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Effect of the scale inhibitor on ion content in reverse osmosis system for seawater desalination

Yuhua Gao[1,2], Zhenfa Liu[1,2,*], Lihui Zhang[1,2] and Haihua Li[1,2]

[1] Institute of Energy Resources, Hebei Academy of Sciences, Shijiazhuang 050081, China
[2] Hebei Engineering Research Center for Water Saving in Industry, Shijiazhuang 050081, China

lzf63@sohu.com

Abstract. A scale inhibitor was synthesized from polysuccinimide with 2-aminoethanesulfonic acid and aspartic acid. The effect of scale inhibitor on ion content in reverse osmosis system for seawater desalination was studied. The results showed that the ion content of permeate water is lower with the scale inhibitor added in RO system for seawater desalination than without scale inhibitor. On the contrary, the ion content of concentrate water is higher when with scale inhibitor in RO system.

1. Introduction

The development of seawater desalination technology is an important way to solve the problem of water shortage. Reverse osmosis technology has been widely used in seawater desalination because of its advantages such as low investment, low energy consumption, small footprint, short construction period, simple operation, fast start and operation [1,2]. But membrane fouling has become the most serious problem in reverse osmosis desalination. The main types of membrane fouling are inorganic scale, organic fouling, colloidal fouling, biological fouling, and so on [3,4]. The formation of membrane fouling could cause the decrease of membrane flux, the increase of pressure and the degradation of membrane, which leads to the decrease of the service life, the increase of energy consumption and cost. Because the water is highly concentrated in the reverse osmosis operation process, some insoluble salts such as $CaCO_3$, $CaSO_4$, $MgCO_3$, $MgSO_4$, $Mg(OH)_2$, $BaSO_4$, $SrSO_4$, CaF_2, and so on, which are easily deposited on the reverse osmosis membrane surface. These insoluble salts are the most widely exist in the membrane seawater desalination plants, and they are mainly reason of membrane fouling in reverse osmosis system [5,6]. So it is necessary to control the formation of these insoluble salts. A very efficient method for the prevention of insoluble salts in the film surface scaling is adding a small amount of scale inhibitor in reverse osmosis system. The scale inhibitor can hinder the crystal growth and have dispersion performance, so insoluble salts of reverse osmosis water before deposition on the membrane surface has been discharged with the concentrated water [7,8]. This study demonstrated the effect of the scale inhibitor on ion content in reverse osmosis system for seawater desalination.

2. Experimental

2.1. Synthesis of the scale inhibitor

Synthesis of the scale inhibitor was through two steps. The first step was the synthesis of polysuccinimide, which was carried out in an electric thermostatic drying oven through pyro-condensation of L-aspartic acid monomer at 240 °C for 4 h. The second step was the synthesis of the scale inhibitor, in which polysuccinimide was first suspended in water. Aspartic acid and 2-aminoethanesulfonic acid were dissolved in NaOH solutions (15%), respectively, which were then added to the suspension of polysuccinimide. The reaction was for 24 h at 25 °C and pH 8 - 9. The solid scale inhibitor was obtained through a separation process in which a double volume of absolute alcohol was added to the liquid and the resultant precipitate was rinsed using deionised water and dried at 80 °C for 48 h. The stock solution of the scale inhibitor (30%) was made through dissolving the obtained solid in deionisedwater. The relevant synthetic reaction is expressed in Figure 1 and Figure 2.

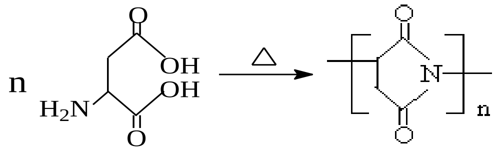

Figure 1. Synthesis route of polysuccinimide

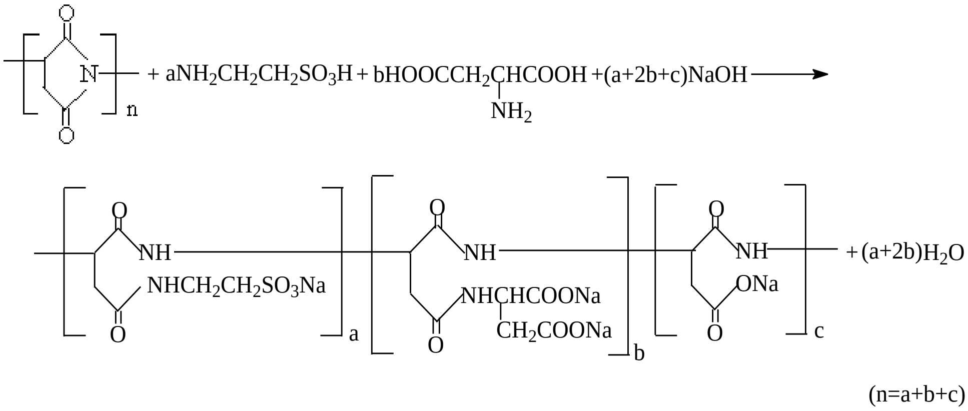

Figure 2. Synthesis route of the scale inhibitor

2.2. Reverse osmosis test for seawater desalination

2.2.1. Operational parameters of reverse osmosis system for seawater desalination. The reverse osmosis test for seawater desalination is carried out in reverse osmosis system (Shandong Sihai Water Treatment Equipment Co., LTD). The reverse osmosis system mainly consists of a quartz sand filtering device, an activated carbon filtering device, a first stage reverse osmosis device, a dosing device, and so on. The operating parameters of the reverse osmosis system for seawater desalination are shown in the table 1.

Table 1. The operating parameters of the reverse osmosis system

System recovery rate	50 %
Feed water conductivity	77800 µs/cm
Feed water flow	860~940 Kg/h
Permeate water flow	430~470 Kg/h
Concentrate water flow	430~470 Kg/h
Membrane pressure	6.8 MPa
Salt removal rate	99.5 %

2.2.2. Feed water quality analysis of reverse osmosis system. The chemical composition of the feed water quality of the reverse osmosis system for seawater desalination is shown in table 2.

Concentration of calcium ion, magnesium ion, chloride ion, total hardness and total alkalinity can be determinated by titrimetric method. Concentration of sulfate ion can be determinated by gravimetric method. Concentration of potassium ion, sodium ion and silica can be determinated by atomic absorption spectrometry.

Table 2. Feed water quality analysis of reverse osmosis system

Ion species	Concentration (mg/L)
Ca^{2+}	889.5
Mg^{2+}	2134.8
Total hardness ($CaCO_3$)	11118.8
Cl^-	18533
Total alkalinity	5377
SO_4^{2-}	2435.4
K^+	75.5
Na^+	6920
SiO_2	0.1
pH	8.04

3. Results and discussion

3.1. Effect of scale inhibitor on ion content of permeate water in RO system for seawater desalination

Table 3. Water quality analysis of permeate water

Ion species	Scale inhibitor dosage (mg/L)				
	0	1	2	3	4
Ca^{2+} (mg/L)	4.4	4.4	4.4	2.2	2.2
Mg^{2+} (mg/L)	18.7	18.7	2.6	2.7	2.7
Total hardness (mg/L)	89.0	88.9	22.2	16.8	16.8
Cl^- (mg/L)	115.2	120.2	115.2	125.2	120.2
SO_4^{2-} (mg/L)	257.6	--	--	--	--
K^+ (mg/L)	1.02	1.01	0.98	0.98	0.95
Na^+ (mg/L)	0.47	0.45	0.44	0.41	0.41
Conductivity (μs/cm)	685	489	420	382	397

Table 3 shows the ion content of permeate water is very low. The ion content is lower with the scale inhibitor added in RO system for seawater desalination than without scale inhibitor. With the increase of the dosage of the scale inhibitor, the ion concentration is getting lower and lower. Especially, sulfate ion content is 0 mg/L when the scale inhibitor is be added. This indicates that the water quality of permeate water is better when the scale inhibitor is added into the RO system.

3.2. Effect of scale inhibitor on ion content of concentrate water in RO system for seawater desalination

Table 4 shows the ion content of concentrate water is very high, and the ion content is higher when with scale inhibitor in RO system. With the increase of the dosage of the scale inhibitor, the ion concentration is getting higher and higher. This is maybe because the presence of the scale inhibitor can chelate metal ions and the subsequent formation of stabilised and soluble chelates and the reduced scale formation.

Table 4. Water quality analysis of concentrate water

Ion species	Scale inhibitor dosage (mg/L)				
	0	1	2	3	4
Ca^{2+} (mg/L)	1333.9	1337.6	1537.6	1794.1	1942.7
Mg^{2+} (mg/L)	2115.7	2132.6	2305.4	2517.6	2585.6
Total hardness (mg/L)	12150	12230	13450	14970	15630
Cl^- (mg/L)	38070	38570	39060	39070	39570
SO_4^{2-} (mg/L)	4963.5	5031.8	5083.2	5129.3	5163.9
K^+ (mg/L)	283.5	291.6	296.4	297.9	299.1
Na^+ (mg/L)	11800	12100	12600	13400	13700
Conductivity (μs/cm)	145400	150200	155400	164200	166600

4. Conclusions

A scale inhibitor was synthesized from polysuccinimide with 2-aminoethanesulfonic acid and aspartic acid. The ion content is lower with the scale inhibitor added in RO system for seawater desalination than without scale inhibitor. With the increase of the dosage of the scale inhibitor, the ion concentration is getting lower and lower. Especially, sulfate ion content is 0 mg/L when the scale inhibitor is be added. On the contrary, the ion content is higher when with scale inhibitor in RO system.

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