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CFD analysis of solar still with PCM

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ABSTRACT

The main objective of this project is the productivity improvement of the solar still by using the phase changing material, the experimental setup was made up of aluminium basin with Phase Changing Material and without Phase changing materials the experiment was conducted in morning 7 am to evening 6 pm hour based productivity and cumulative productivity are also calculated for with and without PCM material, Trimethylolethane and Paraffin C18 material is used for this experiment and the result of Paraffin C18 material produce the more productivity from this experiment, the same values are validate with the CFD analysis also.

1. Introduction

A solar still distills water, using the heat of the Sun to evaporate, cool then collect the water. There are many types of solar still, including large scale concentrated solar stills, and condensation traps (better known as moisture traps amongst survivalists). In a solar still, impure water is contained outside the collector, where it is evaporated by sunlight shining through clear plastic or glass [1–3]. The pure water vapor condenses on the cool inside surface and drips down, where it is collected and removed [4].

Distillation replicates the way nature makes rain. The sun's energy heats water to the point of evaporation. As the water evaporates, water vapor rises, condensing into water again as it cools and can then be collected. This process leaves behind impurities, such as salts and heavy metals, and eliminates microbiological organisms. The end result is pure distilled water [5–8].

Solar stills are used in cases where rain, piped, or well water is impractical, such as in remote homes or during power outages [9–11]. In subtropical hurricane target areas that can lose power for days, solar distillation can provide an alternative source of clean water. Several methods of trapping condensation exist [12].

2. Materials and methods

This method was first used by the peoples of the Andes. A pit is dug into the earth, at the bottom of which is placed the receptacle that will be used to catch the condensed water [13–15]. Small branches are placed with one of their ends end inside the receptacle and their other ends up over the edge of the pit, forming a funnel to direct the condensed water into the receptacle. A lid is then built over this funnel, using more small branches, leaves, grasses, etc. The completed trap is left overnight, and moisture can be collected from the receptacle in the morning [16,17].

This method relies on the formation of dew or frost on the receptacle, funnel, and lid. Forming dew collects on and runs down the outside of the funnel and into the receptacle. This water would typically evaporate with the morning sun and thus vanish, but the lid traps the evaporating water and raises the humidity within the trap, reducing the amount of water that is lost [18,19]. The shade produced by the lid also reduces the temperature within the trap, which further reduces the rate of water loss to evaporation.

2.1. Modern method

The method is very similar to that described above, but a single sheet of plastic is used instead of branches and leaves. The greater efficiency of this type of trap arises from the waterproof nature of the plastic, which doesn't let any water vapour pass through it (some water vapour escapes through the leaves and branches of the first method). This efficiency requires a certain amount of

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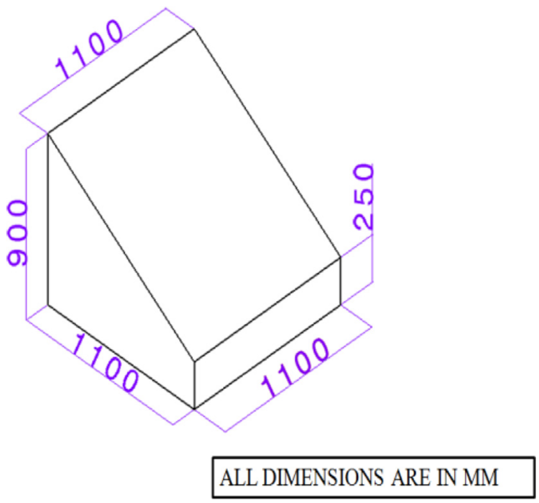

Fig. 1. 2D geometry of solar still.

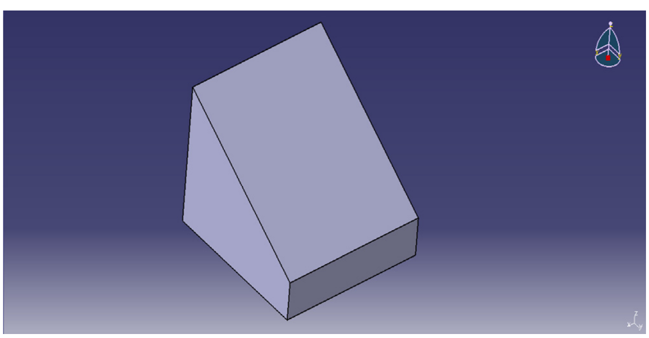

Fig. 2. 3D geometry of solar still.

diligence of the part of the user, in that the plastic sheet must be firmly attached to the ground on all sides; this is often accomplished by using stones to weight the sheet down and/or covering the edges of the plastic sheet with earth (such as that dug out to make the hole in which the trap sits). Weighting the centre of the plastic sheet down with a stone forms the funnel via which the condensed water will run into the receptacle.

2.2. Transpiration method

Water can be obtained by placing clear plastic bags over the leafy branch of a non-poisonous tree and tightly closing the bag's open end around the branch. Any holes in the bag must be sealed to prevent the loss of water vapor.

During photosynthesis plants lose water through a process called transpiration. A clear plastic bag sealed around a branch allows photosynthesis to continue, but traps the evaporating water causing the vapor pressure of water to rise to a point where it begins to condense on the surface of the plastic bag. Gravity then causes the water to run to the lowest part of the bag. Water is collected by tapping the bag and then resealing it. The leaves will continue to produce water as the roots draw it from the ground and photosynthesis occurs.

The vapor pressure of water in the sealed bag can rise so high that the leaves can no longer transpire, consequently when using this method, the water should be drained off every two hours and stored. Tests indicate that if this is not done the leaves stop producing water.

If there are no large trees in the area, clumps of grass or small bushes can be placed inside the bag. If this is done the foliage will have to be replaced at regular intervals when water production is reduced, particularly if the foliage must be uprooted to place it in the bag.

Efficiency is greatest when the bag receives maximum sunshine at all times. Exposed roots are tested for water content. Soft, pulpy roots will yield the greatest amount of liquid for the least amount of effort.

3. Modelling

Modelling of solar still using CATIA software using the commands of sketcher and pad commands in sketch the single slope solar still have the dimensions of base 1.1 m × 1.1 m front wall dimensions of 0.25 m and back wall have the dimensions of 0.9 m the 2D and 3D model of solar still is given below (Figs. 1 and 2).

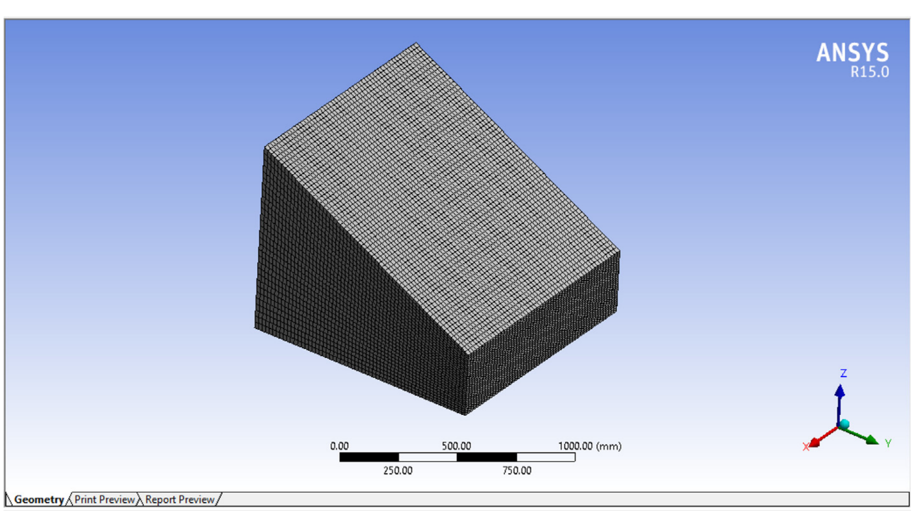

Fig. 3. Mesh geometry of solar still.

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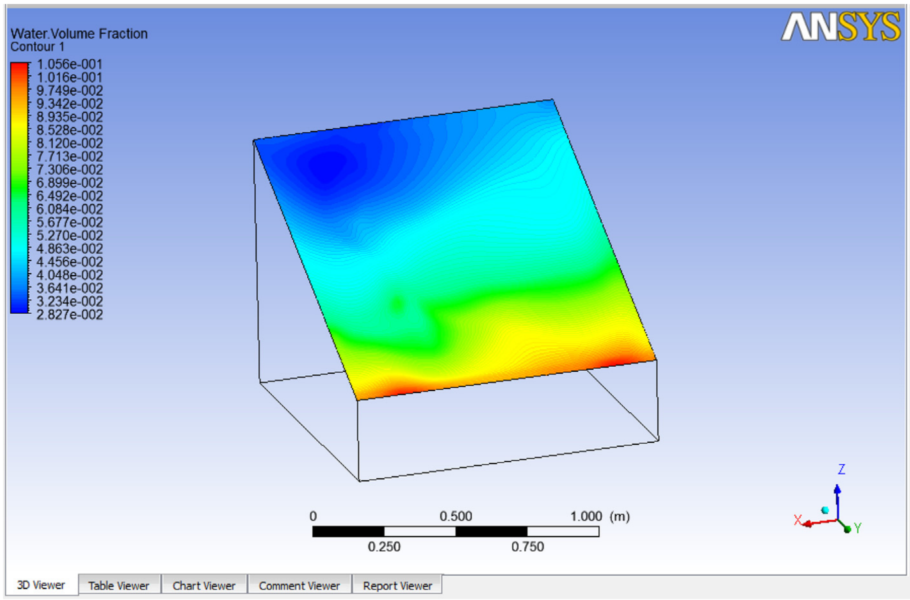

Fig. 4. Contour result of volume fraction of water.

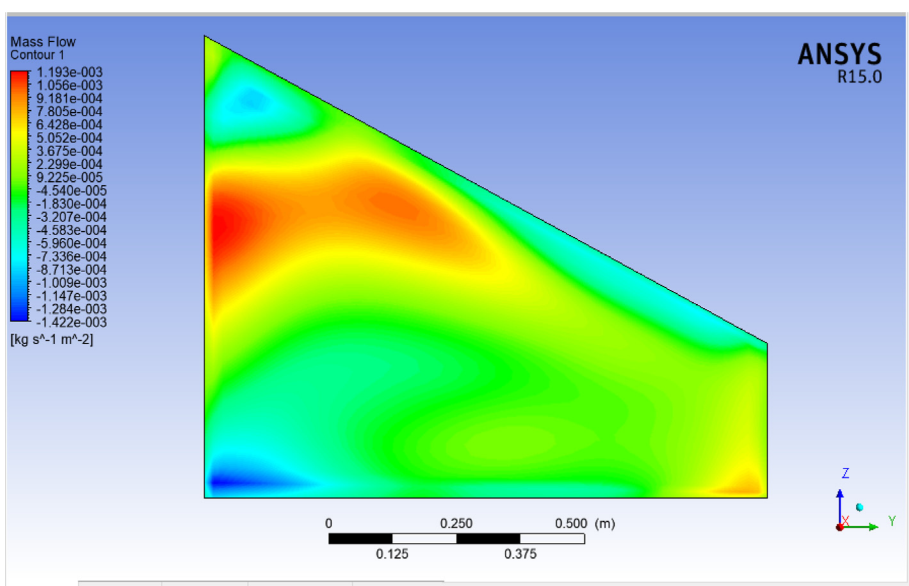

Fig. 5. Contours of mass flow in the solar still.

3.1. Meshing

3.1.1. Mesh quality considerations for FLUENT

FLUENT requires high quality mesh to avoid numerical diffusion. Several Mesh Quality Metrics are involved in order to quantify the quality; however the skewness is the primary metric however the skewness is the primary metric. The aspect ratio and cell size change mesh metrics are also very important. In worst scenarios and depending on the solver used (density based or Pressure based) FLUENT can tolerate poor mesh quality. However some Applications may require higher mesh quality, resolution and good mesh Distribution. The location of poor quality elements helps determine their effect. Some overall mesh quality metrics may be obtained in ANSYS Meshing under the Statistics object (Fig. 3).

4. Analysis

Figs. 4–10.

4.1. Encapsulation of PCMs

4.1.1. Macro-encapsulation

Early development of macro-encapsulation with large volume containment failed due to the poor thermal conductivity of most PCMs. PCMs tend to solidify at the edges of the containers preventing effective heat transfer.

4.1.2. Micro-encapsulation

Micro-encapsulation on the other hand showed no such problem. It allows the PCMs to be incorporated into construction

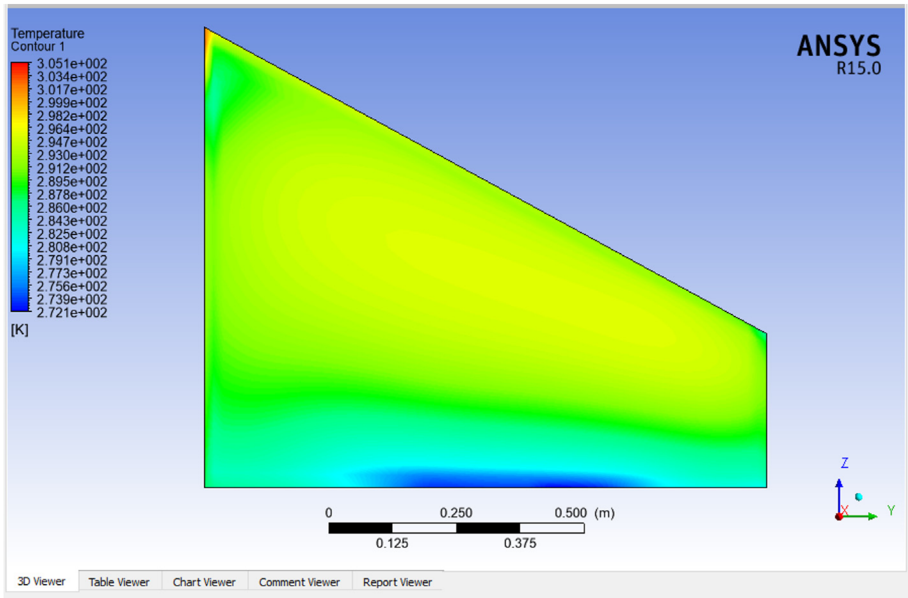

Fig. 6. Contours of temperature in the solar still.

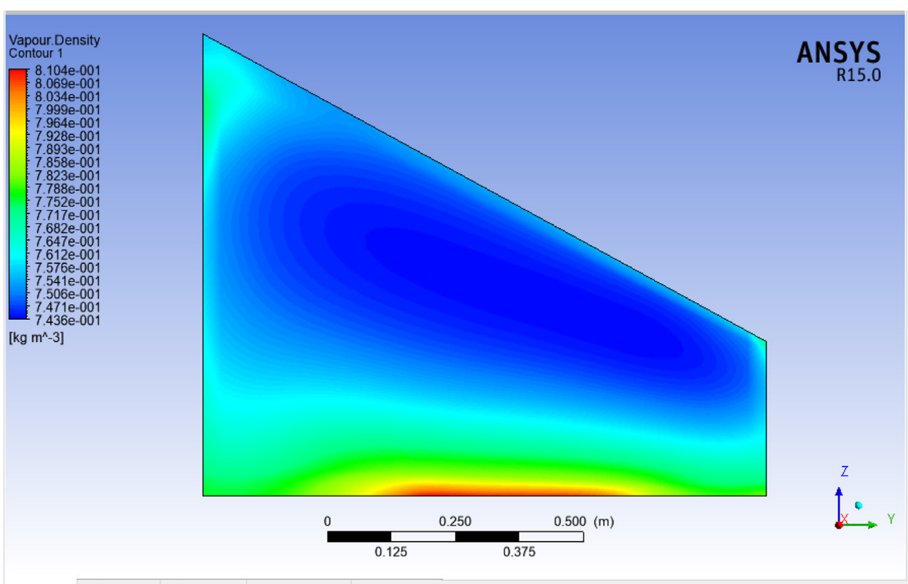

Fig. 7. Contours of vapor density in the solar still.

materials, such as concrete, easily and economically. Micro-encapsulated PCMs also provide a portable heat storage system. By coating a microscopic sized PCM with a protective coating, the particles can be suspended within a continuous phase such as water. This system can be considered phase change slurry (PCS).

5. Result and discussion

Figs. 11–13.

6. Conclusion

From the experimental and numerical analysis of the solar still productivity improvement by using the Phase Changing Materials, Paraffin C18 and Trimethylolethane material, it was capsulaized in the bottom of the basin, the performance analysis of the solar still was compare with PCM materials and without PCM Materials, in this Paraffin C18 material get the high productivity, the same experiment is proved on the numerically also, the numerical analysis done in ANSYS – Fluent Software, Volume fraction of Water results are taken from this analysis Paraffin C18 give the high volume fraction of water so numerically and experimentally the results are conclude with Paraffin C18 material give the high productivity in Solar Still applications.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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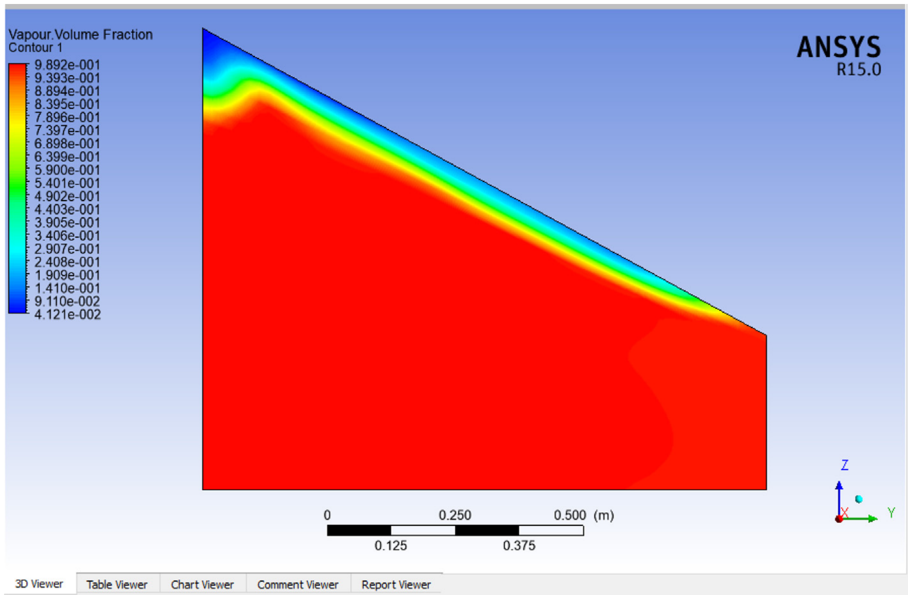

Fig. 8. Contours of vapor volume fraction.

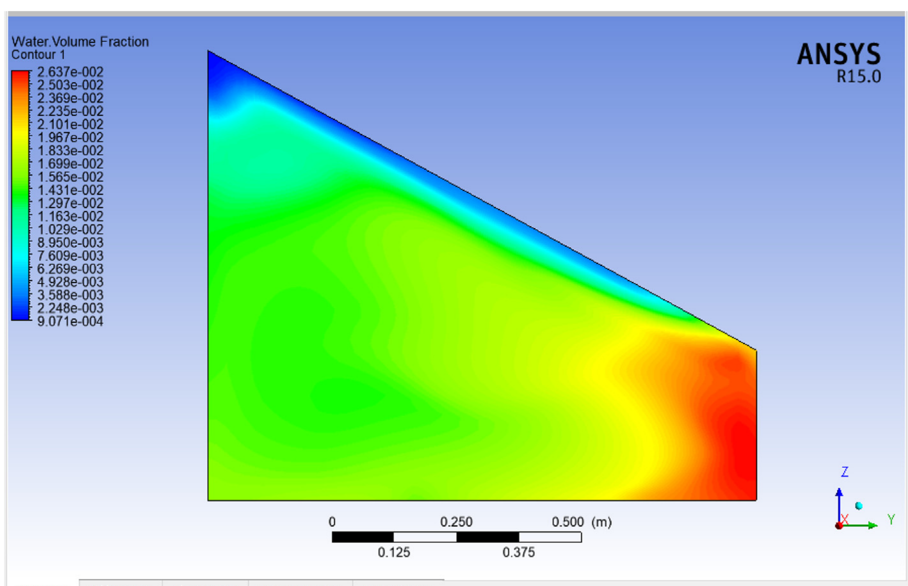

Fig. 9. Contours of water volume fraction in the solar still.

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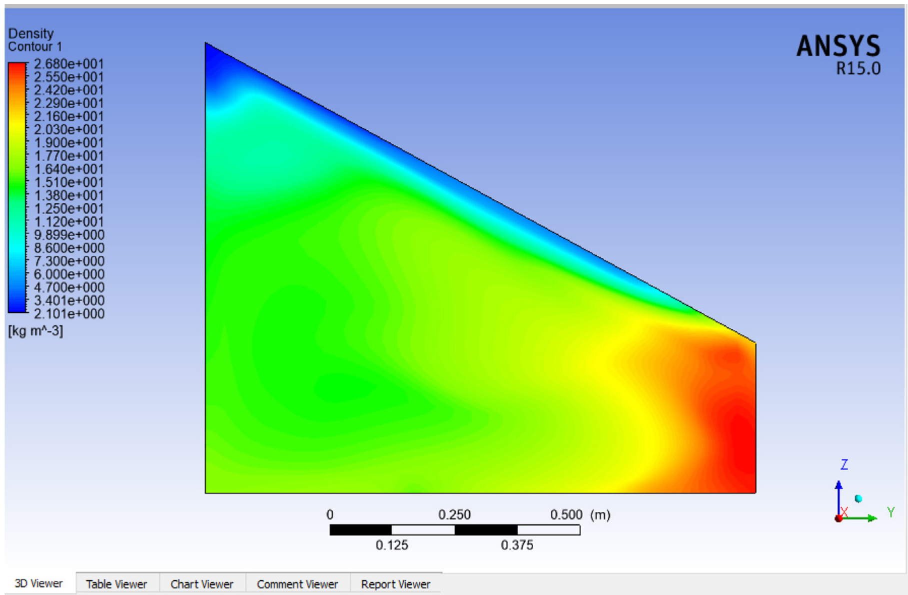

Fig. 10. Contours of density variations in the solar still.

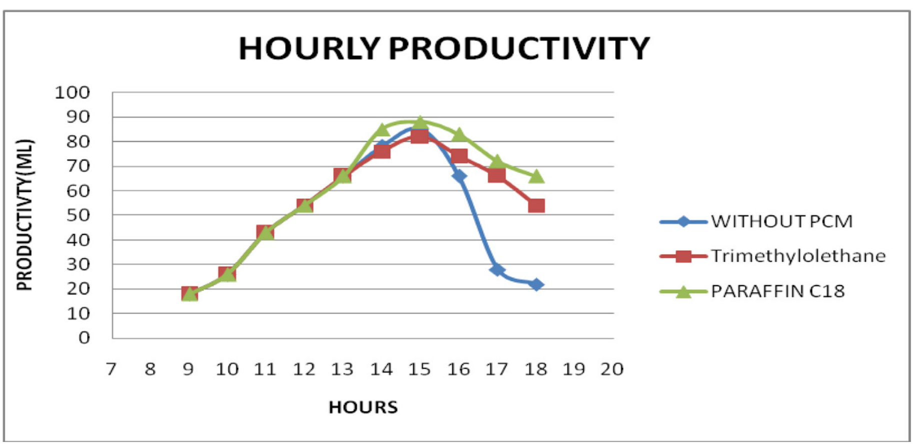

Fig. 11. Productivity (ML) vs hours.

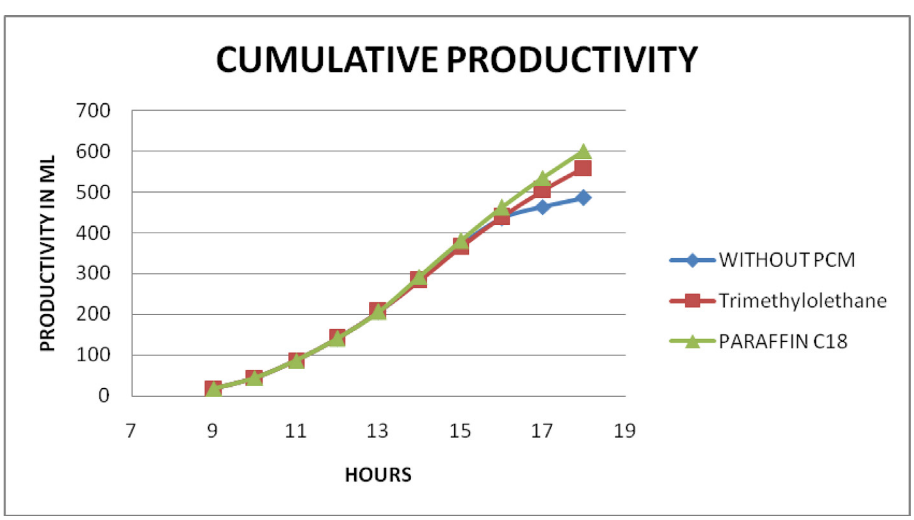

Fig. 12. Productivity in ML vs hours.

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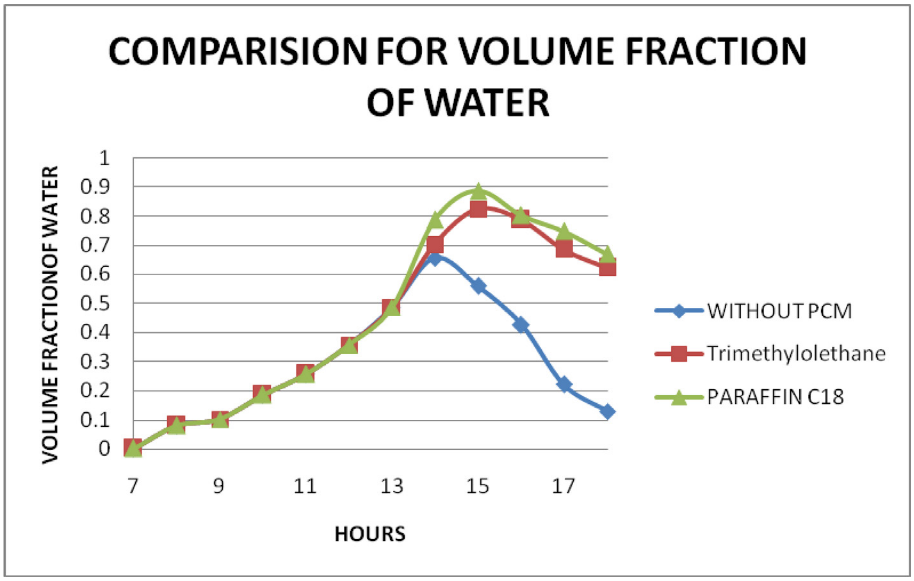

Fig. 13. Volume fraction of water vs hours.

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