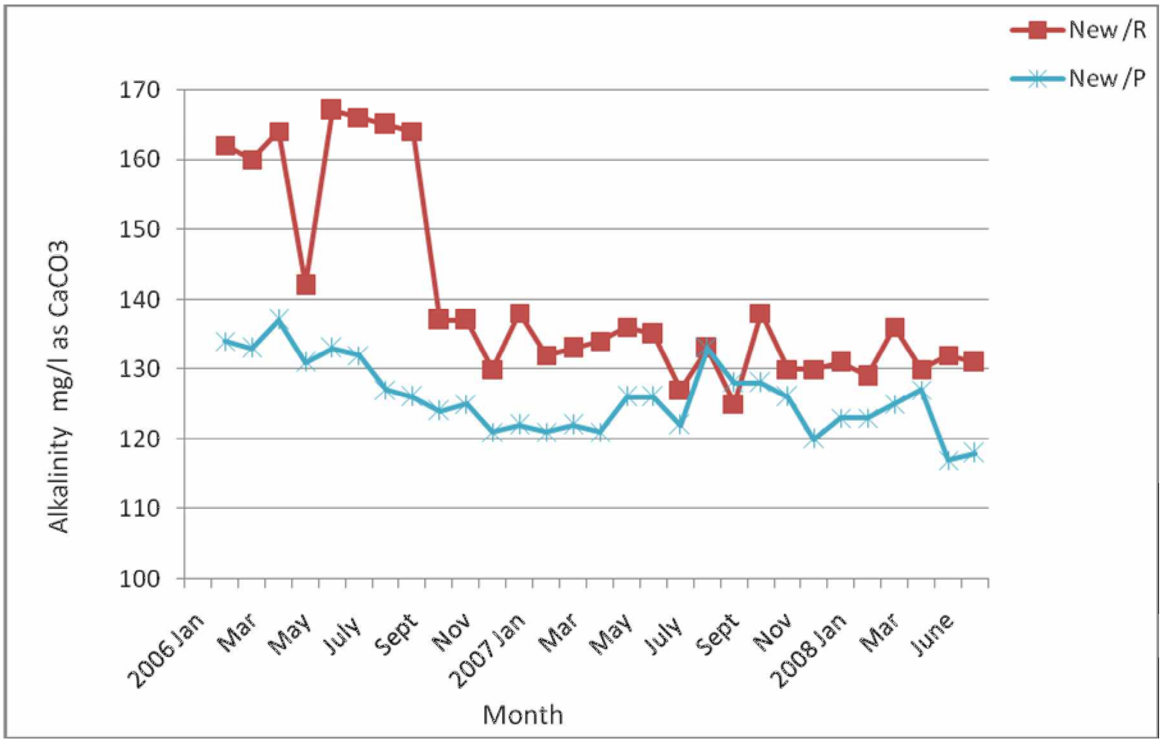

Fig (12): Variation of Alkalinity in Raw & Potable Water at the New Plant

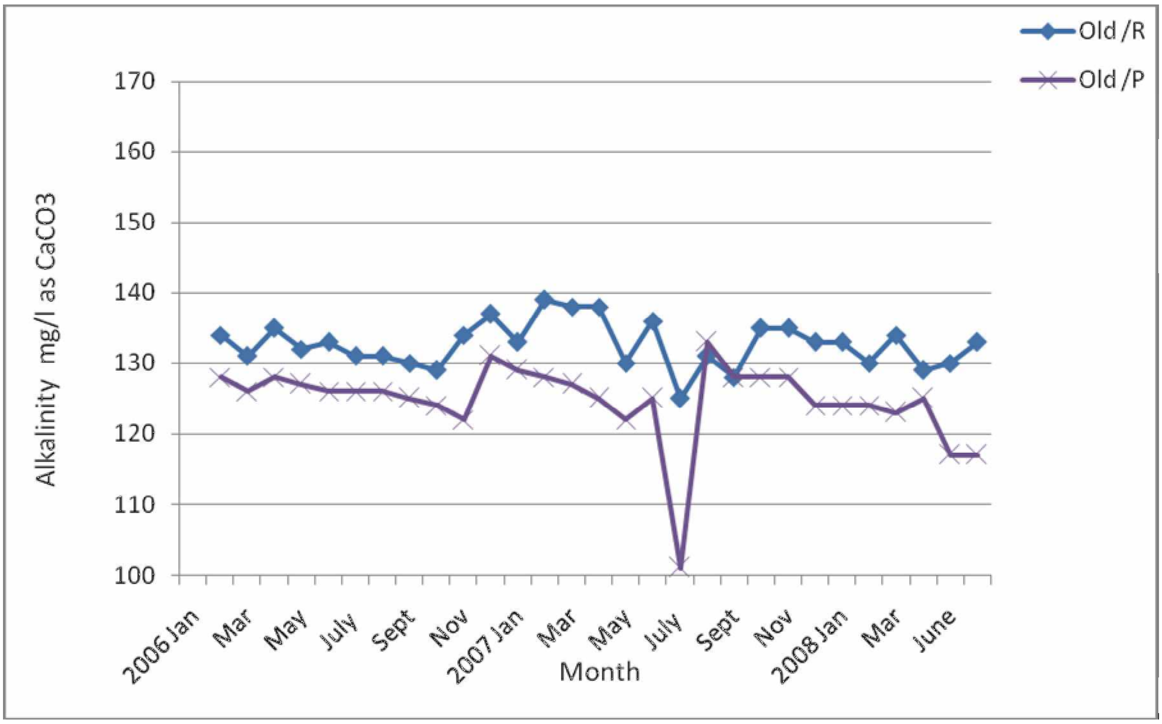

Fig (13): Variation of Alkalinity in Raw & Potable Water at the Old Plant

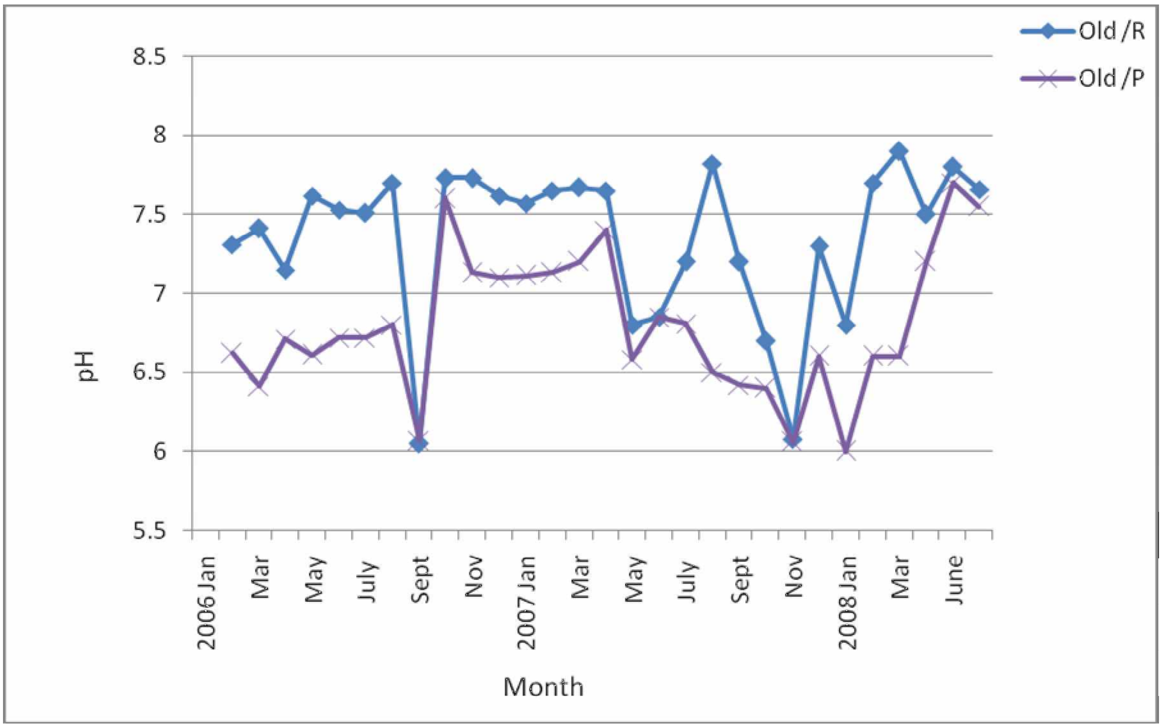

Fig (14): Variation of pH in Raw & Potable Water at the Old Plant

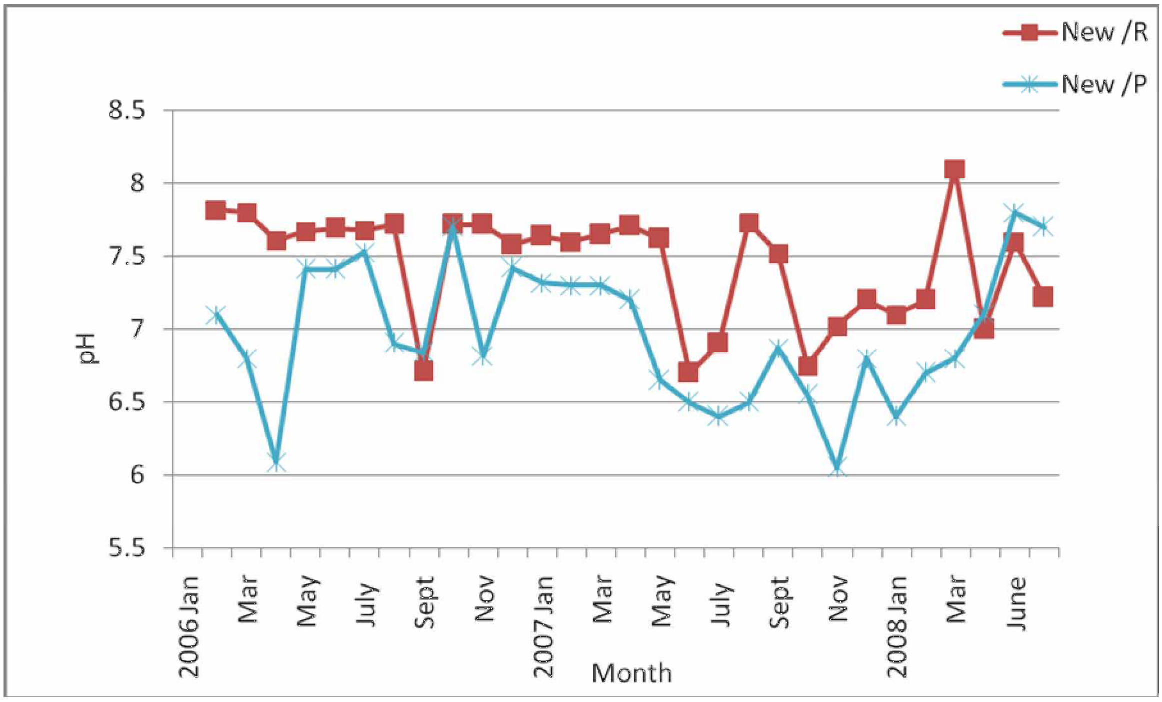

Fig (15): Variation of pH in Raw & Potable Water at the New Plant

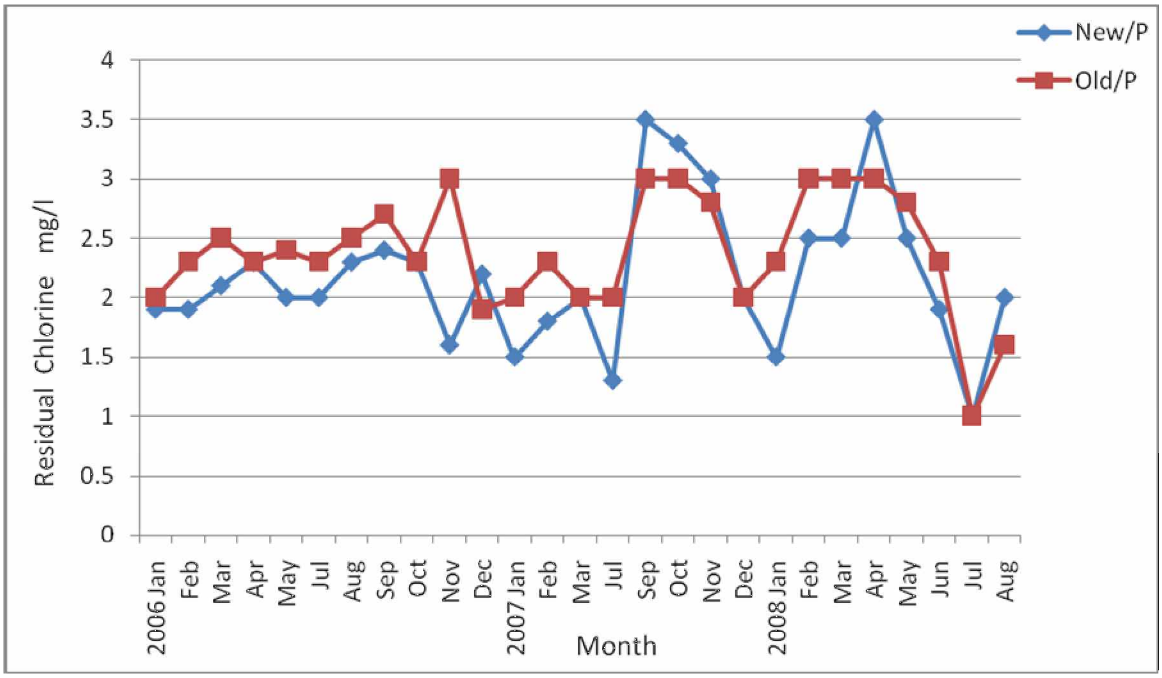

Fig (16): Variation of Residual Chlorine in Potable Water at the Old & New Plants