International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Comparison between Two Chemicals for Reducing Scale Formation in Reverse Osmosis Systems

Najwa S. Majeed[1], Ramzi Ata Abd Alsaheb[2], Zahraa A. Abdul Ameer[3]

[1]Chemical Engineering Department, College of Engineering, University of Baghdad-Iraq

[2]Biochemical Engineering Department, Al-khwarizmi College of Engineering, University of Baghdad

[3]Chemical Engineering Department, College of Engineering, University of Baghdad-Iraq

Abstract: ***In this present research was transacted with the calcium carbonate scale inhibition on the membrane surface of the reverse osmosis desalination system. Influence of changing feed solution flow rate (10-25)l/h, pH of the feed solution (6-10) on the recovery ,penetrate flow rate and total dissolved solid in (RO) system by using solution of calcium carbonate as feed solution was investigated, furthermore the effect of adding two types of scale inhibitor ,zinc chloride and polyamino polyether methylene phosphonate with difference concentration (2-8)mg/l for zinc chloride and (8-15) mg/l for polyamino polyether methylene phosphonate was calculated. The results showed that the permeate rate increases as the feed flow rate augmentation ,while it reducing with time, the total dissolved solids decreases as the feed flow rate increases while it increases with time and recovery rate decreases as the feed flow rate increases and it also decreases with time. It was concluded that the permeate rate decreases as the feed solution pH value increases and it cause high scale forming thus decrease the permeate TDS.By adding the scale inhibitor, it was found that the permeate rate and recovery rates increases as the concentration of inhibitor increases while the total dissolved solids decreases in the permeate with increasing the concentration of both inhibitors .It was discovered that Polyamino polyether methylene phosphonate more sturdy than zinc chloride as scale inhibitor for reverse osmosis desalination system in all concentrations was studied in this article.***

Keywords: Scale-formation, Reverse osmosis, $CaCO_3$ inhibition, Zinc chloride

1. Introduction

In recent last years, pressure driven membrane processes have been utilized in enormous range of fields, such as chemical, medical, textile, petrochemical, electrochemical, water treatment, biotechnology and environmental industries. Especially, reverse osmosis (RO) operations are vastly applied for desalination applications. RO is section of a fast growing market as the request for clean fresh water around the world continues to growing. RO membrane modules are typically structured as spiral-wound systems, consisting of multiple layers of membrane sandwiches separated by spacer sheets and coiled around a central perforated tube. RO provides several advantages among other separation technologies that includes high effectiveness of the membranes in selective metal rejection, high permeability to the water, reduced production costs, fulfillment of the most stringent regulations for public health, environment protection and separation process at room temperature [1].

The reverse osmosis membrane execution in wastewater recuperation is regularly restricted by layer fouling. The nearness of suspended solids, colloidal issue, natural issue and abnormal state of organic exercises in auxiliary emanating (SE) are the primary difficulties in anticipating and controlling fouling amid application. Layer fouling has been the real test to the better operation of the film forms [2].

The reverse osmosis membrane, fouling issues which are a collection of undesirable material at interfaces, is regularly showed in an expansion in operational expenses, fundamentally identified with expanded vitality request, extra work for upkeep, synthetic cleaning, and decreases in membrane life expectancy [3]. The accumulated foul ants on the RO membrane can be categorized into four groups:

Crystalline fouling such as mineral deposition.

a) Organic fouling such as the deposition of the organic matter.
b) Particle and colloidal fouling such as the deposition of clay and slit.

Microbiological fouling which includes the grip and resulting development of microorganisms on the membrane. The initial three sorts of fouling can be controlled by diminishing the grouping of the foulants in the RO sustain water. In correlation, bio fouling control is an a great deal more confused process. Notwithstanding decreasing the grouping of the current microorganisms in the RO sustain water, bio fouling control requires extra endeavors spoken to by keeping up legitimate observing methodologies and controlling the components influencing biofilm advancements, for example, supplement focus and the physio-synthetic cooperation amongst microorganisms and film surface [4].

Film fouling is regularly controlled either by working the framework inside the basic flux go or including chemicals (particularly to avert inorganic scaling and fouling), and/or by pretreatment. Pretreatment is developing as the most encouraging answer for control the fouling as it is basic and simple to execute [5].

The term 'membrane scaling' is regularly utilized when the accelerate shaped is a hard scale on the surface of the membrane. Scaling for the most part alludes to the development of stores of reverse dissolvability salts, for example, CaCO3, CaSO4•xH2O, silica, and calcium phosphate. [6].

Inorganic scales happen when centralizations of sparingly solvent salts , i.e. divalent particles , surpass their solvency limit. Inorganic salts which are the no doubt reasons for scaling are Ca+2, Mg+2, CO3-2, SO4-2, silica and iron. The normal scale sorts are Ca-phosphate, CaCO3, CaSO4, SiO2 and CaF. CaCO3 accelerates have been the most plausible foulants for seawater and wastewater reuse application [7].

Scaling up, for example, CaCO3 and CaSO4 may prompt physical harm of the membrane because of the trouble of scale expulsion and to irreversible pore stopping. Hence, alleviation of scaling is a critical thought in the operation of most RO forms. The potential for CaCO3 scaling exists in a wide range of nourish water, including great, surface or saline waters. Calcium carbonate shapes an overwhelming, very disciple scale and its precipitation in RO plant must be avoided [8]. It is by a wide margin the most well-known scaling species in a few frameworks, including cooling water establishments and oil or gas generation systems. In RO frameworks it appears that the most noteworthy danger of CaCO3 scaling (as with some other inorganic salt) exists in the amass stream at the last segment of the membrane suit. [9, 10].

A standout amongst the most well-known connected pretreatment techniques to avert or control the scaling of various salts in bolster water is to include scale inhibitors. The productivity of an inhibitor is impacted by many factors, for example, its substance plan, its focus, super saturation level of the insoluble salts, and the pH estimation of the encourage water. Some of them are polymeric, inorganic or natural substances being able to be ingested on the surface of the framed crystallites, keeping their bond and development into minimal layers. [11].

Scale inhibitors can be isolated into the accompanying three sorts relying upon their instrument of activity: 1) Chelation, a substance that ties the salt-framing cations and keeps their communication with the salt-shaping anions. 2) Threshold inhibitors, the expansion of which to the arrangement keeps the start and development of salt gems. 3) The third kind of scale inhibitors is a crystallographic pulverizing inhibitor, which does not keep the crystallization of salts, but rather just adjusts the state of the precious stones [12].

This investigation was to discover the framework propensity for scale arrangement at various flow rate esteems and distinctive portrayal of water (at various pH) and how to tackle the scale issue at these conditions, at that point consider two sorts of the restraint materials to be utilized as scale inhibitor in turn around osmosis frameworks.

2. Experimental Work

2.1 System Units

An encourage tank with two weight pumps (high and low weight) was utilized with a rotameter, a pressure gage and a valve at the waste water stream to control the RO framework pressure.

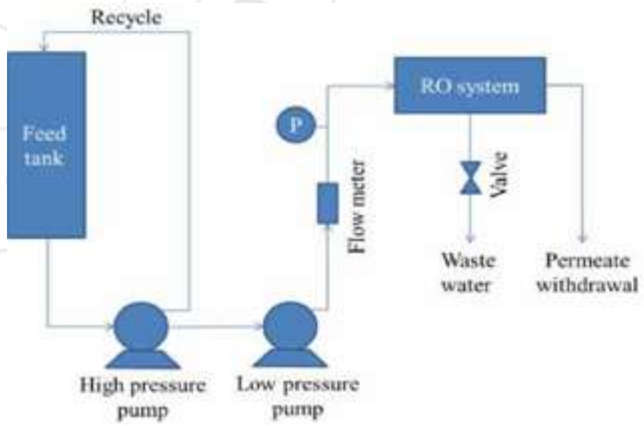
2.2 Feed Solution

Arrangement having an affinity for CaCO3 precipitation was set up in a 100 l l feed solution tank with refined water by dissolving 610 mg/l of CaC12, 511 mg/l of NaHCO3 and 49 mg/l of MgSO4. A coveted super immersion capability of CaCO3 was balanced via cautious expansion of HCl or NaOH arrangement as required to the coveted pH level. Examinations were made by changing the sustain stream rate in the scope of 10 – 25 l/h, the nourish pH in the scope of 6 – 10 and a steady weight of 3 bars without the utilization of hostile to scalants. Tests were rehashed by utilizing a 2, 4 and 8 mg/l arrangement of zinc chloride inhibitor, at that point utilize 8 and 15 mg/l arrangement of Polyamino polyether methylene phosphonate (PAPEMP) inhibitor and compare about the outcomes.

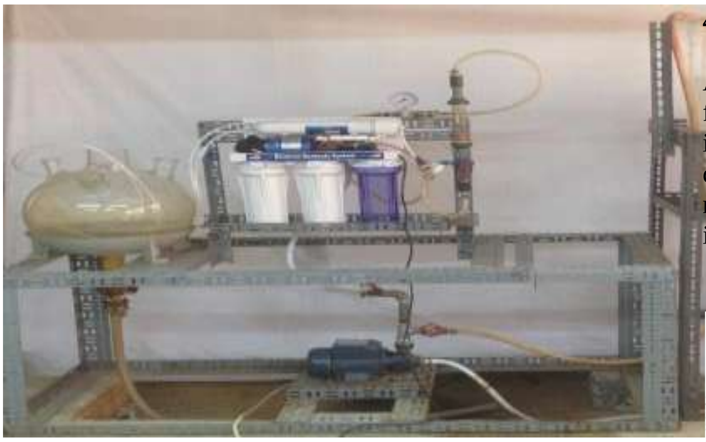
2.3 Reagents

1) Calcium chloride $CaCl_2$, Sodium bicarbonate $NaHCO_3$ and Magnesium sulfate $MgSO_4$ were used to prepare the feed solution.
2) Zinc chloride and Polyamino polyether Methylene phosphonate (PAPEMP) were used as inhibitors.
3) Nitric acid HNO_3 and sodium hydroxide NaOH were used to adjust the pH level of the feed solution.

Reverse osmosis apparatus
Examinations were directed in a constant stream Spiral RO system which comprised of 100 l feed arrangement stockpiling tank, a weight pump, weight and stream measuring and control gadgets and a winding membrane as appeared in Fig. (1)



Schematic diagram of the RO system



RO experimental system
Figure 1: RO experimental system

The spiral membrane system could be operated at pressure of 3 bars providing a feed flow rate in the range of 10 – 25 l/h. The feed solution temperature was held constant at about 40°C.The experimental system enabled the permeate withdrawal (PW) mode in which permeate was withdrawn from the system leading to continuous concentration of the recycling solution which eventually led to bulk precipitation.

3. Experimental Procedure

After preparing the feed solution in the feed tank, the high pressure pump should be operated. A recycle pipe carrying the solution back to the tank will mix the solution and make it homogenous. pH value can be measured using a pH meter device and it should be in the range of 6 – 10 by using doses of NaOH or HCl as needed until reaching the desired value. Turn on the low pressure pump and allow the solution to enter the device after making the pressure gauge at 3 bars by controlling it using a valve in the concentrate water pipe and measure the flow rate of the solution by using a flow meter. The permeate withdrawal will be produced as well as the waste water. After every 15 minutes, a sample of both exit streams should be taken in order to estimate the pH level and the total dissolved solids (TDS). Then the whole system should be cleaned and prepared for the next stage.
Zinc chloride was used in this process by preparing the same feed solution and adding a 2, 4 and 8 mg/l of Zinc chloride at a time to the solution and repeats the same procedure again. Polyamino polyether methylene phosphonate (PAPEMP) have also been used as an anti-scalant with a concentration of 8 and 15 mg/l by repeating the same procedure with Zinc chloride again in order to show the inhibition effects of these two inhibitors.

4. Results and Discussion

Permeate flux is the key performance parameter of reverse osmosis process. Under specific reference condition, flux is an intrinsic property of membrane performance. The flux of a membrane system is mainly influenced by variable parameters including:
i) Feed flowrate.
ii) pH of the feed solution.
iii) Inhibitor concentration.
These factors each effect the performing of the system.

4.1Effect of feed flow rate on permeate rate:

As shown in Fig. (2), It was clear that increasing the feed flow rate in the range of (10 – 25 l/h), the permeate rate will increase while it decreases with time. This suggests decreasing resistance to flow rate by the scales formed at the membrane surface with increasing feed flow rate. An identical trend was observed by other investigation [13].

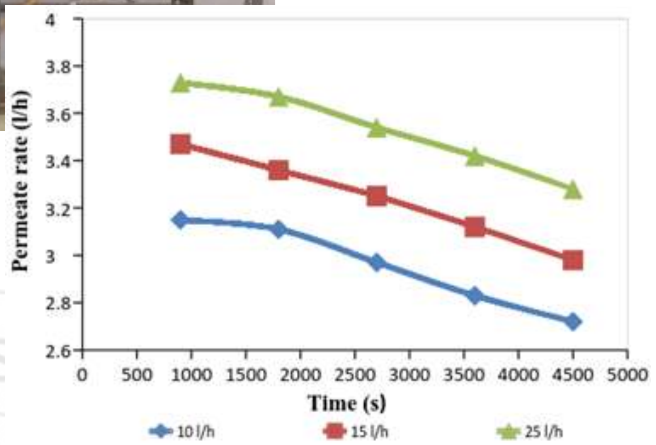


Figure 2: The relation between permeate rate and time at different feed flow rates. (pH = 8, Pressure = 3 bars, Temperature = 40 °C)

4.2 Effect of feed flow rate on permeates TDS:

As shown in Fig. (3), It was clear that the permeate TDS will decrease as the feed flow rate increases in the range of (10 – 25 l/h). As the feed flow rate increases, the concentration of the chemical materials dissolved in the feed solution at the surface of the membrane become greater than the concentration in the permeate side and that leads to a higher TDS before the membrane than the TDS in the permeate side. An identical trend was observed by other investigation [14].

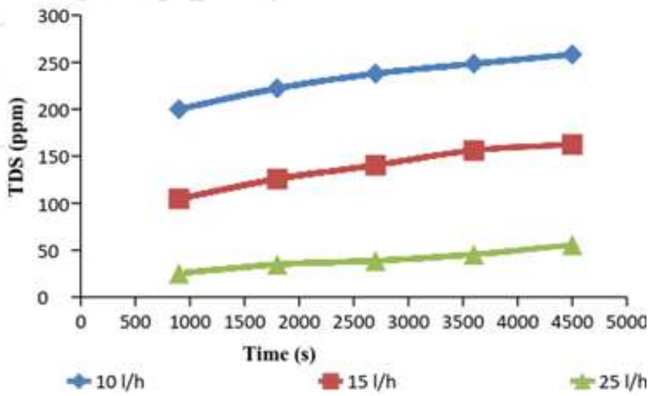


Figure 3: The relation between Total dissolved solids (TDS) with time at different feed flow rates. (pH = 8, Pressure = 3 bars, Temperature = 40 °C)

4.3 Effect of feed flow rate on recovery rate

As shown in Fig. (4), it was clear that the recovery rate decreases with time and it also decreases as the feed flow rate increases.

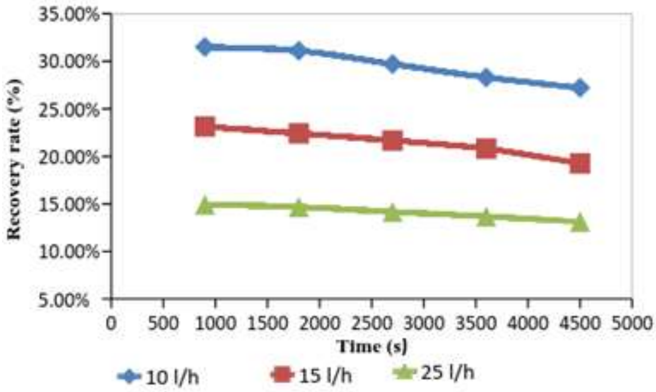


Figure 4: The relation between recovery rate and time at different feed flow rate. (pH = 8, Pressure = 3 bars, Temperature = 40 °C)

4.4 Effect of feed solution pH value on Permeate rate:

As shown in Fig. (5), It was clear that the permeate rate decreases as the pH value increases. The solubility of the chemical materials in the feed solution decreases as the pH value increases and that leads to an accumulation of the suspended solids on the membrane surface which resists the feed flow rate and decrease the permeate rate and that leads to a decrease in the recovery rate.

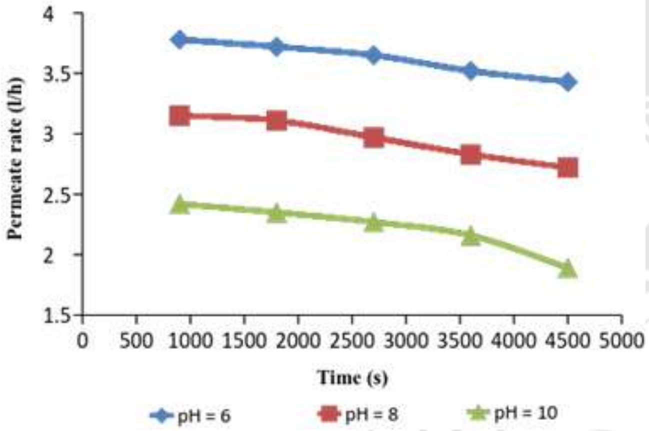


Figure 5: The relation between permeate rate and time at different pH values. (Feed flow rate = 10 l/h, Pressure = 3 bars, Temperature = 40 °C)

4.5 Effect of feed solution pH value on permeates TDS

As shown in Fig. (6), it was clear that increasing the feed solution pH value leads to an increase in Saturation Index (LSI) which gives an indication of high scale forming tendency. The increased scale deposited on the surface of the membrane will lead to a decrease in the size of the membrane holes and this causes a lack of salts transmitted through the membrane and thus decrease the permeate TDS.

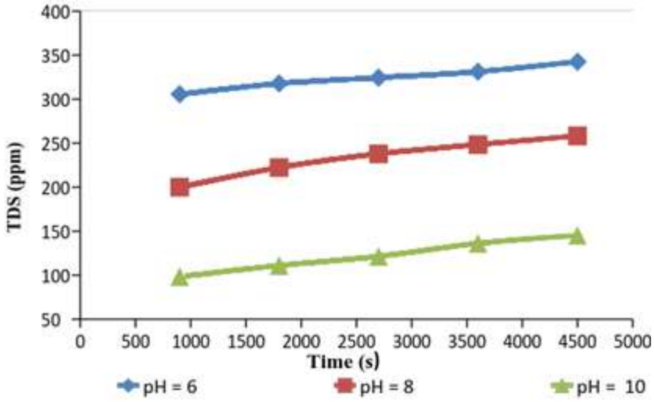


Figure 6: The relation between TDS and time at different pH values. (Feed flow rate = 10 l/h, Pressure = 3 bars, Temperature = 40 °C)

4.6 Effect of inhibitor concentration on Permeate rate

There are three stages in the crystallizing process including occurrence and disappearing of unstable phase, occurrence and disappearing of metastable phase, development of stable phase. Without scale inhibitors, metastable phases usually transform into stable phase, thus the main constitute of formed scale is calcite. When scale inhibitors are added, both formation and transformation of metastable phases are inhibited, which results in the occurrence of aragonite and vaterite. From the fact that more vaterite presents in scale with a more efficient scale inhibitor added, it can seen that the function of scale inhibitor is realized mainly by controlling the crystallizing process at the second stage. As shown in Fig. (7) and Fig. (8), it was clear that the use of scale inhibitor will increase the permeate rate because it decreases the scale formation on the RO membrane surface and that leads to a decrease in the scale resistance to the flow rate.

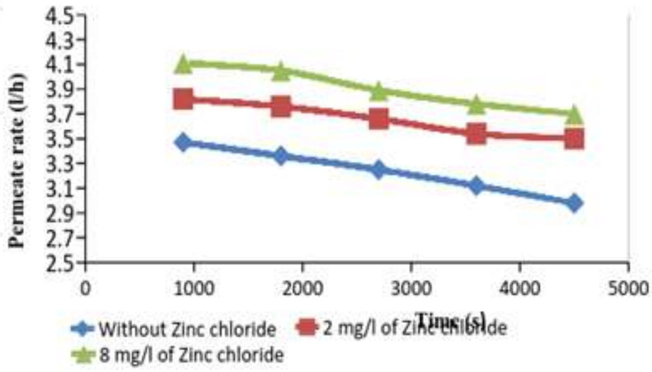


Figure 7: The relation between permeate rate and time with the use of zinc chloride inhibitor. (Feed flow rate = 15 l/h, pH = 8, Pressure = 3 bars, Temperature = 40 °C)

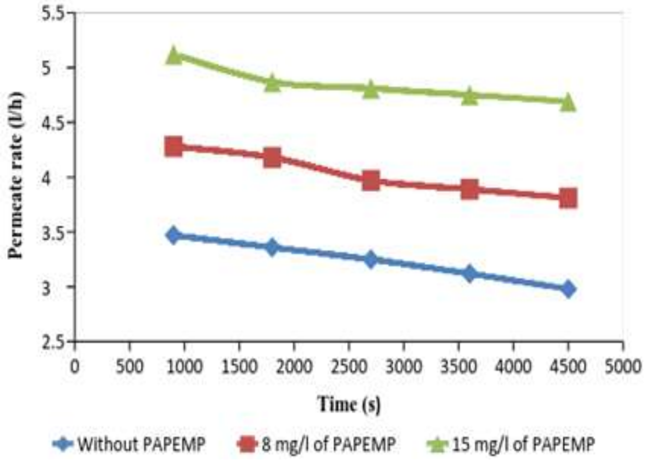


Figure 8: The relation between permeate rate and time with the use of PAPEMP inhibitor. (Feed flow rate = 15 l/h, pH = 8, Pressure = 3 bars, Temperature = 40 °C)

4.7 Effect of inhibitor concentration on permeates TDS

As shown in Fig. (9) and Fig. (10), it was clear that the use of scale inhibitor will decrease the permeate TDS due to its effect on inhibiting scales on the membrane surface.

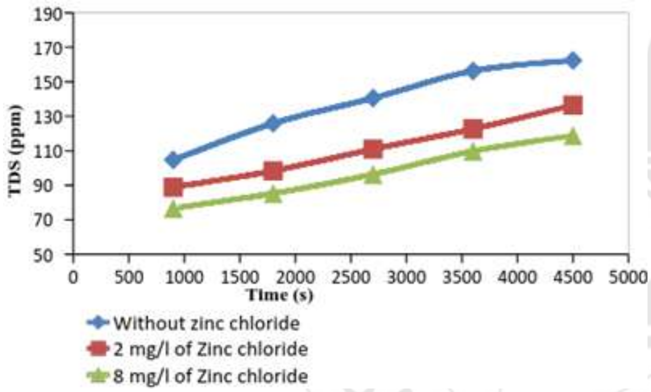


Figure 9: The relation between TDS and time with the use of Zinc chloride inhibitor. (Feed flowrate = 15 l/h, pH = 8, Pressure = 3 bars, Temperature = 40 °C

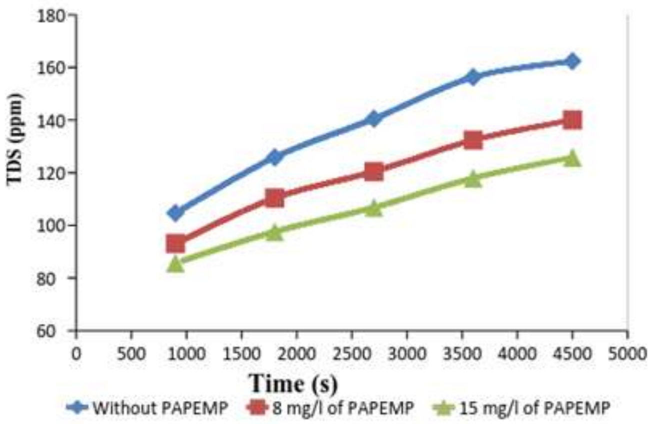


Figure 10: The relation between TDS and time with the use of PAPEMP inhibitor. (Feed flow rate = 15 l/h, pH = 8, Pressure = 3 bars, Temperature = 40 °C)

4.8 Effect of inhibitor concentration on recovery rate:

As shown in Fig. (11) and Fig. (12), it was clear that the use of scale inhibitor will increase the recovery rate due to its effect on increasing the permeate flow rate.

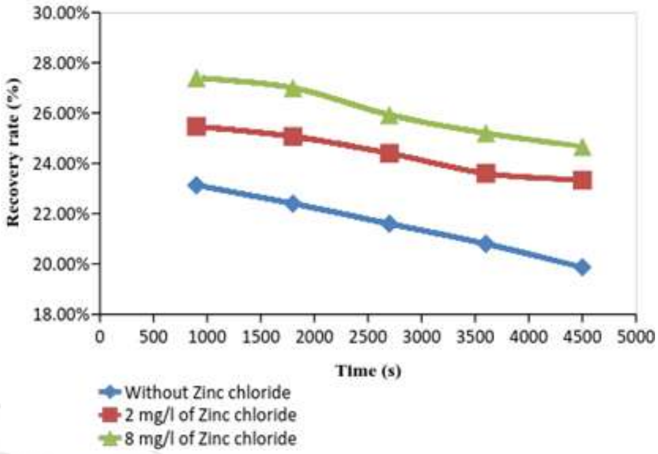


Figure 11: The relation between recovery rate and time with the use of Zinc chloride inhibitor. (Feed flowrate = 15 l/h, pH = 8, Pressure = 3 bars, Temperature = 40 °C)

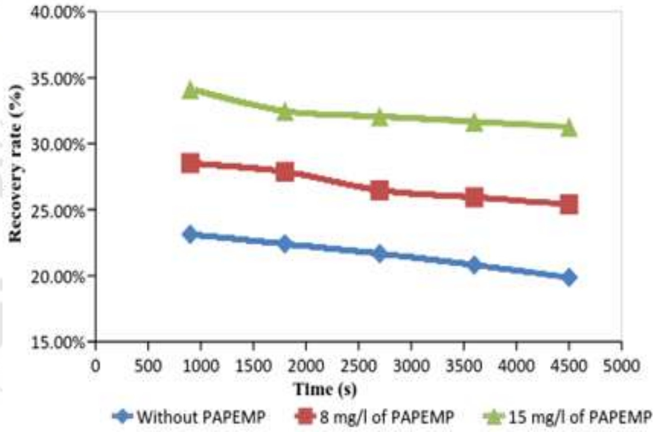


Figure 12: The relation between recovery rate and time with the use of PAPEMP inhibitor. (Feed flow rate = 15 l/h, pH = 8, Pressure = 3 bars, Temperature = 40 °C)

4.9 Effect of inhibitor type on permeate rate

Figure 13 shows the relation between permeate rate and time of different inhibitor types.
From figure 13 it was clear that the permeate rate when PAPEMP inhibitor was used is greater than the permeate rate when zinc chloride inhibitor was used and this means that PAPEMP is more favorable for use as scale inhibitor in RO systems when a higher permeate rate is desired.

Poly amino olyethermethylene phosphonat (PAPEMP) is very effective in preventing calcium carbonate precipitation. The superior performance of PAPEMP has been attributed to its excellent ability to inhibit calcium carbonate crystal growth due to its affinity to the calcium carbonate surface and its excellent calcium tolerance.

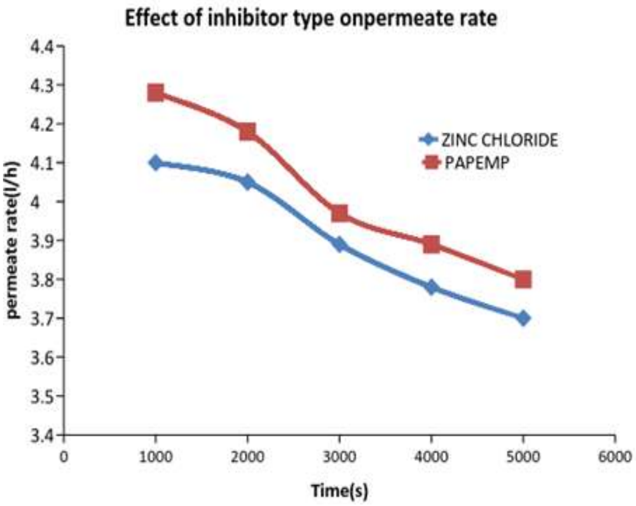


Figure 13: The relation between permeate rate and time using the two types of scale inhibitors (PAPEMP, Zinc Chlorid)

Conclusions

Calcium carbonate restraint utilizing Zinc Chloride and Polyamino Polyether Methylene Phosphonate has been tentatively decided and the accompanying perceptions were made: the first result was Permeate rate increments as the nourish flow rate increments while it diminishes with time, also the Total broke down solids diminishes as the sustain flow rate increments while it increments with time. While notice Permeate rate, recuperation rate and the aggregate broke up solids diminishes as the channel arrangement pH increments. furthermore Permeate rate and recuperation rate increments while the aggregate broke up solids diminishes when Zinc chloride or Polyamino Polyether Methylene Phosphonate was utilized , finally It was discovered through this present study that Polyamino polyether methylene phosphonate more successful than zinc chloride as scale inhibitor of turn around osmosis (RO) system.

References

[1] Vijay Singh, Arijit Das, Chandan Das, G Pugazhenthil, Mekapati Srinivas and Senthilmurugan,(2015), "Fouling and Cleaning Characteristics of Reverse osmosis (RO) Membranes" Chemical Engineering &Process Technology, Volume 6 ,Issue 4.

[2] Santosh R. P., Veeriah J., Kanagaratnam B., Li S., (2012), "Fouling in reverse osmosis (RO) membrane in water recovery from secondary effluent", Rev Environ Sci Biotechnol , 11, 125–145.

[3] N. Pen aa,, S. Gallegoa, F. del Vigoa, S.P. Chestersb(2012)," Evaluating impact of fouling on reverse osmosis membranes performance ", Desalination and Water Treatment, 23–26 April.

[4] Raed A. A., Talal Y., (2012), "Biofouling in RO system: Mechanisms, monitoring and controlling", Desalination, 302, 1–23.

[5] H. K. Shon1, S. Phuntsho1, D. S. Chaudhary1, S. Vigneswaran1, and J. Cho ,(2013)," Nanofiltration for water and wastewater treatment a mini review" Drink. Water Eng. Sci., 6, 47–53.

[6] Ahmed Al-Amoudia,b, Robert W. Lovitt ,(2007)" Fouling strategies and the cleaning system of NF membranes and factors affecting cleaning efficiency" Journal of Membrane Science 303 (2007) 4–28.

[7] Nam Wook Kang, Seockheon Lee, Dooil Kim, Seungkwan Hong and Ji Hyang Kweon,(2011)," Analyses of calcium carbonate scale deposition on four RO membranes under a seawater desalination condition", Water Science & Technology, 64,8.

[8] Robert Y. Ning, Jeffrey P. Netwig,(2002)," Complete elimination of acid injection in reverse osmosis plants", Desalination 143 (2002) 29-34.

[9] Al-Shammiri M. ,Safar M,Al-Dawas(2000)"Evaluation of two different antiscalants in real operation at the Doha research plant"Desalination128(1-16).

[10] Ch. Tzotzi, T. Pahiadaki, S.G. Yiantsios, A.J. Karabelas, N. Andritsos, (2007), "A study of CaCO3 scale formation and inhibition in RO and NF membrane processes", Journal of Membrane Science, 296, 171 – 184.

[11] Azizollah Khormali, Dmitry Gennadievich Petrakov, and Georgy Yuryevich Shcherbakov, (2014)," An In-depth Study of Calcium Carbonate Scale Formation and Inhibition" Iranian Journal of Oil & Gas Science and Technology, Vol. 3, No. 4, pp. 67-77.

[12] HeshengLi.,.WeiLiu,.XijuanQi(2007),"Evaluation of a novel CaSO4 scale inhibitor for a reverse osmosis system",Desalination,Volume 214, Issues 1–3, 15 August 2007, Pages 193-199.

[13] Mattheus F. A. G., Shyam S. S., Salha S. A., Rashid H. A. and Mark Wilf, (2004), "Effect of Feed Temperature and Flow Rate on Permeate Flux in Spiral Wound Reverse Osmosis Systems, Challenges and Opportunities for Engineering Education, Research and Development".

[14] Diego B., (2011), "Factors That Impact RO Filter Performance". Article from Water Quality Products (WQP) magazine.