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Utilization of thermoelectric cooling in a portable active solar still — An experimental study on winter days

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ABSTRACT

In this study, an attempt has been made to produce a portable solar still. Because of the small size and low productivity, some techniques have been used to enhance and improve the performance of solar still. These techniques consist of using a solar collector, a wall covered with black wool, and water sprinkling system to increase evaporation rate and a thermoelectric cooling device to enhance water condensation. All walls are made from Plexiglas to make the still, unbreakable. To evaluate the performance of the still, the equipment was tested under the climate condition of Semnan (35° 33′ N, 53° 23′ E), Iran. The experiments were carried out in nine winter days and the results were measured in the same manner for each day. The results show that ambient temperature and solar radiation have direct effect on still performance but water productivity decreases when the wind speed increases. By comparing between the results of summer and winter, it is concluded that efficiency in summer is higher than winter. The results also show that the cost per liter of still is comparable with other type of solar stills.

1. Introduction

Since 1960, in many areas of the world, demands for potable water have been growing continuously. Potable water not only is important for life and consistency of environment, but also for domestic, industrial and agricultural purpose. Only about 0.014% of global water in the earth is directly available to human being and other organisms. On the other hand by polluting of water resources (lakes, rivers, and underground water) by industrial wastes, the problem of freshwater shortage has increased dramatically. Because sea water constitutes 97.5% of global water, many efforts have been made to convert salty water to fresh water [1].

Availability of freshwater is also important for life in remote areas or arid regions. Despite high solar intensity in those areas, the quality of most water resources is low. Desalination, vapor compression, reverse osmosis and electrodialysis are being used to provide freshwater from saline water. But the cost of energy consumption of these methods is high. On the other hand availability of energy in remote areas and most arid regions is low. Solar desalination is a solution for these problems. Solar stills are cheap, having low maintenance and solar energy is abundant, never lasting, and available on-site, and pollution free. However solar stills suffer from their low productivity [2].

Because of their advantages, solar stills have been an interesting subject for many researchers. In recent years, many attempts have been made either for setting up various types or to increase the performance and productivity of solar stills. Mirza et al. [3] made a simple basin solar still and measured its properties. His still's performance was about 30% and its daily productivity was 3.1 L/m^2. He reported that the output of his solar still varies directly with the amount of insulation it gets, and the ambient temperature. The effects of using fin, wick and sponge, in still productivity were studied by Srithar et al. [4]. They reported 29%, 15.3% and 45.5% increasing in productivity by using wick, sponge and fin, respectively. Kabeel [1] studied the performance of a concave wick evaporation surface solar still. The average daily productivity of his still was 4.1 L/m^2 and it had an average efficiency of 30%. Sadineni et al. [5] studied the performance of a weir-type inclined solar still. Their still's daily productivity was 5.5 L/m^2. They also reported, still has higher performance with thinner water films and by increasing the temperature difference between water and condensing surface. The same results (about the effect of water depth) have been also reported by Phadatare et al. [6]. The still was made by Plexiglas and its maximum daily productivity and efficiency were 2.1 L/m^{2}and 30%, respectively.

Many scientists have studied on improving the performance of solar stills. Rahin et al. [7] used various techniques to improve still productivity. They separated the evaporating and condensing zones, used cupper tube of condensing unit, introduced the black aluminum plate in the basin and used water pumping on the black walls. In all cases productivity of still was increased. The efficiency of their still was 31.1%. Abu-Arabi et al. [8] modeled a solar desalination unit with double glass collector. They concluded that by increasing the water-

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glass temperature difference, the productivity of still increases. The effect of using different rubber thickness and gravel size on still productivity is studied by Nafey et al. [9]. They reported the increasing in daily productivity with increasing in rubber thickness and gravel size. They also reported more improvements with using gravel instead of rubber.

The solar distillation systems are mainly classified into two main categories: passive and active solar still. In passive solar stills, the only parameter which affects on evaporation is solar radiation falling on water. But in active solar stills by using fan, pump or solar collectors, increasing in temperature difference between evaporating and condensing area, and so enhancement on productivity is achieved.

There are a lot of works on active solar stills. Abdallah et al. [10] used a sun tracking system to improve still productivity. With this system, they obtained 22% enhancement in still productivity. Voropoulos [11] studied the effect of using solar collector on the performance of solar still. He reported by using solar collector and storage tank, the productivity is doubled. By thermal modeling of a double slope active solar still, Dwivedi et al. [12] showed that thermal efficiency of double slope active solar still is lower than the thermal efficiency of double slope passive solar still. However, the exergy efficiency of double slope active solar still is higher than the exergy efficiency of double slope passive solar still.

Sanjeev et al. [13] developed a theoretical model for predicting the daily yield from an active double effect solar still. In their equipment, the latent heat of condensation is utilized for further distillation by flowing water over the first condensing cover. They reported that by increasing collector area enhancement on productivity is achieved, but the overall efficiency decreases. They also showed that by increasing the water depth, daily yield and overall performance decrease. To have a maximum yield, they also proposed 1.8 m/s water flow velocity over the cover.

Singh [14] proposed an analytical expression for water temperature of an active solar still with flat plate collectors and parabolic concentrator through natural circulation mode. The results showed that the efficiency in concentrator is higher than parabolic collector. Prasad and Tiwari [15] presented an analysis of a double effect, solar distillation unit coupled compound parabolic concentration (CPC) collector under forced circulation mode. They reported that temperature of water in the lower basin is higher than that of single effect solar still. But due to decreasing temperature difference between water and glass, the daily yield in lower basin is reduced. However the overall efficiency is increased because the second stage absorbed latent heat of condensation of first stage and this enhanced the evaporation rate in second stage.

Kumar and Tiwari [16] designed a hybrid photovoltaic thermal (PV/T)-integrated-active solar still. In their equipment, they used the thermal energy of Photovoltaic panel to heat water in the collector. They reported that hybrid-active solar still gives a higher yield (more than 3.5 times) than the passive solar still.

El-Sebaii et al. [17] studied the thermal performance of a single slop solar still with PCM as a storage medium. They reported that after sunset, the PCM acts as a heat source for the basin water until the early morning of the next day. So the daily output decreases but the productivity at night increases. Their results showed double production of pure water on a summer day with a daily efficiency of 84.3% compare with simple solar still.

Tanaka and Nakatake [18] designed a compact multiple effect diffusion type solar still consisting of a heat-pipe solar collector and a number of vertical and parallel partitions in contact with saline soaked wicks. Their equipment can be folded or separated when it is carried. They produced about 21.8 kg/m^2 day on a sunny autumn day on 24.4 MJ/m^{2}day. They claimed that the productivity of the proposed still is 13% larger than that of the VMED still coupled with a basin type still.

As mentioned before, solar stills are used in remote areas which availability of water is limited. But they are so heavy to being carried easily by humans. Basel [19] made a transportable hemispherical solar still and measured its performance, but the size of the still was large, and he used four wheels to make it transportable.

Due to portability, the size of still must be reduced. So the received solar radiation, the size of condensing and evaporating zones and consequently the productivity and efficiency of still are decreased. To the best knowledge of the authors of the present paper there are not enough investigations on portable solar stills. In the present work, by using the conclusions, mentioned in previous researches [7,8,11], a new and simple design method is proposed to make a portable solar still. Also thermoelectric technology is used to increase temperature difference between evaporating and condensing zone and overcome its low productivity. The daily performance under Semnan climate condition was also evaluated.

2. Thermoelectric refrigeration

In 1821, a German physicist, Seebeck observed that if a closed circuit was made of two dissimilar metals, an electric current is produced in the circuit when the two junctions were maintained at different temperatures. In 1834, Jean Peltier, discovered a reverse phenomenon to that of Seebeck. He found that there is a heating or cooling of a junction of a pair of dissimilar substance, if direct current is passed through them. This discoveries were not used until 1838 when Lenz, a German scientist showed the importance of them. He froze and melted a water droplet by these effects which led to the concept of thermoelectric refrigeration [20].

In commercial types, the TECs consist of P-type and N-type blocks of semiconductor materials. Fig. 1 shows the schematic design of commercial TEC modules. When electrons pass through P-type to N-type semiconductors, cooling effect or Peltier effect occurs.

Thermoelectric coolers have no moving parts, so, they have very long life. They are noiseless, simple, compact in size, easy controllable, suitable for low capacity or case in which the energy cost is not the main consideration. These equipments can operate in any position and they have not any leakage problems. TEC's can efficiently work with photovoltaic panels due to low voltage requirement and they can accept a power supply directly from PV panel.

Because the performance of Peltier devices is almost independent of its capacity, they have definite advantages for cooling small enclosures. So many manufacturers use them for cooling cold boxes especially when the power source is 12 V. The thermoelectric devices are also insensitive to movement, so they are attractive for use in portable devices [20–22]. Fig. 2 shows configuration of the Peltier cooling unit used in this study to cool the condensing zone.

3. Experimental setup

To design a portable solar still, some essential characteristics should be taken into account. It must be less in weight, unbreakable,

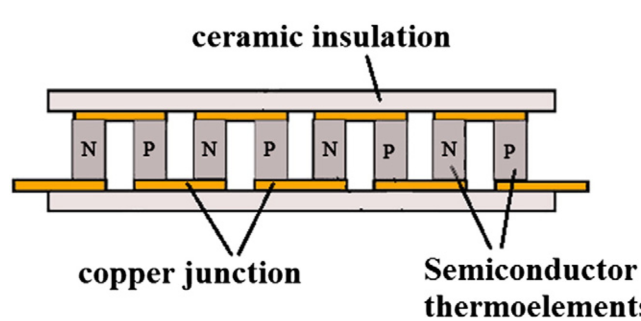

Fig. 1. Schematic designs of commercial TEC modules.

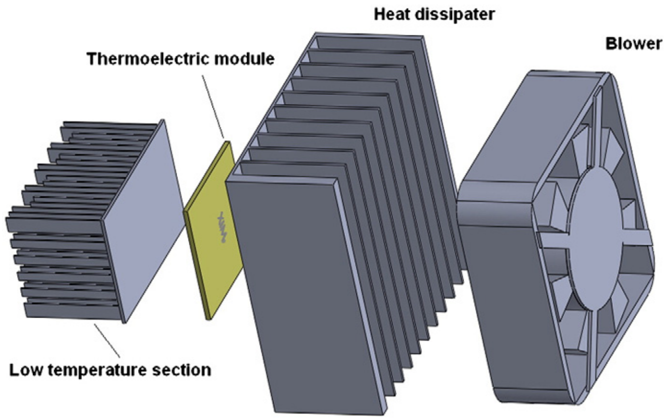

Fig. 2. Configuration of a Peltier cooling unit.

easily mounted, corrosion proof, and if it is an active solar still, it should have a power source. In this study, a 12 V power source was chosen for driving pump, fan and thermoelectric cooler. In this manner the still has the ability to work with photovoltaic solar panels.

The investigated solar still was fabricated from Plexiglas of thickness 10 mm. A schematic diagram of this still and its dimensions are shown in Fig. 3, whereas Fig. 4 is a photograph of the still. As shown in Fig. 3, the device consists of an evaporating and a condensing zone.

At the start of every experiment, evaporating zone which has the maximum capacity of 4 L was filled with raw water. Right side and the bottom of evaporating zone have been fabricated with black colored Plexiglas and also covered with black wool to absorb maximum solar radiation.

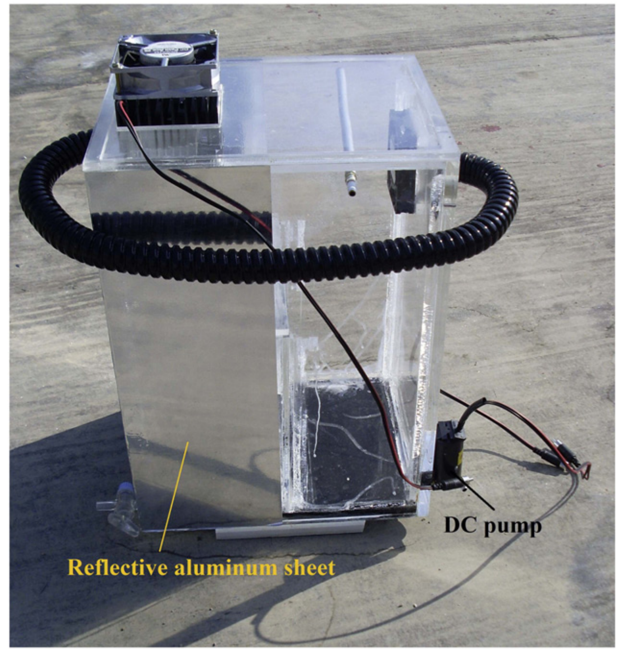

Fig. 4. Photograph of the portable solar still.

Due to portability, the size of still was reduced, so some efforts have been made to compensate reduction in productivity. As shown in Fig. 4, a small DC pump (2 W) was fixed at the bottom of evaporating zone. The pump sends water to a portable parabolic solar collector (40 cm × 24 cm plane area) which is shown in Fig. 5. The collector focuses the solar radiation on a copper tube (18 mm diameter) mounted on the collector's focal length of $f = \frac{r}{2} = 9$ cm to warm water. The collector has been made so that it can be mounted easily and it can be adjusted and inclined in every angle to stand directly against the sun. Then the produced hot water is send to an aluminum tube fixed at the top of evaporating zone. The tube has the diameter of 7 mm and 26 small holes have been drilled on the tube to sprinkle water into the evaporating zone.

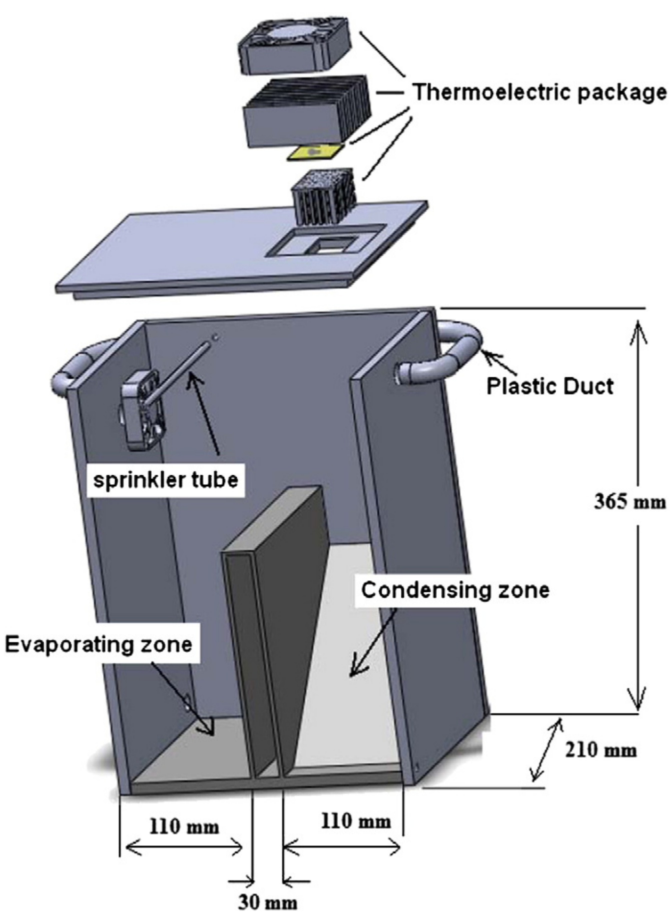

Fig. 3. A schematic drawing and dimensions of the experimental setup

Fig. 5. Photograph of the portable solar collector.

As mentioned before, black sides of the evaporating zone are covered with black wool to enhance absorption of solar radiation. Also due to its capillary effect, the wool increases the wettability and effective evaporating area.

To produce force convection and increasing water evaporation, there is a fan behind the sprinkled water. The fan forces humid air to condensing zone where it contacts to cooling area. A plastic duct is positioned at the other side of device, guides air to pass again to the fan. When the humid air contacts to cooling area, water vapor condenses on the fins which have the temperature lower than dew point temperature of humid air.

As shown in Fig. 3, to prevent heat transfer between evaporating and condensing zone, there is a 30 mm gap between them. Cooling area consist of an arrangement of fins which cooled with thermoelectric cooler. The thermoelectric cooler is also cooled with an arrangement of fins and a fan (0.5 watt power consumption). The TEC's model is TEC1-12706 and it was manufactured by HB Corporation. These fins are mounted at the top side of condensing zone, exactly in front of the humid air flow. The condensed water collect on the fins, drop into the condensing zone. The bottom side is inclined so that droplets can be easily collected and conducted to the outside of still. To prevent the evaporation of condensed water due to solar radiation, all sides of condensing zone are covered with reflective aluminum sheet (Fig. 4).

4. Experimental procedure

Due to the measurement of the performance, the setup was tested under Semnan (35° 33′ N, 53° 23′ E) climate condition. Nine winter days (between 5 and 30 of December 2009) were chosen to collect data and a summer day was chosen to compare winter and summer performance. The experiments were carried out every winter day from 9 a.m. to 4 p.m. In literature it was said that water depth has an inverse effect on still productivity [6,23–26]. So to avoid this, in all case the volume of water at the beginning of experiments kept constant at 3 L. Also due to scale prevention, the still was cleaned before every experiment. During these periods, the ambient climate conditions (solar radiation, ambient temperature and wind velocity), water productivity, and water quality (TDS and PH) were measured. Also for studying the instantaneous effect of climate condition on still performance, another experiment was conducted in one day (12/30/2009), during which the above measurements were recorded every hour.

5. Solar still efficiency

An instantaneous efficiency of a solar still η_i, defined as the ratio of the energy used for water production to the total solar radiation rate [1]. For an active solar still it is given by [25]:

$$\eta_i = \frac{Q_{ev}}{I(t)_c A_c + I(t)_s A_s} \tag{1}$$

$$Q_{ev} = \dot{m}_{ev} L. \tag{2}$$

where Q_{ev} is evaporative heat transfer (w), $\dot{m}_{ev}$ is distilled water production rate (kg/s), A_s is the still base area (m^2),A_c is the collector area (m^2), $I(t)$ is the solar radiation fall upon the still and collector surface (w/m^2) and L is the latent heat of the water (J/kg).

The solar still daily efficiency, η_d, is obtained by summing up the hourly condensate production multiplied by the latent heat of vaporization and divided by the daily average solar radiation over the solar still and collector area, calculated from the following equation [25]:

$$\eta_d = \frac{\sum \dot{m}_{ev} L}{3600\left(\sum \left(I(t)_c A_c\right) + \sum \left(I(t)_s A_s\right)\right)}. \tag{3}$$

6. Experimental uncertainty analysis

Error is the difference between the measured value and the true value of the measurand. There are two types of error: random error and systematic error. Random errors are changed when the experiments are carried out under unchangeable conditions but systematic errors are unchangeable.

The uncertainty is usually expressed as an interval around the estimated value. With any such interval we associate a probability that the actual or true value of the measurand falls within that interval. There are two types of uncertainty: Type A and Type B. Type A is regarded to random errors and can be measured with statistical and repeatedly methods, where Type B is regarded to systematic errors and may be determined by looking up specific information about a measurand such as that found in a calibration report or data book. Because there is no statistical analysis in reading the report of a measuring device (for example digital multi-meter or thermometer), the uncertainties of their reading values are always Type B [27, 28].

The distribution of the errors that make up an uncertainty of Type B is sometimes claimed to be uniform. A uniform distribution in metrology arises more often as an expression of our ignorance rather than as a description of observable fact. Type B occurs when a continuous variable, such as a voltage, is measured and displayed by a digital multi-meter, solarimeter, anemometer, etc. The reason is that, there being no statistical treatment available such as would be provided by usefully repeated measurements, all that is known are the end-points within which the quantity can plausibly vary; hence it must be uniformly distributed between them. Therefore, in our measurements, all measurands are supposed to be distributed uniformly. In these cases the standard uncertainty is expressed as [27,28]:

$$u = a / \sqrt{3} \tag{4}$$

a is the accuracy of the instrument, and u is the standard uncertainty. The uncertainties associated with the experiments are shown in Table 1.

7. Results and discussion

7.1. Experimental results

Solar intensity has a major effect on the performance of solar still [29]. Fig. 6 shows the variation of hourly productivity and solar intensity on the last day of experiments (12/30/2009). Fig. 6 shows that, the solar intensity and the productivity have a same trend except between 2 P.M and 3 P.M in which the solar intensity was constant but due to increasing ambient temperature and decreasing wind velocity, the productivity increased. Also the productivity of the equipment had the maximum value of 250 cm^3/m^2 when the solar radiation was at its maximum value of 728w/m^2. Fig. 7 shows the daily productivity and total solar radiation during 9 days between 5 and 30 of December 2009. It is concluded that the productivity is directly proportional to daily solar radiation.

Table 1
Accuracies, ranges and standard uncertainty of measuring instruments.

	Instrument	Accuracy	Range	Standard uncertainty
1	PH meter	0.01PH	0–14	0.006PH
2	Kipp-Zonen Solarimeter	1 w/m^2	0–5000 w/m^2	0.6 w/m^2
3	Anemometer	0.1 m/s	0.4–30 m/s	0.06 m/s
	Temperature (type K)	0.1°C	−100 to 1300°C	0.06°C
	Relative Humidity	0.1%RH	10 to 95%RH	0.06%RH
4	Volume meter	0.2 mL	0–5 mL	0.115 mL
5	Conductivity meter	1 ppm	0–2000 ppm	0.6 ppm
		10 ppm	2000–20,000 ppm	6 ppm

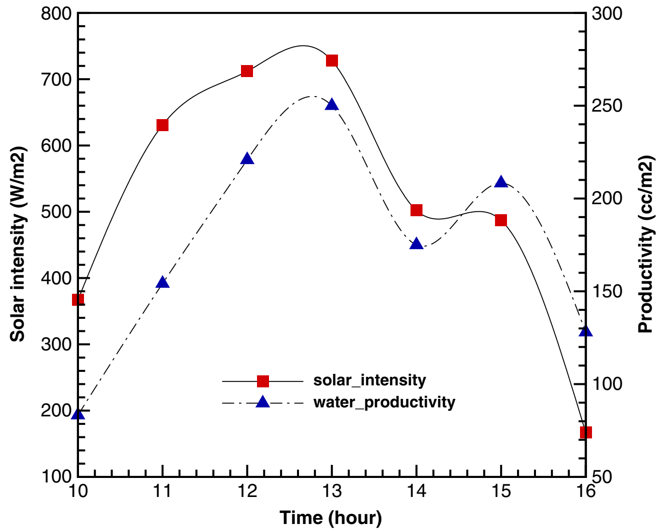

Fig. 6. Variation of hourly solar intensity and productivity on the last day of experiments.

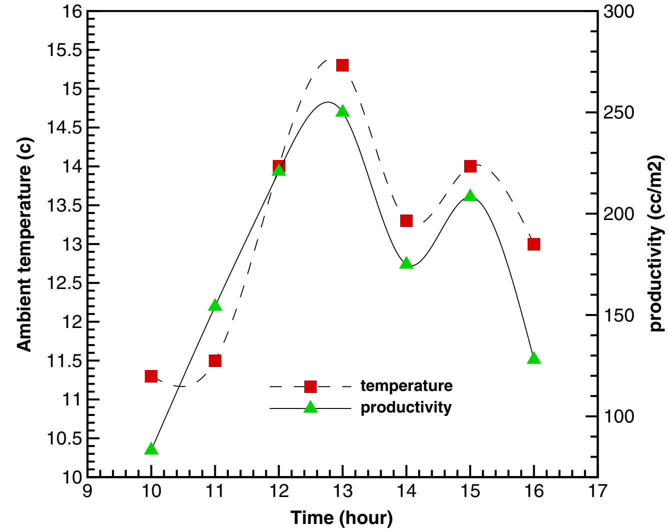

Fig. 8. Variation of ambient temperature and productivity on the last day of experiments.

The effect of ambient temperature on the performance of solar still is shown in Fig. 8. It can be concluded that when the ambient temperature increases, the productivity is also increased. This result is like of the results reported in literature [30–32]. It is seen that between 10 A.M and 11 A.M the temperature was approximately constant but due to increasing solar intensity, the productivity is increased. The variation of daily productivity, mean daily temperature and total radiation is shown in Fig. 9. It is seen that the behavior of productivity and solar intensity curves is more similar than that of ambient temperature, so, it means that dependency of productivity on solar radiation is more than ambient temperature.

Fig. 10 compares the effect of wind velocity and solar intensity on the still productivity. It was concluded that in this equipment, the behavior of productivity and solar intensity curves is more similar than that of wind velocity, so, it means that dependency of productivity on solar radiation is more than wind velocity.

Fig. 11 shows the hourly variation of instantaneous still efficiency during the last day of experiments, calculated from Eq. (1). It can be observed that the instantaneous efficiency increases with time. After 3 p.m. there is a sudden increasing in the efficiency. This is because of decreasing in solar intensity while the evaporation rate of water remains constant due to heat capacity of water. Fig. 12 shows the variation of daily efficiency calculated from Eq. (3) and total daily solar radiation during the period of experiments. Except the last day of experiment, daily efficiency directly trends similar to solar intensity manner. In the last day, solar radiation decreased but due to increasing productivity, the efficiency increased.

Fig. 13 shows the effect of solar intensity and ambient temperature on still productivity in a typical summer day (10/08/2010). It was concluded that like winter days, dependency of productivity on solar intensity is more than that of ambient temperature. Fig. 14 shows the hourly variation of instantaneous efficiency in a typical summer day (10/08/2010). It can be observed that efficiency trends similar to radiation manner except the end of day, at which the solar intensity decreased but because of constant rate of evaporation (due to heat capacity of water), the efficiency increased.

Fig. 15 compares the instantaneous efficiency between summer (10/08/2010) and winter (12/30/2009). The results show that instantaneous efficiency in summer is higher than winter. This is because of higher evaporation rate and higher water production in summer. Also it is concluded that summer efficiency has a maximum in the middle of the day, but winter efficiency has higher value at the end of day.

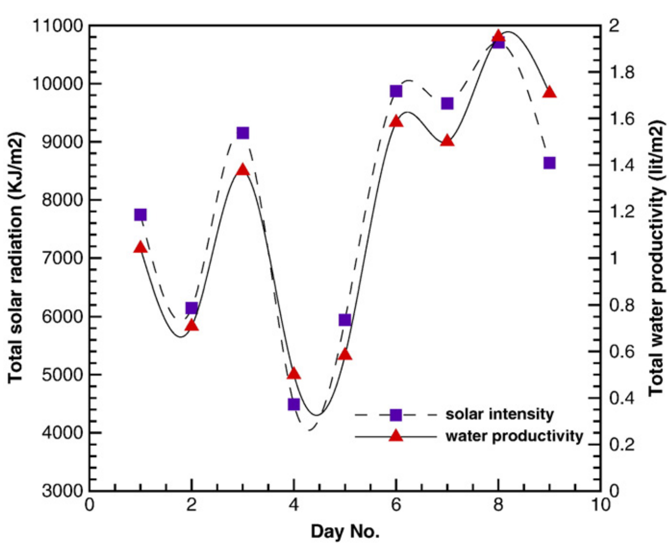

Fig. 7. Variation of daily productivity and total solar radiation during 9 days of experiments.

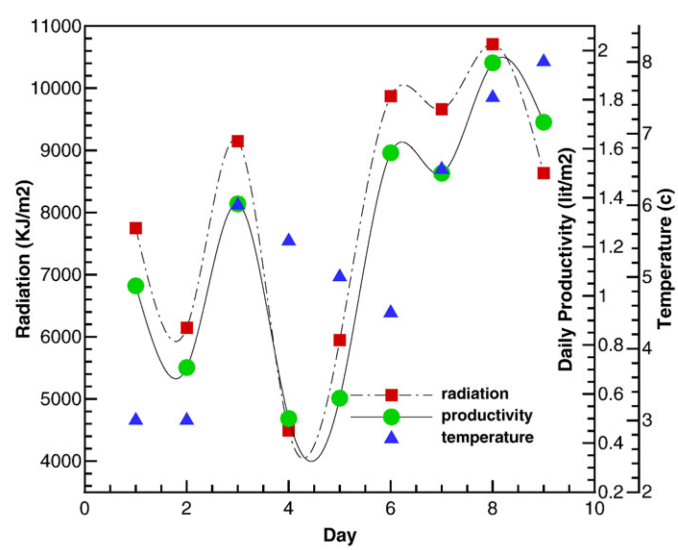

Fig. 9. Variation of mean daily temperature, daily productivity and solar radiation during 9 days of experiments.

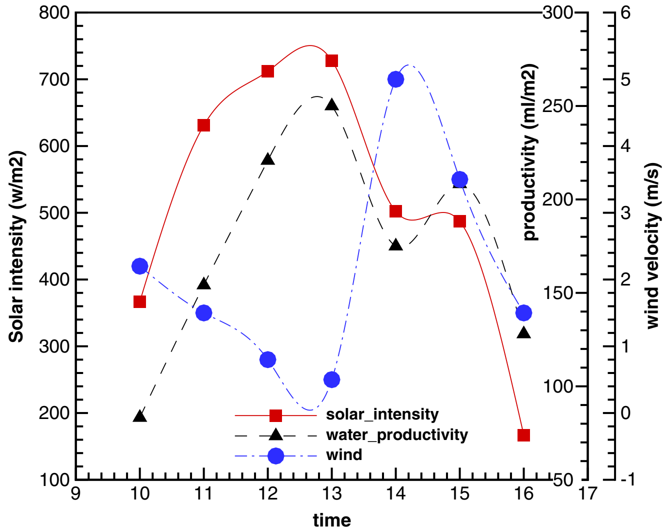

Fig. 10. The effect of wind velocity and solar intensity on the still productivity.

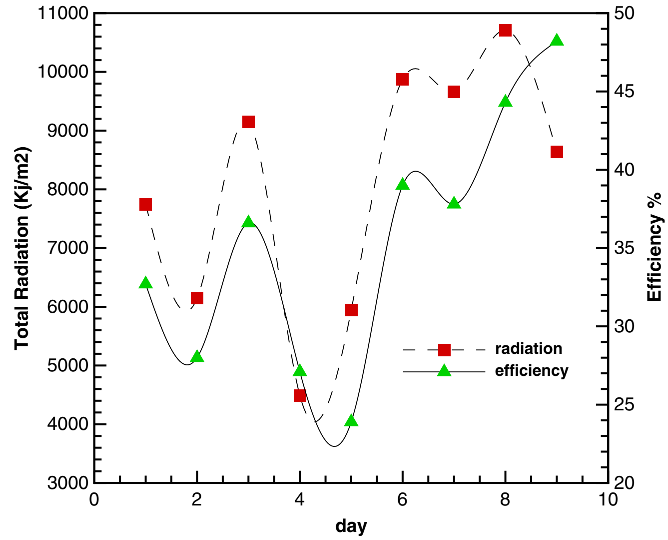

Fig. 12. The daily efficiency versus solar intensity during the period of experiments (winter days).

The device was also been tested without cooling effect of thermoelectric module. For this purpose the thermoelectric module was removed. In this manner the condensing area consisted of only aluminum fins. The device was tested in a summer day (10/08/2010) and results showed that the daily efficiency was only 2.7% for solar intensity of 28,329 kJ/m^2 and productivity of 933 cm^3/m^2. In conventional basin solar still, in a 24-hour experiment in summer climate, the cumulative water production of the still was around 1700 cm^3/m^2 [29]. Without using thermoelectric condenser, the efficiency and productivity are low. This is due to small size of evaporating zone and low absorption of solar intensity. The results show that by using thermoelectric cooler in a sunny winter day and for 7-hour experiment, the productivity was about 1700 cm^3/m^2 (basin area is 0.024 m^2). So by using solar collector and thermoelectric cooler, enhancement in water productivity was achieved.

The PH and TDS of the inlet and distilled water were measured every day. The results for the 3 last days of experiments are shown in Table 2 and confirm the ability of the solar still to produce fresh water.

7.2. Cost analysis

Typically, in designing a solar still the main object is to maintain the cost minimal. Cost estimation for various component used in the present work is given in Table 3. The cost of fabrication was about 290$ which is high in comparison of others, presented in literature [1,3]. The main part of the costs is for Plexiglas container. However this is unavoidable because of portability of the solar still.

Economical analysis of water desalination unit is given by Fath et al. [33], Kumar and Tiwari [34] and Kabeel et al. [35]. The main parameters in cost analysis of solar stills are CRF (capital recovery factor), FAC (fixed annual cost), and SSF (sinking fund factor), ASV (annual salvage value), average annual productivity (M) and AC (annual cost). Also there are other parameters like AMC (annual maintenance operational cost) and finally CPL (cost per litter). AMC is used for calculation of maintenance cost for removing salt deposits, maintenance of DC pump, Fan and thermoelectric module and regular filling of brackish water. Generally 15% of present cost has been considered as maintenance cost [33].

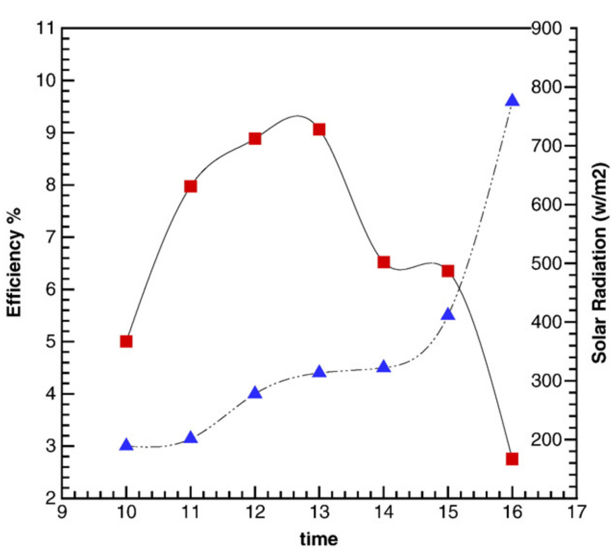

Fig. 11. The hourly variation of instantaneous still efficiency.

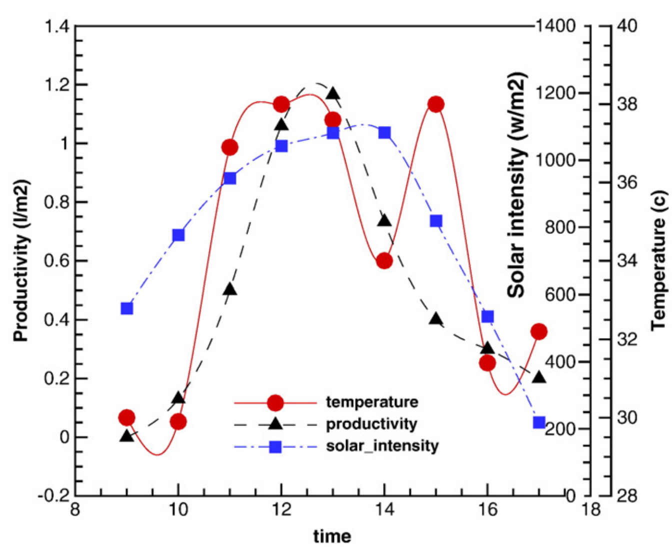

Fig. 13. The effect of solar intensity and ambient temperature on still productivity in a typical summer day (10/08/2010).

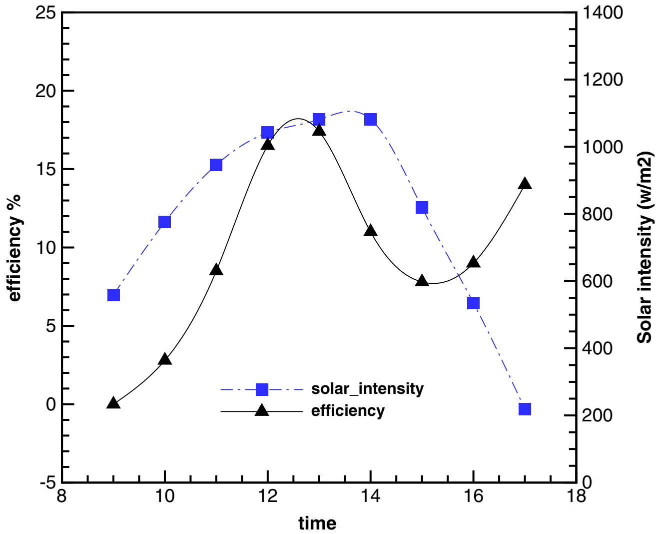

Fig. 14. The hourly variation of instantaneous still efficiency in a typical summer day (10/08/2010).

If P is the capital cost of the system and CRF is the capital recovery factor, the first annual cost of the system FAC can be determined by [35,36]:

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1} \quad (4)$$

$$FAC = P(CRF) \quad (5)$$

where i is the interest rate (12% in Iran) of lending banks and n the life of the system (10 years). The salvage value of the system S was considered as 20% of the cost of usable materials which were saved after the life of system.

$$S = 0.2\,P \quad (6)$$

$$SSF = \frac{i}{(1+i)^n - 1} \quad (7)$$

$$ASV = (SSF)S \quad (8)$$

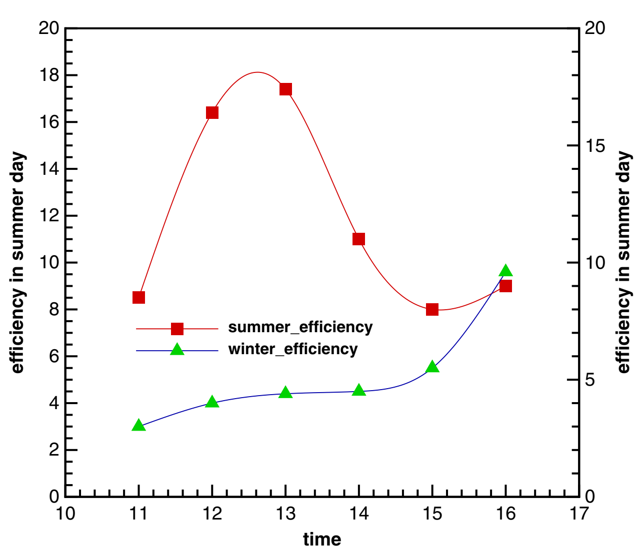

Fig. 15. comparison between instantaneous efficiency in summer and winter.

Table 2
PH and TDS during the 3 days of experiments.

	Day7		Day8		Day9	
	PH	TDS (ppm)	PH	TDS (ppm)	PH	TDS (ppm)
Inlet water	8	635	7.8	568	8.15	592
Distilled water	7.35	110	7.2	131	7.25	128

Table 3
Cost of fabricated solar still in the present work.

Unit	Cost of present solar still$	Salvage value $
Plexiglas container	230	46
Power 12 V	23	–
Collector's material	13	2.6
Thermoelectric cooler	12.5	2.5
DC fan	8	–
DC pump	4	–
Total cost	290.5	51.1

$$AMC = 0.15(FAC) \quad (9)$$

$$AC = FAC + AMC - ASV \quad (10)$$

$$CPL = \frac{AC}{M} \quad (11)$$

where M is average annual productivity. Table 3 provides the amount of salvage value for different parts of thermoelectric solar still. Table 4 provides the results of cost analysis on thermoelectric solar still supposed that average annual productivity of fresh water was 620 L/ m^2 (or 1.2 L/m^2day based on winter productivity). Table 5 provides a comparison between different type of solar still reported in literature [35], and thermoelectric solar still. Results show that this type of still has a reasonable productive cost compare with others.

8. Conclusions

In this work, a new portable solar still was designed, fabricated and experimentally tested during daytime for nine winter days under outdoor of Semnan (35° 33′ N, 53° 23′ E) climate condition. Because of portability, the size of the still must be lower than the conventional type of the solar stills. So for avoiding the reduction in productivity, a thermoelectric cooler is used to condense the evaporated water and a small portable solar collector was used for increasing water

Table 4
Cost analysis of thermoelectric solar still.

Interest rate %	M L/m^2	CRF	FAC	SSF	ASV	AMC	AC	CPL $/L/$m^2$
12	438	0.177	51.4	0.057	2.91	7.71	56.2	0.13

Table 5
Comparison between different type of solar still.

Type	M L/m^2	CPL $/L/$m^2$
Pyramid shape	1533	0.031
Sun tracking	250	0.23
thermoelectric solar still	730	0.13
Single slope	1511	0.035
Transportable hemispherical	1026	0.18
A weir type	1001	0.054

temperature. Based on the results obtained from the experimental work, the following can be concluded:

- The results showed the maximum efficiency of 13% for the still in winter.
- The cost of adding thermoelectric cooler is low, but due to use of Plexiglas material, the cost of the still is higher than the conventional stills.
- The average daily productivity of solar still in 9 days of experiments is 1.2 L/m^2.
- The productivity is increased directly with solar radiation and ambient temperature.
- Measurements on distilled water show that the distilled water is suitable for drinking.
- The effect of solar intensity on productivity is more that the effect of ambient temperature on productivity.
- The cost per litter for this type of still is lower than sun-tracking and Transportable hemispherical solar still.
- Results show that instantaneous efficiency in summer is higher than winter.

The experimental results of this work show the implementation of the thermoelectric cooling device on enhancing the still's productivity. The aim of this work is to begin a new field on improvement of solar stills. There are some suggestions for further works in the field of thermoelectric solar stills:

1. Using thinner plexiglas sheets for walls, to reduce capital cost of still.
2. Using PCM materials or black rubbers as heat absorption medium to enhance water production on night.
3. Reducing the condensing area and increasing evaporating area to enhance water evaporation.
4. Placing the top cover in an angle equals to latitude of city. In this manner it can be possible to use a collecting channel for collecting the condensed water on walls.
5. Using air bubbling system for enhancing water evaporation

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