JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Low-Cost Indirect Evaporative Cooling Systems for Low-Cost Homes

M. Kamakshi Kanchana (Asst. Professor)
B.Design (I.D), Jawaharlal Nehru Architecture and Fine Arts University
Hyderabad, India

Abstract: Availability and affordability have led to small size homes in urban India. Economically weaker and lower-income families live in houses measuring 250-500 Square feet. Inadequate ventilation and steel or cement sheet roofing make these houses very uncomfortable during the harsh summer season. Summer average daytime high temperatures are in the range of 35-45 degrees Celsius. Providing essential utilities to affordable low-cost houses is a very important aspect of making these dwellings liveable. Ensuring the health and comfort of the occupants is the key parameter for any design. Designing low-cost cooling systems for such houses poses many challenges. Non-availability of uninterrupted electric supply and very small sanctioned electric power to homes pose additional design constraints. Desert (swamp) coolers and table/ceiling fans are extensively used in most houses. Desert coolers are noisy and make the rooms very humid. Noisy and humid rooms are uncomfortable and pose a health risk to the elderly and children. This paper proposes a low-cost indirect evaporative cooling system that can effectively address the issue of noise and humidity. The design is based on a simple heat exchanger, fans, water pump, and ducting. The system utilizes the drop in night temperatures effectively. The unit is placed outside and cool air is circulated in the house using a low-cost duct system. A prototype is built and results are reported. The entire design is based on locally available material. Detailed drawings are given so that similar units can be assembled with locally available components.

Keywords: Desert cooler, duct cooling, Indirect Evaporative cooling, low-cost home utilities, swamp cooler.

1.0 INTRODUCTION

Urbanization is rapidly increasing in India. As per 2021 statistics, over 35% of the 1.2 billion population live in urban and semi-urban areas. There are more than 50 urban agglomerates with more than one million population. There are more than 12 mega urban agglomerates with more than 10 million population ("List of million-plus urban agglomerations in India" 2023). Cities are expanding absorbing villages around them (Sanyal 2010). Villages and urban high-rise buildings co-exist. The migrating population lives in houses measuring around 300 square feet. Providing basic facilities for the safe and comfortable living of people living in these houses is a major design challenge. Minimalist architecture, design, and engineering are needed to give affordable and lasting solutions.

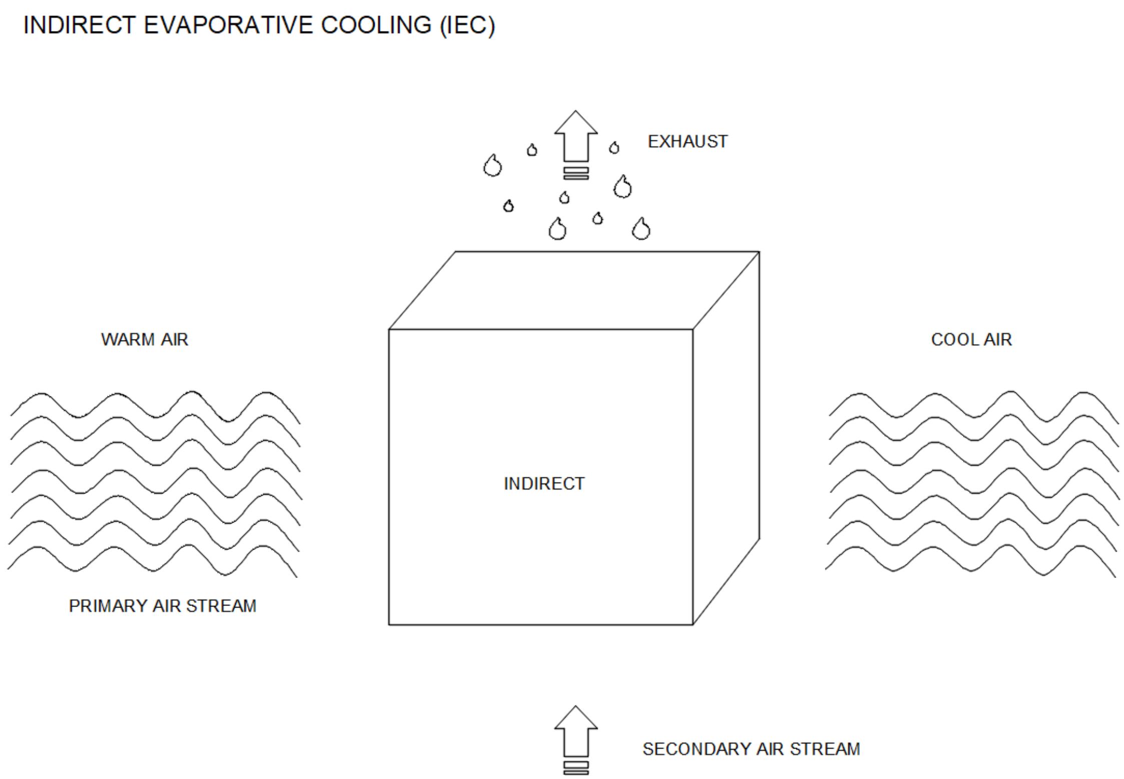
Average daytime summer temperatures are above 35 degrees Celsius in many cities. Cooling the houses with minimum electric power is very important from the standpoint of affordability and also as most houses have limited sanctioned electric power which is less than 1 kilo Watt. Table fans and ceiling fans give little support and are not capable of reducing the room temperature. Desert coolers are an option. However, they produce noise and also throw water directly into the room increasing the humidity. Noise and humidity will cause discomfort to occupants in small rooms and disturb sleep. According to a research article published by Sleep Foundation (Fry and Vyas 2023), disturbed and fragmented sleep can impact the health of people.

According to a medical research report published by the National Library of Medicine (Halperin 2014), sleep disturbances are a threat to the health of people. Lack of proper sleep at night can lead to daytime sleepiness, tiredness, annoyance, and mood changes leading to accidents and low productivity.

Stale and contaminated water in desert coolers also poses health concerns if the water chamber is cleaned regularly and replaced with fresh water (HealthyWA and Department of Health- Government of Western Australia, n.d.). This paper proposes a low-cost indirect evaporative cooling system that can effectively solve the problem of noise and humidity. Design is based on locally available and mass-produced components. Detailed drawings and assembly instructions are provided so that people with minimum technical skills can procure the material and assemble the system.

2.0 Indirect Evaporative Cooling System Concepts

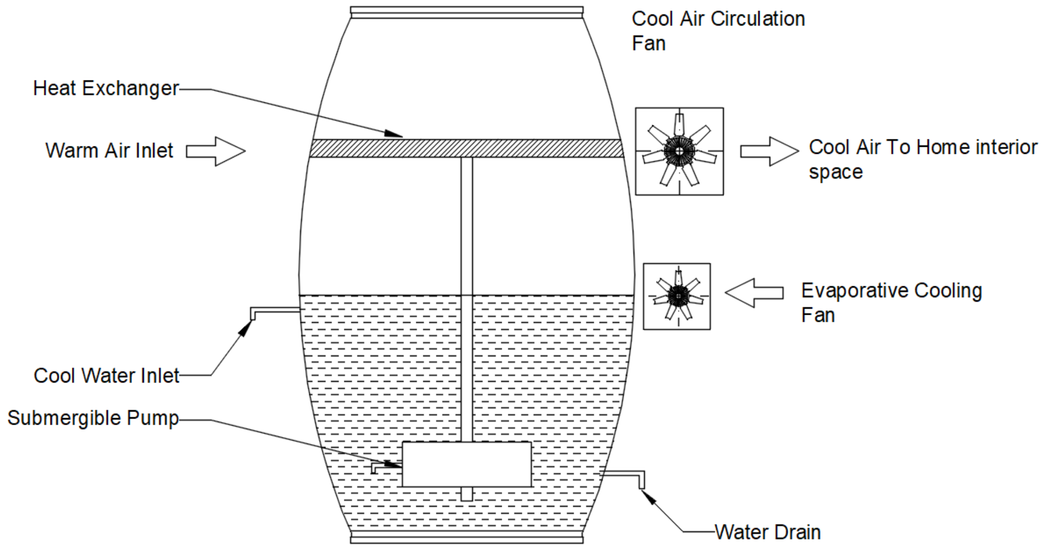
Indirect evaporative cooling and direct evaporative cooling both work on the same principle of lowering air temperature by causing water to evaporate. The main difference with an indirect system is that a heat exchanger is used to cool the air. The evaporative cooling process takes place in the heat exchanger unit. A schematic diagram of the indirect evaporative cooling system is given below.



The system is so designed that the water cooling medium does not come in direct contact with the air that is to be circulated in the room. Warm air passes through a heat exchanger unit in which indirect evaporative cooling takes place. By placing the heat exchanger outside the house, the noise level in the house can be drastically reduced.

3.0 Design of Low-Cost Indirect Evaporative cooling system

The schematic diagram of the unit is given below.

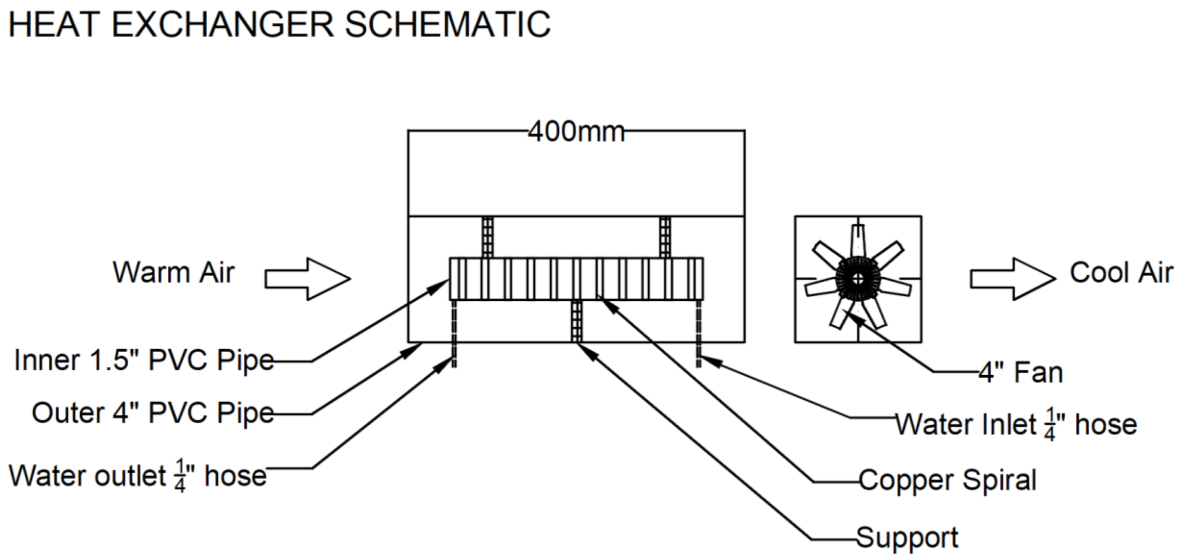


Warm air from the environment enters the heat exchanger unit due to the air draft created by the cool air circulator fan. A submersible water pump circulates cool water on the heat exchanger. The falling water encounters fresh air circulated by a secondary evaporative cooling fan. The design ensures that water is not in direct contact with circulating air.

3.1 Design of heat exchanger

The Heat exchanger is the core component of the system. It is designed using ¼ inch, 25 swg standard copper tubing which is freely available in the market.

The copper tube is wound on a standard 1.5-inch PVC pipe like a helix measuring a length of 15 inches. A transparent ¼ inch hose is connected to both ends. Through one end cool water enters the heat exchanger and leaves through the other end. Submersible pipe continuously circulates the water to make the heat exchanger cool the circulating air. 7.5 meters(25 feet) of tubing weighing 0.7 Kgs is used to build the heat exchanger. The Heat exchanger is inserted into a 4-inch PVC pipe with an exhaust fan mounted on one end. The Schematic diagram of the heat exchanger is given below:



Copper spiral coil is wound on the inner 1.5-inch PVC pipe. It is placed with supports in a large 4-inch PVC pipe. At one end of the 4-inch pipe, a four-inch fan is fixed. Through a quarter-inch plastic hose tube, cool water enters the copper helix and leaves through the other end. The flow of water is in the opposite direction of air. Due to the fan action, warm air enters the large PVC pipe and flows over the heat exchanger, and loses heat. Cool air is pumped out into the room from the outlet end.

The temperature of the water that is circulated in the copper tube is very crucial and it determines the temperature of the outlet air. The air outlet will be a couple of degrees Celsius above the circulating water. Fall-in night temperature and long-wave sky radiation techniques can be used to generate cool water at night. During the daytime, water can be stored in an evaporative cooling chamber and circulated across the heat exchanger based on the requirement. The following research was published previously where I had explained the detail of the technique (Kanchana M 2022).

Thermally efficient ducting is an important element of the system design. Cool air so generated is precious and it is important to pump the same into the interiors with minimum loss. Sheet metal ducts are efficient when properly insulated. However, they are very expensive. A low-cost ducting system can be implemented by using Chimney Aluminium Exhaust Duct Pipe. The following image explains the technique of implementing a simple low-cost system using a chimney duct.

Alternatively, PVC pipe ducting can be used. A duct system allows the design of an indirect evaporative cooling system for homes with improper ventilation. The absence of windows and access to fresh external air can pose a design constraint. However, using PVC or Aluminium Chimney duct systems can be designed (Carsten 2020).

4.0 Prototype Design

A prototype is built using a plastic recycle drum and a submersible pump from a discarded desert cooler. Two standard 4-inch circulating fans are used in the system. One for circulating the air to interiors and the other to perform evaporative cooling of the heat exchanger.

4.1 Bill of material of the prototype

SNO	DESCRIPTION	COST Rs
1	100 Litre Plastic Drum	300
2	Submersible Pump	300

3	Two numbers 4 inch fans	600
4	Copper tubing 1/4inch,25 feet	1500
5	PVC pipes and hoses	200
Total		3000

5.0 Experimental Results

Cool water from the underground sump at around 22 degrees Celsius was used to circulate in the plastic drum. The prototype was placed outside the house and could circulate cool/dry air measuring 24 degrees Celsius into the room with absolutely no noise.

6.0 Conclusion

Designing low-cost systems with minimum resources is essential to give basic comfort to economically weaker sections of society who live in very small homes. Within a budget of Rs. 3,000, a low-cost indirect evaporative cooling system can be built. As the air does not come in contact with the water in the system, the risk related to humidity and contaminated water is removed. Furthermore, as the unit is placed outside the home, noise levels are low creating a noiseless comfortable room for the occupants.

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