EVALUATION OF REGENERATION PERFORMANCE OF LIQUID DESICCANTS USING MEMBRANE DISTILLATION

Seonguk Ha¹, Sanghyun Jeong*¹

¹. School of Civil and Environmental Engineering, Pusan National University
Busan 46241 Republic of Korea
* E-mail: sh.jeong@pusan.ac.kr

ABSTRACT
Liquid desiccants (LDs) are widely used for air-conditioning system but its regeneration is costly. The polluted and humid air contacts with the LD to purify it into clean and comfortable air. LD, which has absorbed moisture and contaminants, is heated to medium temperature and flowed through membrane distillation (MD) process, and only vapor passes through the temperature gradient across the hydrophobic membrane and condenses to clean water. In this study, the MD was used to regenerate two different kinds of LD; weak acid potassium formate (HCOOK), and halide salt lithium chloride (LiCl). Regeneration efficiency of LDs was examined by initial permeate flux, its decline tendency and permeate quality. Further, changes in surface properties of the membranes after the operation were systematically examined by scanning electron microscope observation and contact angle measurement. Flux pattern of HCOOK was slightly higher than that of LiCl. Hydrophobicity of membrane was completely lost after operation with LiCl but after operation with HCOOK, contact angle was measured to 58.1 °. It was also observed that HCOOK was less damaged the membrane. Therefore, HCOOK is better LD in the regeneration using MD process.

KEY WORDS
Liquid desiccant; Membrane distillation; Regeneration.

1. INTRODUCTION
Recently, liquid desiccant (LD) has been actively researched to improve the inefficiency of the existing air conditioning system. Typically used LD with good moisture absorption performance is lithium chloride (LiCl). However, a stable process operation with LiCl is difficult due to corrosive problems and its cost is relatively high. On the other hand, potassium formate (HCOOK) is attracting LD as it is almost no corrosive and less expensive and showed similar dehumidifying performance with LiCl. We conducted the regeneration of two LDs using membrane distillation (MD). It has the advantage of efficient concentrating of LD as well as additional production of clean water. Eventually, this study was conducted to select more suitable LD which can be regenerated sustainably using the MD.

2. MATERIALS AND METHODS
2.1 Liquid desiccants
Two different LDs; LiCl (99%) and HCOOK (99%) were procured from Sigma-Aldrich. Molecular weights of LiCl and HCOOK were 42.39 g mol⁻¹ and 84.12 g mol⁻¹, respectively.

2.2 Membrane
Commercial 0.22-µm pore sized hydrophobic polyvinylidene fluoride (PVDF) membrane (GVHP14250, Durapore, Germany) was utilized in the MD test.

2.3 LD concentration using MD
In this experiment, two different LDs (LiCl and HCOOK) were used, the feed temperatures were set at 60, 70, and 80°C and Permeate temperature was 20°C. Flow rate of LD’s and permeate were 1.0L/min m² and the concentration was started from 50% of the optimum moisture absorption concentration (HCOOK: 70wt%, LiCl: 40wt%). It’s a condition that assumes the LD has absorbed the moisture.

2.4 Analyzing methods
At the permeate water, mass balance measures weight of obtained water and connected computer calculates a flux. After experiment, used membranes are analyzed by Scanning electron microscope (SEM), SEM-EDS and Contact angle.

3. RESULT AND DISCUSSION
3.1 MD performance
Under the condition of 60 °C, a relatively similar flux pattern was observed, and at 70 °C and 80 °C, HCOOK showed a slightly higher flux than LiCl, even though a higher concentration. It is relatively unstable under the condition of 60 °C and the regeneration rate is too low compared to other temperatures. At 80°C, the initial flux was high, but it dropped sharply, and the concentration completion time was similar with that at 70 °C. As a result, flux pattern at 70 °C is most stable.
Fig.1: MD flux pattern in the regeneration of two LDs at different feed temperatures.

3.2 Membrane analysis after MD process
It was confirmed that LiCl covered the membrane surface with small crystals densely, and HCOOK covered the membrane surface while forming a cake. Since LiCl has a small crystal shape, it is likely to enter the membrane pore. The contact angle result of virgin PVDF was 102.2°, and the result measured after the LiCl experiment completely lost the hydrophobicity, so it was impossible to measure the result value. It was confirmed that HCOOK still maintained the hydrophobicity at 58.1° after the experiment.

Although the flux pattern is similar, HCOOK is more densely attached to the membrane surface. It is expected that the flux reduction of LiCl and HCOOK occurs due to scaling and cake formation, respectively. Therefore, it is expected that the flux improvement of HCOOK will be greater during the membrane washing process.

Fig.2: (a-c): SEM images of MD membrane before and after operation with LiCl and HCOOK and (d-f): contact angle images

3.3 SEM-EDS
It was confirmed that the materials covering the membrane were the same as the result of the SEM image through the SEM-EDS. In elemental analysis, Cl ion was 1.58 wt% for LiCl. Therefore, HCOOK is more measured on the membrane surface, but the flux pattern is similar, there is a possibility that LiCl has entered inside the membrane. In the next experiment, it is necessary to analyze the cross section.

Fig.3: SEM-EDS results before and after operation with LiCl and HCOOK.

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4. CONCLUSION
As LiCl was not well concentrated in the MD system due to corrosion and crystal formation, the regeneration efficiency was slightly lower than HCOOK with lower damage of membrane. This indicates that HCOOK is more suitable LD than LiCl for regeneration using MD. SEM analysis also showed that the flux decreased due to fouling in the membrane. To solve this problem, periodic water flushing is recommended that will result in a stable operation with efficient concentration of LD using MD.

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