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Numerical Performance Evaluation of Aqueous LiCl and CaCl$_2$ Solutions as Liquid Desiccant in Dehumidification Systems

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INTRODUCTION

In tropical countries like Indonesia, humidity levels are generally high, with relatively constant temperatures. This explanation emphasizes that in a room, the responsibility of regulating humidity and air temperature to ensure comfort is significant.

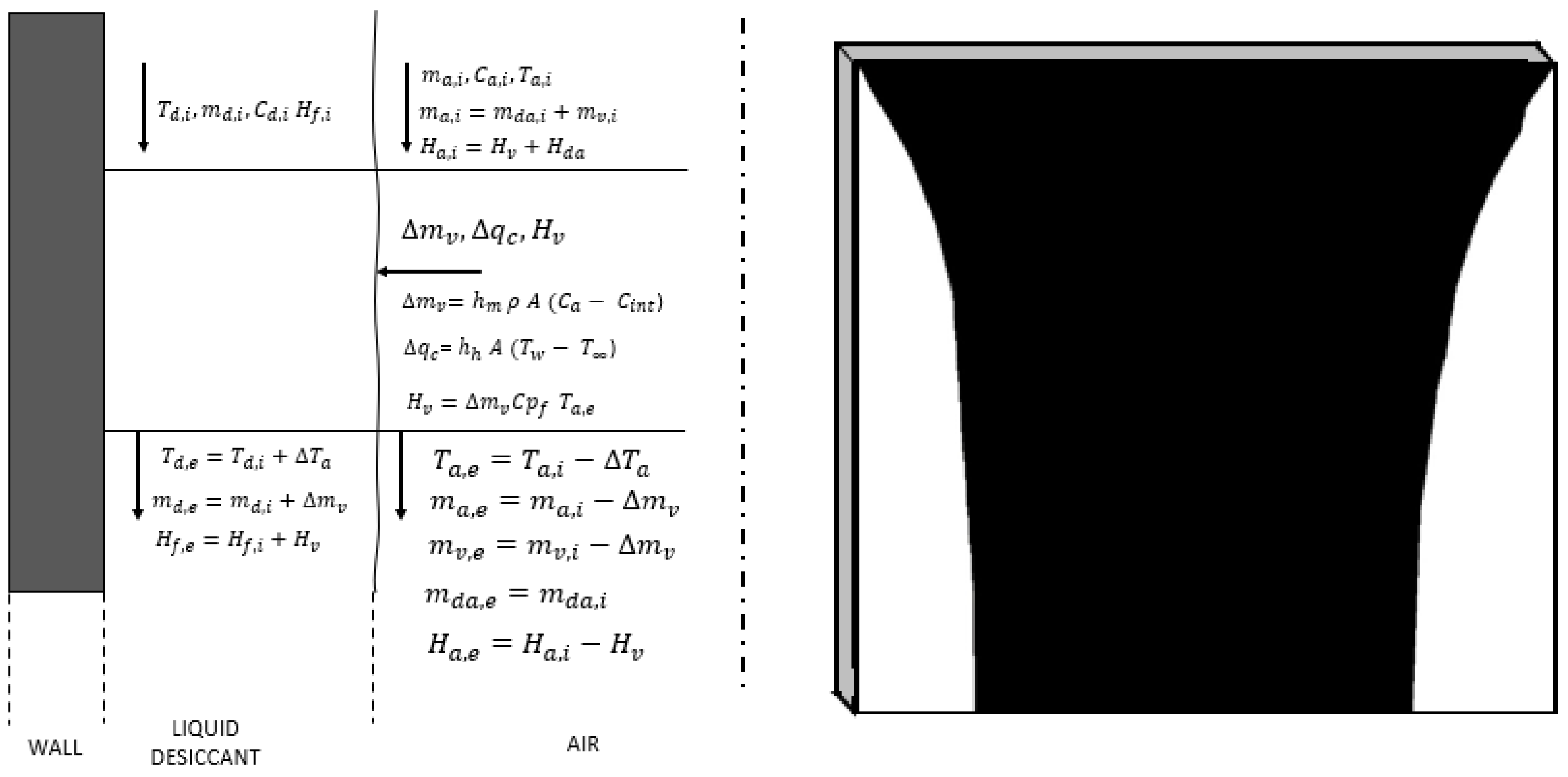
In recent years, new innovations have been developed in household air conditioning with the concept of desiccant fluid [1]. The reason for this innovation, as explained earlier by [2], is due to growing concerns over electricity costs, grid stability, and global warming. These concerns have led to alternative energy sources and a primary focus on energy efficiency.

The purpose of this research is to test the system scheme and types of liquid desiccants used to enhance air quality by reducing humidity. It aims to determine the transfers performance of aqueous LiCl and CaCl$_2$ liquid desiccants by numerical means, including the process of reducing water content in the air by the absorption of water content in the air by the liquid desiccant and the heat and mass transfer phenomena that occur with the liquid desiccants. The research is conducted numerically by simultaneously solving heat and mass transfer equations using the finite difference method explicitly, with the changes of properties values of the liquid desiccant in each control volume.

The differences in fluid characteristics and properties between the aqueous LiCl and CaCl$_2$ solution remarkably affect the reduction water content from the air. The performance of an aqueous LiCl solution with a concentration of 40% (wt. of LiCl) in absorbing water vapor from the air is better than that of the aqueous CaCl$_2$ solution. Apart from performance, considering the corrosive nature of LiCl and the relatively cheaper price of CaCl$_2$, CaCl$_2$ can be considered a fairly reliable alternative liquid desiccant.

METHODOLOGY

With the dimensions of 1 meter high and 0.5 meters width, in the dehumidification system, several control volumes are divided. The heat and mass transfer process inside the control volume is shown in Figure 1.



(a) (b)

Figure 1. Schematic of the desiccant absorption process (a) and wettability of the desiccant over vertical plate

Governing equations

The system is divided into two parts; air side and desiccant fluid side.

- Mass balance in air side

$$\sum \dot{m} = \dot{m}_{da,i} + \dot{m}_{v,i} - \Delta m_v - \dot{m}_{da,e} - \dot{m}_{v,e} = 0$$

- Mass balance in liquid desiccant side

$$\sum \dot{m} = \dot{m}_{d,i} + \Delta m_v - \dot{m}_{d,e} = 0$$

- Energy balance in air side

$$\dot{m}_{da} C p_{da} \frac{\partial T_a}{\partial z} + \dot{m}_v C p_v \frac{\partial T_a}{\partial z} - \Delta Q_c - \Delta H_f = 0$$

- Energy balance in the liquid desiccant side

$$\dot{m}_{da} C p_{da} \frac{\partial T_a}{\partial z} + \dot{m}_v C p_v \frac{\partial T_a}{\partial z} - \Delta Q_c - \Delta H_f = 0$$

RESULTS AND DISCUSSIONS

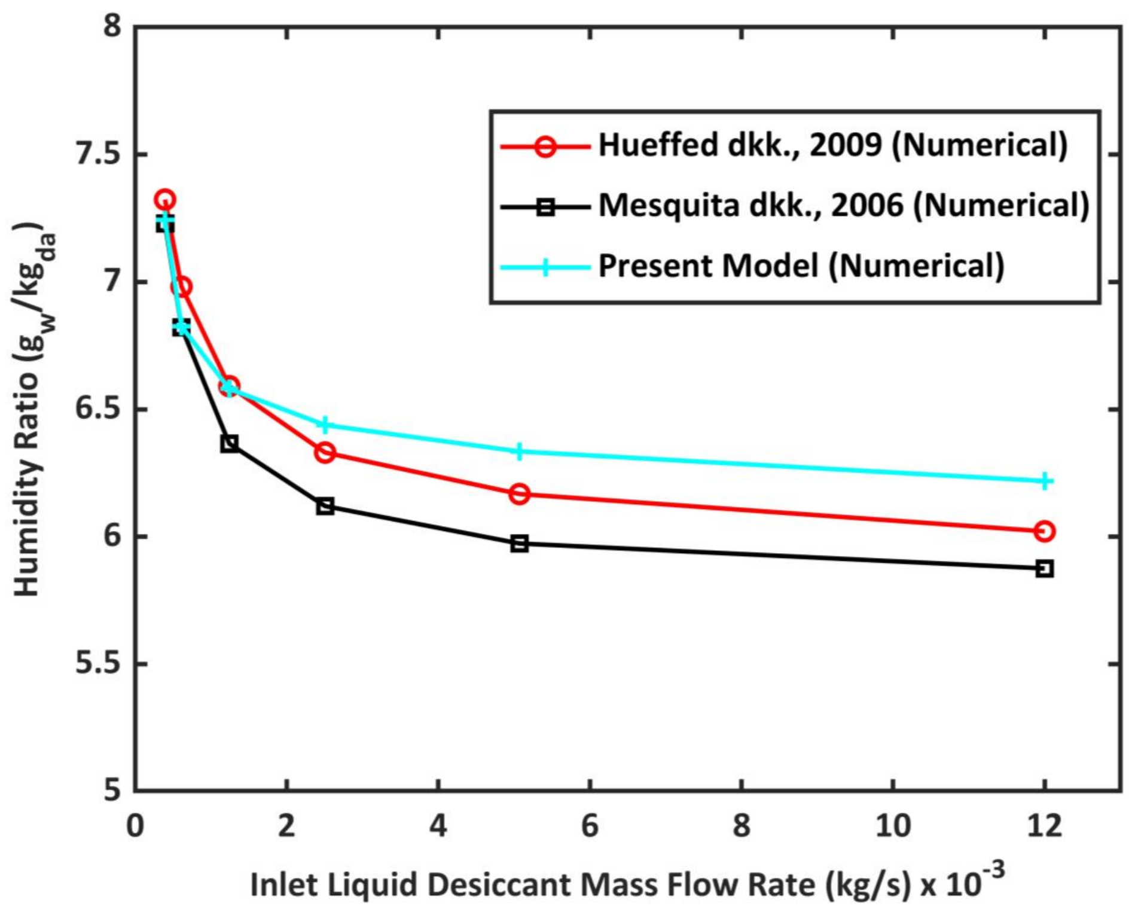


Figure 2. Model validation

The model is validated with the data obtained in the literature [1]–[2] at the same operating conditions and assumptions. Fig. 2 indicates that comparison with literatures values show a deviation less than 5% for a wide range of inlet desiccant mass flowrates.

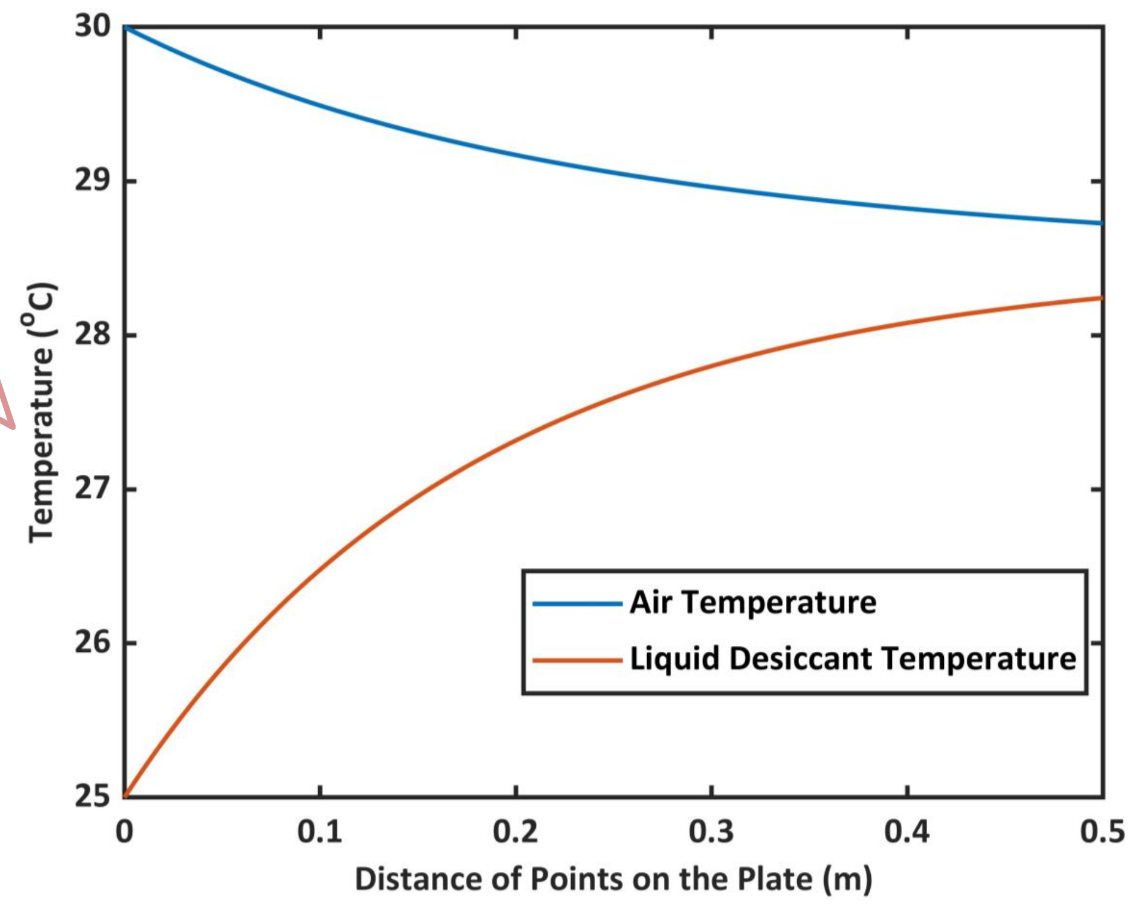


Figure 3. Temperature Distribution

Fig. 3 indicates that during the process of absorbing water vapor from the air, the liquid desiccant leads to an insignificant increase of the desiccant temperature for about 3 °C and a decrease of air temperature for about 1 °C .

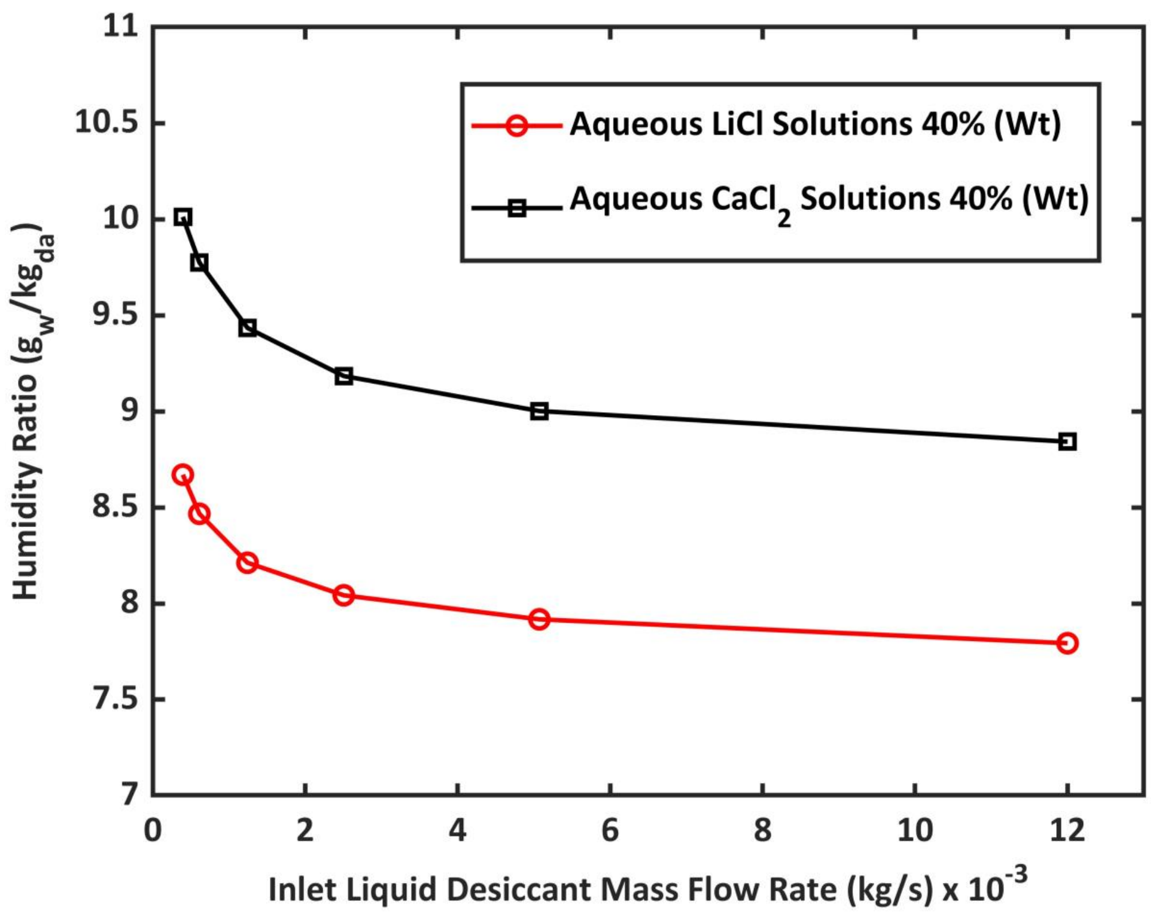


Figure 4. Effect of solution flowrate on the humidity ratio

The differences in fluid characteristics and properties of the aqueous LiCl and CaCl$_2$ solutions remarkably affect the reduction water content from the air. Fig. 4 indicates that the water absorption performance of an aqueous LiCl solution with a concentration of 40% (wt. of LiCl) is better than that of the aqueous CaCl$_2$ solution, 15% higher compared to the LiCl solution.

CONCLUSIONS

- The model can predict the heat and mass transfer process in the liquid desiccant systems with a good agreement compared to the literature.
- The LiCl solution exhibits higher performance in absorbing water vapor from the air compared to the CaCl$_2$ solution. This is because the LiCl solution has a lower saturation pressure than the CaCl$_2$ solution.

REFERENCES

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