Performance evaluation and regeneration of silica gel by using solar energy with Parabolic dish collector

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Abstract - Regeneration of silica gel by using solar energy with parabolic dish collector (PDC) has been investigated. The heat concentrated by Parabolic dish collector (PDC).which has aperture and receiver area 1.76 & 0.58 m2,respectively.the ambient temperature varies from 30 to 46 °C.but the regeneration temperature was commenced to be around 38 °C. Regeneration rate was clearly dependent on solar intensity which varies from time to time. But on an average it was between 600-700w/m2.The moisture content was first accumulated on the surface of silica gel and then gel was regenerated.

Key words: silica gel, regeneration, PDC

I. Introduction

Air conditioning in tropical climates can be done by air dehumidification. For this there is a method of doing this by using solar energy in a PDC. By using PDC silica gel can also be generated. This paper gives the results of regeneration of silica gel by using solar energy with parabolic dish collector Singh and Singh [1] presented a paper on regeneration of silica gel in multi-shelf regenerator. In the presented paper an investigation on the regeneration of solid desiccant (silica gel) in a modified design of dehumidifier called "Multi-shelf Dehumidifier", had been reported. Lounici et al. [2] presented a paper on novel technique to regenerate activated alumina bed saturated by fluoride ions. A novel technique to regenerate adsorbent column is presented. Singh and Pant [3] presented a paper on equilibrium, kinetics and thermodynamic studies for adsorption of As (III) on activated alumina. This paper surmised Contamination of drinking water due to arsenic is a severe health hazard problem.. Dupont et al. [4] presented a paper on desiccant solar air conditioning in tropical climates: Dynamic experimental and numerical studies of silica gel and activated alumina. This paper presented a dynamic study of moist air dehumidification in view of its use in an air conditioning process by evaporative cooling in tropical climates.Ghorai and Pant [5] presented a paper on investigations on the column performance of fluoride adsorption by activated alumina in a fixed-bed. In the presented study, removal of fluoride ions using activated alumina (AA) was investigated in batch and continuous operations. Ghorai and Pant [6] presented a paper on equilibrium, kinetics and breakthrough studies for adsorption of fluoride on activated alumina.

Pramuang and Exell [7] used a compound parabolic concentrator collector to regenerate the silica gel for an air conditioning system. The regeneration rate and regeneration efficiency was greatly dependant on solar radiation but slightly dependant on different initial moisture content of silica gel and number of silica gel beds. Abd-Elrahman et al. [8] presented a paper on experimental investigation on the performance of radial flow desiccant bed using silica gel. In the present work, an experimental investigation on the performance of radial flow desiccant bed using silica gel had been carried out. 39.860 kg of spherical particles of silica gel with an average diameter of 4 m was used to form a hollow cylindrical bed with length of 90 cm and outer and inner diameters of 27.8 and 10.8 cm, respectively.

II. PROPERTIES (THERMAL) OF SILICA GEL

Silica gel is solid desiccant is drying agent used to absorb the moisture in its surroundings. Silica gel is also known as amorphous silicon dioxide with a chemical formula sio2.silica gel blue is semi transparent glassy substance containing an indicator as cobalt chloride. When free from moisture the granules or beads are dark blue in colour as the beads takes up moisture, they turns to light blue gradually .then after addition of more moisture the colour turns pink. Silica gel is a good adsorbent with relative humidities lies between 50 to 80%.so it can be suitable for air conditioning purposes. In this experiment we used two different sizes of silica gel, small size silica gel and large size silica gel having average thickness of 0.003-0.004 m and 0.005-0.007 m respectively. The moisture content on silica gel depends upon the surrounding atmosphere.

The regeneration rate (G_R) was monitored continuously throughout the experimental run by measuring the bulk weight (m_{ds}) of the dry silica gel layers and the rate of change of moisture content of silica gel (dry basis) $dw/_{dt}$, **[Pramuang et al. 2006]**.

$$G_R = m_{ds}\frac{dw}{dt}$$

The adsorption rate (G_A) was monitored continuously throughout the experimental run by measuring the bulk weight (m_{ws}) of the humidified (wet) silica gel layers and the rate of change of moisture content of silica gel (wet basis) $dw/_{dt}$, **[Pramuang et al. 2006]**.

$$G_A = m_{ws}\frac{dw}{dt}$$

The regeneration rate and adsorption rate were measured continually by weighing the silica gel over a specific time period.

III. EXPERIMENTAL SETUP

The experiments have been performed to investigate the regeneration rates of solid desiccant (silica gel). To perform various experiments on regeneration, some level of moisture content should be present in the silica gel (which is indicated by the pink colour of silica gel). For this purpose these desiccant were exposed to humid air over the night. The experimental setup will be installing at the roof of the building. Both the above described process is as follows:
Regeneration process

In Figure 1. Shows the regeneration process, we had a solar parabolic dish collector with manual hand tracking. At the focus point of the dish collector a container is placed which was used as absorber to receive all the reflecting radiation. 1 kg of pink coloured saturated silica gel (both small and large size) puts on the beds of the container and container was placed at the focus point of the parabolic dish collector. Glazing of the glass was used around the container which was open at the top and bottom side. The main function of the glazing was to reduce the heat losses from the container as heat was trapped inside glazing. During the regeneration process the weight of the silica gel was reduced by same amount as weight of moisture evaporated from it.

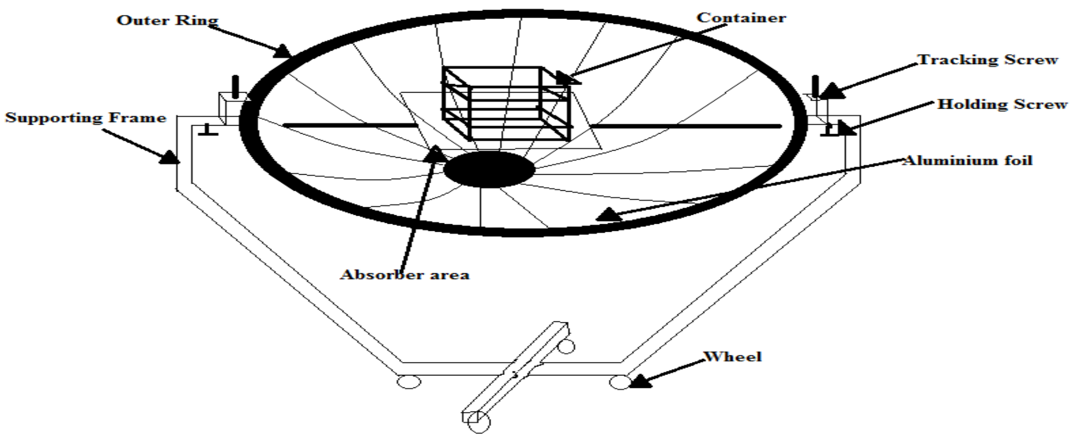


Figure 1: Schematic diagram of experimental setup for regeneration of silica gel

3.1 Adsorption process

In this setup we had two containers of cardboard of same size. Inside these containers both small size and large size silica gel were placed in equal quantity respectively. These two containers placed in the room at room condition of DBT and WBT at room air flow rate. The moisture present in the room air adsorbed by the adsorbent material (silica gel) when room air was flown over these boxes and become dry air.

In this process we measured weight of the silica gel (both small and large size) by the weighing machine at some time period in minutes and the process was continued till silica gel becomes saturated related to initial stage before regeneration.

The experimental system consists of the following parts:

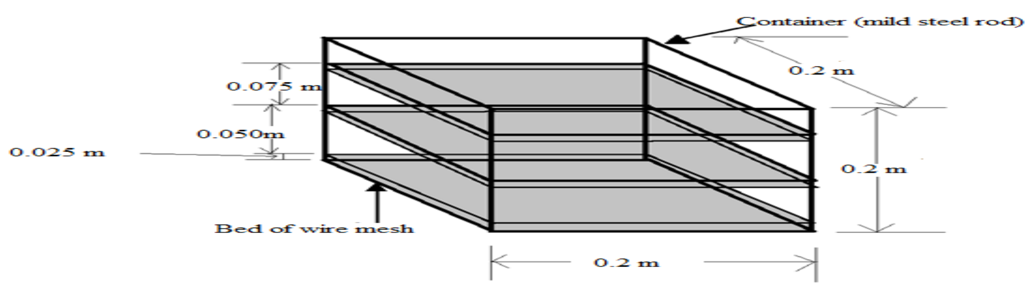


Figure 2: Schematic diagram of the container

The container was placed at absorber frame so that all the reflected rays are incident on the container and increase the temperature. The container painted with the black colour to absorb all radiation fall on it. Three layer of silica gel was place inside the three wire mesh bed respectively to regenerate. These three beds in the container hold 1.0 kg of silica gel. The thickness of each layer of desiccant was 0.025 m. In this experiment we used two different sizes of silica gel, small size silica gel and large size silica gel having average thickness of 0.003-0.004 m and 0.005-0.007 m respectively.

A covering of transparent glass was made to place around the container. The glass glazing used was open at the top and bottom end for the flow of air through the container. The glazing was of square cross section having dimensions (0.25 m × 0.25 m × 0.25 m) as shown in Figure 3.

The four pieces of transparent glass of section (0.25 m × 0.25 m) were joined together with silicon rubber bonding to form a cube of transparent glass with open at the top and the bottom end.

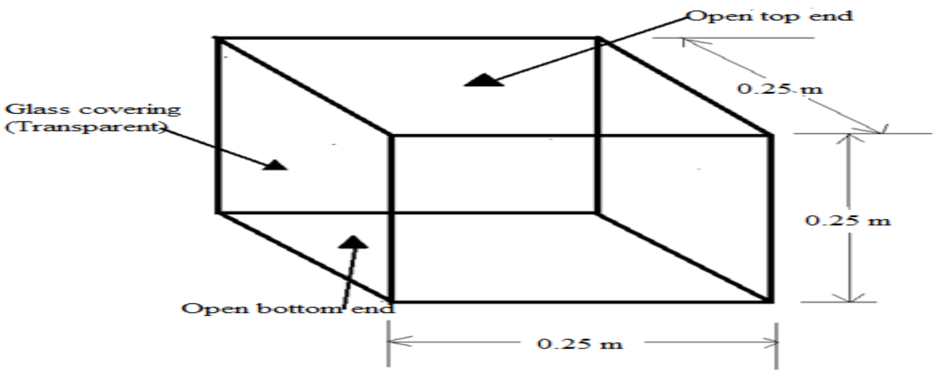


Figure 3: Schematic diagram of the glass glazing

IV. THE MEASUREMENTS

The pyranometer was used for the measurement of global solar radiation received on a horizontal surface. It has sensitive surface which was exposed to total (beam + diffuse + reflected from earth and surrounding) radiations.
A digital weighing machine of 30 kg capacity was used to measure the weight of silica gel during adsorption and regeneration. It was capable of measuring the weight in the range of 0 to 30 kg. It was accurate up to three decimal.
A sling psychrometer is an instrument used for measuring the dry bulb temperature and wet bulb temperature of air. Sling psychrometer measures dry bulb temperature and wet bulb temperature when exposed to atmosphere. A covering of wet cotton cloth was done around the bulb of wet bulb thermometer
The sling psychrometer has the temperature range of 0°C to 70°C with an accuracy of about ±0.1°C.

V. EXPERIMENTAL RESULTS AND DISCUSSION

In this study, the main focus was on the regeneration rate of desiccant (two different size of silica gel) by the parabolic dish collector and then the adsorption process at room conditions. The experimental data was collected in which the ambient temperature varied from 30°C to 46°C in most of the clear sky days (10:30AM hr-03:00 PM). The tests were performed in the morning for regeneration and in room conditions for adsorption from 7:30 P.M. to 12 A.M.
Four cases are considered and various results were obtained.

5.1 Regeneration rate without glass glazing

Table 1: Variation of moisture content, regeneration rate of small size silica gel and solar intensity with time without glass glazing during regeneration.

Time (hr)	Weight (g)	Solar intensity (W/m^2)	Regeneration rate (kg/hr)
10:30	1004.38	898	0.00016
11:00	1003.58	783	0.00098
11:30	1003.09	270	0.0012
12:00	1002.49	293	0.00096
12:30	1002.01	490	0.00046
01:00	1001.78	587	0.0012
01:30	1001.18	513	0.00168

02:00	1000.34	506	0.00068
02:30	1000	760	0
03:00	1000	810	0

Table 2: Variation of moisture content, regeneration rate of small size silica gel and solar intensity with time with glass glazing

Time (hr)	Weight (g)	Solar intensity (W/m^2)	Regeneration rate (kg/hr)
10:30	1004.38	898	0.00254
11:00	1003.11	783	0.00208
11:30	1002.07	270	0.00196
12:00	1001.09	293	0.00144
12:30	1000.37	490	0.00064
01:00	1000.05	587	0
01:30	1000	513	0
02:00	1000	506	0
02:30	1000	760	0
03:00	1000	810	0

Table 3: Variation of moisture content, regeneration of large size silica gel and solar intensity with time without glass glazing

Time (hr)	Weight (g)	Solar intensity (W/m^2)	Regeneration rate (kg/hr)
10:30	1003.09	763	0.00136
11:00	1002.41	810	0.00068
11:30	1002.07	846	0.00196
12:00	1001.09	897	0.00176
12:30	1000.21	867	0.00042
01:00	1000	882	0
01:30	1000	728	0
02:00	1000	756	0
02:30	1000	698	0
03:00	1000	723	0

Table 4: Variation of moisture content,regeneration rate of large size silica gel and solar intensity with time with glass glazing during

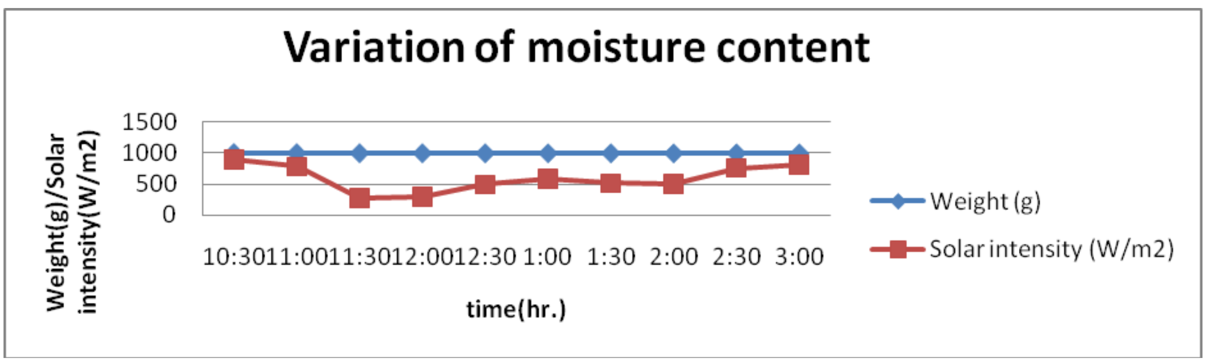
Time (hr)	**Weight (g)**	**Solar intensity (W/m^2)**	**Regeneration rate (kg/hr)**
10:30	1003.09	763	0.00212
11:00	1002.03	810	0.00152
11:30	1001.27	846	0.00176
12:00	1000.39	897	0.00064
12:30	1000.07	867	0
01:00	1000	882	0
01:30	1000	728	0
02:00	1000	756	0
02:30	1000	698	0
03:00	1000	723	0

Table 5: Variation of moisture content, adsorption rate of small size silica gel with time during Adsorption

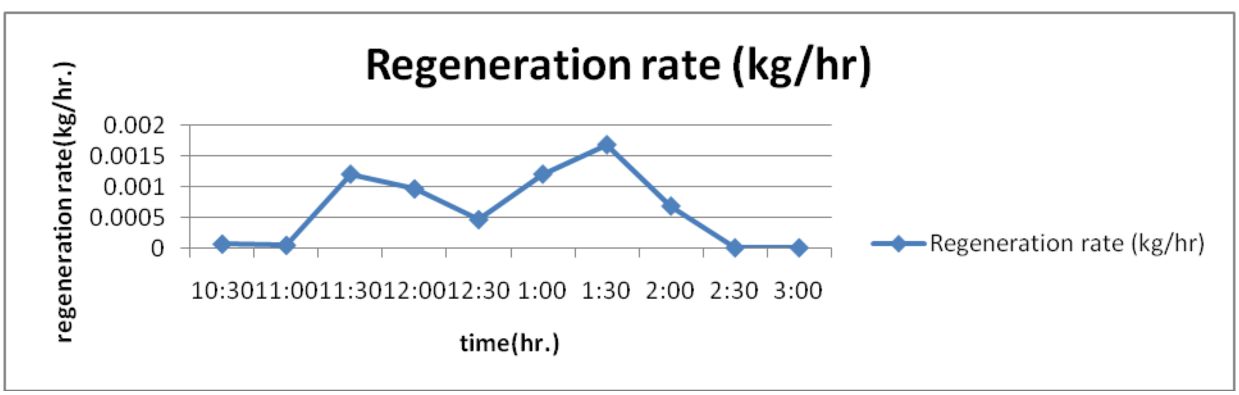
Time (hr)	**Weight (g)**	**Adsorption rate (kg/hr)**
07:30	1000	0.0018
08:00	1000.9	0.0016
08:30	1001.7	0.0004
09:00	1001.9	0.0004
09:30	1002.1	0.00036
10:00	1002.28	0.00042
10:30	1002.49	0.0019
11:00	1003.44	0.00188
11:30	1004.38	0
12:00	1004.38	0

Table 6: Variation of moisture content, adsorption rate of large size silica gel with time during Adsorption

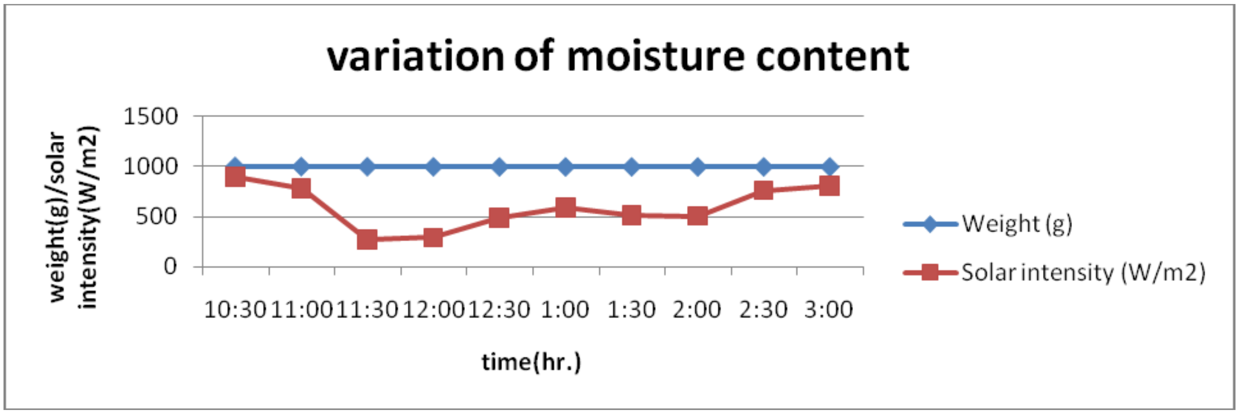
Time (hr)	Weight (g)	Adsorption rate (kg/hr)
07:30	1000	0.00042
08:00	1000.21	0.00022
08:30	1000.32	0.00046
09:00	1001.55	0.00084
09:30	1001.97	0.00070
10:00	1002.32	0.0013
10:30	1002.97	0.00024
11:00	1003.09	0
11:30	1003.09	0
12:00	1003.09	0



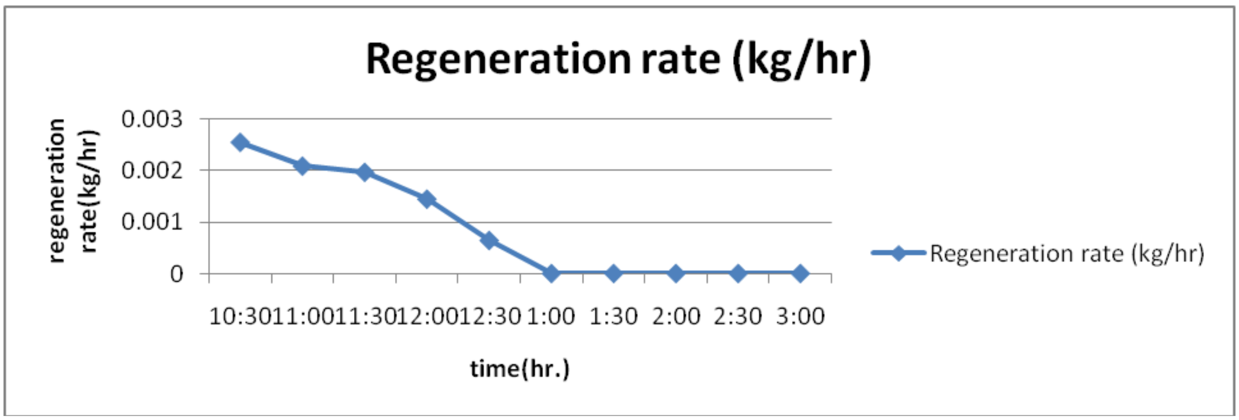
Graph 1: Variation of moisture content of small size silica gel and solar intensity with time without glass glazing during regeneration



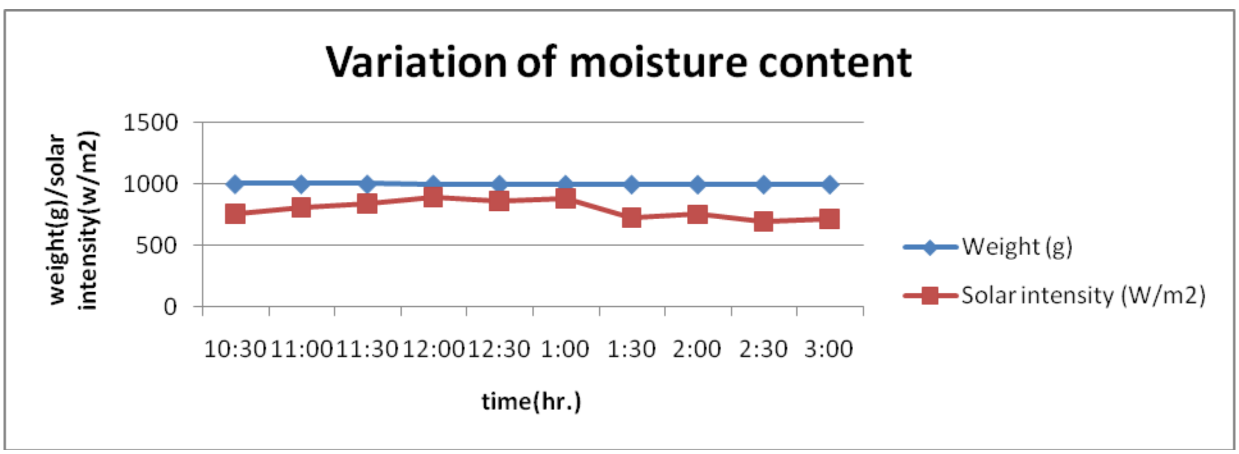
Graph 2: Variation of regeneration rate with time for small size silica gel without glass glazing



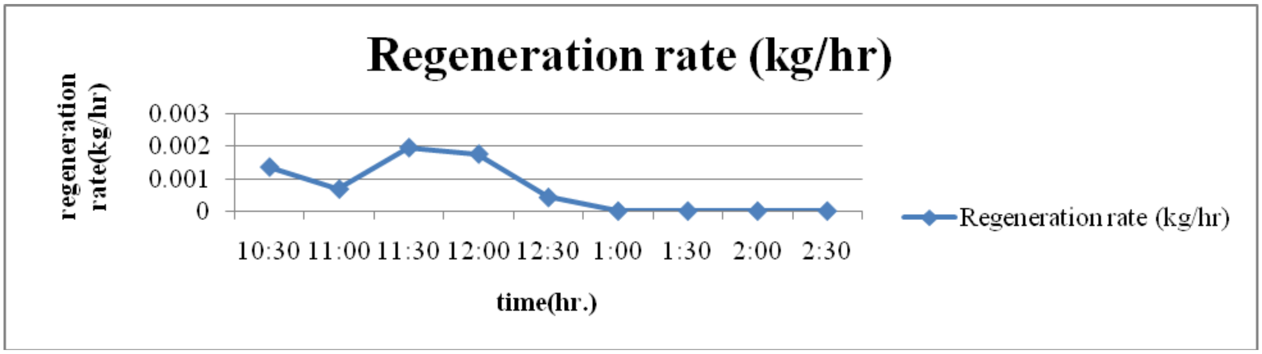
Graph 3: Variation of moisture content of small size silica gel and solar intensity with time with glass glazing during regeneration



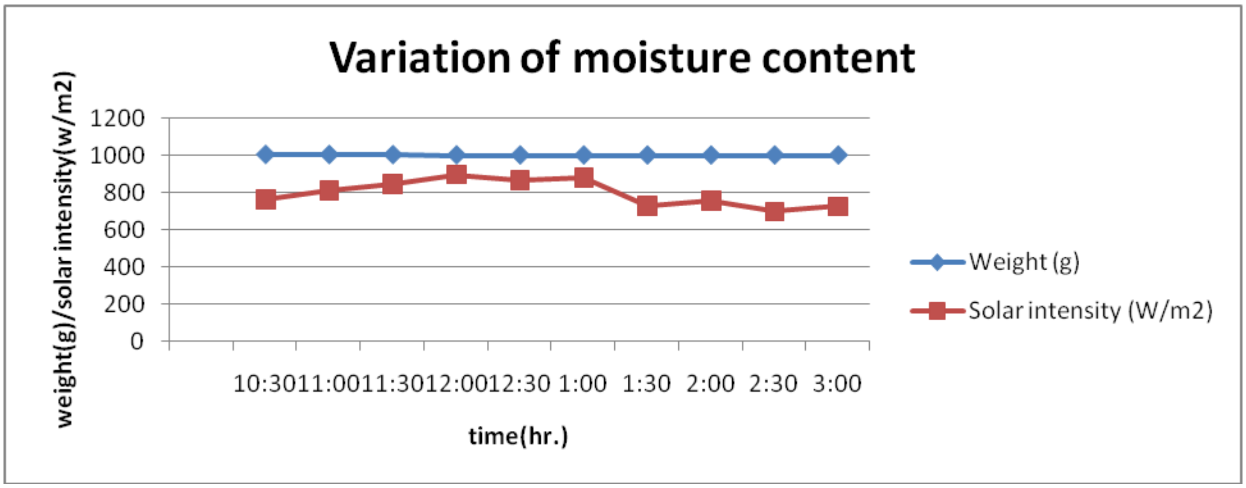
Graph 4: Variation of regeneration rate with time for small size silica gel with glass glazing



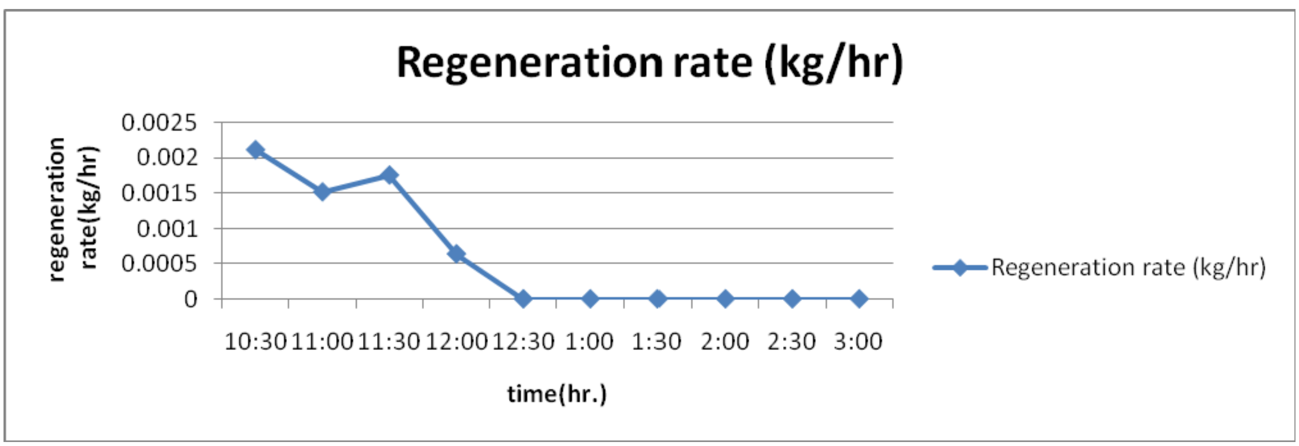
Graph 5: Variation of moisture content of large size silica gel and solar intensity with time without glass glazing during regeneration



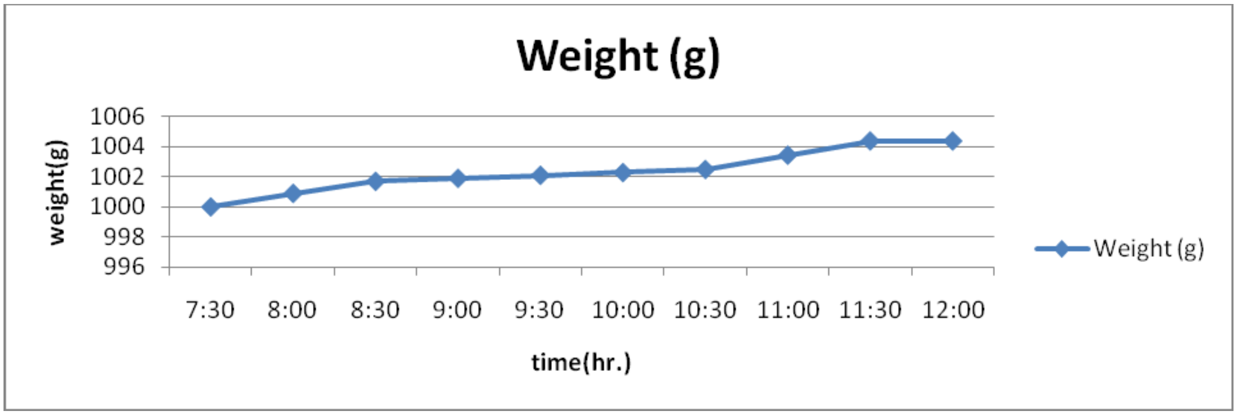
Graph 6: Variation of regeneration rate with time for large size silica gel without glass glazing



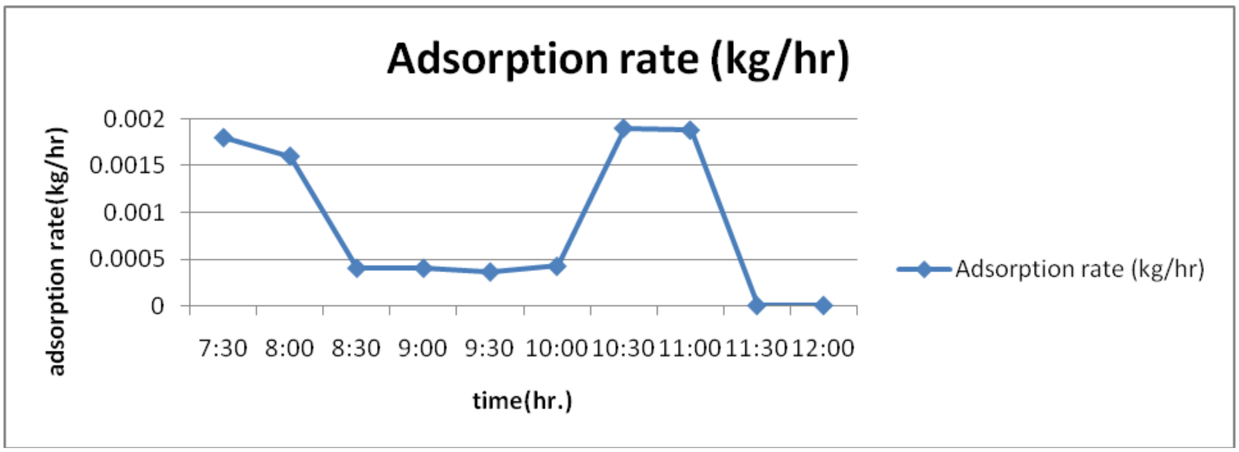
Graph 7: Variation of moisture content of large size silica gel and solar intensity with time with glass glazing during regeneration



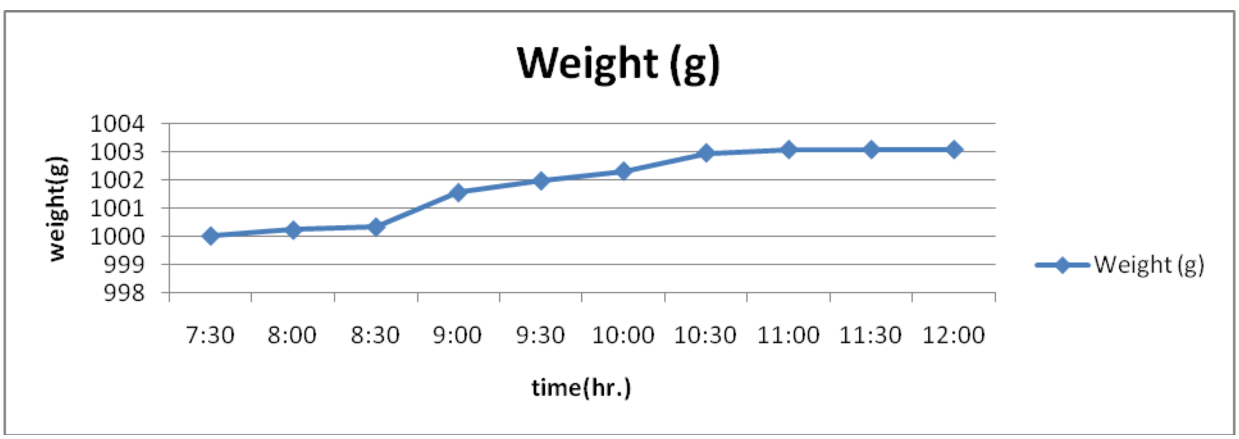
Graph 8: Variation of regeneration rate with time for large size silica gel with glass glazing



Graph 9: Variation of moisture content of small size silica gel with time during Adsorption



Graph 10: Variation of adsorption rate with time for small size silica gel.



Graph 11: Variation of moisture content of large size silica gel with time during Adsorption

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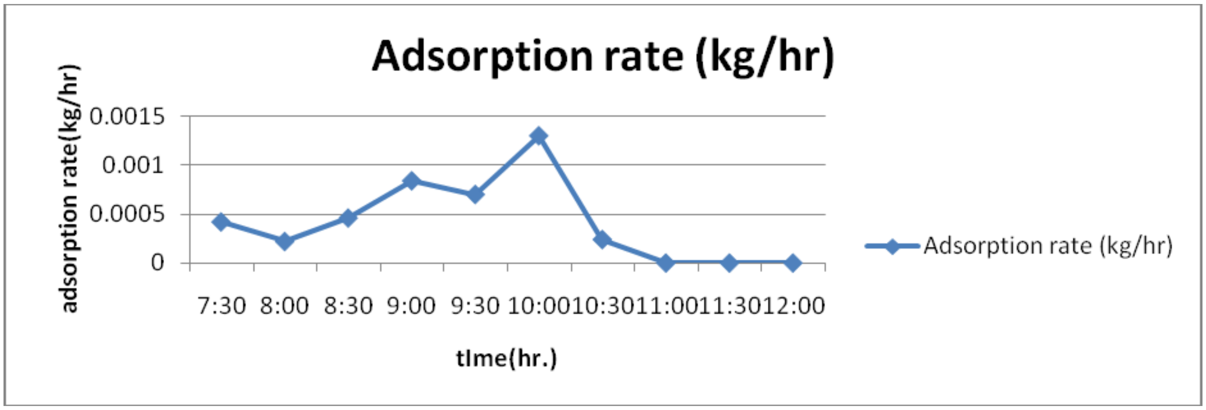

Graph 12: Variation of adsorption rate with time for large size silica gel

6. Conclusions

The main objective of this work was to calculate the regeneration rate, adsorption rate & then compare the performance of the two. The findings with both large & small size of silica gel with & without glass glazing were:

1) The adsorption capacity of large size silica gel was less as compare to small size silica gel & due to this large size silica gel takes lesser time for regeneration as compare to small size silica gel.
2) The adsorption rate for small size gets decreases initially then after that it gets stabilized for small period then increases & finally reaches saturation state. All happened due to rapid change in temperature.
3) For large size silica gel adsorption rate was fluctuating it decreases initially then increases decreases then increases, decreases and then reached its final value. All happens due to the large thickness of size.
4) In small size silica gel without glass glazing regeneration rate was fluctuating. Initially it decreases slightly then increases then decreases then there was again an increases and decreases. Then reached the final state. All happened due to fluctuation in solar energy with time.
5) In small size silica gel with glass glazing regeneration started to a very high point then decreased but stabilizes quickly. This quick stability was all due to concentration of heat inside the glass glazing
6) For a large size silica gel the regeneration rate without glass glazing was decreased initially. Then increases for small period and the continuously decreases. Then reached the final state. All happened due to fluctuation in solar energy with time.
7) For a large size silica gel the regeneration rate with glass glazing decreases initially then increases slightly then decreases but reached final state quickly.
8) In the above said cases with & without glass glazing for both small & large size silica gel regeneration rate gets rapid with glass glazing as compare to without glass glazing.
9) Results were obtained in both with & without glass glazing with the difference in regeneration rates.

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