Study of Potential Corrosion and Scaling for Treated Water of Two Water Treatment Plants in Al-Hilla City

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Abstract

Corrosion causes metals delivering into the conveyed liquid. If the corrosion be very rapid, it will cause pipes cavitations. Then, the intrusion of contaminants into the pipes result in negative suction and if the water has been scaling tendency, a scale layer will introduce, then induce internal scaling and reduce convey potential in pipes. The aim of this research was determining the potential corrosion and scaling of treated water from two water treatment plants in Al-Hilla city. The variation in water stability with time and places of Al-Hilla city was indicated. Values of Langlier Saturation Index, Ryznar Stability Index, Puckorius Scaling Index ,and Aggressive Index, calculated during 8 months between 2007 to 2008. The calculated results showed that the values of Langlier Saturation Index ranged between -0.098 to 0.46, Ryznar Stability Index ranged between 6.91 to 7.81,Puckorius Scaling Index ranged between 6.76 to 7.47,and Aggressive Index ranged between 10.88 to 11.88 in Al-Jadeed WTP in the north. Where in the center Al-Kadeem WTP, Langlier Saturation Index ranged between 0.21 to 0.63, Ryznar Stability Index ranged between 6.63 to 7.30, Puckorius Scaling Index ranged between 6.87 to 7.33, and Aggressive Index ranged between 11.35 to 12.08 .By survey of stability indices, it founded that treated water from these two water treatment plants have moderate corrosion potential, and the corrosivity of water decreased in the water following down stream. The water quality parameters affecting LSI,RSI,PSI, and AI were discussed which were alkalinity, pH, total dissolved solids, temperature, hardness, and calcium concentration.

الخلاصة

الماء المنقول بواسطة الأنابيب أما أن يكون ذو خاصية تاكلية فيسبب تحرر المعادن من الأنبوب وإذا كان التآكل سريع جداً,فانه يسبب تنخر الأنابيب ,أو يكون الماء ذو خاصية تكلسية فيتسبب في إضافة صفائح رقيقة من المعادن على السطح الداخلي للأنبوب وفي كلتا الحالتين يتسبب الماء في تغيير مقطع الأنبوب زيادة أو نقصاناً.هدف هذا البحث هو دراسة هاتين الخاصيتين للماء المعالج الخرج من محطتي الحلة–الجديد والحلة–القديم والذي يجري داخل شبكة توزيع الماء في مدينة الحلة.وقد بين البحث مدى تغير استقرارية الماء مع الزمن والمسافة داخل مدينة الحلة.حسبت مقاييس الاستقرارية PSI, RSI,ASI و AI لثمانية أشهر للسنوات(2007–2008).بينت النتائج بان معدلات مقاييس الاستقرارية الأربعة هي كالتالي: ASI يتراوح بين (0.098- و 0.46) ,RSI يتراوح بين (6.91 و7.81), PSI يتراوح بين(6.76 و7.47), و AI يتراوح بين (10.88و11.88) في محطة الحلة الجديد لتنقية الماء في شمل المدينة.بينما في الوسط (محطة الحلة القديم لتنقية الماء) فان معدلات مقاييس الاستقرارية الأربعة هي كالتالي: ASI يتراوح بين (0.21 و 0.63) ,RSI يتراوح بين (6.63 و7.30), PSI يتراوح بين(6.87 و7.33), و AI يتراوح بين (11.35و12.08). وبإجراء نظرة عامة على مقاييس الاستقرارية نجد أن الماء المعالج الخارج من هاتين المحطتين يمتلك صفة تآكلية متوسطة وهي تقل باتجاه الجريان من الشمال إلى وسط مدينة الحلة. وقد تم مناقشة صفات الماء التي تؤثر على هذه المقاييس (PSI, RSI,ASI و AI) وهي القاعدية,تركيز ايون الهيدروجين,الدقائق الكلية الذائبة,درجة الحرارة,العسرة, وتركيز ايون الكالسيوم.

Introduction

Corrosive water is a term used to describe “aggressive” water that can dissolve materials with which it comes in contact. While aggressive water is usually not dangerous to consume by itself, it can cause serious drinking water quality problems by dissolving metals from plumbing systems. Many homes have pipes, solders and plumbing fixtures made from copper, lead or other metals. Corrosive water can sometimes dissolve enough of these metals to create both aesthetic and health-related problems in drinking water. In certain cases, corrosion can be severe enough to cause leaks in the plumbing system(Swistock and etl.,2011).

Corrosion and scaling may cause of pipe blocking. At result may reduce the flow and create some other problems in the pipelines. It can also damage the pipeline. If it occurs, water leakage increases and so water loss will be high(Davil and etl.,2009).

Calcium carbonate is probably the most common type of scale found in cooling water systems; it forms an extremely tenacious heat insulating deposit. Calcium and bicarbonate alkalinity are found in almost all cooling waters. The addition of heat, or a sharp rise in pH, will cause calcium bicarbonate to decompose and form carbon dioxide and calcium carbonate (Water Services,2004). Calcium and magnesium provide hardness in a solution. By itself, hardness does not present any problems. A calcium solution at a pH of 3 may have hardness, but it is not going to scale. (WIC, 2006).

If water is under-saturated with respect to calcium carbonate, the saturation level will be less than 1.0. When water is at equilibrium, the saturation level will be 1.0 by definition (although our estimation of the ion activity product or solubility product might be in error). Water which is supersaturated with calcium carbonate will have a saturation level greater than 1.0 .Saturation level is the driving force for crystal formation, and crystal growth. As the saturation level increases beyond 1.0, the driving force for calcium carbonate crystal formation or crystal growth increases(BWA,1999).

Water high in calcium, but low in alkalinity and buffering capacity can have a high calcite saturation level. The high calcium level increases the ion activity product. The water might have a high tendency to form scale due to the driving force, but scale formed might be of such a small quantity as to be unobservable. The water has the driving force but no capacity and no ability to maintain pH as precipitate forms (DownHole,2011).

A majority of the indices used routinely by water treatment chemists are derived from the basic concept of saturation. A water is said to be saturated with a compound (e.g. calcium carbonate) if it will not precipitate the compound and it will not dissolve any of the solid phase of the compound when left undisturbed, under the same conditions, for an infinite period of time. Water which will not precipitate or dissolve a compound is at equilibrium for the particular compound (Ferguson, 2005).

Maintenance of an effective water treatment program is essential to minimize scale and corrosion problems in industrial water systems; however, scale and deposits that form will require remedial cleaning (descaling). If not removed, these scale and water-caused deposits may impact the safety of operations personnel, interfere with heat transfer, and cause excessive damage to (or destruction of) the water-using equipment. Cleaning is not appropriate for the removal of deposits when corrosion of the system has advanced to the point where a large number of leaks may result from the removal of the deposits (Guyer, 2011).

Corrosion products can shield microorganisms from disinfectants . These microorganisms can cause many problems such as slimes, bad odor and taste (Bina and Porzamani, 2005).

There are several aspects of the corrosivity of the water that are of importance which include (Ryder and Reynolds,2006):

- Health effects – compliance with the Lead and Copper Rule (LCR) of the Federal and State Safe Drinking Water Act Regulations.
- Aesthetic – Discoloration of distributed water as primarily related to leaching of iron from distribution pipes causing red water or of copper laterals and consumer plumbing systems causing blue water and sometimes a metallic taste to the water.
- Economic – Accelerated corrosion and pitting of iron and steel distribution pipes or storage tanks, and pitting of copper piping of consumer systems, and increased interior roughness causing capacity loss or higher pumping costs.

- Environmental – Minimization of toxic heavy metals in wastewater discharged to wastewater treatment plants with subsequent discharge to the city from corrosion and leaching of copper, lead, nickel, zinc, chromium, etc. primarily from consumer plumbing systems.

Many surface waters require a coagulant such as alum for effective treatment. After treatment and disinfection with chlorine, the water can become aggressive. At present there is no requirement to produce a water that is stable (neither scale forming or corrosive) other than having a pH in the range 6.5 to 8.5 (Gebbie, 2000).

For waters in a pH range of 6.5-9.5, Langelier's formula for the pH at which a water is in equilibrium with calcium carbonate (Ryznar, 1986). By the increase of pH to values more than 8.5 the Langelier index increased to 0.0–0.5 Several effects act to generate the super-saturation condition: the increase in temperature, alkaline scales and the increase in hydroxide ion concentration pH (Al-Rawajfeh and etl, 2005).

Scope of the Present Study

The aim of this study is determining the corrosion and scaling of treated water from Al-Hilla Al-Jadeed and Al-Hilla Al-Kadeem water treatment plants during 2007-2008 based on Langlier Saturation Index (LSI), Ryznar Stability Index (RSI), Pockurius Scaling Index (PSI), and Aggressive Index (AI).The data of water quality were collected from both treatment plants for the period between 2007-2008.The variation in water stability with time and distance is to be indicated.

Study Site Description

Al-Hilla Al-Jadeed treatment plant is located at the main northern entrance of Al-Hilla city, 100 km away to the south of Baghdad. In 1993 the plant was put into operation with feeding areas of Al-Hilla city and Abi-Gharak town with capacity of 10470 m^3/hr. The raw water is treated by conventional treatment and treated water is stored before being pumped to the consumer. The raw water intake comprises a river bank intake. Two low lift pumps with capacity of 1635 m^3/h and six submerged pumps with capacity of 1200 m^3/h (one as a standby) each, discharge to two raw water pipelines (each pipe represents a stream in the plant) with diameter of 1400 mm each. Raw water flows then to the treatment tank(Chabuk and etl, 2009).

Al-Hilla AL-Kadeem treatment plant is the first water treatment plant constructed on Shatt Al-Hilla river in Al-Hilla city . It is located at the city center and the plant was established in 1954 and put into first operation in 1959 and it had many technical problems upon which it has subjected to necessary maintinance in (1999). Before this maintenance, it was serving Tayara AL-Jadeed pumping location and the network. After this maintenance, this plant started serving Tayara AL-Jadeed pumping station only, with capacity 1200 m^3/h.The raw water is drawn from Shatt Al-Hilla river and treated by conventional treatment. Treated water is stored before being pumped to the consumers. The raw water intake comprises a river bank intake. Four low lift pumps (one as standby) with capacity of 400 m^3/hr each, discharging to three raw water pipelines with 350 mm diameter each(Chabuk and etl, 2009).

Water Stability Indices

Although a number of indices have been developed, none has demonstrated the ability to accurately quantify and predict the corrosivity or aggressiveness of water. They can only give a probable indication of the potential corrosivity of a water (Gebbie, 2000).The most common methods used for calculating the stability of water are:

1. Langelier Saturation Index (LSI)

The equation developed by Langelier makes it possible to predict the tendency of water either to precipitate or to dissolve calcium carbonate. The equation expresses the

effects of pH, calcium, total alkalinity, dissolved solids and temperature as they relate to the solubility of calcium carbonate for waters in the 6.5 - 9.5 pH range,LSI is defined as(Water Services,2004):

$$LSI=pH-pHs \quad \text{eq.1}$$

Where:
pH is the measured water pH
pHs is the pH at saturation in calcite or calcium carbonate and is defined as:

$$pHs=(9.3+A+B)-(C+D) \quad \text{eq.2}$$

Where:

$$A=(Log_{10}[TDS]-1)/10 \quad \text{eq.3}$$

$$B=-13.12*Log_{10}(^{\circ}C+273)+34.55 \quad \text{eq.4}$$

$$C=Log_{10}[Ca_2+CaCO_3]-0.4 \quad \text{eq.5}$$

$$D=Log_{10}[\text{Alkanity as } CaCO_3] \quad \text{eq.6}$$

[ ] Concentration in mg/l

A zero value indicates equilibrium, positive value indicates that scaling is likely and a negative value indicates that it is unlikely. Often it doesn't start to form until the LSI exceeds somewhere in the 0.6 region(Davil,2009).

2. Ryznar Stability index (RSI)

The Ryznar Stability index is an empirical method for predicting scaling tendencies of water based on a study of operating results with water of various saturation indices (Ryznar, 1986):

$$RSI = 2pHs - pH \quad \text{eq.7}$$

This index is often used in combination with the Langlier index to improve the accuracy in predicting the scaling or corrosion tendencies of a water.Table1 lists the scale formation or corrosive tendencies of waters with various Ryznar index values (Kawamura,2000).

Table1: Scale and corrosion tendencies of water with various Ryznar index values

RSI Range	Indication
Less than 5.5	Heavy scale formation
5.5 to 6.2	Some scale
6.2 to 6.8	Non-scaling or corrosive
6.8 to 8.5	Corrosive water
More than 8.5	Very corrosive water

3. Puckorius Scaling Index (PSI)

The PSI attempts to quantify the relationship between saturation state and scale formation by incorporating an estimate of buffering capacity of the water into the index.

The PSI index is calculated in a manner similar to the Ryznar stability index, Puckorius uses an equilibrium pH rather than the actual pH (Mirzaei and etl.,2011):

PSI = 2 pHs – pHeq eq.8

Where:

pHs is the pH at saturation in calcite or calcium carbonate

$$pHeq = 1.465 * \mathrm{Log}_{10}[\mathrm{Alkanity}] + 4.54 \quad \text{eq.9}$$

$$\text{and } [\mathrm{Alkanity}] = [HCO_3^-] + 2[CO_3^{-2}] + [OH^-] \quad \text{eq.10}$$

But the above formulae is valid only for pH values below 8.3 (the phenolphthalein reversion point).PSI considers scaling as unlikely to occur if the value is <6 with an increasing likelihood as it goes lower. It is considered as likely to dissolve scale if >7.

4. Aggressive Index (AI)

Aggressive index is defined as:

$$AI = pH_a + \mathrm{Log}_{10}[Ca_2]\,[Alk]$$

eq.11

Where $[Ca_2]$ and $[Alk]$ are the concentration of calcium and alkalinity in mg/l as CaCO3. Water with AI less than 10 are considered highly aggressive, while 10-12 indicate moderate corrosion and above 12 indicate scaling(Kutty and etl.,1992).

Results and Discussion

For determining the water corrosion and scaling of treated water from Al-Hilla Al-Jadeed and Al-Hilla Al-Kadeem water treatment plants, The physical and chemical characteristics of treated water are summarized in Figs. (1 to 6). These characteristics included (alkalinity (Alk),hydrogen ion (pH), total dissolved solid (TDS), temperature (˚C), hardness (Hard), and calcium (Ca)).

In general, the maximum concentrations of (hydrogen ion, and temperature) in Al-Hilla Al-Kadeem treatment plant were within the Iraqi and the WHO standards for drinking water, while the maximum concentrations of (alkalinity, calcium, total dissolved solids, and hardness) didn't meet the Iraqi and the WHO standards for drinking water. The maximum concentrations of (hydrogen ion, temperature, and total dissolved solids) in Al-Hilla Al- Jadeed treatment plant were within the Iraqi and the WHO standards for drinking water, while the maximum concentrations of (alkalinity, calcium, and hardness) in Al-Hilla Al-Jadeed treatment plant were not within the mentioned standards.

The fluctuation of the physical and chemical parameters can be attributed to many factors such as the quality of water fed to the treatment plant or lack of the cleaning and maintenance process in the treatment plant. It was noticed that turbidity removal efficiency achieved in the treatment plants sometimes be low in spite of the low level of turbidity in river water because of the wrong addition of alum dosage or because of the high daily demand which makes the treatment process inefficient. The range of concentration and percentage of samples exceeding health limits of drinking-water at the two treatment plants. Also the maximum concentrations of sulphates,and chlorides ions didn't meet the Iraqi standards and the WHO standards for drinking water at the two treatment plants (Chabuk and etl.,2009).

The calculated results showed that the values of Langlier Saturation Index(Fig.7) ranged between -0.098 to 0.46, Ryznar Stability Index(Fig.8) ranged between 6.91to 7.81, Puckorius Scaling Index(Fig.9) ranged between 6.76 to 7.47 ,and Aggressive Index

(Fig.10) ranged between 10.88 to 11.88 in Al-Jadeed WTP in the north. Where in the center Al-Kadeem WTP, Langlier Saturation Index (Fig.7) ranged between 0.21 to 0.63, Ryznar Stability Index(Fig.8) ranged between 6.63 to 7.30, Puckorius Scaling Index (Fig.9) ranged between 6.87 to 7.33,and Aggressive Index(Fig.10) ranged between 11.35 to 12.00. Table 2 shows the treated water condition of Al-Hilla Al-Jadeed and Al-Hilla Al-Kadeem water treatment plants from view point corrosion and scaling indices, all these indices are indicated that treated water from these two treatment plants was fall in moderate corrosive class.

Table 2: The condition of treated water from Al-Hilla Al-Jadeed and Al-Hilla Al-Kadeem water treatment plants in view of scaling and corrosion indices.

Month	Al-Hilla Al-Jadeed				Al-Hilla Al-Kadeem			
	LSI	RSI	PSI	AI	LSI	RSI	PSI	AI
Nov	Balance	Moderate corrosion	corrosion	moderate corrosion	Balance	Moderate corrosion	corrosion	moderate corrosion
Dec	Balance	Moderate corrosion	corrosion	moderate corrosion	Balance	Moderate corrosion	corrosion	moderate corrosion
Jan	Balance	Moderate corrosion	corrosion	moderate corrosion	Balance	Moderate corrosion	corrosion	moderate corrosion
Feb	Balance	Moderate corrosion	Balance	moderate corrosion	Light Scale	Slight corrosion	Balance	Light Scale
Mar	Balance	Moderate corrosion	corrosion	moderate corrosion	Light Scale	Moderate corrosion	corrosion	Light Scale
Apr	Balance	Moderate corrosion	corrosion	moderate corrosion	Balance	Moderate corrosion	corrosion	moderate corrosion
May	Balance	Moderate corrosion	corrosion	moderate corrosion	Balance	Moderate corrosion	corrosion	moderate corrosion
Jun	Balance	Moderate corrosion	corrosion	moderate corrosion	Balance	Moderate corrosion	corrosion	moderate corrosion

The effect of TDS content on water corrosivity is a complex issue. Both the species and the concentration of ion are important factors. Some species such as carbonate and bicarbonate reduce corrosion, whereas chloride, and sulfate ions markedly accelerate corrosion. Temperature also affects the corrosion process. Higher water temperatures accelerate the rate of corrosion by increasing the rate of the cathodes reaction, the chemical reaction rate generally is doubled for every 8˚C increase in temperature (Kawamura,2000).

Conclusion

Four water stability indices are applied: the Langelier Saturation Index (LSI),Ryznar Stability index (RSI), Puckorius Scaling Index (PSI),and Aggressive Index (AI),methods of calculating these parameters have been outlined. Results indicated that the treated water from two treatment plants was moderate corrosive .The corrosivity indices show that the water corrosivity in the north was increase to the center of city. Corrosivity of the treated water flowing from the WTPs affected by water quality characteristics, alkalinity, calcium and hardness increases will decrease water corrosivity, temperature, sulphates, and chlorides ions increases will increase water corrosivity.

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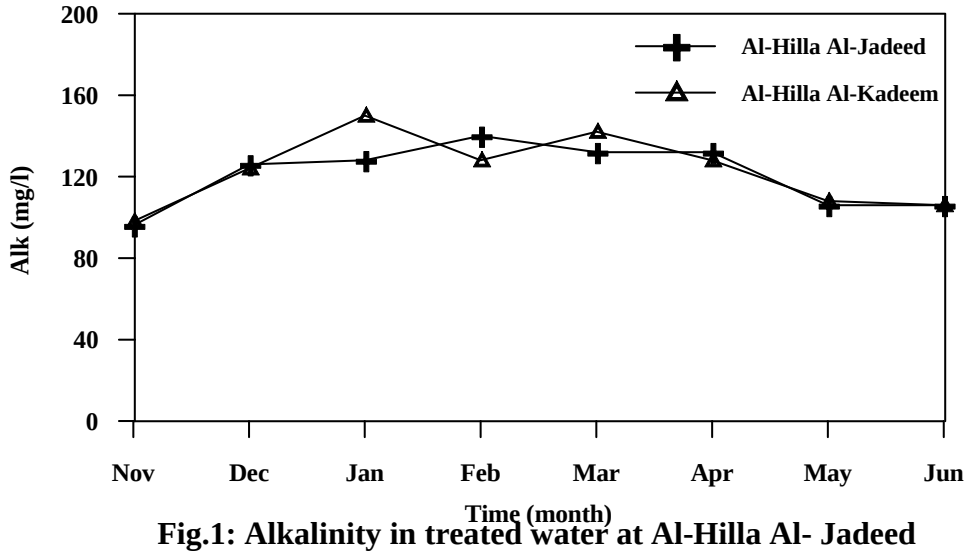

Fig.1: Alkalinity in treated water at Al-Hilla Al- Jadeed and Al-Hilla Al- Kadeem treatment plants.

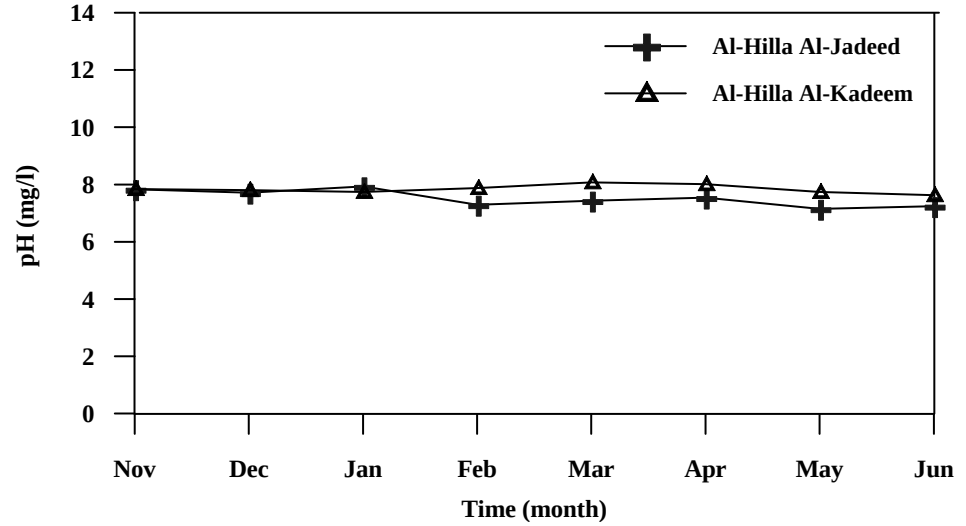

Fig.2: Hydrogen ion concentration in treated water at Al-Hilla Al- Jadeed and Al-Hilla Al- Kadeem treatment plants.

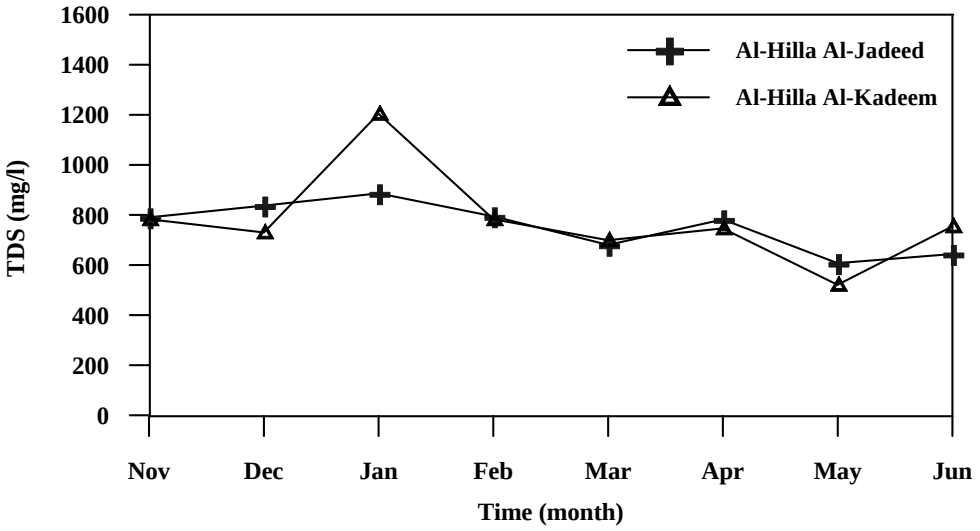

Fig.3: Total dissolved solids concentration in treated water at Al-Hilla Al- Jadeed and Al-Hilla Al- Kadeem treatment plants.

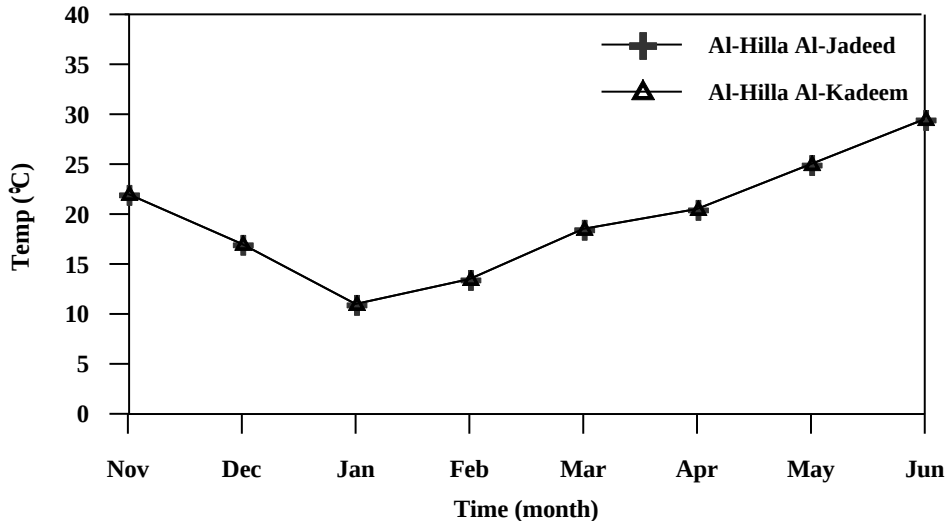

Fig.4: Temperature in treated water at Al-Hilla Al- Jadeed and Al-Hilla Al- Kadeem treatment plants.

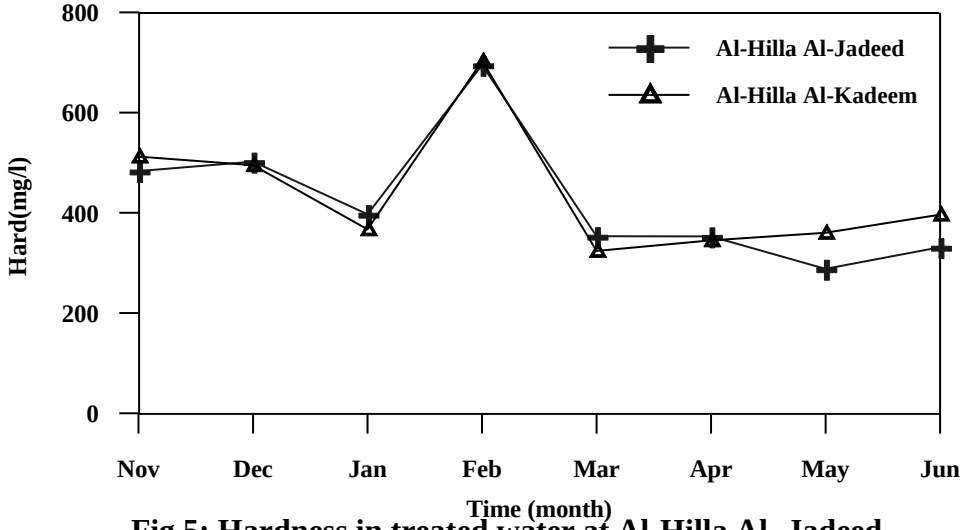

Fig.5: Hardness in treated water at Al-Hilla Al- Jadeed and Al-Hilla Al- Kadeem treatment plants.

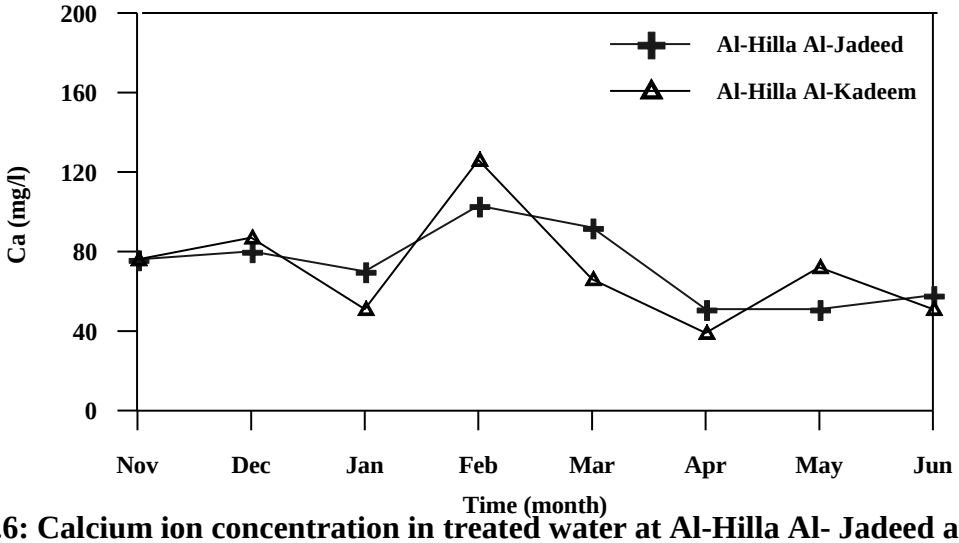

Fig.6: Calcium ion concentration in treated water at Al-Hilla Al- Jadeed and Al-Hilla Al- Kadeem treatment plants.

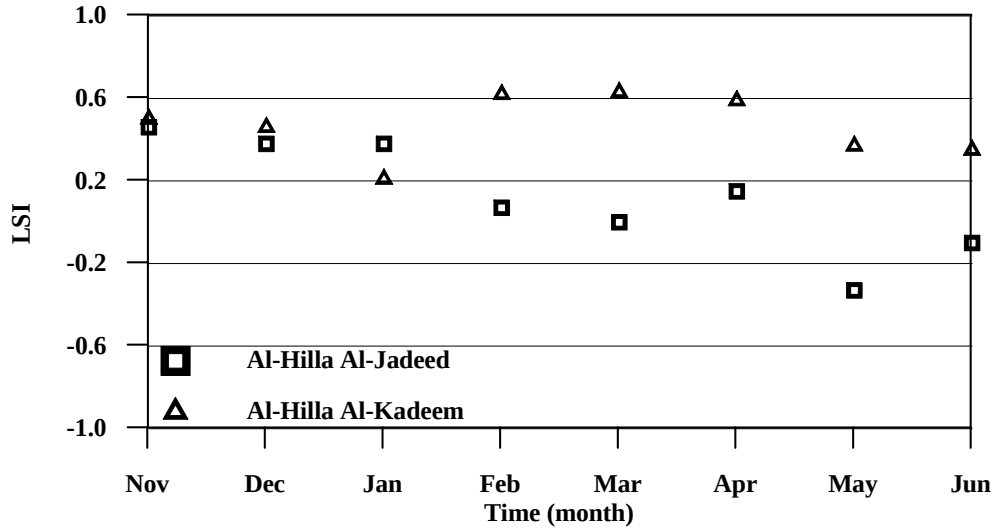

Fig.7: Langelier Saturation Index in treated water at Al-Hilla Al- Jadeed and Al-Hilla Al- Kadeem treatment plants.

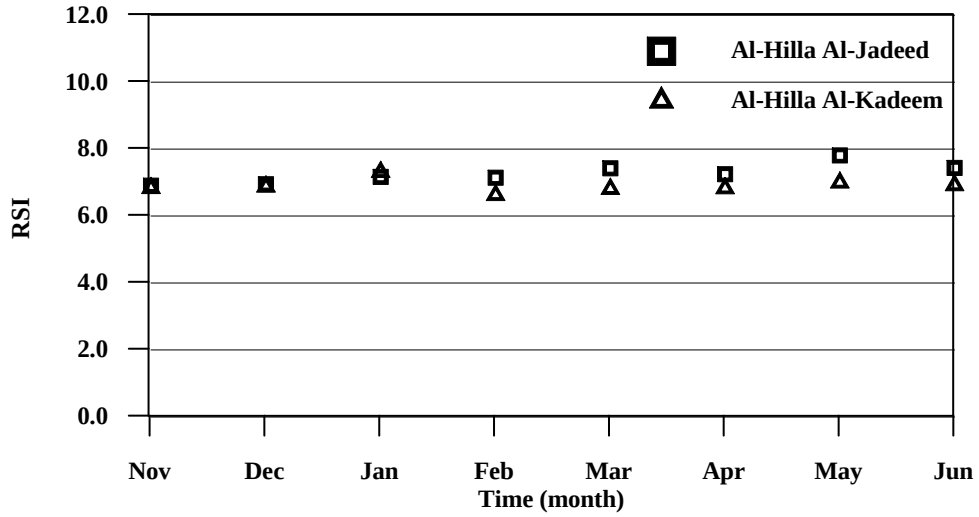

Fig.8: Ryznar stability index in treated water at Al-Hilla Al- Jadeed and Al-Hilla Al- Kadeem treatment plants.

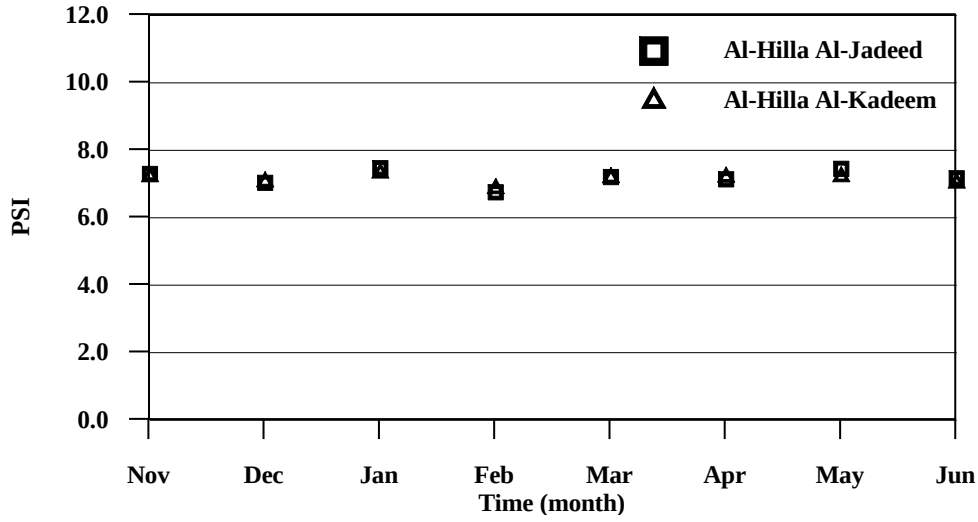

Fig.9: Puckorius Scaling Index in treated water at Al-Hilla Al- Jadeed and Al-Hilla Al- Kadeem treatment plants.

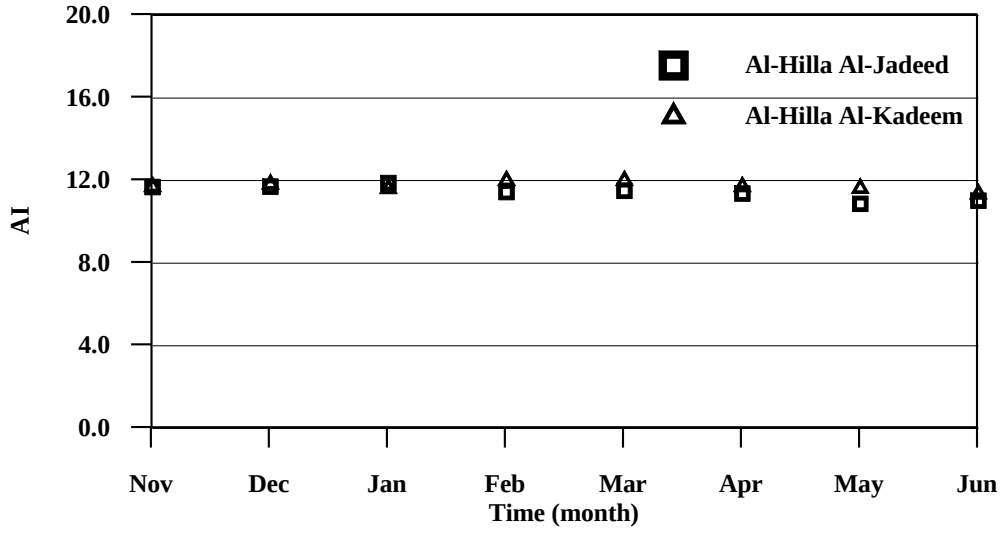

Fig.10: Aggressive Index in treated water at Al-Hilla Al- Jadeed and Al-Hilla Al- Kadeem treatment plants.