

Evaporative cooling: A review of the fundamentals, materials, India past land, cooler brands and applications

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ARTICLE DETAILS

Article History

Published Online: 12 June 2019

Keywords

Evaporation, Heat gains, Thermal Moderation, cooling pads, Past land, Passive cooling.

ABSTRACT

Cooling by means of evaporation is an ancient method of decreasing temperature. Passive cooling techniques are carefully related to the thermal consolation of the occupants, and it's far likely to obtain this relieve by means of decreasing heat gains, thermal moderation and putting off the internal heat. In this paper we're offering a survey on diverse models of coolers, cooling pads, India past land areas and evaporating cooling applications.

1. Introduction

Human beings within the underdeveloped nations and rural areas of growing countries face issues toward preserving fruits and vegetables. Farmers want low cost methods to keep their produce for some days before the goods are allowed into the market place. Inexpensive approaches to cater these desires using indigenously to be had materials is gaining significance. One such fabric which has stuck human beings's attention is 'Clay'. Use of clay closer to cooling has been in existence from a totally long term. Ancient Egyptians have discovered to be the usage of porous clay pots to store water. Pottery gadgets excavated in Indus valley have also proven that many cooling characters increasing features have been added in the water storing pots [1] [2].

There is a few evidence that evaporative cooling become used as early because the antique country of Egypt, around 2500 B.C. Frescos show slaves water jars, which might growth air run around the porous jars and aid evaporation, cooling the contents [3].those jars exist even these days and are called the pot cooler.

Many earthenware pots were exposed in Indus Valley Civilization round 3000 BC which were probably used for storing in addition to cooling water alike to the modern ghara and matki utilized in India and Pakistan. [4].

other such remarkable efforts are from Mansukhbhai Prajapati, an Indian entrepreneur or famous rural innovator in India who developed a fridge out of clay to keep domestic products like culmination and veggies in 2005 [5]. Mansukhbhai Prajapati belongs to Rajkot, Gujarat and he wins 5th National Grassroots Innovation Awards

Prajapati commenced developing the Mitt cool refrigerator in 2001, and he now sells approximately 230 gadgets a month in India, Kenya, and the United Arab Emirates.

The fridge is made from a porous type of clay from Gujarat, the region in India wherein Prajapati has his workshop. You feed water right into a five gallon keeping tank at the top and it progressively drips down through the material. On a warm day, the water evaporates,

cooling the clay and leaving the contents inside incredibly cold. Prajapati says the refrigerator is eight degrees Celsius less heat than room temperature.

Numerous modifications based totally on the 'Zeer Pot' design idea had been made and experiments performed.

Evaluation had been performed at the popular Pot in Pot layout refrigeration approach and it became compared with a new design having higher cover made from clay and it's far having hollow space in that sand and water can be filled and it is considered as moist bulb temperature and additionally it's miles having more than one holes so from that something air is coming could be cooled the use of the evaporation approach. The consequences acquired had been compared and it changed into determined that the new layout refrigerator supplied higher and faster cooling rate than the normal pot in pot refrigeration and also from this Eva transpiration will takes region in order that the sparkling air move will takes vicinity because of. For that reason, this offers a perception closer to methods of improving refrigeration the usage of most effective clay

because the raw cloth. Refrigeration of these kinds will prove immensely beneficial to the agricultural loads and to humans living within the beneath advanced nations. Also as there's no requirement of strength to run the machine, big utilization of these styles of refrigeration structures helps in imparting greener environment to [6].

Steady-state performance of a clay-pot refrigerator which works on the evaporative cooling principle is analysed the procedure of Reynolds flow model of convective heat/mass transfer including outcomes of radiation. For the assumed respiration cooling load of the preserved meals, the maintenance temperature is predicted below a variety of ambient temperatures and relative humidities [7].

The consistent state overall performance of a clay-pot refrigerator is analysed the usage of the Reynolds drift version of mass switch due to Spalding [8]. For a desired geometry, thermal and hydraulic conductivities and cooling load, all parameters consisting of COP, thermal efficiency and inner pot temperature Tcold show expected magnitudes irrespective of

ambient Temperature and relative humidity at ambient condition.

The effect of thermal conductivity of sand+pebbles+water is most prominent. Lower assessment is to be favored to reduce Tcold and increases thermal conductivity. The consequences of thermal conductivity and hydraulic conductivity on cold temperature are determined to be marginal [9].

1.1. Patents

US2,284,905 - EVAPORATIVE COOLER Roy Clay Jackson, Los Angeles, Calif. Application November 13, 1940, and Serial No. 365,512. The invention relates to refrigeration and more particularly to apparatus for maintaining such matter as foods, beverages and the like at a suitable temperature lower than that of the Surrounding atmosphere. An object of invention is to provide refrigeration apparatus adapted to keep foods and similar matter at or below what is ordinarily termed a "safe" temperature, which apparatus takes advantage of the principle of absorption of heat by an evaporating liquid and thereby is enabled to cool efficiently without having to resort to the relatively complicated, expensive and cum be some refrigeration machinery commonly employed in household refrigerators of present design. A further object in this connection is to design the reservoir and arrange it within the cabinet in such a manner that it serves the double Service of Supplying moisture to the receptacles and supporting them in a pendulous manner. So as to permit the air circulating through the cabinet to contact all parts of each receptacle. Still another object is to provide in one of the modifications of apparatus to be described in details. A further object in this connection is to in prove upon prior evaporative coolers by providing means for delivering Water to the absorbent material of the several receptacles which operates: by gravity alone, i.e., independently of capillary action thereby assuring not only continuity and dependability of Supply but also that the Supply to each of the receptacles will be of ample quantity to maintain the entire exterior surface of each of the receptacles at or near the saturation point so as to maximize the rate of evaporation therefore.

US 20150107990A1 Inventor: Najwa H. Samrgandi, Ambridge, PA (US) Pub. Date: Apr. 23, 2015, Appl. No: 14/061,089. The invention discloses a hydrogen/oxygen (HHO) system containing a HHO generator and a Zeer pot which is configured to reduce a temperature inside the HHO generator by evaporation of water on a surface of the Zeer pot. The Zeer pot contains a radiator which cools an electrolytic Solution for the HHO generator. The HHO system also contains a pump and a reservoir tank which is in fluid communication with the radiator to pump the electrolytic solution from the radiator back to the HHO generator, and a demister which is installed downstream of the HHO generator to remove steam from hydrogen and oxygen gas generated in the HHO generator.

Mansukhbhai Prajapati have also patent on Mitti cool refrigerator. There are so many patents on pot refrigeration system. The pot making enterprise have existed from time immemorial; however, the idea of placing a pot in a pot became a unique one. Mohammed Bah Abba holds no patent on this invention and has no control over what is finished along with his concept, at the least some of the other pot maters in Nigeria

2. Physical Principle (Ariah-9.5)

The principle underlying evaporative cooling is the conversion of sensible heat into latent heat. the warm and dry out of doors air is pressured via porous wall or wetted pads which might be replenished with water from cooler's reservoir. Due to low humidity of the incoming air a number of the water gets evaporated. Some of the sensible heat of the air is transferred to water and emerge as latent heat by means of evaporating some of the water. The latent heat follows the water vapour and diffuses into the air. Evaporation causes a go down in the dry-bulb temperature and an increasing push in the relative humidity of the air [10].

An evaporative cooler (also called as swamp cooler, desert cooler and moist air cooler) is a device that cools air through the evaporation of water. Evaporative coolers decrease the temperature of air the usage of the principle of evaporative cooling, unlike standard air-conditioning structures or system which uses vapour-compression refrigeration or absorption refrigerator. Evaporative cooling is the addition of water vapour into air, which causes a reducing of the temperature of the air. The energy had to be needed to evaporate the water is taken from the air in the shape of sensible heat, which impacts the temperature of the air, and converted into latent heat, the energy present within the water vapour element of the air, at the same time as the air remains at a regular enthalpy value. This conversion of realistic warmness or sensible heat to latent warmness or heat is called an adiabatic system as it occurs at a regular enthalpy time. Evaporative cooling therefore reasons a drop in the temperature of air proportional to the realistic warmness or sensible heat drop and a boom in humidity proportional to the latent heat advantage. Evaporative cooling may be visualized the use of a psychrometric chart by finding the initial air condition and shifting alongside a line of constant enthalpy toward a state of higher humidity [11].

Evaporating cooling particular are of two types as:

A. Direct evaporative cooling

Direct evaporative cooling (open circuit) is used to lower the temperature and increase the humidity of air by using the usage of latent heat of evaporation, converting liquid water to water vapour. On this manner, the strength in the air does not vary. Warm dry air is changed to chill moist air. the heat of the out of doors air is used to evaporate water. The RH increases to 70 to 90 % which reduces the cooling effect of human perspiration.

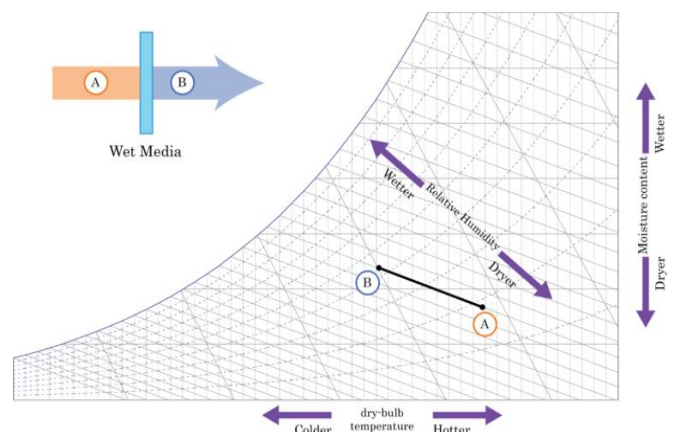


Fig I: Direct Evaporating Cooling [12]

The wet air has to be usually released to outside or else the air turns into saturated and evaporation stops. A mechanical direct evaporative cooler unit makes use of a fan to draw air through a wetted membrane, or pad, which provides a large surface place for the evaporation of water into the air. Water is sprayed on the pinnacle of the pad so it could drip down into the membrane and constantly preserve the membrane saturated. Any extra water that drips out from the bottom of the membrane is accrued in a pan and recirculated to the height. Single level direct evaporative coolers are generally small in size because it simplest includes the membrane, water pump, and centrifugal fan. The mineral content material of the municipal water supply will motive scaling at the membrane, so as to cause clogging over the existence of the membrane. relying in this mineral content and the evaporation price, regular cleansing and renovation is required to make certain most fulfilling overall performance.

Generally, deliver air from the single-stage evaporative cooler will want to be exhausted immediately (one-via float) because the excessive humidity of the supply air. Few design solutions were conceived to utilize the energy within the air like directing the exhaust air through sheets of double glazed windows, consequently decreasing the solar strength absorbed through the glazing [13]. Compared to energy required to gain the equivalent cooling load with a compressor, single stage evaporative coolers consume much less power [14].

Passive direct evaporative cooling can occur everywhere that the evaporative cooled water can cool an area without the help of a fan. This could be completed via use of fountains or extra architectural designs consisting of the evaporative downdraft cooling tower, additionally called a "passive cooling tower".

B. Indirect evaporative cooling

Indirect evaporative cooling (closed circuit) is a cooling system that makes use of direct evaporative cooling further to a few sort of energy exchanger to switch the cool strength to the deliver air.

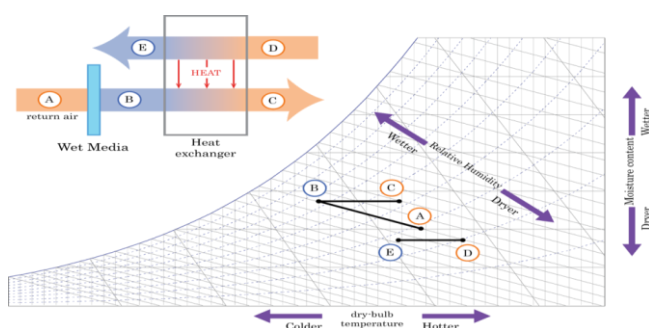


Fig II: The process of indirect evaporative cooling [15]

The cooled wet air from the direct evaporative cooling method by no means comes in direct touch with the conditioned deliver air. The wet air flow is released out of doors or used to chill other outside gadgets consisting of sun cells solar /cells which might be extra efficient if kept cool.

One indirect cooler manufacturer makes use of the so-referred to as Maisotsenko cycle which employs an iterative (multi-step) warmness exchanger which can lessen the temperature to under the wet-bulb temperature [16]. whilst no

moisture is brought to the incoming air the relative humidity (RH) does rise a touch in step with the Temperature-RH components. Still, the extraordinarily dry air attributable to oblique evaporative cooling lets in population' perspiration to evaporate extra without problems, growing the relative effectiveness of this method. Oblique Cooling is an powerful strategy for hot-humid climates that cannot manage to pay for to growth the moisture content of the supply air due to indoor air excellent and human thermal comfort issues. The subsequent graphs describe the procedure of direct and oblique evaporative cooling with the changes in temperature, moisture content and relative humidity of the air.

Passive indirect evaporative cooling strategies are uncommon due to the fact this strategy entails an architectural element to behave as a heat exchanger (for example a roof). This detail may be sprayed with water and cooled through the evaporation of the water on this detail. These techniques are uncommon due to the high use of water, which additionally introduces the risk of water intrusion and compromising constructing shape.

3. Factor Affecting Evaporation

There are four major factors affecting that are important for the rate of evaporation .this is important keep in mind that they usually related to each other to influence the evaporation and the rate of cooling.

A. Relative Humidity

This is the amount of water vapour content in the air as a percentage of the maximum quantity that the air is capable of holding at that temperature .when the relative humidity is low in that air holding of water vapour is very less under this condition air is capable to take additional amount of moisture and if other conditions also meet, the rate of evaporation and cooling rate are more. If relative humidity is more than evaporation, cooling rate will be low.

B. Air Temperature

Evaporation occurs when water absorbs enough amount of energy to change from a liquid to gas. Air during a relatively high temperature will capable to stimulate the evaporative process and also be accomplished of holding relatively great quantity of water vapour. So areas with high temperatures will have higher rate of evaporation and more cooling will occur. With lower air temperature, very less water vapour can be held, and less evaporation and cooling will take place.

C. Air movement

The movement of air is an important factor for evaporation it may natural. As the water from the surface evaporates, then the amount of moisture in the air gets increases so that relative humidity of air increases if the humid air is remains near the surface so the evaporation rate get slows down. On other hand if humid air been removed away and replaces with different air with this evaporation rate will increases.

D. Surface Area

The increases the surface area available for evaporation the more amount of water can evaporate, the increases the rate of evaporation. Its mean evaporation rate is directly proportional to the surface area [17].

4. India Past Land

India reports style of climates starting from tropical inside the south to temperate and alpine within the Himalayan north.

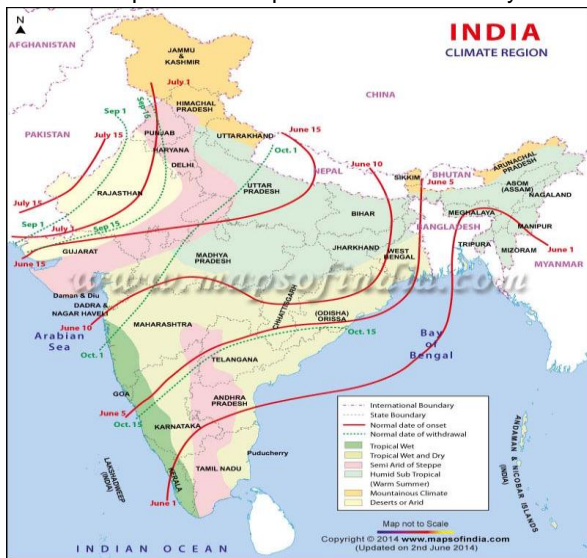


Fig III. Climate regions in india[18]

The improved areas get hold of sustained snowfall for the duration of winters. The Himalayas and the Thar Desert strongly impact the climate of the country.

The Himalayas works as a barrier to the frigid katabatic winds, which blow down from central Asia.

The Tropic of cancer passes through the middle of the country and this makes its climate extra tropical.

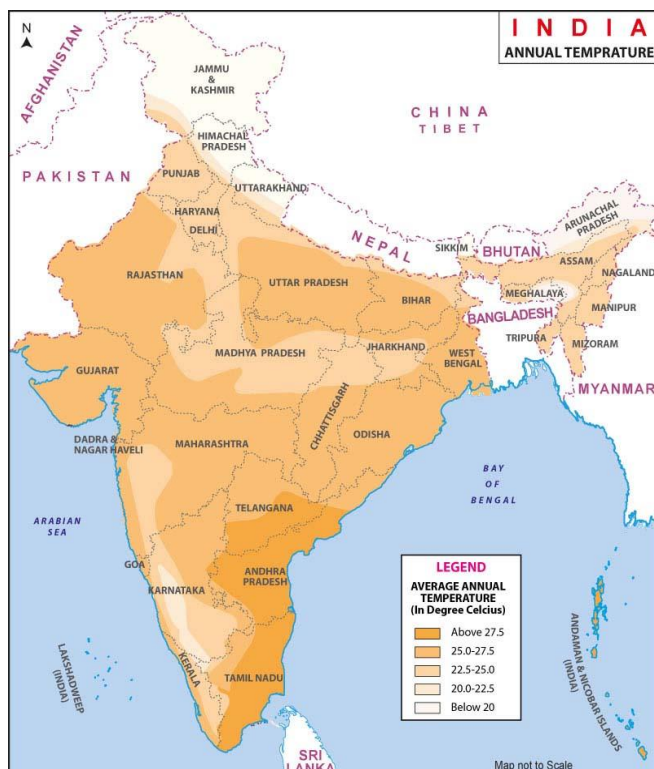


Fig IV: Temperature profile of india[19]

TABLE I. Characteristics of rainfall in India

Type of Rainfall	Areas
Areas of very little rainfall (lower than 50 cm):	Western Rajasthan , northern part of Kashmir, the Deccan Plateau and Punjab.
Areas of low precipitation (50-100 cm):	Eastern Rajasthan, Upper Ganga basin, Southern plains of Karnataka, Punjab, Tamil Nadu, and Andhra Pradesh.
Areas of comparatively heavy rainfall (100-200 cm):	Southern areas of Gujarat, north-eastern Peninsular region, east Tamil Nadu, eastern Maharashtra, Western Ghats, Orissa, Madhya Pradesh, and the central Gangetic basin.
Areas of heavy rainfall (more than 200 cm):	The western seashores, the Western Ghats, Hills of Meghalaya, and the Sub-Himalayan range territories in North East. West Bengal, Assam, Western Coast, and southern part of east Himalayas.

India is a huge tropical country and is renowned for its abundant climatic features [20].

TABLE II. Climatic regions in India

Name of Climatic Region	States or Territories
Tropical Rainforest	Assam and parts of the Sahyadri Mountain Range
Tropical Savannah	Sahyadri Mountain Range and parts of Maharashtra
Tropical and subtropical steppe	Parts of Punjab and Gujarat
Tropical Desert	Most parts of Rajasthan
Moist subtropical with winter	Parts of Punjab, Assam, and Rajasthan
Mountain climate	Parts of Jammu and Kashmir, Himachal Pradesh, and Uttaranchal
Drought	Rajasthan, Gujarat, and Haryana
Tropical semi-arid steppe	Tamil Nadu, Maharashtra, and other parts of South India

5. Cooler Components

There are many components are used within the evaporative cooler. The principle components are given below as:

A. Cooler frame

Cooler body are made up of various materials like as plastic, steels etc. Plastic and steel both substances are typically used as a cooler frame materials. Plastic creates pollution. It isn't eco- friendly. Plastics that act as pollution are categorized into micro-, meso-, or macrodebris, based totally on dimension [21]. today, but, the average customer comes into day by day touch with all types of guy-made plastic substances that have been advanced mainly to defeat herbal decay strategies-substances derived in particular from petroleum that may be molded, solid, spun, or carried out as a coating. Seeing that artificial plastics are in large part nonbiodegradable, they generally tend to persist in natural environments.

The prominence of plastic pollution is correlated with plastics being less expensive and sturdy, which lends to high stages of plastics utilized by humans [22].but, it's far slow to degrade [23]. Plastic pollutants can unfavorably affect lands, waterways and oceans. living organisms, particularly marine

animals, also can be affected through entanglement, direct ingestion of plastic waste, or thru exposure to chemical substances within plastics that purpose interruptions in biological functions. human beings are also stricken by plastic pollution, together with thru the disruption of the thyroid hormone axis or hormone stages. in the UK on my own, more than five million tons of plastic are use on each year, of which an estimated mere 24% makes it into recycling systems. That leaves a closing 3.eight million tonns of waste, destined for landfills [24]. Plastic reduction efforts have passed off in a few areas in tries to reduce plastic consumption and pollutants and promote plastic recycling.

B. Cooling pads

Cooling pads worked as a cooling media. there are many kinds of pads are used for lowering the temperature of water like as timber Wool,CELdek,Straw and Honey Comb cooling pads.



Fig V: Wood Wool Cooling Pad

Timber wool, regarded in general as excelsior in North America, is a product of timber slivers reduce from logs and is in particular used for cooling pads in domestic evaporative cooling systems called swamp coolers.

Timber wool fibers can be compressed and when the strain is eliminated they resume their preliminary volume. Due to its high volume and big surface location, wooden wool can be used for function where water or moisture retention is essential.

The width of timber wool fibers varies from 1.5 to 20 mm, at the same time as their duration is usually round 500 mm (relying at the manufacturing manner).

CELdek collection evaporative cooling pad is utilized in systems wherein high performance cooling is required. it is able to be used for lots special cooling purposes but is mainly appropriate for cooling of stock buildings and greenhouses at the same time as higher air pace is needed.



Fig VI: CELdek Cooling Pads

The CELdek specific pass-fluted design of the pads induces extraordinarily turbulent mixing of air and water for max warmness and moisture switch. CELdek further enhances this layout the usage of unequal angles inside the slope of the corrugations. The 45 degree and 15 degree corrugations are offset to usually direct the water to the air entry aspect of the pad.

Straw pads are product of plywood and galvanized iron frame and the fitted pads are manufactured from straw fiber contained in plastic nets, and they are just like the ones used on evaporative cooling conditioners dimensions (6 m width • 2 m height • 10 cm thickness) in galvanized metallic.



Fig VII: Straw cooling pads

It has water system components supply of water, pump, pipes, and tank.

Honey Comb Cooling is made of cellulose corrugated paper glued in an opposite sequence, which generates air passage inside the pads.



Fig VIII: Honey Comb cooling pad

These sheets have very high ability in absorbing water, large evaporation surface area, excellent permeability and much efficient cooling.

C. Water Circulating Pump

Apart from enthusiasts used in mechanical evaporative cooling, pumps are the most effective different piece of mechanical gadget required for the evaporative cooling system

in both mechanical and passive applications. Pumps can be used for either recirculation the water to the moist media pad or supplying water at very excessive strain to a mister machine for

a passive cooling tower. . Pump disclaimer will range relying on evaporation charges and media pad region.

6. Survey of an Evaporative cooler brands in India

Nowadays in the market there are many brands are commonly used with different specifications

TABLE IV.

Cooler Brands details with ice chamber

Brand	Model	Price	Room Size (in sqft assuming 10ft height)	Cooling Medium	Cooler Body Material	Water Tank Capacity (Litres)	Power Consumption	Ice chamber
Havells	Koolaire 40	10,999	200	Honey Comb	Plastic	40	150	Yes
Orient	Snowbreeze Roto CD3001	7,995	200	Honey Comb	Plastic	30	150	Yes
Symphony	Diet 12i	9,400	150	Honey Comb	Plastic	12	80	Yes
Maharaja White line	Thunder+	9,649	150	Honey Comb	Plastic	20	120	Yes
Hovells	Koolaire 60	12,499	650	Honey Comb	Plastic	45	200	Yes
Orient	Tornado Grand CH6002B	14,995	600	Wood Wool	Plastic	60	240	Yes
Orient	Snowbreeze Slim CD5501H	9,990	350	Honey Comb	Plastic	55	220	Yes
Maharaja White line	Coolz+ Desert	12,999	350	Wood Wool	Plastic	55	165	Yes
Hovells	Koolaire 40	10,999	200	Honey Comb	Plastic	40	150	Yes
Kenstar	Cyclone 12 (KCCCSF1H-FCA)	8,890	200	Wood Wool	Plastic	50	190	Yes

Table V.

Cooler Brands details without ice chamber

Brand	Model	Price	Room Size (in sqft assuming 10ft height)	Cooling Medium	Cooler Body Material	Water Tank Capacity (Litres)	Power Consumption	Ice chamber
Kenstar	Auster XW (KCGAXF2W-FCA)	6,090	100	Wood Wool	Plastic	50	200	No
Symphony	Kaizen Jr	5,699	100	Wood Wool	Plastic	22	95	No
Orient	Magicool DX CW5002B	8,095	250	Wood Wool	Plastic	50	250	No
Symphony	Sumo JR	7,450	250	Honey Comb	Plastic	45	150	No
Havells	Koolaire 60	12,499	650	Honey Comb	Plastic	45	200	No

7. Applications

Before the advent of refrigeration, evaporative cooling changed into used for millennia. A porous earthenware vessel could cool water with the aid of evaporation via its walls; frescoes from approximately 2500 BC display slaves fanning jars of water to cool rooms[25]. A vessel may also be located in a bowl of water, included with a wet cloth dipping into the water, to maintain milk or butter as sparkling as feasible [26].

Evaporative cooling is a common variety of cooling buildings for thermal consolation seeing that it's far particularly cheap and requires less strength than different styles of cooling.

Evaporative cooling is best when the relative humidity is at the low facet, limiting its popularity to dry climates. Evaporative

cooling increases the internal humidity degree appreciably, which wasteland population may additionally admire because the moist air re-hydrates dry skin and sinuses. Therefore, assessing typical weather statistics is an essential process to decide the ability of evaporative cooling strategies for a building. The three maximum critical climate considerations are dry-bulb temperature, moist-bulb temperature, and moist-bulb depression at some stage in the summer layout day. It's far vital to decide if the wet-bulb melancholy can provide enough cooling throughout the summer design day. Via leaving the evaporative cooler. It's far vital to do not forget that the capacity for the outdoors dry-bulb temperature to attain the wet-bulb temperature depends at the saturation performance. A fashionable advice subtracting the moist-bulb melancholy from

the outside dry-bulb temperature, you may estimate the approximate air temperature for applying direct evaporative cooling is to put in force it in places where the moist-bulb temperature of the outdoor air does not exceed 22 °C (71.6 °F) [27]. However, in the example of Salt Lake metropolis, the higher limit for the direct evaporative cooling on psychrometric chart is 20 °C (68 °F). Regardless of this decrease assessment, this climate remains appropriate for this technique.

In places with slight humidity there are numerous cost-powerful uses for evaporative cooling, further to their sizable use in dry climates. as an example, production

vegetation, business kitchens, laundries, dry cleaners, greenhouses, spot cooling (loading docks, warehouses, factories, construction sites, athletic activities, workshops, garages, and kennels) and confinement farming (rooster ranches, hog, and dairy) regularly employ evaporative cooling. In extremely humid climates, evaporative cooling may have little thermal comfort benefit past the increased ventilation and air motion it affords.

8. Conclusion

After study and analyzing Indian weather and temperature details we bring to a close that the evaporative cooling is simplest wherein the temperature is so excessive. The tropical dry weather organizations like as tropical semi-arid (steppe) climate, sub-tropical arid (desert) climate and sub-tropical semi-arid (steppe) climate. Karnataka, central Maharashtra, some parts of Tamil Nadu and Andhra Pradesh experience the

tropical semi-arid (steppe) weather. Rainfall is very unreliable in this kind of weather and the new and dry summers are skilled from March to can also. With scanty and erratic rainfall and severe summers, western Rajasthan witnesses the sub-tropical arid (wilderness) climate. The regions of the tropical wasteland that runs from the areas of Punjab and Haryana to Kathiawar witness the sub-tropical semi-arid (steppe) weather. The maximum temperature in summers goes upto 40°C to 45°C and the rains are unreliable and usually take place at some point of summer monsoon season on this climate. In Karnataka, vital Maharashtra, Tamil Nadu, Andhra Pradesh, western Rajasthan, Punjab and Haryana evaporative cooling is simplest or more valuable.

Due to the analyzing the cooler brands we finish that the coolers with ice chamber are greater powerful than coolers without ice chamber and reading the cooling pads Honey comb, wood Wool and CELdek is generally used as a cooling medium in the coolers because it has higher saturation performance as compared to coconut coir and wood saving.

Acknowledgement

I would like to thank my supervisor Dr.Amit Sharma for his guidance, encouragement, help and valuable suggestions throughout. His untiring and painstaking efforts, methodical approach and individual help made it possible for me to complete this work in time and I also express my deep sense of obligation to my parents and God for their consistent blessings and encouragement.

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