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A NOVEL APPROACH FOR DISTILLATION OF HARD WATER USING PHOTOVOLTAIC EFFECT

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Abstract
The purpose of this machine is to use Photovoltaic energy to carry out the process of water distillation. The solar smokestack distillation equipment comprises the Photovoltaic smokestack, photovoltaic collector, passive condenser, and evaporation system, which were developed and built. The heated air in the collector is discharged at the base of the chimney, where it then ascends. Humidification of the air is achieved by introducing salty water into the heated air flow near the core of the chimney. Currently, the leftover vapours present in the vicinity are highly concentrated and may be used to provide desalinated water. The machine is characterised by its basic design, which makes it easy to assemble and disassemble. It may be used for filtering rainwater throughout the summer season in rainwater collecting systems. The cost of this device is minimal due to the use of American wood and recycled aluminium containers.
Keywords: Solar energy, chimney, heat exchanger, vaporisation system

I. Introduction

Desalination is a chemical process that transforms saltwater into potable water. There are two methods used for desalinating water: thermal distillation and membrane processes. The primary thermal desalination methods are multi-effect distillation, multistage flash distillation, vapour compression distillation, and photovoltaic distillation. Researchers have just created an exciting discovery called the "Photovoltaic smokestack" in the last several years. This work is very valuable for the enhancement of new energy sources.

II. Literature Review

The use of advanced water treatment technology for practical implementation is limited by the need to apply research principles before proceeding with full-scale design. Twelve significant articles on desalination from seven states identified several national research and implementation priorities connected to desalination. Websites are also indexed when relevant. Reclamation's efforts in desalination are influenced by extensive expertise and important publications such as the Desalination and Water Purification Technology Roadmap (2003) and Desalination: A National Perspective (2008).

A. Photovoltaic Desalination Methods

The two fundamental approaches used to achieve the desalination of salt water are direct and indirect procedures. Photovoltaic desalination is a method that harnesses solar energy to generate desalinated water. Extraordinary photovoltaic desalination plants have been created using this technology. The two main categories are the direct approach and the indirect technique. The fundamental mechanism used in the direct technique is a simple cycle that combines a Photovoltaic collector with a distillation process.

Photovoltaic desalination is a process that occurs on a small scale. In addition to identical designs of Photovoltaic distillation (figure 1), the fundamental concept behind it is essentially the same, whereby the thermal energy from the sun causes the evaporation of freshwater from salt water. The water vapour, produced during the process of evaporation in the Photovoltaic distillation system, condenses on a protective glass surface and is then collected in a trough as freshwater. The protective layer conducts radiant energy and facilitates full condensation of water vapour on its inner surface. The brine solution is formed by the remaining salt and unevaporated water in the stagnant basin, which must be removed at certain intervals. Photovoltaic distillation is often used in arid and desolate regions where access to potable water is limited. Photovoltaic distillation machines generate varying volumes of freshwater depending on the geographic location. The use of Unisol Company's photovoltaic stills (Figure 2) is widespread in various small-scale distillation and desalination systems.

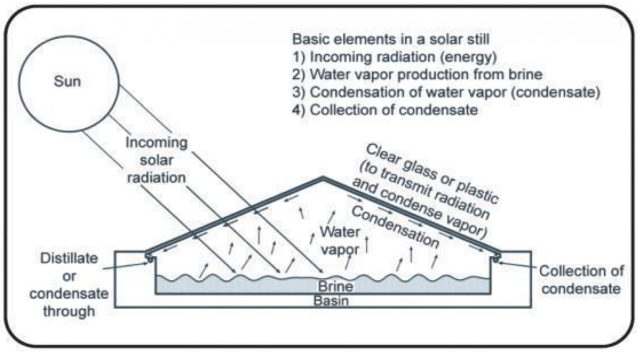

Figure 1: Example of a Photovoltaic distillation process.
Source: MECHELL & LESIKAR (2010)

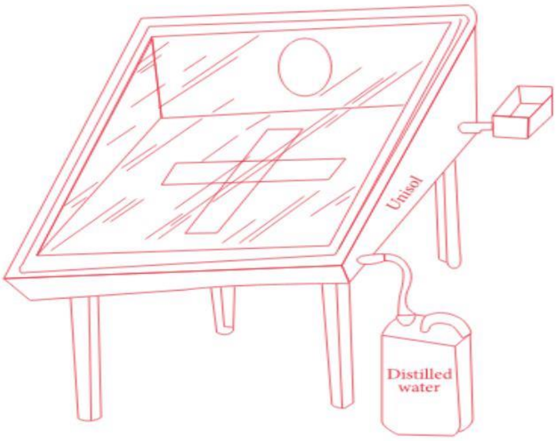

Figure 2: Photovoltaic still

In the direct approach, the position of the incident angle with respect to the solar panel is directly related to the efficiency of water production by photovoltaic distillation. According to Pastohr et al. [3], solar productivity now encompasses a large region but is rather little. Indirect solar desalination processes use either photovoltaic or fluid-based collectors. The production of water relies on the thermal efficiency of the plant indirectly, and as the scale increases, the cost per unit for water production decreases.

B. Photovoltaic Smokestack Desalination System

A prototype Photovoltaic smokestack energy device was created in Manzanares, Spain in

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1981. Since then, researchers have shown strong interest in the development of more efficient Photovoltaic smokestack power systems. The thermal energy stored at the bottom of the solar lake is used in a heat exchanger to warm up the air. A photovoltaic smokestack is used for regulating power generation and desalinating saltwater.Khoo and Lee [12] developed a comprehensive Photovoltaic desalination system (Figure 3) consisting of a Photovoltaic collector, chimney, desalination system, and passive condenser system.

The air within the Photovoltaic collector is heated as the solar radiation directly hits the collection. Consequently, the heated air flows from the Photovoltaic collector to the fireplace and rises upwards as a result of the stack effect. Within the smokestack, a sprinkler (mistifier) emits a fine mist of salt water downwards. The rising heated air in the stack would transfer heat by convection to high-quality water droplets, causing the salt water to evaporate. The water vapour will be expelled via the chimney by the wind and will come into contact with a separate condenser. It will then condense and form fresh liquid water droplets, which will be collected in an outside storage facility. Alvarez et al. [13] described a Photovoltaic collector that uses recycled aluminium jars at a much lower cost.

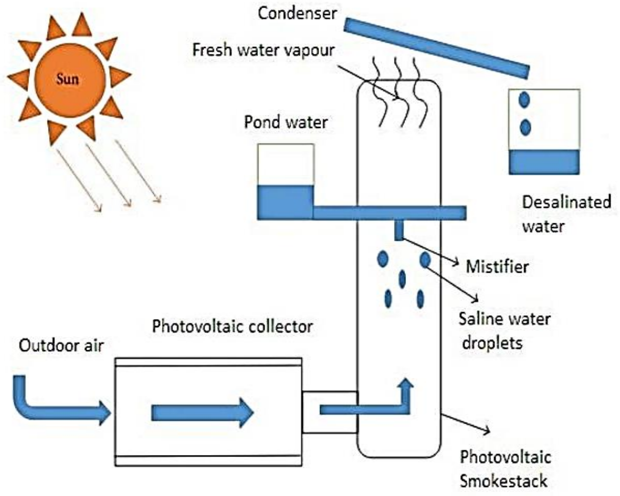

Figure 3: Schematic diagram of Photovoltaic desalination system.

III. Proposed Desalination Plant

The previous project used a recycled aluminium can collector together with a Photovoltaic chimney. The trial setup includes a Photovoltaic collector, chimney, condenser, sprinkler system, submersible water pump, debilitate fan, Photovoltaic panel for power supply, and stand. A scientific model was constructed, sensitivity tests were conducted to improve the system, and the resulting design parameters were then used in the sizing and estimation of the components for production. The completion of the whole framework allowed for the creation of each subsystem operation, and a simplified version was shown using the flowchart shown in Figure (4).

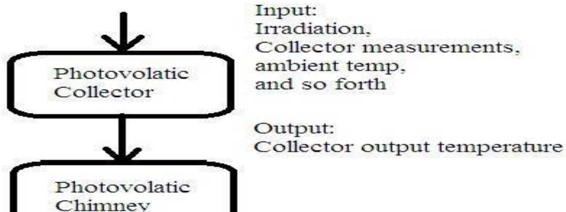

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Figure 4: Flow chart of Photovoltaic desalination system.

IV. RESULTS AND DISCUSSION

Before any water was introduced into the system, the air within the system was heated using a Photovoltaic collector with a minimum solar irradiance of 1000 W/m2. The temperature measurements along the collector and smokestack were recorded in Tables three and four using a reference core thermometer. Table 1 displays the spread of temperatures for the RAC collection.

Time	Inlet Temperature Of Collector (0c)	Outlet Temperature Of Collector (0c)
11.00 AM	28	31
11.15 AM	29	38
11:30 AM	30	43
11:45 AM	31	49
12:00 PM	32	53
12:15 PM	32	59
12:30 PM	34	64
1:00 PM	35	74
1:30 PM	36	82

Due to an increase in solar radiation, the output temperature of the Photovoltaic collector was rising. The outlet temperature of air in the Photovoltaic smokestack is steadily rising, which should cause the mist to evaporate and rise. In order to determine the amount of water that evaporated, the initial and final weight of the water tank were measured, and the difference in weight represents the quantity of water that evaporated via the system. The condenser dividers were maintained at a constant temperature of 10°C by using crushed ice. Initially, evaluations were conducted for the sprinkler device installed near the Photovoltaic smokestack output, at a distance of 0.5 metres from the base of the smokestack. Each test lasted for 1 hour. Subsequent inspections are conducted at the second point, which is located 1 metre away from the stack's base. In addition, temperature measurements were also conducted near the chimney to evaluate the decrease in temperature inside the device when water was injected into the system. Tables 5 and 6 show the air temperature distributions

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within the chimney after water was sprayed into it. The transition from liquid to vapour occurs due to the exchange of heat and mass between water and air. The decrease in temperature at the summit of the chimney is due to thermal losses over the smokestack barrier. The statement indicates the need of implementing accurate insulation on the smokestack in order to minimise the effects of convection and radiation. The cost of air, as determined by an anemometer in a chimney, has been categorised. The air drift rate, excluding mist, reaches its highest point around 12:00 noon, which corresponds to the optimal period for maximum irradiation. Similarly, the movement of air is directly proportional to the rate of mist dispersion, which in turn reduces the level of humidity and increases the density of the air. The airflow rate is influenced by the presence of mist, causing a little decrease in the flow rate compared to when there is no mist.

Table 2: Temperature distribution of air in Smokestack at different heights (before water is sprinkled in Smokestack).

Initial Temperature When No Mist Is Sprayed (^{0}c)			
Height (m)	Trial 1 At 11:00 Am	Trial 2 At 01:00 Pm	Average
2.2	60	68	64
2.5	59	66	52.5
2.8	54	63	58.5
3.1	52	57	54.5
3.4	49	56	52.5

Table 3: Temperature distribution of air in Smokestack at different heights (before water is sprinkled in Smokestack).

FINAL TEMPERATURE WHEN NO MIST IS SPRAYED (0C)			
Height (M)	Trial 1 At 11:00 Am	Trial 2 At 01:00 Pm	Average
2.2	33	33	33
2.5	32	33	32.5
2.8	31	32	31.5
3.1	29	32	30.5
3.4	29	31	30

The smokestack's waft rate, along with the presence of mist, contributes to the decrease in pressure inside the chimney. The impact of smokestack size, height, and solar radiation on the water temperature in the channel and the temperature of the glass cover was clearly seen. The temperature difference ΔT between water vapour and glass in the inner cover increased, leading to an improvement in hourly freshwater production during the daytime. However, throughout the evening, the temperature difference ΔT dropped, resulting in a reduction in freshwater production.

V. CONCLUSION

The daily use of solar energy in the integrated system relies on the thermal energy harnessed

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from solar power to generate fresh water. The primary goal of the project was achieved by the feasible use of a Photovoltaic smokestack for water desalination. Experimental testing was conducted on the mannequin framework using predefined sketch parameters, with a minimum solar illumination of 1000 W/m2. The centre of the smokestack was set as the optimal sprinkler height for condensing and collecting 2.3 L of water by evaporating 3.77 L from the entire setup, which had a height of 3.4 m. The success of the framework is credited to the unique design of the RAC collector combined with the photovoltaic smock stack.

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