Journal of Chemical Health Risks

www.jchr.org

JCHR (2024) 14(3), 3404-3415 | ISSN:2251-6727

Designing Solar Still and Study it's Operating Parameters for Avoiding Chemical Health Risk: A Review

Tushar Sharma[a], Vivek Sachan[a*]

[a] Department of Mechanical Engineering ,School of Engineering and Technology , Shri Venkateshwara University, NH-24, Venkateshwara Nagar, Rajabpur Gajraula, District,Amroha, Uttar Pradesh – 244236.

(Received: 08 February 2024 Revised: 11 March 2024 Accepted: 08 April 2024)

KEYWORDS

Toxicology ; Chemical Health risk**;** Solar desalination; Solar stil .

ABSTRACT:

Life depends on water, and in recent years, the importance of having a sufficient supply of drinkable water cannot be overstated. The traditional methods of desalination necessitate for toxic salt removal expenditure in order to transform chemical toxic brackish water into potable pure water for human health and industrial use with avoiding chemical health risk . After decades of intensive research on a variety of desalination methods, solar desalination is one of the most promising approaches to harnessing renewable sources to provide the human health world with high-quality pure water from chemical toxic water . The necessity of the hour is a small-scale, self-contingent desalination equipment .A cutting-edge tool called a solar still uses solar energy to distil chemical toxic brackish water into pure water for avoiding chemical health risk. Approximately 97% of the water on Earth is chemical toxic brackish or saline salts, making it unfit for human health issues. There are several distillation processes available to turn salty or chemical toxic brackish water into drinkable water using various approaches. Nevertheless, the performance of basin-type solar stills is limited by certain factors, and various research, both experimental and numerical, have explored ways to improve both design and operational techniques. As a result, there has been little use of the most current theoretical initiatives and concepts addressing this issue. This article aims to give a thorough overview of the thermal models created for different kinds of solar stills and the adjustments made to enhance their functionality over time. Our research suggests that a few more factors and design considerations should be made while creating a new solar still. This study is effective because it gives energy researchers ideas into designing solar stills for the production of clean water from chemical toxic brackish or saline salts , which in turn encourages the commercialization of this product for rural human health development by avoiding chemical health risk . Lastly, a broad plan of action is provided for choosing a solar still with a versatile, reliable design. There are also suggestions for additional research included.

1. Introduction

Water is a priceless gift from nature and a significant renewable resource with many inherent benefits for human health use. We live in a world that is famished today. In many nations, the human health community's most pressing need is access to pure, clean drinking water. All living creatures on our planet are suffering health issues greatly by chemical toxic brackish or saline salts, as a result of this contaminated water, human is under a chemical health risk. More gravely, no one can avoid its terrible impacts and it poses a risk to human health. Contaminated water is the medium of transmission for extremely contagious diseases. Additionally, places like pharmacies and hospitals, chemical companies, battery maintenance facilities, labs, etc. require clean water. Compared to industrialized countries, the groundwater resource in developing and impoverished nations is currently being depleted more quickly than it is being replenished. The overuse of chemical pesticides and fertilizers in agriculture is a major contributing factor to the contamination of the depleting subsurface water resources. Because of their growing reliance on ground water and the rapid depletion of other freshwater

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(3), 3404-3415 | ISSN:2251-6727

supplies, Indian villages are facing the problem of overexploitation of this resource. This issue could be partially resolved by using technologies created by scientists and researchers to extract drinkable water from brackish water that is already available.

Due to their rapid depletion, conventional fossil fuel energy sources are in danger of going extinct. Owing to the expanding populace and rising energy requirements, the conventional energy supplies that are currently accessible are severely strained and are being used past sustainable limits. Reducing reliance on traditional energy sources is urgently needed, and investigating non-conventional or renewable sources is necessary. Solar energy with solar still is one of the cleanest, most plentiful, most sustainable energy sources for avoiding chemical health risk. It can be used, among other things, for desalination [1], air and water heating [2], refrigeration [3], solar drying [4], and refrigeration.

One of the basic needs for human survival is access to clean drinking water. There is an abundance of water on Earth, but the majority of it is found in the oceans and is too salty to drink. Clean water is extremely limited, especially in underdeveloped, impoverished, and isolated locations. The water supplies that the residents of these places must rely on are tainted, frequently containing dirt and trash, and posing a risk to their general growth and health [5]. Desalination methods such as thermal, mechanical, and chemical can be used to turn non-drinkable water into drinkable water. These methods all make use of electrical or heat energy produced by burning traditional fossil fuels. Solar energy-based distillation systems are attractive options for producing potable water because of their enormous potential. Currently, nevertheless, these systems only make up only 0.01% of the desalination units in use [6]. This could be explained by the current solar energy-based desalination technologies' low distillate yield. Specifically, effective photo-thermal energy conversion and its subsequent transmission to the water (to be cleansed) to maximize evaporation are necessary to design efficient solar-driven desalination procedures. Put another way, effective solar energy collection [7] and the use of effective heat transfer techniques are necessary for an optimum solar desalination system. Single slope solar stills are among the most straight forward solar energy-driven desalination systems now in use for turning salty or dirty water into drinkable water, especially in isolated, undeveloped areas for avoiding chemical health risk. A great deal of work has previously been done to increase the distillate output from solar power by adding more heat by extrinsic devices such solar ponds, hybrid PVT collectors, concentrating collectors, and flat plate collectors (FPCs) [18-12].

1.1 Solar Radiation

Any description of solar radiation always refers to the electromagnetic radiation that the sun emits. The sun's effective surface temperature is at 5800 K. The Sun is a gaseous globe that undergoes a nuclear fusion event that releases electromagnetic radiation. 3.8 x 1023 kW of energy are produced by the sun in total. Direct beam solar radiation is the term used to describe solar radiation that entered the atmosphere directly. Diffuse solar radiation is the result of sunlight passing through an atmosphere made up of air molecules, water vapor, clouds, dust, and pollution from power plants, forest fires, and volcanoes. Solar radiation has many free, permanent, cost-effective, pollution-free advantages that are available right away. Water is a precious natural resource that is essential to the growth of an economy and, consequently, to the well-being of a country. Water is an essential resource for all living things. The world's surface is covered in water to the extent of one third. The least amount of this fresh water is utilized directly for industrial and human requirements. One of the easiest small-scale desalination techniques is solar still. It can be applied to the process of distilling brackish and contaminated water for human consumption for avoiding chemical health risk. Because the ocean is so large, desalination has the benefit of never running out of sea water, its raw material. Desalination is therefore a drought-proof resource that continuously makes fresh water available, independent of rainfall levels. Basic necessities for human consumption, including clean water for cooking, bathing, and washing, are met by solar desalination for avoiding chemical health risk. A natural evaporation-condensation process called solar desalination is used to purify contaminated or salinized water.

2. Objectives

Solar stills - A solar still is a sealed container that concurrently performs water evaporation and vapor condensation. It has brackish water in its shallow basin

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(3), 3404-3415 | ISSN:2251-6727

beneath the air space. Materials such as asbestos, masonry bricks, concrete, Plexiglas, wood, aluminum, and galvanized iron are typically used to construct an enclosed trapezoidal construction.A glazy, highly transmissive material, such as plastic or glass, covers the top side to allow accumulated water droplets to freely flow off the surface. The enclosures inside side have been painted black to maximize solar radiation absorption. The entire arrangement is fully insulated to minimize thermal losses from basin water to the atmosphere, including the bottom and all four sides.

At the National Physical Laboratory in New Delhi, India, research on solar stills was initiated in 1950. Concentrator type and flat basin type stills were the subjects of these studies. Working with sun stills, the Central Salt and Marine Chemicals Research Institute (CSMCRI), Bhavanagar began in 1946, initially with a tiny laboratory model and then with a pilot plant solar still. This institute set up factories in remote locations, such as Narayan Sorovar in Kutch, which can gather 2400 liters of distillate daily on average. A facility with a 5,000-liter daily capacity was established in Lakshadweep. It takes 8,000 liters per day in Bhareli, Rajasthan, and 15,000 liters per day in Amreli, Gujarat, to establish a process of desalinating brackish water to generate potable water. Tamilnadu Public Works Department is building India's first solar-powered desalination plant to provide potable water in Chennai. The daily production capacity of this facility will be 500 liters of distilled water. In partnership with West Germany and BHEL, the solar energy division of the Energy Research Center at IIT Madras is actively working on research programs to establish a distillation facility.

2.1 Solar Still Operating Principle

A solar still's photographic view is displayed in Figure 1. Within an airtight enclosure, water in the solar still simultaneously evaporates and condenses. To ensure efficient solar radiation absorption, the still's basin is often built from a galvanized iron sheet sprayed with black mutty paint. The still is enclosed at the top by a transparent glass sheet. By adding a silicone sealer to seal the system, the still can be made airtight. The lower end of the glazing has a pipe attached to it so that the distillate output may be collected. In order to minimize heat loss, the still is often insulated on both sides and the bottom.

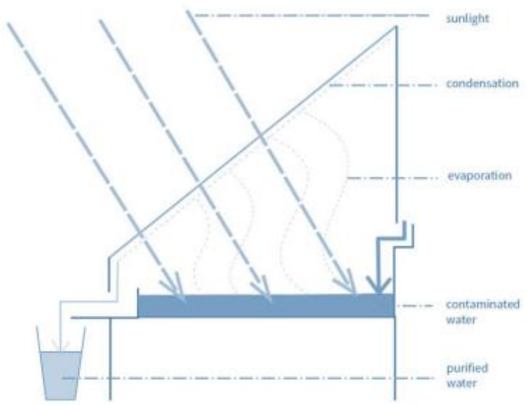

Figure 1: Single slope single basin solar still

To maximize the amount of solar energy that strikes it, the glazing is fixed and inclined. The sun's short-wave radiation enters the still through the glass and is absorbed by the basin. The water in the basin evaporates thanks to this heat. The water that has evaporated rises and condenses on the inside of the glazing. Because of the glazing's slope and gravity, the condensed droplets go downhill and enter the channel attached to the lower end of the glazing surface. Pipes are used to transfer the water in the channel to the storage container. The distillate water produced by a solar still has a far better taste because it is not cooked.

2.2 Classification of the solar still

The traditional solar still is an inexpensive and low-tech way to create freshwater. Low efficiency solar stills are produced using conventional solar stills, which only have one basin and no heat recovery. Many techniques, such as wick-type solar stills, numerous basins, and variations in solar still designs, have been used to increase the efficiency of solar stills [13]. As seen in Figure2, the solar still can be broadly categorized into two types based on how it operates: active and passive.

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(3), 3404-3415 | ISSN:2251-6727

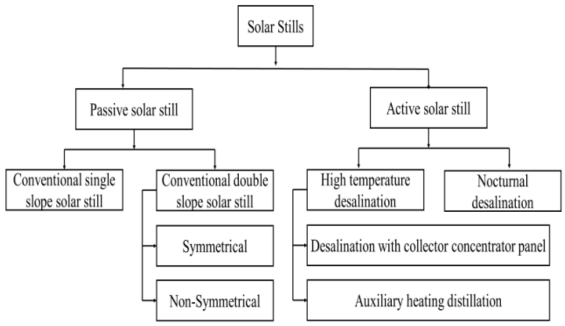

Figure 2: Classification of solar still

2.2.1 Active solar still

The basin water in active solar stills receives additional heat from the outside source. This contributes to the overall production and efficacy of the still. The still can be heated further by connecting it to a variety of external heat-producing sources, such as evacuated tube collectors, solar collectors, hybrid photovoltaic panels, solar ponds, parabolic trough collectors, and so forth. The temperature difference between the brackish water and the condensing glass cover can increase the active solar still's freshwater productivity. By introducing heat energy into the basin from outside sources, such as active solar stills, which are stills with external sources, the temperature of the evaporation surface can be raised [14]. In active solar stills, an external mode provides a source of heat energy to a basin, accelerating the addition of heat to brackish water for rapid evaporation [15]. The external source can include solar collectors, condensers, coolers, and other equipment that improves performance. To increase the rate of evaporation, active solar stills also make use of powered equipment, pumps, or fans.

2.2.2 Passive solar stills

No external heat source is used in the passive solar still to evaporate brackish water. The basin's architecture is changed to improve the solar still's performance. Lower freshwater production as compared to the active kind of solar still is the main disadvantage of the passive form. While the passive kind of solar still has a low operating maintenance cost and is easy to construct, the active type is not cost-effective and requires a large setup cost for residential applications [16].By heating or cooling the PCM, Thermal Energy Storage (TES) preserves energy. Thermal control, electrical systems, power generation, heating, and cooling are just a few uses for the stored energy [17]. Phase change materials are used in solar thermal applications because they are less expensive than chemical energy storage technologies. Phase-change materials have the ability to store energy as both sensible heat (SH) and latent heat (LH) in solar stills. Therefore, compared other reasonable heat storage materials, this material has a higher heat energy storage capacity (SH+LH). Table 1 presents a summary of the various PCM used in the different forms of solar stills.

Table1: Over view of the different PCM used in various types o the solar stills

Sr no.	**Type of solar still**	**PCM Material**	**Productivity**	**Efficiency (%)**	**References**
1	Single basin solar still with double slope	Black dye	Enhanced by 60 %	-	[18]
2	Single basin solar	Potassium	5.29	26	[19]

	Still with double basin	Permanganate and potassium dichromate	ml/day		
3	Perspex rectangular-shaped box	Charcoal granules	15%	32.2	[20]
4	small-scale solar still	Emulsion of paraffin oil, paraffin wax, and water	4.536	-----	[21]
5	Stepped solar still with latent heat storage material	Paraffin wax and Glauber salt	4.6	57	[22]
6	Solar still with PCM storage	Stearic acid	4.998	85.3	[23]
7	Weir type cascade solar still	Paraffin wax	4.85	-----	[24]
8	Weir type cascade	Paraffin wax	6.7	64	[25]

By using a heat-storage material in the basin, reflectors, greater rates of condensation and evaporation, and adding nano particles to the basin water, a single-effect passive solar still can produce more distillate. The efficiency of the still can be increased by producing night time distillate from it by storing excess heat from basin water in different heat storage mediums as inks, sand, stones, and phase-change materials [17].

The temperature of the basin water rises in a passive type solar still because solar radiation can travel through the transparent glass covering and reach the basin liner. This system does not require any additional heat sources. As a result, it can only operate during the hours of sunshine when basin water temperatures are not too high, which results in a rather modest distillate output. In an attempt to overcome the problem of poor distillate output, active solar stills have been constructed and studied. Heat Transfer Coefficient for Pyramid Solar Still is shown in Table 2.

Table2: Heat Transfer Coefficients for Pyramid Solar Still

	Qci(W/m^2)	Qri(W/m^2)	Qei(W/m^2)	Qce(W/m^2)	Qre(W/m^2)	Qbe(W/m^2)

JCHR (2024) 14(3), 3404-3415 | ISSN:2251-6727

PyramidSolarStill	17.22	51.52	127.47	37.11	78.93	4.65
Pyramid Solar Still withTarcoated blue metal	23.41	64.96	247.16	41.43	84.09	5.81
Pyramid Solar Stillwith Phase changematerial(paraffinwax)	24.22	72.83	223.74	43.27	86.14	6.26

3.Methods

3.1 Studies related to improvement in solar still design

By optimizing the operating parameters and refining the thermal design, it is possible to increase the production of solar still waters. Many researchers have employed a variety of methods, including the spherical solar still with internal reflectors and fins, the V-shaped solar still, the double-basin double-slope solar still etc. When an exterior reflector plate was coupled to a V-corrugated absorber plate with fins and energy storage materials, the study discovered that production was at its peak. The low freshwater productivity and efficiency of conventional solar still makes it unpopular when compared to alternative desalination methods. Numerous researchers have worked to improve the design and optimize various operational parameters of the solar still in order to increase its freshwater productivity and efficiency, as illustrated in Figure 3.Since solar energy is erratic and has a low density in nature, thermal storage or other backup energy storage systems are necessary for solar energy to function properly. The hybrid system with energy storage used in the most recent advancements in solar desalination systems shows an increase in freshwater productivity. A hybrid solar still is characterized by the use of two or more heat sources for fresh water generation, desalination, and/or generating systems with another application.

The research focuses on the various designs, operating conditions, and meteorological variables that impact the efficiency of passive solar stills in addition to a cost analysis of the devices. Numerous investigators have employed diverse methodologies, including alterations to absorber energy storage materials, adjustments to the saline water basin, modifications to external heating sources, adjustments to external condensers, adjustments to external and internal reflectors, adjustments to glass covers, and hybrid design.

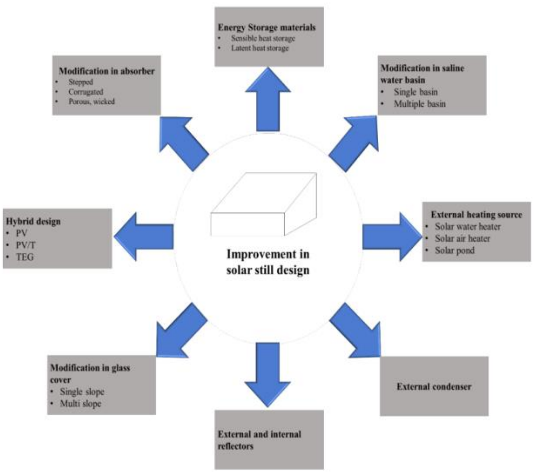

Figure 3: Improvement in solar still design [26]

3.2Modification in the saline water basin

Abed and colleagues carried out tests using a multi-stage solar still that was attached to a solar collector. A heat exchanger coil was used to connect the solar still and collector. As seen in Figure 4. Reddy et al. [27] conducted an experiment on a multi-stage solar desalination system fitted with an FPC to determine the impact on freshwater productivity. An FPC with a surface area of one meter and an evaporative condenser unit make up the multi-stage unit.

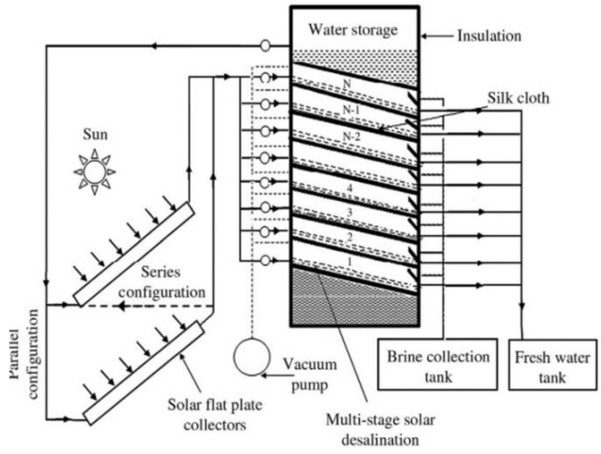

Figure 4: Multi-stage evacuated solar desalination system coupled with flat plate collectors lens [27]

As seen in Figure 5 Shehata et al. [15] conducted a solar still experiment to increase freshwater productivity in the Egyptian climate by utilizing reflectors, ultrasonic waves, and PCM. The utilization of six ultrasonic humidifiers increased the rate of evaporation. For the study, four distinct examples were investigated: a solar still using PCM; a solar still using PCM and ultrasonic humidifiers; a solar still using evacuated solar collector and PCM; and a solar still using PCM and ultrasonic humidifiers in addition to evacuated solar collector. The ultrasonic humidifier significantly increased daily productivity when an evacuated solar collector was included [15].

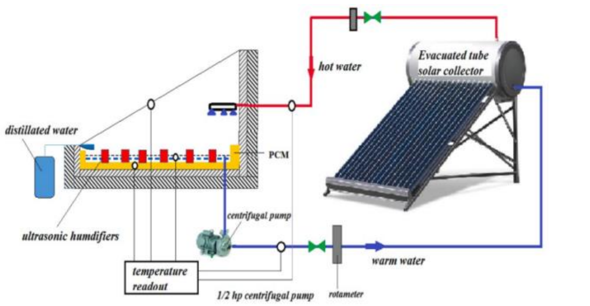

Figure 5: Solar still with evacuated tube solar collector [15].

3.3 External condenser

Experimental research on the double slope solar still connected to an external condenser was conducted by Tuly et al. [28] Black cotton fabric for the wick and paraffin wax are how the solar still stores solar energy. Three types of double slope solar stills traditional, finned, and modified—were used to investigate five distinct scenarios, as seen in Figure 6 Based on a comparative analysis of three double slope solar stills, the modified, finned, and classic solar stills had maximum productivities of 3.07, 2.70, and 2.46 L/m^2, respectively. Maximum efficiency of the modified solar still was determined to be 35.74% with and 30% without the external condenser. Productivity rose by 10% when an external condenser was added to the upgraded solar system. A solar desalination system operating at sub-atmospheric pressure was constructed and tested. Saline water's lower evaporation pressure makes it possible to significantly cut the energy needed to operate the system. The desalination system, which is made up of a solar basin connected to an external air-cooled condenser, was set up using a vacuum pump.

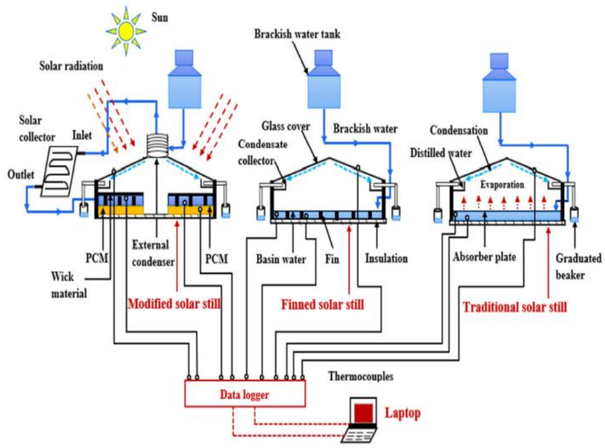

Figure 6: Solar still with external condenser [28]

3.4 External and internal reflectors

A numerical analysis on solar stills with internal and external reflectors was conducted by Tanaka and Nakatake [29]. A geometrical technique was used to calculate the amount of solar radiation that was absorbed on the basin liner after being reflected by the external and internal reflectors, as shown in Figure 7. To properly hit the still's basin liner with reflected sunrays, the exterior reflector was tilted slightly forward. Even with a fairly basic modificationusing both external and internal reflectors—a basin type's daily productivity could be increased by 70% to 100%.

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(3), 3404-3415 | ISSN:2251-6727

Theoretical predictions and practical data agreed fairly well on clear days.

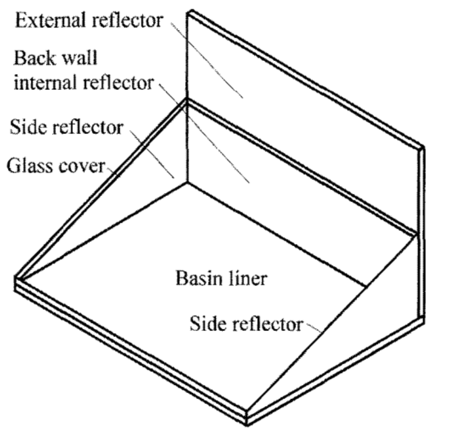

Figure 7: Solar still with internal and external reflectors [29]

3.5 Hybrid design

As seen in Figure 8, Kumar and Tiwari [30] conducted an experimental investigation of the single slope photovoltaic/thermal (PV/T) active solar still in the climate of Delhi, India. To circulate the water, a DC water pump was placed in between the photovoltaic (PV) integrated flat plate collector and the solar still. The recently constructed hybrid (PV/T) active solar system was still self-sufficient and could be used in remote locations without a grid but with an abundance of solar energy, such as when distilled water had to be carried a distance.

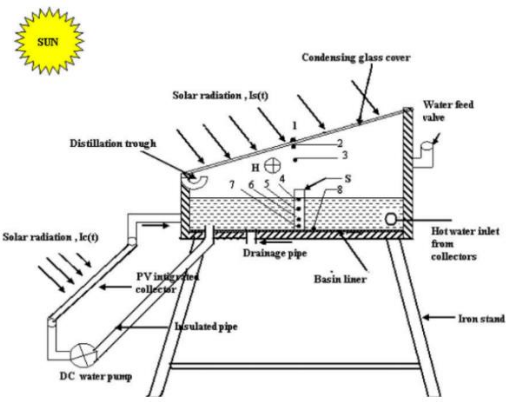

Figure 8: Schematic view of the hybrid solar still (PV/T) [30]

4.Results

4.1 Effect of Design and Operational Parameters on the Performance of Solar Still

The materials used to construct the basin and its shape, the addition of fins, the wick materials used in the still's basin, and multi-effect and multi-basin solar stills are among the design elements that influence a solar still's performance. The operating parameters that contribute to enhancing the yield of a solar still are the water level in the basin, cooling of the condensing surface, integration of the still with energy storage materials, and raising the temperature of the solar still's inlet water in conjunction with other energy storage systems.

4.2 Effect of Absorber Material and Geometry on the Yield of Solar Still

A high absorptivity material is required to capture as much solar energy as possible when building a basin liner. Thermal conductivity is a crucial characteristic of a metal that determines its use in solar applications [31]. Although steel has a poorer heat conductivity than aluminum and copper, steel is nevertheless highly chosen because of this.Nisrin Abdelal and Yazan Taamneh [32] examined the operation of four comparable solar stills, three of which used carbon fiber/epoxy composite absorber plates. A mixture of 2.5 weight percent, 5 weight percent, and 2.5 weight percent graphene nanoplatelets were added to the epoxy composite matrix. The experiment revealed that the yield of a solar still with an epoxy composite basin containing 2.5 weight percent, 5 weight percent, and 2.5 weight percent of carbon nanotubes.

4.3 Effect of Fins on the Yield of Solar Still

Omara et al. [33] tried to increase the absorber's surface area in order to increase the rate at which heat is transferred from saline water to the absorber, thereby boosting the yield of single basin solar stills. In this investigation, a corrugated still and a finned solar still were used; their performances were examined and contrasted with those of a standard solar still. According to their report, the finned solar still has a better efficiency than the other two stills. By employing aluminum pin-fins as the absorber material, Alaian et al. [34] increased the productivity of the solar still and saw a 23% increase over the traditional solar still. The overview of the solar still with fin investigations is shown in Table 3.

Journal of Chemical Health Risks

www.jchr.org

JCHR (2024) 14(3), 3404-3415 | ISSN:2251-6727

Table3: Overview of studies undertaken on fins utilized in solar stills [34]

Sr no.	Type of solar still	Type of Fin-material	Productivity (L/m^2)	Efficiency (%)	Reference
1	Single basin solar still	Rectangular fin – GI	2.81	----	[35]
2	Single basin solar still with fins, sand and sponges	Solid rectangular Fins –GI	3.5	69.1	[36]
3	Single basinsolar still	plate type fin and corrugated fin – Iron	4.55 and 3.95	-----	[37]
4	Single basinsolar still	Flat rectangular fin-stainlesssteel	-----	32.7	[38]
5	Single basinsolar still	Porousfin	7.5	-----	[39]
6	Single basinsolar still	Rectangular fin - Iron	5.37	47	[40]
7	Solar still integrated with fin type mini solarpond	Rectangular solid fin	3	-----	[41]
8	Single basinsolar still	Hollow cylindrical fin – Aluminium	3.8	37	[42]
9	Solarair collector	Rectangular fin	----	----	[43]

4.4 Effect of Design and Operational Factors on Solar Still Performance

The materials used to construct the basin and its shape, the addition of fins, the wick materials utilized in the still's basin, and multi-effect and multi-basin solar stills are some of the design elements that influence a solar still's performance. The operating parameters that aid in boosting the yield of a solar still include the water level in the basin, cooling of the condensing surface, integration of the still with energy storage materials, and raising the temperature of the solar still's inlet water in conjunction with other energy storage systems. Using fins, sponges, and pebbles in the basin resulted in a 98% increase in output of pure water for avoiding chemical health risk.

4.5 Solar Still Yield and The Effect of Environmental Parameters

The operating, design, and environmental factors all affect the solar still's yield. It mostly consists of external factors that are beyond human control, such as wind speed, humidity in the atmosphere, solar intensity, and ambient temperature. The operating parameters are the water depth in the basin, the inlet water temperature, the still's orientation, and the temperature difference between the glazing and the water present in the still's basin. The design conditions are the absorber plate area, the inclination of the glazing material, insulation materials, fins, wick materials, dye, and energy storage materials in the solar still. On the other hand, the pace at which evaporation and condensation occur in a solar still largely determines the still's performance [44]. A stepped solar still with inclined copper trays was conceived and built by Mohammed Shadi S Abujazar et al. [45], who also assessed the device's desalination capacity. Research was conducted to determine how various operational and environmental factors, such as cloud cover, wind speed, humidity, and solar radiation intensity, affected the system's performance. The results showed that environmental factors had a significant impact on the solar still's yield. The temperature differential between the inner and outer surfaces of the glazing as well as the still temperature were seen to rise in response to increased radiation and ambient temperature, which in turn increased the rate of condensation and pure water productivity for avoiding chemical health risk.

5. Discussion

A solar still is a fantastic tool for producing drinkable water, especially for rural health development . Due to its ease of use and straight forward construction, the single basin single slope solar still held the top spot among the several varieties. Nonetheless, due to its reduced productivity, other alternative solar still designs were created by scientists for commercialization. This article examined the various thermal models utilized in both passive and active solar stills and provided a detailed look at the most recent solar still designs. Numerous factors, including economics, material availability, yield requirements, local climate, water quality, and operational concerns, are taken into consideration while choosing a specific design. Because of its basic nature, the single common design might not be useful everywhere in the world. Very few studies have been conducted in real-world field settings, and the majority of applied research on solar stills has only been conducted in laboratories. Extensive studies comparing lab models to real models could be conducted to improve end users' comprehension of the solar still application for pure water generation which make better human health by avoiding chemical health risk.

Refrences

[1] K.S. Reddy, H. Sharon, Active multi-effect vertical solar still: Mathematical modeling, performance investigation and enviro-economic analyses,Desalination. https://doi.org/10.1016/j.desal.2016.05.027.

[2] V.S.Hans,R.P.Saini,J.S.Saini,Heattransferandfriction on factor correlations for a solar air heater duct roughened artificially with multiple v-ribs, Solar Energy.84(2010)898–911. https://doi.org/10.1016/j.solener.2010.02.004.

[3] Y. Wang, M. Li, W. Du, X. Ji, L. Xu, Experimental investigation of a solar-powered adsorption refrigeration system with the enhancing desorption, Energy Conversion and Management.(2018). https://doi.org/10.1016/j.enconman.2017.10.065.

[4] S. Singh, S. Kumar, Testing method for thermal performance-based rating of various solar dryer designs, Solar Energy. 86(2012)87–98.https://doi.org/10.1016/j.solener.2011.09.009.

[5] J. Graf, S.Z. Togouet, N. Kemka, D. Niyitegeka, R. Meierhofer, J.G. Pieboji, Health gains from solar water disinfection (SODIS): Evaluation of a water quality intervention in Yaoundé, Cameroon, Journal of Water and Health. 8 (2010) 779–796. https://doi.org/10.2166/wh.2010.003.

[6] K. Sampathkumar, T. V. Arjunan, P. Pitchandi, P. Senthilkumar, Active solar distillation- A detailed review, Renewable and Sustainable Energy Reviews.14(2010)1503–1526. https://doi.org/10.1016/j.rser.2010.01.023.

[7] V. Bhalla, H. Tyagi, Solar energy harvesting by cobalt oxide nanoparticles, a nanofluid absorption based system, Sustainable Energy Technologies and Assessments.24(2017)45–54. https://doi.org/10.1016/j.seta.2017.01.011.

[8] N.A.R.KumarL;M.Hasanuzzaman,Real-Time Experimental Performance Assessment of a Photovoltaic Thermal System Cascaded With Flat Plate and Heat Pipe Evacuated Tube Collector, Journal of Solar Energy Engineering, Transactions of the ASME. 144 (2021) 011004.

[9] F.M.Abed, Design and Fabrication of a Multi stage Solar Still With Three Focal Concentric Collectors, Journal of Solar Energy Engineering. 140 (2018) 041003

[10] A.H.A. Al-Waeli, H.A. Kazem, M.T. Chaichan, K. Sopian, Experimental investigation of using nano-PCM/nanofluid on a photovoltaic thermal system (PVT): Technical and economic study, Thermal Science and Engineering Progress. 11 (2019)213–230. https://doi.org/10.1016/j.tsep.2019.04.002

[11] S. Kumar, A. Tiwari, An experimental study of hybrid photovoltaic thermal (PV/T)-active solar still, International Journal of Energy Research. 32 (2008) 847–858. https://doi.org/10.1002/er.1388

[12] A.A. El-Sebaii, S. Aboul-Enein, M.R.I. Ramadan, A.M. Khallaf, Thermal performance of

anactivesinglebasinsolarstill(ASBS)coupledtoshallowsolarpond(SSP),Desalination. 280 (2011) 183–190. https://doi.org/10.1016/j.desal.2011.07.004

[13] Al-Kharabsheh, S., Goswami, D.Y., 2003. Experimental study of an innovative solar water desalination system utilizing a passive vacuum technique. Sol. Energy 75, 395–401. https://doi.org/10.1016/j.solener.2003.08.031

[14] Ahmed, A., Qayoum, A., & Mir, F. Q. (2019). Investigation of the thermal behavior of the natural insulation materials for low temperature regions. *Journal of Building Engineering*, *26*, 100849

[15] Shehata,A.I.,Kabeel,A.E.,KhairatDawood,M.M.,Elharidi,A.M.,Abd_Elsalam,A.,Ramzy, K., Mehanna, A., 2020. Enhancement of the productivity for single solar still with ultrasonic humidifier combined with evacuated solar collector:An experimental study. Energy Convers.Manag.208,112592. https://doi.org/10.1016/j.enconman.2020.112592.

[16] Kumar,P.,Rajak,U.,Kumar,S.,Nath,T.,Kumar,V.,Kumar,A.,Shende,V.,2022.Areview of techniques for increasing the productivity of passive solar stills. Sustain. Energy Technol. Assessments 52, 102033

[17] Samykano, M., 2022. Role of phase change materials in thermal energy storage: Potential, recent progress and technical challenges. Sustain. Energy Technol. Assessments 52, 102234. https://doi.org/https://doi.org/10.1016/j.seta.2022.102234

[18] Akash, B.A. mohsen, M.S., osta, O., elayan, Y., 1998. Experimental evaluation of a single- basin solar still using different absorbing materials. Renew. Energy 14, 307–310

[19] Nijmeh, S., Odeh, S., Akash, B., 2005. Experimental and theoretical study of a single-basin solar sill in Jordan. Int. Commun. Heat Mass Transf.32,565–572. https://doi.org/10.1016/j.icheatmasstransfer.2004.06.006

[20] Naim, M.M., Abd El Kawi, M.A., 2003a. Non-conventional solar stills. Part 2. Non- conventional solar stills with energy storage element.Desalination153,71–80. https://doi.org/10.1016/S0011-9164(02)01095-0.

[21] Naim, M.M., Abd El Kawi, M.A., 2003b. Non-conventional solar stills. Part 1. Non- conventional solar stills with charcoal asabsorbermedium.Desalination153,5564. https://doi.org/10.1016/S0011-9164(02)01093-7

[22] Radhwan, A.M., 2005. Transient performance of a stepped solar still with built-in latent heat thermal energy storage.Desalination171,61–76.https://doi.org/10.1016/j.desa1.2003.12.010.

[23] El-Sebaii, A.A., Al-Ghamdi, A.A., Al-Hazmi, F.S., Faidah, A.S., 2009. Thermal performance ofasinglebasinsolarstillwithPCMasastoragemedium.Appl.Energy86,1187–1195. https://doi.org/10.1016/j.apenergy.2008.10.014.

[24] Tabrizi, F.F., Dashtban, M., Moghaddam, H., 2010. Experimental investigation of aweir-type cascade solar still with built-in latent heat thermal energy storage system. Desalination 260, 248–253 https://doi.org/10.1016/j.desal.2010.03.033

[25] Dashtban,M.,Tabrizi,F.F.,2011.Thermalanalysisof aweir-typecascadesolarstillintegrated with PCM storage. Desalination 279, 415–422. https://doi.org/10.1016/j.desal.2011.06.044

[26] P. Manoj Kumar, C. Senthil Kumar, K. Muralidharan, Y. Muniratnam, K. Abraham, V. Manikandan,P.MichaelJosephStalin,S.JeevanPrasanth,Augmenting the performance of conventional solar still through the nano-doped black paint (NDBP) coating on absorber, Materials Today: Proceedings.47(2021),4929–4933. https://doi.org/10.1016/j.matpr.2021.03.721

[27] Reddy K., S. (2012). Performance analysis of an evacuated multi-stage solar water desalination system. *Desalination*, 288:80–92. doi: 10.1016/j.desal.2011.12.016

[28] Tuly, S.S., Rahman, M.S., Sarker, M.R.I., Beg, R.A., 2021. Combined influence of fin, phase change material, wick, and external condenser on the thermal performance of a double slope solar still. J.clean .Production 287 125458 https://doi.org/10.1016/j.jclepro.2020.1254

[29] Tanaka,H.,Nakatake,Y.,2006.Theoretical analysis of abasin type solar still with internal and external reflectors. Desalination 197, 205–216

[30] Kumar, S., Tiwari, A., 2010. Design, fabrication and performance of a hybrid photovoltaic/thermal (PV/T) active solar still. Energy Convers. Manag.

51, 1219–1229. https://doi.org/10.1016/j.enconman.2009.12.033

[31] Ahmed, A., Qayoum, A., & Mir, F. Q. (2021). Spectroscopic studies of renewable insulation materials for energy saving in building sector. *Journal of Building Engineering*, *44*, 103300

[32] Nisrin Abdelal & Yazan Taamneh 2017, ‘Enhancement of pyramid solar still productivity using absorber plates made of carbon fiber/CNT modified epoxy composites’, Desalination, vol.419,pp.117-124

[33] Omara, ZM, Mofreh, HH & Kabeel, AE 2011,’Performance of finned and corrugated absorbers solar stills under Egyptian conditions’,Desalination,vol.277,no.1-3,pp.281-287

[34] Alaian,WM,Elnegiry,EA&Ahmed,MH2016,‘Experimental investigation on the performance of solar still augmented with pin-finnedwick’,Desalination,vol.379,pp.10-15

[35] Velmurugan, V., Deenadayalan, C.K., Vinod, H., Srithar, K., 2008a. Desalination of effluent using fin type solar still. Energy 33, 1719–1727. https://doi.org/10.1016/j.energy.2008.07.001

[36] Velmurugan, V., Gopalakrishnan, M., Raghu, R., Srithar, K., 2008b. Single basin solar still with fin for enhancing productivity. Energy Convers. Manag. 49, 2602–2608 https://doi.org/10.1016/j.enconman.2008.05.010

[37] Omara, Z.M., Hamed, M.H., Kabeel, A.E., 2011. Performance of finned and corrugated absorbers solar stills under Egyptian conditions. Desalination 277, 281–287. https://doi.org/10.1016/j.desal.2011.04.042

[38] Panomwan Na Ayuthaya, R., Namprakai, P., Ampun, W., 2013. The thermal performance of an ethanol solar still with fin plate to increase productivity. Renew. Energy 54, 227–234. https://doi.org/10.1016/j.renene.2012.08.004

[39] Srivastava,P.K.,Agrawal,S.K.,2013.Winterandsummerperformanceofsingleslopedbasin type solar still integrated with extended porous fins. Desalination. 319, 73–78. https://doi.org/10.1016/j.desal.2013.03.030

[40] El-Sebaii, A.A., Ramadan, M.R.I., Aboul-Enein, S., El-Naggar, M., 2015. Effect of fin configuration parameters on single basin solar still performance.Desalination365,15–24. https://doi.org/10.1016/j.desal.2015.02.002

[41] Appadurai, M., Velmurugan, V., 2015. Performance analysis of fin type solar still integrated with fin type mini solar pond. Sustain. Energy Technol. Assessments 9, 30–36. https://doi.org/10.1016/j.seta.2014.11.001

[42] Yousef, M.S., Hassan, H., Kodama, S., Sekiguchi, H., 2019a. An experimental study on the performance of single slope solar still integrated with a PCM-based pin-finned heat sink. Energy Procedia 156, 100–104. https://doi.org/10.1016/j.egypro.2018.11.102

[43] Yousef, M.S., Hassan, H., Sekiguchi, H., 2019b. Energy, exergy, economic and enviro-economic (4E) analyses of solar distillation system using different absorbing materials. Appl. Therm.Eng. 150,30–41. https://doi.org/10.1016/j.applthermaleng.2019.01.005

[44] Ahmed, A., & Qayoum, A. (2021). Investigation on the thermal degradation, moisture absorption characteristics and antibacterial behavior of natural insulation materials. *Materials for Renewable and Sustainable Energy*, *10*(1), 1-10

[45] MohammedShadiAbujazar,S,Fatihah,S&Kabeel,AE2017,‘Seawater desalination using inclined stepped solar still with copper traysina wet tropical climate’, Desalination,vol.423,pp.141–148