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Experimental Investigation of an Integrated Solar Green House for Water Desalination, Plantation and Wastewater Treatment in Remote Arid Egyptian Communities

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Abstract

Desalination/plantation/treatment is the current article target to supply an adequate amount of drinking and irrigation water as well as wastewater treatment for safe disposal to people across the new communities along the remote and arid areas in Egypt. In the present study, an Integrated Solar Green House (ISGH) for water desalination, plantation and wastewater treatment is constructed and field tested under actual meteorological conditions at Giza, Egypt. The ISGH system uses the solar water desalination principle and works by saturating air with moisture vaporizing from brackish/seawater inside a greenhouse followed by dehumidifying, causing freshwater condensation. Different experiments have been performed on the ISGH to evaluate its thermal performance under the actual field meteorological conditions. The results indicated that the present ISGH can be used successfully to provide a low-cost solution in arid areas, where the fresh water is very limited. In addition, it is a relevant method of cultivation that provides desalinated water, cooling environment and humidifying environment in an integrated system. Self-sufficient water production combined with low internal irrigation requirements mean that the ISGH offers significant water saving by reducing agricultural demand. The present system fulfils the safe disposal of treated waste water and to reduce the highly contaminated/ polluted waste water discharged directly or indirectly on the ground water.

Selection and peer-review under responsibility of the Euro-Mediterranean Institute for Sustainable Development (EUMISD)

Keywords: Experimental investigation, Solar Greenhouse, Water desalination, Cultivation, Irrigation, Wastewater treatment, Reuse.

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1. Introduction

Renewable energy sources in Egypt has a remarkable effect for water desalination and benefits as a clean source of energy, cannot be depleted, and don't contribute to global warming or greenhouse gas emissions. Due to these sources are natural, with minimal maintenance and operational procedures costs; they are recently used in water desalination in remote areas. They represent the best option due to the high cost of providing a corresponding conventional facility. Fortunately, Egypt is blessed with good sunshine especially in Upper Egypt and remote areas such as Sinai, Toshka and Owaynat. They receive solar radiation reached 5–8 kWh/m^2day. Therefore, the Integrated Solar Green House (ISGH) for water desalination, plantation and wastewater treatment has good potential in these areas of Egypt where other sources of energy may be unavailable or more expensive. Solar water desalination has considered a promising renewable energy-powered technology for producing fresh water. Humidification–Dehumidification (HDH) of solar desalination will increase the overall efficiency of the system. HDH process depends on mixing air with water vapor, and then extracts water from humidified air by a condenser. The amount of vapour that air can hold depends on its temperature. The ISGH is a new development that produces fresh water from sea or saline water, cools and humidifies the plants growing environment, creating an optimum environmental conditions for the cultivation of valuable crops [1-2]. In the current study, ISGH system extracts fresh water from saline one to be used in plant propagation as a non-conventional agricultural production of high valued organic plants free of chemical fertilizers and any other pollutants. ISGH system includes additional units for domestic wastewater as well as sludge treatment for safe reuse agricultural purposes. In Egypt, while 217 cities are covered with full sanitation system, still more than 3900 villages from 4617 are suffering from absence of wastewater treatment services [3]. Enhanced removal of dissolved Fe and Mn from well water in Delta District, Egypt has been studied. Removal of Fe &Mn exceeded 92% and 96% with residual concentrations less than 0.1 and 0.05 mg/l, respectively. These values fulfilled the Egyptian guidelines for safe water requirements [4]. Treatment of sewage sludge contains pollutants such as heavy metals, organic pollutants and pathogens has been treated by addition of cement kiln dust at its optimum operating condition as coagulant. Results showed that dramatically reduction of organic loads, heavy metals; microbial concentrations and odor controlled for agricultural purposes, with the catalytic properties have been studied. Sewage sludge was used for compost production in combination with agricultural waste, groundwater protection and minimizes the health risk levels as well as reduces air emissions and solid waste disposal [5].

2. Experimental Set-up and Procedure

The integrated Solar Green House (ISGH) for water desalination and plantation system consists of solar Green House, Plantation area, Humidification–Dehumidification (HDH) system, solar water distillation system, solar wastewater treatment system, storage tanks with piping connections as shown in Fig. 1.

2.1. Solar Green House and Plantation Area

It is manufactured from a metal frame in the form of greenhouse shape. It is installed in the experimental field of National Research Centre, Cairo, Egypt. The metal frame is fixed in a concrete platform and then covered by a thin film of transparent plastic sheet to enhance the solar radiation transmission inside the greenhouse as shown in Fig. 2. The dimensions of solar greenhouse (width x length) are 4 m x 10 m while its height 2 m.

2.1.1. The Evaporator

From practical point of view, the evaporator is made as a Built-In inside the green house frame. It is consists of a water absorbent materials that crate a wet thin film that will be evaporated via the hot and dry air. The built-in evaporator surface area is 6.28 m^2. The salty water is accumulated in the evaporator base and then pumped into two solar water distillers as shown in Fig. 3.

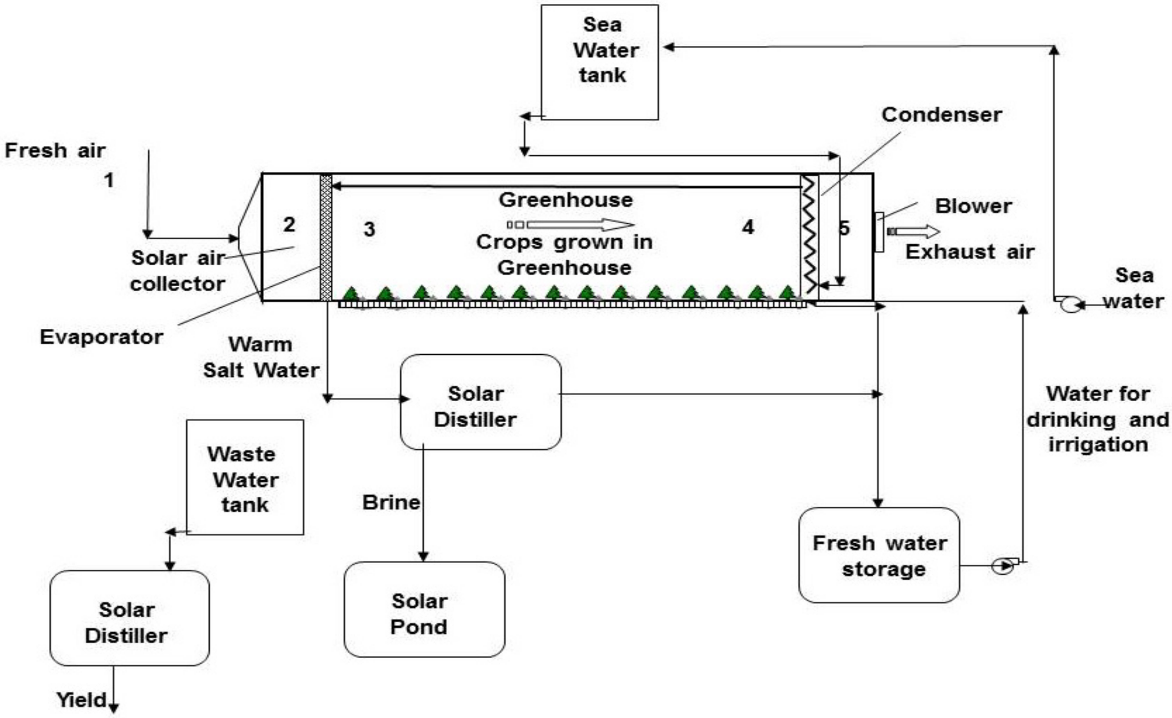

Fig.1. Layout of the Integrated Solar Green House (ISGH)

Fig. 2 (a) **Fig.2 (b)**

Fig. 2 Photographical views of Solar Green House and Plantation Area

2.1.2. The Condenser

The condenser is made as a Built-In inside the green house frame. It is consists of a finned tube surface. The tubes network consists of two horizontal copper tubes of 1" diameter working as a header tubes and 10vertical riser tubes of 0.5" diameter and well welded together to form copper tubes network. Then it is finned by a metal sheet to maximize the heat transfer area of the condenser surface. The area of the finned copper tubes network is 2 m^2. It is incorporated inside the metal sheet condenser surface area that is built in inside the green house frame with a net area of 4.28 m^2 i.e. the total built–in condenser surface area is 6.28 m^2 as shown in Fig. 4. The fin slips are designed with an appropriate angle to allow the humid air to pass through it to be sucked from the bottom of the solar chimney to surrounding.

Fig. 3 (a) **Fig. 3 (b)**

Fig. 3 Photographical Views of the Evaporator

Fig. 4 (a) **Fig. 4 (b)**

Fig. 4 Photographical views of the Condenser

2.1.3. The Solar Air Heater

The solar air heater is made also as a Built-In inside the green house frame with surface area of 2.0 m^2. It is consists of a corrugated black iron sheet placed inside the green house frame as shown in Fig. 5. It is fixed on a metal frame with a tilt angle of 30^0 with a south facing position. The absorber plate absorbed the transmitted solar radiation and then the thermal heat is radiated from the hot absorber plate with a closed enclose between greenhouse western wall and the evaporator wall casing hot space enclose. When the fresh air entered from the green house inlet gate, its temperature is increased and its humidity is decreased. Then the hot and dry air is entered to the wet surface of the evaporator to maximize the amount of moisture in the evaporator outlet humid air prior passing through the condenser surface while the condensation process is occurred and the condensate water is accumulated in the condenser basin and then pumped into the condensate water storage tank.

2.1.4. The Solar Water Distillers

Two solar water distillers are manufactured to produce condensate water to be combined with the condensate water outlet from the condenser. It was manufactured from a sandwich panel galvanized steel metal sheet taking L-type shape solar distiller with glass wool insulation with a tilted glass surface to create

Fig. 5 (a) **Fig. 5 (b)**

Fig. 5 Photographical views of the solar air heater

a cooled surface for water condensation. A complete design and dimensions of the solar distillers are found in the author's previous publication [6]. Fig. 6 shows photographical views of the manufactured solar water distillers. The experimental setup consists of two basic circles, namely water and air; and the following detailed description of both of them.

Fig. 6 (a) Fig. 6 (b)

Fig. 6 Photographical views of the solar water distillers

2.1.5. Air Circuit

The fresh air is passed through the built in – south facing solar air collector at the beginning of SGH that is heated by convective and radiative heat transfer modes which cause the inlet fresh air to be hot and dry. Then the hot and dried air is passed through the thin film –wet surface of the evaporator that is designed to be built-in inside the ISGH frame. Then, the outlet air became moist air that passing through the plantation area and finally condensed on the cooled surface of the condenser that is designed to be built-in inside the ISGH frame and located at the end of the ISGH. After passing through the condenser, the air is exhausted to surrounding via solar chimney with a potential head of 5 m.

2.1.6. Water Circuit

The water circuit starts from the elevated salty raw water tank that is passed through the condenser to make cold surface for moist air condensation and then the warm water is passed through the evaporator which consists of a water absorbent materials that create a wet thin film that will be evaporated via the hot and dry air. The salty water is accumulated in the evaporator base and then pumped into two solar water distillers.

The condensate water from the condenser and the solar water distillers is stored in the distilled water tank to provide fresh water for drinking and irrigation. While the brine salty water outlet from the solar water distillers can be used in the solar pond to store the thermal energy to be used as thermal driving force to operate solar absorption unit which produce cold water that can enhancement the condenser cooling capacity and consequently increase the fresh water productivity.

2.1.7. Solar Wastewater Treatment System

One solar wastewater treatment distiller was manufactured to produce highly purified and decontaminated water to be collected and reused for safe and non-restricted irrigation for plantation and propagation of valuable plants inside the ISGH. The excess treated water was used for external irrigation. It was manufactured from a sandwich panel galvanized steel metal sheet taking L-type shape solar distiller with glass wool insulation with a tilted glass surface to create a cooled surface for water condensation. A complete design and dimensions of the solar wastewater treatment distiller was found in the author's previous publication [6]. Fig. 7 shows photographical views of the manufactured solar wastewater treatment distiller.

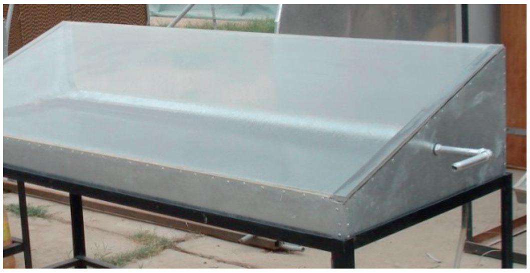

Fig. 7 Photographical view of the solar wastewater treatment distiller

3. Results and Discussion

Several experiments have been done to investigate the ISGH system capability to cover the required water quantities for drinking, domestic uses and irrigation water demand. The measuring instruments used in the present work are digital portable multi parameters of type KIMO, AMI 300 model, that measure air temperature, relative humidity, air speed and air quality. The weather station/data logger connection was used for measurements of solar irradiance, ambient air temperature and wind speed in the testing field. A Kipp and Zonen thermopile Pyranometer of an uncertainty ±16.4 W/mP2P, fixed on a tilted stand in the weather station was used to measure the solar irradiance incident on the system. As an example, the ambient dry and wet bulb temperatures and relative humidity variation in a typical summer day in Cairo is shown in Fig.8.The accumulated amount of distilled water in the two solar water distillers was found to be 16.2 l/day as shown in Fig. 9. The accumulated amount of distilled water in the solar greenhouse condenser basin was found to be 104.5 l/day as shown in Fig. 10.

Treatment of both domestic wastewater as well as produced sludge was carried out to remove organic pollutants and pathogens by the solar wastewater treatment distiller at its optimum operating conditions. Results of the treated wastewater indicated a remarkable reduction of pollutants such as organic contaminants, odour and microbial concentrations has been recorded. The non-contaminated obtained sewage sludge was used for compost production in combination with agricultural solid waste as soil conditioner for sandy soil and as an organic fertilizer. The accumulated amount of distilled water in the solar wastewater treatment distiller was found to be 5 l/day as shown in Fig. 11.

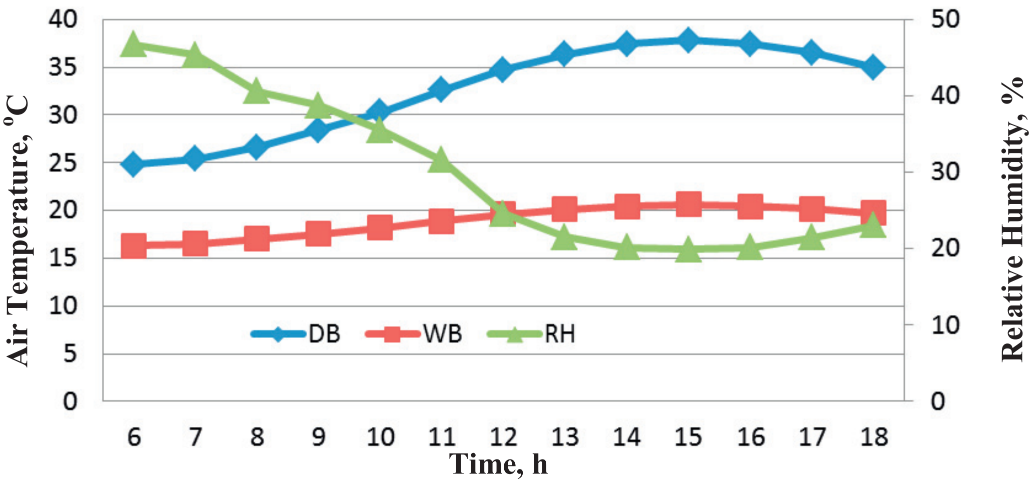

Fig. 8 Ambient dry and wet bulb temperatures and relative humidity variation in a typical summer day in Cairo

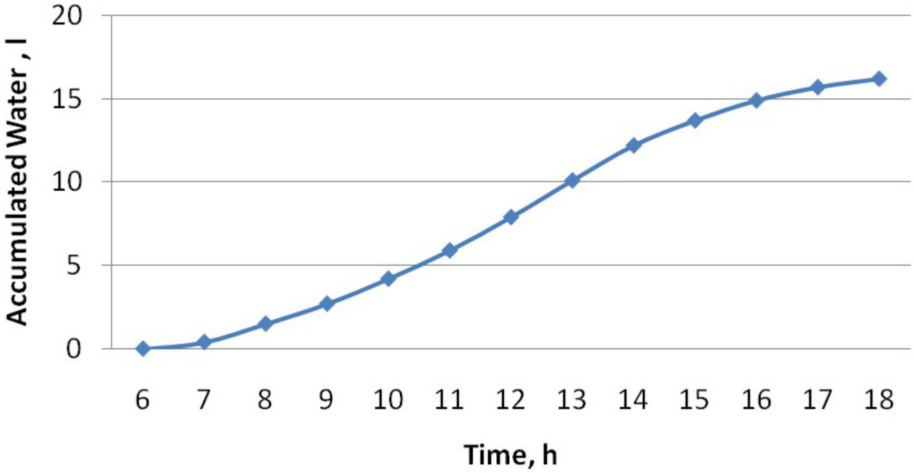

Fig. 9 Accumulated distilled water variation outlet from the two solar distillers

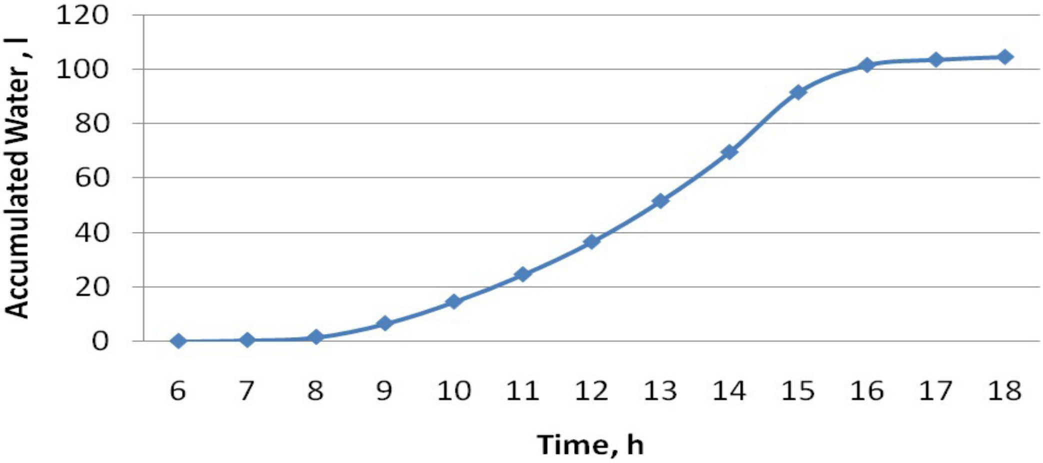

Fig. 10 Accumulated distilled water variation outlet from the SGH condenser basin

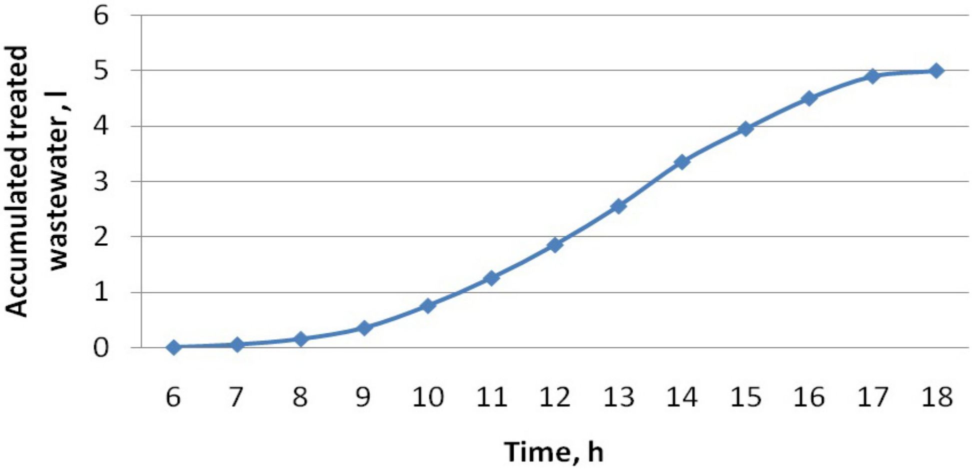

Fig. 11 Accumulated treated water from the solar wastewater treatment distiller

4. Conclusion

The integrated solar green house for water desalination, plantation and wastewater treatment was experimentally investigated to be demonstrated in its actual marketing size to develop Egyptian communities in remote arid areas. The results indicated that the present ISGH can be used successfully to provide a low-cost solution to one of the world's greatest needs-fresh water especially in the arid areas where the fresh water is very limited. In addition, it is a relevant method of cultivation that provides desalinated water, cooling environment and humidification in an integrated system. It is found that the amount of fresh and l/day. While the accumulated amount of treated water in the solar wastewater treatment distiller was found to be 5 l/day. The proposed system can be used for developing such communities suffer from the water shortage problem. The system contains also, a modified wastewater treatment units using the same concept for water treatment and pollution control. Additional units may be added to mitigate the produced sludge as well as solid wastes. Consequently, the system represents a module for zero waste which is the aim of all environmental systems in the coming decades in the 21 Centaury.

References

[1]- Paton, A.C. and Davis. "The seawater greenhouse for arid lands". Proc. Mediterranean Conf. on Renewable Energy Sources for Water Production. Santorini, 10-12 June, 1996.

[2]- Sablani, S., Goosen, M. F. A., Paton, C., Shayya, W. H. and Al-Hinai, H., Simulation of fresh water production using a humidification-dehumidification Seawater Greenhouse. Desalination, 2003.

[3]- Wahaab R.A., "Challenge & Needs of Water Sector in Egypt"; Wasser Berlin International, 23-26 April, Berlin, Germany, 2013.

[4]- Salem M., El-Awady M.Hamdy & Amin E. "Enhanced Removal of Dissolved Iron and Manganese from Nonconventional Water Resources in Delta District, Egypt", Science Direct, Energy Procedia, 2012; 310, 1600- 1611.

[5]- El-Awady M.Hamdy and Ali S.A."Non Conventional Treatment Sewage Sludge using Cement Kiln Dust for Reuse and Catalytic Conversion of Hydrocarbons", Earth & Environmental Science, The Environmentalist, DOI, 2012; 10.1007/s 10669-012-9411-8, ISSN 0251-1088.

[6]- El-Ghetany H.H. and El-Awady M.H. "Novel Integrated Solar Green House for Water Desalination, Plantation and Wastewater treatment in Remote Arid Egyptian Communities: Modelling and Analysis"; Desalination International Journal; in press.