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Experimental investigations to reduce unwanted evaporative losses of drinking water from a clay pot

Vijesh V Joshi[1,3], Manvendra Tiwari[1] , and A Subba Rao[2]

[1]Senior Assistant Professor, Mechanical Engineering, Madanapalle Institute of Technology and Science, Madanapalle, Andhra Pradesh, India

[2]Assistant Professor, Mathematics department, Madanapalle Institute of Technology and Science, Madanapalle, Andhra Pradesh, India

***Abstract*.** Clay pots are being widely used in hot-arid/tropical regions for reducing the temperature of the drinking water and this is due to the evaporative heat losses from the clay pot surface. However, excessive water loss from the surface is inevitable as the clay pot is porous. In this paper, strategy to reduce such unwanted water loss has been presented. It has been observed that more than 50% of water loss can be reduced without compromising the cooling effect.
Keywords. Evaporative cooling, heat transfer through porous media, drinking water preservation, transport phenomena

1. Introduction

Clay pots are being widely used in hot-arid/tropical regions for reducing the temperature of the drinking water. Water in the clay pots gets cooled due to evaporative heat loss from the wall. Nevertheless, the drinking water loss is observed due to excessive evaporative losses that do not contribute to cooling. Hence, it is imperative to address this issue which is of great social importance. Further, very few studies have been reported in the past on the clay pot evaporative cooling. Probably it is due to the continuous modernization which attracted most of the researchers towards the artificial cooling systems.

Evaporative cooling is a natural phenomenon that ensures reduced entropy generation as compared to that in case of the artificial cooling systems. However, it can be coupled with the artificial cooling systems to enhance efficiency (Bartlett, 1996). Moreover, the temperature of water in the clay pots would be such that the drinking feels to be comfortable and satisfactory.

The evaporative heat loss from the pot surface results in water temperature reduction. In a related study, Aimiuwu (1992) performed a study on the influence of convection currents around the pot neglecting the effects of gravity or temperature gradients on the evaporative cooling process of a clay pot and observed that the forced convection could significantly increase the cooling effect as it enhanced the evaporation rate. Further, the evaporative cooling process of clay pots was also found to be influenced by other factors such as humidity, pores' size, and the wall thickness. The effects of gravity (Tajer, 2011; Chauvet et al., 2009) and temperature gradients (Tajer, 2011; Huinink et al., 2002; Yiotis et al., 2004) on the evaporation through pores have been reported. However, these studies only reported on the microscopic effects of gravity and temperature gradients on the drying process

[3]*Corresponding author email: vijeshjoshi23@gmail.com*

through porous media. Therefore, there is a need to carry out an analysis of the influence of gravity on the evaporative phenomenon at the macroscopic level, to get new insight.

The current study investigates the appropriate solutions to reduce unwanted water loss without compromising the cooling effect. The experimental approach that is being reported for the first time can also be used to study Rayleigh-Benard convection with the simple modifications in the proposed set up. In order to replicate Rayleigh-Benard convection, water loss due to porosity of the clay pot should be compensated.

2. Experimental set up

The objective of the present work is to study the water loss and the temperature attainment for strategically painted clay pots. The pot porosity was strategically masked by painting the outer surface of the pot. The photographic view of the experimental setup is demonstrated in figure 1. There were a total of four pots, with one pot being unpainted. Two of the pots were half-painted, with the top half of one pot being painted, and the bottom half of the other pot being painted. Lastly, the fourth pot was fully painted. In the case of unpainted pot, evaporation was able to occur all over its surface, whereas in the case of top-half and bottom-half painted pots, evaporation was only able to occur through the bottom half and top half surfaces, respectively. In the case of the fully painted pot, evaporation was completely inhibited. The largest diameter of the pot was 30 cm whereas its neck diameter was 11 cm. In the making of the pot, sand and clay ratio was kept as 5:1.

To prevent the heat loss from the bottom of the pot to the ground, it was placed over thick EPS (Expanded Polystyrene) insulation. Further, the opening of the pot was sealed to prevent any direct evaporation. This arrangement ensured that evaporation only occurred through the surface of the walls of the pot, and that the process of evaporation occurred as a balancing of heat with the surroundings. For recording the temperature, pre-calibrated PT-100 RTD sensors were used.

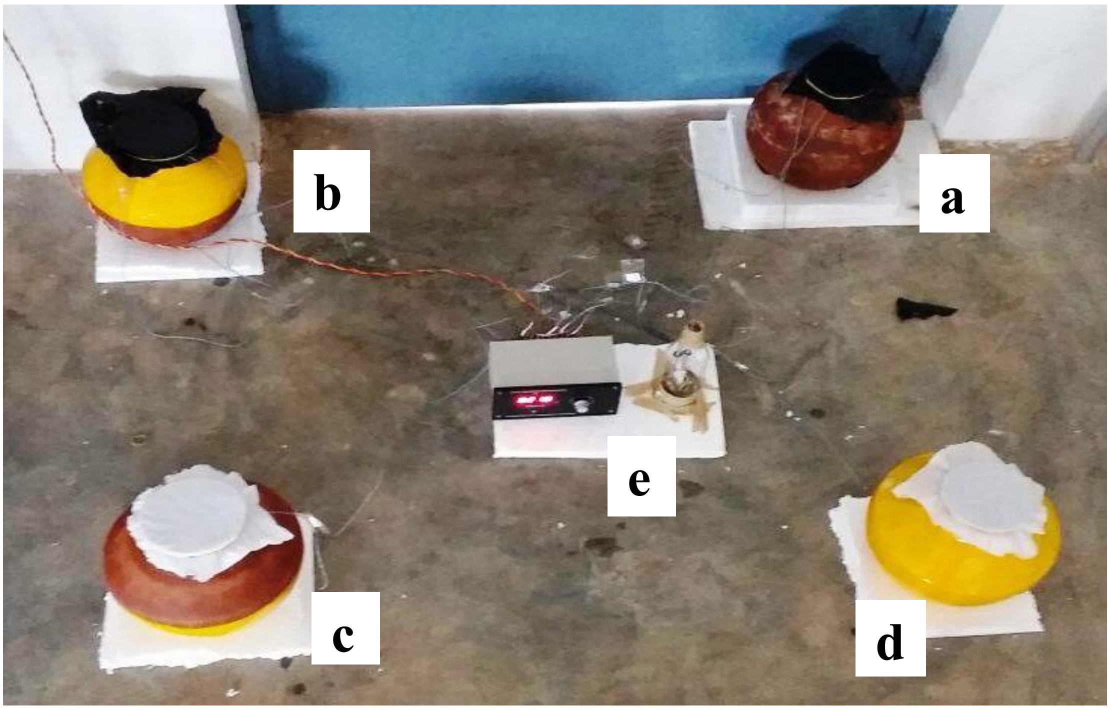
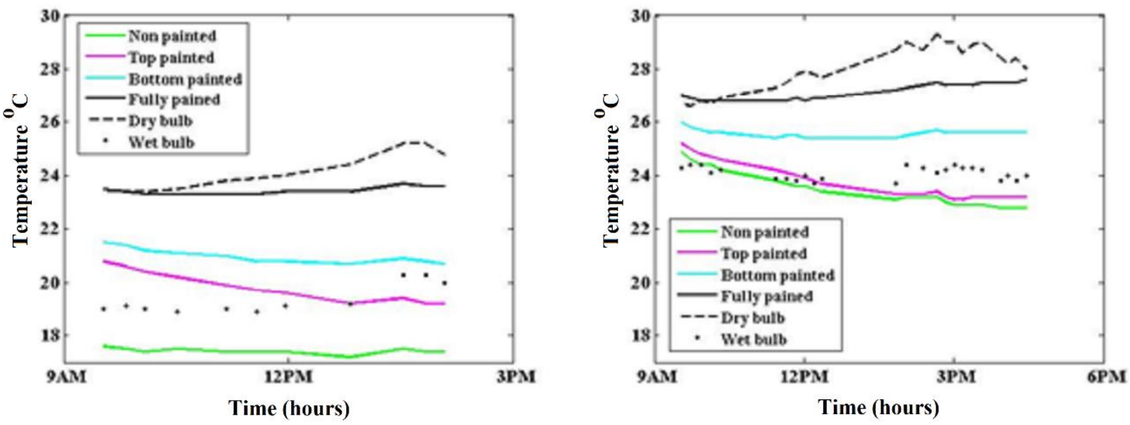


Fig 1 Experimental setup: (a) unpainted pot, (b) top half painted, (c) bottom half painted, (d) fully painted, and (e) temperature display unit and dry/wet bulb temperature measuring unit.

3. Results and discussion

For this experimental work, the data were recorded on February 18, 2017, and March 14, 2017; on the latter day, the outside air was relatively warmer and more humid than that on former; however, on both days, the temperature variations are observed as similar and repeatable. The temperature variations with time for all four cases of strategically painted pots are shown in Figure 2; the two plots correspond to two non-consecutive days in which the outside air conditions were considerably different. As expected, the water temperature of the fully painted pot was higher since evaporation through the pot surface was completely inhibited. The water temperature was found to be approximately 1°C less than the dry-bulb temperature. Conversely, the unpainted pot was measured to have the lowest water temperature. Throughout each day, the water temperature was found to be either similar to or less than the surrounding wet-bulb temperature. On February 18, 2017, it was observed that the temperature was lower than the surrounding air wet-bulb temperature because the surroundings were relatively cooler than that on March 14, 2017. It is interesting to note that the temperature of water in the top-half painted pot was higher than the outside wet-bulb temperature beginning in the morning hours and persisting until 1:00 PM, at which time the water temperature began to decrease to below wet-bulb temperature. It was also observed that the water temperatures in the unpainted pot and top-half painted pot were similar on the day when the outside air was warmer and more humid. This suggests the possibility of the majority of evaporative cooling occurring via the bottom half of the pot. In the case of bottom-half painted pot, the water temperature was constantly higher than the surrounding air wet-bulb temperature. Accordingly, this observation suggests that the majority of the evaporation may have occurred through the bottom half of the pot.



(a) (b)

Fig. 2 Temperature as a function of time, as observed on (a) Feb. 18, 2017 and (b) March 14, 2017. The surrounding air dry-bulb and wet-bulb temperatures considerably differed between the two days, with relatively hotter conditions occurring on March 14, 2017.

On February 18, Figure 2 shows water temperatures during the morning hours of 23.8, 21.9, 21, and 17.9°C in the fully painted, bottom-half painted, top-half painted, and unpainted pots, respectively, whereas the water temperatures were 27, 26, 25.4, and 25°C, respectively, on March 14. On February 18, the painted and unpainted pot temperatures differed by approximately 4 to 6°C between 10 AM and 2 PM. Conversely, on March 14 at 10 AM, this difference was approximately 2°C, and increased to approximately 4°C beginning from 2 PM. The water temperature in the top-half painted pot was observed to be constantly higher than that of the bottom-half painted pot, as is shown in Figure 3. The water temperature difference between these two pots varied approximately 1 to 2°C.

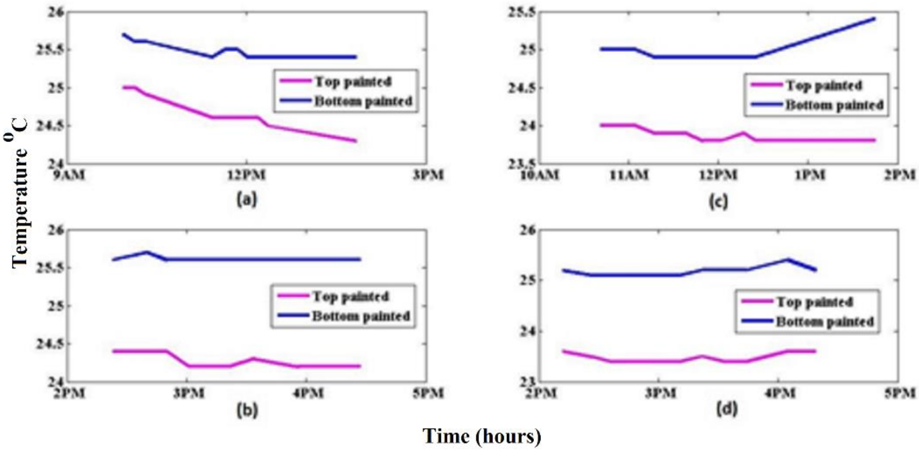


Fig. 3 Water temperature comparison for the top-half and bottom-half painted pots; (a) and (b): March 14, 2017, and (c) and (d): March 15, 2017.

Figure 3 illustrates a comparison of water temperatures for top-half and bottom-half painted pots. Observational results confirmed that the evaporation through the upper half of the bottom-half painted pot was less than that through the lower half of the top-half painted pot. The water temperatures in the cases of the unpainted and top-half painted pot being similar strongly confirms that the driving force (pressure difference) for evaporation is not linear.

Apart from this, the amount of water loss per day (24 hours) was measured by filling the pots with back to the previous level using a beaker. In these experiments, we ensured the level of water being upto the neck at 9AM. Therefore the amount of water loss in 24 hours could be measured using the beaker and are tabulated in table 1. Around 380ml of water was lost from the non-painted pot. On the other hand, the amount of water loss from top half painted pot was around 100ml. It shows that around 27% of the total water loss from the non-painted pot is enough to achieve the same cooling effect. The remaining 73% can be saved.

Table 1: Amount of water loss from the pots with different porosity conditions

Pot porosity	Amount of water loss (ml)	Percentage of reduction (%)
Non-painted pot	380	---
Top half painted	100	73
Bottom half painted	80	79

4. Conclusion

Although evaporative cooling in clay pots is interesting and practical, because of fascination with modern technologies, research interests are more biased toward modern technology. The study of evaporation through the traditional clay pot can facilitate the understanding of fundamental problems and uncertainties related to evaporation. In the current study, water temperature measurements were taken in clay pots under different conditions.

Painting the outer surface of clay pots can effectively inhibit evaporation through the painted portion. In the current experiments, four pots with varied forms of painting (i.e., different levels of evaporation) were studied. The measurements were carried out during the daytime because the temperature of the outside air is relatively higher, and the relative humidity is lower as compared to the night time.

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The water temperature in the fully painted pot (i.e., complete inhibition of evaporation) was found to be constantly higher than that in each of the remaining pots. Accordingly, the water temperature in the unpainted pot was the lowest among all of the pots. In addition, the results from the remaining two pots, the top-half painted (i.e., upper half evaporation inhibition) and bottom-half painted (lower half evaporation inhibition) pots yielded interesting observations. For example, the water temperature in the top-half painted pot was comparatively similar to that in the unpainted pot. The analysis also suggests that the relationship between the height of the clay pot and driving force for the evaporation through its surface is non-linear. Furthermore, it was observed that about 73% of water loss can be minimized by painting the top half but the same cooling effect can be achieved.

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