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Experimental study of the basin type solar still under local climate conditions

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Abstract

This paper presents experimental results obtained using the basin type solar still. The experiments were conducted in Jordan using a solar still with various cover tilt angles of 15, 25, 35, 45 and 55°. An optimum tilt angle for water production was found to be 35° during the month of May. Salt was added to study the effect of the salinity of water on solar distillation. Distilled water production decreased with salinity. The effect of water depth was also studied. The results show that water production decreased in a somewhat linear relationship with increasing water depth in the still. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: Solar still; Water desalination; Jordan

1. Introduction

Remote and arid to semi-arid regions depend on underground water for drinking. Unfortunately, underground water is not always considered to be fresh drinking water. In some instances, the salinity is probably too high for water to be considered as fresh drinking water, instead it is called brackish water. The salinity of brackish water varies with location. In such cases, fresh water has to be either transported for long distances or connected with an expensive distribution water network at extremely high cost for, usually, a small population. Thus, solar distillation becomes very attractive and may be the solution for such a problem.

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According to Howe [1], at an average water consumption of about 400 l/person-per-day, a small community with a total population of 200 can benefit more from solar distillation than transporting water to distances of 16 km or longer at lower costs. For example, a community that is located at about 100 km from a fresh water source can save over 30% in total cost if solar distillation were selected instead of transporting fresh water. During the hot season, solar insolation is high and water is at its peak consumption. Thus, utilization of solar energy for fresh water production becomes a very convenient method. That is why solar stills become very attractive.

In recent years, a number of models for solar distillation have been presented in the literature by various investigators [2–9]. Mainly, they have single or double slope solar collectors. In either case, they operate on absorbing solar radiation through a transparent cover, usually made of glass, which is then transmitted to the water. The distilled water production rate can vary with the design of the solar still and location. The main concern was to enhance the amount of water produced. For example, attempts were made to increase the

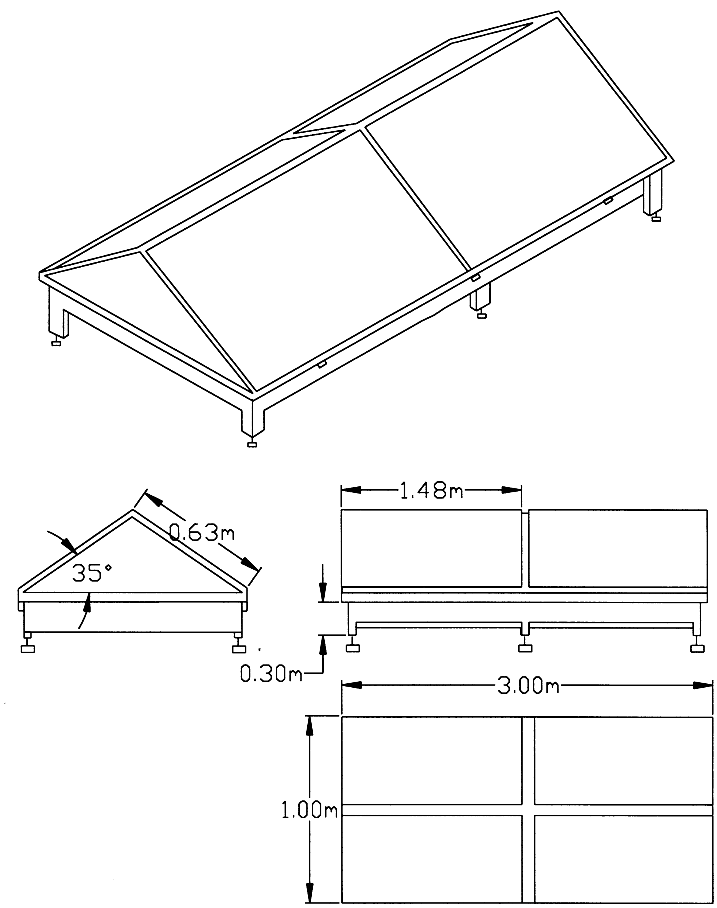

Fig. 1. Schematic diagram of the experimental setup.

productivity of water by using different absorbing materials [10–12]. In other studies, the still was operated at lower pressure [13,14]. The productivity was found to increase by forcing air inside the still [15]. Furthermore, some studies evaluated the performance of the solar still using an internal condenser [16]. In this paper the effects of the cover tilt angle, the salinity of water and water depth will be determined.

2. Experimental

Fig. 1 presents a schematic diagram of the solar still used in this study. Briefly, it consists of a stainless-steel basin type solar still. Its base has an effective area of 3 m^2 (i.e. 3 m length by 1 m width). Thermally treated glass covers, that have 4 mm thickness, can be placed on galvanized iron frames constructed with different tilt angles. The tilt angles used are 15, 25, 35, 45 and 55°. Once the glass covering the frame is placed on the base of the solar still, the entire assembly is made air tight with the help of a rubber gasket and clamps separated at distances of about 25 cm from one another. The system is insulated from below by a 10 cm thick Styrofoam. A black rubber mat, placed at the bottom of the still was used to enhance the amount of solar energy absorbed within the system and, thus, increase the amount of distilled water produced. The distilled water is condensed on the inner surfaces of the glass cover. It runs along the lower edge of the glass cover. The distillate was collected in a bottle and then measured by a graduated cylinder. The system has the capability to collect distillates from two

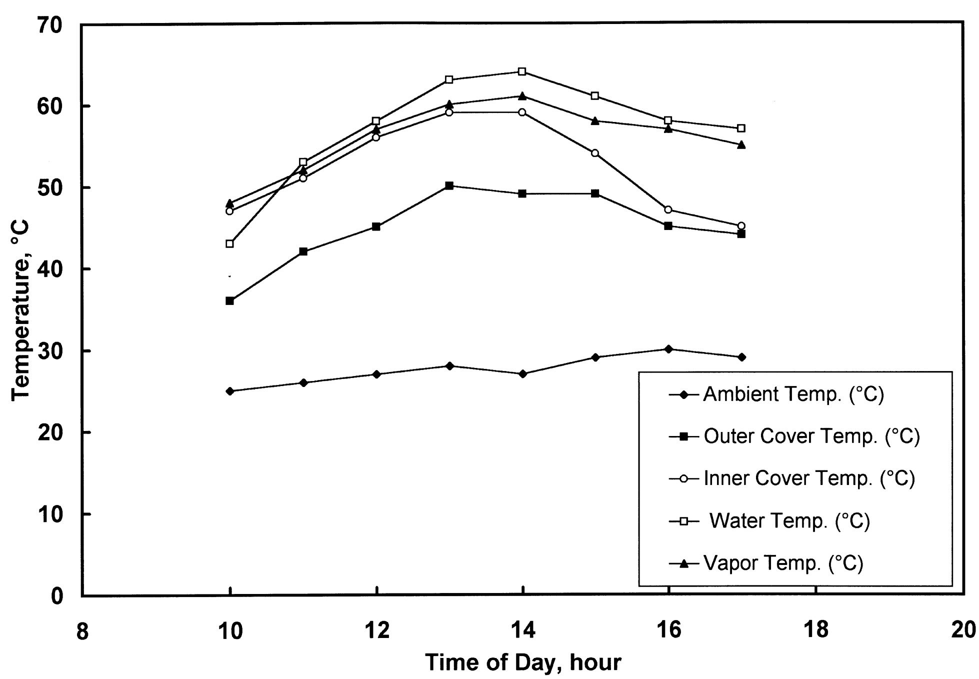

Fig. 2. Hourly variation of temperatures for an experiment conducted on the 24th of May.

sides of the still (i.e. the north and south sides). Thermocouples were located in different places of the still. They record the different temperatures, such as outside glass cover, inside glass cover, solar basin water, inside air temperature and ambient temperature. In order to study the effect of salinity of the water, locally available table salt was used at various salinities. It consists largely of sodium chloride and other additives. All experiments were conducted in Amman, Jordan, during the month of May. The experiments reported were for sunny to mostly sunny days.

3. Results and discussion

Fig. 2 presents the variation of hourly temperatures for an experiment conducted on the 24th day of May using a still with a tilt angle of 35°. Similar trends were noticed for all experiments and the water temperature in the base of the still was always the highest among all the temperatures since the solar energy is absorbed there. The maximum water temperature always occurred between the hours of 1.00 to 2.00 p.m. It ranged between 65 and 75°C. Ambient temperatures for all experiments were in the range 20–30°C.

The volumetric rates of distilled water produced in both sides of the still are presented in Fig. 3. As shown by Fig. 3, the production rate starts very slowly due to warming of the still and the somewhat low solar energy during the morning hours. A peak production rate is obtained at about 2.00 p.m. Furthermore, after 3.00 p.m., it begins to decrease. It is also noted that the north side, which receives lower amounts of solar insolation, produces more distillates than the south side. This is due to the fact that the north side loses more heat and is not exposed directly to sunlight, thereby being cooler, so it condenses more water. The picture

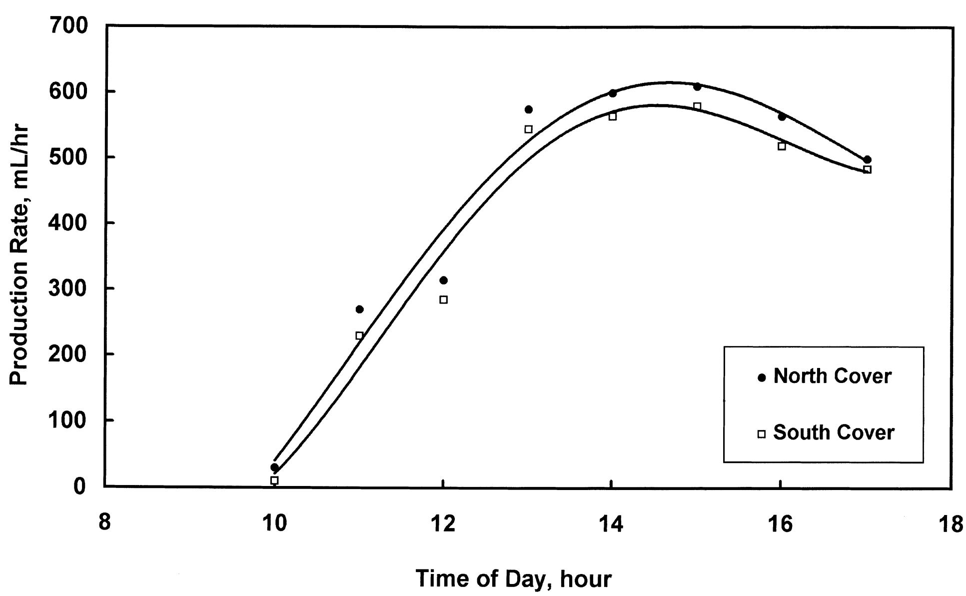

Fig. 3. Volumetric production rate as a function of the hour of the day.

becomes clearer when the total accumulation is presented. It is shown in Fig. 4 for the north, south and the two sides combined. A greater amount of water is collected from the north side than from the south side.

Fig. 5 shows the cumulative amounts of distillates collected from different cover tilt angles. Because of the location and the time of the year, a maximum value was obtained at an angle of 35°. This tilt angle was then used for all other experiments in order to determine other effects on the solar distillation. For example, the effect of salt in the water was determined. It is presented in Fig. 6. As the salt concentration increases in the water, the production rate decreases due to the increase in partial pressure of the salt in the water solution. The effect of water depth in the solar still was determined. It is presented in Fig. 7. The daily collected distillates decreased with increasing water depth in a somewhat linear relationship at a rate of about 0.4 l/cm.

4. Conclusions

For the cases considered in this paper, an optimum cover tilt angle of 35° was determined for maximum water production in the solar still during the month of May. The salinity of water affects distillate production even at low concentration. It decreases with increasing salinity. However, when the concentration is high, a smaller decrease in productivity with increasing salinity is noticed in the experiments. Water depth affects the amount of distillation. It decreases with increasing water depth in a somewhat linear relationship.

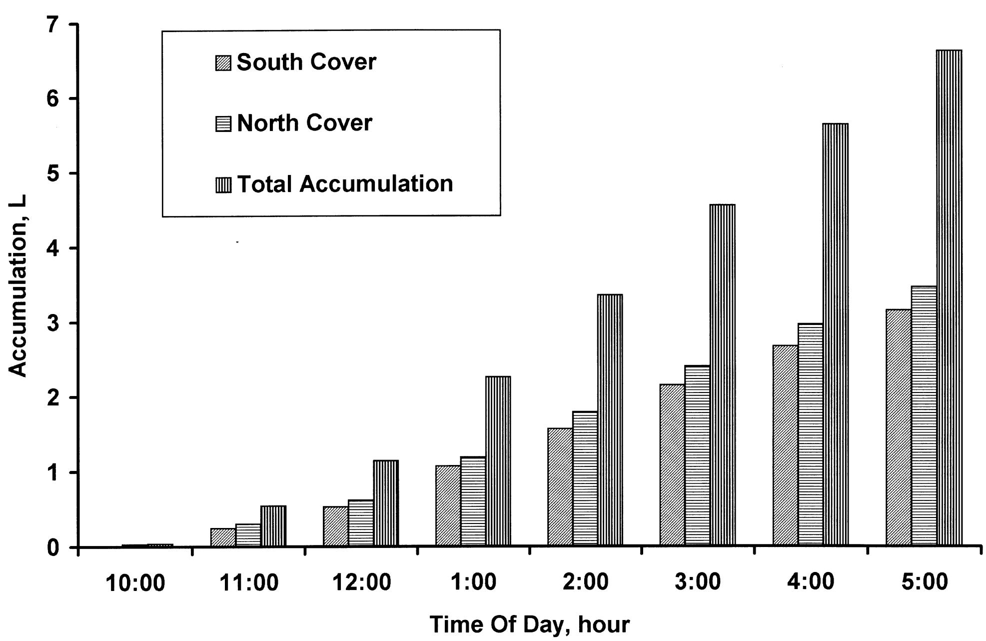

Fig. 4. Cumulative volumetric production as a function of the hour of the day.

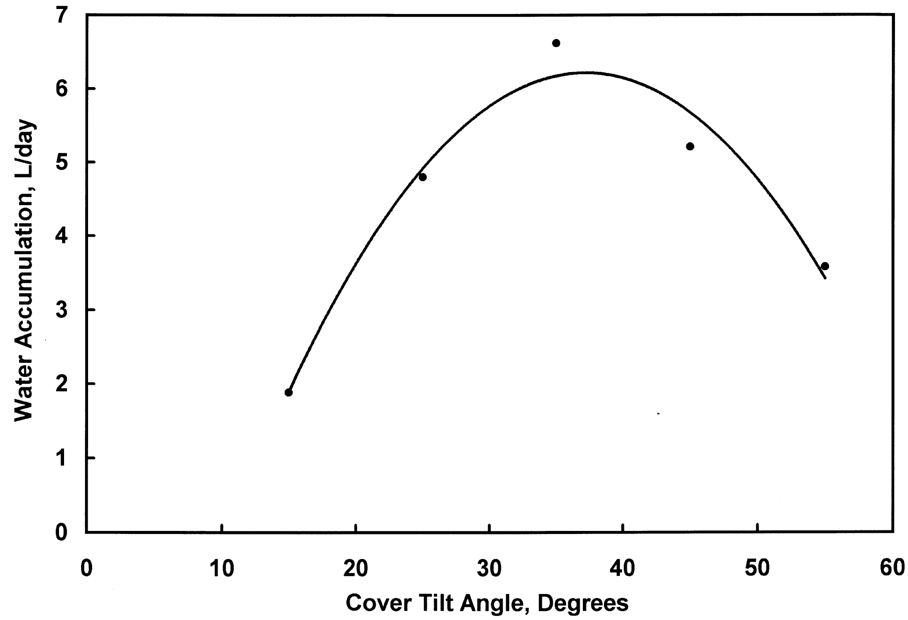

Fig. 5. The effect of cover tilt angle on production of distillates.

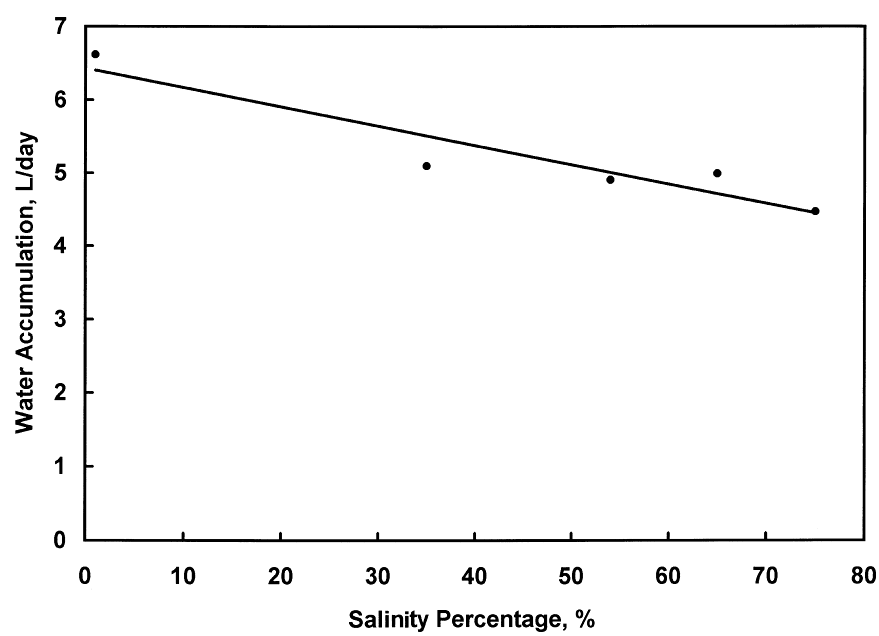

Fig. 6. The effect of salt concentration on production of distillates.

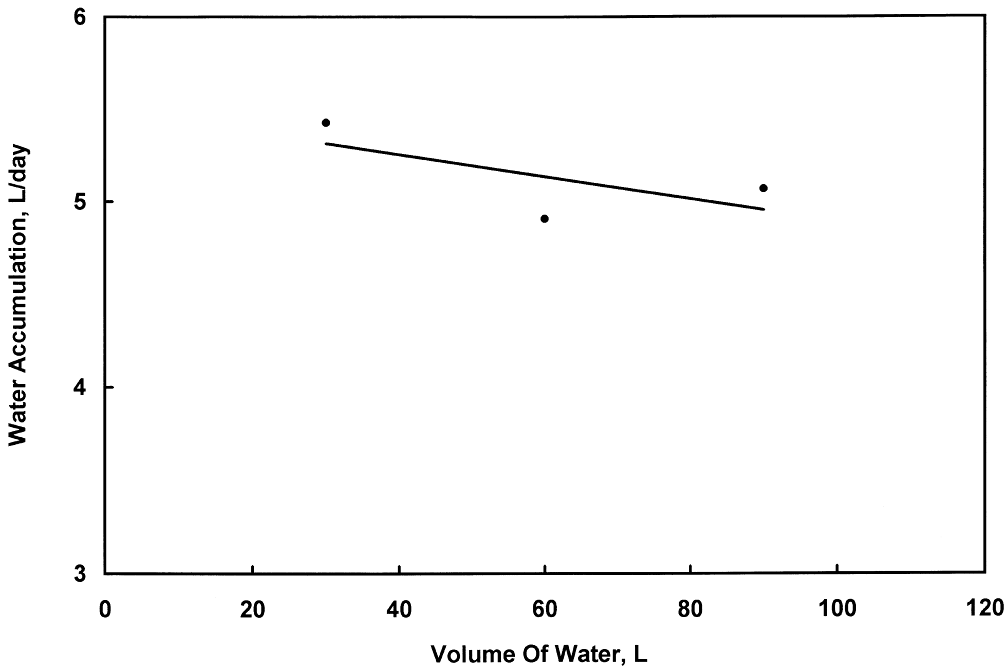

Fig. 7. The effect of water depth on production of distillates.

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