# Enhancing Water Production through Solar Still Technology: A Comprehensive Review

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**Abstract:** *Water scarcity is a pressing global issue exacerbated by increasing population, industrialization, and erratic rainfall patterns. Desalination presents a critical solution to address freshwater shortages. Solar stills, particularly passive designs, offer a sustainable and cost-effective method for obtaining potable water from saline sources. This review explores various types of solar stills, including single and multi-effect passive and active designs, focusing on their principles, efficiency, and design modifications to enhance productivity. Additionally, it discusses the challenges and drawbacks associated with solar stills and proposes strategies for overcoming these limitations.*

**Keywords:** *Water scarcity, Desalination, Solar stills, Passive solar stills, Active solar stills, Design modifications, Efficiency enhancement.*

## I. INTRODUCTION

Water is vital for human survival, supporting crucial activities such as agriculture, irrigation, and domestic use. However, fresh water availability is a growing concern worldwide. Approximately 97% of Earth's water is saline, and only a fraction of 1% is accessible freshwater. Increasing population, industrial pollution, and varying rainfall patterns, especially in arid and desert regions, exacerbate the depletion of existing freshwater sources. Desalination stands as a critical solution for obtaining potable water from saline sources.

Water's importance extends beyond its physical presence; it is integral to economic development and national welfare. The constant freshwater supply faces challenges due to population growth, industrialization, and environmental changes. Health issues often stem from the lack of access to clean water. Industrial and urban expansion have led to increased water pollution, affecting water quality in rural and agricultural areas. Women globally spend an estimated 200 million hours daily collecting water, often from polluted and distant sources. This highlights the urgent need for effective desalination solutions to secure clean drinking water for all. It a simple device to get potable/fresh distilled water from impure water, using solar energy as fuel, for its various applications in domestic, industrial and academic sectors.

A solar still consist of shallow triangular basin made up of Fiber Reinforced Plastic (FRP). Bottom of the basin is painted black so as to absorb solar heat effectively. Top of the basin is covered with transparent glass tilt fitted so that maximum solar radiation can be transmitted in to the still. Ages of the glass are sealed with the basin using tar tape so that the entire basin becomes air tight. Entire assembly is placed on a structure made of MS angle. Out let is connected with a storage container. Provision has been made to fill water in the still basin. A window is provided in the basin to clean the basin from inside. Water is charged in to the basin in a thin layer. The solar still can be effectively used to obtain sufficient quantities of good water from salt water in regions where the insulation of solar energy is high. A square foot of still area can produce approximately 1/2 to 3/4 lb of distilled water per day. The only disadvantage is the large amount of space needed. The solar still consists essentially of a plastic or glass roof tray to hold water, a galvanized steel gutter for collecting distilled water, and concrete or brick side and end walls. The size is dependent on the quantity of water required. The ideal orientation is facing the equator. The water to be distilled is run down in a slow steady stream at the high end and a small overflow at the low end carries away the remaining salts, preventing crystallization. In a hot, dry climate, the depth of water evaporated is about 1/8″ per day; the depth of water in the tray should be between 1/2″ and 1″.

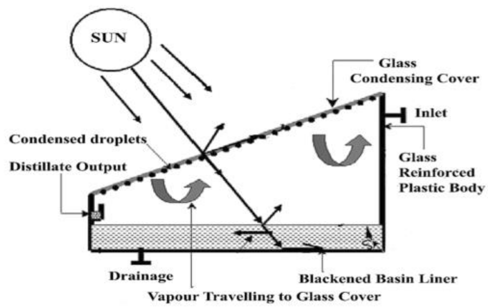


Figure 1 Conventional solar distillation unit [1]

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## II. TYPES OF SOLAR STILLS

### A. Single effect passive solar stills

Single effect passive solar stills, the traditional form of solar distillation units, are characterized by their simplicity and ease of construction, featuring a single glazing layer above the water surface. However, these stills often experience significant heat loss due to the latent heat of condensation escaping through the glazing. This presents a substantial opportunity for enhancing the efficiency of these stills by recovering this lost heat. Ongoing research efforts are focused on various design modifications aimed at improving the performance of these solar stills. A schematic representation of a single effect passive solar still [3]

### B. Multi effect passive solar stills

Multi-effect solar stills are engineered to maximize the use of dissipated heat. These stills are distinguished by having multiple glazing layers over the water surface, which helps in harnessing the latent heat of condensation to boost the thermal efficiency of the still. Compared to single-effect stills, multi-effect solar stills are more productive as they recycle available energy multiple times. There is a growing body of research focused on enhancing the efficiency of these stills through various design innovations. For better understanding, a schematic representation of a multi-effect passive solar still

### C. Single effect active solar stills

The primary limitation of passive solar stills lies in their reliance solely on solar radiation absorbed by the basin water to increase water temperature. To address this challenge, active solar stills have been developed. Similar to single-effect passive stills, single-effect active solar stills feature one glazing layer. However, they are distinct in that they receive additional thermal energy from an external source to boost the water temperature. This elevation in temperature leads to a higher evaporation rate, thereby enhancing the still's efficiency. A schematic illustration of a single-effect active solar still

### D. Multi-effect active solar stills

Multi effect active solar stills are developed to further increase the productivity of the solar stills. These types of stills have more than one glazing covers. To achieve the better evaporation rate of water an additional thermal source is provided by an external source. This additional thermal energy source is mostly provided to the bottom most basin of the still as it receives less solar radiation than other upper basins, due to decrease in transitivity by other additional basins. A schematic diagram of multi effect active solar still.Working principle of solar distillation device.

## III. LITERATURE REVIEW

Kadhum, J. A. [5] addressed the global challenge of limited access to safe drinking water, emphasizing the importance of solar distillation systems in producing clean water for various applications. The study involved developing and testing two types of solar distillers. The first, a conventional tub design, produced 3 liters per square meter daily in summer. The second, a more efficient Type II design with optimized solar exposure, achieved a 22% increase in daily water production, showing promise for global clean water needs.

Alkan, C., et al. [6] explored dicarboxylic acid esters as potential materials for Thermal Energy Storage (TES). They assessed esters derived from adipic, succinic, and oxalic acids combined with 1-hexadecanol using analytical techniques like FTIR and NMR spectroscopy. The esters exhibited distinct melting and crystallization points, suggesting their suitability for TES systems. The study analyzed their thermophysical properties, thermal stability, and performance after 1000 heating and cooling cycles, indicating their potential in TES applications.

Pawar, V. R., & Sobhansarbandi, S. [7] focused on enhancing the efficiency of solar water heating systems using evacuated tube collectors (ETCs) and phase change materials (PCMs). They used CFD modeling and real-world data to study the impact of integrating Tritriacontane paraffin PCM into HPETCs, finding substantial improvements in thermal distribution and efficiency.

Sharon et al. [8] conducted an extensive analysis to identify potential sites for solar desalination along India's coast, based on thermodynamic and enviro-economic evaluations. Experiments in Chennai showed the system's efficiency with highly saline water. The study highlighted the system's energy efficiency, cost-effectiveness, and significant reduction in greenhouse gas emissions.

Rashidi, S., et al. [9] provided a comprehensive review of nanofluids in thermal energy systems, focusing on their impact on condensation and evaporation processes. The study highlighted the advantages and challenges of using nanofluids and recommended future research directions, particularly concerning nanoparticle deposition and suspension.

Y. Tanoto et al. [10] assessed the integration of variable renewable energy into the Java-Bali grid's dynamic operating reserves. Using the National Electricity Market Optimizer, they analyzed scenarios with and without wind and solar resources, finding that VRE integration can reduce costs and enhance grid reserves.

Al-Yasiri, Q., et al. [11] reviewed the use of nanofluids in Flat Plate Solar Collectors (FPSCs) to improve thermal performance. The study focused on parameters like particle size and concentration, identifying challenges and emphasizing the potential of nanofluids to increase the energetic and exergetic efficiency of FPSCs.

Jose, J., et al. [12] combined experimental and computational methods to study the integration of a serpentine copper tube heat exchanger and nanofluids in solar photovoltaic thermal collectors. They examined different coolants and found that Al2O3 nanofluids significantly increased thermal efficiency, confirming these results with CFD analysis.

## IV. WORKING PRINCIPLE OF SOLAR STILLS

Solar distillation is the process which basically uses the heat of the sun directly for obtaining useful water from the salty brackish or sea water. The equipment or the device used is known as solar still. The solar still consists of a shallow basin blackened from the inside to absorb high amount of incident rays and is covered with a transparent glass cover. Fig. 2 presents a schematic diagram and components of a traditional solar still built from a single basin contain saline water and covered by an inclined single glass cover. To reduce heat losses to surrounding the basin was insulated with glass-wood, fiberglass, and wood. The working of solar stills is very simple. A sun's rays that are incident on the glass cover of a still allow the water (to be distilled) to heat up present in the basin causing the process of vaporization. When the rate of vapor production increases, it condenses on the inner surface of the glass casing and consequently condensed water vapor on the inner surface of the glass lid slowly flows through the collecting channel and is assembled into a storage bottle. During this process, salts and microorganisms are left in salt water.

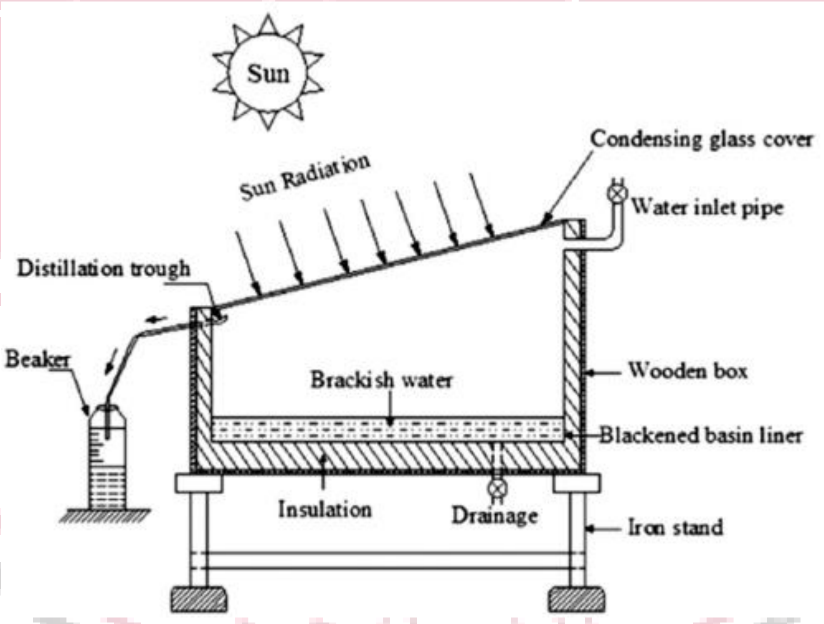


Figure 2 A traditional single basin solar still

The useful fresh water gets collected in the measuring flask through the outlet present on the side of the still leaving behind all the impurities and the salt content. Incoming radiation from the sun is one of the most substantial input variables in solar distillation. There are different types of energy balance and energy losses in the single basin solar still.

## V. CLASSIFICATION OF SOLAR STILLS

Solar distillation is the process which basically uses the heat of the sun directly for obtaining useful water from the salty brackish or sea water. The equipment or the device used is known as solar still. The solar still consists of a shallow basin blackened from the inside to absorb high amount of incident rays and is covered with a transparent glass cover. Fig. 2 presents a schematic diagram and components of a traditional solar still built from a single basin contain saline water and covered by an inclined single glass cover. To reduce heat losses to surrounding the basin was insulated with glass-wood, fiberglass, and wood. The working of solar stills is very simple. A sun's rays that are incident on the glass cover of a still allow the water (to be distilled) to heat up present in the basin causing the process of vaporization. When the rate of vapor production increases, it condenses on the inner surface of the glass casing and consequently condensed water vapor on the

inner surface of the glass lid slowly flows through the collecting channel and is assembled into a storage bottle. During this process, salts and microorganisms are left in salt water.
Active and passive solar stills are two major classification of solar stills. The stills in which sunlight is used directly to evaporate the water comes under the category of passive solar stills. They do not rely on any external devices and operate on the Zeroth law of thermodynamics. In the active solar stills, some additional setup is used to enhance the heat transfer to accelerate evaporation. It can be done through some design modification, integration of an additional device or the combination of both. The solar stills can be further sub-classified into the following three categories.

*A. Basin still*

It is the most simple or conventional type of solar still. It is depicted in Fig. 1.1 and its mechanism has already been discussed above.

*B. Wick still*

The design of a wick type solar still. The wick is a porous material or cloth which is kept at the bottom of the container. The sunlight falling on it transmits through the glass and absorbed by the wick's sur- face. Due to capillary action, the water flowing through the wick rises to its surface and gets heated by the absorbed thermal energy. The heated water evaporates and gets condensed on the inner side of the glass plate by losing its latent heat of evaporation. These condensed droplets trickle down on the sloped glass surface and get collected in a container through the drainage provided for it.

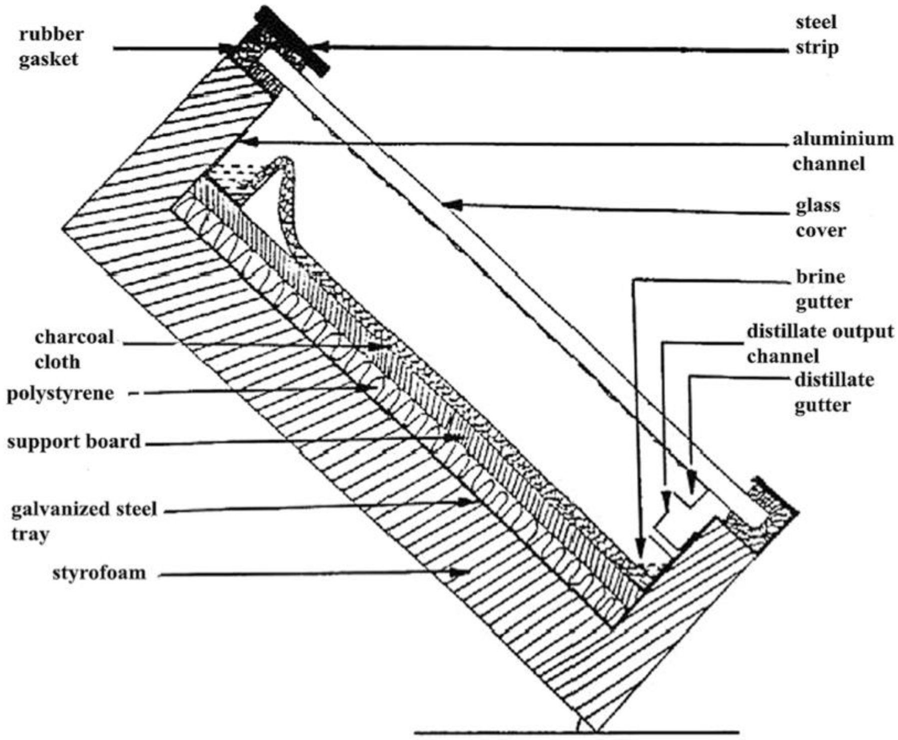


Figure 3 Wick-type solar still [11]

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## VI. DRAWBACKS OF SOLAR STILLS

The main drawbacks of solar stills involve the requirement of large installation areas, lower productivity and higher land cost associated with the larger land requirement. So, the studies mainly focus on enhancing the water production from solar still to negate the limitations as well as on keeping the unit cost of water as low as possible. The productivity of a solar still is influenced by ambient conditions (solar radiation, ambient temperature, wind velocity, etc.), operating conditions (brine water depth, saline concentration, etc.) and design conditions (cover angle, insulation, etc.). The behavior of solar stills with different configurations and different working conditions has been widely studied over the past few decades. Since the distribution of solar radiation around the world is non-uniform, the performance studies of solar still are required to be replicated under the climatic condition of Bhopal. The condition of Bhopal is in favor of the solar still application for drinking water production. In addition, solar still is easy to construct with local labor force using low-cost readily available materials and even illiterate people can operate solar still due to its very simple operations, which make it an excellent choice in the context of Bhopal.

## VII. DESIGN MODIFICATIONS IN SOLAR STILLS TO ENHANCE THE EFFECT OF DESIGN PARAMETERS

The performance of the solar stills can be enhanced by varying some operational parameters like increasing the inlet water temperature or by modification in the design of the still, the use of external and internal reflectors, stepped basin, use of wicks or coupling of external heating source.

### A. *Use of energy storage materials*

The intermittent nature of solar energy makes it imperative that energy storage methods should be employed to increase the productivity of the still when there is no sun- light, especially at nights. Nocturnal productivity in a solar still can be enhanced by the usage of energy storage mate- rials at the base like sand, gravel, rock pebbles.

### B. *Use of porous materials*

Usage of porous materials as absorber surfaces in solar still makes its top surface wet due to capillary effect due to which a thin layer of water is formed on the top. A thin layer of water means higher surface to volume ratio which helps in raising the water temperature quickly, consequently resulting in more productivity. Most of the solar still employing porous materials are known as wick-type still.

### C. *Use of reflectors*

Reflectors are inexpensive and beneficial in increasing the distillate yield of a solar still. They are used to concentrate the solar radiation on the desired area which increases the heat flux received by that area. Waste heat energy from the still is also reduced by the use of reflectors. Many types of external and internal reflectors have been used by the researchers for increasing the efficiency of the stills.

### D. *Use of fins*

The utilization of fins in the solar stills has been found to cause a significant improvement in their performance. Pre-heating time for the brine reduces due to the extended evaporation surface area and an increase in the absorber area.

## VIII. CONCLUSION

Solar still technology holds significant promise in addressing global water scarcity challenges by harnessing solar energy to produce clean drinking water from saline sources. Various types of solar stills, including passive and active designs, offer distinct advantages and have been subject to ongoing research for efficiency improvement. Design modifications such as the use of energy storage materials, porous absorber surfaces, reflectors, and fins have shown promise in enhancing productivity and reducing drawbacks associated with solar stills. Despite limitations such as land requirement and lower productivity, solar stills remain an accessible and sustainable solution, particularly in regions with high solar insolation. Continued research and innovation in solar still technology are crucial for scaling up water production and ensuring access to clean water for all, especially in areas facing acute water scarcity.

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