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Performance of Solar Still with Different Phase Change Materials

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Abstract: Water is basic necessity of man. Fresh water sources are considered to be rivers, lakes and underground water reservoirs. Although, more than two-third of the earth is covered with water and remaining of the earth is land. However, the use of water from such sources is always not good, because of the polluted environment. All over the world, accessing of portable water to the people is narrowing and decreased day by day. Most of the human diseases are due to polluted or un-purified water. Nowadays, each and every country facing a problem of huge water scarcity because of pollution created by manmade activities. Under these circumstances, search for other sources becomes a must. A system is needed which supplies pure water without effecting the ecosystem and environment friendly. Adequate quality and reliability of drinking water supply is a fundamental need of all people on the earth. Fresh water, which was obtained from rivers, lakes and ponds, is becoming scarce because of industrialization and population explosion. The sun is regarded as the source of energy for its constant duration and hygienic state and its remarkable efficiency of not polluting the environment, as other kinds of energy like coal, oil that cause the pollution of atmosphere and environment. Water purification using solar energy has become more popular because it is eco-friendly and cost effective. A solar still is commonly used device for water purification and it doesn't require any electricity for distillation of water. A variety of solar distillation devices have been developed with different materials and in different shapes in different location to improve the efficiency of solar distillation. This article communicate about the distillation of solar still by using different methods in different areas to improve the efficiency of the solar still.

Keywords: Renewable Energy, Water, Solar Energy, Phase Change Materials, Energy Storage Materials

1. Introduction

Energy is an essential factor for the social and economic development of the societies. Renewable energy is accepted as a key source for the future on this earth. The combined effects of the deflection of fossil fuels and the gradually emerging consciousness about environmental degradation have given the first priority to the use of renewable alternative energy resources in the 21st century. All of renewable, solar thermal energy is considered to be practically unlimited in the long term and is a very abundant resource in the world. Many conventional and non-unconventional techniques have been developed for purification of saline water. Among these water purification systems, solar distillation proves to be economical and eco-friendly technique.

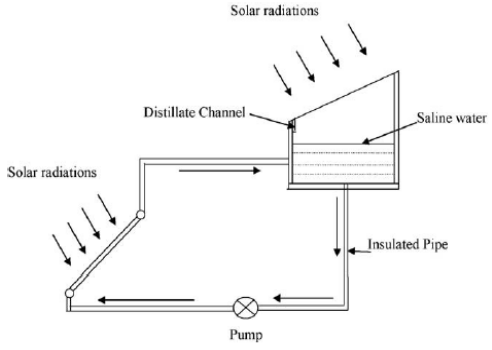

Fig. 1. *Active type solar still.*

There are two different types of solar systems; those are active type and passive type. The parameters which are

affecting the solar still are; water depth in the basin, material of the basin, wind velocity, solar radiation, inclination angle of glass cover and ambient temperature. The yield of water from the solar still is depend on the temperature difference between the water in the solar still or basin and glass cover inner side temperature. The yield from solar still is directly proportional to the temperature difference of water in solar still and in side of the glass cover.

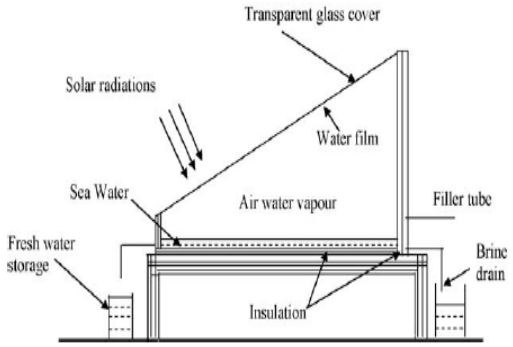

Fig. 2. *Passive type solar still.*

In a passive solar still, the solar radiation is received directly by the basin or solar still water and is only source of energy for raising the water temperature, so the evaporation leading to a lower productivity of pure water. In active type solar system extra thermal energy is supplied to the basin through an external mode to increase the evaporation rate and productivity of pure water. Passive solar systems give lower yield when comparing with active solar systems.

Among the non conventional methods to disinfect the polluted water, the most prominent method is solar distillation. The solar distillation method is more attractive than other methods. This method require simple technology as no skilled workers needed, low maintenance and it can be used anywhere without problems. The work done by previous researchers in obtaining distilled water using solar energy is listed below:

1.1. Literature Review

Al Hamadani A.A.F and Shukla S.K (2011) conducted experimental investigations on a solar still with lauric acid as phase change material (PCM). They found that the higher mass of PCM with lower mass of water in solar still basin increases the daily productivity and the efficiency. The distillate productivity at night and on day for solar still without PCM 30% to 35% and with PCM increased by 127%.

El Sebaii A.A (2009) et al, studied the still performance with and without the stearic acid as PCM by computer simulation on summer and winter days. He concluded as after sunset, the stearic acid (PCM) as a heat source for the basin water until sun rise in the early morning hours of the next day. The PCM becomes more effective at lower masses of basin water during the winter. On a summer day, the daily productivity of the still is higher with PCM.

Mona M Naim and Mervat A Abd El Kawi (2002) had constructed a single stage solar still that made use of phase change energy storage mixer. They found that the use of an energy storage material led to a larger productivity of distilled water and that the larger the concentration of the saline water, lower the productivity. Also higher flow rate and high inlet saline water temperature improved the still efficiency.

Nijmeh S, Odeh S and Akash B (2005), experimentally studied a single basin solar still using various absorbing materials like violet dye, charcoal, potassium permanganate ($KMnO_4$) and potassium dichromate ($K_2Cr_2O_7$). The best result obtained by violet dye i.e. 29%.

Swetha K and Venugopal J (2011), experimentally studied on a single slope single basin solar still by adding a heat reservoir under the liner of the basin using Lauric Acid as a phase change material. They observed that 13% increment when the still is used with sand as heat reservoir and 36% increment when the still is used with Lauric Acid as PCM.

From the literature review it is observed that, experimental investigations were conducted on solar distillation by previous researchers using energy absorbing materials like gravels, sponge, charcoal etc. But the investigations using phase change materials are less. The advantage of using phase change materials is, they are better in energy absorbing as well as release of energy. The energy absorbed by PCM during day time is reduced after sunset, to maintain constant temperature of water in solar still. This helps in increasing the productivity of solar still. Hence, present experimental investigations are conducted using PCMs sodium sulphate (Na_2SO_4), sodium acetate ($C_2H_3NaO_2$) and potassium permanganate (KMO_4) used.

1.2. Experimental Work

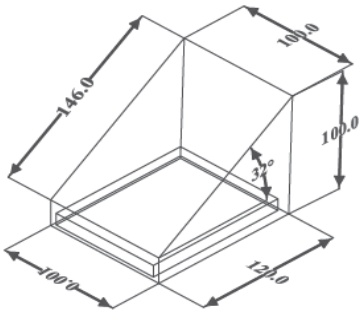

Fig. 3. *Single slope solar still.*

Figure 3 presents a schematic diagram of the solar still used in the present experimental study. It consists of a stainless steel basin which has an effective area of $1m^2$. This solar still is made of stainless steel with all dimensions in cm as shown in figure 3. The stainless steel sheet has a thickness of 0.8mm. It consists of a top cover of transparent glass with a tilt of 32^0 and is coated with black paint to absorb the maximum possible solar energy. This solar still faces south direction. The entire assembly is made air tight with the help of rubber gasket and clamps. Water enters the basin through an inlet valve.

To maintain constant water level of 8 cm, a floater is arranged inside the solar still. The distilled water is condensed on the inner surface of glass cover and runs along its lower edge. The distillate was collected in a bottle and measured by a graduated cylinder. Thermocouples were located at different places of the solar still to measure temperatures such as outside glass cover, inside glass cover, basin water temperature, vapor temperature and ambient temperature. In this experiment, potassium dichromate ($K_2Cr_2O_7$), sodium acetate (CH_3COONa) and Potassium Dichromate (KMO_4) are used as phase change materials. To enhance the performance of solar still, all the experimental works conducted in the month of February in Hyderabad, India.

1.3. Principle of Solar Desalination

A basin of solar still has a thin layer of water, a transparent glass cover that covers the basin and channel for collecting the distillate water from solar still. The glass transmits the sun rays through it and saline water in the basin or solar still is heated by solar radiation which passes through the glass cover and absorbed by the bottom of the solar still. In a solar still, the temperature difference between the water and glass cover is the driving force of the pure water yield. It influences the rate of evaporation from the surface of the water within the basin flowing towards condensing cover. Vapour flows upwards from the hot water and condense. This condensate water is collected through a channel.

1.4. Measuring Instruments

Pyranometer, Multimeter, Glass beaker, Pt-100 type thermocouples and infrared thermometer. Pyranometer is used to measure the direct solar radiation and diffused radiation. Glass beaker is used to measure the distillate water from the solar still. Pt-100 type thermocouples are used to measure the temperature of water which is in the basin or solar still, inclined glass cover inside and outside temperatures. Infrared thermometer is used for measuring the atmospheric temperature.

1.5. Results and Discussion

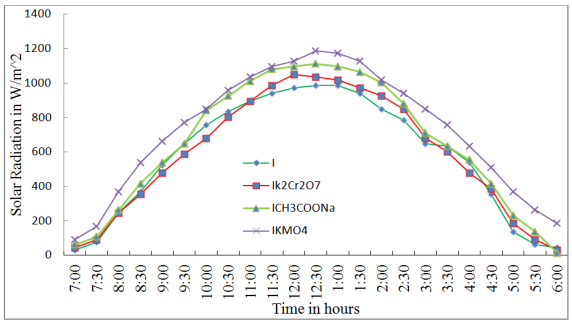

Fig. 4. *Variation Solar Radiation with Time.*

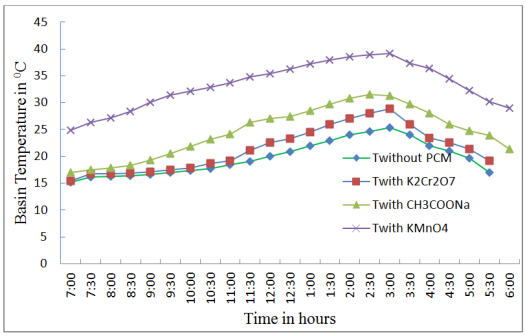

Fig. 5. *Variation of Basin Temperature with Time.*

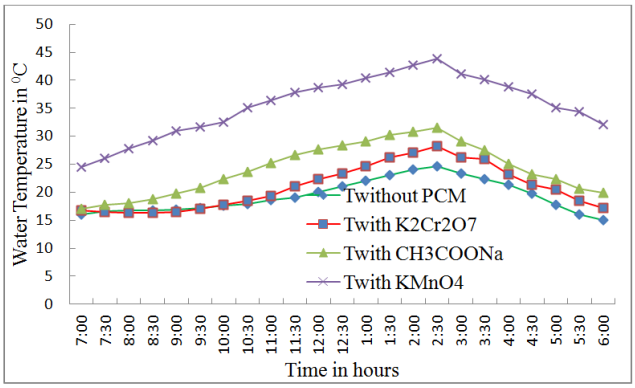

Fig. 6. *Variation Water Temperature with Time.*

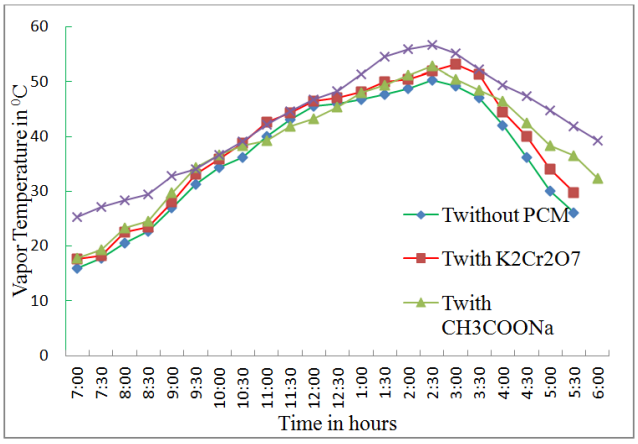

Fig. 7. *Variation of Vapour Temperature with Time.*

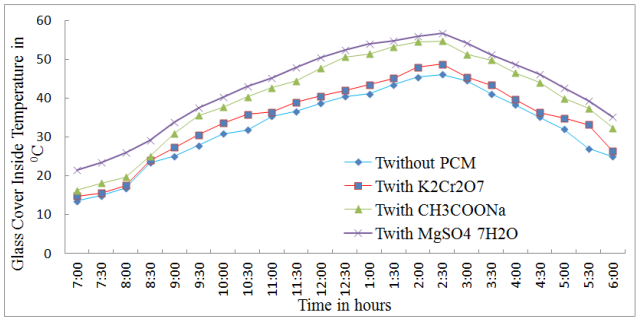

Fig. 8. *Variation of Glass Cover inside Temperature with Time.*

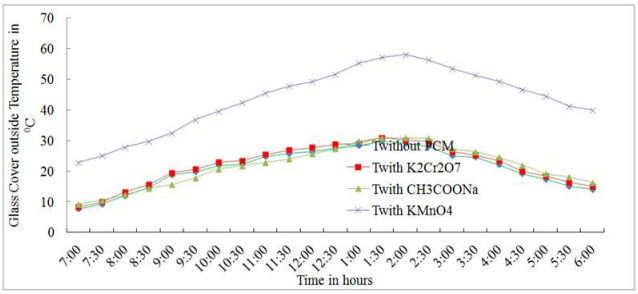

Fig. 9. *Variation of Glass Cover outside Temperature with Time.*

2. Conclusions

Energy and water are the basic necessity for all of us to lead a normal life on this beautiful earth. Solar energy technologies and its usage are very important and useful for the developing and under developed countries to sustain their energy needs. The use of solar energy in distillation process is one of the best applications of renewable energy. The solar stills are user friendly to the human being in the nature.

The present study focuses on the design and fabrication of efficient solar distillation system. It is more economical, therefore, to store water rather than store energy. It is beneficial in the cases of unavailability of electrical energy / fuel energy. Producing fresh water by a solar still with its simplicity would be one of the best solutions to supply fresh water with no technical facilities.

In this present experimental study, presence of Potassium Permanganate (KMO_4) in water could provide better yield when compared to that of Sodium acetate ($C_2H_3NaO_2$) and Potassium Dichromate ($K_2Cr_2O_7$) used as Phase Change Material. This may be due to the melting point temperature of Potassium Permanganate (KMO_4) is 240^0C, Sodium Accetate (324^0C) is higher than that of sodium acetate (324^0C). This experimental work conducted with Potassium Dichromate ($K_2Cr_2O_7$), Sodium Acetate ($C_2H_3NaO_2$) conducted in winter season and with Potassium Permanganate (KMO_4) was conducted in summer season. So, in summer temperature is more and more comparing with winter.

It has been demonstrated that the productivity of a solar still can be greatly enhanced by the use of phase chance materials. Future work should be directed towards preheating the saline water, preheating the saline water at different temperatures, solar still with flat plate collectors and solar still with flat plate collector using different phase change materials.

From the literature review, it is observed that, previous researchers conducted experimental investigations on obtaining distilled water with the help of solar energy in the presence of flat plate collectors, Phase Change Materials (PCM), mirrors, dyes, reflectors, cooling systems etc. But the work using combination of sun tracking system (single axis or double axis) coupled with PCM, dyes, sponges and nano-materials are limited. Hence, there is a scope to conduct experimental investigations on this topic.

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