Comparative Performance Evaluation of Evaporative Cooling Local Pad materials with Commercial Pads

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Abstract- *In this study, a special test setup was designed and fabricated to evaluate the performance of different pad materials. The pads were evaluated for their temperature drop, increase in relative humidity inside the storage chamber.*

For this purpose, the tests were carried out for four different pad materials; CELdek pad, aspen pad, coconut coir and wood savings. The air velocity, water flow rate and pad thickness was kept 11.6 ms^{-1}, 3lpm and 100 mm for all the pad materials. During the tests outside air conditions were 28°C to 35°C and 33-67% relative humidity. The study was taken to compare the local cheaply available pads with commercially pads. Average drop in temperature was 8°C and 9.75°C was observed with Celdek and wood wool respectively. While coconut coir and wood saving pads showed temperature drop of 3.5°C and 3.25°C respectively. The percentage drop in temperature with CELdek and wood wool was 40% and 43% higher as compared to wood savings and coconut coir respectively. The RH inside the storage chamber was maintained above 80% in all pads.

Key Words: *Evaporative cooling, Saturation Efficiency, Relative Humidity, Wood Savings, Coconut Coir*

1. INTRODUCTION

Evaporative cooling is a process that reduces the temperature of air by the evaporation of water in the air stream. Heat in the air which is blown across a wet surface (pad) is utilised to evaporate the water, resulting in a reduction in the dry bulb temperature of air and a corresponding increase in the relative humidity. It is an adiabatic exchange of sensible heat to latent heat. Thus, evaporative cooling is generally more efficient where air temperature is high and relative humidity low (Bucklin *et al*., 1993; Dzivama *et al*., 1999).

In hot climates during the summer months the temperature of the air inside the agricultural buildings can easily exceed 40°C. In current year (2016), during the hot summer months the temperature of ambient air increases to over 46°C causing thermal stress and in some part of the country reported 50°C also.

In India, the tendency to use fan-pad evaporative cooling systems is increasing, but the rate of this increase is inhibited because of the high cost of the commercial pad materials (CELdek). This seems to be true for many countries (Mekonnen, 1996; Al-Massoum *et al*., 1998; Liao & Chiu, 2002; Al-Sulaiman, 2002). Therefore, there is a need to evaluate the locally available cheap pad materials. For this reason, there are many previous studies on locally available materials were evaluated to provide alternative pad material.

2. REVIEW OF LITERATURE

Pad is important part of evaporative cooling system. Many researchers have analyzed the performance of locally, easily available and cheaply cooling pads on cooling efficiency.

Kapdi et al (1997) evaluated brick bat, saw dust and wheat straw and reported that brick batt gave better performance (temp drop 4.2- 8.8°C, RH 85-98 %, SE 48.5-97% over that with wheat straw (temp drop 2.1-5.9°C, RH 65.9-94.3%, SE 32-62.5%) and saw dust (temp. drop 1.5-7.2°C, RH 68.6-95.9%, SE 19-91 %).

Gunhan et al (2007) evaluated the suitability of pumice stones, volcanic tuff and greenhouse shading net as alternative pad to the widely used commercial one CELdek and reported that the volcanic tuff pads can be a good alternative to the CELdek pads at 0.6 m s^{-1} air velocity.

The maximum drop in temperature was observed 20°C as against outside temperature of 45°C and 75% RH with partal wood shavings (Jha S N, 2008).

Kulkarni R K (2011) studied the performance of aspen fibre, rigid cellulose, corrugated paper and HDPE pad and reported saturation efficiency (93.7–87.5%) was observed with aspen fibre followed by 86.2-77.5%, 80.2 – 88.4% and 81.9 – 89.7% with rigid cellulose, corrugated paper and HDPE respectively.

Kulkarni et al. (2015) compared the performance of coconut fibre clay and khus with Celdek pad. They observed effectiveness of 0.84, 0.67 and 0.71 with coconut fibre clays, khus and celdek respectively.

Rigid cellulose pad was tested for its efficacy by Waghchore et al, 2013. They reported that temperature drop of 12°C to 13°C lower than that of outside air temperature (41.5°C).

Comparative study for aspen wood and coconut coir fibre was carried out for their performance by Shrivastava et al, 2014, reported that cooling efficiency of coconut coir fibre pad had similar saturation effectiveness about 60%, but the relative humidity of coconut coir pad is less(40-60%) than aspen wood pad (70-90%). They also reported that pad leaving temperature 13°C lower than that of ambient air temperature.

Maurya et al 2014 evaluated three cooling pads namely; cellulose pad, aspen fibre and coconut coir and observed saturation efficiency higher with aspen fibre (80.99- 68.88%), followed by cellulose pad (64.55- 55.29%) and coconut coir (68.15-50.79%).

Ahmed et al., 2011 studied the comparative performance of three pad materials; celdek pad, straw pad and sliced wood pad and reported that sliced wood pad gave the more drop in temperature and relative humidity (11.77C, 40.73%) with straw pad gave least. Cooling efficiency was also observed higher in sliced wood pad (90%), as compared to celdek pad (85%) and straw pad (76%.

Although commercial pads gave good saturation efficiency, as they are specially made but they are expensive and not suitable to low income farmers and traders. Locally and easily available pads performed better with RH above 90% and maximum temperature drop of 25°C. However, performance is dependent on outside weather but saturation efficiency can further be increased by creating good porosity and air-water contact within pad.

3. MATERIALS AND METHODS

A pad material should be porous enough to allow free flow of air. It should be able to absorb water and allow evaporation. It should have maximum amount of wetted surface area for an adequate period of air water contact time to achieve near saturation. The material should be locally available and inexpensive. Moreover, it should allow easy construction into required shape and size (Liao *et al*., 1998; Dzivama *et al*., 1999). Bearing in mind these properties, some locally available materials such as coconut coir and wood savings were chosen as alternative pad materials for testing in this study. The objective of the present study was to evaluate the performance of each material and to identify a suitable alternative to replace the use of commercial pads.

3.1 Selection and Construction of Pad Materials

Coconut coir and wood savings were selected as these are waste and use as fuel for household chullas in villages. Moreover it is available easily at no cost nearby every temples and carpentry shops. Wood wool was selected as this material is widely used in desert coolers while CELdek use is limited to greenhouses and some large capacity coolers.

Each pad material except CELdek, was filled separately in specially fabricated holder frame to create an evaporative padding. The active surface area of this holder was 900 mm by 300 mm and the thickness was kept 100 mm. The front and the back faces of the pad holder were covered with galvanised wire sieve. The size of the holes of the wire mesh was 25 mm by 25 mm.

Coconut coir was procured from nearby temples, was crushed gently before use. It was then evenly spread in pad holder to have uniform porosity and compactness. Weighed and density calculated. Similarly for wood savings was sorted for use and it was also evenly spread in pad holder for uniform porosity and compactness, weighed and density measured. Thus prepared pad were utilized for study. Wood wool was procured from market; was also evenly spread in pad holder for uniform porosity and compactness. CELdek pad (45x45) was procured and use.

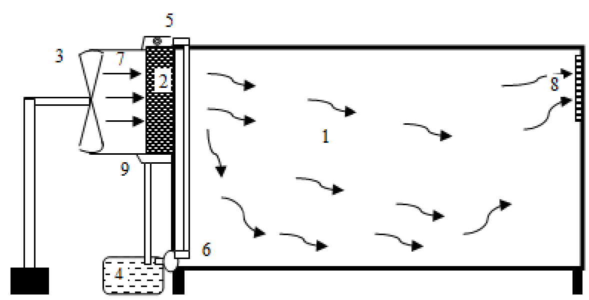

Figure 1: Experimental Set-up

1. Chamber 2. Pad 3. Blower fan 4. Water tank

5. Water spray 6. Pump 7. Duct 8. Air outlet
9. Water collection trough

3.2 Experimental Setup

To compute the cooling performance of the pads, a special cooling chamber having 150kg storage capacity is designed and fabricated. The chamber is hollow having dimensions of 2175x1450x1750mm, a rectangular size air carrying duct (1200x100mm) and pad holder (1200x100x300mm) was fabricated using m s angles and galvanized iron sheets figure 1. A blower fan is fitted at top end and the cooling pad holder box was designed to slide in the pad. An inlet water spray pipe is fitted on the top of the cooling pad holder. Several small holes were made in the pipe to insure uniform distribution of the water. A water trough was provided at the bottom of the pad holder to collect drain water from pad. A complete experimental set is shown in figure 1 with components.

For recording of inlet and outlet temperature of air, two digital thermometers were placed on either side of the pads. Several other devices are used, such as an anemometer to measure the air velocities and electronic regulator to control the speed of the fan for fixing the air velocity. Airflow was maintained 1.33 cu.m/s, water sprayed over the pad at the rate of 3 litre per minute. For continuous supply of water, recirculation type system arranged using pvc pipe, pump and tank. The experiment was performed in the day time (10h to 17:00h). The ambient air dry bulb temperature, wet bulb temperature and relative humidity were recorded. The outlet air temperature, relative humidity was also recorded using thermometer reading.

4. RESULTS AND DISCUSSIONS

4.1. Cooling capacity

The cooling capacity of each pad material calculated. The average cooling capacity of 2717 kJ/h was observed for CELdek while for aspen pad material it was 3513 kJ/h. Cooling capacity of 950 kJ/h and 820 kJ/h was observed for wood saving and coconut coir material respectively.

4.2. Saturation Efficiency

The variation in saturation efficiencies with time through the evaporative cooling media are shown in figure 2. The saturation efficiency ranged between 90.70% to 57.14% for CELdek, 92.20% to 74.24% for wood wool, 65.83% to 25% for wood savings and 67.42 to 30.59 % for coconut coir. The maximum saturation efficiency was observed with CELdek pad followed by wood wool, wood saving and coconut coir. The average saturation efficiency of 49.62% and 46.95% was observed with wood saving and coconut coir respectively. 60-65% SE can be maintained inside the EC storage chamber with wood saving and coconut coir pad material. SE depends on outside air temperature & relative humidity and air-water contact for an air velocity. Commercial pad are prepared for better saturation efficiency by creating more air-water contact. Also SE increased with decrease in outside humidity, which causes more evaporation of water through pad. It means that there is an inverse relation between humidity and saturation efficiency.

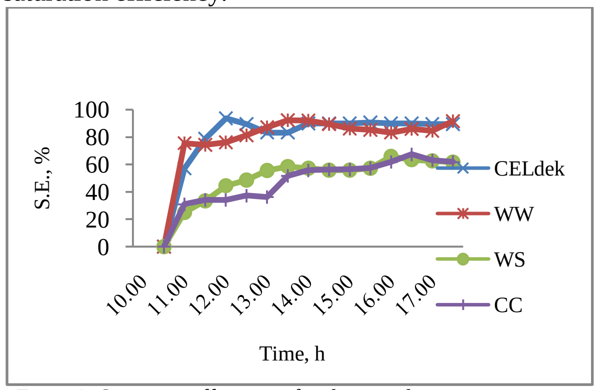

Figure 2: Saturation efficiency of pad material

Table 1: Average drop in temperature.

S. No.	Name of pad	Average drop in temperature, °C
1	CELdek	8
2	Wood wool	9.75
3	Wood savings	3.5
4	Coconut coir	3.25

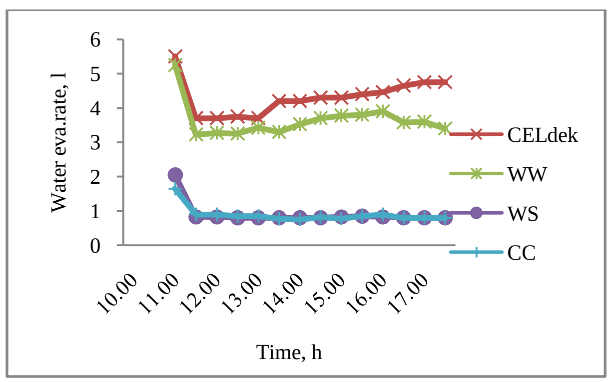

Figure 3: Evaporation of water

4.3. Pad performance

CELdek pad

Figures 4 & 5 shows the variation between outside air temperatures & wet bulb temperature, pad leaving temperature and outside RH & inside RH. The leaving air temperature ranged between 22 to 24°C for cellulose pad. From the figure 4 it is seen that the leaving temperature of air increases with advancement of time. The RH inside ranged between 53% and 74.12%, with an average value of 70.63%.

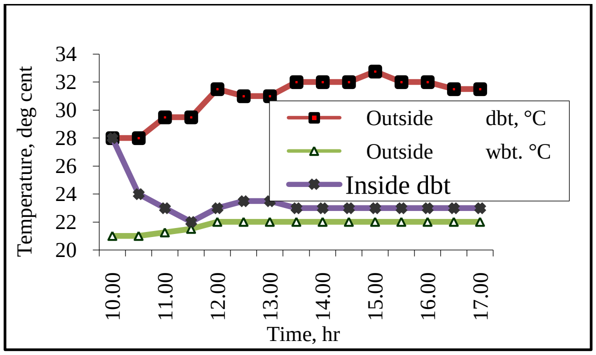

Figure 4: Variation in temperature outside& inside the EC Chamber

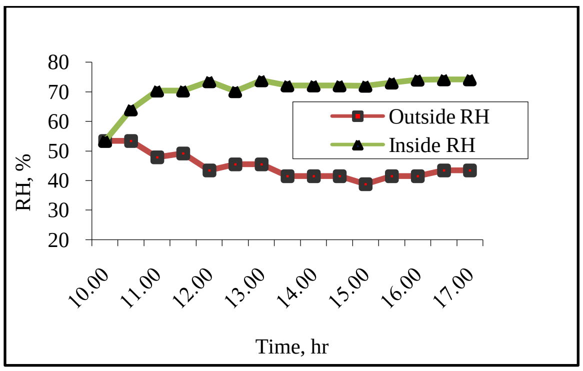

Figure 5: Variation in RH outside & inside the EC Chamber

Wood wool

The variation between ambient temperature, pad leaving temperature and ambient wet bulb temperature is shown in figure 6. The maximum drop in temperature was observed 12.5°C with average drop in temperature observed 10.88°C. Average relative humidity 88.04% was recorded with maximum of 93.00% (figure 7). Drop in temp and RH increased with the advancement of time which remained constant later on with 90± 1%.

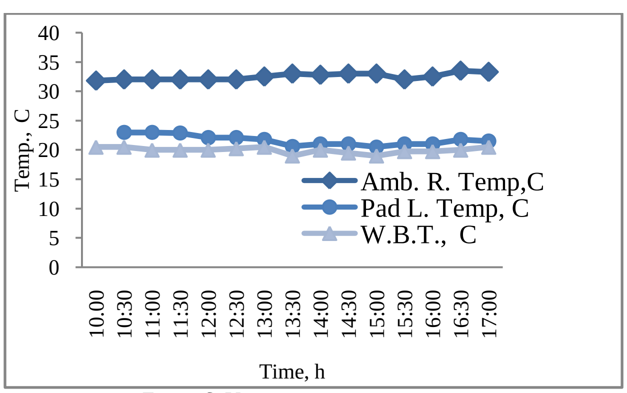

Figure 6: Variation in temperature

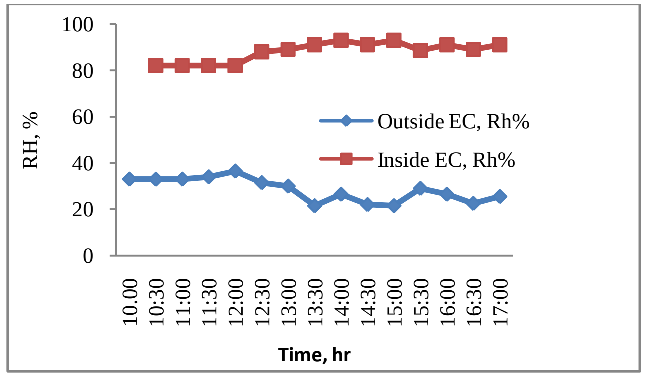

Figure 7: Variation in relative humidity

Wood saving

The variation in outside air temperatures & wet bulb temperature, pad leaving temperature and outside RH & inside RH during testing of the wood saving pad showed in figure 8 & 9. The pad leaving air temperature ranged between 29°C to 29.75°C. The average drop in temperature observed 3.25°C. It was also observed that the leaving temperature of air increases with advancement of time. The inside RH ranged between 81% and 91%, with an average value of 86.23%.

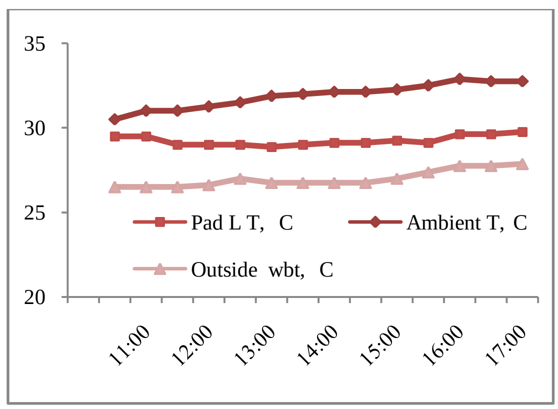

Figure 8: Variation in temperature for wood saving

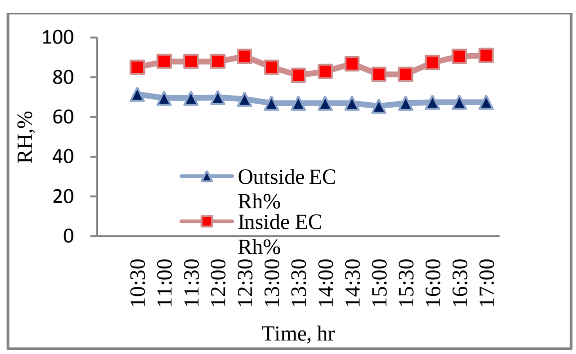

Figure 9: Variation in RH for wood saving

Coconut coir

The variation between ambient temperature, pad leaving temperature and ambient wet bulb temperature is shown in figure 10. The maximum drop in temperature was observed 3.88°C with average drop in temperature observed 3.5°C. Average relative humidity 85.73% was observed with maximum of 87.75% (figure 11). Drop in temp and RH increased with the advancement of time. Due to less water holding capacity and less contact time resulted in lower drop in temperature.

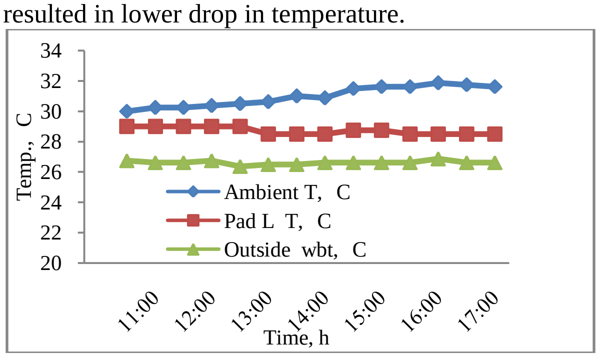

Figure 10: Variation in temperature for coconut coir

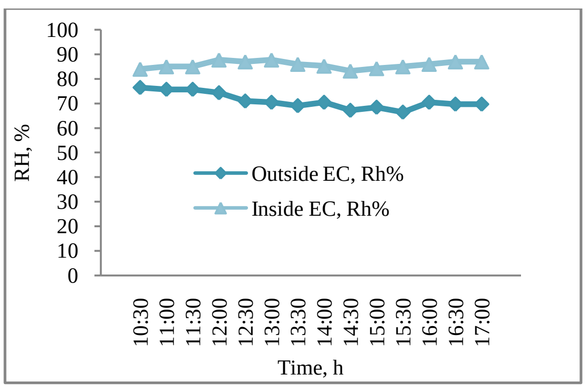

Figure 11: Variation in RH for coconut coir

4.4. Water consumption

In evaporative cooling system cooling is achieved by evaporation of water from pad. Therefore consumption of water is important which determines the requirement of water for particular time of operation of the system. On an average 4.31, 3.64, 0.9 and 0.89 litres of water per hour evaporated from CELdek, wood wool, wood saving and coconut coir pad materials respectively (figure 12). Evaporation of water from wood saving and coconut coir pad materials were almost same.

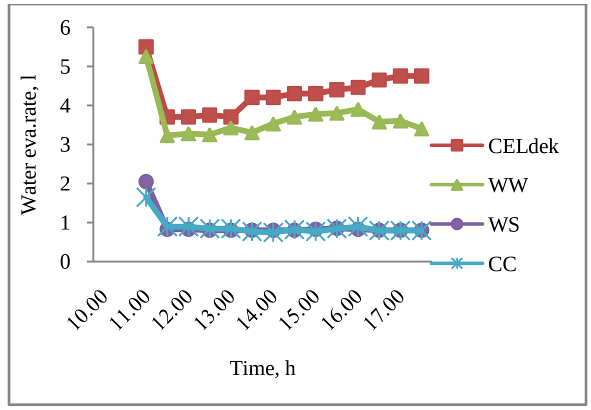

Figure 12. Evaporation of water from pad materials

5. CONCLUSION

The maximum saturation efficiency of 90.70% and 92.20% was observed for CELdek and wood wool pad materials. The higher efficiency is because of more evaporation of water from the pads due to more wetted pad area created within pad.

Wood saving and coconut coir gave maximum saturation efficiency of 65.83% and 67.42% respectively.

Average drop in temperature of 8°C and 9.75°C was observed with Celdek and wood wool respectively. There was no significant difference in temperature drop between coconut coir and wood saving. They showed average temperature drop of 3.5°C. Relative humidity was maintained above 80% in all four pad materials.

The percentage drop in temperature with coconut coir and wood savings was 33-43% lesser as compared to wood wool and CELdek. On an average 4.31, 3.64, 0.9 and 0.89 litres of water per hour evaporated from CELdek, wood wool, wood saving and coconut coir pad materials respectively.

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