A

Dissertation Report

On

# EXPERIMENTAL STUDIES ON A SALT GRADIENT SOLAR POND WITH SEPARATING GLASS AND INTERNAL REFLECTORS

Submitted in partial fulfilment for the award of

**Master of Technology**

In

**Thermal Engineering**

By


**GAUTAM SAINI**

**(2015PTE5084)**


Under the supervision of


**Dr. NIRUPAM ROHATGI**

Associate Professor

Department of Mechanical Engineering



**DEPARTMENT OF MECHANICAL ENGINEERING**

**MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY, JAIPUR**


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**DEPARTMENT OF MECHANICAL ENGINEERING**

**MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY**

**JAIPUR (RAJASTHAN) - 302017**

# CERTIFICATE

This is certified that the dissertation report entitled "**Experimental Studies on a Salt Gradient Solar Pond with Separating Glass and Internal Reflectors**" prepared by **Gautam Saini** (2015PTE5084), in the partial fulfilment for the award of **Master of Technology** in **Thermal Engineering,** of Malaviya National Institute of Technology Jaipur is a record of bonafide research work carried out by him under my supervision and is hereby approved for submission. The contents of this dissertation work, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

Date:

Place:

**Dr. Nirupam Rohatgi**
Associate Professor
Department of Mechanical Engineering
MNIT, Jaipur, India

**DEPARTMENT OF MECHANICAL ENGINEERING**
**MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY**
**JAIPUR (RAJASTHAN) - 302017**

# DECLARATION

I **Gautam Saini** hereby declare that the dissertation entitled **"Experimental Studies on a Salt Gradient Solar Pond with Separating Glass and Internal Reflectors"** being submitted by me in partial fulfilment for the award of **Master of Technology** in **Thermal Engineering** is a research carried out by me under the supervision of **Dr. Nirupam Rohatgi** and the contents of this dissertation work, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma. I also certify that no part of this dissertation work has been copied or borrowed from anyone else. In case any type of plagiarism is found out, I will be solely and completely responsible for it.

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**Gautam Saini**
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(Gautam Saini)

# ABSTRACT

Salt-gradient solar ponds promise to be one of the relatively simple sources of energy collection and thermal storage with a cheap cost per unit area. In solar ponds, saline water is stored in three layers increasing in density. The surface layer, UCZ is homogenous and convective, where the density of saline is close to fresh water. In the middle layer, NCZ saline density increases with depth, thereby natural convection is suppressed and thermal energy is transported only by molecular diffusion that is very slow process. The lowest layer, LCZ is dense and convective, and has a relatively uniform density close to saline saturation. The thermal energy collected in the LCZ can be utilized for various applications.

Objective of the present study was to perform an experiment on salt gradient solar pond with using transparent separator (glass) above LCZ and using internal mirror as internal reflector separately. The main purpose of using transparent separator was to eliminate the diffusion of salt from higher concentration zone (LCZ) to lower convective zone (NCZ) which helps to maintain the salt gradient for longer period of time as a result the flushing of higher concentration salty water from UCZ and injecting of salt into LCZ reduced the requirement of Salt. Maintaining of salt gradient results reduce the losses due to the convection and improved the performance of solar pond. In the second experiment, side mirror used as the internal reflectors. The main purpose of using the internal reflector was to reduce the effect of walls shadow of the pond and increase the effective sunny area which increases the heat content and maximum storage zone temperature. Performance parameter from the both experiment was compare with the parameters of ordinary solar pond and analysed the results.

The results are summarized and discussed for different three modes of experiment. A comparative analysis has been made in the form of graphs and the obtained results have been discussed on the basis of parameters like temperature profile salinity profile, energy storage in LCZ and mean storage temperature.

The maximum temperature in solar pond using mirror was 3.2 $^0$C less and mean storage temperature was 1.67 $^0$C higher than the ordinary solar pond. In solar pond with internal reflector maximum temperature was 9.7 $^0$C and mean storage temperature was 11.32 $^0$C higher than the ordinary solar pond. Mean storage

temperature after 15 days were 37.36 $^{0}$C, 42.76 $^{0}$C and 47 $^{0}$C in ordinary solar pond, solar pond with glass and solar pond with internal reflector. The cause of decreasing mean storage temperature in ordinary solar pond and solar pond with mirror was that as No. of days passes, convection loss starts increase due to high diffusion rate as compare to solar pond with mirror. Maximum LCZ temperature in solar pond with glass was lesser than the solar pond with mirror and ordinary solar pond due to low transmissivity cause by deposition of dust layer above glass. During the third mode of experiment with internal reflectors, the effect of the wall shadow reduced and sunny area increased which increase the useful heat for solar pond. As a result, the highest temperature of the LCZ reaches to 60.5 $^{0}$C on 8$^{th}$ day of the experiment

Salinity of LCZ in solar pond with glass remains same all days of experiment from starting because the glass will not be allowed the diffusion of salt from LCZ to NCZ and the salinity of the UCZ starts increasing with slower rate than the ordinary solar pond because the potential of the concentration difference was lesser by separating the higher concentration zone (LCZ). Salinity of the UCZ after 15 days in ordinary solar pond was 1.08 and it becomes 1.04 (50% reduction) with using the glass. There was no difference in salinity after 15 days in ordinary solar pond and solar pond internal reflector.

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# Nomenclature

| | |
|---|---|
| A | area for absorption of solar radiation ($m^2$) |
| C | specific heat (kJ/kg C) |
| h | solar energy penetration |
| h(x) | solar radiation attenuation function in brine water |
| I | global solar radiation on the horizontal surface per hour (kJ /$m^2$ h) |
| k | coefficient of heat conductivity (W/m K) |
| Pr | Prandtl number |
| q(x) | solar radiation intensity reach the depth of x (W/$m^2$) |
| T | temperature (C) |
| t | time (h) |
| $T_a$ | ambient temperature (C) |
| $T_{avg}$ | daily average temperature (C) |
| $T_g$ | ground temperature (C) |
| $U_{ps}$ | coefficient of heat loss from the surface to surroundings (W/$m^2$ C) |
| $U_{pw}$ | coefficient of heat loss from the side wall to surroundings.(W/$m^2$C) |
| $U_{pg}$ | coefficient of heat loss from the solar pond to ground (W/$m^2$ C) |
| x | depth, distance from surface of the solar pond (m) |
| $\Delta T$ | daily max temperature difference (C) |
| $\Delta x$ | depth step (m) |

## Greek Symbols

| | |
|---|---|
| $\alpha$ | thermal expansion coefficient |
| $\beta$ | saline expansion coefficient |
| $\delta$ | declination angle |
| $\varepsilon$ | porosity |
| $\mu$ | extinction coefficient |
| $\rho$ | density (kg/m3) |
| s | ratio of diffusivities |
| $\nu$ | kinematic viscosity |
| $\omega$ | time angle |

# Abbreviations

| | |
|---|---|
| UCZ | Upper Convective Zone |
| NCZ | Non-Convective Zone |
| LCZ | Lower Convective Zone |
| SGSP | Salt Gradient Solar Pond |
| SSP | Shallow Solar Pond |
| MSSP | Membrane Stratified Solar Pond |
| VSSP | Viscosity Stabilized Solar Pond |

# Chapter 1
# Introduction

Solar energy is a key source for the future, not only in India, but also for the whole world. Therefore, the development and usage of solar energy systems are becoming increasingly vital for sustainable economic development. Of the various systems available for harnessing solar energy, solar ponds are one of the most simple and economic systems for storage and reuse of solar energy storage. A solar pond collects solar radiation and stores it as thermal energy for more than a normal period of time. Solar ponds can be used for: -

- Heating and Cooling of Buildings
- Generation of Power
- Industrial Process Heat
- Desalination
- Heating Animal Housing and Drying Crops on Farms
- Heat for Biomass Conversion

## 1.1 Solar Pond

A solar pond is basically a pool of water which collects and stores solar thermal energy. When sun's rays reach thebottom of the pond, they heat the water adjacent to the bottom and convection current starts within the water pool, due to temperature and consequently density gradients. As a result, hot water rises up and loses heat to the atmosphere. In the solar pond this loss of heat is prevented by different methods giving rise to different types of solar ponds.

## 1.2 Types of Solar Pond

There are two main categories of solar ponds:

### 1.2.1 Non-Convecting Solar Ponds

This type of solar pond suppresses heat losses by preventing convection current within the liquid body. They usually consist of saline water layers, where the salt concentration is highest in the bottom layer and lowest in the shallow surface layer. Some of the non-convecting solar ponds are:

### a) Salt Gradient Solar Pond

The salt gradient solar pond is typically 0.5 – 2 m deep and bottom usually painted black. The convection currents that normally develop due to the presence of hot water at the bottom and cold water at the top are prevented by the presence of strong density gradient from bottom to top. This density gradient is obtained by using a high concentration of suitable salts such as NaCl at the bottom of the pond and negligible concentration at the top. NCZ of the pond acts as the insulating layer and reduce heat loss.

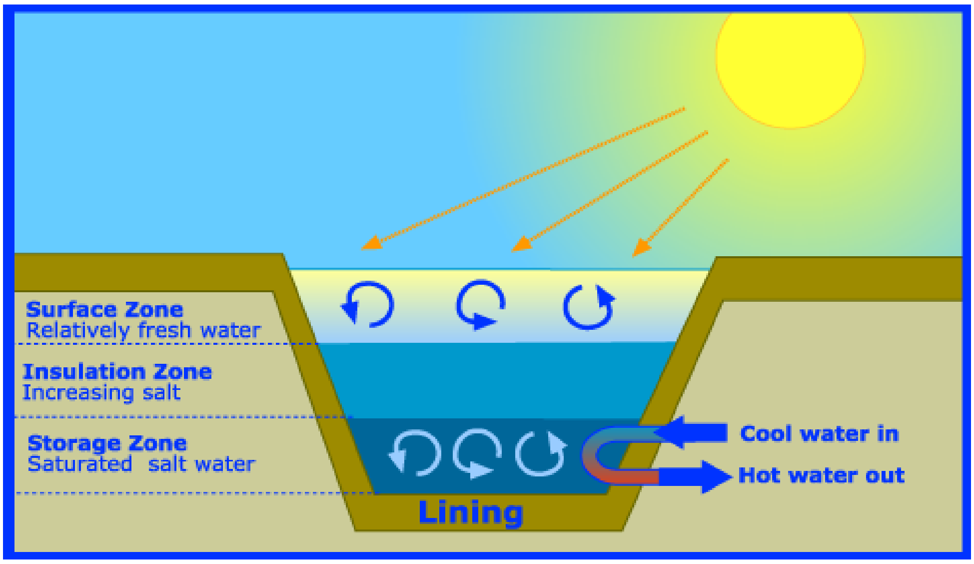


**Fig. 1.1: Diagram of the Salt Gradient Solar Pond**

The salt gradient solar pond consists of three layers. The top surface layer is known as the upper convection zone that is a zone of constant temperature and salinity. The thickness of this surface layer varies from 0.1 to 0.4 m and is formed by fresh water. The second layer is the non-convective zone (NCZ) with thickness ranges from 0.6 to 1.0 m, which acts as an insulating layer of the pond. The density in the NCZ increases with increase in depth. The thickness of the gradient layer depends on the desired temperature, solar transmission properties and thermal conductance of water. The bottom or the third layer is a high-temperature layer identified as the storage layer or the storage zone. This layer has a steady temperature and salinity. Useful heat is usually extracted from this layer. The thickness of this layer, normally termed as a lower convective zone or LCZ, depends on the temperature and the quantity of the thermal energy to be stored.

**b) Membrane Stratified Solar Pond (MSSP)**

Membrane stratified solar pond is a non-salt type solar pond, where a body of liquid is stored utilizing closely spaced transparent membranes. To suppress convection losses, space between successive membranes is kept very small and a large number of highly transparent films are utilized. Three types of membrane arrangements are suggested for these solar ponds; which are horizontal sheets, vertical tubes, and vertical sheets.

**c) Saturated Solar Pond (STSP)**

The problems related to maintaining density gradient in the conventional salt gradient solar pond can be overcome by making the pond saturated at all levels, with salts whose solubility increases with temperature. Such saturated ponds have no apparent diffusion problems and density gradient is self-sustaining depending on local temperature; thus, the main advantage of such a pond is its inherent stability. In these ponds, vertical diffusion of salt is prevented and the density gradient is stable; thus, making the pond maintenance free.

**d) Viscosity Stabilized Solar Pond (VSSP)**

Non-convective layers of solar ponds are ordinarily composed of salt gradient layers. Salt gradient solar ponds, however have a number of difficulties; they may cause environmental pollution in the event of a salt leakage and the salt gradient layer needs frequent maintenance. In order to eliminate these problems, Shaffer proposed a new type of solar ponds using a transparent polymer gel as the non-convecting layer. The polymer gel used is in nearly solid state and has low thermal conductivity; so, the losses due to convection does not take place.

### 1.2.2 Convecting Solar Ponds

Convecting solar ponds trap heat by stopping evaporation rather than by stopping convection. The structure consists of a large bag of water with a blackened bottom, foam insulation below the bag, and two layers of plastic or glazed glass on top of the bag. This design allows convection but prevents evaporation. Sun rays heat the water during the day and at night hot water is pumped into heat-storage tanks.

### a) Shallow Solar Pond (SSP)

The shallow solar pond (SSP) is a solar energy collector that is intended to supply large amounts of heat energy for industrial applications at operating costs competitive with fossil fuel plants. It consists of a polyethylene water bag with a clear top and black bottom, placed within a foam box attached to a wooden frame. The efficiency of SSP could be improved by equipping the solar collector with a thermally insulated cover which also functions as an insulating reflector during the heat collection period. The rate of solar energy collection is increased by means of the reflector redirecting Sun rays onto the collector surface.

## 1.3 Objective of the Study

The aim of the study was to design, fabricate and study the effect of (i) separating glass above lower convective zone and (ii) internal reflectors on the side walls of the solar pond on the performance of a solar pond with respect to the simple solar pond.
During the experimental study, various measurements such as temperature and salinity at various depths and solar intensity have been taken to compare the performance of the Solar Pond in different three cases.

## 1.4 Outline of the Thesis

The thesis has been divided into seven chapters. The brief description and content of each chapter are given below:

***Chapter 1: Introduction***

The chapter describes the importance of solar ponds and gives a description of different types of types of solar ponds in use. Objectives of the present study and outline of the thesis are also presented in this chapter.

***Chapter 2: Literature Review***

This chapter discusses studies done in the field of the solar pond design and experimentation.

***Chapter 3: Salt Gradient Solar Pond***

This chapter describes the working principle of the salt gradient solar pond and theoretical analysis to calculate the efficiency of different layers.

***Chapter 4: Experimental setup***

This chapter describes the design and fabrication of an experimental solar pond. It includes various instruments used during the experiments and construction material employed in the fabrication of the solar pond. The chapter also describes the process of formation of different layers of the solar pond.

***Chapter 5: Experimentation***

This chapter gives the experimental observation of temperature, salinity and solar radiation intensity taken during the experiments.

***Chapter 6: Results and Discussions***

The results obtained from the experimental study conducted are summarized and discussed in this chapter. A comparative analysis has been made in the form of graphs and the results have been discussed on the basis of parameters like temperature profile, salinity profile, energy storage in LCZ and mean storage temperature.

***Chapter 7: Conclusions and Recommendations***

Important conclusions drawn from overall study have been summarized in this chapter. Suggestions for future work are given in the end of the chapter.

# Chapter 2
# Literature Survey

Experimental, mathematical and theoretical studies have been done by many researchers in the field of the solar pond. This chapter gives an overview of the work that has been carried out by various researchers in the field of the solar pond.

## 2.1 Experimental Investigations of Solar Pond

Various experimental studies have been done by the different researchers on a solar pond and the results have been compared with the theoretical study. Some of the following experimental studies are:

**Choubani et al. (2010) [2]** carried out an experimental study in a college of Pondicherry, India. In this project, 10 different types of salts were taken and experiments to find the best heat absorbing salt. Sodium Sulphate and sodium carbonate were used to create a gradient and in a 0.25 $m^3$ solar pond. He observed that the mixed salt salinity gradient solar pond is technically feasible and comparable to the performance of the normal Salt Gradient Solar Pond.

**Sozhan et al. (2013) [3]** experiments on a solar gel pond. In this solar pond, UCZ and NCZ were replaced by a transparent polymer gel, Carbowax, which is insoluble in brine and has good transmissivity characteristics. Experiments were performed on the solar gel pond of 0.25 $m^2$ area at Pondicherry, India, during three months February, March and May 2004. Due to UCZ and NCZ being replaced by gel, there was no evaporation for the UCZ and no diffusion of salt from LCZ. As a result, mean storage temperature of LCZ reached was 60 °C and storage efficiency of LCZ was found to be 19.7%.

**Sifuna et al. (2014) [4]** said that the diffusion of salt was one of the obstacles that affected the efficiency of solar ponds. Salt diffusion from LCZ through NCZ caused the erosion of the salt gradient zone that eventually leads to the appearance of convection currents having a negative effect on the total energy stored in the solar pond. Two small experimental scale salt gradient ponds with surface areas of 0.6 x 0.4 sq. m and 0.2 m depth were constructed. The purpose of the experiment was to quantify and compare the diffusion of salt in an SGSP with and without a transparent polyethylene film between NCZ and LCZ (which allows solar radiation to penetrate but does not allow mass transfer across it). In both the ponds, UCZ salt concentration increased linearly with time, while LCZ salt concentration remained static in a polyethylene film pond but dropped in the pond without a polyethylene film, separating NCZ and LCZ.

**Shekhawat et al. (2014) [5]** conducted experimental studies for assessment of turbidity accumulation rate, its effect on layer transmissivity and how to minimize these effects. Experiments were done in tropical climatic conditions of Jalgaon city in India. A solar pond of 1x 1 x 2.5 $m^3$ was constructed. It was filled with low turbidity chlorinated water. The turbidity at different depth was measured regularly over the period of time. Chlorination was used to reduce biological growth in the water. Based on experimental measurements and data analysis, optimum chlorination dose was determined for various turbidity levels in a solar pond.

**Ganesh et al. (2016) [6]** conducted experiments over the shallow solar pond with and without transparent glass cover. In the shallow solar pond, black sheet of 200 μm thickness was pasted to interior walls for increasing absorption of solar radiation and transparent glass cover of 5 mm thickness was placed over the UZC to avoid evaporation and turbulence due to the wind. As a result, shallow solar pond with glass cover achieved a storage temperature of 81.5 °C, and average efficiency for the solar pond with glass cover increased 7% as compared to one without glass cover.

**Jeffrey et al. (2010) [7]** found that evaporation represents a significant challenge to the successful operation of solar ponds. In their work, suppression of evaporative losses from a salt-gradient solar pond was examined in the laboratory. Two floating part designs (floating discs and floating hemispheres) and a continuous cover were tested.
It was found that floating discs were the most effective solution for suppression of evaporation. As an effect of reduced evaporative losses at the surface, heat lost to the atmosphere was also reduced. This resulted in lower convective losses from the NCZ and the LCZ and hence, increase in temperatures in NCZ and LCZ.

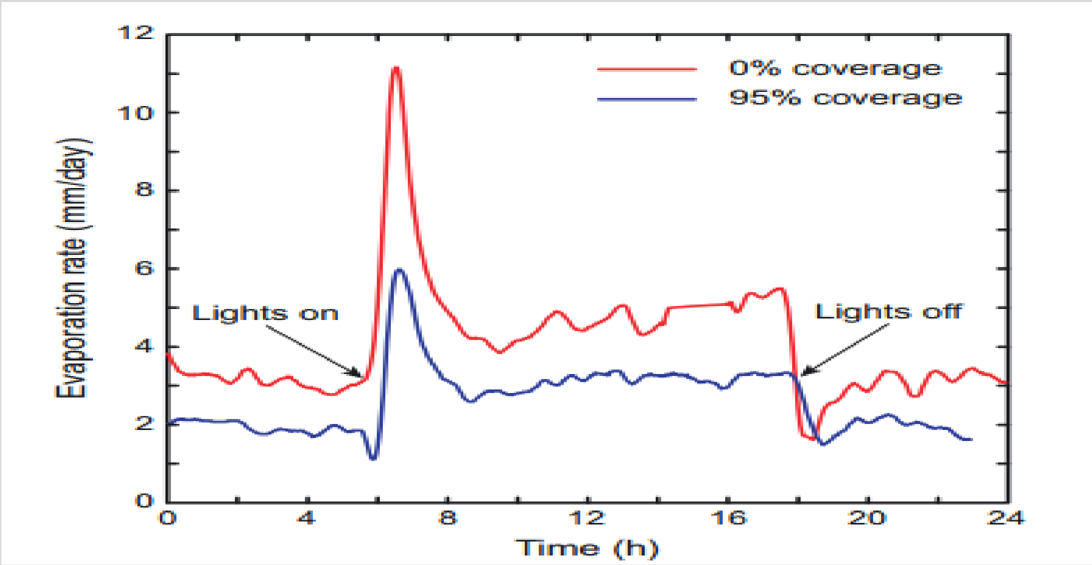


**Fig. 2.2: Evaporation from the Solar Pond Surface During Daily Operation**

**Sifun et al. (2014) [8]** analyzed the efficiency of solar pond with and without polyethene above UCZ which affect the thermal behavior of the solar pond. A polyethene layer of thickness 100 micrometer was used. Experimental results showed that the heat storage zone i.e. LCZ temperature rising rate was considerably higher for solar pond with polyethene above UCZ as compared with single layer porous media solar pond. The polyethene film generated the greenhouse effect where the solar energy was trapped and improved the efficiency of the storage zone. The outcome showed that efficiency of a polyethene stabilized pond rises to almost 69% compared to the conventional solar pond with efficiency of about 52%.

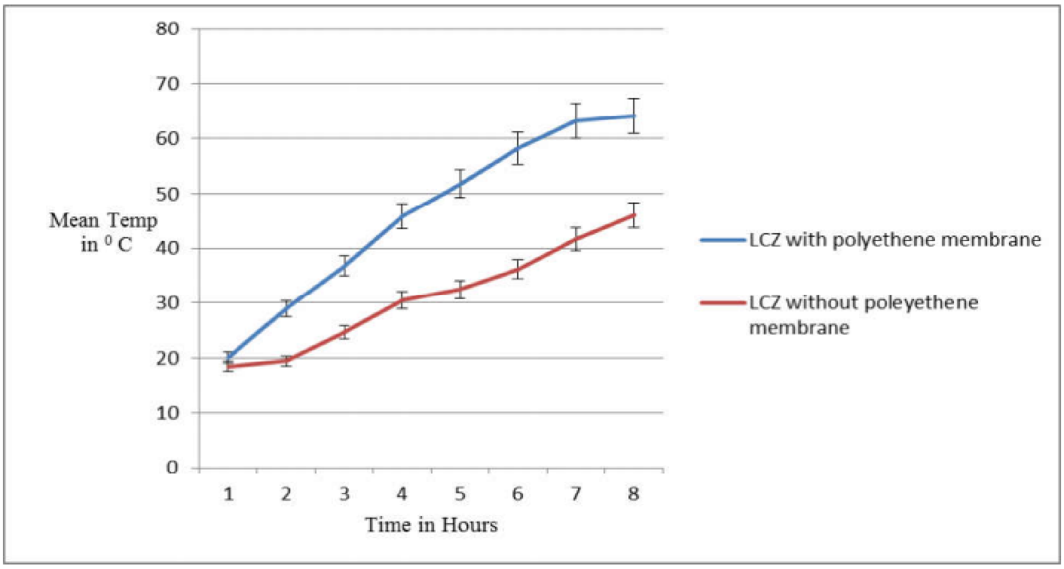


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**Fig.2.3: Temperature Profile for LCZ at 25% Salt Concentration**

## 2.2 Theoretical Works on Solar Pond

Theoretical studies to improve the performance of solar pond have been done by many researchers. Some of the important studies are given below

**Wang et al. (2010) [9]** studied the temperature development of adding coal cinder at bottom of SGSP experimentally and theoretically. One dimensional transient numerical model was used to estimate the temperature development in SGSP. The outdoor experiments were used to qualitatively study the temperature evolution of different bottom treatments and porous materials influence, and also used to validate the mathematical models. Coal Cinder is a normal porous media and low-cost industrial by-product. It is burnt or partly burnt residue of coal. A porous layer of coal cinder was added at the bottom of the solar pond because it has good insulating effect and low thermal diffusivity. Another important reason for selecting this material was that it behaved like a black body which absorbs more of the solar radiation. The results show that adding coal cinder at bottom of SGSP leads to a higher LCZ temperature than the traditional bottom treatment.

**Al-Nimr et al. (2014) [23]** carried out theoretical study on a novel two-layer nanofluids solar pond. The upper layer of the pond was made of mineral oil and the lower layer was made of Nano-fluids. A nanofluid is known to be an excellent solar radiation absorber, and had been tested and verified using the mathematical model. Nano-fluids increases extinction coefficient of the lower layer and therefore thermal efficiency and storage capacity of the pond is enhanced.

The pond combines the concepts of the shallow solar pond. It is a two-layer pond having two liquids of different properties and small depth. The liquid in upper layer must be transparent; chemically stable, non-toxic, commercially available, should not evaporate, having a lower density than the lower layer fluid and should have lower thermal conductivity than the lower layer to act as an insulator. The suggested liquid for this purpose is mineral oil since it has all the properties mentioned above. For the lower layer, Ag water-based nanofluid is chosen. This water-based nanofluid has higher densitythan mineral oil, therefore oil will float above it. Also the water based nanofluid has the advantage of being an excellent solar absorber.

Thus, using of oil as upper layer saves water and protect the pond from different ambient effects. In addition, using nanofluid eliminates the issue of establishing the salinity gradient in the pond. Due to its better solar absorption characteristics, a nanofluid pond will be a better solar energy storage device than a conventional solar pond. It has been seen that the energy stored at 25 cm depth in a nanofluid pond is twice that of the brine pond which is a huge advantage.

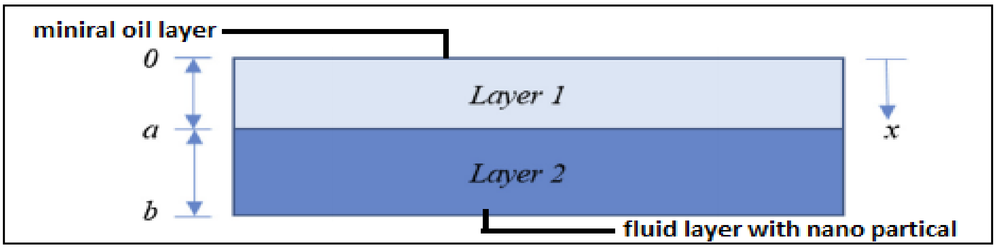


**Fig. 2.1: Novel Two-Layer Solar Pond Using Nanofluids**

**Velmurugan et al. (2007) [10]** reported that in UCZ approximately 45% of the incoming solar radiation is absorbed and remaining is lost due to evaporation, convection and re-radiation. Depending on the thickness of the NCZ, around 15-25 % of the incoming radiation is absorbed under clear water conditions. By using a blackened bottom pond, in LCZ up to 40 % of the total received solar energy can be absorbed. The temperature of this zone varies between 60 °C to 70 °C. At the bottom of the pond, proper insulation is made to minimize heat losses.

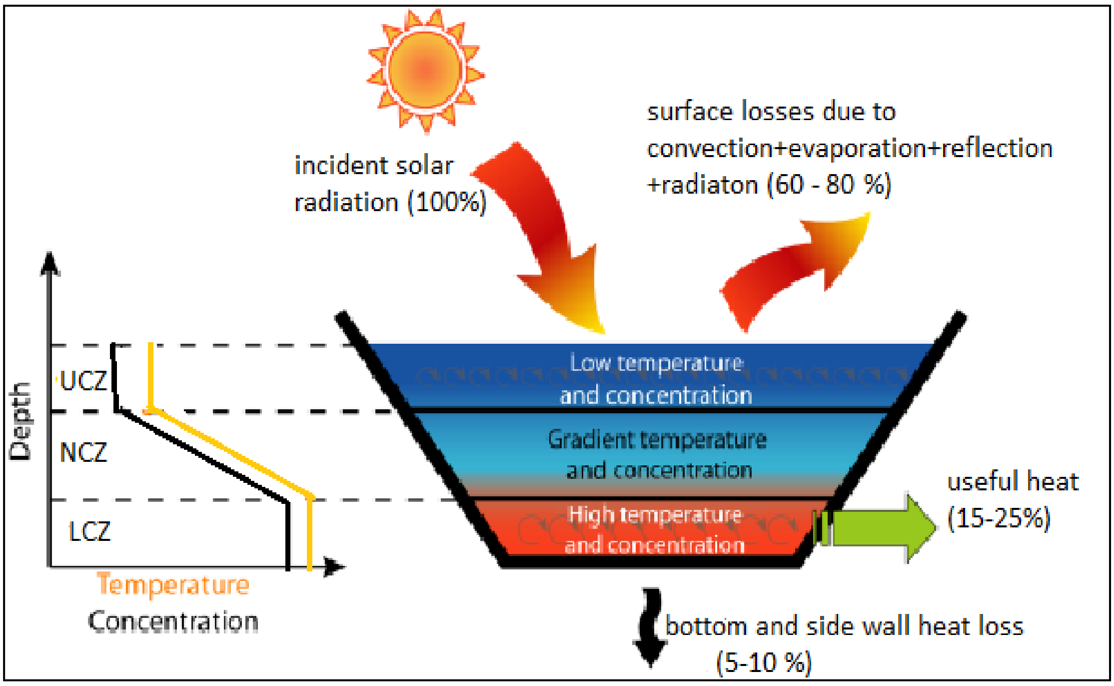


**Fig. 2.4: Heat Flow Diagram of Solar Pond**

**Ganesan et al. (2008) [13]** carried out the study on thermal energy extraction from solar pond with the use of Rankine cycle heat engine. R-134a was used as a working fluid. The solar pond is used as a source of heat for the evaporator. Freshwater circulates through an internal heat exchanger located in the LCZ of the pond and transfers heat to the evaporator. The absorbed heat increases the temperature of a working fluid and causes its vaporization. The theoretical study presents an alternative method of thermal energy extraction from solar pond.

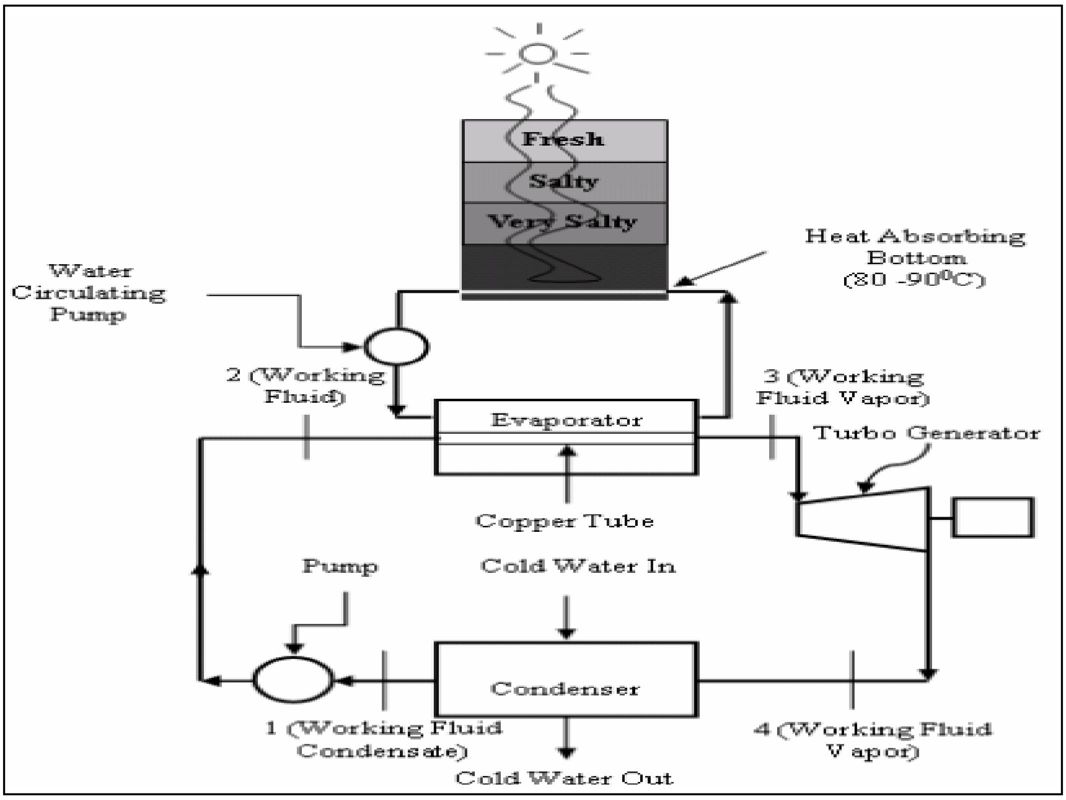


**Fig. 2.5: Schematic Diagram of Rankine Cycle Solar Pond Power Generator**

A maximum thermal efficiency of 27.94 % and specific power of 16.852 kW/m$^2$ can be achieved by using the effective closed Rankine cycle solar pond power generator. To assure a specified minimum amount of power generation and continuous production of power from the solar energy source, closed Rankine cycle solar power generator system is an extremely attractive option.

**Reza et al. (2008) [14]** investigated the effect of solar pond shape on radiation absorption when covered with a glazing plastic. Solar ponds were studied with similar volume and area but different geometric shapes, rectangular and circular. The maximum temperature was found to be highest in the rectangular pond. In addition, analysis showed that the shadow area created in solar ponds depend on some factors such as geographical location, radiation angle, dimension of ponds, date and time in a year. The right choice of the dimensions of the pond decreases shadow area in the pond. The result indicates that rectangular solar pond also has a smaller shadow area. The glazing cover prevented the heat from escaping the surface of the ponds.

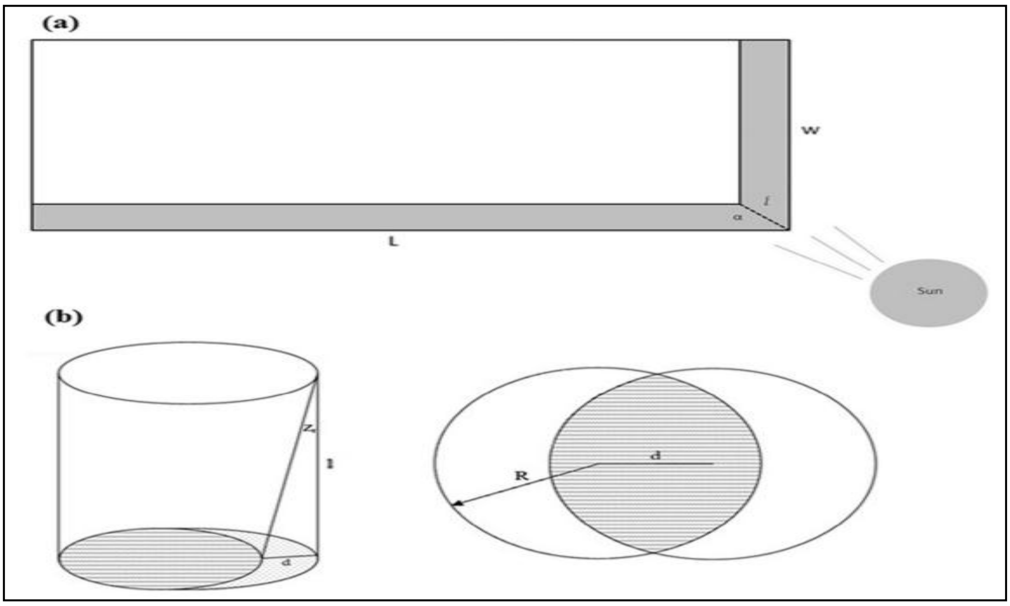


**Fig. 2.6: Schematic Design of the Sunny Area in (a) Rectangular Pond and (b) Circular Pond**

The heat was trapped in the ponds and the temperature increased in UCZ.
To find out the shadow area the following equation was used:

$$S_{sun} = 2R^2 cos^{-1}\left(\frac{d}{2R}\right) - \frac{1}{2} d\sqrt{4R^2 - d^2}$$

Where d is calculated as, $d = l\ \tan . Z_r$

Here, $l$ is the depth and $Z_r$ is the refraction angle of water.

## 2.3 Computer Simulation and Modeling

Several analytical models of various levels of complexity have appeared in the literature but clearly computer simulations offer the possibility of incorporating more realistic assumptions and complex data, without hopelessly complicating the already complex model of the solar pond. Mathematical modeling is used to create equations or relationship between the different performance parameters of the solar pond. Effect of solar intensity, incident angle, depth of different zone, the concentration of different zone, air velocity and other parameters are estimated with the help of simulation and modeling.

**Refaee et al. (2009) [15]** carried out a study on a one-dimensional transient mathematical model for predicting the thermal performance of the salt-gradient solar pond. The model accounts for heat losses from the surface and bottom of the pond, surface evaporation, wind effect, heat extraction, and variations of the brine physical properties with temperature and salinity. Boundary conditions were based on ambient and ground temperatures at Kuwait City. An implicit finite-difference scheme was used to solve the governing system of heat flux equations. A computer code was developed to conduct a parametric study for determining optimum thickness of both the gradient zone and the storage zone in the solar pond. Thestudy recommends optimum values of 1.3 m and 1.4 m thickness for the gradient and storage zone respectively.

**Berkani et al. (2015) [16]** performed experimental studies on three small solar ponds (1m x 1m x 1m); each pond contained one of the consequent salts, namely NaCl, $Na_2CO_3$ and $CaCl_2$ correspondingly. The thermal performance of three ponds was investigated numerically and experimentally over a time of 28 days. A bi-dimensional heat diffusion equation was solved numerically using the finite differences method of Crank–Nicholson. The experimental results showed good agreement with the results obtained by simulation with an error of less than 1.5%. This study showed that thermally $CaCl_2$ pond responds quicker than the two other ponds without attaining saturation.

This study also indicated that solar pond is warmer in its central portion and colder at the periphery close to the walls. This certainly plays an essential role in the SGSP performance and their life span and validates the requirement of insulation to improve the performance and lessen the maintenance.

**Husain et al. (2002) [17]** investigated few mathematical aspects of computer simulation for salt gradient solar pond's thermal behavior. The basic equation governing heat flow in the non-convective zone of the solar pond was solved by finite difference approach using the Crank–Nicholson method. Stability and convergence of the method, particularly for the case of a solar pond, was examined over a broad range of depth difference ($\Delta x$) and time difference ($\Delta t$). It was observed that the mesh ratio which was used to describe the stability and convergence of the technique did not have an absolute value; moderately its value varied with $\Delta$x. While using an actual set of $\Delta$x and $\Delta t$, the stability must be tested with reference to the set being used. Some other mathematical aspects pertaining to the genuine application of the method were also investigated

**Giestas et al. (2009) [18]** analyzed a 2D numerical model where the behavior of a SGSP was described in terms of temperature, salt concentration, fluid density, and viscosity. The discretization of the governing equations was based on the particular formulations. Rectangular geometry was allowed for spectral type approximations as the necessary uniform boundary conditions could easily be imposed. Taking into account the variation of density and viscosity with temperature and salinity enhanced the agreement between the simulation results and the experimental measurements.

## 2.4 Summary of Literature Review

Various experimental, mathematical and theoretical studies have been done by different researchers in this field. Following are the conclusion drawn based on available literature relating to solar pond.

- Non-convective salt gradient zone can be replaced by a transparent polymer gel layer, which floats on a NaCl solution used in the storage zone and reduces the diffusion.
- Polyethene film can be used to reduce the diffusion of salt from LCZ.
- Chlorination can be used to reduce the biological growth in the water and reduce the turbidity of the water for better transmissivity.
- A novel solar pond design with two liquid layers has been studied in which oil is used as upper layer to protect the pond from different ambient effects and nanofluid is used in lower layer improving the absorption characteristics of storage zone.
- Floating discs and floating hemispheres and a continuous cover can be used to reduce the evaporation loss.
- Adding coal cinder at the bottom of the solar pond increases absorptivity of solar radiation in LCZ.
- For similar volume and area of cross section, rectangular solar pond gives more sunny area than the circular solar pond.

# Chapter 3

# Salt Gradient Solar Pond

The salt gradient solar pond is a system to store the energy at the bottom of the pond by creating an artificial salt-gradient above storage zone.

## 3.1 Working Principle

The solar pond works on a very simple principle. It is well-known that when water or air is heated they become lighter and rise up. In an ordinary pond, the sun’s rays warm up the water and the heated water from the bottom of the pond rises and reaches the top and loses the heat into the environment. The net outcome is that the pond water remains at the atmospheric temperature.

The solar pond restricts this process by dissolving the salt in the water. A solar pond has three zones. The top zone is the surface zone, or UCZ (Upper Convective Zone), which is at ambient temperature and has small salt content. The bottom zone is very salty and heavy. It is this region that collects and stores solar energy in the form of heat, and is known as the storage zone or LCZ (Lower Convective Zone). Separating these two zones is the significant gradient zone or NCZ (Non–Convective Zone). Here the salt content increases as depth increases, in a manner creating a salinity or density gradient. The non-convective zone above the lower convective zone acts as an insulating layer and reduces the heat loss from the LCZ. High-salinity water at the base of the pond does not mix up easily with the low-salinity water above it, so when the bottom layer of water is heated, convection occurs individually in the bottom and top layers, with only mild mixing between the two.

The solar energy is thus trapped in the LCZ and withdrawn in the form of hot brine through a heat exchanger.

Salt Gradient Solar Pond is a body of saline water having large lateral dimensions and three vertical zones as shown in Fig. 3.1. The upper convective zone (UCZ) contains saline water with low salt concentration and is designed to absorb turbulence due to wind, hail, raindrops, etc. to minimize its effect on NCZ.

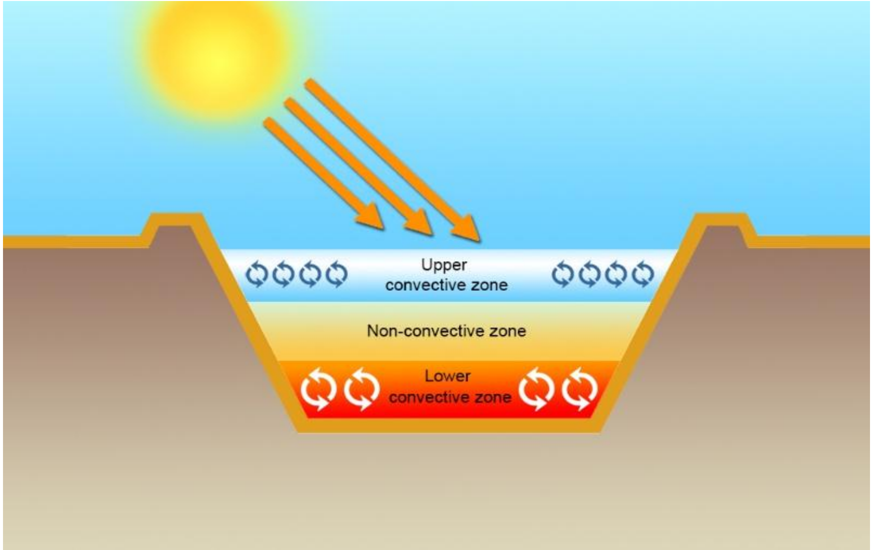


**Fig. 3.1: Principle of Solar Pond**

NCZ acts as an insulating lid over LCZ. NCZ consists of sub salinity layer whose salinity concentration linearly increases with increase in depth. In Due course diffusion of salt occurs. As a result of which this linear profile of salt concentration approaches to a parabolic profile.

The lower convective zone (LCZ) contains uniform salinity throughout its depth. This zone is used for storing heat. Its size is decided according to the heat storage capacity required. The thickness of non-convective zone (NCZ) manages the overall performance of the pond. Heat content in LCZ can be extracted by using a heat exchanger with a brine solution.

## 3.2 Theoretical Analysis of Solar Pond

There are various parameters affecting the performance of salt gradient solar pond such as variation of temperature with depth and time, a variation of concentration with depth, a variation of temperature in storage zone. The efficiency of different layers and amount of thermal energy stored in the solar pond are described below:

### 3.2.1 Efficiency of Different Layers

**Karakavalasa G. et al. [2013]** [21] calculated the theoretical efficiency of three zones in solar pond

**a) Efficiency of Upper Convective Zone**

The efficiency of UCZ is given by:

$$\eta = \frac{Q_{net}}{Q_{in}}$$

$Q_{net} = Q_{in} - Q_{out} = (Q_{solar} + Q_{down}) - (Q_{wa} + Q_{side})$

where,

$Q_{solar}$ = net incident solar radiation absorbed by the UCZ.

$Q_{down}$ = total heat transmitted to the zone from the zone beneath it.

$Q_{side}$ = heat loss to the side walls of the pond.

$Q_{wa}$ = heat loss to the surroundings from the upper layer.

$$\eta_{ucz} = 1 - \frac{(Q_{wa} + Q_{side})}{(Q_{solar} + Q_{down})}$$

$Q_{wa} = U_{wa} A_{ucz} (T_{ucz} - T_{amb})$

$Q_{side} = U_{side} A_{side} (T_{ucz} - T_{side})$

$Q_{down} = \frac{K}{X_1} A_{ucz} (T_{down} - T_{ucz})$

where, K = thermal conductivity, $X_1$ = thickness of the first layer

$Q_{solar} = \beta A_{ucz} h_1$

where,

$h_1$ = ratio of energy reaching layer 1 to solar radiation incident on the pond surface

A = area of the pond.

β = incident beam rate entering the water.

**b) The Thermal (energy) Efficiency for Non-Convective Zone (NCZ)**

$Q_{net} = Q_{in} - Q_{out} = (Q_{solar} + Q_{down}) - (Q_{wa} + Q_{side})$

$$\eta_{ncz} = 1 - \frac{(Q_{wa} + Q_{side})}{(Q_{solar} + Q_{down})}$$

$Q_{wa} = U_{wa} A_{ncz} (T_{ncz} - T_{amb})$

$$Q_{side} = \mathrm{U_{side}A_{side}(T_{ncz} - T_{side})}$$

$$Q_{down} = \frac{\mathrm{K}}{\mathrm{X_1}} \quad \mathrm{A_{ncz}(T_{down} - T_{ucz})}$$

where, K = thermal conductivity, $X_1$ = thickness of the first layer

$$Q_{solar} = \mathrm{\beta A_{ncz}h_1}$$

where,

$h_1$ = ratio of energy reaching layer 1 to solar radiation incident on the pond surface

A = area of the pond

β = incident beam rate entering the water.

**c) The Thermal (energy) Efficiency for Lower Convective Zone (LCZ)**

$$Q_{net} = Q_{in} - Q_{out} = (Q_{solar} + Q_{down}) - (Q_{wa} + Q_{side})$$

$$\eta_{\mathrm{Lcz}} = 1 - \frac{(Q_{wa} + Q_{side})}{(Q_{solar} + Q_{down})}$$

$$Q_{wa} = \mathrm{U_{wa}A_{Lcz}(T_{Lcz} - T_{amb})}$$

$$Q_{side} = \mathrm{U_{side}A_{side}(T_{Lcz} - T_{side})}$$

$$Q_{down} = \frac{\mathrm{K}}{\mathrm{X_1}} \quad \mathrm{A_{Lcz}(T_{down} - T_{Lcz})}$$

where, K = thermal conductivity; $X_1$ = thickness of the first layer

$$Q_{solar} = \mathrm{\beta A_{Lcz}h_1}$$

where,

$h_1$ = ratio of energy reaching layer 1 to solar radiation incident on the pond surface

A = area of the pond

β = incident beam rate entering the water.

### 3.2.2 Energy Stored in the Solar Pond

Useful Energy collection by 1 $m^2$ solar pond per year

Average solar intensity in Jaipur = 600 $W/m^2$

For 1 $m^2$ solar pond area

Energy collected = 600 W

Assuming 8 hours sunny day in 300 days in a year

Energy collected per day = 600 J/s x 8 x 3600 s = 17.28 MJ/day

Energy collected per year = 17.28 x 300 = 5184 MJ/year

Thermal efficiency of a solar pond varies from 15 – 25 %

Assuming 20% efficiency of solar pond

$$\eta_{sp} = \frac{Q_{useful}}{Q_{incident}}$$

$Q_{useful}$ = 0.2 x 5184 MJ/year/$m^2$

$Q_{useful}$ =1036.8 MJ/year/$m^2$

# Chapter 4
# Experimental Setup

The scope of the work involved design of solar pond, i.e. to determine the shape and size of the pond, fabrication/ selection of pond, to install the pipes in the pond to draw the sample of saline water, preparation of three different salinity layers and to construct a diffuser to prepare salinity layers.

Salinity was carefully chosen because higher concentrations lead to more prominent diffusion of salt from the LCZ to UCZ which would require frequent cleaning of UCZ and salt addition at LCZ. On the other hand, lower value of salinity would require lesser gradient in salinity which will lead to lesser temperature gradient because of more convective heat losses and low maximum temperature in the solar pond. The thicknesses of three layers were taken according to guidelines suggested by M.M.O. Dah et al. [22]

## 4.1 Design of Solar Pond

An insulated plastic container, 0.70 m × 0.45 x 0.4 m was selected as a solar pond. The specifications of the set up are :

- Cross-sectional area = 0.7 m x 0.45 m = 0.315 $m^2$
- Depth of the pond = 0.4 m
- Specific gravity of saline solution in LCZ = 1.20
- Specific gravity of saline solution in NCZ = 1.20 to 1.05
- Specific gravity of saline solution in UCZ = 1.0 (Fresh Water)
- Salt (NaCl) concentration in LCZ = 20%
- Thickness of UCZ layer = 0.05 m;
- Thickness of NCZ layer = 0.20 m;
- Thickness of LCZ layer = 0.15 m;
- Thickness of plastic side walls = 0.05 m
- Thickness of bottom wall = 0.07
- Thickness of insulation sandwich in plastic wall = 0.02 m
- Number of pipes for saline water samples = 11

- Space between two saline sample pipes 4cm
- Thermocouples types T- type
- Number of thermocouples = 12
- Gap between thermocouples 7 cm

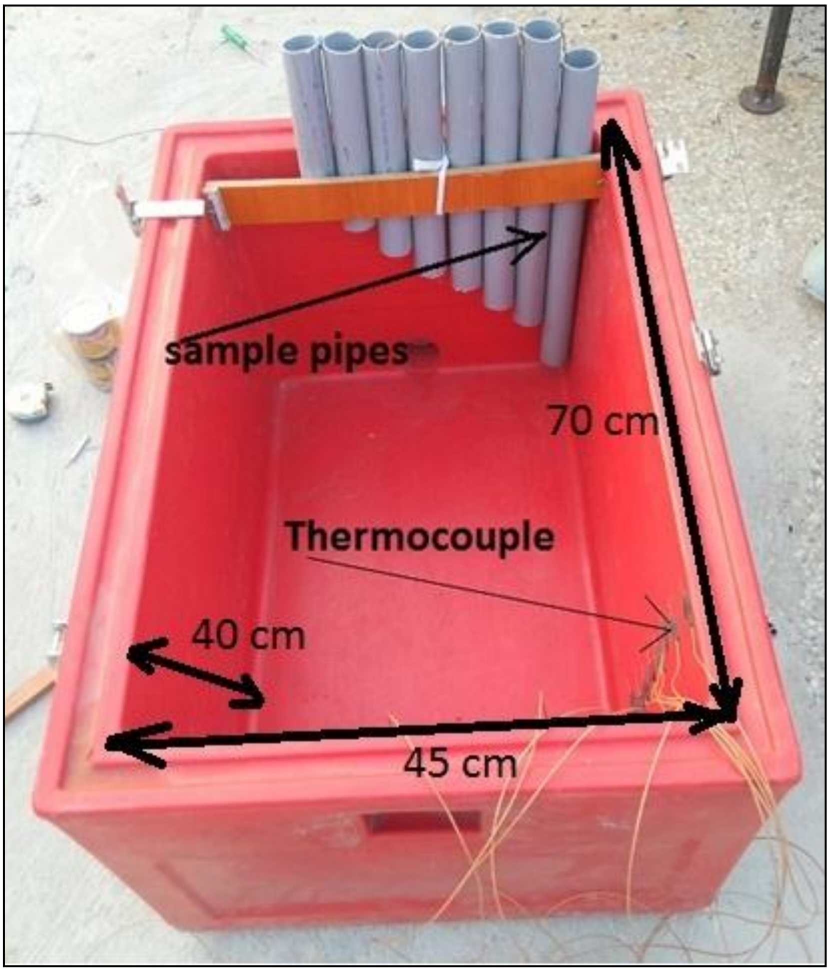


**Fig. 4.1: Solar Pond with Design Parameters**

### a) Selection of Location of Solar Pond

The site selection of solar pond is a very important factor because a small disturbance in salt gradient may disturb the salinity layers of the solar pond. Following considerations were taken in deciding for the location of the experiment:

- Presence of any shade due to walls or trees around the setup
- Availability of water
- Accessibility
- Safety of the experimental setup

After these considerations two alternatives were available, the courtyard of the mechanical workshop and the roof of the Mechanical Engineering Department Office. The rooftop of the department office offered uninterrupted sunlight throughout the day along with the safety of the experimental setup. The solar pond needs special care from any disturbance to the salt gradient, so the location of the experimental setup of the solar pond was chosen at the roof of the Mechanical Engineering Department Office.

### b) Size of the Solar Pond

The decision about the size of the pond is based mainly on required depth of solar pond for obtaining a satisfactory temperature profile. The transimission of the solar radiation to LCZ decreases on increasing the depth of the pond, due to increase in the depth of the layers in NCZ. The depth of the solar pond was chosen to be 40 cm i.e. 5 cm (UCZ), 20 cm (NCZ) and 15 cm (LCZ), as suggested in the literature. Thus, an insulated plastic container of 70 cm x 45 cm x 40 cm was chosen for the experimental study.

### c) Selection of Salt

There are different factors which decide selection of suitable salt for the solar pond like rate of diffusion, temperature-dependent solubility, availability, cost, etc.

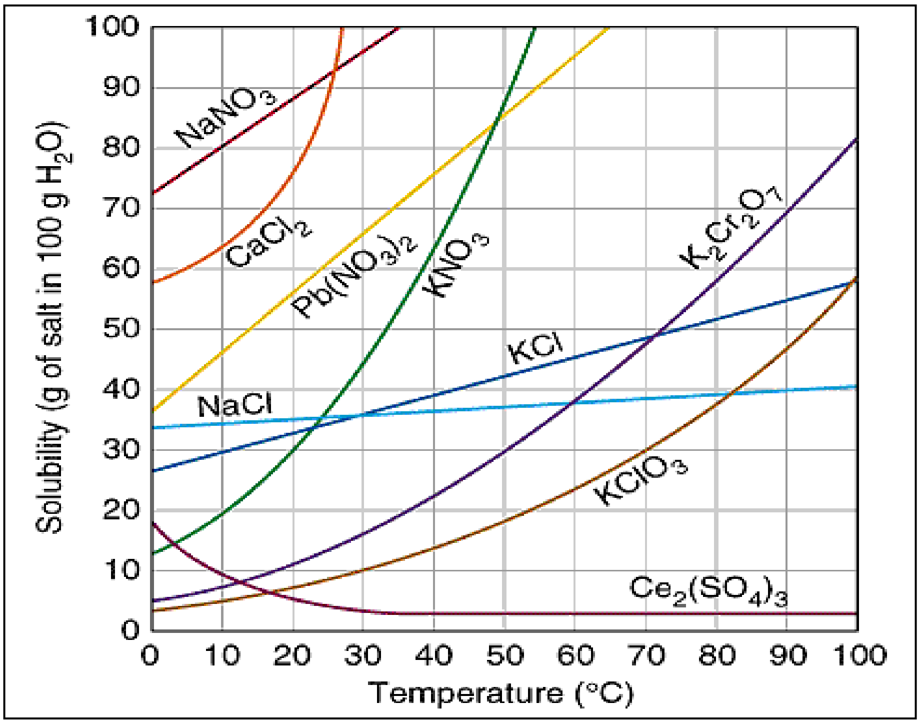


**Fig. 4.2: Variation of Solubility of Various Salts with Temperature**

NaCl was used in the salt gradient solar pond because NaCl has small change in water solubility with increase in temperature as compared to other salts (i.e. 8% variation for the temperature variation of 0°C to 100°C) as shown in Fig 4.2. NaCl (common salt) is also easily available and cheaper.

**d) Quantity of Salt Required for Layer Formation**

The amount of salt required depends on the size of the solar pond and concentration of salt in different layers. Experiments were performed with a salt concentration of 20% by weight in LCZ. The quantity of salt required for each zone is calculated as below:

(i) Salt required for LCZ zone:

Quantity of salt required for LCZ of solar pond with salt 20% salt concentration

Volume of salt water in LCZ = cross section area of pond x depth of LCZ

= 70 x 45 x 15 $cm^3$

= 0.04725 $m^3$

The weight of salt required = $\rho_{water}$ x volume of LCZ x % conc. of salt in LCZ

= 1000 x 0.04725 x (20/100)

= 9.45 kg

(ii) Salt required for NCZ zone

Average conc. of NCZ layer = (conc. of LCZ + conc. of UCZ)/2

= (20 + 0)/2 = 10%

Volume of NCZ = 70 x 45 x 20 $cm^3$ = 0.063 $m^3$

Weight of salt required = $\rho_{water}$ x volume of LCZ x % conc. of salt in LCZ

=1000 x 0.063 x (10/100)

= 6.3 kg

Amount of total salt required in each experiment = 9.45 + 6.3 = 15.75 kg

## 4.2 Construction of Solar Pond

The solar pond in present experimental study was constructed considering all the design parameters. First experiment were performed on an ordinary salt gradient solar pond. In the secondexperiment, a transparent glass above LCZ was installed. In the third experiment, two mirrors were placed on the side walls of the solar pond.

Procedure to construct the experimental setup is described below:

- For drawing the sample of saline water, PVC pipes of different height were attached using a wood strip, as shown in Fig. 4.1.
- For the second experiment, a transparent glass of dimension 69 cm × 44 cm was placed above the lower convective zone with the help of twelve stainless steel clips and four vertical pipes.
- For the third experiment, two mirrors were fixed on the walls of the solar pond as shown in Fig. 4.3.
- Salty water was fed into the pond at different heights to establish salinity gradient using a diffuser.
- Top of the pond was covered by a thin glass plate which helps to protect from wind disturbances, raindrops,dust, and dirtetc.

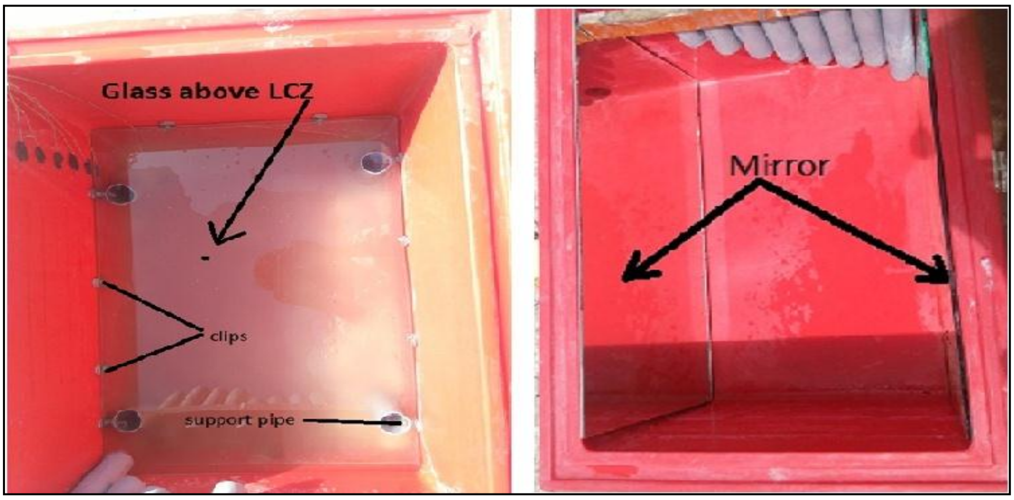


**Fig. 4.3: Construction of Solar Pond with Glass (Left) and Mirror (Right)**

### 4.2.1 Construction Materials

A list of materials used in the construction of the solar pond is given below:

**Table 4.1: Materials Required in the Construction of Solar Pond**

| S.No. | Items | Quantity |
|---|---|---|
| 1 | Thermoplastic insulated box | 1 |
| 2 | PVC pipe 1.5-inch diameter and 20 ft long | 1 |
| 3 | Thermocouple wire T-type | 15 meter |
| 4 | Hydrometer floating type | 1 |
| 5 | Measuring flask | 2 |

| S.No. | Items | Quantity |
|---|---|---|
| 6 | NaCl salt | 70 kg |
| 7 | Solarimeter | 1 |
| 8 | Steel clips | 12 |
| 9 | Transparent glass 69 cm x 44 cm x 5 mm | 2 |
| 10 | Mirror 44 cm x 40 cm x 5 mm | 2 |
| 11 | Temperature indicator | 2 |

### 4.2.2 Establishment of Gradient Layers

The process of layer formation was carried out with utmost care because the entire experimental study depends on it. Initially, a salt solution of 20% concentration was prepared which was poured into the pond up to the thickness of LCZ i.e. 15 cm.

The NCZ zone was divided into 5 small sub-zones, each of 4 cm. These layers were formed with the decreasing salt concentration (for every 4 cm salt concentration was reduced by 3%) using a diffuser. Now in UCZ, raw water was poured slowly through diffuser above NCZ zone and subsequently the level of water was raised to the top of the pond, till the pond was filled completely.

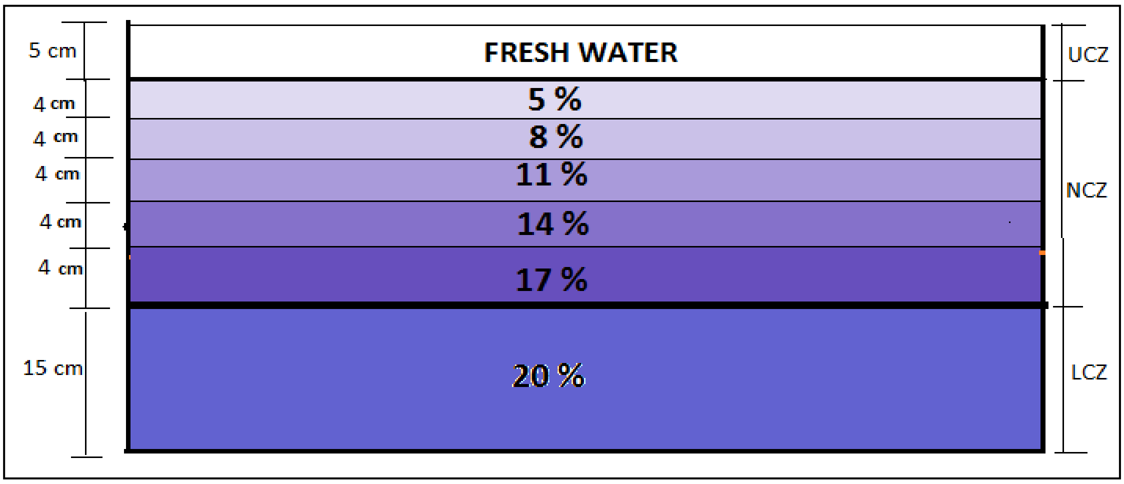


**Fig. 4.4: Preparation of Layers**

## 4.3 Instrumentation Used

### a) Thermocouples

Thermocouples were used to measure the temperature of water at a different depth of the solar pond. Thermocouples are accurate, sensitive and cost effective tools for measuring temperature.

**Table 4.2: Properties of common type of thermocouple wire**

| S.No. | Properties | J -Type | K-Type | T-type |
|---|---|---|---|---|
| 1. | Temperature range | -40°C to +750°C | -200°C to +1350°C | -200°C to +350°C |
| 2. | Sensitivity | 50 μV/°C | 41 μV/°C | 43 μV/°C |
| 3. | Material | Iron-Constantan | Chromal-Alumel | Copper-Constantan |
| 4. | Cost | Rs. 25/meter | Rs. 25/meter | Rs. 22/meter |

Out of these thermocouples; on the basis of operating temperature range and linearity, T-type thermocouples were chosen for the experiment.

### b) Temperature Indicators

Temperature indicator was used to display the temperature of thermocouples. The digital temperature indicator of 8-channel was used which supports T-type thermocouples. Thermocouples are connected to the indicator to measure the temperature of the desired location.


**Fig. 4.5: Temperature Indicator**

### c) Hydrometer

A hydrometer is used to measure the specific gravity of the liquid. Hydrometers are of two types - one for liquids whose specific gravity is less than one and other for liquids whose specific gravity is greater than one. A hydrometer of the range from 1 to 2 was used for the experiments. Along with the hydrometer, a measuring flask of 250 ml capacity was also used to dip hydrometer. A sample of the saline water was filled in the flask and hydrometer dipped into it to measure specific gravity. It's least count was 0.01.

**Fig. 4.6: Hydrometer**

### d) Solarimeter

Solarimeter was used to measure the global solar radiations received on the inclined surface to record the solar intensity. The top surface of the Solarimeter consists of a rectangular photosensor. When sunlight falls on this photo sensor it is converted into electricity. Solarimeter measures global solar radiation which includes both direct as well as diffused solar radiation and displays the total radiation directly in watts per meter square.

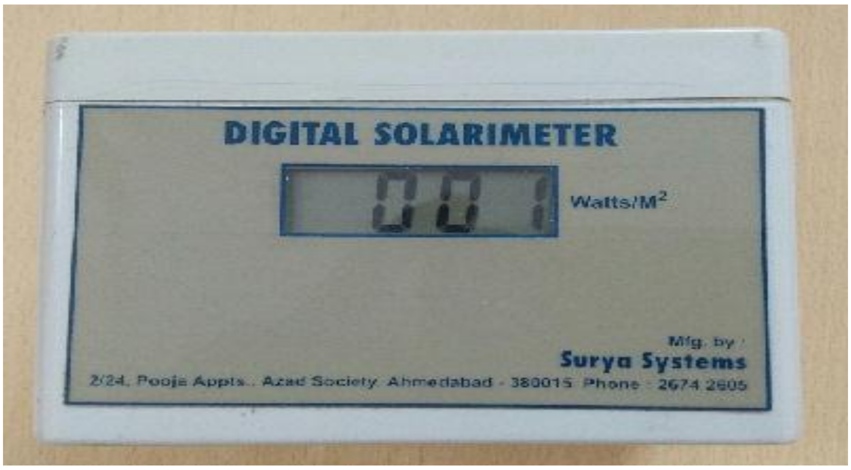


**Fig. 4.7: Solarimeter**

## e) Diffuser

The diffuserwas used to prepare the layers of NCZ without any agitation effect. The diffuser is made-up of two smooth fiber sheets and a PVC pipe as shown in Fig.4.8. The main aim of the diffuser is to supply water at a slower rate which helps in forming thin layers of salty water. It minimizes disturbance to the salt layers and helps in establish the salt gradient in the pond.

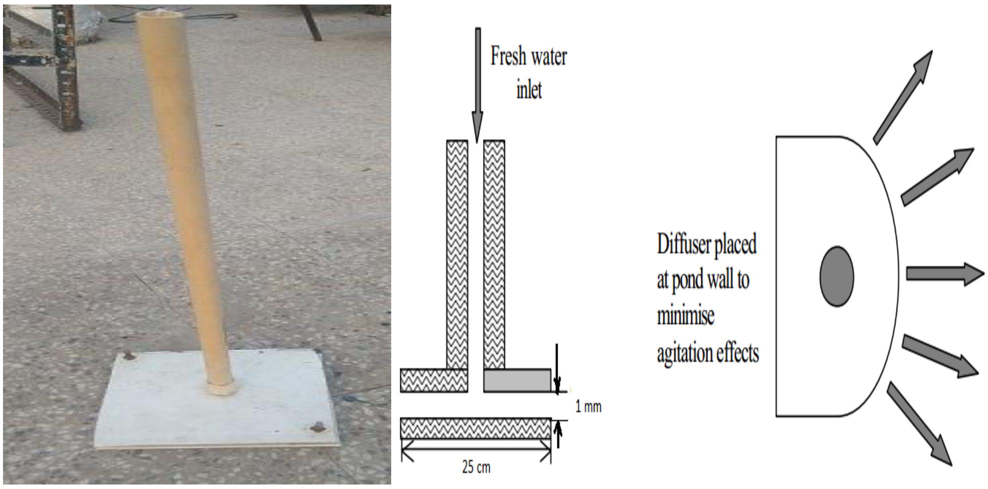


**Fig. 4.8: Diffuser**

# Chapter 5
# Experimentation

## 5.1 Procedure

The study includes three different experiments; an experimental study on the ordinary solar pond, an experimental study on solar pond using transparent glass above LCZ and experimental analysis using mirrors on the side walls of the solar pond. Salinity of 20 % salt concentration in LCZ was formed up to a height of 15 cm from the bottom and then salt concentration was decreased stepwise (i.e. 4% drop in salinity for every 4 cm rise in the height) from salinity of 20% at the interface of LCZ and NCZ to 0% (i.e. raw water) at the interface of NCZ and UCZ. The top layer (UCZ) of the pond had a height of 5 cm which was filled with tap water only.

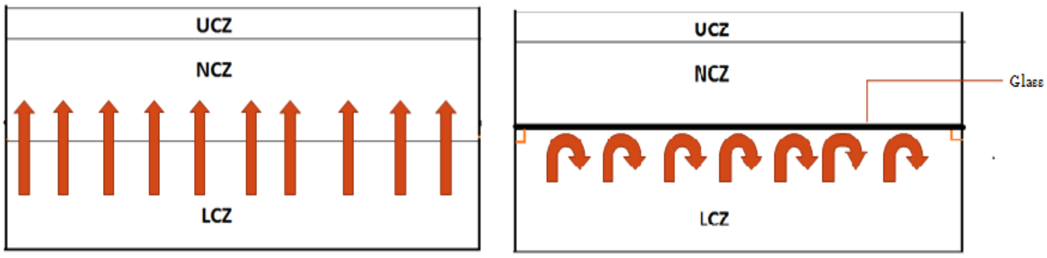


**Fig. 5.1: Solar Pond Without Glass (left) and With Glass (right)**

The second experiment was performed with 20% salt concentration and transparent glass above LCZ. During this study, transparent glass above LCZ was used to reduce the diffusion of salt from the LCZ to NCZ which improved the performance of solar pond. Third experiment was performed with 20 % salt concentration by using mirrors as internal reflectors. Fig. 5.1 shows the elimination of the diffusion using a glass above LCZ.

Six thermocouples were attached to the wall of the solar pond at different depth with a gap of 7 cm for measuring the temperature of saline water. 8 Channel digital indicator with was used to display the temperature reading by the T-type thermocouples. An additional thermocouple was used to measure the ambient temperature. Hourly temperature readings were taken for all the thermocouples from 10 AM to 5 PM. The Same arrangement was used for measuring the temperature of other two experiments i.e. experiment with a transparent glass above LCZ and experiment with mirrors to reduce losses through the walls.

Hydrometer was used to measure the salinity of the sample of saline water. The samples of saline water were extracted through the PVC pipes which were attached to the wall of the solar pond using a wood strip. The salinity of salty solutions was measured daily by extracting samples of 250 ml using rubber pipes at different heights for 15 days during each experiment. The extraction of saline water sample was done in such a manner that there was no mixing of salt layers with the jet of water. Fig. 5.2 shows the arrangement of sample tubes and thermocouples at the side wall of the solar pond. Hourly solar radiation intensity was measured using a digital Solarimeter.

**Fig. 5.2. Arrangements of Sample Pipe and Thermocouples**

## 5.2 Observations

Three experiments were performed on the salt gradient solar pond by collecting data of 15 days for each case.

### 5.2.1 Experimental Observation for Ordinary Salt Gradient Solar Pond

Different experimental measurement of temperature, salinity and solar intensity were taken for the first case during 2nd February to 16th February, 2017, as given in Table 5.1. Temperatures were noted at 7 points (6 in the solar pond starting from the bottom to the top at intervals of 7 cm each at the wall of the pond and 1 ambient temperature) hourly from 10.00 am to 05.00 pm. The measured values of hourly temperatures are given in Appendix A.

In Table 5.1 $T_1$ to $T_6$ represents the following temperatures.

- $T_1$ – 40 cm from the surface (at the bottom of the pond)
- $T_2$ – 33 cm from the surface (7 cm from the bottom)
- $T_3$– 25 cm from the surface (15 cm from the bottom)
- $T_4$ – 19 cm from the surface (21 cm from the bottom)
- $T_5$– 12 cm from the surface (28 cm from the bottom)
- $T_6$– 5cm from the surface (35 cm from the bottom)
- $T_{amb}$– ambient temperature

**Table 5.1 Mean Temperature at Different Height of the Ordinary Solar Pond in First Mode (02/02/17 to 16/02/17)**

| Days | Date | Mean temperatures (°C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 02/02/17 | 27.8 | 27.16 | 25.8 | 23.36 | 20.71 | 18.5 | 25.21 |
| 2 | 03/02/17 | 29.56 | 28.03 | 26.52 | 24.31 | 21.23 | 18.93 | 26.12 |
| 3 | 04/02/17 | 32.51 | 31.33 | 29.41 | 26.83 | 23.82 | 19.5 | 26.61 |
| 4 | 05/02/17 | 35.08 | 33.33 | 32.08 | 29.01 | 24.08 | 20.06 | 26.47 |
| 5 | 06/02/17 | 38.88 | 37.23 | 35.53 | 31.75 | 25.01 | 20.8 | 26.43 |
| 6 | 07/02/17 | 39.92 | 38.11 | 36.46 | 33.46 | 27.83 | 20.02 | 25.86 |
| 7 | 08/02/17 | 43.15 | 41.37 | 39.85 | 36.01 | 30.58 | 22.12 | 28.1 |
| 8 | 09/02/17 | 42.07 | 39.51 | 38.00 | 35.38 | 29.8 | 22.72 | 27.35 |
| 9 | 10/02/17 | 37.8 | 35.7 | 33.31 | 30.91 | 26.75 | 20.02 | 22.87 |
| 10 | 11/02/17 | 39.65 | 37.45 | 35.66 | 33.18 | 29.16 | 23.02 | 27.71 |
| 11 | 12/02/17 | 39.4 | 36.81 | 34.67 | 32.98 | 29.62 | 24.57 | 27.22 |
| 12 | 13/02/17 | 38.22 | 35.85 | 33.58 | 30.71 | 27.4 | 24.61 | 27.5 |
| 13 | 14/02/17 | 37.63 | 36.02 | 33.97 | 30.92 | 27.33 | 24.68 | 27.55 |
| 14 | 15/02/17 | 36.48 | 34.9 | 32.83 | 30.91 | 27.75 | 25.15 | 26.6 |
| 15 | 16/02/17 | 37.36 | 35.52 | 33.45 | 31.36 | 28.31 | 25.8 | 28.02 |

### 5.2.2 Experimental Observation for Solar Pond with a Transparent Glass above LCZ

Similar to the ordinary solar pond, different experimental observations of temperature, salinity, solar intensity and evaporation loss was taken for the second case during 20$^{th}$ February to 6$^{th}$ March, 2017, as given in Table 5.2.

Temperatures were noted at 7 points (6 in the solar pond starting from the bottom to the top at intervals of 7 cm each at the wall of the pond and 1 at ambient temperature) hourly from 10.00 am to 05.00 pm.

**Table 5.2 Mean Temperature at Different Height of the Solar Pond with Using Glass Above LCZ (20/02/17 to 06/03/17)**

| Days | Date | Mean temperatures (°C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | T1 | T2 | T3 | T4 | T5 | T6 | $T_{amb}$ |
| 1 | 20/02/17 | 26.08 | 26.05 | 26.22 | 21.85 | 20.65 | 19.6 | 27.82 |
| 2 | 21/02/17 | 29.5 | 29.46 | 29.61 | 24.7 | 22.35 | 20.57 | 27.53 |
| 3 | 22/02/17 | 32.13 | 32.13 | 32.31 | 26.82 | 24.5 | 21.07 | 27.88 |
| 4 | 23/02/17 | 34.16 | 34.13 | 34.22 | 28.37 | 26.56 | 21.97 | 27.91 |
| 5 | 24/02/17 | 35.33 | 35.31 | 35.42 | 29.25 | 26.93 | 21.87 | 27.9 |
| 6 | 25/02/17 | 36.32 | 36.31 | 36.4 | 29.57 | 27.31 | 22.6 | 28.51 |
| 7 | 26/02/17 | 38.06 | 38.03 | 38.2 | 30.68 | 27.87 | 23.7 | 28.75 |
| 8 | 27/02/17 | 38.30 | 38.27 | 38.35 | 30.97 | 27.8 | 24.63 | 26.61 |
| 9 | 28/02/17 | 38.21 | 38.18 | 38.32 | 30.88 | 27.98 | 26.6 | 28.28 |
| 10 | 01/03/17 | 39.18 | 41.46 | 39.23 | 31.67 | 28.78 | 27.5 | 30.61 |
| 11 | 02/03/17 | 41.52 | 41.46 | 41.62 | 33.03 | 30.11 | 27.82 | 29.61 |
| 12 | 03/03/17 | 42.66 | 42.62 | 42.73 | 34.11 | 31.02 | 27.61 | 28.27 |
| 13 | 04/03/17 | 42.51 | 42.52 | 42.58 | 33.98 | 30.82 | 27.52 | 29.62 |
| 14 | 05/03/17 | 43.12 | 43.1 | 43.13 | 34.95 | 31.57 | 27.63 | 28.73 |
| 15 | 06/03/17 | 42.76 | 42.76 | 42.82 | 34.77 | 31.42 | 27.52 | 28.23 |

### 5.2.3 Experimental Observation for Solar Pond with Internal Reflectors

During experimental studies in first and second case, it was felt that solar radiations falling on the side walls reduce the performance of solar pond. To reduce theeffect of shadow, an experiment was conducted using a mirror of 69 cm × 40 cm × 5 cm fixed to the walls. Same experimental parameter like temperature, salinity, solar intensity and evaporation loss was measured to compare with the solar pond shaving no side mirrors. The salinity profile was same as an ordinary solar pond and it was observed that though there was no notable difference in salinity profiles for 15 days, slight changes are visible in figures. These changes were possibly due to diffusion of salt from the region of higher concentration to a region of lower concentration. There was a huge difference in the temperature profile while using side mirror. The temperature was considerably higher than the ordinary solar pond temperature. All the temperature and other data table is given in Appendix A

**Table 5.3 Mean Temperature at Different Height of the Solar Pond with using Internal Reflector (20/03/17 to 03/04/17)**

| Days | Date | Mean temperatures (°C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | T1 | T2 | T3 | T4 | T5 | T6 | T7 |
| 1 | 20/3/2017 | 41.1 | 39.1 | 37.8 | 33.3 | 30.8 | 29.3 | 33.7 |
| 2 | 21/3/2017 | 44.8 | 42.9 | 41.3 | 35.6 | 32.3 | 30.7 | 34.3 |
| 3 | 22/3/2017 | 46.1 | 44.6 | 43.0 | 38.7 | 34.6 | 31.8 | 35.0 |
| 4 | 23/3/2017 | 46.3 | 44.1 | 42.5 | 38.3 | 34.0 | 30.9 | 34.3 |
| 5 | 24/3/2017 | 48.6 | 45.7 | 43.8 | 39.9 | 34.9 | 32.3 | 36.0 |
| 6 | 25/3/2017 | 49.4 | 46.6 | 43.0 | 39.8 | 35.4 | 32.6 | 34.8 |
| 7 | 26/3/2017 | 50.5 | 47.7 | 44.4 | 40.8 | 36.7 | 33.8 | 35.2 |
| 8 | 27/3/2017 | 52.8 | 50.4 | 46.9 | 42.2 | 38.0 | 34.0 | 36.1 |
| 9 | 28/3/2017 | 52.3 | 49.7 | 46.0 | 41.6 | 37.4 | 33.4 | 35.3 |
| 10 | 29/3/2017 | 51.6 | 49.2 | 45.2 | 41.1 | 37.4 | 33.6 | 36.0 |
| 11 | 30/3/2017 | 50.4 | 48.2 | 44.4 | 40.2 | 36.5 | 32.9 | 36.1 |
| 12 | 31/3/2017 | 49.9 | 47.6 | 44.0 | 39.6 | 36.8 | 32.5 | 35.6 |
| 13 | 1/4/2017 | 49.2 | 46.7 | 43.3 | 39.7 | 35.2 | 32.1 | 35.9 |
| 14 | 2/4/2017 | 48.4 | 45.7 | 43.4 | 39.3 | 34.2 | 31.9 | 36.0 |
| 15 | 3/4/2017 | 47.0 | 43.9 | 40.4 | 37.3 | 34.3 | 31.5 | 35.5 |

## 5.3 Solar Intensity observation

The intensity of solar radiation is also an important factor that affects the performance of salt gradient solar pond. Solar Intensity variation has been shown in Fig. 1(b) to Fig. 6(b). Table 17 in Appendix A shows the average daily solar intensity variation for the first case only. Average solar intensity was 438.24 W/m$^2$ during the first case of 15 days. Maximum solar intensity was 454.44 W/m$^2$ on 10 February, 2017 with a range of 419 W/m$^2$ to 454 W/m$^2$.

Table 34 in Appendix B shows the average daily solar intensity variation for the second case. Average solar intensity during the second case was 459.24 W/m$^2$. Maximum average solar intensity was 477.58 W/m$^2$ on 9 March, 2017 with a range of 416 W/m$^2$ to 477W/m$^2$.

# Chapter 6

# Results and Discussion

Parameter relevant to analyze solar pond performance such as temperature, salinity and solar intensity, etc. were recorded in three different cases for three months i.e. February, March and April of 2017. All three cases were on the same setup with 20% LCZ salt concentration. In first case, experiment was performed on an ordinary solar pond, in second case experiments was performed on a solar pond with a glass above LCZ to reduce the effect of salt diffusion from LCZ to NCZ and in the last case a mirror was used at side walls to reduce the losses through the walls. The results of all three cases are discussed in this chapter.

Temperature of saline solution was measured hourly at six different heights to obtain the temperature profile, while 11 saline samples were measured to obtain the salinity profile. Some other parameters like solar radiation intensity and water evaporation loss were also measured at the surface of the pond.

## 6.1 Temperature Profiles of LCZ

The experiment was performed for three different setups and the temperature at 6 different points in the solar pond and ambient temperature was measured for each case. Average of measured temperature at different height was taken to create temperature profiles with different parameters for all cases.

Initially, the difference between the mean temperature at the bottom of the solar pond and mean ambient temperature was small. When the solar radiation is incident at the solar pond, itis transmitted through the saline water and heating at the bottom of the solar pond begin. As the time increases, the heat starts storing in the lower convective zone and the temperature starts increasing. With the increase in time the diffusion of the salt from the lower convective zone to the non-convective zone starts and the gradient of the salt diminishes. The NCZ acts as the insulation for the LCZ but as the diffusion start, the convection in the NCZ also start which results in the heat loss from the LCZ and thus mean temperature of the storage zone decreases.

Initially the mean temperature at the bottom was 27.8 $^0$C and mean ambient temperature was 25.51 $^0$C. As the time increased the mean temperature start increasing and reaches up to 43.15 $^0$C at the bottom of the solar pond on the7$^{th}$ day (08 February 2017). The temperature in other zones also increases but in lesser proportion than the temperature in LCZ because of convection losses. After 7$^{th}$ day the temperature starts decreasing and on 9$^{th}$ day (10 February 2017), the mean ambient temperature was reduced to 22.87 $^0$C due to the cloudy day and bottom mean temperature was reduced to 37.80 $^0$C. Next day (11 February 2017) was a sunny day with 27.71$^0$C mean ambient temperature and due to this the bottom mean temperature increased to 39.65 $^0$C by about 2 $^0$C. For next five days the mean ambient temperature almost remained same but the bottom mean temperature starts decreasing due to increased convection losses by diminishing salt gradient and on the 15$^{th}$ day ( 16 February 2017) mean bottom temperature reduced to 37.36 °C. The maximum temperature was 50.8 °C on the 7$^{th}$ day (08 February 2017) in LCZ.

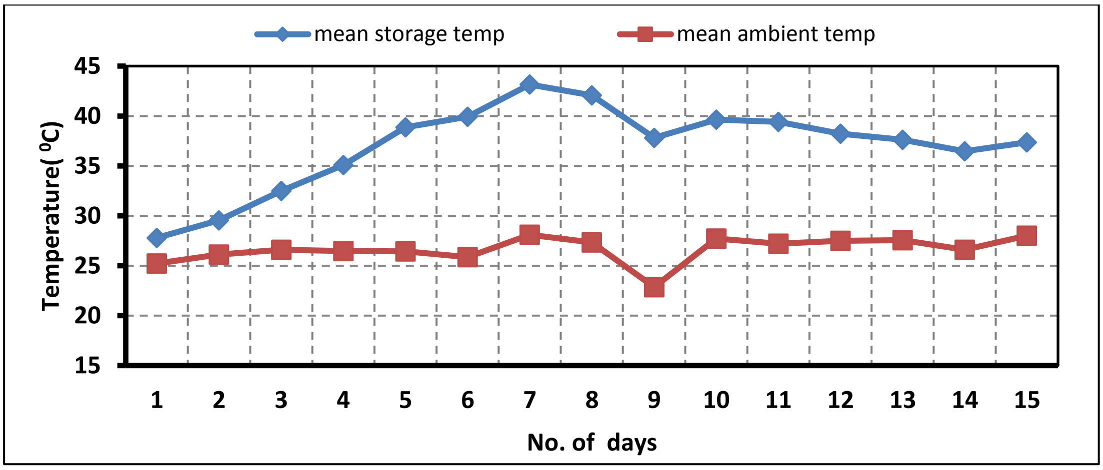


**Fig. 6.1: Mean Storage Temp vs. No. of Days without Using Glass from (02/02/17 to 16/02/17)**

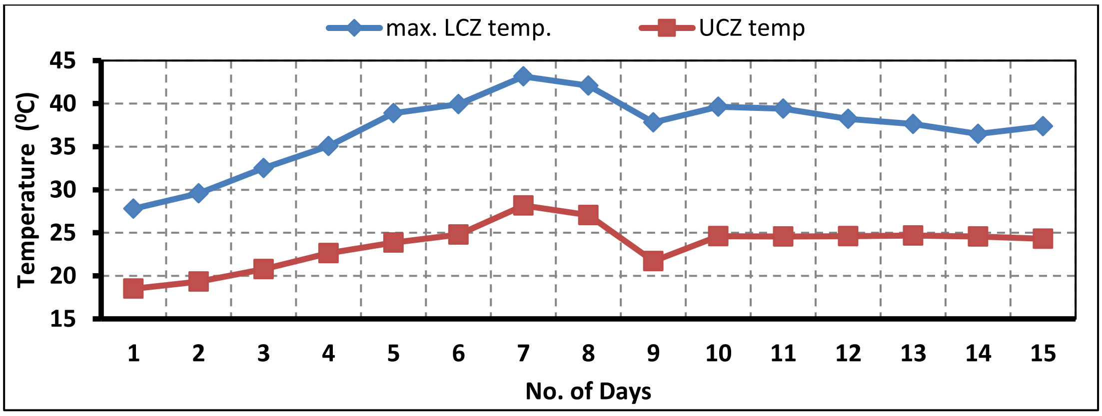


**Fig. 6.2: Variation of Max. LCZ Temp. & UCZ Surface Temp. with Days with glass (02/02/17 to 16/02/17)**

To reduce this problem of the salt diffusion, the experiment was performed using a transparent glass above the lower convective Zone in the second case. The experiment was performed from 20 February 2017 to 06 March 2017. The problem of salt diffusion from LCZ to NCZ was fully eliminated by putting the transparent glass as separator above the LCZ which increases heat storing period. Temperature observations for the second case are given in Table 5.2 with mean temperature at different depths.

The temperature in LCZ remained almost constant with respect to the height of LCZ (15 cm). Temperature $T_3$ was the temperature at the height of 15 cm from the bottom of the pond and just below the transparent glass in LCZ. When solar radiation of low wavelength passes throughthe transparent glass cover, it is converted into radiation of high wavelength.This high wavelength solar radiation was trapped inside the solar pond and heats the water present below the glass cover. The temperature of LCZ was found same due to convective heat distribution. Some fraction of solar radiation was absorbed by the glass due to low transmissivity caused by a deposition of alayer of dust and salt above it. Due to absorption of radiation the glass temperature increased and the temperature just below the glass, was little more than the entire LCZ temperature. The maximum temperature in the storage zone was lesser than the ordinary solar pond due to loss of some radiation by lesser glass transmissivity.

The mean temperature of storage zone was less than the mean ambient temperature on the 1$^{st}$ day (20$^{th}$ February 2017) but as the days increased the temperature started increasing. In LCZ low wavelength radiation is entrapped but high wavelength radiation was not coming out, due to this temperature of LCZ was not decreasing at evening when the intensity of solar radiation disappears. On 27 February, the weather was cloudy at evening so the increase in the storage temperature was very small on that day. The rate of diffusion from NCZ to UCZ was not fully eliminated but reduces excessively.

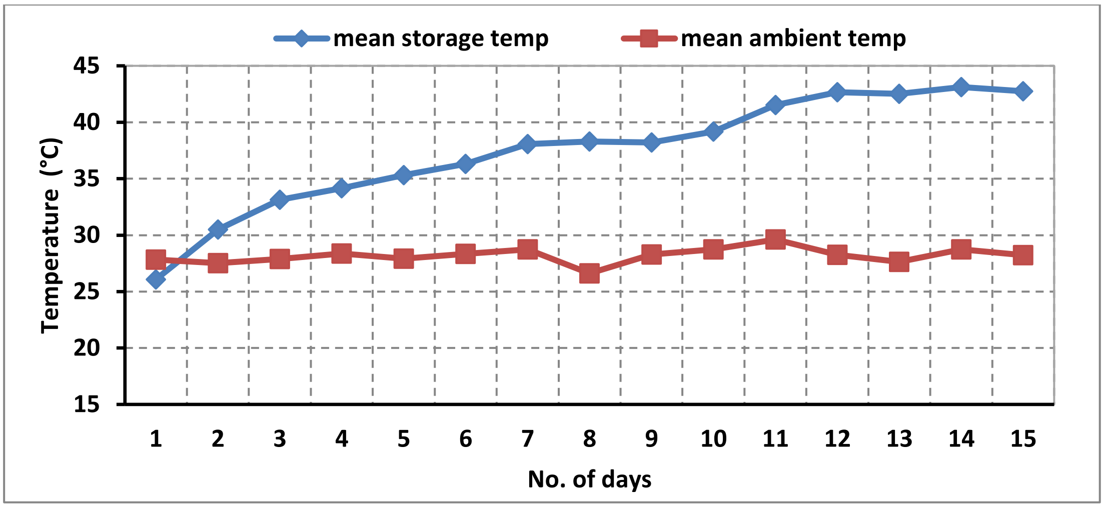


**Fig. 6.3: Mean Storage Temp vs No. of Days Using Glass from (20/02/17 to 06/03/17)**

The temperature of the storage zone kept on increasing withnumber of days passed and reached maxima on 14$^{th}$ and 15$^{th}$ day. In the ordinary solar pond, maximum temperature was achieved on 7$^{th}$ day (08 February) and then it started decreasing due to diffusion of salt but in the solar pond (with glass) maximum temperature was achieved on the14$^{th}$ day (05 March 2017) and remained same on 15$^{th}$ day because there was no or very small diffusion. The average temperature of LCZ i.e. storage zone (average of $T_1$, $T_2$ and $T_3$) was higher in the case of the solar pond with glass in comparison to the ordinary solar pond. The maximum temperature was 47.6 $^0$C on the 14$^{th}$ day (05 March 2017) in the second case.

Fig. 6.5 shows the comparison between mean storage temperature with and without using the glass which shows that the mean storage temperature in the first mode without using glass, increases up to 7 days and then start decreasing. The main reason for decreasing the mean storage temperature was increase in convection losses due to diminishing salt gradient. But in the case of solar pond with glass above LCZ in the second mode, the LCZ temperature keep increasing up to 14 days continuously. The stability of the NCZ was maintained with time and no diffusion of salt from the lower convective zone was recorded. The heat carrying capacity of solar pond with glass cover above LCZ was more and for a longer period of time in comparison of the ordinary solar pond.

The mean storage temperature for the third case was similar to the ordinary solar pond. Maximum storage temperature achieves on the 8$^{th}$ day of an experiment which was

52.8 °C and maximum LCZ temperature was 60.5 °C at the bottom. The cause of higher temperature was lower losses from the wall due to internal reflectors.

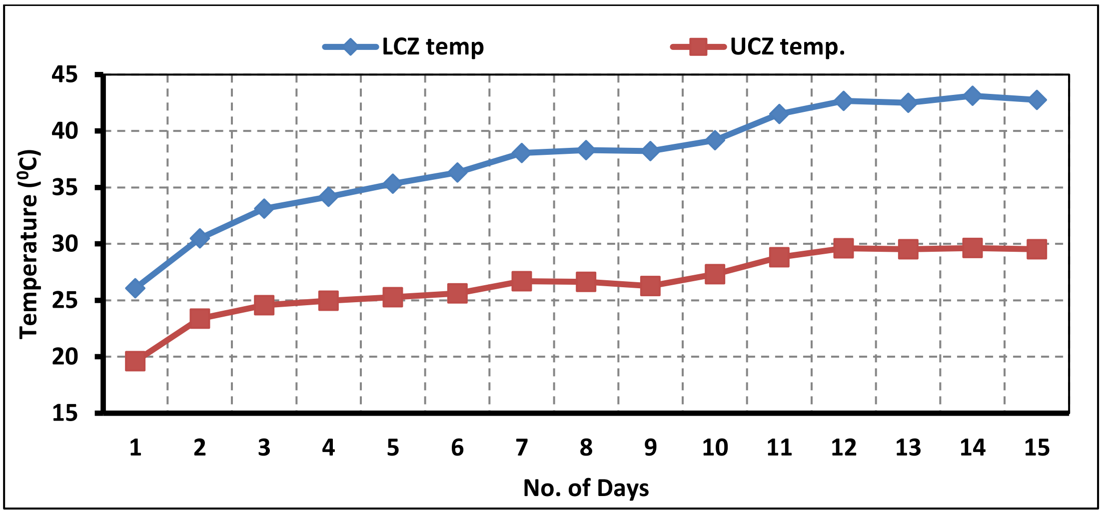


**Fig. 6.4: Variation in Max. LCZ Temp. & UCZ Surface Temp. with Days in without Glass (20/02/17 to 06/03/17)**

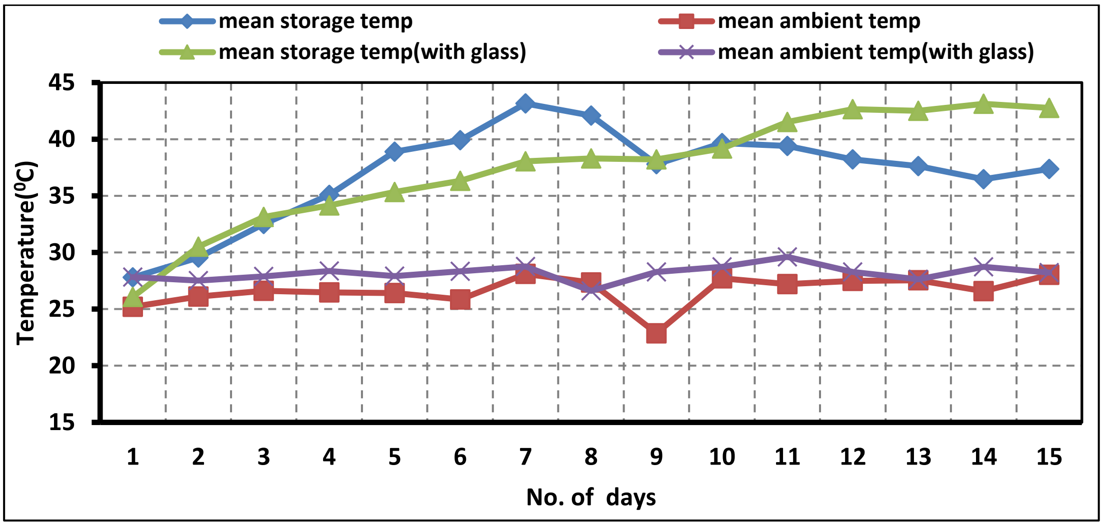


**Fig. 6.5. Comparison between Mean Storage Temperature with and without Glass (20/02/17 to 06/03/17)**

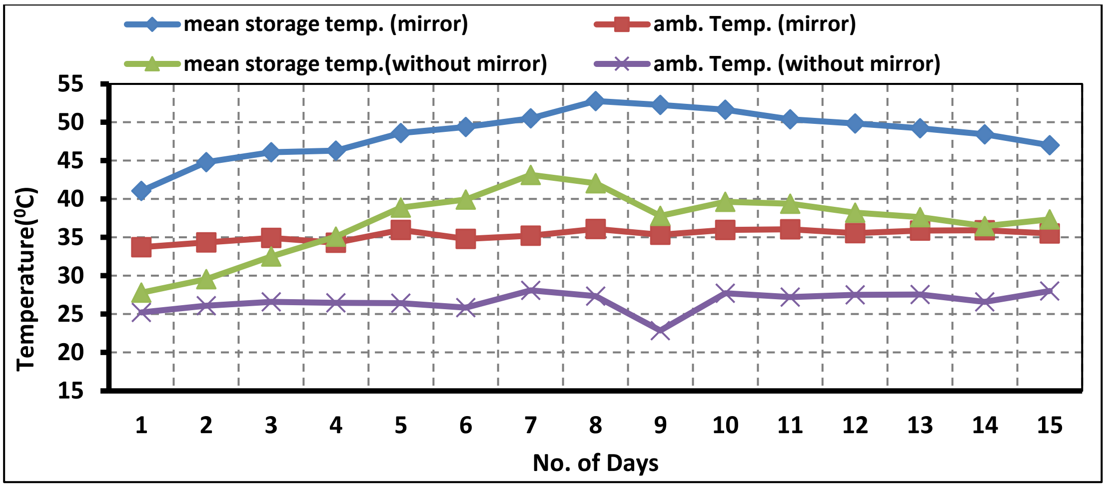


**Fig. 6.6. Comparison between Mean Storage Temperature with and without Side Walls Mirror**

## 6.2 Temperature Profiles of Solar Pond

Temperature variation with respect to the depth of the solar pond was evaluated by drawing the profile for all the modes from average daily temperature obtained, as shown in Table 5.1 and 5.2 at a different point in the pond. The first experiment was performed from February 2-16, 2017 without using glass and then in the second mode with the glass cover over the LCZ, from February 20 – March 6, 2017. In the first and the second case, LCZ temperature progressively increases showing storage of heat as days pass. LCZ temperature increase by about 12.45 °C and 7.43 °C during both the mode in the storage zone with in just 5 days was a good result. The rate of increase in temperature using glass was lower than without using the glass. This was because of the loss of solar radiation due to the low transmissivity of glass with dust layer on it. However, the benefit was that the rate of temperature decrease was also low which results in energy storage for a longer period of time.

The maximum temperature rise above ambient temperature in the first mode was on 7$^{th}$ day (i.e. 8 February) which was 15.02 °C and maximum temperature rise above ambient temperature in the second mode was on 14$^{th}$ day (i.e. 5 March) with 14.39 °C. After reaching the maximum temperature on 7$^{th}$ day in the first mode, temperature starts decreasing but this did not happen in the second mode which had glass cover over the LCZ due to stability of the pond.

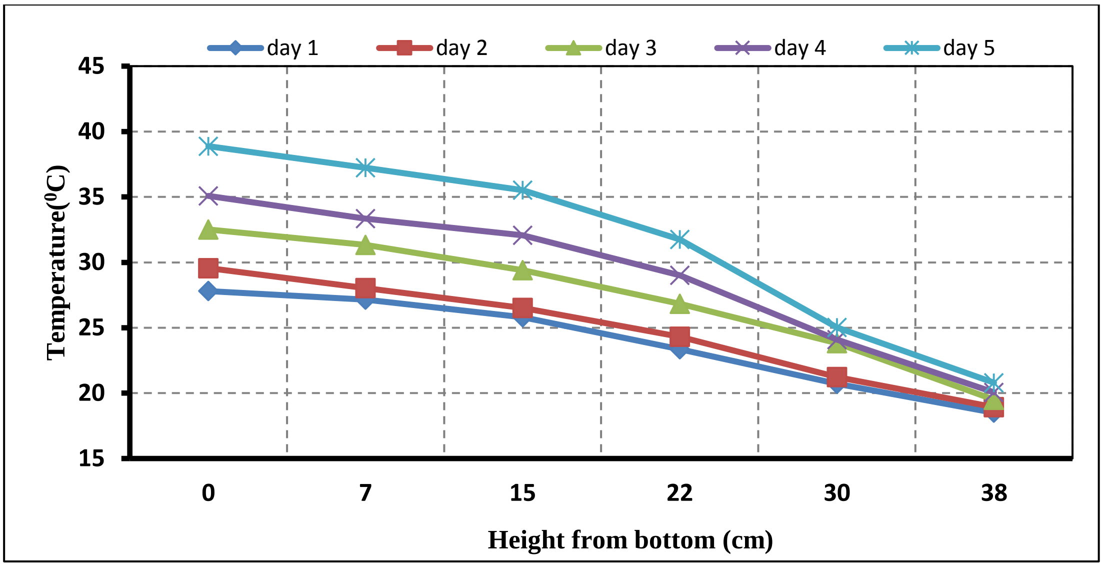


**Fig. 6.7. Average Temperature Distributions Inside the Ordinary Solar Pond for First Five Days of Experiment in Ordinary Solar Pond (02/02/17 to 06/02/17)**

The storage capacity and maximum temperature of the pond also depends on the depth of the pond. As the depth of the pond increases, the capacity to store the heat also increases but maximum temperature decreases due to the lower intensity of solar radiation reaching the bottom layers and increase in thermal capacity of LCZ. The solar pond used at MNIT was 40 cm height. Fig. 6.7 and Fig. 6.10 shows the first five days of the temperature distribution, Fig. 6.8 and Fig. 6.11 show the middle five days of temperature distribution and Fig. 6.9 and Fig. 6.12 shows the last five days of temperature distribution for first and second modes. The third mode of experiment has performed with using a side walls mirror to reduce the effect of side walls shadow.

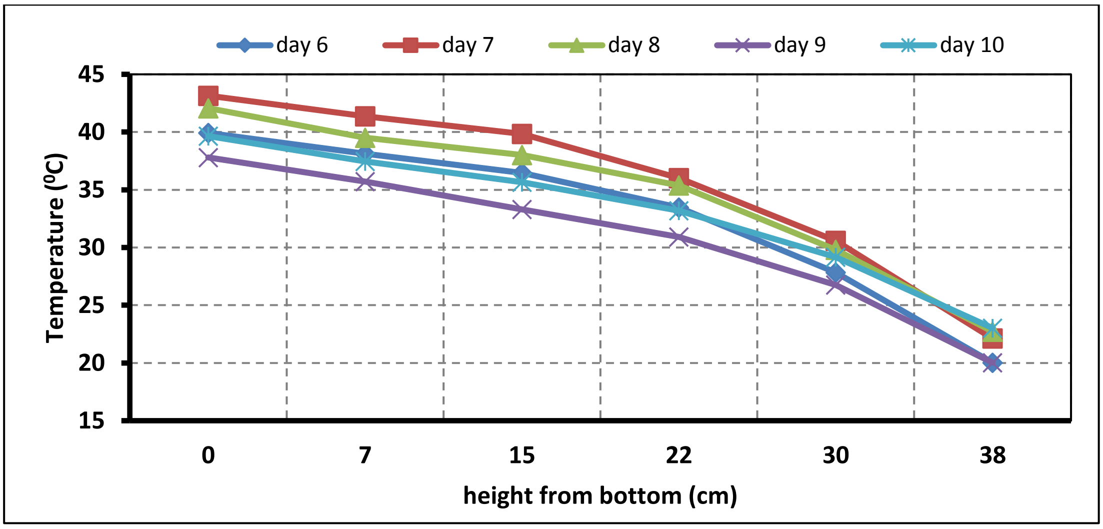


**Fig. 6.8. Average Temperature Distributions Inside the Ordinary Pond for Middle Five Days of Experiment in Ordinary Solar Pond (07/02/17 to 11/02/17)**

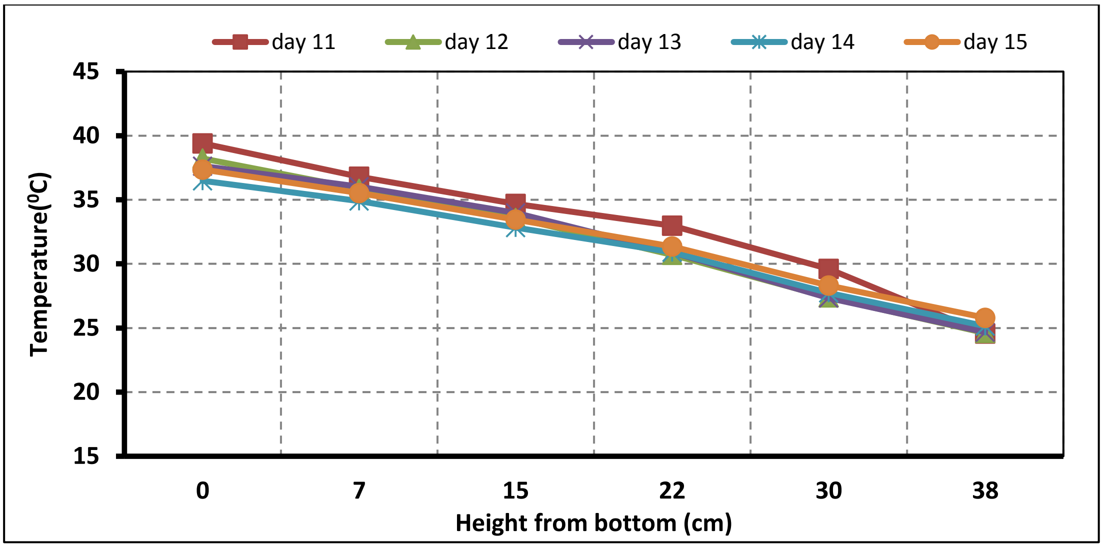


**Fig. 6.9. Average Temperature Distributions Inside the Ordinary Solar Pond for Last Five Days of Experiment in Ordinary Solar Pond (12/02/17 to 16/02/17)**

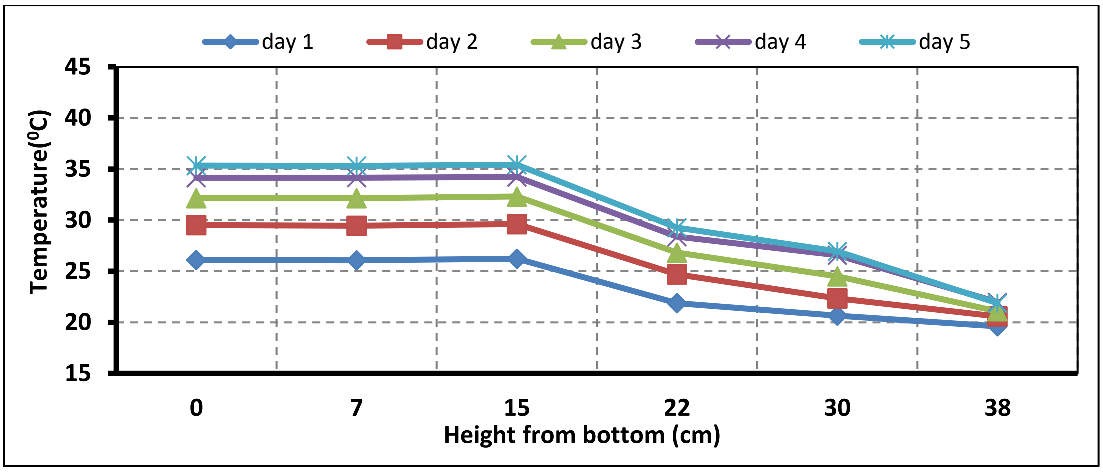


**Fig. 6.10. Average Temperature Distributions Inside the Pond with Glass for First Five Days of Experiment in Solar Pond with Glass (20/02/17 to 24/02/17)**

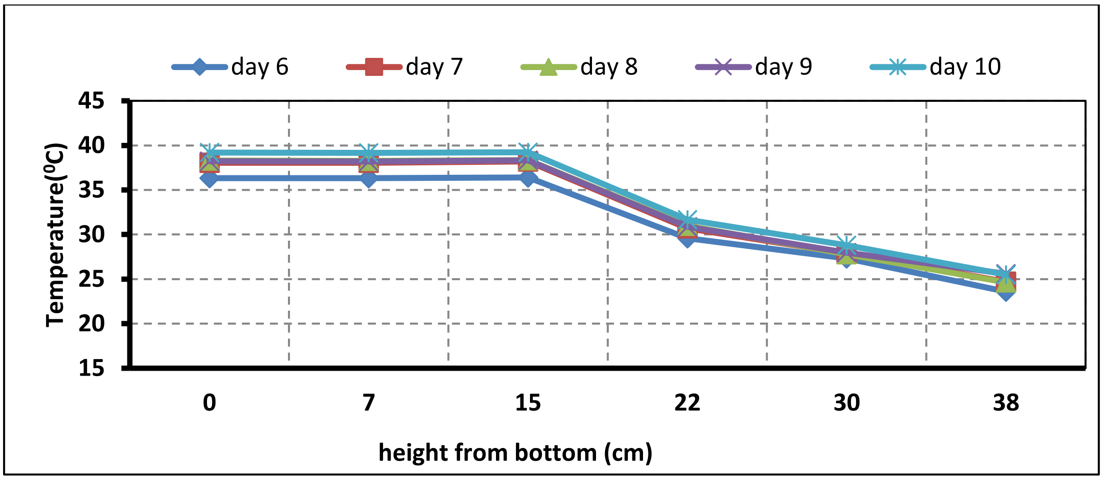


**Fig. 6.11. Average Temperature Distributions Inside the Pond with Glass for Middle Five Days of Experiment in Second Mode (25/02/17 to 01/03/17)**

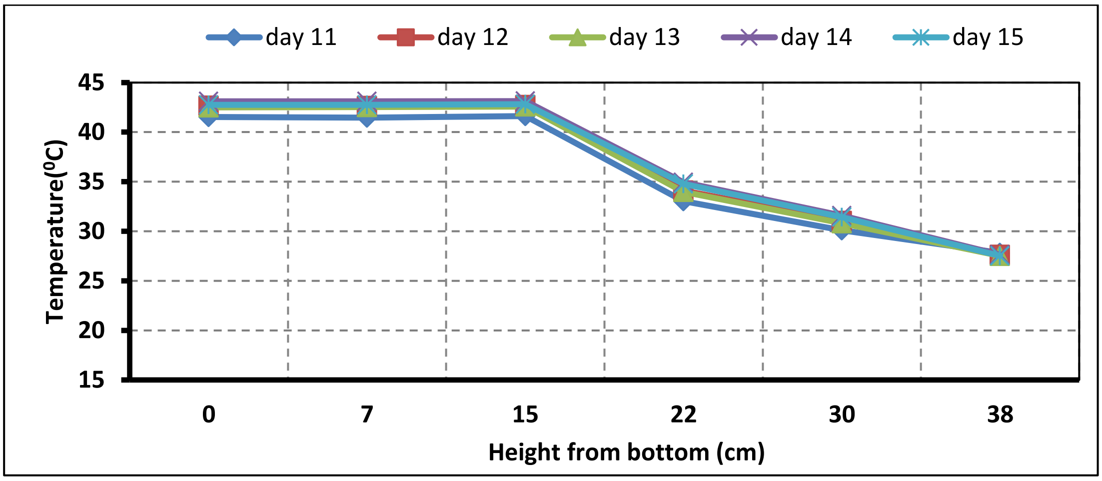


**Fig. 6.12. Average Temperature Distributions Inside the Pond with Using Glass for Last Five Days of Experiment in Solar Pond with Glass (02/03/17 to 06/03/17)**

To reduce the loss of solar radiations through walls, an experiment was conducted in the third mode using a mirror of 69 cm x 40 cm x 5 cm pasted to the walls. Same experimental parameter like temperature, salinity and solar intensity was used to compare the parameter without using the mirrors.

The salinity profile was same as of an ordinary solar pond and it was observed that though there was no notable difference in salinity profiles in 15 days, slight changes are visible in figures. These changes are possibly due to diffusion of salt from the region of higher concentration to a region of lower concentration. There was a high difference in the temperature profile of solar pond with mirrors and temperature was considerably higher than that of ordinary solar pond. All the temperature are given in Table 1 to

Table 15 in Appendix A. The salinity of the pond showed similar variation as the ordinary solar pond.

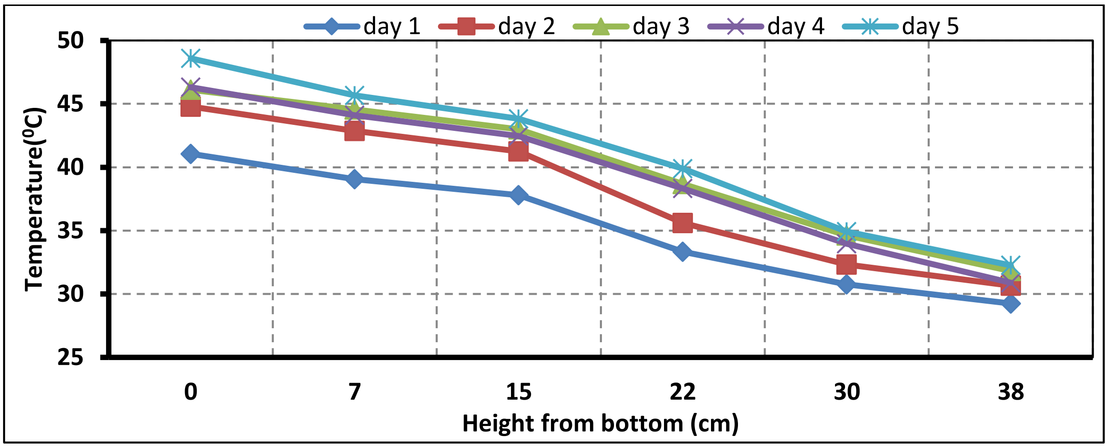


**Fig. 6.13. Average Temperature Distributions Inside the Pond with Internal Reflector for First Five Days of Experiment (20/3/2017 to 24/3/2017)**

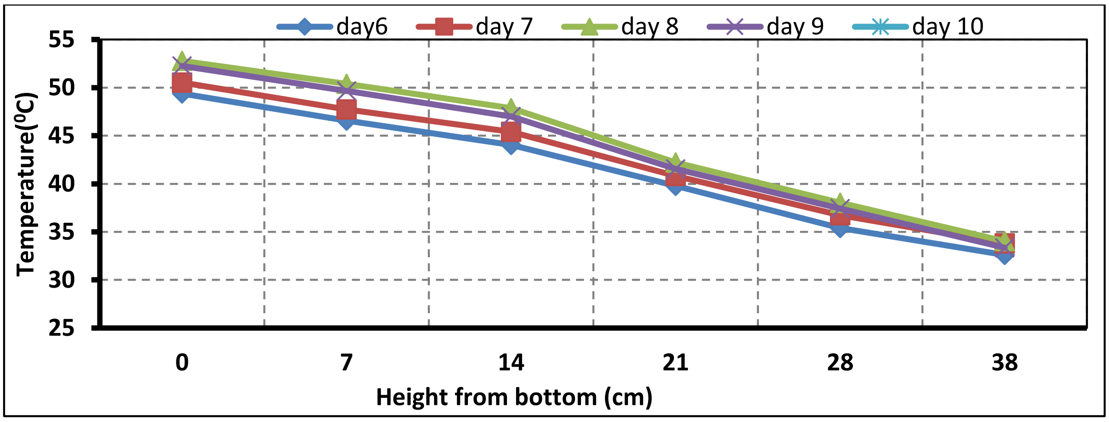


**Fig. 6.14. Average Temperature Distributions Inside the Pond with Internal Reflector for Middle Five Days of Experiment (25/3/2017 to 29/3/2017)**

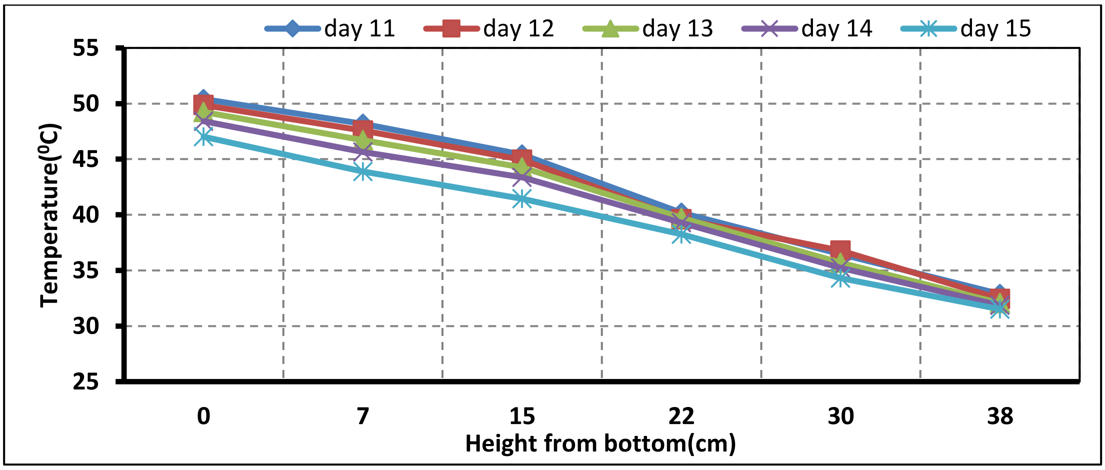


**Fig. 6.15. Average Temperature Distributions Inside the Pond with Internal Reflectors for Last Five Days of Experiment in Third Mode (30/3/2017 to 03/4/2017)**

Maximum mean storage temperature in the first case was obtained on the7$^{th}$ day of the experiment, and on the14$^{th}$ day for the second case and on the 8$^{th}$ day for the third case. It was observed that while there was no significant difference in the day on which maximum mean storage temperature was obtained in the first and third case, the maximum mean storage temperature in the second case was observed much later. Thus, we find that due to the presence of glass cover above the LCZ in the second case, diffusion of salt was significantly reduced which helped in better and longer storage of heat in the LCZ.

## 6.3 Salinity Profiles

The salinity of the salt water at different layer is an important parameter to determine the performance of the solar pond. From the salinities obtained at each layer, the salinity profile can be studied by plotting Specific gravity (salinity) v/s depth.

The salinity profile of first five, middle five and last five days for three cases are shown in Fig 6.16 to Fig 6.26. It can be observed that there was high difference in the salinity profile as days passed for ordinary solar pond and solar pond with glass above LCZ. It was observed that there was a notable difference in salinity profiles in first five days, changes are visible in figures. These changes are due to diffusion of salt from the region of higher concentration to a region of lower concentration in the case of the first mode without the glass above LCZ. In the second mode, the salt concentration in lower convective zone remains constant due to zero diffusion from LCZ to NCZ and the salt gradient remains same for longer period of time. Salt diffusion from NCZ to UCZ is minimized due to lower diffusion potential between high salinity LCZ and NCZ because of separating transparent glass. The disadvantage of using a glass was somewhat low transmission of solar radiation from the glass due to deposition of a layer of dust above it. Salinity profile for second case and the third case was similar due to same diffusion rate.

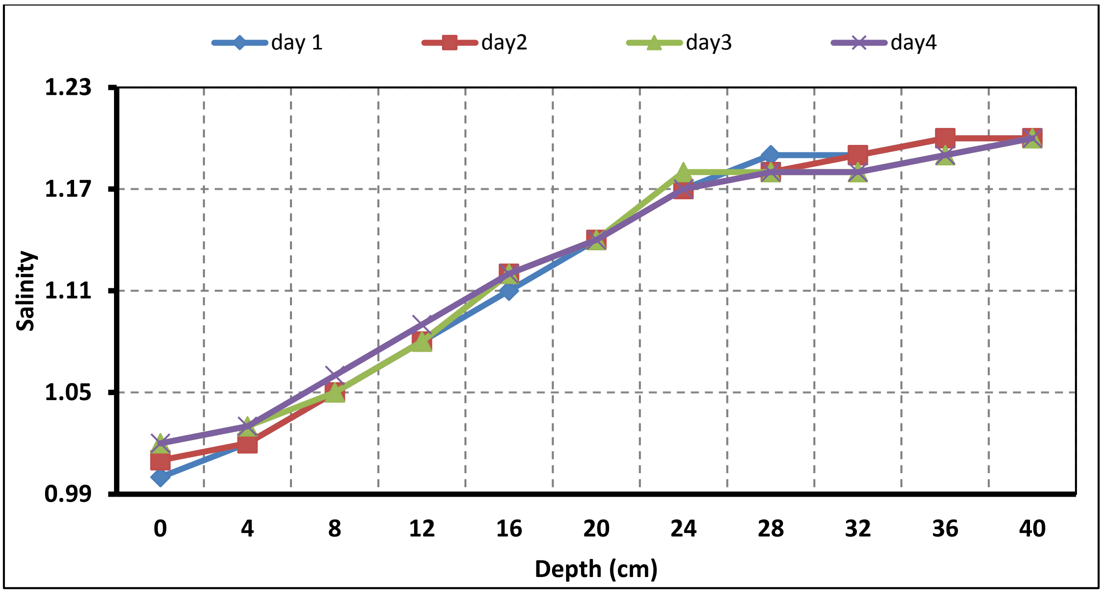


**Fig. 6.16. Salinity Profile for First Five Days in Solar Pond without Separating Glass (02/02/17 to 06/02/17)**

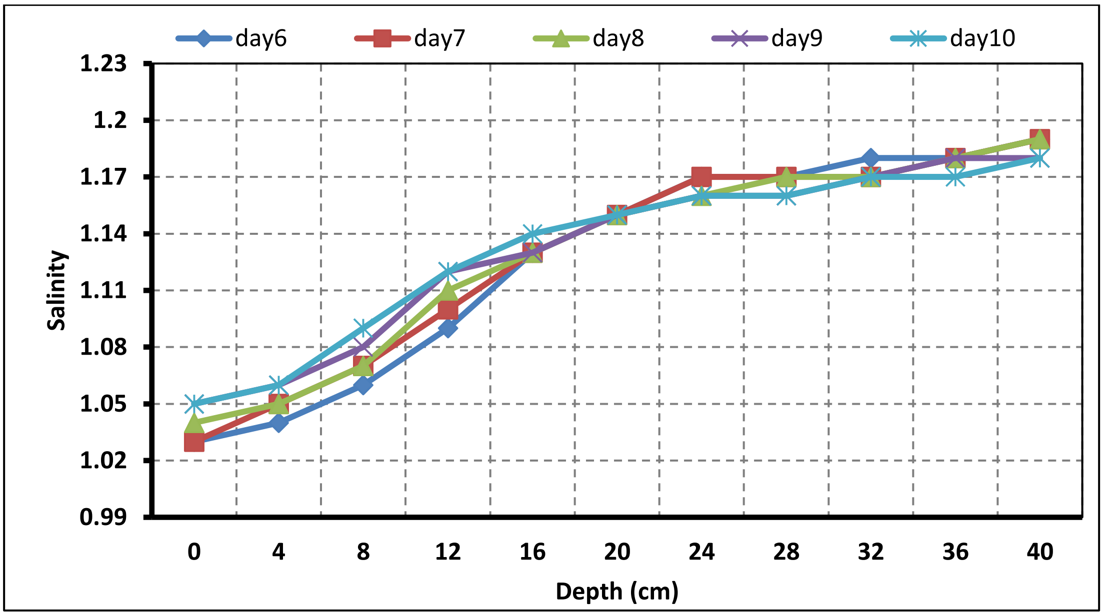


**Fig. 6.17. Salinity Profile for Middle Five Days in Solar Pond without Seprating Glass (07/02/17 to 11/02/17)**

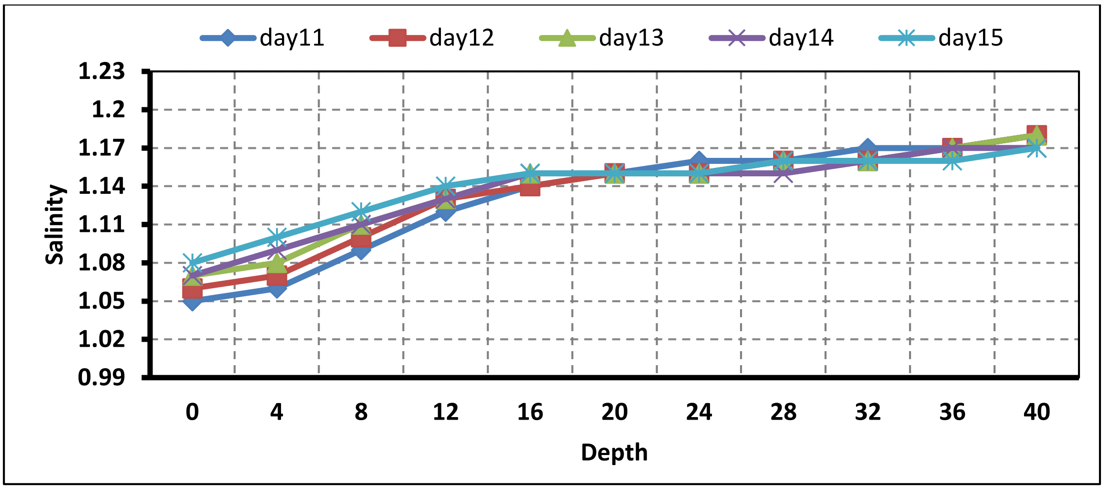


**Fig. 6.18. Salinity Profile for Last Five Days in Solar Pond without Seprating Glass (12/02/17 to 16/02/17)**

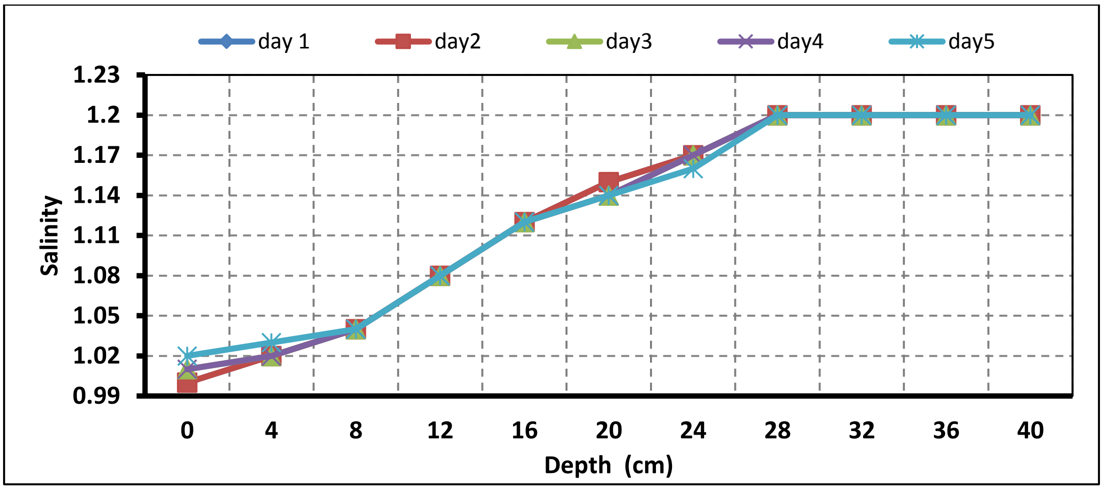


**Fig. 6.19. Salinity Profile for First Five Days in Solar Pond with Seprating Glass (20/02/17 to 24/02/17)**

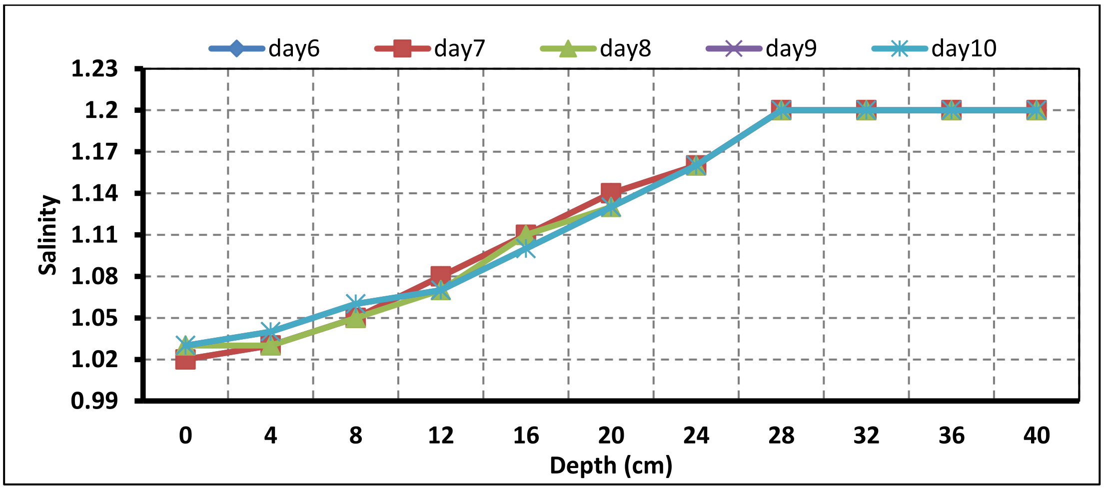


**Fig. 6.20. Salinity Profile for Middle Five Days in Solar Pond with Seprating Glass (25/02/17 to 01/03/17)**

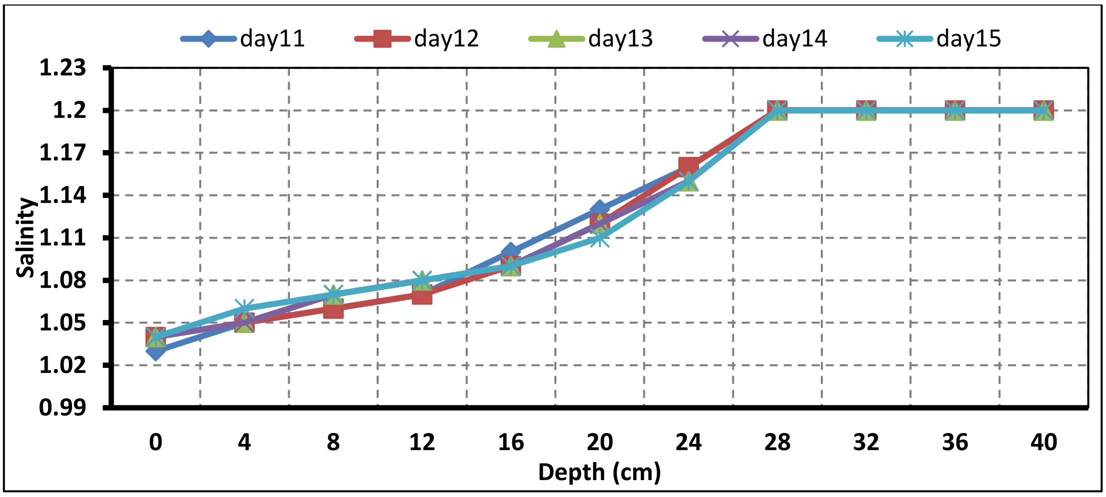


**Fig. 6.21. Salinity Profile for Last Five Days in Solar Pond with Seprating Glass (02/03/17 to 06/03/17)**

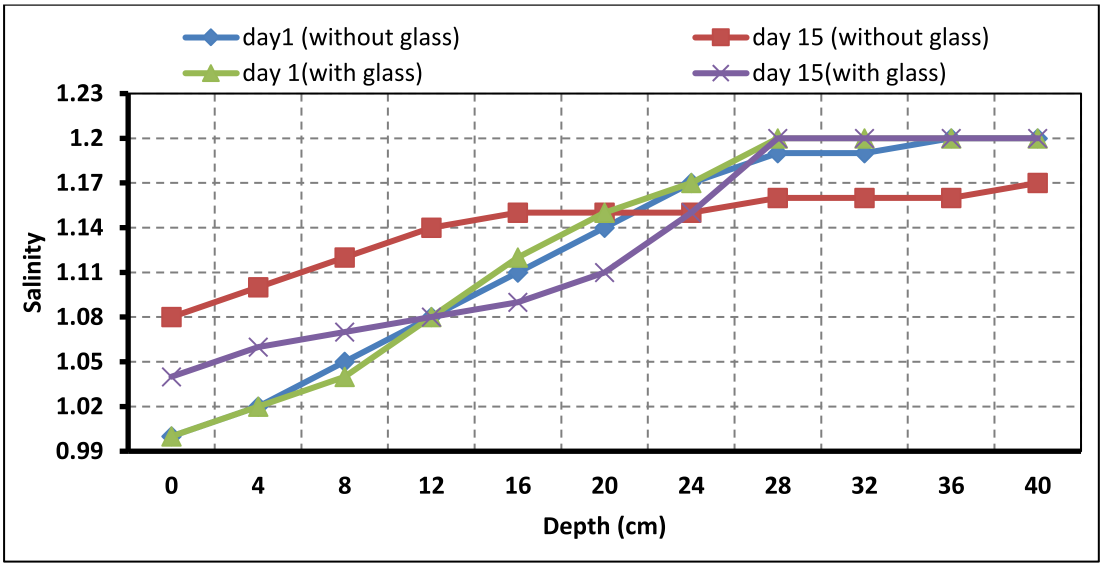


**Fig. 6.22. Salinity Comparison with and without Using Separating Glass**

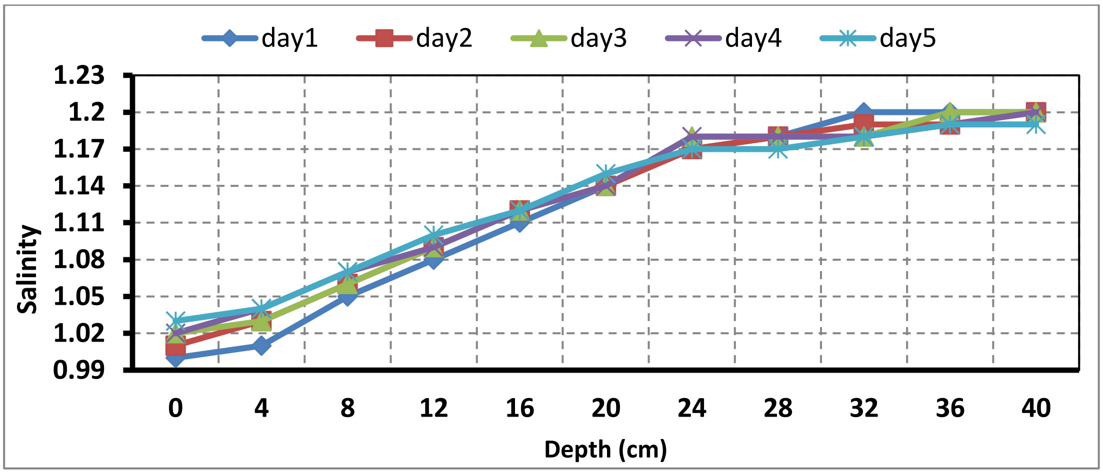


**Fig. 6.23. Salinity Profile for First Five Days in Solar Pond with Internal Reflector (20/03/17 to 24/03/17)**

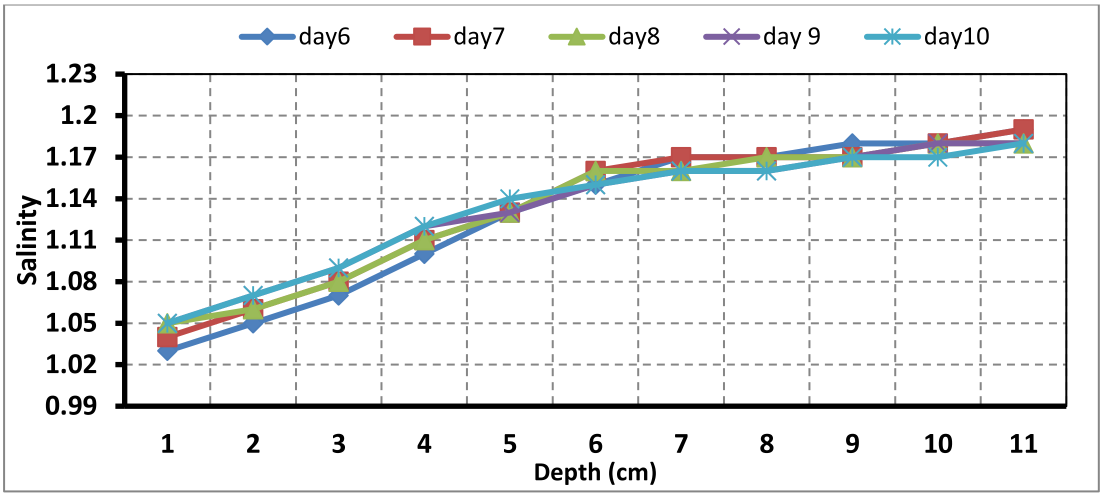


**Fig. 6.24. Salinity Profile for middle Five Days in Solar Pond with Internal Reflector (25/03/17 to 29/03/17)**

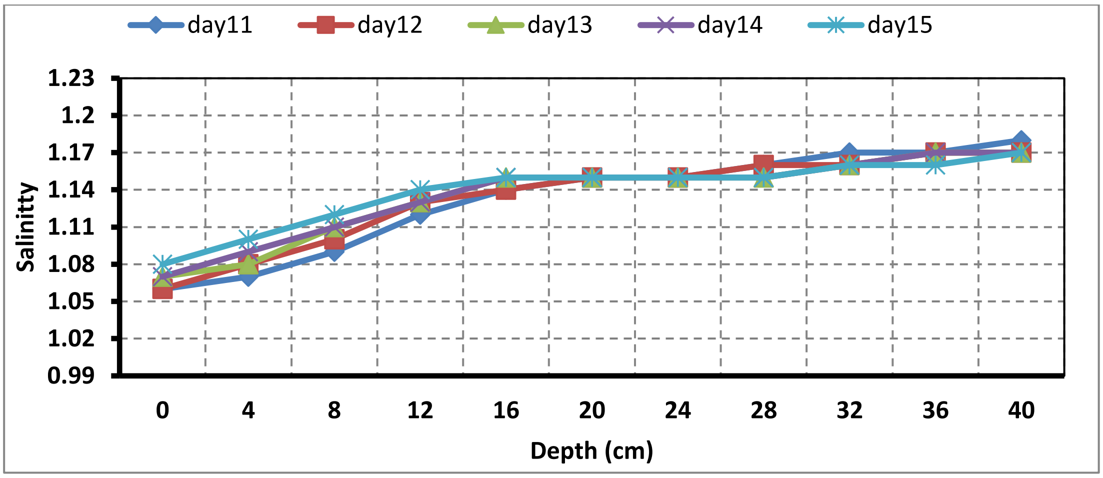


**Fig. 6.25. Salinity Profile for last Five Days in Solar Pond with Internal Reflector (30/03/17 to 03/04/17)**

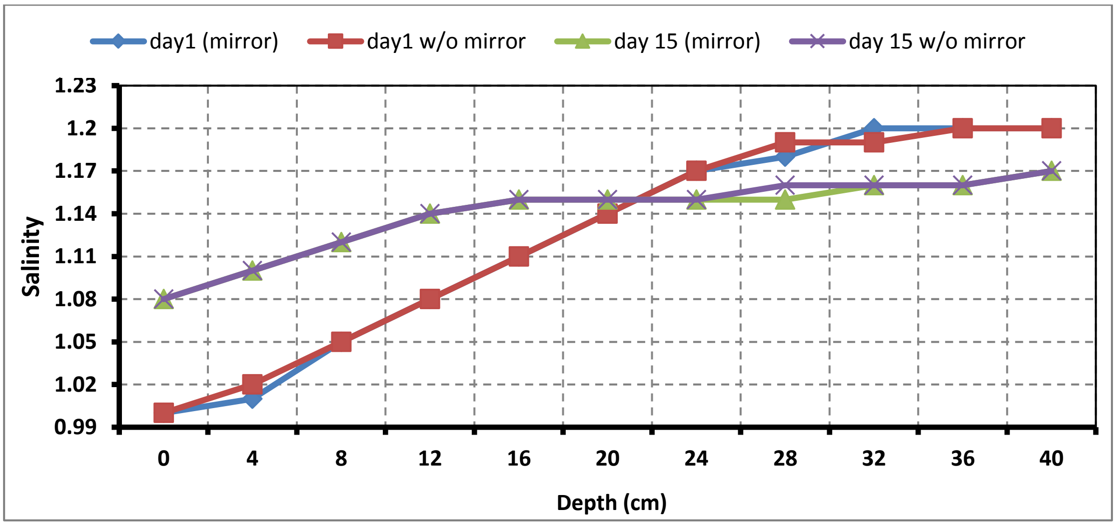


**Fig. 6.26. Salinity Comparison of Ordinary Solar Pond and Solar Pond with Mirror**

## 6.4 Energy stored in LCZ

The useful energy of the solar pond is stored in the lower convective zone, i.e. LCZ having 20% salinity and total 48 kg of water. The stored energy reaches a maximum value then start decreasing due to increase in losses in solar pond with internal reflector and ordinary solar pond. But in the solar pond with glass above LCZ, the losses were reduced due to stability of salt gradient and low convection losses. The variation of stored energy in LCZ is shown in Fig. 6.27, Fig. 6.28 and Fig. 6.29 for three cases respectively. The maximum amount of energy was stored in the solar pond with glass as compare to the two other cases.

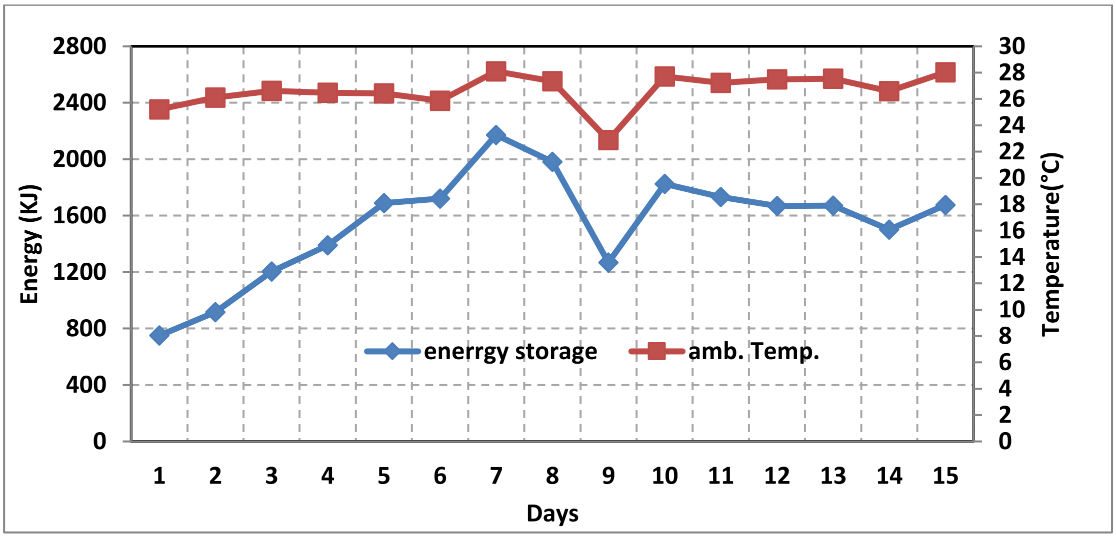


**Fig. 6.27: Ambient Temperature and Thermal Energy Stored in the LCZ with time in Ordinary Solar Pond**

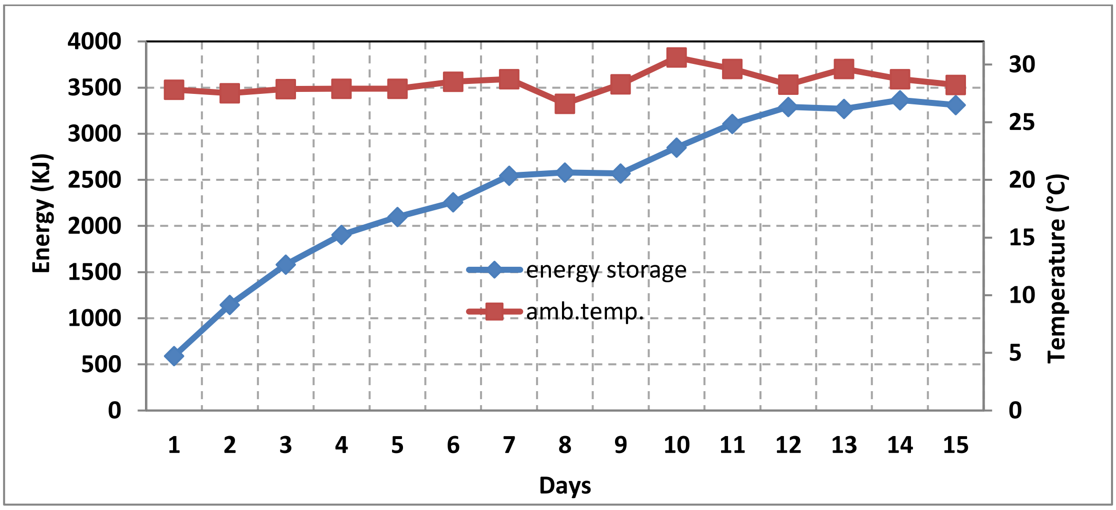


**Fig. 6.28: Ambient Temperature and Thermal Energy Stored in the LCZ with time in solar pond with glass**

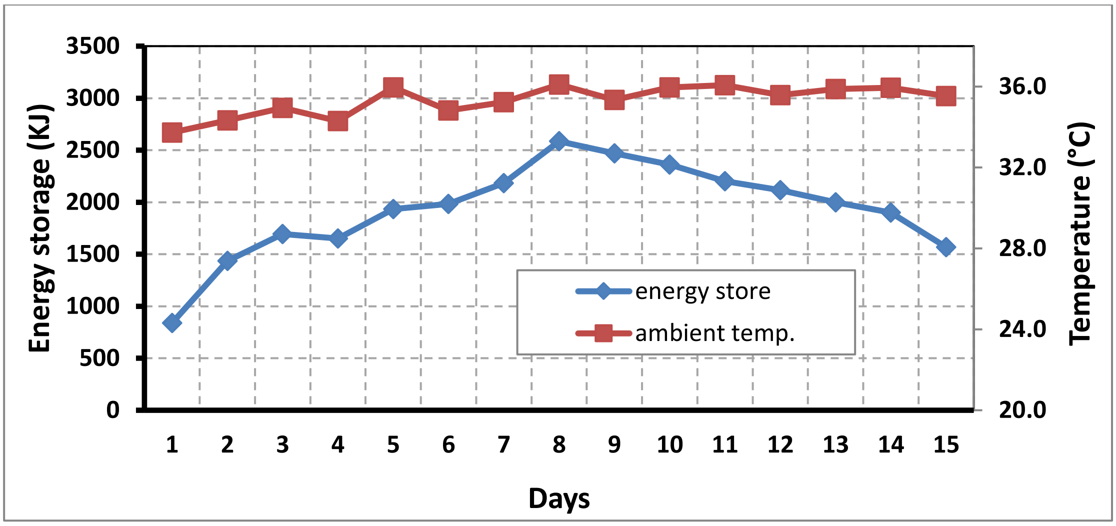


**Fig. 6.29: Ambient Temperature and Thermal Energy Stored in the LCZ with time in Solar Pond with Internal Reflectors**

# Chapter 7

# Conclusions

A salt gradient roof top solar pond was designed and fabricated. Experiments were conducted on the solar pond for three different cases, i.e. a) simple solar pond b) solar pond with a glass separator above the LCZ and c) solar pond without a glass separator but with internal reflectors.

The three cases of the solar pond were studied separately during three different durations of fifteen days. In the first case, i.e. of a simple solar pond, the experiments were conducted from 2$^{nd}$ to 16$^{th}$ Feb., 2017. In the second case, i.e. the solar pond with a glass separator above the LCZ, the experiments were conducted from 20$^{th}$ Feb. to 6$^{th}$ Mar., 2017. And in the third case, i.e. the solar pond without a glass separator but with internal reflectors, the experiments were conducted from 20$^{th}$Mar. to 3$^{rd}$ Apr., 2017.

**Effect of glass separator**

- For Solar Pond with glass separator above LCZ, the stored energy was more as compared to ordinary solar pond. This is due to reduction in convection losses because of low diffusion rate of salt, low no convection losses from LCZ to NCZ. Stored energy has an increasing trend for 15 days of experiment.
- For Solar Pond with glass separator above LCZ, the salinity of the UCZ increased at slower rate which resulted in salt gradient sustaining for longer period of time as compared to ordinary solar pond. Salinity of the LCZ remains constant because it has no diffusion.
- Maximum LCZ temperature in solar pond with glass was less than the solar pond with mirror and ordinary solar pond due to low transmissivity caused by deposition of dust layer / salt above the glass. Average maximum temperature of LCZ was more than other two solar ponds.

**Effects of internal reflector**

- The stored energy was more as compared to ordinary solar pond because the losses from the side walls reduced due to the internal reflectors. The trend of storage energy was similar to ordinary solar pond with a peak near 7-8 days. The temperature of the LCZ starts falling after that.

- Maximum LCZ temperature in solar pond with internal reflector was higher than the solar pond with glass and ordinary solar pond due to reduction in losses from side walls and more radiations reaching the LCZ due to reflection and high ambient temperature. Average maximum temperature of LCZ was more than other two solar ponds due to the same reason.

## 7.1 Future Recommendation

- In the present study effect of separating glass and internal reflectors were studied separately. Their effect can be studied simultaneously.

- If separating glass can be made leak proof, LCZ with 0% salt can be investigated.

- To compare the benefits of the modifications, for each modification separate solar ponds be made and studied simultaneously under similar ambient conditions.

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# Appendix A

## Hourly Temperature of Ordinary Solar Pond in First Mode

**Table 1: Hourly Temperature Measured at Different Depth of Solar Pond (02/02/2017) (day 1)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 21.7 | 21.7 | 21.0 | 19.1 | 17.3 | 15.7 | 20.5 |
| 2 | 11.00 | 23.2 | 22.8 | 21.6 | 20.0 | 18.0 | 16.2 | 22.2 |
| 3 | 12.00 | 26.6 | 25.2 | 24.0 | 22.3 | 19.8 | 18.0 | 26.2 |
| 4 | 01.00 | 29.0 | 28.0 | 26.4 | 24.1 | 21.6 | 19.5 | 28.1 |
| 5 | 02.00 | 31.3 | 30.5 | 28.2 | 25.2 | 22.6 | 20.4 | 30.2 |
| 6 | 03.00 | 32.1 | 31.1 | 28.8 | 25.5 | 23.0 | 20.8 | 27.5 |
| 7 | 04.00 | 30.3 | 30.0 | 28.9 | 26.0 | 22.6 | 19.5 | 24.2 |
| 8 | 05.00 | 28.2 | 28.0 | 27.5 | 24.7 | 20.8 | 17.9 | 22.8 |
| 9 | Mean | 27.8 | 27.16 | 25.8 | 23.36 | 20.71 | 18.5 | 25.21 |

**Table 2: Hourly Temperature Measured at Different Depth of Solar Pond (03/02/2017) (day 2)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 22.3 | 21.8 | 21.1 | 19.5 | 17.4 | 15.9 | 20.3 |
| 2 | 11.00 | 24.1 | 23.0 | 22.0 | 20.4 | 18.2 | 16.4 | 23.4 |
| /3 | 12.00 | 27.5 | 26.1 | 24.5 | 22.4 | 20.1 | 18.1 | 27.5 |
| 4 | 01.00 | 30.1 | 28.5 | 26.2 | 24.3 | 21.9 | 19.5 | 29.0 |
| 5 | 02.00 | 33.5 | 31.2 | 28.5 | 26.0 | 23.1 | 20.8 | 30.4 |
| 6 | 03.00 | 35.4 | 33.0 | 30.2 | 27.6 | 24.0 | 21.8 | 29.5 |
| 7 | 04.00 | 33.1 | 31.5 | 30.8 | 28.3 | 23.6 | 20.5 | 25.9 |
| 8 | 05.00 | 30.5 | 29.2 | 28.9 | 26.0 | 21.6 | 18.5 | 23.0 |
| 9 | Mean | 29.56 | 28.03 | 26.52 | 24.31 | 21.23 | 18.93 | 26.12 |

**Table 3: Hourly Temperature Measured at Different Depth of Solar Pond (04/02/2017) (day 3)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 25.2 | 25.5 | 23.1 | 21.0 | 19 | 16.2 | 21.3 |
| 2 | 11.00 | 27.4 | 26.5 | 24.8 | 22.5 | 19.8 | 16.7 | 24.1 |
| 3 | 12.00 | 30.5 | 29.5 | 27.0 | 24.2 | 21.5 | 18.5 | 27.4 |
| 4 | 01.00 | 34.1 | 32.7 | 29.8 | 26.8 | 23.7 | 20.2 | 30.0 |
| 5 | 02.00 | 37.0 | 35.2 | 32.1 | 28.9 | 25.0 | 21.5 | 31.2 |
| 6 | 03.00 | 38.1 | 37.0 | 33.6 | 30.1 | 26.0 | 22.6 | 29.4 |
| 7 | 04.00 | 35.0 | 34.1 | 34.0 | 31.2 | 25.7 | 21.2 | 26.0 |
| 8 | 05.00 | 32.8 | 31.2 | 30.6 | 30.0 | 23.5 | 19.2 | 23.5 |
| 9 | Mean | 32.51 | 31.33 | 29.41 | 26.83 | 23.82 | 19.5 | 26.61 |

**Table 4: Hourly Temperature Measured at Different Depth of Solar Pond (05/02/2017) (day 4)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 27.4 | 26.5 | 25.0 | 23.1 | 19.1 | 16.7 | 20.8 |
| 2 | 11.00 | 29.5 | 28.3 | 26.8 | 24.5 | 20.3 | 17.0 | 24.2 |
| 3 | 12.00 | 32.5 | 30.8 | 29.4 | 26.6 | 22.3 | 19.0 | 27.3 |
| 4 | 01.00 | 35.8 | 34.0 | 32.4 | 29.0 | 24.4 | 20.8 | 29.8 |
| 5 | 02.00 | 39.2 | 37.3 | 35.4 | 31.7 | 26.6 | 22.2 | 31.4 |
| 6 | 03.00 | 40.8 | 38.6 | 36.7 | 32.9 | 27.7 | 23.1 | 29.1 |
| 7 | 04.00 | 39.5 | 37.1 | 37.2 | 33.5 | 26.9 | 22.0 | 26.1 |
| 8 | 05.00 | 36.0 | 34.1 | 33.8 | 30.8 | 25.4 | 19.7 | 23.1 |
| 9 | Mean | 35.08 | 33.33 | 32.08 | 29.01 | 24.08 | 20.06 | 26.47 |

**Table 5: Hourly Temperature Measured at Different Depth of Solar Pond (06/02/2017) (day 5)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 29.2 | 27.8 | 26.6 | 23.4 | 20.6 | 17.3 | 20.0 |
| 2 | 11.00 | 31.0 | 29.3 | 28.1 | 24.7 | 21.4 | 17.7 | 24.3 |
| 3 | 12.00 | 34.5 | 33.0 | 31.1 | 27.2 | 23.5 | 20.0 | 26.8 |
| 4 | 01.00 | 39.7 | 37.8 | 35.2 | 31.1 | 25.7 | 21.6 | 30.1 |
| 5 | 02.00 | 44.3 | 42.0 | 39.0 | 34.8 | 27.3 | 23.0 | 30.0 |
| 6 | 03.00 | 47.1 | 44.8 | 42.2 | 38.2 | 27.4 | 24.6 | 29.3 |
| 7 | 04.00 | 44.1 | 43.2 | 43.0 | 39.1 | 28.31 | 22.5 | 25.5 |
| 8 | 05.00 | 41.0 | 40.0 | 39.1 | 35.5 | 25.74 | 20.3 | 24.0 |
| 9 | Mean | 38.88 | 37.23 | 35.53 | 31.75 | 25.01 | 20.8 | 26.43 |

**Table 6: Hourly Temperature Measured at Different Depth of Solar Pond (07/02/2017) (day 6)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 30.1 | 28.6 | 27.2 | 25.0 | 20.0 | 16.4 | 19.8 |
| 2 | 11.00 | 32.2 | 30.4 | 28.8 | 26.4 | 21.2 | 17.0 | 23.2 |
| 3 | 12.00 | 36.0 | 34.1 | 32.0 | 29.1 | 24.0 | 19.2 | 26.5 |
| 4 | 01.00 | 40.3 | 38.1 | 35.8 | 32.3 | 27.0 | 20.9 | 30.0 |
| 5 | 02.00 | 45.3 | 43.0 | 40.0 | 36.0 | 31.0 | 22.4 | 30.7 |
| 6 | 03.00 | 48.4 | 46.0 | 43.2 | 39.9 | 34.2 | 23.2 | 28.5 |
| 7 | 04.00 | 45.0 | 43.8 | 43.4 | 40.8 | 34.3 | 21.7 | 25.1 |
| 8 | 05.00 | 42.1 | 40.9 | 40.8 | 38.2 | 31.0 | 19.4 | 22.5 |
| 9 | Mean | 39.92 | 38.11 | 36.46 | 33.46 | 27.83 | 20.02 | 25.86 |

**Table 7: Hourly Temperature Measured at Different Depth of Solar Pond (08/02/2017) (day 7)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 32.3 | 30.5 | 29.1 | 25.7 | 20.5 | 18.5 | 22.5 |
| 2 | 11.00 | 34.5 | 32.5 | 31.0 | 27.3 | 21.7 | 19.10 | 26.8 |
| 3 | 12.00 | 39.6 | 37.4 | 35.6 | 31.7 | 25.1 | 21.3 | 29.4 |
| 4 | 01.00 | 44.8 | 42.4 | 40.1 | 36.5 | 30.0 | 23.0 | 32.0 |
| 5 | 02.00 | 49.4 | 47.2 | 44.8 | 39.6 | 34.7 | 24.5 | 33.1 |

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 6 | 03.00 | 50.8 | 49.6 | 47.1 | 42.9 | 37.8 | 25.3 | 31.0 |
| 7 | 04.00 | 48.1 | 47.8 | 47.7 | 43.5 | 38.2 | 23.8 | 28.2 |
| 8 | 05.00 | 45.7 | 43.6 | 43.4 | 40.8 | 36.7 | 21.5 | 25.5 |
| 9 | Mean | 43.15 | 41.37 | 39.85 | 36.01 | 30.58 | 22.12 | 28.1 |

**Table 8: Hourly Temperature Measured at Different Depth of Solar Pond (09/02/2017) (day 8)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 32.5 | 30.6 | 29.2 | 27.0 | 21.6 | 19.1 | 21 |
| 2 | 11.00 | 34.2 | 32.0 | 30.6 | 28.2 | 22.6 | 19.7 | 24.8 |
| 3 | 12.00 | 38.2 | 35.8 | 33.7 | 31.2 | 25.2 | 21.8 | 28.5 |
| 4 | 01.00 | 43.1 | 40.2 | 38.0 | 35.2 | 30.0 | 23.7 | 30.6 |
| 5 | 02.00 | 47.5 | 44.3 | 42.0 | 38.8 | 33.1 | 25.1 | 32.1 |
| 6 | 03.00 | 49.3 | 46.3 | 44.2 | 41.1 | 35.8 | 25.9 | 30.8 |
| 7 | 04.00 | 47.2 | 44.9 | 44.7 | 41.5 | 36.0 | 24.5 | 26.8 |
| 8 | 05.00 | 44.6 | 42.0 | 41.6 | 39.8 | 36.1 | 22.0 | 24.2 |
| 9 | Mean | 42.07 | 39.51 | 38.0 | 35.38 | 29.8 | 22.72 | 27.35 |

**Table 9: Hourly Temperature Measured at Different Depth of Solar Pond (10/02/2017) (day 9)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 31.8 | 30.1 | 28.8 | 26.6 | 23.1 | 17.3 | 19.6 |
| 2 | 11.00 | 33.1 | 31.8 | 30.1 | 27.4 | 23.8 | 17.8 | 21.1 |
| 3 | 12.00 | 35.8 | 33.6 | 31.7 | 29.0 | 25.0 | 18.4 | 23.2 |
| 4 | 01.00 | 38.2 | 36.1 | 33.2 | 31.3 | 27.1 | 19.6 | 24.3 |
| 5 | 02.00 | 40.5 | 38.1 | 35.0 | 32.6 | 28.5 | 21.4 | 25.7 |
| 6 | 03.00 | 42.0 | 39.5 | 36.5 | 34.0 | 29.8 | 22.5 | 24.2 |
| 7 | 04.00 | 40.5 | 38.8 | 36.4 | 34.1 | 29.1 | 21.9 | 23.3 |
| 8 | 05.00 | 39.5 | 37.6 | 34.8 | 32.3 | 27.6 | 21.3 | 21.6 |
| 9 | Mean | 37.8 | 35.7 | 33.31 | 30.91 | 26.75 | 20.02 | 22.87 |

**Table 10: Hourly Temperature Measured at Different Depth of Solar Pond (11/02/2017) (day 10)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 29.1 | 27.6 | 26.3 | 24.1 | 21.0 | 19.4 | 21.2 |
| 2 | 11.00 | 31.5 | 29.7 | 28.0 | 26.0 | 22.7 | 20.0 | 25.1 |
| 3 | 12.00 | 35.6 | 33.8 | 31.6 | 29.6 | 25.6 | 22.1 | 29.3 |
| 4 | 01.00 | 39.1 | 37.2 | 35.0 | 32.2 | 28.2 | 24.0 | 32.5 |
| 5 | 02.00 | 44.0 | 41.2 | 39.0 | 36.1 | 31.5 | 25.4 | 33.2 |
| 6 | 03.00 | 48.2 | 45.1 | 43.2 | 39.8 | 35.1 | 26.2 | 30.1 |
| 7 | 04.00 | 46.5 | 43.8 | 42.7 | 39.5 | 35.0 | 24.8 | 26.5 |
| 8 | 05.00 | 43.2 | 41.2 | 39.5 | 38.2 | 34.2 | 22.3 | 23.8 |
| 9 | Mean | 39.65 | 37.45 | 35.66 | 33.18 | 29.16 | 23.02 | 27.71 |

**Table 11: Hourly Temperature Measured at Different Depth of Solar Pond (12/02/2017) (day 11)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 30.2 | 28.1 | 27.0 | 25.2 | 22.3 | 19.0 | 21.0 |
| 2 | 11.00 | 32.2 | 30.0 | 28.7 | 26.8 | 24.1 | 20.8 | 25.3 |
| 3 | 12.00 | 36.0 | 33.5 | 31.8 | 29.8 | 26.2 | 23.2 | 29.0 |
| 4 | 01.00 | 38.8 | 36.1 | 34.0 | 31.2 | 28.0 | 24.2 | 31.1 |
| 5 | 02.00 | 43.0 | 40.5 | 38.1 | 35.3 | 31.4 | 26.9 | 32.3 |
| 6 | 03.00 | 47.2 | 43.8 | 41.0 | 39.4 | 35.7 | 28.2 | 29.8 |
| 7 | 04.00 | 45.1 | 42.2 | 39.3 | 39.0 | 35.1 | 27.5 | 26.0 |
| 8 | 05.00 | 42.7 | 40.3 | 37.5 | 37.2 | 34.2 | 26.8 | 23.3 |
| 9 | Mean | 39.4 | 36.81 | 34.67 | 32.98 | 29.62 | 24.57 | 27.22 |

**Table 12: Hourly Temperature Measured at Different Depth of Solar Pond (13/02/2017) (day 12)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 29.3 | 27.8 | 26.0 | 23.6 | 20.6 | 19.0 | 20.5 |
| 2 | 11.00 | 31.2 | 29.7 | 27.8 | 25.0 | 22.1 | 19.5 | 25.7 |
| 3 | 12.00 | 35.1 | 33.4 | 30.8 | 28.1 | 24.5 | 22.1 | 30.2 |
| 4 | 01.00 | 38.0 | 35.7 | 33.0 | 30.5 | 26.8 | 24.0 | 31.8 |
| 5 | 02.00 | 42.2 | 39.5 | 37.0 | 33.8 | 30.1 | 27.1 | 32.6 |
| 6 | 03.00 | 45.3 | 42.2 | 39.8 | 36.2 | 33.3 | 29.0 | 29.5 |
| 7 | 04.00 | 43.5 | 40.3 | 38.2 | 35.0 | 31.6 | 28.6 | 25.7 |
| 8 | 05.00 | 41.2 | 38.2 | 36.1 | 33.5 | 30.2 | 28.0 | 24.0 |
| 9 | Mean | 38.22 | 35.85 | 33.58 | 30.71 | 27.4 | 24.61 | 27.5 |

**Table 13: Hourly Temperature Measured at Different Depth of Solar Pond (14/02/2017) (day 13)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 28.5 | 27.2 | 26.0 | 23.0 | 20.2 | 19.1 | 21.8 |
| 2 | 11.00 | 30.8 | 29.5 | 28.2 | 25.1 | 22.0 | 19.6 | 25.3 |
| 3 | 12.00 | 34.5 | 32.8 | 30.6 | 27.3 | 24.1 | 21.7 | 29.2 |
| 4 | 01.00 | 37.6 | 35.7 | 33.7 | 30.5 | 27.0 | 24.2 | 30.8 |
| 5 | 02.00 | 41.1 | 39.5 | 37.0 | 33.2 | 30.1 | 27.1 | 23.8 |
| 6 | 03.00 | 44.6 | 42.8 | 40.0 | 37.8 | 33.1 | 29.6 | 30.3 |
| 7 | 04.00 | 42.8 | 41.2 | 39.1 | 36.5 | 32.0 | 29.0 | 27.0 |
| 8 | 05.00 | 41.1 | 39.5 | 37.0 | 33.2 | 30.1 | 27.1 | 23.8 |
| 9 | Mean | 37.63 | 36.02 | 33.97 | 30.92 | 27.33 | 24.68 | 27.55 |

**Table 14: Hourly Temperature Measured at Different Depth of Solar Pond (15/02/2017) (day 14)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 26.7 | 26.0 | 24.8 | 23.1 | 20.4 | 18.7 | 21.0 |
| 2 | 11.00 | 28.8 | 27.6 | 26.2 | 25.0 | 22.1 | 20.0 | 24.5 |
| 3 | 12.00 | 32.5 | 30.7 | 29.0 | 27.2 | 24.2 | 22.0 | 28.3 |
| 4 | 01.00 | 36.2 | 34.1 | 32.2 | 30.0 | 27.3 | 24.1 | 30.0 |
| 5 | 02.00 | 41.0 | 39.2 | 36.8 | 33.5 | 30.4 | 27.8 | 31.5 |

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 6 | 03.00 | 44.1 | 42.3 | 39.0 | 36.8 | 33.5 | 30.2 | 29.1 |
| 7 | 04.00 | 42.5 | 40.6 | 38.1 | 36.5 | 32.6 | 29.6 | 25.2 |
| 8 | 05.00 | 40.1 | 38.7 | 36.6 | 35.2 | 31.5 | 28.8 | 23.2 |
| 9 | Mean | 36.48 | 34.9 | 32.83 | 30.91 | 27.75 | 25.15 | 26.6 |

**Table 15: Hourly Temperature Measured at Different Depth of Solar Pond (16/02/2017) (day 15)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 27.1 | 26.2 | 25.0 | 23.2 | 20.8 | 19.7 | 22.4 |
| 2 | 11.00 | 29.4 | 28.5 | 26.7 | 24.5 | 22.2 | 20.7 | 26.2 |
| 3 | 12.00 | 33.5 | 31.5 | 29.6 | 27.0 | 25.0 | 21.7 | 29.6 |
| 4 | 01.00 | 37.1 | 35.0 | 32.8 | 30.6 | 27.7 | 25.0 | 31.6 |
| 5 | 02.00 | 42.3 | 40.1 | 37.6 | 35.0 | 31.7 | 28.5 | 33.6 |
| 6 | 03.00 | 45.6 | 43.5 | 40.2 | 38.1 | 34.8 | 30.7 | 30.3 |
| 7 | 04.00 | 43.1 | 40.6 | 39.0 | 37.2 | 33.3 | 30.0 | 26.4 |
| 8 | 05.00 | 40.8 | 38.8 | 36.7 | 35.3 | 31.0 | 29.1 | 24.1 |
| 9 | Mean | 37.36 | 35.52 | 33.45 | 31.36 | 28.31 | 25.80 | 28.02 |

# Salinity of water at Different Depth of Solar Pond in First Mode

**Table 16: Salinity of Water at Different Depth of Solar Pond without using Glass for 15 days**

| Days | Date | Depth of solar pond ( cm) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 |
| 1 | 02/02/17 | 1.00 | 1.02 | 1.05 | 1.08 | 1.11 | 1.14 | 1.17 | 1.19 | 1.19 | 1.2 | 1.2 |
| 2 | 03/02/17 | 1.01 | 1.02 | 1.05 | 1.08 | 1.12 | 1.14 | 1.17 | 1.18 | 1.19 | 1.2 | 1.2 |
| 3 | 04/02/17 | 1.02 | 1.03 | 1.05 | 1.08 | 1.12 | 1.14 | 1.18 | 1.18 | 1.18 | 1.19 | 1.2 |
| 4 | 05/02/17 | 1.02 | 1.03 | 1.06 | 1.09 | 1.12 | 1.14 | 1.17 | 1.18 | 1.18 | 1.19 | 1.2 |
| 5 | 06/02/17 | 1.03 | 1.04 | 1.06 | 1.09 | 1.13 | 1.15 | 1.17 | 1.17 | 1.18 | 1.19 | 1.19 |
| 6 | 07/02/17 | 1.03 | 1.04 | 1.06 | 1.09 | 1.13 | 1.15 | 1.17 | 1.17 | 1.18 | 1.18 | 1.19 |
| 7 | 08/02/17 | 1.03 | 1.05 | 1.07 | 1.10 | 1.13 | 1.15 | 1.17 | 1.17 | 1.17 | 1.18 | 1.19 |
| 8 | 09/02/17 | 1.04 | 1.05 | 1.07 | 1.11 | 1.13 | 1.15 | 1.16 | 1.17 | 1.17 | 1.18 | 1.19 |
| 9 | 10/02/17 | 1.05 | 1.06 | 1.08 | 1.12 | 1.13 | 1.15 | 1.16 | 1.16 | 1.17 | 1.18 | 1.18 |
| 10 | 11/02/17 | 1.05 | 1.06 | 1.09 | 1.12 | 1.14 | 1.15 | 1.16 | 1.16 | 1.17 | 1.17 | 1.18 |
| 11 | 12/02/17 | 1.05 | 1.06 | 1.09 | 1.12 | 1.14 | 1.15 | 1.16 | 1.16 | 1.17 | 1.17 | 1.18 |
| 12 | 13/02/17 | 1.06 | 1.07 | 1.1 | 1.13 | 1.14 | 1.15 | 1.15 | 1.16 | 1.16 | 1.17 | 1.18 |
| 13 | 14/02/17 | 1.07 | 1.08 | 1.11 | 1.13 | 1.15 | 1.15 | 1.15 | 1.16 | 1.16 | 1.17 | 1.18 |
| 14 | 15/02/17 | 1.07 | 1.09 | 1.11 | 1.13 | 1.15 | 1.15 | 1.15 | 1.15 | 1.16 | 1.17 | 1.17 |
| 15 | 16/02/17 | 1.08 | 1.1 | 1.12 | 1.14 | 1.15 | 1.15 | 1.15 | 1.16 | 1.16 | 1.16 | 1.17 |

# Solar Radiation Intensity in First Mode

**Table 17: Solar Radiation Intensity at the Surface of Solar Pond**

| Day | Date | Time (hours) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | Mean |
| 1 | 02/02/17 | 150 | 385 | 528 | 640 | 653 | 612 | 530 | 312 | 103 | 434.77 |

| Day | Date | Time (hours) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | Mean |
| 2 | 03/02/17 | 137 | 362 | 570 | 612 | 659 | 635 | 528 | 330 | 98 | 436.77 |
| 3 | 04/02/17 | 153 | 342 | 537 | 589 | 640 | 650 | 512 | 298 | 83 | 422.66 |
| 4 | 05/02/17 | 147 | 391 | 523 | 655 | 681 | 638 | 480 | 315 | 107 | 437.44 |
| 5 | 06/02/17 | 144 | 382 | 602 | 680 | 698 | 651 | 528 | 305 | 100 | 454.44 |
| 6 | 07/02/17 | 138 | 328 | 510 | 630 | 661 | 635 | 490 | 290 | 93 | 419.44 |
| 7 | 08/02/17 | 144 | 390 | 560 | 640 | 671 | 642 | 510 | 310 | 95 | 440.22 |
| 8 | 09/02/17 | 145 | 345 | 581 | 682 | 680 | 628 | 515 | 330 | 101 | 445.22 |
| 9 | 10/02/17 | 147 | 290 | 495 | 630 | 665 | 635 | 523 | 303 | 105 | 421.44 |
| 10 | 11/02/17 | 158 | 406 | 598 | 651 | 680 | 634 | 503 | 309 | 97 | 448.44 |
| 11 | 12/02/17 | 153 | 370 | 555 | 701 | 698 | 648 | 491 | 295 | 89 | 444.44 |
| 12 | 13/02/17 | 148 | 396 | 582 | 663 | 697 | 596 | 511 | 280 | 96 | 441.00 |
| 13 | 14/02/17 | 141 | 388 | 562 | 648 | 686 | 628 | 519 | 311 | 103 | 442.88 |
| 14 | 15/02/17 | 157 | 362 | 588 | 650 | 673 | 618 | 495 | 315 | 108 | 440.66 |
| 15 | 16/02/17 | 155 | 380 | 547 | 661 | 693 | 636 | 522 | 306 | 94 | 443.77 |

## Hourly Temperature of Solar Pond in SecondMode

**Table 18: Hourly Temperature Measured at Different Depth of Solar Pond (20/02/2017) (day 1)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 22.6 | 22.5 | 22.5 | 18.1 | 17.2 | 16.2 | 22.8 |
| 2 | 11.00 | 23.0 | 23.0 | 23.2 | 18.8 | 18.0 | 17.0 | 24.2 |
| 3 | 12.00 | 24.1 | 24.1 | 24.4 | 20.0 | 19.2 | 18.3 | 29.5 |
| 4 | 01.00 | 25.6 | 25.5 | 25.9 | 21.2 | 20.5 | 19.7 | 30.8 |
| 5 | 02.00 | 27.0 | 27.0 | 27.4 | 23.0 | 21.6 | 20.6 | 32.1 |
| 6 | 03.00 | 28.2 | 28.1 | 28.4 | 24.3 | 22.7 | 21.9 | 31.8 |
| 7 | 04.00 | 29.0 | 29.0 | 28.9 | 24.6 | 23.0 | 21.7 | 27.3 |
| 8 | 05.00 | 29.2 | 29.2 | 29.1 | 24.8 | 23.0 | 21.4 | 24.1 |
| 9 | Mean | 26.08 | 26.05 | 26.22 | 21.85 | 20.65 | 19.6 | 27.82 |

**Table 19: Hourly Temperature Measured at Different Depth of Solar Pond (21/02/2017) (day 2)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 25.2 | 25.1 | 25.1 | 21.5 | 19.3 | 18.0 | 21.6 |
| 2 | 11.00 | 26.1 | 26.1 | 26.3 | 22.2 | 20.0 | 18.5 | 24.3 |
| 3 | 12.00 | 27.3 | 27.2 | 27.5 | 23.4 | 21.0 | 19.6 | 29.7 |
| 4 | 01.00 | 29.0 | 29.0 | 29.3 | 24.4 | 22.2 | 20.7 | 31.5 |
| 5 | 02.00 | 30.8 | 30.7 | 31.0 | 25.8 | 23.3 | 21.4 | 33.0 |
| 6 | 03.00 | 31.9 | 31.9 | 32.1 | 26.4 | 24.2 | 22.4 | 30.2 |
| 7 | 04.00 | 32.7 | 32.7 | 32.6 | 26.8 | 24.5 | 22.2 | 26.2 |
| 8 | 05.00 | 33.0 | 33.0 | 33.0 | 27.1 | 24.3 | 21.8 | 23.8 |
| 9 | Mean | 29.5 | 29.46 | 29.61 | 24.7 | 22.35 | 20.57 | 27.53 |

**Table 20: Hourly Temperature Measured at Different Depth of Solar Pond (22/02/2017) (day 3)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 28.0 | 28.0 | 28.0 | 23.1 | 21.3 | 18.1 | 22.6 |
| 2 | 11.00 | 29.0 | 29.0 | 29.2 | 24.0 | 22.0 | 18.8 | 25.0 |
| 3 | 12.00 | 30.1 | 30.2 | 30.5 | 25.1 | 23.1 | 20.0 | 29.2 |
| 4 | 01.00 | 31.5 | 31.4 | 31.7 | 26.3 | 24.3 | 21.1 | 32.2 |
| 5 | 02.00 | 33.3 | 33.2 | 33.6 | 27.9 | 25.5 | 22.4 | 33.8 |
| 6 | 03.00 | 34.7 | 34.7 | 34.8 | 28.8 | 26.2 | 23.1 | 31.1 |
| 7 | 04.00 | 35.1 | 35.1 | 35.3 | 29.5 | 27.0 | 22.8 | 23.2 |
| 8 | 05.00 | 35.4 | 35.4 | 35.4 | 29.9 | 26.6 | 22.3 | 23.2 |
| 9 | Mean | 32.13 | 32.13 | 32.31 | 26.82 | 24.5 | 21.07 | 27.88 |

**Table 21: Hourly Temperature Measured at Different Depth of Solar Pond (23/02/2017) (day 4)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 30.8 | 30.8 | 30.8 | 25.1 | 23.1 | 19.0 | 22.2 |
| 2 | 11.00 | 31.6 | 31.6 | 31.8 | 25.9 | 23.7 | 19.6 | 25.2 |
| 3 | 12.00 | 32.6 | 32.6 | 32.7 | 26.8 | 25.0 | 20.5 | 30.0 |
| 4 | 01.00 | 33.7 | 33.7 | 33.9 | 27.9 | 26.1 | 21.8 | 32.2 |
| 5 | 02.00 | 34.9 | 34.8 | 35.0 | 29.0 | 27.5 | 23.0 | 33.2 |
| 6 | 03.00 | 35.9 | 35.8 | 35.8 | 30.1 | 28.6 | 24.1 | 30.8 |
| 7 | 04.00 | 36.8 | 36.8 | 36.8 | 31.0 | 29.4 | 24.0 | 25.9 |
| 8 | 05.00 | 37.0 | 37.0 | 37.0 | 31.2 | 29.1 | 23.8 | 23.8 |
| 9 | Mean | 34.16 | 34.13 | 34.22 | 28.37 | 26.56 | 21.97 | 27.91 |

**Table 22: Hourly Temperature Measured at Different Depth of Solar Pond (24/02/2017) (day 5)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 32.0 | 32.0 | 32.0 | 26.1 | 23.8 | 19.2 | 22.6 |
| 2 | 11.00 | 32.8 | 32.8 | 33.0 | 26.9 | 24.4 | 19.6 | 25.1 |
| 3 | 12.00 | 34.0 | 33.8 | 34.0 | 27.7 | 25.2 | 20.4 | 29.9 |
| 4 | 01.00 | 35.0 | 35.0 | 35.1 | 28.8 | 26.4 | 21.4 | 32.6 |
| 5 | 02.00 | 36.0 | 36.0 | 36.2 | 29.9 | 27.6 | 22.8 | 33.7 |
| 6 | 03.00 | 37.0 | 37.0 | 37.1 | 31.0 | 28.9 | 24.0 | 30.6 |
| 7 | 04.00 | 37.8 | 37.8 | 37.9 | 31.7 | 29.7 | 24.0 | 25.8 |
| 8 | 05.00 | 38.1 | 38.1 | 38.1 | 31.9 | 29.5 | 23.6 | 22.9 |
| 9 | Mean | 35.33 | 35.31 | 35.42 | 29.25 | 26.93 | 21.87 | 27.9 |

**Table 23: Hourly Temperature Measured at Different Depth of Solar Pond (25/02/2017) (day 6)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 32.8 | 32.8 | 32.8 | 26.4 | 24.0 | 21.8 | 22.4 |
| 2 | 11.00 | 33.7 | 33.7 | 33.9 | 27.1 | 24.6 | 22.3 | 25.3 |
| 3 | 12.00 | 34.7 | 34.7 | 34.8 | 28.0 | 25.5 | 23.2 | 30.7 |
| 4 | 01.00 | 35.9 | 35.8 | 36.0 | 29.0 | 26.6 | 24.1 | 32.9 |
| 5 | 02.00 | 37.0 | 37.0 | 37.1 | 30.2 | 27.9 | 25.5 | 34.1 |

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 6 | 03.00 | 38.1 | 38.1 | 38.2 | 31.5 | 29.2 | 26.8 | 33.3 |
| 7 | 04.00 | 39.0 | 39.0 | 39.0 | 32.1 | 30.1 | 26.7 | 26.1 |
| 8 | 05.00 | 39.4 | 39.4 | 39.4 | 32.3 | 30.6 | 26.5 | 23.3 |
| 9 | Mean | 36.32 | 36.31 | 36.4 | 29.57 | 27.31 | 24.6 | 28.51 |

**Table 24: Hourly Temperature Measured at Different Depth of Solar Pond (26/02/2017) (day 7)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 33.8 | 33.8 | 33.8 | 27.2 | 24.5 | 22.5 | 23.2 |
| 2 | 11.00 | 34.9 | 34.9 | 35.1 | 28.0 | 25.2 | 23.1 | 26.1 |
| 3 | 12.00 | 36.1 | 36.1 | 36.4 | 29.1 | 26.2 | 24.0 | 31.0 |
| 4 | 01.00 | 37.8 | 37..8 | 38.1 | 30.2 | 27.4 | 25.2 | 33.2 |
| 5 | 02.00 | 39.2 | 39.1 | 39.4 | 31.3 | 28.5 | 26.4 | 34.6 |
| 6 | 03.00 | 40.4 | 40.4 | 40.5 | 32.5 | 29.7 | 27.7 | 31.8 |
| 7 | 04.00 | 41.0 | 40.9 | 41.0 | 33.3 | 30.5 | 28.4 | 26.0 |
| 8 | 05.00 | 41.3 | 41.3 | 41.3 | 33.9 | 31.0 | 28.3 | 23.5 |
| 9 | Mean | 38.06 | 38.03 | 38.2 | 30.68 | 27.87 | 25.7 | 28.75 |

**Table 25: Hourly Temperature Measured at Different Depth of Solar Pond (27/02/2017) (day 8)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 34.7 | 34.7 | 34.7 | 28.0 | 25.2 | 24.0 | 21.8 |
| 2 | 11.00 | 35.8 | 35.8 | 35.9 | 29.1 | 26.1 | 25.0 | 25.4 |
| 3 | 12.00 | 37.1 | 37.0 | 37.2 | 30.2 | 27.1 | 26.1 | 30.6 |
| 4 | 01.00 | 38.2 | 38.2 | 38.3 | 31.2 | 28.0 | 27.0 | 32.5 |
| 5 | 02.00 | 39.8 | 39.7 | 39.9 | 32.3 | 29.1 | 28.0 | 34.0 |
| 6 | 03.00 | 40.4 | 40.4 | 40.4 | 32.6 | 29.4 | 28.1 | 24.2 |
| 7 | 04.00 | 40.3 | 40.3 | 40.3 | 32.4 | 29.0 | 27.8 | 22.1 |
| 8 | 05.00 | 40.1 | 40.1 | 40.1 | 32.0 | 28.5 | 27.1 | 22.3 |
| 9 | Mean | 38.30 | 38.27 | 38.35 | 30.97 | 27.8 | 26.63 | 26.61 |

**Table 26: Hourly Temperature Measured at Different Depth of Solar Pond (28/02/2017) (day 9)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 34.0 | 34.0 | 34.0 | 27.5 | 24.8 | 23.8 | 22.8 |
| 2 | 11.00 | 35.1 | 35.1 | 35.3 | 28.4 | 25.5 | 24.5 | 25.9 |
| 3 | 12.00 | 36.1 | 36.0 | 36.2 | 29.4 | 26.5 | 25.4 | 29.8 |
| 4 | 01.00 | 38.2 | 38.1 | 38.5 | 30.7 | 27.7 | 26.5 | 33.0 |
| 5 | 02.00 | 39.3 | 39.3 | 39.4 | 31.7 | 28.7 | 26.5 | 34.3 |
| 6 | 03.00 | 40.2 | 40.2 | 40.3 | 32.6 | 29.5 | 27.4 | 32.1 |
| 7 | 04.00 | 41.1 | 41.1 | 41.2 | 33.2 | 30.4 | 28.0 | 25.3 |
| 8 | 05.00 | 41.7 | 41.7 | 41.7 | 33.6 | 30.7 | 28.4 | 23.1 |
| 9 | Mean | 38.21 | 38.18 | 38.32 | 30.88 | 27.98 | 26.6 | 28.28 |

**Table 27: Hourly Temperature Measured at Different Depth of Solar Pond (01/03/2017) (day 10)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 35.1 | 35.1 | 35.1 | 28,3 | 25.5 | 24.6 | 23.2 |
| 2 | 11.00 | 36.0 | 36.0 | 36.1 | 29.0 | 26.1 | 25.2 | 26.2 |
| 3 | 12.00 | 37.1 | 37.0 | 37.2 | 30.0 | 27.0 | 26.1 | 31.1 |
| 4 | 01.00 | 38.6 | 38.6 | 38.7 | 31.1 | 28.0 | 27.1 | 33.6 |
| 5 | 02.00 | 40.2 | 40.2 | 40.2 | 32.2 | 29.1 | 28.1 | 34.7 |
| 6 | 03.00 | 41.5 | 41.5 | 41.6 | 33.5 | 30.3 | 29.3 | 31.3 |
| 7 | 04.00 | 42.2 | 42.2 | 42.2 | 34.2 | 32.0 | 29.9 | 26.0 |
| 8 | 05.00 | 42.8 | 42.8 | 42.8 | 34.7 | 32.3 | 30.0 | 23.8 |
| 9 | Mean | 39.18 | 41.46 | 39.23 | 31.67 | 28.78 | 27.5 | 30.61 |

**Table 28: Hourly Temperature Measured at Different Depth of Solar Pond (02/03/2017) (day 11)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 36.0 | 36.0 | 36.0 | 29.0 | 26.2 | 25.0 | 24.0 |
| 2 | 11.00 | 37.1 | 37.1 | 37.2 | 30.0 | 27.1 | 25.9 | 27.7 |
| 3 | 12.00 | 38.7 | 38.6 | 38.8 | 31.2 | 28.2 | 27.0 | 32.1 |
| 4 | 01.00 | 40.6 | 40.5 | 40.7 | 32.5 | 29.7 | 28.3 | 34.5 |
| 5 | 02.00 | 43.2 | 43.0 | 43.5 | 34.0 | 31.1 | 29.9 | 35.8 |
| 6 | 03.00 | 44.8 | 44.7 | 44.9 | 35.1 | 32.1 | 30.9 | 32.7 |
| 7 | 04.00 | 45.7 | 45.7 | 45.8 | 36.0 | 33.0 | 31.7 | 26.2 |
| 8 | 05.00 | 46.1 | 46.1 | 46.1 | 36.5 | 35.5 | 31.9 | 23.9 |
| 9 | Mean | 41.52 | 41.46 | 41.62 | 33.03 | 30.11 | 28.82 | 29.61 |

**Table 29: Hourly Temperature Measured at Different Depth of Solar Pond (03/03/2017) (day 12)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 37.1 | 37.1 | 37.1 | 30.0 | 27.1 | 25.8 | 22.5 |
| 2 | 11.00 | 38.5 | 38.5 | 38.6 | 31.1 | 28.1 | 26.9 | 25.7 |
| 3 | 12.00 | 39.6 | 39.6 | 39.7 | 32.2 | 29.1 | 28.0 | 30.8 |
| 4 | 01.00 | 41.2 | 41.0 | 41.3 | 33.5 | 30.5 | 29.2 | 33.2 |
| 5 | 02.00 | 44.3 | 44.2 | 44.5 | 35.0 | 31.9 | 30.5 | 34.5 |
| 6 | 03.00 | 46.2 | 46.2 | 46.3 | 36.1 | 33.0 | 31.5 | 31.4 |
| 7 | 04.00 | 47.0 | 47.0 | 47.0 | 37.0 | 33.8 | 32.1 | 25.0 |
| 8 | 05.00 | 47.4 | 47.4 | 47.4 | 38.0 | 34.7 | 32.9 | 23.1 |
| 9 | Mean | 42.66 | 42.62 | 42.73 | 34.11 | 31.02 | 29.61 | 28.27 |

**Table 30: Hourly Temperature Measured at Different Depth of Solar Pond (04/03/2017) (day 13)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 37.5 | 37.5 | 37.5 | 30.2 | 27.1 | 25.7 | 21.8 |
| 2 | 11.00 | 38.5 | 38.5 | 38.6 | 31.0 | 28.0 | 26.7 | 25.1 |
| 3 | 12.00 | 39.4 | 39.4 | 39.5 | 32.1 | 29.0 | 28.0 | 30.2 |
| 4 | 01.00 | 41.0 | 41.1 | 41.2 | 33.2 | 30.3 | 29.0 | 33.0 |
| 5 | 02.00 | 44.0 | 44.0 | 44.1 | 35.0 | 32.0 | 31.5 | 34.0 |
| 6 | 03.00 | 46.1 | 46.1 | 46.2 | 36.1 | 32.8 | 31.2 | 30.6 |

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 7 | 04.00 | 46.6 | 46.6 | 46.6 | 36.8 | 33.4 | 31.9 | 24.1 |
| 8 | 05.00 | 47.0 | 47.0 | 47.0 | 37.5 | 34.1 | 32.2 | 22.2 |
| 9 | Mean | 42.51 | 42.52 | 42.58 | 33.98 | 30.82 | 29.52 | 29.62 |

**Table 31: Hourly Temperature Measured at Different Depth of Solar Pond (05/03/2017) (day 14)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 38.1 | 38.1 | 38.1 | 31.1 | 28.0 | 26.2 | 23.0 |
| 2 | 11.00 | 38.8 | 38.8 | 38.9 | 32.0 | 28.8 | 27.0 | 26.3 |
| 3 | 12.00 | 40.1 | 40.1 | 40.2 | 33.1 | 29.8 | 28.2 | 31.4 |
| 4 | 01.00 | 41.6 | 41.5 | 41.6 | 34.2 | 31.0 | 29.1 | 33.4 |
| 5 | 02.00 | 44.8 | 44.7 | 44.9 | 35.6 | 32.2 | 30.3 | 34.6 |
| 6 | 03.00 | 46.8 | 46.8 | 46.9 | 37.0 | 33.6 | 31.5 | 32.0 |
| 7 | 04.00 | 47.2 | 47.2 | 47.2 | 37.8 | 34.2 | 32.2 | 25.5 |
| 8 | 05.00 | 47.6 | 47.6 | 47.6 | 38.8 | 35.0 | 32.6 | 23.6 |
| 9 | Mean | 43.12 | 43.1 | 43.13 | 34.95 | 31.57 | 29.63 | 28.73 |

**Table 32: Hourly Temperature Measured at Different Depth of Solar Pond (06/03/2017) (day 15)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 38.0 | 38.0 | 38.0 | 31.1 | 28.1 | 26.2 | 22.2 |
| 2 | 11.00 | 38.6 | 38.6 | 38.6 | 31.9 | 28.8 | 27.0 | 26.0 |
| 3 | 12.00 | 40.0 | 40.0 | 40.2 | 33.0 | 29.9 | 28.2 | 31.5 |
| 4 | 01.00 | 41.3 | 41.3 | 41.4 | 34.0 | 30.7 | 29.0 | 33.0 |
| 5 | 02.00 | 44.2 | 44.2 | 44.3 | 35.3 | 32.0 | 30.1 | 34.1 |
| 6 | 03.00 | 46.3 | 46.3 | 46.4 | 36.8 | 33.3 | 31.2 | 31.5 |
| 7 | 04.00 | 46.7 | 46.7 | 46.7 | 37.5 | 34.0 | 32.0 | 24.6 |
| 8 | 05.00 | 47.0 | 47.0 | 47.0 | 38.6 | 34.6 | 32.5 | 23.0 |
| 9 | Mean | 42.76 | 42.76 | 42.82 | 34.77 | 31.42 | 29.52 | 28.23 |

# Salinity of water at Different depth in Second Mode

**Table 33: Salinity of Water at Different Depth of Solar Pond with using Glass for 15 days**

| Days | Date | Depth of solar pond (cm) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 |
| 1 | 20/02/17 | 1.00 | 1.02 | 1.04 | 1.08 | 1.12 | 1.15 | 1.17 | 1.2 | 1.2 | 1.2 | 1.2 |
| 2 | 21/02/17 | 1.00 | 1.02 | 1.04 | 1.08 | 1.12 | 1.15 | 1.17 | 1.2 | 1.2 | 1.2 | 1.2 |
| 3 | 22/02/17 | 1.01 | 1.02 | 1.04 | 1.08 | 1.12 | 1.14 | 1.17 | 1.2 | 1.2 | 1.2 | 1.2 |
| 4 | 23/02/17 | 1.01 | 1.02 | 1.04 | 1.08 | 1.12 | 1.14 | 1.17 | 1.2 | 1.2 | 1.2 | 1.2 |
| 5 | 24/02/17 | 1.02 | 1.03 | 1.04 | 1.08 | 1.12 | 1.14 | 1.16 | 1.2 | 1.2 | 1.2 | 1.2 |
| 6 | 25/02/17 | 1.02 | 1.03 | 1.05 | 1.08 | 1.11 | 1.14 | 1.16 | 1.2 | 1.2 | 1.2 | 1.2 |
| 7 | 26/03/17 | 1.02 | 1.03 | 1.05 | 1.08 | 1.11 | 1.14 | 1.16 | 1.2 | 1.2 | 1.2 | 1.2 |
| 8 | 27/03/17 | 1.03 | 1.03 | 1.05 | 1.07 | 1.11 | 1.13 | 1.16 | 1.2 | 1.2 | 1.2 | 1.2 |
| 9 | 28/03/17 | 1.03 | 1.04 | 1.06 | 1.07 | 1.1 | 1.13 | 1.16 | 1.2 | 1.2 | 1.2 | 1.2 |

| Days | Date | Depth of solar pond (cm) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 |
| 10 | 01/03/17 | 1.03 | 1.04 | 1.06 | 1.07 | 1.1 | 1.13 | 1.16 | 1.2 | 1.2 | 1.2 | 1.2 |
| 11 | 02/03/17 | 1.03 | 1.05 | 1.06 | 1.07 | 1.1 | 1.13 | 1.16 | 1.2 | 1.2 | 1.2 | 1.2 |
| 12 | 03/03/17 | 1.04 | 1.05 | 1.06 | 1.07 | 1.09 | 1.12 | 1.16 | 1.2 | 1.2 | 1.2 | 1.2 |
| 13 | 04/03/17 | 1.04 | 1.05 | 1.07 | 1.08 | 1.09 | 1.12 | 1.15 | 1.2 | 1.2 | 1.2 | 1.2 |
| 14 | 05/03/17 | 1.04 | 1.05 | 1.07 | 1.08 | 1.09 | 1.12 | 1.15 | 1.2 | 1.2 | 1.2 | 1.2 |
| 15 | 06/03/17 | 1.04 | 1.06 | 1.07 | 1.08 | 1.09 | 1.11 | 1.15 | 1.2 | 1.2 | 1.2 | 1.2 |

# Solar Radiation Intensity in Second Mode

**Table 34: Solar Radiation Intensity at the Surface of Solar Pond using Glass above LCZ**

| Day | Date | Time (hours) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | Mean |
| 1 | 20/02/17 | 151 | 388 | 538 | 655 | 678 | 653 | 538 | 320 | 109 | 447.77 |
| 2 | 21/02/17 | 161 | 402 | 560 | 670 | 683 | 660 | 518 | 339 | 113 | 456.22 |
| 3 | 22/02/17 | 142 | 360 | 590 | 683 | 691 | 673 | 530 | 318 | 95 | 453.55 |
| 4 | 23/02/17 | 162 | 403 | 541 | 703 | 715 | 695 | 550 | 330 | 112 | 467.88 |
| 5 | 24/02/17 | 148 | 393 | 542 | 688 | 697 | 652 | 532 | 288 | 112 | 450.22 |
| 6 | 25/02/17 | 153 | 410 | 583 | 693 | 709 | 690 | 539 | 323 | 98 | 466.44 |
| 7 | 26/03/17 | 146 | 375 | 561 | 658 | 678 | 653 | 522 | 345 | 106 | 449.33 |
| 8 | 27/03/17 | 168 | 396 | 541 | 693 | 706 | 688 | 413 | 116 | 31 | 416.88 |
| 9 | 28/03/17 | 154 | 398 | 581 | 710 | 722 | 692 | 545 | 333 | 123 | 473.11 |
| 10 | 01/03/17 | 163 | 406 | 598 | 687 | 705 | 687 | 532 | 316 | 103 | 466.33 |
| 11 | 02/03/17 | 159 | 390 | 567 | 695 | 698 | 652 | 512 | 331 | 92 | 455.11 |
| 12 | 03/03/17 | 142 | 388 | 603 | 709 | 707 | 678 | 529 | 322 | 101 | 464.33 |
| 13 | 04/03/17 | 168 | 407 | 585 | 713 | 723 | 698 | 538 | 323 | 102 | 473.00 |
| 14 | 05/03/17 | 177 | 420 | 578 | 682 | 688 | 681 | 549 | 348 | 113 | 470.66 |
| 15 | 06/03/17 | 163 | 412 | 615 | 710 | 712 | 687 | 541 | 338 | 123 | 477.88 |

# Hourly Temperature Variation in Third Mode

**Table 35: Hourly Temperature Measured at Different Depth of Solar Pond (20/03/2017) (day 1)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 35.2 | 34.3 | 33.0 | 31.6 | 29.1 | 27.8 | 29.2 |
| 2 | 11.00 | 38.8 | 36.2 | 34.1 | 32.0 | 29.7 | 28.1 | 32.3 |
| 3 | 12.00 | 40.1 | 38.3 | 36.0 | 32.9 | 30.9 | 28.8 | 36.1 |
| 4 | 01.00 | 41.5 | 39.4 | 37.1 | 33.5 | 30.9 | 29.4 | 37.5 |
| 5 | 02.00 | 42.5 | 40.3 | 38.0 | 34.1 | 31.3 | 30.1 | 37.2 |
| 6 | 03.00 | 43.8 | 41.6 | 39.2 | 35.0 | 31.9 | 30.6 | 34.2 |
| 7 | 04.00 | 44.5 | 42.1 | 39.9 | 35.5 | 32.2 | 30.8 | 33.1 |
| 8 | 05.00 | 42.1 | 40.3 | 37.2 | 32.1 | 30.1 | 28.4 | 30.3 |
| 9 | Mean | 41.06 | 39.06 | 36.81 | 33.33 | 30.76 | 29.25 | 33.73 |

**Table 36: Hourly Temperature Measured at Different Depth of Solar Pond (21/03/2017) (day 2)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 36.6 | 35.5 | 33.8 | 31.8 | 29.2 | 28 | 29.6 |
| 2 | 11.00 | 39.8 | 38.6 | 36.0 | 33.0 | 30.4 | 29.3 | 33.2 |
| 3 | 12.00 | 43.0 | 41.8 | 39.2 | 34.5 | 31.4 | 30.0 | 36.6 |
| 4 | 01.00 | 46.3 | 44.1 | 41.2 | 36.0 | 32.5 | 31.1 | 38.5 |
| 5 | 02.00 | 48.5 | 46.3 | 43.3 | 37.8 | 34.2 | 32.2 | 37.2 |
| 6 | 03.00 | 49.2 | 47.0 | 44.2 | 38.4 | 34.9 | 32.6 | 35.2 |
| 7 | 04.00 | 49.6 | 47.3 | 44.3 | 38.3 | 34.7 | 32.1 | 33.4 |
| 8 | 05.00 | 45.3 | 42.4 | 40.1 | 35.1 | 31.3 | 30.0 | 31.0 |
| 9 | Mean | 44.7875 | 42.875 | 40.2625 | 35.6125 | 32.32 | 30.66 | 34.33 |

**Table 37: Hourly Temperature Measured at Different Depth of Solar Pond (22/03/2017) (day 3)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 37.2 | 36.1 | 34.4 | 32.8 | 30.1 | 28.5 | 30.7 |
| 2 | 11.00 | 41.0 | 39.6 | 37.8 | 34.2 | 32.0 | 30.1 | 34.1 |
| 3 | 12.00 | 45.3 | 44.0 | 41.1 | 37.0 | 34.6 | 31.8 | 37.3 |
| 4 | 01.00 | 47.8 | 46.1 | 43.3 | 39.5 | 35.5 | 32.5 | 39.1 |
| 5 | 02.00 | 49.2 | 48.0 | 45.2 | 41.9 | 36.8 | 33.3 | 37.1 |
| 6 | 03.00 | 50.7 | 49.2 | 46.3 | 42.5 | 37.5 | 34.0 | 36.2 |
| 7 | 04.00 | 51.0 | 49.3 | 46.3 | 42.2 | 37.3 | 33.7 | 33.8 |
| 8 | 05.00 | 46.7 | 44.2 | 41.6 | 39.40 | 33.1 | 30.6 | 31.3 |
| 9 | Mean | 46.1125 | 44.5625 | 42 | 38.6875 | 34.6125 | 31.8125 | 34.95 |

**Table 38: Hourly Temperature Measured at Different Depth of Solar Pond (23/03/2017) (day 4)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 37.8 | 35.6 | 34.5 | 32.8 | 30.2 | 28.6 | 28.8 |
| 2 | 11.00 | 40.7 | 38.2 | 36.5 | 33.9 | 31.0 | 29.0 | 32.5 |
| 3 | 12.00 | 44.3 | 42.1 | 39.2 | 36.2 | 32.5 | 30.1 | 36.2 |
| 4 | 01.00 | 47.4 | 45.0 | 42.1 | 38.1 | 34.0 | 31.1 | 38.6 |
| 5 | 02.00 | 50.2 | 48.7 | 45.3 | 39.7 | 35.5 | 32.4 | 38.8 |
| 6 | 03.00 | 51.2 | 49.3 | 46.1 | 43.0 | 37.1 | 33.0 | 36.2 |
| 7 | 04.00 | 51.7 | 49.6 | 46.0 | 43.3 | 38.8 | 32.7 | 33.0 |
| 8 | 05.00 | 47.2 | 44.3 | 42.1 | 39.7 | 32.7 | 30.2 | 30.3 |
| 9 | Mean | 46.3125 | 44.1 | 41.475 | 38.3375 | 33.975 | 30.8875 | 34.3 |

**Table 39: Hourly Temperature Measured at Different Depth of Solar Pond (24/03/2017) (day 5)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 39.1 | 37.6 | 35.2 | 33.4 | 31.0 | 29.6 | 31.0 |
| 2 | 11.00 | 42.4 | 39.7 | 37.5 | 36.0 | 32.3 | 30.2 | 33.1 |
| 3 | 12.00 | 46.8 | 44.2 | 40.3 | 38.3 | 34.0 | 31.5 | 37.4 |
| 4 | 01.00 | 49.7 | 47.0 | 43.1 | 40.0 | 35.8 | 33.0 | 40.0 |
| 5 | 02.00 | 53.8 | 50.3 | 47.7 | 43.1 | 37.0 | 34.2 | 39.7 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 6 | 03.00 | 54.5 | 51.2 | 48.5 | 44.2 | 37.5 | 34.5 | 36.4 |
| 7 | 04.00 | 54.2 | 50.5 | 48.3 | 44.0 | 37.8 | 33.7 | 34.1 |
| 8 | 05.00 | 48.2 | 44.8 | 42.0 | 40.1 | 33.9 | 31.4 | 31.2 |
| 9 | Mean | 48.5875 | 45.6625 | 42.825 | 39.8875 | 34.9125 | 32.2625 | 35.95714 |

**Table 40: Hourly Temperature Measured at Different Depth of Solar Pond (24/03/2017) (day 6)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 39.4 | 37.2 | 35.8 | 33.9 | 31.8 | 29.6 | 30.6 |
| 2 | 11.00 | 43.1 | 40.2 | 37.9 | 36.3 | 32.5 | 30.8 | 33.2 |
| 3 | 12.00 | 46.5 | 43.8 | 39.8 | 38.0 | 34.0 | 31.6 | 36.7 |
| 4 | 01.00 | 50.3 | 48.0 | 43.5 | 40.2 | 36.2 | 33.0 | 39.2 |
| 5 | 02.00 | 54.8 | 51.6 | 46.8 | 42.1 | 38.0 | 34.5 | 38.4 |
| 6 | 03.00 | 56.0 | 53.1 | 48.5 | 43.8 | 39.1 | 35.2 | 36.2 |
| 7 | 04.00 | 54.8 | 51.6 | 48.4 | 43.3 | 37.5 | 33.5 | 33.8 |
| 8 | 05.00 | 50.1 | 47.0 | 43.6 | 40.6 | 34.0 | 32.1 | 30.5 |
| 9 | Mean | 49.375 | 46.5625 | 43.0375 | 39.775 | 35.3875 | 32.6 | 34.825 |

**Table 41: Hourly Temperature Measured at Different Depth of Solar Pond (25/03/2017) (day 7)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 41.3 | 40.0 | 38.2 | 35.0 | 32.3 | 30.1 | 30.6 |
| 2 | 11.00 | 44.5 | 42.1 | 39.8 | 36.3 | 33.5 | 31.4 | 33.2 |
| 3 | 12.00 | 48.3 | 46.0 | 42.1 | 38.8 | 35.0 | 32.8 | 36.8 |
| 4 | 01.00 | 51.5 | 48.4 | 44.7 | 40.6 | 36.8 | 33.8 | 40.2 |
| 5 | 02.00 | 55.8 | 52.5 | 47.8 | 43.2 | 39.2 | 35.4 | 39.1 |
| 6 | 03.00 | 57.1 | 54.3 | 49.9 | 45.0 | 40.5 | 37.0 | 36.5 |
| 7 | 04.00 | 54.9 | 51.8 | 48.6 | 45.8 | 40.2 | 36.1 | 34.0 |
| 8 | 05.00 | 50.8 | 46.8 | 44.0 | 41.8 | 36.3 | 33.7 | 31.5 |
| 9 | Mean | 50.525 | 47.7375 | 44.3875 | 40.8125 | 36.725 | 33.8 | 35.2375 |

**Table 42: Hourly Temperature Measured at Different Depth of Solar Pond (26/03/2017) (day 8)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 42.7 | 40.5 | 39.0 | 36.1 | 33.0 | 30.3 | 31.5 |
| 2 | 11.00 | 46.1 | 43.8 | 40.9 | 37.3 | 34.8 | 32.0 | 34.5 |
| 3 | 12.00 | 50.1 | 48.0 | 44.2 | 40.1 | 36.0 | 33.1 | 37.8 |
| 4 | 01.00 | 56.2 | 53.8 | 49.3 | 43.7 | 38.8 | 35.2 | 41.3 |
| 5 | 02.00 | 60.3 | 58.8 | 53.1 | 47.3 | 42.1 | 36.5 | 40.0 |
| 6 | 03.00 | 60.5 | 58.8 | 52.8 | 46.5 | 41.6 | 36.1 | 37.2 |
| 7 | 04.00 | 55.1 | 52.4 | 48.8 | 45.1 | 41.0 | 35.5 | 34.4 |
| 8 | 05.00 | 51.2 | 47.0 | 44.3 | 41.5 | 37.0 | 33.5 | 32.1 |
| 9 | Mean | 52.775 | 50.3875 | 46.87143 | 42.2 | 38.0375 | 34.025 | 36.1 |

**Table 43: Hourly Temperature Measured at Different Depth of Solar Pond (27/03/2017) (day 9)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 42.5 | 40.1 | 38.5 | 35.2 | 32.6 | 30.0 | 30.8 |
| 2 | 11.00 | 45.8 | 43.7 | 40.6 | 37.0 | 34.2 | 31.2 | 33.6 |
| 3 | 12.00 | 49.8 | 47.5 | 43.3 | 39.7 | 35.1 | 32.5 | 37.1 |
| 4 | 01.00 | 55.4 | 53.1 | 48.8 | 43.4 | 38.5 | 34.5 | 40.1 |
| 5 | 02.00 | 59.6 | 57.7 | 51.8 | 46.3 | 41.3 | 35.8 | 38.8 |
| 6 | 03.00 | 60.3 | 58.0 | 51.2 | 45.6 | 40.3 | 35.2 | 37.0 |
| 7 | 04.00 | 54.3 | 50.8 | 47.8 | 44.6 | 40.8 | 34.3 | 34.1 |
| 8 | 05.00 | 50.3 | 46.4 | 43.2 | 40.6 | 36.5 | 33.3 | 31.2 |
| 9 | Mean | 52.25 | 49.6625 | 46 | 41.55 | 37.4125 | 33.35 | 35.3375 |

**Table 44: Hourly Temperature Measured at Different Depth of Solar Pond (28/03/2017) (day 10)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 42.6 | 40.3 | 38.4 | 35.0 | 32.7 | 30.3 | 31.3 |
| 2 | 11.00 | 44.6 | 42.8 | 40.0 | 36.2 | 34.2 | 31.3 | 34.2 |
| 3 | 12.00 | 48.3 | 47.0 | 42.8 | 38.9 | 34.6 | 32.4 | 38.2 |
| 4 | 01.00 | 54.0 | 52.0 | 47.6 | 42.3 | 37.7 | 34.5 | 41.0 |
| 5 | 02.00 | 59.1 | 57.2 | 50.9 | 46.5 | 41.3 | 35.6 | 39.2 |
| 6 | 03.00 | 60.1 | 57.7 | 51.3 | 45.8 | 41.2 | 36.1 | 37.3 |
| 7 | 04.00 | 54.3 | 50.2 | 47.5 | 43.9 | 41.0 | 35.0 | 35.0 |
| 8 | 05.00 | 50.0 | 46.1 | 42.8 | 40.5 | 36.5 | 33.4 | 31.5 |
| 9 | Mean | 51.625 | 49.1625 | 45.1625 | 41.1375 | 37.4 | 33.575 | 35.9625 |

**Table 45: Hourly Temperature Measured at Different Depth of Solar Pond (29/03/2017) (day 11)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 41.6 | 40.1 | 38.2 | 34.4 | 31.8 | 30.1 | 32.1 |
| 2 | 11.00 | 44.2 | 42.3 | 39.7 | 36.1 | 33.7 | 31.0 | 34.6 |
| 3 | 12.00 | 47.1 | 45.6 | 42.0 | 38.2 | 34.5 | 32.1 | 38.2 |
| 4 | 01.00 | 52.2 | 50.3 | 46.9 | 41.4 | 36.3 | 33.8 | 41.3 |
| 5 | 02.00 | 57.3 | 55.6 | 50.2 | 45.1 | 39.8 | 34.7 | 39.4 |
| 6 | 03.00 | 58.2 | 56.3 | 51.0 | 45.0 | 40.1 | 35.0 | 36.8 |
| 7 | 04.00 | 53.4 | 49.7 | 46.2 | 42.1 | 39.6 | 34.1 | 34.7 |
| 8 | 05.00 | 49.2 | 45.4 | 41.2 | 39.0 | 35.8 | 32.2 | 31.4 |
| 9 | Mean | 50.4 | 48.1625 | 44.425 | 40.1625 | 36.45 | 32.875 | 36.0625 |

**Table 46: Hourly Temperature Measured at Different Depth of Solar Pond (30/03/2017) (day 12)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 41.2 | 39.7 | 37.4 | 33.2 | 31.0 | 29.8 | 31.0 |
| 2 | 11.00 | 44.0 | 42.1 | 39.4 | 35.0 | 32.5 | 30.9 | 33.8 |
| 3 | 12.00 | 47.2 | 45.5 | 41.8 | 37.7 | 33.5 | 31.5 | 38.0 |
| 4 | 01.00 | 51.3 | 49.7 | 46.5 | 41.0 | 35.8 | 33.2 | 40.6 |
| 5 | 02.00 | 56.2 | 54.3 | 50.2 | 44.6 | 46.0 | 34.6 | 39.1 |

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 6 | 03.00 | 57.5 | 55.6 | 50.3 | 45.1 | 40.3 | 35.1 | 36.8 |
| 7 | 04.00 | 53.2 | 49.5 | 45.9 | 42.0 | 39.2 | 33.2 | 34.2 |
| 8 | 05.00 | 48.3 | 44.2 | 40.2 | 38.3 | 36.0 | 31.3 | 31.1 |
| 9 | Mean | 49.8625 | 47.575 | 43.9625 | 39.6125 | 36.7875 | 32.45 | 35.575 |

**Table 47: Hourly Temperature Measured at Different Depth of Solar Pond (31/03/2017) (day 13)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 41.3 | 39.6 | 37.2 | 32.5 | 30.5 | 29.8 | 31.5 |
| 2 | 11.00 | 44.2 | 42.1 | 39.5 | 36.3 | 33.3 | 30.5 | 34.2 |
| 3 | 12.00 | 47.3 | 45.6 | 41.3 | 38.0 | 34.2 | 31.6 | 37.9 |
| 4 | 01.00 | 50.2 | 48.5 | 44.2 | 40.3 | 35.6 | 32.5 | 41.3 |
| 5 | 02.00 | 55.0 | 52.7 | 48.7 | 45.0 | 38.5 | 34.0 | 40.0 |
| 6 | 03.00 | 56.8 | 53.8 | 50.0 | 45.6 | 38.8 | 34.4 | 36.9 |
| 7 | 04.00 | 52.1 | 48.7 | 45.2 | 42.1 | 36.6 | 32.8 | 34.0 |
| 8 | 05.00 | 47.0 | 42.7 | 40.1 | 38.0 | 34.1 | 30.8 | 31.2 |
| 9 | Mean | 49.2375 | 46.7125 | 43.275 | 39.725 | 35.2 | 32.05 | 35.875 |

**Table 48: Hourly Temperature Measured at Different Depth of Solar Pond (01/04/2017) (day 14)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 40.7 | 38.5 | 36..0 | 32.3 | 30.1 | 29.0 | 32.2 |
| 2 | 11.00 | 43.1 | 41.3 | 38.3 | 35.4 | 31.8 | 30.2 | 34.5 |
| 3 | 12.00 | 46.7 | 45.2 | 41.5 | 38.2 | 33.8 | 31.5 | 38.1 |
| 4 | 01.00 | 49.7 | 47.3 | 44.0 | 40.1 | 35.2 | 32.4 | 41.4 |
| 5 | 02.00 | 53.8 | 51.2 | 46.7 | 43.8 | 36.7 | 33.6 | 39.9 |
| 6 | 03.00 | 55.8 | 52.3 | 48.0 | 45.2 | 37.7 | 34.5 | 36.2 |
| 7 | 04.00 | 50.7 | 46.8 | 45.1 | 41.6 | 35.1 | 32.6 | 34.3 |
| 8 | 05.00 | 46.8 | 42.6 | 40.0 | 37.7 | 33.5 | 31.0 | 31.0 |
| 9 | Mean | 48.4125 | 45.65 | 43.37143 | 39.2875 | 34.2375 | 31.85 | 35.95 |

**Table 49: Hourly Temperature Measured at Different Depth of Solar Pond (02/04/2017) (day 15)**

| S.No. | Time | Temperature($^0$C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_{amb}$ |
| 1 | 10.00 | 39.8 | 36.8 | 33.6 | 31.1 | 29.5 | 28.8 | 31.7 |
| 2 | 11.00 | 42.5 | 38.3 | 35.2 | 32.8 | 30.1 | 29.2 | 33.8 |
| 3 | 12.00 | 45.2 | 42.1 | 39.0 | 35.3 | 32.5 | 30.8 | 37.5 |
| 4 | 01.00 | 48.1 | 45.3 | 41.5 | 38.7 | 35.1 | 32.2 | 40.6 |
| 5 | 02.00 | 51.3 | 48.3 | 44.6 | 40.8 | 37.7 | 33.5 | 39.6 |
| 6 | 03.00 | 53.7 | 50.2 | 46.0 | 42.3 | 39.3 | 34.0 | 36.0 |
| 7 | 04.00 | 50.2 | 47.6 | 43.5 | 40.0 | 37.1 | 32.8 | 34.2 |
| 8 | 05.00 | 45.3 | 42.6 | 40.1 | 37.0 | 33.1 | 30.8 | 30.8 |
| 9 | Mean | 47.0125 | 43.9 | 40.4375 | 37.25 | 34.3 | 31.5125 | 35.525 |

# Appendix B

## Solar Intensity Variation

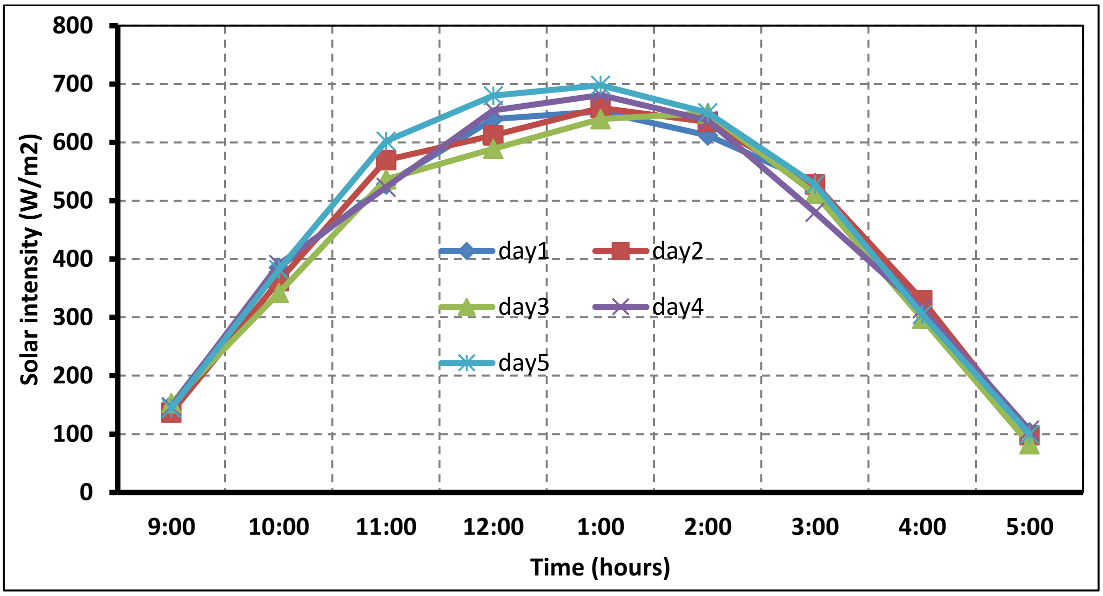


**Fig. 1.b. Solar Radiation Intensity Variation for First Five Days in First Mode (02/02/17 to 06/02/17)**

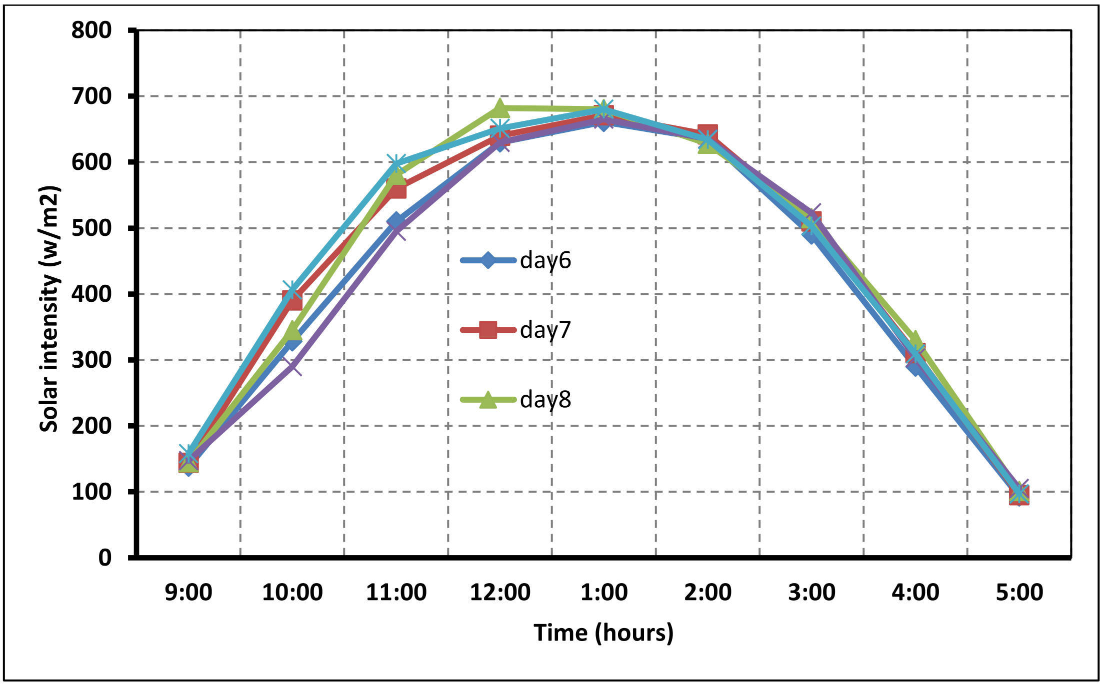


**Fig. 2.b. Solar Radiation Intensity Variation for Middle Five Days in First Mode (07/02/17 to 11/02/17)**

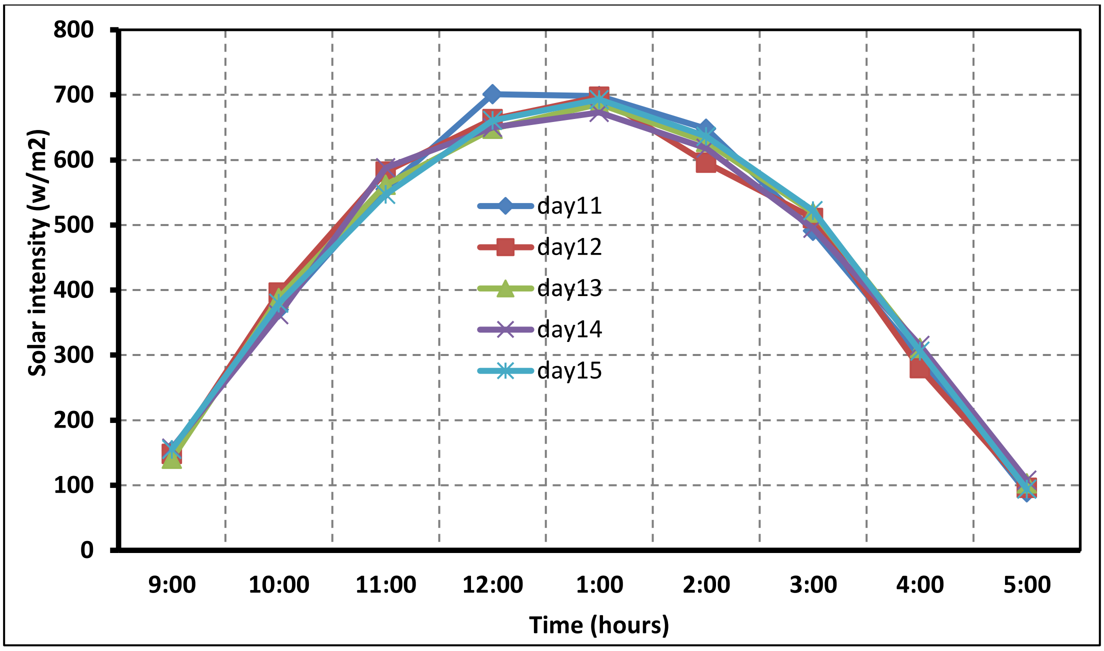


**Fig. 3.b. Solar Radiation Intensity Variation for Last Five Days in First Mode (12/02/17 to 16/02/17)**

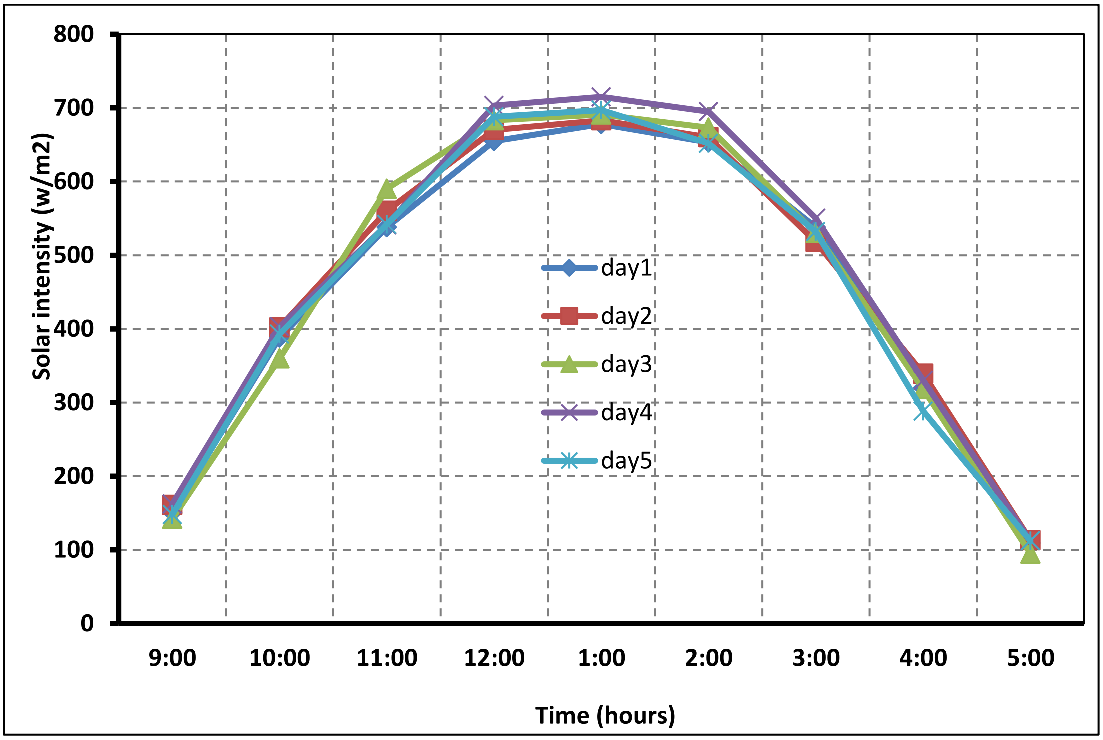


**Fig. 4.b. Solar Radiation Intensity Variation for First Five Days in Second Mode (20/02/17 to 24/02/17)**

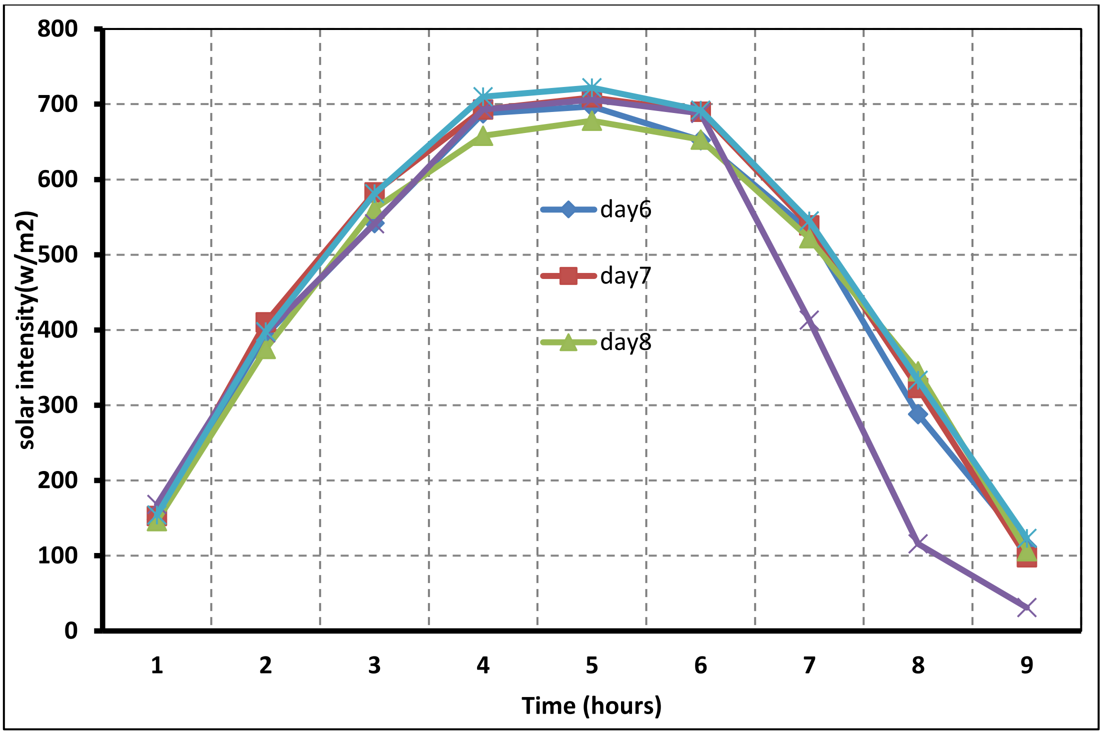


**Fig. 5.b. Solar Radiation Intensity Variation for Middle Five Days in Second Mode (25/02/17 to 01/03/17)**

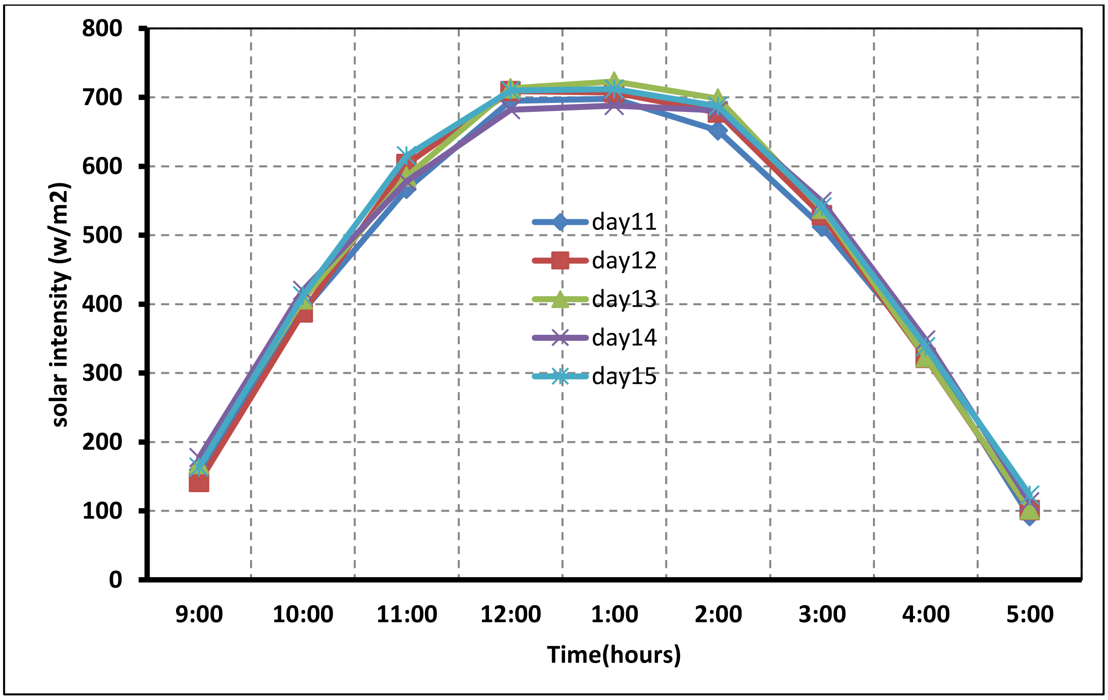


**Fig. 6.b. Solar Radiation Intensity Variation for Last Five Days in Second Mode (02/03/17 to 06/03/17)**

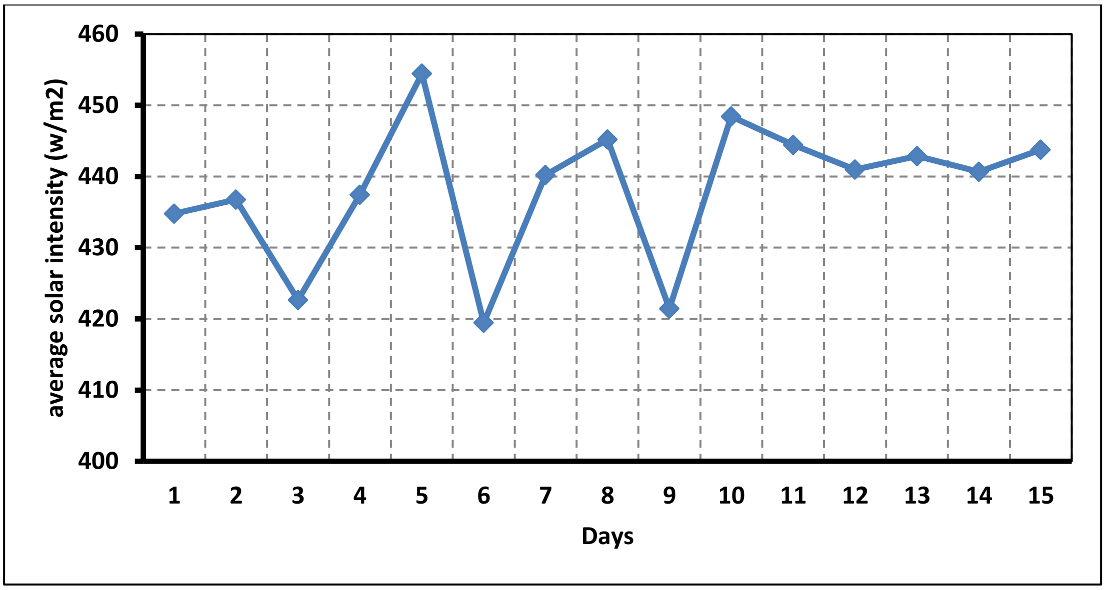


**Fig. 7.b. Means Solar Radiation Intensity Variation for without Using Glass in First Mode (02/02/17 to 16/02/17)**

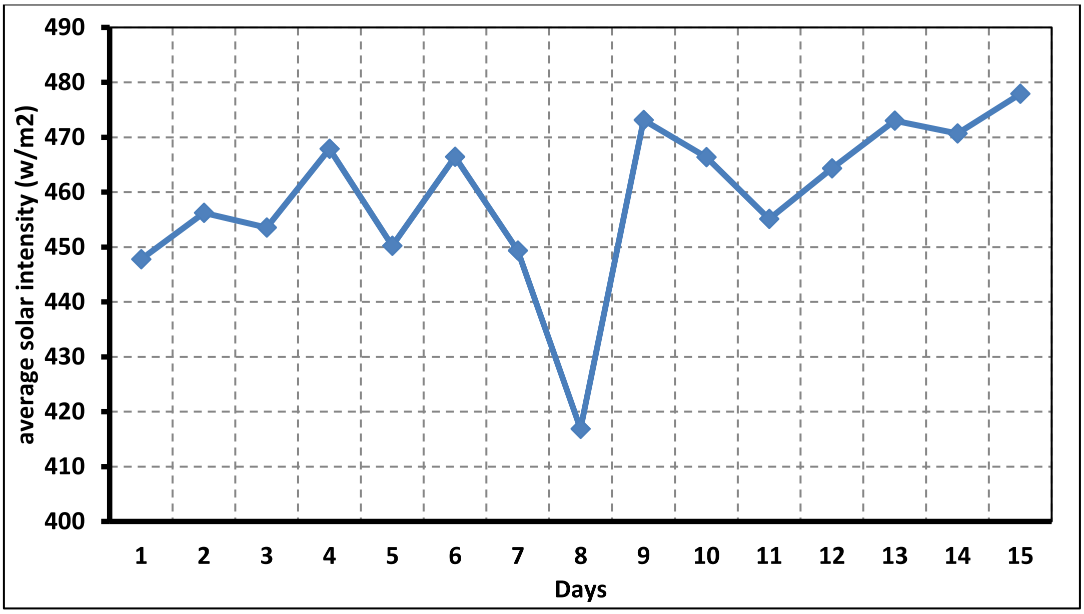


**Fig. 8.b. Means Solar Radiation Intensity Variation for with Using Glass in First Mode (02/02/17 to 16/02/17)**