REPUBLIC OF TÜRKİYE

ALTINBAŞ UNIVERSITY

Institute of Graduate Studies

Mechanical Engineering

THERMAL ANALYSIS OF A ‘V’ TYPE SOLAR STILL USING ULTRASONIC HUMIDIFIER POWERED BY PV

Iman Fouad Hani HANI

Master’s Thesis

Supervisor

Asst. Prof. Dr. Yaser ALAIWI

Istanbul,2023

THERMAL ANALYSIS OF A ‘V’ TYPE SOLAR STILL USING ULTRASONIC HUMIDIFIER POWERED BY PV

Iman Fouad Hanı HANI

Mechanical Engineering

Master’s Thesis

ALTINBAŞ UNIVERSITY

2023

The thesis titled THERMAL ANALYSIS OF A 'V' TYPE SOLAR STILL USING ULTRASONIC HUMIDIFIER POWERED BY PV prepared by IMAN FOUAD HANI HANI and submitted on 08/08/2023 has been **accepted unanimously** for the degree of Master of Science in Mechanical Engineering

Asst. Prof. Dr. Yaser ALAIWI

Supervisor

Thesis Defense Committee Members:

Asst. Prof. Dr. Yaser ALAIWI	Department of Mechanical Engineering Altınbaş University	_____
Asst. Prof. Dr. Abdullahi Abdu IBRAHIM	Department of Electrical and Computer Engineering Altınbaş University	_____
Asst. Prof. Dr. Ahmed SADIK	Department of Mechanical Engineering Hasan Kalyoncu University	_____

I hereby declare that this thesis meets all format and submission requirements for a Master's thesis.
Submission date of the thesis to Institute of Graduate Studies: ___/___/___

I hereby declare that all information/data presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the abovementioned rules and conduct.

Iman Fouad Hani HANI

Signature

DEDICATION

I dedicate this thesis to my family, who has always encouraged, supported, and empowered me in my academic pursuits. My father and mother, whose unwavering love and encouragement have been my constant source of strength throughout the years. I extend my gratitude to my supervisor, who has guided me through the research process with his expertise and patience. His invaluable feedback and support have been instrumental in shaping the direction and outcome of this thesis.

ABSTRACT

THERMAL ANALYSIS OF A ‘V’ TYPE SOLAR STILL USING ULTRASONIC HUMIDIFIER POWERED BY PV

HANI, Iman Fouad Hani
M.Sc., Mechanical Engineering, Altınbaş University,
Supervisor: Asst. Prof. Dr. Yaser ALAIWI
Date: 08/2023
Pages: 66

This research based on an experimental analysis that carried out to achieve the study goals. A comparative analysis executed to determine the heat transfer rate, performance, and amount of clean and pure water generated depending on two solar stills. One of them is a traditional ‘V’ type solar still. The other system integrates an ultrasonic humidifier and a solar PV system into a ‘V’ type solar still. Moreover, in addition Nano materials was utilized in the two cases study to show the impacts of these Nano fluids on performance the traditional and modified solar still. The results of the research showed that utilizing a Nano fluid provided a significant impact in enhancing performance of the studied solar stills. the temperature of vapor and water had increased the thermal conductivity as well enhanced.

Keywords: Nanomaterials, Thermal Analysis, Solar Still, Humidifier, Ultrasonic.

TABLE OF CONTENTS

LIST OF TABLE

Pages

LIST OF FIGURES

Pages

ABBREVIATIONS

CSS	:	Conventional Solar Stills
ETSC	:	Evacuated Tube Solar Collector
FPSC	:	Flat-Panel Solar Collector
MSS	:	Modified Solar Stills
SS	:	Solar Still

1. INTRODUCTION

1.1 RESEARCH BACKGROUND

Scientists and engineers have been looking for smart solutions and investigating intelligent methods that can provide clean and pure water [45], [46] for drinking, cooking, and other uses in areas where the drinking water is minimal, and a high amount of polluted water does exist. Numerous solutions have been developed, including boiling, sedimentation, activated carbon filtration, chemical distillation, ultraviolet light, and reverse osmosis [1],[2]. Another innovative method for providing clean drinking water is the solar still system.

A solar still system is a renewable energy product works on obtaining purified water utilizing energy obtained from the sun [3],[4]. The solar-still depends on the sun energy more than fossil fuels. When there are no other energy sources available, solar stills can still be environmentally responsible and provide clean water for drinking and cooking. After the water is evaporated, it is then cooled and collected into a separate tank. Over the last decades, numerous types of solar still systems have been developed and used worldwide. These systems include single or double slope basin still, V-type solar still, and hemispherical solar still [3],[4], [44].

Solar still technology is characterized by its higher economic feasibility and performance, as only solar radiation is needed to operate and generate clean drinking water [48]. The majority of the world's population can get clean, drinkable water thanks to solar stills. Others are used in impoverished regions of the world where there are no alternative sources of clean drinking water [5]–[7]. Some solar stills are used in households to help minimize energy expenses and pollution. Furthermore, solar stills are environmentally friendly, as they do not use fossil fuels or depend on electrical power to operate and purify polluted water [8][9].

1.2 PROBLEM STATEMENT

Solar still plays a critical role in providing fresh and pure sources of water for areas that are far away from clean drinking water [49]. Notwithstanding, solar stills have some

limitations and key obstacles mirrored by the provision of lower pure water amounts for applications where a greater quantity of fresh water is demanded. In this context, engineers and scholars have been working via R&D to use intelligent methods and practical approaches that can enhance the performance of solar stills and improve their production potential of pure water from solar energy. One of these state-of-the-art techniques is the integration of ultrasonic humidifiers.

Several articles and research publications explored the beneficial impacts of integrating ultrasonic humidifiers into the solar still system [50], [51],[52]. Nonetheless, ultrasonic humidifiers consume a significant amount of electrical power. Thus, alternative and sustainable solutions are required. Here, solar PV systems can provide an effective solution to offer sufficient electricity to enable the operation of ultrasonic humidifiers without the need to use the electrical grid. Using ultrasonic humidifiers and a solar PV system can remarkably improve the sustainability of solar still and improve freshwater production [8],[10],[11].

In this work, an experimental analysis will be conducted to analyze key contributions and critical benefits of ultrasonic humidifiers and solar PV system integration into a 'V' type solar still to improve the evaporation rate and increase the quantity of pure water generated via solar energy. In addition, this research will conduct a comparative analysis to compare the evaporation rate, performance, and amount of purified water produced using two solar stills; the first one is conventional, while the second solar still uses ultrasonic humidifiers and solar PV panels. Figure (2) illustrates the use of an ultrasonic humidifier and a solar PV system in the solar still to improve its performance in generating clean drinking water.

1.3 RESEARCH SIGNIFICANCE

This work is conducted based on some key relevances. Firstly, this research will classify major solar still systems' characteristics, beneficial contributions, and advantages in purifying polluted water with higher performance. In addition, this research will shed light on major solar still systems types and classifications according to the area of application in which they are used. Furthermore, the research will identify the critical impacts and

advantageous effects of integrating ultrasonic humidifiers and solar PV systems into the solar still system to increase its freshwater productivity.

The study will identify the vital contributions of ultrasonic humidifiers and solar PV systems to the solar still properties in terms of evaporation rate, heat transfer, thermal efficiency, and its potential to generate purified water. An experimental analysis is carried out to achieve the study goals. A comparative analysis will be executed to determine the heat transfer rate, performance, and amount of clean and pure water generated depending on two solar stills. One of them is a traditional 'V' type solar still. The other system integrates an ultrasonic humidifier and a solar PV system into a 'V' type solar still. Moreover, the importance of the theoretical study is summarized thus:

To improve the previous studies with solar still systems benefits and economic and environmental benefits.
To identify major solar stills classifications and areas of application.
To conduct an experimental work to predict the benefits and critical role of ultrasonic humidifiers and solar PV systems integration into the solar still system on its thermal evaporation rate and effectiveness in producing purified drinking water.
To go on conducting research and improving (R&D) on solar still systems to enhance their contribution and thermal efficiency.
The importance of research in the practical field lies in the following
The requirement for basic improvements in solar still systems.
The requirement for a larger amount of clean water for applications with higher demand on water and limited pure water.
The necessity to validate the effectiveness of ultrasonic humidifiers and solar PV systems in improving the water distillation process efficiency to produce clean water using 'V' type solar stills.

1.4 RESEARCH MAIN AIM AND SECONDARY OBJECTIVES

The main goal of this research to examine the beneficial role of ultrasonic humidifiers and solar PV systems in improving the water distillation process using 'V' type solar still

system. It is vital to implement a group of minor objectives that can guarantee the successful execution of this research. These minor objectives include:

To execute previous studies, describe main solar still systems' characteristics, beneficial contributions, and advantages in purifying polluted water with higher performance.
To highlight major solar still system types and classifications according to the area of application in which they are used.
To shed light on critical ultrasonic humidifiers' and solar PV systems' contribution to improving the quantity of purified water produced using 'V' type solar still systems.
To conduct experimental-comparative analysis to determine the evaporation rate, heat transfer amount, performance, and volume of purified drinking water generated using two solar stills; the first is conventional, and the second uses ultrasonic humidifiers and a solar PV system.
To investigate and correct the results due to a panel of solar still specialists and heat transfer experts.

1.5 THESIS STATEMENT

This research is executed to examine the beneficial role of ultrasonic humidifiers and solar PV systems in improving the water distillation process using 'V' type solar still system.

1.6 RESEARCH QUESTION

This research is executed to offer some answers to the research questions.
What are the major solar still systems' characteristics, beneficial contributions, and advantages in purifying polluted water with higher performance?
What are the key limitations and critical challenges of solar stills in offering a large amount of purified freshwater?
What are the main solar still system types and classifications?
How can the thermal efficiency and evaporation rate be enhanced in the 'V' type solar still?
To what extent could the implementation and integration of ultrasonic humidifiers and solar PV systems into the 'V' type solar still promote the water distillation process's

thermal efficiency, evaporation rate, heat transfer, performance, and overall volume of purified water produced?

1.7 RESEARCH HYPOTHESIS

This research is conducted to quality the ultrasonic humidifiers' and solar PV systems' critical function in improving the thermal efficiency of the solar stills. The research hypothesis will be validated or invalidated based on the experimental findings of this study. These hypotheses are presented in the following paragraphs:

Null Hypothesis, H_o – which supposes that: "The integration of ultrasonic humidifiers and solar PV systems into the 'V' type solar stills would not accomplish any improvements in the purified water production, the thermal efficiency, or the evaporation frequency."

Alternative Hypothesis, H_a – which assumes that "Integrating ultrasonic humidifiers and solar PV systems into the 'V' type solar stills can achieve considerable benefits in terms of solar still's economic feasibility."

Sub Hypothesis, $H_{a,1}$ – which assumes that: "Using ultrasonic humidifiers and solar PV systems in the 'V' type solar still can contribute to significant environmental advantages."

Sub Hypothesis, $H_{a,2}$ – which assumes that: "The employment of ultrasonic humidifiers and a solar PV system in the 'V' type solar still helps improve the rate of heat transfer, and the overall system's performance."

Sub Hypothesis, $H_{a,3}$ – which assumes that "Ultrasonic humidifiers and a solar PV system integration into the 'V' type solar still is crucial to elevating the speed at which water is distilled from the solar radiation, the evaporation rate, and quantity of purified drinking water generated."

1.8 RESEARCH ORGANIZATION

The architecture of this thesis contains five chapters that can be organized as follows:
Chapter One, which has the INTRODUCTION as a title, presents the brief background, problem statement, research significance, research's major aim and minor objectives, research hypothesis, and the research questions.

Chapter Two, which has the LITERATURE REVIEW as a title, presents some previous research papers that related to this thesis.

Chapter Three, which has the title of RESEARCH METHODOLOGY, describes some related work, carry out some experimental analysis, and explains the experimental results in terms of modification and verification.

Chapter Four has the title of RESULTS AND DISCUSSIONS explains and discusses the experimental results.

Chapter Five, which has the title CONCLUSIONS AND RECOMMENDATION, shows the primary study's findings in connection with the research's numerical results. In addition, this chapter presents a number of recommendations and essential ideas for future work that will help scientists and engineers make further advancements in their works.

2. LITERATURE REVIEW

2.1 AIM AND INTRODUCTION

Chapter 1 presented the research background, problem statement, study goal and objectives, questions, hypotheses, and study significance. This chapter presents more detailed data and illustrations Critical Contributions and Beneficial Impacts of Still Solar's Systems. Chapter two will also focus on key limitation and critical challenges of solar stills in offering a large amount of purified freshwater. The data are collected from several publications from Ph.D. and master dissertations and web research engines, such as ScienceDirect, ResearchGate, Google Scholar, Academia, and conference proceedings and journals.

2.2 CRITICAL CONTRIBUTIONS AND BENEFICIAL IMPACTS OF STILL SOLAR'S SYSTEMS

By examining the critical contributions and main benefits of high-frequency ultrasonic humidifiers integrated into solar stills to increase the productivity of distilled water [12] they depended on experimental work by which high-frequency ultrasonic humidifiers were integrated into a solar still that operated according to Suez city weather conditions, Egypt. The study was conducted between August and September 2020. The research results confirmed that increasing the humidification rate of the solar still using high-frequency ultrasonic humidifiers while reducing the water height contributed to remarkable improvement in distilled water generation. A higher number of ultrasonic humidifiers (six units) achieved maximum purified water production than four and two units. Also, 10 mm of water height offered better performance in the freshwater generation than heights of 2 cm and 3 cm. Also, the results revealed that the daily freshwater productivity reached 7.72 kg/day, while the overall system efficiency was 33.84%. Additionally, the overall system cost of energy amounted to 0.03437 USD/L [12].

A literature review was carried out to discuss many methods and techniques utilizing solar still systems. This paper mentioned many techniques worked on enhancing obtaining drinking fresh water. Many desalitation systems have been improved to find solution deal

with lack of drinking fresh water. The paper showed that efficiency of solar stills is weak when vaporization and condensation occurs at one place. This paper mentioned that efficiency became higher when dissociate the case of occurring vaporization and condensation at one place utilizing humidification-dehumidification solar stills. This study proved using renewable resources providing fresh water in important issue because using fossil fuel results in environmental pollution. The literature review confirmed that many factors can affects (HDH) system such as salt-water temperature inlet of humidify, solar power, air stream ratio. Also, it was noticed effective performance when gathering both of (HDH) systems with energy plants. Additionally, productive capacity can enhance by 21%to 31 % per day when air conditioner is utilized to produce hot air. Moreover, when water temperature is increased in the dehumidifier exit results in reducing energy wastage in the dehumidifier. It was noted, daily productive capacity increases by reducing water height with hot air flow ratio. Furthermore, water production percentage enhanced by 23.1% utilizing tiny capsulated phase changed material [13].

Depending on suggested design idealizes solar still with cylinder geometry shape and a circulating Plexiglass coating, wiped constantly on the interior face. A particular methodology installation of the vaporization and intensification parts was depicted. A physical model was fabricated in order in order to examine thermal performance, water production and quality. the experiment lasted two days in different weather conditions. the suggested design utilizes a condenser and two absorbers: one is lowers and appears in the saline water while the second one is inflexed and located above the lower hemisphere of the cylindrical coating. nano conductor is utilized to avert unwanted condensed water vaporization owing to the heat set free by the bottom absorber [14].

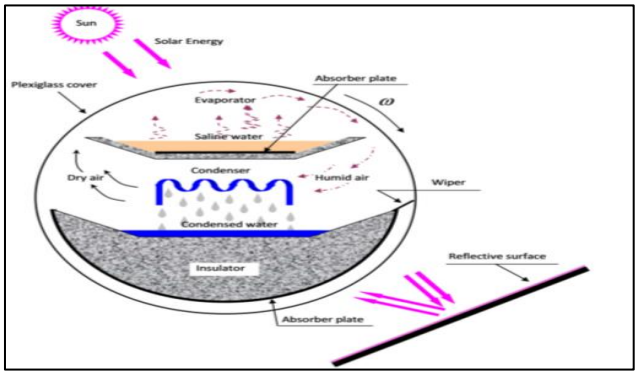

Figure 2.1: Cylindrical Solar Still Depended in Experimental Work [14].

The study revealed the circulate of the coat allows reasonable boosting the thermal achievement, the water production and the quality of the suggested solar still design. The coat temperature is reduced by 0.83◦ and enhanced by 2.08◦ for each 1◦ of atmospheric temperature. In addition, minimized by 0.017◦ and enhanced by 0.2◦ for each 1 W/m2 of solar radiation. The water temperature is enhanced by 0.67◦ and by 2.92◦ for each 1◦ of atmospheric temperature, as well as by 0.013◦ and 0.292◦ for each 1 W/m2 of solar radiation.

A study conducted to discuss the influence of boosting the vaporization and condensation procedures inside an improved solar stills system by locating ultrasonic moisteners inside a piece of cottons in the tank water [5], [6]. The test considered the following solar stills: the first system was considered the improved solar still model and the second one the traditional model. Three ultrasonic moisteners were fixed interior the tank water of the solar still. the thermoelectric cooler was connected to the cooling cabin. Figure 2.2 depicted test configuration.

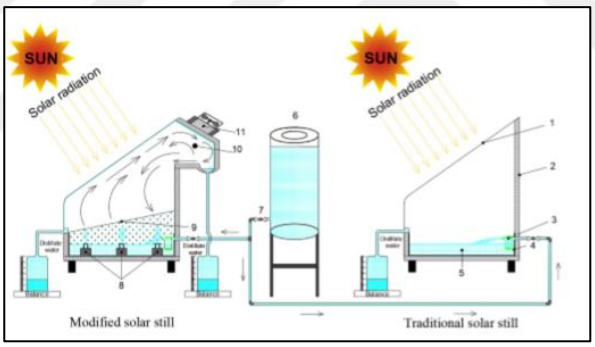

Figure 2.2: Test Configuration [16].

Both solar distillers consist of wooden panels. Plexiglass was utilized to coat the solar distillers with by inclination equals to 35◦.solar still was connected to Plexiglas utilizing Aluminium canal. The PV panel was inclined with 35◦.Ultrasonic moistener utilized a steel membrane to transform electronic prognostic with a high-periodicity into vibration a high-periodicity mechanical which dissipated the water stratum into fog drip. To augment interaction face and tank water vaporization quality interior improved solar still, it was utilized three ultrasonic moisteners and these ultrasonic were located in tank water interior a frame coated using a black cotton piece. The suggested crossbred technique resulted in minimizing the space between the vaporization and condensation outer side .

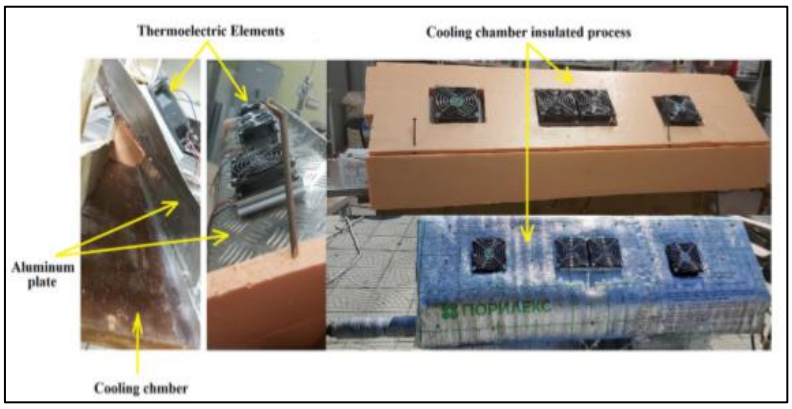

Figure 2.3: Cooling Chamber, Thermoelectric Elements [15].

At the beginning of each experience, it was considered 5cm for depth water, which was appropriate for the submergence ultrasonic moistener. A k-kind thermocouple was utilized to evaluate the temperatures of inner of the tank, tank water, outer side of the cotton net, plexiglass coat, and inner surface of the cooling cabin. To evaluate the production of dripped water per hour from the cooling cabin, it was considered 2 cylinders with an ability of 1 L. To shed light the characteristics of the water during period of the experiment, it was taken into account E-1 TDS and EC meters to evaluate the whole deiced solids and electrically conductive capacity. the research concluded that the producing of dripped water inside the cooling cabin was boosted by means of fixing Peltier cooling. Also, configuration enhanced the intensification steam in the canal of the cooling cabin. Productive capacity was developed locating ultrasonic moistener in a cotton net inside tank water. Productive capacity of improved solar still enhanced by 124% by comparing with the conventional solar still [15].

Via research included experimental work to investigate impact of slope solar still combined with ultrasonic vaporizer with high periodicity, exterior solar for heating water, PCM capsules on behaviour of solar still. The experimental work was executed according to Baghdad city climate. Realistic model basically made up of traditional solar still, solar for heating water, PCM capsules, ultrasonic vaporizer with high periodicity, provide water basin, water basin, PV system, water compressor, and control centre. The solar still was made up of wooden. The length and depth of solar still 1 m ,0.5 m respectively and the small and big side height is 0.26, 0.61 m respectively. To boost the absorption properties, the still tank was coated by black paint. however, pollywood insulator was fixed along all sides and below the tank to prevent the temperature loss from the tank. For solar still

merged with (PCM), 20 capsules were utilized in this test. The solar heater was improved with a rectangle shape. Diameter of the water heater pipe is a 0.02 m. water is pumped utilizing force 12v DC with 36-watt power. The dimension of pollywood is 0.9 × 1.1 m utilized to carry the absorber sheets and pipes. Four models of HFU vaporizer were utilized in this research to and get distilled water.

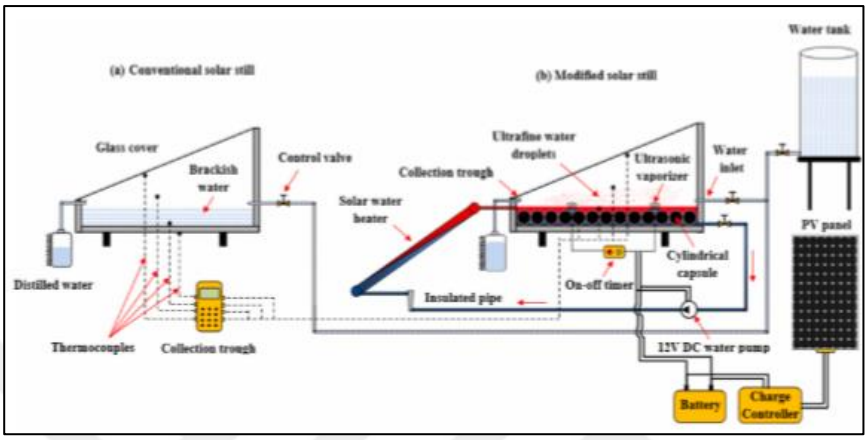

Figure 2.4: Test Set Up [17].

The results showed that utilizing cylindrical capsules enhance productive capacity of water by percentage up to 30.6%. water productivity was improved about 415% utilizing an outer solar water heater and ultrasonic vaporizer with high periodicity. Moreover, results affirmed that when the operation period of ultrasonic vaporizer increases results in a negative influence on water productive capacity and thermal quality [17].

In the field of the research, Test was conducted to investigate the behaviour of two single-inclination solar stills and these systems contains air space with1 17cm,37cm, the constant depth of water was 2cm. moreover, an ultrasonic atomizer utilized to estimate influence of the water atomization procedure on the behaviour of the solar still. Two conventional single-slope solar stills, the same inclination and with various air space, were oriented to the southern orientation, solar stills are placed, in a salt water tank, with 2cm constant depth which is take into account the best depth for producing water. leakage water was prevented utilizing Hair fibre located on the sides and inner of the solar still.

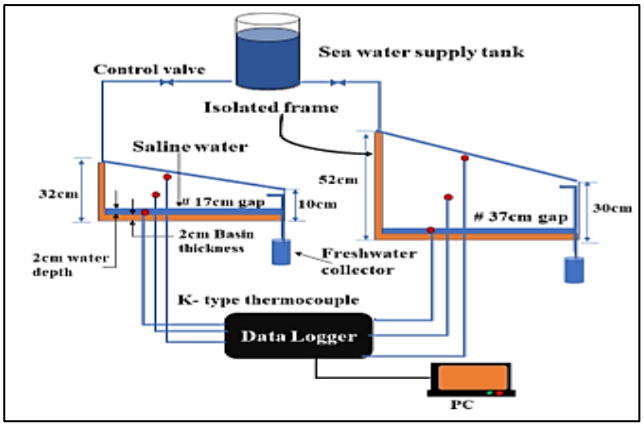

Figure 2.5: Single-Slope Solar Stills [18].

The researcher affirmed that minimizing the air gap helped to enhance the yield of model by 70%. utilizing an ultrasonic atomizer, coated with a canal, increased the yield. The achievement of the specimen solar stills was compared to same ones runned in different places and the findings affirmed the great impact of Aswan weather conditions on boosting the behaviour of solar systems [18].

An experimental work made up of gathering water splash and atmospheric air injection, that can boost the water–air interface. Furthermore, it contributes enhancing the still performances. (RSM) model is come from test configuration utilizing the plan of test process to examine the duo interaction impacts of the running factors, i.e., splashing depth, water temperature, and water and air current ratio. by depending on findings of RSM, a statistical model was mentioned in this study to evaluate the maximum quantity of steam from solar still. Good agreement was achieved between the findings came from the statistical model and the test findings. The achievement of this model was performed utilizing the variance analysis methodology. The results indicated that the basic effecting factors in the order of influence on the productive capacity is atmospheric air mass flow, sea water heat and scattered water mass stream. The duo interaction impacts of the parameters were taken into account and depicted for design recommendations [19].

A study was carried out to examine the beneficial impact and advantageous role of integrating ultrasonic humidifiers into the solar still to foster its freshwater productivity. [20] relied on an experimental analysis through which they explored and compared the performance, economic profitability, and water productivity of two solar stills. The first one was conventional, while the other one contained cotton cloth that covered the solar

still into which ultrasonic humidifiers were integrated. The dimensions and working conditions of the two solar stills were identical to make the analysis more valid. Also, a detailed study was conducted to evaluate the annual freshwater water product cost. Their analysis findings indicated that using ultrasonic humidifiers in solar stills contributed to a practical solution associated with the relatively lower production rate of purified drinking water. Further, the experimental outputs revealed that using a cotton cover with an ultrasonic humidifier improved the evaporation rate. Thus, more distilled water production was guaranteed. Moreover, the findings affirmed which the purified water productivity yield of the second solar still (which employed ultrasonic humidifiers) was significantly larger by roughly 68% than the conventional solar still. Also, the thermal efficiency of the second solar still was 110% higher (1.1 times higher) than the traditional solar still. Besides, it was found that utilizing ultrasonic humidifiers in the solar still contributed to considerable energy savings and higher economic feasibility compared with the first solar still. The second solar still had around 34.9% less cost than the first one [20].

An experimental work implemented through which two cases were considered. The first case included a traditional solar still, while the second case consisted of a solar still integrated with ultrasonic humidifiers with high periodicity with PCM capsules. In addition, a solar PV panel was used to offer an adequate amount of electrical power to operate the high-frequency ultrasonic humidifiers. Their experimental analysis was carried out in Baghdad depending on Iraqi weather conditions. Based on the analysis obtained, the research results indicated that using high-frequency ultrasonic humidifiers, phase change material capsules, and a solar PV panel contributed to considerable improvements in freshwater productivity, which increased by around 30.6% in comparing to conventional solar still in the first case. Also, the findings indicated that using high-frequency ultrasonic humidifiers and an external solar heater significantly increased freshwater productivity, that was 415% more than the traditional solar still. Also, the cost of energy of the proposed solar still amounted to 0.028 USD/L compared with 0.037 USD/L of the first solar still. Moreover, the new solar still's efficiency was 39.3% operating for thirty minutes and 34.2% when it was operated for sixty minutes [21].

A study was conducted to investigate the critical role and beneficial contributions of ultrasonic humidifiers and solar PV systems integration into a solar still to enhance the steaming rate and quantity of purified drinking water generated. [22] depended on an experimental work that analyzed four cases, which include (1) solar still with phase change material, (2) solar still with ultrasonic humidifiers and phase change material PCM, (3) solar still with evacuated solar collector and phase change material, and (4) solar still with PCM and ultrasonic moisteners combined with an evacuated solar collector. The solar evacuated tube collector's capacity amounted to 200 litres. Further, a PV panel is used in their work to provide sufficient electrical power for ultrasonic humidifiers to operate. They applied their study in Alexandria, Egypt. They measured the purified productivity depending on the three summer months. They integrated six ultrasonic humidifiers into their investigated solar still to enhance the water evaporation frequency. Their experimental analysis revealed that integrating ultrasonic humidifiers into the solar still enhanced the freshwater production of the solar still by 44% and 25%, corresponding to water heights of 35 mm and 25 mm. In addition, the research results confirmed that using ultrasonic moistener and phase change materials in the solar still led to a significant increase in the overall freshwater productivity. Also, it was found that employing ultrasonic humidifiers, and solar PV panels made the solar still system more economically feasible and increased purified water production [22].

2.3 KEY LIMITATION AND CRITICAL CHALLENGES OF SOLAR STILLS IN OFFERING A LARGE AMOUNT OF PURIFIED FRESHWATER

In this regard, research about the lack of potable water and noticed that it is a source of concern around the world, and this is what prompted them to think of producing fresh water from polluted water or sea water through specialized systems and devices. Perhaps one of the most prominent devices for seawater purification is energy The solar system that works according to the principle of evaporation and condensation to produce fresh water.

Solar energy can be classified into two types: single phase or multiphase and this varies by design. In this paper, the researchers explored the different designs of multi-stage solar panels with stacked phases and the challenges they face. The researchers found that the

highest distillation yield achieved by the vacuum system with a flowing water bottom was 28.04 kg / m 2 / day at atmospheric pressure, while at the vacuum pressure of 0.03 bar the yield was 53.21 kg / m 2 / day. And with the independent multi-stage system with a flat-panel solar collector (FPSC) the average yield was 7.36 litres / m2 / day, while with an evacuated tube solar collector (ETSC) the output was 16 litres / m2 / day. In terms of challenges, the researchers found that the factors affecting multi-stage solar energy with the phases of the stack and the waterbed apply whether the waterbed is stagnant or flowing.

First the salt content and other related pollutants: Because seawater comes into contact with the phase trays, brine residue lining the phases clogs up gradually because of impurities in the seawater ،and constantly maintenance and cleaning is required. As the salinity concentration increases and the volume of the water basin (the bottom of the water) increases, the rate of evaporation decreases.

Second: The stages of dependency stacking: One of the challenges is the dependency of multi-stage solar energy stacked on each other. As the stages above the first stage, (the second stage) based on it. (The first stage) to furnish thermal energy via the latent heat of condensation to produce the distillate and if one of the lower stages be unsuccessful or encounters any problem, the heat will not be transferred in really to the higher stages stacked and will not produce any distillate.

Third: the sump or condensate collector: Condensate, when formed at the bottom of the trays, is collected in the distillate with all systems where the trough is placed alongside a sloping tray or under a slant tray. Corrugated trays have better rates of condensate collection. Also, the condensing surface of the tray has to be angled so that the condensate does not fall back into the saltwater pond but collects. by trough.

Fourth: A stagnant water bed on a tilted stage tray: A system with a stagnant water bottom in the stage cannot maintain a flat or flat salt water depth because the salt water is shallower at the top end of a sloping tray and deeper at the bottom end of the tray. Figure (2.1)

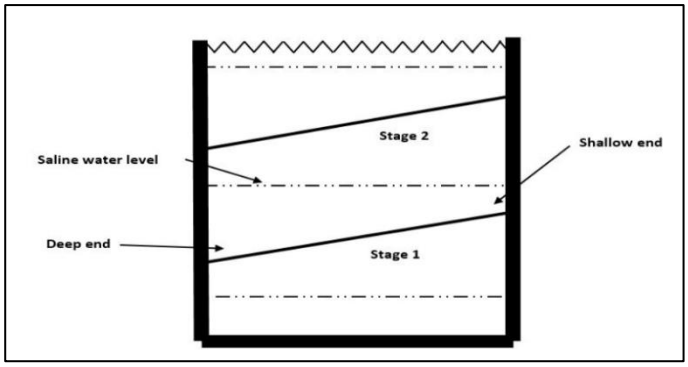

Figure 2.6: Stage Trays at 8° From the Horizontal [23].

The depth of the water at the lower end of the upper stage tray is directly commensurate to the angle of the tray, that is, the greater the angle of the tray, the greater the salt water and the saltwater depth cannot be maintained 5 cm.

Fifth: The trend of the distillate product from the individual stages

In a system with bottom water, in either its stagnant or flowing states, the direction of the downstream phases is produced more distillates than the upper stages. However, in multi-stage solar the last stage was producing more distillates. And there is sometimes a cumulative distillation product, and not every stage was also mentioned on the basis of an individual return.

The researchers also examined the costs associated with building, maintaining, and operating the system over its lifetime, which are relatively higher than the cost of a passive device. They found that the cost to produce a distillate per gallon (CPG) ranged from approximately 0.00182993 to $0.3631/gallon. These costs increase significantly when additional equipment (eg pumps) are combined into multiple stages.

The study found that the high cost of each distillate could be justifiable increasing the yield liken to the passive product. In addition, the improvements are unlimited and new configurations can be introduced to promote the output of the distillate, while contributing to straightforwardness of operation, and reducing maintenance and operating costs [23].

The possibility of applying solar energy as an option for converting saline water to fresh drinking water, but the low productivity of solar snapshots is a major problem and

therefore the rise request for fresh water cannot be met. As the use of solar energy for desalination includes several processes such as heating, evaporation and condensation.

The researchers studied improving the performance of the solar panels through several methods and choosing the most appropriate among them, focusing on the challenges of climatic and design conditions and optional parameters that affect the productivity of the solar panels.

The researchers found that it is possible to obtain a higher yield of daily distillates by combining good solar radiation intensity, stable type of solar energy, and higher temperature regions.

The agents that impact the productivity of solar distillation include: First, climatic parameters (intensity of solar radiation / wind speed / ambient temperature / dust and cloud cover / longitude and latitude of the site), secondly design parameters (selection of materials / water depth / area of the absorber plate / Thermal energy storage materials/ cover plate inclination/ cover plate thickness/ use of internal and external reflectors/ gap distance/ sun tracking system/ thickness of insulation materials) Third: Operational parameters (water content of salt / water flow rate / use of pigments).

One of the reasons for the low productivity of solar panels that hinders meeting the high demand for fresh water is the presence of dust and dirt particles on the surface of the condensation, and this reduces the transmission ability of the glass cover. For the basin due to its ability to conduct heat and its ability to resist corrosion, and in terms of evaporation, when maintaining a minimum water depth of about 1 cm for imitative solar energy, it , promote evaporation and provides higher productivity, and because the evaporation rate raise with the increase in the surface area of the absorbent plate, the graduated basin will provide Higher surface area and with the use of fins the surface area improvement is greater. They also found that when the wind speed was increased from 0 to 10 ms to about 50% improved productivity.

The researchers recommended that for high yield, tilted solar panels should be used by making the angle of inclination equivalent to the latitude of the site. When the V-shaped corrugated absorber panel is mixed with fins and energy storage materials combined with

external reflective panels, this creates improved conditions to enhance productivity, while increasing the thickness of the material. Insulators (such as foam and sawdust) reduce heat loss in solar still and thus promote productivity. Also, a sun tracking system, whether it is a single axis or double axis in solar still, can enhance productivity. Finally, the use of pigments on solar roofs increases productivity and reduces the gap between the absorber panels and the condensing mantle It can enhance the performance of solar energy [24].

Solar Energy Productivity and Efficiency (SS), as one of the solar water desalination systems, where researchers observed that the improvement of the solar evaporation process by nano/nano materials. It can form a strategy to conquer the bottleneck in the traditional solar still and ameliorate its performance.

The researchers explored factors that enhance productivity and efficiency like particle concentration, material type, system configurations, and solar density, as well as the thermal conductivity and solar absorbance of micro/nano particles used. Porous structure, surface properties and thermal design are key factors for porous materials.

What improves the evaporation process in solar distillation is the enhancement of both the thermal conductivity of the base fluid and the absorption of the sun using nanoparticles.

When nanoparticles are added, the yield is improved compared to conventional still images by up to 93.9% for inactive SS and 285% for active SS.

And the daily productivity of nanoparticle-based SSs ranges from 3 to 7 l/m2, for passive SSs and for active SSs 4 to 9 l/m2 and in terms of cost, it hardly increases. 0.01 - 0.027 USD/L, and for the active 0.021 - 0.05 USD/L.

Another way to enhance solar energy is suitable porous materials. Key factors for achieving high performance through porous materials (eg paper films, artificial air or hydrogel and natural biomaterials used in solar evaporation system to improve SS) include high solar energy absorption, low thermal conductivity, and hydrophilic surfaces. In performance, materials with a nanometric design usually outperform materials with a micrometric design.

And since nanomaterials are characterized by their ability to better manipulate the aspects of heat transfer, mass, light absorption, and surface properties. However, they noticed that the evaporation rate under one sun across the porous nanomaterials could reach 4 kg/(m2/h) which is significantly higher than the theoretical maximum value of 1.5 kg/(m2×h), so it was recommended The researchers check the rate of evaporation.

The researchers also identified the challenges of using micro/nano-particles, such as (Erosion and corrosion of components / stability of nanofluids / the trade-off between complexity and productivity). phase for solid-liquid reaction.

The researchers recommended the need to monitor the performance of systems after long-term exposure to solar radiation and salt water. They also suggested researching the impact of solid-liquid interaction as a way in the field of solar water desalination. Where as, multi-stage SS with nano/micro-materials presents a new strategy for improving SS in the future. The daily yield of multi-stage passive SS from porous materials may reach 10-20 l/m2 [25].

The low productivity of solar panels that makes it unable to meet the high demand for fresh water, solar panels are the devices used for solar desalination (conversion of salt water into fresh water using solar thermal energy). The researchers discussed appropriate methods to increase the efficiency of solar footage such as preheating the feed water, forced convection and energy storage. First, the researchers categorized the solar stills into three types (Basin still / Wick still / Diffusion still) . The Basin still is the most simple or traditional type of solar still and is shown in Figure (2.2)

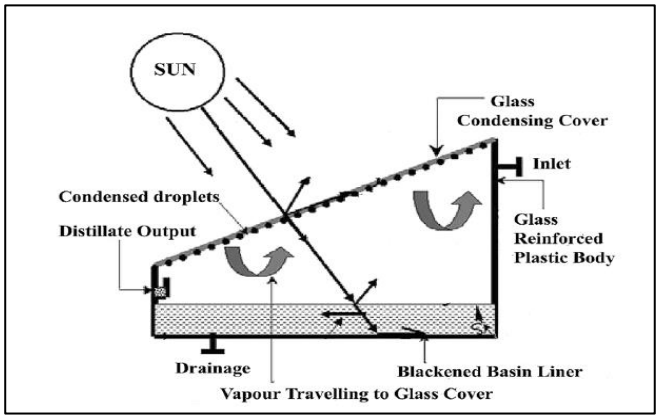

Figure 2.7: Conventional Solar Distillation Unit [26].

Then they studied the factors that affect the productivity of the solar shots were (climatic conditions/ depth of the aquarium water/ cover slope/ cover thickness/ cover material/ temperature difference of cover water and glass/ insulation material and thickness/ surface evaporation area).

The researchers found that increased productivity is achieved by increasing the rate of evaporation by decreasing the depth of the basin water. The angle of inclination of the cover and the orientation are the important factors to increase the productivity as the angle of inclination of the cover equal to the angle of the latitude of the site receives the maximum amount of solar radiation. Also, the presence of porous sorbents in the ponds increases productivity by up to 273%. And the sun tracking system is effective in improving the performance of the system. Which achieves an increase in productivity is reducing the optimum thickness of the insulation, which increases the thermal efficiency of the device, while the use of reflectors and capacitors increases productivity by 165%. The integration of solar energy with heat exchangers or collectors increases thermal efficiency and system productivity [26].

The topic of covering fresh water needs through desalination systems based on fossil fuels. Excessive combustion of fossil fuels leads to rapid depletion and pollution of the local environment in addition to threatening the sustainability of life. So, solar energy-based desalination systems Sea water as a clean alternative. The researchers turned toward studying solar gradient snapshots, which convert solar energy into the heat required to produce fresh water in seawater desalination. The researchers found that to develop gradient solar shots and improve performance, there are enhancement techniques and developmental trends such as simple gradient shots under different environmental and operational conditions, gradient shots with an absorber panel and modifications to the glass cover, as well as gradient solar trough additions improvements. When using internal and external reflectors in Kafr El-Sheikh, Egypt, the highest productivity reached 8,100 liters / m2 / day. With a theoretical productivity of 13.257 liters/m2/day, it is possible to improve this constant productivity by about 5.157 liters/m2/day by adding more modification techniques. The researchers recommended the use of these improvements as they have low construction and operating costs and are able to meet a large amount of

fresh water needs of small communities in coastal areas, islands, rural areas, and hot, arid and harsh regions such as the Middle East.

However, the gradient solar energy still needs more integration from the new modifications. Attention should be paid to designing the modified footage to achieve better and effective absorption of solar heat as well as the evaporation of sea water. In order to increase productivity and reduce costs to market this type of promising solar photovoltaic in hot arid and harsh regions [27].

A study conducted to work on creating a water desalination system that works on solar energy by adopting a solar collector with a built-in condenser in addition to the presence of a pump for emptying in order to produce fresh water. A comparison was made between this innovative system and the traditional water desalination system that relies on solar energy without a pump For discharge and this comparison was for several operating conditions and the temperatures of the two solar desalination systems were measured, and through the recorded degrees of heat and water productivity, the performance and quality of these two systems studied in the research were evaluated.

From the results extracted from this research, it was found that increasing the degree of salinity in the water reduces the productivity of fresh water, and this productivity is related to the highest temperature. By comparing the two systems, it was found that the system equipped with a vacuum station improved the value of water productivity by reducing the boiling of water, where the productivity values recorded a value of 10.94 and 7.27 litres / day for the value of the flow rate of 0.80 and 0.40 litres / hour in the groundwater tanks, by adopting the developed system equipped with the pump and the normal system, respectively. By studying the cost of the distilled litre, it was found that the lowest costs were 0.031 and 0.030 US dollars / liter for the distilled litre for the flow rates of 0.80 and 0.40 litres / hour for the groundwater tank, for the two systems equipped with pump and normal, respectively [28].

A research work to search for presenting an economic feasibility study in order to benefit from tube solar energy in the field of water desalination in the Kingdom of Saudi Arabia in order to provide clear visions for stakeholders, as tube solar energy is one of the best

modern technologies for the production of clean and fresh water, as heat loss during the condensation process is the reason Basic in the low productivity of tube solar energy.

The study relied on the results of many researches in examining the feasibility of using solar distillation and the possibility of this use. The multiple effects were analyzed from the adoption of dissolved solid materials in which there is a condenser in order to track the gravel inside the basin and in order to track the solar energy. The results of this study showed that the use of these materials It has a great potential for heat recovery and for its reuse, and from the extracted results, it is considered that the active solar snapshots are highly efficient, as TSS has great potential and is better when compared to the solar snapshots with multiple basins. It was also recommended to adopt a triple or double number of effects, and more effects are not recommended. Because it leads to a decrease in the productivity of fresh water, and TSS can be adopted in the investments of large projects, due to its great potential. When calculating the productivity of the TSS, it was found that 4.51 litres / m2 is the productivity of the single, while the rest of the productions were 7.24, 8.92, and 10.03 litres / m2 for the double, triple and quadruple, respectively. Also, the productivity was increased by 60.5% for the double effect, while the rest of the increases were 97.8% and 122.4% for triple and quadruple effects.

When determining the CPL for the added solids, it was found that 0.0088 USD for the single effect, while it was 0.0067 USD for the double effect, 0.0066 USD for the triple effect and 0.0072 for the quadruple effect [29].

A study was executed to search for available water resources in China and the development of solar energy, as the large number of people in China required a huge amount of fresh water, so it was necessary to find supportive ways to increase water sources through desalination. The research presented how to desalinate water through the use of sustainable energy in China. A comparison of the methods used in desalinating water through solar energy. Through previous research and historical studies, it was found that the water problem is found mainly in northern China and has also appeared in southern China to a lesser extent. 1.39 x 1016 kWh is the annual insolation in China. The highest annual solar energy rise in the world is enjoyed by some provinces of China's Qinghai Plateau. Since Shandong, Hebei, Liaoning and Tianjin take most of the existing radiation, they make use

of technology from this ray to address water shortage problems. using the desalination process.

In China, in 2020, a third five-year plan was drawn up for the desalination process of sea water, amounting to more than 2.2 million tons / day. Where the desalination scale in 2017 was less by a ton / day, reaching 1.2 million tons / day, so quick plans were made for desalination, as SWRO and LT-MED were relied on in seawater desalination operations in China [30]. The process of desalination without leaving an impact on the environment is one of the main requirements by making use of solar energy that provides well-pure distilled water. Models to enhance the work and productivity of solar energy. The researchers presented an analysis of a number of solar distillers of the rotating components such as the cylinder, disc and column, and the process of emphasizing the importance of following up on solar energy on a permanent basis to secure safe drinking water in an economical and high productivity. The cylinder (9.22 L/m2/d & 350%), the vertical disc distillation device (16.5 L/m2/day & 617.4%), the vibratory distillation (5.8 L/m2/day & 132%) and the spinning column (0.83). l/m2/day & 39.49%. One of the results of the research is that the rotary cylinder distillation device has a higher productivity than the traditional one and that if the wind turbines are combined with the traditional distillation mechanism, we get an increase in the evaporation rate and from it we get a greater increase in the production of drinking water. Therefore, the use of an internal or external fan increases the productivity value Distillation is an effective way to increase the production value of drinking water [6].

In the search for a model work methodology that evaluates the process of evaporation and heat transfer in the TTS system through the formation of a device that predicts the quality of water desalination through solar energy. The efficiency of more than 100% of the traditional solar thermal snapshots was demonstrated through the development of the number of stages. The modeling process showed that the quality of the TMSS capillary feed is not great and it is limited during the condensation process due to heat dissipation during condensation and by reducing the loss, a large gain value can be guaranteed. This research is based on developing a model to improve the performance of multi-stage solar energy TMSS by understanding the process of transferring mass and heat through solar

steam. But through an upper limit determined by the engineering configuration of the device [31].

2.4 CHAPTER SUMMARY

Through a theoretical review of the previous literature, we found out that there are several factors that help increase the productivity of solar sectors in order to produce more fresh water, and the studies revealed the existence of many challenges and obstacles that impede this process, studies confirmed that it is one of the factors that enhance productivity and efficiency such as Particle concentration, material type, system configurations, solar density, as well as thermal conductivity and solar absorption of the micro/nano particles used, rate of evaporation, cover tilt angle direction and direction, and the presence of porous absorbent materials in ponds. One of the appropriate ways to increase the efficiency of solar captures Such as feed water preheating, forced convection and energy storage. As the factors affecting the productivity of solar distillation are related to climatic parameters, design parameters and operating parameters.

The factors that affect the productivity of solar shots include (climatic conditions / depth of water in the basin / slope of the cover / thickness of the cover / cover material / temperature difference of cover water and glass / insulation material and thickness / area of surface evaporation). (Content of salt and other related pollutants/Stacking stages depends on the collecting trough or condensation collector/Standing water layer on inclined stage tray/Direction of distillate of individual stages). Among the reasons for the low productivity is the presence of dust and dirt particles on the surface of condensation and the problem of corrosion and evaporation, and from the challenges of using fine / nano particles, such as (erosion and corrosion of components / stability of nanofluids / trade-off between complexity and productivity). Several strategies have been suggested during the research to overcome these obstacles.

Through a theoretical review of the previous literature, we found out that there are several factors that help increase the productivity of solar sectors in order to produce more fresh water, and the studies revealed the existence of many challenges and obstacles that impede this process, studies confirmed that it is one of the factors that enhance productivity and

efficiency such as Particle concentration, material type, system configurations, solar density, as well as thermal conductivity and solar absorption of the micro/nano particles used, rate of evaporation, cover tilt angle direction and direction, and the presence of porous absorbent materials in ponds. One of the appropriate ways to increase the efficiency of solar captures Such as feed water preheating, forced convection and energy storage.

As the factors affecting the productivity of solar distillation are related to climatic parameters, design parameters and operating parameters. The factors that affect the productivity of solar shots include (climatic conditions / depth of water in the basin / slope of the cover / thickness of the cover / cover material / temperature difference of cover water and glass / insulation material and thickness / area of surface evaporation). (Content of salt and other related pollutants/Stacking stages depends on the collecting trough or condensation collector/Standing water layer on inclined stage tray/Direction of distillate of individual stages). Among the reasons for the low productivity is the presence of dust and dirt particles on the surface of condensation and the problem of corrosion and evaporation, and from the challenges of using fine / nano particles, such as (erosion and corrosion of components / stability of nanofluids / trade-off between complexity and productivity). Several strategies have been suggested during the research to overcome these obstacles.

This thesis will be a serious attempt to develop solar stills and deal with different aspects from the aspects addressed by previous studies, as it will study critical ultrasonic humidifiers' and solar PV systems' contribution to improving the quantity of purified water produced using 'V' type solar still systems. In addition, determining the evaporation rate, heat transfer amount, performance, and volume of purified drinking water generated using two solar stills; the first is conventional, and the second uses ultrasonic humidifiers and a solar PV system.

3. THEORETICAL STUDY AND EXPERIMENTAL WORK

3.1 INTRODUCTION

This chapter includes a theoretical study that includes a summary of the experimental tests used in the model, in addition to study the properties of the nanomaterials used in the experimental work. It also provides information about of the tools and instrumentation used in the experimental test. the experimental test was executed to analyse key contributions and critical benefits of ultrasonic humidifiers and solar PV system integration into a 'V' type solar still to improve the evaporation rate and increase the quantity of pure water generated via solar energy. The stages of experimental work will be described that was adopted two solar stills; the first one is conventional, while the second solar still uses ultrasonic humidifiers and solar PV panels.

3.2 THEORETICAL STUDY

3.2.1 Tools and Instrumentation

3.2.1.1 Ultrasonic processor

An ultrasonic processor can be applied to separate, disband and sheer target substance specimens via its concentrated ultrasonic frequencies [53]. Its applications represented in biological, chemical, manufacture and environmental areas [32]. concentrated voice waves are obtained by the sonicator unit, these waves reflect in the room and raise the vibration resistance of target substances, separating these substance specimens effectively [33]. this device can employ very great power to specimens as small as 1 ml. It is often utilized for breaking up microorganism cells, in can be utilized for tiny-scale substances handling [54], [55]. it is provided with a quality voice-proof room and metal elevating stand. It is designed for separate nanoparticles in fluid with a small amount, homogenize fluid state [34] from co-sedimentation and blend multi-chemical in one sol with higher quality than any other ways.

3.2.1.2 KD2 pro

The KD2 Pro is a device designed to be held in hand utilized to gauge thermal characteristics [35], [56]. The major KD-2 Pro package made up of a inspector and one sensor equipment. There are various sensors obtainable to buy that users can entered into any substance. The thermal conductivity and resistivity are gauged using one needle sensors: whereas the binary -needle sensor gauge thermal conductivity, resistivity, volumetric specific thermal ability and diffusivity [36].

3.2.1.3 NDJ-5S viscometer

The viscometer is a tool utilized to gauge the viscosity of a liquid [37]. Viscosity is the physical amount which refers the internal friction of the liquid [57]. It is the capability of the liquid to stand strains [38]. It is a significant indicator to determine some end products or semi-end products.NDJ-5S is an intelligent tool, relying on the technique of A 16-bit elevated -performance one slice, that has completely modified the prior rotor technique . Stepper motor operates precisely and constant as the controlling speed system. after that, torque sensor will drive rotor cycle in a steady velocity. When rotor exposes viscous strength in the experimented fluid, the viscosity of the experimented fluid will illustrate on the monitor by experimenting and processing. Comparing to the same tool, this instrument has the merit of elevated measure precise, constant in rotate velocity, expand working voltage. It is very suitable for persons to select the rotor and rotor speed of the experimenting fluid rightly [58], due to the function of gauged value occupies entire scope.

3.2.1.4 Ultrasonic humidifier

An ultrasonic humidifier is a very useful machine. It contains a stocked of water and a diaphragm or another kind of shaking items [59]. The diaphragm shakes at an very elevated frequency, in which it exceed the scope of mankind hearing (this is the reason they’re named ultrasonic humidifiers). The shakes push tiny water particles into the air. as soon as these droplets access the air, the water steams, water temperature doesn't increase at any point, thus these humidifiers are called “cold mist” humidifiers. nevertheless, several humidifiers achieve evaporation without increasing temperature. ultrasonic humidifiers utilize shakes to emits water particles to the air. Ultrasonic humidifiers,

nevertheless, steam water in the humidifier and emit water steam into the air. these devices achieve this by transform the water into vapor [39]. Other ultrasonic humidifiers absorb the water via a filter of certain type, then releases cold air via the filter using a fan [40]. This leads to steam the water and emits water steam into the room. Ultrasonic humidifiers are small devices and combined since the humidifying machinery is extremely simple. Ultrasonic humidifiers do not create any temperature increment, making them safer than evaporate humidifiers which boil water to generate water steam [40], [60].

3.2.1.5 PV- panels

PV panels transform the sun radiation into electrical power. although insolation energy does not require cost and it is free, the transformation effective of PV panels have a significant task in their improvement and energy involvement [41]. Photovoltaic are constructed for the transforming of thermic energy into electrical energy[62] , whereas solar panels transform sun light into heat. Four main kinds of solar panels: monocrystalline, polycrystalline, PERC, and thin-film panels. Photovoltaic panels convert solar radiation into DC electric power [61], as this power goes along the charge controller device which administers the battery supply and discharging operation, that stores the power created by the panels.

3.2.2 Nanomaterial Definition and Its Properties

3.2.2.1 Nano materials

Nano materials can be identified as a group of materials where at least one distance is smaller than almost 100 nanometres. Nanomaterials are significant substances since at this scope valuable vision, magnetic, electrical, and other characteristics. These arises characteristics have the ability for high influences in, mechanics, electronics, medicine, and another area [42]. Engineered nanomaterials [43] are sources developed at the molecular standard to enable benefit of their little size and new features that are mostly not seen in their traditional, bulk peers. The two major causes why substances at the nano scope can have various characteristics are increased relative surface area and novel quantity impacts.

the most significant feature of nanomaterial includes: (1) great fraction of surface particles, (2) great surface power, (3) locative confinement, and (4) minimize defections.

3.2.2.2 Nanocomposites Contributions in Solar Still

Fig 3.1 illustrates of how to utilize nanocomposites in a solar system, such as solar still (SS). It made up of a tightly-isolated tank where water with nanocomposites is gathered at its foundation. The top surface of the tank is coated by a well-sealed glazier coat to reduce vapor seepage.

solar radiation entering the still via the glass is soaked up by nanoparticles, consequently the nanoparticles is heated up. Nanoparticles soak up a great quantity of insolation and empty the temperature to a basic liquid (water) and the water particles start to evaporate quicker. steam molecular are moved up from the water surface to the air inside the still by normal convection and the air gets filled by steams. When this saturated air hits the cold internal glazier surface, condensation of steam particles starts to form. This condensate water slides down owing to gravity and collects external the still as stilled water.

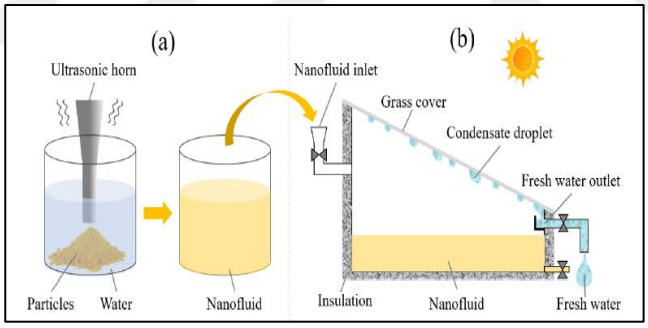

Figure 3.1: Using Nano Materials in Still Water [42].

3.3 EXPERIMENTAL WORK

3.3.1 Nanofluid Preparation

The first step of this work is preparation of the nanofluid with volume fraction equals to (1,3 and 5) % with nanoparticles diameter 50nm. The characteristics of pure water and nanoparticles at 300 K. The 1200W ultrasonic Processor was used for homogenizing, dispersing and mixing nanofluid and Figure 3.2 shows it.

Figure 3.2: 1200W Ultrasonic Processor for Homogenizing Nanofluid Produced by MTI Corporation [43].

3.3.2 Thermophysical Properties Measurement of Nanofluid

KD2 PRO was utilized to determine the heat conductivities of Cu Nano-fluid. The distilled water was used to calibrate and verification of the KD2 PRO. Figure 3.3 shows the KD2 PRO used in the thermal conductivities' measurement in this investigation. Cu-Water heated from 15 to 55 °C for the pure water and volume fraction (1,3,58) % .

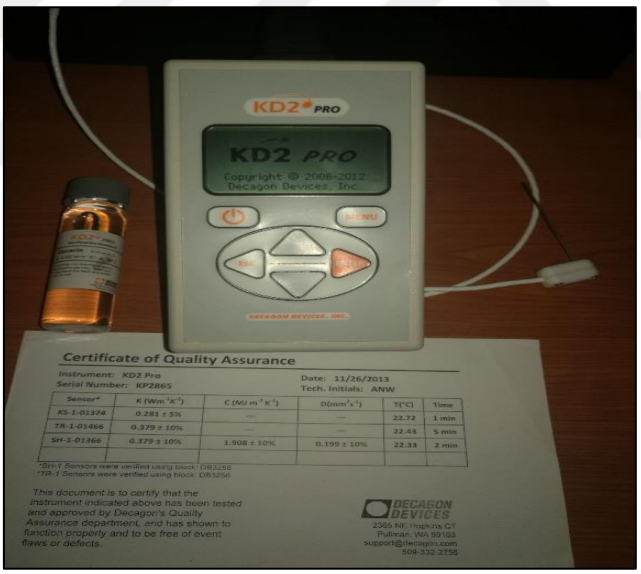

Figure 3.3: KD2PRO Measuring Device for Thermal Conductivity of Nanofluid Produced by Decagon Device Int [35].

Same experiments were applied to determine the dynamic viscosity of the pure water and nanofluids using the rotary-viscometer. The process of the measuring requires at least 3 minutes before recording the data to reach the steady state conditions. Figure 3.4 shows the rotary-viscometer device.

Figure 3.4: NDJ-5S Viscometer Measuring Device for Dynamic Viscosity of Nanofluid [37].

FESEM photograph for the Al2O3 and TiO2 nanofluids shown in Figure 3.5. Nanomaterials have characterized the ability to absorb solar radiation, which increases the heat transfer rate to water and thus improves the evaporation rate inside the solar still. In this study, three different nanomaterials (Al2O3, TiO2) were used, which process good thermal properties in addition to their low cost as shown in figure (3.5).

Initially, all nanomaterials were dissolved by ethanol 99.9% as a solvent and then dispersed by a magnetic stirrer for 6 hours to obtain a nanomaterial solution. After that this solution is mixed with black paint to prepare the coated plate. The aluminium coated plates possessed 1%, 3%, 5% of Al2O3 and TiO2 nanomaterials as shown in the figure (3.6). Finally, all the coated plates were put in the modified solar stills basin respectively.

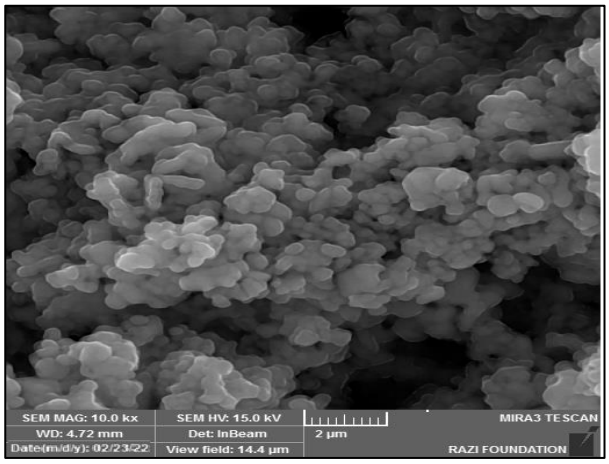

Figure 3.5: Morphology of Al2O3 Nanoparticles at 200nm [57].

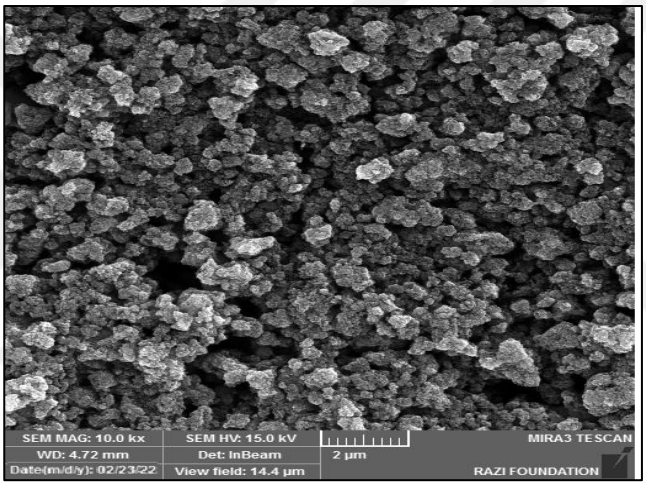

Figure 3.6: Morphology of TiO2 Nanoparticles at 200nm [62].

3.3.3 Test Set Up

In this study, experimental tests were conducted in the city of Najaf, Iraq (32.1 N° 44.19 E°) during different months of the year. During the operating hours from 8:00 am to 22:00 pm, the effect of weather conditions on the performance of the solar system was examined. Therefore, the obtained results are discussed by comparing Conventional Solar Stills (CSS) and Modified Solar Stills (MSS) as depicted in Fig 3.7.

Figure 3.7: Test Configuration [42].

The experimental tests adopted two types of solar stills the first type traditional slope basin kind has been manufactured and built from 8mm thickness glass. The tank horizontal efficient surface of solar still was 0.25 m² (0.5m x 0.5 m) and the height of the basin is 0.5m. the thickness value of glass cover utilized in the solar still was 8 mm and the slop angle of the glass cover for solar still was selected at 25° with due to the horizontal. The traditional solar still adopted in the research is illustrated in figure (3.8).

parts the solar still were coated with black paint for raising the solar radiation sucktion effectivity. The tank was fixed at simple inclination to assure that the influx of condensate water is directed the exit tube. A tube with half inch diameter and valve were installed and linked to the lower side of tank channels to assure optimum collection of the stilled water.

The main objective of this work is to improve the thermal performance of solar stills, thereby increasing the production of distilled water by several techniques. The main condition for upgrading a solar still is to increase the rate of evaporation and condensation.

Another method used to enhance thermal performance is the two types of solar still that is called modified solar still as depicted in Fig3.10 which was adopted using the Ultrasonic Humidifier which is powered by PV panel illustrated in Fig 3.9 . It's used to increase the vapor through the system and mix it.

Therefore, the shape of the solar still and nanotechnology plays an important role in improving solar stills production, as described in the literature review section. Therefore, in this regard, the nanoparticles can be used by increasing the thermal properties of the system, thereby increasing the evaporation rates of the solar still. Such as Al2O3 and TiO2. The particle size of these nanomaterials is about 30nm, the purity is 99.8%, the concentration of use is 1%, 3%, and 5%, and the water depth is 2cm, 5cm, and 8cm.

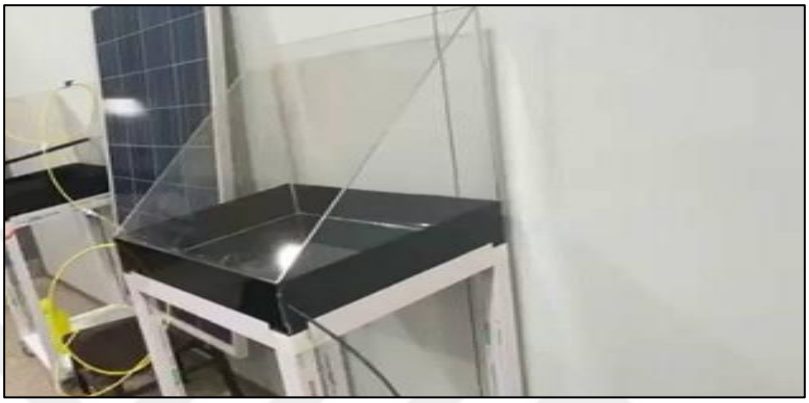

Figure 3.8: Conventional Slope Basin Solar Still [42].

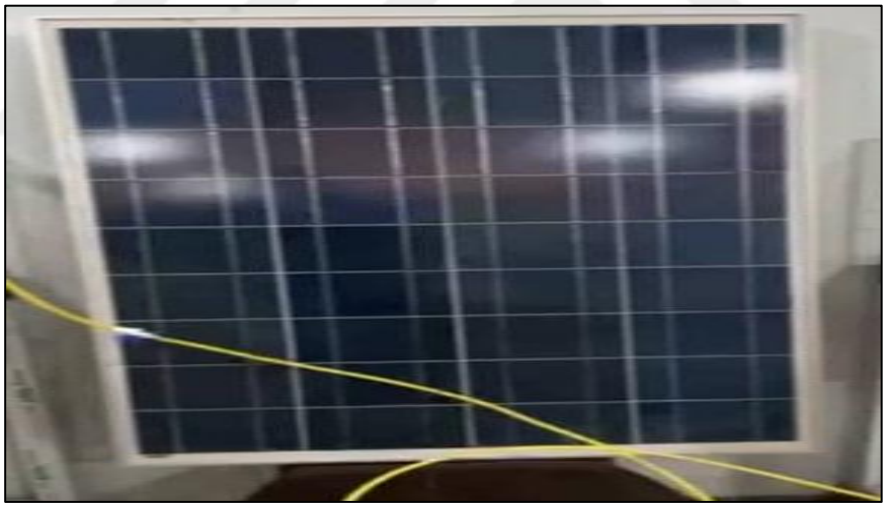

Figure 3.9: PV-Panel [62]

Figure 3.10: Modified Solar Still [58].

Nanomaterials are used to study nanomaterials that have a significant impact on the production of solar stills by changing the internal evaporation rate. All nanomaterials are applied to aluminium plate (50*50) cm. The coating process was carried out by mixing the nanomaterials with a large amount of black paint and then spraying it uniformly on the aluminum panel.

Initially, the nanomaterials AL2O3 and TiO2 with concentrations of 1% 3% and 5% in 2,5 and 8cm water depth were used. All results obtained were obtained within days per nanomaterial, as well as a comparative study between conventional (CSS) and modified (MSS) solar stills.

Result of the experimental tests will be demonstrated by figures shown in chapter four that will show all the results observed from the experimental work and a discussion of AL2O3 and TiO2 nanomaterials, respectively.

4. RESULTS AND DISCUSSION

4.1 INTRODUCTION

This section provides the experimental results obtained in this research illustrating the performance of two types of solar stills and discusses the benefits of utilizing Nanofluids, as well, utilizing humidifier with PV- panels in enhancing the performance of still water. Comparison between conventional solar stills and improved solar stills will be conducted moreover, summary will be provided. Lastly, the results of the research will be concluded and recommendations for further work will be mentioned.

4.2 DISCUSSION THE RESULTS

The improvement of evaporation rate and thermal conductivity will be studied according to the following parameters:

a. Impact of modified solar still and comparing with the traditional solar still
b. Impact of water depth variation on the performance two types of solar still systems.
c. Impact of adding 3% concentration of nanomaterials to the modified solar still
d. Impacts the water depth variation in modified solar still and by using nanomaterials.
e. Impact of the concentration of nanomaterials variation with adding Ultrasonic Humidifier.

4.2.1 Impact Of Modified Solar Still And Comparing With The Traditional Solar Still

In this case, A comparison was executed between the traditional solar still and the modified solar still which was adopted by adding ultrasonic humidifiers and PV panels and both two cases of solar stills have no Nanomaterials, Fig. 4.1 presents the local time insolation and ambient, vapor and water temperature variability for both of conventional and modified solar still with constant water depth. The experimental program was at 16 /5/022. The two cases study of solar stills was experimented at constant water depth.

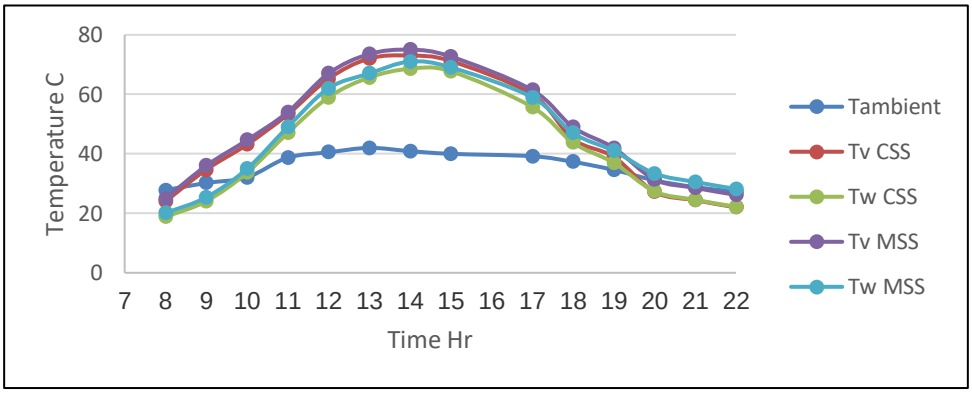

Figure 4.1: Temperature Distribution for CSS and MSS at 16/5/2022 for Ambient, Vapor Temperature and Water Temperature Without Nanomaterials.

It can be shown from Figure 4.1 that the hourly insolation begins to raise from local time of 8:00 to access the highest value at local time of 14:00 and it reduces gradually until the end of the day. It is obvious that the vapor temperature of modified and conventional solar still has the maximum value at 75°C, 73°C respectively and reached to the minimum value at 25°C, 21°C respectively while the water temperature of modified and conventional solar still has the maximum value at 71°C, 69°C respectively and reached to the minimum value at 21°C, 29 °C. according to what mentioned, we realize that adding ultrasonic humidifier and powered it by pv panels has a slightly contribution in increasing water temperature and vapor temperature .moreover both of water temperature and vapor temperature increased according to the ambient and at the local time 14:00 were higher than ambient temperature by 45% .Additionally, the temperature of water and vapor started to increase at 8:00 and reached the maximum value at local time 14:00,then it dropped gradually and reached the minimum value at the end of the day.

4.2.2 The Effect Of Water Depth Variation On The Cases Study Solar Still Systems

Different of water depths (2-5-8)cm were selected to study the impacts of water depth variation on the two cases study traditional and modified solar still systems so that the water temperature was recorded during the local time which was started at 8:00 and ended at 22:00.

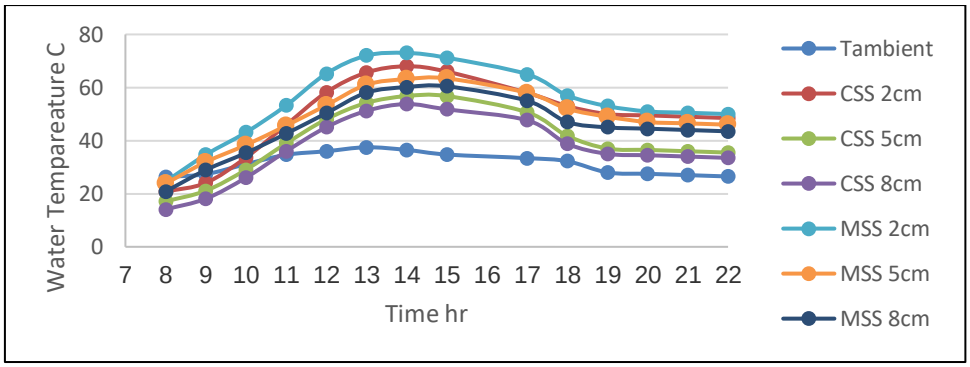

Figure 4.2: Water Temperature Distribution for CSS and MSS at 1/6/2022 for Ambient Without Nanoparticles at 2,5 and 8 cm.

Figure 4.2, It is obvious that the water temperature of modified solar still system for different water depths (2-5-8)cm reached to 74°C, 63°C, 60°C and for conventional solar still and with the similar different water depths (2-5-8) cm achieved value at 68°C, 57°C, 54°C respectively .In addition, the values of water temperature and for some cases exceeded the ambient temperature at time local started from 9:00 and the entire cases exceeded the ambient at local time start from 11:00. From these records measures, it was revealed a slightly enhancement in water temperature when using modified solar still and by comparing it with traditional one the enhancement ratio of water temperature ranged from 7 % to 10% .moreover, according to the both cases study traditional and modified solar still, we noticed that when water depth decreases , the water temperature increase by percentage ratio up to 14 % when comparing the water temperature at 2cm water depth to 8cm of water depth.

4.2.3 The Effect Of Adding 3% Concentration Of Nanomaterials To The Modified Solar Still

In this section, It was studied the performance of modified solar still by adding 3% of the concentration of nanomaterials (Al2O3, TiO2) in case of 2cm water depth so that the water temperature was recorded during the local time which was started at 8:00 and ended at 22:00

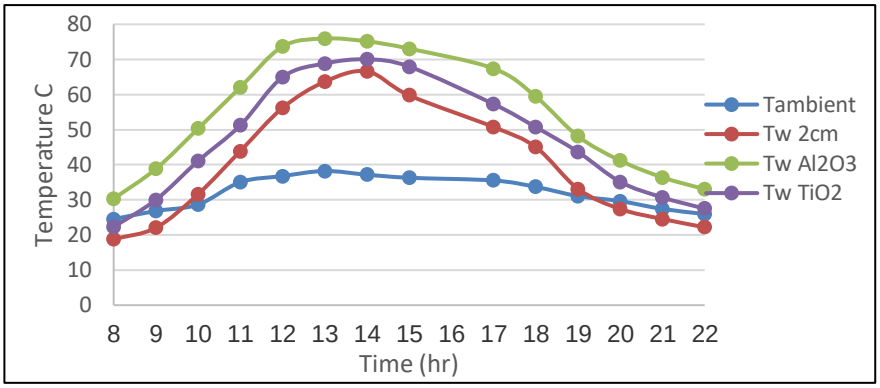

Figure 4.3: Water Temperature Distribution for MSS at φ=3% of Al2O3 and TiO2 Nanomaterial at 20/6/2022 at 2 cm Water Depth.

Figure 4.3 illustrates that adding 3% of Al2o3 contributed to increase the water temperature by percentage up to 9 % by comparing to using modified solar still without nano materials, while adding 3 % of Tio2 contributed to increase the water temperature by percentage up to 4 % by comparing to using modified solar still without nanomaterials. Moreover, the water temperature obtained using Al2o3 exceeded the ambient temperature at local time 8:00 while , the water temperature obtained using Tio2 exceeded the ambient temperature at local time 9:00.

Also, It was studied the performance of modified solar still by adding 3% of the concentration of nanomaterials (Al2O3, TiO2) in case of 5 cm water depth so that the water temperature was recorded during the local time which was started at 8:00 and ended at 22:00 as illustrated in Fig.4.4

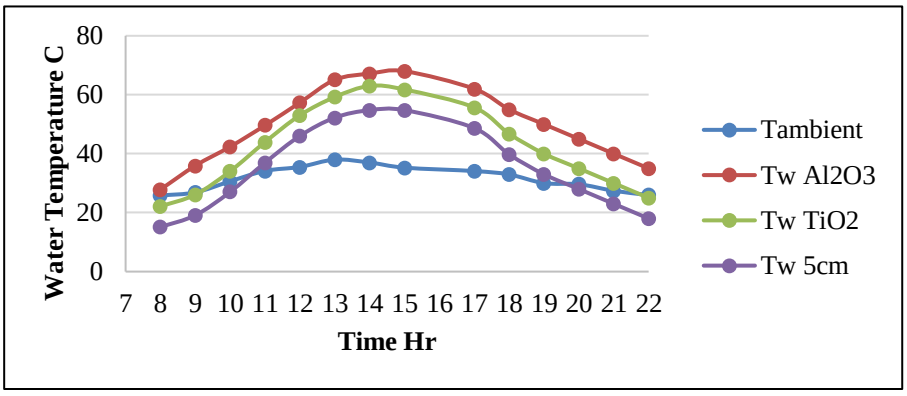

Figure 4.4: Water Temperature Distribution for MSS at φ=3% of Al2O3 and TiO2 Nanomaterial at 22/6/2022 at 5 cm Water Depth.

Figure 4.4 illustrates that adding 3% of Al2o3 contributed to increase the water temperature by percentage up to 14 % by comparing to using modified solar still without nanomaterials, while adding 3 % of Tio2 contributed to increase the water temperature by percentage up to 8 % by comparing to using modified solar still without nanomaterials. Moreover, the water temperature obtained using Al2o3 exceeded the ambient temperature at local time 8:00 while, the water temperature obtained using Tio2 exceeded the ambient temperature at local time 11:00. Also, , it was observed that the number of nanomaterials had an effect on the steam and water temperature at the end of the day when the ambient temperature dropped to a minimum value.

Moreover, It was studied the performance of modified solar still by adding 3% of the concentration of nanomaterials (Al2O3, TiO2) in case of 8 cm water depth so that the water temperature was recorded during the local time which was started at 8:00 and ended at 22:00 as illustrated in Fig.4.5

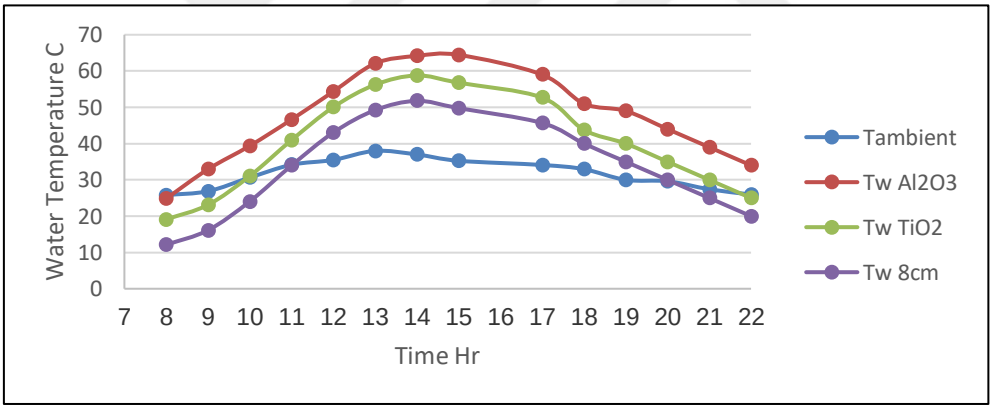

Figure 4.5: Water Temperature Distribution for MSS at φ=3% of Al2O3 and TiO2 Nanomaterial at 24/6/2022 at 8cm Water Depth.

Figure 4.5 shows that adding 3% of Al2o3 contributed to increase the water temperature by percentage up to 13 % by comparing to using modified solar still without nanomaterials, while adding 3 % of Tio2 contributed to increase the water temperature by percentage up to 7 % by comparing to using modified solar still without nanomaterials. Moreover, the water temperature obtained using Al2o3 exceeded the ambient temperature at local time 8:00 while, the water temperature obtained using Tio2 exceeded the ambient temperature at local time 11:00. This result shows that aluminum oxide has higher thermal conductivity and density compared to titanium oxide.

4.2.4 Impacts The Water Depth Variation In Modified Solar Still And By Using Nanomaterials

The aim of this parameter is to show impacts of water depth variation that was selected (2-5-8) cm in performance of modified solar still and adding 3% of Al2o3 as nanomaterial.

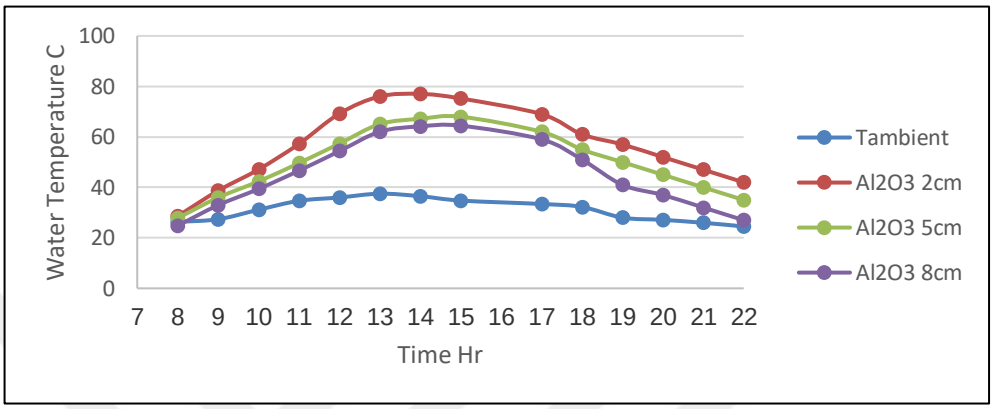

Figure 4.6: Water Temperature Distribution for MSS at φ=3% of Al2O3 Nanomaterial at 2,5 and 8 cm Water Depth.

The results were organized in Fig 4.6 and for all water depth cases, the value of water temperature exceeded the ambient temperature at 8:00 and at the peak local time 14:00 the variation between water temperature of cases study and ambient ranged from 24 % to 77%. furthermore, the highest value of water temperature had been achieved using water depth 2cm and this value reduces with per increment of water depth. Furthermore, it was observed that the number of nanomaterials had an effect on the steam and water temperature at the end of the day when the ambient temperature dropped to a minimum value.

Moreover, adding Tio2 nanomaterials to the modified solar still was studied to show impacts of water depth variation that was selected (2-5-8) cm in performance of modified solar still as depicted in Fig 4.7.

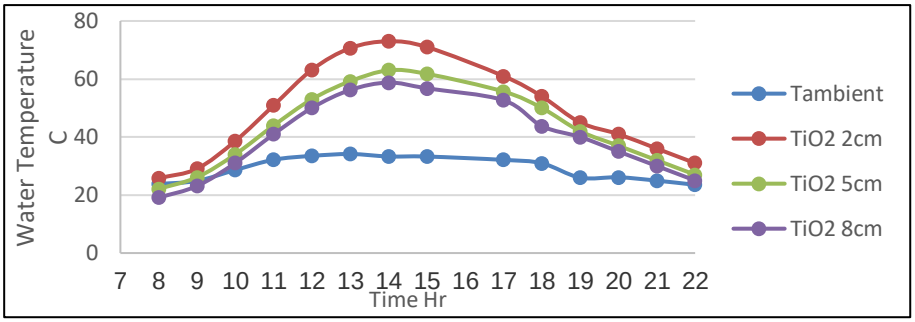

Figure 4.7: Water Temperature Distribution for MSS at φ=3% of Al2O3 Nanomaterial at 2,5 and 8 cm Water Depth.

From Figure 4.7, it was noticed that the water temperature of cases study related to using Tion2 nanomaterials exceeded the ambient temperature at local time between 9:00 and 10:00 while the water temperature in case of using Al2o3 exceeded before this period. In addition, water temperature had been increased with decreasing water depth value.

4.2.5 Impact Of The Concentration Of Nanomaterials Variation With Adding Ultrasonic Humidifier

This part investigates impacts of increasing the concentration of nanofluids in solar still in addition to using Ultrasonic Humidifier to study performance of the modified solar still. Two nanomaterials had been used (Al2o3,Tio2) with different concentrations (1-3-5)% and the water depth for all cases was constant and equals 5cm.

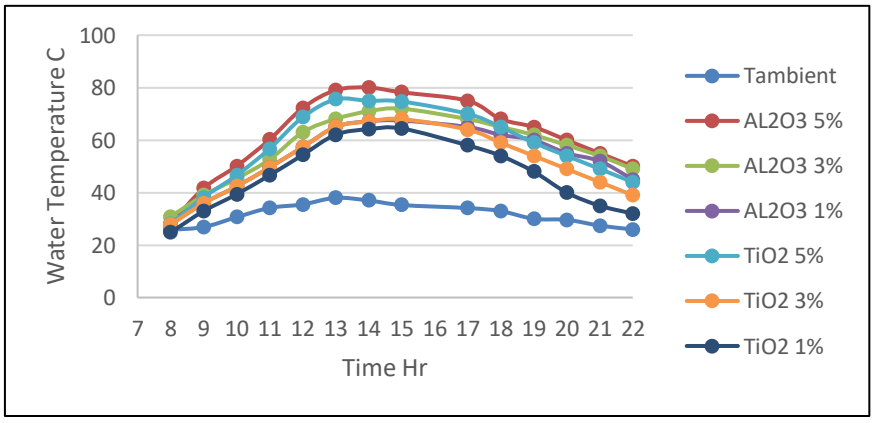

Figure 4.8: Water Temperature Distribution for MSS at φ=1,3 and 5% of Al2O3 and TiO2 with Ultrasonic Humidifier at 5 cm Water Depth.

The results obtained by Fig 4.8 illustrates that increasing the concentration of nanomaterials contributed to increase the water temperature, possibly due to the

absorption of solar radiation by the nanomaterials, resulting in increased heat transfer to the water. Furthermore, it was observed that the number of Nanomaterials had an effect on the steam and water temperature at the end of the day when the ambient temperature dropped to a minimum value. Moreover, This results shows that aluminium oxide has higher thermal conductivity and density compared to titanium oxide. Also, The results illustrate that adding 5% of Al2o3 increased the water temperature by 13% comparing to adding 1% concentration of Al2o3 while adding 5% of Tio2 contribute to increase the water temperature by 11% comparing to adding 1% concentration of Al2o3.

4.2.6 The Impacts Of The Concentration Of Nanomaterials Variation With No Ultrasonic Humidifier

This section was conducted in order to examine impact of adding concentration of nanofluids in solar still in addition to without using Ultrasonic Humidifier to study performance of the modified solar still. Two nanomaterials had been used (Al2o3,Tio2) with different concentrations (1-3-5)% and the water depth for all cases was constant and equals 5cm.

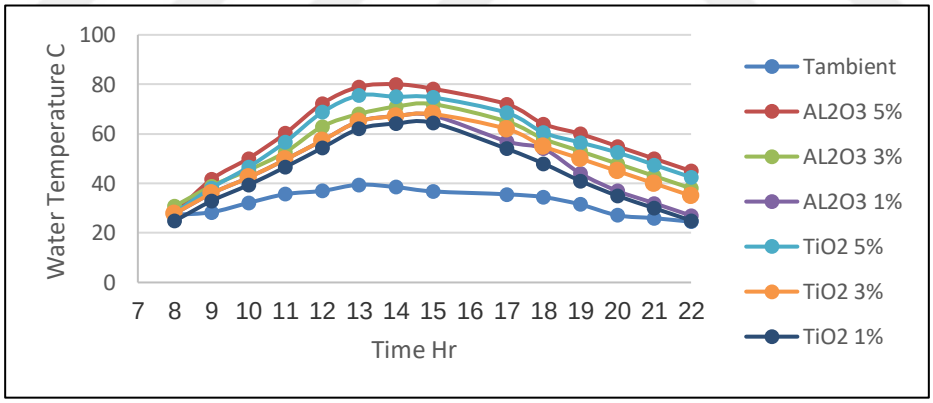

Figure 4.9: Water Temperature Distribution for MSS at φ=1,3 and 5% of Al2O3 and TiO2 Without Ultrasonic Humidifier at 5 cm Water Depth.

Figure 4.9 shows that temperature of water decreased by comparing it with Figure 4.8 and thus, thermal conductivity decreased in case of using no ultrasonic humidifier. consequently, that using ultrasonic humidifier ha a great impact on enhancing thermal conductivity.

4.2.7 Nanomaterials Contributions

4.2.7.1 Titanium oxide (TiO2) nanomaterials

Figure (4.2) shows the effect of 3% concentration of AL2O3 nano materials on vapor and water temperature in MSS, compared to CSS. The temperature of the vapor and water was observed to increase with the ambient temperature until 2-3pm, then drop to a minimum at 3-6 pm. This behavior has also been observed with nanomaterials. When the Nano coated plates were placed in the MSS basin, the temperature of the steam and water became higher than that of the CSS, possibly due to the absorption of solar radiation by the nanomaterials, resulting in increased heat transfer to the water. Furthermore, it was observed that the number of Nanomaterials had an effect on the steam and water temperature at the end of the day when the ambient temperature dropped to a minimum value. Table (4.1) shows the amount of productivity for 1,3 and 5% concentrations.

4.2.7.2 Titanium oxide (Tio2) nanomaterials

The productivity of CSS and MSS is listed in Table (4.1). It was observed that MSS was more productive than CSS two days at a time. The productivity of MSS increased by about 31.8% to 46% when increasing the concentration of TiO2 without using the Ultrasonic and from 35% to 56% with using it. The increase in productivity is due to the increase in ambient temperature when exposed to nanomaterials.

Table 4.1: Accumulated Daily Productivity of CSS and MSS for Days at ø=1% , 3% and 5% of TiO2 Nanomaterial.

Concentration	Date	Daily productivity (ml/day)			Daily productivity rise without UH	Daily productivity rise with UH
		CSS	MSS without UH	MSS with UH		
1%	10/7/2022	440	550	580	31.8%	35%
3%	14/7/2022	470	630	660	34%	40.4%
5%	18/7/2022	500	730	780	46%	56%

4.2.7.3 Aluminium oxide (AL2O3) nanomaterials

Table (4.2) shows the productivity of solar stills "CSS and MSS" when Al2O3 nanomaterials were used at 1% to 5% concentrations. It is observed that productivity increases when Al2O3 nanoparticles are higher than TiO2. However, it is observed that the increase in productivity decreases with the lowest heat capacity and thermal conductivity of titania compared to alumina. The productivity of MSS increased by about 34.7% to 51.9% when increasing the concentration of AL2O3without using the Ultrasonic and from 41.3% to 64.4% with using it. The increase in productivity is due to the increase in ambient temperature when exposed to nanomaterials.

Table 4.2: Accumulated productivity of CSS and MSS for two Days at ø ø=1% , 3% and 5% of Al2O3 Nanomaterial.

Concentration	**Date**	**Daily productivity (ml/day)**			**Daily productivity rise without UH**	**Daily productivity rise with UH**
		CSS	**MSS without UH**	**MSS with UH**		
1%	25/7/2022	460	620	650	34.7%	41.3%
3%	29/7/2022	485	700	760	44.3%	56.7%
5%	3/8/2022	520	790	855	51.9%	64.4%

5. CONCLUSION AND RECOMMENDATIONS

5.1 RESEARCH SUMMARY

This research based on an experimental analysis that carried out to achieve the study goals. A comparative analysis executed to determine the heat transfer rate, performance, and amount of clean and pure water generated depending on two solar stills. One of them is a traditional ‘V’ type solar still. The other system integrates an ultrasonic humidifier and a solar PV system into a ‘V’ type solar still. Moreover, in addition Nanomaterials was utilized in the two cases study to show the impacts of these nanofluids on performance the traditional and modified solar still. the objectives of these study were investigated to assure their achievements as follows.

a. The first objective “To execute previous studies, describe main solar still systems’ characteristics, beneficial contributions, and advantages in purifying polluted water with higher performance.”

   This objective was done in chapter two by conducting a comprehensive literature review of the recent researches addressing enhancing the performance solar stills the benefits of several solar stills in producing purified water.

b. The second objective “To highlight major solar still systems types and classifications according to the area of application in which they are used”

   After reviewing the most recent studies adopts solar stills to product stilled water, the study adopted two types of solar stills: the first one is a traditional ‘V’ type solar still. And the second one integrates an ultrasonic humidifier and a solar PV system into a ‘V’ type solar still

c. The third objective “To shed light on critical ultrasonic humidifiers’ and solar PV systems’ contribution to improving the quantity of purified water produced using ‘V’ type solar still systems”

   Recent previous studies and literature reviews affirmed the ability of ultrasonic humidifiers and solar PV systems in enhancing performance of solar still by increasing evaporation rate, heat transfer, thermal efficiency, and its potential to generate purified water.

d. The fourth objective “To conduct experimental-comparative analysis to determine the evaporation rate, heat transfer amount, performance of two solar stills; the first is conventional, and the second uses ultrasonic humidifiers and a solar PV system”

This objective conducted in chapter four in which, the results showed the enhancement the performance of two types of solar still. moreover, utilizing a nanofluids provided a significant impact in enhancing performance of the studied solar stills.the temperature of vapor and water had increased as well the thermal conductivity enhanced

e. The fifth objective “To investigate and correct the results due to a panel of solar still specialists and heat transfer experts”.

The results were calibrated by verifying the results of the research by experts and specialists in the field of solar distillers. The experts praised the work presented and the reliability of the results provided by the experimental work.

a. It was revealed that adding ultrasonic humidifier and powered it by pv panels has a slightly contribution in increasing water temperature and vapor temperature.
b. The results showed that the temperature of water and vapor increases when water depth reduces and this leads to enhancing thermal productivity.
c. According to the results obtained in this research, regular dispersion of the nanomaterials in the basic liquid led to solar absorption improvement, moreover enhancing both the performance and the quality of the solar still.
d. blending of nanomaterials with the tank water lead to raising its thermal conductivity, water heat and coefficient of convective temperature transmit and according to that, immediate the evaporation ratio raises. because, the nanomaterials operate as a heat saving substances and offer an adequate power to the water and enhance the still performance.
e. The productivity of distilled water was enhanced with increasing the nanomaterials volume fractions.
f. Nanomaterials achieve the capacity to absorb immediately the insolation owing to the perfect identical among its vision absorption spectrum and the solar radiation spectrum.

g. The productivity of MSS increased by about 34.7% to 51.9% when increasing the concentration of AL_2O_3without using the Ultrasonic and from 41.3% to 64.4% with using it. The increase in productivity is due to the increase in ambient temperature when exposed to nanomaterials.
h. The productivity of MSS increased by about 31.8% to 46% when increasing the concentration of TiO2 without using the Ultrasonic and from 35% to 56% with using it. The increase in productivity is due to the increase in ambient temperature when exposed to nanomaterials.
i. Utilize AL2O3 was more efficient and effective than using Tio2 in which, the thermal productivity enhanced more by using AL2O3. as well, vapor temperature and water temperature increased.

5.2 RECOMMENDATIONS

a. It is essential to utilize a wiper fixed at the still tank to prevent sedimentation of nanomaterials.
b. It is recommended to select the proper nanoparticles concentration.
c. more work is demanded to validate the confident of using nanoparticles in solar stills systems from economic and environmental views
d. it has to concentrate on improving a non-poison and economic nanomaterials to cut costs of nanofluid based solar still.
e. More studies and research tasks are required to investigate the impact of nanomaterials deposition on the productivity of solar stills.
f. More work should be conducted to study of utilizing combined-nanomaterials or PCM-nanomaterials on the performance of solar stills.
g. it is necessary to validate the benefits of the usage of nanomaterials for improving the productivity of several specific designs of solar stills.

REFERENCES

[1] A. Dėdelė, N. I. Nikiforov, A. N. Madieva, and A. Miškinytė, "Potential of Water Vending Machine to Remove Trihalomethanes and Heavy Metals During High and Low Water Seasons in Petropavlovsk," *Polish Journal of Environmental Studies*, vol. 31, no. 3, pp. 2049–2058, 2022, doi: 10.15244/pjoes/143255.

[2] S. Sharma and A. Bhattacharya, "Drinking water contamination and treatment techniques," *Applied Water Science*, vol. 7, no. 3, pp. 1043–1067, 2017, doi: 10.1007/s13201-016-0455-7.

[3] M. R. Diab, F. A. Essa, F. S. Abou-Taleb, and Z. M. Omara, "Solar still with rotating parts: a review," *Environmental Science and Pollution Research*, vol. 28, no. 39, pp. 54260–54281, 2021.

[4] A. F. Muftah, M. A. Alghoul, A. Fudholi, M. M. Abdul-Majeed, and K. Sopian, "Factors affecting basin type solar still productivity: A detailed review," *Renewable and Sustainable Energy Reviews*, vol. 32, pp. 430–447, 2014, doi: 10.1016/j.rser.2013.12.052.

[5] Ali. F. Muftah, M. A. Alghoul, A. Fudholi, M. M. Abdul-Majeed, and K. Sopian, "Factors affecting basin type solar still productivity: A detailed review," *Renewable and Sustainable Energy Reviews*, vol. 32, pp. 430–447, Apr. 2014, doi: 10.1016/j.rser.2013.12.052.

[6] M. R. Diab, F. A. Essa, F. S. Abou-Taleb, and Z. M. Omara, "Solar still with rotating parts: a review," *Environmental Science and Pollution Research*, vol. 28, no. 39, pp. 54260–54281, Oct. 2021, doi: 10.1007/s11356-021-15899-8.

[7] A. Shukla, K. Kant, and A. Sharma, "Solar still with latent heat energy storage: A review," *Innovative Food Science & Emerging Technologies*, vol. 41, pp. 34–46, Jun. 2017, doi: 10.1016/j.ifset.2017.01.004.

[8] E. M. S. El-Said and G. B. Abdelaziz, "Experimental investigation and economic assessment of a solar still performance using high-frequency ultrasound waves atomizer," *Journal of Cleaner Production*, vol. 256, p. 120609, 2020.

[9] A. Shukla, K. Kant, and A. Sharma, “Solar still with latent heat energy storage: A review,” *Innovative food science & emerging technologies*, vol. 41, pp. 34–46, 2017.

[10] G. ABDELAZIZ, E. El-Said, M. Dahab, M. Omara, and S. Sharshir, “Recent Developments of Solar Stills and Humidification De-humidification Desalination Systems: A Review,” *Journal of Petroleum and Mining Engineering*, vol. 23, no. 2, pp. 57–69, 2021, doi: 10.21608/jpme.2022.86431.1090.

[11] S. W. Sharshir, A. Joseph, A. W. Kandeal, and A. A. Hussien, “Performance improvement of tubular solar still using nano-coated hanging wick thin film, ultrasonic atomizers, and cover cooling,” *Sustainable Energy Technologies and Assessments*, vol. 52, p. 102127, 2022.

[12] G. B. Abdelaziz, M. A. Dahab, M. A. Omara, S. W. Sharshir, A. M. Elsaid, and E. M. S. El-Said, “Humidification dehumidification saline water desalination system utilizing high frequency ultrasonic humidifier and solar heated air stream,” *Thermal Science and Engineering Progress*, vol. 27, p. 101144, 2022.

[13] H. Nasr Aboelmaaty, “A detailed Review of Solar Desalination Systems with Different Enhancement Methods,” *SVU-International Journal of Engineering Sciences and Applications*, vol. 3, no. 1, pp. 49–63, Feb. 2022, doi: 10.21608/svusrc.2022.126110.1035.

[14] F. Alqurashi, R. Nciri, A. Alghamdi, C. Ali, and F. Nasri, “Experimental Performance Investigation of an Original Rotating Solar Still Design under Realistic Meteorological Conditions,” *Energies*, vol. 15, no. 11, Jun. 2022, doi: 10.3390/en15113995.

[15] N. T. Alwan *et al.*, “Enhancement of the Evaporation and Condensation Processes of a Solar Still with an Ultrasound Cotton Tent and a Thermoelectric Cooling Chamber,” *Electronics (Switzerland)*, vol. 11, no. 2, Jan. 2022, doi: 10.3390/electronics11020284.

[16] N. T. Alwan *et al.*, “Enhancement of the Evaporation and Condensation Processes of a Solar Still with an Ultrasound Cotton Tent and a Thermoelectric Cooling Chamber,” *Electronics (Basel)*, vol. 11, no. 2, p. 284, Jan. 2022, doi: 10.3390/electronics11020284.

[17] A. H. Abed, H. A. Hoshi, and M. H. Jabal, “Experimental investigation of modified solar still coupled with high-frequency ultrasonic vaporizer and phase change material capsules,” *Case Studies in Thermal Engineering*, vol. 28, Dec. 2021, doi: 10.1016/j.csite.2021.101531.

[18] M. Roshdy, S. A. Elhady, M. Shaban, and M. F. C. Esmail, “Experimental investigation of the performance of a single-slope solar still under Aswan climate conditions,” *IET Renewable Power Generation*, vol. 15, no. 16, pp. 3901–3914, Dec. 2021, doi: 10.1049/rpg2.12306.

[19] K. Hijjaji, N. Frikha, S. Gabsi, A. Kheiri, and M. Khalij, “Using DOE and RSM procedures to analyze and model a spray evaporation type solar still,” *International Journal of Energy and Environmental Engineering*, vol. 12, no. 3, pp. 551–561, Sep. 2021, doi: 10.1007/s40095-021-00392-2.

[20] N. T. Alwan, S. E. Shcheklein, and O. M. Ali, “Experimental study and economic cost analysis about enhancement productivity for a conventional solar still combined with humidifiers ultrasonic,” *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, pp. 1–17, 2021.

[21] A. H. Abed, H. A. Hoshi, and M. H. Jabal, “Experimental investigation of modified solar still coupled with high-frequency ultrasonic vaporizer and phase change material capsules,” *Case Studies in Thermal Engineering*, vol. 28, p. 101531, Dec. 2021, doi: 10.1016/j.csite.2021.101531.

[22] A. I. Shehata *et al.*, “Enhancement of the productivity for single solar still with ultrasonic humidifier combined with evacuated solar collector: An experimental study,” *Energy Convers Manag*, vol. 208, p. 112592, Mar. 2020, doi: 10.1016/j.enconman.2020.112592.

[23] M. M. Mkhize and V. Msomi, “Challenges and progress made towards the improvement of a multistage solar still desalination system,” *Desalination Water Treat*, vol. 222, pp. 23–35, 2021, doi: 10.5004/dwt.2021.27063.

[24] L. D. Jathar *et al.*, “Effect of various factors and diverse approaches to enhance the performance of solar stills: a comprehensive review,” *J Therm Anal Calorim*, vol. 147, no. 7, pp. 4491–4522, Apr. 2022, doi: 10.1007/s10973-021-10826-y.

[25] G. Peng *et al.*, “Potential and challenges of improving solar still by micro/nano-particles and porous materials - A review,” *J Clean Prod*, vol. 311, p. 127432, Aug. 2021, doi: 10.1016/j.jclepro.2021.127432.

[26] S. S. Narayanan, A. Yadav, and M. N. Khaled, “A concise review on performance improvement of solar stills,” *SN Appl Sci*, vol. 2, no. 3, p. 511, Mar. 2020, doi: 10.1007/s42452-020-2291-5.

[27] A. Shmroukh and S. Ookawara, “Stepped Solar Stills’ Development and Improvement for Seawater Desalination,” *SVU-International Journal of Engineering Sciences and Applications*, vol. 2, no. 2, pp. 26–36, Dec. 2021, doi: 10.21608/svusrc.2021.86943.1012.

[28] M. M. Morad, H. A. M. El-Maghawry, and K. I. Wasfy, “A developed solar-powered desalination system for enhancing fresh water productivity,” *Solar Energy*, vol. 146, pp. 20–29, Apr. 2017, doi: 10.1016/j.solener.2017.02.002.

[29] F. Alshammari, M. Elashmawy, and M. M. Z. Ahmed, “Cleaner production of freshwater using multi-effect tubular solar still,” *J Clean Prod*, vol. 281, p. 125301, Jan. 2021, doi: 10.1016/j.jclepro.2020.125301.

[30] C. Chen, Y. Jiang, Z. Ye, Y. Yang, and L. Hou, “Sustainably integrating desalination with solar power to overcome future freshwater scarcity in China,” *Global Energy Interconnection*, vol. 2, no. 2, pp. 98–113, Apr. 2019, doi: 10.1016/j.gloei.2019.07.009.

[31] L. Zhang, Z. Xu, B. Bhatia, B. Li, L. Zhao, and E. N. Wang, “Modeling and performance analysis of high-efficiency thermally-localized multistage solar stills,” *Appl Energy*, vol. 266, p. 114864, May 2020, doi: 10.1016/j.apenergy.2020.114864.

[32] A. S. Ali, “Application of nanomaterials in environmental improvement.,” *Nanotechnology and the Environment.*, 2020.

[33] F. de C. Dutra, V. G. de Resende, and A. Dias, “Use of Carbon-based Nanomaterials on the Cold Agglomeration of Iron Ore Fines,” *ISIJ International*, vol. 59, no. 4, pp. 660–664, Apr. 2019, doi: 10.2355/isijinternational.ISIJINT-2018-289.

[34] H. Z. Akbas, Z. Aydin, O. Yilmaz, and S. Turgut, “Effects of ultrasonication and conventional mechanical homogenization processes on the structures and dielectric properties of BaTiO3 ceramics,” *Ultrason Sonochem*, vol. 34, pp. 873–880, Jan. 2017, doi: 10.1016/j.ultsonch.2016.07.027.

[35] R. M. Sarviya and V. Fuskele, “Review on Thermal Conductivity of Nanofluids,” *Mater Today Proc*, vol. 4, no. 2, pp. 4022–4031, 2017, doi: 10.1016/j.matpr.2017.02.304.

[36] M. Hemmat Esfe, S. Esfandeh, S. Saedodin, and H. Rostamian, “Experimental evaluation, sensitivity analyzation and ANN modeling of thermal conductivity of ZnO-MWCNT/EG-water hybrid nanofluid for engineering applications,” *Appl Therm Eng*, vol. 125, pp. 673–685, Oct. 2017, doi: 10.1016/j.applthermaleng.2017.06.077.

[37] W. Ji, L. Yang, Z. Chen, M. Mao, and J. Huang, “Experimental studies and ANN predictions on the thermal properties of TiO2-Ag hybrid nanofluids: Consideration of temperature, particle loading, ultrasonication and storage time,” *Powder Technol*, vol. 388, pp. 212–232, Aug. 2021, doi: 10.1016/j.powtec.2021.04.069.

[38] Q. Wang, Y. Song, J. Sun, and G. Jiang, “A novel functionalized food packaging film with microwave-modified konjac glucomannan/chitosan/citric acid incorporated with antioxidant of bamboo leaves,” *LWT*, vol. 166, p. 113780, Aug. 2022, doi: 10.1016/j.lwt.2022.113780.

[39] N. T. Alwan, S. E. Shcheklein, and O. M. Ali, “Experimental study and economic cost analysis about enhancement productivity for a conventional solar still combined with humidifiers ultrasonic,” *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, pp. 1–17, May 2021, doi: 10.1080/15567036.2021.1924318.

[40] Z. Feng, X. Zhou, S. Xu, J. Ding, and S.-J. Cao, “Impacts of humidification process on indoor thermal comfort and air quality using portable ultrasonic humidifier,” *Build Environ*, vol. 133, pp. 62–72, Apr. 2018, doi: 10.1016/j.buildenv.2018.02.011.

[41] A. M. Manokar, D. P. Winston, A. E. Kabeel, and R. Sathyamurthy, “Sustainable fresh water and power production by integrating PV panel in inclined solar still,” *J Clean Prod*, vol. 172, pp. 2711–2719, Jan. 2018, doi: 10.1016/j.jclepro.2017.11.140.

[42] H. Rauscher, K. Rasmussen, and B. Sokull-Klüttgen, “Regulatory Aspects of Nanomaterials the EU,” in *Chemie Ingenieur Technik*, vol. 89, no. 3, pp. 224–231, Mar. 2017, doi: 10.1002/cite.201600076.

[43] M. F. Hochella *et al.*, “Natural, incidental, and engineered nanomaterials and their impacts on the Earth system,” *Science (1979)*, vol. 363, no. 6434, Mar. 2019, doi: 10.1126/science.aau8299.

[44] Attia, M. E. H., Kabeel, A. E., Bellila, A., Manokar, A. M., Sathyamurthy, R., Driss, Z., & Muthusamy, S. (2021). A comparative energy and exergy efficiency study of hemispherical and single-slope solar stills. *Environmental Science and Pollution Research*, *28*, 35649-35659.

[45] Bhardwaj, A., Dagar, V., Khan, M. O., Aggarwal, A., Alvarado, R., Kumar, M., ... & Proshad, R. (2022). Smart IoT and machine learning-based framework for water quality assessment and device component monitoring. *Environmental Science and Pollution Research*, *29*(30), 46018-46036.

[46] Calik, S., 2023. Green Technology and Smart Solutions for Capitalist Cities in the Twenty-First Century. In *Capitalism at a Crossroads: A New Reset?* (pp. 323-336). Cham: Springer International Publishing.

[47] Mahmood, F., & Al-Ansari, T. (2022). Design and analysis of a renewable energy driven greenhouse integrated with a solar still for arid climates. *Energy Conversion and Management*, *258*, 115512.

[48] Hashemi, S. A., Kazemi, M., & Passandideh-Fard, M. (2022). Experimental characterization of a solar still integrated with a spiral collector using energy, exergy, economic, and environmental (4E) analyses. *Sustainable Energy Technologies and Assessments*, *53*, 102521.

[49] Sathyamurthy, R., El-Agouz, S. A., Nagarajan, P. K., Subramani, J., Arunkumar, T., Mageshbabu, D., ... & Prakash, N. (2017). A review of integrating solar collectors to solar still. *Renewable and Sustainable Energy Reviews*, *77*, 1069-1097.

[50] Abd Elaziz, M., El-Said, E. M., Elsheikh, A. H., & Abdelaziz, G. B. (2022). Performance prediction of solar still with a high-frequency ultrasound waves atomizer using random vector functional link/heap-based optimizer. *Advances in Engineering Software*, *170*, 103142.

[51] Sanserwal, M., & Singh, P. (2021). Single Slope Single Basin Active Solar Still Integrated with ETCs: A Review. *Recent Advances in Mechanical Engineering: Select Proceedings of RAME 2020*, 117-130.

[52] Dumka, P., & Mishra, D. R. (2020). Performance evaluation of single slope solar still augmented with the ultrasonic fogger. *Energy*, *190*, 116398.

[53] Koshani, R., & Jafari, S. M. (2019). Ultrasound-assisted preparation of different nanocarriers loaded with food bioactive ingredients. *Advances in Colloid and Interface Science*, *270*, 123-146.

[54] Kumar, V. (2020). Ultrasonic-assisted de-agglomeration and power draw characterization of silica nanoparticles. *Ultrasonics Sonochemistry*, *65*, 105061.

[55] Huang, J., Han, X., Zhao, X., & Meng, C. (2021). Facile preparation of core-shell Ag@ SiO2 nanoparticles and their application in spectrally splitting PV/T systems. *Energy*, *215*, 119111.

[56] Aberoumand, S., & Jafarimoghaddam, A. (2018). Tungsten (III) oxide (WO3)–Silver/transformer oil hybrid nanofluid: Preparation, stability, thermal conductivity and dielectric strength. *Alexandria engineering journal*, *57*(1), 169-174.

[57] Mizerovskiy, L. N., & Smirnov, P. R. (2021). Viscosity and Internal Friction in Liquids. *Russian Journal of General Chemistry*, *91*, 1797-1806.

[58] Fu, K., Zhang, P., Wang, L., Huang, X., & Fu, D. (2020). Viscosity of 2-ethylhexan-1-amine (EHA)-diglyme, EHA-triglyme and EHA-tetraglyme non-aqueous solutions and its effect on initial absorption rate. *Journal of Molecular Liquids*, *302*, 112518.

[59] Putra, I. D. G. A. T., Sunu, P. W., Temaja, I. W., Sugiartha, N., Sugina, I. M., & Suirya, I. W. (2020, February). Investigation on application of ultrasonic humidifier for air conditioning system. In *Journal of Physics: Conference Series* (Vol. 1450, No. 1, p. 012050). IOP Publishing.

[60] Mohammed, M., Alqahtani, N., & El-Shafie, H. (2021). Development and evaluation of an ultrasonic humidifier to control humidity in a cold storage room for postharvest quality management of dates. *Foods*, *10*(5), 949.

[61] Shaikh, M. R. S. (2017). A review paper on electricity generation from solar energy.

[62] Sampaio, P. G. V., & González, M. O. A. (2017). Photovoltaic solar energy: Conceptual framework. *Renewable and Sustainable Energy Reviews*, *74*, 590-601.