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Solar distillation using a blackened mixture of Portland cement and alluvial sand as a heat storage medium

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HIGHLIGHTS

- Topic solving water shortage by producing distilled water with low costs
- Use of available, clean and cheaper material and energy
- Possibility of nocturnal distillation for a significant time
- Encouraging results

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ABSTRACT

Solar energy is one of renewable energies source to produce drinkable water to supply isolated low-density population areas such as those located in southern Algeria.
Alluvial sand and Portland cement are composed by several metal oxides which some of them can play a role of photocatalysts.
In aim to increase the yield of conventional solar still, different mixture layers of equal masses of Portland cement and alluvial sand have been used to observe both of the heat storage system amount and the photocatalysts effects on the output of distillate.
Experimental results conducted at Ouargla University showed that:

- The gain is 39.70% after adding 300 g of adhered layer i.e. 1.811 (kg of mixture/m^2 of absorber area)
- 200 g of mixture i.e. 1.207 (kg of mixture/m^2 of absorber surface) improves the yield by 31.61%.
- 100 g of adhered layer i.e. 0.604 (kg of mixture/m^2 of absorber area) increases the yield by 25.49%.
- However, a layer of 400 g i.e. 2.414 (kg of mixture/m^2 of absorber surface) enhances the yield by only 33.08%.

Physical analysis of distillate shows that not only the layers improve the still production, but also enhance the quality of distilled water produced because of the photocatalysts effect.

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1. Introduction

Fresh water is a basic human requirement and without clean water the life will be impossible. Supplying the population in drinkable fresh water is becoming an increasingly important problem in many parts of the world.

The solar distillation using conventional still is the most friendly environmental manner and economical way to distillate brackish, underground saline water or seawater.

Algeria has substantial solar energy throughout its territories which constitutes a considerable asset for arid and semi-arid localities. The mean solar irradiance period in the town of Ouargla (south of Algeria) – (latitude 31.95′ N, longitude 5.40′ E and altitude 141 m) is around 3500 h per year, delivering some 2650 kWh/($m^2 \cdot yr$) of solar irradiance on the horizontal surface [1–2].

The significant groundwater resources of Algeria are located in the south. About 76% of the underground water resources are situated in the Sahara [3]. The salinity levels in these parts are variable and some sources have salinity levels of up to 8 g/l; and this is well beyond the allowed 550 ppm salt levels for human consumption [4]. This high solar radiation band and the vast underground water potential can be utilized to convert saline water to potable water where the demands for fresh water are increasing faster than ever.

Increasing the process of heat transfer in conventional solar still is one of the key issues of energy saving.

The use of additives is a technique applied to increase the water heat transfer performance in the basin. The attempts are made to enhance the efficiency of conventional solar still by using different absorbing materials (charcoal, dyes and sponges).

Capillary action by the charcoal partially immersed in a liquid and its reasonably black color and surface roughness reduce the system thermal inertia although that the presence of charcoal leads to a marked reduction in start-up time.

Naim et al. [5] Proved that the used of charcoal particles bed increases the productivity by 15% over the wick-type solar stills.

The use of dyes darkens the water and increases its solar irradiance Absorptivity. Rajvanshi [6] used black Naphthylamine at a concentration of 172.5 ppm to increase the still productivity. He found that the yield increased by as much as 29%.

The use of absorbing material such as coated and uncoated sponge and black rock was a plus in improving the performance of single solar still. Abdallah et al. [7] have used pieces of coated sponge to enhance efficiency of solar still; however, the negative point was on the metallic wiry sponges that corrosion started to appear in certain parts of the sponge.

The photocatalysis process is a great environmental application with high potential in the near future if used in the processes to water purification, treatment and distillation. Patel et al. [8] and Sindal et al. [9–11] used photocatalysts with different metal oxides namely: PbO_2, CuO, ZnO, TiO_2, and MnO_2 they show that the rate of production of distilled water was increased to a remarkable extent.

Heat storage system was another technique which has been used to keep the operating temperature of absorber high enough to produce distillate during the lack of sunshine, overnight, or when solar irradiance is low.

The use of latent heat storage system using phase change material (PCM) is an effective way to store thermal energy and has the advantage of high energy density and the isothermal nature of the storage process. This technique of storage medium is recently used; Rai et al. [12] have used Zinc Nitrate Hexa-hydrates. They observed that an enhancement of 33.5% was observed compared with conventional solar still productivity.

Kantesh [13] has used Bitumen as PCM, and he recorded that the efficiency of the still was increased by 27%.

Ramasamy [14] used Paraffin wax as latent heat thermal energy storage sub-system to enhance the still performance nevertheless, the disadvantages of phase change material is corrosion when in direct contact with metal pipings or housings.

Swetha et al. [15] have used a sand and lauric acid as PCM; they resulted that adding a layer of sand enhances the yield by 13%, but using lauric acid gives the best result with an increment of 36%. Al-Hamadani et al. [16] have also used this technique; they found that the energy efficiencies for solar still integrated with lauric acid and myristic acid are found to be 39.6% and 34.4% respectively.

Sellami et al. [4] carried out an experimental study by coating distiller basin with layers of blackened alluvial sand as heat storage system; they investigated the effect of the sand mass and sand particles diameters on the daily output of distillate; their results revealed that for a fixed mass of sand layer, the yield improvement was inversely proportional to the sand particles diameter. Because of storage system and photocatalyst effect, the output in distilled water for fixed particles diameter increases with the increase of the sand mass to an optimum value of (2.268 kg of sand/m^2 absorber area) with an amelioration in distilled water of 43.28% compared with conventional still.

Recently, as an innovative material, nanosized particles have been used in suspension within conventional solar still saline water. The suspended metallic or nonmetallic nanoparticles improve the transport, the heat transfer and the evaporative characteristics of the water. The fluids with nanosolid particles suspended in them are called “nanofluids”. Srivastava et al. [17] used the floating porous materials in the basin. They found that the better yield with the jute fabric as compared to cotton cloth with around 12% better distillate output than cotton cloth. Gnanadason et al. [18] have experimentally studied this technique in aim to analyze and compare the enhanced performance in the case of vacuum single basin solar still using nanofluids with the case of simple conventional still. They found that addition of nanoparticles in the basin surface increases the water temperature by increasing heat transfer rate and thereby increasing the evaporation rate and hence the rate of condensation on the cooler surface.

Our aim in this experimental study is to enhance the daily output of conventional solar still using heat storage system. This latter was used to keep the operating temperature of absorber high enough to produce distillate during the lack of sunshine, overnight, or when solar irradiance is low. This idea was achieved by coating the entire surface of the absorber by layers of dry powder cement; wet cement and mixed wet cement with alluvial sand in order to observe both of heat storage system amount and photocatalysts effects on the daily output and the quality of distillate.

The cause of choosing alluvial sand and Portland cement as photocatalyst materials for this experimental study is that because in