Results of theoretical and experimental studies of the tilt-multistage solar water desalination plant

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Abstract. This paper presents the results of an experimental study of an inclined-multistage solar water desalination device in the climatic conditions of the Bukhara region. At the same time, changes in temperature in the elements of the device during the season and during the day, as well as changes for water received from the device at this time, are shown in the graphs. Studies carried out in natural conditions showed that the maximum water consumption of 7.5 liters was reached from the surface of 1m2 of the device in July. Based on the generalization of the results of numerous experimental studies, a regression equation was developed that evaluates the effectiveness of the device.

1 Introduction

Water and solar energy are natural resources and essential resources for all living organisms on earth. Water and energy are basic human needs. The availability of clean drinking water in domestic services and agriculture, as well as in industry, is the most urgent need of human society in many countries [1]. The amount of available fresh water on the globe is limited and almost constant, but with the rapid growth of population, the demand for fresh water around the world will increase significantly. Unfortunately, we are constantly losing fresh water supplies, mainly due to the use of fresh water in industry. Industrial waste and sewage continue to pollute groundwater. Polluted water is not only harmful to human health, but also has a negative impact on all living organisms in this world. Drought and desertification are accelerating all over the world, which complicates the problem of fresh water scarcity [2, 3].

2 Literature review

As a convenient solution to these problems, desalination of salt water using solar-powered desalination plants is considered to be economically and environmentally efficient [4]. Traditional solar water heaters have a simple technical design and are passive solar installations. Their production is economical and does not require highly qualified technical personnel for the manufacture and operation of the device. However, traditional solar water

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purification devices still have some drawbacks that sometimes prevent this system from being used for large-scale production [5].

Solar water makers are simple devices that can be used to convert salt water into fresh water. The mode of operation of the device on solar energy is simple; it works based on the condensation of evaporated water by evaporating the brine. This process is repeated continuously [5-6].

3 Analysis

Schematic and full-scale images of devices used in the study of heat and mass transfer processes in an inclined multi-stage solar water treatment device are shown in figure 1.

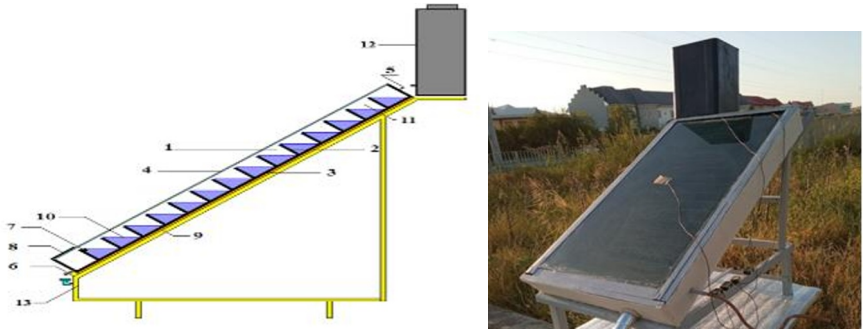

Fig. 1. Schematic and general view of a tilting multi-stage solar water desalination plant.

1-metal case of the device; 2 - steps of the device; 3-base of the device; 4 - transparent surface (glass); 5-pipe for pouring brine; 6 - outlet pipeline for desalinated water; 7-outlet pipeline for excess brine; 8-protective coating against beam hit; 9-thermal insulation material; 10-surface of the brine; 11-volume occupied by the steam-air mixture; 12-capacity for storing brine; 13-wooden base on which the device is placed;

The experimental device works according to the following principle. The inclined multi-stage solar desalination plant is placed at a certain angle to the wooden base 13; the brine storage tank 12 passes the brine through the desalination pipe 5 into the metal body of the device 1. The stages of the device 2 are filled with saline, excess salt-water exits through the outlet pipeline 7. The thermal insulation material 9 is installed outside the base of the device 3, and on top of it, a wooden material protects the surrounding thermal insulation. Salt water inside the chamber sections of the device evaporated by absorbing heat from inside the bottom of the chamber, and then condensed on the transparent surface of the device (glass) 4. The distillate was collected in a separate tank through the desalination water outlet pipe 6, and the amount of collected water was measured using a beaker. During the whole season, experimental studies were carried out on the device, during which the temperature of the external environment, the temperature of salt water, the temperature of the vapor-air mixture, the temperature of the transparent surface on the inside of the device, the temperature between the base and the insulating layer, as well as the amount of fresh water obtained from the device were measured. The results obtained during the experiments are presented graphically in figures 2 and 3[6-7].

4 Discussion

In this paper, as an example, a graph of the dependence of temperature, that is, the temperature of the environment and the elements of the device, on the time obtained during

a one-day experiment on July 10 and 11, 2022 on the territory of the Bukhara region, is shown in figure 2. The amount of fresh water received at this time respectively represented in the graph in figure 3.

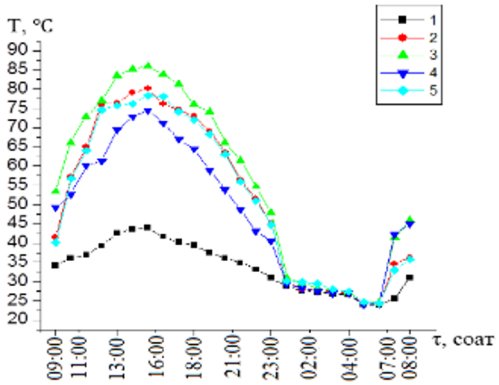

Fig. 2. Graph of the dependence of the ambient temperature and the elements of the device on time.

1-Outside temperature, °C, 2-Salt water temperature, °C, 3-Vapor-air mixture temperature, °C, 4-Inside transparent surface temperature, °C, 5-Temperature between base and insulation layer.

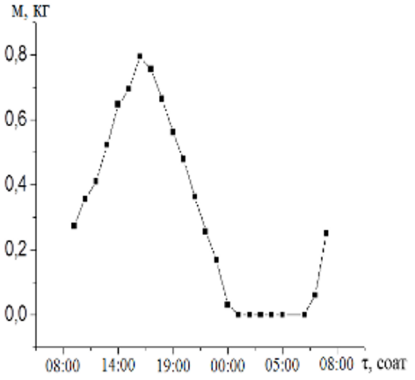

Fig. 3. Graph of the daily amount of fresh water received.

The change in average temperatures at the measurement points during the season (from May to October) and the resulting average amount of water during this time are respectively presented in the graph in figure 4 and figure 5.

The results of the study show that from one square meter of the sloped multi-stage solar water maker, you can get an average of about 6 liters of fresh water per day during the season.

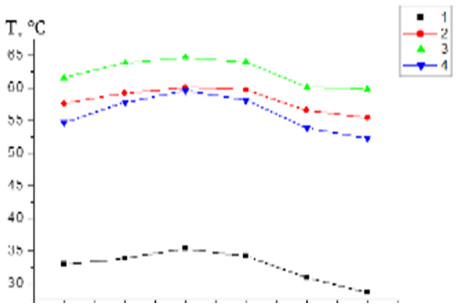

Fig. 4. A graph of the dependence of the ambient temperature and device elements on time (May-October)

1-Outside temperature, °C, 2-Salt water temperature, °C, 3-Vapor-air mixture temperature, °C, 4-Inside transparent surface temperature, °C,

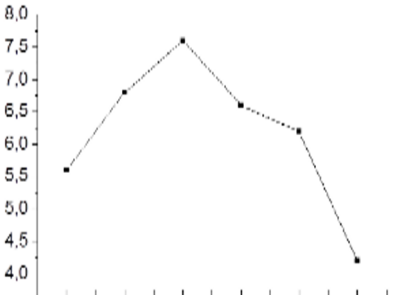

Fig. 5. Graph of the average amount of desalinated water received in May-October (2022-year)

As a result of the processes of conducting pilot studies at the installation, distilled water and its composition were obtained from it, the chemical composition of the physiological solution and the resulting distillate in the experimental installation was checked in the SEOM laboratory of the Bukhara region of the Ministry of Health of the Republic of Uzbekistan,

and a protocol was obtained based on the results of the check. The obtained protocol conclusions, as well as the results of comparing the water content in drinking water according to Uz SES, are shown in Table 1.

Table 1. The chemical composition of the brine and the resulting distillate in the experimental setup

№	Substances in water	Composition of water before treatment	Composition of water after treatment	Composition of drinking water according to Uz SES
1	water day	26.02.2020 y.	26.02.2020 y.	
2	Smell, On the score 20 ° C	0	0	2
3	Taste, Score 20 ° C	3	0	2
4	Color, Score 20 ° C	2	0	20 (25)
5	Turbidity, mg/dm^3	0,98	0	1,5 (2)
6	RN	8,0	5,0	6-9
7	Nitrite, mg/dm^3	0,18	нет	
8	Nitrates, mg/dm^3	20,2	нет	45
9	General hardness, mg/dm^3	37,4	0,28	7(10)
10	Dry residue, mg/dm^3	3361	63,0	1000 (1500)
11	Sulphates, mg/dm^3	1238	21,3	400 (500)
12	Iron, mg/dm^3	0,06	нет	0,03
13	Fluorine, mg/dm^3	0,08	нет	0,07
14	Chlorides, mg/dm^3	955	5	250 (350)

The regression equation was developed based on the generalization of the results of experimental studies conducted during the 2022 season (May-October) on an inclined multi-stage solar plant for desalination:

$$M_к = 0{,}66 + 0{,}007 \cdot q_T + 0{,}07 \cdot (T_a - 273{,}15)$$

In this equation:

$M_к$ is the amount of fresh water received from the device per day,

q_T is the average number of hours of sunshine during the day,

T_a is the moderate amount of temperature during the day.

The regression equation obtained on the basis of the results of an experimental study is suitable for the range $200\ \text{Wt/m}^2 \leq q_T \leq 600\ \text{Wt/m}^2$ $283\ \text{K} \leq T_0 \leq 313\ \text{K}$. It was found that the value of the correlation coefficient is 0.98.

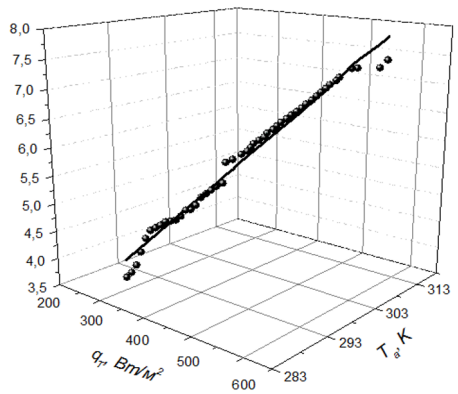

Fig. 6. Daily results obtained depending on the amount of fresh water, solar radiation and outdoor temperature.

5 Conclusion

The results of an experimental study of the installation of an inclined-multistage solar water desalination plant in the climatic conditions of the Bukhara region are presented. At the same time, changes in temperature in the elements of the device during the season and during the day, as well as changes for water received from the device at this time, are shown in the graphs. Experimental studies carried out in natural conditions have shown that a maximum water consumption of 7.5 liters was achieved from a device with a size of 1 m^2 in July from the surface. Based on the generalization of the results of numerous experimental studies, a regression equation was developed that evaluates the effectiveness of the device, and it was found that the value of the correlation coefficient is 0.98.

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