Technologies for Purified Water Extraction Using Single-Slope Solar Stills Equipped With Magnets and Graphite Fins

Abbas Sahi Shareef, Hayder Jabbar Kurji*, Ali Bani Khassaf, Iman M Abd Zaid
Mechanical Engineering Department/ University of Kerbala-Iraq
**Corresponding Author*

Abstract: **In this paper, we will discuss the classifications of the solar still and the influences on its operation. And the effect of some additions on the productivity of the solar still,.we will make several comparisons on the traditional Solar Still device with the addition of some accessories that affect the performance of the device (fins and magnets), provided that the work of the device remains passive by studying some** experimental **and theoretical research published in this field to know the effect of these additions, types, preparation and Their sizes and the way they are arranged inside the device basin so that we can have a clear view of a good starting point in the upcoming work to develop the work of the device and reach better productivity.**

Keywords: **Solar Desalination, Phase Change Material , fin, Graphite, passive solar still**

I. INTRODUCTION

One of the most important renewable energy sources is solar energy, sustainable and environmentally friendly energies in the first place, which can be exploited in many fields. Where the sun provides us with heat and light. Light is used to generate electrical energy, as for the heat generated by solar radiation, it is used for many different purposes.There is a finite amount of fresh water on planet. Over two-thirds of the surface of the world is covered by water, but more than 97% of that water is either salty or contaminated. Fresh water makes up the remaining almost 2.6%. The amount of fresh water that humans and other organisms can access is less than 1%. Even this tiny fraction is thought to be sufficient to sustain life on Earth, but as the population grows, so does the demand for fresh water. Water that has been contaminated cannot be utilized for drinking purposes since it contains dangerous microorganisms and dissolved substances. The world faces a shortage of fresh water and drinking water in both wealthy and developing nations. The techniques utilized to produce fresh water[1]. Kuan, M., et al (2019) [2] numerically analyzed the performance of a heat pump–assisted solar still with the concept of latent heat released during the condensation of water vapor regenerated using compression heat pump for preheating the inlet saline water before entering into the solar still basin. They improved the productivity by about 62% when compared to CSS during summer climate conditions . Hansen et al. (2015) [3] researched an inclined solar still with different new wick elements and wire mesh. Various wick elements related to the wood pulp, coral fleece, and polystyrene sponge were recycled in flat absorbable and stepped absorbable plates. The maximum yield of 4.28 L/ day was reported when adopting coral fleece along with wire mesh coated on the stepped type absorbable plate. Kabeel et al. (2020)[4] compared the productivity of a solar still using cement-coated red bricks with CSS and reported with 45% improved productivity. The results observed that the cement-coated red bricks have good heat absorption rate compared to normal red bricks. Dumka et al. (2019) [5] improved the solar still performance using sand filled in cotton bags as sensible heat storage material for different quantities of basin saline water. The excess heat absorbed in solar still basin was stored using sand during the peak sunshine hours. The result reported with improved energy efficiency of about 31.3% for 40 kg and 28.9% for 50 kg when compared to CSS . Jani and Modi (2017) [6] studied the performance of the double slope solar stills using square and circular fins. They have improved the efficiency of the solar still by 54.2% using circular fins and 26.8% using square cross-sectional fins. The results also showed that the maximum productivity was observed at 1- cm water depth Design parameters on still using phase changing materials were studied by Khandagre et al. (2019) [7]. The experimental investigation was done on a double slope still. The basin was coated by using a blackened absorbing surface, and the phase changing material (PCM) (paraffin wax) was placed on the still basin, which was called as an organic PCM. The comparison study was done between organic and inorganic PCM. Eutectics are used as an inorganic PCM. By using this yield of the still, it improves from 8.02 to 8.07 L/m2 /day, which was more than the CSS, whose improvement was 4.01 to 4.34 L/m2 /day. Hidouri and Mohanraj (2019) [8] experimented in a heat pump– augmented solar still with different glass angle inclinations and improved the energy efficiency by 84.5%. They also reported that the glass positions in solar still have a major role on performance enhancements. Sharshir et al. (2017) [9] conducted experiments on solar still using graphite nanoparticles, film cooling, and phase change materials. Their results reported that the productivity of the solar still was improved by 73.8% when compared to CSS. Dumka Pankaj et al (2019) [10] has been used for the evaluation of internal heat transfer coefficients, internal efficiency, exergy efficiency, and exergy destruction. The average partial pressure difference between basin water and inner condensing cover surface for MSS has been found to be 77.99% higher than CSS when experiments were carried out for 13 h. The maximum value of evaporative heat transfer coefficient of MSS leads over the CSS by 28.65% at 13:00 h. The distillate yield recorded during the xperimentation for MSS is 49.22% higher as compared to CSS. It seems that the magnetization of water has enhanced the overall internal efficiency and exergy efficiency of MSS over CSS by 49.17% and 110.26% respectively. Gnanaraj and Velmurugan et al (2019) [11] improved the performance of double slope solar still using fins, black granite, wick, reflector, and internal and external modifications by 58.4%, 69.8%, 42.3%, 93.3%, and 171.4% respectively when compared to CSS. Their results also showed that the internal and external modifications in the solar still could improve the overall thermal performance when compared to the usage of heat storage materials in the basin.Nazari et al. (2018) [12] conducted experiments on a single slope solar still coupled with thermo-electric channel and nanofluid. They improved the productivity, energy efficiency, and exergy efficiency of solar still using thermo-electric channel by 38.5%, 38.9%, and 31.2%, respectively. In addition, the solar still with thermoelectric channel and 0.08% of nanofluid has enhanced the productivity, energy efficiency, and exergy efficiency by 82.4%, 81.5%, and 92.6%, respectively. Yousef et al. (2019) [13] improved the energy and exergy efficiencies of the CSS using different absorbing materials by 25% and 5%, respectively. The cost of productivity and carbon credit was reported as 0.0343 USD and 226.6 USD, respectively. Their results also proved that the heat-absorbing materials have significantly reduced the exergy losses in the solar still basin. Dhivagar et al. (2020) [14] made 4E analysis of gravel coarse aggregate sensible heat storage material–assisted solar still. It was reported that the energy and exergy efficiencies were improved by 32% and 4.7%, respectively. The productivity cost was estimated as 0.0618 USD per liter and the payback period was estimated as 4.3 months. The coarse aggregate solar still has 8.27 tons of CO2 emissions during the lifetime of 10 years. Ramasamy Dhivagar1 & Murugesan Mohanraj (2021) [15] compared The results showed that the productivity, energy, and exergy efficiency of GPF-MSS were improved by 19.6%, 21.4%, and 18.1%, respectively, when compared to CSS

II. SOLAR COLLECTOR

Solar collectors of different types are used to capture sun radiation and transform them into heat, which may then be utilized for a variety of purposes, for example supply of electrical energy, water heating, treatment of salt water, building heating [16]. There are various forms and kinds of sun collectors, as seen in the figure (1).

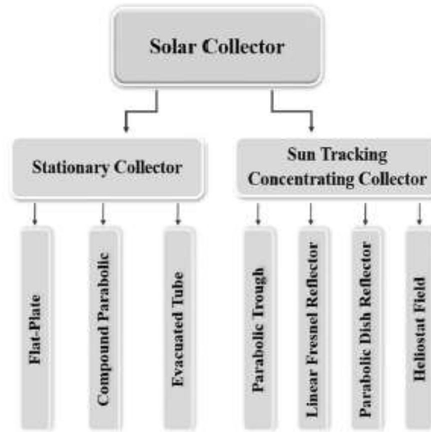

Fig. 1 Classification of solar collectors [16]

A. *Concentrating collectors*

To obtain the most sun radiation, it is important to keep tracking of the solar position, and there are various kinds of these complexes, for example: parabolic trough collectors, Fresnel reflectors that are linear, reflectors with a parabolic dish, and central tower receivers.

B. *Fixed collectors*

These solar collectors stay stable and face the sun at a certain tilt angle, with several varieties for example compound parabolic collectors, flat plate collectors, and vacuum tube collectors, as seen in figure (2).

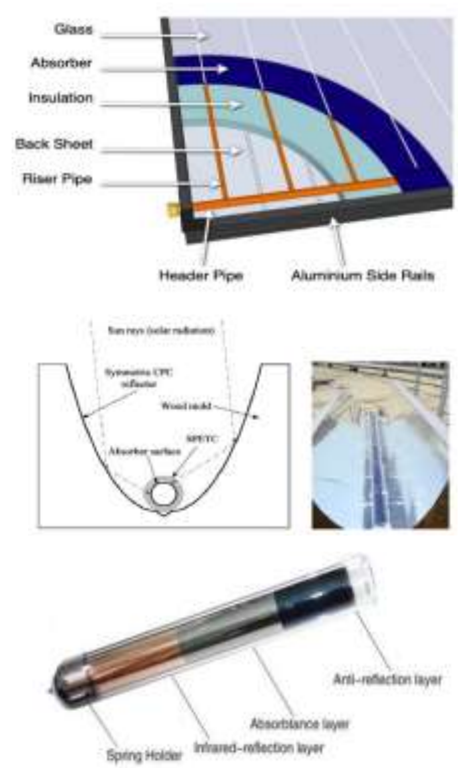

Fig. 2. Fixed collectors (Flat plate, Compound parabolic, and Evacuated tube collectors) [16]

The following solutions can help to tackle the challenge of delivering fresh water to arid places [17].

1. Water transportation from other places.
2. Purification of salty water.
3. Extraction Water via atmospheric air.

Water transportation in these areas is typically prohibitively expensive, and Purification is dependent on the existence of salt water supplies, which are typically scarce in dry locations.

III. SOLAR DISTILLATION MECHANISM

The solar water purification system operates in the same way as rain does, with water-absorbing heat, evaporating, and then condensing. Solar water distillation processes provide a closed-loop system that is more efficient due to the system's total administration, which allows it to be adjusted according to the conditions. The solar still unit, as illustrated in Figure 1, has a glass cover, a water-resistant basin, and a black liner to maximize solar energy absorption. The basin is filled with salt or somewhat saline water and let to heat up naturally under the sun. The steam then rises and falls on the glass cover, which is slanted at an angle and accumulates in a bowl. The residual salty water and suspended materials are left in the basin and will be removed later [18].

As indicated in fgure 3, there are various classic distillates, including (single slope, Double slope glazing cover, V-shape and Spherical solar still).

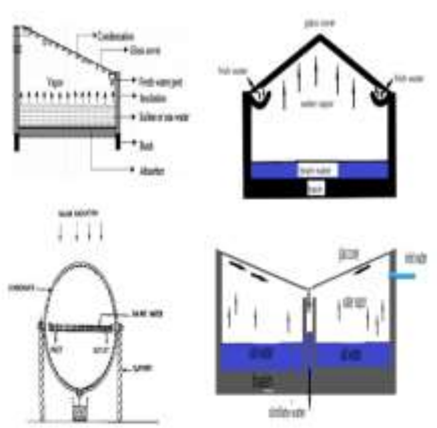

Fig.3 (Single slop, double slop, spherical and v type solar still).

Hashim [19] devised a single slop distillate with a double basin (SSDBS) and performed a daily experiment to compare the new distillate to the standard distillate. The performance of a new solar distiller with a glass cover with four faces was experimentally studied by Shareef and others [20].

, and the experiment was conducted in the city of Karbala, Iraq. The results of the investigation showed that the daily work efficiency of the distillate was 48 percent at a temperature of 24.9 Cand and the daily production amount was 6 liters/day.

A. Solar still

Distillation is a well-liked therapy approach all around the world. It is not surprising that numerous solar distillation systems have been created and enhanced during the past few years. The distillation process' primary drawback is its heavy reliance on traditional energy sources, which has a negative environmental impact. Solar stills, which can be thermally driven by a free and pure source of energy, are a component of distillation systems. The basin type solar still is a straightforward, easily constructed, low maintenance, and cost-effective equipment. Despite these benefits, its low productivity prevents it from being widely used [21]. Ther for the solar still can by classified as ashown in fiqure (4).

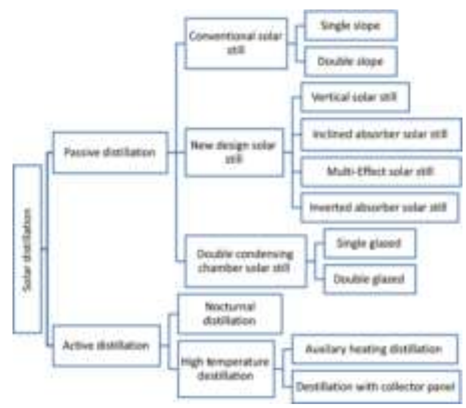

Fig. 4 Solar still distillation classifications [22].

B. Types of Solar Stills

Two types of solar stills can be distinguished.

1). passive solar still

uses solar energy as its main source of heat energy, while those that combine it with solar thermal energy are used to directly heat water before distillation takes place. This development rate is explained by the low operating temperature and vapor pressure [23]. As ashown in the fiqurer(5).

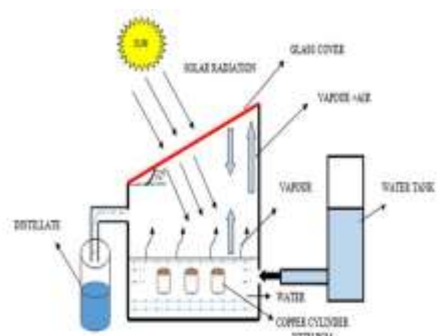

Fig. 5 passive solar still .

2). Active solar stills:

These stills use extra thermal energy in the form of either a solar collector or any extra thermal energy produced by any industrial facility to combine with passive solar for faster evaporation. factors affecting the production of basin-type solar stills.1.2 Passive solar stills can be categorized in a variety of ways, such as by the size, form, number of basins, heat storage choices, and evaporator design and materials (such as wicks). Numerous basins or wicks can be used to provide multiple effects during distillation for a significantly larger output [18].

C. climate variables

1) Solar radiation:

The most important component for still productivity is solar radiation. Numerous studies have looked into how solar radiation affects still productivity, and their findings show that solar still productivity rises as incident solar radiation increases.

2). Wind speed

The coefficient of heat transfer from the condensing covers to the surroundings rises as wind speed rises. This widens the temperature gap between the water bulk and the cover, enhancing the natural [19].

3). Relative humidity

Because of the low convection coefficient between the still and its surroundings and the lower saturation temperatures of the steam inside the still, the distilled water decreased as the relative humidity increased for a given ambient temperature, as can be seen from the effect of relative humidity at different ambient temperatures [20].

3). Temperature difference

Brine temperature is important for all heat fluxes from basin water, including evaporation, free convection, and radiation, when taking into account the heat transport phenomena. Higher water temperatures result in faster evaporation because the barrier between liquid and gaseous states may be broken with less energy. Another way to look at it is that water will evaporate at saturation temperature at a particular pressure (atmospheric pressure), and the higher the brine temperatures, the closer they are to saturation temperature. As a result, it is not surprising that certain methods use leftover heat to warm brine. Solar stills, in actuality, require only a few degrees Celsius to ten degrees Celsius above environmental temperature in order to operate properly [21]..

5). Dust and Cloud Cove

Dust buildup on the still's glass cover considerably reduces its transmittance, which eventually lowers the productivity of the distillate. Cloud cover significantly lowers and significantly lessens the direct component of solar radiation [22].

D. Design parameters

1). Solar reflectors

Internal reflectors are practical devices for focusing and rerouting solar radiation. When the sun is not very strong or the local temperature is not too high, they are advised. To improve the flexibility of the absorber plate layout, such as the vertical solar absorber plate that is useful in recovering vapor latent heat of condensation, external reflectors are desired to be employed. When the sun is weak or the local temperature is fairly low, external and/or interior reflectors are advised [23].

2). angle of the glass cover's inclination

The results of the current investigation showed that the production of a solar still could be quite sensitive to the choice of glass inclination angle. Under the same meteorological conditions, stills with inclination angles between 30 and 35 degrees are likely to yield less pure water than stills with different inclination angles. This might be as a result of the still performance being more sensitive to temperature and wind at this angular range. Stills with inclination angles greater than 35 might expect output levels similar to those below 30. Due of the higher material and construction costs, employing stills with great inclination angles does not appear to provide any real advantages [24].

The findings of this study lead one to the conclusion that the ideal glass inclination angle for .

3). The inlet water's temperature

The temperature of the saline water regulates the evaporation rate since the latter rises as the temperature of the unpurified water does. The solar still is heated by combining parabolic concentrators, plate collectors, and a small solar pond. The entire solar still water may require a significant amount of energy to be heated. The temperature of the water-free surface area affects evaporation rate in a direct proportion. To improve the water-free surface area, we can utilize baffle suspended absorber plates [25].

4). Thickness of cover plate

Two more elements that have a considerable impact on the productivity of solar stills are the cover plate's thickness and the material used for the condensing cover. Highly transgressive missive content Due to their strong propensity to absorb radiation, materials like glass are frequently utilized as cover plate materials for solar stills. The highest solar still productivity is obtained with a 2-mm-thick cover plate and declines with an increase in cover plate thickness. As a result, stills with lower cover plate thickness are preferred for stills with better productivity. that cover plates made of glass and plastic with lower densities can have productivity comparable to copper. To achieve optimum productivity, the material and thickness of the cover plate must be properly chosen [16].

5).Waterdepth

Any solar still system's production is influenced by the depth of the feed water. A brief duration of operation (often 1-2 days) with shallow water depth increases production. Depth is proportional to period of operation. Numerous research on various water depths have revealed that depth and solar still productivity are inversely related. The productivity of the solar still was high at a little depth of 0.1 m, according to Singh and Tiwari's investigation into the effects of various water depths, including 0.05, 0.1, and 0.15 m. Even though there is more water present in the solar, it still takes longer for the water to heat up.

6). Gap

Evaporating and condensation cover separation The performance of the solar still is enhanced by reducing the gap distance between the evaporating surface and the condensing cover. More significant than the impact of cover slope is the influence of gap distance. By reducing the gap distance, the cover slope's walls will be shorter and their shadowing impact will be lessened. A reduction in the gap distance from 13.0 to 8 cm for the same cover slope and an increase in output of 11% result from the saturated air taking less time to reach the condensing surface and continuous and quicker air flow in the still [26].

7). Systems for Tracking the Sun

Simply described, sun tracking is the process of sensing and following the sun's solar radiation from sunrise to dusk. There are two ways to do this: manually or via an automated device. The explanation for sun tracking is not implausible. Since the basin-type solar still needs to heat the brine for evaporation and condensation to occur, a significant amount of the sun's irradiance must be delivered into the still basin. It follows that higher sun intensity will result in faster evaporation and higher condensate, which will ultimately result in a larger distillate yield [27].

IV. PHASE CHANGE MATERIAL (PCM)

Phase change materials (PCM) can release a lot of energy while melting or solidifying and have a high heat of fusion [22].

A. Classification of PCM

Hydrocarbons, paraffin, and wax are examples of organic phase change materials, while molten salts and minerals are examples of inorganic phase change materials. Organic compounds have a melting point of roughly 60°C, allowing them to be used in temperatures as low as around 100°C. Inorganic compounds have a high melting point and can withstand temperatures of up to 1250 degrees Celsius, making them ideal for high-temperature applications. As ashown in the fiqurer(6).

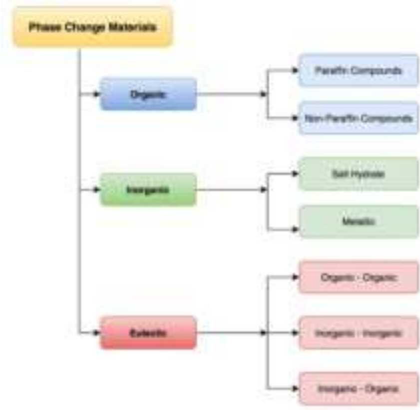

Fig 6 TThe classification of phase-change materials [22].

1). Organic Phase Change Materials

Organic materials, which comprise types of paraffin and non-paraffin, are compounds that enter the element of carbon in their atomic composition. These materials are distinguished by their capacity to melt and freeze repeatedly without losing any of their qualities in the process. Congruent melting and the concomitant heat change potential for fusibility is what it's called. These materials are usually corrosion resistant and crystalline without or with little cooling; this means that self-nucleation occurs [23].

2). Inorganic Phase Change Materials

Salts, metals, and salt hydrates phase transition materials are all examples of inorganic substances. It is distinguished by its high density, which causes growing enthalpy per volume and allows the phase shift to cover a wide temperature range. They exhibit the disadvantages of lack of thermal stability, corrosion, phase separation and separation, and sub-cooling [24].

3). Eutectics

A eutectic is a compound made up of two or more chemicals that can be classified as organic, inorganic, or organic-inorganic. It is notable for having a low melting point, known as the eutectic point. Each component melts and freezes in the same way, resulting in a combination of crystals [23].

V. FIN

The flat plate basin's fin-integrated solar still reduces the amount of time needed to prepare the saline water before it evaporates. Fins speed up the rate of heat transmission from the basin to the salt water, increasing the still's output [28].

A. Graphite

Natural graphite is a corrosion-resistant substance with a low density (2.1 g.cm-3 vs. aluminum's 2.7 g.cm-3), extremely high thermal conductivity (300-600 W.m-1.K-1 in the in-plane direction), and a negligible coefficient of thermal expansion As ashown in the table(1). Due to these characteristics, graphite is a fantastic material for use in heat exchangers, HVAC systems, energy conversion systems, and automobile parts. The heat exchanger business has employed synthetic graphite in their products. However, a fundamental barrier preventing their wider acceptance has been the expensive fabrication of thermal products built from synthetic graphite. Natural graphite thermal goods can be mass produced affordably and with lower manufacturing and material costs thanks to the roll-embossing method. Due to their distinct characteristics, graphite heat exchangers (G-HEX) built from rolled graphite sheets could.

Table 1 Lists the typical graphite laminate materials' properties [29].

PROPERTY	UNITS	DIRECTION	VALUE
Density	g/cm^3	------------	1.33
Thermal conductivity	w/m.k	In-plane	233
Thermal conductivity	w/m.k	thickness	4.5
Thermal Anisotropy	--------------	----------	52
CTE	10^{-6} m/m/^{o}c	In-plane	-0.77
Resistivity	Uohm.m	In-plane	4.9
Young Modulus	Gpa	In-plane	13
Flexural Strength	Mpa	In-plane	11
Shear Strength	Mpa	In-plane	0.18

VI. MAGNETIC FIELD

For more than 50 years, several aspects of the impact of magnetic fields (MF) on water treatment have been studied, and many researchers are still interested in this topic. The research first centered on safeguarding industrial facilities or domestic heating systems against the development of hard scales at high temperatures; more recently, the effects of MF in the liquid phase were examined in a number of fundamental features and potential practical applications [27].

Four different types of magnetized water (MW) were measured under the same conditions to determine the impact of magnetic field (MF) on the partial physical properties of water. It was discovered that after the MF treatment, the characteristics of TW had changed, as evidenced by an increase in evaporation rate, a drop in specific heat, and **a rise in boiling** point; the changes were dependent on the magnetization effect. Additionally, magnetic field strength (MFS) significantly affects the magnetization effect; the MFS of 300 MT was shown to be the ideal magnetizing condition [30].

A. The effect of the viscosity of water by magnetic fields

Based on stronger hydrogen bonding, a greater absolute viscosity was experimentally clarified in the presence of an applied magnetic field compared with no area. The measurement is shown to slowly rise at increasing temperatures. Ghauri and Ansari [17] present these results in their experiment on the permanent magnet utilized with a field strength of 7.5 kg and a middle flow duration of water recorded was (336.27s) at (25.0 °C). The table below illustrates how a magnetic field affects water's viscosity [24]. As shown in table (2).

Table 2 Viscosities at varying temperatures with standard deviations and densities of water. Subscript (0) refers to no magnetic field applied [24].

T (K)	ρ_0(kg dm^{-3})	$\eta_0 \pm$SD(mPa s)	$\eta \pm$SD(mPa s)	$\Delta\eta = \eta - \eta_0$
298	0.997 04 (0.997 07)	0.8904	$0.8915 \pm 3 \times 10^{-5}$	0.0011
303	0.995 65 (0.995 67)	$0.7972 \pm 2 \times 10^{-5}$ (0.7975)	$0.7986 \pm 2 \times 10^{-5}$	0.0014
308	0.994 03 (0.994 06)	$0.7192 \pm 3 \times 10^{-5}$ (0.7194)	$0.7209 \pm 6 \times 10^{-5}$	0.0017
313	0.992 21 (0.992 24)	$0.6533 \pm 5 \times 10^{-5}$ (0.6529)	$0.6551 \pm 6 \times 10^{-5}$	0.0018
318	0.990 21 (0.990 25)	$0.5965 \pm 5 \times 10^{-5}$ (0.5960)	$0.5984 \pm 5 \times 10^{-5}$	0.0019
323	0.988 04 (0.988 07)	$0.5470 \pm 2 \times 10^{-5}$ (0.5468)	$0.5490 \pm 4 \times 10^{-5}$	0.0020

B. The effect of the Water surface tension under magnetic fields

The surface tension of a flat interface is equal to the free Helmholtz energy per unit area of the interface minus the entropy per unit area of the interface times the temperature. The abundance of hydrogen bonding gives water a high surface tension. The surface's internal energy will rise, the body's entropy will decrease, and there may be a significant net increase in Helmholtz's free interface energy as a result of hydrogen bond stabilization and an increase in the number of hydrogen bonds on the surface. Since hydrogen bonds enhance the actual volume relative to Helmholtz free energy due to their stability, Gibbs free energy does not rise with external effort (pressure-volume term). As a result, the difference in the surface level (4 cm at 10 Tso-called Moses effect) [28]indicates that the net increase in the Gibbs free energy must be equal to the Gibbs free energy. In the figure (7) , the magnetic devices (m1 = 3300 gauss, m2 = 2900 gauss, m3 = 5000 gauss and electromagnetic m = 900 gauss) are mounted on experimental system in order to obtain magnetized water. as shown in table (3).

Table 3 Surface tension relation with magnetic fields.

B (T)	$\sigma \pm$ standard error (mN/m)
0	71.96 ± 0.14
2	72.12 ± 0.14
4	72.19 ± 0.14
6	72.45 ± 0.14
8	72.86 ± 0.14
9	72.99 ± 0.15
10	73.31 ± 0.16

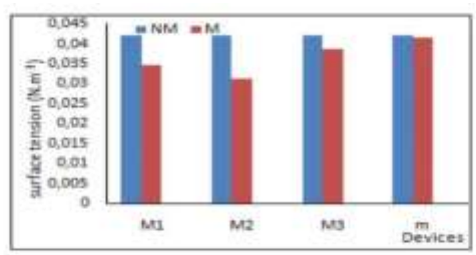

Fig. 7 Effect magnatic treatment of water on surface tension

C. *Magnetic Field Effects on Evaporation Rate*

Temperature, moisture, and magnetic forces all have an impact on evaporation. According to Yun-Zhu et al. [29]. A strong magnetic field causes evaporation rates to increase (8 tesla). The strength of the hydrogen bonds and the shift of the Van der Waals forces at the liquid/gas boundary determine this parameter. The aforementioned study has motivated us to do more research on water's surface tension and its role in evaporation.As shown in the figure (8) They were mostly concerned in determining the significance and reproducibility of tests conducted under typical settings for a few days or even weeks. If these results are confirmed, it might mean that water evaporates more quickly [30].

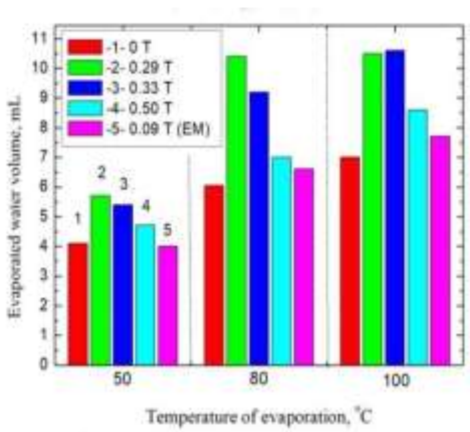

Fig. 8 The Effects of the Magnetic filed on Evaporation Rate

Table 4 showing the method used and the percentage of production

References	Used technique	Productivity compared to CSS
Belyayev et al. (2019)	heat pump	62%
Kabeel et al. (2020a)	cement-coated red bricks	45%
Dumka et al. (2019a)	sand filled in cotton bags	31.3% for 40 kg 28.9% for 50 kg
Jani and Modi (2017)	Square fins circular fins	26.8% 54.2%
Khandagre et al. (2019)	phase changing materials (paraffin wax)	93%
Hidouri and Mohanraj (2019)	different glass angle inclinations	84.5%
Sharshir et al. (2017)	using graphite nanoparticles, film cooling, and phase change materials	73.8%
Pankaj Dumka et al (2019)	the magnetization of water	49.22%
Gnanaraj and Velmurugan (2019)	Fins black granite wick Reflector internal and external modifications	58.4% ,69.8% ,42.3% 93.3%, 171.4%
Nazari et al. (2018)	thermo-electric channel nanofluid	38.5% 82.4%
Ramasamy Dhivagar1 & Murugesan Mohanraj (2021)	Graphite plate fins	19.6%

VII. CONCLUSION

1. Solar energy is one of the most efficient renewable energy sources since it can be found in some of the world's most environmentally favorable places.
2. Phase change materials increase distillate output by enabling water evaporation to go on through the night since they store large amounts of thermal energy.
3. The distillation system's effectiveness is increased by the inclusion of a magnetic field. It increases the amount of clean water produced and the rate of evaporation.

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