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Experimental Investigation of Various Factors Influencing Solar Still Production for Seawater Desalination

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Abstract

With the abundance of water resources, freshwater availability is constantly decreasing worldwide. Seawater desalination is therefore given a lot of attention. Recently the use of renewable energy sources has grown significantly in the effort to reduce carbon emissions. Hence, the design, construction, and investigation of a single-slope basin solar still as a desalination system powered by renewable energy are the subjects of this study. To produce fresh water from seawater using a single slope solar still, experimental studies were conducted the effects of solar radiation, temperature variations, basin water amount, wind speed on daily production of the distillate output. Experimental results show that hourly distillate output and various temperatures increases with solar radiation intensity as a result hourly distillate output reaches to its maximum limit during noon time, when still receives maximum radiation. In addition to that basin water volume, and distillate output production are found to be having an inverse relation. Moreover, the daily production is affected by variations in wind speed and rises as wind speed increases.

Key words: *Solar Energy; Distillation; Solar still.*

1.Introduction

There is a finite amount of fresh water on planet. Over two-thirds of the surface of the world is covered by water, but more than 97 % of that water is either salty or contaminated. Fresh water makes up the remaining almost 2.6%. The amount of fresh water that humans and other organisms can access is less than 1%. Even this little fraction is thought to be sufficient to sustain life on Earth, but as population grows, fresh water consumption rises steadily. [1]. Polluted water cannot be used directly for drinking purpose as it has harmful microbes and dissolved substance. Many developed and developing countries of the world are facing the problem of supply of drinking water and fresh water.

Oman has a high ratio of "sky clearness" [2] and receiving one of the highest solar energy densities in the world. Fossil fuels have become very unsustainable as a result of constant price increases, greenhouse gas emissions that occur, and adverse effects on the marine ecology. Further, these technologies are not suitable for remote villages, arid area and small islands [3].To fulfill this requirement solar desalination is one of the methods to produce pure water from brackish/saline water using a device, called solar still. Solar-stills provide the advantage of being simple, easy to operate and maintain, requiring no conventional energy for operation, however due to low and inconsistent productivity ranging from 2 to 5 L/m2 /day, their use has remained poor. Harnessing solarenergy for safe water will ensure sustainability in order to meet the increasing demand of fresh water from 15-20 L/person/day to 75-100 L/person/day.

Moreover, fresh water is available only in the northern and southern end of the country (Oman) while water in other regions is brackish or saline [4]. A report published by the International Water Management Institute (IWMI) in 2007 has classified Oman as one of the countries experiencing 'physical water scarcity' [5]. Oman is included as one of the locations where freshwater resources are "completely rare" in the data for the availability of freshwater resources available around the world that were published by UNESCO in 2015. [6]. Phase-change technology called thermal desalination has been employed since the ancient of time to transform seawater into drinkable water. The single effect desalination process, another name for the straightforward thermal desalination system. Thermal desalination processes are practically employed with sea water of any salinity and has very less water treatment requirements. Due to this, these technologies are very popular in the region with high salinity sea water and share almost 34% of the World's [7-8] and almost 64% of MENA region [9] total installed desalination capacity.

Due to this unrelenting pressure on water resources, Oman and other GCC nations are compelled to use desalination plants that use seawater to produce fresh water in order to balance supply and demand. The first desalination plant in Oman has been installed in 1976 at Al Ghubra and Massira with Multi-Stage Flash technology MSF) producing 18930 m^3 /day and 126 m^3 /day of desalinated water respectively.

Oil and natural gas being the non-renewable sources, other GCC countries have already set their targets for diversifying their energy resources to renewable type, for example, Qatar aims to generate 20% of its energy from renewable by 2024 [10].

In order to minimize production costs and boost competitiveness across economic sectors, Oman Vision 2040 seeks to lessen the country's reliance on non-renewable resources. Oman is therefore among the best locations in the world to install solar thermal technologies, such as desalination, as the circumstances urged us. Solar thermal has a lot of potential for the nation, but it hasn't yet been fully exploited. In the nation, there aren't many solar thermal installations.

2. Experimental Setup And Procedure

Fabrication of solar still

The reported work was done at Mechanical Section, Engineering Department, University of Technology and Applied Sciences, Shinas, Sultanate of Oman (24.7242° N, 56.4608° E). The actual view of experimental setup i.e. conventional single slope basin type solar still is shown in Fig. 1

Figure 1: Typical pictures of fabricated solar still

Plywood sheet of 20 mm thickness was used for the construction of solar still. External and internal mirrors are mounted on all inner walls of the solar still to get more intense radiation.

The basin made up of galvanized iron were kept 90cm × 75cm × 0.10 m. The basin area is black coated to increase radiation absorption. Window glass of 5 mm thickness is used as transparent covers. The covers were inclined at 23^0. Since the geographical location of Shinas Oman lying at 24° in northern hemisphere thus it is suitable to receive maximum solar radiation.

Still was insulated by 50 mm thermocol. Collection troughs were provided below the lower edges of the covers to collect the condensate. Outlets were provided to drain the water through drilled hoses and to store in jars. Provisions were made to supply raw water, drain the basin water and insert thermocouples. Silicon sealant was fixed all along the edges of the still. All these arrangements are made to make the still air tight. Water gets evaporated and condensed on the inner surface of the glass cover. It runs down the lower edge of the glass cover.

Experiments were conducted and the readings were taken from morning 8 a.m. to 6 p.m., Solar radiation was measured in unit W/m^2 using standard pyrometer. Mercury and digital thermometers were used to measure ambient and various other temperatures.

3. Results And Discussions

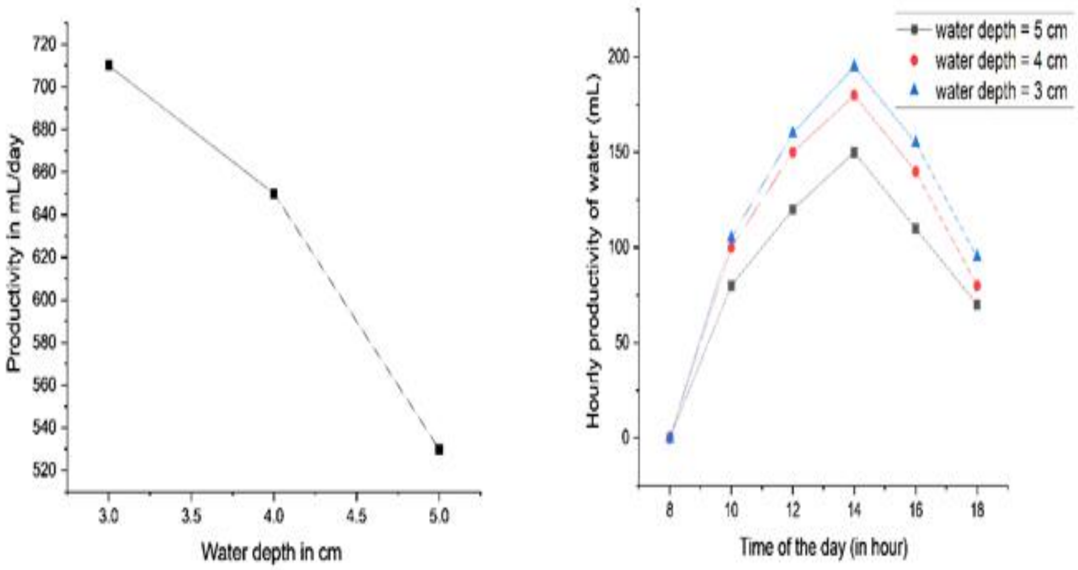
All the selected water depths were tested in University of Technology and Applied Sciences Shinas, Oman at 1200 m above the sea level. The effects of water depth operational were evaluated.

a. Effect of water depth on the solar stills productivity:

The experimental results have shown with no doubt that the water depth has a significant influence on the increased productivity. Various basin water depths (5 cm, 4 cm and 3 cm) were tested in the experiment; the results were compared in each time with those obtained from the other tested water depth in the same experiment. The experiment was carried out during the April and May, 2023 as clarified in table 1.

Results are shown for all the tested water depths. It is seen from Fig.2, that maximum productivity is obtained at 2 PM for all the depths. In addition to that Fig. 2 showing that maximum productivity (Lit/day) is obtained for minimum water depth, that is for 3 cm.

Moreover, Fig 2 showing that comparison of obtained productivity from 8 AM to 6 PM for water depth of 5, 4 & 3 cm, showing productivity is 9.28 % increased for water depth 3 cm as compare to water depth of 4 cm, and increase of 22.64 % for water depth 4 cm in productivity than that obtained from the depth 5.



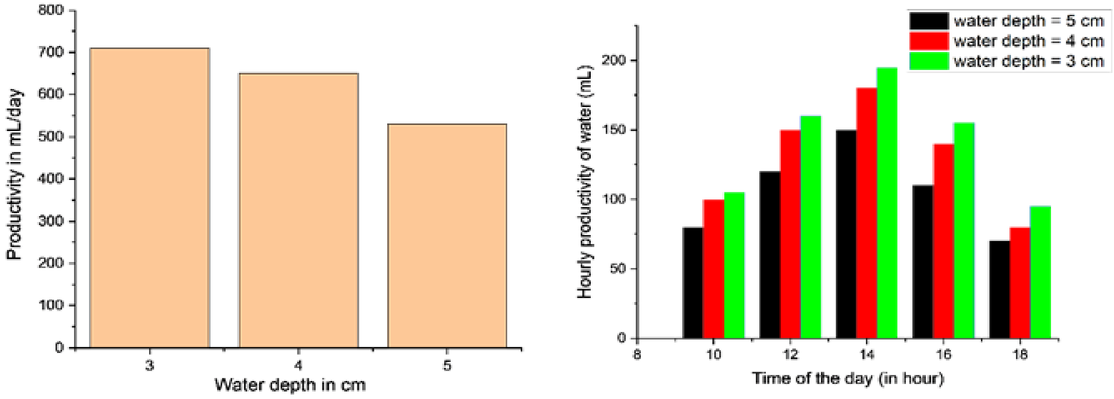


Figure 2: Productivity versus time of day for various water depth of basin.

Table 1: Table of testing the water depths

Tested depths of brackish water	Measurement Month May 2023 Average sunshine duration 10 hrs/day Average solar radiation density is 900 Watt/m^2, day Productivity (mL/day)	Percentage of increase of productivity
3 cm	710	9.20 %
4 cm	650	22.64 %
5 cm	530	-

b. Effect of wind velocity on the productivity:

The observed results in the figure 3 showing that higher wind velocity gives higher productivity. This may be because condensation rate is increased when the outside glass cover is cool due to higher wind speed, so enhancing productivity.

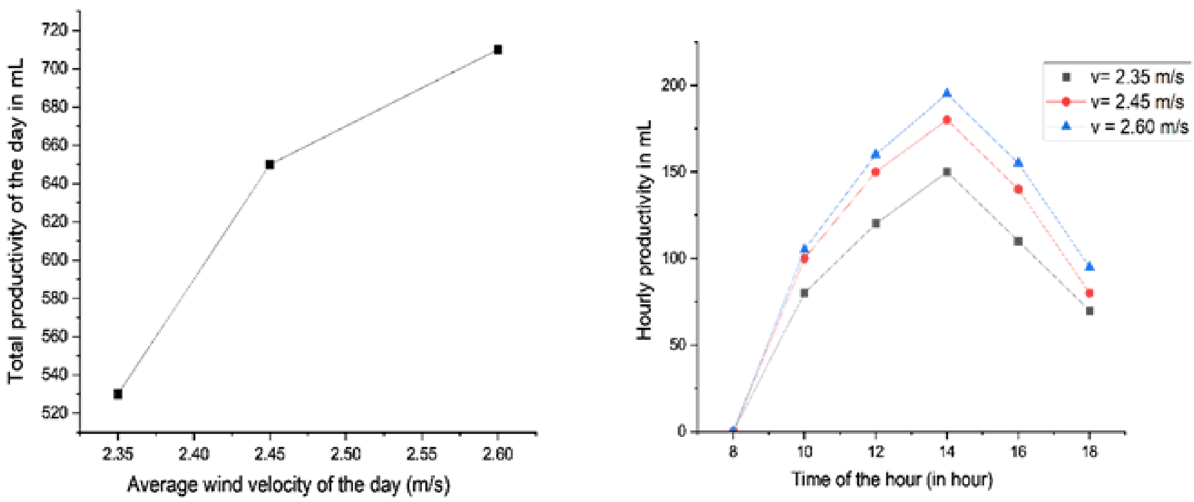


Figure 3: Effect of wind speed on productivity

Table 2: Table of testing the water depths

Sample	**TDS (mg/L)**		**EC (µS/cm)**		**PH**		**Salinity (ppt)**	
	Before	After	Before	After	Before	After	Before	After
Sea Water	33000	64.4	53000	100	8.14	7.77	34.1	0.1
Limits	50 - 300		50-800		6.5 - 8		< 0.5	

The quality of the feedwater and output water generated by the solar still was examined, and considerable improvements were discovered. The quality of distilled water totally complies with WHO standards

Conclusions

The major interesting results of the present work can be summarized in the following points:

1. Due to a number of financial and technological advantages, such as the low cost of the technology, including the cost of the raw materials and manufacturing, the idea of using greenhouse solar stills to obtain fresh water was found to be a very appealing method for meeting even a small-scale demand.
2. Effective solar energy use could reduce the need for expensive conventional energy sources and satisfy the demands for energy conservation.
3. The possibility of increasing the water productivity could be reached by lowering the water depths on the basin- absorbing plate.
4. The quality of output water was examined and found to be fit for drinking water.

References

[1] Tiwari et al., 2003; Kumar et al., 2015Tiwari, G., Singh, H., and Tripathi, R. Present status of solar distillation. Solar Energy 75, 367–373. (2003).

[2] Norton Rose, http://www.nortonrosefulbright.com/knowledge/publications/75892/omans renewable-energy-potential-solar-and-wind. (2nd May 2017).

[3] G. Xiao, X. Wang, M. Ni, F. Wang, W. Zhu, Z. Luo, K.Cen. " A review on solar stills for brine desalination", Applied Energy , vol. 103, pp. 642–652 (2013).

[4] S. Al Shibli, "Sultanate of Oman's Strategy for Securing Water Resources" (2014).

[5] International Water Management Institute, "Helping the world adapt to water scarcity", (2008).

[6] U. Nations, "Water for a Sustainable World" (2015).

[7] A. A. Mabrouk, "Techno-economic analysis of tube bundle orientation for high capacity brine recycle MSF desalination plants", Desalination, vol. 320, pp. 24–32 (2013).

[8] C. Li, Y. Goswami, and E. Stefanakos, "Solar assisted sea water desalination : A review", Renew. Sustain. Energy Rev., vol. 19, pp. 136–163 (2013).

[9] H.Sewilam and P. Nasr, "Desalinated Water for Food Production in the Arab Region", Water-Energy-Food Security Nexus in the Arab Region, W. S. Kamel Mostafa Amer, Zafar Adeel, Benno Böer, Ed. Springer (2015).

[10] AL Mohammed, "Chapter No. 6: The Vision for Oman's Economy: Oman 2020.," no. 6, pp. 125–164 (2012).