Energy 38 (2012) 31–36

Contents lists available at SciVerse ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

# Exergy and economic analysis of a pyramid-shaped solar water purification system: Active and passive cases

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ARTICLE INFO

*Article history:*
Received 25 August 2011
Received in revised form
28 December 2011
Accepted 29 December 2011
Available online 24 January 2012

*Keywords:*
Solar still
Fresh water
Active system
Passive system
Exergy
Cost analysis

ABSTRACT

An exergy analysis has been conducted to show the effect of a small fan on the exergy efficiency in a pyramid-shaped solar still. The tests were carried out in Mashhad (36° 36′ N), for two solar still systems. One of them was equipped with a small fan (active system), to enhance the evaporation rate while the other one was tested in passive condition (no fan). To examine the effects of radiation and water depth on exergy efficiency, experiments in two seasons and two different depths of water in the solar still basin were performed. The results show that during summer, active unit has higher exergy efficiency than passive one while in winter there is no considerable difference between the exergy efficiency of the units. Results also reveal that the exergy efficiency is higher when the water depth in the basin is lower. Finally, the economic analysis shows a considerable reduction in production cost of the water (8–9%) when the active system is used.



## 1. Introduction

Water is one of the most abundant resources covering three-quarter of the planet's surface, about 97% of this amount is saline, and only 3% is fresh water suitable for humans, plants, and animals needs, so that the fresh water shortage is going to be a profound social crisis after the oil crisis in the world [1,2].

Consequently, provision of fresh water is still one of the main problems in arid remote areas in the world. Solar desalination systems can solve part of the problem in the areas where solar energy is available [3]. Solar stills can be used to prevent the greenhouse gas emissions produce from the production of fresh water [4].

In Iran with abundant saline-water resources, solar distillation can be one of the best solutions and a simple way for distilling water [5].

During the last decades, many studies have been made to find the solutions of improving the performance of the conventional solar still. For instance, it has been found that the productivity of solar stills can be improved by utilizing; fin, sponges, pebbles, black rubber and sand in solar still, coupling the solar still with parabolic concentrator, solar ponds or solar collector, using solar still with wicked concave surface, tube-type solar still, weir-type inclined solar still, and energy storage media [6–15].

Recently the status of different types of solar stills and the history of previous researches in this field have been reviewed [16]. Tiwari and Tiwari [17] have collected a helpful summary consist of required information concerning different types of solar stills including design methods and modeling.

The use of exergy analysis in actual desalination processes from a thermodynamic point of view is of growing significance to recognize the sites of maximum losses and improve the performance of the processes [18]. The literature of exergy analysis of solar stills can be found in references [19–24].

Kwatra [19] carried out an exergy analysis for describing the performance of multiple-effect solar stills. Nunez et al. [20] with an exergy analysis on a single slope passive solar still showed that attempts should be directed towards better collector design, still cover materials, evaporation-condensation modifications and the reduction of collector-brine temperature gap.

Kumar and Tiwari [21] compared the exergy efficiency of a single slope solar still in passive case with an active one where the solar still was coupled with a photovoltaic thermal system. They concluded that the exergy efficiency of the active solar still was nearly 5 times higher than the passive one. Tiwari et al. [22] made

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doi:10.1016/j.energy.2011.12.046

an theoretically exergy study of a single slope solar still coupled with a flat collector and investigated the effects of the number of collectors and water depth on exergy efficiency. It was found that by increasing of the water depth, the exergy efficiency decreases.

Recently, Gaur and Tiwari [23] theoretically optimized the number of collectors for a PV/T hybrid active solar still on the basis of energy and exergy analysis.

Dwivedi and Tiwari [24] evaluated the exergy efficiency of a double slope solar still coupled with a flat collector in a constant water depth. They observed that the exergy efficiency of double slope active solar still is higher than the exergy efficiency of double slope passive solar still.

A review in the literature reveals the exergy analysis of a pyramid-shaped active solar still has not been studied yet. The present work concentrates on the testing and exergy analysis of a pyramid-shaped solar still for both passive and active systems. Also, an economic analysis has been conducted in order to obtain the cost of water produced by means of the active pyramid-shaped solar still.

## 2. Experimental set up

Two units of a pyramid-shaped solar still have been built to examine the effects of different parameters under the same weather conditions. The two were identical, but only one of them was equipped with a small fan with a negligible power consumption (~2 Watts) to enhance the productivity of fresh water. The schematic diagram of the pyramid-shaped solar still for the active system is shown in Fig. 1. The solar still has an effective basin area of 0.9 $m^2$ and 0.25 m height. The solar still construction has been made of polyethylene. The thicknesses of side walls and the base are 8 mm and25 mm, respectively. A glass cover with the glass inclination of 36° has been fixed with respect to the horizontal axis. The glass inclination was the same as the latitude of the test location in order to receive the maximum annual solar radiation [25]. The solar radiation incident passes through the glass with a thickness of 4 mm and subsequently the solar heat is absorbed by a black plate in the bottom of the basin. Thus, the saline water is heated, and evaporation takes place. The distillate water is collected by a channel which is of galvanized steel sheet and connected to outlet (drain pipe). A hole in the still sidewall allows inserting two K-type thermocouples with accuracy of ±0.5 °C for measuring the basin water temperature as well as the inside air temperature. The fan has been installed in the middle of one of the side walls in the active solar still.

The experiments were conducted during the summer and winter seasons to examine the solar still performance. The results are presented only for two typical days in June (summer) and two typical days in January (winter). Also, to study the water depth effect on the performance of solar still; the tests were conducted for two different water depths. The water depth of 4 cm was considered as the reference depth and 8 cm was selected to investigate the effect of increasing the water mass in the basin up to 2 times of its reference value.

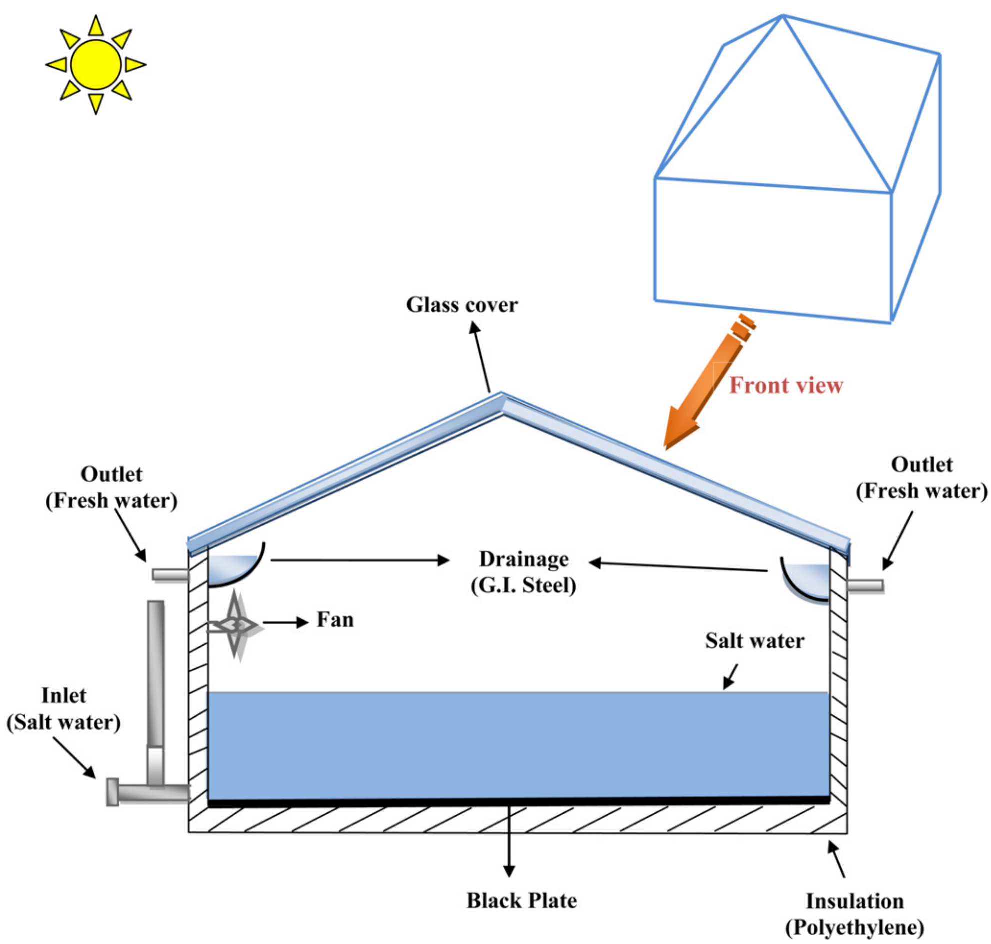


**Fig. 1.** Schematic of the active solar still.