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Effect of aluminum balls on the productivity of solar distillate

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Abstract

Drinking water has become a real global problem, despite the abundance of unsaturated saltwater and colorless, which do not meet the requirements of the World Health Organization. The El Oued, in the southeastern part of Algeria, contains vast quantities of salt water and non-potable water. Solar distillation can be used as a solution to resolve this trouble. To provide drinking water, we use free sunlight to treat salt water. The traditional solar distillation device, which is one mile long (0.5×0.5 m), is designed to confirm the effectiveness of this solution. The traditional single slope solar distillation, its dimensions (0.5×0.5 m), is designed to confirm the effectiveness of this solution. Solar distillation is an environmental, economic and simple technique, but it needs some modifications to increase the distilled water production. In this work, we added aluminum balls inside the solar distillate box. In this work, we added 42 aluminum balls with a diameter of 2 cm inside a solar distillates box; positioned as follows (6 balls x 7 balls). The results showed that aluminum balls increased the distillation of distilled water by about 27.16 %.

Introduction

The solar desalinationis a highly developed technology but each technique has its advantages and disadvantages [1,2]. Solar distillation is the most economical way to purify or quench water. The efficiency of this technique is relatively low as compared to other distillation modes, but this process requires the sun's radiation to function. The variation of seasons has a remarkable influence on this type of technique [3,4]. For desalination and salt water, there are many methods. Among them, the evaporation process occurs in this way by transferring heat. Therefore, multi-effect distillation consists of some effects of the evaporator. Thus, the distilled water can be produced from salt water. Azimibavil and Dehkordi [5] researched the multi-effect distillation. This plant produces 80 m^3/day of pure water every year [6]. This method has much popularity during the last two decades, which based on the membrane operations and nowadays takes about 60 % of all the desalination activities around the world. It is defined as a pressure-driven membrane process, when the pressure raises pushes the salt water through a special membrane.This fact allows the selectively passing water molecules only and not dissolving salts to pass with it. When reverse osmosis is used to purify non-potable water, it is pressed from one side through the semi-permeable membrane. To be successful, the pressure is higher than the osmotic pressure to not cause the reverse osmosis water flow. If the membrane has high water permeability, and this membrane is insoluble in dissolved solutions, the pure water will be crossed by the membrane and is known as the fresh water. The problem of this method is the severe fouling, which occurs in the membrane, heavy gauge piping, complex pumps, and maintenance demands. While, one of the main advantages of reverse osmosis is its low energy consumption [7]. This method is achieved more attention in several industrial applications such as the power generation and the seawater/brackish desalination. It is considered as one of the pressure-driven membrane processes. This technology presents important compensations such as extremely low hydraulic pressure, less energy consumption, easy to clean, low cost, rejects high salt and features high water flow. In the forward osmosis method, low osmotic pressure pushes the feed water solution into the suction solution with high osmotic pressure [8]. Kumar et al. [9] performed experimental investigations on Conventional Solar Still (CSS) with symmetrical square tubes fins at the basin. A small amount of paraffin wax was stored in the hollow space in the fins tubes. The results showed that the efficiency of solar still with fins filled with PCM was 95 % and without the PCM was 64 %. Al-harahsheh et al. [10] studied the PCM effect on the solar water collector. The results confirmed that the distillate production produced 4300 ml/day.m^{2}in the period after sunset.Omar et al. [11] experimentally conducted studies on corrugated solar still and vertical finned passive solar still. The authors confirmed that vertical finned gives a 40 % increase in productivity and the corrugated solar still gives 21 % higher productivity as compared to the conventional method. Kabeel et al. [12] experimentally compared the performance of the CSS and CSS with graphite. The authors confirmed that the daily production from the CSS with graphite was 7.73 l/m^2, the production from the CSS was about 4.41 l/m^2.Akash et al. [13] developed a comparison between different materials such as black rubber matt, Black ink and black dyes inside the solar still for the thermal energy storage. The researchers confirmed that the black rubber mate was more productive with 38 % as compared with other materials. The increase in distillate output was about 29 % for the Black ink and 25 % for the black dye. El Sebaii et al. [14] developed experimental studies on vertical finned still solar stills. The researchers increased the number of fins in static areas and confirmed that the productivity was improved by almost 13.7 %. Sarhaddi et al. [15] theoretically studied the effect of PCM on competencies of weir type cascade solar still. The results showed that productivity, energy, and exergy efficiency with PCM was 4940 ml/day.m^2, 74.35 % and 8.59 %, respectively. However, without using PCM, these values were 3840 ml/day.m^2, 76.69 %, and 6.53 % respectively. Alaian et al. [16] developed an experimental effect of the augmented with pin-finned wick. They that there was an improvement on the productivity of the fixed system when using pin-fined wick by 23 %.Samuel et al. [17]studied the effect of different storage material (ball salt storage and sponge) in solar still. They concluded that the daily production with ball salt storage was 3700 ml/m^2, and 2700 ml/m^2 when using for sponge. Nafey et al. [18] conducted the experiment on use black gravel and black rubber in a basin still. The results showed that the production was increased by 19 % for use thick black gravel with 10 mm thickness, and 20 % for black rubber of 20 to 30 mm as compared to the CSS without storage. Sakthivel and Shanmugasundaram [19] conducted the influence of the black gravel on the performance of a solar still. In this work, 20% of the improvement in productivity has been observed with the black gravel of 60 mm thick. Velmurugan et al. [20] considered the effect of the performance passive solar still when using vertical fins. Compared to the conventional method, 45.5 % of the productivity increase has been obtained with the vertical fins. Omara and Kabeel [21] studied the effect of yellow sand bed and black sand bed in a solar still. They concluded that the daily production was improved by 42 % with the black sand bed, and by 17 % with the yellow sand bed as compared with the CSS. El-Sebaiiet al. [22] conducted a study to optimize the black rubber thickness and size of the black gravel materials. The results confirms that black rubber with a size of 10 mm thickness improves the productivity equal to 20 % comparing to the black gravel material witha size between 20 and 30 mm. Abdel-Rehim and Lasheen [23] experimentally investigated the effect of glass balls packed layer in a solar still. The results showed that the performance of the solar still was improved by 5 % as compared to the CSS. Rajaseenivasan and Srithar [24] developed experimental studies on solar stills using circular fins and using square fins. Compared to the wick surface, it has been observedan increase in the productivity equal to 45.8 % for the square fins and 36.7 % for the square finned still. Tabrizi and Sharak [25] considered the impact of using sand bed thick of 12cm down the solar still basin. Compared to traditional still, an improvement in daily production has been observed and it is equal to 12 %. Indeed, the construction cost increases by 10% by using the sandy heat reservoir. Dumka etal. [26] conducted an experimental study to compare the solar still with a conventional one by increasing 100 number of sand-filled cotton bags to enhance energy storage capacity. The researchers observed that the cumulative yield of improved distillate for 30 and 40kg of basin water was 28.56 and 30.99 % higher, respectively, as compared to the CSS for the same conditions. Mousa and Naser [27] developed a model to predict water temperature change over time in a solar basin containing phase change materials (PCM). Then, they validated the model by comparing their results with numerical results and measuring them empirically. The researchers concluded that there was a good agreement between numerical calculations and experimental measurements. Mousa el al. [28] placed the wax (tricosan) as a PCM in submerged copper tubes in a solar distillation basin. Then, they investigated the effect of varying PCM mass-water ratio equal to 0, 0.17, 0.35 and 0.51, on the water temperature change over the whole day. The results indicated that freshwater production was strongly influenced by PCM mass change during the day and night.

In this work, we conducted experiments in the El Oued city of southeastern Algeria. The experiment consists on the same area of two solar distillations, exposed to sunlight in the same place, same position, same nature of the water and same amount of water. The first distiller is considered as a reference (CSS) and the second distiller comprises in its basin with aluminum balls as a Modified Solar Still (MSS). Particularly, we have used 30 identical and evenly spaced aluminum balls with a diameter of 2cm each. This aluminum balls is considered as a sensitive thermal storage material to get better the yield. The experiment was conducted on May 6, 2019 to see the effect of aluminum balls on solar distillation. Readings were taken on every one-hour solar radiation, atmospheric temperature, basin water temperature, and glass temperature between the hours 8:00 AM and 6:00 PM for both experiments.

Section snippets

Geographical coordinates in the region

The El Oued is located in the southeast of Algeria with a population of more than 700,000 inhabitants, and an area of 54,573 km^2. The decimal geographical coordinates are 33.3683° of latitude and 6.8674° of longitude with an average height of 60m. The El Oued area is very rich in salty groundwater and is not suitable for drinking.Fig.1 shows the distribution of groundwater in the El Oued.…

Solar distillation description

The solar distillation apparatus shown in Fig.2 consists of a wooden box 50cm of long, 50cm of wide,…

Climatic conditions

The main factor of the solar distillation is the solar rays. To determine the proper functioning, we measure the solar radiation, the ambient temperature and the temperatures of both sides of the glazing and the water temperature. As presented in Fig.4, the experimentwas carried out on the 06/05/2019 at the renewable energy laboratory of the University Of El Oued Algeria in the climatic conditions indicated in the Tble1.…

Analysis of experimental errors

The error is highly probable in all experimental studies. For this…

Hourly changes of solar irradiant, ambience, briny water and glass temperatures for the CSS and MSS

Fig. 5, Fig. 6 display the periodic changes of solar irradiant, ambience temperature (T_a), theoretical and experimental briny water temperature ($T_{b.w}$) and glass temperature (T_g) for the CSS and MSS, respectively. From the diagrams, it is identified that solar irradiant rises linearly and get its topmost value of 1120W/m^2 at 1 P.M. The temperatures of ambience, briny water and glass has the similar tendency like solar irradiant. Since it is base for all the temperatures. The maximum hourly…

The daily cumulative yield

Table4 shows the cumulative distillate recorded results from the CSS and the MSS, during the 8 hours of the day of the experiment on 06 May 2019 from 8 AM to 6 PM, and compared them to the daily cumulative results of other research using reasonable storage materials. Through the results of table4, we note that the results obtained through our work are much better than other techniques.

The water we got is distilled water, suitable for many uses in industry and in research laboratories. We can…

Conclusions

From the experimental research of two solar stills (CSS and MSS) the following conclusions has been arrived.

- In MSS with aluminum balls the difference between $T_{b.w}$ and T_g is 12 °C and without aluminum balls is 8 °C. Higher the difference between $T_{b.w}$ and T_g produced the higher distilled water production.…
- The MSS produced the daily freshwater conversion of about 5.09 kg, where the CSS produced only 3.71 kg, which is 27 % lesser as compared to the MSS.…
- The daily TE and daily EE of the CSS is 27.5…

…

CRediT authorship contribution statement

Mohammed El Hadi Attia: Conceptualization, Investigation, Resources, Writing - original draft. **Zied Driss:** Conceptualization, Methodology. **A. Muthu Manokar:** Resources, Writing - original draft, Writing - review & editing. **Ravishankar Sathyamurthy:** Writing - review & editing, Formal analysis, Validation.…

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

Research data for this article

Data not available / Data will be made available on request

Further information on research data ↗

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> …It was explored that the black granite achieved the optimal performance among the investigated SSMs, showing 76 % amelioration in the daily potable water production compared to the traditional still. Attia et al. (2020) experimentally studied the impact of aluminum balls on the performance of hemispheric solar still (HSS). It was proven that the pure water distillation was increased by 27.20 % by the aluminum balls utilization.…

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