Solar Still Performance Enhancement using PCM & Nanoparticles

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ABSTRACT: *Safe drinking water has become a sacred resource with the increases in population and degree of industrialization. Due to both the water available has lost its quality and have become very unsafe to drink. Solar distillation offer a cheap remedy to purify brackish water. Solar distillation works on the similar principle as the water cycle and helps to remove dissolved salts and impurities from the water. Though it is a cheap and convenient method, its two major drawbacks are low productivity and being non-functional in the absence of sun. To deal with the stated problem a study has been carried out to enhance solar still working using nanoparticle and PCM. The yield obtain with conventional solar still is 4.6 l/m² .The yield obtain with solar still incorporated with PCM and nanoparticles is 5.2 l/m.²*

1. INTRODUCTION

According to WHO 785 million people do not have access to safe drinking water. It is estimated that around 2025 8 billion people will face water scarcity with 2/3 population of the world will have to live in water stressed areas. Scarcity of water is the situation where people don't get sufficient safe water to meet basic daily requirements. It include water stress, water shortage and water crisis. In water crisis a region do not have sufficient unpolluted portable water to meet its demand. Contaminated water is the source of diseases like diarrhea, dysentery, polio, cholera etc. providing people with safe/uncontaminated water is very essential for sustaining human life especially in the developing country such as India. It is estimated that liberty of safe drinking water can reduce 9% of global disease problem and reduce deaths by 6.4%.

India though have made considerable improvement in making available safe drinking water, its large population has put a massive stress in water resource planning and rural area are generally neglected. As 21.2% of diseases in the country are water born it has become necessary to provide safe water to the people at a low capital cost.

Solar still provide a cheap method for the purification of water especially ground water containing soil, humus etc. Though convenient its daily yield is low. Many research has been carried out to increase its productivity. Anil Yadav and Anshul Yadav [1] conducted an experiment on single flat plate collector and studied effect of fluctuation of solar radiation, absorber plate temperature etc. and found out the efficiency of the collector to be 72.7% and effective loss of heat coefficient to be 36.73%. Anil Kumar and P. Vishwanath [2] studied different solar still and presented the result that double sloped solar still with solar collector give doubled the yield than passive double sloped still. Srivastava and Agrawal[3] revealed that cost of production for high performance plat is Rs 5.07 whereas cost of production of conventional solar still plant is Rs 7.9 Shanmugan and Palani [4]conducted the study by incorporating PCM and miscellaneous basin absorbing material and founded that the yield with wick material is 7.460 kg/m²day. Gnanadason and Kumar[5] used vacuum basin with multiwall carbon nanotube and concluded that the vacuum inside basin increased evaporation rate and improves the productivity by 40% and nanotube improve the efficiency by 50% by rising water temperature and hence average output was found to be 4L/m²day and 150% overall increased efficiency compared to conventional still. Sahota and Tiwari [6] used 0.12% concentration of Al_2O_3 nanoparticle with 35 kg and 80 kg of base fluid and found the enhancement to be 12.2% and 8.4% respectively. Kabeel and Omara [7] added cuprous oxide nanoparticles in black paint with the weight concentration of 10% and 40% and concluded 16% and 25% increased distillation respectively. Tiwari and Bihari [8] founded that the coliform bacteria in water when treated with ultrasonic irradiation for short period of time before low concentration treatment with Ag nanoparticles, enhanced antibacterial properties. Sebaii and Ghamdi [9] conducted numerical analysis using steric acid as a pcm beneath the basin with thickness of 3.3cm increased heat transfer coefficient by 27% with productivity of 9.005 kg/m²day compared to 5 kg/m²day with conventional solar still. Dasthan and Tabrizi [10] used 18 kg of paraffin wax (PCM) material beneath absorber plate with thickness of 2cm which resulted in 81% increase in productivity compared to that wit PCM. Kabeel and Abdelgaied [11] coupled hot air injection with modified PCM based solar still and recorded the yield to be 9.36 L/m². Ashik and Zari [12] concluded that the latent heat storage material increases the water output but decreases exergy efficiency of the still.

1.1 Solar still:

Solarstill is a simple device which work on the principle similar to water cycle of the earth. In water cycle the water is evaporated from water bodies and surface of the earth,

water vapors rises up where its temperature decreases and they start condensing forming clouds, the cloud precipitates in the form of rain and replenish the water bodies.

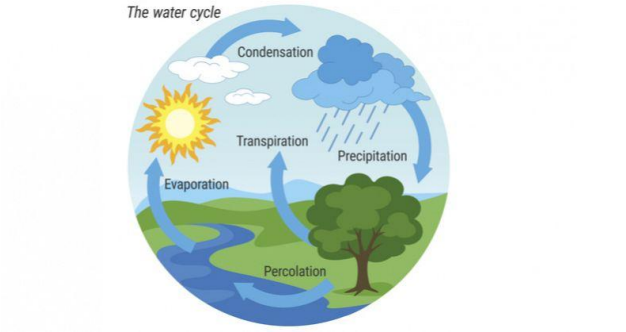

Fig 1: water cycle [15]

Similarly in solar distillation process, the basin water get heated up by absorbing heat from the sun through glass. The water vapor rises and get condensed on the glass surface leaving all the impurities behind. As the glass covering the basin is tilled at an angle, the condensed water droplets slid down the glass and get collected in the container through a U shape connector connecting the end of glass cover and container.

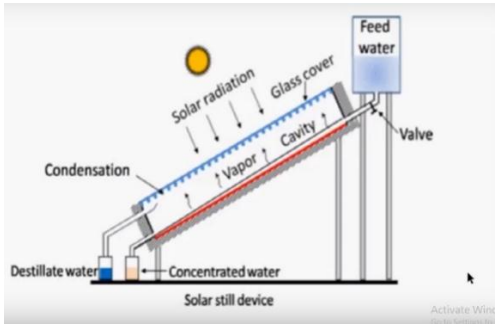

Fig 2: conventional solar still [14]

Few factors affecting solar still performance:

1. Solar insolation: It is the amount of solar radiation rays which strike the surface of the glass. The output generated by the solar still depends directly on the intensity of solar radiation as higher the intensity of radiation higher will be the temperature inside the basin and higher will be the rate of evaporation.
2. Speed of wind: wind speed does not have any direct contribution to the yield of solar still. But it helps to lower the temperature of glass cover which improves condensation of water vapors. Therefore high wind speed in desirable.
3. Ambient temperature: it is established by hinai [13] that with 10°C increase of ambient temperature productivity is increased by almost 8%.
4. Water level of basin: lower the water level higher is the yield of solar still.
5. Inclination of glass cover: inclination of glass cover is decided by the latitude of the location. As the latitude of India is 28.86◦N tilt angle of 15◦ provide best performance [14].

As wind speed, solar irradiation and ambient temperature cannot be controlled, main focus to improve output is given to design parameter such as type of solar still, water depth and glass tilt etc.

Other applications of solar still:

1. Application of Solar Stills for the Alcohol Distillation.
2. Application of Solar Stills for Wastewater Treatment.
3. Application of Chilton-Colburn Analogy.

1.2 Phase Change Material:

A Phase Change Material (PCM) is a material which have extreme fusion of heat, liquefying & solidifying at a particular temperature, is able to absorb and liberate high quantity of heat without noticeable change in the phase of the material.

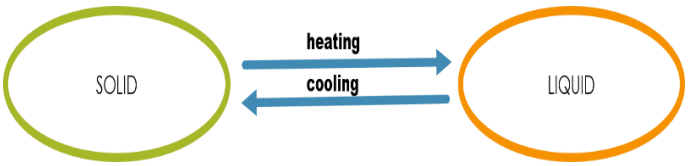

Fig3: Latent heat transfer process

Latent heat absorption and liberation due to phase change from solid to liquid and vice versa is profitable compared to sensible heat absorbing method as the phase change is almost isothermal which acts as interim and almost infinite thermal capacitor, reducing increase in temperature with minimum change in volume of the material. The high transfer of heat throughout the liquefying process and the solidification process, both taking place without causing noticeable variation in temperature, is the reason why PCM is being given serious consideration as source of heat storage. Phase change material offers a more advantageous solution for energy storage system. The usage of some infrastructure for heat transfer, PCMs is a more efficient means of heat storage. Phase change material have generated very significant interest in recent years due to their potential for data storage, heat storage, cooling effect etc.

PCMs are generally of two types

1. Organic
2. Inorganic.

Organic PCMs are further divided into paraffin and non-paraffin. Organic PCMs melt and crystallize repeatedly without phase separation and non-corrosiveness. Paraffin wax composed of straight chain alkenes such as CH3–$(CH2)_n$–CH3. Solidification of alkene chain releases a great quantity of latent heat. Latent heat of fusion increases with increase in length of chain of material. Technical grade paraffin's are employed as PCMs in latent heat storing devices because of cost consideration. It is good in their chemical properties and lags in their thermal property.

Phase change material is being used in the following applications:-

- House heating, warm water.
- Construction materials.
- Catering.
- Electronics.
- Green houses.
- Temperature Peak Stabilization

1.3 Nano particles:

Nano-particles as the name suggest is a particle having dimensions up to 100nm.

Nowadays nanoparticles are has given a new direction to modern science by providing the link between macroscopic material and microscopic atoms or molecule. Advancement toward nanoparticles study has been set in motion due to the improved in technology which allow research at microscopic level. Nanoparticle has been making maximum contribution in material science technology. Study of nanoparticles has also opened new ways to fabricate material by making desirable changes at their most fundamental yet stable structure. Some of such improvement include elasticity, strength, resilience and anti-creep properties. Nanoparticles has also played significant role in biomedical where it is used to diagnose and cure diseases such cancer. Nanoparticles are also famous for their antibacterial properties in which the most effective is silver.

Nanoparticles show different properties then either their bulk. Few of the reason for his is high aspect ratio, freer electron and more brownian movement of the nanoparticles. Also when the size of a particle come close to de Broglie wavelength of charge carrier the periodic boundary condition of the particle structure are destroyed and atomic density is changed. When the wavelength of particle come to that of light, quantum mechanics helps to understand its behavior. Schrodinger equation solution gives the physical state of the system. The time-dependent one-dimensional Schrödinger equation is given by

$$i\hbar\frac{\partial\Psi}{\partial t} = -\frac{\hbar^2}{2m}\frac{\partial^2\Psi}{\partial x^2} + V(x)\Psi(x,t) \equiv \tilde{H}\Psi(x,t),$$

Nano particles shows extraordinary thermal properties and hence has been employed to improve the properties of heat related devices such as solar heater, heat exchanger etc. stability and mutual interaction of nanoparticle with fluid plays a significant role in application of nanofluids.

Here nanoparticles are used to increases solar radiation absorption and also to increase the surface area of water to aid in evaporation process.

2. EXPERIMENTAL SETUP

A conventional solar still consist of basic three element which are:

1. Basin in which water is supplied. The removed impurities are also collected at the bottom of the basin.
2. Glass cover through which solar radiation are transmitted to water. It is tilted at an angle to admit maximum solar radiation according to the latitude of the place
3. Collection tank is connected at the lower end of the glass cover in which pure water is collected.

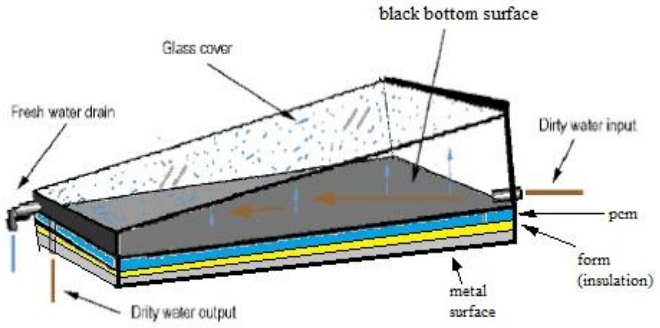

Fig 4: proposed design

The size of the basin is selected to be 30×24 inch. The glass cover is set at an angle of 20◦ as the latitude of the Gwalior is 26.21◦N.

The bottom layer of the basin is divide into four layer. The bottom most layer is of wood which support the weight of the solar still. The layer above it is of foam with thickness 1cm to provide insulation. The second layer from the top is of phase change material which is selected to be paraffin wax with melting point of 37°C as the average temperature of Gwalior in the month of April to May is about 38°C. The top most layer is of metal which is in contact with water. Basin surface is black painted to increase surface

absorptivity. The wall of the basin is painted white to reflect the incoming solar radiation to the water surface.

The water is manually mixed with nanoparticle Al_2O_3 and supplied into the basin with the inlet valve provide at the bottom. A slug removal valve is also provided at the bottom to remove the impurities left behind

Properties of PCM and nanoparticles are as follow:-

Chemical formula:	C_nH_{2n+2}
Melting point	37 °C
Density:	0.9 g/m^3

Table 1: properties of PCM

Chemical formula	Al_2O_3
Density	3.9 g/cm^3
Melting point	2040°C
Thermal conductivity	0.7 W/m-C at 0.12% of concentration.

Table 2: properties of nanoparticles [20]

We know that

Mass = Density ×volume

Volume = length × breath × thickness = 76.2 × 60.96 ×0.2= 929.0304cm^3

Therefore,

Mass = 238.2g

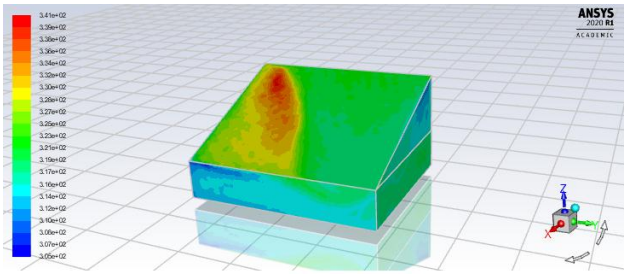

Fig 5: CFD contour analysis of PCM based solarstill

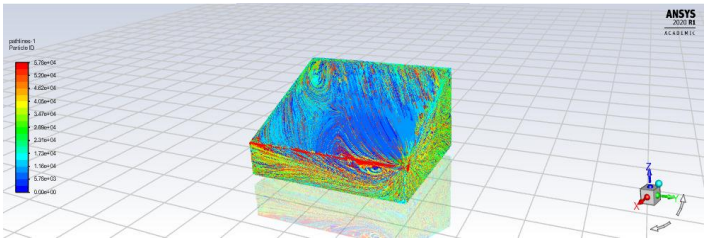

Fig 6: CFD pathlines analysis of PCM based solar still

3. RESULT AND DISCUSSION:

The daily yield is found to be 5.2 L/m^2. The CFD analysis of PCM based solar still gives the minimum temperature of 302.89 k and maximum temperature of 336.35 k. The mass of the PCM used for the thickness of 2cm is calculated to be 238.2g.

4. CONCLUSION

With the incorporation of PCM and nanoparticles the yield is observed to be increased by 17.74%. It is observed that due to the presence of PCM the yield per hour has been decreased but it is well compensated as the time period of working of solar still has also increased. The PCM based solar still is found best suited for winter season or when the irradiation of sun are comparatively less.

5. ACKNOWLEGMENT

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