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Review

Review of the impact of liquid desiccant dehumidification on indoor air quality

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A R T I C L E   I N F O

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A B S T R A C T

Liquid desiccant dehumidification has received much attention in recent years due to its effectiveness in humidity control and great potential in energy saving of buildings. At the same time, indoor air quality (IAQ) problems associated with liquid desiccant dehumidification also aroused people's attention since IAQ has a great significance for human health and life. This paper focuses on the impact of liquid desiccant dehumidification on IAQ and reviews recent achievements and progress in this respect. The recent researches in this field are reviewed on: (1) The removal capability of liquid desiccant solution for volatile organic compounds. (2) The remove, filter, kill or deactivation effect of liquid desiccant solution on bacteria and virus. (3) The capture function of liquid desiccant dehumidification system for particulate matter. (4) The carryover of liquid desiccant.

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Contents

1. Introduction

The humidity and temperature control is a major task for air conditioning system. Until the end of the 20th century, due to the restrictions of the corrosion problem of inorganic salt solutions

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Table 1
Typical air pollutants in indoor air [13].

Group	Definition/example	Origin	Toxic effects
Particles	Very small liquid or solid substances in suspension in the air: mists, dust, pollen, cigarette smoke, viruses, bacteria, molds	Outdoor air, combustion, carpets, human activity, decaying building	Irritation to eyes and/or respiratory tissues, allergies, cancer, indirect effect through biological production of toxins
Gaseous pollutants	VOCs, CO, CO_2, NO_x	Combustion, human activity, building materials, furniture, cleaning products, mold development etc.	Irritation to eyes and/or respiratory tissues, allergies, cancer, effects on the respiratory liver, immune, reproductive and/or nervous system

(such as lithium chloride (LiCl) solution, lithium bromide (LiBr) solution, and calcium chloride ($CaCl_2$) solution), the volatile problem of triethylene glycol (TEG) solution and the low energy utilization efficiency, liquid desiccant dehumidification has not been widely used in civil buildings [1]. In recent years, with the development of corrosion resistant materials (especially the plastic) and the improvement of the heat and mass transfer efficiency, liquid desiccant dehumidification technology is becoming increasingly attractive due to its effectiveness in indoor air humidity control [2], and its high efficient utilization of low-grade heat, such as solar energy, geothermal power and industrial waste heat [3–7]. Compared with conventional condensing dehumidification methods, liquid desiccant dehumidification approaches show superiorities as follows [8]: The cold and heat offset phenomenon in the conventional air conditioning system can be avoided; Air temperature and humidity can be adjusted independently; Low-grade energy or renewable energy can be utilized as the main driven energy source; High density energy storage can be realized; and so on. Since it has so much advantages and great potential, there are many achievements in regard to liquid desiccant dehumidification have been achieved by many researchers over the past several years. These achievements related to [6]: experiments and modeling of the heat and mass transfer between air and desiccant, performance evaluation of liquid desiccant dehumidification and regeneration, technology development of dehumidifiers and regenerators, and new application of liquid desiccant dehumidification. At present, liquid desiccant dehumidification air-handling equipment has been industrialized production [1]. In recent ten years, liquid desiccant dehumidification has been applied in nearly ten million square meters of floor space, which include offices, hotels, exhibition museums, and airport terminals in China [1].

At the same time, indoor air quality (IAQ) problems associated with liquid desiccant dehumidification also aroused people's attention. In modern society, more and more people are spending most of their time indoors [9], and thus the IAQ has important effects on human health and work efficiency [10]. IAQ is another challenge to the heating, ventilation, and air-conditioning (HVAC) industry, particularly in more humid climates [11]. An added benefit of liquid desiccant air-conditioning system (LDAS) is the positive effect on IAQ, viz. remove indoor air pollutants. Indoor air contamination is a complex problem involving gaseous contaminants (such as VOCs), biological pollutants (such as bacteria and virus), and particles (such as dust and smoke) [12,13]. The origin and toxic effects of typical air pollutants in indoor air are listed in Table 1.

Fig. 1 shows the operating principle of a LDAS [14]. The LDAS consists of packed-bed dehumidifier where the mass (water) transfer is from the processed air to the desiccant, packed-bed regenerator where the mass (water) transfer is from the desiccant to the processed air, hot water heat exchanger, inter-stage heat exchanger, etc. The driving force for mass transfer is the surface vapor pressure difference as depicted in Fig. 2 [15] between the air and the desiccant [16]. As shown in Fig. 1 [14]: Concentrated liquid desiccant from the regenerator comes to the dehumidifier, after being cooled by the diluted desiccant from dehumidifier in the inter-stage heat exchanger; The concentrated desiccant is mixed with the desiccant in the tank of dehumidifier, then pumped into the cooling water heat exchanger, and finally sprayed into the packing and contacts the processed air; The diluted desiccant from dehumidifier then comes to the regenerator to be re-concentrated. The liquid desiccant includes organic desiccant, such as TEG solution, and inorganic salt solutions, such as LiBr solution, LiCl solution, and $CaCl_2$ solution. TEG solution is the earliest solution utilized in LDAS. However, TEG solution is gradually replaced by some salt aqueous solutions, such as LiBr solution and LiCl solution, due to the organic ingredient may evaporate into the processed air [14]. Compared with organic liquid desiccants, salt solutions (LiBr, LiCl or $CaCl_2$ solution) won't vaporize into air under ambient conditions [14].

For the air treatment process of LDAS, the heat and mass transfer through direct contact between air and solution, thus it has the function of removing harmful substances in the air, such as VOCs, bacteria, virus as well as particulate matter (PM), and can improve IAQ. However, on the other hand, it may have a negative impact on IAQ due to the carryover of liquid desiccant. Because of this reason, the safety of LDAS has been questioned since it is proposed.

This paper is intended to present a literature review of research works done by many researchers concerning various aspects of the impact of liquid desiccant dehumidification on IAQ. Recent developments related to the removal capability of liquid desiccant solution for VOCs, the kill or deactivation effect of liquid desiccant solution on bacteria and virus, the capture function of liquid desiccant dehumidification system for PM, and the carryover of liquid desiccant are reviewed.

2. Removal capability for VOCs

Indoor air pollution from VOCs is known to pose a risk to human health [17]. Therefore, remove these VOCs from indoor air has a great significance for human health. There is nowadays no single fully satisfactory method for VOC removal from indoor air due to the difficulties linked to the very low concentration ($\mu g/m^3$ range), diversity, and variability at which VOCs are typically found in the indoor environment [12]. Moschandreas et al. [18] pointed out that a liquid desiccant-based, gas-fired dehumidification system using LiCl solution has the capacity to remove indoor pollutants. In addition, Chung et al. [19] and Hines et al. [20] reported that both organic and inorganic liquid desiccants have the capability of removing air pollutants, and the removal of chemical pollutants is completely depended on the solubility of them in different liquid desiccant. Therefore, an additional benefit of the LDAS is that it can remove a certain amount of VOCs to a certain degree during the air dehumidification process.

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