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DESALINATION AND WATER QUALITY ASSESSMENT USING SINGLE-SLOPE PASSIVE SOLAR STILL

Myint Kalyar[1], Cho Mar Kyi,[2] and Nyo Nyo Win[3]

Abstract

The United Nations' Sustainable Development Goal (SDG-6) emphasizes the need for clean water and sanitation by 2030. This research intended to generate freshwater from seawater by desalination process using conventional single slope passive solar still. This work was carried out from 2023 March 31 to April 10 for 11 days. Freshwater 1061 ml was distilled from 2 L of seawater. Average freshwater productivity was 96.45 ml per day. Water quality assessment was conducted using a Horiba Multiparameter U-54G and Portable Multiparameter DO 110 to measure the physicochemical parameters such as temperature, electrical conductivity (EC), salinity, turbidity, total dissolved solids (TDS), pH, ORP, DO, and O_2. Additionally, heavy metal constituents Cd, Cr, Pb, As, and Cu were analyzed with a Shimadzu (AA- 7000) Atomic Absorption Spectrophotometer. Results were compared with WHO's drinking water quality standards, specifically National Surface Water Quality Standards in Myanmar, (NSWQS) Class II and Class V. The seawater exhibited all its quality parameters within the acceptable range of Class V. For both seawater and freshwater, the concentrations of Cd, Cr, and Cu fall within the WHO drinking water quality norms, but Pb and As slightly exceed permissible limits. The obtained freshwater meets Class II standards with a salinity of 0.02 ppt and a pH value of 7.41. From the point of view of freshwater quality, it is likely attributed to contaminants from solar still construction and the quality of the original seawater. Despite this, the freshwater parameters remain within class II permissible levels. Those findings contribute directly to targets 6.4 and 6.7 within SDG-6, which focus on efforts and initiatives related to water and sanitation. Consequently, this research can provide important access to fresh water for rural communities, while supporting an affordable and simple technology.

Keywords: Desalination, Single-Slope Passive Solar Still, Freshwater, WHO's Water Quality,

Introduction

Access to clean freshwater is vital not only for safeguarding human health but also for mitigating poverty, ensuring food security, fostering peace and human rights, sustaining ecosystems, and supporting education. The World Population in 2023 is about 8.1 Billion (at mid-year) according to the UN. 45% of the world's population live in rural areas. In Myanmar, 70% of the people live in rural areas with 51.48 million of Myanmar's population by UNFPA-Myanmar, 2015. According to the UN World Water Development Report (2023), nearly two-thirds of the global population faces severe water scarcity for at least one month annually. Therefore, desalination is one of the solutions to water scarcity issues and it is also a fact to implement the target 6.7 of SDG 6; "By 2030, expand international cooperation and capacity building support to developing countries in water-related activities and programs including desalination". The main source of water is seawater not only for the people in the coastal area but also for the different types of marine carriers such as scientists and researchers, fishing and shipping, etc. Desalination is indeed a modern innovative technology used to produce freshwater from brackish or saline sources such as seawater [A. Fadi,2018]. This process is particularly valuable in freshwater-scarce resource regions such as coastal, rural, and remote areas. Moreover, the establishment of SDG 6 "Ensure availability and sustainable management of water and sanitation for all" confirms the importance of water and sanitation in the global political agenda. To meet Target 6.4 of SDG 6 is "Increase water use efficiency and ensure freshwater supplies by 2030". Freshwater has an acceptable salinity below 0.5 parts per thousand (ppt) of dissolved salts while seawater has an average salinity of around 35 ppt [M.Saif,2023]. There is a need to develop efficient and sustainable methods for seawater desalination by freshwater scarcity resources. [Dsilva Winfred Rufuss,2016]. Desalination plays a crucial role in providing freshwater for various marine activities and careers in coastal areas [Mulyanef,2018]. Efficient

[1] [1]Department of Physics, Dawei University

[2] Department of Physics, Dawei University

[3] Department of Physics, Mawlamyine University

and cost-effective desalination plants should be built in coastal areas to ensure a regular supply of freshwater [Diabil, H.A.N.,2022].

In this research, the optimal combination of desalination technology and renewable energy was used to generate freshwater from seawater. Using home-crafted single-slope passive solar still across the desalination technology holds particular significance for coastal, rural, and remote areas due to its simplicity, cost-effectiveness, utilization of renewable energy, and simple technology systems.

Materials & Methods

Experimental Set Up: The locally constructed prototype of a single-slope single-basin solar still is designed to harness solar radiation and optimize the evaporation-condensation process. The structure of the still was comprised of 6 mm thick glass panels, and an aluminum liner sealed with silicone rubber to prevent water leakage of the basin. The wooden tray is used as the container of the still. The dimension of the single basin is (60 cm × 35 cm × 17 cm) and the area of the inclined roof is (62 cm × 35 cm) with a 40° inclination angle. To minimize heat loss, the wooden tray container is black-painted and the rice husk serves as an insulator. The condensed water, also known as distilled water, was collected along aluminum grooves situated beneath the roof on all four sides inside the still. The pilot scale of the single-slope single- basin solar still is depicted in Fig.1 (a) & (b) featuring the schematic diagram and a photograph. The luminous intensity of sunlight was measured by HI 97500 Luxmeter and different temperatures were measured by thermometers.

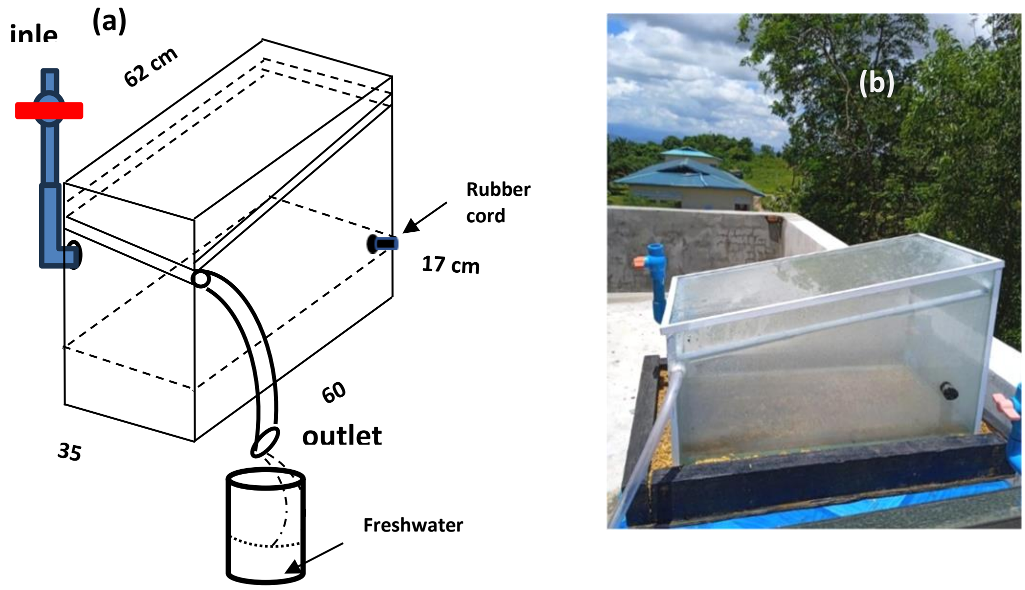

Figure 1(a). Schematic diagram and (b). Photograph of Single Slope Solar Still.

Experimental Procedure

The seawater sample was collected at a depth of 5.5 ft from MaungMaGan Beach in the Tanintharyi Coastal region at Latitude N 14° 8´32´´and Longitude E 98°5´25´´. 2 L of seawater was put into the basin and initiated evaporation under a sufficient temperature and leading to condensation due to the temperature difference between the inside and outside of the still cover. Solar radiation intensity and ambient temperature were measured as the climatological factors and glass temperature, seawater temperature, and amount of fresh water were recorded as the solar still's parameters. This work was carried out from 2023 March 31 to April 9 for 11 days. Data collection was made 5 times a day hourly from 10 am to 3 pm.

Equipment for Water Quality Analysis: Physicochemical parameters such as temperature, electrical conductivity (EC), salinity, turbidity, total dissolved solids (TDS), pH, ORP, DO, and O_2 were measured with Horiba Multiparameter U 54 G and Portable Multi-Parameter DO 110. Some of the constituent elements of Cd, Cr, Pb, As, and Cu were measured by Atomic Absorption Spectrophotometer (AA-7000 Shimadzu) as shown in Fig.2.

Figure 2. *Atomic Absorption Spectrophotometer* (AA-7000 Shimadzu)

Results

Dependence of Freshwater Productivity on Climatic Factors and Solar Still Parameters

Variation of hourly freshwater productivity with climatological factors including solar radiations or luminous flux and ambient temperature (T_a) and different temperatures or still parameters such as the seawater temperature (T_s) or basin water temperature, glass temperature (T_g) (exterior glass surface) were depicted in the following figures (3 -14) for 11 days from 31.3.2023 to 10.4.2023. A comparison of daily freshwater production, overnight freshwater production, and total freshwater production was represented as a histogram in Figure 14. Figure 15 depicts the hourly maximum productivity of freshwater for each day.

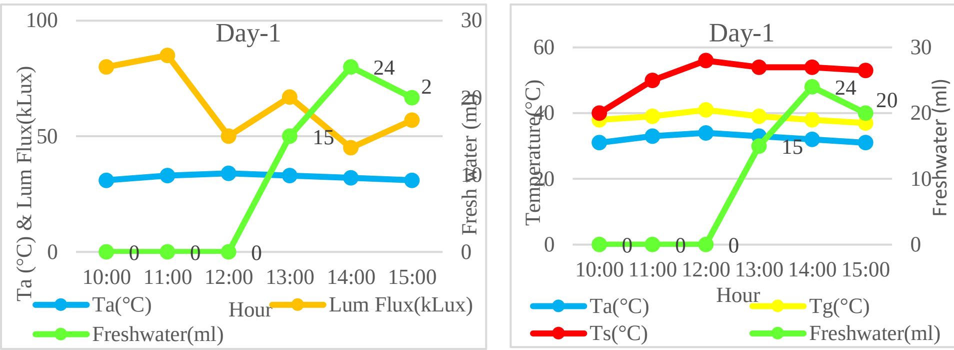

Figure 3(a), (b). Variation of hourly freshwater productivity with climatic factors & different temperatures for 31.3. 2023.

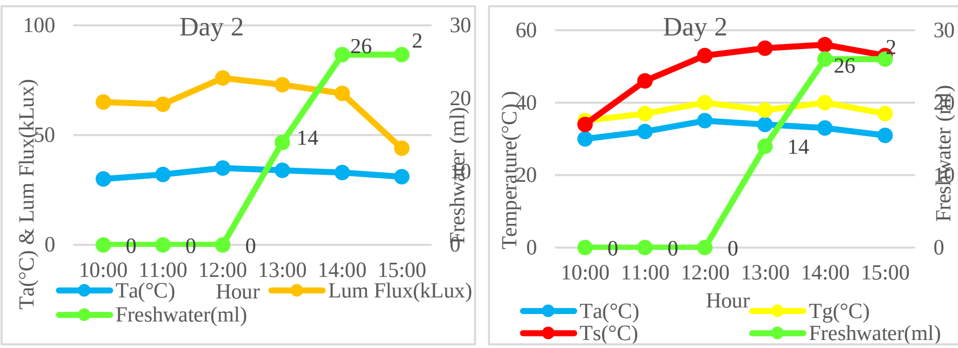

Figure 4(a), (b). Variation of hourly freshwater productivity with climatic factors & different temperatures for 1.4. 2023.

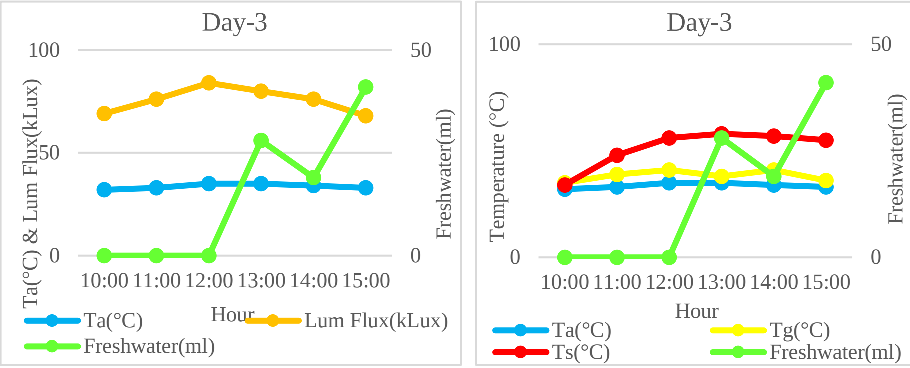

Figure 5(a), (b). Variation of hourly freshwater productivity with climatic factors & different temperatures for 2.4. 2023.

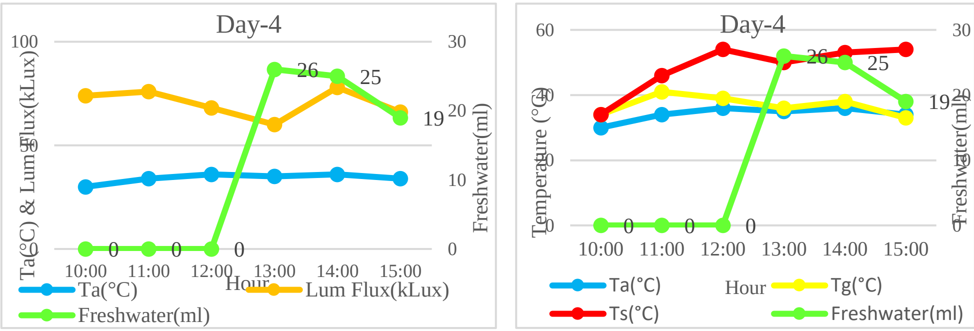

Figure 6(a), (b). Variation of hourly freshwater productivity with climatic factors & different temperatures for 3.4. 2023.

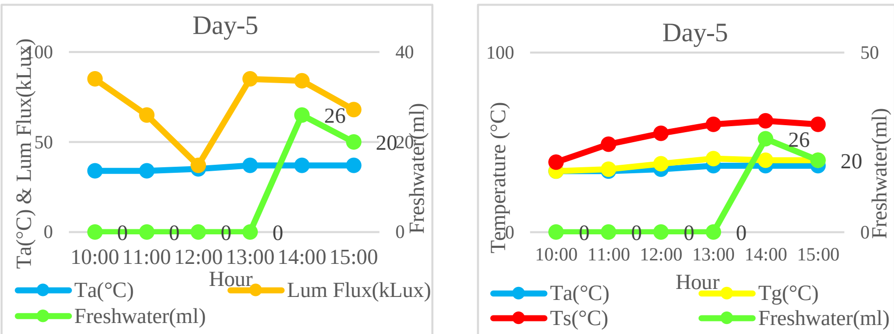

Figure 7(a), (b). Variation of hourly freshwater productivity with climatic factors & different temperatures for 4.4. 2023.

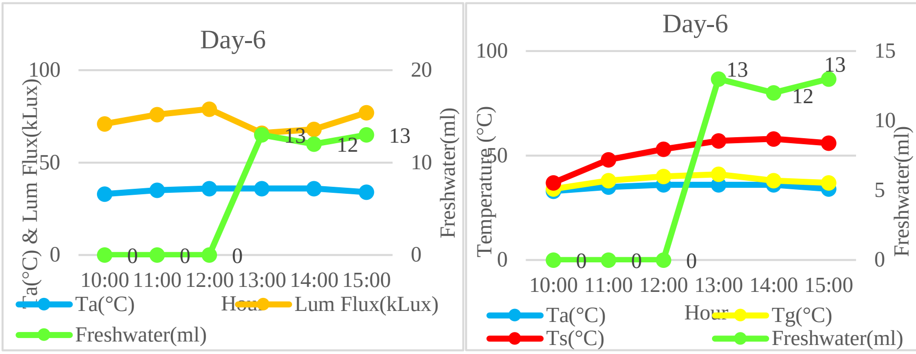

Figure 8(a), (b). Variation of hourly freshwater productivity with climatic factors & different temperatures for 5.4. 2023.

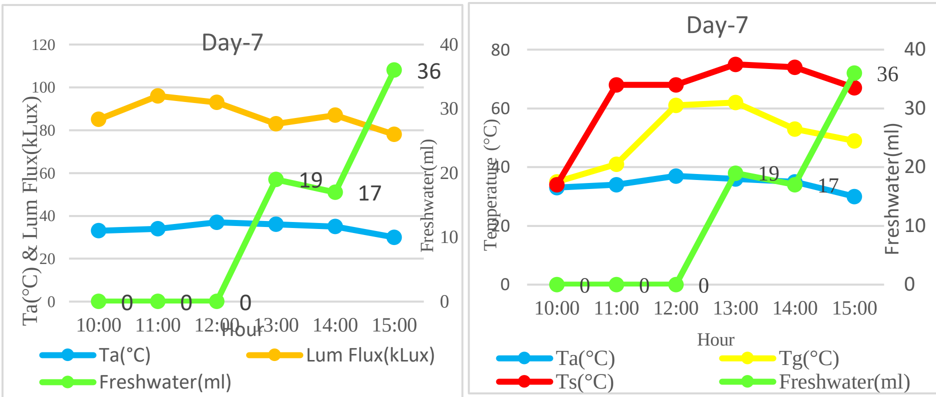

Figure 9(a), (b). Variation of hourly freshwater productivity with climatic factors & different temperatures for 6.4. 2023.

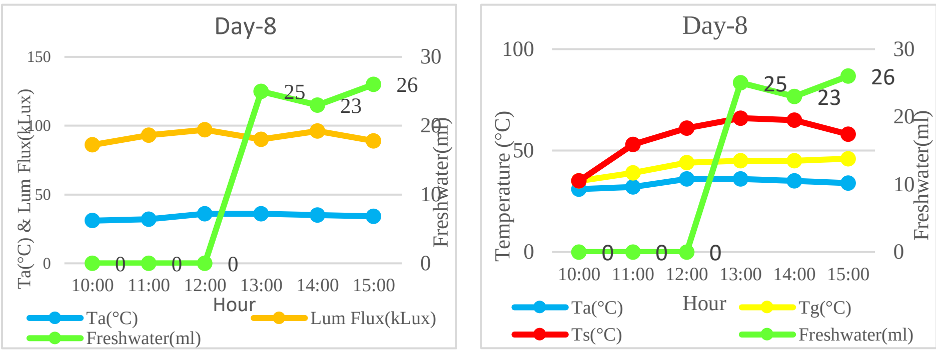

Figure 10(a), (b). Variation of hourly freshwater productivity with climatic factors & different temperatures for 7.4. 2023.

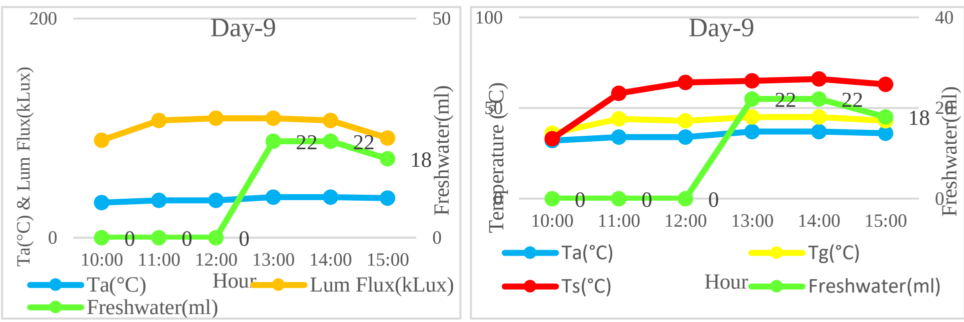

Figure 11(a), (b). Variation of hourly freshwater productivity with climatic factors & different temperatures for 8.4. 2023.

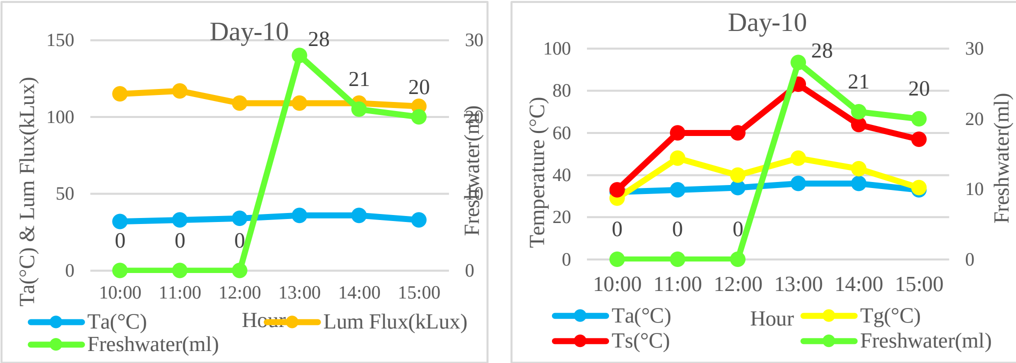

Figure 12(a), (b). Variation of hourly freshwater productivity with climatic factors & different temperatures for 9.4. 2023.

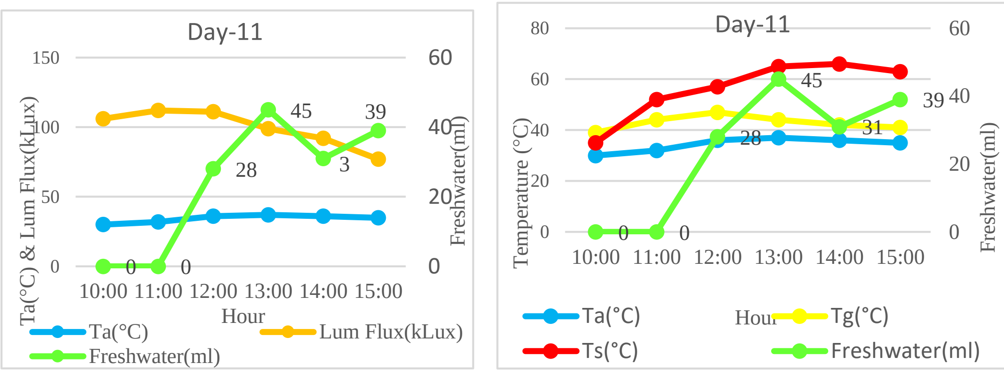

Figure 13(a), (b). Variation of hourly freshwater productivity with climatic factors & different temperatures for 10.4. 2023.

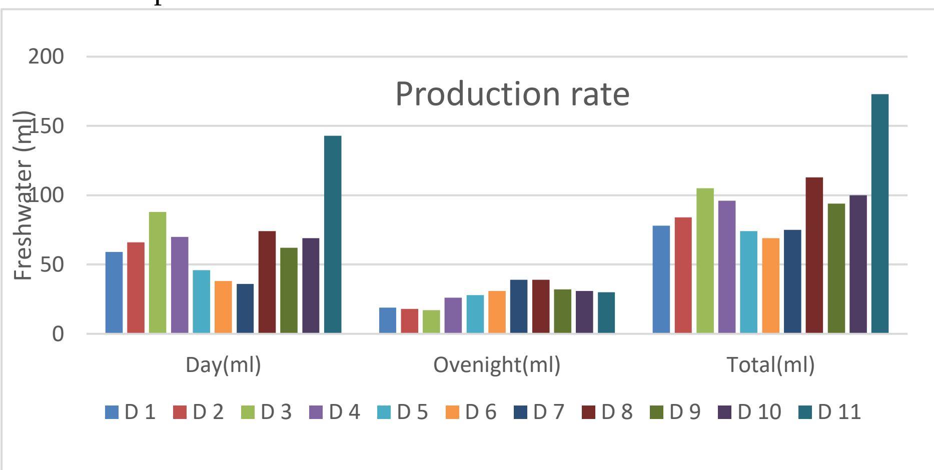

Figure 14. Comparison of daily freshwater production, overnight freshwater production, and total freshwater production

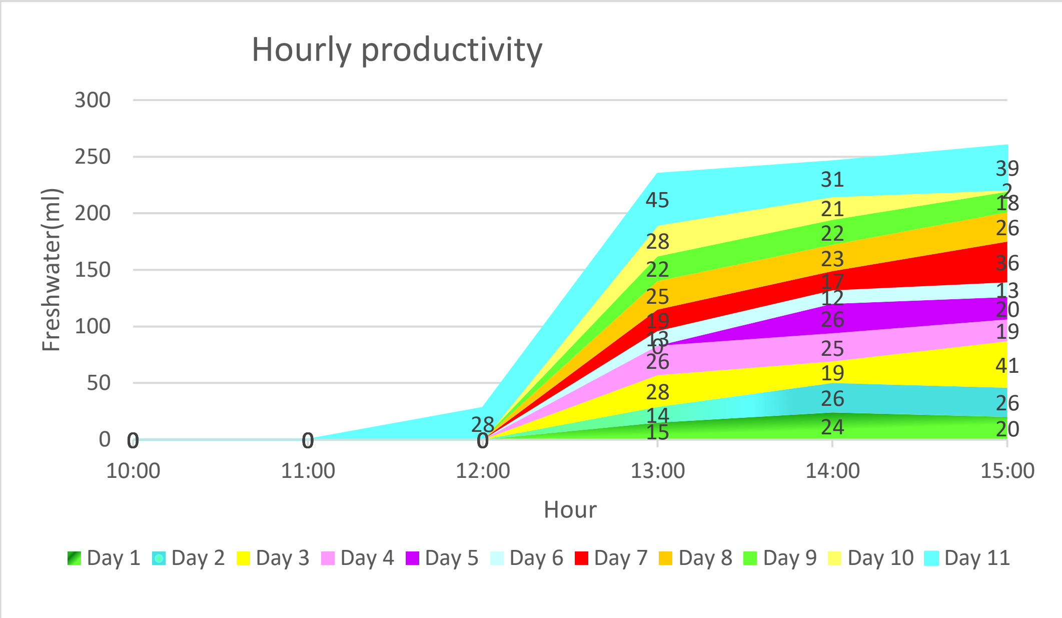

Figure 15. Hourly maximum productivity of freshwater

Water Quality: Physicochemical Parameters

Priority *waterbodies shall be classified from Class I to Class V by intended water use.* In this study, the obtained data were compared with Class II and Class V of the National Surface Water Quality Standards (NSWQS) adopted from the WHO's water quality guidelines.

The resulting physicochemical parameters of seawater and freshwater are listed in Table 1, Table 2, and Table 3. The resulting physical parameters of both samples, seawater and freshwater are presented in Table 1. The resulting data for seawater was compared with class V standards, while the data for freshwater was compared with class II standards.

Table 1. Comparative Analysis on physical parameters of water samples and standard data (NSWQS)

Quality Parameters	Seawater	Std Class. V (NSWQS)	Freshwater	Std Class. II (NSWQS)
Temperature(°C)	30	-	31	-
EC (mS/cm)	42	6	0.05	1.5
Salinity (ppt)	26.9	35	0.02	0.5
Turbidity (NTU)	51	100	0	25
TDS(NTU)	25.6	2000	0.032	

Table 2. Comparative Analysis on chemical parameters of water samples and standard data (NSWQS)

Quality Parameters	Seawater	Std Class.V(NSWQS)	Freshwater	Std Class.II (NSWQS)
pH	9.5	6-9	7.41	6-9
ORP (mV)	187	-	282	-
DO (mg/L)	5.6	>4	4.32	> 4
O_2 (%)	8.9	-	6.3	-

Table 3. Comparison of constituent heavy metal concentrations of seawater and freshwater with WHO's drinking water quality standards

Elements	Seawater	Freshwater	WHO's Permissible Limits	Unit
Cadmium (Cd)	0.0017	0.0032	0.003	ppm
Chromium (Cr)	0.0097	0.0243	0.05	ppm
Lead (Pb)	0.0186	0.1735	0.01	ppm
Arsenic (As)	0.6989	0.8182	0.05	ppm
Copper (Cu)	0.0076	0.1186	0.3	ppm

Discussion

Freshwater Productivity Analysis:

By observing the graphs of variation of hourly freshwater productivity with climatic factors & different temperatures for 11 days, shown in Figure 3(a),(b). to Figure 13(a),(b)., it was found that condensed freshwater can start after being exposed to sunlight for 3 hours. It was obvious that the rate of freshwater productivity depends on the intensity of solar radiation and ambient temperature because the productivity rate exhibits an increase following periods of elevated luminous flux and higher ambient temperature, particularly around noon and in the afternoon. This phenomenon shows the correlation between climatic factors and productivity rate. Based on the overnight production rate, the maximum milliliters of freshwater were collected on Day 7 and 8. The total amount of collected freshwater was 1061 ml from 2 L of seawater.

Water Quality Assessment:

To examine the quality of seawater and obtained freshwater were analyzed as the physical and chemical parameters. Some physicochemical parameters and constituent elements were investigated as the priority parameters for human health protection and environmental conservation. As shown in Table 2 the resulting physical parameters of both samples, seawater and freshwater were compared with class V and class II respectively.

By observing the histogram of Figure 16., it was found the physical characteristics of seawater and freshwater quality were under the respective permissible levels of the standards NSWQS. In particular, a freshwater's salinity of 0.02 ppt demonstrates its conformity with accepted standards as freshwater typically maintains a salinity below 0.5 parts per thousand (ppt) in dissolved salts.

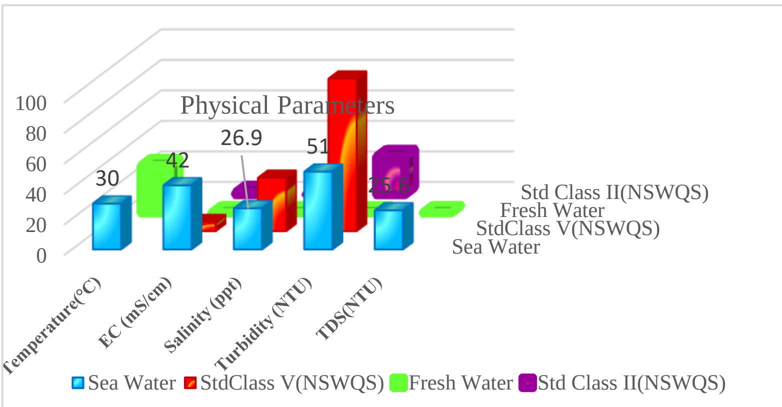

Figure 16*. Comparative analysis of physical parameters for seawater and freshwater with corresponding standards.*

Chemical parameters

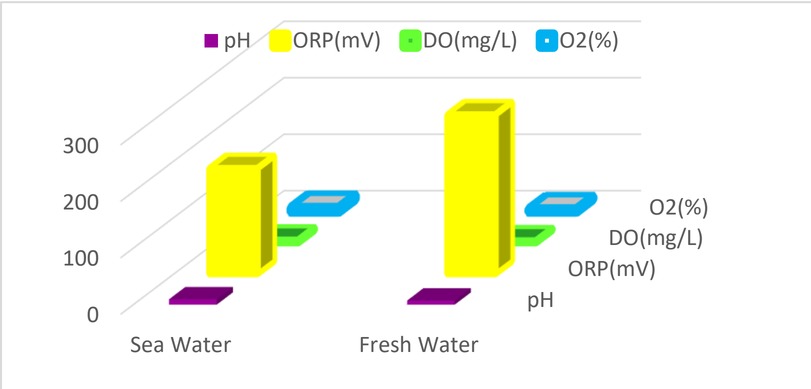

Figure 17. Comparison of chemical parameters for seawater and freshwater

The comparative analysis of chemical parameters of seawater and freshwater such as pH, ORP, DO, and O_2 were shown in the histogram of Figure 17. The key component pH level of freshwater is 7.41 is under the permissible level of class II. Optimal drinking water contains dissolved oxygen (DO) concentrations between 6.5-8 mg/L. In this study, the permissible DO level (>4 mg/L) for both standard Class II and Class V is crucial. The DO content of 5.6 mg/L for seawater and 4.32 mg/L for freshwater falls within the acceptable range, confirming the water's healthiness. Testing the heavy metal contaminants is essential for assessing water quality for intended use. In this scope, some of the heavy metal content Cd, Cr, Pb, As, and Cu were compared with the WHO's drinking water quality standards. The concentrations of Cd, Cr, and Cu are within the permissible range except Pb and As.

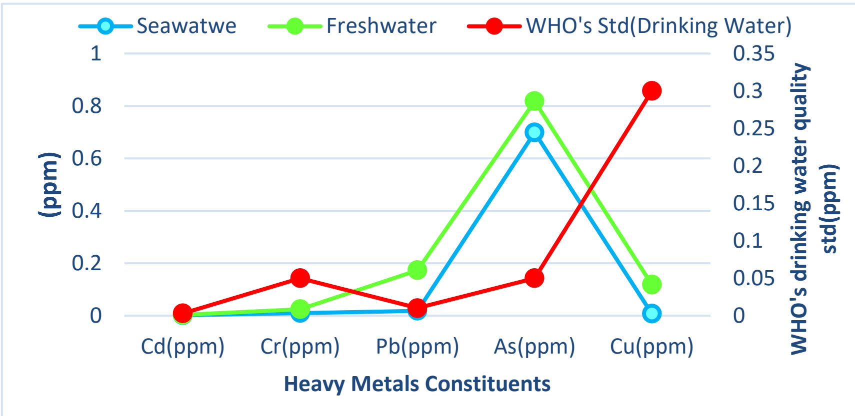

Figure 18. Comparative analysis of heavy metal contents in seawater and freshwater with WHO's drinking water quality standards.

Conclusion

The noteworthy finding of this research is the successful implementation of home-crafted conventional single-slope passive solar still to generate freshwater from seawater. The research findings of water quality conformed with the WHO's drinking water quality standards. However, the observed exception of slightly exceeding some of the heavy metal content might be due to the contaminants from the construction of solar still and initial seawater quality. This indicates the need for further research to obtain more reliable water quality data. The optimal combination of cost-effective, eco-friendly solar still and simple technology of desalination contributes directly to the realization of UN's SDG-6 targets. The integration of desalination and water quality assessment through a single slope passive solar still represents a promising step towards a sustainable water future.

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