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# The Contribution of Adsorbent Materials (Silica Gel and Sawdust) in Removing Water Vapor: A Case Study in Iraq

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**ABSTRACT**

This research aims to remove the moisture (latent load) generated by the occupants of the space due to the addition of water vapor resulting from the natural breathing process, the perspiration that evaporates in the air of the space. In sum, the dehumidification system (DS) reduces the amount of latent load or removes it completely to reduce the load on the air conditioner. In this study, adsorbent materials, such as silica gel-Blue and sawdust were used and their effectiveness was compared when used in dehumidification. The results of these experiments for June showed that the adsorption rate and temperature of the blue silica gel - Blue were 20% and 34°C, while the humidity and temperature increased to 52% and 36°C when using sawdust (when rotating the dehumidifying system hourly). Moreover, for July, the adsorption percentages of silica gel-Blue were 8%, while the moisture content of sawdust increased to 49%, while the adsorption percentage in August when using silica gel - Blue was 10% and the relative humidity increased until it reached 39% when using sawdust. While the temperatures in July and August reached their maximum value when using silica gel - Blue and sawdust at 35°C and 36°C, respectively. The water vapor absorption rate in June, July, and August is 83.39 g, 70.82 g, and 65 g, respectively. While the drying process increased during these months due to the increase in solar radiation. Therefore, silica gel - Blue has proven its effectiveness by absorbing moisture more efficiently than sawdust. However, when drying sawdust, it was more effective and faster drying than silica gel - Blue.

## 1. Introduction

Numerous issues are brought on by air pollution, which has detrimental consequences on the entire world, including climate change and general health. Moreover, the impact on the environment in general. However, through a succession of efforts that entice people to switch to clean energy, such risks can be lessened and ultimately eliminated with the development of renewable and "clean" energy and raising consciousness and understanding of its beneficial effects in our lives [1]. When the weather conditions present an extra problem for Iraq that is marked by low relative humidity during this season and Iraq's dry summer season is scorching, therefore electricity demand is seasonal, with a peak in the summer months due to rising temperatures in most sections of the nation. During the summer, peak electricity demand is predicted to be roughly 50% higher than average consumption, widening the gap between network electrical supply (which works at maximum capacity) and demand [2]. To assist

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alleviate the effects of climate change while simultaneously lowering operational costs, it is vital to operate the air conditioner system efficiently while ensuring thermal comfort and air quality in the building sector. Temperature and humidity play a major role in these situations, effects on occupants, equipment, building materials, and other items susceptible to temperature and humidity variations are reduced when these variables are set at a suitable level. Poor interior temperature conditions, for example, have a detrimental impact on people's productivity and efficiency, and they cause materials and equipment to deteriorate at a faster pace or even malfunction. As a result, the HVAC system's primary purpose is to meet the requirements for climate comfort while avoiding undesirable impacts [3].

Another vital issue associated with the latent load that shows up during summer in hot countries is a significant rise in internal humidity resulting from the breathing of the occupants of the space, which provides an uncomfortable environment. Heating, ventilation, and air conditioning (HVAC) systems, as well as humidifiers, can help to mitigate the problem. Complex HVACs, on the other hand, which maintain both temperature and humidity are costly and energy intensive [4]. Al-Samari [5] had achieved the potential for utilizing geothermal energy for air conditioning in the environment of Iraq. However, the issue of a high level of humidity surfaced after the geothermal system demonstrated its efficacy in providing the space's occupants with a suitable degree of air conditioning [6]. As a result, this study looked into ways to use a Silica gel-Blue to minimize the load of dehumidification on the air conditioner by adsorbing moisture and then drying it using solar energy. A desiccant is used in an effective energy-saving dehumidification method [7]. Desiccants, which directly adsorb moisture from the air, are often used in air conditioning systems in tropical and subtropical regions with high humidity to reduce the latent heat load from fresh air [8]. Good desiccant materials should have high transient dehumidification capability as well as a sizable sorption capacity. Numerous researchers have investigated a variety of materials as a desiccant. Activated carbon, activated alumina, zeolite, and molecular sieve are all extensively used materials in desiccant dehumidifier systems. Every substance has a different set of advantages and adsorption qualities [9].

There are numerous studies on dehumidification; the one used in this study aims to eliminate moisture. Hamed et al. [10] used a rotating wheel with 350 narrow slots, each of which is covered by a textile layer that has been saturated with a solution of lithium chloride that absorbs 95 g of water every hour. Mahmood et al. [11]. A silica gel-Blue air cooling system for farm storage of fruits and vegetables in Pakistan was studied when used with a low temperature regenerative periodic total heat exchanger and radiant ceiling cooling, the system can save (13-19%) of energy during year-round operation when compared to the direct introduction of untreated fresh air. Yang et al. [12] compared the dehumidification capacities of activated alumina and silica gel-Blue at (25 °C). It focuses on the use of solar radiation to absorb moisture from a surface and remove it. By way of a system the shape of a container that contains the adsorbent material, with a glass top cover that allows sunlight to pass through [13]. Several materials, including dried cow dung, coco peat, sawdust, and silica gel-Blue, were used for the comparative investigation of moisture sorption and desorption characteristics. The results of the experiment revealed that silica gel has the highest moisture adsorption rate while sawdust has the lowest adsorption rate [14].

Iraq does not find it difficult to develop new energy resources; especially since it is considered one of the richest countries in the world because it contains many natural resources especially. One of the most important renewable energy sources is the sun and Iraq is characterized by its strong sun for lengthy periods; according to weather statistics, Baghdad receives roughly 3300 hours of brightness radiation per year. In January, the sun's radiation intensity per hour is 416 $W/m^2$ and in June, it is 833 $W/m^2$. Solar brightness hours in most nations throughout the world, including Spain, which is one of the most advanced countries in terms of solar energy consumption, cannot compete with Iraq in any manner [15][16]. Al-Samari et al. [17] designed an absorption refrigeration system and estimate the heat energy used by solar energy by proposing and analyzing the parabolic trough solar collectors (PTSC), as a source of thermal energy. Iraq needs renewable energy sources largely because of what it suffers from a shortage in electrical energy sources, whose presence is important, especially in the summer. Therefore, it was easy to exploit the available solar energy in summer to dry the adsorbent used in this research. Based on the comprehensive literature survey mentioned above, it can be noted that the global demand for conditioning systems is increasing. Among these and other reasons, it was necessary to find solutions to reduce energy consumption and use environmentally friendly materials and methods. Therefore, many researchers used adsorbents to remove moisture as a low-cost and environmentally friendly material. Where this study is the first of its kind in Iraq that uses the adsorption process to remove moisture and to design a special system for this purpose.

The purpose of this study is to evaluate the ability of adsorption materials to reduce indoor humidity and improve human comfort levels. Additionally, two distinct materials will be examined. The first step is to use silica gel-Blue to adsorb humidity before moving the high-humidity materials outside to dry and replacing them with dry ones. This process will be repeated several times throughout the course of an hour. Following the same approach as before, the second material, sawdust, will be tested to determine its effectiveness in reducing humidity by switching out the inside and outside materials every hour.

## 2. Methodology

In this study, silica gel - Blue and sawdust were both used as adsorbents. The purpose of the study was to compare the ability of these two materials to absorb moisture. Based on the room's approximate 72m$^3$ size and the eight people who will be using it, the recommended amount of silica gel-Blue, or around 6 kilograms, was determined. This study found that Eq. (1) was used to determine the moisture content and that Eq. (2) was used to determine the mass of water vapor under the assumptions of temperature 25 °C and humidity 40% and 60%, respectively. A 350 g difference in the mass of water vapor when the humidity was dropped from 60% to 40%. It would require 3 kg of silica gel - Blue on each side of the system, assuming that 1 kg of the material absorbs 150 g of moisture. Since 6 kg of silica gel-Blue was required for the theoretical calculations, the apparatus was created using these dimensions and specifications. That is why the system was designed with these dimensions and measurements. The moisture content was calculated in Eq. (1) where w is the humidity ratio, mw is the mass of water vapor in kg, and (ma) is the mass of dry air in kg as shown in Eq. (1) [18]:

$$w = \frac{m_w}{m_a} \tag{1}$$

For dry air and water vapor, the ideal gas equation and Dalton's rule apply where they can occupy the same volume at the same temperature where (Pws) is the saturation pressure of water vapor of moist air in (pa) and Pat is atmospheric pressure in (pa) and $w_s$ humidity ratio of the saturated moist air (kg/kg dry air) as given in Eq. (2). It is possible to rewrite Eq. (1) as:

$$w_s = 0.62198\ \frac{P_{ws}}{P_{at} - P_{ws}} \tag{2}$$

By dividing the latent load by the latent heat of evaporation, which may be used to determine the amount of water vapor that is released by each individual it was obtained where ($m_n$) is the amount of water vapor in kg/s, (ql) is latent load in W and ($h_{gf}$) is the latent heat of evaporation in kJ/kg. as given in Eq. (3) [19]:

$$m_n = \frac{q_l}{h_{gf}} \tag{3}$$

The amount of water vapor produced by these individuals was calculated to approximate a room with eight people. Each person's latent load in the office is 55W according to ASHRAE [20] when the difference between the specific enthalpies of water vapor ($h_g$) and water liquid ($h_f$) is 2441.34 kJ/kg and the temperature is 25.5

°C. The amount of water vapor produced by one person during an hour was 81.0 g/h, which means that the total mass of water vapor generated in the room for 8 people was about 648 g/h after calculating ($m_n$) from Eq. (3). A revolving cylinder, 24 racks, two fans, a transparent polymer cover that encloses the cylinder, six sensors connected to an Arduino, and a computer that records the data make up the system's major components. One of the two symmetrical sections of the system designs the moisture remover portion of the dehumidification system. As the component of the system inside the room that will adsorb more moisture, this component is thought to be the most crucial in this experiment. Additionally, the other half of the system is the solar system (Drying system), which when exposed to sunshine, is in charge of drying the adsorption material. As seen in Figure 1 the system was created as a rotating iron cylinder that was mounted in the experimental room's window and had a height of 140 cm and a diameter of 50 cm. The cylinder shape was chosen (rather than any other geometric shape) because it is simple to rotate and because it avoids angles that might be challenging to rotate as shown in Figure 2.

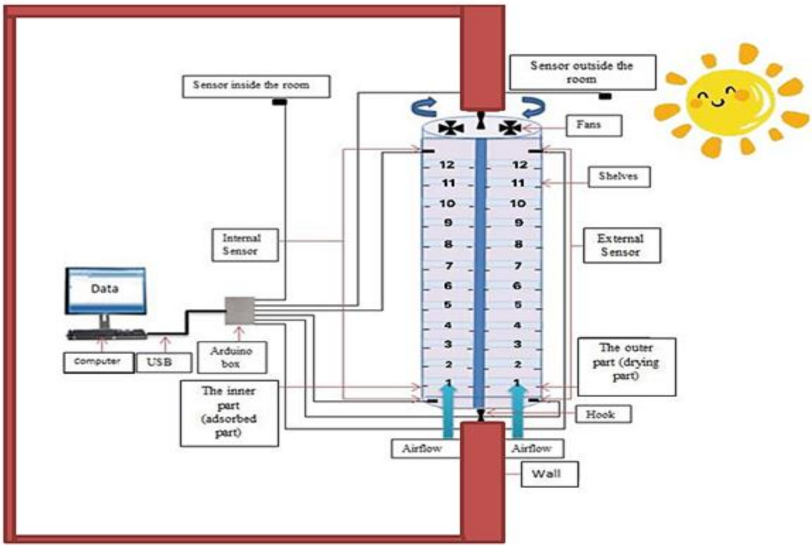


**Figure 1.** Schematic of the dehumidifier system.

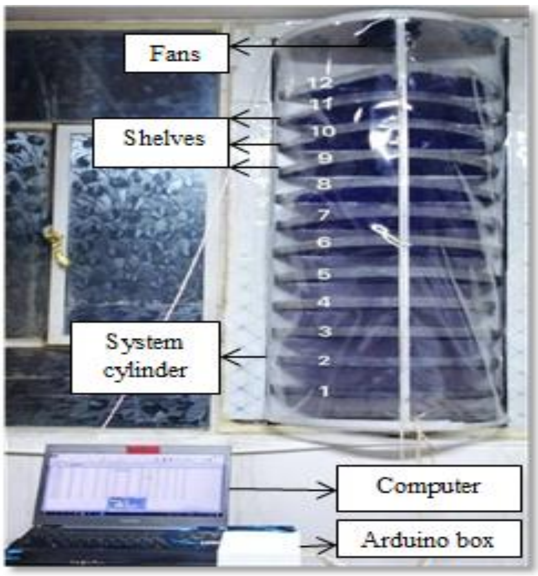


**Figure 2.** The actual dehumidifier system.

The cylinder was divided into two equal sections by placing an iron piece with a 2 mm thickness in the center of it and cutting the cylinder longitudinally along its length. The cylinder is covered from the top, and a fan that circulates the air inside the system is located in the center of each component. After passing through silica gel-Blue, the system's airflow was measured and determined to be 1.816 m/s, while sawdust had an airflow rate of 2.286 m/s. A digital anemometer was used to measure the air speed, which ranged from 0.80 to 40 m/s. Place the system in the room's window where the experiment will be conducted. Using a moisture generation source, create a humid environment inside the room that mimics the moisture produced by the people using the area. Install sensors at the top and bottom of the two symmetrical portions of the system (at the entry and exit). Two other sensors are also present; one is placed within the space to measure the humidity and temperature there, while the other is placed outside in a shaded location to measure the temperature and humidity of the surrounding air. 24 shelves are built into this system, which is framed in acrylic. There were 12 of these semi-circular shelves, each with a diameter of 50 cm, mounted on each of the iron piece's two sides. During the experiment, the adsorbent is placed on a sieve at the bottom of the shelf. Each shelf (inside, exterior) of the adsorption material should be filled once with 250 g of Silica Gel-Blue.

## 3. Results and discussion

In this part, the results of moisture adsorption were studied using locally available adsorbents. The desiccant materials are Silica Gel-Blue pellets and sawdust. To remove (the latent load) the moisture generated by the occupants of the space due to the addition of water vapor resulting from the natural breathing process, in addition to the perspiration that evaporates in the air of the space. A dehumidification system reduces the amount of latent load or removes it completely to reduce the load on the air conditioner. The principle of the dehumidifying system is to operate the fans that were installed at the top of the dehumidifying system, which works on the principle of clouds. The fans draw moisture from the bottom of the dehumidifying system so that the moisture-laden air passes over the adsorbent materials and begins its work by adsorbing moisture until the air comes out at the last shelf of air with low humidity. On the other side of the dehumidification system, the process of drying the adsorbent materials is carried out through exposure to solar radiation. This process takes place from the hour 7:00 until 19:00, at a rate of rotation once every hour and throughout the summer season in Iraq.

### *3.1. Effect of relative humidity on adsorbents in June, July, and August.*

In this part, a comparison of the amount of relative humidity inside the room is shown in three cases for June, July, and August. The rotation of the dehumidification system is carried out every hour due to two reasons, the first reason is to increase the efficiency of the adsorption process using absorbent materials and the second reason is to dry the adsorbent materials that were inside the room and to facilitate the process of using them again. Figure 3 shows the silica gel - Blue and sawdust adsorption process to moisture during June under one scenario. Where the dehumidification system rotates once per hour from the time the experiment starts at 7:00 AM until 7:00 PM. The maximum humidity level was reached when the moisture removal system was not in use and the room's humidity reached 53%. Sawdust was next, with a maximum humidity of 52% when used, followed by silica gel - Blue at 36%. This is evidence of the effectiveness of silica gel - Blue in adsorption moisture more than sawdust under the same experimental working conditions.

Figure 4 shows the effectiveness of adsorption materials in July. The experiment was conducted in the same conditions as the previous experiments, starting from 7:00 until 19:00, as well as in terms of rotation at a rate of rotation once per hour for the dehumidification system. The highest values of moisture were reached when no moisture removal system was used, followed by sawdust and finally silica gel with a percentage of 49%, 47%, and 25%, respectively.

Figure 5 shows the dehumidification with the same conditions as the previous experiments but for August, the experiment started at 7:00 and ended at 19:00. The maximum moisture value was 47% when the dehumidification system was not used. The moisture content reached 39% when sawdust was used. The highest humidity inside the room reached 31% and then returned to its lowest at 28% when using silica gel - Blue. As a result of the effectiveness of silica gel- Blue in removing moisture, its effectiveness appears compared to the rest of the cases.

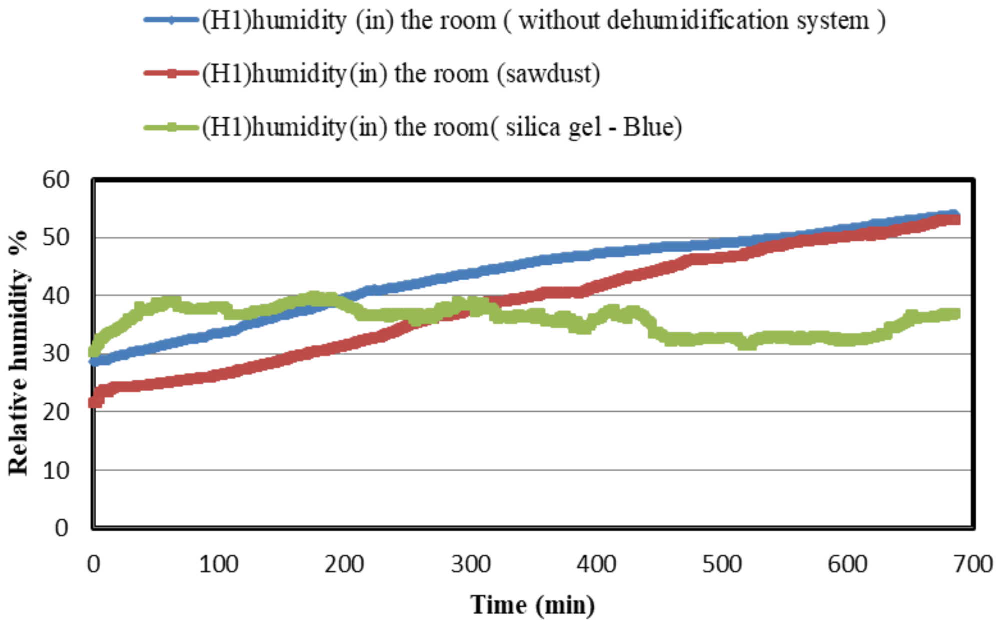


**Figure 3.** The relative humidity inside the room in June.

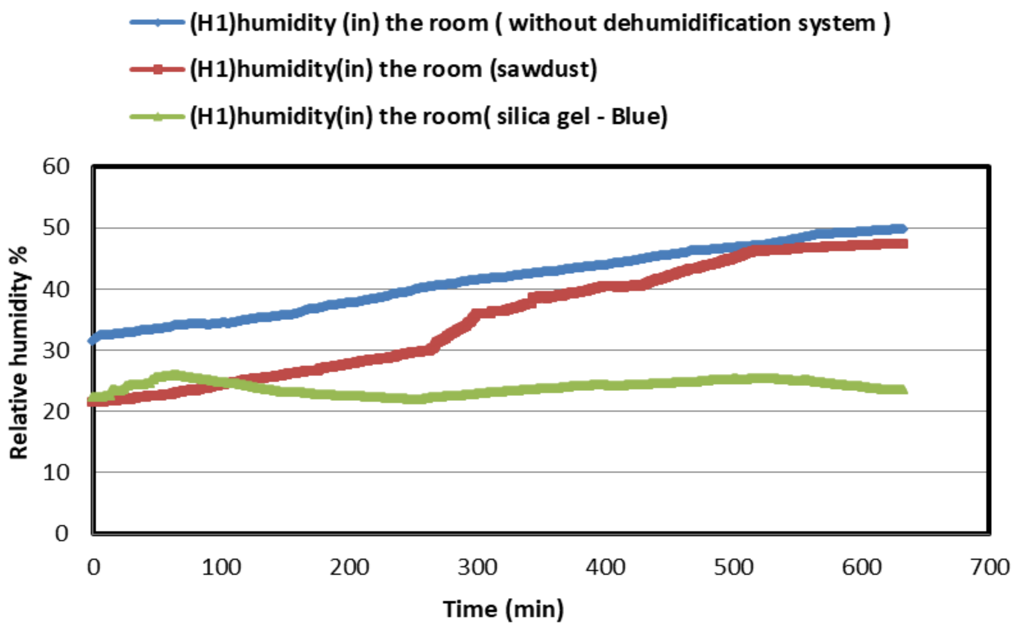


**Figure 4.** The relative humidity inside the room in July

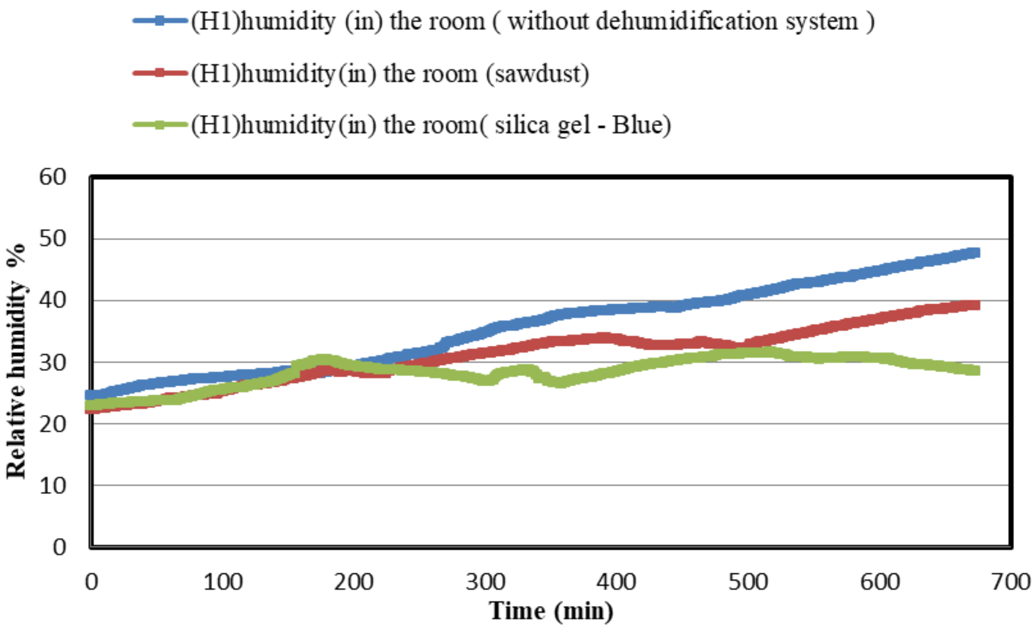


**Figure 5.** The relative humidity inside the room in August

### *3.2Efficiency of sunlight in drying adsorption materials*

After the process of dehumidifying the interior of the room, the dehumidification system is rotated and exposed to sunlight to start the drying process of the adsorbent materials. In June, July, and August the rotation of dehumidifying system is carried out every hour and exposing it to the sun to dry the adsorbent materials after the moisture adsorption process. Figure 6 shows the drying process in June, where we notice that while using silica gel - Blue, the highest relative humidity reached 28% in the morning and decreased to 16% after drying at noon. While in the case of sawdust, the highest moisture value reached 30% in the morning and decreased to 13% after drying at noon.

Figures 7 and 8 show the comparison of the drying process between the adsorption materials in July and August, respectively. Sawdust is more effective in drying than silica gel-Blue. It was concluded that the highest adsorption rate was in the early hours of the morning. The highest drying rate was during the light hours. As a result of the high temperatures from all the previous results, conclude that the adsorption efficiency of silica gel - Blue is better than sawdust, but with that, sawdust dehydrates faster than silica gel- Blue.

### *3.3Temperatures with and without using a dehumidifying system*

Figure 9 shows the same experiment in June, where it is noticed that the temperature values are close to each other, but the highest value remained when the dehumidification system was not used, where it reached 38 °C, followed by the temperature when using sawdust is 36 °C and then the silica gel - Blue with the temperature 34 °C. As for July and August, we saw a noticeable rise in temperatures compared to the previous months, since these two months are among the hottest summer seasons in Iraq, and the effect of this appears significantly in the increase in temperatures inside the buildings (the room of the occupants of the space to be dehumidified).

From Figure 10, the highest value of the temperature in July was 40 °C when not using the dehumidifying system, and it reached 36 °C and 35 °C when using sawdust and silica gel, respectively. In August, the highest value of temperature was when using the dehumidifying system, then sawdust and finally silica gel - Blue, which reached 38 °C, 36 °C, and 35 °C respectively as shown in Figure 11.

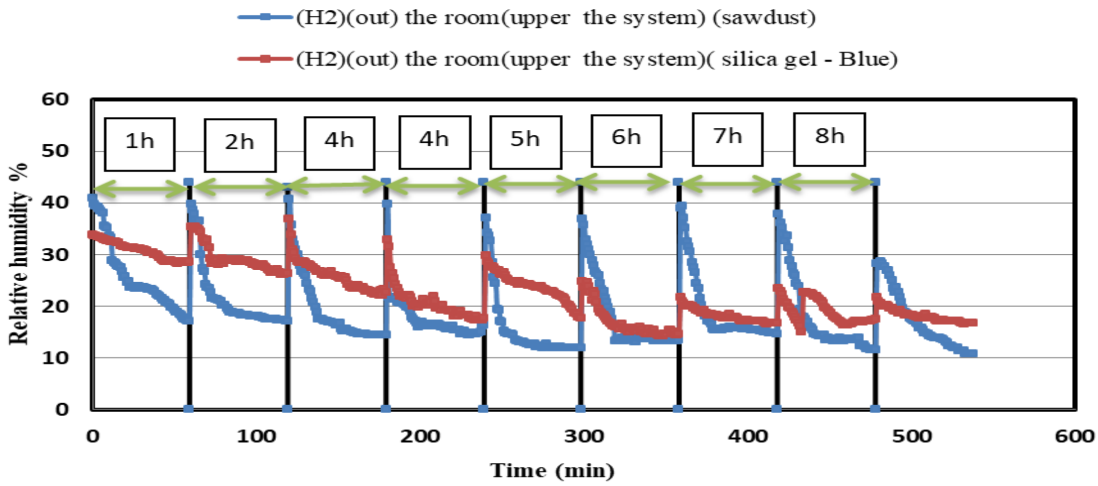


**Figure 6.** The drying response of the adsorbents in June

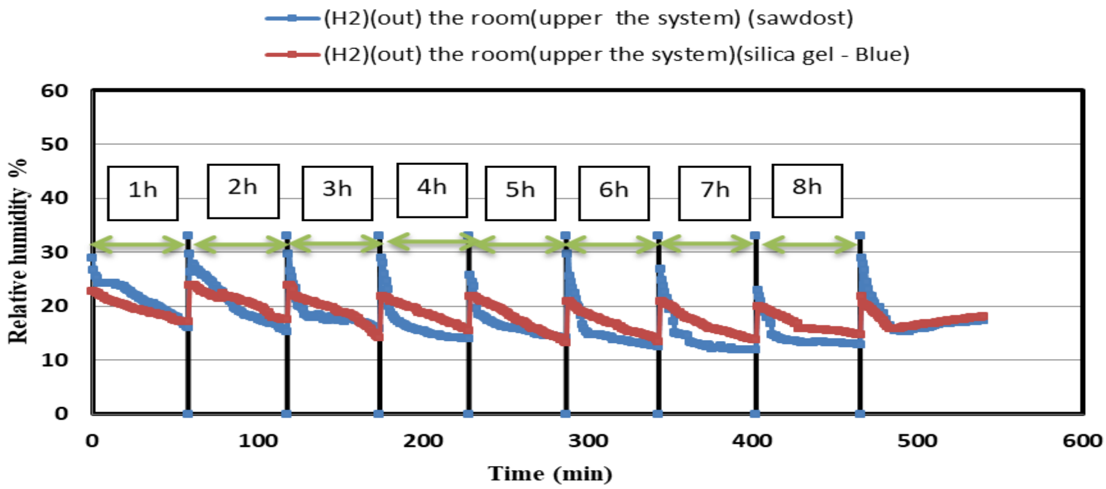


**Figure 7.** The drying response of the adsorbents in July

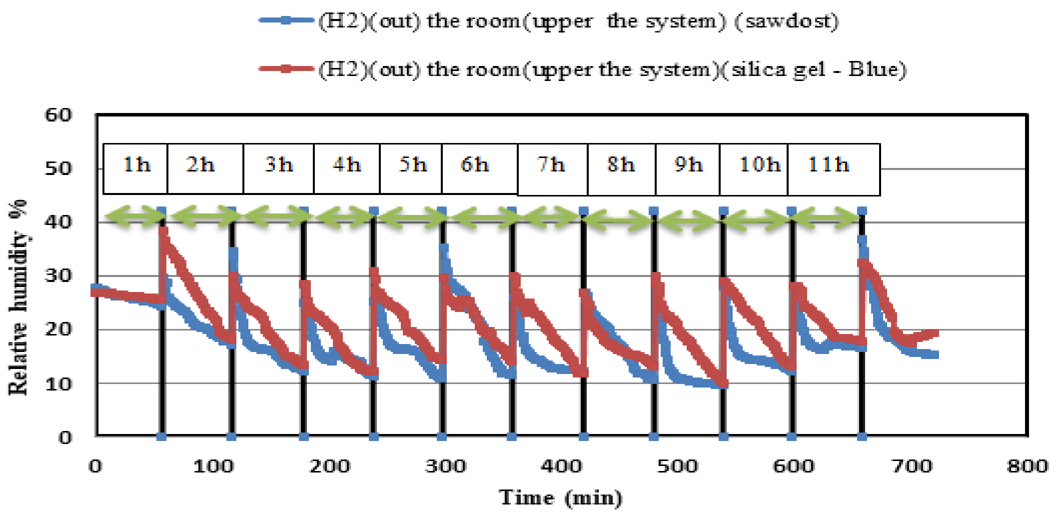


**Figure 8.** The drying response of the adsorbents in August.

However, the temperature has not yet achieved the desired comfort level According to the ASHRAE. The reason for this is the fact that the adsorption process is exothermic. It can be concluded that the greater the renewal process of the absorbent material, the greater its contribution to lowering the temperature, and this can be observed when compared to April after the renewal of the material was every three hours. Therefore, the importance of the geothermal system, which represents one of the clean energy sources has proven effective in significantly reducing temperatures [9].

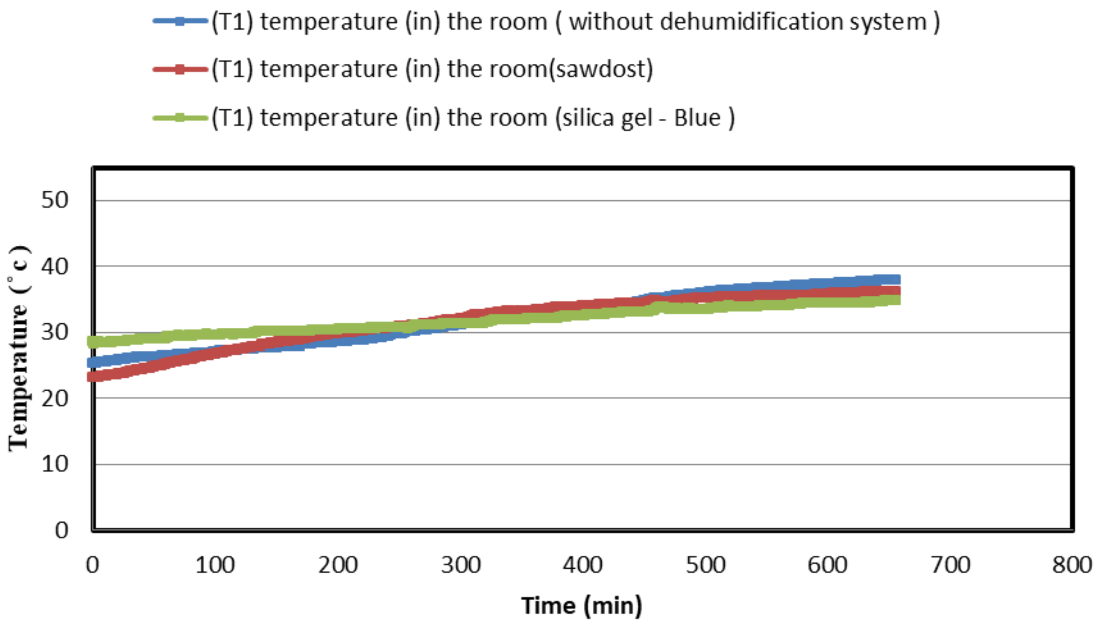


**Figure 9.** The temperature inside the room in June.

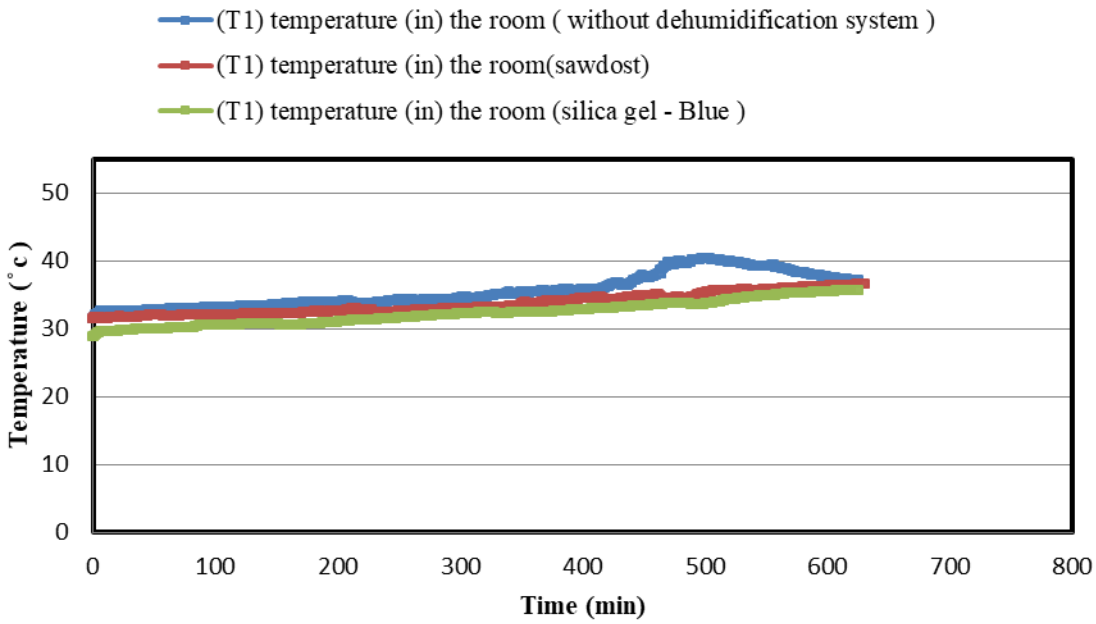


**Figure 10.** The temperature inside the room in July.

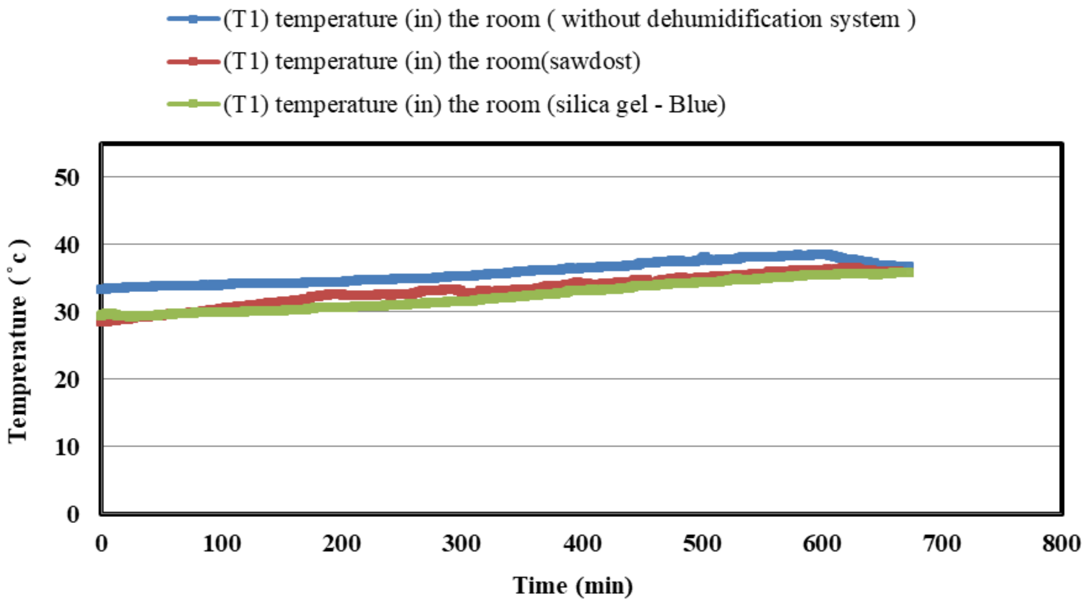


**Figure 11.** The temperature inside the room in August

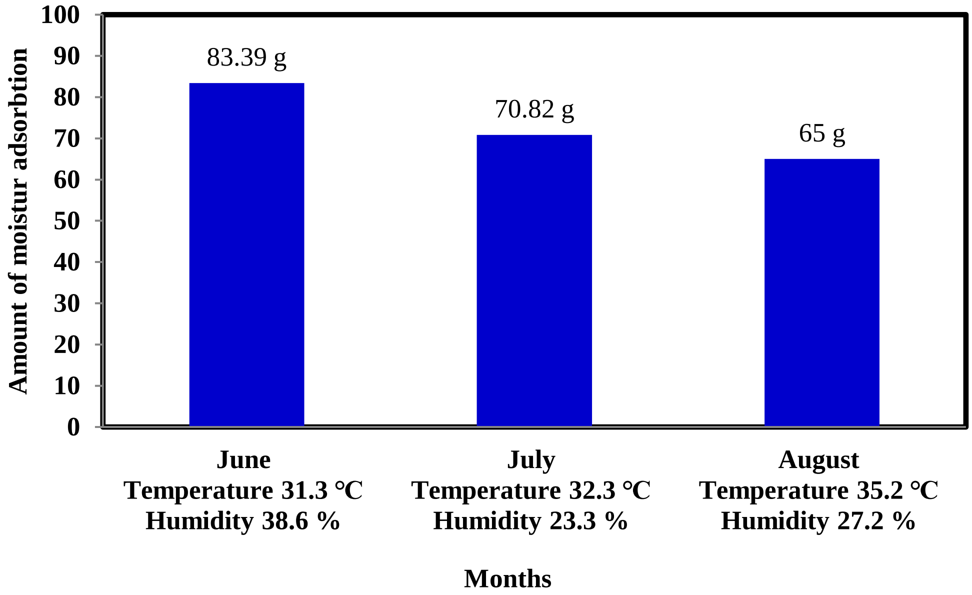


**Figure 12.** The amount of water vapor adsorbed by silica gel-Blue during the different summer months

### *3.4 Efficacy of frequent use of silica Gel - Blue*

This part shows the amount of water vapor that was adsorbed by silica gel-Blue over three months as shown in Figure 12. As can be seen, the adsorption activity reached its peak in June at 83.39 g, and then it gradually decreased until it reached its lowest point in August, which was 65 g. These quantities were calculated by weighing the silica gel after each adsorption process and after each rotation of the dehumidification system. Given that, the weights were measured at the hour 13:00, when the temperature rise was at its highest. however, it is important to keep in mind that adsorption conditions varied over the time of the test, particularly relative humidity, which would undoubtedly affect the amount of moisture absorbed as well.

## 4. Conclusions

The research aimed to study the effectiveness of a 72 $m^3$ room's dehumidification system and adsorbent materials to remove moisture using silica gel-Blue and sawdust, (two widely accessible adsorbent substances). The performance characteristics of two different types of adsorbents: sawdust and silica gel - Blue (two widely accessible absorbents) were compared. It has been empirically evaluated in a variety of operational settings. The investigation led to the following crucial conclusions:

1. For June, the results of this work noticed that the use of silica gel - Blue reduced the humidity from 39% to 31%. Nevertheless, when using sawdust, it led to a continuous increase in the relative humidity from 21% to 52%, and this means that the adsorption rate of silica gel - Blue is 20%. In addition, the highest temperature was 36°C when using sawdust and 34°C when using silica gel – Blue.
2. For July, the adsorption rate of silica gel was 8%, while in sawdust, the relative humidity continued to rise from 21% to 49%. In addition, the temperature when using sawdust was 36°C, while in silica gel - Blue it was 36°C.
3. For August, the adsorption rate of silica gel was 10%, while the moisture content when using sawdust increased from 22% to 39%. In addition, the temperature inside the room when using sawdust and silica gel was the same in July due to the similarity of the temperature conditions between these two months.
4. The drying rate showed its effectiveness significantly during the months in which the experiments were conducted, as the lowest drying rate was in the morning period, while the highest drying rate was at noon due to the high temperatures at that time of the day. However, it can be noted that the drying rate of sawdust was faster than Silica gel - Blue in the same experimental conditions.
5. An improvement in the adsorption rate was observed during June. The adsorption rates were 83.39 g, 70.82 g, and 65 g in June, July, and August, respectively. Based on the above, it can be concluded that the adsorption capacity was reduced due to the reuse of silica gel - Blue several times. In addition, the high temperature during those months contributed significantly to the decrease in humidity.

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