Membrane distillation for shale gas plant water treatment: Effect of membrane fouling

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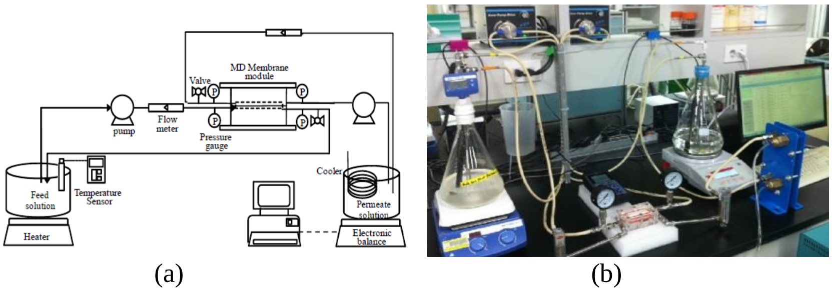
Introduction

Non-conventional oil resources such as shale gas are becoming essential and the prospects for these resources are favorable all over the world. But there is a concern that environment on water supplies and wastewater due to the expanded application of technology (GREGORY, *et al* (2011)). If not settled, it would be an impossibility to apply in real situation, there are concerns that shale gas would contaminate underground water since it use water including chemicals in the mining process, waste of water resources and trouble of polluted liquid waste treatment. Conventional method of the treatment is pre-treatment to remove grease and oil through the filtering grit and chlorine oxidation method, and to be disposed by the reverse osmosis (RO), evaporation, crystallization. But the old method is hard to deal with that because it contains too much ion, oil and grease. Also, It is confirmed that the temperature of shale gas plant water used to abstract the shale gas is raised by 70~80℃ from 20℃. So, we used Membrane Distillation process to recycle the geothermal energy sources and to deal with shale gas plant water. Direct Contact Membrane Distillation can separate and remove the specific things through porous membrane of micro pore using vapor pressure difference as temperature difference of water, and can get the high pure water (Alkhudhiri, *et al* (2012)). Furthermore, it has a possibility to be used in food industry, water conversion and diverse advanced applications. In the system, it showed high rate of water transmission and ion elimination, and was stable relatively. But the oil of shale gas plant water and grease and surfactant contaminated capacity of the MD membrane with polymer Also, the capacity of MD membrane was decreased because the high level of ion in shale gas plant water laid thick on the surface of MD membrane. To solve these problems, we applied Direct Contact Membrane Distillation to handle shale gas plant water, and studied mechanism of the membrane pollution and the capacity of MD by quality of feed water.

Material and methods

The test was carried out in laboratory and the constitution of devices is as Fig. 1. We used the DCMD in several MD operating type, and we made a small flat module, effective membrane area   in this test. The membrane of Polyvinylidene fluoride (pore size, 0.22 μm) of Millipore was used to the resolution filter for MD. Temperatures of inflowing water were 60℃, low level of temperature relatively, and 70, 80℃, the temperature using after abstracting real shale gas. The inflowing temperature of produced water was fixed with 20℃. Besides, the flow rate of produced water and recycling inflow-water was in ratio of 1.5:1, fixed with 400 mL/min, 260 mL/min each. The density of Shale gas plant was made by considering each material's density as Table 1. The test was carried out 3 kinds of the synthesis inflowing water by an extent of density. Also, we made the synthesis inflowing water including water-soluble cutting oil and water-insoluble gasoline to facsimile the oil of real waste water and grease. We measured feedwater permeated through the membrane of water tank by using an electronic scale, and measured the rate of removing ion of the produced water through electronic conducting system. We photographed the picture of the membrane surface by SEM(Scanning Electron Microscopy), and observed a pollution level of membrane and degree of hydrophilic by measuring a contact angle of the membrane surface and LEP.



(a) (b)

Fig. 1. Laboratory-scale MD system (a) schematic diagram (b) photography of the system.

Table 1. Range of constituents in flowback water from development in the Marcellus Shale

Constituent	Low (mg/L)	Medium (mg/L)	High (mg/L)
Total dissolved solids	66,000	150,000	261,000
Total Suspended solids	27	380	3,200
Hardness (as $CaCO_3$)	9,000	29,000	55,000
Alkalinity (as $CaCO_3$)	200	200	1,100
Chloride	32,000	76,000	148,000
Sulfate	-	7	500
Sodium	18,000	33,000	44,000
Calcium	3,000	9,800	31,000
Strontium	1,400	2,100	6,800
Barium	2,300	3,300	4,700
Bromide	720	1,200	1,600
Oil and grease	10	18	260

Results and Discussion

As a result of long-term test, the operation was impossible because water flux was rapidly decreased in the recovery ratio 70%, in medium range by the concentration of synthesis flowback water like Fig. 2 and water flux was completely decreased under the recovery ratio 78%. In high range, the operation was impossible under recovery ratio 48%, because the water flux was decreased rapidly under recovery ratio 40 %. The rate of electric conduction of produced water was appeared as high rate of removing ion 99.99 %, until a point before water flux was decreased in all concentration range. On the other hand, the rate of electric conduction was increased from a point that water flux was rapidly decreasing in all concentration range like Fig. 2. This result was expected to the contamination of MD membrane because of long-term operation.

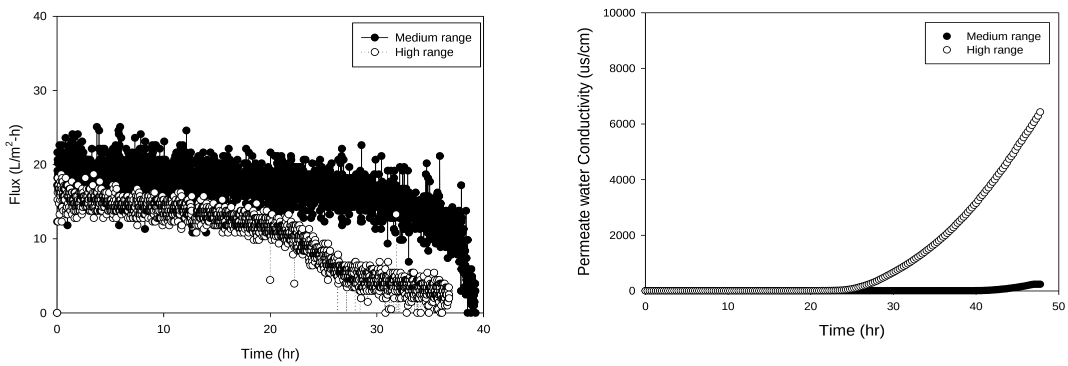


Fig. 2. Laboratory-scale MD system (a) schematic diagram (b) photography of the system.

Conclusions

A new way to apply DCMD for controlling water of shale gas plant was carried out in this test. First of all, it was possible to treat the flowback water by using DCMD despite of high osmotic pressure as considering only the ion. When the operation was higher than the range of recovery ratio, water flux was rapidly decreased, and the rate of electric conduction was also higher. When the high concentration of shale gas plant water was operated over the maximum recovery ratio, water flux was suddenly decreased by forming of scale layer, and LEP of Membrane was rapidly decreased and being hydrophilic.

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