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# Improving the yield of fresh water in conventional solar still using low cost energy storage material

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ABSTRACT

As there is a larger need for drinking water, expensive methodologies are employed in order to get portable drinking water. This work aims at improving the yield of freshwater from a conventional solar still using the different low-cost energy storage material. Theoretical and experimental studies are carried out to analyze the performance of a single slope solar still. From this study, it is observed that the yield of freshwater from the solar still with spherical ball salt storage achieves the maximum yield of 3.7 kg/m$^2$ as compared to a conventional single slope solar still with sponge and without any storage material as 2.7 and 2.2 kg/m$^2$ respectively. The deviations between theoretical and experimental values for with spherical ball salt storage, with sponge and conventional solar still are found as 16.1%, 9.7% and 4.0% respectively. Payback period of the present solar still is found as 4.3 months as it is quicker than other conventional single slope solar still. Finally, single slope solar still with spherical ball heat storage gives low cost of water.

## 1. Introduction

In earlier centuries, the possible method of getting safer portable water was by using a conventional boiler to heat the water to saturation limit and condensing the steam or vapor to freshwater. Desalination in membrane process is converting waste or salt water into useful one, by pumping the input water which consumes 20% of electrical energy. Furthermore, pretreatment of saline water is required in order to avoid fouling effect on the membrane surface.

Solar desalination appears to be the easiest and cheapest method of producing potable water. During the 19th century, basin type solar stills were designed and fabricated to get freshwater from saline water using solar energy. Many review papers have addressed only on the prospective design configuration. Basin type solar still is one of the breakthroughs of the 20th century, as many researchers carried out experiments to augment the freshwater yield. For augmentation purpose, many used integrating methodologies such as flat plate collector, parabolic trough collector techniques which are unaffordable from the economic aspect for people living in the rural areas. During the 21st century, change in geometry of solar still appeared to be important phenomenon on improving the yield [1–11].

Storing energy is one of the best techniques used to recover the heat from any thermal applications. Energy can be stored in either form – like changing the phase transformation of material (as in the case of latent heat thermal energy storage – LHTES) or change the internal energy of a material (as in the case of sensible heat thermal energy storage – SHTES). These techniques can be utilized in order to improve the efficiency of thermal systems. Phase change materials (PCM's) like organic, inorganic and eutectic substances can be used as latent heat storage material. Gravels, mild steel scraps, sponges can be used as sensible heat storage [12,13]. Most of the researchers carried out investigations on exergy and energy analysis of various latent heat and sensible heat thermal energy system. Thermal conductivity plays a vital role for practical application such as solar still desalination, solar thermal collectors, and solar PV/T collector's. PCM's are substances that are capable of storing energy and release a larger amount of heat when compared to sensible heat thermal energy storage. Also, as the material changes they are having a higher latent heat of fusion and lower melting point. PCM is having a greater impact on the applications such as solar desalination [14,15], heat exchangers [16], thermo-electric coolers [17], net zero energy buildings [18] and solar water heaters [19], and it is having ability to reduce the temperature fluctuation and enhance the thermal energy

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**Nomenclature**

| | |
|---|---|
| $A$ | area (m$^2$) |
| AFC | annual first cost (Rs.) |
| $C$ | specific heat capacity (J/kg K) |
| CRF | capital recovery factor (–) |
| $h$ | heat transfer Co-efficient (W/m$^2$ K) |
| $h_{fg}$ | latent heat of vaporization (J/kg) |
| $i$ | rate of interest (%) |
| $I$ | total radiation (W/m$^2$) |
| $k$ | thermal conductivity (W/m$^2$ K) |
| $L$ | thickness (m) |
| $n$ | number of years |
| $p$ | partial pressure (N/m$^2$) |
| $Q$ | heat transfer (W) |
| $T$ | temperature (°C) |
| $t$ | time step (s) |
| $U$ | overall heat transfer coefficient (W/m$^2$ K) |
| $u$ | wind velocity (m/s) |
| $Y$ | salinity (g/kg) |
| SFF | Sinking Fund Factor |
| CF | Cash flow (Rs.) |

*Greek symbols*

| | |
|---|---|
| $\alpha$ | absorptivity |
| $\varepsilon$ | emissivity |
| $\tau$ | transmissivity |
| $\sigma$ | Stefen Boltzmann constant ($5.67 \times 10^{-8}$ W/m$^2$ K$^4$) |

*Subscripts*

| | |
|---|---|
| $a$ | ambient |
| $av$ | average |
| $b$ | basin |
| $c$ | convection |
| $e$ | evaporation |
| $equ$ | equivalent |
| $g$ | glass |
| $p$ | payback |
| $r$ | radiation |
| $w$ | water |

storage. Many reviewers have reported that thermal conductivity and latent heat of fusion are the essential properties of PCM based paraffin wax [20].

Murugavel and Srithar [21] experimentally investigated a double slope solar still with different energy storage material with indefinite shape. The results show that the use of sensible heat storage material inside the basin increases the fresh water production by 45% with ¾″ quartz rock. The materials used in the basin were mild steel scraps, ¼″ quartzrock, washed stones and red bricks.

Velmurugan et al. [22–25] investigated a solar still with mini solar pond, fins, pebbles and sponges for improving the yield. Results show that the yield is improved by 47% with sponge and 57% with fins than conventional solar still.

Srivastava and Agrawal [26] investigated a solar still with porous fins. Porous fins were held vertically in the basin dividing the basin into '*n*' separate basins each with filling space for water and black cloth. The modified porous fins reduce the water temperature by 25% than the conventional solar still. The yield modified solar still was found to be 7 and 4 kg/m$^2$, and increased by 30% and 45% than conventional solar still for summer and winter conditions respectively. For the same conditions, the maximum achievable during noon is observed to be 1.2 and 0.6 kg/m$^2$ h with modifications. Distillate output also depends on the depth of water in the basin, which is found that the increase from 4 cm to 6 cm have no effect on the change of output from the modified solar still. Furthermore, when the water depth is decreased from 4 to 3 cm, the increase in the distillate was found about 22.2%.

Omara et al. [27] experimentally investigated a solar still with corrugated fins. Comparative results show that evaporation depends on saline water temperature. In that case, the solar still with fins the saline water temperature is higher than the corrugated during the forenoon and during the afternoon the corrugated solar still water temperature is higher. Also, comparing the yield of a finned and corrugated absorber, the fresh water yield increased by 5% and 25%, respectively, than a conventional solar still.

Srivastsava and Agrawal [28] experimentally analyzed the solar still with modifications such as boosting mirrors and low inertia floating absorbers. The absorber was of blocks with thermocol pieces attached to jute cloth for floating effect. Since the absorber was floating only a small amount of water will be evaporated from the floating absorber. Thermocol pieces float in water and due to its weight a wavery motion arises in the basin, and the cloth was wetted. Mirrors on the side walls of the solar still boost the solar intensity to heat and evaporate the water. The results showed that modified still evaporation entirely depends on floating absorber temperature. Due to the porosity and higher heat absorption with a low mass of floating material, water from the surface was quickly evaporated, and the temperature was increased by 16.66%.

Rajaseenivasan et al. [29,30] investigated the utilization of sensible heat storage material on a single and double basin double slope solar still. Productivity thus not only depends on the specific heat capacity and also on size of material. The size of material inside the basin increases the free surface area inside the basin for better evaporation of saline water. From the review of Harris Samuel et al. [31] it is identified that the use of sensible heat energy storage with specified dimensions will improve the yield of solar still. Also, the use of latent heat energy storage materials such as molten salt in cuboidal boxes and cylindrical containers will increase the surface area of water as well as act as excellent heat storage. Similarly, the yield of fresh water is greatly affected by keeping latent heat storage material at the bottom of the basin as this reduces the temperature of water during the sunshine hours for charging the material (phase change from solid to liquid).

This paper communicates the theoretical and experimental analysis of a conventional single slope solar still using low cost energy storage material improving the yield of fresh water. Experiments are carried out with spherical ball heat storage as it increases the surface area of water and act as excellent energy storage. Also, experiments are carried out with different sponge materials for better capillary action and evaporation from the surface layer of water. Furthermore, a detailed economic analysis was carried out to analyze the payback period, selling price of water, cost of fresh water produced of present and previous model solar still.

## 2. Theoretical approach

### 2.1. Energy balance on basin surface

The energy balance of the basin surface is given be,

Heat energy absorbed by basin surface through transmittance = Heat transfer between basin and water + Heat lost by conduction