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Experimental investigation of a multi-effect active solar still: The effect of the number of stages

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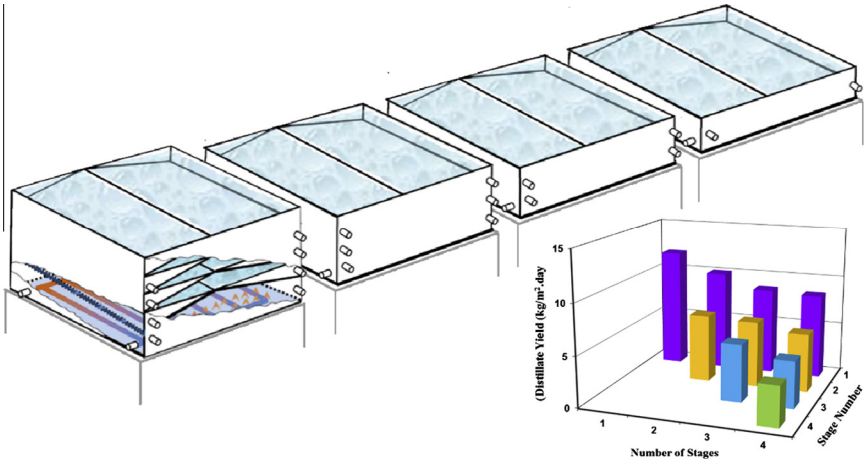
HIGHLIGHTS

- The effect of number of stages in a multi-effect active solar still was studied.
- The system performance in continuous and non-continuous modes was compared.
- Experiments were performed on 4 similar solar stills with different stages.
- Productivity can be predicted by a quadratic function of number of stages.
- Productivity enhancement by adding more stages is higher in continues mode.

GRAPHICAL ABSTRACT



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ABSTRACT

In this work, the effect of the number of stages on the productivity of a multi-effect active solar still was experimentally investigated for the first time. Moreover, system performances in continuous and non-continuous modes were compared. For this purpose, indoor experiments were conducted on 4 similar solar still devices with different stages (1–4 stages) in order to accurately control the environmental conditions. In addition, water production was hourly measured during the whole 24-h experiment. The results show that with increased number of stages, distillate production can be predicted with a quadratic function. Moreover, adding a maximum of 6 and 10 additional stages can significantly increase production in continuous and non-continuous modes, respectively. It was also concluded that with more stages, the production enhancement is more in the continuous mode compared to the non-continuous mode, in a way that there is no significant difference between the performance of the single-stage device in continuous and non-continuous modes.

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1. Introduction

One of the methods for addressing the water crisis is desalination, which is recognized as a stable source for the production of water. The problems arise from the consumption of a significant amount of energy during the desalination process [1]. Since this process needs a significant amount of energy, supplying it with fossil fuels will result in many adverse effects on the environment due to the emission of significant amounts of greenhouse gases (about 3.8 kg CO_2-equivalents (CO_2-e) per m^3 of desalinated water) [2]. Renewable energies are recommended in order to deal with this problem. One of the available renewable energies for the desalination of brackish water is the solar energy. Research has indicated that solar stills may be economically viable if a small deal of water is required, and it is costly to provide the pipework required for supplying an arid area with water [3].

Valuable research has been conducted on various types of solar stills to date [4]. Solar stills can be classified into passive and active and also single-stage and multi-effect groups based on different viewpoints. Passive systems [5] receive energy from merely direct solar irradiation. Furthermore, other than the solar energy received directly, active systems [6–8] receive energy from an external resource to expedite water evaporation rate. Single-stage systems [9,10] use the input energy only once, while multi-effect systems [11,12] reuse the energy released from the vapor condensed in the next stage for desalination.

As the name suggests, a multi-effect active solar still is a device benefiting from the advantages of both multi-effect and active systems. Having multiple stages is its most prominent feature compared to ordinary solar stills and allows for multiple practical use of the input energy. However, due to thermal dissipation and the fact that systems are not ideal, this is not fully achieved in real conditions. Therefore, the effect of the number of stages is one of the most important parameters in multi-effect solar stills which should be investigated.

Fernandez and Chargoy [13] investigated the annual performance of a 7-stage solar still. They concluded that the basic principle of multi-effect desalination of seawater is sound and reliable, and can result in very simple operation of the ensuing apparatus. However, further effort must be made to determine a more successful sizing of the distillation unit.

To our knowledge, no experimental research has been conducted on the optimization of the number of stages in multi-effect

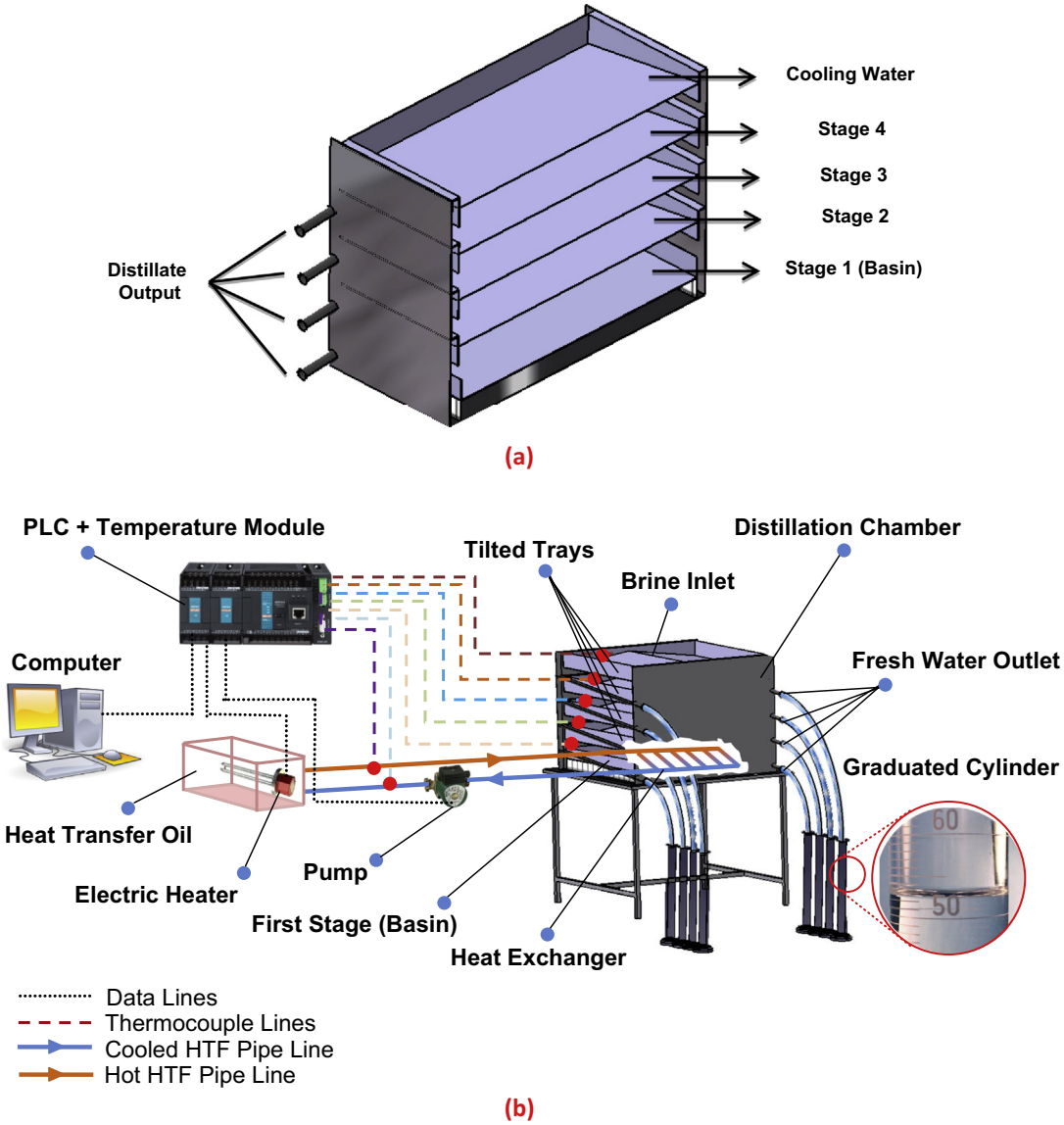

Fig. 1. The schema of the 4-stage device (a) a cutaway diagram of the evaporation chamber and (b) the experimental set-up.