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INVESTIGATION UNDER CONTROLLABLE CONDITIONS ON SOME PARAMETERS AFFECTING PERFORMANCE OF DIFFERENT SOLAR STILL CONFIGURATIONS

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ABSTRACT

Trails were carried out under controllable conditions using solar rays simulator to investigate parameters which affect the performance of four different solar still configurations that used for sea water desalination. Two single slope still angles of 20° and 30° (SSSA 20° and 30°) were compared with other two double slope still angles of 20° and 30° (DSSSA 20° and 30°) configurations. Each still had the same steel basins with the same dimensions of 0.80 m long, 0.50 m wide, 0.10 m high and 2 mm thick. Parameters affects the still productivity and performance of different configurations in terms of glazing area, distance between water surface and the glazing cover and the effect of using three different absorbing materials were considered. Matt black fiberglass, matt black paint covered with 6 mm glass cover thickness and matt black paint only were investigated as absorbing material types. The still performance includes the following determinations: efficiency (η) and the coefficient of performance (C.O.P). The distilled water and its salinity were determined for each solar still configuration.

Keywords: Parameters, solar stills productivity, efficiency and coefficient of performance

INTRODUCTION

Different parameters influence the solar still performance. These parameters can be classified as design, operational and meteorological or climatic. Due to the continuously changes in the weather conditions, the design and climatic conditions parameters cannot be investigated in repeatable conditions. The controllable investigation conditions (under the solar simulator apparatus assist enable carrying out such investigations in repeatable conditions. A combination of different design, operational and environmental parameters were considered to improve the solar still performance (in terms of the daily productivity per the square meter). These parameters includes: increasing the basin temperature, evaporation and condensation surface areas, decreasing cover temperature, minimizing basin and sides heat losses and utilization of the shaded zone. These parameters were considered, without losing the credit of solar still simplicity in design and operation and its low cost (Fath, 2000).

Several modifications were applied to improve the solar stills performance. These modifications included using the solar collectors, to recover the latent heat of condensation, improving the configurations and flow patterns to increase the heat transfer rates; also, using less expensive materials for still construction to reduce the cost (Abu-Arabi and Quteishat, 2003).

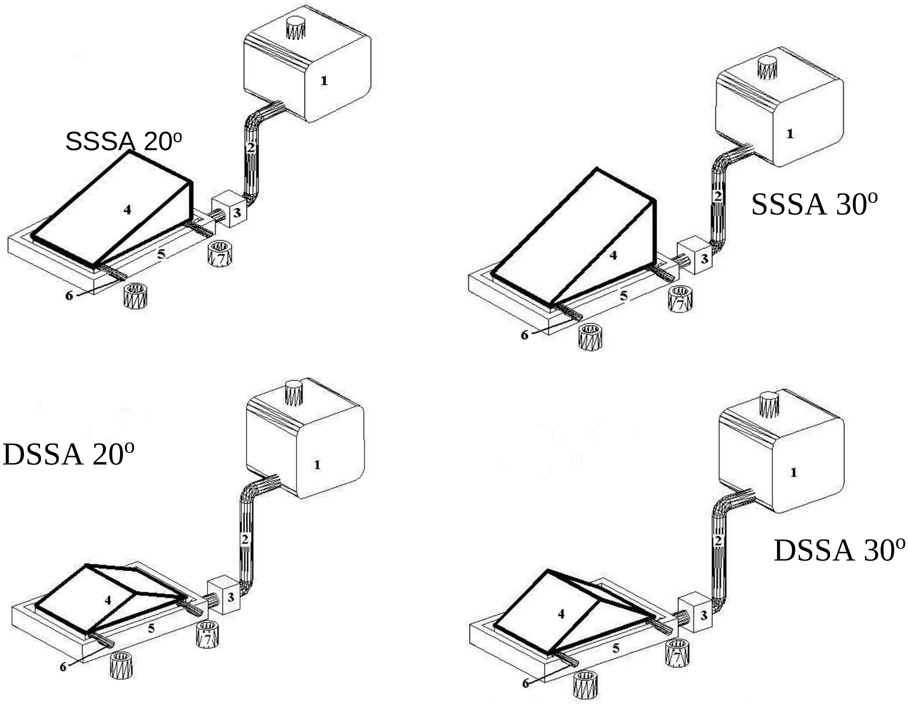
The behavior of a solar still coupled with hot water storage tank experimentally led to a higher distilled water output Voropulos *et al.* (2003).

Reducing the air gap between water surface in the basin and the glazing cover obtained the optimum yield. Decreasing the gab distance led to overall daily productivity exponentially increases in any season (Sherif and Abdel-Hadi, 2001). Using various absorbing material were addressed to enhance the water absorptivity for solar radiation includes dissolved salts, i.e. potassium permanganate and potassium dichromate, violet dye and charcoal by Nijmeh *et al.* (2005). The study found that, adding potassium permanganate resulted in twenty six percent improvements in efficiency. The best result was obtained by using violet dye with an increase of about twenty nine percent above the comparison trials. Using an absorbing mat black rubber increases the daily solar still productivity thirty eight percent (Bilal *et al.*, 1998). Water depth in the basin has a significant effect on the still productivity (Tripath and Tiwari, 2006). As the water depth is inversely proportional to the productivity of still, decreasing the water depth from 3.5 to 2 cm, the productivity increased by 25.7%. This can be attributed to the decrease in the heat capacity for the solar still, as water mass have a profound effect on the distillate output of the solar still system (Mamlook and Badran, 2007). Increase and/or intensify the solar radiation from 720 to 840 Wm^{-2} increased the solar still productivity by fifty six percent under the same investigation conditions. This was due to the linear increase in the absorbed solar energy by the still basin (Mamlook and Badran, 2007). Fath and Hosny (2002) found that, higher ambient temperature during daylight improves the solar still productivity due to the less energy loss.

This study aims to: investigate some parameters affecting the performance of different solar still configurations**.** These parameters are difficult to be investigated in the open environment under the prevailing weather conditions. The outcome from the study was used in consequent study to investigate and analyze the thermal behavior and balance for single slope still type under the open environmental conditions.

MATERIALS AND METHODS

Experimental works were carried out to investigate the parameters which affect the performance of the common solar stills that used for the sea water desalination under controllable conditions of a solar simulator at the Agricultural Engineering Department of the Faculty of Agriculture, Suez Canal University, Ismailia, Egypt. The four different experimental units are presented schematically in Fig. (1). Each unit made up of the following components: preheating feeding tank, water leveling unit, transparent glazing cover 6 mm thick and steel basin. Two single slope still angles of 20° and 30° with the horizontal plane (SSSA 20° and 30°) were compared with other two double slope still configurations of angles 20° and 30° (DSSSA 20° and 30°). Physical properties of various materials which used in solar distillation unit are given in Table (1).The different four glazing configurations have similar basin area of 0.80 m long, 0.50 m wide and 0.10 m high and the same thickness of 2 mm, but it differs in the glazing collecting area, and the gab between the glass cover and water surface for the same depth as it is presented in Table (2).



1: Preheating feeding tank 2: Feeding plastic hose pipe 3: Water leveling unit
4: Transparent glass cover 5: Water basin 6: Plastic channel
7: Vessel.

Fig. (1): Set-up of the four different solar still units

Table1: Physical properties for the solar still components (Gebhart, 1993).

Materials	Thermal conductivity,(*K*), W m^{-1} k^{-1}	Density, (*ρ*), kg m^{-3}	Specific heat, (C_p), J kg^{-1} k^{-1}	Thermal diffusivity, (*θ*), m^2 sec^{-1}
Steel	14.9	7900	477	3.95×10^6
Glass	0.78	2700	840	3.43×10^{-7}
Wood	0.14	615	1317.5	1.72×10^{-7}

Table (2): Glazing surface area of the four configurations

Still configuration	SSSA20°	SSSA30°	DSSA20°	DSSA30°
Surface area, m^2	0.8083	1.0626	0.63	0.646

The transparent covers were sealed by rubber silicone sealant to prevent vapor leakage and hot air leakage, since leakage in this area can drastically curtail affects the production rate and it remains elastic for quite a long time Samee *et al.* (2005). For each of the four different configurations three different absorbing materials were applied for water basin. Basin bottom and sides were coated by matt black fiberglass, matt black paint covered with 6 mm glass cover thickness and matt black paint coating only of 0.95 absorptivity and emissivity (Norton, 1992). Matt black fiberglass that is shown in Fig. (2) composed commercial fiberglass, gelcoats which consists of resin using as adhesive substance mixed with a colored pigment (black dye) beside chemical substances for hardening the final materials (Tiwari and Tiwari, 2007).

Two plastic channels were mounted in each basin side with an enough slope to allow the distilled water to run outside distillation unit in the container. Two plastic grading containers were used to collect the produced fresh water for volume and its salinity determination.

Methodology

Global incident solar radiation was determined within the duration of this study in Wm^{-2}.

Glazing cover transmissivity determination: Trails were carried out on a fixed transparent glazing of 6 mm thick. The glazing was divided into cells to determine the transmissivity, multiple instantaneous readings were measured inside and outside the cover for each cell at the same time, the cover transmissivity was found to be 82 % from the total incident solar radiation.

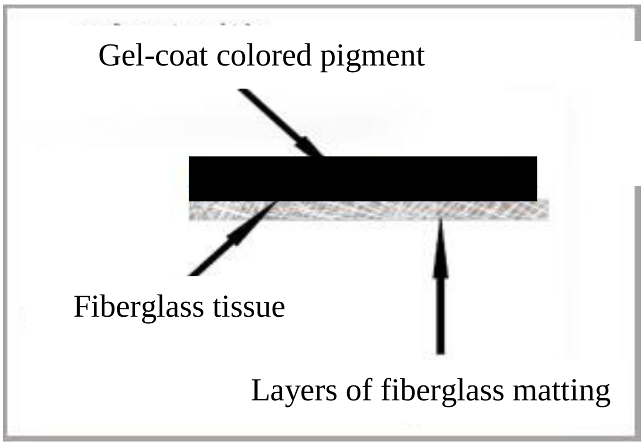


Fig. (2): Schematic diagram of the fiberglass tissue layers.

Effect of absorbing material types on the still performance: Effect of the different absorbing materials on the still performance was investigated for the different four configurations. Each absorbing material was used with the different four glazing cover configurations, still productivity in liter/m^2 was considered to judge the performance of each still configuration as a result of applying the absorbing material. These absorbing material types includes new techniques and new absorbing material which were investigated against a common black paint. The new technique was covering the basin bottom and internal sides after painting with the common black paint by a 6mm transparent glass pane to avoid the curusion due to the salted water. Meanwhile the new absorbing material was using black fiberglass which prepared in layers according to fig (2). These investigations were carried out indoors under a stable incident rays in a controllable conditions with a facility of the solar simulator for water depth of 0.5 cm throughout the operating period of 9 hours.

Effect of rays incident angle on the still performance for the different water depths: Effect of the rays incidence angles for different basin water depths on the still performance was examined. These depths were investigated laboratory under controllable conditions with different rays tilt angles. Angles of 15°, 20°, 25°, 30° and 35° were carried out on different basin water depths of 0.5, 1, 1.5, 2 and 2.5 cm throughout the operating period of 9 hours.

Determination of still productivity: Daily productivity of the solar still defines as the total volume of distilled water in liter produced by the still within a day per unit heat collection area was determined. Volumes of saline (sea) water and fresh (distilled) water were also determined.

Salinity measurement of the distilled water: water salinity was determined in ppm (part per million) using a conductivity meter for the used saline and distilled water.

Still performance

Determination of the still efficiency: The solar still efficiency represents the ratio of the amount of energy utilized in the still water vaporizing and the amount of incident solar energy on the still glass cover. The steady state efficiency for the solar still was calculated from the following equation (Hamdan *et al.* 1999):

$$\eta = \frac{m\, L_w}{I\ A_g\ \Delta t} \qquad (1)$$

Where m, L_w, G, A_g and Δt are the mass condensate collected in a time interval, the water latent heat of evaporation, the hourly solar radiation flux, the glass collecting area and the time interval, respectively. Also, daily efficiency was determined for the solar still according to the following formula (Swelam, 2005):

$$\eta_d = \frac{\Sigma\ m.\, L_w}{\Sigma\ A_g\ .\, I.\, t} \qquad (2)$$

Where, the hourly condensate production (m) multiplied by the latent heat of evaporation (L_w), divided by the summation of the average daily solar radiation (I) and average of the whole still area.

The coefficient of performance (C.O.P): The C.O.P. (dimensionless unit) was used to determine the specific design parameter and its effect on the still performance. The C.O.P is an indicator for the still hourly performance. It can be computed from the following equation (Swelam, 2005):

$$COP = \frac{Y\, .\, \rho_W\, .\, L_W}{I} \qquad (3)$$

Where, Y: solar still productivity rate, $m^3.m^{-2}.sec.^{-1}$, $\rho_{w:}$ water density, $kg.m^{-3}$, L_w: water latent heat of evaporation, $J.kg^{-1}$, and I: the intensity of incident radiation on the horizontal plane, Wm^{-2}.

Normalized temperature

To omit the effect of the ambient air temperature differences, the normalized temperature (*N,_T*) for the solar still components for different three absorbing material types were determined formulae for water temperature ($N,_{Tw}$), inner glass surface ($N,_{Tgi}$), inner basin temperature ($N,_{Tbi}$) and air temperature inside the basin ($N,_{Tai}$) according to the following:

$$N,_{Tw} = \frac{T_w - T_{ao}}{I}\ ;\ N,_{Tgi} = \frac{T_{gi} - T_{ao}}{I}\ ;\ N,_{Tbi} = \frac{T_{bi} - T_{ao}}{I}\ \text{ and }$$

$$N,_{Tai} = \frac{T_{ai} - T_{ao}}{I} \qquad (4)$$

Where: T_w is the water temperature, (^oC), T_{gi} is the inner glass cover temperature, T_{bi} is the inner basin temperature, (^oC), T_{ai} is the air temperature inside still, (^oC), T_{ao} the ambient air temperature, (^oC) and *I,* the incident radiation in (Wm^{-2}).

Instrumentations

Incident solar radiation: A simple apparatus was used to determine the global radiation, it composed a solar cell connected to a digital multimeter. A previously calibration was carried out against an American made apply Pyranometer before the experimental campaign. The short circuit reading obtained from the cell was converted into Wm^{-2} according to Mujahid and Alamoud (1988) and, Duffie and Beckman (1991).

Temperature measurements: Temperatures inside and outside solar still unit were measured by BTC 100 digital thermocouples which previously calibrated against standard mercury thermometer (-10 up to 100°C scale) with standard deviation of ± 0.47°C, between both readings.

Relative humidity: The ambient air relative humidity (RH) solar still inner air was measured hourly within the investigation period by a means of dry and wet bulb temperatures. The RH was determined using the digital psychometric chart.

Volume of the distilled water and its salinity: grading containers were used to determine the volume where total soluble salts were measured laboratory using the conductivity meter (M4310, U.K made by JENWAY LTD).

RESULTS AND DISCUSSIONS

Absorbing materials effect on the still components temperatures.

Effect of coating the still basin on the distillation processes was tested. The obtained results from indoor investigations under controllable conditions under the solar simulator were analyzed for basin water depth of 0.5 cm (i.e. total water volume in the basin was 2 liters) with average seawater salinity of 33984 ppm. Theses tests were executed under an average incident radiation of 634Wm^{-2} with standard deviation of ±6Wm^{-2} (between the radiation readings), average ambient air temperature of 33.5°C with standard deviations of ±0.2°C (between the temperature readings) for the different four cover configurations.

It was noticed that, basin water temperatures for the three different absorbing material types was increased gradually within the trail period of 9 hours until reached the maximum temperature value near the end of the operating time, as shown in Fig. (3). Continuous increases in water temperatures due to existence of the transparent glass cover which acts as a convection shield to reduce losses from the beneath absorber plate, letting in the coming solar rays and opaque to the infrared rays from the absorber plate wherever it has heating effect (Badran and Al-Hayek, 2004) as well as the trail carried out under the controllable conditions, which led to existence ambient air temperature differences.

Formulae given in equation (4) were used to normalize the obtained components temperature of the different four configurations. To normalized the basin water temperatures when the matt black fiberglass, matt black paint covered with 6 mm glass cover thickness and matt black paint only for different four cover configurations in $^{o}Cw^{-1}m^{-2}$ against the operating time of 9 hours as shown in Fig. (3) A, B and C, respectively.

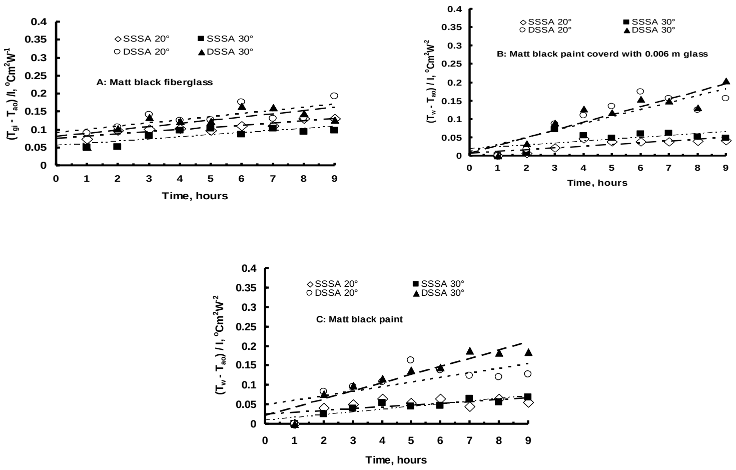


Fig. (3): Normalize water temperature values for the different configuration with different absorbing materials within the investigation period

Average still components temperatures and its normalized values for the different four glazing cover configurations and different three absorbing material types are listed in Table (3). Meanwhile, Figure (3) illustrates the normalized values for the water temperature increase above the ambient per the unit of incident radiation for different investigated designs using the three investigated absorbing materials. Linear fitting line was applied in Fig. (3), the absorbing material techniques A, B and C were positively increased for the normalized values obtained with the exposure time and relationships between the normalized water temperature values and the exposure time to the indoors simulated rays.

Table (3): Averages temperatures and its normalized values still of different absorbing material types used for the different still configurations

	SSSA 20°			SSSA 30°			DSSA 20°			DSSA 30°		
	MFG	**MBPG**	**MBP**	**MFG**	**MBPG**	**MBP**	**MFG**	**MBPG**	**MBP**	**MFG**	**MBPG**	**MBP**
T_w ,	38.2	39	39.1	39.1	40	41.4	37.2	38.6	38.7	38.5	39.2	40.2
N,$_{Tw}$,	0.033	0.030	0.048	0.062	0.044	0.044	0.076	0.106	0.106	0.083	0.111	0.126
T_{ai},	42.6	47.1	46.4	45.5	47.2	47.7	45.7	44.3	43	48.5	48.3	44.8
N, $_{Tai}$,	0.069	0.086	0.126	0.113	0.096	0.085	0.225	0.205	0.129	0.251	0.266	0.185
T_{bi} ,	40	39.6	44	40.2	40.3	47.2	44.2	45.8	40.1	46.1	46.5	40.4
N,$_{Tbi}$,	0.045	0.031	0.099	0.071	0.046	0.081	0.197	0.234	0.129	0.208	0.236	0.131
T_{gi},	46.5	40.4	42.3	41.8	42.3	43.4	40.8	40.3	40.1	41.4	42.3	43.2
N, $_{Tgi}$,	0.105	0.036	0.082	0.084	0.061	0.056	0.136	0.130	0.129	0.126	0.163	0.185

\(MFG: Matt black fiber glass, MBPG: matt black paint with 6mm glass cover thickness and MBP: Matt black paint only)

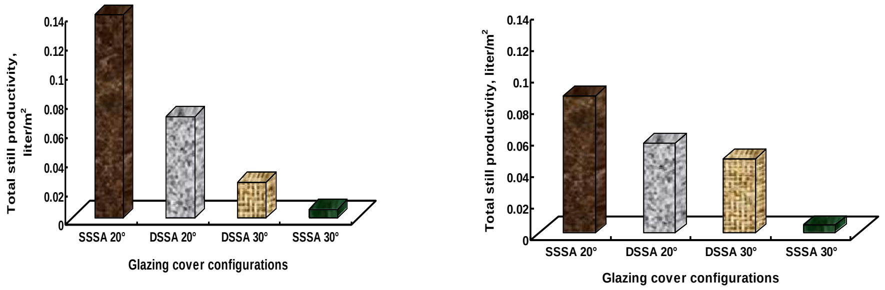
Effect of absorbing material types on the still productivity: The still average productivity for operating period of 9 hours using the three different absorbing materials can be arranged in descending order as: SSSA 20°, DSSSA 20°, DSSSA 30° and SSSA 30°; which were found to be 0.083, 0.013, 0.012, and 0 liter/m^2, respectively. This result obtained when the basin water depth was of 0.5 cm and average incident rays intensity of 617Wm^{-2} (with standard deviation of ±27 Wm^{-2}) and average relative humidity of 61.3%. The absorbing material type effect on the still productivity for the highest configuration outcomes (SSSA20°) revealed it can be arranged in a descending order to be matt black fiber glass, matt black paint only and matt black paint covered with 0.6mm glass, as the still productivity was found as 0.1, 0.087 and 0.062 liter/m^2, respectively.

Figure (4) represents the obtained results from comparative study that was carried out on the productivity of different still configurations as affected by absorbing material type. The still productivity from figure (4) in case of the single slope still with angle of 20°, SSSA 20° configuration with different three absorbing material types as it is given in table (3), was higher than the other configurations although water temperatures and its normalized values for different three absorbing material types, were lower than these configurations. This might be referred to:

- The sum heat transferred by radiation, convection and evaporation inside solar still from water surface to the inner surface of the glass cover (Q_1) in case of SSSA 20° configuration was higher than the other configurations with different absorbing material types illustrated the schematically in figure (5), also, it is given in our following study.
- At higher temperature values the still showed lower productivity values as the still components already warmed and the heat utilized in evaporation decreasing after reaching the maximum thermal capacity (Swelam, 2005).
- Water droplets falls back to the water basin resulted a decrease in the amount of water collected and accordingly the still productivity.

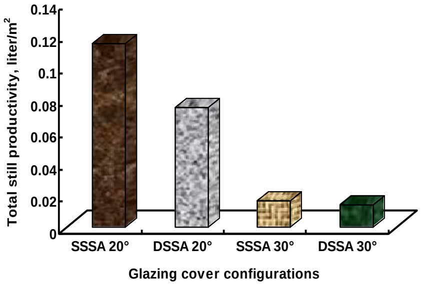
Table (4): Comparison between average still efficiency (%) for different four configurations and different absorbing material types

Glazing cover configurations	Absorbing material types			Average efficiency,%
	Matt black fiberglass	Matt black paint covered by 6 mm glass	Matt black paint only	
SSSA 20º	14.9	11.9	14.3	13.7
SSSA 30º	0.68	0.49	1.5	0.89
DSSA 20º	11.4	9.3	13.5	11.4
DSSA 30º	4.02	7.4	2.4	4.60
Average efficiency, %	7.75	7.27	7.92	



Fiberglass

Matt black paint with 6mm thick glass



Matt black paint

Fig. (4): Effect of the absorbing material types and for different configurations on the still productivity

Gab distance effect on the still productivity

The spacing between water surface and glass cover (as a result of water depth), and the glass cover slope (either single or double slope) affects the still productivity. Increasing the inclination of single slope solar still glass cover increased condenser area (inner glass cover surface) and enhanced energy loss rate but increase spacing between water surface and glass cover led to lower water temperature and lower productivity, so that minimized glazing cover slope is desirable to minimize solar radiation reflected from it. This fact is obvious from the obtained results from using the different absorbing materials for different investigated still configurations. It was found that, productivity outcomes from lower stills glazing tilt angle (20^{o}) for either single or double slopes (for different absorbing materials) was higher than higher angles (30^{o}). For instance comparing SSSA 20^{o} and SSSA 30^{o}configuration, it was found that, when the condensation surface area was increased from 0.8038 to 1.0626m^2, the still productivity decreased from 0.14 to 0.00625 liter/m^2 for the same absorbing material (i.e. matt black fiberglass) also it was noticed for the different absorbing mateials. Using the matt black paint only as an absorbing material, resulted in average still productivity for the different investigated configurations arranged in descending order as: SSSA 20^{o}, DSSSA 20^{o}, SSSA 30^{o} and DSSSA 30^{o}, as the average productivity were found to be 0.11, 0.075, 0.016 and 0.013 liter/m^2, respectively. Also, this fact was revealed when the matt black fiber glass and the matt black paint covered with 6mm glass were used. The configuration in term of its productivity can be arranged in descendent order as: SSSA20^{o}, DSSSA20^{o}, DSSSA30^{o} and SSSA30^{o}. Its productivity were (0.14 and 0.078), (0.07 and 0.057), (0.025 and0.047) and (0.00623 and 0.005) liter/m^2, respectively.

Effect of the incident rays tilt angles and basin water depths on the still productivity:

It was found that, SSSA 20^{o} configuration with matt black fiberglass gave the highest productivity as compared with other configurations for the same operation period of 9 hours. When the basin water depth decreases; the still productivity was increased during lighting on period (which represents the daylight period) under the open environmental conditions. This increase in the productivity might refers to the decreases in the water depth in the basin, the brine have a lower heat capacity which results in a higher water temperature in the basin and thus higher evaporation rate. Also, it was observed that incident rays with tilt angle of 25^{o} gave highest still productivity as compared with the other different incident rays tilt angles and different basin water depths where it produced 0.22 liter/m^2 at basin water depth of 0.5 cm under average incident solar radiation of 623 Wm^{-2}, average ambient air temperature of 34^{o}C.

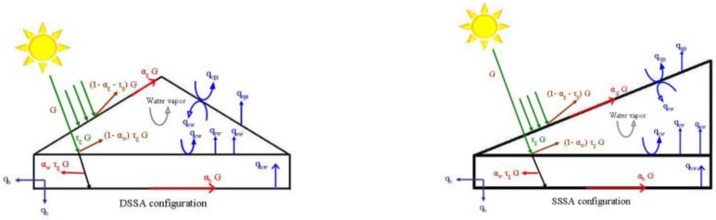


Fig (5): Heat transfer mechanism in both single and double slope solar stills configurations

Effect of the absorbing material types and the glass-cover slope on the still efficiency for different configurations: Table (4) represents the average still efficiency which was calculated according to equation (1) under simulated rays intensity to that falls on the investigation region for the four different configurations of different three absorbing material types, with stable water depth at 0.5cm. It was found that, reducing the glass cover temperature helps in increasing the still productivity. Increasing the temperature differences between the inner side of the glass cover and water in the basin increased the air-mass natural-circulation inside still. It increases both convective and evaporative heat transfer between basin water and cover. The cooler inner glass cover surface increases the condensation rate. As water evaporation depends upon the natural convection circulation of air mass inside the still which is the function of temperature difference between the water and the glass cover. This differences in the temperature is the driving force for the circulation of air and the water temperature (Cooper, 1979). Also the water evaporation rate depends on exposure area of water in the basin with air mass in circulation inside the still (Kwatra, 1996). Reduction the inner glass cover surface temperature and increase of the basin water temperature increased the condensation rate and resulted an increase in the still productivity.

Using matt black fiberglass as absorbing material for different four configurations gave average efficiency of 7.75% while, matt black paint only gave an average 7.92%. Painting the still basin with matt black paint only (absorptivity of 95%, according to Norton, 1992) then covering the paint with 0.006 m glass cover thickness (transmissivity of 82%) resulted in average efficiency of 7.27%. That mean the matt black paint only then matt black fiberglass has better efficiency compared to painting the still basin with matt black paint then covered (the basin absorbing surface) it with 6 mm glass cover thickness. This due to the average solar incident rays in case of matt black paint only (i.e. 604 Wm^{-2}) for different four glazing cover configurations lower than other absorbing material types (i.e. 613 and 634 Wm^{-2}) for matt black paint covered with 6 mm glass cover thickness and matt black fiberglass respectively) as well as inversely relationships between still efficiency and solar incident rays as observed from equation (1). Also, the laboratory investigations revealed that the still efficiency is affected by the glazing cover configuration, glazing cover slope angle and the type of the basin absorbing material as it is given in Table (2).

Effect of the different parameters on the still C.O.P: The different parameters affect the still C.O.P. such as absorbing material type, glazing cover configuration, glazing cover slope angle, solar incident rays angle and basin water depth were examined.

Table (5) represents the coefficient of performance (C.O.P) of the still calculated from equation (2) according to Swelam, (2005). The given results in the table are for the indoor investigations under simulated rays to that of the sun for different four glazing cover configurations with different three absorbing material types and different solar incident rays angles, respectively. From table (5), the effect of applying matt black fiberglass, matt black paint covered with 6 mm glass cover thickness and matt black paint only as absorbing material types resulted in average C.O.P of $2.29x10^{-3}$, $2.07x10^{-3}$ and $2.37x10^{-3}$ respectively. Also it is noticed that, matt black paint only gave highest average C.O.P as well as the still efficiency with the same sequence and under the same controllable conditions which previously mentioned in still efficiency.

Water salinity: Salinity values of the distilled water are represented in table (6). It is noticed that, for all the still configurations the distilled water salinity listed in Table (6) are accepted to fulfill the different purposes such as, a drinking and sanitary usage (for human drinking according to Joseph, *et al.*, (2005), agriculture (irrigation of the agricultural crops). Degree of restriction on distilled water usage is given in Table (7) as: none, light to moderate and severe since the first water class or degree are used for all agricultural crops, the second class can be used for moderately tolerant crops such as wheat, soybean, sorghum, rye and safflower while the third used for tolerant crops such as cotton, sugar beet, barley, asparagus and date palm (U.C.C.C.,1974) and finally animals such as dairy cattle, beef cattle, sheep, livestock and poultry (A.D.A.F.F., 2002).

Table (5): Still C.O.P for different four glazing cover configurations and different three absorbing material types

Glazing cover configurations	Absorbing material types		
	Matt black fiberglass	Matt black paint covered with 0.006 m glass cover thickness	Matt black paint only
SSSA 20°	4.90x10^{-3}	3.90x10^{-3}	4.70x10^{-3}
SSSA 30°	3.03x10^{-4}	2.10x10^{-4}	6.60x10^{-4}
DSSA 20°	2.90x10^{-3}	2.30x10^{-3}	3.50x10^{-3}
DSSA 30°	1.08x10^{-3}	1.90x10^{-3}	6.40x10^{-4}
Average C.O.P	2.29x10^{-3}	2.07x10^{-3}	2.37x10^{-3}

Table (6): Salinity of distilled water for different three absorbing material types used for feeding water average salinity of 33984 ppm

Glazing cover configurations	salinity of the distillated water, (ppm)		
	Matt black fiberglass	Matt black paint covered with 0.006m glass cover	Matt black paint only
SSSA 20°	177.3	143.3	121.6
SSSA 30°	23.71	23.71	288
DSSSA 20°	68.82	301.6	96
DSSSA 30°	42.30	486.4	160

Table (7): Water salinity interpretations for different purposes according to A.D.A.F.F., (2002) [A]; N.A.S., (1974) [B] and U.C.C.C., (1974) [C]

Purposes	Water salinity, ppm	Rating
Sanitary[A]	<100	Excellent
	100-1000	Good to fair
	1000-1200	Poor
	>1200	Unacceptable
Animals[A]	Water salinity, ppm	Rating
{Dairy cattle}	3500	Maximum level
Beef cattle	4800	
Cheep	7150	
Livestock and poultry[B]	<960	Excellent
Agriculture[C]	Water salinity, ppm	Degree of restriction on use
	< 450	None
	450-2000	Light :Moderate
	> 2000	Severe

Conclusions

The study can be conducted the following conclusions:-

- Increasing the condensation surface area and the gab between the basin water surface and the glass cover, the still productivity decreased for the different investigated configurations.
- The still productivity increased as the basin water depth decreases, during lighting on periods, (daylight period under the open environmental conditions).
- Coupling solar still with storage tank increased the basin water temperature as it increased the temperature difference between the basin water and the glass cover which leads to a better productivity and efficiency.
- Efficiency determinations for the solar still revealed that; slope the glass cover with an angle of 20^o either for the single slope or double slope configurations gave higher efficiency as compared with the slope of 30^o. Meanwhile, efficiency of the single slope of 20^o was higher than that for double slope with the same angle. It was 13.7% and 11.4%, respectively.
- Applying the matt black fiberglass, matt black paint covered with 6mm glass thick and matt black only as absorbing materials for the four different stills resulted in average efficiency of 7.75, 7.27 and 7.92%, respectively.
- The effect of applying matt black fiberglass, matt black paint covered with 6 mm glass cover thickness and matt black paint only as absorbing material for the different solar still configurations resulted in average C.O.P of 2.29x10^{-3}, 2.07x10^{-3} and 2.37x10^{-3}, respectively**.**
- Obtained desalinated water salinity is accepted not for drinking water (500 ppm) only but for the different agricultural purposes also.

NOMENCLATURES

A_g	Glazing surface area, m^2	T_{ai}	Air temperature inside still, ^oC
I	Rays intensity, Wm^{-2}	T_{amb}	Ambient air temperature, ^oC
L_w	Water latent heat of evaporation, Jkg^{-1}	T_{wb}	Water temperature, ^oC
m	Mass of condensate water, kg	T_{wt}	Water temperature inside preheating feeding tank, ^oC
q_{cw}	Convective heat transfer from water surface to the inner glass surface, Wm^{-2}	T_{gi}	Inner glass temperature, ^oC
q_{ew}	Evaporative heat transfer from water surface to inner glass surface, Wm^{-2}	T_{go}	Outer glass cover temperature, ^oC
q_{rw}	Radiative heat transfer from water to inner glass surface, Wm^{-2}	T_b	Basin temperature, ^oC
q_{bw}	Convective heat transfer coefficient between the black basin and water, Wm^{-2}	T_{bi}	Inner basin temperature, ^oC
q_{cga}	Convective heat transfer from the outer glass cover to the atmosphere, Wm^{-2}	T_{bo}	Outer basin temperature, ^oC
q_{rgs}	Radiative heat transfer from the outer glass cover to the sky, Wm^{-2}	ΔT	Temperature difference between two consecutive effects, ^oC

q_b	Conductive heat transfer from the bottom to the atmosphere, Wm^{-2}
q_1	Total energy transfer within the still from water to glass cover, Wm^{-2}
q_2	Total energy transfer between the still and its surroundings, Wm^{-2}
T	Temperature, ^oC
T_{ao}	Air temperature outside the still, ^oC
Δt	Time interval, *sec*

Latin Symbols

α	Absorpitivity, %
ρ	Density, kgm^{-3}
τ	Transmissivity, *%*
η	Still efficiency, *%*

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دراسة تحت ظروف محكمة لبعض العوامل المؤثرة على اداء اشكال مختلفة لمقطرات شمسية

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أجريت التجارب بقسم الهندسة الزراعية - كلية الزراعة - جامعة قناة السويس بالإسماعيلية لاختبارأربعة أشكال مختلفة من المقطرات الشمسية تحت ظروف اختبار محكمة بإستخدام المضاهى الشمسى و ذلك للتحكم فى الظروف البيئية المحيطة بالتجربة و امكانية تكرارها وتقييمها تحت نفس ظروف الأختبار و ذلك نظرا لصعوبة الأختبارات تحت ثبات الظروف الجوية. و تتكون كل وحدة من وحدات التقطيرالشمسية المختبرة من: خزان تسخين للمياه أولى عبارة عن تنك بلاستيكى أسود، انابيب ماء و نظام للحفاظ على منسوب الماء فى حوض الماء يعمل بنظرية الأوانى المستطرقة ، حوض للماء بأبعاد: 80، × 0.50 ×10، م طول وعرض وإرتفاع والغطاء الزجاجى ثم قنوات التجميع على الترتيب. و قد تم وإختبار أربعة تصميمات من الأغطية الزجاجية : غطائين ذو ميل من جانب واحد بزاوية ميل على الأفقى 20˚ ، 30˚ (SSSA20º and SSSA30º) و غطائين ذو ميل من جانبين بزاوية ميل على الأفقى 20˚ ، 30˚ (DSSA20º and DSSA30º) على الترتيب كما تم إختبار مدى تأثير إستخدام ثلاث مواد ماصة لكل وحدة من الوحدات المختبرة على أدائها من حيث إنتاجية المقطر، كفاءته و معامل اداؤة بالأضافة لدرجات حرارة مكوناته تحت نفس ظروف الأختبار، كما تم دراسة تأثير زواية سقوط الأشعة على أداء المقطر. وتم إختبار المواد الماصة لكل نوع مقطر من الأربعة تحت الدراسة. وقد اختيرت المواد الماصة لتقليل تاكل الطلاء الأسود المدهون به الحوض بواسطة الماء المالح (مما يقلل من امتصاصية الأشعة الساقطة وذلك بتغطيته بالزجاج الشفاف بسمك 6مم و اختبار مادة ماصة جديدة تقاوم التاكل و المواد الماصة المختبرة هى: مادة الفيبرجلاس الإسود واللون الإسود المطفى المغطى بلوح زجاج بسمك 6 مم والتى تم مقارنتهم بطلاء الحوض باللون الإسود المطفى الغير مغطى. كما تم تقييم أداء وحدة التقطير الشمسى من حيث كفاءة الوحدة و معدل الأداء. كما تم قياس كمية الماء المقطر الناتج من كل وحدة تقطير شمسى.

و قد توصلت الدراسة إلى النتائج التالية :-

- أن إنتاجية وحدة التقطير الشمسى إنخفضت بزيادة الفراغ بين سطح الماء فى الحوض و الغطاء الزجاجى.
- بزيادة مساحة سطح التكثيف وانخفاض عمق الماء فى الحوض ، فإن الإنتاجية تزداد وذلك فى أثناء فترة الإضاءة بإستخدام المضاهى الشمسى (و التى تمثل فترة سطوع الشمس و ذلك من شروق الشمس إلى فترة الغروب فى الظروف المناخية السائدة لمنطقة الدراسة).
- وجد أن إستخدام خزان تسخين الماء مع وحدة التقطير الشمسى أدى لزيادة انتاجية الوحدة المختبرة حيث أثر ليس فقط فى ارتفاع درجة حرارة الماء فى الحوض ولكن أيضا بزيادة الفرق فى درجة الحرارة بين سطح الماء فى الحوض و السطح الداخلى للغطاء الزجاج مما أدى إلى زيادة زيادة إنتاجية الوحدة و بالتالى كفاءتها0
- أظهر تقدير كفاءة وحدة التقطير الشمسى أن زاوية ميل غطاء وحدة التقطير بزاوية 20˚ أنسب من الزاوية 30˚ حيث حيث كانت كفاءتها أعلى و أن كفاءة المقطر الذى يميل سطحة من جانب واحد بزاوية 20˚ كان اعلىمن الكفاء فى حالة ميله او من جانين حيث كانت الكفاءة 13.7 و 11.4% على التوالى.
- استخدام الثلاثة مواد الماصة مع الأربعة انواع مقطرات والتى تضمنتها الدراسة اظهرت أن كفاءتها فى حال استخدامها هى على التوالى 7.75 و 7.27 و 7.92 % على التوالى للمواد الماصة الصوف الزجاجى الأسود المطفى، الطلاء الأسود المطفى و المغطى ب 6مم زجاج و الطلاء الأسود الغير مغطى.
- متوسط معامل الأداء لمختلف وحدات التقطير الشمسى المستخدمة كنتيجة لاستخدام المواد الماصة وجدت 2.29 × 10^{-3} عند إستخدام الفيبرجلاس الإسود وذلك بالمقارنة بالمواد الماصة الأخرى مثل ، اللون الإسود المطفى المغطى بلوح زجاج بسمك 6 مم و اللون الإسود المطفى الغير مغطى حيث كان معامل الأداء كالأتى: 2.07 × 10^{-3} ، 2.37 × 10^{-3} على الترتيب0
- ملوحة المياة المقطرة الناتجة من التقطيرات الشمسية باشكالها المختلفة وجدت من خلال الدراسة أنها تقع فى الحدود المسموح بها ليس فقط للشرب والأستخدام الأدمى (500 جزء فى المليون) بل و لجميع الأغراض الزراعية من رى المحاصيل على مستوى تحملها للملوحة و لجميع أنواع الحيوانات المزرعية 0