IOP Conf. Series: Materials Science and Engineering **377** (2018) 012024 doi:10.1088/1757-899X/377/1/012024

# Performance Evaluation of an Eco-Cooler analysed by varying the Physical and flow Parameters

**Bhanuprakash Ch[1] , Vinod Mummina[2] and Mahesh chakravarthi V[3]**

[1] Ph.D student and Assistant professor, Vishnu Institute of Technology, Bhimavaram, Andhra pradesh, India
[2]Assistant professor, Vishnu Institute of Technology, Bhimavaram, Andhra pradesh, India
[3]Assistant professor, Vishnu Institute of Technology, Bhimavaram, Andhra pradesh, India
E-mail: bhanuanju2012@gmail.com

**Abstract.** With the overall temperature rise across the globe and the sweltering heat these summers, one can safely assume that households will see a furious shoot-up in their electricity bills this year. While the urban population resorts to air-conditioning to escape the heat wave, the poor clamour for shade in varied confinements. About 300 million people in India live without access to power. The perfect solution for the poor to the problem of rising temperatures is the 'Eco-Cooler', a cooling device that can run without electricity. The process involves creating grids made from repurposed plastic bottles cut in half and installed on windows as per size. Based on the direction of the wind and the pressure created by airflow, the Eco-Cooler decreases the temperature by five degrees Celsius at optimal conditions.

## 1. Introduction
Eco-Cooler is a device which consists of grids of repurposed bottles which are cut into half and the brims are inserted into a cardboard sheet. The Eco-Cooler is then fixed to a window which is in the direction of maximum air flow so that the wider end of the bottles faces outside. The air passes through the bottles and gets compressed while passing through the neck. The compressed air while leaving the brim will expand rapidly and gives cooler air.

A wind catcher is a traditional Persian architectural element to create natural ventilation in buildings [1]. Wind catchers come in various designs: uni-directional, bi-directional, and multi-directional. The devices were used in ancient Egyptian architecture. Wind catchers remain present in Iran and can also be found in traditional Persian-influenced architecture throughout the Middle East. Nowadays Iranians have changed the wind catcher into an evaporative cooler and use it widely. There are 9 million evaporative coolers in central Iran, and in just the first two months of year 1385 in the Persian/Iranian calendar (April–May 2006) 1,30,000 evaporative coolers were sold in Iran [2]. Zero electricity air conditioning is eco-friendly method to cool down natural air. The further advantage of this method is to reuse the waste items like empty bottle soda plastics. The set-up of Zero Electricity Air Conditioning consists of the following things Thermo coal Sheets, Bottle Cans, Small Strands, and Phase Changing Material [3].

In the present paper an attempt has to be made for poor people who are very badly affected by the summer sun, as it is a very low cost, zero electricity equipment for providing optimum cooling inside the house. The Eco-Cooler has been tested intensively in the laboratory for its performance at different air velocities and temperatures. It is analyzed by varying the diameters of the plastic bottles thereby determining the best possible diameter of the bottle for obtaining greater reduction in room temperatures.

### *1.1. Nozzle*
A nozzle is a device designed to control the direction or characteristics of a fluid flow (especially to increase velocity) as it exits (or enters) an enclosed chamber or pipe. A nozzle is often a pipe or tube of varying cross sectional area and it can be used to direct or modify the flow of a fluid (liquid or gas). Nozzles are frequently used to control the rate of flow, speed, direction, mass, shape, and/or the pressure of the stream that emerges from them. In a nozzle, the velocity of fluid increases at the expense of its pressure energy

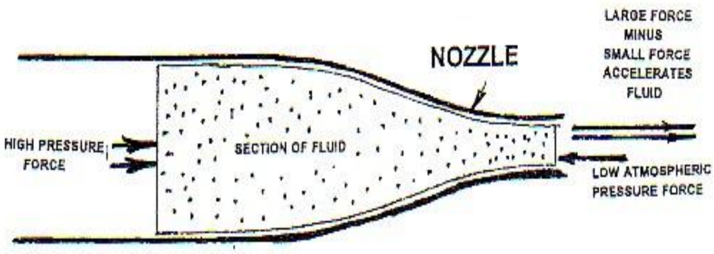


**Figure 1.** In this case simply justify the caption so that it is as the same width as the graphic.

### *1.2. Windmill Anemometer*
This is also a mechanical device that helps in finding out the velocity of the wind. It is very similar to the normal windmill, in which the axis of rotation runs parallel to the direction of the wind, thus making it horizontal. But the wind keeps on changing its direction. Therefore, the axis has to change its direction, so an aero vane is also combined in the device. An aero vane consists of a propeller and a tail, so that precise wind speed and direction measurements can be obtained.

### *1.3. Indoor Air Quality*
Indoor air quality (IAQ) is a term which refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants. IAQ can be affected by gases (including carbon monoxide, radon, and volatile organic compounds), particulates, microbial contaminants, or any mass or energy stressor that can induce adverse health conditions. Source control, filtration and the use of ventilation to dilute contaminants are the primary methods for improving indoor air quality in most buildings. Residential units can further improve indoor air quality by routine cleaning of carpets and area rugs.

### *1.4. Pressure Gradient Force*
The pressure-gradient force is the force which results when there is a difference in pressure across a surface. In general, a pressure is a force per unit area, across a surface. A difference in pressure across a surface then implies a difference in force, which can result in acceleration according to Newton's second law of motion, if there is no additional force to balance it. The resulting force is always directed from the region of higher-pressure to the region of lower-pressure. When a fluid is in an equilibrium state (i.e. there are no net forces, and no acceleration), the system is referred to as being in hydrostatic equilibrium. In the case of atmospheres, the pressure gradient force is balanced by the gravitational force, maintaining hydrostatic equilibrium. In Earth's atmosphere, for example, air pressure decreases at altitudes above Earth's surface, thus providing a pressure gradient force which counteracts the force of gravity on the atmosphere.

## 2. Principal of operation

Tin huts in the sun get extremely hot, as anybody who has left a car in the sun will know, much hotter than the outside temperature. This condition will make the lives of poor very miserable to stay in tin houses during summer. Eco-Cooler is the perfect solution for them. The Eco-Cooler works on the basis of few fundamental science principles.

The Eco-Cooler is placed on the window in the direction of maximum air flow. The wider open ends are placed outside the window allowing the air in without letting additional solar radiation to come in. When the air enters the wider end of the bottle facing towards the wind direction outside of the window the air passes through the bottleneck and gets compressed in there. This compression will increase the velocity of the air at the expense of its pressure. This compressed air undergoes rapid expansion soon after it exits the brim of the water bottle. This rapid expansion lowers the temperature of the air stream and creates some sort of low pressure there which in turn draws the surrounding air into the stream.

This explanation might not convince everybody. We have a small experiment for those people who are not convinced with the previous explanation. Place your hand at a distance of 15 centimetres from your mouth and blow air onto your hand with your mouth wide open, as shown in figure 3.

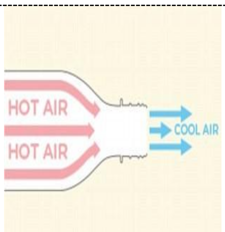


**Figure 2.** A picture showing the working principle of Eco-Cooler.

**Figure 3.** A person blowing air onto his hand with his mouth wide open.

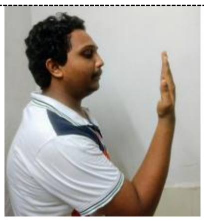

**Figure 4.** A person blowing air onto his hand with his lips pursed.

**Figure 5**. Digital anemometer with an inbuilt temperature sensor.

One can definitely feel warm air striking his hand in the first case. Repeat the same experiment by pacing your hand at a distance of 15 centimetres from your mouth and blow air onto it, this time, by keeping your lips pursed, as shown in figure 4. One can feel cooler air striking his hand in the second case. This is what the Eco-Cooler actually does.

## 3. Experimental setup

### *3.1 Equipment Used*

The figure 6 and 7 shows the experimental setup of anemometer and a thermometer to measure the air velocities and temperatures, respectively. We have opted for a digital anemometer with an inbuilt temperature sensor in it for measuring the readings. The instrument has a windmill type anemometer and a NTC thermometer in it.

*3.2 Laboratory Evaluation*
Before being installed in the classroom, the Eco-Cooler has been intensively tested in laboratory for different air velocities and different cross sections of the bottles. We have selected three different types of water bottles with different dimensions. The reason for opting those three types of water bottles is that they are the most used type of water bottles in the market. This makes them easily available for anybody who wants to make an Eco-Cooler.

We made up a setup to take the readings of the velocities and temperatures of air entering and leaving the bottles. Different air velocities are achieved by employing a table fan as wind source. Care has been taken while cutting the bottles such that even after cutting the bottles their dimensions are exactly the same as mentioned afore.

## 4. Results

*4.1 Specimen 1*
The first bottle we have tested was that of the dimensions with base diameter as 3 inches and the brim diameter as 1 inch. The bottle is cut into half using a cutting blade. A cardboard box has been selected and it is punched with a hole of exactly the same diameter as of the bottle brim, so that it will perfectly fit into the cardboard box. The bottle is inserted into the punched hole and the setup is kept in front of a table fan so that the air can pass through the bottle. The speed of the fan is varied and the corresponding velocity and temperature readings at the entry and exit of the bottle are recorded using the digital anemometer and the inbuilt thermometer.

**Figure 6.** Measuring the velocity and temperature of air at the entry of specimen 1

**Figure 7.** Measuring the velocity and temperature of air at the exit of specimen 1

**Table 1.** Velocities and Temperatures readings for specimen 1

| S.NO | Inlet velocity (kmph) | Exit velocity (kmph) | Inlet temperature ($^0$c) | Exit temperature ($^0$c) |
|---|---|---|---|---|
| 1 | 10.5 | 11.7 | 30.8 | 30.2 |
| 2 | 13 | 14.1 | 30.8 | 29.8 |
| 3 | 16 | 17.3 | 30.8 | 29.5 |

*4.2 Specimen 2*
The second bottle we have tested was that of the dimensions with base diameter as 2.75 inches and the brim diameter as 1 inch. The bottle is cut into half using a cutting blade. The bottle is inserted into the

punched hole and the setup is kept in front of a table fan so that the air can pass through the bottle. The speed of the fan is varied and the corresponding velocity and temperature readings at the entry and exit of the bottle are recorded using the digital anemometer and the inbuilt thermometer.

**Table 2.** Velocities and Temperatures readings for specimen 2

| S.NO | Inlet velocity (kmph) | Exit velocity (kmph) | Inlet temperature ($^0$c) | Exit temperature ($^0$c) |
|---|---|---|---|---|
| 1 | 10.5 | 11.2 | 30.8 | 30.4 |
| 2 | 13 | 13.6 | 30.8 | 30.1 |
| 3 | 16 | 16.5 | 30.8 | 29.9 |

*4.3 Specimen 3*

The second bottle we have tested was that of the dimensions with base diameter as 4 inches and the brim diameter as 1 inch. The bottle is cut into half using a cutting blade. The bottle is inserted into the punched hole and the setup is kept in front of a table fan so that the air can pass through the bottle. The speed of the fan is varied and the corresponding velocity and temperature readings at the entry and exit of the bottle are recorded using the digital anemometer and the inbuilt thermometer.

**Table 3.** Velocities and Temperatures readings for specimen 3

| S.NO | Inlet velocity (kmph) | Exit velocity (kmph) | Inlet temperature ($^0$c) | Exit temperature ($^0$c) |
|---|---|---|---|---|
| 1 | 10.5 | 12.1 | 30.8 | 29.9 |
| 2 | 13 | 14.4 | 30.8 | 29.5 |
| 3 | 16 | 17.6 | 30.8 | 29.1 |

*4.4 Inference*

The obtained results from the testing of specimens clearly shows that the maximum reduction in temperature can be achieved by employing the specimen 3 i.e. the bottle with base diameter of 4 inches and the throat diameter of 1 inch.

Unfortunately, we were unable to procure the required number of specimen 3 type bottles that would make up the Eco-Cooler for our classroom. So, we proceeded with the second best of the three specimens, bottle with the base diameter of 3 inches and the brim diameter of 1 inch, which can be easily procured to fabricate the Eco-Cooler.

*4.5 Prototype Evaluation*

The prototype model of the Eco-Cooler has been installed in the classroom and the values of the velocity and the temperature are recorded at an interval of one hour during our college working hours for 14 days. The data collected during those 14 days has showed the evidence of efficient working of the Eco-Cooler in our classroom. Everyday readings were tabulated and the average of those readings is presented in the following table.

**Table 4**. Average readings of the velocity and temperature of the Eco-Cooler

| **S.no** | **Date** | **Inlet velocity (kmph)** | **Exit velocity (kmph)** | **Inlet temperature ($^0$c)** | **Exit temperature ($^0$c)** |
|---|---|---|---|---|---|
| 1 | 27/02/2017 | 12.47 | 12.97 | 29.73 | 27.82 |
| 2 | 28/02/2017 | 13.21 | 13.72 | 29.05 | 27.16 |
| 3 | 01/03/2017 | 14.23 | 14.67 | 28.96 | 27.16 |
| 4 | 02/03/2017 | 12.50 | 12.94 | 30.31 | 28.32 |
| 5 | 03/03/2017 | 14.30 | 14.70 | 30.44 | 28.48 |

| | | | | | |
|---|---|---|---|---|---|
| 6 | 04/03/2017 | 13.32 | 13.73 | 30.80 | 28.90 |
| 7 | 06/03/2017 | 12.51 | 12.96 | 31.27 | 29.32 |
| 8 | 07/03/2017 | 15.38 | 15.80 | 30.60 | 28.72 |
| 9 | 08/03/2017 | 13.05 | 13.47 | 30.91 | 29.21 |
| 10 | 09/03/2017 | 12.51 | 13.05 | 31.21 | 29.34 |
| 11 | 10/03/2017 | 13.08 | 13.47 | 30.87 | 28.97 |
| 12 | 11/03/2017 | 15.38 | 15.80 | 30.04 | 28.31 |
| 13 | 13/03/2017 | 14.23 | 14.68 | 35.13 | 33.21 |
| 14 | 14/03/2017 | 12.51 | 12.96 | 31.76 | 29.98 |

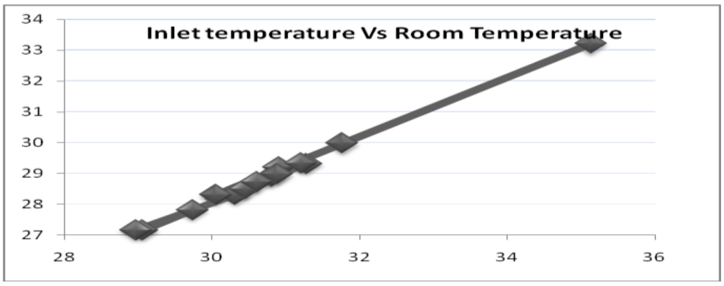


**Figure.8.** Inlet temperature Vs Room temperature

The average of the inlet temperature for the 14 days is 30.79 $^0$C.
The average of the exit temperature for the 14 days is 28.92 $^0$C.
So, the average net reduction in temperature for the 14 days period is:
Average inlet temperature – Average exit temperature
i.e. 30.79 - 28.92 = **1.87 $^0$C**

We have obtained an average net reduction in temperature of our classroom by an approximate 2$^0$ Centigrade.

## 5. Conclusion

Temperatures are getting intolerable these days, day by day the temperatures are increasing due to industrialisation, global warming, pollution etc. As always, whatever may be the case, the poor are the most affected. Our solution, Eco-Cooler, will definitely work well within the tin houses of the poor among the southern hemispheric countries. This zero electricity, zero pollution, low cost, easy to make, and, easy to install cooling device will help the poor in surviving the summer heat by reducing the indoor temperature up to 3 $^0$Centigrade at optimal conditions when installed in the house. Our results have also suggested that the use of the bottle with 4 inch diameter at the base and 1 inch diameter at the brim will yield better results compared to the other two bottles of different dimensions. Our device will ensure that the poor people can battle the ever increasing day temperatures without expending more of their money, in some cases, any of their money. Not only for humans, Eco-Coolers can be employed effectively in cattle farms and pet houses which provides the animals a great sense of relief from the sweltering summer heat without costing a heap on the farmer’s head.

## References

**[1]** Malone, Alanna. *"The Wind catcher House"*. Architectural Record: Building for Social Change. McGraw-Hill.

**[2]** McClellan, C. H., Evaporative cooling Application Handbook, Sun Manufacturing, Texas, 1989.

**[3]** Akshansh Mishra, Anish Das Gupta, Amit Kumar Mandal and Anand Singh zero electricity air conditioning using phase changing materials International journal of thermal engineering (IJTE) Volume 4, Issue 1, Jan–June 2016, pp. 10–14, Article ID: IJTE_04_01_002.