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Investigation of the Effect of Parameters Related to the Absorbent Fabric on the Performance of The Stepped Solar Still Using the Taguchi Method

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ABSTRACT: Providing fresh water has been one of the most important concerns of mankind and various methods have been used to solve this concern. In this regard, one of the simplest devices is the stepped solar still. In this research, the effect of using fabric as an absorbent material and its related parameters on the amount of freshwater production has been investigated experimentally. In this regard, stepped solar still has been built and the parameters related to the fabric and their interactions have been tested. These parameters were: type, color, number of layers, and the angle of the fabric relative to the surface of the steps, as well as the height of the water weir in each step. The experiments were designed using the Taguchi method. Among the examined parameters, the color and the material of the fabric have been identified as the most effective factors in increasing the volume of produced fresh water. The results showed that the maximum water production during the day was 2790 ml/m2 using black cotton fabric in three layers with an angle of 90 degrees relative to the steps' surface and a water weir height of 1 cm.

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1- Introduction

There are many ways to distill salt water and produce fresh water. Furthermore, many devices have been created and used in this field. The stepped solar still is one of the most common devices in this field. El-Agouz [1] investigated and compared the stepped solar still device with the conventional type. As a result of investigating the effect of installing a storage tank and black cloth on the efficiency of distillation on the stepped solar still device, he has found that the yield of the modified device is 20% higher than the normal type.

Xiao et al. [2] have presented a new type of stepped solar still with a channel under the fixed basin of the device in order to increase the amount of heat transfer and have investigated the effects of this channel on the efficiency of fresh water. Their results showed that when the depth of the channel is equal to 1 cm, the heat transfer rate from the surface of the stairs of the device to the water is improved by 44%, and as a result, the average temperature of the salt water inside the device and the overall extraction rate of the device have respectively improved up to 16.4% and 51.7%.

Kabeel et al. [3] investigated the use of a wick on the sides of each stair of a stepped solar still to increase water extraction. The results showed that the use of the wick increased the efficiency of the device by 53% at a cost of $0.039 per liter of water. Alaudeen et al. [4] investigated the effect of various variables of the stepped solar still. The topics investigated by them were the use of heat storage materials as well as wicks. The results have shown that the use of pebbles as a heat storage material as well as the use of wick have increased the rate of evaporation and water extraction from the device.

In the conducted research, the effect of variables such as the use of absorbent materials, heat storage materials, the installation of internal and external reflectors, etc., on the increase of water extraction from solar stills has been studied. The investigation of these variables has been done in order to increase the water temperature, increase the distillation rate, reduce costs, and generally with the main goal of improving the performance of the solar still. In the current research, the fabric is used as a cheap and available absorbent material, and its related parameters have been investigated to improve the performance of the device as an innovation. The fabrics used in this research were cotton, dense fustian, and polyester fustian. The studied parameters were: type of fabric, color of fabric, number of layers of fabric, angle of fabric relative to the surface of the stairs, and height of water weir. Another innovation of this research was to examine all five parameters simultaneously.

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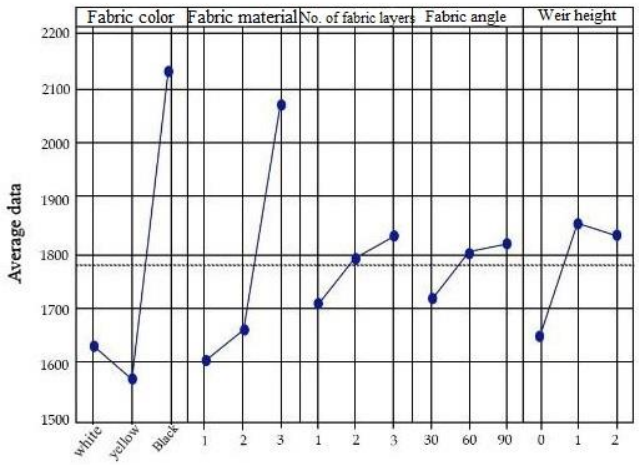

Fig. 1. The graph of the average effect of variables on the amount of produced water in the experiments

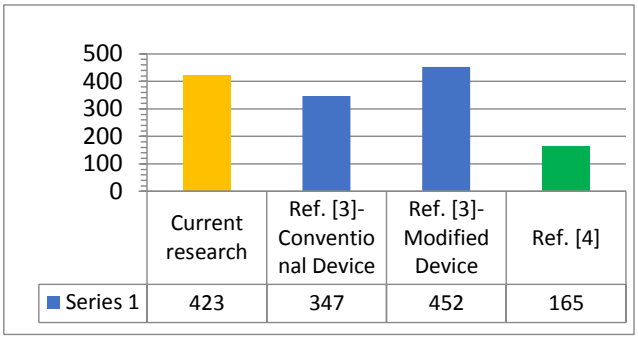

Fig. 2. Comparing the amount of hourly average of produced water in milliliters per square meter in this study with other similar research

2- Methodology

In this research, a stepped solar still similar to the dimensions and sizes of other researchers has been manufactured, and by conducting various experimental tests on it in Arak city in the months of June and July, the effect of using fabric on the performance and amount of fresh water production has been investigated. Finally, in order to obtain the regression equations related to the amount of water production according to the experiment variables, statistical and theoretical work has been done.

3- Results and Discussion

Following the experiments, the results were analyzed. The effect of each of the five parameters on the amount of fresh water produced has been investigated using different methods, including the Manova test, regression analysis, and the Taguchi method. The results of the experiments showed that among the 3 types of fabrics, cotton, dense fustian, and polyester fustian had the highest water absorption, respectively. In terms of absorbing sunlight and heat, black is the most effective of the three fabric colors, followed by yellow and white. Also, the results have shown that with the increase in the number of fabric layers, more water remains in the stairs, so the amount of fresh water production in the device has increased. Another checked parameter was the fabric angle. Among the selected angles, the 90-degree angle had the highest efficiency in the device, and after that, 60 and 30 degrees have been effective in increasing the efficiency of the device. The height of the water weir was the final parameter considered, with the highest efficiency in the state with a weir height of 1 cm, then in the state with a weir height of 2 cm, and finally in the state without a water weir. The results of all experiments are summarized in Fig. 1.

4- Validation

In order to better compare the results and draw correct conclusions, in Fig. 2, the hourly average amount of water production per surface unit in the current research is compared with references [3] and [4]. As can be seen, the current research compared to the conventional device in reference [3] as well as the research done in reference [4] has achieved better results, and compared to the modified device in reference [3], there is only a 6% difference. Therefore, the results obtained in this research are appropriate and have an acceptable trend.

5- Conclusion

The results obtained from this research showed that the best type of absorbent fabric to be used in a stepped solar still was cotton, which has better water absorption due to its fiber type and the density of its texture. Also, black has performed better due to absorbing more energy than other investigated colors. In addition, when using more layers of absorbent fabric, the amount of water absorbed increased, and as a result, the output of fresh water was higher. Also, the maximum amount of water extraction during the day in various experiments from 10:00 a.m. to 16:00 p.m. was equal to 2790 ml/m^2, using three layers of black cotton fabric at an angle of 90 degrees with respect to the surface of the stairs and with 1 cm-high water weirs.

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