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Effects of Magnetic Field on the Performance of Solar Distillers: A Review Study

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HIGHLIGHTS

- A complete survey on the factors that affect the performance of solar pyramid stills is explained.
- Specific categorization of these factors is suggested.
- Solar radiation is the strongest affecting parameter on the pyramid solar distiller performance.
- Promising future scopes of work on the pyramid solar still is suggested.

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ABSTRACT

Due to the rising demand for treated water, the enhancement of potable water yield technologies, such as traditional solar distillers, is a pressing concern. Solar desalination is one of the easiest techniques for producing fresh water from salt water. It has several benefits, not the least. It utilizes free solar energy. Moreover, it is a simple and inexpensive technique compared to other alternatives. They are, nevertheless, relatively inefficient devices. Many studies have been done to boost the daily output of solar stills by using many active strategies to produce a large amount of evaporation and condensation compared to a basic standard type distiller. The magnetic field (MF) is one of the most important and recent techniques affecting the productivity of the solar still due to its positive impact on the water evaporation rate. The primary focus of the current study is to review the effects of magnetic field approaches on the distillate production, performance, and thermal efficiency of several types of solar distillers. Based on previous studies, the magnetic field is responsible for increasing the partial pressure difference between water and glass cover. The change occurs in the hydration shells of the saltwater, which should enhance the evaporation rate and improve the performance of solar still. Besides, the magnetic field significantly reduces the surface tension of salty water, which leads to increased evaporation. Furthermore, the intensity, direction, position, and magnet sizes of magnetic have a strong effect on the rate of water evaporation as well as the rate of heat transfer.

1. Introduction

Water is the second most essential fluid on Earth, after air, for the survival of all humans. The Earth's surface is covered in water to about a two-thirds extent (71 percent), yet more than 7% of this water cannot be used since it exists in the ocean, ice caps, glaciers, earth, and aquifers [1]. Therefore, the amount of freshwater available for human use is only about 1 percent worldwide. Consequently, the demand for desalinated freshwater increases daily [2, 3]. In addition, the uses of freshwater, such as cooking, drinking, and agriculture, place it in a precarious position. As a result, the provision of safe drinking water is a global concern [4, 5]. Therefore, the search for new means of water purification has become a requirement of the hour. There are many ways to desalinate seawater or purify water, the most prominent of which is using solar distillation plants based on renewable energy [6, 7]. Hayder A. Dhahadet al. Engineering and Technology Journal 40 (04) (2023) 020-130 122 the only technical and cost-effective solution to the problem of water scarcity is to desalinate the endless sources of water in the seas and oceans, which are sufficient to meet all human demands [8, 9, 10]. According to the 2016 International Desalination

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Association (IDA) report, more than 120 nations utilize desalination processes to produce potable water. Approximately 30 million cubic meters per day are produced by approximately 4000 units worldwide [11, 12]. Solar stills are mostly recommended for desert regions because of their inexpensive initial installation and operating costs, wide area requirements, and low productivity for meeting the potable water needs of small villages and households. Numerous studies have revealed a variety of adjustments that can be made to single-slope solar stills to increase the amount of distillate produced [13, 14, and 15]. At low elevations, the performance of double slope sun stills is superior to that of single slope solar stills [16, 17]. Although it uses less energy, the cost of solar-distilled drinking water is now several times higher than the cost of water given by the bulk of municipal utilities. This is despite the fact that solar distillation requires less energy. In comparison, water that has been distilled by the use of solar energy is available at a price that is much more reasonable [18, 19]. Figure 1 includes the research objective and scope of all steps of this study.

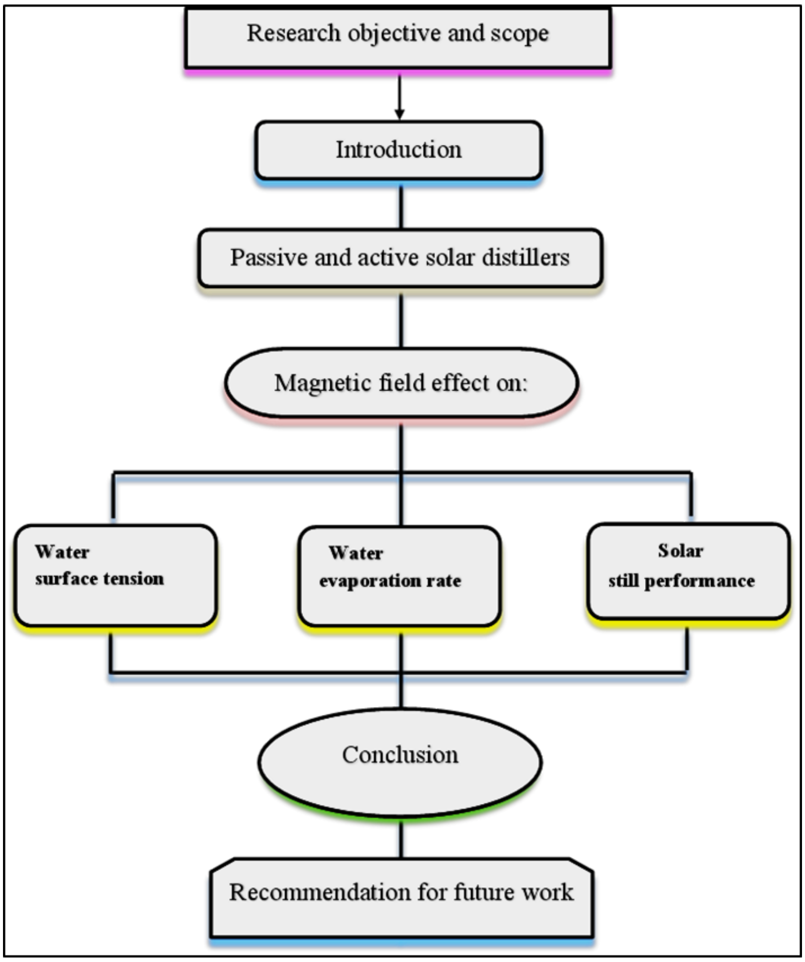

Figure 1: Flowchart for present work

2. Passive and Active Solar Distillers

A solar distiller is a simple device that utilizes solar radiation to transform available brackish or salty water into fresh water. It directly affects our environment's hydrological cycle [20,21]. Solar distillers are usually classified into two groups: passive and active solar stills. Both passive and active solar stillness describe solar stillness. Passive solar still uses the sun's energy to create potable water. In the Active solar still, additional thermal energy is supplied from the solar collector to make clean water or to pre-heat water before it enters the apparatus in another manner [22,23].

The amount of water generated by solar still fluctuates based on three factors: meteorological or climate, operational, and design parameters. People can't control the environment where the solar still works, but design and operational parameters can be easily changed to make it work more efficiently [24,25]. The authors' work was important because it provided insight into the benefits of using many active strategies to increase the evaporation and condensation rate compared to a basic standard type distiller. The classification of solar distillation with different designs of passive and active distillers are given in Figure 2 [26] .Many studies have been done to boost the daily output of solar stills by adding thermal solar collectors, heat exchangers, solar ponds, and hybrid Photo Voltaic Thermal (PV/T) systems [27]. Other studies have tried to cool the condensing surface by running water over it to enhance the temperature differential between it and evaporated water [28]. A flowing water layer can lower the glass's temperature [29]. Using intermittent water on the lid [30] has the same effect. Surface temperature is affected by wind speed. Air movement enhances convective heat transfer from the cover to the atmosphere. This enhances evaporation, condensation, and distiller output [31].

Researchers have created solar distillers with solar collectors [32-34], condensers [35], low-pressure solar stills, those with heat recycling [36], their configuration, color multi-stage/multi-effect solar stills, and hybrid solar still/PV systems to boost production [37,38]. However, due to low productivity, solar distillates aren't commercially viable. Using phase change materials (PCM) with a high latent heat capacity to absorb energy has been studied [39,40]. Other researchers analyzed graded solar still and a simple solar distiller with a single basin, employing a PCM to store energy. Continuing distillation after dusk increased PCM storage distillation productivity. A large temperature difference between the water and the glass cover, which was cooler, helped [41,42].

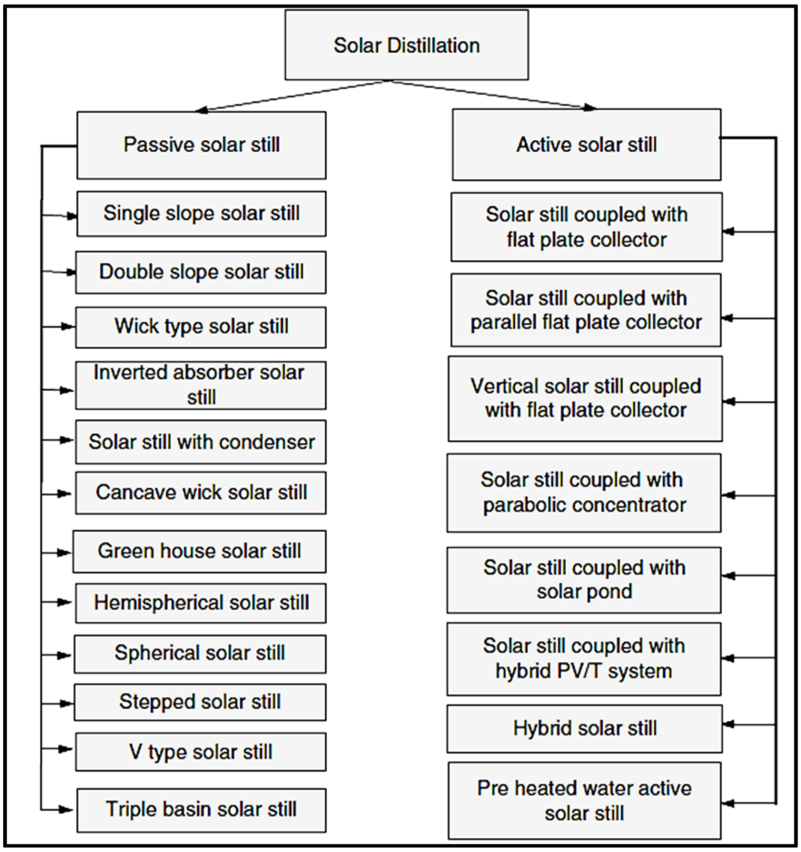

Figure 2: Various designs of passive and active solar distillers [26]

Researchers and scientists have analyzed the impact of magnetic fields on the past water evaporation rate. They found that magnetization strongly affects the rate of water evaporation [43,44,45,46]. Therefore, the magnetic field is one of the most significant and recent techniques affecting the productivity of solar stills.

To the best of our knowledge, there have been no previous review studies that expand on the concept of the effect of magnetic effect technology on the performance of the solar still and its relationship to the rates of water evaporation that have occurred thus far. Here, the research was carried out to review the magnetic field technique's impact on enhancing the distillate yield, performance, and thermal efficiency of the different types of solar distillers.

3. Magnetic Field Effect on Water Treatment

Magnetic fields (MF) have been studied in various water treatment applications for more than 50 years, and many researchers find these fields to be particularly intriguing. Initially, the effects of MF in the liquid phase were examined in terms of their fundamental properties and potential practical uses. Then, in the flowing section, as in the recent papers [47-49], the effect of MF on the surface tension and evaporation rate of water was briefly studied.

3.1 Magnetic Field Effect on Water Surface Tension

Water is one of the highest surface tension liquids, with a surface tension force of roughly 72 N/m at room temperature. When most previous studies on the magnetic field effect on the surface tension property of water were examined, it was discovered that increasing the MF reduced the surface tension. According to Toledo et al. [50], a magnetic field reduces surface tension. Cai et al. [51] observed that the magnetic field significantly decreases the surface tension of salty water. Besides, Amor et al. [52] lowered the surface tension of saltwater by 24 percent by utilizing a magnetic field under hot climate settings. Likewise, Wang et al. [53] observed that magnetic fields decrease surface tension and specific heat capacity. They found that the MFs of 300 MT were the best magnetizing condition.

3.2 Magnetic Field Effect on Water Evaporation Rate

Evaporation is the progressive process of water molecules leaving a liquid and entering the surrounding. Hydrogen bonding is the fundamental intermolecular force that binds water molecules together in the liquid phase. Therefore, evaporation must include breaking hydrogen bonds; nevertheless, the influence of the magnetic field on hydrogen bonds in water is still a subject of intense discussion. Consequently, numerous studies [43,54,56] have examined the influence of magnetic fields on water's physical and chemical properties.

Wu Songhai et al. [57] discovered that as the intensity of magnetic induction increases, the water evaporation rate also increases. The evaporating rate is increasing with the intensity of the MF and is still independent of the flow rate at low MFs (15 MT). However, at high MFs (0.27 T), evaporation is proportional to the flow rate.

Additionally, Seyfi et al. [58] confirmed that the direction of the magnetic field is critical; they demonstrated that while tangential magnetic fields had no discernible effect on the water-air interface, perpendicular magnetic fields increased the evaporation rate by up to 18.3 percent. They ascribed these findings to weakened hydrogen bonds caused by Lorentz forces. Similarly, Guo et al. [59] verified that the evaporation rate rises considerably when a high MF (more than 8 T). This parameter is influenced by the surface of the liquid/gas interface, the fluctuation in the strength of hydrogen bonds, and the Van der Waals forces. Because of the above, it seemed worthwhile to conduct additional research on the impact of static magnetic fields on water's evaporation rate and surface tension. The impact of the MF depends on the time, the magnetic position, and magnetic density, as shown in Figure3, the relation between evaporation rate and MF [52].

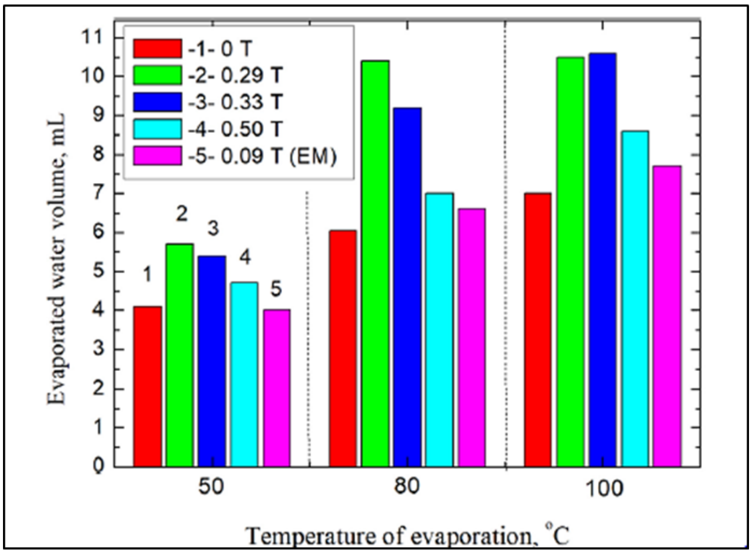

Figure 3: Evaporation of Water in A Uniform MF [52]

4. Magnetic Field Effect on Solar Still Performance

Pankaj et al. [60] evaluated experimentally and theoretically the performance of solar stills with permanent ferrite ring magnets (MSS) and compared the result with a traditional solar still (TSS) under Guna (India) climate conditions. The results showed the MSS produced a distillate yield that was 49.22 percent greater than TSS during the experiment. It would appear that the magnetization of water has led to an increase of 49.17 percent in the energy and exergy efficiency of MSS compared to TSS. Exergy loss in the basin region has been greatly reduced, just as in MSS, thanks to the installation of permanent magnets. The arrangement of static magnetic elements in basin water and a schematic view of CSS and MSS are shown in Figure 4. Likewise, Kaviti et al. [61] studied the impact of permanent magnets on the performance of single-slope type solar stills under experimental Hyderabad (India) weather conditions. During the test, three different sizes of magnetic were taken (M-1: 32 mm internal diameter, 70 mm external diameter, and 15 mm thickness; M-2: 25 mm internal diameter, 60 mm external diameter, and 10 mm thickness; M-3: 22 mm internal diameter, 45 mm external diameter, and 9 mm thickness) with the condition of 2 cm of water. The convective, radiative, and evaporative heat transfer rates were significantly enhanced by magnetic solar still with M-1, M-2, and M-3. The MSS's total internal heat transfer coefficient and instantaneous efficiencies led conventional solar still by 25.52% and 28.8%, respectively, with M-1. Due to different magnet sizes, MSS's cumulative productivity with M-1, M-2, and M-3 was 21.66%, 17.64%, and 15.78% higher than traditional type solar still. The arrangement of magnets in modified solar still is shown in Figure 5. On the other hand, Manoj and Dhananjay [62] determined the influence of magnetization on the performance of double slope solar still with a 2 m^2 basin area and a 15° top cover angle in Guna, India. A permanent ferromagnetic ring was evenly scattered in the basin water, and a sheet of blackened galvanized iron was placed over them to ensure the magnetic field was uniformly distributed. A comparison is also made using an identical still without this arrangement. Significant increases of 171.83 percent in heat transfer rate, 57.58 percent in exergy efficiency, 31.13 percent in productivity, 21.8 percent in the evaporative heat transfer coefficient, 16.26 percent in the overall heat transfer coefficient, and 22.64 percent in experimental efficiency were observed. Inference suggests that magnetization significantly improves solar still performance.

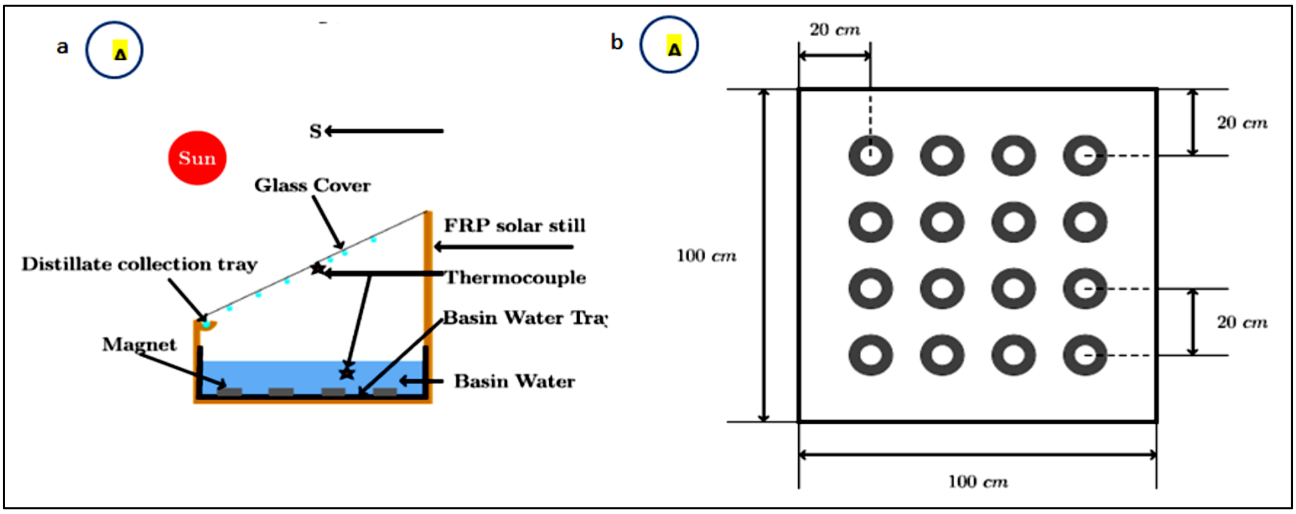

Figure 4: Magnetic solar still **a)** Schematic view of MSS. **b)** Arrangement of magnets elements in basin water [60]

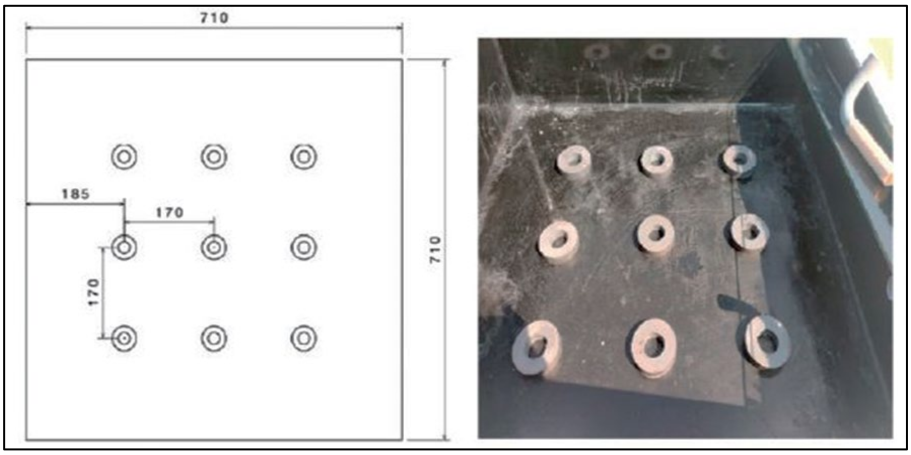

Figure 5: **A**rrangement of magnets elements in basin water (All dimensions are in mm) [61]

Ramasamy and Murugesan [63] improved the performance of single slope solar still by employing graphite plate fins with magnets (GPF-MSS) in the basin of solar still and compared it to a traditional solar still (TSS) under the same weather circumstances in Coimbatore, India Figure 6 When compared to TSS, the findings demonstrated that GPF-MSS exhibited increased distillate output, energy, and exergy efficiency by respective percentages of 19.6%, 21.4%, and 18.1%. When compared to TSS, the exergy destruction in the basin was greatly decreased in GPF-MSS due to the absorption of sensible heat by graphite plate fins and magnets. This was the case when comparing GPF-MSS to TSS. The quality of water obtained from both solar stills has met the Bureau of Indian standards (BIS) requirements.

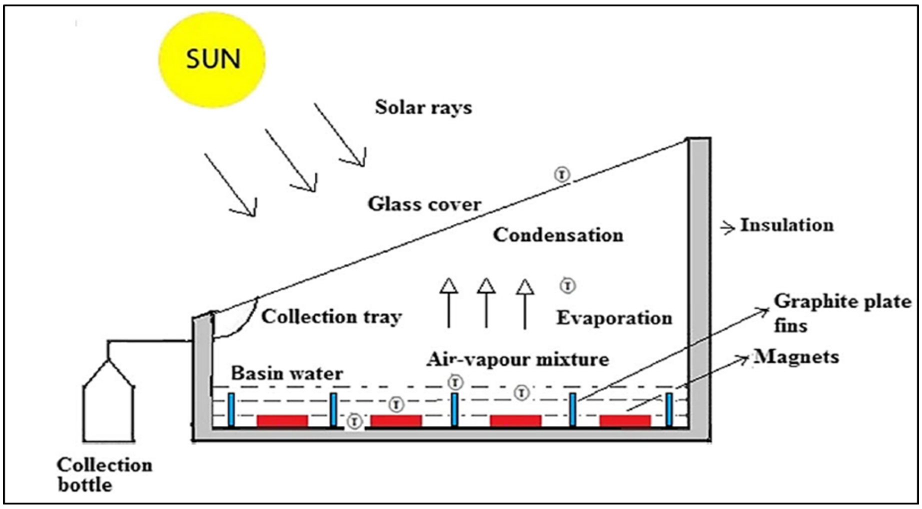

Figure 6: Schematic representation of modified solar still [63]

Mohammad et al. [64] provided a novel method to illustrate the magnetic field's impact on enhancing the performance of a standard-type solar distiller. The effects of a multilayer solenoid's applied magnetic field on streamline patterns, temperature, mass fraction contours, and water generation rate are described. As depicted in Figure 7, the effects of significant parameters such as intensity ($0 \leq NI \leq 100000$) and magnetic field position (Xc = 0.15, 0.49, and 0.83 m) on the rates of heat and mass transfer are investigated. The generation rate of water and the heat transfer rate is rising functions of magnetic field strength. In a magnetic field with NI = 10^5 and Xc = 0.83 m, the water yield and the convective heat transfer rate can be enhanced by 38 to 48%.

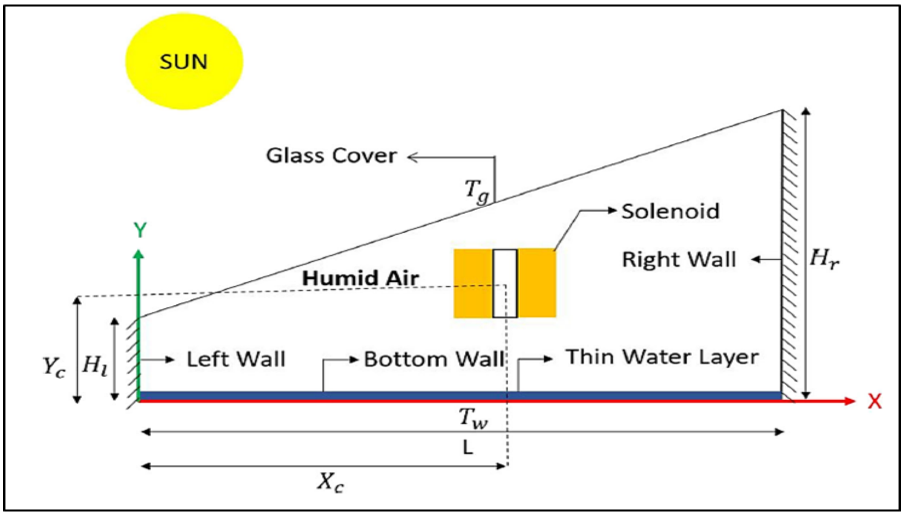

Figure 7: 2D schematic diagram of a CSS with a magnetic technique [64]

Dhivagar et al. [65] examined the thermodynamic study of a single slope solar distiller utilizing graphite plates and block magnets (GPBMSS) in Coimbatore's summer and winter climates, India. The results indicated that the hourly productivity of GPBMSS was single slope solar 19.6% and 22.8% greater than traditional solar still during the summer and winter, respectively. The cumulative yield of GPBMSS was estimated to be 3.93 kg/m^2 and 3.56 kg/m^2 for summer and winter 12-hour observations, respectively. In addition, the energy and exergy efficiency of GPBMSS were significantly enhanced by 20.6% and 18.1% compared to conventional solar still during summer days and by 18 and 19 percent during winter days. Furthermore, the findings demonstrated that the heat storage capacity of the graphite plates and water magnetization in GPBMSS significantly reduced exergy losses.

Dhivagar et al. [66] studied the productivity of distillers by utilizing block magnets (BMSS) and disc magnets (DMSS) while examining their findings in the context of the climate of Coimbatore, India (see Figure 8). According to the findings, the hourly yield in BMSS was 5.8 percent and 13.7 percent greater, respectively, compared to the productivity in DMSS and CSS. For observations that lasted for 12 hours, it was determined that the cumulative output of BMSS, DMSS, and CSS was approximately 3.15 kg/m^2, 2.8 kg/m^2, and 2.15 kg/m^2, respectively. In general, the findings demonstrated that magnetizing salty water has significantly improved the efficiency with which the solar still operates and the quantity of labor that is accomplished daily. Summary of the effect of magnetic fields on solar still performance are shown in the Table 1.

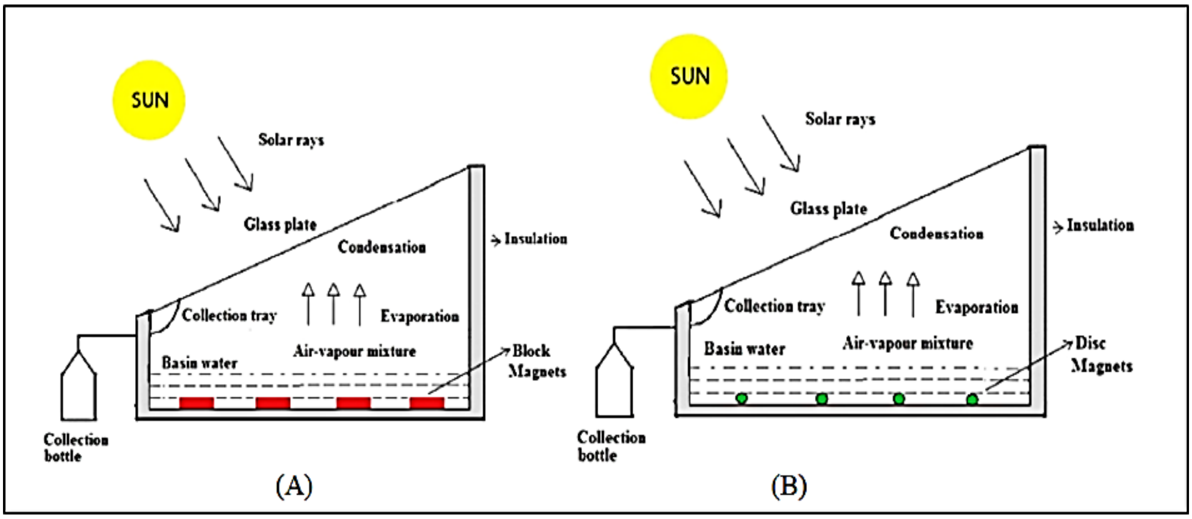

Figure 8: Single slope solar still, **a)** Diagrammatic representation of the BMSS b) DMSS diagram [66]

Table 1: Summary of the effect of magnetic fields on solar still performance

Location	Nature of study	Maximum productivity/ Increment %	Conclusion// Remarks	Ref.
Guna (India)	Experimental	49.22%	Permanent ferrite ring magnets MSS produced a distillate yield of 49.22 percent greater than CSS.	[60]
Hyderabad (India)	Experimental	21.66%	Due to different magnet sizes, MSS's cumulative yield output with M-1, M-2, and M-3 was 21.66%, 17.64%, and 15.78 % higher than CSS	[61]
Guna (India)	Experimental	31.13%	Heat transfer increased by 171.83%, exergy efficiency by 57.58%, and distillate production by 31.13%.	[62]
Coimbatore, (India)	Experimental	21.4%	The findings demonstrated that GPF-MSS exhibited increased productivity, energy efficiency, and exergy efficiency by respective percentages of 19.6%, 21.4%, and 18.1% when compared to CSS.	[63]
(Iran)	Theoretical	38%	The results revealed water output and convective heat transfer rate could be enhanced by 38 to 48%.	[64]
Coimbatore, (India)	Experimental	3.93 kg/m^2	The cumulative yield of GPBMSS was calculated to be 3.93 kg/m^2 and 3.56 kg/m^2 for summer and winter, respectively.	[65]
Coimbatore, (India)	Experimental	3.15 kg/m^2	The cumulative yield of BMSS, DMSS, and CSS was approximately 3.15 kg/m^2, 2.82 kg/m^2, and 2.15 kg/m^2, respectively.	[66]

5. Conclusion

Solar desalination will be vital for future water purification processes because society's freshwater demands are increasing daily and will continue to rise in the coming years due to population growth and industrial expansion. A solar distiller is a unique device that can successfully address the clean water needs of rural and distant places. Many researchers are developing innovative solar distillation unit designs to address the constraints of conventional stills. The objective of this study was to review the effect of magnetic field approaches on the distillate production, performance, and thermal efficiency of several types of solar distillers. The following conclusions can be reached based on prior research:

1) The magnetic field significantly reduces the surface tension of salty water and specific heat capacity, increasing evaporation.
2) As the intensity of magnetic induction increases, the water evaporation rate also increases.
3) The direction of the magnetic field affects the evaporation rate.
4) The impact of the MF depends on the time, the magnetic position, and magnetic density.
5) Permanent ferrite ring magnets solar still (MSS) produced a distillate yield of 49.22 percent greater than CSS. In addition, it appears that the magnetization of water has increased MSS's internal and exergy efficiencies relative to CSS by 49.17% and 110.26%, respectively.
6) Magnet sizes have a direct effect on solar still performance as well as yield output.
7) The generation rate of water and the heat transfer rate is rising functions of magnetic field strength and location.

6. Recommendation for Future Work

Future studies should:

1) Concentrate on optimizing the magnets' geometric arrangement and magnetic field intensity.
2) Evaluate the influence of element form on evaporation rate and solar still productivity.
3) Examine the effects of inserting the element within or outside the basin.
4) Integrate the magnetic field effect with appropriate modifications.

Abbreviations

MF	Magnetic Field
IDA	International Desalination Association
PV/T	Photo Voltaic Thermal
PV	Photo Voltaic
PCM	Phase Change Material
MFs	magnetic field strength
mT	Millitesla
T	Tesla
MSS	Magnetic Solar Still
TSS	Traditional Solar Still
M	diameter
GPF	Graphite Plate Fins
BIS	Bureau of Indian standards
NI	intensity
Xc	magnetic field position
CSS	Conventional Solar Still
GPB	graphite plates and block
BMSS	block magnetic solar still
DMSS	disc magnets solar still

Author contribution

All authors contributed equally to this work.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

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