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RESULTS OF EXPERIMENTAL STUDIES ON A SOLAR WATER DESALINATION DEVICE

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Abstract. *Currently, approximately 97% of Earth's water is saline, about 2% is locked in glaciers and polar ice caps, and only about 1% is readily accessible freshwater suitable for human consumption. However, because freshwater resources are unevenly distributed across the globe, many regions experience severe shortages of potable water, forcing local populations to rely on saline or highly mineralized water for domestic use. Consequently, water-related diseases remain a significant public health concern in many parts of the world. To address this challenge, extensive research has been conducted worldwide to develop and improve energy-efficient and environmentally sustainable desalination technologies. Among these, solar water desalination devices have attracted considerable attention as a promising solution due to their utilization of renewable solar energy. This paper analyzes the current state of solar concentrator-based water desalination devices. In addition, the efficiency of utilizing renewable energy, the freshwater production performance of these devices, and the influence of environmental conditions on their operational performance are comprehensively evaluated.*

The article examines the relationship between drinking-water quality and human health, presents experimental results for the proposed device, and draws conclusions from the findings.

The experimental study showed that environmental factors had a significant impact on freshwater production efficiency: the daily freshwater yield was 6.5 L under clear-sky conditions and 2.5 L under variable cloud cover.

The experimental results highlight the need for further research to improve freshwater production technologies. Improving the freshwater production efficiency of such devices remains a key priority for providing sustainable and safe drinking water to communities experiencing water scarcity.

Keywords: *freshwater, water scarcity problem, solar concentrator-based water desalination systems, solar radiation, solar tracking system, dual-axis movable mechanical drive, solar energy, electrical energy consumption, reactor surface temperature.*

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QUYOSH SUV CHUCHITGICH QURILMASI TAJRIBA TADQIQOT NATIJALARI

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Annotatsiya. *Hozirgi kunda Yer sharidagi suv resurslarining taxminan 97 % ini sho‘r suvlar, qutb va tog‘ muzliklari, atigi 1 % ini esa inson iste’moli uchun yaroqli chuchuk suv resurslari tashkil etadi. Biroq chuchuk suv zaxiralarining Yer yuzida notekis taqsimlanganligi sababli dunyoning ayrim hududlarida aholi ichimlik suvi taqchilligiga duch kelmoqda hamda ayrim hollarda iste’mol uchun sho‘r yoki minerallashgan suvlardan foydalanishga majbur bo‘lmoqda. Bu esa suv bilan bog‘liq turli kasalliklarning tarqalishiga va aholi salomatligiga salbiy ta’sir ko‘rsatmoqda. Mazkur muammoni bartaraf etish maqsadida dunyo olimlari tomonidan sho‘r suvlarni chuchuklashtirishning energiya tejamkor va ekologik xavfsiz texnologiyalarini yaratish hamda takomillashtirish bo‘yicha keng ko‘lamli ilmiy tadqiqotlar olib borilmoqda. Xususan, qayta tiklanuvchi energiya manbalariga asoslangan quyosh suv chuchitish qurilmalari istiqbolli yechimlardan biri sifatida e’tirof etilmoqda. Ushbu maqolada quyosh konsentratorli suv chuchitish qurilmalarining zamonaviy rivojlanish holati tahlil qilindi. Shuningdek, bunday qurilmalarda qayta tiklanuvchi energiya manbalaridan foydalanish samaradorligi, chuchuk suv ishlab chiqarish unumdorligi hamda qurilmaning ishlash ko‘rsatkichlariga atrof-muhit omillarining ta’siri ilmiy jihatdan baholandi.*

Maqolada ichimlik suvi sifatining inson salomatligiga ta’siri o'rganildi, taklif etilgan qurilma tajribada sinovdan o'tkazildi va natijalar asosida xulosalar chiqarildi.

Tajriba natijalari atrof-muhit omillari chuchuk suv ishlab chiqarish samaradorligiga sezilarli ta’sir etishini ko‘rsatdi: ochiq havoda sutkalik chuchuk suv miqdori 6,5 l, o‘zgaruvchan bulutli havoda esa 2,5 l ni tashkil etdi.

Ichimlik suvi taqchilligini kamaytirish maqsadida taklif etilgan quyosh suv chuchitish qurilmasidan olingan eksperimental natijalar shuni ko'rsatadiki, chuchuk suv ishlab chiqarish texnologiyalari bo'yicha chuqur tadqiqotlar olib borish juda muhimdir. Bunday qurilmalarning chuchuk suv ishlab chiqarish samaradorligini oshirish suv tanqisligidan aziyat chekayotgan jamoalarni barqaror va xavfsiz ichimlik suvi bilan ta'minlashning asosiy ustuvor vazifasi bo'lib qolmoqda.

Kalit so‘zlar: *chuchuk suv, suv tanqisligi muammosi, quyosh konsentratorli suv chuchitgichlari, quyosh radiatsiyasi, quyosh kuzatuv tizimi, ikki o‘qli harakatlanuvchi mexanik yuritma, quyosh energiyasi, elektr energiya sarfi, reaktor sirtidagi harorat.*

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РЕЗУЛЬТАТЫ ЭКСПЕРИМЕНТАЛЬНЫХ ИССЛЕДОВАНИЙ СОЛНЕЧНОГО КОНЦЕНТРАТОРНОГО УСТРОЙСТВА ДЛЯ ОПРЕСНЕНИЯ ВОДЫ

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Аннотация. *Современные оценки показывают, что примерно 97 % водных ресурсов Земли составляют солёные воды, около 2 % запасов приходится на полярные и ледниковые льды, и лишь около 1 % доступно в виде пресной воды, пригодной для потребления человеком. Однако из-за неравномерного распределения пресноводных ресурсов по всему миру во многих регионах наблюдается острый дефицит питьевой воды, в результате чего местное население вынуждено использовать солёную или высокоминерализованную воду в бытовых целях. Следствием этого является сохранение высокой распространённости заболеваний, связанных с качеством воды, что представляет собой серьёзную проблему общественного здравоохранения во многих странах мира. Для решения данной проблемы во всём мире ведутся масштабные исследования, направленные на разработку и совершенствование энергоэффективных и экологически устойчивых технологий опреснения воды. Среди них особое внимание привлекают солнечные установки для опреснения воды, рассматриваемые*

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как перспективное решение благодаря использованию возобновляемой солнечной энергии. В данной статье анализируется современное состояние солнечных концентраторных установок для опреснения воды. Кроме того, комплексно оцениваются эффективность использования возобновляемой энергии, производительность данных устройств по получению пресной воды, а также влияние условий окружающей среды на их эксплуатационные характеристики.

В статье рассмотрено влияние качества питьевой воды на здоровье человека, представлены результаты экспериментальных исследований предложенного устройства и сформулированы выводы.

Экспериментальное исследование показало, что факторы окружающей среды оказывают значительное влияние на эффективность производства пресной воды: суточная выработка составила 6,5 л при ясной погоде и 2,5 л при переменной облачности.

Результаты экспериментальных исследований предложенного солнечного устройства для опреснения воды, разработанного для решения проблемы дефицита питьевой воды, свидетельствуют о необходимости дальнейших исследований, направленных на совершенствование технологий получения пресной воды. Повышение эффективности производства пресной воды с использованием подобных устройств остаётся одним из ключевых приоритетов обеспечения устойчивого и безопасного доступа к питьевой воде для населения, испытывающего дефицит водных ресурсов.

Ключевые слова: *пресная вода, проблема дефицита воды, солнечные опреснительные установки с концентратором, солнечная радиация, система слежения за Солнцем, двухосевой подвижный механический привод, солнечная энергия, потребление электрической энергии, температура поверхности реактора.*

Introduction

At present, ensuring a sustainable supply of high-quality freshwater for the population and the agricultural sector has become one of the most pressing global challenges. In this regard, the development and implementation of energy-efficient technologies based on renewable energy sources, particularly solar energy, have emerged as one of the priority directions in scientific research and technological innovation.

It is well known that approximately 97% of the Earth's total water resources consist of saline water contained in oceans and seas, while about 2% is stored in glaciers and polar ice caps. Only about 1% of the world's water resources is available as freshwater suitable for human consumption [1]. However, the limited availability of freshwater resources, together with the increasing impacts of climate change, rising ambient temperatures, contamination of freshwater reservoirs, and continuous population growth, has led to a steady increase in the demand for potable water. Consequently, the pressure on available freshwater resources continues to intensify, resulting in a gradual decline in accessible drinking water supplies. According to current projections, nearly one-quarter of the world's population will experience water scarcity by 2035. By 2050, this figure is expected to increase to approximately 50% of the global population [2].

Global water scarcity is a pressing issue currently at the forefront of scientific attention, with numerous researchers worldwide working on developing desalination systems, enhancing their efficiency, and meeting freshwater supply demands. Notably, research conducted by Ettore Morosini, Igor Matteo Carraretto, and Giampaolo Manzolini analyzed an innovative integration of thermal seawater desalination technologies powered by sensible waste heat recovered from the supercritical CO_2 cycle of a concentrated solar power plant. The specific thermal energy consumption of the individual stages was 89 kWh/m³ for forward osmosis and 187 kWh/m³ for vacuum membrane distillation. For the integrated zero-liquid-discharge system as a whole, the specific thermal energy consumption was 156 kWh/m³ at a water recovery ratio of 95%, and the annual freshwater production of the plant was estimated at 3.39 million cubic meters [3].

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Researchers Nilesh S. Wakchaure, Purnanand V. Bhale, Rohan R. Pande, and Rajesh Prajapati proposed a humidification-dehumidification desalination system—featuring a closed-loop, jacketed solar water heater—to mitigate water scarcity by maximizing freshwater production per unit of collector area, reducing costs, and enhancing environmental benefits. Experimental results from the developed system showed that at an optimal mass flow rate ratio of 2.5, the maximum daily freshwater yield reached 17.72 kg/m², and the ratio of produced water to the thermal energy consumed for evaporation reached 1.79. The study highlights this system as a promising solution for community-scale desalination or for treating wastewater discharged from reverse osmosis processes in the textile industry [4].

Chinese researchers Xin Lu, Xiaomin Yin, and Youming Hu proposed and experimentally tested a new type of hybrid system designed for seawater desalination and electricity generation. The system uses parabolic trough collectors as the heat source for both electricity generation and seawater desalination. Research results indicate that the system has an electricity generation capacity of 79.07 MW and a freshwater production volume of approximately 3,700 tons. The water desalination efficiency of the system was found to be 57%. The production costs for the freshwater and electricity were $2.2/m³ and $0.055/kWh, respectively. However, despite these performance figures, the system's capital cost of $765 million severely limits its widespread adoption [5].

Scientists Yingfei Huang, Amr Omar, Robert A. Taylor, and Greg Leslie conducted a study using an open-source, multi-dimensional tool—integrating GIS data, the System Advisor Model (SAM), a custom-developed techno-economic model, and multi-criteria decision-making (MCDM) methods—to assess site suitability with a spatial resolution ranging from 0.5 to 50 km. The study identified locations suitable for installing CSP-MED systems under current climatic conditions. It was determined that these sites offer a system payback period of 15 to 21 years and the potential for electricity generation exceeding 5 kWh/m² per day. While this system is considered beneficial for planning and installing large-scale solar desalination facilities, such systems are viable primarily for large-scale regional projects; in areas facing severe water scarcity, the extensive organizational and economic efforts required may not align with the region's economic situation [6].

According to the review by Mohamed T. Abdelghany and Mehmet Fatih Orhan, efficiency-enhancement measures applied to solar-powered desalination units and systems have been reported to increase freshwater productivity by more than 183% relative to the corresponding baseline configurations, with an exergy efficiency of 8.21%. Furthermore, it was demonstrated that the cost of desalinated water decreased significantly, falling within the range of $0.011 to $0.023 per liter [7].

The shortage of potable water is not only a global concern but also one of the major environmental and socio-economic challenges facing the Republic of Uzbekistan. While urban populations are generally supplied with drinking water through centralized water distribution systems, residents of remote areas with underdeveloped infrastructure, particularly those located in desert and semi-desert regions, continue to experience limited access to safe drinking water. In many of these areas, local communities are forced to use canal water, drainage water, and groundwater as sources of drinking water. Since these water sources often fail to satisfy sanitary and hygienic quality standards due to their high salinity and mineralization levels, their consumption may adversely affect human health and contribute to the development of various infectious and chronic diseases. In particular, the high salinity of groundwater significantly increases the risk of physiological disorders and several associated health complications [8].

In response to these challenges, considerable research efforts are being devoted in Uzbekistan to improving potable water supply systems, developing desalination technologies based on renewable energy sources, and enhancing the energy efficiency of solar-powered water desalination devices. The development of solar concentrator-based desalination devices is of particular scientific and practical importance, as such technologies contribute to reducing the consumption of conventional energy resources while simultaneously improving environmental sustainability. These research activities are fully consistent with the priorities established by the Resolution of the President of the Republic of Uzbekistan No. PQ-4477, dated October 4, 2019, "On Approval of the Strategy for the

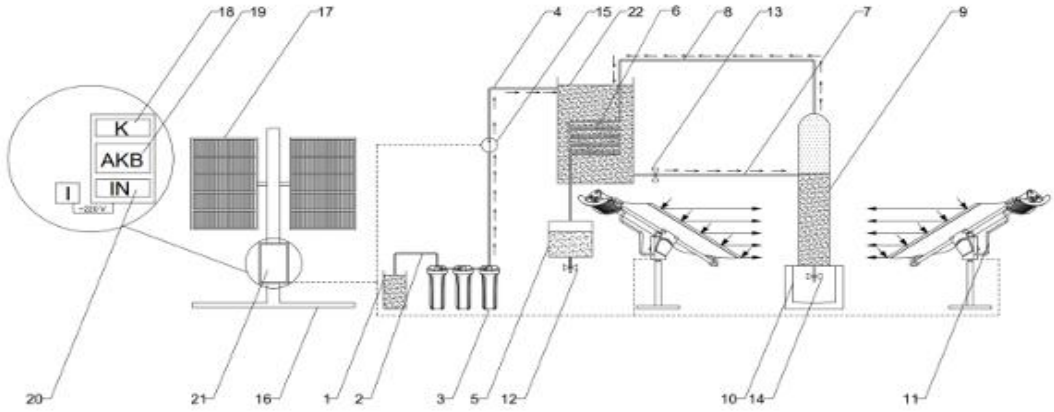
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Transition of the Republic of Uzbekistan to a Green Economy for the Period 2019–2030," which emphasizes the diversification of energy consumption, expansion of renewable energy utilization, and improvement of energy efficiency [9].

The objective of this study is to experimentally evaluate the operational performance of a solar concentrator-based water desalination device, determine its principal technological parameters, and investigate the influence of environmental factors on freshwater production efficiency under experimental operating conditions.

Materials and Methods

Based on the research objectives presented above, an experimental investigation was conducted to evaluate the operational performance of a solar concentrator-based water desalination device utilizing renewable solar energy as its primary energy source. The experimental studies were carried out under the climatic conditions of Qarshi City, Kashkadarya Region, Republic of Uzbekistan, in order to assess the device performance under actual environmental operating conditions. Figure 1 below shows the schematic diagram of the device used for the experimental study.



1 – saline artesian water well; 2, 4, 7 – water pipes; 3 – mechanical water filtration unit; 5 – fresh water tank; 6 – steam condenser; 8 – water vapor pipe; 9 – heat receiver-evaporator; 10, 16 – metal supports; 11 – solar concentrator; 12, 13, 14 – valves; 15 – water pump; 17 – photovoltaic panel; 18 – controller; 19 – storage batteries; 20 – inverter; 21 – control unit; 22 – saline water tank.

Figure 1. Schematic diagram of a solar-concentrator water desalination unit.

Table 1 summarizes the instruments used in the experimental study, along with their measurement ranges and accuracies.

Table 1. Measuring instruments used in the experimental study and their characteristics [10–12]

Device name and description	Device measurement range and accuracy	Image of the device
Photovoltaic Data Logger MacSolar	From 50 to 1000 W/m², measurement error <1%	
UNI-T UTi320V+ professional thermal imager	temperature from −20°C to +550°C, measurement error ±2%	
HTC-2 electronic thermometer-hygrometer	Temperature ≤70°C, humidity 100%, measurement error 1%	

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The proposed experimental desalination device consisted of a parabolic trough solar concentrator, a copper tubular reactor serving as the solar energy receiver and thermal absorber, a thermally insulated saline water storage tank, a heat-exchanger tube installed inside the saline water reservoir, a steam extraction compressor, a thermally insulated freshwater collection tank, a feed pump supplying saline water to the reactor, and interconnecting plastic pipelines that provided hydraulic circulation throughout the system. Figure 2 below shows the experimental device for solar-concentrator-based water desalination.



Figure 2. Experimental device for solar-concentrator water desalination.

The total electrical power consumption of the feed pump and the steam extraction compressor was 184 W, which was sufficient to ensure stable operation of the experimental setup during the desalination process.

The experimental investigation was performed by continuously monitoring eight principal operating parameters that characterize the thermal and operational performance of the proposed desalination device. These parameters included ambient air temperature, relative humidity, solar irradiance, reactor surface temperature, saline water temperature inside the reactor, saline water tank temperature, generated steam temperature, and freshwater tank temperature. To ensure the reliability and consistency of the experimental observations, all measurement data were recorded at one-hour intervals throughout the experimental period.

Results

The experimental results obtained on 28 and 29 April 2026 are presented in Tables 2 and 3, respectively.

Table 2. Experimental operating parameters recorded on 28 April 2026.

№	Time	Date	28.04.2026							
		Ambient temperature, ^{0}C	Relative humidity %	Solar irradiance, W/m^2	Absorber–evaporator surface temperature, ^{0}C	Saline water temperature inside the absorber – evaporator, ^{0}C	Saline water tank temperature, ^{0}C	Generated steam temperature, ^{0}C	Freshwater tank temperature, ^{0}C	Produced water, *l*
1	8^{00}	25	60	730	58	30	18	32	0	0.07
2	9^{00}	30	44	893	67	57	18.5	33	24.8	0.44
3	10^{00}	32	33	930	77	70	19	34	25	0.65
4	11^{00}	33.5	33	961	80	85	19.7	43	25	0.91

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5	12^{00}	33	33	970	85	88	19.9	43	25.1	0.98
6	13^{00}	35	27	972	90	91	20	36	25	1.00
7	14^{00}	35	23	991	80	83	21	38	25	0.87
8	15^{00}	37	15	935	70	60	21	37	25.3	0.57
9	16^{00}	34	12	886	69	60	21.2	36	24.6	0.57
10	17^{00}	32	16	726	66	52	22	42	25	0.46

The experimental results obtained on 28 April 2026 showed that both solar irradiance and ambient air temperature had a significant influence on the reactor surface temperature. As solar radiation intensity increased during the daytime, the reactor temperature also increased, resulting in enhanced evaporation of saline water and improved freshwater production. Under these favorable weather conditions, the proposed desalination device produced 6.5 L of freshwater during the experimental period. The electrical energy required for operating the feed pump and the steam extraction compressor was supplied entirely by the photovoltaic panel, demonstrating the capability of the system to operate using 100% renewable solar energy. The total daily electrical energy consumption was 1.63 kWh.

Table 3. Experimental operating parameters recorded on 29 April 2026.

№	**Time**	**Date**	**29.04.2026**							
		Ambient temperature, ^{0}C	**Relative humidity, %**	**Solar irradiance, W/m^2**	**Absorber–evaporator surface temperature, ^{0}C**	**Saline water temperature inside the absorber–evaporator, ^{0}C**	**Saline water tank temperature, ^{0}C**	**Generated steam temperature, ^{0}C**	**Freshwater tank temperature, ^{0}C**	**Produced water, *l***
1	8^{00}	26	30	720	40	15	17	30	0	0.00
2	9^{00}	27	29	860	70	55	17.8	28	22	0.71
3	10^{00}	32	22	980	77	40	18.9	34	22.4	0.23
4	11^{00}	31.5	25	500	58	34	19.2	31	22.4	0.07
5	12^{00}	34	27	958	77	55	20	37	23	0.1
6	13^{00}	34	26	353	60	30	21	33	23	0.09
7	14^{00}	32	30	313	40	42	20	32	22.6	0.2
8	15^{00}	33	24	670	51.4	48	21	37	22.6	0.31
9	16^{00}	38	18	720	61.5	53	21	37	22.6	0.5
10	17^{00}	33	22	680	63.5	44.6	21.8	42	23	0.29

In contrast, the experimental investigation conducted on 29 April 2026 exhibited relatively lower performance due to unfavorable meteorological conditions. The presence of cloud cover and moderate wind reduced the intensity of incident solar radiation and increased convective heat losses from the reactor surface, thereby decreasing the thermal energy available for the evaporation process. Consequently, the daily freshwater production decreased to 2.5 L, which is approximately 62% lower than on the previous day. Nevertheless, the entire electrical demand of the desalination device continued to be supplied by the photovoltaic panel, while the total electrical energy consumption during the experiment was 1.52 kWh.

To verify the energy self-sufficiency of the device, an electrical energy balance was estimated. The combined power demand of the feed pump and the steam extraction compressor is 184 W;

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therefore, the measured daily consumption of 1.63 kWh (28 April) and 1.52 kWh (29 April) corresponds to equivalent full-load operating times of approximately 8.9 h and 8.3 h, respectively, which is consistent with the 08:00–17:00 measurement period. The daily energy supplied by the photovoltaic panel was estimated as $E_{PV} = P_{rated} \cdot \Sigma(G_i \cdot \Delta t)/G_{STC} \cdot PR$, where P_{rated} = 550 W is the rated power of the panel, G_i is the hourly solar irradiance given in Tables 2 and 3, Δt = 1 h, G_{STC} = 1000 W/m², and PR ≈ 0.75 is the assumed performance ratio (assuming that the panel receives the measured irradiance). The cumulative irradiation over the measurement period was 8.99 kWh/m² on 28 April and 6.75 kWh/m² on 29 April, which gives an estimated PV output of about 3.7 kWh and 2.8 kWh, respectively. Thus, the PV generation exceeded the electrical demand of the device by a factor of approximately 2.3 and 1.8, while the storage batteries (Figure 1, item 19) compensated for short-term drops in irradiance. The specific electrical energy consumption was 0.25 kWh per litre of freshwater on 28 April and 0.61 kWh/L on 29 April; under unfavorable weather it increases considerably, because the auxiliary equipment operates at constant power while the evaporation rate decreases.

The experimental data presented in Tables 2 and 3 indicate that the freshwater production capacity of the proposed solar concentrator-based water desalination device is significantly influenced by variations in environmental and meteorological conditions. The amount of freshwater produced during the desalination process was found to vary continuously throughout the day owing to fluctuations in solar radiation intensity and changes in atmospheric conditions.

The principal factors affecting the operational performance of the desalination device include variations in solar irradiance, ambient air temperature, relative humidity, and wind conditions. Changes in solar irradiance directly affected the thermal energy absorbed by the reactor, resulting in corresponding variations in both the reactor surface temperature and the temperature of the saline water inside the reactor. Moreover, fluctuations in ambient temperature and relative humidity influenced the overall heat transfer process, whereas wind-induced convective heat losses reduced the reactor temperature, thereby decreasing the evaporation rate and freshwater production efficiency.

These findings demonstrate that the thermal behavior and productivity of the proposed desalination device are strongly dependent on prevailing environmental conditions. The relationships among the measured operating parameters are further illustrated by the graphs presented below.

As shown in Figures 3 and 4, on 29 April 2026 the ambient air temperature rose gradually from 26 °C at 08:00 to a maximum of 38 °C at 16:00, while the relative humidity varied within 18–30% and reached its minimum at 16:00. Thus, the experiment was carried out under hot and dry atmospheric conditions.

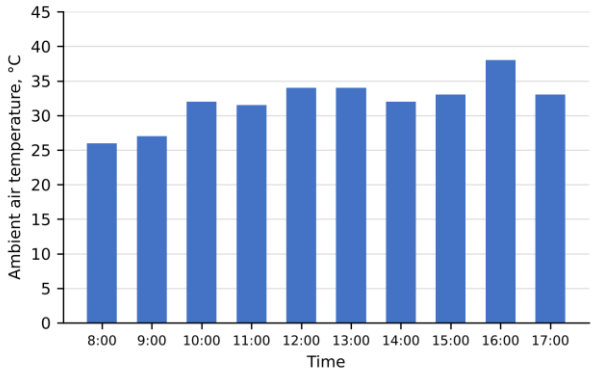


Figure 3. Temporal variation of ambient air temperature on 29 April 2026.

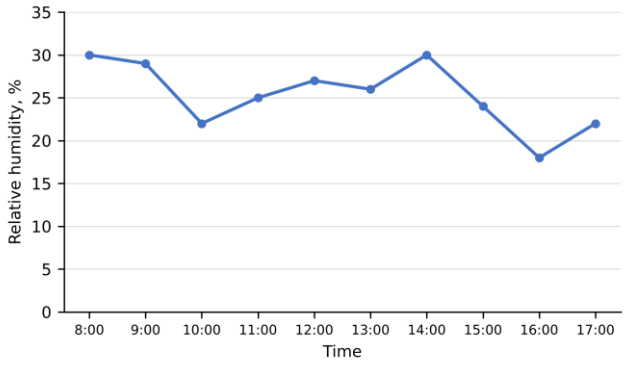


Figure 4. Temporal variation of ambient relative humidity on 29 April 2026.

Figure 5 shows that solar irradiance was unstable during the day: it peaked at 980 W/m² at 10:00 and then dropped sharply to 500 W/m² at 11:00 and to a minimum of 313 W/m² at 14:00 owing to cloud cover. These fluctuations were directly reflected in the absorber–evaporator surface temperature (Figure 6), which reached its maxima of 77 °C at 10:00 and 12:00, when irradiance was highest, and fell to 40 °C at 14:00, when irradiance was lowest.

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The saline water temperature inside the absorber–evaporator (Figure 7) followed the same pattern, ranging from 15 to 55 °C, with peaks at 09:00 and 12:00. Figure 8 confirms that solar irradiance was the dominant factor governing the absorber–evaporator surface temperature, whereas the ambient air temperature changed in a much narrower range and had a considerably smaller effect. The unstable irradiance and heat losses due to wind therefore explain the reduced freshwater production of 2.5 L on this day.

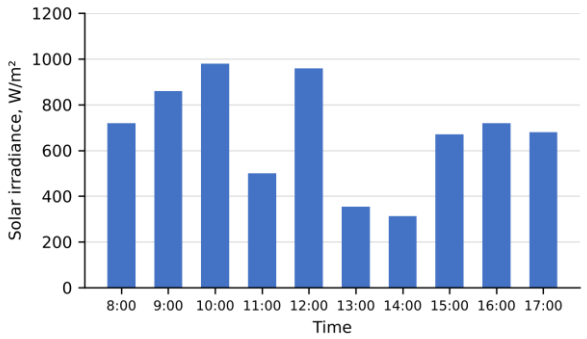


Figure 5. Temporal variation of solar irradiance on 29 April 2026.

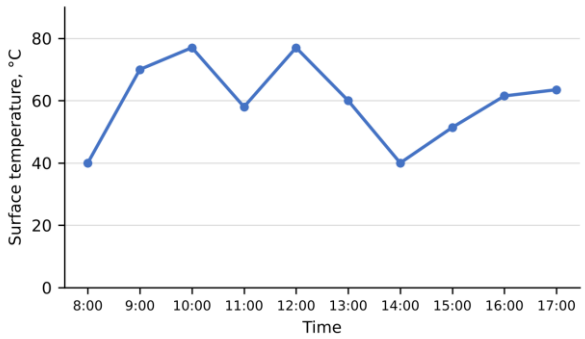


Figure 6. Temporal variation of the absorber–evaporator surface temperature on 29 April 2026.

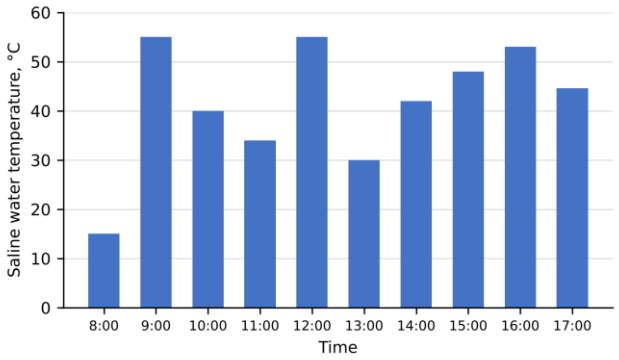


Figure 7. Temporal variation of saline water temperature inside the absorber–evaporator on 29 April 2026.

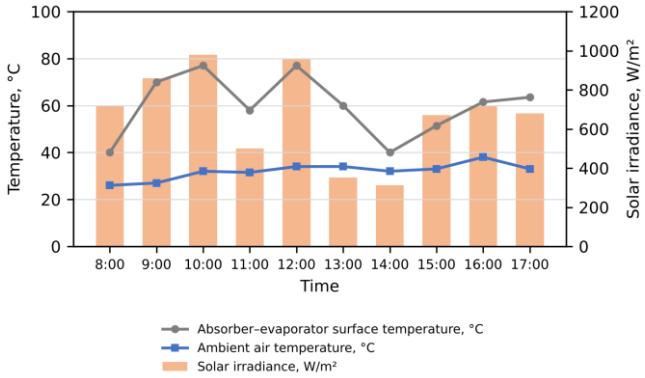


Figure 8. Effect of ambient air temperature and solar irradiance on the absorber–evaporator surface temperature on 29 April 2026.

Conclusion

The increasing scarcity of freshwater resources resulting from global climate change has become one of the most critical environmental and socio-economic challenges worldwide. This problem is particularly severe in arid and remote regions lacking centralized drinking water supply systems, where local populations are often compelled to rely on saline or hygienically unsafe water sources for domestic consumption. The prolonged use of such water may contribute to the spread of water-related diseases and pose significant risks to public health. Furthermore, the extensive use of saline water for agricultural irrigation accelerates soil salinization and leads to a gradual decline in soil fertility, thereby adversely affecting agricultural productivity.

The experimental investigation of the proposed solar concentrator-based water desalination device demonstrated its potential as an effective and environmentally sustainable solution for freshwater production under the investigated operating conditions. Owing to the concentration of solar radiation on the absorber–evaporator, the device began producing freshwater within the first hour of operation and reached an hourly yield of up to 1.0 L/h at a solar irradiance of about 970 W/m².

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A quantitative comparison with conventional solar stills under identical operating conditions will be the subject of further research.

The experimental results further confirmed that the proposed device operates with low electrical energy consumption while utilizing renewable solar energy as its primary energy source, thereby providing an environmentally friendly alternative to conventional desalination technologies. A single photovoltaic panel with a rated power output of 550 W was sufficient to satisfy the entire electrical energy demand of the system throughout the experimental period: its estimated daily output exceeded the measured consumption of 1.52–1.63 kWh by a factor of about 1.8–2.3. Consequently, the device can operate without relying on grid electricity or fossil-fuel-based power sources, thereby eliminating the direct greenhouse gas emissions associated with conventional electricity consumption during operation.

Under the experimental operating conditions, the daily freshwater production was 6.5 L under clear-sky conditions (28 April) and 2.5 L under variable cloud cover (29 April), i.e., about 4.5 L per day on average. The observed variations in freshwater productivity were primarily attributed to changes in solar irradiance and prevailing weather conditions, confirming that environmental factors play a significant role in determining the operational efficiency of the proposed desalination device.

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