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RESEARCH ARTICLE

Impact of Silica gel, Calcium chloride and Charcoal on White Mold Fungus

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ABSTRACT

In the rainy season and fall, the spaces where there is no sunlight experienced the growth of white fungus (molds) which spread on surfaces of wooden furniture and other places. Like other molds, this is again harmful for health. This may cause respiratory disease, allergies, headaches and dizziness. The prevention of growth of molds is possible by adsorption of excess moisture in those places. This could be achieved by desiccant silica gel, calcium chloride and charcoal. This Research work is evaluating the performance of dehumidification by above desiccants. The obtained Humidity ration over the period of 50 days for desiccants silica gel, calcium chloride and charcoal were 38±5, 41±5 and 46±5. Efficiency over the period of 50 days for desiccants silica gel, calcium chloride and charcoal were 50±4, 47±4 and 40±4.The Adsorbent silica gel was best adsorbent amongst desiccants silica gel, calcium chloride and charcoal. Inverse modified Gompertz equation (IMGE) is taking the inverse of predicted values obtained from above equations. The IMGE approach is used to simulate the retardation of growth of Molds. Experimental values are consistent with the predicted values by IMGE. In the future, the thermal effect on growth of white fungus could be studied and simulated.

Keywords: mold, white fungus, humidity ratio, efficacy, Modified Gompertz equation, process innovation etc.

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1. Introduction

White mold is a genre of fungus which grows and spreads on surfaces of wooden furniture, lignite, metal, and polyester. It also infects clothes and bags. It appears as a white sticky substance with a powder-like texture that thrives in the presence of moisture in air [1]. It often spreads downward from ceilings to lower portions of walls, growing rapidly once relative humidity exceeds 60% [2,3]. White mold has harmful effects similar to other molds, and longer exposure can cause respiratory diseases, allergies, headaches, and dizziness [4,5]. Therefore, treatment of mold is essential for maintaining a hygienic environment. Cleaning of surfaces where it grows mainly moist furniture, carpentry work, clothes, and even metals is critical, but prevention through moisture control is more effective [6]. Among the commercially viable options for prevention of mold, adsorption of excess atmospheric moisture has emerged as the best strategy to retard fungal growth [7,8]. The most common and widely used adsorbents are silica gel, calcium chloride, and activated charcoal [9,10]. Silica Gel: Silica gel is a porous granular material derived from silicon dioxide. It adsorbs excess moisture from the air, thereby preventing mold proliferation [11]. Though relatively costly, silica gel is highly effective where even small amounts of moisture can cause severe damage, such as in electronic circuits [12]. Calcium Chloride Bags: Calcium chloride is a deliquescent salt that strongly absorbs water vapor and prevents mold formation on surfaces [13]. It acts as a low-cost dehumidifier suitable for household and large-space applications, where it can absorb more than 200% of its weight under high humidity conditions [14,15]. Activated Charcoal: Activated charcoal contains a highly porous structure that allows it to adsorb moisture and retard the growth of mold and bacteria [16]. It is inexpensive, scalable for larger areas, and in some applications also functions as an insulator or barrier to leakage and seepage [17]. White Vinegar: In addition to adsorbents, simple biocidal treatments like white vinegar have antifungal and antibacterial effects. Repeated application can eliminate over 90% of mold species, including dangerous black molds, when allowed to rest for an hour or more [18,19]. Mechanism of Prevention: The above substances effectively control humidity through adsorption or absorption. In adsorption, water vapor adheres to the surface of porous desiccants such as silica gel and activated charcoal [20]. In absorption, as in calcium chloride, moisture penetrates into the material until deliquescence occurs [13]. Over time, desiccants become saturated and require regeneration or replacement to maintain performance [21]. Numerous studies confirm that maintaining RH below 50% drastically suppresses mold growth, making desiccant use one of the simplest and most reliable approaches to prevention [22,24]. More advanced composites such as silica $CaCl_2$ hybrids and bio-desiccant blends have been reported to further enhance performance [25,26] but inexpensive desiccants remain the most practical choice for household and storage environments.

2. Materials and methods

The composites of activated charcoal, Silica gel and calcium Chloride were prepared which shows better adsorption rate than traditional parents' substituents. A prepared Composite showed high adsorption of moisture, adsorption rate and higher COP for cooling systems. It showed better results than Zeolites, activated carbon and silica gel and best suited at standard operating conditions [1].

Table 1. Adsorbent characteristics [2-6]

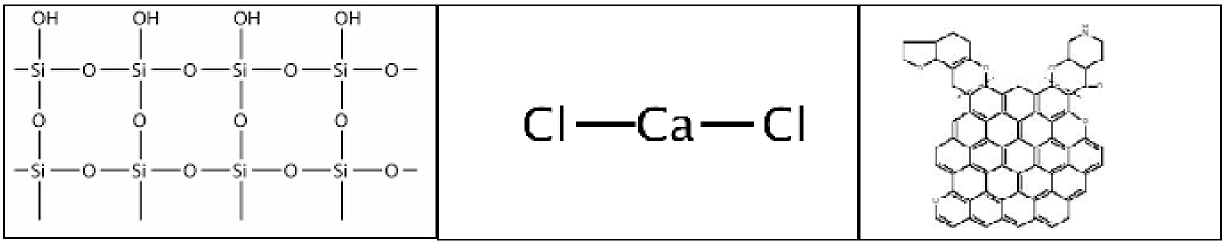
Adsorbent	Adsorbate	Heat of Adsorption (KJ/Kg)	Remarks
Silica Gel (SiO_2xH_2O)	Moisture (H_2O)	2800	Cooling and Dehumidification. Not suitable above 200°C. Small size applications. Expensive
Calcium Chloride ($CaCl_2$)	Moisture (H_2O)	3000	Large Application/ Household.
Charcoal	Moisture (H_2O)	2300-2600	Inexpensive.

2.1. Desiccants Feedstocks

Silica Gel (SiO2+xH2O) - It is derived from pure silica and chemically impregnated with water (5%). If it is heated above 200ºC it will lose its adsorption properties. It is available in various pore sizes. For better adsorption a bigger surface area needs which can be achieved by smaller pore sizes. It is available in Type A (2-3 nm) and type B (up to 0.7nm). Type B is Recommended as a desiccant for dehumidification in cooling systems. [2-5].

Calcium Chloride (CaCl2)- It is widely used for large household applications. It is the best adsorbent in solid state and dissolves into water once it is saturated. It can still be utilized at lower temperature cooling systems.

Charcoal - it is available in many forms, but powder forms have more surface area and ability to absorb excess moisture in air. The fine particles act as a better desiccant than coarse grain charcoal. It is obtained from carburizing and pyrolyzing coal, wood, synthetic polymers and lignite etc.



Silica Gel **Calcium Choride** **Charcoal**

Figure 1. Chemical Structure of Silica gel, calcium chloride and charcoal.

2.2. Design of Experiment

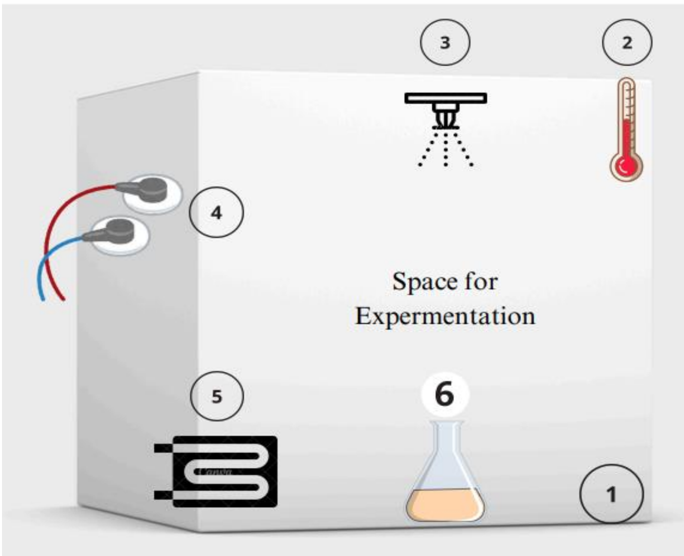


Figure 2. Schematic Diagram of Experimentation Setup

The setup used for the experiments comprises the following sub systems.

1. Space of Experimentation. Cupboard size 3ft * 4t.

2. Thermocouples and Thermometer to Temperature Measurement

The temperature measurement, Dry Bulb Temperature (DBT) and wet Bulb Temperature (WBT) measured with this sub system.

3. Sprinkler to maintain Humidity.

4. ECU Sensors to measure the Humidity Ratio, Specific weight, humidification, Heating and Cooling.

5. Evaporator heater and cooler.

6. Desiccants taken for study are Silica Gel, Calcium Chloride and charcoal

2.3. Dehumidification measurements

The Dry Bulb Temperature (DBT), Wet Bulb temperature is Measured and feeder to the Electronic Panel. The Psychrometric charts help to evaluate the Humidity of respective desiccants over a selected period of experimentation.

7. Efficiency Measurement -

The amount of Reduction in Humidity Ratio to the initial humidity ratio is coined as efficacy here in the experimentation. It is the quantitative parameter to study the effectiveness of respective desiccants over the period of experimentations.

8. Efficiency Calculations = $(Final\ Humidity\ -\ Initial\ Humidity)$ / Initial Humidity

9. The Periods-The rainy season cycle is chosen for the experimentation i.e. from June-september months of the year. Each Desiccant is kept in separate space for evaluation of the parameters.

10. Standard Procedures

The Experimentations conducted by standard Protocol of APHA 2005.

11. Precautions: The Experimentation performed under the controlled environment of the same rainy cycle and winter cycle. The moisture is created through sprinklers in a closed chamber. Direct sunlight is forbidden.

12. Process Parameters

Relative Humidity (RH or ⌀) : It is the ratio of water vapor present in air to the maximum possible water vapor suspension at the given state.It has a value ranging from o to 1. The lowest value Zero ‘0’ denotes absence of water vapor and the highest value Zero ‘1’ denotes max moisture content in an air.

Dry BulbTemperature (DBT) : the temperature of air recorded by ordinary thermometer.

Wet Bulb temperature (WBT) : The temperature on air recorded by wetted wick attached to an ordinary thermometer.

Specific humidity (w) : It is the amount of water vapor to the mass of dry air. It is accounted for as grams of vapor present per kilogram of dry air.

Relative humidity and specific humidity are very much required in the design process.Estimate of Relative humidity and specific humidity are required. Measurement of Dry bulb temperature and wet bulb temperature are essential.

Dew point Temperature (ADP) : may also be known as apparatus dew point. The point below which the water vapor starts condensing and turns to liquid state.

3. Results and discussions

Humidity Ratio or Relative Humidity (RH) : It is the ratio of water vapor present in air to the maximum possible water vapor suspension at the given state. If we have air at high temperature then water present in air evaporates and mass of water vapor in air increases. If we decrease the temperature of air the water vapor accommodation capacity of air decreases and air attains saturation point.Beyond saturation point if we decrease the temperature then vapor starts condensing since it has reached humidity to unity value.

Humidity Ratio Vs Time in days for different desiccants silica gel, calcium chloride and charcoal is as shown in Figure 3.The conducted experiments clearly depicts the humidity decreases after application periods of desiccant silica gel, calcium chloride and charcoal.This is due to the fact that, over the period the excess moisture present in air is absorbed by the desiccants by Adsorption.The obtained Humidity ratio over the period of 50 days for desiccants silica gel, calcium chloride and charcoal were 38±5, 41±5 and 46±5.The Adsorbent silica gel was best adsorbent amongst desiccants silica gel, calcium chloride and charcoal.

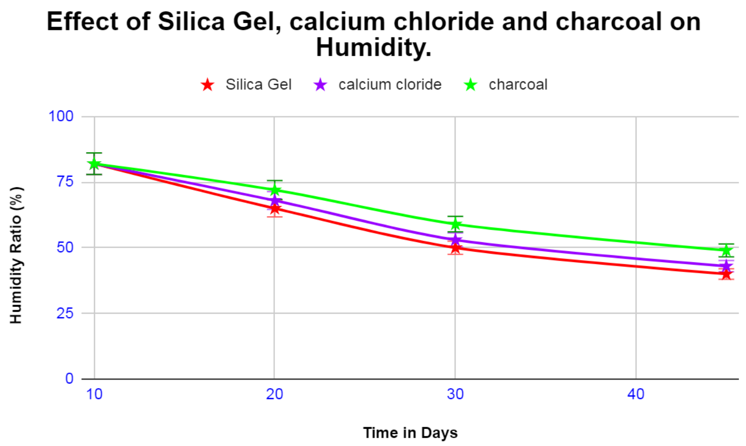


Figure 3. Humidity Ratio Vs Time in days for different desiccants silica gel, calcium chloride and charcoal.

Efficacy is a quantitative efficiency evaluation of the desiccants. It is calculated as Change in humidity to the original humidity.It is to compare the performance and dehumidification capabilities of desiccants.

$$Efficacy = (Change\ in\ humidity\ /\ the\ initial\ humidity) * 100. \qquad \text{Equation 1}$$

Efficacy Vs Time in days for different desiccants silica gel, calcium chloride and charcoal is as shown in Figure 4. The conducted experiments clearly depicts the higher trend of efficacy of desiccants after application periods of desiccant silica gel, calcium chloride and charcoal.This is due to the fact that, over the period the excess moisture present in air is absorbed by the desiccants by Adsorption and gives better results.The obtained efficacy over the period of 50 days for desiccants silica gel, calcium chloride and charcoal were 50±4, 47±4 and 40±4.The Adsorbent silica gel was best efficacy amongst desiccants silica gel, calcium chloride and charcoal.

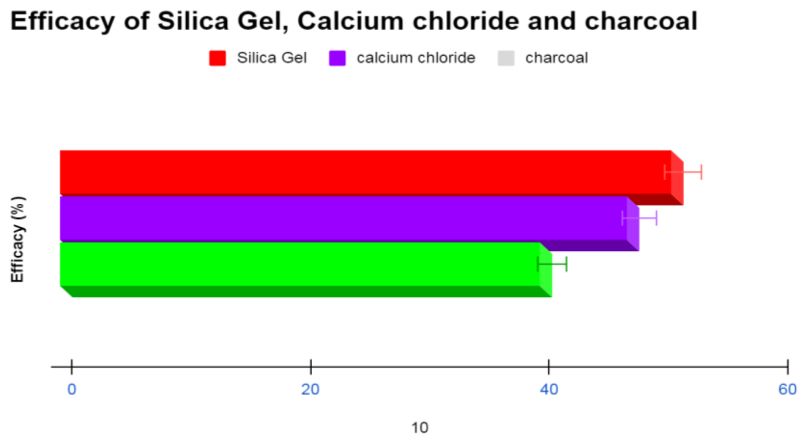


Figure 4. Efficiency Vs Time in days for different desiccants silica gel, calcium chloride and charcoal.

Specific humidity Vs Time

We know the relation of specific humidity and humidity ratio. With the help of Dalton's law of partial pressure and definition of specific humidity and relative humidity. We can derive

$$Relative\ Humidity\ (\varnothing)\ = \frac{Total\ Pressure\ (P) * Specific\ Humidity\ (w)}{Specific\ Humidity\ (w)+0.622\ saturation\ Pressure\ (Pg)} \quad \text{Equation 2}$$

The experimental values of total pressure (P) is 101 kpa and saturation pressure (Pg) is 3.122 kpa. So we can convert above equation into

$$Specific\ \ Humidity\ (w) = \frac{1.9419 * Relative\ Humidity\ (\varnothing)}{101-3.122 * Relative\ Humidity\ (\varnothing)} \quad \text{Equation 3}$$

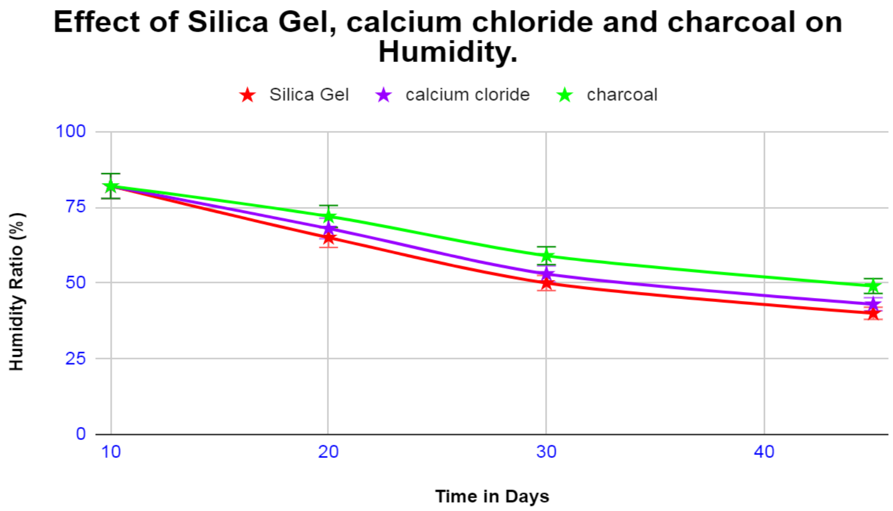


Figure 5. Specific humidity Vs Time.

Specific Humidity Vs Time in days for different desiccants silica gel, calcium chloride and charcoal is as shown in Figure 5. The experimental values are calculated from the equation 3.The conducted experiments shows that the specific humidity decreases after application periods of desiccant silica gel, calcium chloride and charcoal.This is due to the fact that,The cooling and dehumidification occurs in the space and over the period the excess moisture present in air is absorbed by the desiccants by Adsorption.The obtained Specific humidity over the period of 50 days for desiccants silica gel, calcium chloride and charcoal were 0.0116±0.004648, 0.012067±0.004826 and 0.0286±0.005145 gms of vapor per kg of dry air.The Adsorbent silica gel recorded lowest specific humidity than calcium chloride and charcoal.

4. Mathematical Modeling by Inverse modified Gompertz equation (IMGE)

The Gompertz Equation is very useful in various biological aspects. It has unique characteristics to predict the microbial growth, population or weight of flora and fauna [7].

Gompertz Function is as follows.

$$P = M * exp\{-exp(c1 - c2 * t)\} \quad \text{Equation 4}$$

P = Population or microbial growth function dependent variable.

M = Max Value P can Achieve

C1 & C2 = Both Decide shape of Curve.

T = independent variable time in days.

The Experimental values are taken into account to fix the values of Max Value Growth (P) and

C1 & C2 to predict the curve shape.Inverse modified Gompertz equation (IMGE) is taking the inverse of predicted values obtained from above equations over a period of 50 days..

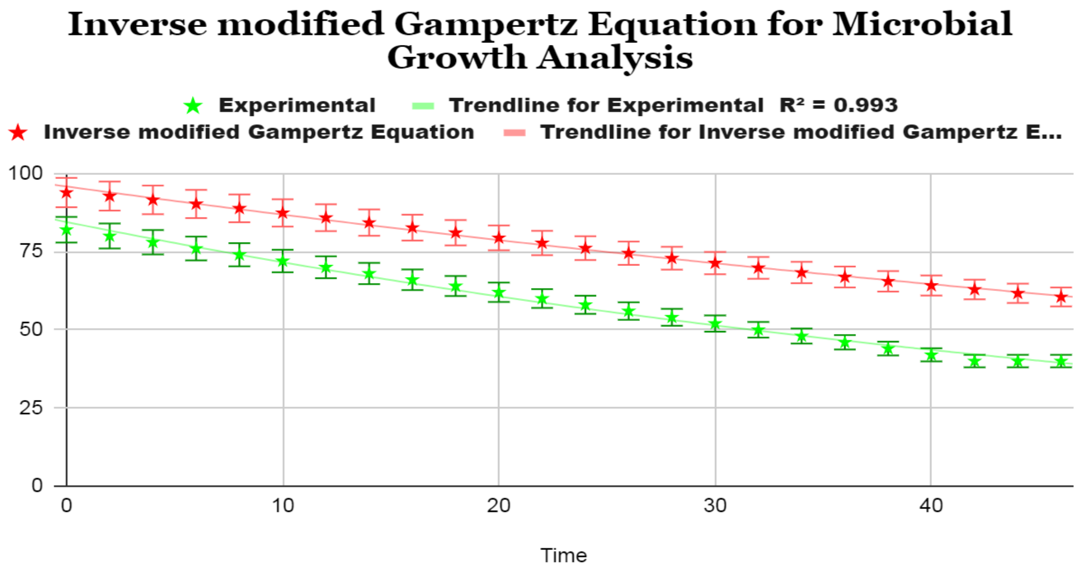


Figure 6. Simulation of Retardation of growth of Mold by Inverse Modified Gompertz equation (IMGE) Vs Experimental values.

Bacterial Growth By IMGE is as shown in Figure 6. The Experimental values are consistent with the predicted values by IMGE. The Predicted values are slightly higher compared to experimental due to the fact that the ideal condition and assumption while mathematical interpretations.The R2 is close to 1 so, predicted values are acceptable.

5. Conclusion

The literature review clearly shows the silica gel is good adsorbent and use for expensive devices where smaller moisture can create huge damage. The calcium chloride is widely used for large applications. The conducted experiments clearly depicts the humidity decreases after application periods of desiccant silica gel, calcium chloride and charcoal.This is due to the fact that, over the period the excess moisture present in air is absorbed by the desiccants by Adsorption.The obtained Humidity ratio over the period of 50 days for desiccants silica gel, calcium chloride and charcoal were 38±5, 41±5 and 46±5.The Adsorbent silica gel was best adsorbent amongst desiccants silica gel, calcium chloride and charcoal.

The conducted experiments clearly depicts the higher trend of efficacy of desiccants after application periods of desiccant silica gel, calcium chloride and charcoal.This is due to the fact that, over the period the excess moisture present in air is absorbed by the desiccants by Adsorption and gives better results.The obtained efficacy over the period of 50 days for desiccants silica gel, calcium chloride and charcoal were 50±4, 47±4 and 40±4.The Adsorbent silica gel was best efficacy amongst desiccants silica gel, calcium chloride and charcoal.The Adsorbent silica gel recorded lowest specific humidity than calcium chloride and charcoal.

Inverse modified Gompertz equation (IMGE) is taking the inverse of predicted values obtained from above equations.The IMGE approach is used to simulate the retardation of growth of Molds.The Experimental values are consistent with the predicted values by IMGE. The predicted values are slightly higher compared to experimental due to the fact that the ideal condition and assumption while mathematical interpretations.The R2 is close to 1 so, predicted values are acceptable.In the future, The thermal effect on growth of white fungus could be studied.

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