

Employment of Some Organic Dyes as Chemical Converters in Construction and Testing Of a Basin Type Solar Still

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Received: 21/3/2010, Accepted: 5/10/2010

Abstract

The performance of a basin type solar still, with removable cover, was tested using organic dyes as liquid thermal converters contained in sealed glass tubes. The choice of the optimum mixture was based on a study of the influence of concentration of individual components on thermal performance of every mixture. A comparison, in terms of yield per day, was made of performance of this new still with a similar still, the basin of which had been painted black with ordinary black paint. The new still showed better output.

Introduction

The use of chemicals in enhancing performance of basin type solar still has been the subject of research of number of workers (Garg et al., 1979; Rajvanshi, 1981 and Sodha et al., 1980). In general the work involved dissolving a certain amount of organic dyes in the water to be subjected to distillation (Rajvanshi, 1981). Choice of materials was based on their thermal performance and the absence of toxicity (Bouker et al., 2001; Samee et al., 2007; Kim et al., 2007 and Velmurugan et al., 2008). In one case (Al- Abbasi et al., 1992) a gaseous converter was employed. The converter was sealed in glass tubes. In the present work, the toxicity criteria were overcome by sealing the converter solution into glass tubes. The still we tested had a removable cover so as to facilitate changing of the converter tubes and/ or cleaning the still.

Experimental

Test of the thermal performance of the converter:

Eight tubes were used in this still where seven of them containing 85 mL each of the selected mixtures of aqueous dye solutions, the eighth one, containing distilled water were used as blank. The tubes were placed on a stainless steel frame inclined at an angle of 40 °C to the horizontal and left

facing south. Daily temperatures changes were monitored by means of copper – Constantine thermocouples, fixed to the middle of the tubes through holes in the stoppers, connected to a Comark type multi- channel thermometer. Spectrum of the individual and mixed organic dyes was held using Uv-visible spectrophotometer.

Construction of the solar still

The still used was of internal basin area measured 104 x 60.5 cm while the dimensions of the tubes were 80 cm long and 4 cm internal diameter. The eight tubes were held on suitable supporters parallel to the basin of the still as shown in figure (1).

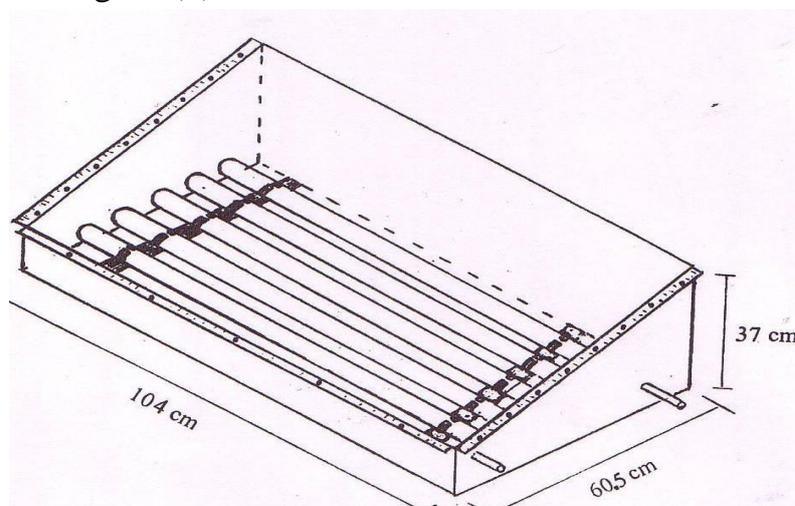


Fig. (1): Schematic diagram of the solar still.

The tubes were arranged longwise at the depth of 5 cm below the water level. The bottom and the sides of the basin were well insulated by a single layer of, rock wool, 5 cm thick. The insulated aluminum basin was placed inside an outer, aluminum basin with insulator in between. The whole still was covered with a removable aluminum frame, holding 0.4 cm thick glass pane, inclined at an angle of 20 to the horizontal. The condensed water was collected by means of an aluminum channel situated beneath the lower edge of the glass cover. This channel ends into a (1 cm) bore copper tube connected to rubber tubing whereby the distillate is collected into an external vessel. The volume of water collected, which was daily, measured by a graduated cylinder. The vapor leakage was overcome by sealing the joints and openings with silicon rubber. The slopping side of the still was facing south throughout the experimental period. The temperature readings were measured by a Comark type digital thermometer through upper – Constantine thermocouples fitted to bottom, side, water level, and both sides of the glass pane. The global solar radiation, incident on the glass surface of the still, was automatically recorded hourly, using a data acquisition system.

Results and Discussion

Choice of the converters was based, in general, on the idea that substance absorbing visible radiation over special regions of the solar spectrum (Hautala et al., 1977; Abdul- Gahni et al.,1986 and Abdul- Gahni, et al.,1987). There is presently no substance that absorbs overall the solar spectrum region. In this work we employed mixed solutions of absorbers whose collective spectra more or less cover the solar radiation spectrum. The thermal performance of each mixture was tested and choice was made of the mixture with the best temperature output. Accordingly various concentration of each mixture of (M₁-M₇) was subjected to sunlight and the optimum concentration thereof is shown in Table (1).

Table (1): Concentration of each individual dye in mixtures (1-7)

Mix.	Concentration * 10 ⁻⁵ M							Concentration * 1M		
	Erichrome Black T	Rhodamine B	Methylene blue	Congo red	Malachite green	Crystal violet	Safranine O	NiCl ₂	CoCl ₂	Cu(NO ₃) ₂
M1				4.5	5.0	5.0				
M2	4.5	2.0				5.0				
M3		2.0	4.5		5.0					
M4					5.0	5.0	4.5			
M5		2.0	3.5	4.5						
M6		2.0	4.0				5.0			
M7								0.1	0.2	0.2

Fig. (2) shows visible spectra of the tested mixtures. They all show a maximum absorption at region 500-700 nm matching to a great extent with the solar spectrum.

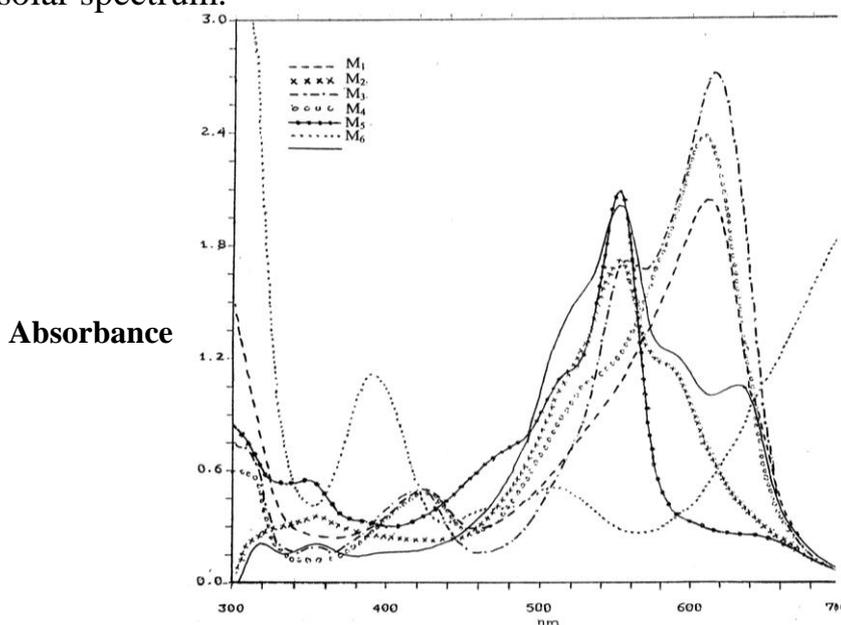


Fig. (2): Absorption spectra of individual dyes (M1-M7).

Fig. (3) on turn illustrates the thermal performance of the mixtures compared with water. Photofading of organic dyes which were earlier reported for similar situation (Savarino et al., 1989) showed its action in our case. In all these cases long term exposure of the mixtures to sunlight led to photofading of all organic dye mixtures (M_1 , M_2 , M_6), however their thermal performance did not decline sharply. Mixture (M_5) which was reported earlier (Abdul- Gahni et al., 1986) to be photostable lost its capability and deemed to be enviable, at least in our present work. Mixtures in term (M_3 , M_4) with organic dyes showed a moderate thermal performance with high resistance to deterioration. This situation makes us believe that in mixtures (M_3 & M_4) interdye side reaction among components is absent. It is possible those products resulting from interdye reactions are not heat producing (Aydın et al., 2009).

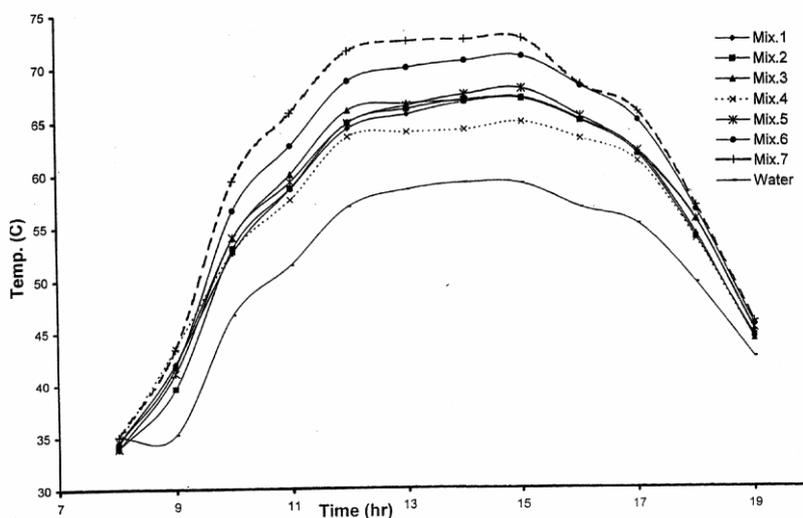


Fig. (3): Thermal performance plots of M1-M7.

This is tantamount to a slowing down of heat producing reactions or reduction in the heat forming reaction (Porter et al., 1970; Garg et al., 1979; Desai et al., 1954). However, in case of inorganic mixture (M_7) all the solar insolation absorbed is utilized in heat producing reversible photochemical reaction which is direct reaction. This result confirmed our previous results in which a combination of inorganic mixture was utilized, successfully, as a chemical converter in a parabolic solar concentrator (Naoum et al., 1992).

Optimization of the individual component concentration was performed on mixtures (M_3 , M_4 , M_7) in order to determine which component concentration plays decisive role in enhancing thermal performance, in addition to increase the chances of attaining the best temperature results. Table (2) gives the composition of the selected mixtures.

Table (2): Concentration of each individual dye in mixtures (3, 4, 7)

Mix. 3	Conc. * 10 ⁻⁵ M			Mix. 4	Conc. * 10 ⁻⁵ M			Mix. 7	Conc. * 1 M		
	Rhodamine B	Methylene blue	Malachite green		Malachite green	Crystal violet	Safranin O		NiCl ₂	CoCl ₂	Cu(NO ₃) ₂
a	2.0	2.0	5.0	a	5.0	5.0	2.5	a	0.2	0.3	0.3
b	2.0	4.0	2.5	b	2.5	5.0	2.5	b	0.2	0.2	0.3
c	2.0	4.0	5.0	c	5.0	2.5	2.5	c	0.2	0.3	0.2
d	4.0	2.5	2.5	d	5.0	5.0	4.5	d	0.3	0.2	0.2
e	4.0	2.0	5.0	e	2.5	5.0	4.5	e	0.3	0.3	0.2
f	4.0	4.0	5.0	f	5.0	2.5	4.5	f	0.3	0.2	0.3
g	4.0	4.0	2.5	g	2.5	2.5	4.5	d	0.2	0.2	0.2

Figs. (4a-4c) display the thermal performance of the optimum mixtures (M_{3g}, M_{4f}, and M_{7g}).

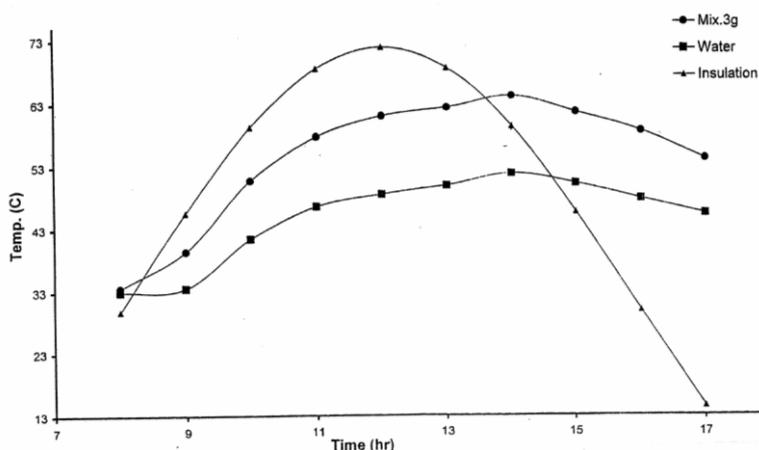


Fig. (4a): Thermal performance plots of optimum mixture M3g.

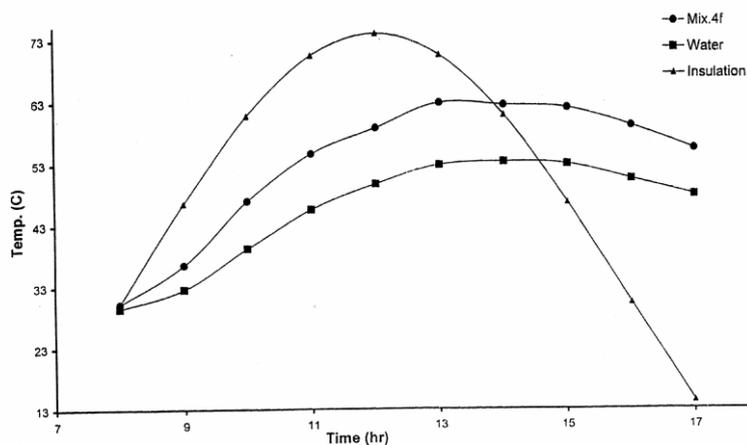


Fig. (4b): Thermal performance plots of optimum mixture M4f.

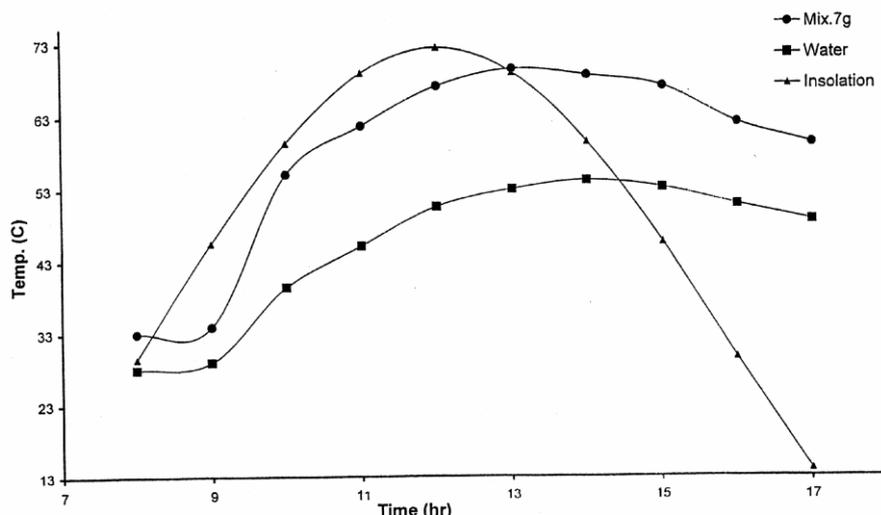


Fig. (4c): Thermal performance plots of optimum mixture M7g.

The optimum mixture finally attained was then employed in the final test of actual performance of the still. In this final run the basin contained twenty liters of tap water, whilst each of the five tubes contained (400 mL) (i.e. a total of two liters of the converter solution was used). Figures (5-7) show a comparison of the productivity of two stills one painted the other unpainted both containing identical tubes with same mixture. In the painted still, rays that reach the bottom of the basin are reflected at the basin surface mostly towards, with chances of being absorbed by the liquid converter above them in the case of the painted still. However, efficiency of the absorption process by the paint may not be very high. Rays that are scattered by the paint in all directions with lesser chance of arriving may be absorbed by the converter.

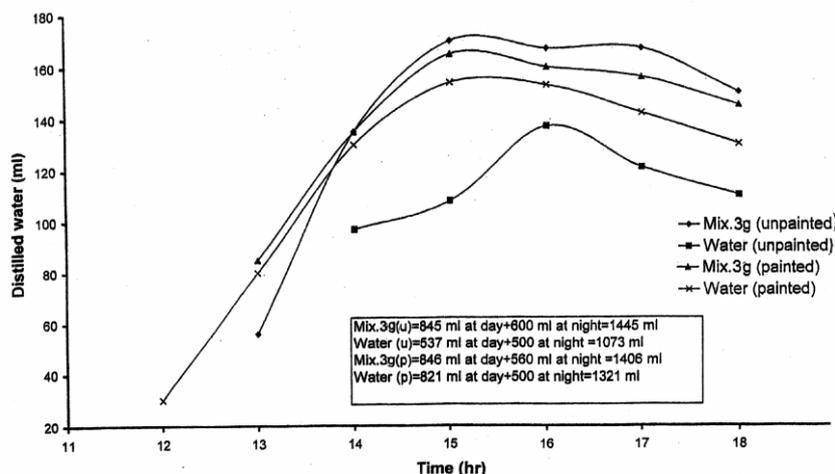


Fig. (5): Comparison of the productivity between painted and unpainted solar stills using chemical converters of M3g.

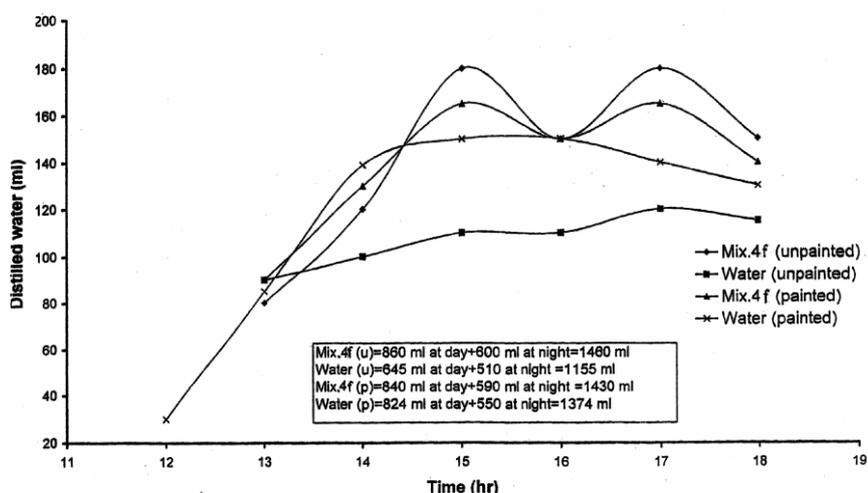


Fig. (6): Comparison of the productivity between painted and unpainted solar stills using chemical converters of M4f.

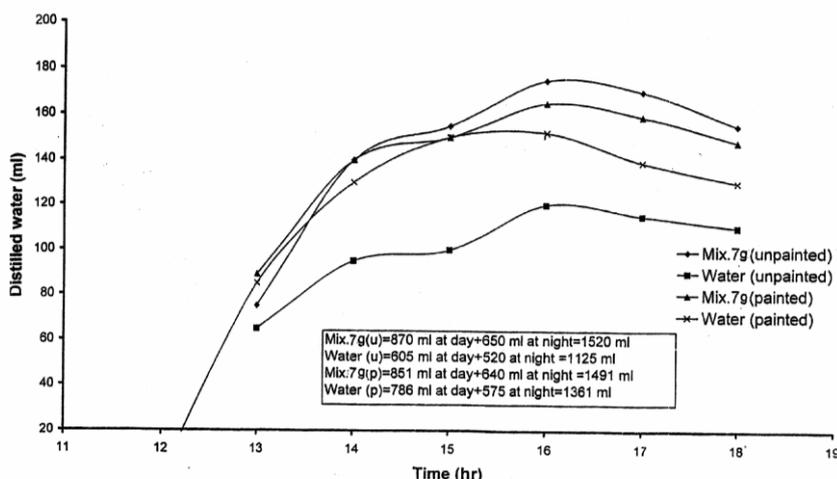


Fig. (7): Comparison of the productivity between painted and unpainted solar stills using chemical converters of M7g.

The productivity in using of photochemical conversion which has previously been observed to be even better than international standard selected surfaces. The paint may also have unacceptable health hazards in addition to the possibility of reaction with elements, which causes hardness of the water in addition to difficulty of cleaning the painted surfaces. The enclosed converter solution, on the other hand, does not come into contact with the tap water inside the basin and therefore there is no possibility of any toxicity or contamination of the distilled water.

Conclusion

The unpainted basin using chemical converters showed better productivity than that of a black painted similar still with and without using chemical converters.

Acknowledgment

The authors wish to thank Mrs. S. M. Saeed and Mr. A. D. Salmanb for their useful aids throughout the course of the research.

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استخدام بعض الصبغات العضوية كمحولات كيميائية في تصميم وتشغيل مقطر شمسي حوضي

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تاريخ الاستلام: ٢٠١٠/٣/٢١، تاريخ القبول: ٢٠١٠/١٠/٥

الخلاصة

تم تصنيع مقطر شمسي حوضي ذات غطاء متحرك و تم اختبار ادائه باستخدام محولات كيميائية سائلة موضوعة في انابيب زجاجية مغلقة مثبتة في قاعدة المقطر الشمسي. اعتمد عملية اختيار المزيج الامثل للصبغات على دراسة تأثير تراكيز مكونات كل مزيج على ادائها. تم مقارنة اداء المقطر المصنع، بصبغة المنتوجية اليومية للماء المقطر، مع مثيلتها المطلي قاعدتها بصبغة سوداء عادية ، حيث تم تسجيل اداء افضل للمقطر الشمسي الذي استخدم فيه الصبغات العضوية.