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PERFORMANCE OF POROUS -BASIN SOLAR STILL

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ملخص البحث

هذه الدراسة تشتمل على بحث أداء نوعين من الأجهزة الشمسية لإزالة ملوحة المياه تحت الظروف الجوية لمدينة القاهرة ، حيث أجريت في الفترة من ٣٠ / ٩٧/٨ إلى ١٨ / ٩ / ٩٧ خلال خمسة عشر يوما ، أحدهما عبارة عن النوع التقليدي ذو الحوض ، بينما الآخر تم تزويده بمادة مسامية (حبيبات من البازلت) ، كل منهما بمسطح حوض مساحته ٠.٨٥ متر مربع ، مغطى بالزجاج الذي يميل على الأفقي بزاوية قدرها (٢٠) درجة . وقد تم إجراء عشرة إختبارات في تلك الفترة تبدأ الساعة التاسعة صباحا حتى السادسة مساءً ، حيث سجلت شدة الأشعة الشمسية ودرجة حرارة كل من الجو والزجاج والماء بالأحواض وكذا حجم المياه المقطرة الناتجة . في هذه التجارب لكلا النوعين تبين تأثير إرتفاع المياه بالحوض على كمية الناتج من المياه المتكاثفة . وقد وضحت النتائج أن النوع المزود بمادة مسامية أفضل أداء عندما يكون إرتفاع المياه بالحوض ١.٦ سم مقارنة بالنوع التقليدي بينما الأخير يكون أفضل عند إرتفاع المياه بقيمة ٥ سم .

Abstract

In this study, the performance of two different types of solar stills has been investigated during a period of fifteen days from 30. 08 to 18. 9. 1997, under the climatic conditions of Cairo city. One of the two stills is from the conventional basin type, while the other is porous -basin still. Both stills are of equal basin area ≈ 0.85 m^2 and covered by single glass inclined with an angle of 20 degree to the horizontal basin base. Ten daily tests have been performed during this time period. The daily test starts at 9 A.M. and ends at 6 P.M. During the test, measurements were made in terms of the solar flux, ambient, glass cover and basin water temperatures and distillate productivity. In these tests, the effect of basin water depth on the still performance has been investigated for both still types.

The results showed that the porous -basin still with 1.6-cm basin water depth has better performance than the conventional still. Daily distillate productivity of about 2.3 liter/m^2 could be obtained from the porous still. On other side, a best performance of the conventional still could be achieved for 5-cm basin water depth, with daily distillate productivity of about 2.1 liter/m^2

1. Introduction

The earliest documented work on the conventional solar still appeared in 1872 by Wilson [1], who used a number of basin-type solar stills with total area of 4700 m² to supply potable water. Since then, many researchers have reported much work on the solar distillation.

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Frik and Sommerfeld [4] proposed a solar still with inclined evaporating cloth (single wick). They concluded that the system is relatively economical but suffers from limitation of having part of the cloth dry at times. Some time later, Moustafa and Brusewitz [5] have studied the performance of different types of solar stills and concluded that the wick-type collector evaporating system is better than basin-type solar still. However, the proposed system suffered from having many controls and correspondingly higher cost.

Soda *et al.* [6] have investigated experimentally the performance of a multiple-wick solar still, wherein a blackened wet jute cloth forms the liquid surface. This wet jute cloth was oriented to intercept maximum solar radiation and, consequently, attain high temperatures on account of its low thermal capacity. The wet surface was created by a series of jute cloth pieces of increasing length separated by thin polythene sheets. These cloth pieces were arranged along an incline with its upper edges dropped in a saline water tank. Suction by the capillary action of the cloth fiber provides a surface of the liquid. This arrangement ensures that all the surfaces, irradiated by the sun, are wet at all times. The results showed that on a cold sunny day in Delhi, the distillate production was 2.5 l/m^2 per day, corresponding to an overall efficiency of 34%. The still cost was less than half of the cost of a conventional basin type of the same area.

Recently, Al-Karaghouli and Minasion [7] developed a floating-wick solar still, based on the good capillary property of jute wick [8]. The proposed still is a conventional single-basin type provided with a black jute wick floated with a polystyrene sheet. The floating wick was arranged to appear only half centimeter above the water level in the still. This ensures sufficient water flux due to water suction by the capillary action of the jute fibers. Both azimuth and altitude tracking were used to receive maximum solar radiation incident on the still. Pivoting a flat mirror about a horizontal axis performed altitude tracking. Results of this study showed that the floating wick type solar still gave higher productivity than the common tilted-wick type [4], and than the conventional basin-type still, however, with some problems in operation and maintenance. A maximum daily output of about 10.5 l/m^2 could be obtained from this still.

The recent trend of improving the performance and productivity of solar distillation stills as well as its economy promoted recent studies to develop less expensive and more efficient solar stills by using porous basins. Madian and Zaki [9] among other researchers have investigated experimentally the effect of using porous basin on the yield of a solar still. In this experiment, the still construction cost was greatly reduced by eliminating the concrete structure and the black lining material used in the still basin. Instead of this, carbon powder (obtained free of charge from oil-fired power plants) was used. The results showed that an average yield of 2.5 - 4 l/m^2 per day could be achieved by using the carbon powder. The investigation showed also that removing the basin insulation caused reduction in the still productivity by about 13% - 17%. Economic analysis of the proposed design for a plant of [illegible] m3/day productivity showed that potable water production cost of 2.4 US dollar per one m^3 (distilled water) could be achieved.

It is clear from the above-presented literature review that the solar still data, available in literature from different sources, are still scarce and scattered. Therefore, in the present work, an experimental investigation on the conventional single-basin solar still will be performed under the climatic condition of the city of Cairo. In this investigation, the effect of using porous layer in the still basin will be examined.

2. Experimental Installation

Figure 1 shows the construction of the test loop. The system involves two stills separated by a vertical 6-mm thickness glass sheet to avoid shadow effect. The heat exchange between the two stills through the separating glass sheet may be considered negligible. This due to the relatively low thermal conductivity of glass and the small temperature difference between to still rooms. The two flat basins are made from polished 1.25-mm steel sheets and covered by 6-mm glass sheet inclined with angle of 20^0 to the horizontal. The bottom and sides of both solar stills was thermally isolated by foam layer of 5-cm thickness. The inner basin surface is painted black to enhance solar energy absorption. One basin contains 20-mm layer of black solid grains of pazalt. The ratio of porosity volume to grains volume = 0.514 and the average volume of grains is $0.22cm^3$ .Thus, the system comprises two different types of solar stills. One is a conventional basin still, while the other is a porous-basin still. Each still is provided with a V-drain aluminum channel for the drainage of distillate to a collection bottle. Copper-Constantane thermocouples, connected to a voltmeter through an on-off switch, are used for the measurement of basin water, glass cover and ambient temperatures. The accuracy of temperature measurement is about $\pm$ 0.3 °C. The solar radiation is measured by using a Swiss made pyranometer with a brand name HAENNI, at $\pm$ 0.004 kW/m^2 accuracy.

2.1 Operation

Solar energy allowed into the still heats the water. The water evaporates only to condensate on the underside of the glass due to the effect of temperature drop across the glass cover. When water evaporates, only the water vapour rises, leaving contaminants behind. The gentle slope of the glass cover directs the condensate to the collection V-channel, which in turn delivers the water to the collection bottle.

Over a period of fifteen days from 30-8 to 18-9-1997, ten tests have been performed simultaneously on both solar stills, for basin water depths = 1, 1.6, 2.7, 5 and 8 cm. These values of water depth is the initial values at the start of test. The decrease in water depth was found from the preliminary tests about 2.5 mm. Therefore, a make-up water has been made to compensate this decrease during the expected maximum productivity time. The compensation water is supplied manually to the still at a temperature of about 35 °C from the water supply line exposed to the sun on the roof. In this way, the maximum deviation in water depth from its initial value was less than ± 1.5 mm. During the test, solar radiation, ambient air temperature, glass cover temperature, water temperature and distillate production were measured in equal time intervals of 15 minutes. The hourly mean values of these measurements have been calculated by taking the average of each four subsequent readings. The time period of test extends from 9 A.M. to 6 P.M.

3. Results and Discussion

A typical sample of measured data is that obtained on the day of 2nd of September of 1997. These data are presented in Fig. 2, in terms of the variation in solar radiation, ambient temperature, distillate productivity as well as water and glass cover temperatures versus hourly intervals. It is observed that the response of the solar still follows closely the solar irradiation.

3.1 Variation of glass cover and basin water temperatures

Figure 3 shows the hourly variation in water and glass temperatures of the conventional basin still (left) and of the porous-basin still (right), for different water depths.

In general, the results of both solar stills indicate that for higher basin water depth,

1- maximum water temperature, attained near or afternoon, will be lower for both stills.
2- time at which the basin water temperature reaches maximum value will be later.
3- basin water temperature at the end of the daily test at 6 P.M. will be higher
4- time required for heating the water (during the starting stage) up to the temperature of the glass cover, will be longer.

3.2 Distillate Productivity

Figure 4 displays the hourly distillate productivity during the day time, of the black-painted basin still for different basin-water depths. It is clear that for certain water depth, the productivity increases with time to reach its maximum value nearly afternoon, then, decreases again with time. It is noted that increasing water depth decreases the maximum value of distillate productivity as well delays the time at which this maximum value occurs. However, after a few hours from this time of maximum productivity, the effect of water depth is reversed. The higher the water depth the lower the rate of still productivity will be.

Figure 5 shows the hourly distillate productivity of the porous-basin still, for the same different basin-water depths used in the conventional still (cf., Figs 4 and 5). The effect of increasing water depth on the porous still productivity seems to be similar to that in the case of conventional basin still shown in Fig. 4 except for the case of water depth [illegible] cm

Comparison the productivity of both stills is presented in Fig. 6a , for two different water depths = 1 and 2.7 cm, where the productivity curves of porous -basin still are represented by dashed lines. It is clear that for 1-cm water depth, the porous still productivity is much lower than the conventional still productivity. This may be explained as follows: For 1-cm water depth, the water level in the porous basin is below the porous layer by about 1 cm. In this situation, the evaporating free surface of water is very small, and limited by the area of gaps between the grains on the upper surface of porous layer. Hence, the evaporating water process may be mainly controlled by the capillary action of the porous layer. However, for water depth = 1.6 cm, the porous still seems to be more efficient than the conventional still (cf., Fig. 6b). In this case of 1.6-cm water depth, the water free surface is below the upper surface of the porous layer by about 3- mm. Hence, Pazalt grains of the upper surface are not wetted. Thus, these dry grains attain high temperatures on account of its low thermal capacity. This results in high still productivity.

The accumulative daily productivity per day versus basin water depth is shown in Fig. 7. It is clear that the increase in basin water depth has a considerable effect on the still productivity. The conventional black-painted basin with water depth = 5 cm achieves best daily productivity. Daily distillate productivity of about 2.1 liter/m^2 could be attained. On other side, a best performance of the porous still could be achieved with 1.6-cm water depth. The daily distillate productivity was about 2.3 liter/m^2 The night productivity was about 5% of the daily productivity for the porous still, while it was about 8% for the conventional still. This is due to the effect of still thermal capacity. Therefore, the effect of water depth is very complicated.

3.3 Still Efficiency

The still efficiency, defined by the ratio of daily evaporative heat energy to the daily incident solar energy on the still, as a function of basin water depth is shown in Fig. 8 for both stills. It is clear that the porous -basin still has maximum efficiency = 41.3 % at water depth = 1.6 cm, while of the conventional still has maximum efficiency = 37.5 % at water depth = 5 cm. These results are consistent with the results shown in Fig. 7.

3.4 Comparison of Present Data with Other Data.

Comparison of present productivity data with other data obtained by Farid and Hamad [10] is shown in Fig. 9. The comparison shows that the present data are in close range with these data of Farid and Hamad. This may be attributed to the reason that these data of Farid and Hamad were obtained under climatic conditions very close to that of the present tests

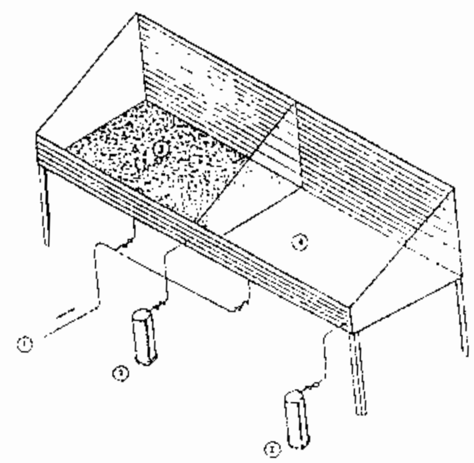
4. Conclusions and Recommendations

The performance of two types of solar stills has been investigated, namely: conventional basin still and porous basin still. The effect of basin-water depth on the distillate productivity has been investigated for both stills.

The study showed that the use of porous layer of black pazalt grains in the basin of solar still improves its distillate productivity. This is under the condition of using the proper water depth in the porous basin. The obtained results showed that the porous - basin still with porous layer of 2-cm height yields maximum daily distillate productivity of about 2.3 liter/m^2 for basin water depth = 1.6 cm. However, maximum daily distillate productivity of 2.1 liter/ m^2 could be obtained from the conventional still for basin water depth = 5 cm.

For future studies, the following recommendations may be made:

1- Perform solar still testes for several weeks during the four seasons of the year to achieve better knowledge on the effect of using porous substances in the basin of a solar still.
2- Investigate the effect of applying vacuum in such a porous -basin still on its performance.
3- Examine the effect of the permeability of porous substance on the productivity of porous stills.



1-water supply and drain 2-distillate bottle
3 - Porous -basin still 4 – conventional still

Fig. 1 Schematic drawing of test loop

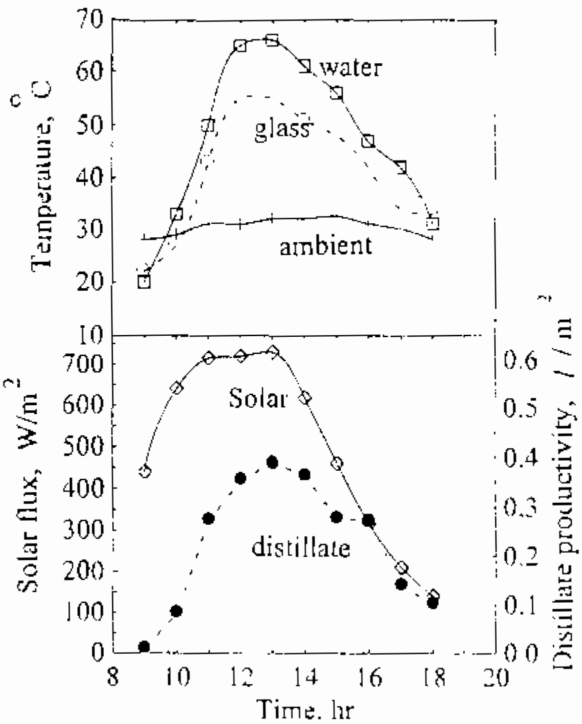


Fig. 2 Hourly variatic of water, glass cover and ambient temperatures, solar radiation and still productivity

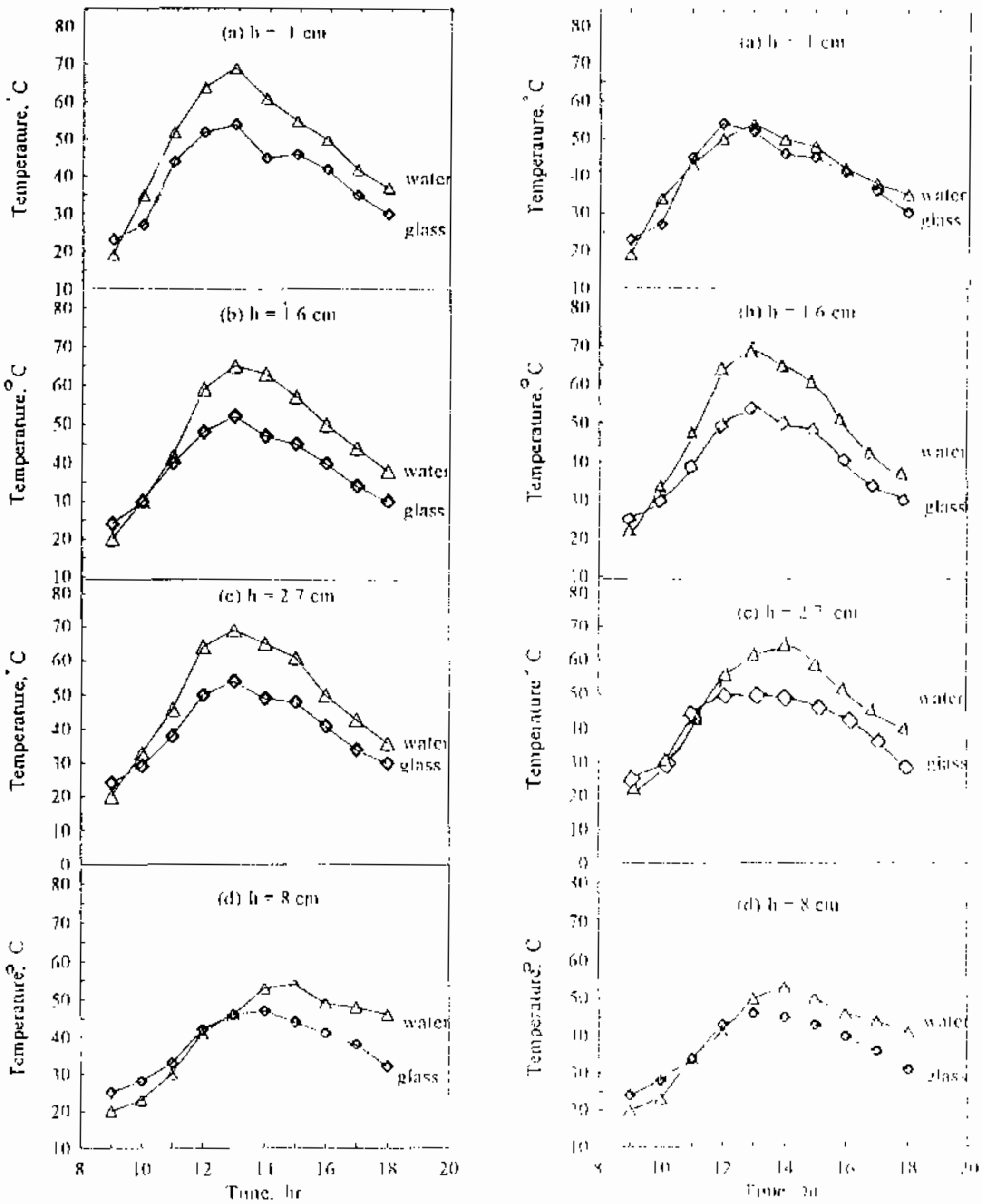


Fig. 3 Variation of water and glass temperatures of conventional basin still (left) and of pours-basin still (right), at different water depth

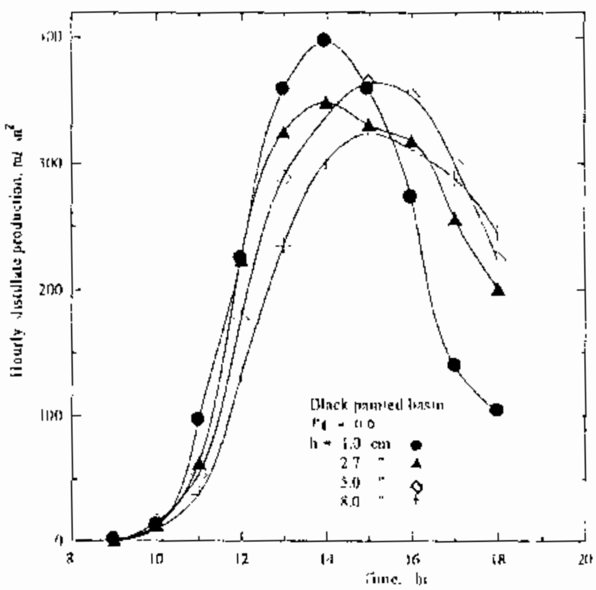


Fig. 4 Hourly distillate productivity of black painted basin still, for different water depth

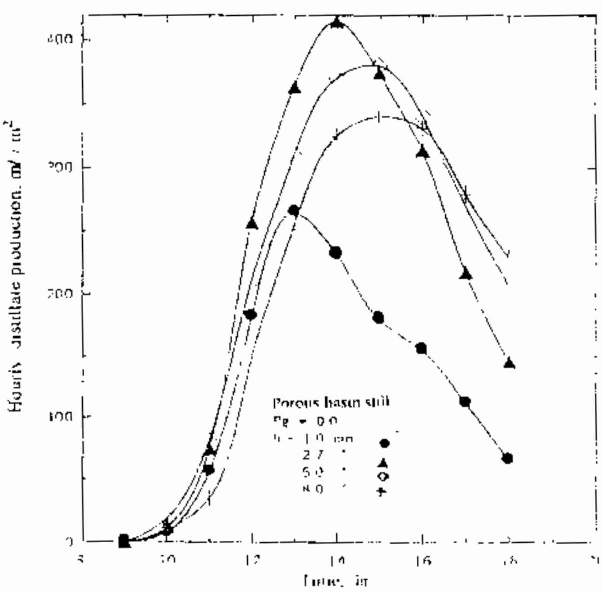
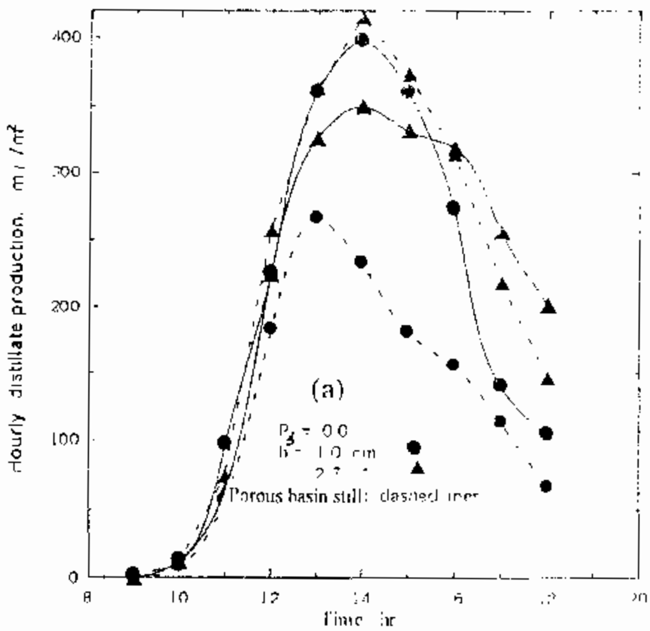


Fig. 5 Hourly distillate productivity of porous basin still, for different water depth.



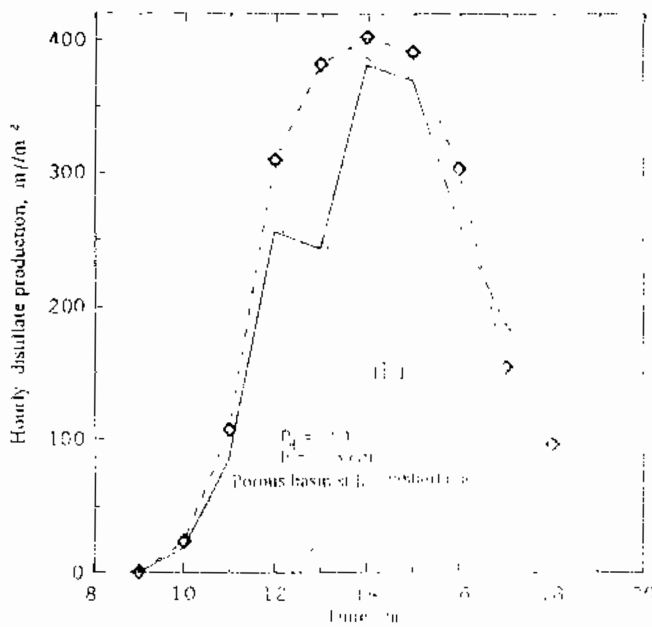


Fig. 6 Comparison of hourly productivity of both stills. Solid lines: black painted basin. Dashed lines: Porous basin still

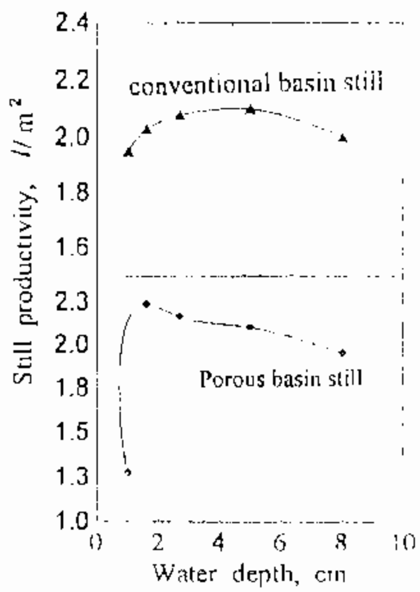


Fig 7 Daily still productivity as a function of basin water depth

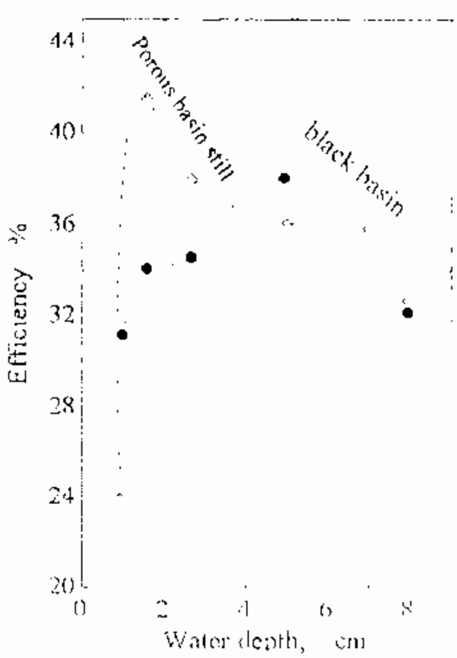


Fig 8 Solar still efficiency as a function of basin water depth

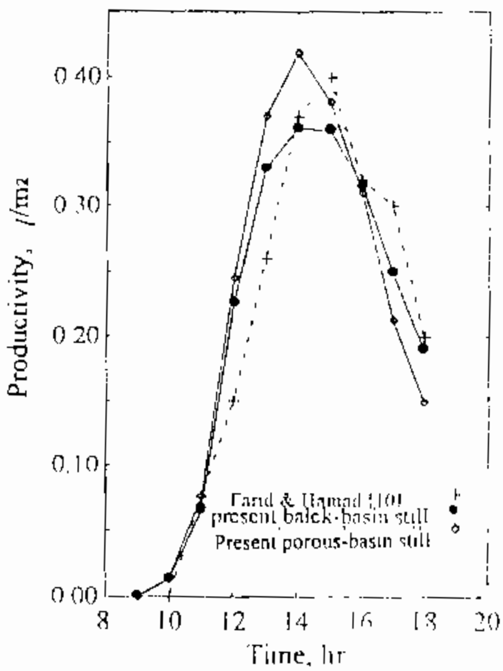


Fig. 9 Comparison of present data with other data from ref [10]

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