IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 11, Issue 5 Ver. II (Sep- Oct. 2014), PP 30-35
www.iosrjournals.org

Performance of Solar pond Greenhouse Heating System in Jordan

Aiman Al Alawin[1]
[1](Mechanical Engineering Department, Faculty of Engineering Technology / Al Balqa Applied University, Jordan)

Abstract: *The performance of a solar pond greenhouse heating system was investigated. The performance was monitored by continuous measurements of both the salt and temperature profiles. Two simple heat exchangers were used one to extract the trapped heat from the lower convective zone and the other to dissipate heat into the greenhouse. It was found that over the period of operation of the integrated system both temperature and salt gradients nearly unchanged. The effect of wind on the system's performance was studied by introducing a net of a plastic ropes to serve as wind brakes. Furthermore, the effect of heat removal (extraction) on the salt profiles was not significant. Finally, the obtained data were in good agreement with previously obtained numerical data.*

Keywords: *Convective zone, Energy, Greenhouse, Heat exchanger, Solar pond, Solar radiation.*

I. Introduction

The solar energy reaching earth's surface is large enough to meet current world energy requirements if properly used. One option that could be used to utilize solar energy is solar pond. A solar pond, due its method of construction and size, is an inexpensive energy collection and storage system. The pond is either dug in the ground or local topographical features can be employed.

As the name suggests, the salinity-gradient solar pond is a pond in which a salinity gradient is established. More specifically, over some range in depth the concentration of salt dissolved in water increases with depth [1]. Solar pond performs both as a collector of energy and as long-term thermal storage system (energy can be stored from summer to winter).

Solar pond consists of three distinguished zones, namely; Upper Convective Zone (UCZ), Non Convective Zone (NCZ), and Lower Convective Zone (LCZ). The UCZ is a homogeneous layer of low salinity brine or fresh water with a temperature which is close to that of the ambient. The UCZ appears to be formed as a result of thermal cycling and wind action. For a better solar pond performance it is advised to minimize the thickness of this zone [2]. In the NCZ salt content increases with depth, so this layer serves both as an insulating layer and part of heat collection and heat storage medium. The third zone is the LCZ in which the salt and temperature are nearly constant, this layer serves as the main heat collection, heat storage and heat removal medium.

Solar ponds are attractive for their long term heat storage capability which makes it suitable for a wide spectrum of applications such as: house heating, electricity generation, agricultural applications and water desalination.

In some cases the harness of the atmosphere surrounds the greenhouse propagates inside it and as a result the probability of vegetation damage increases (such cases happen in Jordan from one time to another) which makes it necessary to introduce protection procedures that may takes many pictures such as: air heating, injection of hot water or smoke, and soil heating. In the present work the performance of a solar pond greenhouse heating system is to be studied.

The idea of creating artificial solar pond was first presented by R. Bloch [3]. However, serious work was carried out in occupied Palestine by H. Tabor in the period between 1958 and 1966 at a time in which the solar ponds becomes unsatisfactory from economical point of view. In 1974 research work restarted both in occupied Palestine as well as in the United States of America due to the large increase in energy prices (energy crisis). Solar pond activities in the USA began through the Ohio Agriculture Research and Development Center (OARDC) in Wooster Ohio, at which 156 m2 surface area and 3 m depth solar pond was constructed in 1975 to meet winter heat requirement of a single family residence [4].

In Jordan which is characterized by a good average quantity of solar radiation, unfortunately, very limited work was carried out on the utilization of solar pond. Most of such works were carried out using artificial solar ponds in small tanks. Banat [5] conducted a small laboratory solar pond tank with a 2 m2 surface area and 1 m depth. Carnalite salt from Dead Sea was used to create the pond. Reading for both temperature and specific gravity were taken. During his investigation, Banat developed a mathematical model to predict the thermal and diffusion behavior of the pond.

El- Baz [6] performed experiments in large tanks to study factors affecting the stability of the solar pond under Jordanian climate conditions and he found out that plastic rings can work as wind suppressers and can improve the performance of Salt Gradient Solar pond (SGSP) considerably. Moreover, he carried out experimental investigations on local clays for their potential use as lining materials in solar ponds.

The first small scale real solar pond in Jordan was constructed in 1994 at University of Jordan (Amman) with full description of this pond is given in [7]. This pond is 56 m2 surface area and 2 m deep, with walls that are inclined at 45 o and is constructed using reinforced concrete.

In this work the utilization of solar energy stored in this (8x7m) solar pond for green house heating will be studied. Although this work was carried out using a small scale solar pond, it may be considered as a feasibility study to construct a large pond in the Dead Sea area, where different sites can be employed for such construction.

II. Analysis of Solar pond

The energy governing he solar pond operation may be obtained by simply writing the energy balance for the pond:

$$Q_{in} = Q_{extracted} - Q_{loss} = Q_{stored}$$

Q_{in} : is the input solar energy, $Q_{extracted}$: is the extracted energy (load), Q_{loss} : is the energy loss, and Q_{stored} : is the stored energy.

Experimental measurements show that portion of the incident radiation is absorbed by the top layers of the pond leading to an approximately exponential decay in solar intensity with water depth such that the radiation energy intensity at any depth is given by [8]:

$$Q_{in} = frac(x|_{NCZ}).I_s.A_{surface}$$

Where $frac(x|_{NCZ})$: is the fraction of solar radiation at depth x and is defined as [5]:

$$frac(x|_{NCZ}) = 0.313.\exp(-0.28x)$$

I_s : is the hourly solar radiation that reaches the surface of the pond

The total heat loss from the storage zone is composed of two parts; heat loss from the LCZ in the upward direction due to the difference between the ambient temperature and the temperature of the LCZ, the second part is the heat loss through the pond's walls, these losses can be expressed as:

$$Q_{loss} = Q_{top} + Q_{bottom} + Q_{side-walls}$$

$$Q_{top} = U_{top}.A_{surface}.(T_x - T_{ambient})$$

$$Q_{bottom} = U_{bottom}.A_{bottom}.(T_x - T_{ground})$$

$$Q_{side-walls} = U_{side-wall}.A_{side-wall}.(T_x - T_{ground})$$

Where Q_{top}, Q_{bottom}, and $Q_{side-walls}$: are the heat loss from the top bottom and sides of the solar pond respectively, U_{top}, U_{bottom}, and $U_{side-wall}$: are the overall heat transfer coefficients for the top, bottom and sides portions of the pond from the point of interest respectively, $A_{surface}$, A_{bottom}, $A_{side-wall}$: are the surface area, bottom area , and side areas of the pond and have the values of (56 m^2, 12 m^2, and …….., respectively, T_x: is the temperature of the solar pond at location of interest, $T_{ambient}$: is the ambient temperature, and T_{ground}: is the temperature of the ground.

Generally the useful heat extracted from the storage zone of the SGSP represents only a fraction of the solar radiation incident on the pond surface. The ratio of the quantity of the heat stored in the pond to the total incident radiation is referred as pond's thermal efficiency which may be written as:

$$\eta_{thermal,pond} = \frac{Q_{stored}}{Q_{in}}$$

The overall efficiency of the system is the ratio of the useful energy to the input energy:

$$\eta_{overall,pond} = \frac{Q_{extracted}}{Q_{in}}$$

III. Experimental work

The pond as shown in figure 3.1, was constructed by a previous work. Full construction details are given in [7].

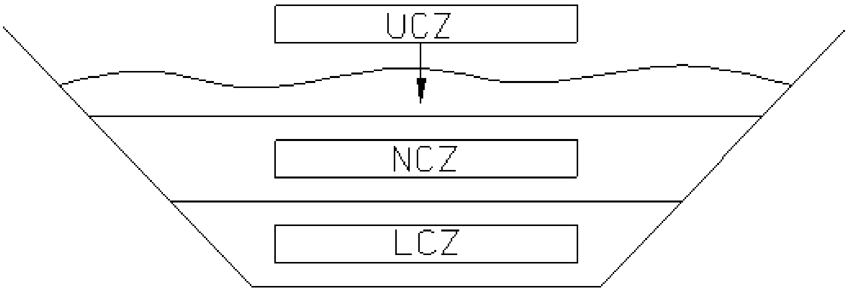

Fig. 3.1. Schematic Diagram shows the three zones in the Salt Gradient Solar Pond (SGSP)

Pond Filling: Initially the fresh water was introduced to a 1.4 m height in the pond, after which 16 tons of Carnalite salt ($KCl \cdot MgCl_2 \cdot 6H_2O$) was dissolved in this quantity of water with the aid of a one horse power pump. The next step was to fill up the pond to establish the salt gradient without disturbing the brine. The fresh water was injected into the concentrated brine using a simple 30 cm diffuser (two parallel circular discs with a small gap between them). First the diffuser was lowered to a depth of 40 cm from the free surface of the brine, which represents the lower boundary of the NCZ, and fresh water injected, then diffuser was raised steadily at an intervals of 2.5 cm each until the 80 cm NCZ was formed.

Heat Extraction System: to extract the trapped thermal energy in the LCZ of the solar pond a 65 m long thermo pipe is used as an in-pond heat exchanger which is shaped in a zigzag way and fixed to a 4x3 m rectangular carbon steel frame such that the exchanger will be at 0.8 m from the bottom of the pond.

The in-pond heat exchanger is connected through thermo pipes to another heat exchanger which is placed in the greenhouse (load). The green house heat exchanger was assembled using 50 m long 3/4" diameter commercial carbon steel pipes.

Measurement of temperature profile: the temperature profile along the height of the pond was measured using an array of fixed copper-constantan thermocouples type (T) placed 30 cm from the inclined wall of the pond.

Measurement of concentration profile: Maintaining a stable salt gradient is an essential element in the performance and operation of the SGSP. So measurement of salt concentration profile is very important, and was carried out by simply withdrawing samples from certain known locations inside the pond using simple manual liquid pump, then 50 mL of the samples were weighted to determine the specific gravity.

Wind brakes: the shear forces of the wind on a large body of water generate waves and surface drift. The wind kinetic energy transferred to the water is consumed partially by viscous losses and partially by mixing of the top surface water with the somewhat denser water just below the surface. A surface mixed zone can have considerable deterious effect upon both the temperature profile and pond's efficiency. It is better to keep the mixed UCZ thickness as small as possible as it absorbs some of the solar radiation on its way downward as well as the increase in UCZ will be on the account of the insulating layer thickness (NCZ). In the present work a net of plastic ropes 5 mm in diameter was employed as wind brakes. The net consists of (0.5x0.5)m squares.

IV. Results

In this work the first real solar pond in Jordan was used. It was filled and the different zones of the pond were formed in December. Having achieved stability the history of the pond was recorded by the measurement of both temperature and salt gradient profiles. The concentration measurements were recorded on weekly basis throughout the experiment period.

Figures 4.2 through 4.4 show the salt concentration (specific gravity) profiles after one two and three months after the preparation of the pond. From these figures it is clear that there exist three distinguished zones, namely; LCZ, NCZ, and the UCZ, with their heights being (15 cm), (65 cm), and (100 cm) respectively. From the figures it appears that salt profile approximately identical this means that the pond was stable. Finally it may be noticed from the figures that the value of the specific gravity in the lower convective zone is 1.16.

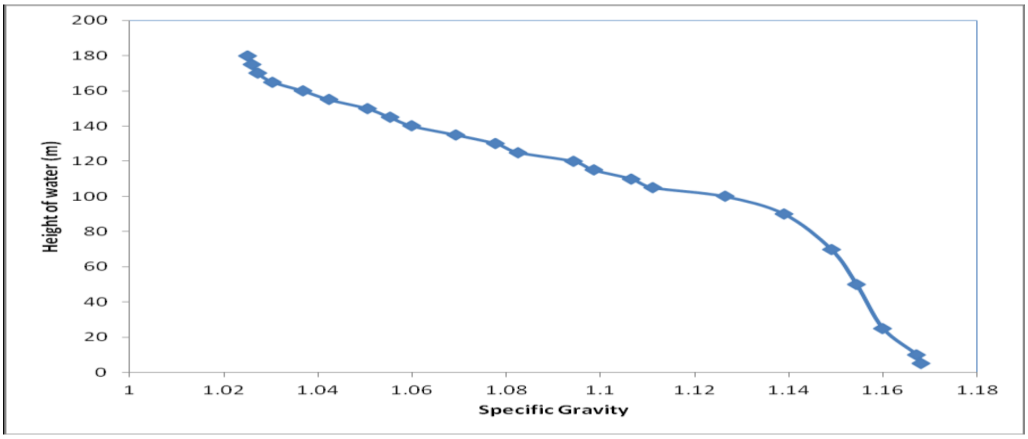

Fig. 4.2. Salinity gradient profile after one month from the establishment of the pond

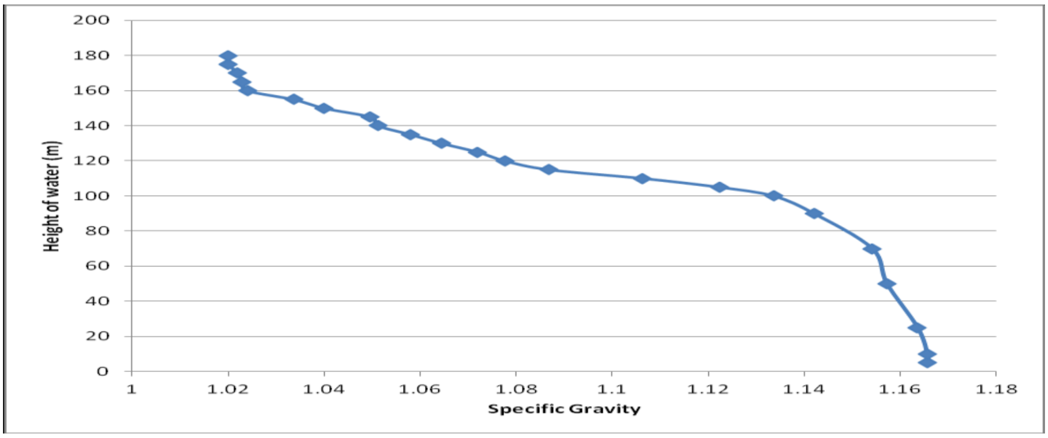

Fig. 4.3. Salinity gradient profile after two months from the establishment of the pond

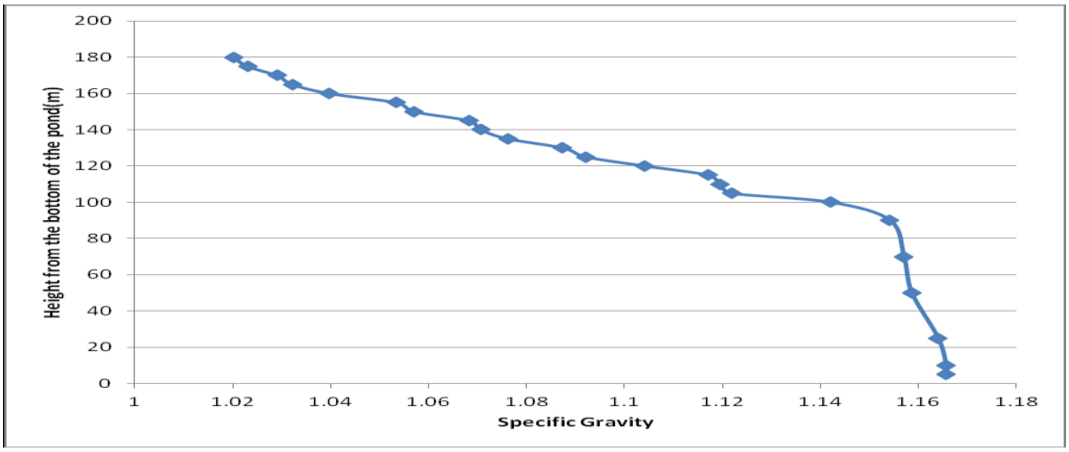

Fig. 4.4. Salinity gradient profile after three months from the establishment of the pond

The temperature was recorded three times daily at 7:30, 12:30, and 15:30 from March, 20 to April, 30. Sample of these measurements will be represented in this paper.

Figure (5) shows temperature profile 40 days after the establishment of the pond. Temperatures were recorded midday with an ambient temperature 7.7 ^{o}C. from the figure and as expected the maximum temperature was recorded in the lower convective zone with a value of 38 ^{o}C.

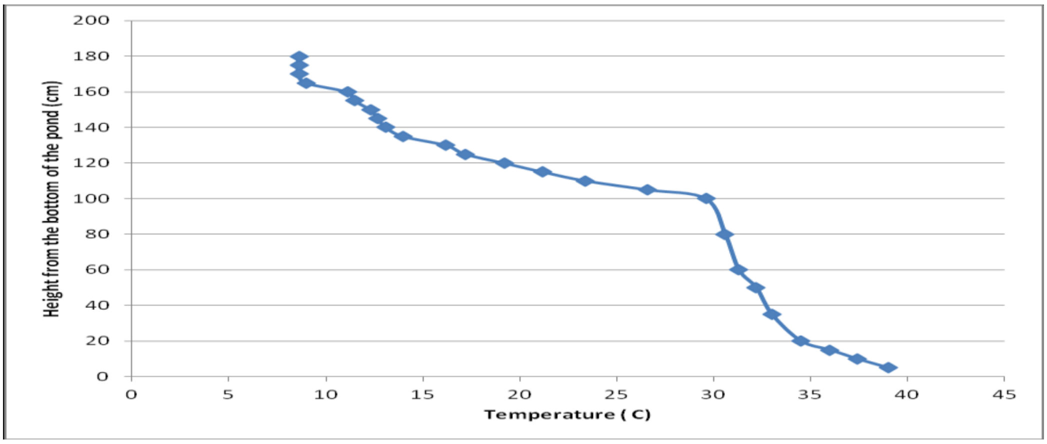

Fig. 4.5. Temperature profile after one month from the establishment of the pond at 12:30 pm [T (ambient) = 7.7°C].

Figures (6) and (7) present temperature profiles 125 days after the creation of the pond. Boundaries of the pond's zones are clear. 46 °C was the maximum recorded temperature in the lower convective zone. Moreover, Lower Convective Zone was noticed to have homogeneous temperature throughout its depth.

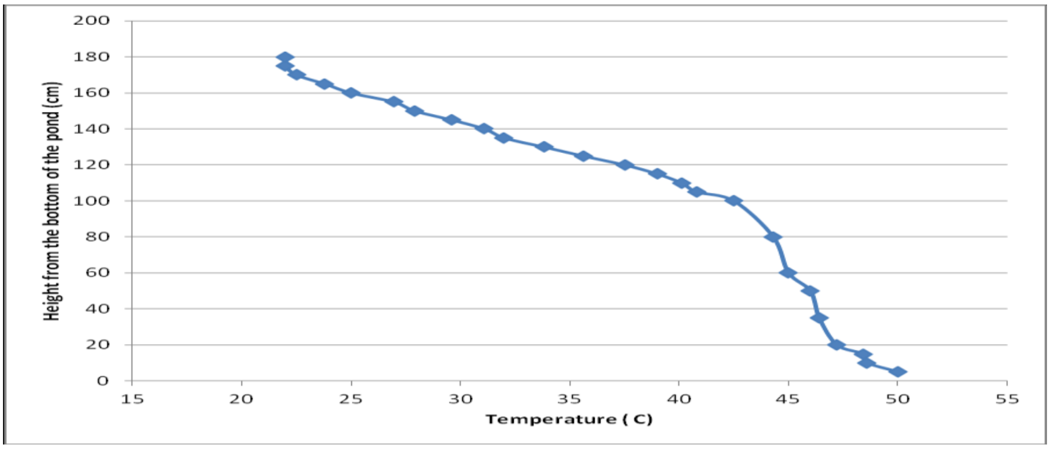

Fig. 4.6. Temperature profile after four months from the establishment of the pond at 7:30 pm [T (ambient) = 15.2°C].

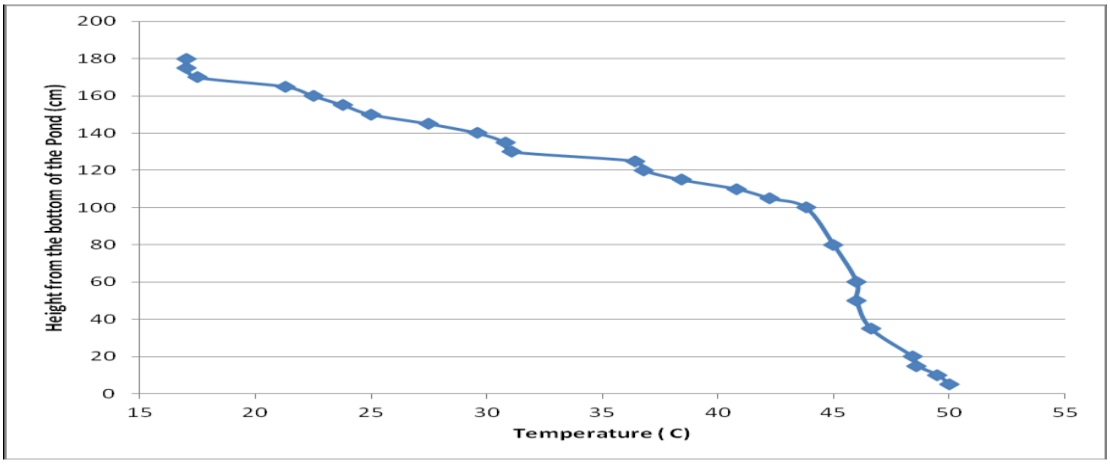

Fig. 4.7. Temperature profile after four months from the establishment of the pond at 12:30 pm [T (ambient) = 26.2°C].

The history of the lower convective zone was recorded over four months as shown in Figure (8). From the history of the pond it may be noticed that the average temperature of the lower convective zone increases with the life of the pond. The maximum temperature achieved was 55 °C. To evaluate the obtained results it is important to compare them against numerical ones. In this paper the results were compared against numerical results that obtained by computer program developed by Al Qasem [7]. Good agreement was noticed between recorded experimental and numerical data.

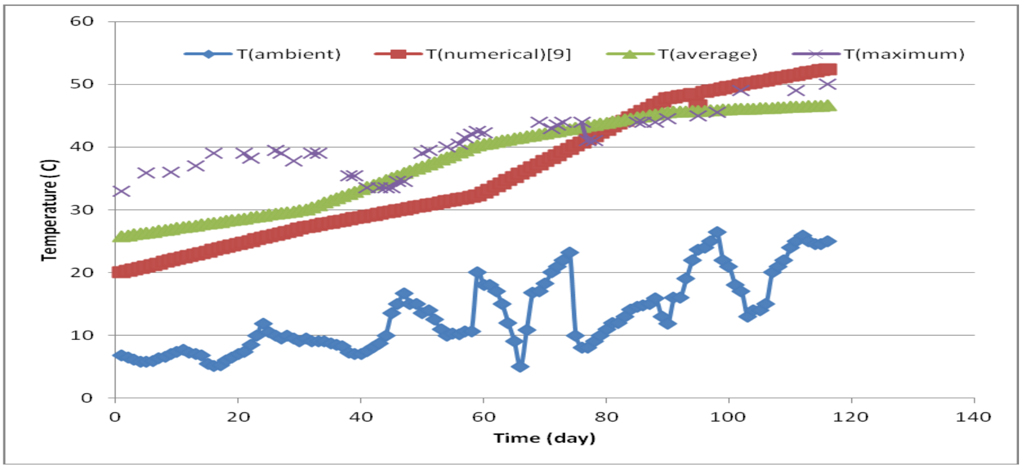

Fig. 4.8. Temperature history at 12:30 pm. For the first four months after the establishment of the pond

V. Conclusion

Based on the above mentioned experimental results, the following conclusions can be drawn:

- The Salt Gradient Solar Pond is suitable for Jordan climate especially in the Dead Sea region because of the availability of relatively high solar radiation intensity, low cost of salt, and relatively low wind effect,
- The heat removal from the pond dose not disturb the concentration profile
- A continuous washing for the pond surface is required especially in summer to compensate the evaporation effect on the UCZ,
- Introducing a net on the surface of the pond as a wind brake will reduce the wind effect which in its role leads to elongate the life of the pond and improve its performance,
- The performance of the pond is greatly affected by the dirt on its surface , so continuous surface cleaning is required to maintain a good performance of the pond, and
- Rain has negligible effect on the salt gradient and the stability of the pond.

References

[1] J. R. Hull, C. E. Nilson and P. Golding, Salinity Gradient Solar Pond (CRC, Press, Inc,1989).
[2] C.F. Koot, The Steady State Salt Gradient Solar Pond, Solar Energy Journal, 23, 1979, 37-45.
[3] H. Tabor, Solar Pond, Solar Energy Journal, 27, 1981, 181- 194.
[4] S.A. Shah, T. H. Short and R. P Fynn, Modeling and Testing A salt Gradient Solar Pond in Northeast Ohio, Solar Energy Journal, 27, 1981, 393- 401.
[5] F. Banat, A study of Carnalite Salt Gradient Solar Pond, M.Sc. thesis, University of Jordan, 1990.
[6] A. El-Baz, Performance of the Salinity Solar pond in Jordan, M.Sc. thesis, University of Jordan, 1993.
[7] E. Al Haj Qasem, Numerical and Experimental Investigation of SGSP-Greenhouse Heating system, M.Sc. thesis, University of Jordan, 1994.
[8] H. C. Bryant and I. Colbeck, a Solar Pond for London, Solar Energy Journal, 19, 1977, 321- 322.