



Design And Fabrication Of Thermosyphon Water Purification System

¹Mr. D.H.Pachchinar, ²Gulam Hussain Mashoqe Rabbani, ³Mohammed Sohaib, ⁴Mohd Qutubuddin, ⁵Shaik Ahmed, ⁶Shaik Wajid.

¹Assistant Professor, Lords Institute of Engineering and Technology, Hyderabad-500091, India.

^{2,3,4,5,6} students, Lords Institute of Engineering and Technology, Hyderabad-500091, India.

Abstract: As a part of our project, we are planning to fabricate Thermosyphon Water Purification System by using Thermosyphon system, solar dish and PCM to produced clean drinking water. Purification reduces the concentration of particulate matter including suspended particles, parasites, bacteria, algae, viruses, and fungi as well as reduces the concentration of a range of dissolved and particulate matter. These Thermosyphon purification system is a modification of conventional solar still but the efficiency achieved is much higher than the conventional solar still. There are 5 major components in our design consists of upper basin, lower basin, Thermosyphon system, solar dish and PCM chamber. The impure water is taken into Lower basin and upper basin, Initially the temperature of water in the lower basin is low, so to increase the temperature of the water. Thermosyphon loop system is connected with the lower basin. A solar dish is also used to increase the rate of evaporation in the upper basin the energy from the lower basin is transferred to the condensing cover and the side walls of the tank which is been wasted to surroundings will be captured by upper basin. We will be using phase changing material (PCM), which helps the purification to work on absence of sunlight. So, our basic design of the project is to increase the rate of evaporation and condensation process.

Keywords: Phase changing material (PCM), Thermosyphon, Filtration, Natural Adsorbents and solar dish.

I. Introduction

Solar energy has been identified as one of the excellent and sustainable alternate energy sources for the future. It is necessary to develop an efficient solar water heating system for economical usage. Drinking water is a high priority for quality of life. Water resources are coming under increasing pressure due to population growth, wastage, and overuse. Water purification is an important part of civilization. The history of water purification is very old. People knew that water could be purified with heat, and they practiced sand and gravel filtration, boiling, and straining. Their primary motivation in doing this was to make water taste better, as they couldn't yet distinguish between water that's clean and water that's foul. They knew to try to reduce

the turbidity of the water, but didn't know much about chemical contamination or microorganisms. Then, in 1854, there was another breakthrough: researchers discovered that an epidemic of cholera spread through water, and that the outbreak had been less intense in areas that had sand filters. John Snow discovered it was caused by sewage water contaminating the water pump, and used chlorine to purify it. This helped establish the practice of water disinfection and chlorination.

1.1. Filtration Techniques.

Filtration, the technique used to separate solids from liquids, is the act of pouring a mixture onto a membrane filter paper that allows the passage of liquid the filtrate and results in the collection of the solid.

There are several types of water filtration techniques are available in the market namely,

1. Reverse Osmosis (RO) Systems
2. Activated Carbon Filters
3. Ultraviolet (UV) Water Purification Systems
4. Distillation Systems
5. Ion Exchange Systems
6. Ceramic Filters
7. Ozone Water Purification System

1.1.1. Distillation

Water has a lower boiling point than the contaminants and minerals within it. This means that if you boil untreated water, the water will turn into vapor and leave everything else behind. Then the condenser lets the steam return to liquid water in a separate area from where it started. This is the concept behind purifying water through distillation. Water distillation is a water purification process that uses a heat source to vaporize water and separate it from the contaminants within. Most frequently, the undesirable elements are what you find naturally in ground or surface water.

1.1.2. Solar Distillation

Solar distillation is a process in which the energy of the sun is directly used to evaporate freshwater from sea or brackish water. The process has been used for many years, usually for small scale applications. The advantage of solar water distiller is that it runs on the energy of the sun, rather than needing an external power source. Since solar stills use the heat of the sun directly and do not employ solar cells to generate electricity, the overall cost of a solar still is relatively low. Moisture inside the distil chamber evaporates due to the sun's heat and condenses upon cooling down. When the water vapour condenses, it forms water droplets that get collected and can be used for drinking. The salts or minerals in the water do not evaporate with the water. Hence, the contaminants are left behind, while only the water gets extracted from the solution.

1.1.3. Thermosyphon system

Thermosyphon system work on the principal of heat rising. In an open loop system, potable water enters the bottom of the collector and rises to the tank as it warms. In colder climates, an antifreeze solution, such as propylene glycol, is used in the closed solar loop, and freeze tolerant piping, such as cross linked Polyethylene(PEX), is used for the potable water lines in the attic and on the roof. Several international manufacturers make thermosyphon systems. The advantage of this system over the batch heater is that solar

heat is stored in a well-insulated tank, so hot water can be used any time, without the penalty of overnight losses.

1.1.4. PCM (Phase change material)

PCM stands for Phase Change Material, which is a substance that is capable of storing and releasing large amounts of thermal energy through the process of changing its physical state. PCM is commonly used in applications that require temperature control, such as in building insulation, electronics cooling, and thermal energy storage systems. The most common type of PCM is a solid liquid material that can absorb and release heat energy as it melts and solidifies. For example, a PCM used in building insulation can absorb heat during the day when the building is exposed to sunlight, and then release the heat at night when the temperature drops. This can help to reduce the amount of energy needed to heat or cool the building, resulting in energy savings and reduced greenhouse gas emissions.

II. LITERATURE REVIEW

The main purpose of this literature review is to summarize the earlier works on the water purification system and to address the drawbacks of the earlier works.

Bill B. Wang et.al (2021) (1) has Research on drinking water purification technologies for household use by reducing total dissolved solids (TDS). He has concluded that by heating water to around 50°C (122°F), TDS and water hardness will decrease the most. Also, the boiling process is effective in killing microorganisms and removing contaminants. This process cannot surpass 10 minutes, as the concentration of the ions in the water is too high, which poses human health risks if consumed. These, along with activated carbon and NaHCO₃ additives, are inefficient methods that have minimal effects for lowering TDS and Electrolysis is one of the most effective methods of eliminating TDS.

Mohammed Hamed Alhamdo et.al (2021) (2) was researched on Investigative study of thermal performance of thermosyphon solar collector, the water temperature within the tank and operating liquid temperature within the entrance and exit of absorbable pipe respectively, It is found that all developed models under study have greater thermal performance than conventional model. This performance improvement is clearly notice through the increase of the operating liquid temperature in thermosyphon and water temperature within the tank respectively.

Marcia Barbosa Henriques Mantelli et.al (2020) (3) was researched on Design of Thermosyphons and Heat Pipes. He has concluded that Heat pipes and thermosyphons are highly efficient heat transfer devices that use two-phase cycles of fluids as the operating principle.

Lagouge Tartibu et.al (2020) (4) has done research on Development of solar-powered water purification systems and have developed several concepts on solar powered water purification system. The first concept was developed based on the solar water distillation method. The proposed design incorporates some features such as heating coils, a manual water pump, a stepper motor, a double water tank, a filtering conveyor, batteries, a battery casing, and an inlet water faucet. The second concept was developed based on the parabolic dish. The main features incorporated in the development of this design concept includes an electronic water pump, an inlet water tank, a clear perspex plastic cover, a boiler container, and piping systems. The third concept was built based on the method of solar water purification by distillation and the

heating coils solar water purification system. The main features incorporated in the development of this design concept include heating coil, rotating flat solar panel, perspex plastic cover, batteries, and mild steel support structure.

Kirellos Emad Samir et.al (2020) (5) has studied Gray Water Treatment Using Solar Powered Thermosyphon Rankine Cycle and concluded that the purpose of his study is to investigate the performance of a two-phase closed thermosyphon Rankine engine, experimentally. Water is used as a working fluid. The present experimental work investigated the effects of the filling ratio total nozzle exit area to the turbine inlet area and condenser cooling water flow rate. The output power increases within creasing of condenser cooling water flow rate. The maximum output power produced at minimum area ratio but the optimum turbine rotational speed at an are a ratio of 3.1%. The maximum value of the output power without load from the present turbine.

Mohammad Behshad Shafii et.al (2020) (6) have done research on Distilled water production with combination of solar still and thermosyphon heat pipe heat exchanged coupled with indirect water bath heater and concluded that the IWBH, heat the gas in the natural gas pressure reduction stations. The distilled water is employed as the intermediate fluid to transfer heat from the heat source to the gas. The production of distilled water, thermal efficiency and energy efficiency of solar still in the passive type were corresponding to the solar intensity and the ambient temperature. But, inactive type, other factors also involved.

Shabiimam M. A et.al (2018) (7) has review on Treatment of Water Using Various Filtration in this review study is to discuss about the various filtration techniques available. Natural substitutes used as a filtering medium which are less expensive or which may be a byproduct of any agricultural or manufacturing process. Ratnesh kumar Sharma et.al (2018) (8) has studied the Solar Water Purification Using Evacuated Tubes and concluded that the Single slope desalination unit is setup with Evacuated tubes which helped in increased water temperature inside the basin through thermosyphon principle. The Major finding of their work is evacuated tubes helps in increasing the water temperature inside the basin and direction insertion of tubes in basin helped in the conservation of heat loss and the productivity can be improved by making a double slope solar still.

Sasa Pavlovica et.al (2017) (9) has Studied on Experimental investigation and parametric analysis of a solar thermal dish collector with spiral absorber. Solar tracking dish collectors are able to produce heat at high temperatures. Important considerations for solar collectors are manufacturing costs, complexity, efficiency, uniform flux distribution and working fluid selection. In this work, a simple, low-cost solar collector with dish reflector and spiral absorber was investigated experimentally and numerically.

Abid et.al (2017) (10) compared a solar dish collector with a parabolic through collector and the final results proved that the dish technology performs better.

Amin Mohammadi and Mehrpooya (2016) (11) investigated an integrated micro gas turbine with solar dish collectors to be used between the gas preheater and the combustion chamber. According to the final results, a high exergetic performance was achieved because the solar energy led to lower fuel consumption.

A. Kalogirou et.al (2009) (12) has researched on Thermosyphon Design and Concluded that thermosyphon systems typically employ one of two types of solar collectors, flat plate collectors or evacuated tubes. Early on in the project, they decided that a flat plate collector was the better option of the two for our purposes,

due to its simpler design, lower cost, and easier installation. A flat plate collector typically consists of a black absorber contained in a weatherproof box glazed on the front and insulated on the back. Inside this box is a network of tubes through which the water flows.

B. Klaus et.al (2008)(13) has reported on natural water purification and water management by artificial ground water recharge and he has concluded that compared with other methods of water treatment, artificial ground water recharge is ecologically sustainable and cheaper than chemically induced coagulation, ozone floe filtration, the application of reverse osmosis, ultraviolet beams, ultra-filtration, or activated charcoal. Artificial groundwater recharge has proved very successful at many sites in Germany over a period of more than 100 years.

2.1. Objective of the Project

1. The main object of the project is to reduce the water purification time. 2. The object of the project to run the system without any external Conventional energy sources such as electricity, gas, petroleum. 3. To avoid change in properties of a material. A sincere attempt is made to accomplish almost all objectives as mentioned above and make it practically feasible. 4. To increase the rate of evaporation. 5. To increase the rate of condensation of a system by using Phase changing material . 6. It must be low in cost and commercially viable for all people. 7. Increase rate of delivery at the outlet and 8. To get Low PPM water gets at the outlet.

III. DESIGN

Modelling of Thermosyphon purification system. We have opted SOLIDWORKS V22 Design software for 3DmodellingofThermosyphon water purification. We have drawn a Rectangular box of size600mm*457mm*660mm length, width, and height respectively. Then we have divided the basin into two parts. After that we have drawn inclined condensing cover on the upper part of the basin and also for the lower part of the basin.

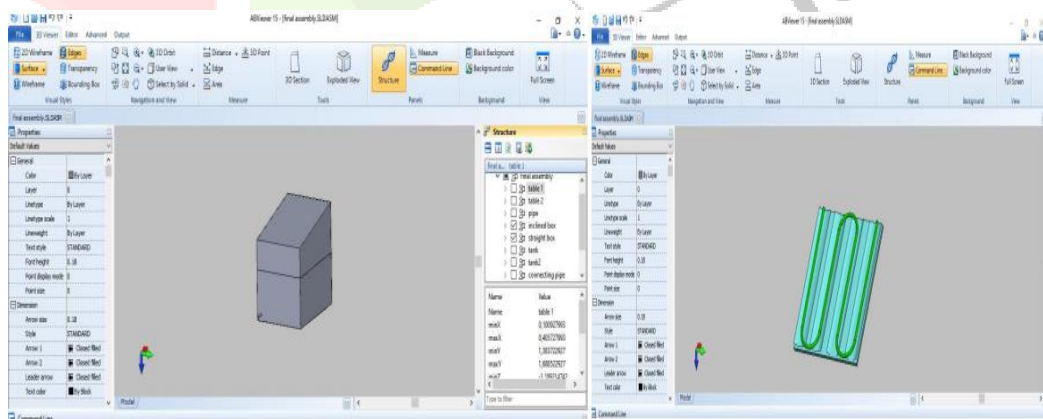


Fig.3.1. Basin and Thermosyphon system

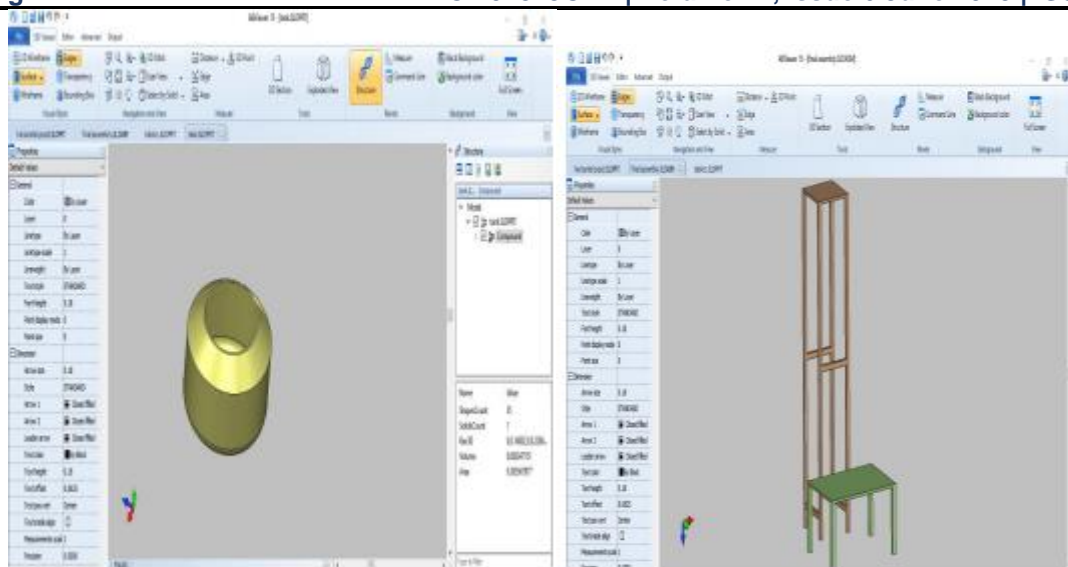


Fig. 3.2. Water Supply & Collection tank

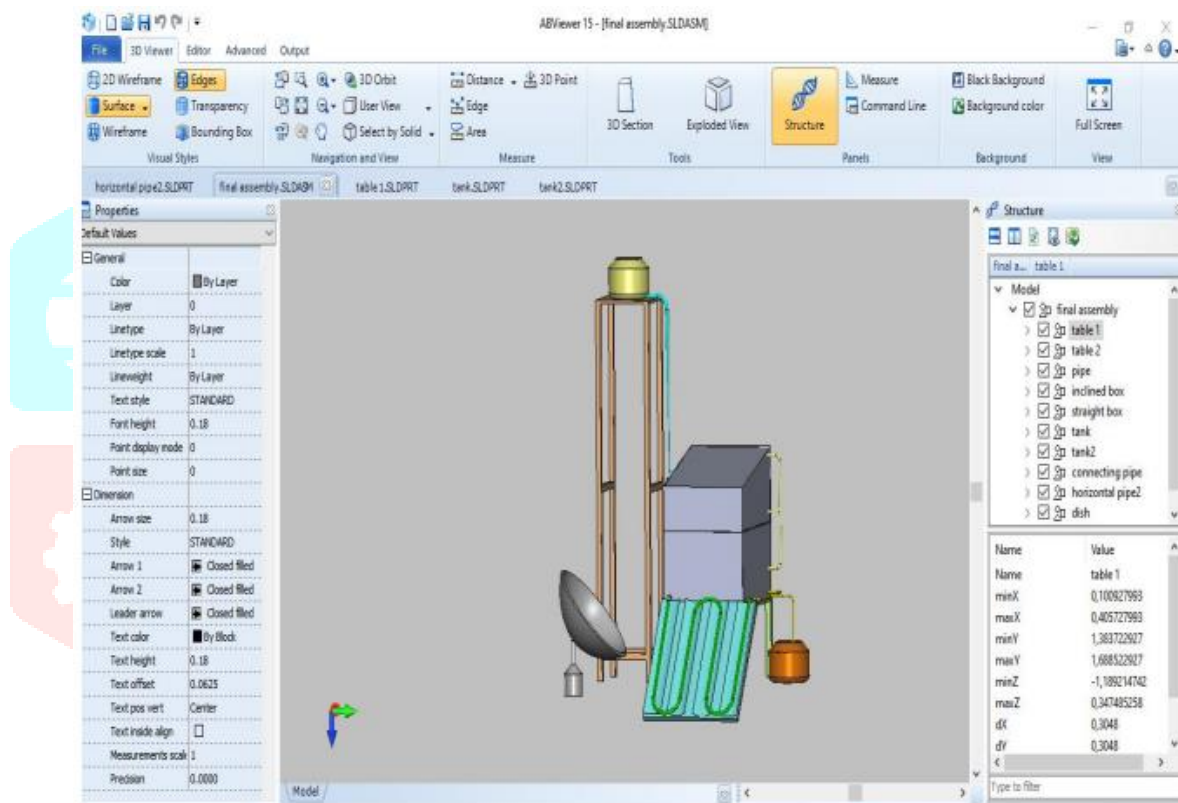


Fig.3.3. Assembled Drawing

IV. METHODOLOGY

The Thermosyphon water purification works on the principle of solar distillation. The sun's energy heats water to the point of evaporation. As the water evaporates, water vapor rises, condensing on the glass surface for collection. Saline water is filled in the black painted lower basin and upper basin. This is enclosed in a completely air-tight surface. A sloping transparent cover is provided at the top. Then solar radiations are allowed to fall on it. Solar radiation is transmitted through the cover and is absorbed in the black lining. The solar radiation falls on the upper basin which increases the temperature of water and evaporation takes place. Water from the lower basin enters the copper loop. The thermosyphon loop is designed so that efficient amount of solar radiations are focused on the copper pipe and the water in the copper loop get heated. This increases the internal temperature of the copper loop causing the saline water to evaporate leaving behind all

the salt contents, insecticides, herbicides, bacteria, viruses, etc. We are also using a solar dish concentrator to evaporate the water in upper basin it increases the rate of evaporation and increases amount of water purified. The resulting vapour rises and condenses as pure water on the underside of the cover and is collected in the condensate channel due to the inclination provided to the glass covers. Finally, freshwater is obtained.

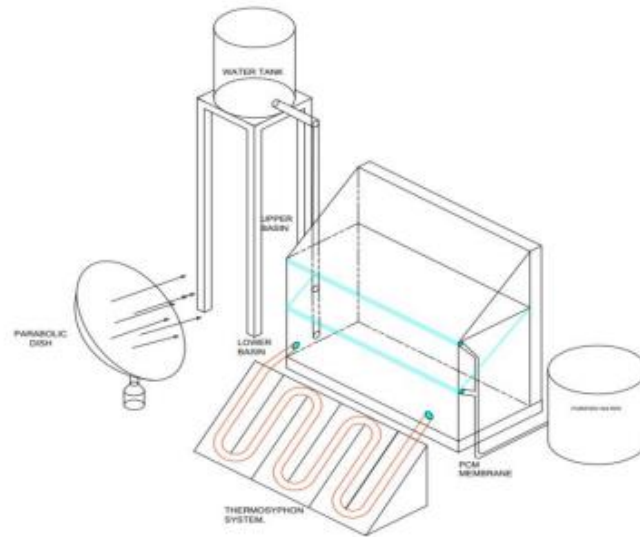


Fig.4.1. Line diagram of Thermosyphon water purifier

4.1. Component Description

4.1.1. List of components

1. Basin
2. Transparent Cover
3. Thermosyphon Loop
4. PCM Chamber
5. Solar dish collector
6. Supply And Delivery System
7. Sealant

4.2. Fabrication of Thermosyphon Water Purification System

4.2.1. Fabrication of basin support structure

To start the fabrication an angular of 1inch width and thickness 2mm is selected as the material for support. Then the desired length of 2 feet is measured using a measuring tape and marked on the angular using a marker. This step is done to ensure that the length is cut correctly and to ensure the accuracy of final product. After the pipe is marked then it can be cut using angel grinder. In this step it is necessary take safety precaution to minimize the risk of injury. once safety precaution are done then the angle grinder is used to cut the desired length of angular. Total six lengths of same size of 2 feet are cut.

The above process is employed to cut the four lengths of 2feet and 2inch and 6 length of 1.5 feet. The proper marking and measuring tool are used to ensure the accuracy of the structure. The grinding is done to edges to remove the unwanted material.

4.2.2. Fabrication of stands for basin and water tank

To make the stand for water tank same procedure used as above and same mild steel square pipe is used, But instead of cutting 1 feet length 5 feet length is cut and for upper base 1feet pipes are cut. After cutting the square pipes are assembled and welded using arc welding. After which the grinding is done to smooth the sharp edges.

4.2.3. Fabrication of thermosyphon loop

Then a cooper pipe which is bend in loops is fitted in to holes provided in the basin front glass. The copper pipe is supported using rods supports at the bottom of the stand

4.2.4. Fabrication of PCM Chamber

The PCM chamber is made using aluminium sheets. First the aluminium sheet is marked with required dimensions using tape and marker. Then the sheet is cut using sniper and then bend using vice and clamp or metal bracket. If there is a need of joining the ends they joined using fasteners. After that it is filled with paraffin wax which is a PCM matrial. This PCM chamber is placed below the basin.

V. Results and Discussion

Hourly variation of Upper basin water temperature and Lower basin water temperature It has been observed that temperature is maximum around 11 a.m to 2p.m. Hourly variation values of basin water the temperature. The maximum value of temperature attained is at around 12 p.m which are 89°C & 75°C for Upper basin water temperature and Lower basin water temperature respectively. It was found that maximum yield was obtained during the period of the high-temperature of the basin water. There is maximum temperature in the lower basin as it is attached to the thermosyphon system. The water from the inlet of the basin is initially at low temperature but the water moves through the hole provided in the lower side and follows the loop. Therefore, extra energy is transferred to the lower basin water. The condensing cover in the upper basin is an aluminum sheet due to which heat conduction is good resulting in the transfer of heat from the lower basin to the upper basin. The majority of temperature in the upper basin mainly depends upon direct heat received from sunlight and some heat received from the lower basin. These result in the lower temperature of the upper basin when compared to the lower basin. Glass temperature is another main parameter, which affects the performance of the solar still. The rate of evaporation increased with reduction of glass temperature. The rate of evaporation of water from a water surface will be higher than the rate of release of heat from the glass cover to ambient by convection and radiation processes. If the heat loss from glass cover to ambient can be increased and that heat loss is used for further distillation, then overall efficiency of the distillation unit under active modes of operation can be increased significantly, as in the case of double basin solar still. This can be obtained by flowing the water over the glass cover for fast heat transfer through the lower glass cover and then condensing the evaporated water from the upper glass cover as distillate.

5.1. The effect of double basin coupled with thermosyphon:

1. The temperature of the water in the lower basin is increased in comparison with single basin effect distillation due to the reduced heat losses.
2. The hourly output in the lower basin is reduced due to the reduced temperature difference between the water and glass temperatures. However, the overall output is increased due to re utilization of the latent heat of evaporation in the second effect.
3. Hourly variation of distillate output (Yield) in Litre/m². It is observed that the maximum yield is obtained during 11 a.m to 1p.m as shown in fig.5.2. The maximum yield achieved is 2.26 litres/m² /hour and the total yield achieved is 13.66 litres/m² /day. The efficiency of the model is also increased due to attachment of thermosyphon system, PCM, and solar dish.

Table 1. Temperature Readings

Time (Hr)	Ambient temperature 'T _a '	Temp. Of water in upper basin 'T _{wu} '	Temp. Of water in lower basin 'T _{wl} '
7 a.m	26	26	39
8 a.m	29	38	53
9 a.m	31	44	68
10 a.m	33	52	78
11 a.m	35	68	87
12 p.m	39	75	89
1 p.m	40	72	85
2 p.m	39	64	78
3 p.m	36	59	76
4 p.m	33	52	63
5 p.m	30	43	54
6 p.m	28	38	46
7 p.m	27	33	42

5.2. Observations

Thermosyphon solar still purifier productivity : 13.66 lt/m² /Day

- 1) Purity: Recommended TDS (for drinking purpose) : < 500 ppm
- 2) TDS: Around 130-160 ppm.

VI. CONCLUSIONS

In conclusion, the project for a thermosyphon water purification system utilizing phase change material presents a promising solution for addressing the urgent need for clean drinking water in regions where freshwater is scarce and saltwater is abundant. The use of PCM as a heat storage material provides numerous advantages, including improved energy efficiency, reduced heat loss, and extended heat retention. The project has demonstrated the technical feasibility and economic viability of the system through extensive simulations and experiments, validating the proposed design. After development, the project has achieved successful implementation of the thermosyphon water purification system using PCM, providing a sustainable and cost-effective solution for water desalination. However, the project has also identified several practical challenges, such as material selection, system integration, and maintenance requirements, which must be addressed to ensure the long-term reliability and durability of the system. Overall, the project has made significant progress in developing a practical and scalable solution for water scarcity challenges, highlighting the potential of the thermosyphon water purification system using PCM to address global water crises. Further research and development are necessary to refine the system and optimize its performance, but the project provides a solid foundation for future innovation and implementation.

REFERENCES

- 1) Drinking water purification technologies for household use by reducing total dissolved solids(TDS), Redlands East Valley High School, Redlands, California, United States of America PLoS ONE 16(9):e0257865 DOI:10.1371/journal.pone.0257865 License CCBY4.0 September 2021.
- 2) Investigative study of thermal performance of thermosyphon solar collector, Journal of Engineering and Sustainable Development 25(2):46-57 DOI:10.31272/jeasd.25.2.6LicenseCC BY 4.0 March 2021.
- 3) Design of Thermosyphons and Heat Pipes, Marcia Barbosa Henriques Mantelli Department of Mechanical Engineering, Federal University of Santa Catarina, Florianopolis, Santa Catarina, Brazil.2020.
- 4) Development of solar-powered water purification systems and have developed several concepts on solar powered water purification system Conference: 9th International Conference on Appropriate Technology At: Tshwane University of Technology, Pretoria 2020.
- 5) Gray Water Treatment Using Solar Powered Thermosyphon Rankine Cycle Kirellos, International Undergraduate Research Conference, Military Technical College. iugrc. journals article 246552.Emad Samir, 2020
- 6) Distilled water production with combination of solar still and thermosyphon heat pipe heat exchanger coupled with indirect water bath heater – Experimental study and thermoeconomic analysis M. Beshad May 2020Applied Thermal Engineering 176DOI:10.1016/j.applthermaleng.2020.115437
- 7) Treatment of Water Using Various Filtration Techniques , Shabiimam M. A, TehsinKazi , Poshekar Anas and Sakharkar Shifa ,Assistant Professor, Civil Engineering, Anjuman.I Islams. Kalsekar Technical Campus, Panvel, Mumbai .November 2018.

- 8) Solar Water Purification Using Evacuated Tubes Ratnesh kumar Sharma, Dheeraj Dahiya*, Govind Kumar, Dinesh Meena, Department of Mechanical Engineering, Poornima Group of Institutions, Jaipur, 2018.
- 9) Experimental investigation and parametric analysis of a solar thermal dish collector, SasaPavlovica , Evangelos Bellosb , Willem G. Le Rouxc, Department of Thermal Engineering, National Technical University of Athens, Zografou, Heroon Polytechniou, 15780 Athens, Greece. Article in Applied Thermal Engineering April 2017.
- 10) A solar dish collector with a parabolic through collector, Abid,2017.
- 11) Exergy analysis and optimization of an integrated micro gas turbine, compressed air energy storage and solar dish collector process, Renewable Energies and Environment Department, Faculty of New Sciences and Technologies, University of Tehran, Tehran, Iran, Journal of Cleaner Production Volume 139, 15 December 2016.
- 12) Thermosyphon Design and Concluded that thermosyphon systems typically employ two types of solar collectors, flat plate collectors or evacuated tubes in Solar Energy Engineering Soteris A. Kalogirou2009.
- 13) Natural water purification and water management by artificial ground water recharge, Klaus Journal of Zhejiang University SCIENCE B 9(3):221-6 DOI:10.1631/jzus.B0710635, April 2008.

