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Efficiency and Reliability of Reverse Osmosis Desalination Systems

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Abstract

This study is concerned with the evaluation of the effect of Euphrates River water quality in Al-Samawa region during the period 1984-2003 on efficiency and reliability of reverse osmosis desalination systems by calculating the calcium sulfate scaling index depending on the following indicators: - TDS, Ca+2, Mg+2, Na+1, Cl-1, So4-2, HCO3-1. It was found from data analysis that this index for these units is greater than permissible limit. Also, the fitted relationship between this index and TDS is logarithmic, i.e. this index varies more rapidly than TDS, and consequently it is more representative to the water quality than TDS.

***Keywords*:** desalination, reverse osmosis.

Introduction

Water quality control is an important protection issue. The analysis of the existing water quality parameters and trend of their change is useful for making quantitative decision, such as whether water quality is improving or getting worse over the time. These decisions are important in planning of water pollution control program.

Many studies concerned with quality of Iraqi's river water had been done. Jehad, 1984 carried out a study on the effects of Tharthar canal salty water on the quality of the Euphrates water. Saleh, 1989 carried out a study on the operation rules for Euphrates river system. Nasser, 2001 carried out a study about the variation of salinity indication parameters of Tigris River in Baghdad city. Al-Tikriti, 2001 carried out a study on the reduction in water resources of Euphrates River in Iraq due to the water storage strategies adopted by Turkey and Syria in the last years. The study concluded that this reduction indeed affects the water quality in this river. The study predicted that further decreasing of the flow average from 100-200 m^3/sec to 50-100 m^3/sec for Euphrates River will result in general increase in the concentrations of the hydrochemical parameters. The maximum percentage increase in these concentrations may be 4.31% for TDS and 27.9% for So_4 which indicates that the rate of increase of So_4 concentration will be greater than of TDS. The study indicated that the middle Euphrates is the most critical area from environmental point of view. Specially, this region extends from down Hindiya barrage to Al-Samawa city. This is because this area was suffering from low water quality because of high agricultural density. Moreover, the river has many tributaries and many drains which flow into the river directly.

To increase the efficiency and life of a reverse osmosis system, effective pretreatment of the feed water is required. Selection of the proper pretreatment will maximize efficiency and membrane life by minimizing: Fouling, Scaling and Membrane degradation. Fouling will refer to the entrapment of particulates such as iron floc or silt, whereas Scaling will refer to the precipitation and deposition within the system of sparingly soluble salts such as calcium sulfate ($CaSO_4$) (Technical Manual, 1995).

Demineralizing process, preceded by a reverse osmosis desalination units is the common practice in all electric power stations and industries demineralize water using Euphrates River water (Musaib and Nassiriya electric power station). Studies (Jehad, 1984; Saleh, 1989 & Al-Tikriti, 2001) give evidence about exceeding maximum permissible level of dissolved solid for drinking water governed by World Health Origination

(WHO) standards in most parts of Euphrates River basin. This initiates the necessity of desalination of river water for drinking purpose using reverse osmosis unit on a large scale in the future, similar to the status in Basrah city.

In the reverse osmosis process, water flow selectively out of a concentrated salt solution, diffuses through a semi permeable membrane into a dilute solution. The limiting factor of efficiency and life of a reverse osmosis system is mostly of a chemical nature, i.e. precipitation and scale formation by calcium carbonate or sulfate. Scaling of a reverse osmosis membrane may occur when sparingly soluble salts are concentrated within the element beyond their solubility limit. Therefore, the risk of the scaling increases with increasing feed concentration of sparingly soluble salts (Editors of Power, 1967).

Two feed water quality indexes measure the scaling potential in reverse osmosis system. Firstly, Langelier Saturation Index (LSI) measures the tendency of calcium carbonate to precipitate from water under given conditions of calcium hardness, alkalinity, pH, temperature and total dissolved solid (Technical Manual, 1995 & ASTMD 3739-88). Calcium carbonate scaling prevention can be controlled by acid addition alone so that the (LSI) in the concentrate stream must be negative (Technical Manual, 1995). So that calcium carbonate scaling prevention can be achieved easily. Secondly, Quality Index is the ratio of ionic product for $CaSO_4$ in the concentrate stream (IPc) to the solubility of product (Ksp) in the concentrate stream. There is potential of scaling with $CaSO_4$, when this index is grater than 0.8. However, this index could be 1.5 if sodium hexameta-phosphate is used as scale inhibitor (Tech. Manual, 1995 & ASTM D4692-87).

When the salinity of feed water to the reverse osmosis system is very high (for example, TDS for brackish water ranged between 5000ppm to 15000ppm and TDS for sea water in the range of 35000ppm), the LSI and $CaSO_4$ scaling index is beyond adjustable limit using acid and scale inhibitor, strong acid cation exchange resin softening, weak acid cation exchange resin dealkalization or lime softening with lime or lime plus soda ash will be a must. This will increase the complexity, cost and reliability of the desalination system, so that the reliability of industrial, power generation, and drinking water system they serve (Tech. Manual, 1995).

The aims of the present study are: evaluating the calcium sulfate scaling index for a representative chemical analysis of Euphrates water at selected region for a period (1984-2003), evaluating the trend of change of this index, correlating this index with TDS values and evaluating the potential risk increase on efficiency and reliability of reverse osmosis units using Euphrates water as feed water.

Study Area

Quality of Euphrates River water near Al-Samawa region was selected to represent the quality status of the river in this region and beyond to the south. The study area is characterized by densely agriculture activities, to the north of this area, drainage systems are being with all their pollutants disposed to Euphrates river, so as waste disposal from many towns to Euphrates river directly as shown in Fig.(1). The concentration of dissolved solid increased far beyond upper permissible limit that subjected by WHO standard as in Fig.(2). So, desalination of water using reverse osmosis process is necessary and, consequently, scaling risk increased also.

Fig.(1):Study area.

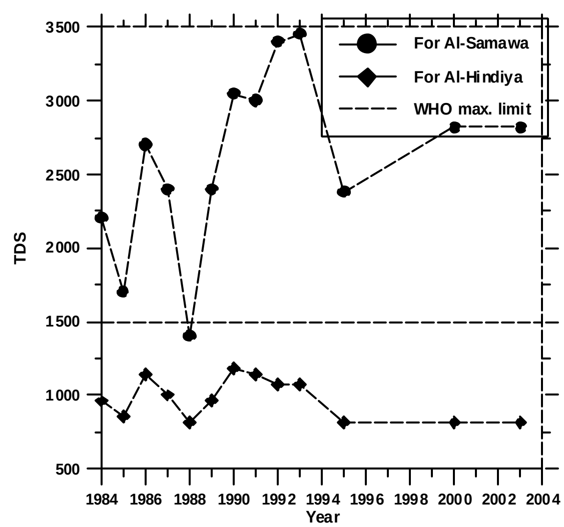

Fig.(2):Variation of total dissolved solid versus time (Al-Tikriti, 2001 and Ministry of Water Resources).

Procedure

The annual mean of hydrochemical parameters at Al-Samawa region are taken from reference (Al-Tikriti 2001) for period 1984-2000 and also from the General State of Dams and Reservoirs/Ministry of Water Resources for year 2003. These parameters include (TDS, Ca^{+2}, Mg^{+2}, Cl^{-1}, So_4^{-2}) concentrations are shown in Table(1). Records are extended from 1984 to 2003 which are considered to be both sufficient and representative to the trend of hydrochemical parameters. Na^{+1} and HCO_3^{-1} concentrations were calculated based on total dissolved solid (TDS) and the equality of summation of equivalent weights of cations with that of anions.

For the determination of the calcium sulfate scaling index (Technical Manual, 1995), (IP_c/K_{sp}) for each year based on data in Table(1). Where IPc is ion product for $CaSo_4$ in concentrate stream and K_{sp} is solubility product.

a) Calculate the ionic strength of the concentrate stream (I_c).

$$I_c = I_f \times \frac{1}{1-Y} \quad (1)$$

Where:

- Y is recovery of the reverse osmosis system which is taken to be 0.75 as a usual value implemented in reverse osmosis system (Technical Manual, 1995).

- I_f is the ionic strength of the feed water which is

$$I_f = \frac{1}{2}\sum (m_i \times Z_i^2) \quad (2)$$

Where: -

- m_i = molal concentration of ion (i) in (mole/kg).
- Z_i = ionic charge of ion (i).

b) Calculate the ion product (IP_c) for $CaSo_4$ in concentrate stream.

$$IP_c = \left[\left({}^{m}Ca^{+2}\right)_f \times \frac{1}{1-Y}\right]\left[\left({}^{m}So_4^{-2}\right)_f \times \frac{1}{1-Y}\right] \quad (3)$$

Where:-

- $({}^{m}Ca^{+2})_f = mCa^{+2}$ in feed,(mole/l).
- $({}^{m}So_4^{-2})_f = mSo_4^{-2}$ in feed, (mole/l).

c) By using calculated ionic strength of the concentrate stream (I_c) from Eq.(3) and Fig.(3), the solubility product (K_{sp}) for $CaSo_4$ in the concentrate stream can be specified. If $IP_c = K_{sp}$, $CaSo_4$ scaling can occur, and adjustment is required. For a safe and conservative pretreatment design, adjustment should be made if $IPc = 0.8K_{sp}$ (Technical Manual, 1995).

Table(1):The annual mean of hydrochemical parameters at Al-Samawa region (Al-Tikriti, 2001 and Ministry of Water Resources)**.

Year	TDS mg/l	Ca^{+2} mg/l	Mg^{+2} mg/l	Na^{+1}* mg/l	Cl^{-1} mg/l	So_4^{-2} mg/l	HCO_3^{-1}* mg/l
1984	2200	195	120	366	560	900	59
1985	1700	160	105	232	330	700	173
1986	2700	240	150	431	700	900	279
1987	2400	230	130	350	500	850	340
1988	1400	150	90	145	200	500	315
1989	2400	260	160	244	400	800	536
1990	3050	240	160	538	800	1000	312
1991	3000	240	160	513	800	850	437
1992	3400	300	240	461	800	1350	244
1993	3450	340	200	478	800	1100	532
1995	2377	251	126	317	465	811	407
2000	2820	155	135	603	754	1035	138
2003	2820	155	135	603	754	1035	138

* calculated

** These data, as mentioned in (Al-Tikriti, 2001), are represented the arithmetic mean of 12 readings during the year, i.e. one reading for each parameter during the month, at control locations. These locations are Al-Hindiya barrage and upstream of Al-Samawa region. Although the monthly value for each hydrochemical parameter during the 2000 differ from corresponding value during 2003, but the annual mean of these parameters are remained constant for years 2000 and 2003 as shown in Table(1).

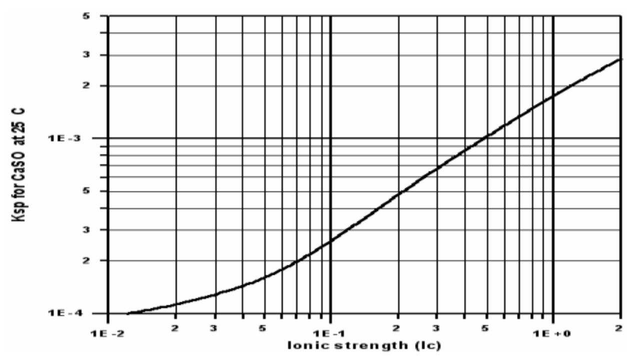

Fig.(3): Ksp for $CaSO_4$ versus Ionic Strength (Technical Manual, 1995).

Results and Discussion

By using the procedure described in previous section, values of calcium sulfate scaling index (IP_c/K_{sp}) are calculated for Euphrates River at Al-Samawa region for the period (1984-2003) as shown in Fig.(4). These values were exceeded the upper permissible limit which is equal to (1.5) for scaling prevention of reverse osmosis system. This index reached the maximum value of (2.18) in 1992, whereas it reached minimum value of (1.13) in 2000. However, this low value is due to reduction in total dissolved solid and calcium ions concentration in the river because increasing the flow rate of the river and reducing the supply of river with water stored in Al-Tharthar depression. According to Fig.(2), the total dissolved solid (TDS) increases from Al-Hindiya region toward Al-Samawa city and, consequently, it is will increase beyond the Al-Samawa city until Basrah city passing through Nassiriya region and other regions. This increment will lead to increase the values of calcium sulfate scaling index (IP_c/k_{sp}) and consequently the reverse osmosis system used for desalination of water for drinking or industrial purpose will suffer from potential risk of scaling.

Also, the fitted relationship between calcium sulfate scaling index with TDS is logarithmic as shown in Fig.(5) “this fit is achieved by GRAPHER Version 1.09”. This means that this index varies more rapidly than TDS and consequently it is more representative to the water quality than TDS.

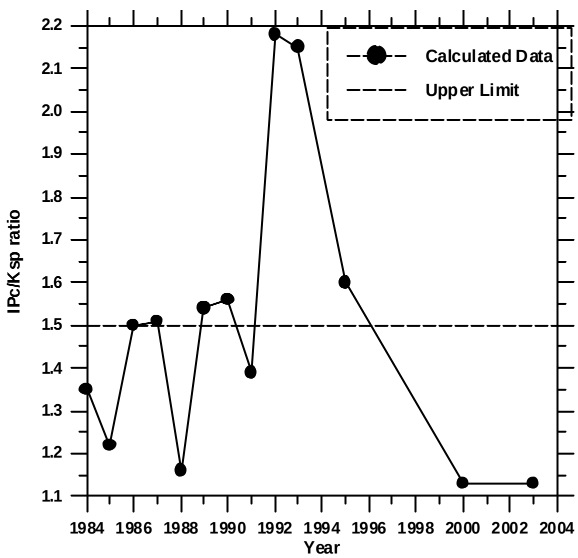

Fig.(4):Variation of calcium sulfate index versus time for Al-Samawa region

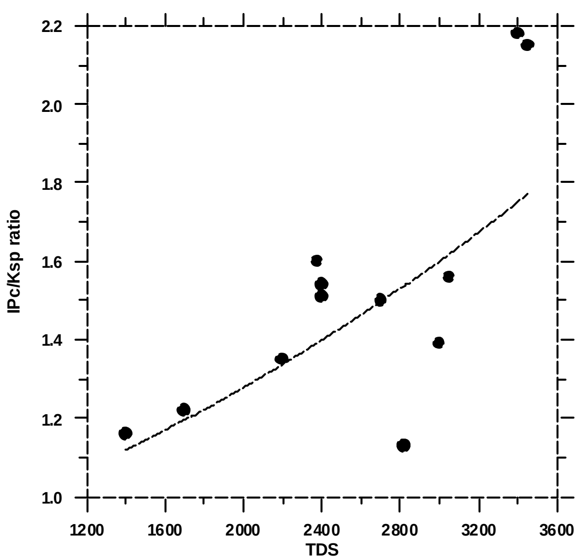

Fig.(5):Variation of calcium sulfate index versus total dissolved solid for Al-Samawa region

Conclusions

1. Calcium sulfate scaling index (IP_c/K_{ps}) of Euphrates water in the study area exceeds the upper limit for scaling prevention of reverse osmosis system during the study period. It reached maximum value of 2.18 in 1992.

2. The reason of reduction of value of scaling index to lower limit in year 2000 was due to reduction in TDS and calcium ions concentration in the river because increasing the flow rate of the river and reducing the supply of river with water stored in Al-Tharthar depression.

3. The calcium sulfate scaling index has more sense for water quality than that of TDS.

References

1. Jehad, A.K., µEffect of Tharthar Canal Salty Water on the Quality of Euphrates Water¶, M.Sc. Thesis, University of Tech., 1984.
2. Saleh,W.M.,µOperation Rules for Euphrates River System¶, M.Sc. Thesis, Collage of Eng., Uni. of Baghdad, 1989.
3. Nasser, N.O., µVariation of Salinity Indication Parameters of Tigris River in Baghdad City (1990-1999)¶, M.Sc. Thesis, Collage of Eng., Uni. of Baghdad, 2001.
4. Al-Tikriti, H.N.,µForecasting of Pollution Levels in Accordance with Discharge Reduction in Selected Area on Euphrates River¶, M.Sc. Thesis, Callege of Eng., Uni. of Baghadad.2001.
5. Twort, A.C., Law, F.M., and Crowley, F.W., µWater Supply¶, Edwarad Arnold, 1974.
6. Editors of Power, µPower Generation System¶, McGraw- Hill, 1967.
7. µFILMTEC Membrane Elements¶, Technical Manual, Dow chemical company, 1995.
8. ASTM D3739-88, µStandard Practice for Calculation and Adjustment of the Langelier Saturation Index for Reverse Osmosis¶, 1988.
9. ASTM D4692-87, µStandard Practice for Calculation and Adjustment of Sulfate Scaling Salts ($CaSo_4$, SrS_4 and B_4So_4) for Reverse Osmosis¶, 1987.
10. Larsson, E., and J. Persson “Viability of Membrane Bioreactor Technology as an Advanced Pretreatment for Onsite Wastewater Treatment”, M.Sc. Thesis, Lulea University of Technology, etda. Libraries, 2004.