Investigation the Stability of Treated Water Produced from Six Stations in Babylon

Hadeel Ali Abdulhussein
Babylon University/ College of Engineering
rawansaad2003@yahoo.com

Abstract

Corrosion and scaling are mutual problems appeared in water distribution systems. The strictness of such problems depends on the quality of the water conveyed and the characteristics of the pipeline material. For solving and minimizing such problems, the probability of corrosivity and scaling of water as well as the factors effecting them should be investigated.

Four water stability indices (Langlier Saturation Index (LSI), Ryznar Stability Index (RSI), Pockurius Scaling Index (PSI), and Aggressive Index (AI))were used to investigate the stability of treated water from six selected water treatment plants in Babylon province (Al-Hillah Al-Jadeed, Al-Hillah Al-Kadeem, Al-Taiyara, Al-Hussain, Al-Mahaweel and Al-Hashmia) during 2009-2013. According to LSI the treated water quality of the all stations was oversaturated with $CaCO_3$ during the whole studied period (positive LSI values) with a potential of forming a protective layer from calcium carbonate. RSI, PSI and AI results displayed that the water quality was of moderately corrosive which can be considered not harmful for water distribution systems.

Keywords: water stability, langier Saturation index, Ryznar Saturation Index, Pockurius Scaling Index, Aggressive Index

الخلاصة

التآكل وتكـون الترسـبات (scaling) مشـاكل شـائعة ظهـرت فـي شـبكات توزيـع الميـاه. شـدة مثـل هذه المشاكل تعتمد على نوعية المياه المنقولة وخصائص المواد المصنعة منها خطوط انابيب نقل المياه الأنابيـب. لايجـاد الحلول والتقليل من هذه المشاكل، ينبغي التحقق من احتمالية قدرة الماء على التآكل وتكـون الترسـبات والقشـرة فضـلا عن العوامل المؤثرة عليها.

استخدمت أربعة من مؤشرات استقرارية المياه (مؤشـر التشـبع لانجليـر (LSI) ، مؤشـر الاسـتقرار ريزنـار (RSI) ، مؤشر بوكوريوس(PSI) ، ومؤشر التأكل (AI) للتحقق من استقرارية المياه المعالجـة مـن سـت محطـات مختـارة لمعالجـة الميـاه في محافظة بابل (الحلة الجديد ، الحلة القديم ،الطيارة، الحصين ، المحاويل والهاشمية) . للفترة من (2009الى 2013) .

وفقا لمؤشر لانجلاير كانت نوعية المياه المعالجة لجميع المحطات مشبعة بكربونات الكالسيوم CaCO3 طوال فترة الدراسـة حيث كانت قيمة المؤشر قيم موجبة مـع احتمـال تشـكيل طبقـة واقيـة مـن كربونـات الكالسـيوم . اظهـرت نتـائج المؤشـرات (مؤشر الاستقرار ريزنار(RSI) ، مؤشر بوكوريوس(PSI) ، ومؤشر التأكل (AI)) أن نوعية المياه للمحطات المدروسة هي معتدلة مـن حيث احتمالية التأكل والتي يمكن اعتبارها غير ضارة لشبكات توزيع المياه.

الكلمات المفتاحية :- استقرارية المياة ، مؤشر التشبع لانجلير ، مؤشر الاستقرار ريزنار ، مؤشر بوكوريوس ، ومؤشر التأكل .

1.Introduction

Control of water quality in the distribution and plumbing systems pursues to preserve the fundamental properties of water through its distribution from the point of treatment to the users. The end water must be entirely stable in its physiochemical characteristics. As well the distribution system and accessory arrangements should have no be reactivity towards the water being conveyed (**Alsaqqar *et.al.*, 2014)**.

Three forms of water effect faced the piping systems: aggression, corrosion and fouling. Fouling is the gathering of unwanted substances on industrial equipment surfaces, aggression is the atomization of cement material while corrosion is the end result of the electrochemical reaction between water and metal equipments **(Loewenthal *et.al.*, 2004)**.

Corrosive water can dissolve minerals like calcium and magnesium, also harmful metals like lead and copper can be dissolved from plumbing utilities. Scaling waters deposit a film of minerals on pipe walls and may prevents corrosion of metallic surfaces. It also can be harmful and can impairment appliances if the scale formation is too rapid, in extreme cases, scale may clog pipes **(Qasim *et.al.*, 2000)**.

The effective factors that creating the phenomenon of corrosion and deposition by water is including physical, chemical and biological factors. Physical factors are include the current and temperature and chemical factors affecting in the rate of corrosion are including alkalinity, hardness, conductivity, dissolved oxygen, sulfate and chloride ions. Corrosion can cause a metallic smell and sometimes the smell of water is decay **(Choramin *et.al.*, 2015; Al-Rawajfeh and Al-Shamaileh, 2007)**

Many surface waters require coagulants such as alum to enhance treatment. Water can become aggressive after treatment and disinfection with chlorine. When a cation is add to a water, say aluminum from alum, alkalinity consumed. The same is also true when add chlorine gas **(Gebbie , 2000).**

Increasing the Ca concentration will decrease the corrosivity of water, as Ca is important in various roles, including calcium carbonate scales, mixed iron/calcium carbonate solids and the formation of a passivating film on the surface of the pipe **(Schock, 1989)**. As a result the conveyed flow will be reduced. Scale can be formed from a variety of dissolved chemical species but two reliable indicators are hardness and alkalinity (**Shankar, 2014).**

Physical and chemical parameters, microbial biofilms can create corrosion too (microbial corrosion) **(Davil *et.al.*,2009).** Studies have revealed that if circumstances urges the formation of a protective calcium carbonate layer, then corrosion will be minimized in general (**Gebbie, 2000).**

Distribution systems pipes are nearly always buried, the surrounding soil temperature remains relatively constant. However, the water temperature within a pipe can change all over the year due to seasonal variants of the water source. Thus, a pipe may show different corrosion behavior in the winter versus the summer **(McNeill and Edwards, 2002)** .

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 *et.al.*, 2009).**

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).**

(Mirzaei *et.al.*, 2011) determined the Possibility of utilization of Karkheh River water for drip irrigation. The water quality of the river was examined in 5 stations along the river in a 30-year period. To prognosticate the potentiality of carbonate calcium sedimentation and the corrosion in the irrigation equipments, Langelier Saturation Index (LSI) and Ryzner Stability Index (RSL) were used, respectively. The results also showed that the LSI was positive in all stations and it is possible that droppers clog due to carbonate calcium deposition. RSL was in most cases below 6.8 and there is little possibility of metal parts corrosion in trickle irrigation system. Chemical clogging due to deposition of calcium carbonate, magnesium carbonate and calcium sulphate, is among the first parameters that should be studied before designing trickle irrigation system.

The outcomes of a study carried out by **(Al-Husseini, 2012)** to determine 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 treated water from these two water treatment plants has moderate corrosion potential, and the corrosivity of water decreased in the water following down stream.

Hoseinzadeh *et.al.*, 2013) evaluated corrosion and scaling potential of water treated by "Takab city water treatment plant using field observation of water treatment plant, and study of physical and chemical parameter values of water which were in acceptable standard levels. The calculated values of LSI indicated slightly scale forming and corrosive, RI showed heavy corrosion, AI showed water is non-aggressive and based on PSI results water is likely to dissolve scale.

(Al-Baidhani and mokif, 2013) evaluated the treated water stability from nine water treatment plants in Babylon governorate using stability indices. The values of LSI were positive for all treatment plants which indicate the water not corrosive, LSI values for all station were between (0-0.98). RSI values showed the water is balance to corrosive with values between (6.54-7.78) and the water corrosivity decreases as pH, Ca and alkalinity concentrations increase. Aggressive index values were between (11.74-12.47) which indicate moderate corrosion.

Another study by **Alsaqqar *et.al.*, 2014)** investigated the water quality parameters related to chemical stability included temperature, alkalinity as mg/L Ca-CO3, calcium mg/L as Ca, pH and total dissolved solids (TDS) mg/L for different samples from WTPs within Baghdad city. The two water quality indices, Langelier saturation index (LSI) and the Ryznar stability index (RSI), were calculated in order to evaluate the chemical stability of the drinking water samples. The results of LSI and RSI of the effluents from Baghdad's WTPs during 2000-2013 classified that corrosive water is produced and this indicates that the water is not safe for domestic use and will need the further treatment.

(Choramin *et.al.*, 2015) studied the potential for corrosion and fouling water of Bhmnshyr by using five indicators which are LSI, RSI, PSI, AI and LI between (2005-2014), the indices were calculated monthly, seasonally and annually. Bahmanshir River water is highly corrosive in cold months and seasons also that the annual general corrosive water has risen.

This paper intended to evaluate the potential of scale formation and corrosivity of treated water from six water treatment plants in Babylon province for the period (2009-2013) throughout using stability indices.

2. Study Area

All the six water treatment plants studied are located on the Euphrates river, which represent the main source of water in Babylon province. The stations studied are Al-Hillah Al-Jadeed, Al-Hillah Al-Kadeem, Al-Taiyara, Al-Hussain, Al-Mahaweel and Al-Hashmia water treatment plants. The water quality data used in determining the stability indices (Langlier Saturation Index (LSI), Ryznar Stability Index (RSI), Pockurius Scaling Index (PSI), and Aggressive Index (AI)) were obtained from Babylon Water Directorate for the period between 2009-2013 to calculate the spatial and temporal variation in water stability.

3.Water Stability Indices

3.1. Langelie Saturation Index

Calcium carbonate saturation index (Langelier index) is commonly used to evaluate the scale forming and scale dissolving tendencies of water. It can only give a probable indication of the potential corrosivity of a water **(Gebbie, 2000; Davil *et.al.*, 2009; Hoseinzadeh, 2013)**

LSI = pH − pH*s* (1)

where:

LSI: Langlier saturation index

pH: the actual water pH.

pHs: pH of water at Carbonate Calcium saturation condition

pH*s* = (9.3+ *A*+ *B*) − (*C* + *D*) (2)

$A = \frac{[Log_{10}(TDS)-1]}{10}$ (3)

$B = -13.12 \times Log_{10}(°C + 273) + 34.55$ (4)

$C = [Log_{1o}(Calcium\ hardness) - 0.4]$ (5)

$D = Log_{1o}[Alkalinity\ \ as\ CaCO_3]$ (6)

TDS in ppm, Temperature, T in ^{o}C, Ca hardness in ppm (as CaCO3) and alkalinity in ppm as (CaCO3)

Table (1): LSI values and their indicsations

Results Index	Indicattion
LSI<0	Water is under saturated with respect to calcium carbonate
LSI=0	Water is considered to be neutral.
LSI>0	Water is supersaturated with respect to calsium carbonate ($CaCO_3$) and scale forming may occure.

3.2. Ryznar Stability Index (RSI)

A Stability Index developed by John Ryzner in 1944. 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 (**Shankar**, 2014).

The Ryznar index (RSI) takes the form:**(Al-Baidhani and Mokif, 2013; Al-Ssaqqar *et.al.*, 2014)**

RSI = 2(pH*s*) − pH = pH*s* − LSI (7)

Table2: Various Ryznar index values and their description

Rl Value	Significance
RI<5.5	Heavy scale likely to form
5.5<RI<6.2	Moderate scale formation likely
6.2<RI<6.8	Water is considered neutral
6.8<RI<8.5	Water is aggressive and corrosion is likely
RI>8.5	Water is considered very aggressive, and substantial corrosion is possible

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.

Puckorius uses an equilibrium pH rather than the actual pH **(Mirzaei *et.al.*, 2011, Davil *et.al.*, 2009; Al-Husseini, 2012; Hoseinzadeh, 2013):**

PSI = 2 pHs – pHeq (8)

Where:

pHs is the pH at saturation in calcite or calcium carbonate

pH_{eq}= pH of water at equilibrium condition, $Alkalinity$ in ppm

$$pH_{eq} = 1.465 \times Log_{10}[Alkalinity] + 4.54 \quad (9)$$

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:**(Al-Husseini, 2012; Al-Baidhani and Mokif, 2013; Choramin *et.al.*, 2015)**

$$AI = pH + Log_{10}[Ca^{+2}][Alk]$$

Where [Ca^{+2}] and [Alk] are the concentration of calcium and alkalinity in ppm as

CaCO3.

Table (3): Aggressive index ranges and descriptions

AI value	Description
Less than 10	Water is highly corrosive
10-12	Moderately corrosive
More than 12	Scaling

4.Results and Discussion:

The values of treated water quality parameters from all the six water treatment plants studied were within the Iraqi standards for the investigated years. The average annual values of the physical and chemical parameters of treated water for five years (2009-2013) are summarized in table (4).

pH is a very important factor affecting water stability through its effect on the added coagulants and disinfectant dosages, pH annual average values ranged between (7.8-7.9).

Alkalinity ranges were between 119.8 in Al-Hashmia to 123.3 in Al-Hussain stations. Alkalinity is a key factor in estimating the corrossivity and scaling potential of water, Corrosivity of water decreases as the alkalinity increases.

Total hardness and calcium concentrations for the six stations along the studied period were within the standards for drinking water with average annual values of (404.4 to 429.4) and (92 to 97.4) for hardness and calcium in Al-Hussain and Al-Hashmia stations. It is evidence that low calcium concentration leads to low hardness value as it consider the prevalent constitute causing hardness and Increasing the Ca concentration will decrease the corrosivity of water.

Temperature has also a considerable effect on water corrosivity and scaling. Higher water temperatures increase the rate of corrosion through enhancing the rate of the cathodic reaction, water temperature were between 23 and 26.8. Average annual TDS values ranged between 729.4 to 793.4 which are included within Iraqi standards, some constituents of TDS have an improving effect on the corrosion process as chloride while others have decreasing effect like bicarbonate.

Table (4): Summery of The average annual values of the physical and chemical parameters of treated water for five years.

Al-Hashmia	**TDS**	**CA**	**TH**	**ALK**	**PH**	**T**
	793.4	93.5	400.9	119.8	7.8	26.8
Al-Mahaweel	787.4	97.4	429.4	122.3	7.8	25.3
Al-Hussain	745.6	92	404.4	123.3	7.9	24.2
Al-Taiyraa	767.9	94.8	410.2	122.54	7.8	24.9
Al-Hillah Al-Qadeem	729.4	92	404	120.6	7.8	23
Al-Hillah Al-Jadeed	773.8	95.8	413.5	122.6	7.8	25

The variations in LSI, RSI, PSI and AI for the stations are represented in figures (1-8). LSI annual values were (0.3) in Al-Hashmia station at 2009 as the minimum value of the index through five years under observation while the optimum value achieved was (0.76) in Al-Hussain station at 2010, fig.(1). The Langlier Saturation Index indicated that the treated water from all the stations is oversaturated with $CaCO_3$ and there is a potential to scale formation (LSI greater than zero), with increasing of LSI value the scaling potential increases. The same manner was seen in fig.(2) for the average monthly values which indicated the same $CaCO_3$ saturation state of the water with more tendency for scale forming (greater LSI values) with highest and lowest values in Al-Hashmia station in November and February.

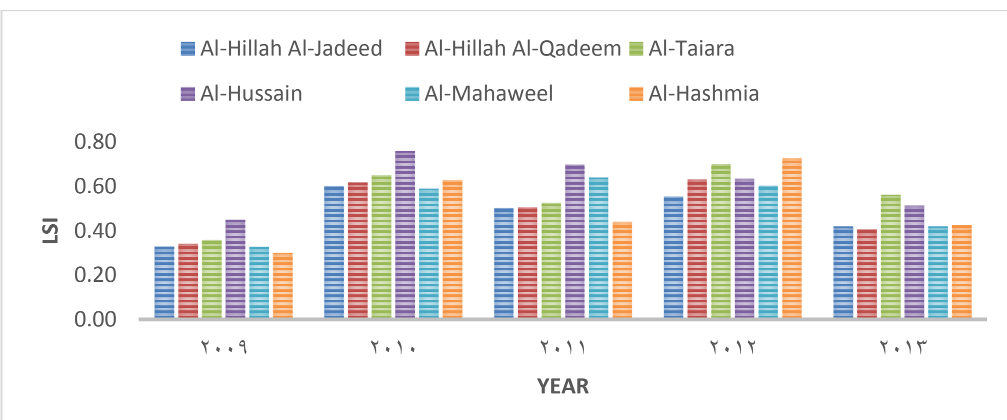

Fig.(1) temporal and spatial variation of LSI values

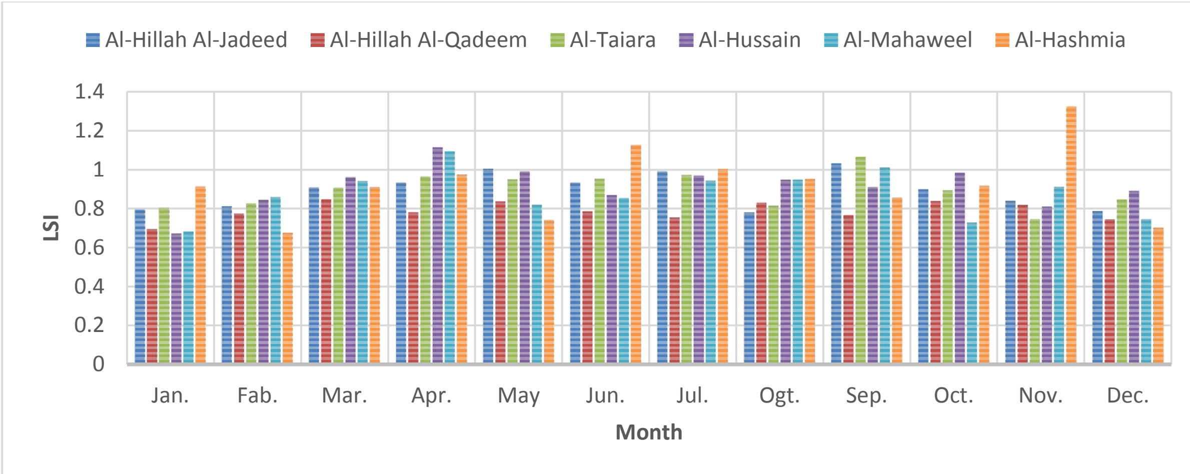

Fig.(2) average monthly LSI values for the stations during the period (2009-2013)

Figures (3,4) shows RSI values, it can be seen that the water in 2010 and 2012 wad tends to be non-scaling or corrosive with the range of RSI values of (6.4-6.79), in 2009, 2011 and 2013 the water tends to be little corrosive with average values (6.6-6.96). Average monthly RSI values showed that the water is non-scaling or corrosive (moderate).

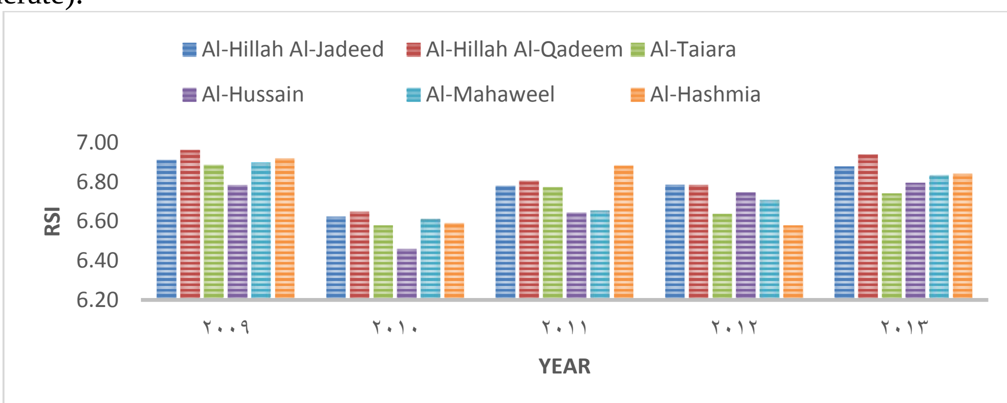

Fig.(3) temporal and spatial variation of RSI values

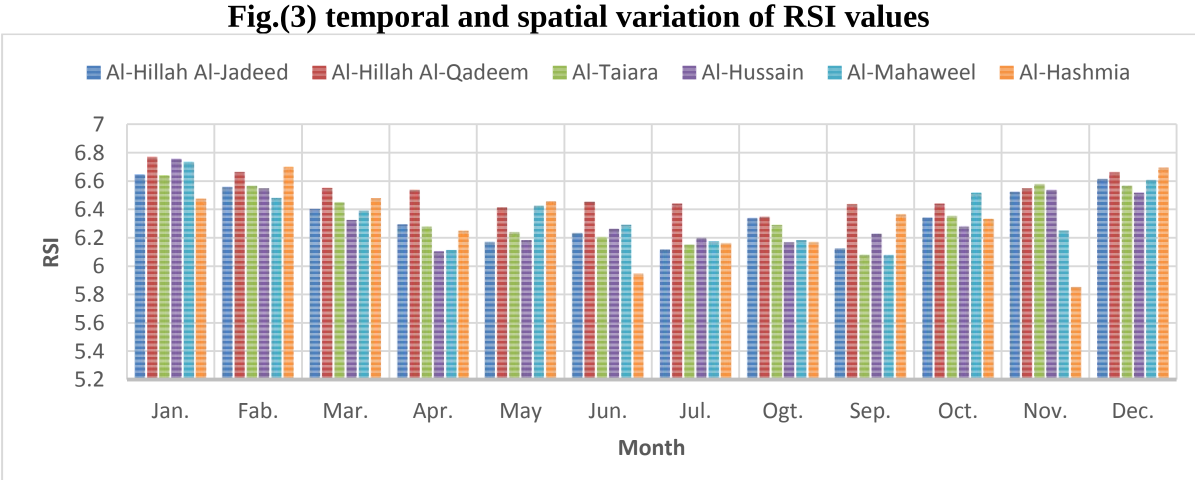

Fig.(4) average monthly RSI values for the stations during the period (2009-2013)

Average annually and monthly PSI results showed the water is moderately with values ranged between (6-7) except in months January, February, march , November and

December, PSI values reached (7.2) as presented in figures (5, 6). Aggressive index out comes revealed that the water is moderately corrosive as shown in figures (7,8) for average monthly and annually AI values.

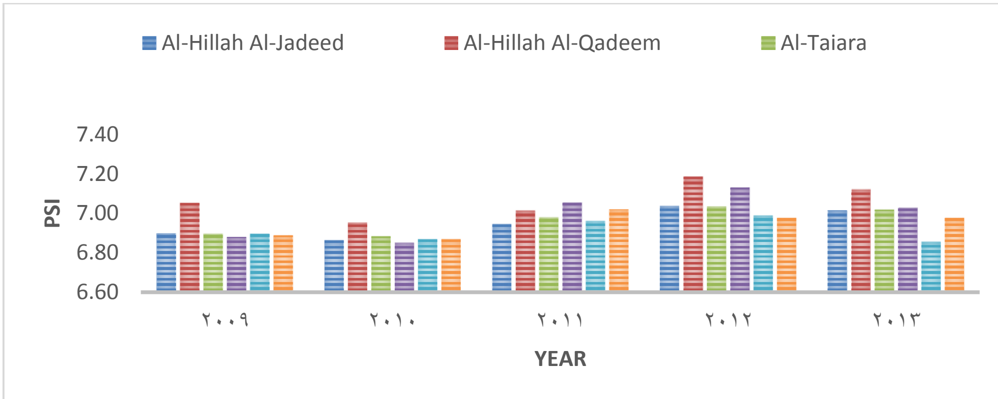

Fig.(5) temporal and spatial variation of PSI values

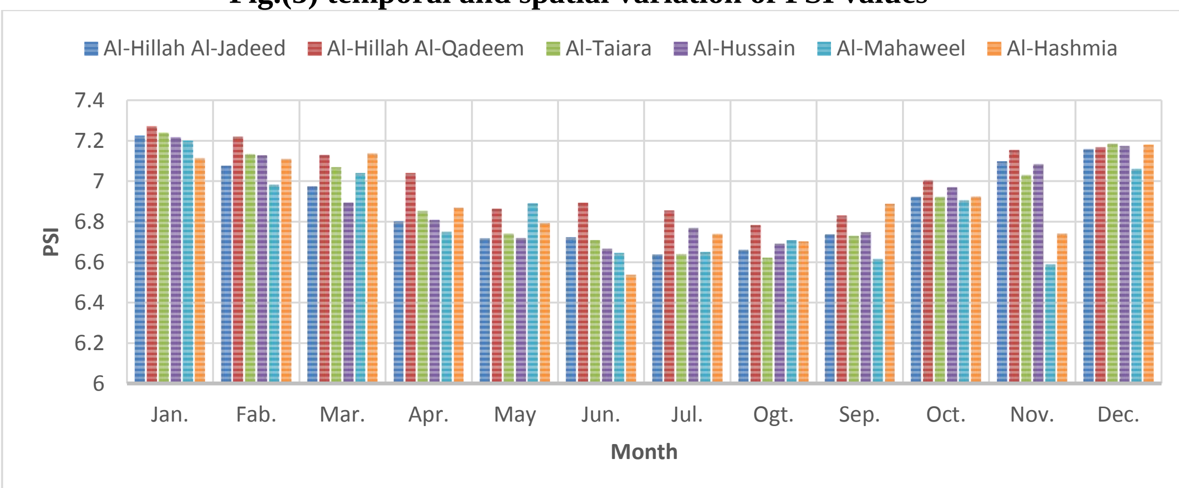

Fig.(6) average monthly PSI values for the stations during the period (2009-2013)

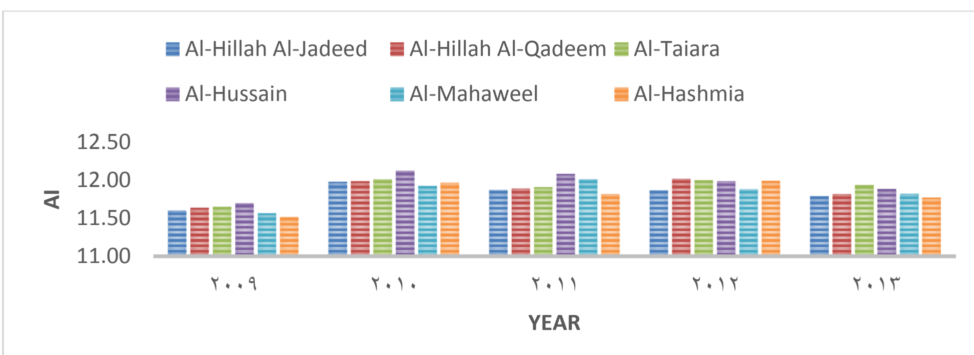

Fig.(7) temporal and spatial variation of AI values

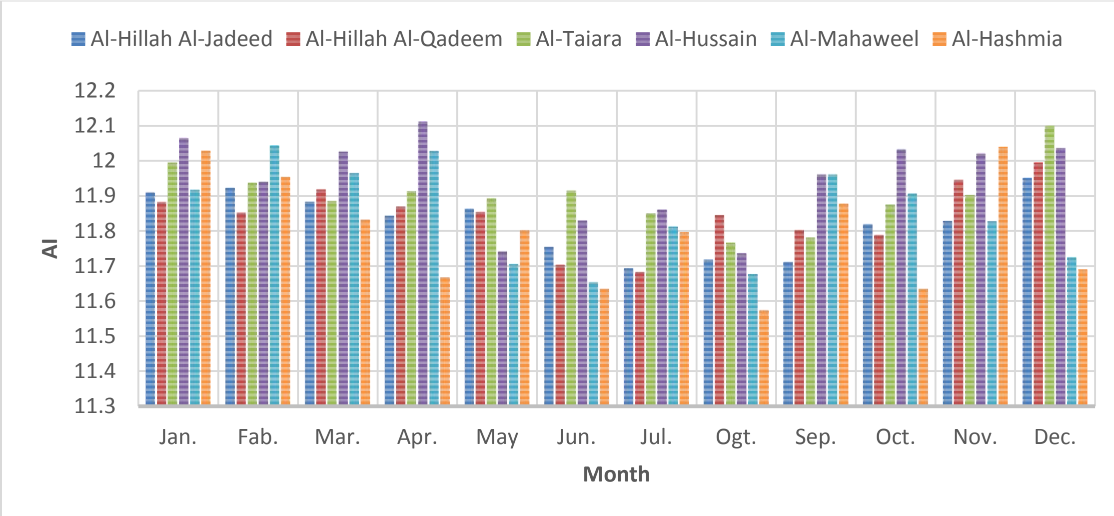

Fig.(8) average monthly ASI values for the stations during the period (2009-2013)

Table (5): the average water stability indices values for the period (2009-2013)

Station	LSI	RSI	PSI	AI
Al-Hillah Al-Jadeed	0.483	6.790	6.9474	11.827
Al-Hillah Al-Qadeem	0.502	6.822	7.0588	11.872
Al-Taiyara	0.561	6.717	6.9558	11.903
Al-Hussain	0.613	6.680	6.9827	11.961
Al-Mahaweel	0.518	6.734	6.9062	11.847
Al-Hashmia	0.506	6.757	6.9405	11.818

5.Conclusions

The results that can be concluded from the present paper and the results summery in table (5) that according to LSI the treated water quality of the all stations was oversaturated with $CaCO_3$during the whole studied period with a potential of forming a protective layer from calcium carbonate. Otherwise, relating to RSI, PSI and AI the water quality was of moderate corrossivity which can be considered not harmful for water distribution systems. All the physiochemical analysis results of the treated water parameters conducted that there were within the Iraqi standards.

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