ORIGINAL RESEARCH PAPER

SEPARATION OF WATER VAPORS FROM AIR BY SORPTION ON SOME COMPOSITE MATERIALS

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Abstract: This work presents an experimental investigation of the kinetics of water vapor sorption on two composites synthesized by impregnating activated carbon and activated alumina respectively with lithium bromide (named as MCA2 and MCC2 respectively). The obtained results showed an increase in water amount adsorbed on both composite materials. Due to different chemical natures of the host matrices, the water sorption kinetics on MCC2 is faster compared to that of MCA2. The presence of calcium chloride instead of lithium bromide in alumina pores will determine a shorter breakthrough time and a higher adsorption rate of water vapors.

Keywords: *activated carbon, air drying, alumina, calcium chloride impregnation, composites, lithium bromide, sorption kinetics, water vapors*

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INTRODUCTION

Water sorption properties of composite materials can be influenced by the properties of each component. Incorporating inorganic salts (chlorides, bromides, nitrates of alkaline and rare-earth metals) into pores of some mesoporous or microporous matrices can affect their sorption capacity.

Salt dispersion in pores and its interaction with the matrix can change the properties of the salt [1-3]. The chemical nature of salt, its content, the chemical nature and the porous structure of the host matrix and the preparation conditions can also influence the sorption properties of the resulted composites [4-7].

Due to the hygroscopic nature of lithium bromide, this salt is used in absorption heat pumps, in drying units and air conditioning. Sorption properties of lithium bromide in bulk state are also well known.

In our prior work, we approached the study of water vapors adsorption on composite materials based on alumina and activated carbon impregnated with calcium chloride solution [7-9].

In the present work is investigated the adsorption of water vapors on composite materials resulted by impregnation of activated carbon and alumina with lithium bromide. Thus, it is shown that sorption properties of lithium bromide are similar to those of calcium chloride.

MATERIALS AND METHODS

Commercial activated carbon and activated alumina were milled and sieved in order to obtain 1mm particles. To confine lithium bromide in their pores, this materials were immersed in a solution of lithium bromide 15 w% and than dried at 200 ^{o}C to constant weight, when the anhydrous salt is formed [10-12]. The salt content in the composite material was determined to be 8.5 % and 13.2 %. These sorbents were denoted as MCA2 and MCC2.

The experimental water adsorption process was conducted in a fixed granular bed operated under isothermal regime. Description of the experimental set-up and its operation is found in our previous work [13]. The fixed adsorbent bed has a height of 0.1 m and a diameter of 1.5 10^{-2} m.

The experimental adsorption data were obtained at an atmospheric pressure, a temperature of 30 ^{o}C and flow rate ranged between 200-400 L/h. Air relative humidity and temperature at the bed output were measured by means of two digital psychrometers.

The mean water concentration in composite materials (MCC2, MCA2 and MCA1) and the adsorption rate are given by the relationships (1) and (2):

$$M_s \cdot (X - X_o) = M_v \int_0^t (C_0 - C)dt \qquad (1)$$

where: M_s-the mass of dry sorbent, kg; X-the water concentration in composite materials at $t = t$; X_o- the water concentration in composite materials at $t = 0$; M_v - gas phase (air) flow rate, $m^3 \cdot s^{-1}$; C_o, C-water vapors concentration in gaseous phase at the inlet and respectively outlet of the adsorbed bed, $kg \cdot m^{-3}$; t-time, s.
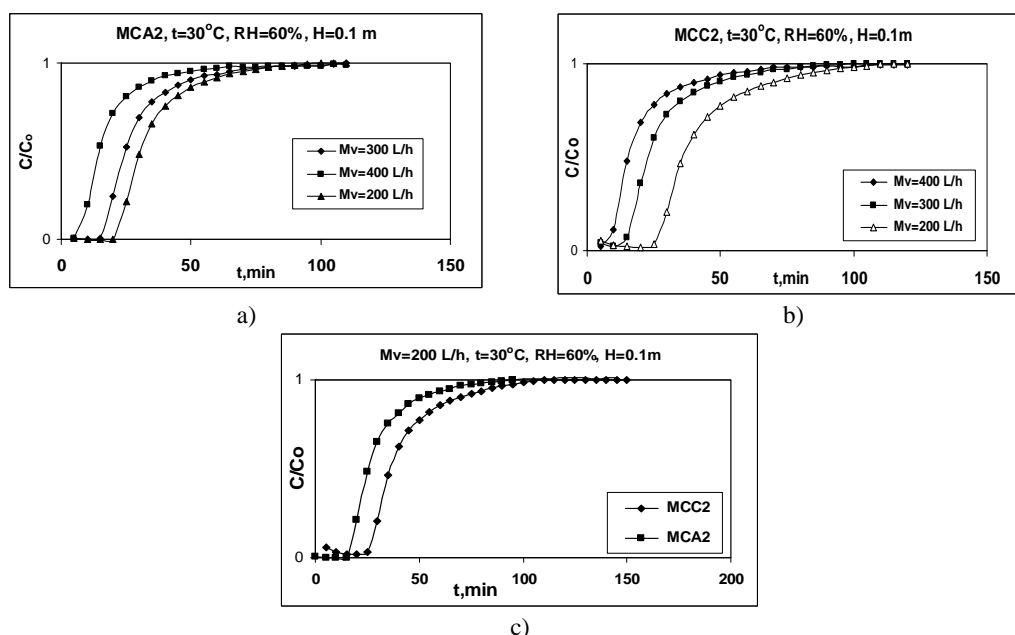
$$v_a = \frac{M_v (C_0 - C)}{V_{ST}(1 - \varepsilon)} \qquad (2)$$

where: V_{ST}- adsorbent volume, m^3; ε- fixed granular bed porosity;

RESULTS AND DISCUSSION

The present study emphasizes the influence of gas flow rate on the performance of two composite materials for water vapor adsorption.
Figure 1 presents gas flow rate influence on breakthrough curves.


Figure 1. Breakthrough curves of water vapor adsorption on composites dependence on the gas flow-rate

The flow rate effect on the breakthrough curves was investigated at a relative humidity of 60 %, a bed height of 0.1 m and a temperature of 30 ^{o}C by varying the gas flow rate from 0.2 to 0.4 m^3· h^{-1}. It is noticed that at higher flow rates the breakthrough occurred earlier due to a lower residence time of the wet air stream in adsorption column and consequently due to a shorter contact time between the adsorbate and adsorbent. The breakthrough occurs earlier in case of alumina impregnated with lithium bromide.
In Figure 2 is presented the concentration of water adsorbed on MCA2 and MCC2 for different values of the gas flow rate. It can be noticed that the concentration of the adsorbed water increases in time, until it tends to become constant. Also, adsorbed water concentration increases with the gas flow rate. In Figure 2a it can be observed that a flow rate of 0.4 m^3· h^{-1} will determine a smaller concentration of water adsorbed. This might be explained by the fact that the air flow value may be too large for this bed height, the time contact being too small and air flows throughout the bed without significant water vapor adsorption.

Figure 2c presents a comparative study of the water vapors adsorption composite material resulted from activated carbon impregnation (MCC2) and the composite material resulted from alumina impregnation. The two experiments were conducted under the same conditions (gas flow rate 200 L·h^{-1}, a relative humidity of 60 % and a temperature of 30 °C). As can be noticed, the composite material (MCC2) has a higher water adsorption capacity than the composite material (MCA2), due to a different porosity of the host matrix and a better impregnation.

a)   b)

c)
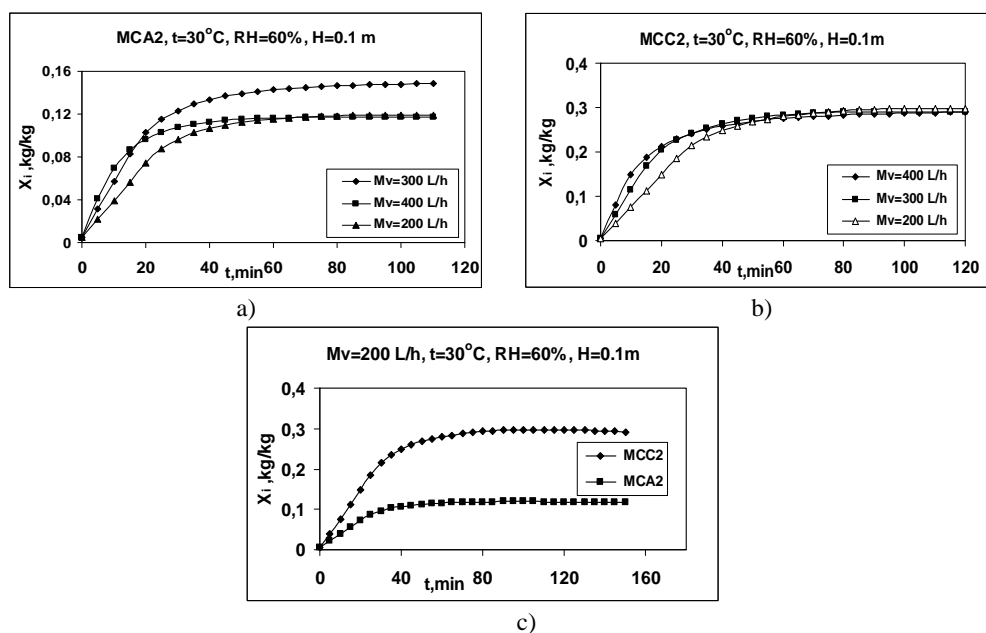
Figure 2. *Concentration of water in solid adsorbent bed*

a)   b)

c)
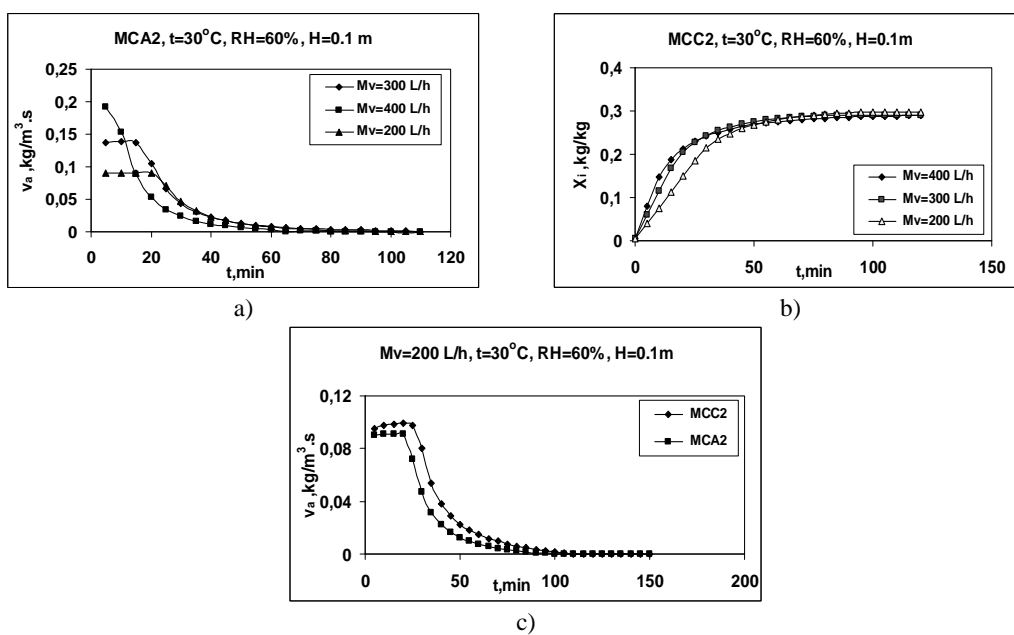
Figure 3. *Adsorption rate of water vapors on composites MCA2 and MCC2*

In Figure 3 is presented the adsorption rate on MCC2 and MCA2 for different values of the gas flow rate. The adsorption rate of water vapors is higher as the gas flow rate increase.

Figure 3 shows that in the process of adsorption there are two stages: the first stage of adsorption with a constant adsorption rate followed by a stage with decreasing adsorption rates.

The influence of the chemical nature of the salt can be noticed in Figure 4.

a)

b)

c)
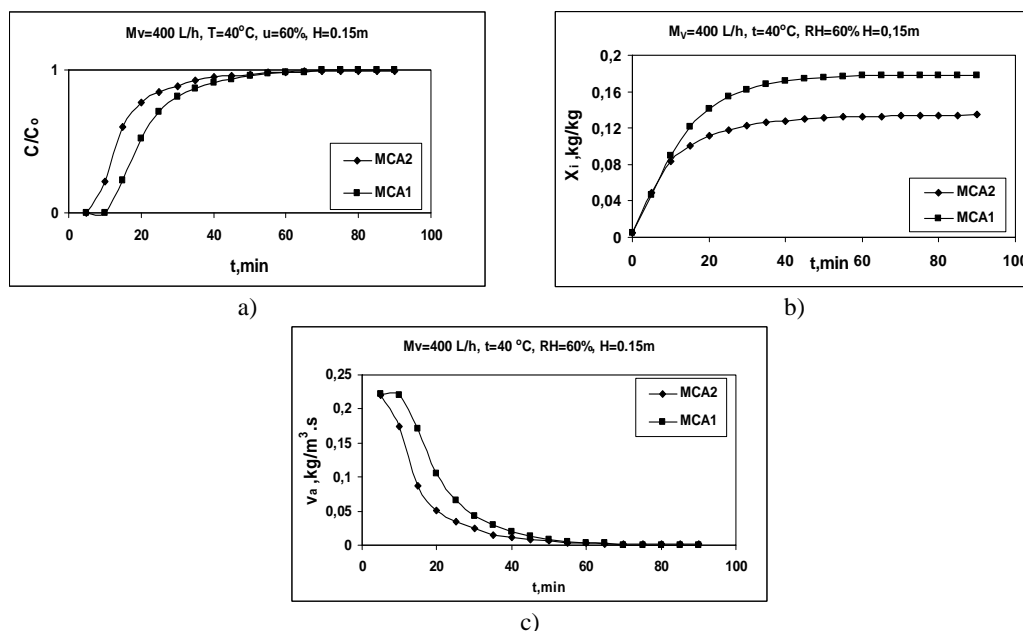
Figure 4. *Breakthrough curves, concentration of water in solid adsorbent bed and adsorption rate of water vapors on composites MCA1 and MCA2*

A comparison on water sorption capacity in the system "LiBr confined to activated alumina" (MCA2) with those obtained for calcium chloride impregnated to the same host matrix (MCA1) shows the following characteristics of these systems:

   a) the breakthrough occurred earlier in case of alumina impregnated with lithium bromide;

   b) a strong influence the sorption properties of salt hydrates;

   c) a higher adsorption rate of water vapors on composite MCA1 compared to MCA2.

CONCLUSIONS

The present paper deals with a kinetic study on water vapor adsorption on some composite materials obtained by impregnation of activated carbon and activated alumina with lithium bromide solution.

Dynamic adsorption of water vapor from air by porous adsorbents in a fixed-bed column was studied. Breakthrough curves of these systems were determined for various operating conditions.

Some characteristics of water sorption capacity in activated alumina impregnated with lithium bromide (MCA2) and calcium chloride (MCA1) were studied.

ACKNOWLEDGMENTS

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