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DIFFERENT MATERIAL FOR BUILDING SOLAR STILL AND THEIR IMPACTS ON ITS EFFICIENCY: AN ANALYSIS

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ABSTRACT

Nowadays the potable water available is exhausting due to tremendous usage and also due to the pollution created by human beings. To overcome this state of the problem we are using desalination of water by single slope solar still. In comparison to various impurities removing processes Solar still desalination process is very uncommon as this Solar still provides a cost-effective and efficient means of producing clean and safe drinking water from brackish water. This paper presents a model for creating a single slope solar still with FRP (Fibre reinforced plastic) material and Plaster of Paris as Phase changing material to desalinate the water, also the still is designed optimized with internally reflecting walls to get the maximum efficiency of desalination.

Keywords: Solar Still, Experimental Study, Materials, Energy Efficiency, Desalination, Analysis.

I. INTRODUCTION

Earth is consist of three fourth amount of water as comparing to the total land found. Nowadays, most parts of the world suffer from a lack of potable water. This problem is caused by a number of variables, including global warming, groundwater depletion, and contamination as a result of inadequate water management. As a result, only 2% of the world's accessible water is potable, while the remaining 98 percent is saline. Because human survival is dependent on potable water, and because of rapid population growth and industrial water usage, there has been interest in implementing processes for large-scale production of potable drinking water from saline water, such as reverse osmosis, flash evaporation, distillation, and other methods. However, these procedures take a significant quantity of fossil fuel energy and have a significant environmental impact. As a result, in order to build an appropriate desalination process, it is required to employ technology that is obligated to safeguard the environment while also providing renewability, dependability, and affordability in order to address the problem of water shortage. As we all know, solar energy is a never-ending renewable energy source that may be used without incurring significant costs. As a result, we are employing a single basin solar still for the desalination process, in which brackish water is distillated using solar light at a low cost and with no influence on the environment. Solar stills are simple to build, run, and maintain, making them a viable option for producing distilled water in distant places where technological skills are lacking and expensive materials are unavailable. The single slope solar still ("still"), shown in Fig. 1, is the most widely used system, in which the heat is collecting and the distillation process is taking place in the same basin.

Greenhouse effect is created because of the Solar radiation due to which the water from the basin is evaporated, which in the starting was filled with brackish or otherwise contaminated water. The water which is evaporated is then condenses as droplets on the glass cover, which flow to the bottom of the glass due to the gravity and are collected as distilled water. In the basin, the undesired particulate particles are left behind. The main downside of these stills is their poor conversion efficiency, which means they only generate a little amount of freshwater every day [3]. Several heat transfer-based analytical and numerical studies have been undertaken in the past to enhance performance. Most existing models, on the other hand, disregard the basin's local shadows, resulting in inflated theoretical performance. When the sun is low and far to the east or west, these effects are more noticeable in the morning and evening. The walls deflect solar rays from reaching the still, lowering its instantaneous performance and limiting its total production. In order to improve the effectiveness of the solar still, the absorber plate area has also been adjusted to receive the greatest amount of solar light heat.

II. METHODOLODY

Desalination, also known as **desalting**, is a method of removing salts dissolved in seawater and in some cases salty water called brackish waters of inland seas, groundwater with a high mineral content (e.g., geothermal brines), and municipal wastewaters.

Present desalination techniques need a lot of energy, mostly in the form of fossil fuels, which makes it a pricey process. As a reason, it's frequently used only in circumstances when fresh water isn't available. Desalination plants also emit a lot of greenhouse gases and brine wastewater, both of which are bad for the environment. Sun desalination is an old solar technology that has been used for over 2000 years.albeit they were used to create salt rather than drinking water. Solar stills were first used in the seventeenth century. In 1872, a large-scale solar still was created to provide drinking water to a Chilean mining settlement. 200,000 inflatable plastic stills were created for the US Navy's life-boats during WWII, marking the first time that mass manufacturing happened. The latent heat of vaporisation of water requires 2260 kilojoules per kilogramme (kJ/kg) of energy to evaporate water. This indicates that distilling brackish water takes a heat input of 2260 kJ to create 1 litre (i.e. 1kg, because the density of water is 1kg/liter). This precludes any recovery of latent heat that is rejected when water vapour is condensed, as the efficiency of the system in question will be less than 100%. Although 2260 kJ/kg is necessary to evaporate water, just 0.2 kJ/kg is required to pump a kilogramme of water through a 20m head.

Solar distillation is a very easy treatment for brackish water sources that contain dissolved salts. Water is evaporated in this method, and the vapour condenses as pure water utilising the sun's energy. Salts and other contaminants are removed during this procedure. Solar distillation is used to make water drinkable, as well as distillated water for batteries made of lead acid it also used in labs, and hospitals, as well as commercial items like rose water. To maintain electrolyte balances and for flavour, drinking water should contain 100 to 1000 mg/l of salt. For safe drinking water, some salty water may need to be added to the distilled water.

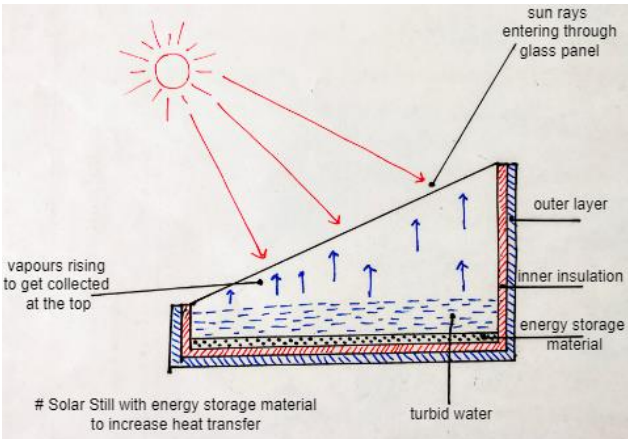

Figure 1: Desalination of water

Solar Still

Solar stills are called stills because they distil, or purify water or in other words Solar still is a simple way of distilling water, using the heat of the Sun to drive.

Evaporate humidity from the soil, and ambient air to cool a condenser film. Basically there are two types of solar still first is box and second is pit stills. In a solar still, impure water like (brackish water, sea water or municipal wastewaters) is contained outside the collector, where it is evaporated by sunlight shining through clear plastic or glass. The pure water droplets are condensed on the cool plastic surface and drips down from the weighted low point, where it is collected and extracted. The box type is more sophisticated. Distillation mimics how nature generates rain, therefore the basic concepts of solar water distillation are simple yet effective. Water is heated to the point of evaporation by the sun's energy. Water vapour rises when the water evaporates, condensing on the glass surface to be collected. By this process impurities Contaminants like salts and heavy metals are removed, as well as microbiological organisms too. The final outcome is water that is purest of rainfall.

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III. WORKING OF SOLAR STILL

Solar still works on the same evaporation and condensation principles as rainwater. Ocean water evaporates, only to cool, condense, and fall back to earth as rain. When water evaporates, only pure water is removed, leaving all contaminants behind. Solar stills imitate this natural occurrence. The top cover of a solar still is made of glass, while the internal surface is composed of a waterproof membrane. To improve absorption of the sun's rays, this inside surface is made of a blackened material. To partially fill the basin, cleaning water is poured into the still. The glass cover allows sun radiation (short-wave) to pass through into the still, which is 10 degrees Fahrenheit. The charred base absorbed the most of it. As the water heats up, so does the moisture content of the air trapped between the water's surface and the glass cover. The base also emits infrared (long-wave) radiation, which is reflected back into the still by the glass cover, trapping the solar energy within the still (the "greenhouse" effect). The vaporised water from the basin evaporates and condenses on the interior of the glass lid. The salts and microorganisms in the original water are left behind throughout this procedure. Condensed water drips from the slanted glass lid into an inner collection trough and then into a storage container. Solar still has no moving components and relies solely on the sun's energy to function. Each morning or evening, the still is filled, and the entire water output for the day is gathered at that time. After the sun sets, the still will continue to generate distillate until the water temperature drops. Each day, feed water that roughly surpasses distillate output should be provided to ensure adequate cleaning of the basin water and the removal of surplus salts left behind during the evaporation process.

Material

Fibre-reinforced plastic (FRP) is a composite material comprised of a polymer matrix reinforced with fibres. It is also known as fiber-reinforced polymer or fiber-reinforced plastic. Most common fibre glass are Glass (in fibreglass), aramid, basalt or carbon (in carbon fibre reinforced polymer), are the most common fibres. Other fibres, such as paper, wood, or asbestos, have been utilised on rare occasions. Although phenol formaldehyde resins are still used, the polymer is commonly an epoxy, vinyl ester, or polyester thermosetting plastic.

FRP are oftenly used in the aerospace, automotive, marine, and construction sectors . Ballistic armour and cylinders for self-contained breathing equipment are common examples.

FRP material have low thermal conductivity due to which it is very suitable material for using as a heat insulation wall for solar still as it will trap the heat inside the solar still and because of this increases the efficiency of solar still in cost effective price.

FRP structural supports and attachments can assist maintain appropriate inside temperatures regardless of the weather by reducing heat transfer.

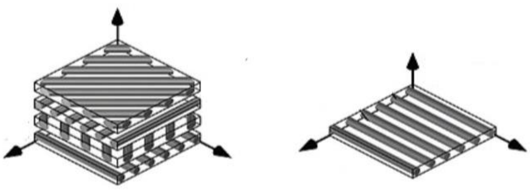

Figure 2: Fibre-reinforced plastic

Glass

we are using clear transparent glass which will help in transmitting the sun light in the inner walls of solar still which in turn will make the water evaporate and on the surface of the glass it will condensate and will be collected in a fresh container.

Glass will also help in creating the green-house effect which will increase the temperature inside of the solar still. we will apply a non-reflective coating on the upper surface of the glass so that the sun rays at the steep angle won't reflect back and goes inside the solar still.

IV. MODELING AND ANALYSIS

PCM

PCMs are phase change materials that are also known as energy storage materials, basically, they absorb energy and change their phase from one to another and store the energy in the form of latent heat. Now, this latent heat is utilized later when needed. In our project, we are using PCMs in order to make the solar still work in situations when there is no sun, the PCMs will store energy during sunlight and release them at sunset, this energy will help in further desalination of water.

Problems with PCMs:

Paraffin

PCMs are great materials, most commonly used PCM in solar stills is Paraffin and the problem with paraffin is that it is a toxic material so it's very harmful if consumed and it sometimes leaks during the phase change process from solid to liquid. So, it should not be the ideal choice when designing a solar still for desalination of water.

Salt Hydrates

Because of their inexpensive cost, high specific heat capacity, high latent heat capacity, and high thermal conductivity, salt hydrates are appealing as PCM. and they have issues as well. The problem with salt hydrates is that during the phase change process they melt non uniformly and won't revert back to its original state. Other issues of using salt hydrates are that they are toxic in nature and can be really harmful for humans.

Fatty Acids

Carboxylic acids with a lengthy hydrocarbon chain are known as fatty acids. These fatty acids have been discovered to be both caustic and combustible. They are twice or thrice as costly as the paraffin wax.

In order to increase the efficiency of our solar still above mentioned PCMs are not the ideal choice So to overcome this problem we are using Plaster of Paris as a PCM material because of its unique properties making a good choice for choosing it.

POP and its uses in Solar Still

POP stands for (Paris of Plaster), which a quick setting gypsum plaster containing of a whiter powder is called calcium sulfate hemihydrate. It gets harden when the moisture is supplied and allowed to dry. The term "plaster of Paris" comes from the fact that it is made from the plentiful gypsum found around Paris. Its chemical formula is ($CaSO_4.H_2O$).

When dried, pop does not shrink or break, making it an ideal medium for casting moulds, precasting, and holding decorative components on ceilings and cornices. It can also be used for medicinal purposes, such as plaster casts to keep damaged bones immobilized until they recover.

Pop properties

- Generally it is white in color and available in powdered form.
- When water is added, gypsum crystals develop, leading to the formation of a solid state.
- At 473 Kelvin, plaster of Paris produces anhydrous calcium sulphate. The dead charred Plaster of Paris is another name for it.
- It is non-reactive in nature
- It is non-corrosive to other metals
- It is non-flammable and non-combustible

Another important property of Plaster of Paris is that it is a energy storing material, which stores energy in the form of heat based on the temperature it is exposed to. So, in this paper we are using plaster of Paris as an ESM material in order to improve the efficiency of our Solar Still. We will be making the bottom of our water container from plaster of Paris where the brackish water will be storing and when the sun rays enters from the glass of solar still to evaporate water for desalination process, Our POP container will absorb some amount of solar energy and once the sunlight heat will get reduced and outside temperature becomes lower than that of plaster of Paris our container will release its energy stored in the form of heat, so by this we can some-how use our solar still in the evening and even at night too.

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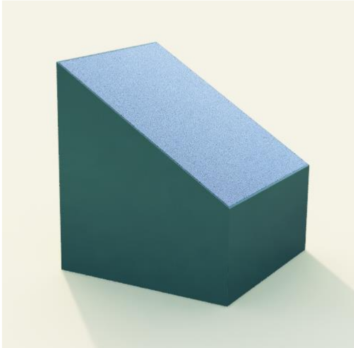

Figure 3: 3D Model of Solar Still with walls

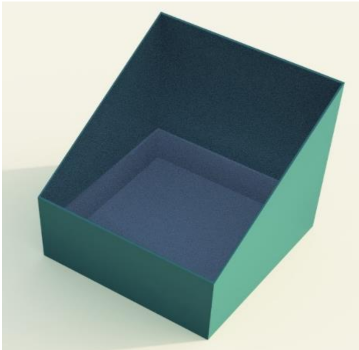

Figure 4: 3D Model of Solar Still inner-walls

V. RESULTS AND DISCUSSION

We compared the solar stills with and without the layer of plaster of Paris at the bottom of the container and the results are presented below in the form of temperature diagrams. We did all the analysis and testing on a computer using Ansys software. We performed the CFD analysis of both the solar stills in the software made the diagrams and compared them with each other to get an idea of how much a layer of plaster of Paris is affecting the efficiency of our solar still design. There are a few assumptions made for the sake of this comparison and the parameters set for these are mentioned below.

We have used FRP sheet on the exterior wall, as it is used as the holding material for everything its participation in the process of heat transfer is set to be 0. In the non POP version we have used wood on the bottom layer and its thickness is set to be 0.001 m and in the plaster of Paris version the thickness of the pop layer used is set to be 0.001 m. The heat flux for plaster of Paris is negligible so, its set to be 1 KW/m^2 and heat flux for the wood is set to be 3 KW/m^2 . As the top of the solar still we have used glass as it is transparent and allows sunlight to enter through it and traps the heat inside, the density of the glass used is set to be 2500 kg/m^3 , its thermal conductivity is set to be 750 and specific heat is 1.15 J/K-Kg.

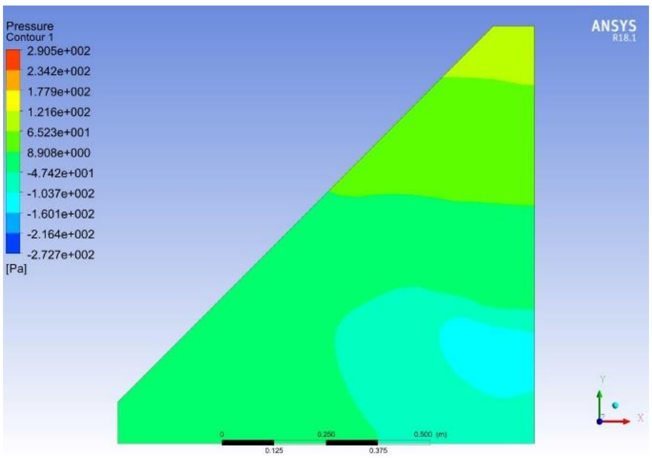

Figure 5: Contour of Non-POP Pressure Chart

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The diagram on the top is the pressure chart for pop version and the chart on the bottom is the on the pop layer at the base.

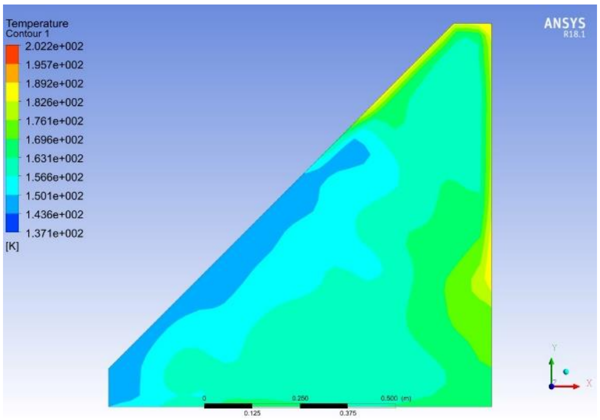

Figure 6: Contour of Non-POP Temperature Chart

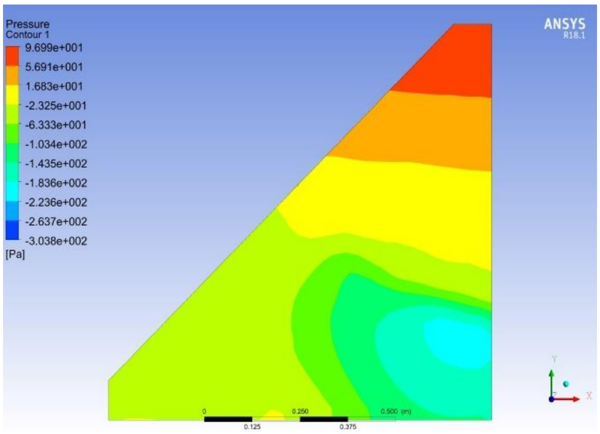

Figure 7: Contour of POP Pressure Chart

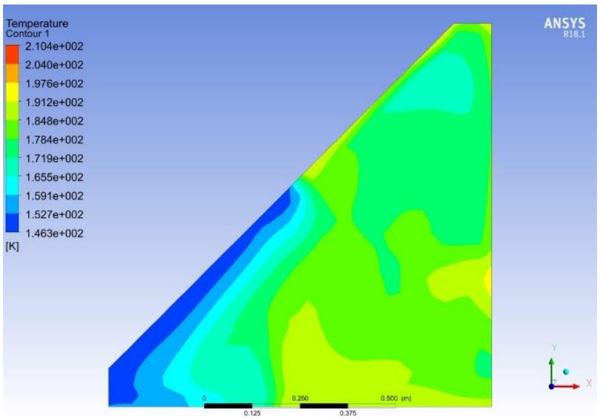

Figure 8: Contour of POP Temperature Chart

The diagram on the top has a wooden layer at the base of the still and the diagram at the bottom have a plaster of Paris layer at the base of the solar still. As it clearly visible that there is significant change in the temperature just by using a plaster of Paris layer at the bottom of the base of thickness 0.001 m. The part with more yellow colors has higher temperature as compared to the parts having more blue color.

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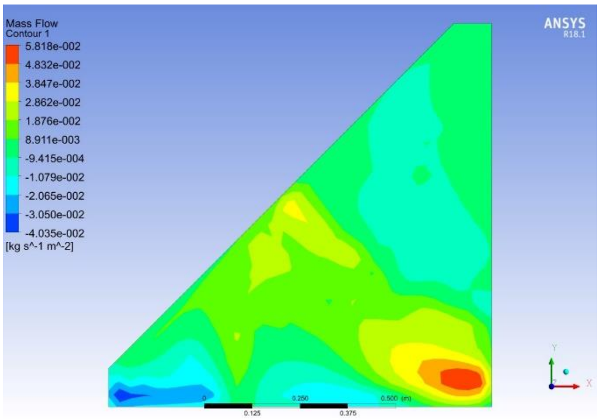

Figure 9: Contour of Non-POP Mass flow rate Chart

This is the mass flow rate of the solar still where wood is used in the base layer.

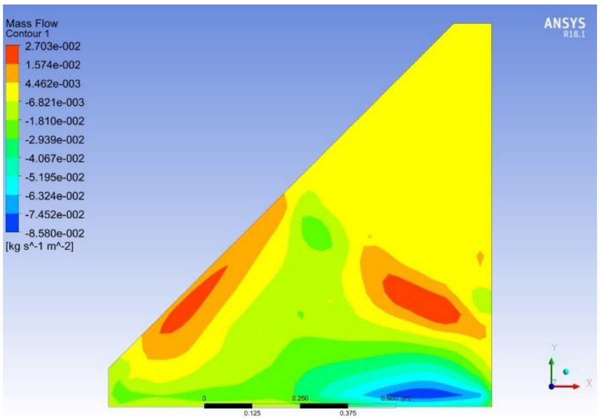

Figure 10: Contour of POP Mass flow rate Chart

This is the mass flow rate of the solar still in which pop is used in the base layer, as you can clearly see from both the comparisons the mass flow rate is significantly higher than the1st diagram.

VI. CONCLUSION

In this study, A water desalination system works on solar energy was designed Keeping in mind the economy of system using with different materials in order to improve the efficiency of solar still.

Some important conclusions can be drawn as follows:

1. To overcome the problem of lacking of portable water, desalination process using solar still is used as sunlight is a renewable source of energy and freely available with no cost as well as solar still is environment friendly and also economic in cost.
2. To make the body of solar still FRP (Fiber reinforced polymer) material is used because of its lightweight and durability also its thermal conductivity is very low, which makes this material a perfect choice for using it as a heat insulating wall of solar still. It will help to trap the solar heat inside the solar heat and therefore it increases the efficiency of solar still.
3. PCMs are the phase changing materials which stores the energy in the form of latent heat and can release it whenever needed but commonly used paraffin are toxic in nature and if get leaked can be hazardous so to overcome this problem we are using Plaster of Paris which is also a Phase changing material and stores the solar energy when incident on it and can release the energy in the form of latent heat during the sunset period and even in night and this improves the efficiency by increasing the output desalinated water.
4. Plaster of Paris can be used as a good alternative to the other energy storage materials as it is non-toxic, non-corrosive and non-flammable in nature and plays a significant role of trapping the heat inside the solar still to evaporate and clean more water at a time and increase the efficiency of the solar still.
5. Solar still in which plaster of Paris is used as a layer of insulation will yield higher efficiency as compared to the other solar stills without this layer of insulation. Also, its better to use POP than using other toxic phase

change materials like paraffins and salt hydrates. POP is a good energy storage material to be used in solar stills.

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