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Solar Distillers with Different Types of Condensers: A Detailed Review

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Abstract

Access to potable water for the global population is gradually decreasing every day. Most human diseases are attributed to the use of contaminated or impure water sources. The need for water purification does not disrupt the ecosystem. Solar still is a water purification technology that produces ultra-pure distilled water without any harmful impact on the environment. Solar still systems provide sustainable solutions for fresh water production. There are various environmental and operational factors that are necessary to optimize the design of the still. Researchers have evaluated different designs to enhance the productivity of solar stills. The studies mentioned in this research paper demonstrated that the integration of a solar still with an exterior or internal solar condenser resulted in an effective and efficient productivity. This thorough inquiry seeks to show, depict and assess the condition of distinct solar stills together with various concentrator setups.

Keywords: Solar Still, Solar Distillation, Condenser Types, Review

1. Introduction

Water is a critical resource for economic progress and well-being. However, the increasing need for fresh water is a major concern, especially in emerging countries. The absence of safe drinking water is a serious health problem, and pollution from population increase, industry, and urbanization results in

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water shortages in rural areas and agriculture. A total of 3.575 million people die annually from water-related ailments, and most rural communities are uninformed of the hazards [1].
Solar stills provide distinct advantages for applications in distant places with limited access to fresh water owing to their simplicity, minimum operational cost, maintenance needs and environmental friendliness. Solar energy is clean and free, which reduces the use of fossil fuels and pollution. However, solar stills have restricted production of distilled water compared to other desalination processes, rendering them uneconomical. The normal production of conventional solar stills is between 2 to 5 liters/m2 per day. The principal desalination procedures, such as steam pressure distillation, reverse osmosis, and electrolysis, require electricity as the input energy [2]. However, several countries have been seriously affected by energy crises owing to their dependency on old energy sources, harming their environment and economic advancement. Solar stills may provide a solution for delivering fresh water to remote villages and small islands, solving the difficulties of water shortages, and providing clean water for these places.

2. Solar Still System

Solar stills are classic water production methods that employ a box with a small container of water at the bottom and slanted glass at the top. The sun's rays are absorbed by the black bottom side of the pond, and the water condensed at the bottom of the glass cover plate. This boosts the temperature of the glass, resulting in decreased output at maximum light. It is done using a closed system, where water is the working fluid [3]. There is a substantial temporal lag between the sunshine curve and steady-state yield curve, presumably owing to higher glass temperatures. The glass cover also condenses energy to the surrounding environment, resulting in a limited total output and loss in efficiency. including the implementation of a water layer on a glass plate, which serves to absorb a portion of thermal energy and consequently lowers the temperature of the glass substrate. Nevertheless, the enhancement in yield was not substantial, as a fraction of the incident solar radiation was reflected by the molecules formed within the dynamic water film. An alternative method involves the application of a water heat exchanger, which facilitates a rapid reduction in the temperature of the glass due to the process of condensation [4]. A variety of factors influence the efficacy of solar still production, encompassing the intensity of solar radiation, velocity of the wind, ambient temperature, differential temperature between the water and the glass, exposed surface area, area of the absorber plate, temperature of the incoming water, glass overlap, and the depth of the water. Although the output of solar stills remains constrained, they represent a viable and sustainable approach for the generation of potable water [5].

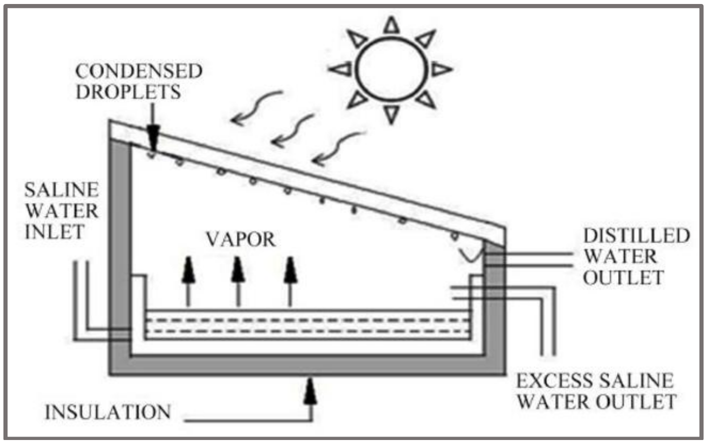


Figure 1. Diagram of a solar still with a single basin.

3. Conventional Solar Still with Condenser

The conventional solar still with a condenser is one of the simplest and most widespread thermal desalination technologies, relying on the principle of evaporation and condensation using solar energy. In this system, brackish or slightly brackish water inside the tank is heated by solar radiation, causing it to evaporate. The water vapor then travels to the condensing surface (glass cover or condenser) where it cools and turns into pure distilled water, which is collected in a dedicated channel. The presence of the condenser improves heat transfer and enhances the condensation rate, positively impacting the overall productivity of the still. This, combined with the simple design and low operating costs, makes this type of still suitable for remote and arid regions [6].

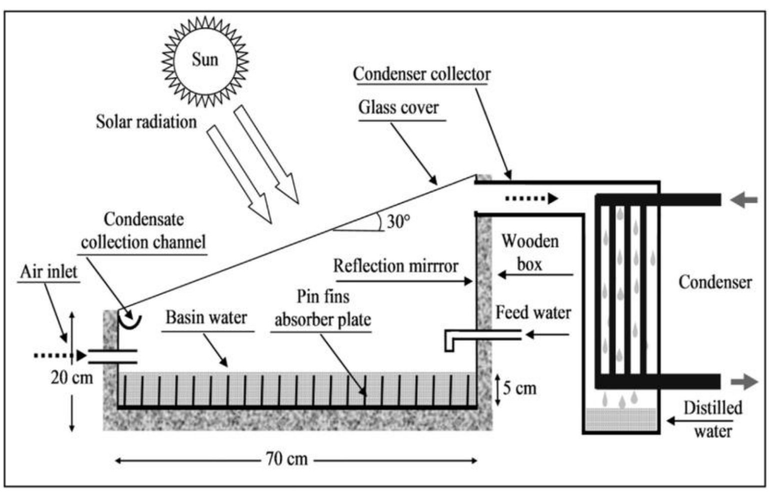


Figure 2. Schematic showing solar still with condenser.

4. Types of Condensers Used in Solar Stills

Researchers have made considerable efforts to devise several types of solar stills to maximize the daily pure water production. They determined that a solar still integrated with condensers exhibited much greater efficiency than a still lacking a condenser. Condensers associated with solar stills can be categorized into three types: integrated, exterior, and internal condensers. Table 1 presents a straightforward comparison of various solar stills categorized according to their respective types of condensers. They were evaluated based on location, daily yield, improvement rate (where productivity enhancement surpasses that of traditional solar stills), efficiency, and experimental observations.

4.1 Integrated condensers

Feilizadeh et al. [7]. The researchers conducted an experimental investigation into the impact of thermosiphon solar stills. Figure.3 depicts the experimental apparatus. Within the solar still tank, steam readily condensed, and the resulting droplets were gathered internally. The study employed a V-shaped condenser. In this research, the water-filled condenser and evaporator produced distillate yields up to 66% higher than alternative distillers. To regulate water evaporation and condenser temperature, water was applied to the outer surface of the V-shaped condenser, which consequently enhanced the condenser's efficiency.
Mohaisen et al. [8]. Combined a warm sink condenser with a solar still plan appeared in Figure 4. The study proposes a detached single-slope solar distillation unit with an inbuilt condenser to move forward condensation rate and efficiency Outside blades are utilized to upgrade condenser execution The framework was tried in Mashhad city for seven continuous summer days, comparing it to a customary sun-oriented still in Tehran The comes about appear balances increment distillate within the condenser by 35% but as it were a 5 increment in by and large efficiency due to 8% diminish in distillate on the glass cover The proposed still can increment every day generation by up to 92.3% and 86% separately.

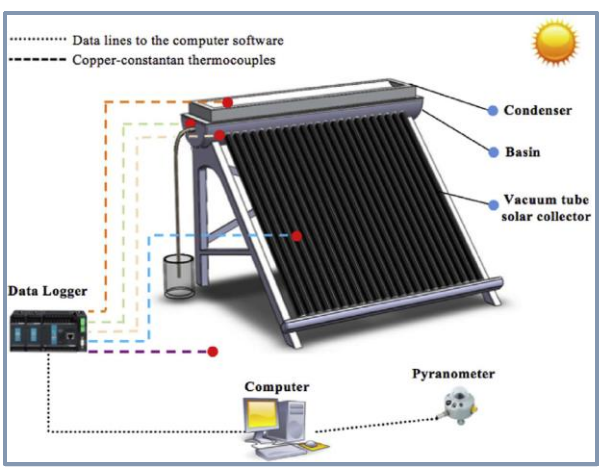


Figure 3. Diagrammatic representation of the solar still connected to the condenser and evacuated tubes.

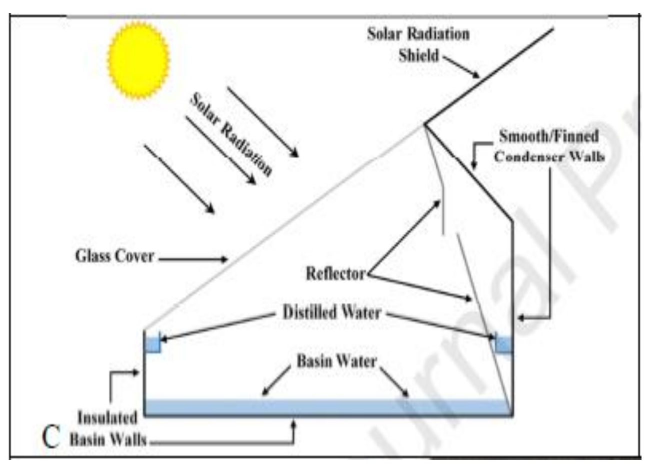


Figure 4. Heat sink condenser solar still

Abbas et al. [9]. This study aims to improve distilled water production in a modified solar still using innovative technologies based on condenser-like absorber plates and glass covers. The effectiveness of longitudinal stripped trough absorber plates and a W-shaped glass cover was analyzed under Iraqi climatic conditions using experimental and numerical methods. Two identical solar stills with trough absorber plates of one square meter were designed and constructed using local materials. Two absorber plates were manufactured from stainless steel, one solid and the other cut. In addition, two glass covers were constructed, one pyramid-shaped and the other W-shaped. The experimental and numerical results indicated that the use of the cut absorber plates and modified glass cover resulted in a 20% increase in distilled water production compared to a conventional glass cover and standard absorber plate, as indicated in Figure 5.

Al-Hamadani et al. [10]. Created a novel solar still featuring a condenser aimed at enhancing distillate productivity in CSS, as illustrated in Figure 6. A conventional solar still with a cooled condenser attached to the back of the device to increase efficiency. The solar still was made of iron, resulting in efficient heat loss and better peak performance compared to conventional stills.

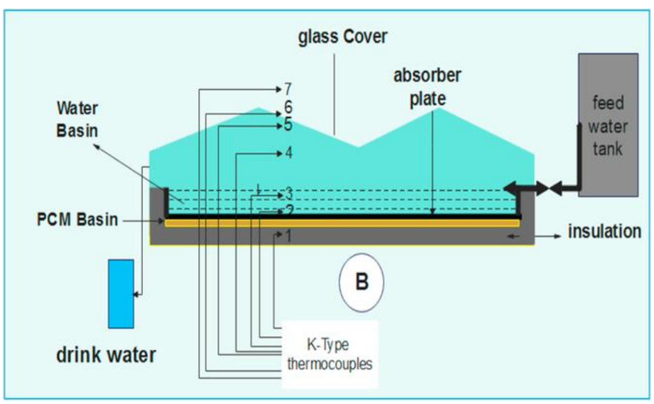


Figure 5. Diagram of a solar still with a condenser and phase change material (PCM).

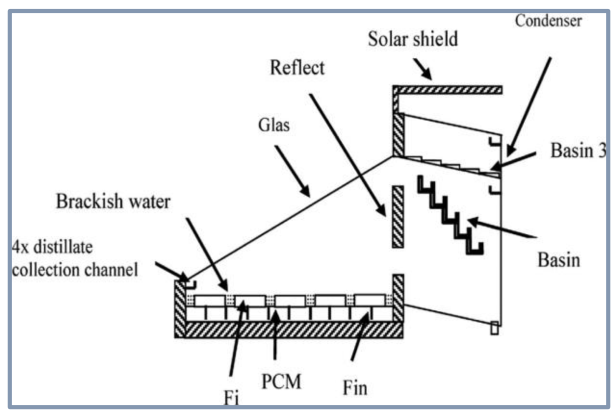


Figure 6. Diagrammatic representation of a solar still with condenser.

4.2 Exterior condensers

Ahmed HM [11]. Evaluated how well a solar still connected condenser worked. The experimental steps are shown in Figure 7. In this instance, three distinct solar still designs are compared. The two condensers and one traditional solar still were connected from the back of the still. Performance was tested in all three seasons. In the other still, the condenser was connected only to the upper side of the still, whereas in the third still, it was connected to both the upper and lower sides of the still's back. The results demonstrate that a condenser with the top and bottom sides facing the rear of the still produces 30% more than a conventional still, and a condenser with the upper side facing the back of the still gives 15% more. Additionally, one might do better in summer than in autumn or winter.

Samadony et al [12]. This article presents an experimental investigation of a modified stepped solar still that has an exterior condenser in addition to internal and external reflectors. The still was equipped with a suction fan to extract water vapor. A comparison between the regular solar still and modified stepped solar still was carried out. Stepped stills with a condenser and those with both reflectors and a condenser were found to be approximately 66% and 165% more productive than the standard still, respectively, as shown in Figure 8.

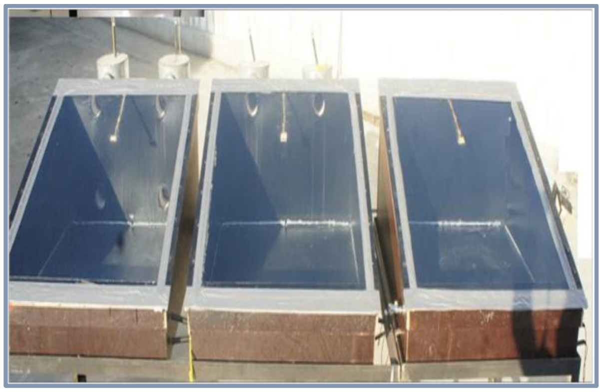


Figure 7. solar still with a novel condenser.

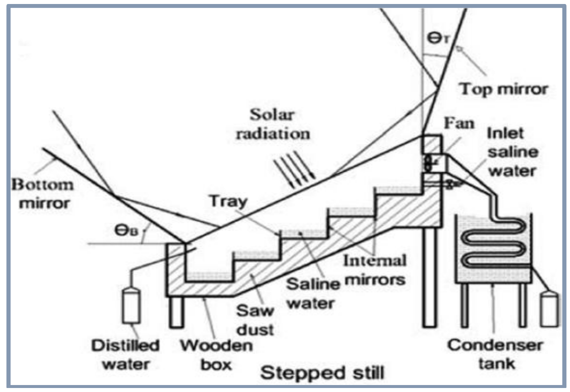


Figure 8. Schematic diagram of stepped solar still with mirrors and condenser.

Omara et al. [13]. The efficiency of the solar still was increased by adding a condenser and making some improvements by adding high absorption materials and fins to increase the area. The enhanced solar still produces 1.5 times greater than that of the conventional solar still, as illustrated in Figure 9. The incorporation of nanomaterials into modified solar stills enhances distillate yield.

Rabhi et al. [14]. An experimental comparison was made between the performance of a solar still and a finned solar still with an external condenser, as shown in Figure 10. A fan is used inside the still to transfer hot steam to the condenser, thus regulating the temperature between the absorber and the glass cover. Moreover, the fins raise the temperature of the absorber basin in the solar still, and the results indicate that the finned basin integrated with the condenser results in greater water production than a conventional still or a still equipped with only a finned absorber.

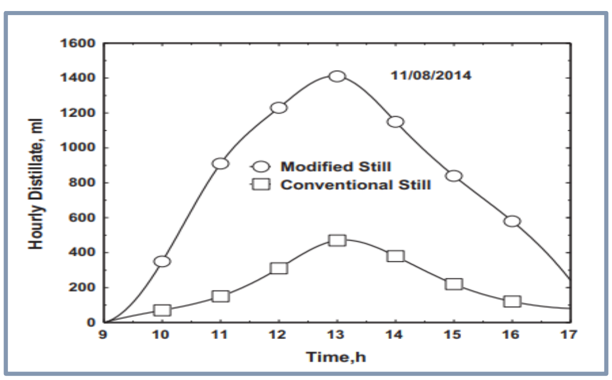


Figure 9. Comparative analysis of simple solar still and modified solar still with condenser.

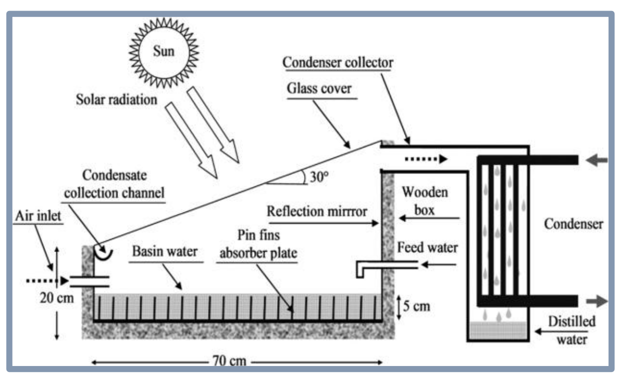


Figure 10. Schematic of solar still with pin fins absorber and external condenser.

Kumar RA et al. [15]. Enhanced the efficacy of the conventional solar still by making Two solar stills were modified to boost distillate productivity by 39.49% compared to CSS as shown in Figure11. The new solar still had an agitation effect and exterior condensation using a shaft and DC motor. The exhaust fan and external condenser facilitated the air movement and vapor condensation. The redesigned still was also more affordable than the normal still, suggesting its potential for enhanced distillation.

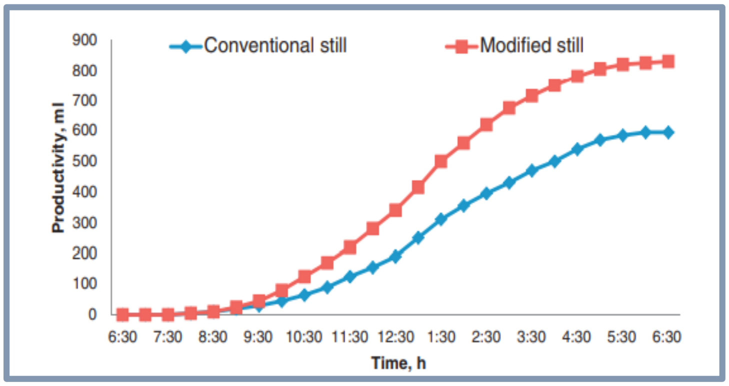
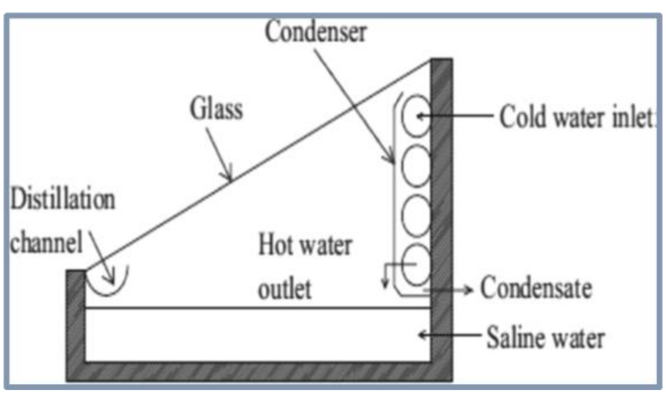


Figure 11. Comparison of modified stills.

4.3 Internal condensers

Al-Jubouri et al. [16]. Created a solar still with an internal condenser with a new design, as shown in Figure 12. The condenser was designed to have eight passages of copper tubes with a diameter of 10 mm and length of 1.2 m. After adding the condenser, the wall cooling process increased and the condensation area increased. The solar still with a new design with an internal condenser provides a higher daytime efficiency than the CSS.

Kodesh et al. [17]. Constructed a solar desalination system simulation model, as seen in Figure 13, where the solar collector was linked to the intended evaporation/condensation chamber. Every component in this model was made of polymeric materials. The developed technique was perfect for solar desalination since it was resistant to corrosion. Furthermore, it was found that the system's design produced more than 11 kg/m2 of distillate each day while maintaining a 2 cm space between the condenser and evaporator surfaces.



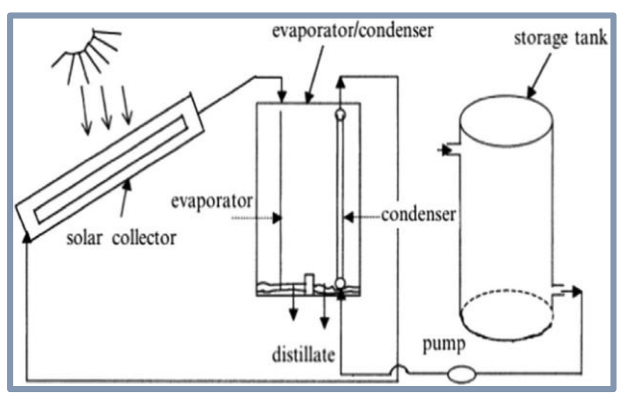


Figure 12. Cross-sectional view of the still with condenser.

Figure13. Schematic diagram of solar still connected with solar collector and condenser.

Table 1. Summary of various research studies on solar distillation devices.

Author [Reference]	Location	Optimization Type	Result
1. Built-in Condenser			
Feilizadeh. et al. [7]	Iran	A V-shaped condenser	the water-filled condenser and evaporator give a distillate yield of up to 66% compared to other distillers
Mohaisen et al. [8]	Iran	combined a heat sink condenser with a solar still design	The results reveal that with the presence of the condenser, the productivity of the solar still increases by more than 35%.
Abbas et al. [9]	Iraq	Basin with absorber fins	The integration of a condenser significantly decreases heat loss, resulting in a 73% enhancement in the efficiency of the new design compared to CSS.
Al-Hamadani et al. [10]	India	Basin with fins	The incorporation of a condenser effectively reduces heat loss and demonstrates superior performance during the afternoon and nighttime across all seasons when compared to CSS
2. Exterior condensers			
Ahmed HM [11]	Bahrain	Connecting two condensers in different states	The results show that the condenser produces 30% more than a conventional distillation device.
Samadony et al [12]	Egypt	stepped solar still that has an exterior condenser in addition to internal and external reflectors	Stepped stills with a condenser and those with both reflectors and a condenser are found to be roughly 66% and 165% more productive than the standard still, respectively
Omara et al. [13]	Egypt	by integrating external condensers, corrugated	The enhanced solar still produces 1.5 times greater distillate output

		absorber surfaces into the CSS design	compared to the conventional solar still
Rabhi et al. [14]	Tunisia	solar still with fins and an external condenser	The results show a fins absorber paired with a condenser produces better water production than a typical still or a still fitted solely with a fins absorber
Kumar RA et al. [15]	India	exterior condensation	The efficiency of the traditional solar still is improved by 39.49% compared with the traditional solar still.
3.Internal condensers			
Al-Jubouri et al. [16]	Iraq	Internal condenser	The results showed a significant improvement in the production and efficiency of the modified solar stills
Kudish et al [17]	Germany	Use of evaporator/condenser chamber	By keeping the condenser and evaporator surfaces 2 cm apart, the developed system produces more distillate—roughly 11 kg/m^2 per day.

5. Conclusion

The above assessments indicate that condensers enhance the efficiency of solar distillers by altering their design and method of addition; thus, the primary points are as follows:

1. The condenser in a solar still performs best in the afternoon, outperforming a conventional solar still.
2. Changing the shape of the condenser to cylindrical, square, rectangular, or other configurations can lead to different results.
3. The use of phase change materials increases the efficiency of distillation equipment and increases production hours after sunset, as they retain large amounts of heat needed to heat the basin water.
4. Using a modified condenser design increases the output of the still at low cost for integrated, external, and internal condensers.
5. The vapor formed inside the still may be directed to the condenser using a fan and external devices; therefore, the volume inside the still grows, lowering the heat loss. In addition, this heat might be dissipated inside the condenser, leading to a still outlet.

6. Improved efficiency can be achieved by reducing the heat loss at the bottom and sides. Higher water temperatures and an inner glass cover enhance the heat loss. The condenser maintains this temperature difference inside the solar still, which improves the efficiency of the solar still.

Declaration of generative AI and AI-assisted technologies in the writing process

-None

Disclosures

The authors have no conflicts of interest to declare in relation to this report.

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أجهزة التقطير الشمسية مع أنواع مختلفة من المكثفات: مراجعة مفصلة

الخلاصة: يتناقص وصول سكان العالم إلى مياه الشرب تدريجيًا يومًا بعد يوم. تُعزى معظم الأمراض البشرية إلى استخدام مصادر مياه ملوثة أو غير نقية. لا تُخلّ الحاجة إلى تنقية المياه بالنظام البيئي. التقطير الشمسي هو تقنية لتنقية المياه تُنتج مياهًا مُقطّرة فائقة النقاء دون أي تأثير ضار على البيئة. تُوفّر أنظمة التقطير الشمسي حلولًا مستدامة لإنتاج المياه العذبة. هناك عوامل بيئية وتشغيلية مُختلفة ضرورية لتحسين تصميم جهاز التقطير. قيّم الباحثون تصاميم مُختلفة لتعزيز إنتاجية أجهزة التقطير الشمسية. أظهرت التجارب أن دمج جهاز التقطير الشمسي مع مُكثّف شمسي خارجي أو داخلي أدّى إلى تصميم فعّال وكفؤ.

الكلمات المفتاحية*.* أجهزة التقطير الشمسي، التقطير الشمسي، أنواع المكثفات، مراجعة.