CLIMA 2016 - proceedings of the 12th REHVA World Congress

volume 9

Heiselberg, Per Kvols

Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

Removal Efficiency for Airborne Particles and VOCs in Liquid Desiccant Dehumidifier

Dong-Seob Yoon[1], Sung-Joon Lee[2], Joon-Young Park[3], Jae-Weon Jeong[*4]

[1,2,3]*Division of Architectural engineering, College of Engineering, Hanyang University, Seoul, 133-791, Republic of Korea*

[1]dbsehd89@hanyang.ac.kr

[2]jaylynlee@hanyang.ac.kr

[3]jego2000@hanyang.ac.kr

[*4]*Division of Architectural engineering, College of Engineering, Hanyang University, Seoul, 133-791, Republic of Korea*

[*4]jjwarc@hanyang.ac.kr

Abstract

This study investigated the removal effect for particles and volatile organic compounds (VOCs) in liquid desiccant dehumidifier through experiments. In liquid desiccant dehumidifier, outdoor air is dehumidified by directly sprayed lithium chloride solution. Removal efficiency was used to evaluate the ability to capture airborne particles and VOCs. Particles larger than PM 2.5 in ambient air and one representative VOCs, toluene were considered. The contaminants concentration was measured at inlet and outlet stream of liquid desiccant dehumidifier. The removal efficiency was calculated when the process air containing contaminants bypassed and passed through packed bed of liquid desiccant dehumidifier respectively. The flow speed was set to 1.9 m/s, acceptable airflow speed of ASHRAE standard 52.2. The condition of process air was constantly maintained at 28-31 degree Celsius of temperature and 52-53% of relative humidity during experiments. Particles were analyzed according to its size range: PM 2.5-5, PM 5-10, PM 10-. The results of experiments showed that the better capturing ability can be expected for larger particles. Overall particle removal efficiency represented 43.9%, 56.1% and 70.5% in size range of PM 2.5-5, PM 5-10, PM 10-25 respectively. Overall VOCs removal efficiency showed 23.9% for toluene. When particle removal efficiency is converted to MERV (Minimum efficiency reporting value), liquid desiccant has similar filtering efficiency to filter of MERV 8 which is typically applied to commercial buildings.

Keywords – removal efficiency; airborne particles; VOCs; liquid desiccant;

1. Introduction

Comfortability of occupants has been as important as energy consumption in building for decades. For this, many kinds of HVAC techniques are proposed and developed. Among them, liquid desiccant has been issued for its energy saving potential and effective latent load handling[1]. And effects other than dehumidification of liquid desiccant has been studied as well, espcially potential to remove the contaminants which is harmful to human body. Liu et al. and Yu et al. [1,2] mentioned that liquid desiccant has potential to remove a number of pollutants from air stream. According to national renewalble energy laboratory (NREL)[4], results of particle capture experiment indicated no remarkable differernce in the inlet and outlet concentraiton of particles size of from 0.5 to 10 microns. And Slayzak et al.[5] proposed liquid desiccant air conditioner of developed configuration that can capture and deactivate contaminants using electrostatic and strong acid desiccant solution. Slayzak et al.[6] also mentioned that desiccant solution has biocidal effect. Following to unpublished results of NREL, 99.99% of bacillus was deactivated when bacillus was exposed to 40% LiCl solution at 60℃ for 4-6 hours. Brian et al.[7] examined desiccant-based cooling systems to determine the sanitizing effect on airborne microorganisms such as bacteria and fungi. As results of field test, desiccant wheel made 39-64% and 32-72% reduction for bacteria and fungi respectively.

In this study, the ability to capture airborne particles and VOCs of packed bed liquid desiccant dehumidifier was examined by experiments. And filtering efficiency was also evaluated.

2. Liquid desiccant dehumidifier

Liquid desiccant dehumidifies the air without refrigerant by spraying desiccant solution, as distinct from conventional system that dries air by cooling under dewpoint. The outdoor air is dehumidified by vapor pressure

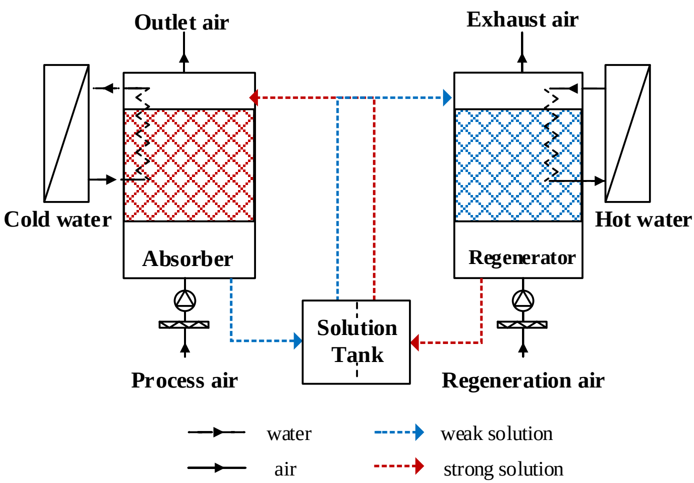


Fig. 1 Schematic diagram of liquid desiccant dehumidifier

difference between air and desiccant solution. It consists of absorber and regenerator. In absorber, the process air is dehumidified by desiccant solution of high concentration. After absorbing moisture, the desiccant solution becomes diluted to weak solution. In order to achieve dehumidifying effect continuously, it is needed to regenerate solution in regenerator. In regenerator, moisture of solution is evaporated by heat and then desiccant solution becomes strong solution again. Litium chloride (LiCl), lithitm bromide (LiBr) and calcium chloride ($CaCl_2$) are commonly used as desiccant media. The main advantage of liquid desiccant is effective handling latent load with low energy consumption [8]. So, it has good applicability in hot and humid climate. Fig.1 shows schematic diagram of liquid desiccant dehumidifier used in paricles and VOCs removal experiments. The liquid desiccant uses 36-40% of LiCl solution as desiccant solution. It sprays LiCl solution to packed bed having 104.8m^2 of reaction area and the process air is dehumidified by passing through the packed bed with direct contact to desiccant solution. In this process, airborne particles and VOCs can be removed by adsorption or scavenging action of sprayed solution.

3. Experimental setup

Removal efficiency experiments were conducted to evaluate filterting ability for airborne particles and VOCs. Ambient air carrying fine particles due to industrial environment was used as particle source. For VOCs source, vaporized varnish from liquid varnish containing high concentration of toluene was used. Particle concentration was measured by P-TRAK PARTICLE COUNTER, TSI which has 0.1% of residual error and detects particles size of 0.3-25 microns. Toluene were measured by INNOVA 1312 multigas monitor which has detection limit of 50 ppb. The specification of measurement devices are shown in Table 1.

Each measurement device was located in inlet and outlet stream of liquid desiccant to calculate the concentraion reduction of contaminants. Contaminants concentration were measured in average value of every 1 minute for 30-60 minute. Air flow rate was set to 800 cfm in duct of 35mm x 35mm. So, the air velocity was maintained at 1.9 m/s which is one of acceptable flow speed for filtering test standard designed by American society of heating, refrigerating and air-conditioning engineers (ASHRAE) [9]. The duct was neutralized by grounding with copper wire to prevent particulate contaminants from being attached to duct by electrostatic effect. The maesurements were conducted twice; the process air flew through the liquid desiccant unit (stream 1) and bypassed without any direct contact with desiccant solution through bypass duct (stream 2). Stream 1 includes the removal by adsorption of packing in liquid desiccant and scavinging action of directly spraying desiccant solution. Stream 2 is comparison condition to examine the net efficiency of liquid desiccant dehumidifier. Fig.1 shows the air path of 2 streams and the location of mesurement devices in liquid desiccant dehumidifier. Throughout the experiments, temperature and relative humidity of ambient air were constantly maintained in range of 28-31 °C and 52-53% respectively.

Table 1 Specification of measurement devices

Particle counter	Size range	0.3 to 25 ㎛
	Concentration limit	2.1 x 10^8 particles/m^3
	Flow rate	0.1 cfm (2.83 L/min)
	Operating range	5 to 3°C of Temp 20 to 95% of RH
Multigas monitor	Detection limit	50 ppb
	Reference condition	20°C, 1 atm, RH 60%
	Temp coefficient	± 10% of detection limit/°C
	Sample volume	140 cm^3/sample

As the evaluation index for filtering ability, removal efficiency was considered. The removal efficiency is the ratio of removed concentration of contaminant to inlet concentration of contaminant. And it is expressed as (1).

$$\varepsilon = \left(1 - \frac{C_{outlet}}{C_{inlet}}\right) \times 100\ (\%) \qquad (1)$$

where,
ε = Contaminant removal efficiency (%)
C_{outelt} = Contaminant concentraiton of outlet (ppb)
C_{inlet} = Contaminant concentration of inlet. (ppb)

The capturing ability for fine particles and VOCs of liquid desiccant dehumidifier was accessed with net removal efficiency. Net removal efficiency of liquid desiccant dehumidifier is obtained as the difference between the removal efficiency in stream 1 and 2 (2).

$$\varepsilon_{net} = \varepsilon_{stream1} - \varepsilon_{stream2} \quad (2)$$

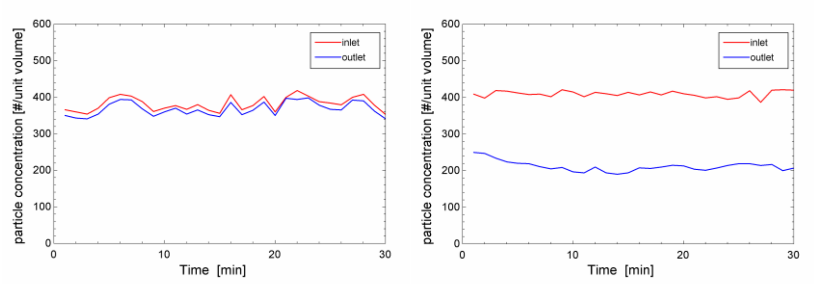
Where,
ε_{net} = Net removal efficiency (%)
$\varepsilon_{stream1}$ = Removal efficiency in stream 1 (%)
$\varepsilon_{stream2}$ = Removal efficiency in stream 2 (%)

Fig. 2 Liquid desiccant dehumidifier

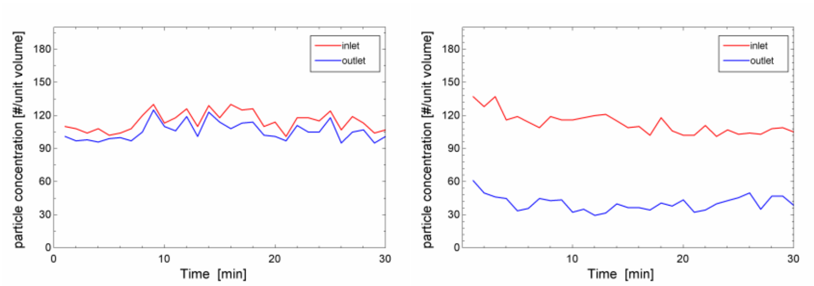
4. Results

In this paper, contaminant removal experiments were conducted to examine the capturing ability of liquid desiccant dehumidifier. As the results of contaminant removal experiments, it was found that the liquid desiccant dehumidifier has effect on capturing both fine particles and VOCs.

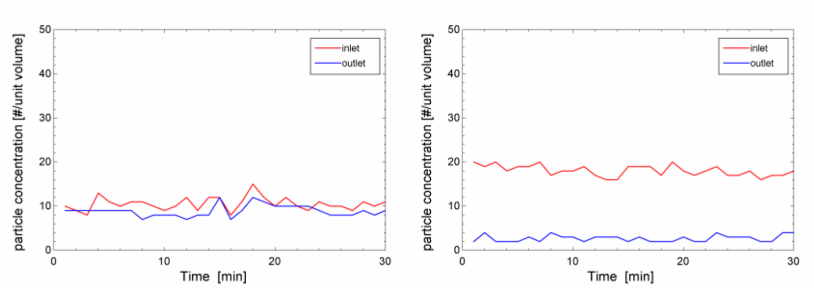
The measured data was grouped by diameter range of particles: 2.5-5 micons, 5-10 microns, 10-25 microns. Since ambient air was used as inlet process air without additional particle source addition, the concentration of particles showed higer in larger particles. Fig. 3 shows particle concentration in inlet and outlet of liquid desiccant dehumidifier when the process air passes stream 1 (liquid desiccant dehumidifier) and stream 2 (bypass duct). The left side of figure represents the case of stream 2 and right side shows result of stream 1. From that the particle concentration of inlet and outlet was maintained at certain level, experiments proceeded in steady-state condition. The particle removal efficiency was 3.52%, 7.83% and 14.61% for the particles size of 2.5-5 in outlet stream closely tracked that in inlet stream in entire size groups. Thus, when the process air passed bypass duct not being affected by liquid desiccant dehumidifier, no remarkable change in particle concentration occurred.



(a) 2.5-5 microns



(b) 5-10 microns



(c) 10-25 microns

Fig. 3 Particle concentration

However, when the process air passed through liquid desiccant dehumidifier (stream 1), significant decrease in particle concentration was found. In particles size range of 2.5-5 microns, particle concentration in inlet stream was maintained at 400 particles per unit volume (2.83 L), while that in outlet stream was maintained below 300 particles per unit volume. And similarly, in particle sizes range of 5-10 microns and 10-25 microns, particle concentration of process air obviously dropped during dehumidification process. The particle removal efficiency of stream 1 showed 48.24%, 64.14% and 84.93% for the particles size of 2.5-5 microns, 5-10 microns and 10-25 microns respectively. The larger particles showed the more decrease in its concentration while the air passed the liquid desiccant dehumidifier.

In VOCs removal experiment, results similar to the particle removal experiments were obtained. When the process air carrying VOCs passed bypass duct, toluene showed negligible reduction in concentration having 7.72% of removal efficiency. While, in the case that process air passed thorough liquid desiccant dehumidifier, toluene decresed from 3.55 ppm to 2.26 ppm (Fig.4). The removal efficiency indicated 31.36%.

In results, liquid desiccant dehumidifier can remove both particulate pollutant and gaseous pollutant. Particles and VOCs concentration reduction in stream 2 showed 3-14% while that in stream 1 showed 35-85%. The net removal efficiency for each contaminant and its uncertainty is specified in Table. 2. Experiments showed that the liquid desiccant dehumidifier has 45-70 % of contaminants removal efficiency for particulate contaminants and about 30% of removal efficiency for gaseous contaminants with low uncertainty. For particles larger than 2.5 microns, higher removal efficiency was obtained than that for VOCs.

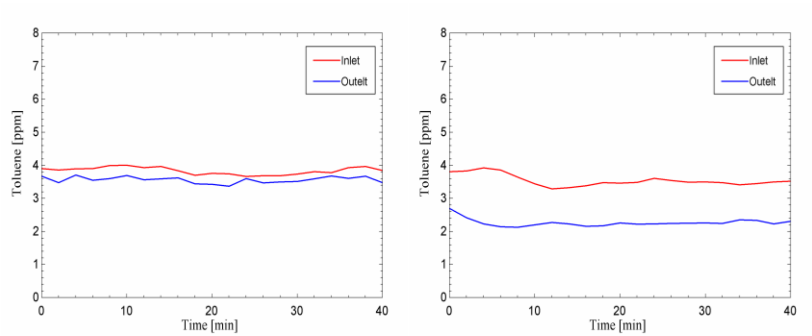


Fig. 4 VOCs (toluene) concentration

Table 2 Removal efficiency for particles and VOCs

Fine particles			
	PM 2.5-5	PM 5-10	PM 10-25
$\varepsilon_{stream1}$	48.24 ± 0.07	64.14 ± 0.05	84.93 ± 0.02
$\varepsilon_{stream2}$	3.52 ± 0.14	7.83 ± 0.13	14.61 ± 0.12
ε_{net}	44.72 ± 0.15	56.31 ± 0.14	70.31 ± 0.12
VOCs (toluene)			
$\varepsilon_{stream1}$	35.97 ± 0.15		
$\varepsilon_{stream2}$	7.14 ± 0.16		
ε_{net}	28.83 ± 0.22		

5. Conclusions

The removal efficiencies for fine particles and VOCs of packed-bed type liquid desiccant dehumidifier were investigaed through field experiments. In conclusions, it turned out that the liquid desiccant dehumidifier has the ability to capture the particulate contaminants and VOCs. In terms of particles, it has 44.72%, 56.31% and 70.31% of net removal efficiency for the particles whose size is 2.5-5 microns, 5-10 microns and 10-25 microns repectively. Thus, the better removal efficiency can be expected in the larger particles. For VOCs, the contaminant removal effect was observed in toluene. Approximately 28.83% of toluene were removed during the dehumidification process. Considering that the concentration of each contaminants in inlet and outelt were maintained at certain level consistently at hot and humid climate (29℃, RH 50%) ,when the liquid desiccant dehumidifier mostly operates, it shows the practical indoor air quality enhancement effect of liquid desiccant dehumidifier in field. Classifying the performance of liquid desiccant dehumidifier as a filter device according to minimum efficiency reporting value (MERV), it has comparable filtering effect with a filter of MERV 8 usually applied to commercial buildings. And also removal efficiency for microbial contaminant of liquid desiccant dehumidifier will be investigated for further works.

Acknowledgment

This work was supported by a National Research Foundation of Korea (NRF) grant funded by the Korean government (No. 2015R1A2A1A05001726).

References

[1] Rafique MM, Gandhidasan P, Bahaidarah HMS. Liquid desiccant materials and dehumidifiers – A review. Renewable and Sustainable Energy Reviews (2016) 56:179–95.
[2] Liu X, Li Z, Jiang Y, Lin B. Annual performance of liquid desiccant based independent humidity control HVAC system. Applied Thermal Engineering (2006) 26:1198–207.
[3] Yu BF, Hu ZB, Liu M, Yang HL, Kong QX, Liu YH. Review of research on air-conditioning systems and indoor air quality control for human health. Int J Refrig 2009;32:3–20.
[4] Lowenstein a, Slayzak S, Kozubal E. A zero carryover liquid-desiccant air conditioner for solar applications. ASME/Solar06, Denver, USA 2006:1–11.
[5] Slayzak S, Ren S, Ronald D, Daniel M, Todd B, Joseph P. Using liquid desiccant as a regeneralble filter for capturing and deactivating contaminants. United States Patent (2007), US 7,306,650 B2.
[6] Slayzak S, Blake D, Ryan J, Vinzant T. Liquid desiccant regenerable filters for indoor environmental quality and security. National Renewable Energy Laboratory Center for Buildings and Thermal Systems and National Bioenergy Center report(2003),
[7] Kovak B, Heimann PR, Hammel J. The sanitizing effects of desiccant-based cooling. ASHRAE Journal (1997) 39:60–4.
[8] Dieckmann J, Roth K, Brodrick J. Liquid Desiccant Air Conditioners. Ashrae Journal (2008) 23:90–5.
[9] ASHRAE, 2007, ASHRAE Standard 52.2, Method of testing general ventilation air-cleaning devices for removal efficiency by particle size. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc, Atlanta.
[10] Demakos PG, Improving IAQ with liquid desiccant dehumidification, 2009, http://hpac.com/humidity-control/improving-iaq-liquid-desiccant-dehumidification.