Article

Solar still innovations involving renewable energy: A sustainable industrial effluents remediation and recycling design

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Abstract
In the world's dry regions, where freshwater resources are few, and industry and agriculture use water of inferior quality. These have the ability to impact the environment as well as the water quality used by humans and industry. This investigation establishes a complete, consistent framework for modeling the condensation of industrial waste after it has been discharged and kept in an evaporation pond. Solar stills are utilized to cleanse industrial wastewater using evaporation ponds as a case study. This method is designed for small, straightforward installations in off-grid regions having access to both salty wastewater and renewable energy sources. Desalination is therefore one of the most efficient means of supplying industry and agriculture. Among the potential energy systems is the technology for concentrating solar electricity.

Keywords solar still; water quality; industrial waste; evaporation ponds; renewable electricity; desalination.

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1 Introduction

By directing the sun's beams to a confined receiving area, a focusing device may harness solar energy. Utilizing a concentrating system is useful due to its low-cost design, easily accessible components like as mirrors and receiver tubes, and compatibility with fossil fuel technologies to construct a hybrid system. One of the focusing ways that can create enormous amounts of power and heat applications constitute a parabolic trough collector (Lippke, 1996; Kalogirou, 2002)

With the proper parabolic trough concentrating solar system (PTCSS) design, low, medium, and high-temperature applications are achievable. To create hot water, design and build a parabolic trough collector with a smooth 90° rim angle and fibreglass reinforcement. According to studies on five parabolic trough solar collectors with varying rim angles employed in a low enthalpy process, maximum efficiency of 67% and temperature of around 110°C may be obtained at a rim angle of 90° (ValanArasu and Sornakumar, 2007; Jaramillo et al., 2013).

Some regions are failing to keep up with the growing demand for water. Consequently, the demand for desalination methods and industrial waste recycling has skyrocketed. In addition to many others, membrane filtering and distillation are two well-known desalination techniques. Some have questioned their excessive energy use and detrimental environmental impact (Zarei et al., 2018).

Using the sun's rays, saltwater greenhouse distillation or humidification and dehumidification of the greenhouse's air can store extra energy at a lower cost. The water produced via greenhouse techniques can be utilized for irrigation, industry, and public consumption (Mahmoudi et al., 2010). The long-term solution to resource depletion in arid, industrializing places like Africa is a coordinated strategy that incorporates water management and conservation (Goosen et al., 2003). Solar evaporation is used to supply the greenhouse's plants and animals with sufficient water to survive in a salty environment. Recent research has examined a range of solar desalination techniques, with an emphasis on air-drying systems. Despite the fact that these methods have been known for some time, greenhouse crop production has only recently adopted them

2 Evaporation Pond Concept

The depletion and deterioration of natural resources, especially water, is one of the greatest concerns of the twenty-first century. The majority of water in Morocco comes from conventional sources. Desalination, reuse, and recycling of treated wastewater are nontraditional water sources that have been developed in recent years to protect the environment and limit the use of natural resources (Lrhoul et al., 2021). An evaporation pond (Fig. 1) is a walled earthen pond in which concentrate evaporates spontaneously due to the sun's heat. As the freshwater evaporates from the ponds, the minerals in the concentrate transform into salt crystals. These salt crystals are routinely extracted and discarded off-site. In evaporation ponds, salty solutions have been drained of water since the 1800s using ponds for evaporation.

According to Pontius et al. (1996), evaporation ponds can be an effective solution to dispose of industrial effluent, particularly in nations with dry, warm climates, high evaporation rates, and inexpensive land. Sealing evaporation ponds can lessen the likelihood that they will pollute the groundwater. Alameddine and El-Fadel (2007) show that evaporation ponds are most effective in regions that are fairly warm and dry, having high evaporation rates, being flat, and having low land prices. Therefore, they strive to limit the quantity of effluent by allowing it to evaporate, which may lead to the formation of salt. Ahmed et al. (2000) devised a method for rating disposal basins based on basin size, the ratio of inflow volume to outflow volume.

Fig. 1 Evaporation pond illustration.

Considering their utility, evaporation ponds are associated with several ecological and environmental problems. For example, if the evaporation ponds overflow with wastewater, it might have a severe effect on the neighboring ecosystem (soil, and groundwater contamination). In addition, as open water surfaces, evaporation ponds act as a magnet for a broad range of avian and mammalian species; however, if the quality of the wastewater contained in these ponds is poor and exceeds the limitations, this might result in an increase in the mortality of these species (Abdeljalil et al., 2022).

3 Solar System Illustration

As a particular form of solar thermal collector, parabolic troughs are made of mirror-polished metal and are straight in one dimension but curved like a parabola in the other. Along the optical axis, any incoming solar radiation is focused on the receiver. In the receiving tube, concentrated solar irradiation warms a heat transfer fluid. There are several businesses and home use for hot fluid, including but not limited to power generation, space heating, and the creation of domestic hot water. The configuration is represented in Fig. 2.

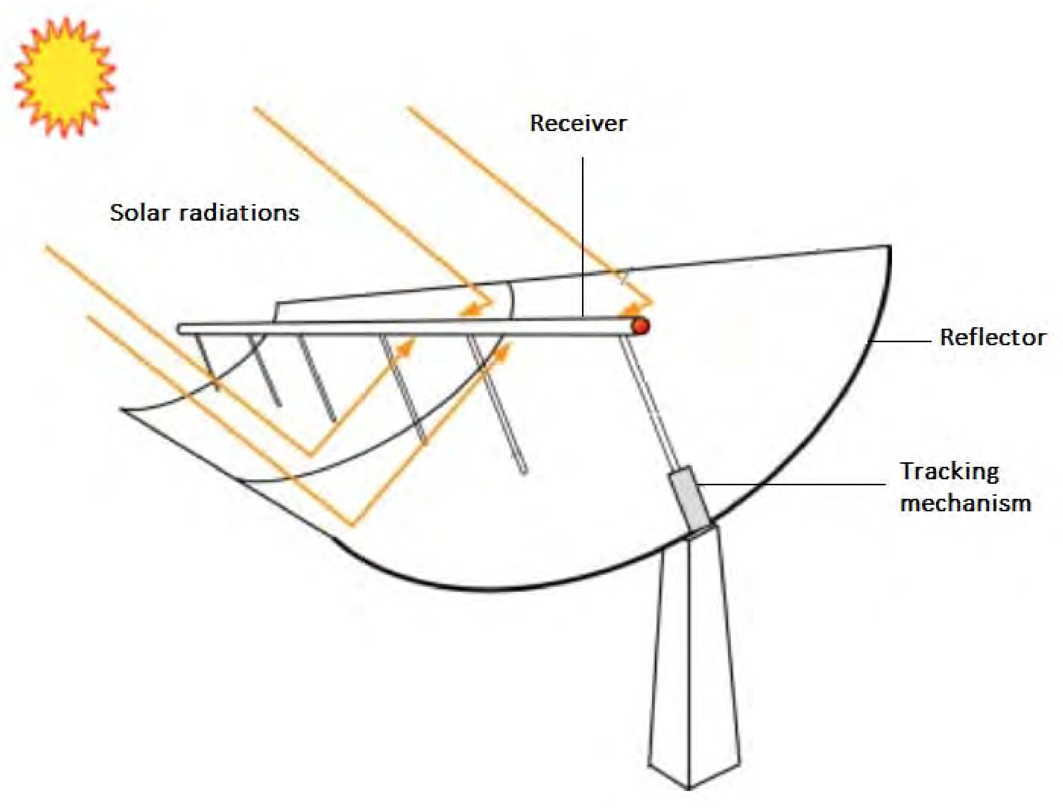

Fig. 2 Parabolic trough collector.

4 Photovoltaic Module Principles

The photovoltaic cell is the primary component of photovoltaic (PV) systems, as it is responsible for converting the chemical energy of sunlight into the electrical energy we use every day. For a PV module or panel, each PV cell must be connected in series. These modules are strung in series to form a string and then connected in parallel to form a PV array with the required voltage and current. Using a nonlinear voltage-current curve derived the equivalent circuit seen in Fig. 3, the behavior of a PV module can be anticipated; this model is commonly referred to as the one-diode model. This model, the most prevalent PV module model under typical operating conditions, may be mathematically described in Fig. 3 (Bakhshi et al., 2014; Lo Brano et al., 2010).

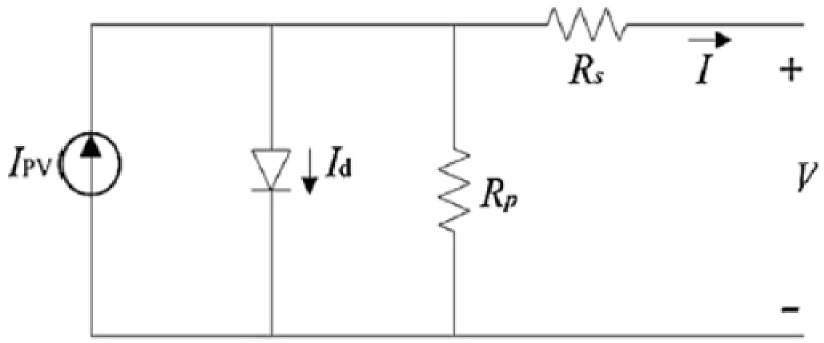

Fig. 3 One diode model PV module**.**

Inverter simulation model, optimal power point tracking (MPPT) inverters, and the construction of grid-connected photovoltaic (GCPV) systems may all benefit from the mathematical model of PV modules. This has prompted a substantial amount of research on the five previously unaccounted-for factors.

5 Solar Still Coupled With Condenser

A small number of authors have studied the effect of adding a passive condenser on a single-slope, basin-type solar still's performance (Nijegorodov et al., 1994). Here, we differentiate between two solar thermal-electrical water purification distillation systems. Using a low-powered exhaust fan to extract humid air from a basin-style still and chill it in a condenser is the first method. Thermal efficiency is increased by more than 100 percent compared to a normal still. Using a concentrator-collector, water is scalded within the receiver tube in the second method. A low-power vacuum pump is used to lower the boiling point of water by around 10°C (Fig. 4) (Madhlopa and Johnstone, 2009).

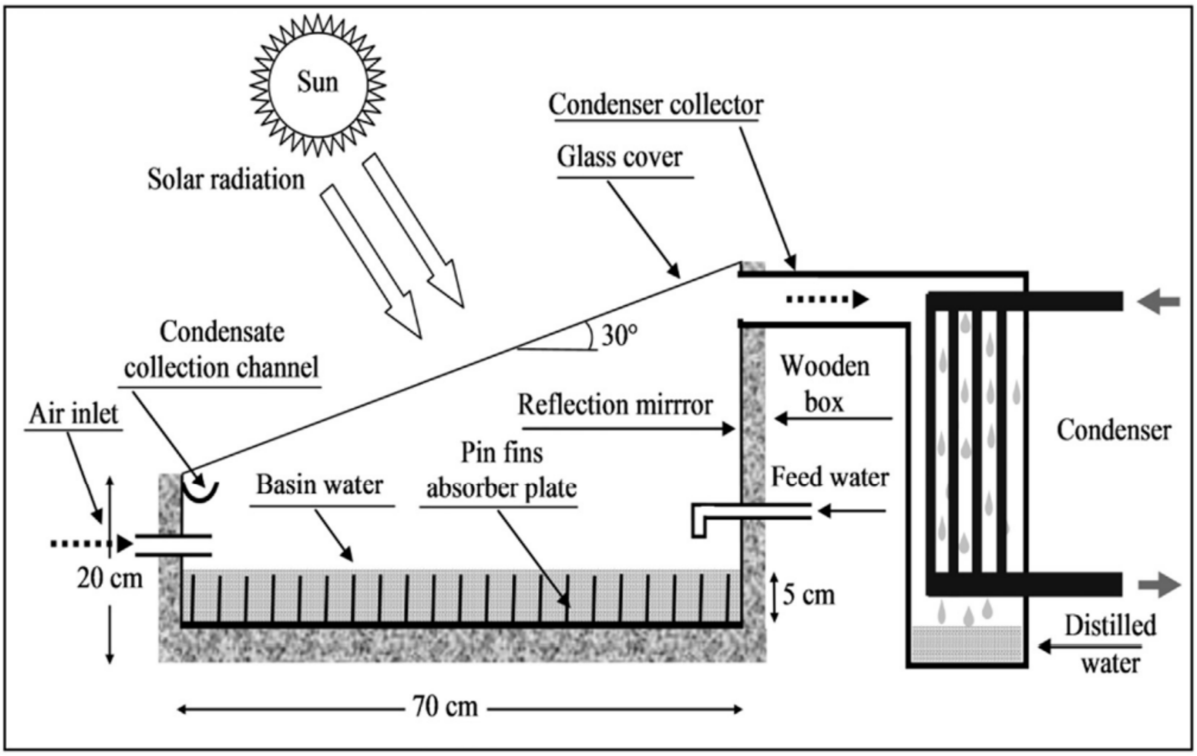

Fig. 4 Solar still coupled with a condenser (Rabhi et al., 2017).

Theoretically, a revolutionary solar still with a secondary condenser has been developed. The screen shields the condenser from sun radiation. This solar still can be used globally and can be manufactured using affordable materials (Kabeel et al., 2014). The current system performance with the condenser is tested and compared to that of a conventional solar system running in the same location and weather conditions. According to the data, the present version remains better to the previous one in terms of distillate output. According to research (Madhlopa and Johnstone, 2009), The principal disadvantages of doing scientific research are their high cost and length of time. As a result, a number of scholars have concentrated on computer modeling to better comprehend.

6 Sun Tracking' Solar Still

Some authors have utilized solar tracker systems to enhance distillation yield (Hession and Bonwick, 1984). A sun tracking system for usage with numerous collectors and frames was investigated. Others have created a tracking system that can be used as an enhancer for single-axis solar concentrating systems (Kalogirou, 1996).
On a collector consisting of six parabolic reflectors with trackers, research was conducted (Ibrahim, 1996). A study was conducted to determine the effect of a two-axis sun tracking system on the thermal performance of compound parabolic concentrators CPC (Khalifa and Al-Mutawalli, 1998); the tracking of CPC collectors demonstrated superior performance with a 75% increase in collected energy compared to a stationary collector of identical design.

The solar still was spun to follow the sun's course using automated sun-tracking equipment and a sun-tracking system (Abdallah and Badran, 2008) intended to improve its efficiency. The use of sun tracking increased productivity by around 22%, as determined by a comparison of fixed and sun-tracked solar stills, resulting in a 2% increase in overall efficiency. Sun tracking is preferable than stationary systems and can enhance production (Kabeel and El-Agouz, 2011).

7 Experimental Approach of Solar Still

Kabeel et al. (2014) examined the impacts of predominantly deploying a fan as a vacuuming method and an external condenser (Fig. 5). Nanoparticles of aluminium and cuprous oxide were added to the solar water still to increase its efficiency. They concluded that the mathematical model of PV modules is applicable in several sectors, including dynamic analysis of inverters, MPPT in inverters, and the development of GCPV systems. Therefore, researchers have concentrated their efforts on these five characteristics.

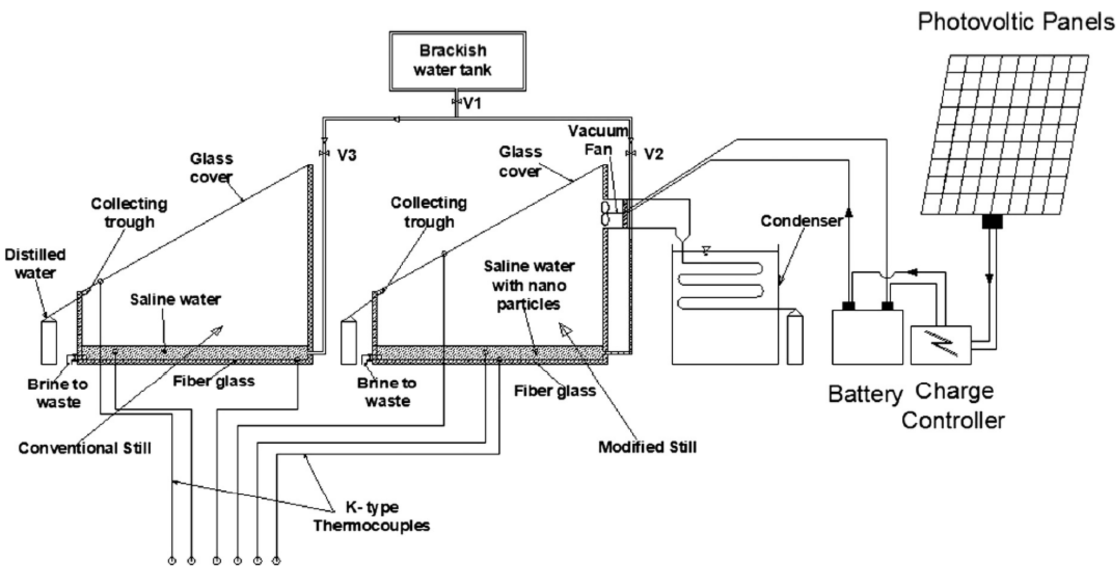

Fig. 5 Solar still illustration (Kabeel et al., 2014).

8 Pyramid Design of Solar Still

Abdelal and Taamneh (2017) studied the effectiveness of a sun desalination unit by comparing the outputs of four pyramid solar stills with the same dimensions but different basin materials. All of the primary components of the manufactured solar stills are depicted in Fig. 6. Investigations showed that when 2.5 and 5 wt% carbon nanotubes (CNTs) were introduced to the absorber plate, the distillate rose by 65 and 109 percent, respectively. Adding graphene nanoplatelets (GnPs) to the epoxy matrix (density: 1.20103 kg/m^3, heat capacity: 1.40 kJ/kg K, thermal conductivity: 0.20 W/m K) boosted still productivity by 30% (Xiao et al., 2018).

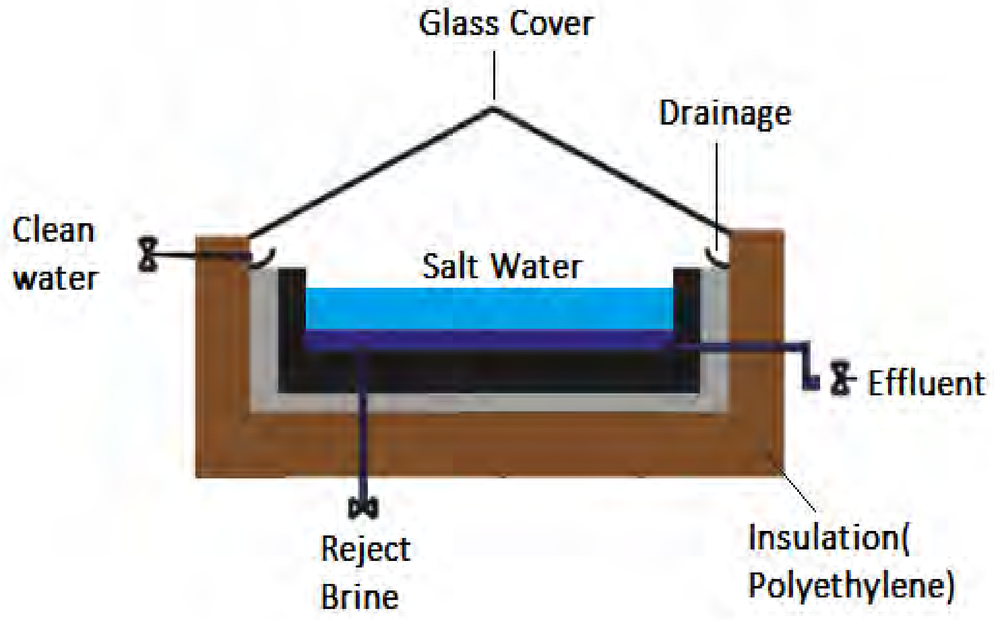

Fig. 6 Solar still pyramid design.

Among the suggested improvements are sponge cubes, a greenhouse, an external condenser, solar tracking, reflectors, solar tracking reflectors, a flat plate solar collector, and phase change material paired with solar stills. The addition of a color may diminish the quality of the distillate, a drawback shared by both methods.

9 Economical Perspectives

The economic aspect has a substantial impact on decision-makers in every profession. One purpose of financial analysis for solar still systems is to determine the unit cost of fresh water (Yagos et al., 2022) (in liters or cubic meters) and the relative relevance of different expenses to the industry as a whole. This indicates the most urgent areas for immediate cost reduction and improvement (Banat and Jwaied, 2008). Even if solar technology has not yet reached its full potential in the areas of the globe where it is most needed, it is nevertheless a reliable source of energy today.

Environment, local availability of materials, and labor costs all play a part in shaping design's continuing development. Polythene, solid plastic, or glass may be used to cover solar stills. This illustrates that solar energy is still very inexpensive overall. The cost of a solar still system may increase or decrease based on a variety of factors. The local environment and the variety of aesthetic ideas are examples of such elements. These factors impact the cost-effectiveness of solar thermal systems, but they also provide major, location-independent benefits. Comparable to the solar still, fan-ventilated greenhouses may minimize energy use by operating at lower speeds, as discussed by Davies et al. (2008).

The majority of solar distillation facilities are designed with locally accessible, less costly materials, compounding the problem. In this scenario, rates may vary significantly based on your location. The practicality of the two solar-powered freestanding water distillation units (Fiorenza and Sharma, 2003) was ultimately determined by economic studies undertaken to forecast the anticipated water cost (compact and large).

Presently, capacitors and inverters are not required to provide the minor electrical needs of fans and pumps, but research indicates that solar panels will be used for this purpose in the future. This will help folks who live off the grid to lower their carbon impact while still receiving safe drinking water. Only one percent of the world's deserts would need to be utilized for concentrated solar-generating installations to fulfill global demand. The considerable economic potential exists for these technologies to regenerate forests and provide essentials such as food, water, and electricity.

Extensive study has been performed to better comprehend the difficulties of supplying desalination plants with the necessary energy. Wind and solar energy are both sustainable, clean energy sources. Mahmoudi et al. (2009) studied and analyzed five productive rural districts to assess whether or not wind energy might be used to power solar still systems. They stated that wind energy is an efficient source of generating electricity and might be utilized to power salt water-based solar still devices.

10 Future Works Scope and Proposal

It is advocated that the CSP innovation utilizing parabolic collectors are applied to increase the usage of renewable energy by solar thermal systems. Using the recommended method, the energy required to boil the wastewater prior to its evaporation in the solar still would be reduced. CSP parabolic collectors will be powered by PV renewable energy in order to guarantee complete tracking of the sun. Using this approach will not be prohibitively expensive. Operating and maintenance costs are also manageable. As the collectors are already installed at these power plants, this approach for recycling wastewater will be more efficient and cost-effective (Adam et al., 2022).

Clear skies throughout the year imply that this solution's candidate is appropriate. The subject of addressing the energy needs of the industry using renewable sources has been investigated. Both solar concentrated solar power and solar photovoltaic electricity contribute to a sustainable and clean energy grid. This study investigated the possibility of utilizing concentrated solar power (CSP) and photovoltaic energy (PV) to power wastewater solar distillation, which has been proposed for wastewater recycling and clean water production.

Power supplies of the solar thermal system, including pumps, condensers, and fans, will significantly rely on the electricity provided by the CSP and PV arrays. In addition to the solar distiller's ecologically friendly wastewater recycling process, various treatments that have been the subject of several research may be used to recycle sludge. To enhance the processing conditions for producing ceramic bricks from a mixture of sludge from water treatment and typical ceramic paste, for instance, an experimental design was implemented (Ramirez Zamora et al., 2008).

Although photovoltaic (PV) energy represents one of the most commonly used renewable energy sources, its output quality is hampered by significant constraints. Variables like module temperature and solar radiation intensity have a significant influence on the efficiency of PV panels. Scientists have studied this issue and created a number of solutions, such as the one given by Agyekum et al. (2021b), both front and rear surface cooling to regulate the temperature of the PV module. Consequently, comparable ideas may be made to maintain the high efficiency of the PV panels that power our solar array. Still is an alternative way for enhancing the flow of fresh water. In contrast, combining angled solar still with a regular solar still boosts productivity with minimum extra cost. As a result of the solar still's slanted design, salty water may be pumped into it using gravity alone, avoiding the need for a pump (Lakhdari et al., 2021). Future solar collectors might be powered by tracking photovoltaic panels, which would heat wastewater before it is piped into a solar still. This eco-friendly approach will permit rapid and efficient wastewater recycling (Fadaei, 2022).

11 Conclusions

During the past several decades, several desalination technologies have been designed and implemented to increase the water supply in dry parts of the world. Since the high expense of desalinization is a major impediment. A solar still that purifies wastewater through evaporation is driven by a thermoelectric solar power system that creates electricity through a low-temperature Rankine cycle. Fields of parabolic-trough collectors concentrate the sun's rays on a central, wastewater-filled Heat Collector Element (HCE). As sludge circulates through the solar still and the receivers, it is heated.

As a consequence of the foregoing revision of passive solar still with a single basin, the following strategies and modifications were used to increase its efficiency: The effectiveness and output of the still depended on variables such as its position, the amount of solar radiation, the air temperature, the level of the water in the basin, the material, depth, and angle of the glass cover, the wind speed, and its heat capacity. Compared to other characteristics, the depth of the water in the basin has the greatest effect on the effectiveness of the still.

The majority of the physicochemical characteristics of industrial wastewater collected in an evaporation pond are linked in some way. Due to the industrial effluent, the physicochemical characteristics of the wastewater in the evaporation ponds increased. This will increase water contamination. Nonetheless, a large number of measured values in the research region were higher than permitted for specific elements of wastewater quality. Consequently, using a solar still to recycle wastewater is a potential technique for mitigating future environmental and ecological disasters. Solar collectors made from synthetic polymers are another alternative for cost reduction. Solar stills provide the opportunity to deliver drinkable water at an affordable price. Different cost-estimating methodologies make it difficult to set consistent, interchangeable pricing across all entities.

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