STUSY OF THE EFFECT OF INTERCOOLING ON THE PERFORMANCE OF LIQUID DESICCANT BED

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ABSTRACT

In this Research, effect of inter cooling on the performance of liquid desiccant bed has been experimentally investigated. Experimental system involves structured packing bed composed of cellulose paper and two heat exchangers as a two stage inter cooling for the bed. Calcium chloride solution was used as a liquid desiccant. The bed performance was tested at different air and solution flow rates and solution concentrations. The inlet and outlet air, water and solution temperatures, inlet and outlet air relative humidity, air and water flow rates are measured then moisture removal rate and dehumidification efficiency are calculated. The results show that The inter cooling significantly enhances the performance of desiccant bed and the adsorption process can be done at nearly isothermally. The enhancement in bed performance can be more than 50% due to inter cooling. Moisture removal rate increases by increasing air and solution flow rates. With inter cooling, dehumidification efficiency more than 80% can be reach and without cooling this value is up to 55%.

Keywords: Desiccant, water, calcium chloride, Intercooling, dehumidification.

1 INTRODUCTION

The industry standard conventional air conditioners such as window air conditioning, split air conditioner and central air conditioning are all struggling to cope with the new economic and environmental challenges and working to gain access to improved levels of ventilation, low electricity consumption, air fineness and reducing greenhouse gas emissions rate level. Since these air conditioners consume a large amount of electricity to remove moisture from the air in industrial processes and indoor and because the conventional air conditioners systems do not meet these requirements, so it was necessary to use a new alternative.

This alternative is removing moisture from air using absorbent material, and this material is a solution that reduces energy and greenhouse gas consumption in the warm moist places. Liquid desiccant material system are used to dehumidify air. This systems works to reduce the water vapor content in the humid air through the water vapor pressure difference between the moist air and desiccant material. The performance of this system depends on moisture absorbent material on a range of conditions such as; temperature and moisture of incoming air to dehumidifier, absorbent concentration, solution temperature, the flow rates of both air and dried material inside dehumidifier.

Dehumidifiers using packed towers with random packing or structured packing are popular owing to larger contact areas, Wang et al. (2016). This paper presents an experimental study on the dehumidification performance of a counter flow liquid desiccant dehumidifier using structured packing with a high specific surface area (650 m^2 m^{-3}). New empirical equations correlating the moisture effectiveness and the enthalpy effectiveness with critical inlet parameters are developed. The results show that the critical height increases with the desiccant flow flux. For the packing studied in this work, the height should not be higher than 0.4 m when the desiccant flow flux L is less than 1.3 kg m^{-2} s^{-1}, Wang et al. (2013). The parameters in the correlation equations of the heat and mass transfer coefficients were determined from experiment data. The empirical correlations for mass transfer coefficients and the dehumidification effectiveness of packed-type dehumidifiers are usually determined from experimental data due to the complicated coupled heat and mass transfer occurring in a dehumidification process. Experimental study on the liquid desiccant dehumidifier is also beneficial to clearly understanding and enhancing the coupled heat and mass transfer, Zhang et al., (2012). A number of theoretical and empirical models of different types of dehumidifier were developed, Bassuoni (2014) and Woods and Kozubal (2013). In past decades, many people show much interest in air dehumidification using liquid desiccant for air humidity control in air conditioning systems, which work at atmospheric pressure. Researchers mainly focused on performance analysis and theoretical model of liquid desiccant dehumidifier used in air conditioning Koronaki et al. (2013) selected dehumidification efficiency and moisture removal rate as performance indexes to compare the dehumidifying performance of three commonly used desiccants including LiBr, LiCl and $CaCl_2$ aqueous solution under different operating parameters, Gao, et al. (2012). Dehumidifier is the core component in a liquid desiccant air-conditioning system, whose efficiency directly affects the whole performance. In this study a cross-flow dehumidifier was established in which LiCl solution and Celdek structured packing were used. The results show that the outlet parameter values of air and solution can be easily gained with enthalpy efficiency and moisture efficiency which was obtained from experimental regression. By increasing the thickness, width or height simultaneously, better performance of Dehumidifier can be achieved without increasing the pressure loss.

There are many designs of dehumidifiers using liquid substances Jain, Bansal (2007). These designs receive much attention because of their high efficiency. These dehumidifiers are designed with different sizes and used a variety of materials such as metals, plastics, ceramics, etc, which provide a larger contact area between air and dried material. In the dehumidifier, volume size is the same but these fillings cause lower air pressure drop through the dehumidifier. Abdul-wahab et al (2004)., focused on the towers packed randomly. Chung (1994), Chung et al (1996), Lazzarin et al (1999), Fumo and Gosuami (2002) used drying packed cellulose corrugated paper towers, that has the largest surface area in contact in a relatively small area of dehumidifier. Yin et al. (2008) used plate fin heat exchanger design as an internally cooled dehumidifier. Internally cooled dehumidifier was shown to have higher dehumidification performance compared to an adiabatic dehumidifier. Liu et al. (2006b) simulated the performance of internally cooled dehumidifiers with different flow configurations of air and desiccant. Counter-flow configuration was reported to have the best dehumidification performance.

Experimental and numerical studies of the liquid desiccant air dehumidification with internally cooled dehumidifiers were investigated. For such dehumidifiers, the desiccant solution directly contacted the humid air in the dehumidifier. Heat and mass transfer processes occurres between the desiccant solution and air. The desiccant solution was cooled by indirectly contacting cooling mediums such as water, air, and refrigerant etc. It was found that the internally cooled dehumidifiers provided better dehumidification performances compared to the adiabatic ones. Xiong et al. (2010) showed that the COP of the system increased from 0.24 to 0.73 when used a novel two-stage liquid desiccant dehumidification. Gandhidasan and Mohandes (2011) simulate the relationship between the inlet and outlet parameters of the dehumidifier in the liquid desiccant system. The results show that the dehumidification process can be alternatively modeled using artificial neural network with a Principle of liquid desiccant cooling based evaporative cooler. With reasonable degree of accuracy. Khan (1998) presented the performance analysis of an internally cooled absorber using thin plate heat and mass exchanger cooled by direct evaporation with lithium chloride as desiccant. effectiveness and humidity effectiveness were brought out to define the thermal performance of the absorber. It was found that the number of mass transfer units had great effect on the enthalpy and humidity effectiveness. Khan and Martinz (1998) numerically investigated an internal cooled dehumidifier using tube-fin exchanger with air crossing flow using one-dimensional finite difference model.

Many researchers indicate that the use of dried material in air conditioning systems lead to reduce the energy used in cooling and dehumidification by removing the latent load from the air.

2 DEHUMIDIFICATION PROCESS

The dehumidification process is the one that uses liquid desiccant to remove moisture from the ventilation air before being introduced into a conditioned space. The air may directly come in contact with the desiccant in a counter-flow manner. The process is a simultaneous heat and mass transfer process. The humidity level of air and the concentration of the desiccant will be decreased. The performance of the system is determined by the moisture removal rate and the dehumidification effectiveness.

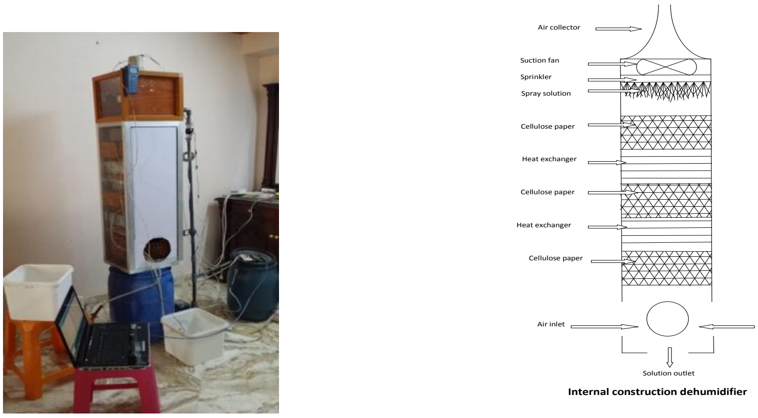
3 EXPERIMENTAL SETUP

The experimental setup is designed to study the effect inter cooling on the removal moisture from air using absorbent materials to moisture shown in Figure 1. The setup is made of an aluminum frame work of 130 cm high, 33 cm length and 30 cm width two heat exchangers stuffed with cellulose paper. A transparent cover is used in order to see what is happening inside the test reg. It was connected to each of the solution tank and water cooling tank by tow pumps each one 0.5 HP. Control valve is installed before the solution tank so as to control the amount of solution flowing through the spray orifices. An open cooling cycle is used. This setup is installed in Kafr El-Sheikh city, Egypt, close to the river Nile and the average temperature is 35-37° C and humidity of 70-80% in July. The following measurements are carried out.

1. Temperature and humidity sensors are placed in air entering the setup.
2. Temperature and humidity sensors are placed in air out the setup.
3. Flow rate sensor is installed before the sprayers.
4. Thermocouple is placed at the cooling water exit.
5. Velocity of air was measured using a vane meter placed just above the suction fan.

The setup is covered with polyurethane transparent sheets in order to see what is happening inside as shown in Figure 1a. A pump (0.5 hp) is used to cerculate the desiccant solution (calcium chloride) within the dehumidifier. A 60 liters tank is used with a valve to control the amount of solution flowing into the dehumidifier tower.The solution returns to the tank again and then as shown in figure 2. A corrugated cellulose paper or regular polygon which is inclined at an angle of 45 º and a height of 4.3 mm is uded. This is used to increases the contact surface area between the moist air and the desiccant material The solution from the bottom of the tower is brought to regeneratio, and then returns to the tank for mixing with air.

During the regeneration prosess; heat is librated. In the current study, two stage cooling process are used in order to reject the heat generated from this chemical process. The cooling process in the present work was developed in order to increase the performance of the dehumidification process. Solution flow sensor consists of a plastic valve body and a water rotor. When solution flows through the rotor, it rolls. Its speed changes with different rates of flow. And to read solution flow rate in liters per hour is obtaibed.



(a) (b)

Figure 1. (a) Main components of packed bed liquid desiccant cooling system (b) Dehumidifier construction.

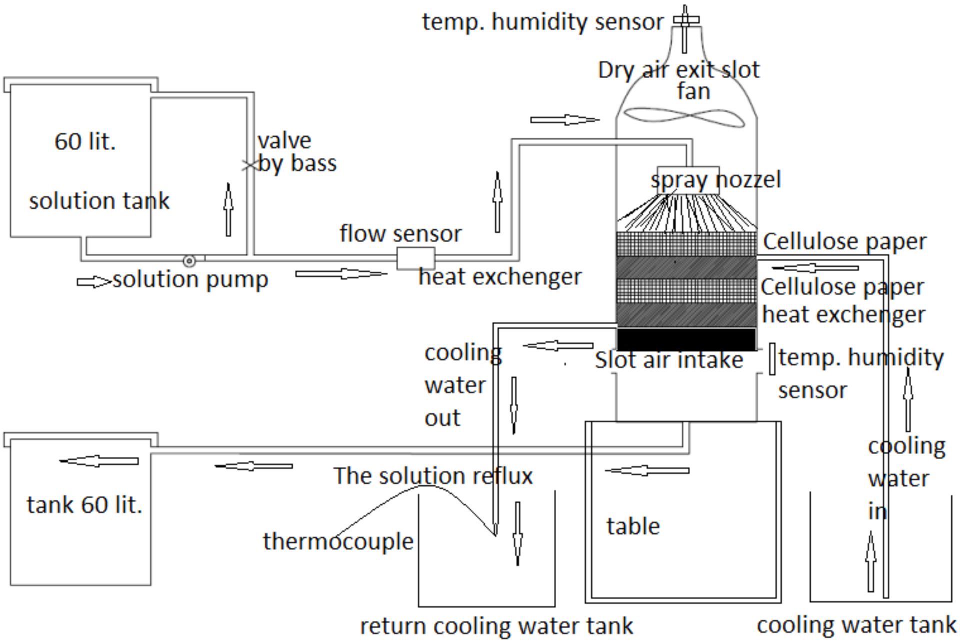


Figure 2. schematic diagram of the experimental apparatus forliquid desiccantdehumidification system

Heat exchanger (HE) is made of nine cooper pipes 8 mm diameter. The solution falls on the HE surface area, which is 30 cm length, 35 cm width and15 cm height. Fin spacing is 4 mm. The cooling water enters and leaves at the same side of HE. The desiccant solution was sprayed to the fins from the top and flows downwards by gravity, at the same time the air is blown from the bottom counter-flowing with the desiccant solution.

The following instruments are used to measurements:

a) Air temperature is measured by K-type thermocouple with accuracy of up to ± 0.1ºC. thermocouple are connected to data logger BK precision 630 dual device. See Table 1.
b) A DHT 11 humidity and temperature sensor measures the temperature and humidity of air; humidity accuracy ± 5% and temperature accuracy ± 2%. See Table 1.
c) The desiccant solution flow rate is measured using flow meter sensor type FS 300A G3/4 inch with accuracy ± 3% (Q). See Table 1.
d) Air is measured with a Wind speed device with measurement range (0.4 - 25 m/s). See Table 1.
e) ARDUINO UNO is used where it is connected to the computer. See Table 1.

EES program (2007) was used to calculate the air humidity ratio by using the measured values of air temperature and humidity sensor .

4 PERFORMANCE INDICES

4.1 Moisture Removal Rate (MRR)

This parameter can be viewed as a direct performance indicator of the system since it tells how much moisture can be absorbed by the desiccant. It can be calculated from the difference of the humidity ratios between the inlet and outlet air and the air flow rate, as shown in Eq. (1), Wang et al. (2016).

$$MRR = \dot{m}_a (\omega_{out} - \omega_{in}) \qquad (1)$$

where $\dot{m}a$, ωout and ωin are the variables to be defined as air mass flow rate, outlet humidity ratio and inlet humidity ratio respectively.

4.2 Dehumdification Effectiveness (η)

The dehumidification effectiveness is defined as the ratio of the actual dehumidifying capacity to the theoretical or maximum one which would occur when the humidity ratio of the outlet air is in equilibrium with the inlet desiccant as shown in Eq. (2) Wang et al. (2016).

The absorber efficiency is the ratio of the actual humidity ratio variation of the air passing through the dehumidifier to its variance under ideal conditions, The dehumidification effectiveness is defined as the ratio of actual change of the humidity ratio to the maximum possible change, where ω equ is the equilibrium moisture content (humidity ratio) of air in equilibrium with the solution at its inlet conditions. It is a function of solution temperature and concentration and represents the minimum humidity level to which the air can theoretically be dehumidified as shown Equation (2):

$$\eta = \left(\frac{\omega\ in - \omega\ out}{\omega\ in - \omega\ equ}\right) \times 100\% \tag{2}$$

where ω_{out}, ω_{in} and ω_{equ} are defined as outlet humidity ratio, inlet humidity ratio and equilibrium moisture; respectively.

4.3 Air mass flow rate ($\dot{m}a$)

The air flow rate through fan meter can be calculated as shown Eq. (3).

$$\dot{m}a = \rho_a V_{min}\ A \tag{3}$$

where ρ_a, V_{min} and A are the density of dry air, the measured volume flow rate and area respectively.

4.4 Determining the percentage of the solution concentration.

Four solution concentrations are used in this study (42, 38, 34 and 30% by weight) where the test begins concentrations of 42% and ends at 30%. This gives the salt dissolved in a mass of 60 kg needed to conduct the experiment as shown in Equation (4).

$$X = \left(\frac{\text{mass of solute (salt)}}{\text{mass solution (salt + water)}}\right) \times 100\% \tag{4}$$

5 RESULTS AND DISCUSSIONS

Parameter analysis on the dehumidification performance. The influences of six inlet parameters of the air and the desiccant including air flow rate, air inlet temperature, air inlet humidity ratio, desiccant flow rate, desiccant inlet temperature and desiccant inlet concentration. the prediction curves for the moisture removal rate obtained from the new correlations are also compared with the experimental data reported by another researcher

5.1 Effect of inlet solution temperature

The effect of desiccant solution temperature on the moisture removal rate is studied. The MRR decreases rapidly with increasing temperature of the desiccated solution because of the increase in vapor pressure of the solution. Figure 3. shows the influence of the solution temperature on the moisture removal rate from air. At solution temperature of 25ºC and 38ºC, the air flow rate 0.724 kg/m²s and solution concentration was 42%, the MRR is 0.0012 kg/s and 0.00048 kg/s; respectively. This means that an increase in temperature from 25 ºC to 38ºC reduces MRR by 42%. At the same conditions of solution temperature 25ºC and 38ºC, air flow rate 0.724 kg/m²s and solution concentration 42% without using internal cooling, the MRR is found to be 0.0009 kg/s and 0.00022 kg/s; respectively, i.e. an improvement of 33% and 118%; respectively when using dehumidifiers with internal cooling.

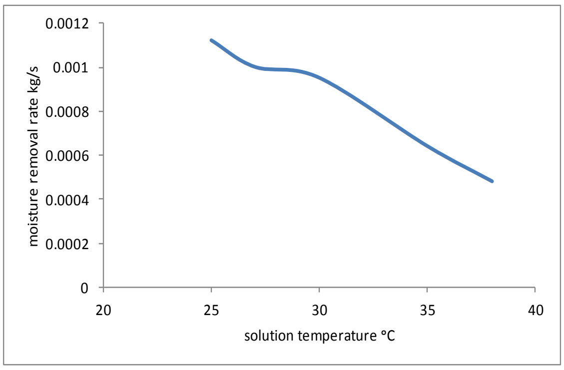


Figure 3. Effect of desiccant temperature on the moisture removal rate.

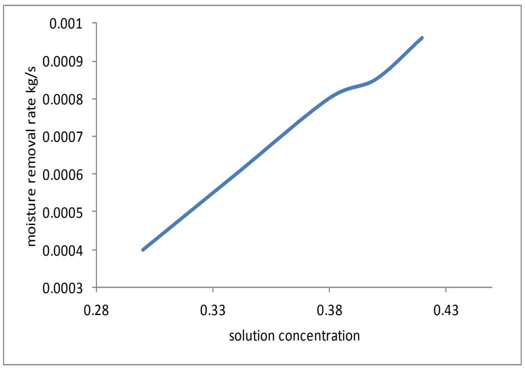


Figure 4. Effect of solution concentration on the moisture removal rate.

5.2 Effect of inlet solution concentration

The effect of the desiccant solution concentration on MRR is investigated. The vapor partial pressure of desiccant material decreases with increasing concentration of the desiccant solution, and this raises the mass transmission between the desiccant solution and air. This means that moisture removal rate increases with increasing concentration of the solution. These results agree with the observations reported by Zurigat et al. (2003). Figure 4. shows the influence of the desiccant solution concentration on MRR. At solution concentration of 30%, the air flow rate 0.724 kg/m²s, and solution temperature was 30ºC the MRR equals to 0.0004 kg/s. Increasing the concentration from 30% to 42%, the air flow rate 0.724 kg/m²s, and solution temperature was 30ºC the moisture removal rate increased by 41%. At the same conditions with solution temperature was 30ºC and without internal cooling, MRR equals to 0.0002 kg/s, i.e. an improvement of 100% when using dehumidifiers with intercooling.

5.3 Effect of inlet solution flow rate

The effect of desiccant solution flow rate on the moisture removal rate of air stream is shown in Figure 5. The moisture removal rate increases rapidly with increasing desiccant solution flow rate. This is because increasing flow rate of desiccant solution increases the mass transfer rate of water vapor from air. On the other hand, the very high flow rates of desiccant solution causes some resistance to air flow and a relatively higher noise level. This result is in agreement with studies reported by Factor and Grossman (1980), Patnaik et al. (1990), Pontis and Lenz (1996) , Zurigat et al. (2003), Gandhidsan (2004), and Elsarraj (2007). At small solution flow rate of 0.5 kg/m²s, solution temperature was 30ºC, the air flow rate $\dot{m}_a$=0.724 kg/m²s, and solution concentration was 42% the MRR equals 0.00148 kg/s and increasing the solution flow rate to a higher value of 2.8 kg/m²s and at the same condition from air flow rate, solution temperature, solution concentration. the MRR reaches 0.0084 kg/s, i.e. an increase of 17%.

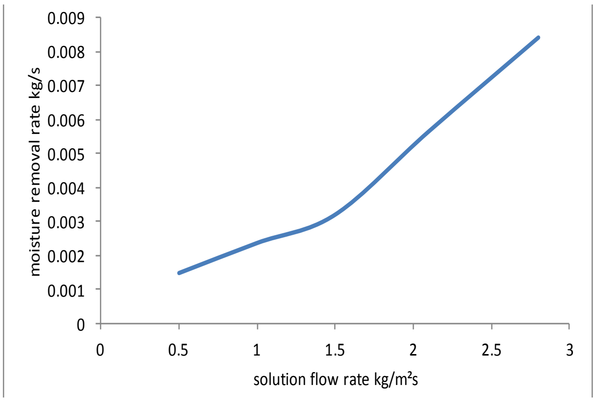


Figure 5. Effect of solution flow rate on the moisture removal rate.

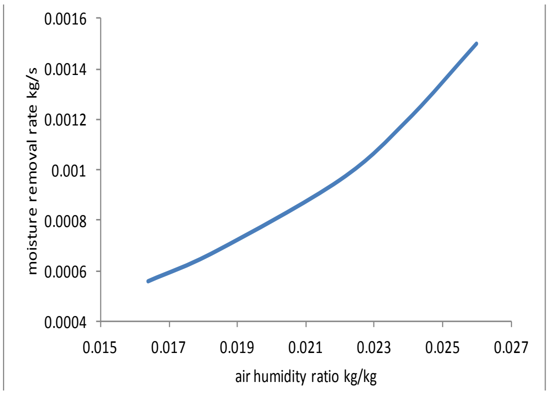


Figure 6. Effect of air humidity ratio on the moisture removal rate.

5.4 Effect of air inlet humidity ratio

Increasing the air inlet humidity ratio increases the amount of moisture removed in the dehumidifier. The water vapor partial pressure of the air increases with increasing air inlet humidity ratio, which increases the mass transfer potential. However, the air humidity ratio does not affect the desiccant solution properties (like absorbability), wetting of the surface and dehumidification effectiveness. The results showed good agreement with those of Chen, et al. (1996) , Patnaik, et al. (1990), Oberg and Goswami (1998), and Fumo and Goswami (2002). Figure 6. shows the relation between the moisture removal rate and air inlet humidity ration. Increasing the air inlet humidity ratio from 0.00164 kg/kg to 0.026 kg/kg, solution temperature was 30ºC, the air flow rate 0.724 kg/m²s, and solution concentration was 42%. MRR increases from 0.00056 kg/s to 0.0015 kg/s.

5.5 Effect of air inlet temperature

Figure 7. shows the effect of the inlet air inlet temperature on the moisture removal rate. Heat is transferred from the hot air to the desiccant solution which increases the solution temperature and thus raise the partial pressure of the desiccant material and therefore the amount of moisture removed from the air is decreased. This result is in agreement with the experimental results done by Yin et al., (2007), Fumo and Goswami, (2002), Mago and Goswami, (2003), and Moon et al., (2009). Increasing the inlet air temperature from 27ºC to 38ºC, the air flow rate 0.724 kg/m²s, and solution concentration was 42%. the MRR decreses from 0.00096 kg/s to 0.00084 kg/s, i.e. by 12.5%. When using dehumidifier without internal cooling, at air temperature from 27ºC to 38ºC, air flow rate 0.724 kg/m²s, and solution concentration 42%. the MRR decreased from 0.0008 kg/s to 0.00059 kg/s; an improvement of 16% and 42%; respectively when using internal cooling.

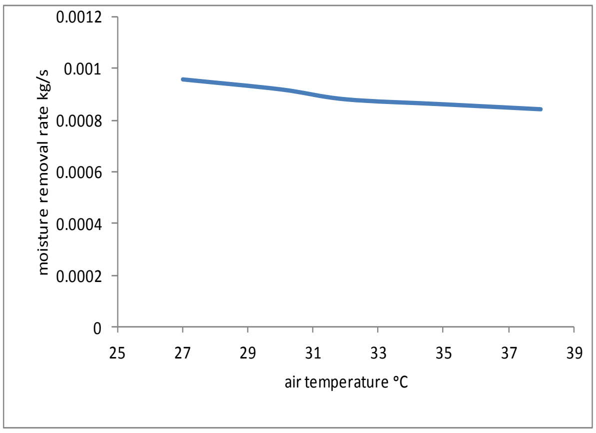


Figure 7. Effect of air inlet temperature on the moisture removal rate

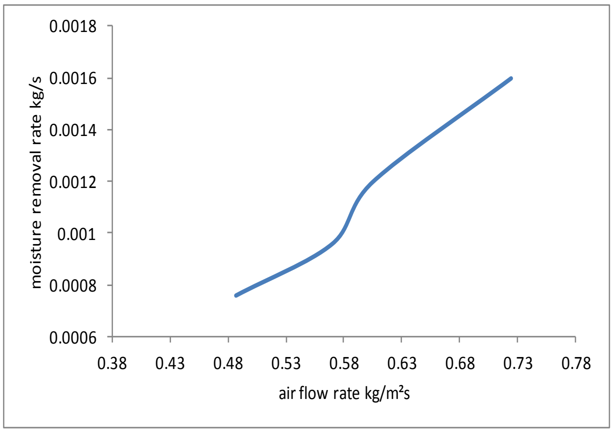


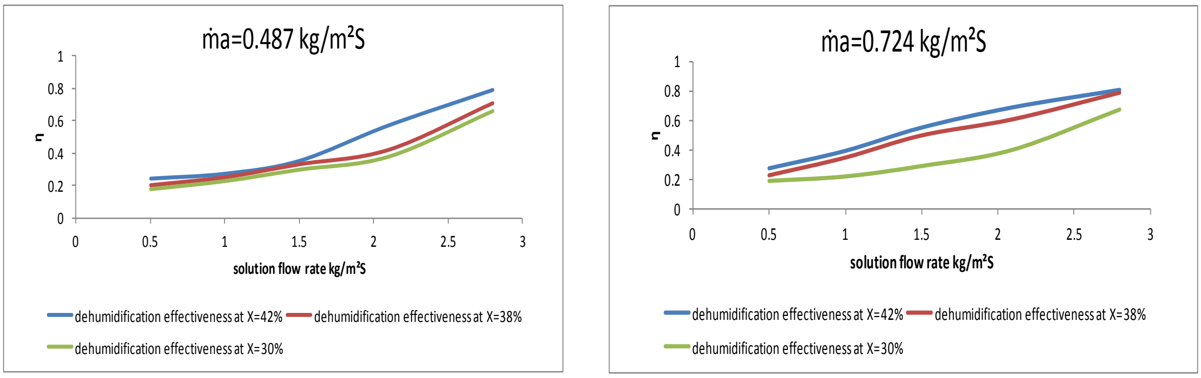
Figure 8. Effect of air flow rate on the moisture removal rate

5.6 Effect of air flow rate

Figure 8. shows The effect of air flow rate on moisture removal rate. The moisture removal rate increases with the increase air flow rate as a result of increaseing the mass transfer between the desiccant and air. These results are in good agreement with studies reported by Chen, et al. (1989), Oberg and Goswami (1998), Fumo and Goswami (2002) and Zurigat, et al. (2003). Increasing the air flow rate from 0.487 kg/m²s to 0.724 kg/m²s, solution temperature was 30ºC, the solution flow rate 2.8 kg/m²s, and solution concentration was 42%. increases the MRR from 0.00076 kg/s to 0.0016 kg/s. In the case of using a dehumidifier without internal cooling, the results (at air flow rate 0.487 kg/m²s and 0.724 kg/m²s, solution temperature 30ºC, solution flow rate 2.8 kg/m²s, and solution concentration 42%) shows that MRR is 0.0006 kg/s to 0.0011 kg/s; respectively; an improvement of 27% and 45%; respectively when using dehumidifiers with intercooling.

5.7 Dehumidification effectiveness

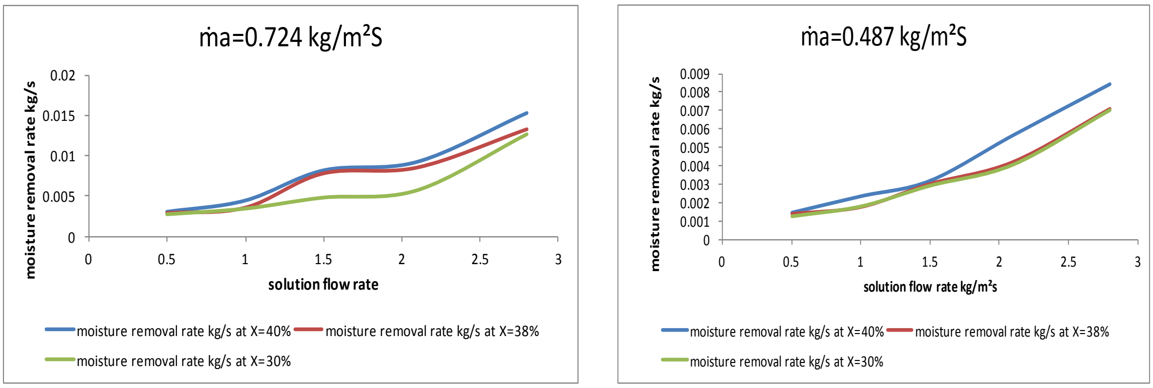
Figure 9. Shows that the relationship between the solution flow rate and dehumidification effectiveness at different values of air flow rate. It is find that at the solution flow rate 2.8 kg/m²s the effectiveness increases with increased concentration and increased air flow rate. Therefore, we find that the effectiveness at a concentration of 42% and air flow rate 0.724 kg/m²s was equal to 0. 81%. At the same concentration and the same flow rate of the solution but the air flow rate of 0.487 kg/m²s the effectiveness was equal to 0.79%. this meams The dehumidification effectiveness decrease with decreasing the desiccant concentration or desiccant flow rate or both.



(a) **(b)**

Figure 9. Dehumidification effectiveness: (a) at $\dot{m}_a$=0.724 kg/m²s and (b)at $\dot{m}_a$=0.487 kg/m²s.

5.8 Moisture removal rate at different desiccant concentrations



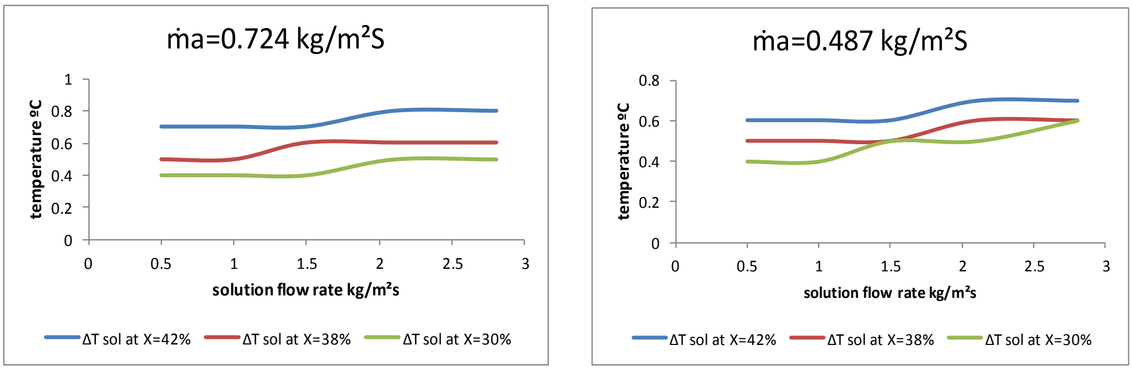
(a) **(b)**

Figure 10. Moisture removal rate: (a) at ṁa=0.724 kg/m^{2}s and (b) at ṁa=0.487 kg/m^{2}s).

Figure 10. Shows the relationship between the solution flow rate and moisture removal rate from the air. Figure 10 (a) when the amount of air ṁa=0.724 kg/m^{2}s and Figure 10 (b) when the amount of air ṁa=0.487 kg/m^{2}s. With Comparing the figures, find that when the flow rate of the solution 2.8 kg/m^{2}s, concentration 42%. The moisture removal rate from the air varies depending on the amount of air through dried. Therefore, find that with the increase in the desiccant flow rate and increase the concentration and increase the air flow rate increases the of moisture removal rate. At concentration of 42% and a high solution flow rate of 2.8 kg/m^{2}s, decreasing the air flow rate from 0.724 kg/m^{2}s to 0.487 kg/m^{2}s (i.e. by 33%), MRR decreases from 0.01537 kg/s to 0.00846 kg/s, i.e. by 45%.

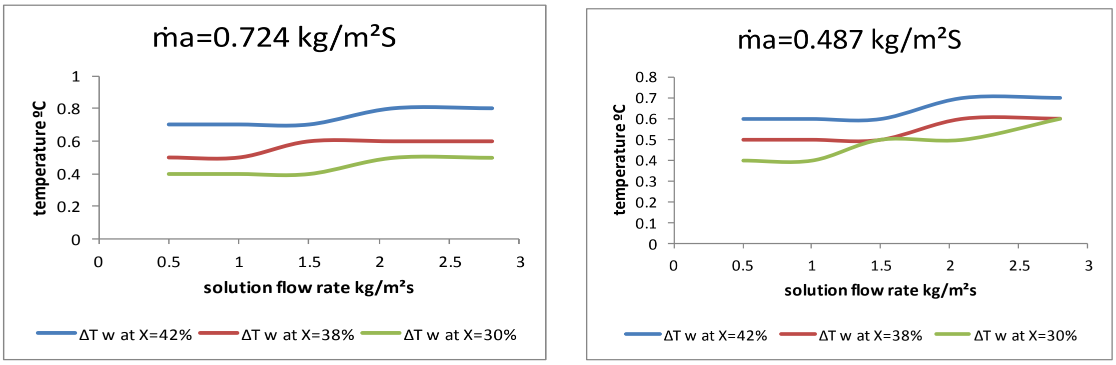
5.9 Solution temperature at different concentrations

Figure 11 (a) and (b) shows the relationship between the solution flow rate and the change in temperature of the solution resulting from the chemical reaction between the solution and air at constant air flow rate and solution concentration of 42%. It is found that the difference in desiccant temperature increases insignificanly with increasing solution flow rate and with increasing the air flow rate through the humidifier. At a high solution flow rate of 2.8 kg/m^{2}s, decresing the air flow rate from 0.724 kg/m^{2}s to 0.487 kg/m^{2}s, the difference in solution temperature between inlet and outlet changes from 0.8ºC. to 0.6ºC.



(a) **(b)**

Figure 11. Change in solution temperature ((a) at $\dot{m}_a$=0.724 kg/m^{2}s (b)at $\dot{m}_a$=0.487 kg/m^{2}s).



(a) **(b)**

Figure 12. Change in cooling water temperature: (a) at $\dot{m}_a$=0.724 kg/m^{2}s (b)at $\dot{m}_a$=0.487 kg/m^{2}s.

5.10 Cooling water temperature

Figure 12. illustrates the difference in cooling water temperature with solution flow rate at the three solution concentrations. From Fig.12 it is found that the change in cooling water temperature increases with the increase air flow rate, solution flow rate and solution concentration. From the experiments, it turns out that the change in cooling water temperature increases insignificanly with change for solution concentration as a result of the heat generated due to the chemical reaction between the solution and air. The heat generated is greater with at higher concentrations. It is found that at solution flow rate and is 0.5 kg/m^{2}s and air flow rate 0.487 kg/m^{2}s, the increase in cooling water temperature of 0.6ºC, 0.5ºC and 0.4ºC is recorded at solution concentrations of 42%, 38% and 30%; respectively.

5.11 Air temperature

Figure 13 shows the relationship between the flow rate of the solution and the difference in temperatures air at inlet and outlet of the dehumidifier. Found that with the increase in the flow rate of the solution and install the amount of air through the dehumidifier the difference in air temperature increasing for each concentration. And also he found that this difference increased with increasing concentration of the solution. From the results, it is found that the change in air temperature increases with change for solution concentration and the air flow rate also as a result of the heat generated due to the chemical reaction between the solution and air. The heat generated is greater with at higher concentrations. It is found that at solution flow rate and is 2.8 kg/m^{2}s and solution concentrations of 42%,, decreasing the air flow rate from 0.724 kg/m^{2}s to 0.487 kg/m^{2}s, the decrease in cooling water temperature was 2.3ºC and 1.7ºC; respectively.

Figure 14. shows the relationship between the solution flow rate and the difference in temperature of the air at inlet and outlet dehumidifier. When increase the air flow rate and increase desiccant concentration. Therefore found that. difference in temperature of air was increase. At any solution flow rate.

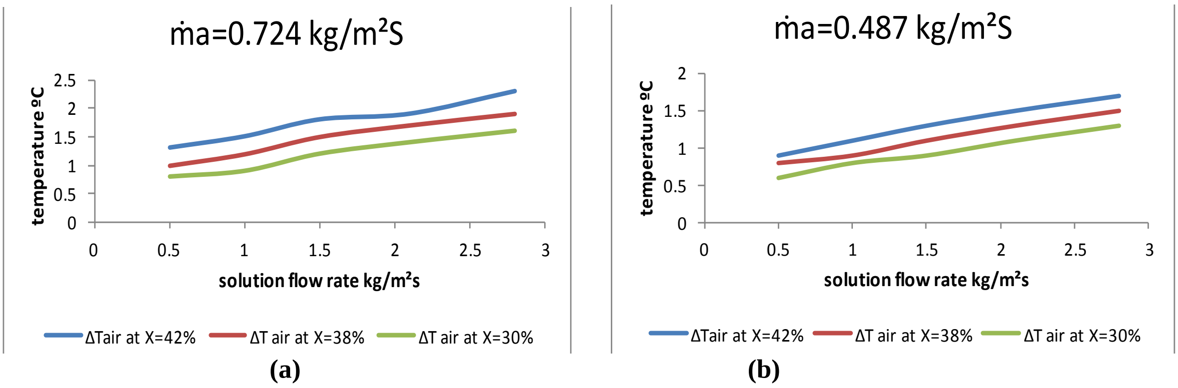


Figure 13. Change in air temperature: (a) at $\dot{m}_a$=0.724 kg/m²s (b) at $\dot{m}_a$=0.487 kg/m²s.

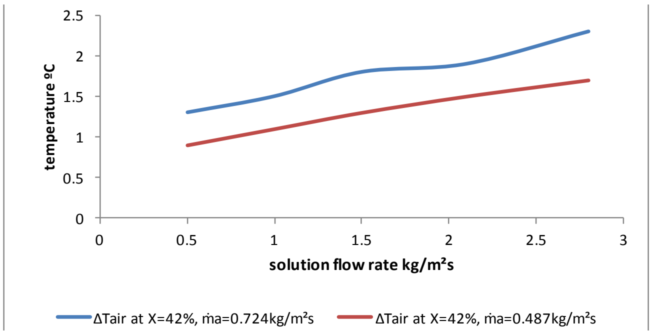


Figure 14. Change in air temperature at different values of air flow rates.

6 CONCLUSIONS.

In his work, Air conditioning using absorbent materials are mainly used to conserve energy as an environmentally friendly option. In this experimental study, the dehumidification effectiveness and the heat removal rate of a counter flow dehumidifier using calcium chloride solution is investigated at different solution concentrations from 30% to 42%, different solution flow rates and also different air flow rates. A two stage internal cooling is used. The following conclusions can be drawn.

This study indicates that MRR from air increases with increasing air flow rate. Increaseing the desiccant flow rate increases air temperature as well as solution temperature. The dehumidifier works well espcially when increasing the solution flow rates and concentration and decreasing air and solution temperatures. These results are in good agreement with results published by others.

Using intercooling improves the dehumidifier effectiveness from 61% to 81%. and its moisture removal rate for solution concentration 42%, solution flow rate 2.8 kg/m²s and air flow rate 0.724 kg/m²s. The moisture removal rate is improved by about 16% to 118% when using intercooling.

Nomenclature

ω_{in}	Inlet humidity ratio	ω_{equ}	equilibrium moisture
$\dot{M}_a$	air mass flow rate		
ω_{out}	outlet humidity ratio	V_{min}	the measured volume flow rate.
MRR	moisture removal rate	A	area
M	desiccant flow rate	η_h	dehumidification effectiveness
X	salt concentration in solution (kg/kg s)		

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