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(Review Article)

Experiment of a stepped solar still water distillation divice combine with auxiliary condenser

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Abstract

At the present, there were many research and manufacture subjects the distilled water equipment by using solar energy in Viet Nam. Most of them were designed on traditional type which have a complex shape, cumbersome and low performance. With the aim of this study is to make a simpler, lighter equipment and enhanced production of distilled water, we fabricated a water distillation device which has ladder shape combine with a condensing auxiliary and using solar energy with an area of 1 m^2 (evaporation area). The experimental study has established at inclined angles 20^0, 25^0, 30^0 ; circulate and does not circulate steam under conditions at Nha Trang City in 10/2023. The results showed that when the depth distilled water layer is 1cm at the inclined angle 250, the device gave the highest yield, production of distilled water reach 4.9l/m^2 (from 7am to 17pm) corresponding to the average radiation of 635W/m^2. The efficiency of the distillation equipment with circulation 7.1% higher than does not steam.

Keywords: Solar still; Stepped solar still; Auxiliary condenser; Water productivity; Steam circulation

1. Introduction

Water is an essential ingredient to sustain life just like the air. Human, plants and animal all need water to survive. Water is an important factor that directly or indirectly impacts on economic and social fields, from agriculture, industry, tourism to health issues. The human demand about clean and pure water for drinking is increasing, especially in areas with scarce water sources such as remote areas, borders and islands, arid places or polluted water sources, salty water… Creating water distillation equipment to turn alum water, brackish water, and salty water into fresh water for people is truly meaningful, especially in countries affected by climate change like Vietnam [1].

The main content of this article presents research on manufacturing a water distillation device using solar energy in a step-shaped combined with an auxiliary condenser and performing experimental measurements as well as providing an assessment of the application potential. This device comes into practice in Nha Trang City in particular and Vietnam in general.

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2. Experiment

2.1. Operating principle diagram

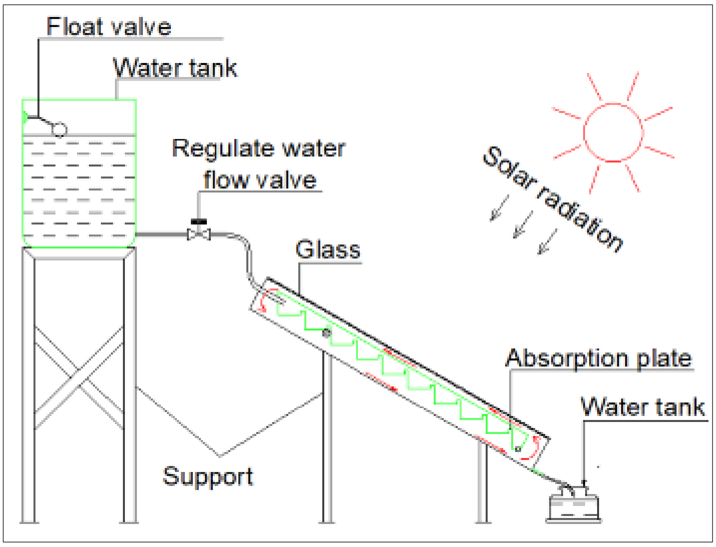

Figure 1 Schematic diagram of experimental setup

2.2. Structure

The body structure of the device is made of 201 stainless steel, 1mm thick.

- Overall body dimension: A = 1250x800x105mm
- Covering glass has a thermal conductivity coefficient k_g = 0,78(W/m^{0}C), area of A_g = 1250x800mm = m^2, thick l_g = 0.004m.
- Auxiliary condenser is made of aluminum with dimension is 1250 x 800mm, thick 0.3mm.
- There are 10 steps in total, the dimension of each step is 1200 x 60 x 10mm, The steps are painted black to absorb solar energy. The steps are covered with 0.1mm thick insulation, with a thermal conductivity coefficient of λ_i =0,035W/m.K

2.3. Experimental process

The device is located in Nha Trang City with co-ordinates 10^{o}51'49'' North, 106^{o}36'59'' East, at a height of 10 meters above the ground, the device is placed in the north-east and south-west directions, deviated 30 degree from the main east-south direction.

The measuring device has evaluation index as Table 1. Solar radiation, temperature at nodes and wind speed are all measured directly by the machine at certain times.

Figure 2 Experimenting in parallel with two distillation equipment using solar energy in a stepped solar still

Temperature metter b) Solar power Meter c) Digital anemometor

Figure 3 Measuring devices are used during the experiment

Table 1 Measurement equipment parameters

Number	Device	Range	Accuracy
1	12 channels temperature recorder PCE – T 1200	-100÷1300oC	Error 0.1%
2	Thermocouple type K	-50÷1000oC	±5%+0.5oC
3	Solar power Meter PCE – SPM1	0÷2000 W/m^2	±10 W/m2 ,±5%
4	Smart sensor AR826 digital anemometor	0÷15m/s	±0.1m/s

Water at ambient temperature is supplied to the distillation trough at 7a.m. Water from the tank fills all steps. Then water is supplied with a certain flow rate of 1 liter/hour, make sure to maintain a water level of 1cm in every step. The author used completely water in the city to do this research. In this article, the author experiment on 2 completely identical models, just unlike inclined angels 20^0, 25^0, 30^0, to draw conclusion about the optimal inclined angel for a stepped solar still water distillation device. After that, author will keep on experimenting to compare and evaluate the distillation performance of the device with and without steam circulation.

Previous to experiment, surface of cover glass was cleaned so that dirt does not affect the experimental result.

Table 2 Experimental plans

Experimental	Content	Note
Plan 1	OP1 (30^0) và OP2 (20^0) comparison experiment	OP *(option)*
Plan 2	OP2 (20^0) và OP3 (25^0) comparison experiment	
Plan 3	Comparison experiment with steam circulation OP4 and without steam circulation OP5	

2.4. Conclusion

Experimental measurement results of the solar radiation intensity (Is), the ambient temperature (T_{mt}) is also the temperature at the water surface (T_{sw}), the temperature at the top surface of covering glass (T_{go}), the auxiliary condenser plate surface temperature (T_{co}) và sản lượng nước and distilled water output over time will be shown through graphs in Plan 1, Plan 2 và Plan 3. To obtain accurate and objective measurement and statistical data, the author conducted each experiment on many different days. However, the author only gives basic data for a typical day for each experiment in this article.

2.4.1. Plan 1: OP1(30^0) và OP2 (20^0) comparison experiment

From the measurable data shown in graph 4, 5 and 6, we can see that: The amount of solar radiation that OP1 receives is larger than OP2 during the period time from 7am to 10am. Conversely, The amount of solar radiation that OP2 receives is larger than OP1 during the period time from 11am to 17pm. Along with that, the temperature of the covering glass and water surface also has a similar tendency to change. And the total amount of solar radiation throughout the day that OP2 receives is also larger. This leads to the daily distilled water output in OP2 being greater than OP1, equivalent to about 6.8%.

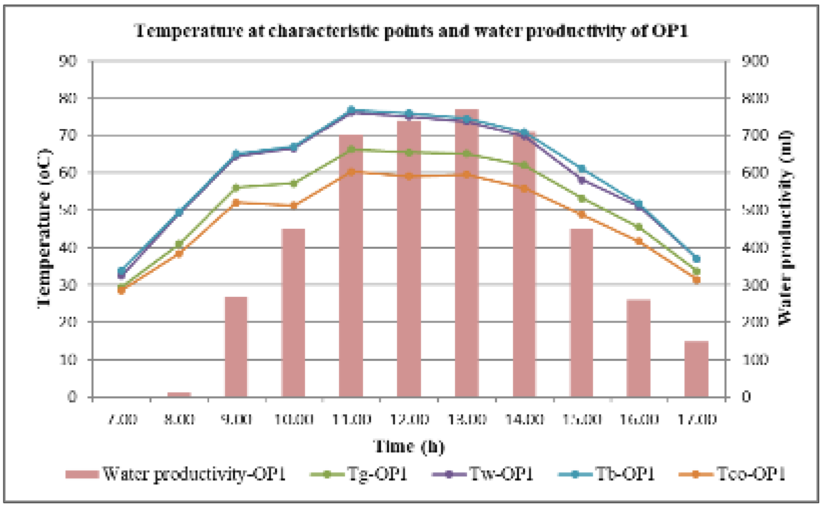

Figure 4 The chart shows the characteristic parameters of OP1 measured on 1/10/2023

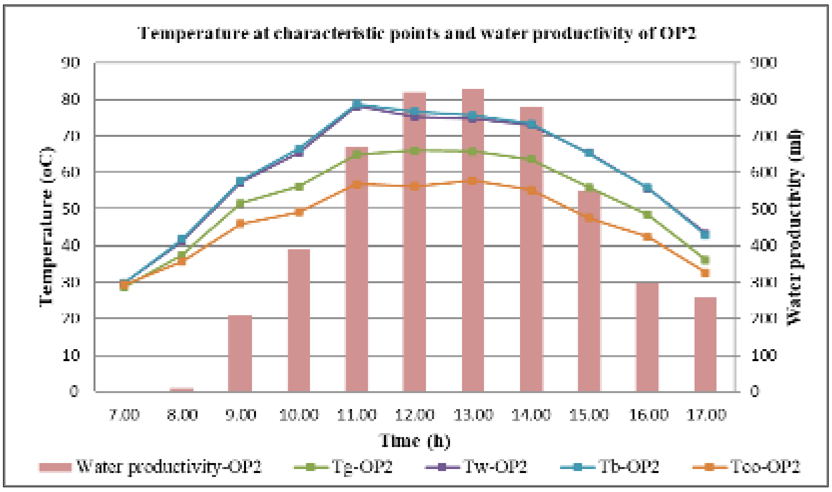

Figure 5 The chart shows the characteristic parameters of OP2 measured on 1/10/2023

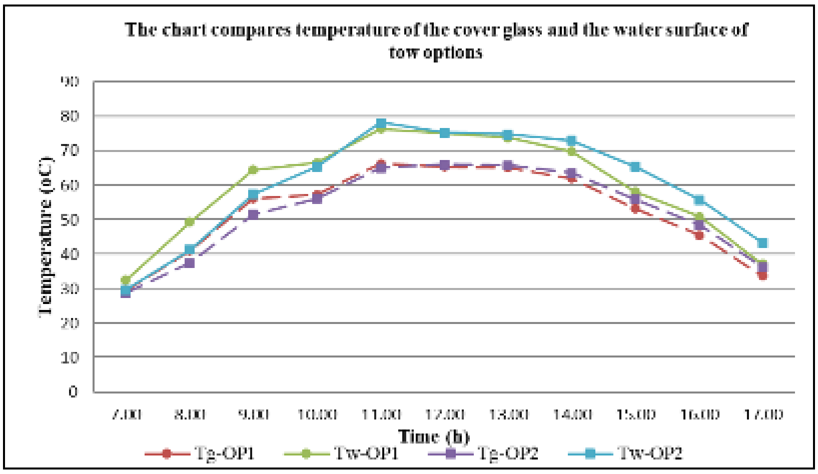

Figure 6 The chart compares the cover glass and water surface temperatures of OP1 and OP2 during on 1/10/2023

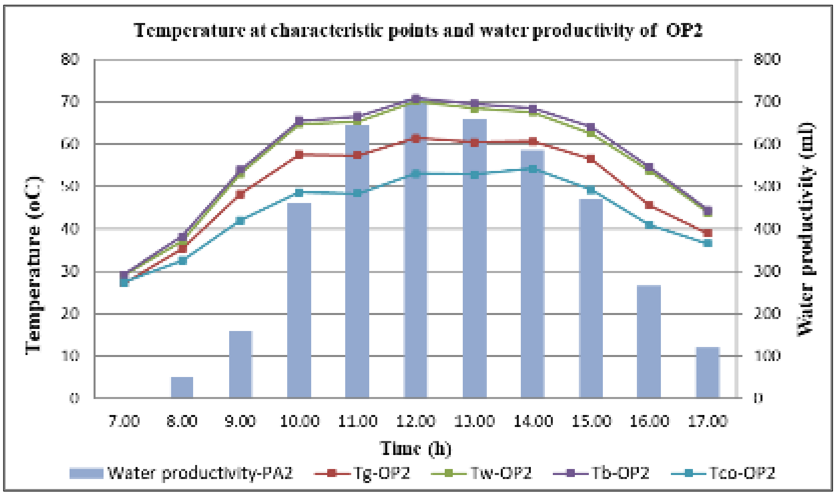

Figure 7 The chart compares the amount of solar radiation and water productivity of OP1 and OP2 during on 1/10/2023

2.4.2. Plan 2: OP2 (20⁰) và OP3 (25⁰) comparison experiment

After doing plan 1, we can see that the daily distilled water output in OP2 (20^0) being greater than OP1 (30^0). Therefore, we will compare OP2 and OP3 in this plan. From the measurable data shown in graph 8 and 9, we can see that The amount of solar radiation that OP3 receives is larger than OP2 during the period time from 7 am to 5pm, equivalent to about 3,5%. Although the amount of solar radiation is not significantly different, the temperature and daily distilled water output of OP3 are still greater than OP 1 (Fig 10,11)

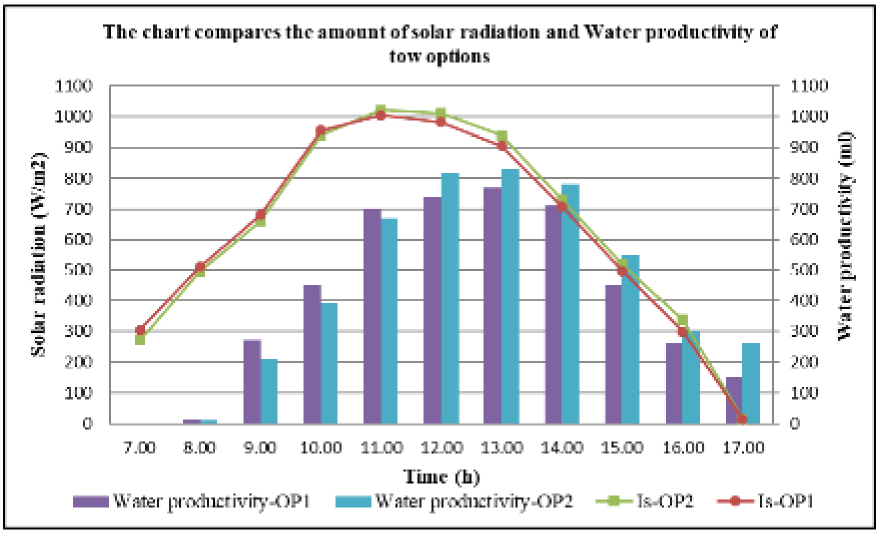

Figure 8 The chart shows the characteristic parameters of OP2 measured on 5/10/2023

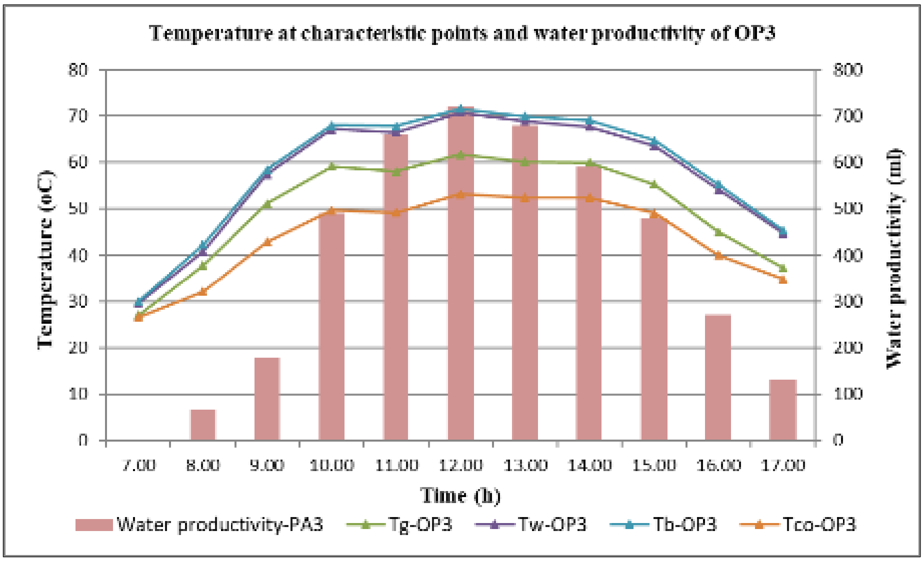

Figure 9 The chart shows the characteristic parameters of OP3 measured on 5/10/2023

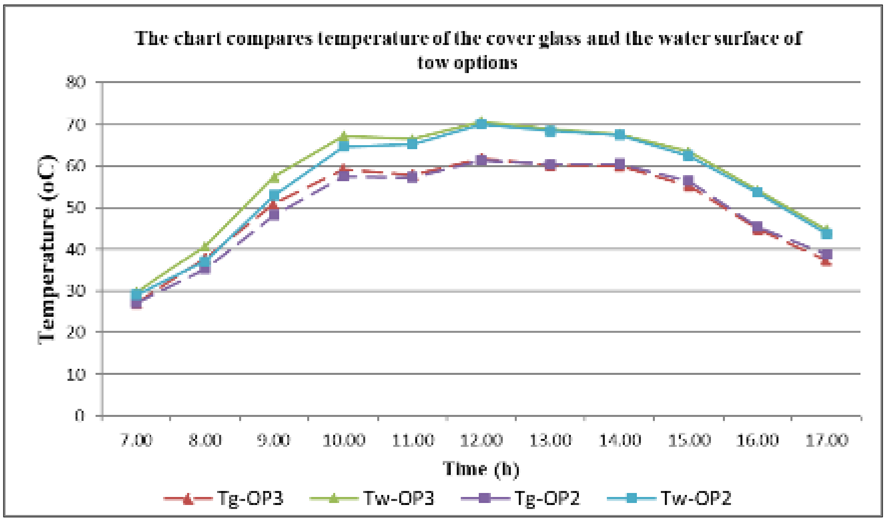

Figure 10 The chart compares the cover glass and water surface temperatures of OP2 and OP3 during on 5/10/2023

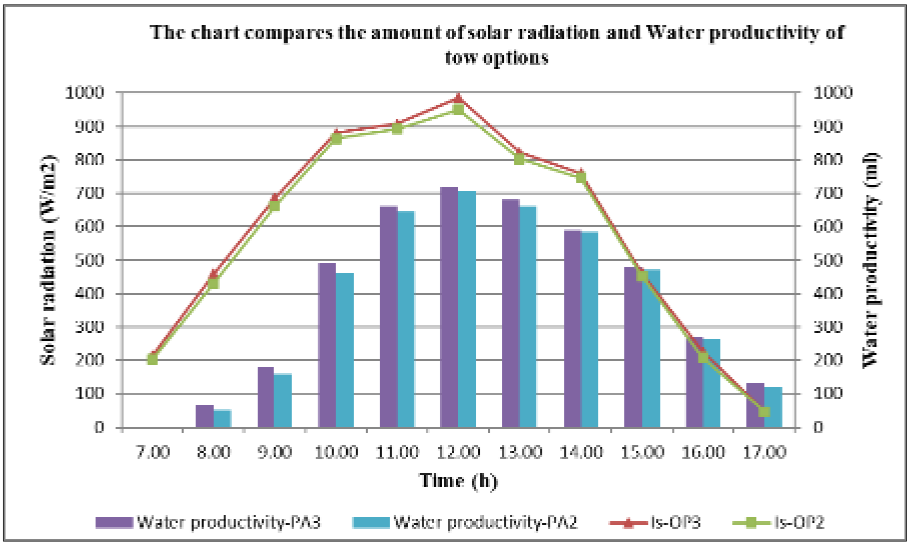

Figure 11 The chart compares the amount of solar radiation and water productivity of OP2 and OP3 during on 5/10/2023

Conclusion: From Plan 1 and Plan 2, we see that OP3 is the option with a inclined angle of 25^0 degrees, capable of receiving more solar radiation and greater distilled water output than the other two options. Therefore, a inclined angle of 25^0 degrees will be the optimal inclined angle for a stepped solar still water distiller.

2.4.3. Plan 3: : Comparison experiment with steam circulation OP4 and without steam circulation OP5

From theoretical analysis of factors affecting the device's distilled water productycity, the author designed this stepped solar water distillation device with a steam circulation and auxiliary condenser surface (Fig 1) to improve distilled water productycity. To verify this, the author conducted Plan 3. From conclusion of plan 1 and 2, we conduct experiments with two parallel devices at an angle of 25^0 degree. At the same time, block the air circulation gaps at the top and bottom of one device, preventing moist air from circulating to the auxiliary condenser surface on the underside.

The distilled water productycity is determined by the temperature at water surface and the difference between the water surface's temperature (T_{sw}) and the covering glass surface (T_{go}).. Therefore, the greater the temperature of the water surface and the greater the difference between the temperature of the water surface and the covering glass surface, the greater the distilled water productycity. Looking at Fig 12, 13 and 14, we see that from 7am to 5 pm in OP5 there is no steam circulation, so the water temperature and covering glass surface are higher than in OP4. Conversely, due to steam circulation and condensation at the auxiliary condenser surface, the water and covering glass temperatures at OP4 are lower. This makes the temperature difference between the water surface and the covering glass larger, the water vapor pressure ratio near the covering glass surface is reduced (the surface temperature of the coated glass panel decreases), this leads to increase the difference in water vapor pressure between the evaporation surface and the condensation surface, thereby promoting the evaporation process at the water surface. This leads to a higher increase in distilled water output at OP4 compared to OP5 by about 7,1%, which shown in Fig 15.

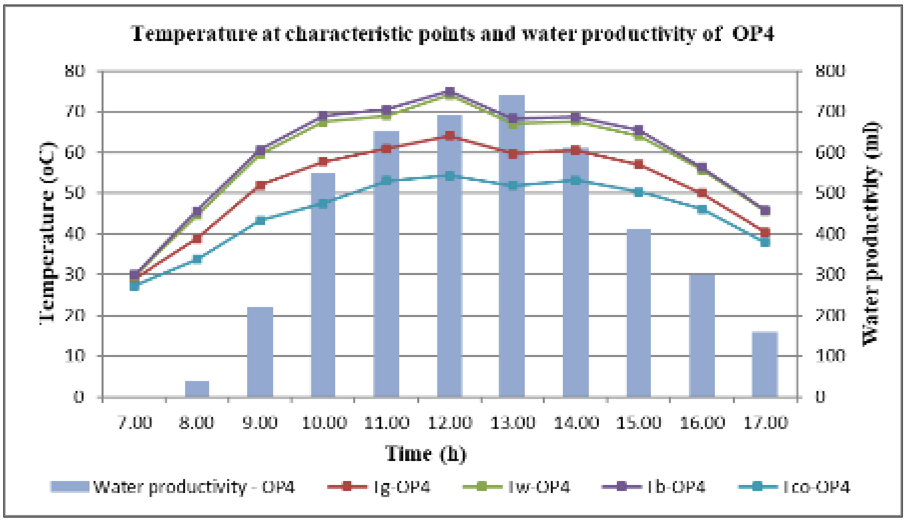

Figure 12 The chart shows the characteristic parameters of OP4 measured on 10/10/2023

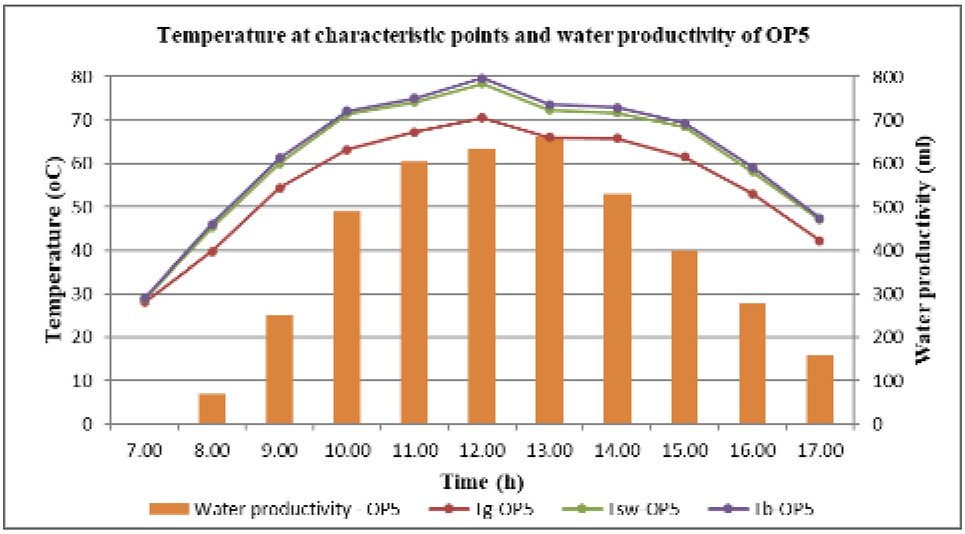

Figure 13 The chart shows the characteristic parameters of OP5 measured on 10/10/2023

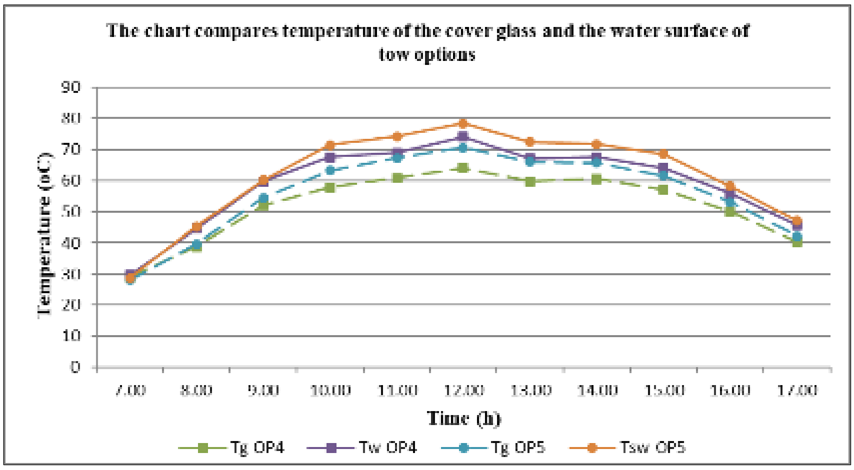

Figure 14 The chart compares the cover glass and water surface temperatures of OP4 and OP5 during on 10/10/2023

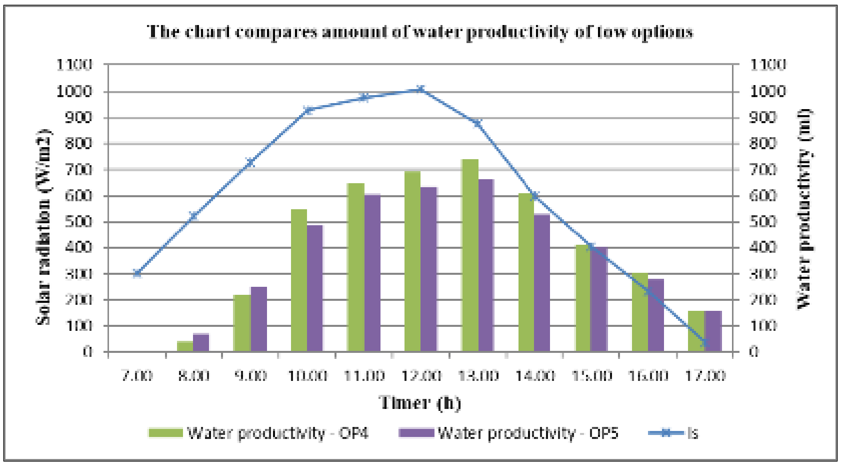

Figure 15 The chart compares the amount water productivity of OP4 and OP5 during on 10/10/2023

From the distilled water productycity, combined with the simple design, ease of manufacture, and low cost, the group of authors proposes the practical application of water distillation equipment using solar energy to contributing to solving water scarcity for people in areas lacking clean water or polluted water sources.

3. Conclusion and Recommendations

The review has highlighted the importance of cloud-native technologies in achieving scalability and resilience in software development. Key components such as container orchestration platforms and service meshes play a crucial role in enabling dynamic scaling and fault tolerance. Best practices like distributed tracing, circuit breaking, and chaos engineering are essential for designing resilient cloud-native applications. However, organizations must also address challenges such as complexity, security, and compliance when adopting cloud-native technologies. Embracing cloud-native technologies is essential for organizations looking to build scalable, resilient, and adaptable software systems. By leveraging trends like serverless computing, edge computing, and hybrid/multi-cloud architectures, organizations can stay ahead of the curve and meet the evolving demands of modern IT environments. Innovations in scalability and resilience, such as AI-driven autonomy and immutable infrastructure, offer opportunities for organizations to optimize performance and mitigate risks effectively. Moving forward, organizations should prioritize research and implementation efforts in areas such as AI-driven autonomy, zero-trust security, and observability. Investing in DevSecOps practices, continuous learning, and collaboration across teams is crucial for successful adoption of cloud-native technologies. By embracing these recommendations and staying informed about emerging trends and innovations, organizations can position themselves for success in the increasingly competitive landscape of cloud-native software development.

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