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Use of Portland cement as heat storage medium in solar desalination

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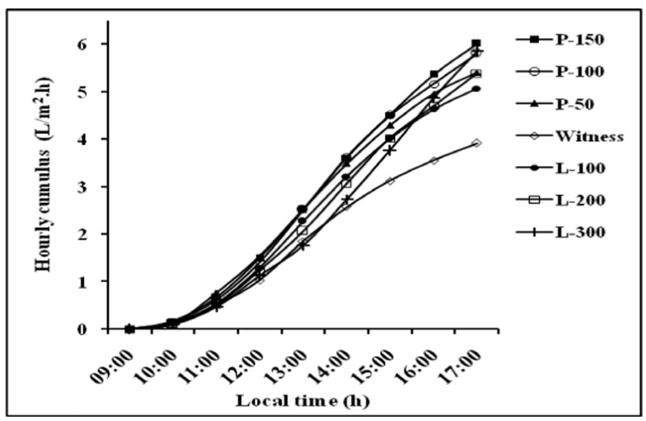
HIGHLIGHTS

- Topic solving the problem of water shortage for small communities in remote areas.
- Using cheap and available materials with renewable and clean energy.
- Possibility of a longer distillation time (nocturnal distillation).
- Producing distilled water with low cost price compared with other methods.
- Encouraging and satisfying results.

GRAPHICAL ABSTRACT



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ABSTRACT

In aim to increase the yield of conventional solar still, Portland cement has been used in two forms: sprayed powder and adhesive layer in order to study firstly their thermal behavior on the output, secondly to see the effect of the heat storage medium amount on the yield and thirdly to see the photocatalyst behavior of the cement on the quality of distillate; the experiments carried out in Ouargla University revealed that:

- For the same amount, powder cement is more beneficial in quantity term but in term of quality and according to distilled water analysis, the cement layer is better. This improvement in quantity and quality of distillate is due from side to the heat storage medium and to the other side to photocatalyst behavior of Portland cement.
- Best result is obtained by spraying 150 g i.e. 0.906 (kg of powder cement/m^2 of absorber area) which led to an improvement of the output by of 51.14%.

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Contents

Nomenclature

G	solar irradiance (W/m^2)
P	powder cement
L	cement layer
m	cement mass (kg)
T_a	ambient temperature (°C)
T_{ai}	temperature of trapped air and vapor inside the still (°C)
T_{ba}	basin temperature (°C)
T_{gc}	inner side glass-cover temperature (°C)
T_{is}	insulation temperature (°C)
T_{iw}	input water temperature (°C)
T_{sw}	basin water temperature (°C)
ΔT	$[T_{sw} - T_{gc}]$ (°C)

1. Introduction

Nowadays, the lack of potable water is still a problem worldwide. Most of the water reservoirs are saline or polluted by wastes and/or bacteria; hence, they are not potable. On the other hand, great dependency of industrial communities to energy resources such as fossil fuels has intensified usage of renewable energy. One of these energies is solar energy. The latter can be used as a permanent useful source because its production is cost free; and its usage has no harmful impact on the environment [1].

Considering the nearly endless saline ground water resources, solar desalination of brackish water is an increasing attractive solution for small communities of southern Algeria where solar energy and underground water are abundant. About 76% of the Algerian underground water resources are situated in the Sahara [2]. However, this water is too salty (≥3 g/l) and this is well beyond the allowed 550 ppm salt levels for human consumption [3].

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.yr) of solar irradiance on the horizontal surface [4].

For years, improving the heat and mass transfer within the basin type solar still is one of the major occupation of most researchers throughout the world to reduce energy losses and thus to enhance distiller efficiency.

Some investigators carried out a mathematical model by computer simulation in order to determine specific relationships of the key parameters which govern different heat and mass transfer mode within the solar still [1,5–9].

Generally, all theoretical study of solar still design is always followed by experiments to validate the model obtained [5,8,10]. The gap and the difference between theoretical and experimental model should be minimal; or in other words, the convergence between them should be maximal.

The use of heat storage medium [11,12] or PCM (phase change material) [13–15] is one of several techniques used by researchers. The heat storage medium was used in the still absorber to keep its temperature high enough to produce distillate during the lack of sunshine, overnight, or when solar irradiance is low [16–19].

The heat storage medium is the use of materials with low thermal conductivity i.e. with high thermal capacity to store energy within absorber plate. Different materials have been used like gravel and sand [3–20] to increase and lengthen the production time for a few hours after sunset.

Other investigators carried out experimental studies using different absorbing materials (Charcoal, dyes, Bitumen and blackened sponge) [21,22]. This technique was applied to improve the irradiative water absorbance and then enhance the heat transfer performance in absorber which leads consequently to an increase of distiller efficiency [23,24].

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.

Different metal oxides (semiconductors) namely: PbO_2, CuO, ZnO, TiO, and MnO_2 additional to certain other metal sulphides namely: ZnS, CuS, CdS… Have photo-catalytic property [25,26]. Those metal sulphides have been used as photocatalysts which enhance remarkably the quantity and the quality of distilled water [25,27–28]. Metal oxides which play the role of photocatalysts have the criterion to adsorb organic and some inorganic compounds. This adsorption process leads to energy release and enhances the quality of distilled water by the mechanism explained below.

The metal oxide or semiconductor has an energy gap between its valence and its conduction band. The process of photocatalysis is the absorption of a photon whose energy is above the difference between the valence and the conduction band.

The absorption of the photon leads to a formation of (electron-hole) on the semiconductor surface by the emission of an electron in the conduction band and the formation of a hole in the valence band. In the presence of water and oxygen (air), this electron-hole will allow the formation of free radicals which initiate red-ox reactions in molecules adsorbed at the metal oxide surface and thus, degrading them and causing the formation of CO_2 and H_2O with heat release. Owing to their high red-ox potentials, the photo-generated electrons and holes have been found to breaks down almost all types of inorganic, organic, and microbial contaminants [29–31].

Our aim in this experimental study is to enhance the daily output of conventional solar still by using Portland cement as heat storage medium.