iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** VI **Month of publication:** June 2018

DOI: http://doi.org/10.22214/ijraset.2018.6172

Evaporating Cooling System : A Review

Mukesh Kumar[1,] Amit Sharma[2]
[1]Research Scholar, Department of Mechanical Engineering, D.C.R.U.S.T Murthal Sonipat Haryana -131039, India
[2]Associate Professor, Department of Mechanical EngineeringD.C.R.U.S.T Murthal Sonipat Haryana -131039, India

Abstract: Cooling by evaporation is an ancient method of lowering temperature. Passive cooling techniques are closely related to the thermal comfort of the occupants, and it is likely to achieve this relieve by dropping the heat gains, thermal moderation and removing the inside heat. In this paper we are presenting a survey on various models of coolers and pads in India sector and the modeling and designing of an evaporating cooling system.
Keywords: Evaporation, Passive Cooling, Modeling and designing, Thermal comfort

I. INTRODUCTION

People in the underdeveloped countries and rural regions of developing countries face problems towards preserving fruits and vegetables. Farmers need affordable ways to preserve their produce for a few days before the goods are let into the market. Inexpensive ways to cater these needs using indigenously available materials is gaining importance. One such material which has caught people's attention is 'Clay'. Use of clay towards cooling has been in existence from a very long time. Ancient Egyptians have found to be using porous clay pots to store water. Pottery items excavated in Indus valley have also shown that many cooling characters increasing features were added in the water storing pots [1] [2].

There is some evidence that evaporative cooling was used as early as the Old Kingdom of Egypt, around 2500 B.C. Frescos show slaves water jars, which would increase air run around the porous jars and aid evaporation, cooling the contents [3].These jars exist even today and are called the pot cooler.

Many earthenware pots were exposed in Indus Valley Civilization around 3000 BC which were possibly used for storing as well as cooling water alike to the modern ghara and matki used in India and Pakistan. [4].

Other such noteworthy efforts are from Mansukhbhai Prajapati, an Indian entrepreneur who developed a refrigerator out of clay to store domestic products like fruits and vegetables in 2005 [5]. Prajapati started developing the Mitt cool fridge in 2001, and he now sells about 230 units a month in India, Kenya, and the United Arab Emirates. The fridge is made of a porous type of clay from Gujarat, the region in India where Prajapati has his workshop. You feed water into a 5 gallon holding tank at the top and it gradually drips down through the material. On a warm day, the water evaporates, cooling the clay and leaving the contents inside relatively cold. Prajapati says the fridge is eight degrees Celsius less warm than room temperature.

Several modifications based on the 'Zeer Pot' design concept have been made and experiments carried out.

II. PHYSICAL PRINCIPLE

The principle underlying evaporative cooling is the conversion of sensible heat to latent heat. The warm and dry outdoor air is forced through porous wall or wetted pads that are replenished with water from cooler's reservoir. Due to low humidity of the incoming air some of the water gets evaporated. Some of the sensible heat of the air is transferred to water and become latent by evaporating some of water. The latent heat follows the water vapor and diffuses into the air. Evaporation causes a drop in the dry-bulb temperature and a rise in the relative humidity of the air [6].

An evaporative cooler (also swamp cooler, desert cooler and wet air cooler) is a device that cools air through the evaporation of water. Evaporative coolers lower the temperature of air using the principle of evaporative cooling, unlike typical air conditioning systems which use vapour-compression refrigeration or absorption refrigerator. Evaporative cooling is the addition of water vapour into air, which causes a lowering of the temperature of the air. The energy needed to evaporate the water is taken from the air in the form of sensible heat, which affects the temperature of the air, and converted into latent heat, the energy present in the water vapour component of the air, whilst the air remains at a constant enthalpy value. This conversion of sensible heat to latent heat is known as an adiabatic process because it occurs at a constant enthalpy value. Evaporative cooling therefore causes a drop in the temperature of air proportional to the sensible heat drop and an increase in humidity proportional to the latent heat gain. Evaporative cooling can be visualized using a psychometric chart by finding the initial air condition and moving along a line of constant enthalpy toward a state of higher humidity [7].Evaporating cooling are mainly two types are as:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue VI, June 2018- Available at www.ijraset.com

A. Direct evaporative Cooling

Direct evaporative cooling (open circuit) is used to lower the temperature and increase the humidity of air by using latent heat of evaporation, changing liquid water to water vapour. In this process, the energy in the air does not change. Warm dry air is changed to cool moist air. The heat of the outside air is used to evaporate water. The RH increases to 70 to 90% which reduces the cooling effect of human perspiration. The moist air has to be continually released to outside or else the air becomes saturated and evaporation stops. A mechanical direct evaporative cooler unit uses a fan to draw air through a wetted membrane, or pad, which provides a large surface area for the evaporation of water into the air. Water is sprayed at the top of the pad so it can drip down into the membrane and continually keep the membrane saturated. Any excess water that drips out from the bottom of the membrane is collected in a pan and recirculated to the top. Single stage direct evaporative coolers are typically small in size as it only consists of the membrane, water pump, and centrifugal fan. The mineral content of the municipal water supply will cause scaling on the membrane, which will lead to clogging over the life of the membrane. Depending on this mineral content and the evaporation rate, regular cleaning and maintenance is required to ensure optimal performance.

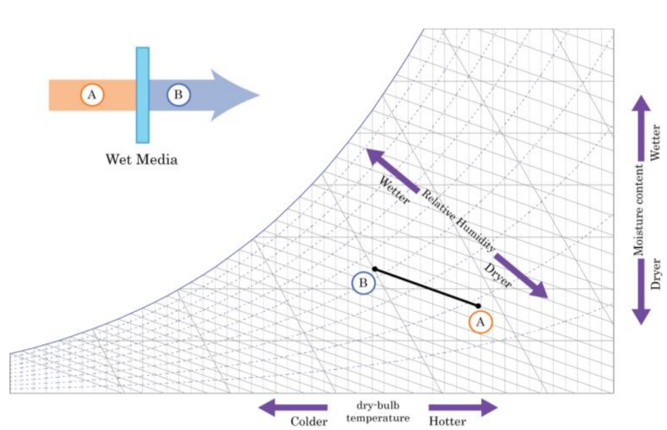


Fig I: Direct Evaporating Cooling

Generally, supply air from the single-stage evaporative cooler will need to be exhausted directly (one-through flow) because the high humidity of the supply air. Few design solutions have been conceived to utilize the energy in the air like directing the exhaust air through two sheets of double glazed windows, thus reducing the solar energy absorbed through the glazing[8]. Compared to energy required to achieve the equivalent cooling load with a compressor, single stage evaporative coolers consume less energy [9].

Passive direct evaporative cooling can occur anywhere that the evaporative cooled water can cool a space without the assist of a fan. This can be achieved through use of fountains or more architectural designs such as the evaporative downdraft cooling tower, also called a “passive cooling tower”.

B. Indirect evaporative cooling

Indirect evaporative cooling (closed circuit) is a cooling process that uses direct evaporative cooling in addition to some type of heat exchanger to transfer the cool energy to the supply air. The cooled moist air from the direct evaporative cooling process never comes in direct contact with the conditioned supply air. The moist air stream is released outside or used to cool other external devices such as solar cells which are more efficient if kept cool.

One indirect cooler manufacturer uses the so-called Maisotsenko cycle which employs an iterative (multi-step) heat exchanger that can reduce the temperature to below the wet-bulb temperature [10] .While no moisture is added to the incoming air the relative humidity (RH) does rise a little according to the Temperature-RH formula. Still, the relatively dry air resulting from indirect evaporative cooling allows inhabitants' perspiration to evaporate more easily, increasing the relative effectiveness of this technique.

Indirect Cooling is an effective strategy for hot-humid climates that cannot afford to increase the moisture content of the supply air due to indoor air quality and human thermal comfort concerns. The following graphs describe the process of direct and indirect evaporative cooling with the changes in temperature, moisture content and relative humidity of the air.

Passive indirect evaporative cooling strategies are rare because this strategy involves an architectural element to act as a heat exchanger (for example a roof). This element can be sprayed with water and cooled through the evaporation of the water on this element. These strategies are rare due to the high use of water, which also introduces the risk of water intrusion and compromising building structure.

III. 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 with a relatively high temperature will able to stimulate the evaporative process and also be capable 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 [11].

IV. INDIA PAST LAND AND MAPS

India experiences variety of climates ranging from tropical in the south to temperate and alpine in the Himalayan north. The elevated areas receive sustained snowfall during winters. The Himalayas and the Thar Desert strongly influence the climate of the country. The Himalayas work 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 more tropical. India is a big tropical country and is famous for its diverse climatic features [12].

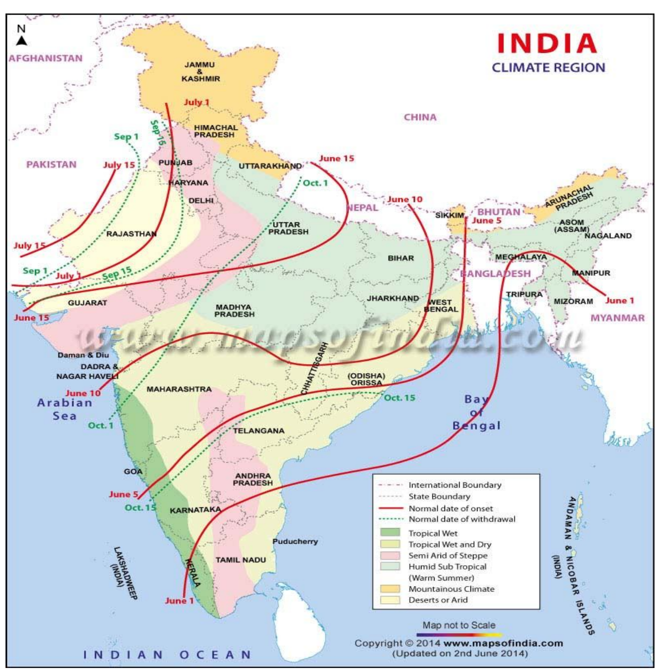


Fig III.Climate regions in india

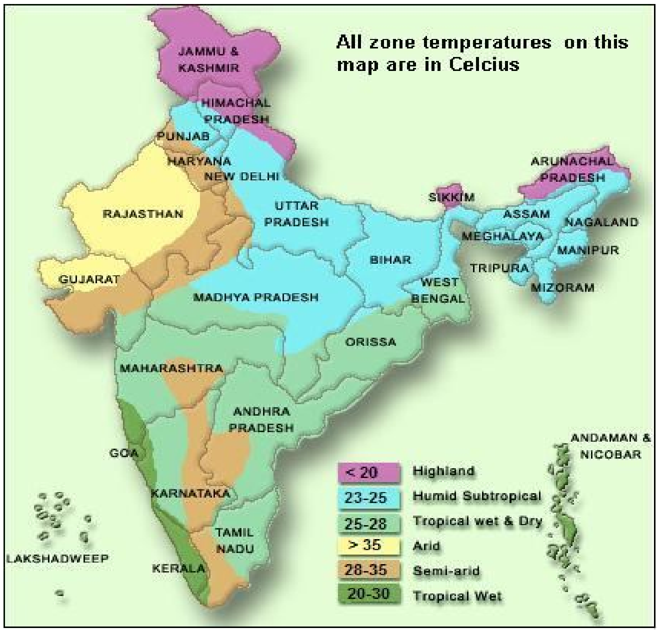


Fig IV: Temperature profile of india

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.

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

V. COOLER COMPONENTS

There are many components are used in the evaporative cooler. The main components are given below as:

A. Cooler Body

Cooler body are made up of different materials like as plastic, steels etc. Plastic and steel both materials are generally used as a cooler body materials. Plastic creates pollution. It is not eco- friendly. Plastics that act as pollutants are categorized into micro-, meso-, or macrodebris, based on size [13]. Today, however, the average consumer comes into daily contact with all kinds of man-made plastic materials that have been developed specifically to defeat natural decay processes-materials derived mainly from petroleum that can be molded, cast, spun, or applied as a coating. Since synthetic plastics are largely nonbiodegradable, they tend to persist in natural environments.

The prominence of plastic pollution is correlated with plastics being inexpensive and durable, which lends to high levels of plastics used by humans [14].However, it is slow to degrade[15]. Plastic pollution can unfavorably affect lands, waterways and oceans. Living organisms, particularly marine animals, can also be affected through entanglement, direct ingestion of plastic waste, or through exposure to chemicals within plastics that cause interruptions in biological functions. Humans are also affected by plastic pollution, such as through the disruption of the thyroid hormone axis or hormone levels. In the UK alone, more than 5 million tonns of plastic are consumed each year, of which an estimated mere 24% makes it into recycling systems. That leaves a remaining 3.8 million tonns of waste, destined for landfills[16]. Plastic reduction efforts

have occurred in some areas in attempts to reduce plastic consumption and pollution and promote plastic recycling.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue VI, June 2018- Available at www.ijraset.com

B. Cooling pads

Cooling pads worked as a cooling media. There are many types of pads are used for reducing the temperature of water like as Wood Wool,CELdek,Straw and Honey Comb cooling pads. Wood wool, known primarily as excelsior in North America, is a product made of wood slivers cut from logs and is mainly used for cooling pads in home evaporative cooling systems known as swamp coolers.

Fig V: Wood Wool Cooling Pad

Wood wool fibers can be compressed and when the pressure is removed they resume their initial volume. Due to its high volume and large surface area, wood wool can be used for applications where water or moisture retention is necessary. The width of wood wool fibers varies from 1.5 to 20 mm, while their length is usually around 500 mm (depending on the production process). CELdek Series evaporative cooling pad is used in systems where high efficiency cooling is required. It can be used for many different cooling purposes but is particularly suitable for cooling of livestock buildings and greenhouses when higher air velocity is required.

The CELdek unique cross-fluted design of the pads induces highly turbulent mixing of air and water for optimum heat and moisture transfer. CELdek further enhances this design using unequal angles in the slope of the corrugations. The 45 degree and 15 degree corrugations are offset to continually direct the water to the air entry side of the pad.

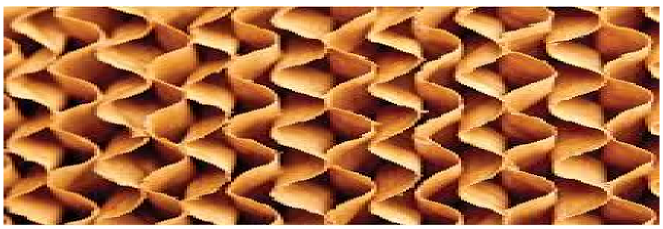


Fig VI: CELdek Cooling Pads

Straw pads are made of plywood and galvanized iron frame and the fitted pads are made of straw fiber contained in plastic nets, and they are similar to those used on evaporative cooling conditioners dimensions (6 m width · 2 m height · 10 cm thickness) in galvanized steel .It has water system components source of water, pump, pipes, gutter and tank.

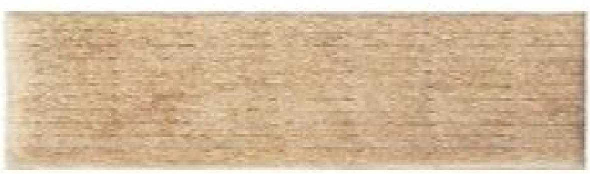


Fig VII:Straw cooling pads

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue VI, June 2018- Available at www.ijraset.com

Honey Comb Cooling Pads are made of cellulose corrugated paper glued in an opposite sequence, which generates air passage inside the pads. These sheets have very high ability in absorbing water, large evaporation surface area, excellent permeability and much efficient cooling.

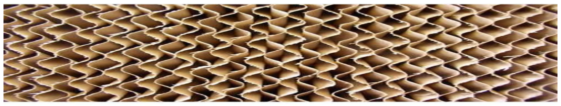


Fig VIII: Honey Comb cooling pad

TABLE III: Colling pads with saturation efficiency

Cooling pads	Saturation Efficiency
CELdek	90%
Wood wool	95%
Coconut Coir	70%
Wood saving	68%

C. Water Circulating Pump

Apart from fans used in mechanical evaporative cooling, pumps are the only other piece of mechanical equipment required for the evaporative cooling process in both mechanical and passive applications. Pumps can be used for either recirculating the water to the wet media pad or providing water at very high pressure to a mister system for a passive cooling tower. . Pump specifications will vary depending on evaporation rates and media pad area.

VI. SURVEY OF AN EVAPORATIVE COOLER BRAND IN INDIA

Today 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 Materia l	Water Tank Capacity (Litres)	Power Consump tion	Ice chambe r
Havells	Koolaire 40	10,99 9	200	Hone y Comb	Plastic	40	150	Yes
Orient	Snowbre eze Roto CD3001	7,995	200	Hone y Comb	Plastic	3 0	150	Yes
Symph ony	Diet 12i	9,400	150	Hone y Comb	Plastic	12	80	Yes
Mahara	Thunder	9,649	150	Hone	Plastic	20	120	Yes

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue VI, June 2018- Available at www.ijraset.com

ja White line	+			y Comb				
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 (KCCCS F1H-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

VII. APPLICATIONS

Before the advent of refrigeration, evaporative cooling was used for millennia. A porous earthenware vessel would cool water by evaporation through its walls; frescoes from about 2500 BC show slaves fanning jars of water to cool rooms[17]. A vessel could also be placed in a bowl of water, covered with a wet cloth dipping into the water, to keep milk or butter as fresh as possible [18].

Evaporative cooling is a common form of cooling buildings for thermal comfort since it is relatively cheap and requires less energy than other forms of cooling.

Evaporative cooling is most effective when the relative humidity is on the low side, limiting its popularity to dry climates. Evaporative cooling raises the internal humidity level significantly, which desert inhabitants may appreciate as the moist air re-hydrate dry skin and sinuses. Therefore, assessing typical climate data is an essential procedure to determine the potential of evaporative cooling strategies for a building. The three most important climate considerations are dry-bulb temperature, wet-bulb temperature, and wet-bulb depression during the summer design day. It is important to determine if the wet-bulb depression can provide sufficient cooling during the summer design day. By leaving the evaporative cooler. It is important to consider that the ability for the exterior dry-bulb temperature to reach the wet-bulb temperature depends on the saturation efficiency. A general recommendation subtracting the wet-bulb depression from the outside dry-bulb temperature, one can estimate the approximate air temperature for applying direct evaporative cooling is to implement it in places where the wet-bulb temperature of the outdoor air does not exceed 22 °C (71.6 °F)[19]. However, in the example of Salt Lake City, the upper limit for the direct evaporative cooling on psychometric chart is 20 °C (68 °F). Despite this lower value, this climate is still suitable for this technique.

In locations with moderate humidity there are many cost-effective uses for evaporative cooling, in addition to their widespread use in dry climates. For example, industrial plants, commercial kitchens, laundries, dry cleaners, greenhouses, spot cooling (loading docks, warehouses, factories, construction sites, athletic events, workshops, garages, and kennels) and confinement farming (poultry ranches, hog, and dairy) often employ evaporative cooling. In highly humid climates, evaporative cooling may have little thermal comfort benefit beyond the increased ventilation and air movement it provides.

VIII.CONCLUSION

After studying and analyzing Indian climate and temperature details we conclude that the evaporative cooling is most effective where the temperature is so high. The tropical dry climate groups 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) climate. Rainfall is very unreliable in this type of climate and the hot and dry summers are experienced from March to May. With scanty and erratic rainfall and extreme summers, western Rajasthan witnesses the sub-tropical arid (desert) climate. The areas of the tropical desert that runs from the regions of Punjab and Haryana to Kathiawar witness the sub-tropical semi-arid (steppe) climate. The maximum temperature in summers goes up to 40°C and the rains are unreliable and generally take place during summer monsoon season in this climate. In Karnataka, central Maharashtra, Tamil Nadu, Andhra Pradesh, western Rajasthan, Punjab and Haryana evaporative cooling is most effective.

After studying and analyzing the cooler brands we conclude that the coolers with ice chamber are more effective than coolers without ice chamber.

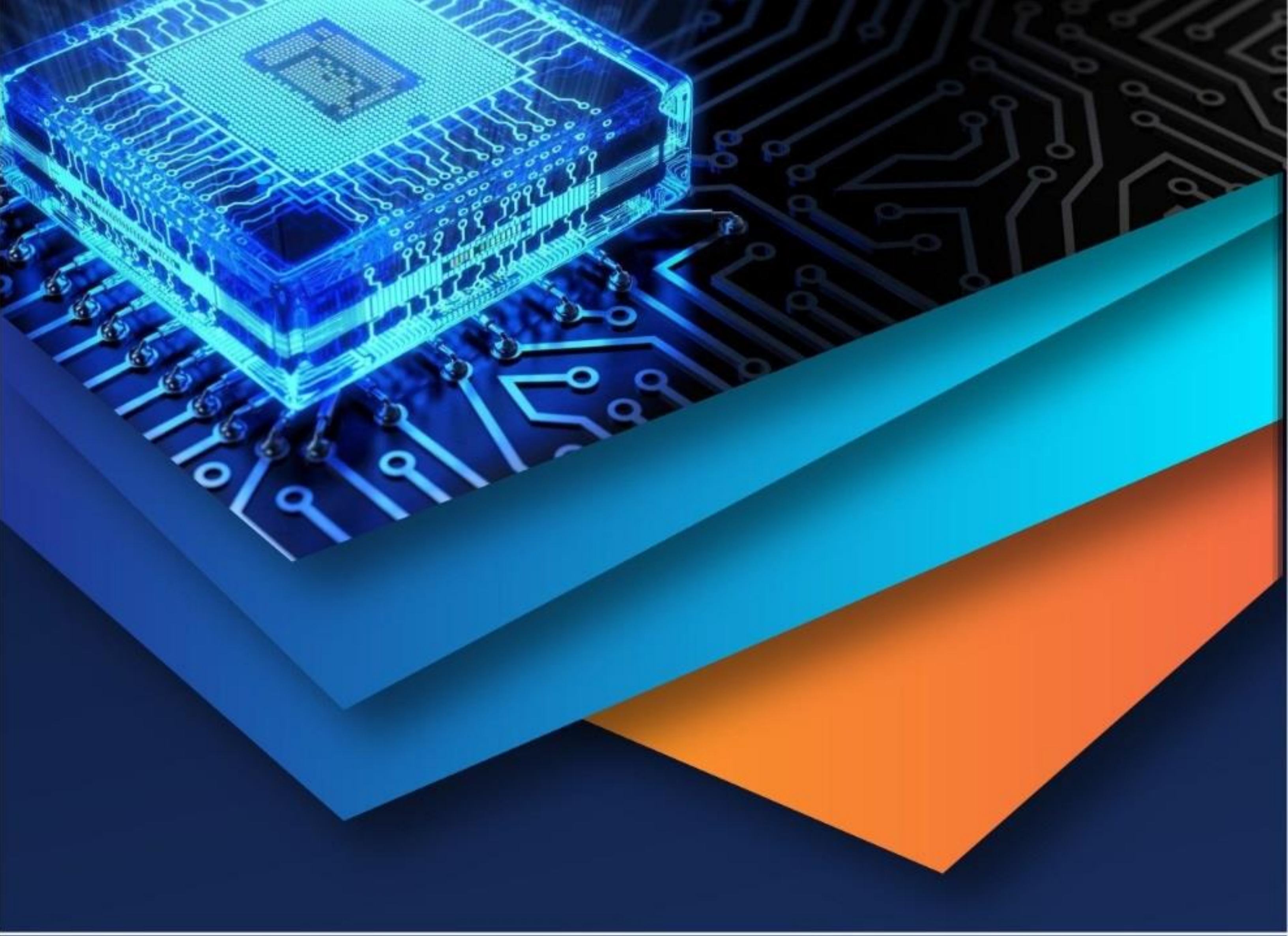
After studying and analyzing the cooling pads Honey comb, Wood Wool and CELdek is commonly used as a cooling medium in the coolers because it has higher saturation efficiency as compared to coconut coir and wood saving.

REFERENCES

[1] Zhiyin Duan, Changhong Zhan, Xingxing Zhang, Mahmud Mustafa, Xudong Zhao, Behrang Alimohammadisagvand, Ala Hasan, Indirect evaporative cooling: Past, present and future potentials, Renewable and Sustainable Energy Reviews, 2012, 6823 – 6850.
[2] George Dales, Jonathan Mark Kenoyer, Leslie Alcock, Excavations at Mohenjo Daro, Pakistan: The Pottery, UPenn Museum of Archaeology, 1986.
[3] Evans, Lisa. "The Advent of Mechanical Refrigeration Alters Daily Life and National Economies throughout the World".
[4] George F. Dales, Jonathan M. Kenoyer, Leslie Alcock. Excavations at Mohenjo Daro, Pakistan: the pottery.
[5] Fifth National Biennial Grassroots Technological Innovation and Traditional Knowledge Awards, 2009, 43-48.
[6] A.W.Date "Heat and Mass transfer analysis of a clay-pot refrigerator" International Journal of Heat and Mass Transfer 55(2012) 3977-3983
[7] Mc Dowall, R. (2006). Fundamentals of HVAC Systems, Elsevier, San Diego, page 16.
[8] Peck, John F.; Kessler, Helen J.; Lewis, Thompson L. (1979). "Monitoring, Evaluating, & Optimizing Two Stage Evaporative Cooling Techniques". Environmental Research Laboratory, University of Arizona.
[9] Givoni, Baruch (1994). Passive and Low-Energy Cooling of Buildings. Van Nostrand Reinhold
[10] http://www.coolerado.com/products/material-resource-center
[11] Zahra Giabaklou And John A. Ballinger A Passive Evaporative Cooling System by Natural Ventilation Received 4 July 1995; accepted 4 March 1996. Budding and Environment, Vol. 31, No. 6, pp. 503-507, 1996.
[12] https://en.wikipedia.org/wiki/Climate_of_India

[13] Hammer, J; Kraak, MH; Parsons, JR (2012). "Plastics in the marine environment: the dark side of a modern gift". Reviews of environmental contamination and toxicology. 220: 1–44. Doi: 10.1007/978-1-4614-3414-6_1.
[14] Hester, Ronald E.; Harrison, R. M. (editors) (2011). Marine Pollution and Human Health. Royal Society of Chemistry. pp. 84-85. ISBN 184973240X
[15] Lytle, Claire Le Guern. "Plastic Pollution". Coastal Care. Retrieved 19 February 2015.
[16] Mathieu-Denoncourt, Justine; Wallace, Sarah J.; de Solla, Shane R.; Langlois, Valerie S. (November 2014). "Plasticizer endocrine disruption: Highlighting developmental and reproductive effects in mammals and non-mammalian aquatic species". General and Comparative endocrinology. Doi: 10.1016/j.ygcen.2014.11.003
[17] "History of Evaporative Cooling Technology". AZEVAP. 2005. Retrieved 22 November 2013.
[18] Cryer, Pat. "Food storage in a working class London household in the 1900s". 1900s.org.uk. Retrieved 22 November 2013
[19] Givoni, Baruch (1994). Passive and Low-Energy Cooling of Buildings. Van Nostrand Reinhold.

.



10.22214/IJRASET

INDEX COPERNICUS
45.98

IMPACT FACTOR:
7.129

TOGETHER WE REACH THE GOAL
IMPACT FACTOR:
7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY