

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 13, December 2015

Performance Test on Solar Still for Various TDS Water and Phase Change Materials

K.Palpandi¹ R.Prem Raj²

¹Assistant Professor, Dept. of Mechanical Engineering, Sasurie College of Engineering, Tirupur, Tamilnadu, India,

¹Assistant Professor, Dept. of Mechanical Engineering, Sasurie College of Engineering, Tirupur, Tamilnadu, India,

ABSTRACT: Objective of this study is to evaluate the performance improvement of single basin type solar still using different TDS (Total dissolved salts) water and change in absorbing materials with phase change material. In this project a solar still (single basin) which can be used for water desalination has been designed. The basin area required for the production of 5.5 liters per day of fresh water was determined as 2.47m² and black chromium paint for absorbing solar radiation to increasing the evaporation of water and the top cover glass was calculated using the formulae. 2D drawing of the slope type solar still with 24⁰ tilt angle was created for the required basin area. Theoretical analysis was carried out to calculate the incident and useful solar radiation of the location (TIRUNELVELI) tilt angle and the performance improvement of the solar stills. The effect of solar still study was carried out by using phase change material and thus enhance the productivity of water. The phase change material store the solar energy which can also be used during night time for desalination. The selected PCM is palmitic acid, because the melting temperature of palmitic acid is 60⁰C. The experimental setup was fabricated and test was conducted using sea water and bore well water to compare which water has highest yield and higher efficiency.

KEYWORDS: Solar desalination; Single basin solar still; Absorbing materials; Design modification; TDS water; Phase change materials; Productivity

1. INTRODUCTION

Fresh water shortage has become an international concern for remote zones. This shortage has led to disease and death. 79% of the global water content is salty, whereas 20% is brackish and leave us with the rest for the whole world to consume[1]. The remedy for this shortage leaves us with alternate techniques such as solar distillation process and so on. Passive solar distillation uses solar radiation as the only resource in purifying the water, whereas in active solar distillation, it includes the employ of fans, pumps, sun collectors etc. for enhancing the productivity. Even though the use of solar distillation has an efficiency of 30-40% due to the loss of heat during condensation, it's the most effective method in non-conventional water purifications[2]. It consists of wick type solar still instead of a basin. That still is produced pure water from impure water by absorbed solar energy in water which get evaporated and condensed on top of glass roof [3]. Water is stored in a specifically designed container with a glass roof top. Sun rays were allowed to incident on the still. The surface of the still is blackened to increase the heat absorption. This absorption led to the change in moisture content between the surface and the still. Due to this, evaporation occurs inside the surface, which is restricted by the glass rooftop. Salts were settled in the leftover water of basin. Special collection method is used to contain the condensed water in the glass rooftop. Fresh water is can be produced from salt water by using thermal storage energy. The water vapour is separated from brackish water and later it is condensed and stored in separated chamber [4]. Carry out the various absorbing materials of black gravel and coated and uncoated materials of metallic wiry sponge to improve productivity also charcoal particles for reducing heat loss from solar still [5]. Extensive review on use of different solar still for solar desalination systems. A survey of various modification of reflecting

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 13, December 2015

mirrors on inside solar still and step wise solar still with sun tracking system to increase solar still capacity hence capture more solar energy [6].

The solar still used with rubber materials to improve absorption, heat storage and evaporation effect was analysed. The depth of basin water were varying to increase productivity of solar still [7]. Experimentally studied the solar still coupled with a solar water heater to increase saline water temperature and using aluminium absorber plate to high amount of heat absorbed from sun rays [8]. Designed the new conventional solar still within solar collector, external reflector and sun tracking system used to receive large solar insolation with vacuum technique and other novel particles on the solar stills [9-11]. Attempted to find out the effect of single basin solar still with PCM as a storage medium that to be during night time [12-15]. Developed solar desalination system involved the heat storage medium and heat recovery system (roof heat) with black die of absorbing material to improve productivity [16-17].

In conventional basin type solar still, the still consists of a shallow basin lined with a black, impervious material, which contains saline water (or) bore water inside of the still. Solar radiation received at the surface is absorbed effectively by the black surface and heat is transferred to the water in the basin. Temperature of the water increases and it increases the rate of evaporation. A sloping transparent cover is provided at the top. Water vapour produced by evaporation rises upward and condenses on the inner surface of the glass cover which is relatively cold. Condensed water vapour trickles down into the trough and from there it is collected in the storage container as distilled water [17].

II. EXPERIMENTATION

Single basin type solar still was designed and fabricated to evaluate the performance without and with the phase change material. Basin area of the conventional solar still 1m^2 . High side wall depth is 0.65m and the low side wall depth is 0.2m. The solar still is made of 2mm thickness Aluminium sheet and the whole basin surface is coated with black chromium paint to increase the absorptive of solar radiation. The bottom and side wall of the basin were insulated by 10mm thickness thermocol. To collect the distillate output, a trough made of plastic is connected at low side of basin. PVC pipes were connected to the trough to drain the distilled water to external calibrated measuring jar. The top glass cover is made of 4mm acrylic sheet and inclined at 24°C . Outer casing of the solar still provided with plywood to protect the other components of the solar still.

A vertical gap beneath the horizontal portion of the basin liner is provided to upload or unload the PCM through a pipe which takes care of the volumetric expansion of the melting PCM as well. The operational and melting temperature of PCM, in fact, governs the applicability of the different type of PCMs. The palmitic acid relates to the class of fatty acids that have superior properties, such as melting congruency, better chemical stability, non-toxicity and better thermal reliability over many other PCM. The water evaporates and condenses on the inner sided of the glass plate after releasing the latent heat. During the sunshine, when the absorber temperature is higher than the temperature of PCM, the heat is transferred to PCM and charging process is started to store solar energy as a sensible heat till PCM reaches its melting temperature. Additional charging heat is stored as the latent heat during the melting process. When the absorber temperature is lower than PCM (after sunset), reverse process is occurred till the PCM layer is fully solidified.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 13, December 2015

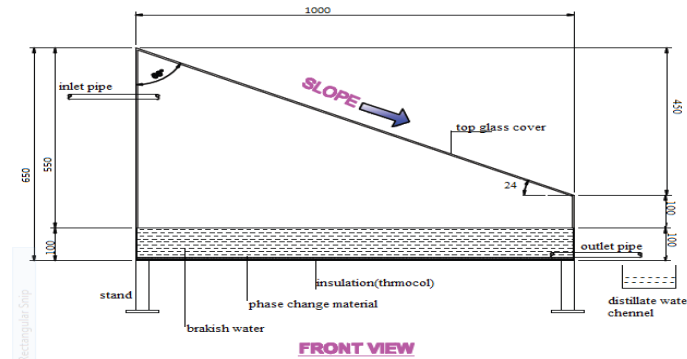


Fig 2.1 2D model of solar still

The Figure 2.1 shows the 2D drawing of single basin solar still on front view by Auto CAD software for detailed of experimentation. Length and width of the solar still is 1000 mm, longer height is 650 mm, lower height is 200 mm, thickness of the PCM layer is 2 mm, and insulation of themocol sheet layer is 4 mm. which is used to fabrication purpose.

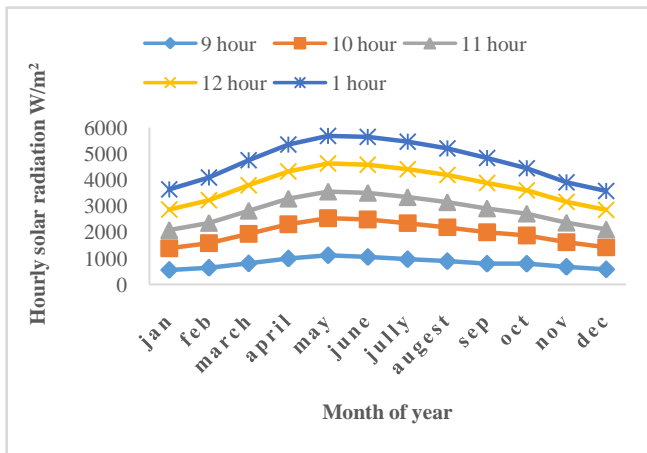


Figure 2.2 Theoretical solar intensity of slope type solar still

In the Figure 5.1 shows the variation of solar intensity based on months. The solar intensity is gradually increase with decrease when various months.

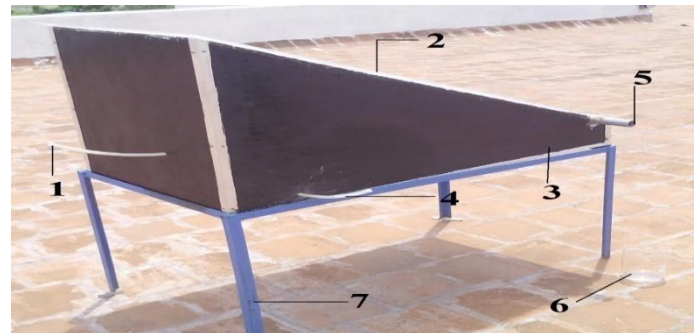


Fig 2.3 Experimental setup

The Fig 2.3 shows the photographic view of the experimental setup. The components of the experimental setup includes the following (1) Salt water inlet, (2) Acrylic glass cover, (3) Black chromium paint, (4) PCM inlet valve, (5) Distilled water outlet, (6) collecting tank, (7) stand.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 13, December 2015

2.1 EXPERIMENTAL PROCEDURE

- Salt water is allowed to pass to the setup through the inlet valve.
- The PCM is loaded to the PCM chamber through the charging valve.
- Allow the absorber plate to collect the solar radiation.
- Measure the temperature of the absorber plate, water and phase change material.
- The temperature was noted using temperature sensor.
- Also the quantity of distilled water was measured. The readings were noted for a time interval of 1 hour.
- Distillate water was tested in TWAD BORD for drinking purpose.

III.RESULT AND DISCUSSION

The theoretical analysis of solar still is done and following various geometrical Parameters was done and following results were obtained. The Black chromium paint and PCM is used in solar still. Variation in efficiency with and without PCM bottom layer of solar still. The different TDS of bore and sea water used in solar still for comparison of hourly distillate water.

3.1 Theoretical results

The hourly incident solar radiation and useful solar incident radiation on the single basin slope type solar still was theoretically calculated. It depends on the cover tilt angle, latitude of the location, hour angle and declination for the all climatic conditions of TIRUNELVELI, India.

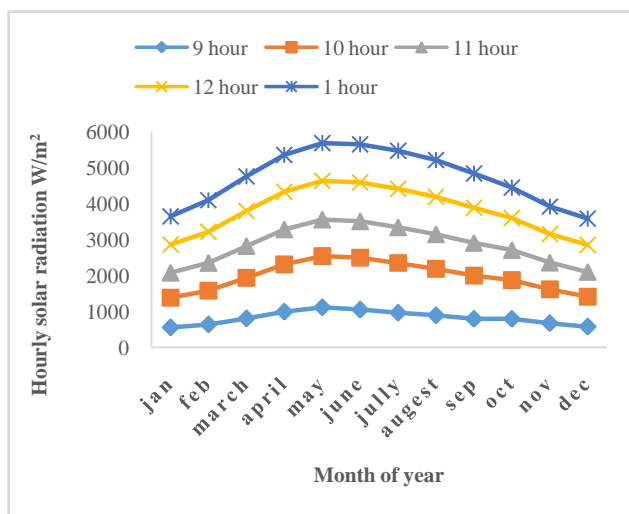


Fig 3.1 Theoretical solar intensity of slope type solar still

In the Fig 3.1 shows the variation of solar intensity based on months. The solar intensity is gradually increase with decrease when various months.

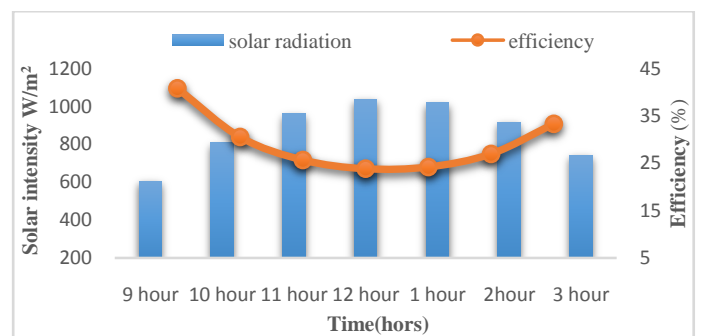


Fig 3.2 Theoretical efficiency of single slope type solar still

Figure 3.2 represent the daily efficiency of the solar still with respect to the daily useful solar radiation. Theoretical efficiency variation for the number of hours are shown in the graph. On 9th hour theoretical efficiency is 40% and for the 3rd hour theoretical efficiency is 33%.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 13, December 2015

3.2 Experimental results

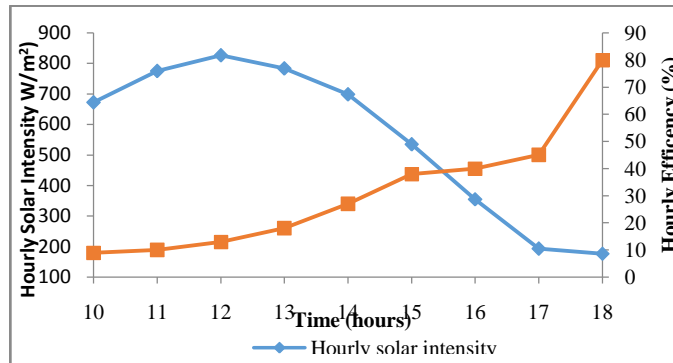


Fig 3.3 Hourly efficiency of bore water in solar still

Figure 3.3 explains about the hourly efficiency of bore water in the solar still without PCM and the hourly solar radiation with respect to the time. The efficiency of bore water was 27.24%. The cumulative distillate production was 2050ml for the experimentation time 9 hours.

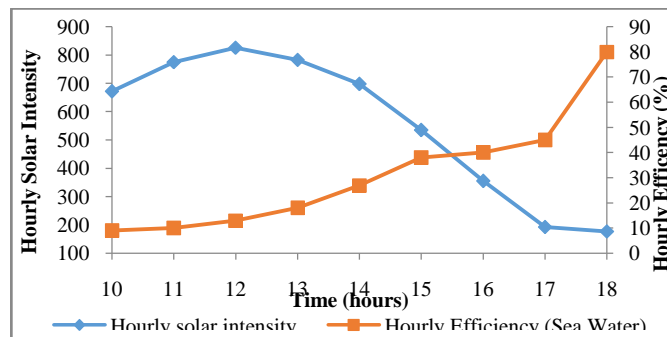


Figure 3.4 Hourly efficiency of sea water in solar still without PCM

Figure 3.4 explains about the hourly efficiency of the sea water in solar still without PCM and the hourly solar radiation with respect to the time. The efficiency of sea water was 24.64%. The cumulative distillate production was 1870ml for the experimentation time of 9 hours.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 13, December 2015

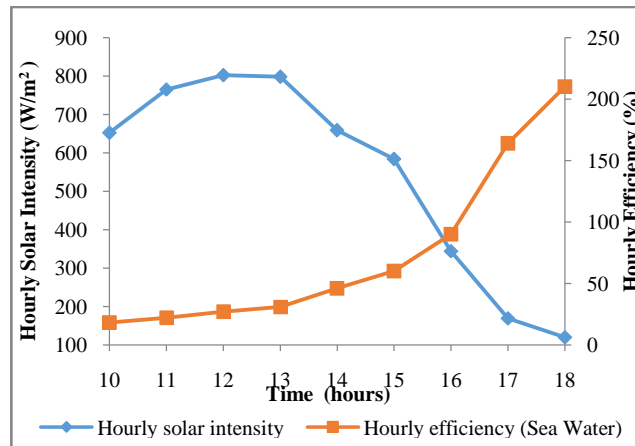


Figure 3.5 Hourly efficiency of sea water in solar still with PCM

The hourly efficiency of sea water in solar still with PCM and the hourly solar intensity with respect to time is shown in the figure 3.4. The efficiency of sea water with PCM for experimentation time of 9 hours is 37.15% and cumulative distillate yield was 3400ml.

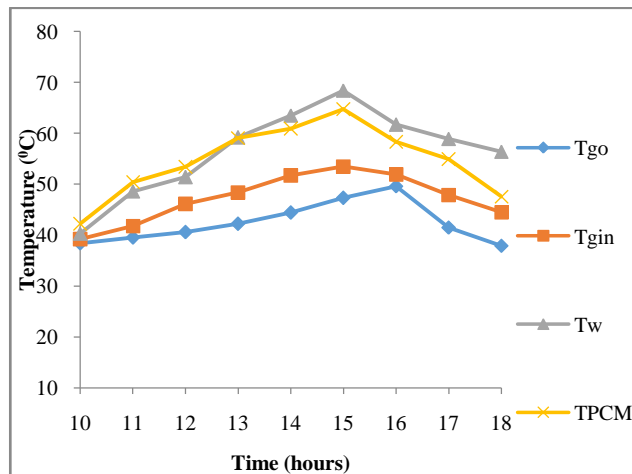


Figure 3.6 Various temperature with respect to time

Figure 3.6 shows the temperature variations of basin water, inner and outer surfaces of absorber plate and the PCM. It is clear from the figures that the increase in temperature is directly proportional to the input solar energy. The latent energy stored in the palmitic acid keeps the system operational during the night to deliver the distillate output.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 13, December 2015

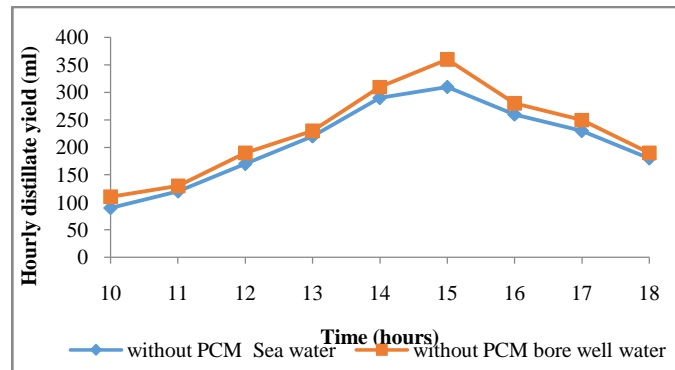


Figure 3.7 Hourly distillate yield of Sea water and bore water

The hourly distillate yield of sea water and bore water with respect to time is shown in the figure 3.7. Hourly distillate yield is higher from bore water compared with sea water because high amount salt and minerals is obtained in sea water hence low amount distillate water produced. Cumulative distillate yield of the bore water was 2050ml and sea water was 1870ml.

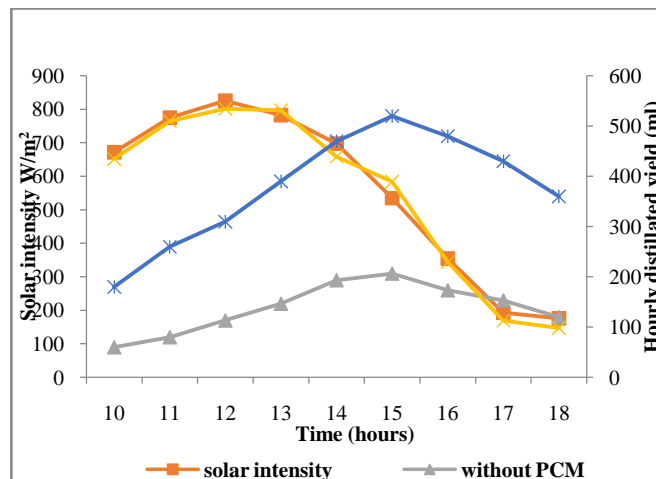


Figure 3.8 Variation of productivity in sea water with respect to time

The hourly distillate yield with and without PCM for the same experimental day is shown in the figure 3.8. Without PCM the cumulative yield of the day was 1870ml and with PCM (palmitic acid) the yield was 3400ml. During the night time solar intensity radiation will not be as high as in the day time. In order to overcome this problem PCM (palmitic acid) could be applied for the better performance of the solar still during the low solar intensity periods. The distillate water productivity of solar still with PCM is higher when compared to solar still without PCM. During the time interval 15 hour the distillate water productivity for the solar still with PCM is found to be 210 ml greater than without PCM.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 13, December 2015

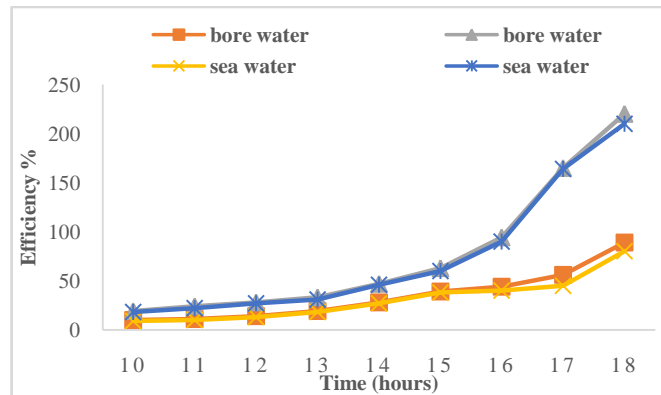


Figure 3.9 Variations of efficiency of solar still

The hourly efficiency with and without PCM for the same experimental day is shown in the figure 3.9. Without PCM the hourly efficiency of the sea water was 24.64% and with PCM of the efficiency was 37.15%. Without PCM the hourly efficiency of the bore well water was 27.24% and with PCM of the efficiency was 39.18%.

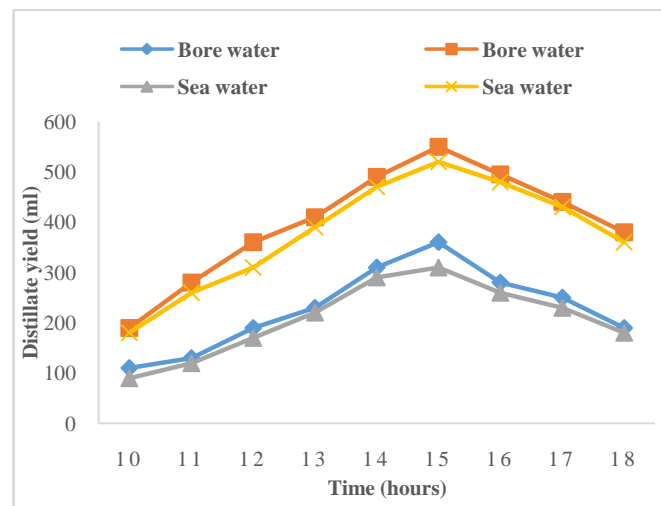


Figure 3.10 Various water of distillate yield in solar still

The hourly distillate yield with and without PCM for the same experimental day is shown in the figure 3.10. Without PCM the cumulative distillate yield of the sea water was 1870ml and with PCM the cumulative distillate yield of the sea water was 3400ml. without PCM the cumulative distillate yield of the bore water was 2050ml and with PCM the cumulative distillate yield of the bore water was 3595ml.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 13, December 2015

3.2 WATER QUALITY ANALYSIS

The water characteristics test have been carried out in the District water laboratory and TWAD Board before and after the solar distillation of the water.

Table 3.1 Physical examination of data from the water

BIS 10500 Physical examination	Acceptable limits	Before test		After test	
		Sea water	Bore well water	Sea water	Bore well water
Appearance	-	Clear	Clear	Clear	Clear
Colour	5	Colourless	Colourless	Colourless	Colourless
Odour	Agreeable	None	None	None	None
Turbidity	1	8	0	1	0
Total dissolved salts	500	16078	398	52	40
Electrical conductivity micS/cm	-	23997	577	73	54

Table 3.2 Chemical examination of data from the water

BIS 10500 Chemical examination	Acceptable limits	Before test		After test	
		Sea water	Bore well water	Sea water	Bore well water
pH	6.5-8.5	8.06	7.31	6.8	6.5
Ph. Alkalinity as CaCO ₃ mg/L	-	0	0	0	0
Total Alkalinity as CaCO ₃ mg/L	200	112	142	16	14
Total hardness as CaCO ₃ mg/L	200	3420	178	26	18
Calcium as Ca mg/L	75	880	44	6	2
Magnesium as Mg mg/L	30	293	16	1	1
Sodium as Na mg/L	-	3480	48	7	4

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 13, December 2015

Potassium as K mg/L	-	660	12	1	1
Iron as Fe mg/L	0.3	0.00	0.00	0.00	0.00
Manganese mg/L	0.1	0.00	0.00	0.00	0.00
Free Ammonia as NH ₃ mg/l	0.5	1.12	0.40	0.4	0.23
Nitrite as NO ₂ mg/L	-	0.03	0.06	0.26	0.21
Nitrate as NO ₃ mg/L	45	6	1	1	1
Chloride as Cl mg/L	250	8050	87	10	7
Fluoride as F mg/L	1.0	0.8	0.0	0.2	0.0
Sulphate as SO ₄ mg/L	200	353	32	5	2
Phosphate as PO ₄	-	0.08	0.06	0.01	0.01

Table 3.1 and 3.2 represent the water data details in before and after the solar distillation of the water for drinking purpose. From the physical examination of the water, turbidity of the sea water is reduced from 8 NTU to 1NTU and turbidity of the bore well water is maintain in actable limits, total dissolved solids of the sea water is reduced from 16078 mg/L to 52 mg/L and total dissolved solids of the bore well water is reduced from 398 mg/L to 40 mg/L, similarly the electrical conductivity of the sea water is reduced from 23997 micS/cm to 73 micS/cm and the electrical conductivity of the bore well water is reduced from 577 micS/cm to 54 micS/cm.

IV.CONCLUSION

Experimental performance analysis of a single basin solar still was carried out for both the conditions with and without PCM. The sea and bore well water was used in that still. The efficiency of the solar still varies with the design of the solar still, temperature difference between the water, top glass, outer and inner surface of absorber plate, salt concentration and solar intensity. Without PCM hourly yield of sea water in solar still was 1870ml and with PCM hourly yield of sea water in solar still was 3400ml. Without PCM hourly yield of bore water in solar still was 2050ml and with PCM hourly yield of bore water in solar still was 3595ml.

The efficiency of solar still obtained after the experimental work of hourly yield of both bore well and sea water with PCM is 39.18% and 37.15% and without PCM is 27.24% and 24.64%. By the comparison of hourly yield and efficiency bore well water seems to be good, though the efficiency and hourly yield is less for sea water, in future sea water can be purified and used for drinking purpose since the total dissolved salts and turbidity can be reduced to the permissible limit of TWAD board by solar desalination and also for the reason of insufficient bore water.

REFERENCES

- [1] Saravanan .M and Manikandan .k; “Experimental analysis of single slope stepped solar still with without latent heat thermal energy storage system” International journal of research in Environmental science and technology (2012); 2(4): 92-95.
- [2] A.E.Kabeel, Z.M.Omara, F.A.Essa “Enhancement of modified solar still integrated with external condenser using Nano fluids” seventeenth international water technology (2013) 5-7.
- [3] Prof. Alpesh Mehta , Arjun vyas, NitinBodar “Design of solar distillation system”

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 13, December 2015

- [4] Salah Abdallaha, Mazen M. Abu-Khader, Omar Badran; "Effect of various absorbing materials on the thermal performance of solar stills" Desalination 242 (2009) 128-137.
- [5] Alia. F. Al-hamadani and shailendra K. Shukla "Modelling of solar distillation system with phase change material storage medium" thermal science, (2014) 2pp. s347-s362.
- [6] Salah Abdallah, Omar Badran, Mazen M. Abu-Khader "Performance evaluation of a modified design of a single slope solar still" desalination 219 (2008) 222-230.
- [7] S.K. Shukla "Application of solar distillation systems with phase change material storage" International journal of ambient energy (2014) 978-3-642
- [8] Bilal a. Akash and mousa S. Mohsen, Omar osta, and Yaser Elayan "Experimental evaluation of a single-basin solar still using different absorbing materials" renewable energy,(1998)1-4,pp.307-310.
- [9] K. Kalidasa Murugavel, Kn.K.S.K. Chockalingam, K. Srihar "progress in improving the effectiveness of the single basin passive solar still" desalination (2008) 677-686.
- [10] A.S.Abdullah "Improving the performance of stepped solar still" desalination (2013) 60-65.
- [11] V.Sivakumar, E.Ganapathy sundaram "Improvement techniques of solar still efficiency" Renewable and sustainable energy reviews, (2013) 246-264.
- [12] El-Sebai and A. Al- Ghamdi, F.S.Al.hazmi, Adel S. Faidah "Thermal performance of a single basin solar still with PCM as a storage medium" applied energy (2009) 1189-1195.
- [13] Rahul Dev, Sabah A. Abdul-Wahab, G.N. Tiwari"Performance study of the inverted absorber solar still with water depth and total dissolved solid" Applied energy (2011) 252-264.
- [14] Young-Deuk Kim, Kyaw Thu, Moawya E.Masry, Kim Choon Ng, "Water quality assessment of solar-assisted adsorption desalination cycle" desalination (2014) 144-151.
- [15] George M. Ayoub, Lilian Malaeb, "Economic feasibility of a solar still desalination system with enhanced productivity" desalination (2014) 27-32.
- [16] Sivakumar "Enhancing the performance by increasing the productivity of water in solar desalination system with roof heating" international journal of advanced technology and engineering research (2014) 2250-3536.
- [17] Moses koilraj Gnanadason, Palansamy Senthel kumar, Gopal sivaraman "design and Performance analysis of a modified vacuum single basin solar still" renewable energy (2011) 388- 395.