Experimental Study of a Single – Basin Solar Still for Water Desalination

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Abstract:

An experimental investigation of single – basin solar still for distilled water production is presented. A solar still system of water-basin of 85x85 cm and 12cm height was designed and manufactured using available materials. A glass cover of 3 mm thickness fixed with inclination angle of $37°$in addition to mirrors fixed inside the solar still on the inner sides wall. The water basin base was painted using black dye. The insulating material is a rock wall of about 3cm thickness was used to insulate the solar still body from out side. The results show that the distill water production rate depends on the ambient temperature, water-basin temperature and water – vapor temperature. Also, the single-basin solar stilled designed and manufactured can be used reliably to produce drinking water in small remote areas such as villages in southern Iraq.

Key words: solar energy, desalination, solar still, experimental technique

دراسة تجريبية لتحلية المياه باستخدام المقطرات الشمسية احادية الحوض

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الخلاصة:

تم تصميم وبناء منظومة تقطير المياه احادية الحوض باستخدام الطاقة الشمسية من المواد المتوفرة محليا. تتكون المنظومة من حوض الماء المراد تقطيره بابعاد 85x85 سم وبارتفاع ١٢ سم وقد طليت قاعدة الحوض باللون الاسود لزيادة امتصاص اشعة الشمس الساقطة على الحوض . تم وضع غطاء زجاجي بسمك ٣ ملم وبشكل مائل بزاوية مقدارها ٣٧ درجة يغطي السطح العلوي المواجه للشمس من المنظومة. بطنت المنظومة من الداخل بواسطة مرايا تعمل على عكس الاشعاع الشمسي داخل حوض ماء المنظومة كما عزلت المنظومة من الخارج بواسطة عازل بسمك ٣سم والذي يستخدم عادة في التبريد لغرض منع تسرب الحرارة الى الخارج. تم قياس كل من درجة حرارة المحيط (الجو)، درجة حرارة ماء الحوض ودرجة حرارة البخار المتكون داخل المنظومة باستخدام ثرموميتر الكتروني. بينت النتائج التي تم الحصول عليها ان كمية الماء المقطر الناتج يعتمد اعتمادا اساسيا على درجة حرارة الجو وكذلك على درجة حرارة ماء الحوض ودرجة حرارة البخار المتكون. وبناءا على النتائج التي تم الحصول عليها فانه من الممكن استخدام مثل هذه المنظومة لانتاج الماء الصالح للشرب في

مناطق القرى والارياف حيث اعداد السكان القليلة مثل ماهو موجود في القرى جنوب العراق.

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Introduction:

The supply of drinking water is one of the major problems in developing countries. Clean water is a basic human necessary, and without water the life will be impossible. Solar distillation or desalination is a process to distill brackish/saline water by utilizing solar energy. The main advantage of this process is that it does not utilize costly conventional fossil fuel, which create pollution problem and the solar energy is naturally available.

Solar still has been used to produce low yield, but safe and pure supplies of water in remote areas. For households without access to portable water a simple solar still can easily produce the water needed for drinking and cooking . Also, distilled water can be used for industrial process (water jackets, batteries and chemical solution) [Badran(2007)].

The basic principles of solar water distillation are simples yet effective, as distillation replicates the way nature purifies water. The sun's energy heated water to the point of evaporating. As the water evaporates, water vapor rises, condensing on the glass surface for collection. This process removes impurities such as salts and heavy metals, as well as destroys microbiological organisms.[Al-Hyek and Badan(2004)].

Many experimental and theoretical investigations have been done on single slop stills. Al-Hinai et al.(2002) used mathematical method to predict the productivity of a single basin solar still in Oman. Abu- Hijleh and Rababa (2003) showed that the daily production of solar still can be greatly inherence using sponge cubes. Al-Karaghouli and Alnaser(2004) investigated single and double basin. El-Sebaii(2004) studied the effect of wind speed on the daily productivity of some active and passive solar still using computer simulation for different solar still designs. Imad and Badran(2004) showed that the productivity of asymmetric type still having mirrors on its inside walls was higher than that of type still and more efficient. Nijmeh et al.(2005) studied the effect of using different absorber materials on the productivity of a single – basin solar still. Phadatare and Verma(2007) studied the effect of water depth on internal heat and mass transfer in a single solar still. Badran(2007) studied experimentally the performance of a single slop solar still using different operational parameters.

In the present work an experimental study of a single – basin solar still for water distillation was curried out. The distilled water productivity, the water – basin temperature, vapor temperature and ambient temperature were measured.

Experimental setup:

A single basin type solar still was designed from locally available materials and locally components. Basin is the major part of the solar still. It absorbs the incident radiation that is transmitted through the glass cover. The basin liner should be resistant to the hot saline water. It has a high absorbance to solar radiation and resistance to accidental puncturing in the case of the damage (possibly by broken glass) , it should be easily repaired. The basin liner made of Galvanized of 85x85 cm with maximum height of 12 cm. Glass of 3mm thickness was used, it was fixed at angle of 37° with the horizontal (see Fig.(1a&1b)). Glass cover has been sealed with silicon rubber, which is the most successful because it will make strong contact between the glass and many other materials. The sealant is important for efficient operation. An insulating material is used to reduced the heat losses from the side walls of the solar still. The insulating material is a rock wall of about 3cm thickness. Mirrors fixed inside the solar still on the inner sides wall. The aim of the mirror is to concentrate and reflect the scattered rays of the incident solar radiations in the solar still. A distillate channel (which has U shape) used to collect the condensate from the lower edge of glass cover and carry it to storage. Three digital thermometers used at various locations to measure the following temperatures: water – basin , water vapor and ambient temperatures respectively.

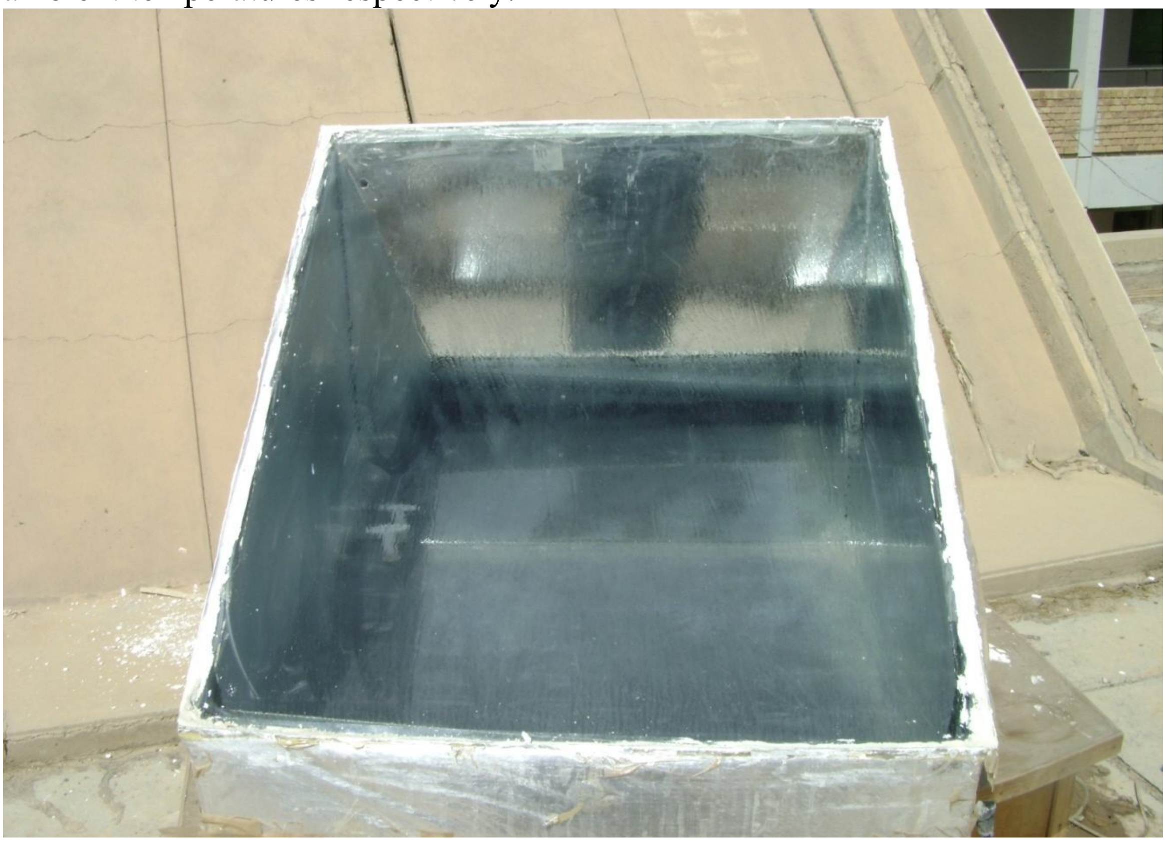


Fig.1a. Picture of experimental setup

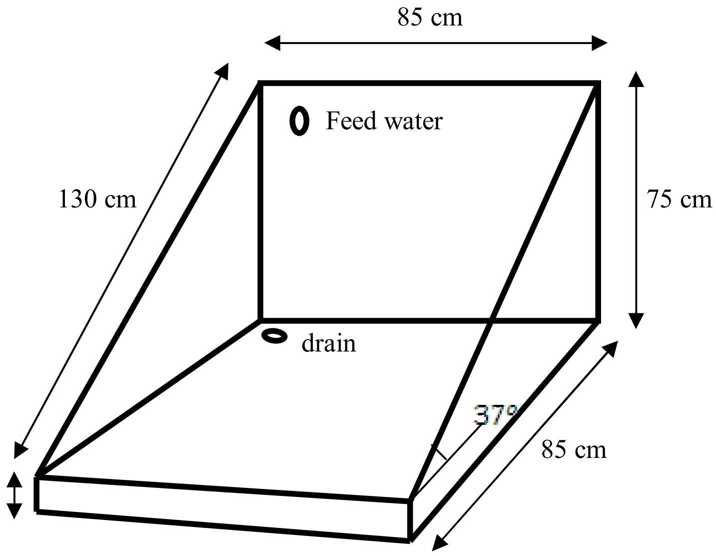


Fig.1b. Schematic diagram of experimental setup

Results and discussions:

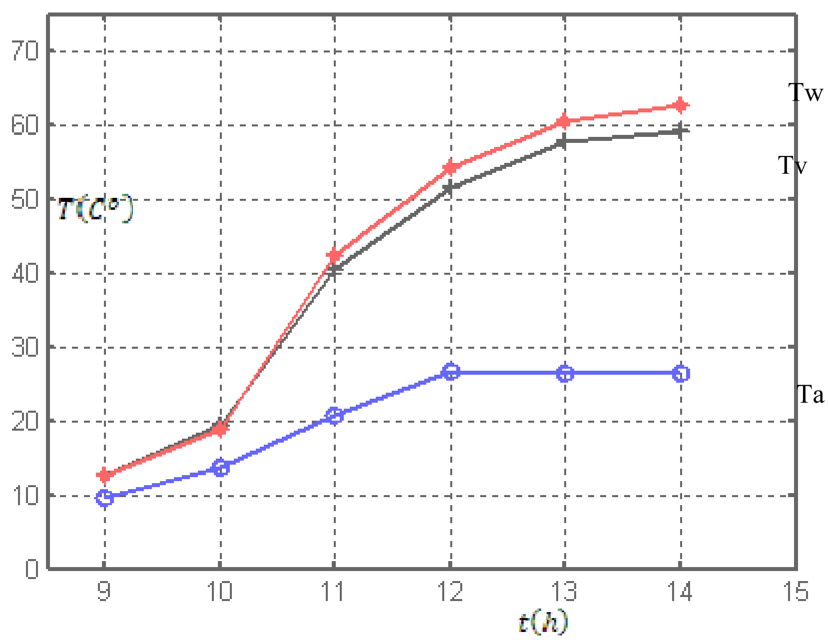
The experiments were conducted at winter season where the temperature always is low and the weather almost be cooled. The weather's temperature represents the most important parameter for solar still distillation efficiency, in addition to the other parameters such as wind speed and sunshine.

Figure(2) shows the variation of ambient temperature, water – basin temperature and water- vapor temperature with time of exposure of solar still to the sun. At first hour (morning) where the ambient temperature low, the water vapor and water- basin temperatures recorded few increases and when the time go on, it is clear shown the increases in temperature for both water-basin and water vapor temperature. This increases begin growing up with time although the ambient temperature is still low. This due to that : the heat transfer through the glass begin accumulated in water-basin due to the absorption by basin and reflection by mirrors, which result in water evaporation . The maximum temperature was recorded at afternoon . This is also seen in Fig.(3) with few differences. Fig.(4) shows the variation of distilled water production with the time. It can bee seen clearly that the distilled water production increases with time till the maximum amount and then nearly produced at constant rate. This behavior is not different from Fig.(2)and Fig.(3) above for temperatures. Due to the differences in ambient temperatures between to days it can be seen that the differences in distilled water production, therefore at the first day when the average weather temperature equal to 20.58C^{o} (represent the average weather temperature along day) when the ambient temperature was low the distill water production less than the second day where the ambient temperature begin increases (average weather

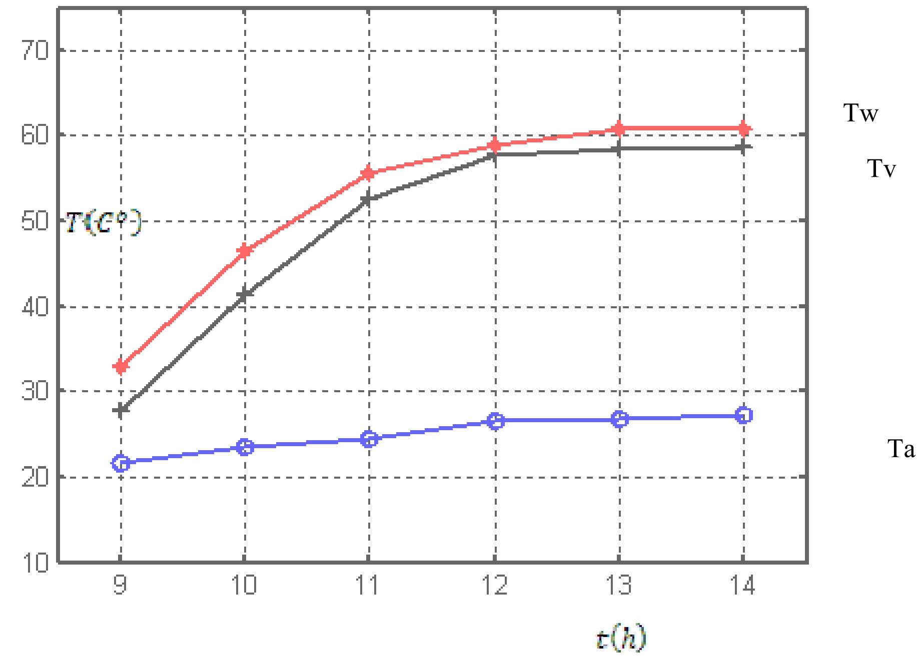
temperature equal to 25.03C^{o}) . Figs.(5&6) show the variation of distilled water production with ambient temperature, water vapor temperate and water basin temperature. It can be seen that the distilled water production increases independently with ambient temperature when its value becomes high enough, while the distilled water production remained dependent on both water-basin temperature and water vapor temperature.
The laboratory testes of feed water (un-distilled water) and distilled water produced were done and the following results were shown in table 1 below.

Thable.1: Physical tests of un - distilled and distilled water

Run No.	Physical Tests	Before distillation	After distillation
1&2	TDS	3.5 ppt	0.3 ppt
1&2	PH	8.3	8.4
1&2	EDTS	2.90 ppt	0.3 ppt



C^{o}Fig.(2): Variation of temperature with the time at average weather temperature equal to 20.58



C°Fig.3. Variation of temperatures with the time at average weather temperature equal to 25.03

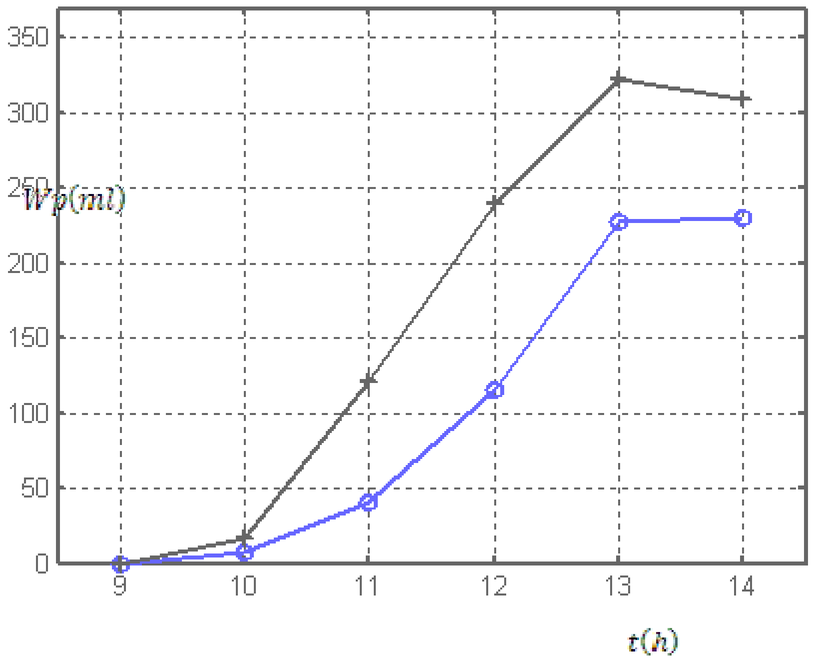
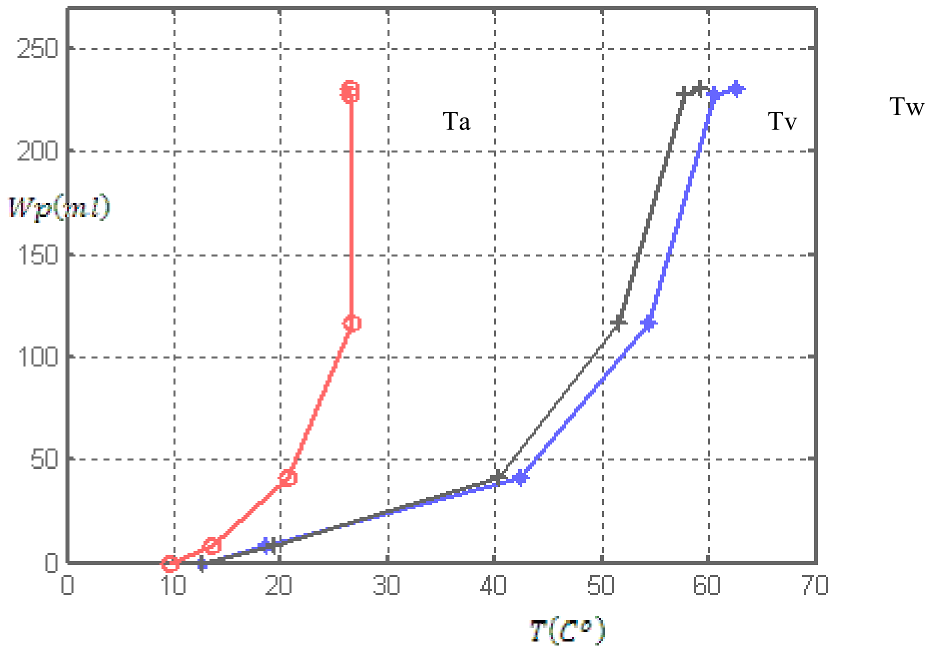
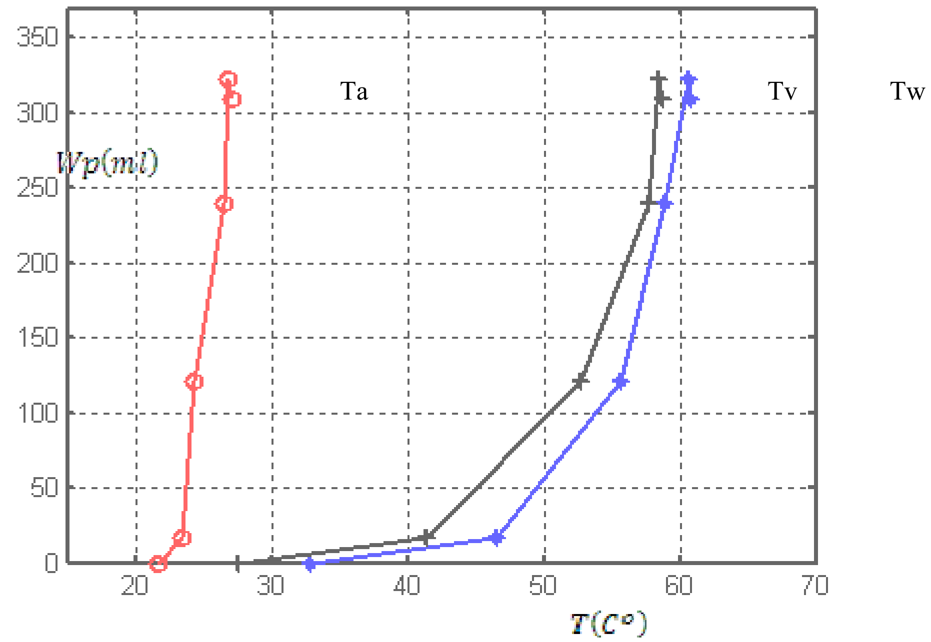


Fig.4. Variation of water Distillate with the time



C°Fig.5. Variation of water Distillate with temperature at average weather temperature equal to 20.58



C°Fig.6. Variation of water Distillate with temperature at average weather temperature equal to 25.03

Conclusions:

An experimental investigation for single – basin solar still method for water distillation was carried out. The following conclusions are made:

1- The water-basin temperature and water-vapor temperature increases fastly corresponding to low increases in ambient temperature.

2- The distilled water production rate increases with time and reaches a constant value corresponding to that the ambient temperature reaches its maximum value.
3- The distilled water production rate depends on ambient temperature , water basin temperature and water vapor temperature.
4- The ambient temperature represents the main parameter that affects effected on the distilled water production rate especially at first working hours when its still not reaches at maximum value.
5- In general, according to the experiment conditions , it can be recommended that the single basin solar still is more useful to use in water desalination especially in small remote areas such as villages of southern of Iraq.

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Nomenclatures:

T	average weather temperature along a day (C°)
Ta	ambient temperature (C°)
Tv	water – vapor temperature (C°)
Tw	water – basin temperature (C°)
Wp	produced distill water (ml)
t	time (hour)