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The Effect of Construction Material on the Desalination Plant Using Solar Mirrors

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Abstract— *The objective of this study is to determine the best material for building the direct Solar desalination plant using concentrated mirrors. The study was applied on three pilot plants that were erected in the experimental laboratory site area of faculty of engineering, Ain Shams University, Cairo, Egypt. This study was made in four months covered spring and summer seasons which simulated the best climatic period to help in obtaining the best performance of the pilot plants.*

The three applied materials were steel, glass & acrylic. The applied raw water were prepared in the lab using sodium chloride and distilled water. Each pilot occupies 2m2 and consisted from three serial channels on three levels inside the trapezoidal shape room with flat bottom and inclined roof. The system used three mirrors of galvanic steel to concentrate sun rays on saline water channels for the all sunshine period. The system used a very small pump with flow rate 40 l/h to ensure enough retention time in the pilot to heat water and evaporate it.

The measurements for water temperature, TDS, pH, and flow rates of inlet and outlet were made. Also air temperature & humidity ratio out and inside each pilot were measured. The sunshine period had been taken during all days of the study period.

The results of fresh water were varied from 8 l/h to 18 l/h with acrylic plant and 8 to 20 l/h with glass plant and with steel it achieved variation between 15 – 30 l/h which were good in quality and quantity of produced fresh water with minimum cost. The study show that the recovery ratio was (10%-45%) with acrylic plant and (20%-50%) with glass plant and from (37% - 75%) with steel plant which is a good ratio for all solar desalination plants compared with other systems of desalination. The produced TDS from all plants in the fresh water was between 20 -60 ppm that may need some salt additives to meet the range of WHO recommendation No. 7.

The retention time inside all units was almost the same to ensure the comparison validity. The steel plant achieved the higher productivity with also the lower in construction cost but it need also the higher running cost before the need of repainting every year.

Keywords— *Water Treatment, Seawater Desalination, Solar Desalination, Renewable Energy & Construction Materials.*

I. INTRODUCTION

Water resources in Egypt are limited to the Nile River, rainfall and flash floods, deep groundwater and desalination of sea and brackish water. Each resource has its usage limitation, even these limitations are related to quantity, quality, space, time, or exploitation cost [1].

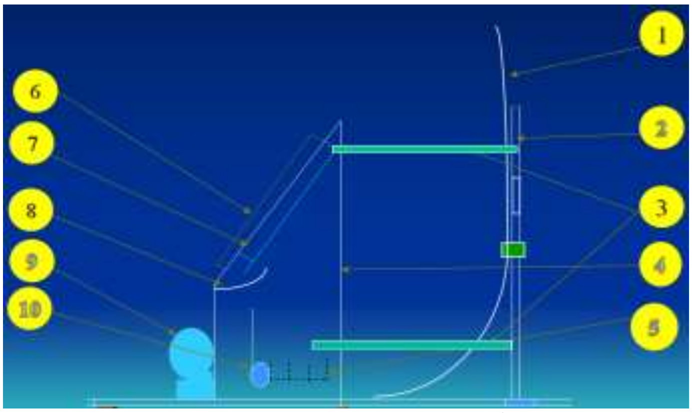
With the population growth increase, with the increase in water needs for industrial and agricultural needs and the stability in the Egypt fresh water resources quantities with probability for its decrease in near future. A need raised to develop low cost technology to deal with seawater as water resource. The solar desalination seems to be one of the best solutions for such case.

Solar-powered desalination processes are generally divided into two categories, direct and indirect systems [3]. The direct systems are those where the heat gaining and desalination processes take place naturally in the same device. The basin solar still represents its simplest application of working as a trap for solar radiation that passes through a transparent cover.

In indirect solar system, the plant is separated into two subsystems, a solar collector and a desalination unit. The solar collector can be a flat plate, evacuated tube or solar concentrator and it can be coupled with any of the heat distillation unit types which use the evaporation and condensation principle, such as MSF, VOC, MED and MD for possible combinations of thermal desalination with solar energy. Systems that use PV devices tend to generate electricity to operate RO and ED desalination processes [2].

In 2002 Dr. El Nadi proposed an idea of a low-cost desalination unit that depends on solar rays' concentrations by concave mirrors [4].

Meshaly, O., et al., [4] made a model for that unit figure 1 and proved that this idea is applicable to produce fixed quantity with good quality for produced desalinated water. His study covered the main elements affected the unit operation and obtains its best values for the system success.



1. Solar collector.	6. Mirror surface.
2. Condenser humidifier.	7. Vertical fixed.
3. Fresh water channel.	8. Horizontal fixed (arms).
4. Inside Sea water channel.	9. Glass face.
5. Plant body	10. Open out for saline.

Fig. 1. Pilot Plant Model [4]

Also it deduced the optimum area for the used mirror and the best methodology for humidifier condenser & the saline water internal channel path length. The system achieved low power

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consumption compared to all other desalination systems per m^3 production. The initial cost, operation cost is minimized compared to other systems. The system saves about 70% of the needed area, 75 % of the initial costs and 40 % of the running costs when compared with old direct solar desalination system.

El Hosseiny, O.M., et al. [5] continued the experimental work on the previous solar plant model. His study was divided into two phases first experimental work by operating the plant in the site under several climatic conditions and the second was identifying design criteria for the plant. The study deduced the design equations and proved the plant productivity from fresh water between 25 – 180 l/d/m^2 due to weather variation among a year.

El Sergany, F. A. GH. [6] had continued her study on the same pilot plant. The study concluded that the climate conditions: air temperature and sun shine rate are affecting the system efficiency by big effect that the summer production is more than 180% of winter production and about 100% more than the average production. The mirror surface area is proportional gradually with the production rate. Also the shape of this mirror and the convection angle affects the fresh water production. The optimal convection angle was 15° and the area should not less than the plant open side area to get the maximum production value at summer period.

El Nadi, et al. [7] suggested applying this plant all over coastal places in Egypt and other hot countries and some modification on the plant to be applied such as using multiple longer mirrors, increasing the length and the number of channels and studying the K factor in different locations, thus to increase the plant's efficiency.

Naguib, A.H.M., et al. [8, 9] made a pilot from acrylic sheets consisted of a sloped back box, three serial seawater channels divided into two series V-shaped channels, two fresh water channels, a solar collector of red copper pipes to reduce the temperature of the sloped back, mirrors of chrome sheets and dosing pump to feed the pilot with raw seawater flow rate of seawater (52-54 l/h), TDS 19500 ppm gave low fresh water rate (0.67-1.08 l/h) because of acrylic material, and TDS (20-40 ppm).

Amin, R.A., et al., [10] modified Naguib acrylic pilot to improve its applicability. The study proved that the modifications made enhancing by 60% in productivity and recovery ratio.

II. Materials & Methods

The seawater desalination system using solar rays concentrating mirrors was applied in this study on three materials of construction to determine the most suitable material for such system which proved in previous studies its applicability and high recovery ratio.

III. Operation Program

The pilot operation program was designed to cover most of climatic conditions in Egypt, so the study period was about four months to cover the best climatic conditions in summer to determine the pilot recovery ratio under the climatic period.

Fig. 2. The steel pilot plant

Fig. 3. The Glass pilot plant

Fig. 4. The acrylic pilot plant

The program of operation was consisted for each pilot unit from the following items:

1. Air temperature is measured several times during operation day.
2. The volume of raw seawater is recorded daily before and after operation.
3. The volume of fresh water and brine are recorded after operation.
4. Working hours of operation is recorded to calculate the flow rate of raw seawater, desalinated water, and brine.
5. Three different samples are taken daily from different location to measure parameters and their changes.
6. Every location of samples represents a type of water in the operation:

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- Sample (1): raw seawater
- Sample (2): desalinated water
- Sample (3): brine

7. The measured parameters are pH value, water temperature, TDS.

IV. Results & Discussions

The results of the work done due to the operation of the three different constructed materials pilot plants during the study period from April 2018 till July 2018 to measure the factors and calculate the recovery ratio and the efficiency are presented here after in following tables 1, 2 & 3 and figures 5.

TABLE 1. Average Raw Water Analysis Results

Date	T of air °C	T of raw °C	T of inflow °C	Humidity %	pH	Q l/hr	TDS ppm	Sunshine Period hr
April	29	27	34	52	7.4	40	25940	12:19
MAY	34	30	42	53	7.4	40	24920	12:59
JUNE	36	40	60	48	7.6	40	28600	13:14
JULY	37	41	65	55	7.6	40	31370	13:55

TABLE 2. Average Desalinated Fresh Water Analysis Results

Plant Material	Date	Tfresh °C	Q l/hr	pH	TDS ppm
Acrylic plant	April	33	8	7.3	60
	MAY	42	10	7.2	60
	JUNE	51	12	7.1	60
	JULY	54	18.2	7.2	60
Glass Plant	April	38	10	7.3	40
	MAY	46	14	7.3	43
	JUNE	55	17	7.2	38
	JULY	60	20	7.2	36
Steel Plant	April	40	13	7.3	30
	MAY	47	21	7.2	27
	JUNE	58	24	7.2	24
	JULY	63	30	7.2	20

TABLE 3. Average saline water analysis results

Plant Material	Date	T of saline °C	Q l/hr	pH	TDS ppm
Acrylic plant	April	35	32	7.6	25970
	MAY	43	30	7.5	25130
	JUNE	54	28	7.8	28750
	JULY	56	21.8	7.8	31440
Glass Plant	April	39	30	7.5	25960
	MAY	47	26	7.6	25120
	JUNE	56	23	7.6	28730
	JULY	61	20	7.5	31420
Steel Plant	April	41	27	7.6	25960
	MAY	47	19	7.5	25110
	JUNE	59	16	7.5	28710
	JULY	63	10	7.6	31400

From the four months results the effects of the studied parameters as temperature, inflow rate, TDS concentration, pH value and air humidity could be illustrated here after.

From the four months results, it is observed that the constructed material affected on the production quantity as illustrated in figure 5. Also the material type has variable reflection on productivity with weather variations.

The results of fresh water were varied from 8 l/h to 18 l/h with acrylic plant and 10 to 20 l/h with glass plant and with steel it achieved variation between 13 to 30 l/h which were very high compared with the traditional solar desalination plants (4 to 10 lit /d /m2) [5] about 26 to 39 times the production capacity. The desalination plant assisted with solar concentrating rays mirrors needs very small area compared with the traditional solar desalination plants about 1/26 up to 1/ 39 the required area for the traditional plant. It needs almost similar to the Reverse Osmosis plant [5] but with out the pre treatment part. Also, these values were good generally in quality and quantity of produced fresh water with minimum cost compared with other desalination systems.

The recovery ratio also affected by the plant construction material and the air temperature variation as illustrated in Figures 6 &7.

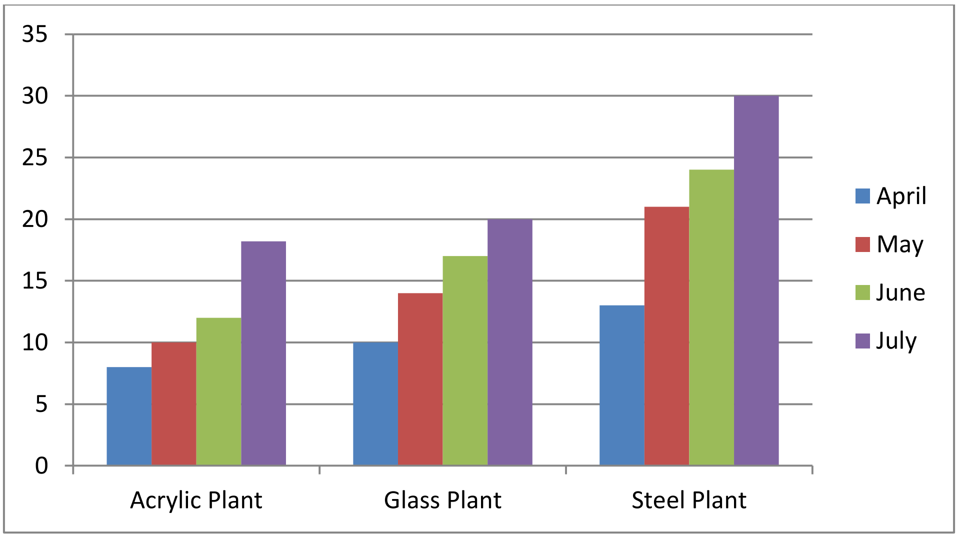

Fig. 5. Different desalinated Flow Rates in l/h for the three testeed plants

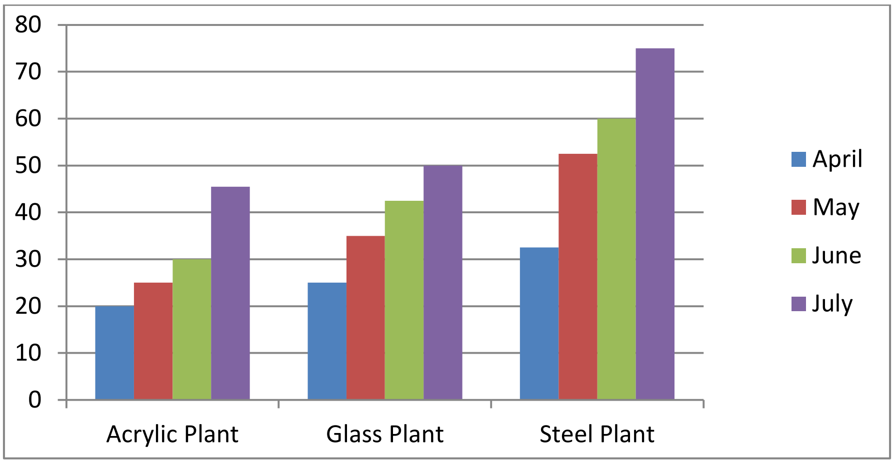

Fig. 6. Different Recovery Ratios (%) For The Three Applied Plants

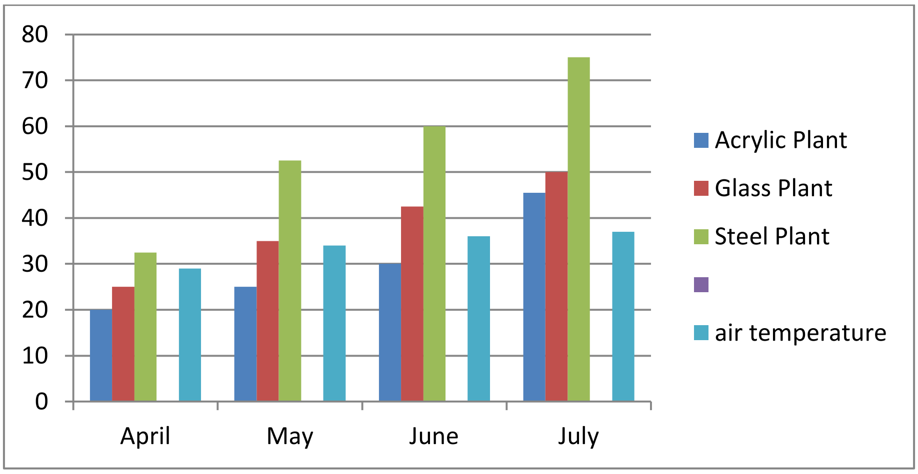

Fig. 7. Air Temperature (ºC) and the Recovery Ratio (%) For The Three Applied Plants

The study show that the recovery ratio was (20%-45%) with acrylic plant and (25%-50%) with glass plant and from (32% - 75%) with steel plant which is a good ratio for all solar desalination plants compared with other systems of desalination.

The produced TDS from all plants in the fresh water was between 20 -60 ppm that may need some salt additives to meet the range of WHO recommendation No. 7.

The retention time inside all units was almost the same to ensure the comparison validity. The steel plant achieved the higher productivity with also the lower in construction cost but it needs also the higher running cost for the need of repainting every year.

Table 4 shows the comparison technically and financially between the three applied materials plants.

The comparison shows that the steel plant was the best in productivity, recovery ratio and effluent concentration as technical points. The steel plant also is the lowest in required area and construction cost. In the other hand its running cost is the higher value due the need for isolating painting to prevent the corrosive effect of sea water and oxidation by water vapor that make its life age very small not exceed 10 years.

The Glass plant even it is the most critical construction material for its feasibility to break, that may also decrease its life age. But still it is better than the acrylic plant for all the technical and financial parameters except the running cost it is higher.

TABLE 4. Technical & Financial comparison

Plant Type		**Acrylic Plant**		**Glass Plant**		**Steel Plant**	
Comparison Face	**wt**	**value**	**wt**	**value**	**wt**	**value**	**wt**
Productivity L/h/m2	10	8 - 18	5	10 - 20	7	13-30	10
Recovery Ratio %	10	20 - 45	5	25 -50	7	32-75	10
TDS effluent conc. ppm	10	60	6	36-40	8	20-30	10
Area need in m2/100 m3/d	10	960 - 430	8	770 - 385	9	590 - 257	10
Construction cost LE/m3/d	10	80000	7	60000	9	50000	10
Running cost LE/m3/d/year	10	6000	10	10000	8	20000	4
Total	60	Third	41	Second	48	First	54

The acrylic plant was the lower in everything except the running cost it is the best in it but the other parameters specially the productivity that affected on all other parametersmake it the werst solution for such type of desalination plants

V. CONCLUSIONS

Due to the discussion of the study results the following conclusions could be obtained:

1. The desalination plant assisted with solar concentrating rays mirrors needs very small area compared with the traditional solar desalination plants about 1/26 up to 1/ 39 the required area for the traditional plant.
2. The results of fresh water were varied from 8 l/h to 18 l/h with acrylic plant and 10 to 20 l/h with glass plant and with steel it achieved variation between 13 to 30 l/h which were very high compared with the traditional solar desalination plants (4 to 10 lit /d /m2) about 26 to 39 times the production capacity.
3. The recovery ratio was (20%-45%) with acrylic plant and (25%-50%) with glass plant and from (32% - 75%) with steel plant which is a good ratio for all solar desalination plants compared with other systems of desalination.
4. The produced TDS from all plants in the fresh water was between 20 -60 ppm even the inlet TDS was between 24900 and 31400 ppm that are very good results.
5. The comparison shows that the steel plant was the best in productivity, recovery ratio and effluent concentration as technical points.
6. The steel plant also is the lowest in required area and construction cost. In the other hand its running cost is the higher value due the need for isolating painting to prevent the corrosive effect of sea water and oxidation by water vapor that make its life age very small not exceed 10 years.

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