Reduction of The Energy Usage of Sea Water Desalination with Electrodialysis Process

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Abstract

Seawater desalination is a real challenging problem for Indonesia wich has large area of sea. In electrodialysis the driving force is the electric power to remove the ions from the raw water to be desalinated. For desalination of seawater with electrodialysis, the energy demand is relatively high,. because the need for electrical power is proportional to the salt content of the water. Other factors which make high energy consumption on electrodialysis process are, high electrical resistance, fouling and concentration polarization. Fouling on ED membranes caused by dissolved organic compounds in the raw water will increase resistance in membrane surface. Concentration polarisation on the surface of the membrane, will cause the electric current used at ED process to increass. The aim of the study is to reduce the energy usage on the desalination with implementation an ED process. Fouling can be reduced by pretreatment of the raw water by ultrafiltration membrane. To minimize the requirement of the electrical energy, limiting current (I_{lim}) is used. The limiting current is the current required to transfer all the available ions.

First, the research was done with a conventional process without using limiting current, as a controlling process. The best results were temperature 30^0C, concentration 35,000 ppm and at rate 5 cm/s, the fresh water 1000 ppm and reduced current 40-50%.

Introduction

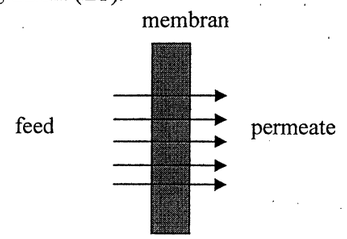
A water source which is quite abundant in areas around a beach is sea water, with it's high salt content which is around 25,000-40,000 ppm. The available salt content reduction process, or desalination, are: by evaporation, distillation, and with membrane process. In desalination with membrane process, there are three methods available: Reverse Osmosis, Membrane Distillation, and Electrodialysis. From several literatures, there are data acquired which say that for low salt content, Electrodialysis is the method which can yield sufficiently efficient and clear products, because Electrodialysis process works based on: the amount of electric current needed which fits the amount of the ion to be moved. The aim of the research to study the mechanism of reduction of energy use in desalination of sea water by Electrodialysis.

Seawater

The TDS of sea water is very high (35,000-50,000 ppm) which depends on location, weather, and whether or not there are pollutants from nearby cities, households, and industries. Some examples of sea water content in several places: normal sea water content is 35,000 ppm, 42,000 ppm in Red Sea, more than 50,000 ppm around Arabic Peninsula (Hartono, 1994), while sea water content of Madura Strait area is 30,000-35,000 ppm.

Overview of membrane technology

Membrane is generally defined as a permeable thin layer which functions as a separator based on it's physical characteristic. Separation process at membrane is essentially a selective displacement of matter which is caused by thrust force associated with determining parameter between two separated medias, such as electric potential difference (ΔE), pressure gradient (ΔP), concentration gradient (ΔC), and temperature gradient (ΔT).



Driving Force : (ΔE), (ΔP) , (ΔC), (ΔT)

Figure 1. Scheme of separation by membranes (Mulder, 1990)

Electrodialysis

Electrodialysis (ED) is an electrochemical separation process by the ions migrate across the anion and cation selective membrane from a dilute solution into a more concentrated solution due to electrical current flow direction. Unidirectional or DC electrical current can be obtained from AC to DC current using a converter.

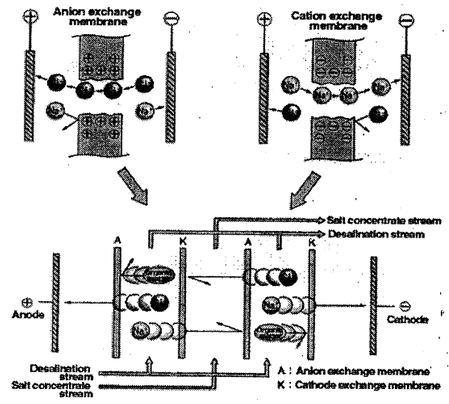


Figure 2. Electrodialysis Tues.

Research Method

The research method of reduction of energy usage in sea water desalination process for producing fresh water with electrodialysis method is a laboratory research method with the research stages as follow:

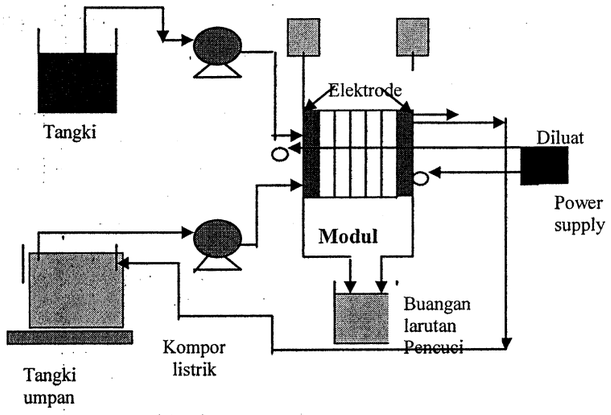


Figure 3. Process scheme with Electrodialysis Desalination Equipment

Results and Discussion

To compare whether or not reduction of energy usage of sea water happens in this research, conventional desalination is done as a comparison (control).
Sea water desalination process with various conventional treatments.

Table 1. Results of Conventional Desalination sea water for 25 000 ppm concentration, T = 25^{0}C, at a flow rate of 5 cm / sec and 10 cm / sec, first batch..

Time (menit)	consentration (ppm) 5 cm/sec	10 cm/sec	Current (A)
0	25.000	25.000	5
15	21.700	21.800	5
30	19.200	19.500	4
45	18.500	18.700	3
60	17.100	17.900	2,5
75	16.500	16.100	2,5
90	16.100	15.800	2
120	15.900	15.700	2

Table 2 Results of Sea Water Desalination in the conventional for 25,000 ppm concentration , T = 25 ^{0}C at a flow rate of 5 cm / sec and 10 cm / sec, batch number; 2.

Time (minute)	Consentration (ppm) 5 cm/sec	10 cm/sec	Current (A)
0	15.900	15.700	4
15	14.100	14.400	3,5
30	13.500	13.300	3,5
45	12.200	12.500	3
60	10.800	11.800	3
75	10.600	10.900	2,5
90	9.700	10.500	2
120	9.600	10.200	2

Table 3 Results of Seawater Desalination conventionally for 25.000 ppm concentration, T = 25 ^{0}C at a flow rate of 5 cm / sec and 10 cm / sec, batch number; 3

Time (minute)	Cosentration (ppm) 5 cm/sec	10 cm/sec	Current (A)
0	9.600	10.200	3
15	8.500	9.100	3
30	7.900	8.200	2,5
45	7.100	7.500	2,5
60	6.700	6.300	2
75	6.400	5.400	2
90	6.100	5.100	2
120	5.800	4.900	2

Table 4. Results of Seawater Desalination conventionally for 25.000 ppm concentration , T = 25 ^{0}C, at a flow lane 5 cm / sec and 10 cm / sec, batch number; 4

Time (minute)	Consentration (ppm) 5 cm/sec	10 cm/sec	Current(A)
0	5.800	4.900	3
15	4.700	4.200	2,5
30	3.900	3.600	2,5
45	3.100	3.000	2
60	2.700	2.600	2
75	2.400	2.500	1,5
90	2.200	2.400	1,5
120	2.100	2.400	1,5

Table 5. Results of Desalination sea water for 25 000 ppm concentration and temperature T = 25^{0}C, at a flow rate of 5 cm / sec and 10 cm / sec, 11.5 volts, first batch.

Time (minute)	Consentration (ppm) 5 cm/sec	10 cm/sec	Current (A)
0	25.000	25.000	3
15	22.400	22.600	3
30	19.100	20.700	3
45	18.600	18.300	2,6
60	17.400	17.100	2,5
75	16.100	16.300	2
90	15.600	15.400	1,4
120	15.300	15.100	1,2

Table 6. Results of Sea Water Desalination and for 25.000 ppm concentration temperature T = 25 ^{0}C, at a flow rate of 5 cm / sec and 10 cm / sec batch number; 2

Time (minute)	Consentration (ppm) 5 cm/dt	10 cm/dt	Current (A)
0	15.300	15.100	1,5
15	14.200	13.700	1,5
30	12.700	12.500	1,5
45	11.500	11.900	1,3
60	10.200	11.300	1,2
75	9.600	10.800	1,1
90	9.300	10.300	1
120	9.300	8.9000	0,8

Table 7. Seawater Desalination results for the concentration 25 000 ppm, and temperature T = 25 0C at a flow rate of 5 cm / sec and 10 cm / sec batch number; 3

Time (minute)	Consentration (ppm) 5 cm/sec	10 cm/sec	Current (A)
0	9300	8900	1
15	8500	8000	1
30	7800	7200	1
45	7200	6500	1
60	6500	6000	0,9
75	5800	5400	0,8
90	5200	4800	0,7
120	4700	4400	0,6

Table 8. Results for Sea Water Desalination 25 000 ppm concentration, and temperature 25 0 C, at a flow rate of 5 cm / sec and 10 cm / sec batch number; 4

Time (minute)	Consentration (ppm) 5 cm/sec	10 cm/sec	Current(A)
0	4700	4400	0,6
15	4200	4000	0,6
30	3600	3500	0,6
45	3100	3100	0,6
60	2600	2500	0,5
75	2200	2100	0,4
90	1700	1800	0,3
120	1500	1550	0,2

Results of conversion of Seawater Desalination based on research

The data acquired from the results of sea water desalination process, then each amount of conversion acquired is calculated. Those results are put into tables as follow :

Table 9. % . Conversion percentage of sea water desalination for 25,000 ppm concentration, at various temperatures, flow rates, and current strengths, for batch 1

Temperature (^{0}C)	% Convertion rate (5 cm/dt)	% Convertion Rate (10 cm/dt)	Current(A)
25	38,8	39,6	2,3
30	53,6	51,6	3,2
35	23,6	28	3,5

Calculations of energy demand at sea water desalination process with Electrodialysis process
Energy calculations based on conventional sea water desalination process.
Using equation (1) ; E = BLABLABLA
With : n = number of cell pairs
I = current (A)
V = voltage (volt)
t = time (hour)

Table 10. Result of calculation of conventional sea water desalination for 25,000 ppm, various temperatures, 5 cm/second flow rate, 10 cm/second, t = 4 hours, volume = 8 lt

Temperature (^{0}C)	Total Current (A)	E (Energy), watt.hour/lt
25	10,65	42,6
30	13,05	52,2
35	13,20	52,8

Result of calculation of energy demand based on sea water desalination process . with Electrodialysis research plan-wise.

Table 11. Result of calculation of sea water desalination for 25,000 ppm, various temperatures, 5 cm/second flow rate, 10 cm/second, t = 8 hours, volume = 8 lt

Temperature (^{0}C)	Total Current(A)	E (Energy), watt, hour./lt
25	4,9	9,8
30	5,9	11,8
35	8,8	17,6

Conclusion

Based on the result of this research, data analysis and discussion, this research concludes several things as follow:

1. Parameter of feed's temperature and concentration has effect on sea water desalination effect using ED.

2. Parameter of feed's flow rate has effect that is not too significant on fresh water TDS result, at sea water desalination process using ED.
3. Feed optimum temperature which can produce fresh water with the best TDS content is at 30°C.
4. The success of reduction of electrical energy usage at this research reaches up to 66% efficiency.
5. Factors which can cause hindrances in sea water desalination process with ED process are the presences of fouling and polarization concentration.

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