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(RESEARCH ARTICLE)

Research analysis on development of portable evaporative cooler for desert climatic zone

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Abstract

The primary aim of this study is to empirically examine the viability of utilizing ice as a cooling agent in order to enhance the air cooling efficiency of a portable cooler through the utilization of latent heat of fusion. A portable air cooler has been constructed using a polyurethane insulation box that is readily accessible in the market. The box has been combined with a galvanized iron conduit, which has a square cross section measuring 3 inches by 3 inches, to facilitate the passage of air. This tunnel effectively isolates the airflow from the ice, while nevertheless facilitating thermal conduction between the ice and the surrounding air. The experimental testing of this system was conducted within a range of ambient temperatures, specifically between 34.6 ℃ and 30 ℃. According to the test results, the system demonstrates the capability to lower the temperature of air by up to 11.4 ℃. The findings also indicate that the cooling efficiency of the system is influenced by fluctuations in air temperature, room temperature, and duration.

Keywords: Atmospheric Temperature; Room Temperature; Outlet Temperature; Relative humidity**;** Thermal efficiency

1. Introduction

In the Sultanate of Oman, the prevailing average temperature is at approximately 36°C. Consequently, the utilization of diverse equipment, including air conditioners, coolers, and fans, becomes imperative to ensure a suitable and pleasant thermal environment for human occupants. The cost of such technology is relatively high, rendering it unaffordable for a significant portion of the population. Students residing in different urban areas, individuals experiencing economic hardship, and families belonging to the lower middle-class socioeconomic strata are particularly susceptible to the adverse effects of high temperatures during the summer season in India. The cost associated with the acquisition, maintenance, operation, and installation of conventional coolers and air conditioners is prohibitively high for those in question. Individuals residing in hostels and rental apartments encounter a challenge pertaining to the limited installation space resulting from the comparatively smaller room sizes. Individuals who frequently travel to different cities and relocate often encounter challenges related to the transportation of large and heavy gear, as well as additional costs associated with the absence of portable appliances.

1.1. Objectives

In order to create a portable air cooler that is compact, user-friendly, and capable of providing enhanced cooling capabilities without significantly impacting ambient humidity levels, while remaining within an accessible price range.

Our primary emphasis is on students residing in hostels, students who live as tenants, and tenants belonging to lower middle-class households.

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The primary objective of this project is to mitigate the impact of heat waves that occur in the hottest months of the summer season, specifically May and September.

2. Literature Review

In their study, Sahare et al. (1) proposed alterations to the current cooler design. The installation of a refrigerated box made of mild steel was carried out inside the cooler tank. Additionally, a rubber cushion was applied to isolate the cooler tank from external sources of heat, hence minimizing heat loss. With the exception of the front face, which corresponds to the door of a refrigerated box, all other surfaces of the box are in direct touch with the water contained in the tank. To validate the proposed model, a series of experiments were conducted in a controlled environment within a room located in Raipur, Chhattisgarh, India, under certain climate conditions. The box contained an assortment of fruits and vegetables, while an equivalent quantity of fruits and vegetables were housed in the adjacent room, where daily measurements of weight reduction were recorded. A finding was made indicating that apples placed outside experience a greater reduction in weight compared to apples stored within the confines of a refrigerated container. The temperature of the apples decreased when they were placed inside the box, whereas it climbed when they were left outside. The condition of the apples was favorable when compared to apples from external sources. Internally, the gravitational force was exerting a decelerated downward acceleration compared to the external environment.

In their study, Manjunatha Y R et al. [2] put out a novel strategy that serves as a superior substitute for traditional cooling methods, while also incorporating temperature monitoring. The device in question is a thermoelectric cooling system that utilizes the Peltier effect to achieve localized cooling, and is equipped with Bluetooth connectivity. This approach enables the simultaneous detection of both bodily temperature and ambient conditions, while also providing the capability to regulate temperature through manual or automated means. The primary procedure involves utilizing the Bluetooth module to monitor both body temperature and ambient parameters, which are subsequently shown on a visual interface.

The liquid crystal display (LCD) module and mobile screen. Individuals have the option to select between cooling or warming effects from the cooling system and heating device. The researchers reached the determination that cooling systems with temperature control, which integrate Bluetooth technology for monitoring purposes, exhibit greater reliability and efficiency compared to alternative cooling systems. The application of this technology in the medical domain involves the utilization of a portable refrigeration system for the purpose of keeping blood and pharmaceuticals. While the cooling capacity of the device is confined to a certain region, its efficiency can be enhanced by augmenting the quantity of Peltier plates. Portable air conditioners have the capability to expedite the process of increasing or decreasing the temperature. The utilization of Peltier-based air cooling systems presents a viable option for boosting performance in comparison to conventional air conditioning systems.

Passive cooling coupled with renewable energy sources was successfully accomplished by Sujatha Abaranji et al. [3]. The water storage medium utilized in this system is composed of a porous substance, hence obviating the requirement for a pump and sump. The usefulness of the porous material as a cooling medium is examined through experiments conducted at three distinct relative humidity (RH) levels, namely low, medium, and high. The constructed setup is subjected to testing in order to assess its performance. The evaluation of a direct evaporative cooling system involves the assessment of its cooling capacity, efficiency, and rate of water evaporation. Vermicompost is utilized as a substitute for the pump and sump due to its notable capacity for water retention. There is no need to switch materials every time. In contrast, the vermicompost is regenerated through the utilization of a sun dryer once the conclusion of the experiment. The circulation of hot air over the vermicompost additionally serves as a preventive measure against the transmission of any existing mold spores in the surrounding air. The findings indicate that under conditions of low relative humidity (RH), vermicompost exhibits an average reduction in temperature of 9.5°C. In addition, the removal of the pump in the process of vermicomposting results in a notable decrease of 21.7 percent in energy consumption. Consequently, vermicompost presents itself as a potentially more energy-efficient substitute for the conventional pad-pump-sump evaporative cooling system. Moreover, the integration of this direct evaporative cooling system with solar-assisted vermicompost drying can facilitate the establishment of a hygienic and environmentally friendly indoor environment. This approach has the potential to facilitate the implementation of ecologically sustainable year-round thermal regulation in building cooling systems.

In their study, Sudaporn Sudprasert et al. [4] conducted an investigation to ascertain the extent of thermal comfort achieved through the utilization of evaporative air coolers. Additionally, they sought to identify the various factors that influence thermal comfort while employing an evaporative air cooler inside interior settings, specifically within the tropical climate of Thailand. A comparative analysis was conducted to examine the thermal comfort levels reported by

individuals exposed to evaporatively cooled air in contrast to those exposed to natural air, based on the outcomes of a survey. The identification of factors influencing thermal comfort was achieved by the utilization of a multiple regression model. The findings of this study indicate that evaporative air coolers offer a thermal comfort level of 0.6, which corresponds to a somewhat cool sensation on the thermal sensation scale. This level is lower than the 0.0 rating, which represents a neutral feeling, offered by fans. It is advisable to utilize evaporative air conditioners with a high velocity of 1.4 m/s indoors in order to alleviate discomfort resulting from the presence of humid air. The results of the regression analysis indicate that air temperature and velocity are the primary factors influencing thermal experience during the utilization of evaporative air conditioning in Thailand.

The study conducted by M. C. Ndukwu et al. (5) investigated recent advancements in evaporative cooling systems, specifically focusing on enhancing cooling efficiency through the utilization of membrane air treatments, dew point type, and heat pipe type heat exchangers in both indirect and direct evaporative cooling applications. However, the feasibility of implementing these improvements in agricultural storage remains largely unexplored or scarce in existing literature. Several studies have examined the utilization of different materials, including agricultural residues, for air-water contact in evaporative cooling systems across different climates. However, the majority of these analyses have primarily investigated the impact of air flow rate and pad thickness on thermal efficiency. Unfortunately, the evaluation and presentation of energy efficiency and evaporation loss associated with these materials have been largely neglected in most cases. The commercialization of evaporative cooling systems in poor nations is hindered by a lack of awareness and a lack of comprehensive economic and cost analysis, which are necessary to convince farmers of the financial advantages they offer.

3. Methodology

The present study will employ a rigorous methodology to investigate the research question at hand. This section will outline the specific approach and procedures that

- This proposed device aims to provide an environmentally friendly portable air cooler that utilizes ice instead of refrigerant to generate cool air.
- In this study, a solitary polystyrene/polyurethane insulation box will be employed to provide comprehensive insulation, hence extending the duration of ice preservation.
- A zigzag-shaped duct made from galvanized iron sheet is being constructed to function as an air route.
- In this experiment, a substantial ice slab weighing approximately 15 kg will be positioned on the duct with the intention of lowering the temperature of the duct walls. Consequently, this will result in the cooling of the air that is being circulated within the duct.
- The duct possesses a cross-sectional area measuring 3 inches by 3 inches. The flow of air traverses the duct and encounters the internal surface of the duct, resulting in collisions between air molecules and the duct walls. These collisions lead to the dissipation of heat from the air, resulting in a decrease in temperature.

3.1. Components

The process of selecting different components employed in this project.

The installation box made of polystyrene or polyurethane.

Polyurethane is a category of polymers that consists of organic units connected by carbamate (urethane) linkages. Polyurethane polymers are conventionally and predominantly synthesized through the chemical reaction between a di- or triisocyanate and a polyol. Polyurethane foam is extensively utilized in various applications such as high resilience flexible foam seating and stiff foam insulation panels.

For this project, a Polyurethane insulation box with a capacity of 50 liters was utilized.

The device under consideration is a direct current (DC) motor equipped with a fan.

For this project, a 12-volt DC motor with a maximum rotational speed of 30,000 RPM was utilized. The motor was coupled with a 4-inch diameter plastic fan consisting of four blades.

The galvanized iron duct is a type of duct made from iron that has been coated with a layer of zinc to enhance its corrosion resistance.

A duct with a square cross-sectional area of 3x3 inches is constructed to facilitate the passage of air while preventing any interaction with water or ice. Heat loss occurs as air flows through a duct.

The direct current (DC) power source.

The entire system is powered by a 12-volt, 4-ampere hour battery.

A temperature sensor is a device that is used to measure and detect changes in temperature.

The product in question is the XH-W1209, a digital temperature controller module with a display and an NTC waterproof temperature sensor. The W1209 Mini Thermostat Temperature controller is an affordable 12V device that features a 7-segment display and a 3-switch keypad for the purpose of adjusting temperature and various other settings. The module is equipped with a temperature sensing NTC thermistor and possesses a precision of 0.1 degrees Celsius.

The XH-W1209 12V Digital Temperature Controller Module, equipped with a display and NTC waterproof temperature sensor, is a cost-effective and efficient thermostat controller.

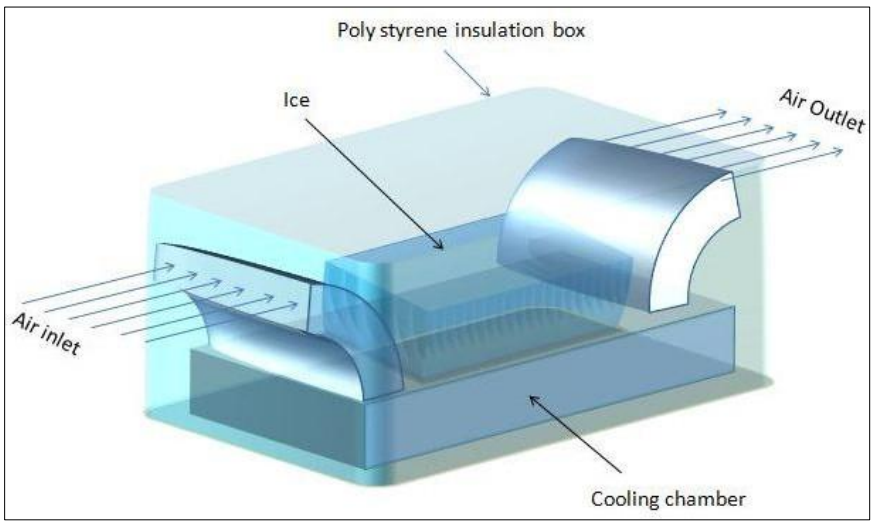

Figure 1 Portable air cooler

3.2. Calculations

3.2.1. DC Motor

Given specifications:

We have used 12 volt, 1.5 Amp and max 30000 rpm DC motor to operate the ducted fan.

P = Voltage* Current

= V * I

= 12 V * 1.5 A

= 18 Watt

3.2.2. Cooling

We have not calculated anything for cooling because the cold air from the outlet is our primary goal in our project, not cooling the entire testing space. We are only using ice which will provide cool air on the basis of latent heat of fusion and conduction. After the successful testing of our project we will try to add some additional features to do cooling in more efficient manner.

Below here is the 24 hours' observation table that we made between time, atmospheric temperature, room temperature and outlet temperature.℃

Table 1 Temperature Observation

Time	Atmospherictemperature (in ℃)	Room Temperature (in ℃)	Outlet Temperature (in ℃)
16:15	42	34.6	31.5
17:15	41	33.9	18.6
18:15	40	32.2	18.5
19:15	38	32.6	18.4
20:15	37	32.9	17.3
21:15	35	33.2	16.5
22:15	35	32	16.9
23:15	34	32.6	15.3
00:15	34	32.5	15.2
1:15	33	32.2	15
2:15	31	30.7	14.8
3:15	31	30.4	14.3
4:15	30	30.3	14.2
5:15	30	30.2	14
6:15	30	30	13.9
7:15	31	30.3	13.7
8:15	32	30.8	13.5
9:15	33	31.5	13.4
10:15	35	32.3	13.2
11:15	36	32.7	12.9
12:15	37	33	12.5
13:15	39	33.3	12.2
14:15	40	33.5	11.4
15:15	40	33.9	11.5

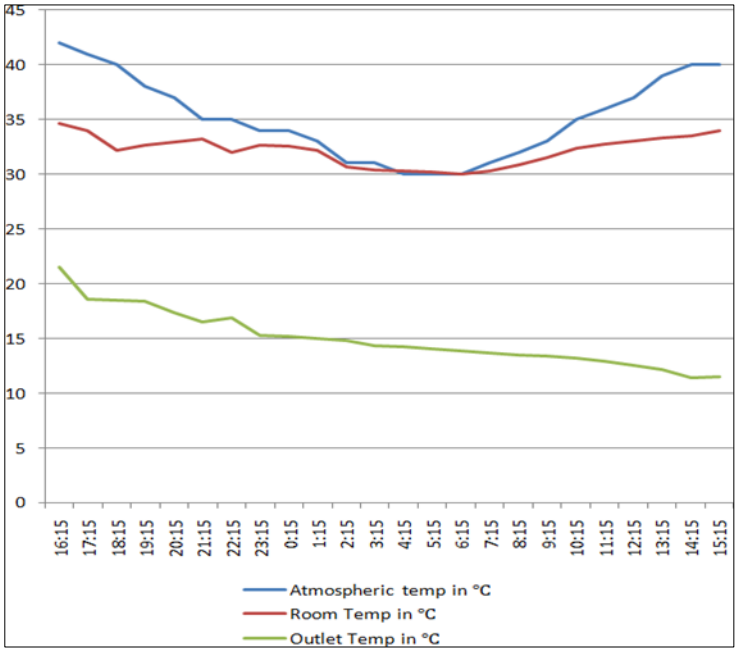

Figure 2 Graph Time Vs Temperature

4. Conclusion

A portable air cooler has been effectively conceived and constructed. The device fulfills the fundamental cooling requirements of individuals amidst the challenging climatic conditions seen throughout the summer season in India. The portable air cooler effectively meets the consumer's requirements while maintaining a cost-efficient approach. The maintenance requirements for the portable air cooler are relatively simple. One notable characteristic of this device is its portability, facilitating convenient movement from one location to another. Due to its compact size, this particular item would be well-suited for placement in various settings, such as bedrooms, drawing rooms, or even smaller hostel rooms. Due to the utilization of ice as a medium, the process is entirely devoid of contamination. Nevertheless, the current state of the design remains at the prototype level. Further experimentation is required in order to accurately ascertain the efficiency, durability, and reliability.

The following is a compilation of recommendations aimed at enhancing the functionality and performance of this portable air cooler.

- Enhancing the duct design with the incorporation of rounded corners.
- One potential method for increasing the cross-sectional area of a duct is by adding an additional inch to its dimensions, while ensuring that the inlet and outflow maintain the same dimensions.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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