Experimental investigation into the performance of the solar pond in Kerbala

M H Abbood¹, M Alhwayzee² and M A Sultan¹

¹ Mechanical Engineering Department, College of Engineering, University of Kerbala, Iraq.
² Petroleum Engineering Department, College of Engineering, University of Kerbala, Iraq.
E-mail: mohadglia2@gmail.com

Abstract Solar ponds are a low-cost technology options for harnessing solar energy. An experimental model for a solar pond was designed for Kerbala, Iraq, with the aim of heating water. The surface area of the pond was 7.29 m², at a depth of 1 m, and with walls tilted at an angle of 45°. The experiment was conducted in February, March, and April, in the winter and spring seasons of 2020. Two types of salt were used in this work: sodium chloride and potassium chloride. Solar radiation was recorded daily, and the measured solar irradiance ranged between 360 W/m² and 1384 W/m². Solar radiation was focused on the surface of the pond using two reflecting mirrors, the first being a flat surface and the second a concave shape, with a concavity depth of 0.1 m. Both mirrors were 1 m long by 0.8 m wide. The experimental results showed that the highest temperature of water in the pond was 44 °C, achieved using sodium chloride, while using potassium chloride produced a maximum temperature of 40 °C. The useful energy and the experimental thermal efficiencies were found to be 28.2 MJ per hour and 11.6%, respectively.

Keywords: salinity gradient, solar pond, sodium chloride, reflectors.

1- Introduction

Due to ongoing increases in need for energy that have caused surges in fossil fuels consumption for energy production, environmental concerns about the pollution caused by the use of that type of fuel have been intensified, highlighting the need to find alternatives to provide clean, safe, and environmentally friendly energy. In terms of renewable energy, one of the most abundant types is solar energy, especially where solar radiation can be converted into thermal energy. The high temperatures in Iraq, especially in the summer, make the use of solar pond technology a good choice for converting solar radiation into stored thermal energy in that region. The working principle of a solar pond is based on absorbing solar radiation energy and storing it in layers of water. The thermal efficiency of a solar pond can thus be calculated as the useful energy (the thermal energy stored in the storage layer of the pond) over a period of time, divided by the solar radiation, multiplied by the total area of the solar pond [1]. One type of pond, the salinity gradient
solar pond, depends on the properties of a saline solution to restrict convection, making it possible to use stored energy in several applications, the most prominent of which is water heating, at a later stage [1]. Many research papers have investigated solar pond technology with the aim of improving the design and performance the solar ponds in terms of storing thermal energy in both laboratory and open-air conditions [1].

Aiman [2] established a solar pond in Jordan with an area of 56 m$^2$ and a depth of 1.8 m. The temperature and salinity scale were recorded, which indicated that there were three main layers: UCZ, NCZ, and LCZ. The lowest specific gravitational value in the LCZ layer was 1.16. Aiman [2] concluded that both the dust that settled on the surface of the pond and the wind had a significant impact on the pond’s performance, and continuous cleaning increased its efficiency, while the development of a network of ropes reduced the impact of the wind [2].

A solar pond with a surface area of 1 m$^2$ and a depth of 2 m was built, and reflecting mirrors were used to focus the solar radiation on the surface of the water to increase the evaporation process; their movement was manually controlled. The researcher studied several factors affecting the evaporation process, including wind speed, ambient temperature, relative humidity and the amount of solar radiation. From the experimental results, that both wind speed and relative humidity were found to have an inverse relationship with the rate of evaporation, while radiation has a direct relationship. The maximum evaporation rate occurred when the relative humidity reached 67.6%, and increasing the number of reflective mirrors increased the pond temperature and reduced the surface area required for the pond to be effective [3].

Muhammad et al. [4] constructed solar ponds in various shapes (rectangular and circular) during the three-month summer season. The surface area of the rectangular and circular ponds were 63 and 51 cm$^2$, respectively, both with depths of 60 cm. Test results showed that the maximum temperatures of the rectangular and circular ponds were 74 and 71 °C, respectively, with the difference attributed to the presence of a smaller shadow area in the rectangular pond. The researchers thus analysed the shadow areas formed in ponds, which depend on several factors such as geographical location, angle of radiation, and the dimensions of the pond. The use of plastic sheeting on the surface of the pond was found to raise temperatures, and at the end of the experiment, the temperature difference between the top layer and the surrounding environment was 13 °C [4]. Balaji [5] studied the effect of sodium sulphate and sodium carbonate salts on solar pond performance in a solar pond with a surface area of 2.5 m$^2$ and a depth of 2 m, in the Dead Sea region in Jordan. Based on the experimental results, he found that solar pond performance was stable for a long period, and that the maximum temperature over 15.3 hours was 45 °C, while this was 60 °C within 10 hours, suggesting a thermal efficiency of 18.68%.

Khaldoon et al. [6] analysed the temperature distribution and salt concentration in the layers of water in a solar pond rig. Their experimental results showed that the temperature of the LCZ reached 85 °C due to the good insulation in the pond, which contributed to maintaining high temperatures even with the extraction of thermal energy during the day. The researchers concluded that building a stepwise solar pond near a salt water source would reduce costs [6]. Sathish et al. [7] created a solar pond with an area of 1.7 m$^2$ and a depth of 0.5 m in India. The performance of the pond was monitored with both sodium chloride salt and coal cinders. NaCl showed better performance as compared to coal cinder in terms of storing more energy due to the presence of a saline gradient. In their experimental work, they observed that the maximum storage temperature for sodium chloride salt was 43 °C while that for coal was 37 °C, and that the period between the hours of two and four in the afternoon was the peak period for solar energy, as in this period the amount of radiated energy on the surface of the pond increased, while in the mornings the temperature decreased due to there being less radiation [7]. Ito and Azam [8] assessed feasibility in salinity gradient solar ponds (SGSP) in Saskatchewan, Canada. Highlights of their work included the global assessment of SGSP from
theoretical and practical viewpoints, the assessment of salinity and environment parameters, and valuation of thermophysical property mechanisms affecting SGSP, and the use of simulations to examine transient heat diffusion in SGSP. Their results suggested that, due to high solar insolation (1,100 to 1,400 kWh/m²), Saskatchewan was a suitable location for thermal energy harvesting from saline water bodies, based on the solar radiation absorbed under a gradient of salt concentration. Thermal conductivity increases with temperature but decreases with increase in water salinity (0.55 to 0.675 W/m.K), while the opposite is true for density (1,000 to 1,200 kg/m³). Similarly, the specific heat capacity increases slightly with temperature and correlates inversely with salinity (3,000 to 4,200 J / kg K).

In Turkey, Sogukpinar [9] compared numerical results with the experimental results for a specific district, modelling a prototype salinity gradient solar pond with a square cross-section, isolated walls, and seven layers as used in previous experimental studies. Numerical calculations were then performed using the Finite Element Method in COMSOL, which showed that maximum temperature was found at 600 hours into the 720 hours of total simulation, and that after that temperature remained constant. Significant heat loss was observed at the pond's top surface, as the side wall and foundation were lined with rock wool. According to the numerical analysis carried out for 81 provinces, only one solar pond temperature remained below 300 K, that in Edirne; solar pond temperatures remained below 310 K in five further provinces, while the solar pond temperature for 31 provinces was measured above 320 K [9].

More recently, Osamah et al [10] briefly demonstrated the historical context for solar ponds and examined solar ponds world-wide using an overview of the literature. The work also described and addressed the theoretical context of heat and mass transfer that governs the activity of solar ponds. Solar ponds are one of the most promising and significant sources of renewable energy, and a basic energy balance technique can be used to model the overall efficiency of a solar pond. Solar ponds are also particularly useful energy resources in remote areas. Many parameters affect solar pond efficiency, however, and these parameters may thus be seen as limitations with regard to cost and operating performance. In order to achieve smooth installation and operability of a solar pond, these parameters should be assessed: it should be easy to access a water supply for pond creation and external rinsing; good solar radioactivity should be available for higher thermal activity; lower wind velocities are preferred to minimise mixing between three zones of the pond and to limit wind-borne debris to preserve purity; and a lower vaporising rate is desirable to decrease the required input of water [10].

The aim of the present work was to study a salinity gradient solar pond, in terms of its performance as a source of hot water. The pond was designed to take full advantage of the solar radiation falling on its surface to allow a comparison of the addition of two types of salts with respect to their properties and effectiveness in thermal storage. The use of reflective surfaces with a tracking system to monitor the sun’s effects on the performance of the pond further facilitated this. The research also aimed to study the performance of a simple heat exchanger in terms of extracting heat from the pond.

2. Experimental Setup

2.1 Solar pond rig installation.

A solar pond with a square surface area and inclined 45° sloping walls was constructed with three layers, UCZ, NCZ, LCZ, of 0.1, 0.6, and 0.3 m thickness, respectively and a surface area of 7.29 m². The walls were made of plywood and glass wool with a black liner added to enhance thermal insulation, as shown in figure
1. After construction, the pond was exposed to natural solar radiation and other climatic factors. As seen in Figure 2, 11 k-type thermocouples were used: six of these were positioned at 0.1, 0.3, 0.5, 0.7, 0.9, and 1 m from the bottom of the pond, within the water, and one was placed at the heat exchanger inlet and another at the outlet, with one at the pond bottom and one at the pond walls; the final thermocouple was positioned to read the ambient temperature. Measurement of solar radiation was taken daily for a period of 12 days, from 8 am to 5 pm, during the test period for each type of salt used, as shown in the figures 3 and 4. The temperatures of the pond layers over 24 hours were measured during the test period from 25 February to 2 April. Data were recorded for two types of salts, sodium chloride and potassium chloride. The test period of each salt was 12 days with three different salt concentrations examined for each. The temperature of the liquids flowing to and from the heat exchanger were measured at specified times for the saturated mixture, and the useful energy and overall efficiency of the pond were calculated.

Reflecting mirrors were used in conjunction with a sun tracking system to increase the concentration of solar radiation on the surface of the pond and thus reduce the necessary surface area. The sun tracking system used a motor to control the movement of the reflecting mirrors and photoresistors to sense sunlight and search for the best direction to allow the mirror to get the largest amount of sunlight to focus on the surface of the solar pond. There are two types of such system, one-axis and two-axis systems, and in this research, a one-axis tracker was used that tracked the sun from east to west, as shown in figure 3.

**Figure 1.** Experimental salinity gradient solar pond in Kerbala.
3. Materials and Methodology

3.1 Salts.

Several different salts can be used in solar ponds to store thermal energy, each of which has different characteristics and affects the performance of the pond differently. Two types of salts were used in this work, sodium chloride and potassium chloride. These salts have the advantage of being easily obtained due
to good availability in the market and thus being of lower cost relative to other types of salts. In addition, they are stable at high temperatures and have suitable solubility.

3.2 Water quality.

The water used in the construction of the solar pond was produced using reverse osmosis equipment commonly used to purify water for human use. The specifications of this water are such that it contains a very low percentage of salts and other solids. The percentage of solid particles in the local municipal water was 360 TDS, while that in the water used in the pond had a reading of 14 TDS. The thermal conductivity of this water is thus minimal, so salt was added gradually and to form the required layers of the solar pond.

3.3 Preparation of salt concentrations.

The concentration of salts for each layer of the pond was determined according to the function of each layer. The upper layer, pure water, had a ratio of 0 to 0.005% salts to allow solar radiation to enter the lower layers, while the middle layer had increases in concentration with depth to create three gradients, 2, 3, and 4%, respectively. The lower layer had an increased concentration at specific times to study the effect of each concentration on the temperature in that layer.

3.4 Measurements.

The temperature, solar radiation intensity on the pond, and salt concentration of water were measured using the following devices:

a- Temperature meter, TM500 Thermometer, 12 nodes.
b- K-type thermocouples.
c- Solar power meter with TES-132 datalogging.
d- Salt concentration meter (EC/TDS Meter, Mi 306).

The relevant devices are shown in Figure 4 (a-d), respectively.
Figure 4. Devices used for measurement: a- Temperature meter, b- Thermocouples, c- Solar power meter, d- Salt concentration meter

3.5 Useful energy and pond thermal efficiency calculations.

The thermal efficiency of a solar pond can be calculated from the useful energy for the highest salinity concentration, as in the following equation [11]:

\[ \eta = \frac{Q_u}{I} \quad (1) \]

where \( Q_u \) is the quantity of useful energy, calculated as

\[ Q_u = M_s \cdot c_p \cdot \Delta T \quad (2) \]

where

\[ M_s = V_{LCZ} \cdot \rho_s \quad (3) \]

\[ \rho_s = \rho_w \cdot (1 - C) + \rho_{salt} \cdot C \quad (4) \]

and

\[ c_p = \frac{[(\rho_w \cdot c_p_w \cdot (1 - C) + \rho_{salt} \cdot c_p_{salt} \cdot C)]}{\rho_s} \quad (5) \]
where \( C \) is the salt concentration in water; \( V_{lcz} \) is the volume of the LCZ layer (0.309 \( m^3 \)); \( \rho_w = 997 \text{ kgm}^{-3} \), \( \rho_{NaCl} = 2160 \text{ kgm}^{-3} \) and \( \rho_{KCl} = 1987 \text{ kgm}^{-3} \) are the densities for water, NaCl salt, and KCl salt, respectively; \( c_{pw} = 4.18 \text{ kJkg}^{-1}.\text{K}^{-1} \) and \( c_{NaCl} = 0.88 \text{ kJkg}^{-1}.\text{K}^{-1} \), and \( c_{KCl} = 0.69 \text{ kJkg}^{-1}.\text{K}^{-1} \) are the specific heats for water, NaCl salt and KCl salt, respectively [12]; and \( M_s = 399.4 \text{ kg} \) and \( 362.8 \text{ kg} \) for NaCl and KCl solution respectively. Additionally, \( \Delta T \) is the temperature difference between the lower convective zone and ambient air, while \( I \) is the solar energy incident on the pond such that

\[
I = H_o \times A
\] (6)

where \( H_o \) is the solar irradiance on the solar pond calculated using the equation for solar radiation on a horizontal surface for a period between hour angles \( \omega_1 \) and \( \omega_2 \) defined as [16]

\[
H_o = 12 \times \frac{3600}{\pi} \times G_{SG} \left( 1 + 0.033 \times \cos\left( 360 \times \frac{n}{365} \right) \right) \times \\
\left( \cos \varphi \cos \delta (\sin \omega_2 - \sin \omega_1) + \frac{\pi (\omega_2 - \omega_1)}{180} \sin \varphi \sin \delta \right)
\] (7)

\[
\delta = 23.45 \times \sin \left( 360 \times \frac{284 + n}{365} \right)
\] (8)

where \( G_{SG} \) is the solar constant of 1,367 \( \text{ wm}^{-2} \) and \( n \) is the day of the year, \( \varphi \) is the latitude angle, \( \delta \) is the declination angle, and \( A \) is the surface area of the solar pond.

3.6 Experimental Procedure.

The pond was filled with water in stages, beginning with a 0.3m thickness LCZ layer to which sodium chloride salt at a concentration of 10.7% was added. The concentration of this layer was increased until it reached its maximum percentage of 26%, the saturation point. Then, the NCZ layer was added in three levels, each with a thickness of 0.2 m, with different salt concentrations ranging from 2% to 4%, increasing with depth. Finally, the UCZ layer was added; this was salt free and 0.1m thick. The pond was left for several days until its layers had been warmed by solar radiation. Temperatures were then recorded using thermocouples and solar radiation was recorded during the research period. The pump connected to the heat exchanger was operated and the flow velocity of the fluid used in the exchanger controlled during temperature measurement. These steps were repeated for potassium chloride salt.

4. Results and Discussion

Solar pond temperatures and the daily intensity of radiation were recorded; the highest readings for the later, of 1384 \( \text{ W/m}^2 \), were found at about 2:00 pm, as shown in figures 5 and 6. The results also showed the highest temperatures when using sodium chloride salt as compared to potassium chloride salt. Figures 7 and 8 show the temperatures at three concentrations (10.7%, 19.4% and 25.4%) for sodium chloride and potassium chloride salts in the lower zone of the pond. Figure 7 shows that temperatures increased with increasing NaCl salt concentrations, while Figure 8, for the potassium chloride salt, shows that for the same concentrations, the temperature rose until it reached 40 °C and then began to gradually decrease. Comparing the two graphs, the highest accessible temperature at a concentration of 25.4% was found with NaCl salt at 44.5 °C. It can thus be concluded that sodium salt has a higher heat storage capacity than potassium salt; further, in terms of cost, sodium chloride salt is the least expensive and most abundant salt on the market.
Figure 5. Maximum and minimum values of daily solar irradiance on the solar pond with NaCl salt.

Figure 6. Maximum and minimum values of daily solar irradiance on the solar pond with KCl salt.
Figure 7. Maximum temperature in the LCZ with variable NaCl concentrations.

Figure 8. Maximum temperature in LCZ with variable KCl concentration.

Figures 6 and 7 show the fluid temperature in the heat exchanger used to extract heat from the solar pond. Across the three flow rates, 0.5, 0.75, and 1 L/min., the liquid reached its maximum temperature at a flow of 0.5 L/min. Comparing the use of sodium chloride salt with that of potassium chloride in the solar pond, the experimental results show that sodium chloride salt has a higher storage capacity for heat than potassium chloride salt, as shown in figures 9 and 10. Sodium chloride salt is thus the best choice for heat extraction.
Based on the useful energy and the value of radiation entering the pond, the thermal pond efficiency was calculated. The useful energy was 28.2 MJ for one hour, giving an efficiency of about 11.6% when sodium chloride salt was used, as shown in Figures 11 and 12.

**Figure 9.** Outlet temperature of the heat exchanger for various flow rates of NaCl salt mixture.

**Figure 10.** Outlet temperature of the heat exchanger for various flow rates of KCl salt mixture.
A comparison with previous research, shown in Table 1, taking into consideration the size of the heat storage layer in the pond, suggests that the optimisation of the solar pond system by adding mirrors with a solar tracking system and the use of sodium chloride salt offer the best means of providing suitable temperatures for applications that need low temperatures, especially during winter months. Renuka [13] obtained an efficiency of 11.21% and Kasaeian et al. [14] obtained an efficiency of 9.68%, while the efficiency obtained from this research was 11.6%; the thicknesses of the thermal storage layers were 0.8 m, 0.8 m, and 0.3 m, respectively. With regard to the useful energy, Alcaraz et al. [15] obtained a useful energy of 13.3MJ per
hour, while in the current work, the obtained useful energy was 28.2 MJ for one hour. The area of the pond used in Spain was 500 m² and the thickness of the lower layer was 0.6 m, as shown in table 2.

**Table 1.** Comparison of maximum thermal efficiency and thickness of solar pond storage layer for the highest brine concentration of NaCl salt.

| Study                | Year | Efficiency (°C) | Thickness LCZ (m) | Country |
|----------------------|------|-----------------|-------------------|---------|
| Renuka [13]          | 2016 | 11.2            | 0.8               | India   |
| Kasaeian et al. [14] | 2017 | 9.68            | 0.8               | Turkey  |
| Current work         | 2020 | 11.6            | 0.3               | Iraq    |

**Table 2.** Comparison of useful energy with area and thickness of solar pond for the highest brine concentration of NaCl salt.

| Search number        | Year | Useful Energy (MJ) for one hour | Thickness LCZ (m) | Area of Solar Pond (m²) | Country |
|----------------------|------|---------------------------------|-------------------|-------------------------|---------|
| Alcaraz [15]         | 2015 | 13.3                            | 0.6               | 500                     | Spain   |
| Current work         | 2020 | 28.2                            | 0.3               | 7.29                    | Iraq    |

5. Conclusion

Within the experimental work carried out over a period of three months, two types of salts and reflective mirrors with a tracking system for solar energy. The conclusions below were thus drawn:

1. When sodium chloride salt with a concentration of 25.4% was used, the temperature of the deepest layer of the pond reached 44 °C; it reached 40 °C when potassium chloride salt was used.

2. The calculated useful energy and efficiency of the solar pond were higher when sodium chloride salt was used as compared to the use of potassium chloride salt; the results were 28.2 MJ and 11.6% for NaCl salt and 19.8 MJ and 7.3% for KCl, respectively.

3. Sodium chloride salt was the best salt for solar pond applications in terms of temperature and cost.

4. The experimental results also showed that the beneficial energy and thermal efficiency increased with increasing salt concentrations in the pond and higher temperatures within the pond layers. The results also showed that the sodium chloride salt improved the performance of the solar pond.
Nomenclature

| Symbol | Description                  | Unit       |
|--------|------------------------------|------------|
| SGSP   | Salinity Gradient Solar Pond | ---        |
| UCZ    | Upper Convective Zone        | ---        |
| NCZ    | Non-Convective Zone          | ---        |
| LCZ    | Lower Convective Zone        | ---        |
| NaCl   | Sodium Chloride              | ---        |
| KCl    | Potassium chloride           | ---        |
| TDS    | Total Dissolved Solids       | $Mscm^{-1}$|
| Qu     | Useful energy                | $w$        |
| I      | Solar energy incident        | $wm^{-2}$  |
| $\eta$ | Efficiency                  | $\%$      |
| Ho     | Solar irradiance             | $wm^{-2}$  |
| A      | Area of pond                 | $m^2$      |
| C      | Salt concentration in water  | $\%$      |
| Ms     | Mass of brine                | $kg$       |
| $C_p_b$| Specific heat of brine       | $KJ Kg^{-1} K^{-1}$ |
| $C_p_w$| Specific heat of water       | $KJ Kg^{-1} K^{-1}$ |
| $C_p_{salt}$ | Specific heat of salt | $KJ Kg^{-1} K^{-1}$ |
| $V_{lcz}$ | Volume of LCZ               | $m^3$      |
| $\rho_s$ | Density of brine            | $Kgm^{-3}$ |
| $\rho_w$ | Density of water            | $Kgm^{-3}$ |
| $\rho_{salt}$ | Density of salt   | $Kgm^{-3}$ |
| $\Delta T$ | Temperature difference    | $^\circ C$ |

References

[1] Karakavalasa G, Chukka S K 2013, Solar Pond Technology, *International Journal Of Engineering Research*, Vol 1, Issue 2.

[2] Aiman A 2014, Performance Of Solar Pond Greenhouse Heating System In Jordan, Jordan. *Iosr Journal* Vol. 11, Issue 5 Ver. Ii , Pp 30-35.

[3] Amal W Q 2016, Using Solar Evaporation Ponds For The Treatment Of The Desalination Plants Brine, *Islamic University – Gaza, Palestine*, http://hdl.handle.net/20.500.12358/19373.

[4] Mohammad R A, Hassan B T , Ali K N , Mohsen P 2015, Experimental Investigation Of Heat Absorption Of Different Solar Pond Shapes Covered With Glazing Plastic, Iran, *Solar Energy* 122, 569-578

[5] Balaji B 2016 Experimental Investigation On A Mixed Salt Salinity Gradient Solar Pond, *International Journal* Vol 8. No.1 – Pp.252-261.

[6] Khaldoon A Mohammad A Raed B and Hisham B 2017, Establishing Small-Scale Salt Gradient Solar Pond Experiment, *Sustainable Resources Management Journal*, 2(4), 01-10.
[7] Sathish D, Veeramanikandan M., Thirunavukkarasu R., Tamilselvan R. and Karthickmunisamy T. 2018, Thermal Performance On Portable Mini Solar Pond Using NaCl And Coal Cinder, Vol. 877, Pp 430-435.

[8] Ito M and Azam S 2019, Feasibility of Saline Gradient Solar Ponds as Thermal Energy Sources in Saskatchewan, Canada, Journal of Environmental Informatics Letters 1(2) 72-80.

[9] Sogukpinar H 2020, Numerical study for estimation of temperature distribution in solar pond in diverse climatic conditions for all cities of Turkey, Turkey, Environ Prog Sustainable Energy. 39:e13255.

[10] Osamah A H A, Anees A K, Hammed B M and Mustafa S M 2020), Solar pond as a low grade energy source for water desalination and power generation, Renew. Energy Environ. Sustain. 5, 4, https://doi.org/10.1051/rees/2019008.

[11] Rohan V V 2015, Design of a Solar Pond as an Energy Storage System for the Pasteurization process in Dairy ,Sweden, International Journal of Science and Research (IJSR) ISSN 2319-7064.

[12] Theodore L B, Adrienne S L, Incropera F, Dewitt D P 2011 Introduction to heat transfer, sixth edition, Chapter 2, Introduction to Conduction, p (78).

[13] Renuka A P 2016 , Efficiency And Thermal Analysis Of A Salinity Gradient Solar Pond, India, LISRSET Vol. 2 | Issue 4 | Print Issn: 2395-1990 | Online Issn : 2394-4099.

[14] Alibakhsh K, Mohamad A, Fathollah P D 2017, Energy Analysis And Shadow Modeling Of A Rectangular Type Salt Gradient Solar Pond , Iran, Solar Energy 146. Pp. 161-171. Issn 0038-092x.

[15] Alcaraz A, Valderrama C, Cortina J., Akbarzadeh A., Farran A 2018 Thermal Performance Of 500m2 Salinity Gradient Solar Pond In Granada, Spain Under Strong Weather Conditions, Spain, solar energy 171, 223-228.

[16] Duffie J A, Beckman W A 2013 Beckman. Solar Engineering of Thermal Processes. Fourth Edition. Chapter 1. P(37).