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EXPERIMENTAL STUDY OF WATER DEPTH AND NANOTECHNOLOGY EFFECTS ON THE PRODUCTIVITY OF ACRYLIC PYRAMID SOLAR STILL

Ibrahem Hamdi Khalf KHALF

Master’s Thesis

Supervisor

Asst. Prof. Dr. Yaser ALAIWI

Istanbul, 2022

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The thesis titled EXPERIMENTAL STUDY OF WATER DEPTH AND NANOTECHNOLOGY EFFECTS ON THE PRODUCTIVITY OF ACRYLIC PYRAMID SOLAR STILL prepared by IBRAHIM KHALF and submitted on 15/12/2022 has been **accepted unanimously** for the degree of Master of Science in Mechanical Engineering.

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ABSTRACT

EXPERIMENTAL INVESTIGATION OF THE ENHANCEMENT PARAMETERS ON THE PERFORMANCE OF INCLINED V TYPE SOLAR STILL USING NANO COATINGS

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Recently, the person's share of water decreased, so it was necessary to rely on water distillation to solve this crisis, and in light of the development of the use of renewable energies such as solar energy and wind energy, as they are the ideal alternative to traditional energy sources and the best solution towards sustainable development, because they are energy sources With the advent of nanotechnology and its great development, it was necessary to combine it with solar energy in the field of water distillation with solar stills , In this study, we presented , through laboratory experiment, the effect of changing the depth of water in a pyramidal solar still with the use of nanotechnology in coating the basins once using nanoparticles (cuo), once using nanoparticles (AL2O3) at different concentrations of 1%, 4%, 7% and at depths The different types of water in the distilled basin are 1 cm, 4 cm and 7 cm, The results were to improve the productivity of distilled water in the pyramidal solar still when the basins were painted with a coating incorporated with nanoparticles, With the increase in the depth of the water in the basin, the thermal efficiency of the distiller and the productivity of the distilled water improved.

Keywords: Nanoparticles, Nanotechnology, Distillation, Productivity.

TABLE OF CONTENTS

Pages

LIST OF TABLES

Pages

LIST OF FIGURES

Pages

LIST OF SYMBOLS

SODIS	:	Solar water disinfection
CSS	:	Conventional solar stills
MSS	:	Modified solar stills
T	:	Temperature
Tw	:	Temperature of the water
Ø	:	Concentration

1. INTRODUCTION

Exceptionally environmentally friendly forms of energy are in high demand worldwide. It is now a concern on a global scale to reduce pollution and emissions of greenhouse gases to safeguard the environment better. Although energy derived from fossil fuels is still easily accessible and shows no sign of disappearing soon, the days of abundant, low-cost energy are ending. It is therefore of the utmost importance to investigate alternative forms of energy, particularly renewable forms of power, and to address the environmental issues associated with energy sources, For this reason, renewable energy sources are the basis for sustainable development in all fields, whether industrial, engineering, petroleum, military and other vital industries, The field of water distillation, purification and desalination is one of the vital areas, especially in places where there are few sources of fresh water, and when We use renewable energy sources in this process instead of traditional energy sources, as we have made great strides in the sustainable development that we talked about, and in continuation of the continuous development approach in this field and the emergence of nanotechnology, it was necessary to use this technology in this field, and therefore we will be We have come a long way towards achieving more development in this field, so here when we study water purification by using a renewable energy source, which is solar energy, By using nanotechnology, we are fully aware of the amazing results of this study, and its great role in achieving development in this field. Its role in preserving the environment is a clean energy source that does not result in carbon emissions polluting the environment, but what is nanotechnology?

1.1 NANOTECHNOLOGY

The term nanotechnology was used for the first time in 1974 by the world Norio Taniguchi [1]. where nanotechnology means manipulating atoms [2]. Or it can be defined as the technology of nanoparticles [3].And it can also be defined as the technology of processing matter on the atomic or molecular scale, where the size of nanoparticles reaches sizes from 1 to 100 nanometres [4]. This technology does not belong to biology but belongs to materials science, which is a technique that deals with nanoparticles. Nanotechnology is used in many fields, such as the fields of medicine, where small nanomaterials are manufactured the size of blood cells and used to identify and diagnose many diseases, and in the field of engineering [5]. where nanofluids are used in the field of refrigeration, the field of aviation, where they are used in the manufacture of precision equipment, and the field of Energy in the manufacture of energy storage batteries, and fields of industry such as the manufacture of clothing and precision devices, and the field of water purification (the subject of study), The most important difficulties facing this technology are the small size of nanoparticles and the difficulty of controlling them, and the difficulty of predicting and directing the results of changing particles, and thus the inability to predict and predict some results, As this technology has many advantages, it has many negatives, the most important of which is its danger to human health, as it causes many diseases such as cancer and others.

1.2 NANOPARTICLES

Nanoparticles is a new and rapidly growing field, and the sources of the nanoparticles may be [6],[7].

a. Products of combustion

b. Particles formed in space as a result of certain reactions

c. Removal of radioactive materials 4 - particles that were

d. Manufactured and engineered for a specific purpose

1.2.1 Nanoparticles

Nanoparticles are small particles ranging in size from 1 nanometer to 100 nanometers, and they are named after the nanometer unit, And the field of nanoparticles is an evolving field, as we see that every day there is the discovery and invention of new nanoparticles that have certain physical and thermal properties, to use them in certain fields, it takes several shapes, Figure 1.1. shows the shapes of nanoparticles [8].

1.2.2 Shapes Of Nanomaterials

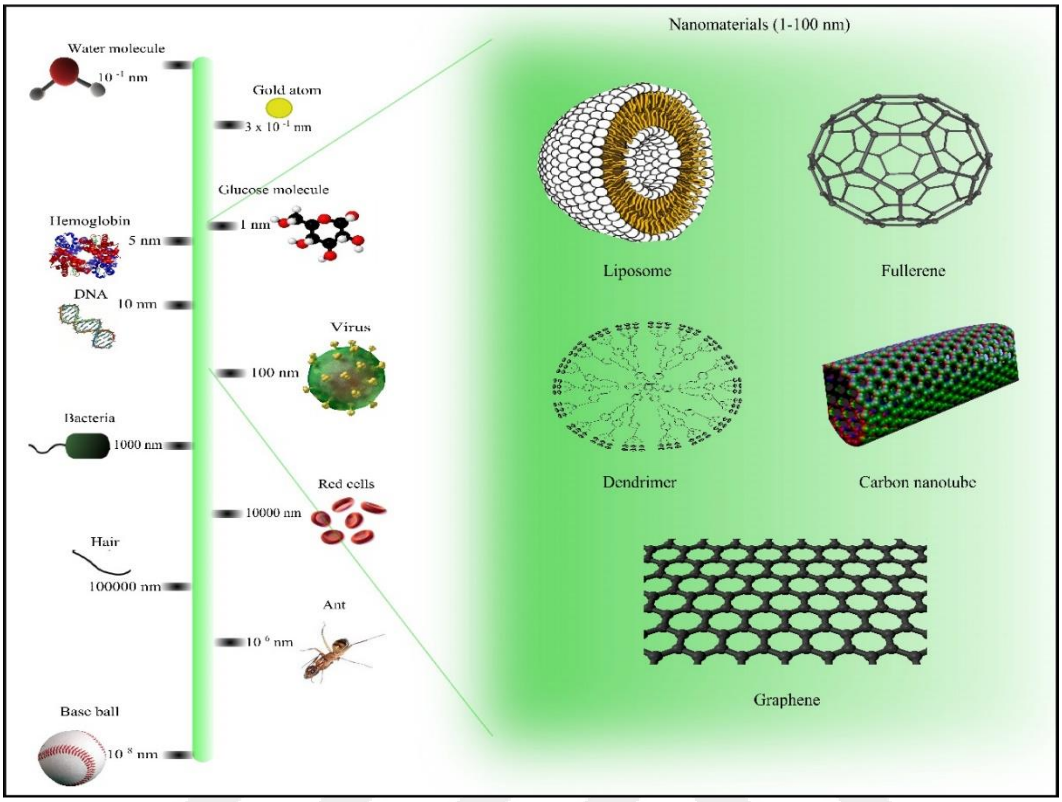

Figure 1.1: Nanoparticle Shapes [6].

As shown in fig 1.1. Comparing the shapes and sizes of nanoparticles Quantum dots: It is a three-dimensional semiconductor structure, and its dimensions range from 2 nano to 10 nano, equivalent to from 10 to 50 atoms per diameter.

a. (Nano balls) Fullerene: It is a form of carbon symbolized by c60.

b. Nanoparticles: An atomic grouping that may reach one million atoms, gathers in the form of balls.

c. Nanotubes They are tubes such as metal oxides and have many uses in industrial fields.

d. Nanofibers: It has many spiral, hexagonal, and wheat-like shapes, and it has many good mechanical properties such as strength, rigidity, and bearing tensile stress.

e. Nanowires: These consists of wires with a diameter of less than 1 nanometre.

1.3 SOLAR DISTILLATION

Solar distillation is the use of the sun's heat to evaporate water to purify it, then re-collect it and cool it through the solar still shown in Figure 1.2.

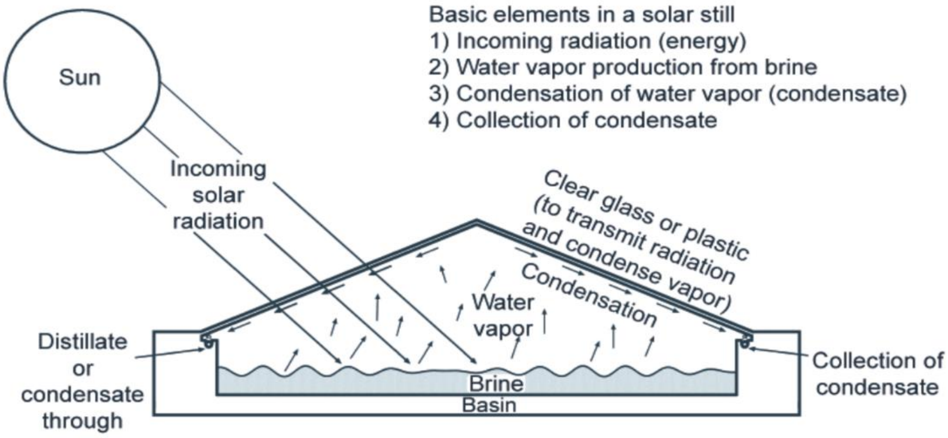

Figure 1.2: Pyramidal Solar Still [8].

Where the water evaporates by bright sunlight and then the pure water vapor condenses on the cool inner surface of the transparent collector and drips into the tank [8].

1.3.1 The Solar Still Consists

a. Metal chassis.

b. Glass panels in one or two directions.

c. A tank for collecting water [9].

1.3.2 The Main Elements Of A Hierarchical Water Distillation System

a. Thermal energy and its source is solar radiation.

b. The source of steam, often from steam turbines.

c. Condensation.

d. Condensed water collection.

1.3.3 Types of Solar Distillation Systems

Due to the lack of fresh water sources, people began to purify and desalinate water, there are several systems for the distillation and desalination of water, whereby fixed designs for solar energy are manufactured [10].

a. A spherical solar device.

b. Pyramidal solar system.

c. Double basin solar system.

d. Hemispherical solar system.

1.4 PYRAMIDAL SOLAR STILL

The use of solar energy in water desalination is done through what is known as solar distillation devices (solar still), including the pyramidal solar still (the subject of the study), where studies have shown that the use of concentrated solar energy [11]. The pyramidal shape is one of the important forms, to focus the sun's rays and double the production, especially if the depth and slope increase, Where many studies have found a direct relationship between the depth and slope of hierarchical distillates on the one hand, and the quantity of product on the other hand [11]Not only that but when doing thermal and economic analysis, it was found that the hierarchical shape achieves excellent rates in terms of thermal efficiency and economic cost [12].

1.4.1 Nanotechnology Effect & Acrylic Pyramid Still

There are many water desalination techniques, but recently a new technology has appeared, which is water desalination using nanotechnology, which uses membranes of nanoparticles to soften the water and remove pollutants [13]. Where it is preferred to improve water by nanotechnology, especially with regard to purification, treatment, and filtration [14]. What makes the use of nanotechnology effective in the process of improving water:

i. It gives a larger surface area exposed to tempering, cooling, purification, and treatment.

ii. It gives a smaller volume with the large surface area it gives.

iii. Facilitating chemical and biological reactions.

iv. It gives a change in the physical and biological properties for example, nano-cellulose is one of the best nanoparticles in nanotechnology when used in the process of desalination and water treatment, as it gives a larger surface area with high durability to cellulose particles, where nano-cellulose is used as a nano-membrane that acts as a filter to remove bacterial and chemical contaminants [15].

1.4.2 Water Depth and Nanotechnology Effect in Acrylic Pyramid Still

The rate of water evaporation and condensation depends mainly on the surface area in the distillation process, and the pyramidal distiller provides this greatly but is one of the best types, and when the depth of the water increases, the productivity increases,

It gives high performance [11]. As considering the hierarchical shape as a geometric shape, we find that it is a shape that focuses these solar rays on one side and on the other hand increase the area exposed to drip, and the slope of the pyramidal shape at the same angles allows more time for exposure to temperature from all sides, and works on the ease of collecting water in collection tanks, Of course, the greater the depth of the water, the greater the area exposed to dripping [16].

1.5 RESEARCH PROBLEM

The main problem is that the use of nanotechnology in the treatment and purification of water is a technology in the stage of development, whether in research, or in terms of practical use, so resorting to previous studies and previous research had some difficulties due to the lack of much research on this subject on the one hand, and on the other hand, the actual use It has limited and therefore the dependence on plants operating with this technology and benefiting from it was difficult to a large extent, that is, we can say in short that the limited production of solar energy and ways to increase its productivity by adding nanomaterials to obtain water in the purest possible form is the main problem, and a group of other problems falls under it such as The lack of practical and advanced technical capabilities, which led to spending a lot of material and moral effort, Which consequently led to the exhaustion of a lot of time to complete the work and get the results.

1.6 RESEARCH OBJECTIVE

The purpose of the study is to know the effect of the depth of water in the hierarchical solar still on the desalination and water treatment process to know which forms are better to work as solar distillates, and the effect of changing the depth of water on the distillation process and to prove that increasing the depth leads to an increase in the efficiency of the desalination process through solar distillation in terms of quantity Production, quality, production, and cost.

1.7 RESEARCH IMPORTANCE

The importance of the study is due to the importance of the subject itself, as the issue of water treatment using nanotechnology and a source of renewable energy is important for many workers in the field, whether the importance of water desalination in light of the continuous decreasing per capita share of water, or the importance of using the solar system as a clean renewable source Preserves the environment, in addition to the use of an emerging technology, which is nanotechnology, makes the study more important, and the study can also be considered an important reference for students, scholars, and workers in this field.

1.8 RESEARCH QUESTIONS

a. What is nanotechnology?

b. How effective is the use of nanotechnology in water distillation processes?

c. What is the effect of the hierarchical shape on the efficiency of the water production and distillation process?

d. What is the effect of water depth on the process of producing and distilling water?

e. How effective is the use of solar energy in the water distillation process?

f. What is the methodology that we will use in the research?

g. What are the expected results of research and laboratory experiment?

1.9 RESEARCH HYPOTHESIS

a. The first hypothesis is the effectiveness of using nanotechnology in water distillation processes.

b. The second hypothesis is that the hierarchical shape increases the efficiency of the production and distillation process of water.

c. The third hypothesis is, the greater the depth of the water, the greater the effectiveness and efficiency of the process of producing and distilling water.

d. The fourth hypothesis is the effectiveness of using solar energy in the water distillation process

e. The fifth hypothesis is that the expected results of research and laboratory experiment are to increase the efficiency of water production and distillation if we use the pyramidal distiller, and we increase the depth of the water.

1.10 METHODOLOGY

The methodology here is to conduct a laboratory experiment on the effect of the hierarchical shape and water depth on the efficiency of the distillation process, where we will conduct an investigation, analysis, and comparison of the results when increasing the depth (water depth) in acrylic pyramidal solar stills (to know the effect of the hierarchical shape and increasing depth on the distillation process, where we will do A laboratory mini-distillation device, in a hierarchical shape, and conducting distillation operations at different depths, then we use the comparative research methodology to compare the results we obtained from one side to know the effect of changing the depth of water, as well as a comparison between the results we have reached with other researches and the results of others.

1.11 THE EXPECTED RESULTS

The expected results of research and laboratory experiment are to increase the efficiency of water production and distillation if we use the pyramidal distiller, and we increase the depth of the water.

1.12 THE STUDY EXPOSED

The obstacles to studying of water depth effect and nanotechnology effect on the productivity of acrylic pyramidal solar still, such as:

a. Financial obstacles

b. Technical obstacles

2. LITERATURE REVIEW

2.1 INTRODUCTION

The use of nanotechnology has developed tremendously in the recent period and has entered almost all fields, including the field of solar water distillation, and due to the importance of solar energy as a clean and renewable source of energy, it has become necessary to link it to water distillation processes, and it has become necessary for researchers and scholars to pay attention to this subject and make studies on it.

1n study for Study the performance of solar ponds based on the size of nanoparticles, A mathematical model was used and developed according to the requirements to find out the effect of the size of nanoparticles on the work of solar thermal collectors and their economic efficiency, The validity of the model was compared by review numerical results and their comparison with empirical data found in international research [14]. The most important results of the research are the agreement of experimental and numerical results, in addition to the decrease in the effectiveness of solar energy with the increase in the size of nanoparticles, and the recovery period and cost of distilled water decrease with the increase in the size of nanoparticles.

The energy of light rays is related to the electric field, and the electric field is related to the permittivity. as excel the relative permittivity of the Perspex from which the pyramidal shell is made is greater than the relative permittivity of air, and the energy of the Perspex pyramid cover plate is on the power of the plate without the pyramids [17].

The effect of the incidence angle on the computed radiation was demonstrated by projecting the whole beam onto the base of the pyramids. The height-to-base ratios of 1.6, 1.1, and 0.6 were investigated in a 3D model of varying dimensions for fall angles and hierarchical cover. According to the results, the optimum performance across all three sizes was attained by hierarchical coverings with a height to base length ratio of 1.1. Modelling the solar panel's radiation both with and without the pyramids was simulated using the applicable model. To demonstrate how the pyramidal covers affected the solar panels' radiation, the researchers used two different treatments. In order to examine the impact of varying the radiation source's angle, three pyramids of varying diameters were subjected to treatment. The model is created in ANSYS-ICEM, then the network exported to FLUENT. Higher corners of panels without covers for radiation falling on the panel were found for all accidents tested, As there is a file and a hierarchical cover to increase the homogeneity of the incident distribution of rays on the photoelectric panels, In the case of pyramids with R = 1.1, the change becomes apparent at an angle of incidence ranging from 70up to 95 the percentage increase in braking power was 0.3%, In the study, they used the realistic simulation methodology by making a hierarchical model and studying and analysing the results, then they followed the comparative research methodology in analysing the results, and the model as shown in Figure 2.1.

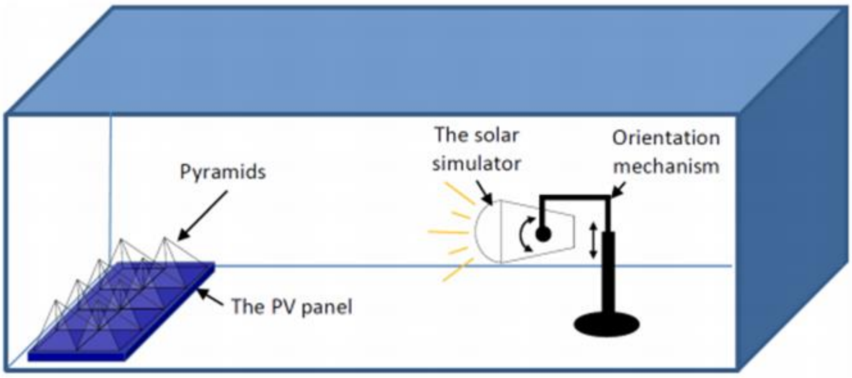

Figure 2.1:The Device Used In The Experiment [17]**.**

They explained that if small particles with good thermal conductivity characteristics are added, this will contribute to increasing the efficiency of the cooling fluid, as it leads to reducing the heat load on the heat exchangers by reducing heat pumping, and that this technology will have a great impact and impressive results in the near future, Also, the use of particles that have good thermal conductivity properties will reduce the procedures for pumping heat energy into the heat exchangers, and thus can reduce the sizes and weights of the heat, And that researchers and everyone related to the subject must make more effort and work so that the world can benefit from this great technology [17].

The solar distillation unit is designed and manufactured to compare the yield of solar distillation without and with LHTESS, The experiment was carried out in a hot and humid atmosphere using paraffin wax as an LHTESS because of its special properties in addition to being economical, During sunny days the hourly productivity is higher in the case of solar energy without LHTESS, An improvement of about 36% was observed in the production of non-saline water using LHTESS as compared to solar energy without LHTESS, It was found that during the bright brightness of the sun, the non-salty water produced from the stillness is higher, The solar distillation apparatus with and without LHTESS was found to be 4 L/ m2 during 2 hours and 3 L/m2 during hot weather and in cold weather. The efficiency was found to be 3 L/ m2 per day and 2 L/ m2 per day for still With and without LHTESS running [18].

To improve the properties of nanofluids, the effect of nanoparticles on viscosity, electrical conductivity, and surface/surface tension of base fluids has been studied. The laboratory and laboratory results indicated a change in the viscosity, especially in the case of using oils as a basic fluid in the cooling process. Careful analyses were suggested for these results. And that by reducing the size of the particles to increase their surface area, and using an effective suspension and dispersal method that also increases the surface area, the problems of viscosity effect with the presence of these particles may be solved This is done through three stages, the first stage is the hydration of the particles, the second stage is the prevention of agglomeration of the particles, and the third and final stage is the stability of the particles, Improving dispersion is done by using electromagnetic waves, where magnetic flux is used to induce dispersion, and the stability of particle dispersion is stabilized by using electrostatic stabilizers, It is also possible to add some catalysts that help tension in the cooling fluid and reduce the process of agglomeration of nanoparticles, mono nanofluids are fluids that contain only one type of nanoparticles, but if more than one type is used and suspended in the main fluid, the fluid in this case is called a hybrid nanofluid. Suspending these particles in the main fluid to obtain the advantages of both types of particles, new attempts and studies are being done every day in this field, and new particle are proposed to make new hybrid nanofluids [19].

1n study [20]. When a comparison was made between the pyramidal solar still and the traditional distiller, as the traditional distiller has only two sides, while the pyramidal distiller has four sides, it was proved that the thermal feasibility and economic feasibility of the material, compared to the other conventional distiller, is much better in terms of solar radiation and the amount of distilled water produced as well as Costs for a pyramidal still compared to a conventional still, As the surface area of the pyramidal still is almost double the surface area of the traditional double-sided distiller, and this led to an increase in the solar radiation energy used, and the researcher used the comparative and quantitative research methodology, to make a comparison between the pyramidal solar still and the traditional one as shown in fig 2.2.

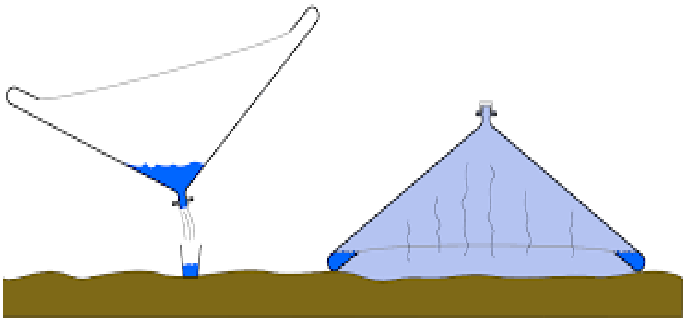

Figure 2.2:Double-Sided Traditional Solar Still [20]

Water is the basis for people's lives, especially pure, unpolluted water. Global warming and weather changes cause a lack of water sources for human and life use. Purification of polluted and salty water is one of the most important ways to obtain pure water, The research aims to show the extent of similarity and difference in the performance of the solar monoclinic distillation through low-salt and distilled water that uses drying [21]. Mathematical modelling was carried out and an experimental study was conducted for drying a chemical dye in impure water to show the similarity and difference in the effectiveness of the solar still, Mathematical modeling was carried out and an experimental study was conducted for drying a chemical dye in impure water to show the similarity and difference in the effectiveness of the solar still, The research showed an increase in the effectiveness of solar distillation using dye, and the resulting water percentage improved by 45% when using chemicals, and the maximum effectiveness reached 50% at a depth of 30 mm when thymol blue solution, It was noted that the effectiveness was the highest when using thymol blue solution for all altitudes, followed by the effectiveness when using methyl orange solution 43%.

The Modification of solar energy that depends on heat and associated with electrical energy the tube collector features anti-bacterial and anti-magnetic hybrid nanofluid , Getting clean water through solar energy is an advanced method, but there is Legionella bacteria that causes pneumonia spread in solar systems operating in cold weather, This article discusses the use of the antibacterial effect of a hybrid nanofluid for the purpose of disinfection as well as the use of the magnetic property of the nanofluid to increase the rate of heat transfer, As shown in Figure 2.3. The HNF Stability phenomenon that has been postulated. (a) A graphical representation of the steric effect; (b) an update on the stability of the suggested HNF; and (c) a schematic illustration of the clogging of nanoparticles, the results of comparing nanofluids with normal solar distillation showed an increase in efficiency and energy ratio by incorporating thermoelectric cooling, Still the solar channel has the CSP collector and adding iron oxide and silver nanoparticles to the liquid [22].

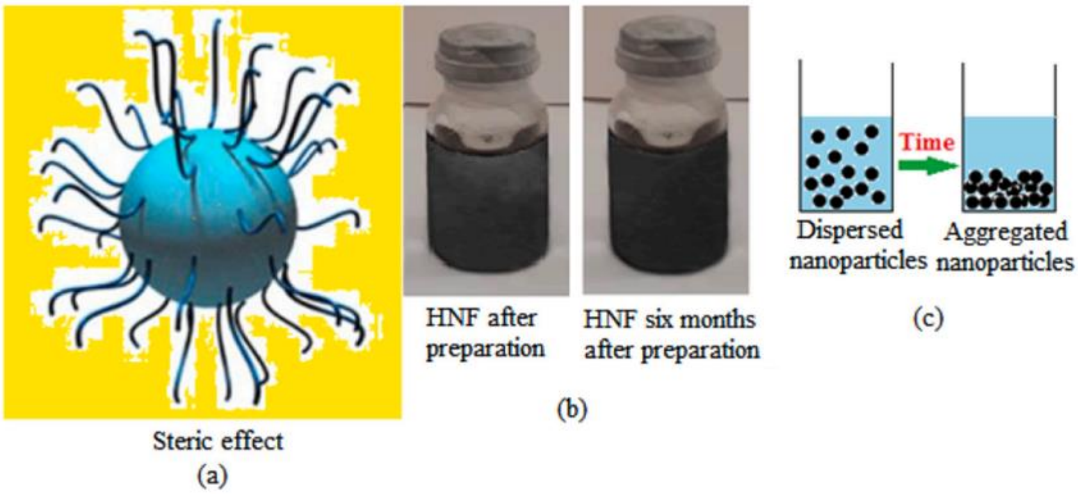

Figure 2.3:Clusters Of Nanoparticles [23]**.**

Solar energy systems are characterized by high efficiency in terms of obtaining pure water from impure water, compared to conventional systems, Two identical solar roof panels were tested at the same time under the same conditions and one of the panels was modified with coil interlacing the pump featured a special vacuum to reduce pressure inside and left the other as a reference tool The proportions of aluminium oxide nanomaterials 0.4%, 0.5%, and 0.7% were used with water inside the modified distillate fraction, It was higher than the products produced. The modified material containing 0.5% aluminium oxide nanoparticles also produced the highest percentage of the distillate water, 45% contains no nanoparticles, followed by 38% and 24%, 0.7%, and 0.3% aluminium oxide nanoparticles [24].

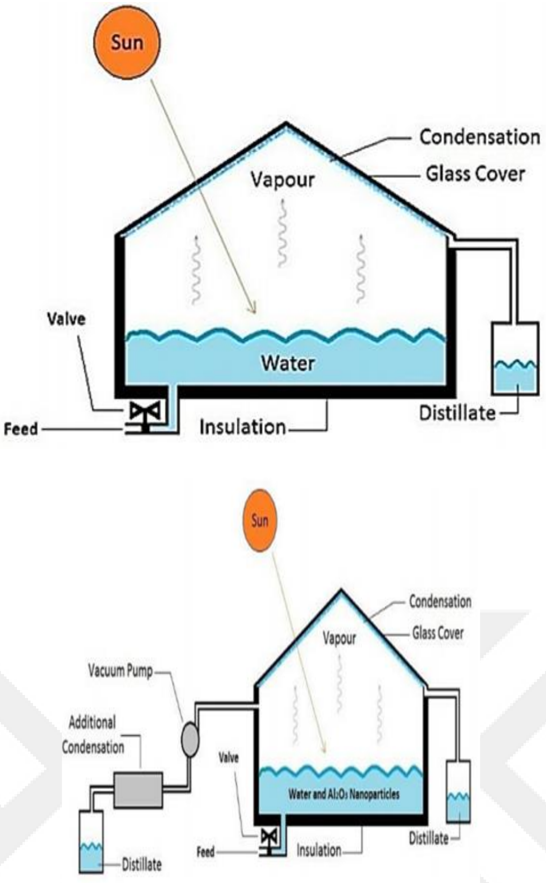

Figure 2.4: (Modified& Conventional) Fixed Board [22].

In order to test if the addition of nano-aluminium oxide or nano-metallic copper particles increases the amount of water generated by the desalination process utilizing solar radiation, two solar energy images with comparable characteristics were developed [21]. The two solar collectors were installed next to each other, and the measured parameters were taken at the same time, The nanomaterial was added to one, each one individually but in different proportions, while others contain only water, A monitoring centre was used to sample glass, water, ambient temperature, and solar radiation every 60 minutes. As a result, the addition of nanomaterials increases the number of capacitors, and the most effective concentration of 0.35% of aluminium oxide and 0.7% of copper was found. In these ratios, increase efficiency equal to 8%, recording a parameter 10%, It was found that copper oxide appears strongly on aluminium oxide capacitors in proportions except by 0.35%.

About Solar distillation with the use of nanoparticles, Because of rising levels of both population and industrialisation, there is an ever-increasing demand for clean water, there is a percentage of the solution in the waters of the seas and oceans, and therefore it must be desalinated to become usable, Discuss this research desalination method and possible developments for that. He also discussed matters affecting distillation, This research concluded that desalination using solar energy is the most effective because it does not require external energy or complex and costly energy sources, Flaw solar distillation systems it is the low productivity and therefore the factors affecting distillation must be improved to increase productivity, A number of researchers looked into the influence that nanofluid had on productivity and discovered that it had positive impact on the amount of water that was distilled [24].

On hybrid nanofluids and the behaviour of hybrid nanofluids in heat exchanger tubes, they used a hybrid nanofluid consisting of copper and titanium particles, with different concentrations, of hybrid nanofluids in heat exchanger tubes, they used a hybrid nanofluid consisting of copper and titanium particles, with different concentrations, and they found that the heat transfer coefficient increased significantly when they used the hybrid nanofluid. Also, the higher the concentration of copper and titanium particles in the liquid, the higher the heat transfer coefficient [25], as shown in fig 2.5.

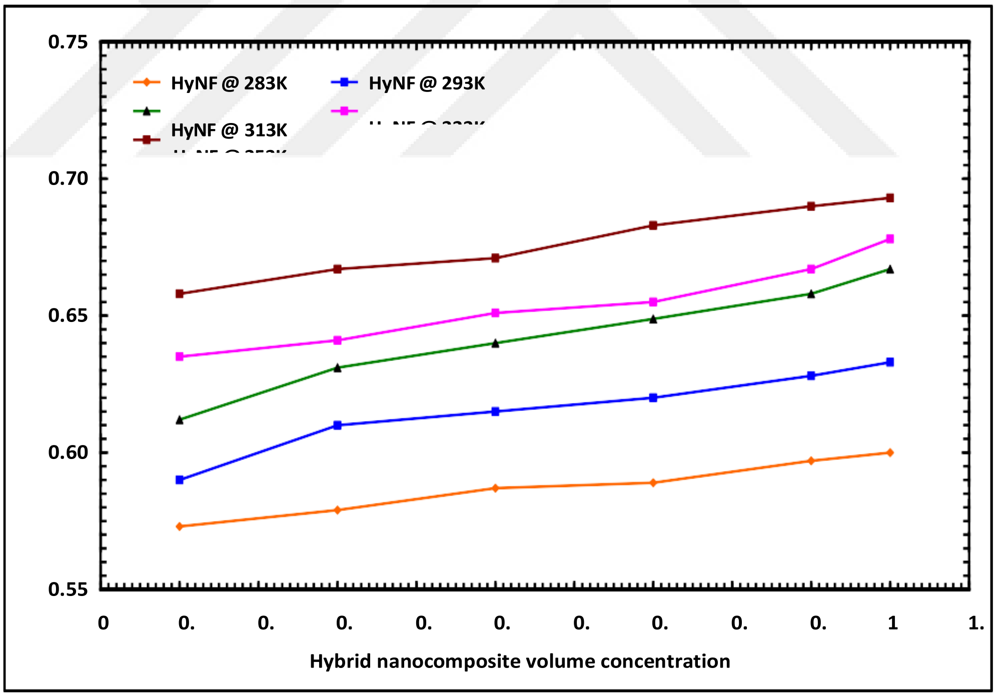

Figure 2.5: The Relationship Between The Concentration Of Nanoparticles And The Heat Transfer Coefficient [24].

The concept of "nanometre" was first proposed in 1925 by the Nobel Prize-winning chemist Richard Zsigmondy, As he was the first to coin the term nano, and used nanometre as a unit of measurement, and used that with gold foams, As for the modern nanotechnology, it is due to Richard Feynman, winner of the 1965 Nobel Prize in Physics, where he presented a new concept of nanotechnology, which is the atomic manipulation of molecules, and it was a completely new idea, and he is considered the godfather of nanotechnology, Fifteen years later, Taniguchi is the first to use "nanotechnology" to describe semiconductor processes that They occurred in the order of nanometres, Then comes the stick a single atom or molecule. The golden age of nanotechnology began in the eighties when Kyoto, Small, and Corel, discovered fullerenes, Drexler proposed the idea of a nanoscale [26].

When compared to traditional energy sources like oil and coal, renewable energy sources have a significant competitive advantage, is the use of renewable energy sources., especially as they are depletable and permeable energy sources, and they are clean energy sources that do not cause any harmful heat emissions to the environment such as carbon dioxide and other harmful gases, and industries that depend on systems Refrigeration represents a wide sector of the industry in any country, It was crucial for this industry to adopt the utilization of renewable energy sources. [27], [28].

Improvement of a Pyramidal Solar Still using nanofluids, where this research presented an experimental approach for a new hybrid system of the modified solar pyramid still combined with vacuum tubes and nanofluids to obtain high thermal performance. The current work compares the performance and costs of three different units; The reference conventional solar still and two hierarchical solar stills are the conventional hierarchical solar still and the modified hierarchical solar constant, MPSS was combined with vacuum tubes, as well as nanofluids consisting of copper oxide (CuO) and carbon black (CB) nanomaterials at 1.5 wt.%. According to the resulting data, the percentage improvement in total fresh water was 4.77 and 26.6% in the case of MPSS over CPSS and CSS, respectively. The improvement rate in freshwater production was 57.098% in the case of using nanofluids to 60% when hybrid nanofluids were used [29].

About the Effect of insulation and water height on the effectiveness of the pyramid solar acrylic panel, the surface area exposed to solar radiation in the solar panels is related to the rate of evaporation and condensation, As the solar pyramid has a larger surface area than other types. In this research, the water height was changed from 1.5 to 4 cm without insulation and with isolation from external conditions. It was found that the effectiveness of the solar pyramid without insulation is less than the performance of the solar pyramid with insulation, Insulation performs a major function in improving efficiency by heating the water, The effectiveness of the solar pyramid remains higher at the minimum water depth is 1.5cm for the insulated condition and the non-insulated condition, Fresh water rate the base of the solar pyramid without insulation is 3.3, 3, 2.3, 2 kg / m2 insulation 4, 3.42, 3 and 2 kg/ m2 1.5, 2.5, 3.25 and 3.5 cm in the same order, In the water depth of 1.5 cm, the effectiveness of the solar pyramid is with insulation 20% and 8.3% which is greater than conventional solar distillation, Increase the efficiency of solar panels to about 3% with insulation, daily for solar panels without insulation were found at 26%, [30].

First Approach to Still-altitude Nanofluidic-Based Solar for Desalination and Solar Water Disinfection (SODIS). Water Desalination, 491, 114592. regarding solar energy with nanofluids, to desalinate and purify water, Where the performance of two hierarchical distillation devices with a nanofluid was studied once, where the silver nanofluid was used because of the outstanding advantages such as excellent optical properties, high thermal conductivity, and antibacterial properties. Water analysis the results were impressive in terms of the percentage of bacteria present in the water, not only that, but they found that the use of nanofluids had an impact on the production process, where the production improved dramatically, as a result of using nanofluids, just as the nanofluids work on the surface area subjected to distillation, they found that they work on the speed of softening and condensation of water [31].

In a study [32]. Separating the TiO2 nanofluid's flow has an influence on in order to quantify heat transfer and flow separation of TiO2 nanofluid in the annular space of two concentric cylinders, the SST k-model and finite size method were used. This is in response to the fact that, in the wake of energy crises, many researchers have turned to exploring new ways to improve the thermal performance of heat exchange equipment. The two cylinders are in perfect alignment with one another. We found that the heat transfer coefficient could be improved the most when using TiO2 nanoparticles of a specific size within a specific range of ratios and a specific Reynolds number. Analogous to the shape of an annular tube As the nanoparticle size fraction rises, the surface heat transfer coefficient also rises.

Hybrid nanofluids are liquids with better physical and thermal properties than monolithic nanofluids. Hybrid nanofluids are a new liquid produced by dispersing two different types of nanoparticles in the base liquid. Some researchers have mentioned that hybrid nanofluids increase the efficiency and gain of the nanofluid. Good thermal and physical properties, much better than monolithic nanofluid [32].

Converting salt water to fresh water has become an absolute necessity of life, so researchers had to make more effort and money to develop this field, This study was devoted to the subject of the effect of water depth on the efficiency of the process, as a result of distilling the sun through a pyramidal solar still, The study proved that increasing the depth of the water led to an improvement in the efficiency of the distiller in terms of productivity, and the cost of production as well. The study proved that changing the angle of inclination of the cap has an effective effect on the hierarchical solar distillation process. At an angle of inclination of 50, the improvement was equivalent to 41%, and when the angle of inclination became 40 The improvement increased by 11%, The study also proved the relationship between water mass and water depth to the improvement of the water production process [33].

In study for mathematical and experimental investigation of the effect of energy storage materials and salt water depth on the performance of hierarchical solar distillation energy is used in the process of heating water and converting it into steam, and given the urgent need for fresh water, researchers are trying to find solutions to make the process of distillation and water treatment, a more efficient process in terms of productivity and economic cost, They found that increasing the depth led to an improvement in productivity, as the productivity increased by 13.98% when the depth was increased from 20 mm to 30 mm, they found that increasing the depth led to an improvement in productivity, as the productivity increased by 13.98% when the depth was increased from 20 mm to 30 mm, and this is with thermal storage, but with no thermal storage, the productivity increased by 5.9%, when the depth changed from 20 to 30 mm, And when the experimental results were compared with the results, there was a great agreement between the results, and the students used the practical experimental method, and the comparison method in order to dissuade them from confirming the agreement of the results, Figure 2.6. shows the device used in the practical experiment, Figure 2.7. also shows one of the experimental models of the square hierarchical solar distiller, which are the models that have been conducted practical experiments, where the square hierarchical shape is the best hierarchical form to improve the production process, especially that the hierarchical forms are multiple, including square, triangle, rectangular pyramid and circular pyramid.

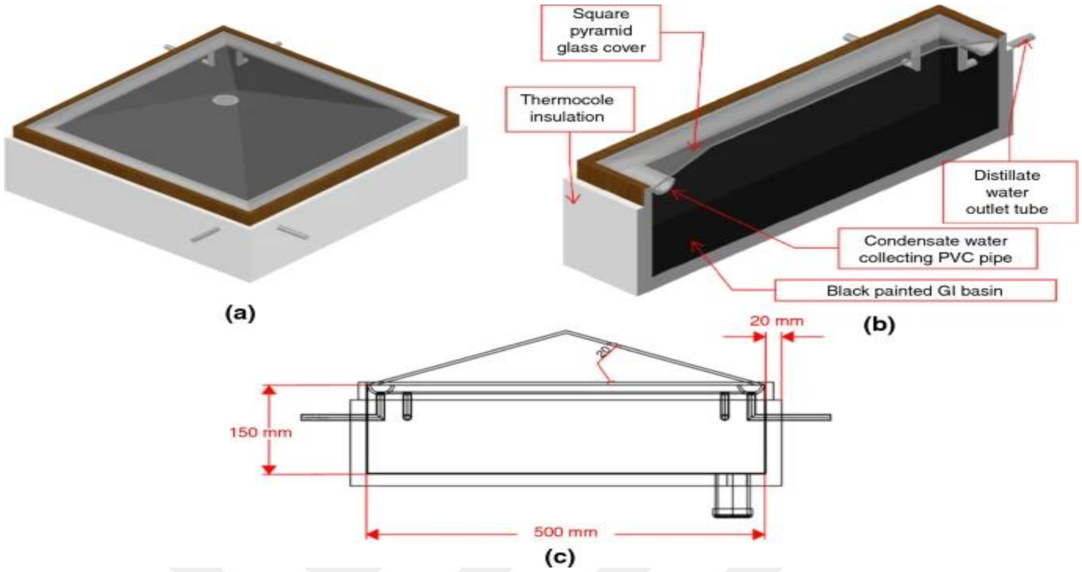

Figure 2.6: The Diagram Of The Square Hierarchical Solar Distiller [34]**.**

Figure 2.7:The Experimental Models Of The Square Hierarchical Solar Distiller [35]**.**

Of the effect of orientation and water depth on improving water productivity in a study of the effect of orientation and water depth on improving water productivity, by using nanotechnology the productivity is improved, and by using the experimental and comparison methodology, the researchers worked using .1% of aluminium oxide (Al 2 O 3). water.

Experiments were carried out at different depths and in different directions, east, west, south, and north, and once using copper as nanoparticles, where a single nanofluid with a single slope was used, Higher productivity was achieved at depths of 20 mm and 10 mm with the use of 0.1% of copper nanoparticles for the north and south oriented glass covers. The site where the experiments take place [35].

Evaluate and determine the factors that affect the triangular pyramidal shape, and the effect of water mass, and a comparison was made between the square pyramidal distiller and the triangular pyramidal distiller, with experiments conducted on different areas and the results were as follows, with changing the swabs from smaller to larger, productivity increased and gradually improved with the gradation of areas But the improvement in the case of the square pyramid is better than the improvement in the triangular pyramid, The reason for the improvement is that small area produce small amounts of water and large areas produce large amounts of water. It was also noted that with the increase in the water mass and the area of the pyramid, the productivity was greater, and in the square pyramid the productivity was greater than the triangular pyramid, and they concluded that the square pyramidal distiller is better than the pyramid Triangle, and the greater the mass of water and the area, the greater the improvement in productivity, The researchers used the in vitro simulation methodology and the comparative research methodology to compare the results in [36].

1n other study for making a comparison between square and triangular pyramidal solar stills, They found that the solar stills in general give a production efficiency higher than the traditional ones with an improvement in productivity of up to 60%, and they found that the square solar stills give a production efficiency with an improvement of 19%, and they confirmed that the percentage of improvement may vary from one experiment to another according to the site in which the experiment is conducted and other factors. Such as slope angles, directions, and the area of the distillate itself was indicated in [37].

2.2 THE NOVELTY OF THE STUDY

Analysing and comparing the laboratory results of productivity and the improvement that occurs to it, both in terms of the production quantity per litter and the cost of producing a liter of water, using the pyramidal distiller at different depths of water, In the literature review and previous studies, many experimental studies investigated the effect of water depth, but few studies used nanotechnology.

The materials were used as a nano-liquid to increase heat transfer, in a way that suits the laboratory experiment. Many did not care about studying the thermo-economic investigation in the previous studies, most of which are laboratory studies.

3. METHODOLOGY

3.1 DISTILLATION BACKGROUND HISTORY

Water distillation is the process of evaporating water and then condensing the steam to obtain fresh water, by using a heat source to affect the evaporation process. In the past, they evaporated seawater to obtain salt, but recently they use the heat of the sun to evaporate water to obtain fresh water, which is known as the process of solar distillation, The method of distillation by sunlight receives great attention, because it is the cheapest method, as it does not cost any fuel, in addition to the fact that solar energy is a clean source that does not produce any carbon emissions that cause pollution to the environment, and a renewable source in light of the continuous decrease in non-renewable energy sources such as petroleum, coal and natural gas, In the past, distillation was done using mirrors and lenses to direct and focus sunlight to evaporate salty seawater. Harding was the first to use the solar distillation process in Chile in 1872 to produce fresh water for miners[40], where he built basins of bricks covered with cement and with glass panels installed at a slope, towards a tank to collect water, These were the traditional methods they used to obtain fresh water, especially in remote, isolated rural areas, Until an American scientist called Maria Telex came and prepared a distiller made of aluminium corners and covered with vibrators from the four directions to collect the largest possible amount of sunlight. The first of them absorbs heat from the sun's rays, so part of the water evaporates and condenses, and extends the layer under it with heat, And the development will continue, until we reach multi-stage distillation, to concentrated solar distillation, and then to multi-effect solar distillation, until nanotechnology appears, And it is combined with the solar distillation process to improve the performance of solar stills in terms of efficiency and productivity, not only solar distillation but also water treatment and desalination processes, as well as the development of solar cells that generate steam until this technology became a basic pillar of the solar distillation process [38].

3.2 SOLAR DISTILLATION TYPES

The idea or principle of solar distillation is one, which is to rely on the heat of the sun to evaporate the water, then condense this vapor, and then recombine the vapor that has been evaporated, the difference is only in the technique used in the distillation process, and the method of using the heat of the sun, so we can divide the types of distillation processes into three main types:

a. Solar distillation using direct and constant sun heat, where the sun's heat is used to evaporate the water in the basins, but due to the change in the brightness of the sun during the day, the volume of productivity changes, and therefore this method is useful in cases of producing small quantities of water, see figure 3.1. which shows solar distillation using constant and direct sunlight [39].

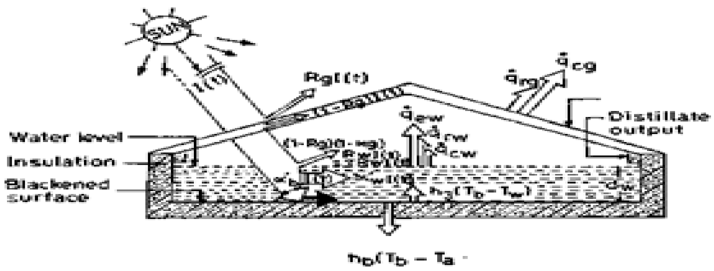

Figure 3.1:Solar Distillation Using Constant and Direct Sunlight [39].

b. Solar distillation using concentrated sunlight, where the sun's rays are concentrated through the solar collectors, and directed to large tubes containing water, this water evaporates and turns into steam that is condensed by condensers, and then it is collected in other tanks, and this method is the most appropriate and best way to produce large quantities of water, unlike the first method See figure 3.2. which shows an example of a solar distillation system by concentrating sunlight [40].

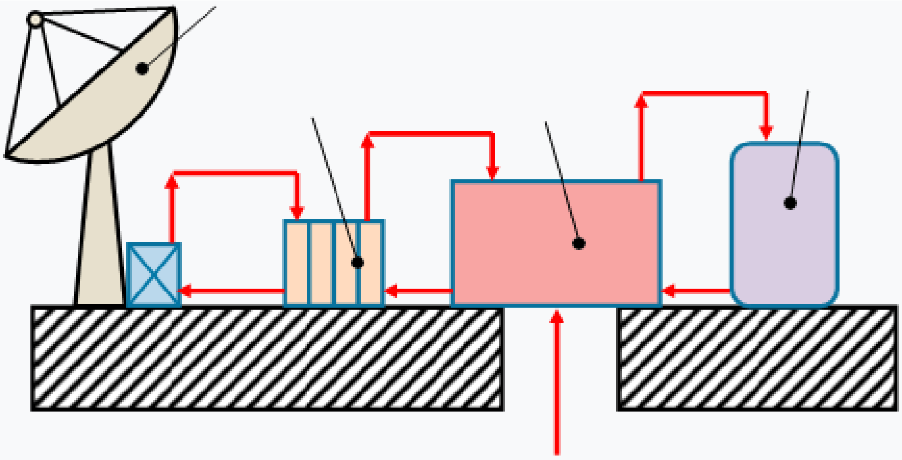

Figure 3.2:An Example Of A Solar Distillation System By Concentrating So Special Collection Basins [40].

c-multi-stages affect solar distillation in this method, distillation takes place in several stages, this process is the basis of the solar distillation process, multi-stage or multi-effect solar distillation is a process of distillation that takes place in stages where the steam that is condensed in the first stage and whose temperature is somewhat high, is used to be condensed in the next stage see fig 3.3 [31].

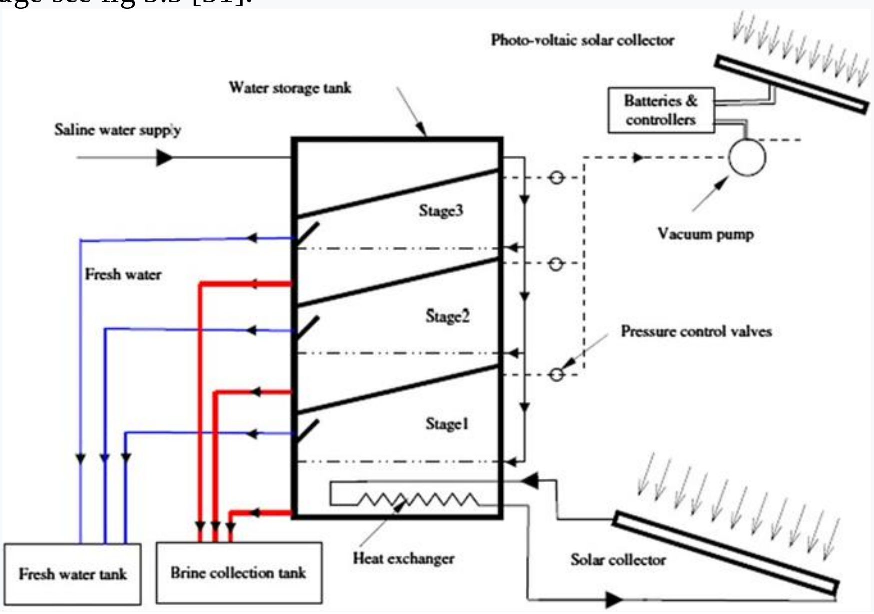

Figure 3.3:Multi-Stage Or Multi-Effect Solar Distillation [31].

3.3 SOLAR STILLS

Solar stills are devices that distill water, and they consist of three main actions:

a. A main basin containing the water to be evaporated [42]. And this basin is painted in a black color that helps absorb the temperature.

b. Glass cover This cover is tilted and takes a certain slope according to the type of distiller.

c. The collection basin, which is the basin in which the distilled and condensed water is collected.

There are many types and classifications of distillates, Solar stills see figure 3.4 are divided into two main types [43].

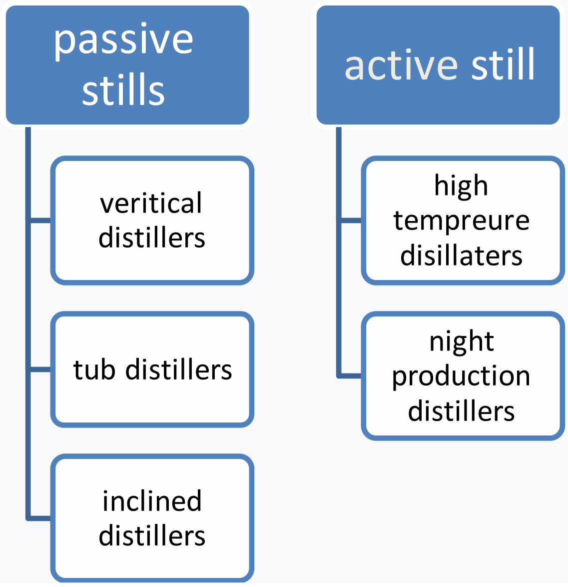

Figure 3.4: Types of Distillers [43].

The tub-type distillers are the most common, and they are divided according to the basin, they are either single-tub, dual-slope, or multi-slope, such as the solar pyramidal still under study, Figures, 3.5, 3.6, 3.7,3.8 and 3.9. show the shapes of some types of distillates [42].

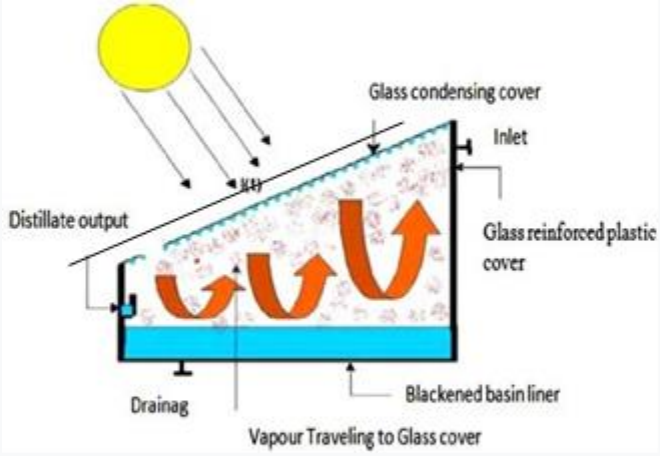

Figure 3.5:Solar (Basin Still) [42]**.**

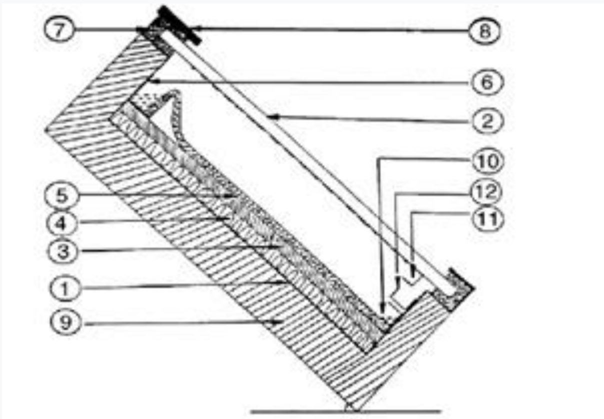

Figure 3.6:Solar Type Wick (Inclined Still) [42]**.**

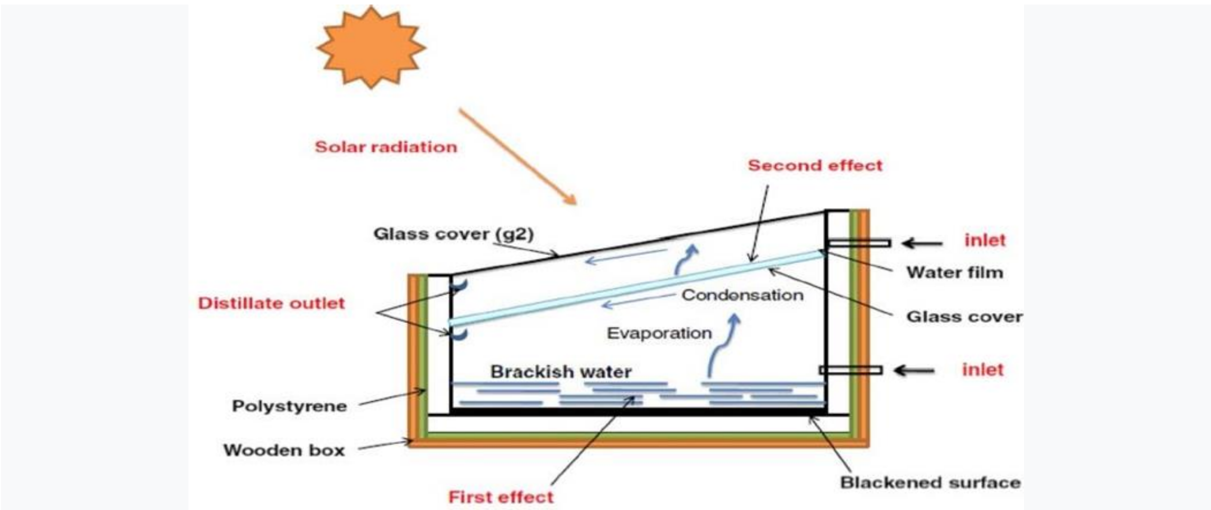

Figure 3.7:Solar Effect (Double Still) [42].

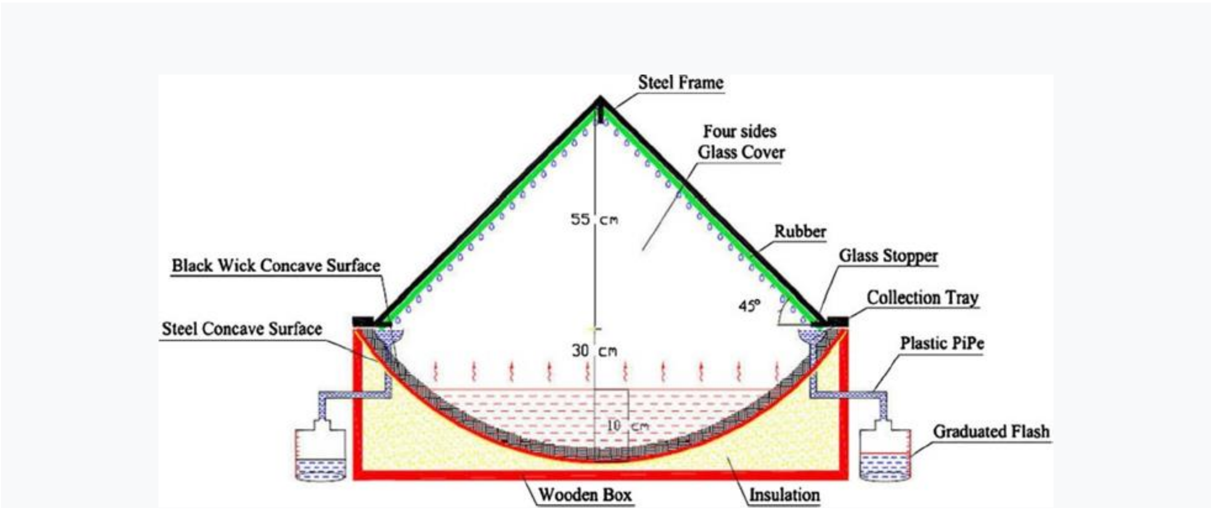

Figure 3.8:Capillary Concave Solar Water Distiller [42].

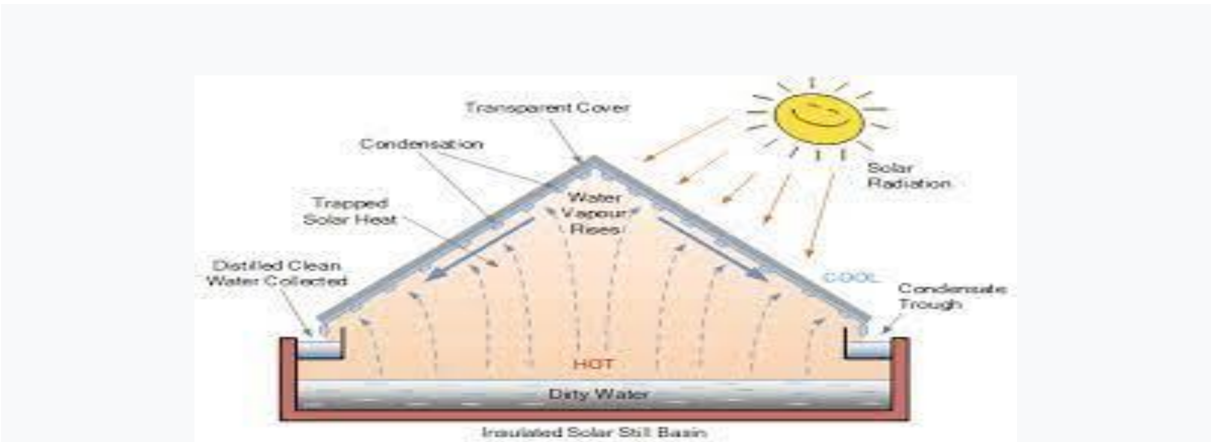

Figure 3.9:Pyramidal Solar Still [44].

3.4 FACTORS AFFECTING THE PERFORMANCE OF SOLAR STILLS

The factors affecting the performance and productivity of the solar distiller are factors affecting the efficiency of thermal performance and affecting productivity, as it is known, improving the thermal performance of the distiller is closely related to productivity, as the improvement of thermal performance, among these factors, are:

a. Water depth factor, which is the factor that we will study and analyze during this study [45].

b. Geographical location is one of the factors influencing the design and performance of distillation plants, as the average brightness capacity is very destructive to determine the appropriate system and distiller, as well as directions are very important, as well as the proximity of the location to the water source, distribution means and roads [46].

c. Solar power system design: As the design of the solar energy system is one of the most important factors affecting the performance of the system, the better the design, the better the performance of the system, as the design must take into account the nature of the water source, the nature of the location, and the amount of water required to be produced The system consists as shown in Figure 3.10. of solar collectors, collection basins, condensers, glass lids, in addition to water basins, and water transport means [41].

d. Paints: paints for sinks are one of the influencing factors in terms of the nature of the paint, its color, and the nanomaterials combined with the paint, as it is known that Black color is one of the colors that absorb the heat of the sun's rays, and therefore it is one of the best colors, the material of the paint itself is important in terms of thermal and physical properties, the more the material from which the paint is made, the better its thermal and physical properties, the more effective the paint, and the addition of materials and nanofibers with thermal and physical properties are better the paint more effective [51].

3.4.1 Pyramid Solar Still

Pyramidal solar stills are distillates of the dual-slope type, which fall under the passive classification, in which there is no external heat source other than the heat of the sun, and the outer cover is in the form of a pyramid, It is one of the multi-directional distillers, and this is what distinguishes it from other types of distillers, It is one of the multi-directional distillers, and this is what distinguishes it from other types of distillers, Another advantage of solar stills is that they give a larger surface area that is exposed to the sun, and the surface area of water exposed to distillation is large, which leads to an increase in productivity, Like the rest of the distillers, it works according to the same principle, which is its dependence on the direct heat of the sun to evaporate the water, which is condensed and re-assembled in special collection basins, See Figure 3.10 [44].

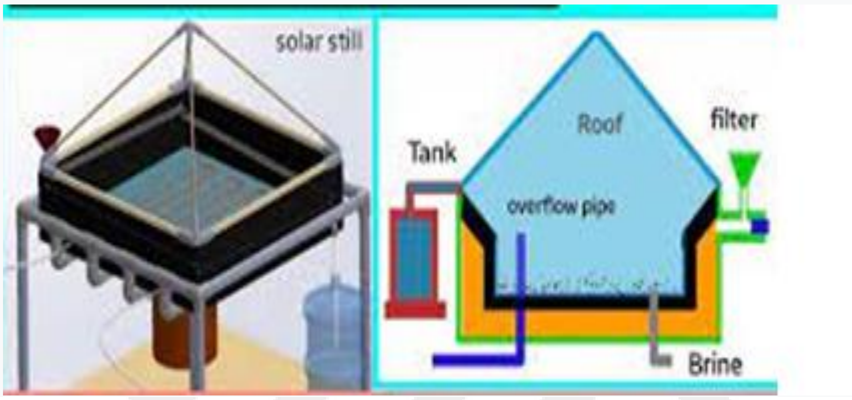

Figure 3.10: (B)Special Collection Basins [44].

3.4.2 The Effect of Water Depth in The Pyramid Still

Many previous studies and laboratory experiments proved the positive effect of increasing the depth of water on improving productivity in solar stills, especially in the pyramidal solar stills, this is also what we will do in this study, where we will study the effect of changing the depth of water on improving the productivity of the pyramid solar still [53]. As Figure 3.11 shows the relationship between productivity and the type of distillation in the case of using the plastic cover and the glass cover with the use of solar collectors.

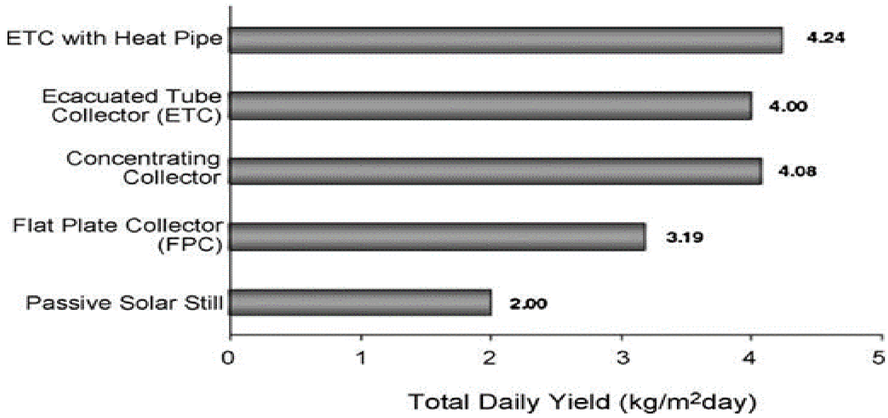

Figure 3.11:The Relationship Between The Type Of Distiller And The Yield [53].

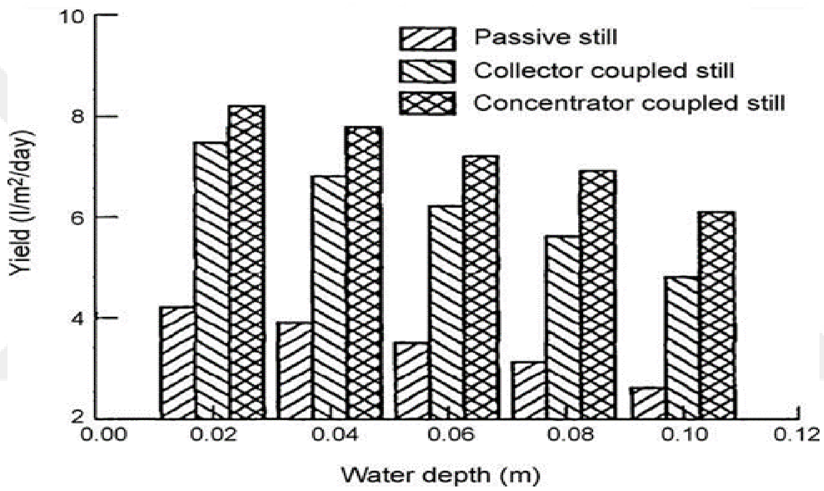

Figure 3.12: The Relationship Between Water Depth and Productivity [53].

As Figure 3.12. shows the relationship between productivity and water depth, and as can be seen from the graph of the relationship, the improvement in the productivity of the distillate increases with the increase in water depth.3-5 nanotechnology & solar stills.

Some studies also confirmed the improvement of the thermal performance and productivity of the solar stills, as well as the low cost in the case of increasing the depth of the water. See Figure 3.13, 3.14, and table 1[47]. As the relationship between the change in the depth of the water and the change in the intensity of the sun [48]. It has been proven that during the daylight hours and as a result of the change in the intensity of solar radiation see Figure No. 3.14.

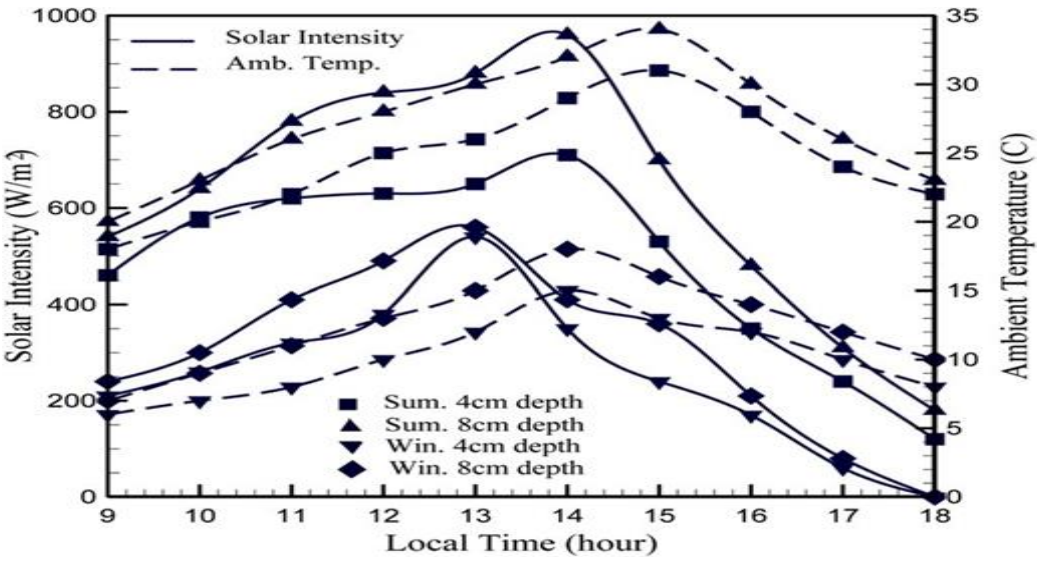

Figure 3.13 : The Seasonal and Annual Changes in Solar Radiation and Air Temperature at a Given Location and Time (9 a.m.–6 p.m.)

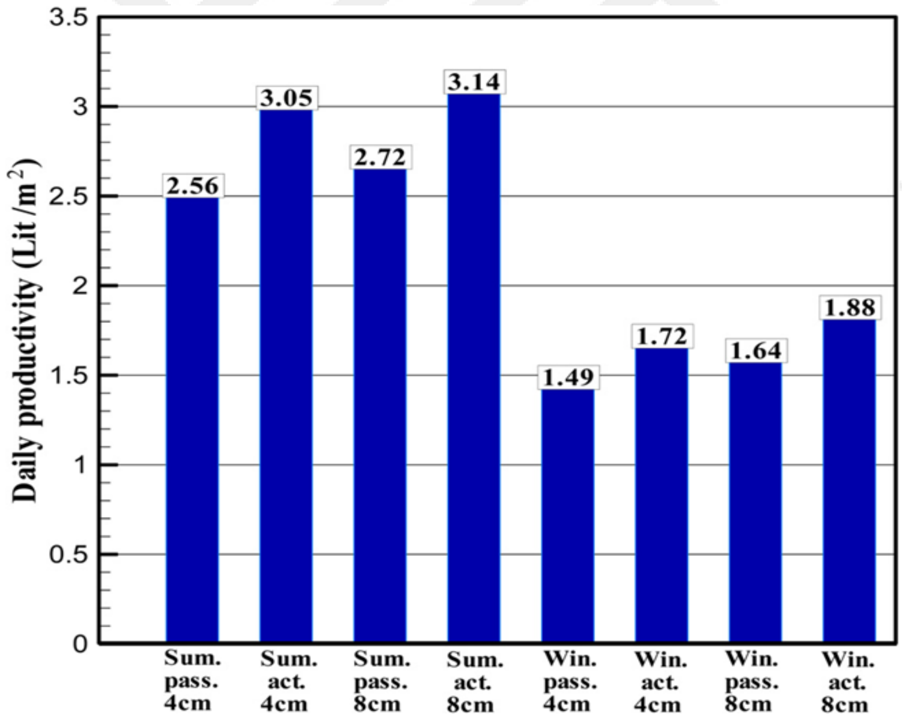

Figure 3.14:Relationship Between Productivity And Increasing The Depth Of Water [49]**.**

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Table 3.1: The Relationship Between the Cost of Production and The Increase in Water Depth.

The results of cost analysis for present work.									
Type of solar still	Interest rate (%)	M (Lit/m2)	CRF	FAC	SFF	ASV	AMC	AC	CPL ($/Lit/m)
Passive (4 cm depth)	12	604.28	0.18	25.5	0.06	1.71	3.83	27.6	0.046
Active (4 cm depth)	12	697.56	0.18	27.2	0.06	1.82	4.08	29.5	0.042
Passive (8 cm depth)	12	665.11	0.18	25.5	0.06	1.71	3.83	27.6	0.042
Active (8 cm depth)	12	762.44	0.18	27.2	0.06	1.82	4.08	29.5	0.039

3.5 NANO TECHNOLOGY& SOLAR DISTILLATION

In the old days, man resorted to the process of water distillation, especially in places where there are no fresh water sources, but with the passage of time the per capita share of water decreases, so man was forced to desalinate sea water and treat some other water sources, And when we look at the history of distillation processes, from its use in salt extraction, to primitive desalination processes, to giant desalination plants, and this process is in constant development, and therefore because it is a vital process for humans, When the use of renewable energy appeared as an ideal alternative to traditional energy sources, it was associated with water distillation processes, as they are permanent sources and their cost became good and did not result in any environmental damage, Also, when nanotechnology appeared and developed rapidly, it quickly integrated into all fields, including the field of solar water distillation, as it led to improving the efficiency and productivity of water distillation plants [50].

3.5.1 Nanotechnology

Nanotechnology has become one of the most important achievements of the twenty-first century, as particles ranging in size from 1 to 100 nanometres are called nanoparticles during the industrial revolution, nanoparticles were studied, meaning they are not new. Honored with the Nobel Prize in Chemistry in 1925. As the first person to use a microscope to determine the size of particles like gold colloids, he is often credited with the invention of the term "nanometer" to characterize their dimensions., The term nanotechnology was used for the first time in 1974 by the world Norio Taniguchi [1]. When nanotechnology means manipulating atoms [2].Or it can be defined as the technology of nanoparticles [4]. And it can also be defined as the technology of processing matter on the atomic or molecular scale, where the size of nanoparticles reaches sizes from 1 to 100 nanometres [3]. This technology does not belong to biology but belongs to materials science [51]. Technique that deals with nanoparticles. Nanotechnology is used in many fields, such as the fields of medicine, where small nanomaterials are manufactured the size of blood cells and used to identify and diagnose many diseases, and in the field of engineering, where nanofluids are used in the field of refrigeration, the field of aviation, where they are used in the manufacture of precision equipment, and the field of Energy in the manufacture of energy storage batteries, and fields of industry such as the manufacture of clothing and precision devices [52]. And the field of water purification (the subject of study), The most important difficulties facing this technology are the small size of nanoparticles and the difficulty of controlling them, and the difficulty of predicting and directing the results of changing particles, and thus the inability to predict and predict some results, As this technology has many advantages, it has many negatives, the most important of which is its danger to human health, as it causes many diseases such as cancer and others.

3.5.2 Solar Distillation Using Nanotechnology

Much of the literature provided glimpses of Progress related to the use of nanofluids in different types of solar energy, and many research papers related to the use of nanofluids in single slope, double slope [59]. solar still integrated with the condenser, hybrid, etc.,

Focus on providing interested researchers with a good road map on the ability of nanofluids to enhance the performance of various kinds of solar distillates, wherein the use of nanotechnology has resulted in an increase in the production rates of all kinds of distillers that were measured, whether single-slope or dual-slope. However, it is evident from the data presented above that water depth and nanotechnology have a significant effect on solar distillates' efficiency and output, see figure (3.15-3.23), This is done through studies and laboratory experiments [53], [37].

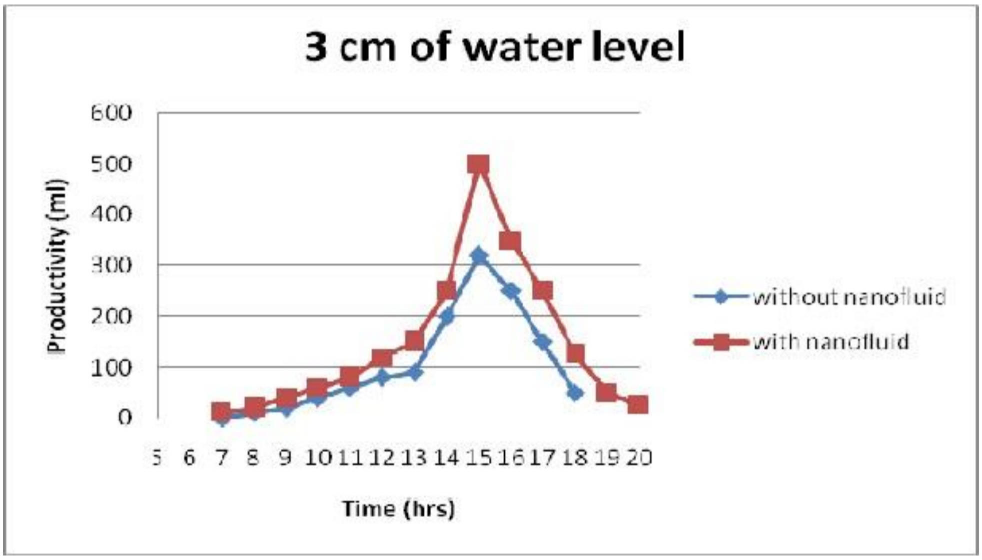

Figure 3.15:Time-Efficiency Analysis of CNT-Water Nanofluid and Conventional Methods[37].

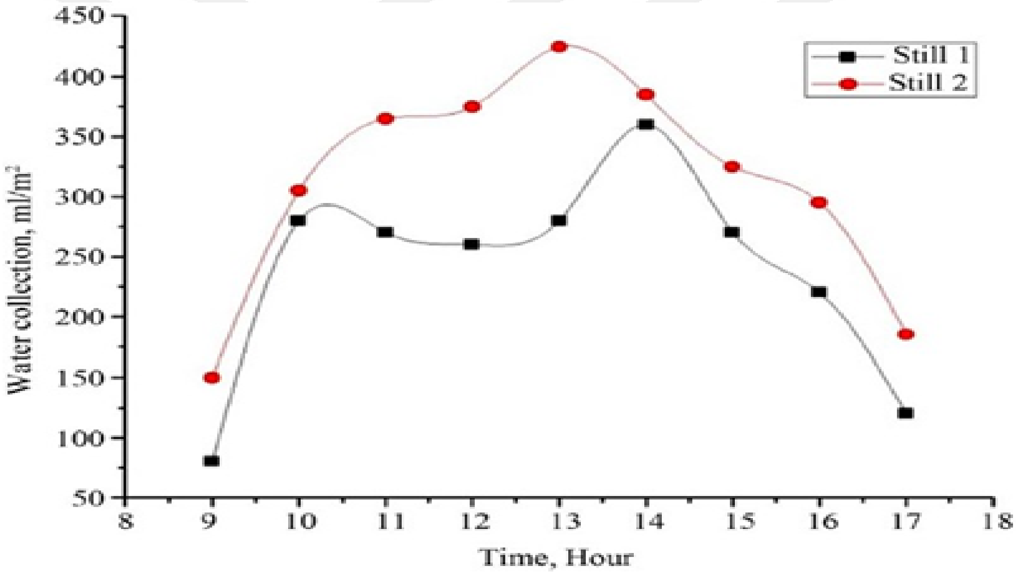

Figure 3.16:Time-Water-Collection-Relationship With and Without CNT-Water Nanofluid[37].

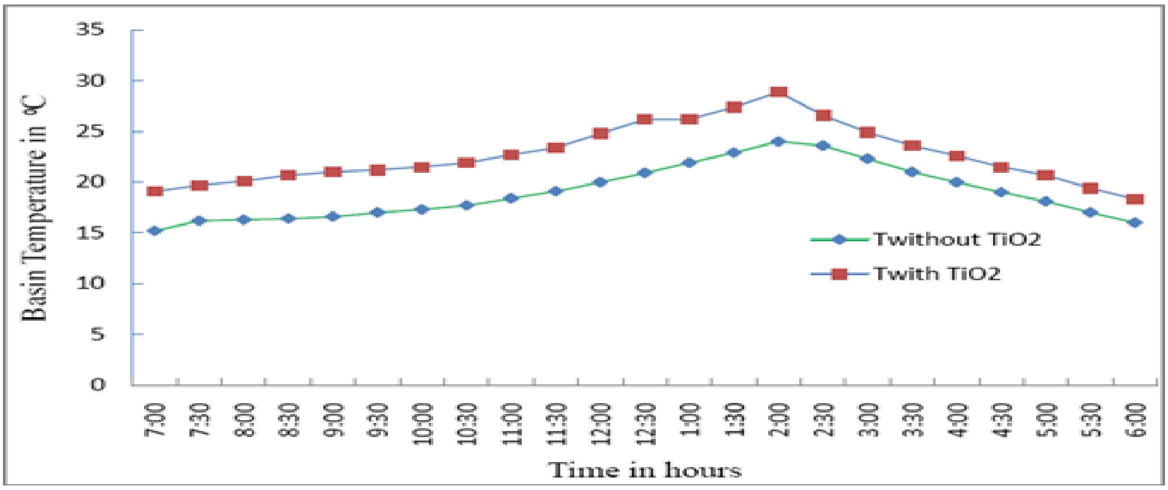

Figure 3.17: Effects of TiO2-Water Nanofluid on the Temporal Variability of Basin Temperature [54].

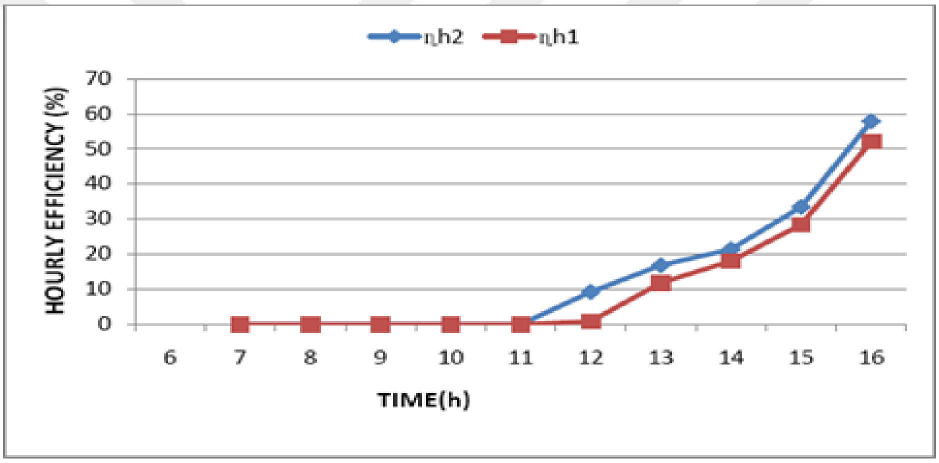

Figure 3.18: Changes in Hourly Productivity Caused by White Walls and Nanoparticles (Blue) and Black Walls and Water (Red)[55].

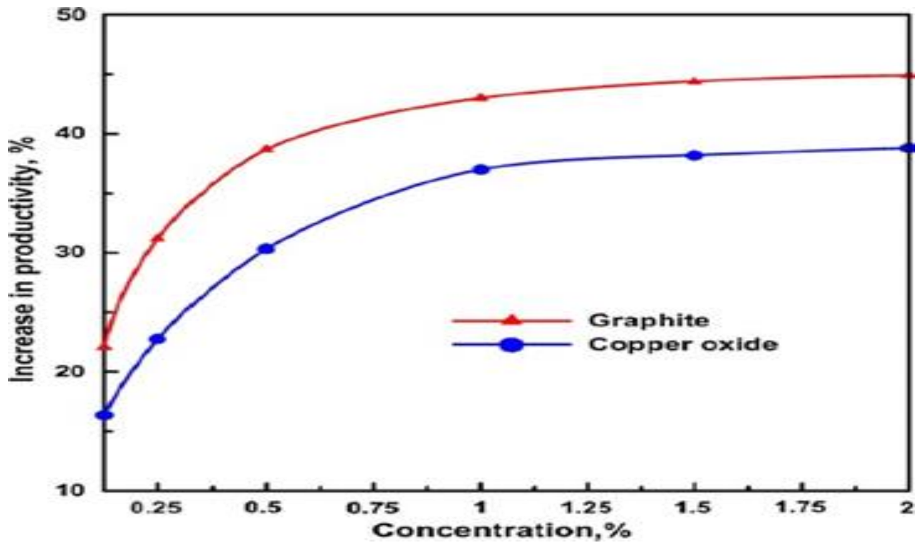

Figure 3.19: Concentration Effects on Graphite and Copper Oxide Micro-Flakes' Productivity[56]**.**

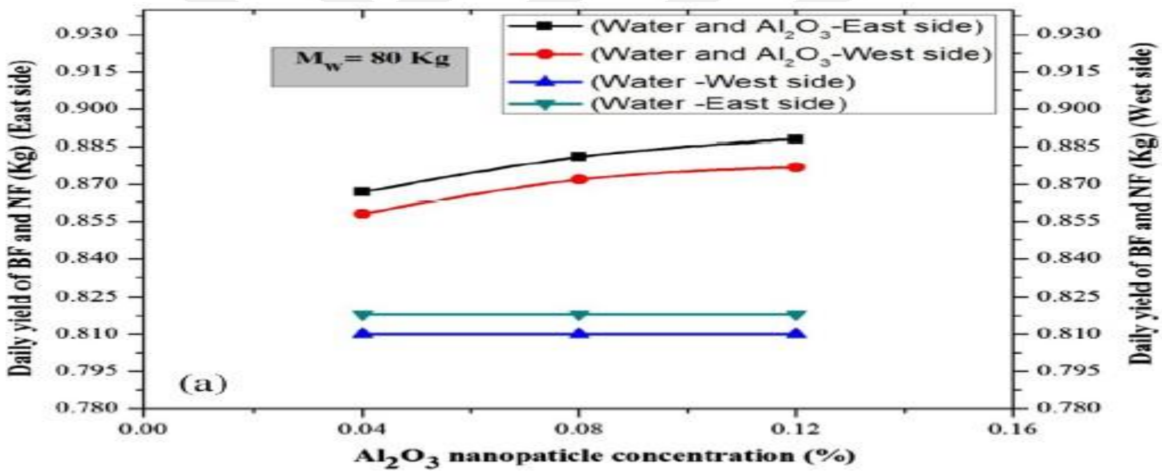

Figure 3.20: Concentration of nanoparticles in 80 kg of water and the resulting daily yield variation for the base and nanofluids[57]**.**

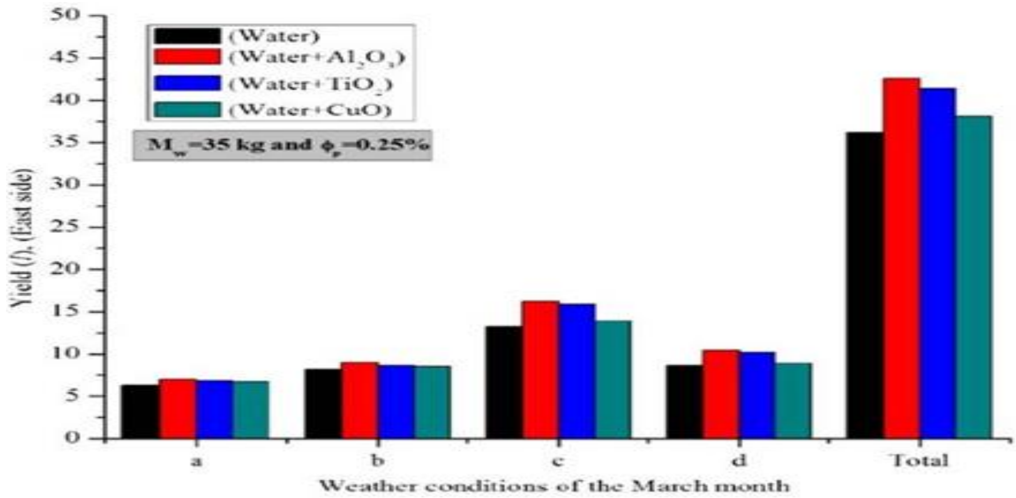

Figure 3.21: Changes in Outcome (Yield) Caused by Temperature and Weather for Both Conventional and Nanofluids[57].

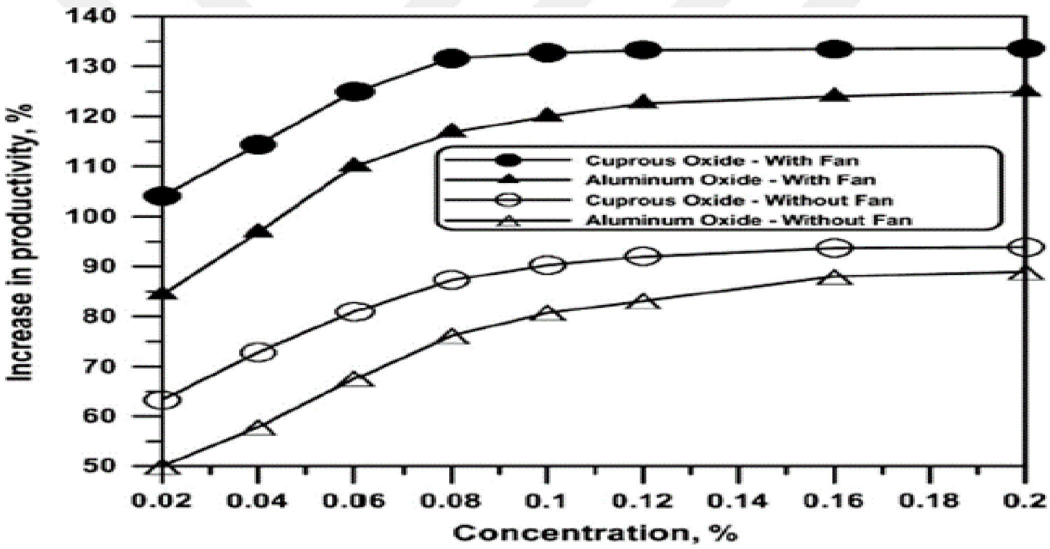

Figure 3.22: Comparison Of Nanofluids' Productivity Increase With And Without A Vacuum Fan[58].

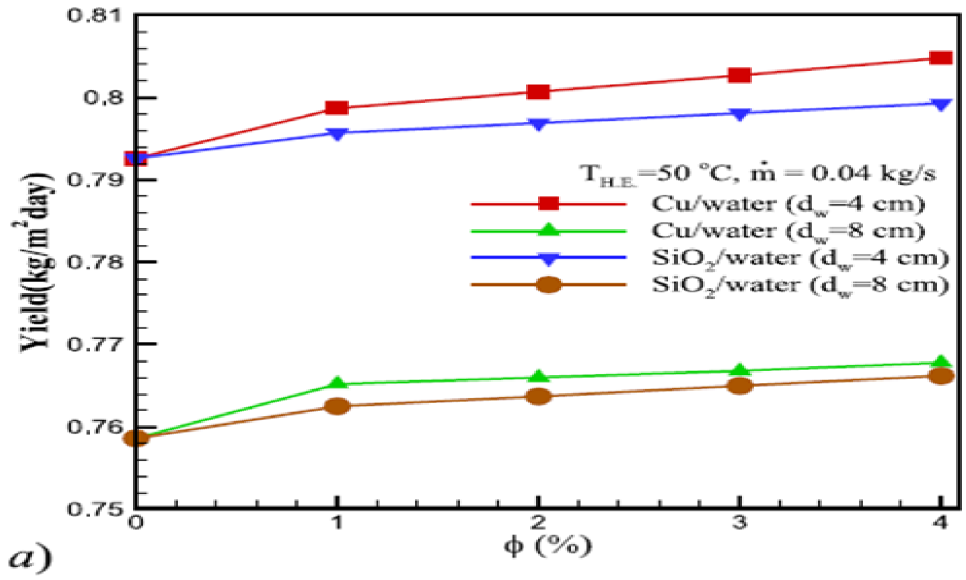

Figure 3.18: Effect of Nanoparticle Volume Fraction on Yield for a Range of Nanofluids and Water Depth[33].

Here we must mention the most important uses of nanotechnology in the processes of water distillation [59]. And water desalination with solar energy, where nanoparticles that have good thermal and physical properties can be used in combining them with water basin coating materials and linking them to the effect of water depth on improving Productivity of distilled water, and nanotechnology [41]. can be used in the treatment and water filtration processes to produce fresh water. How nanotechnology can be used to develop heat production from solar energy by adding nanoparticles to solar cells to improve their performance and raise their efficiency [60].

3.6 NANOFLUID PREPARATION

The first step of this work is the preparation of the nanofluid with a volume fraction equal to (1,4 and 7) % with a nanoparticle's diameter of 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 3.24. shows it.

Figure 3.19:1200W Ultrasonic Processor for Homogenizing Nanofluid Produced by MTI CORPORATION.

3.6.1 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 3.25. shows the KD2 PRO used in the thermal conductivity measurement in this investigation. Cu-Water heated from 10 to 60 °C for the pure water and volume fraction (1,4,7) %.

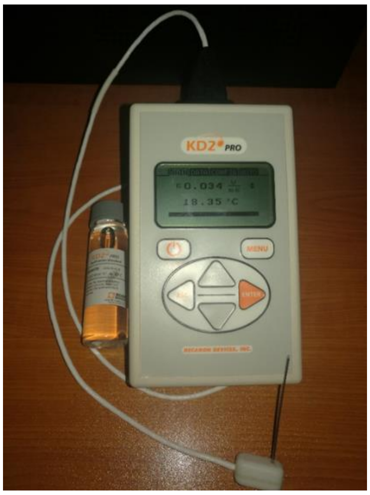

Figure 3.25: KD2PRO Measuring Device for Thermal Conductivity of Nanofluid Produced by DECAGON DEVICE INT

The same experiments were applied to determine the dynamic viscosity of the pure water and Cu-Water nanofluids using the rotary-viscometer. The process of measuring requires at least 3 minutes before recording the data to reach the steady state conditions. Figure 3.26. shows the rotary-viscometer device.

Figure 3.20: NDJ-5S Viscometer Measuring Device for Dynamic Viscosity of Nanofluid.

FESEM photograph for the CuO and Al2O3 nanofluids shown in Figure 3.27and figure 3.28 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, two different nanomaterials (CuO, AL2O3) were used, which process good thermal properties in addition to their low cost.

Initially, all nanomaterials were dissolved in 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%, 4%, and 7% of CuO and Al2O3 nanomaterials. Finally, all the coated plates were put in the modified solar stills basin respectively.

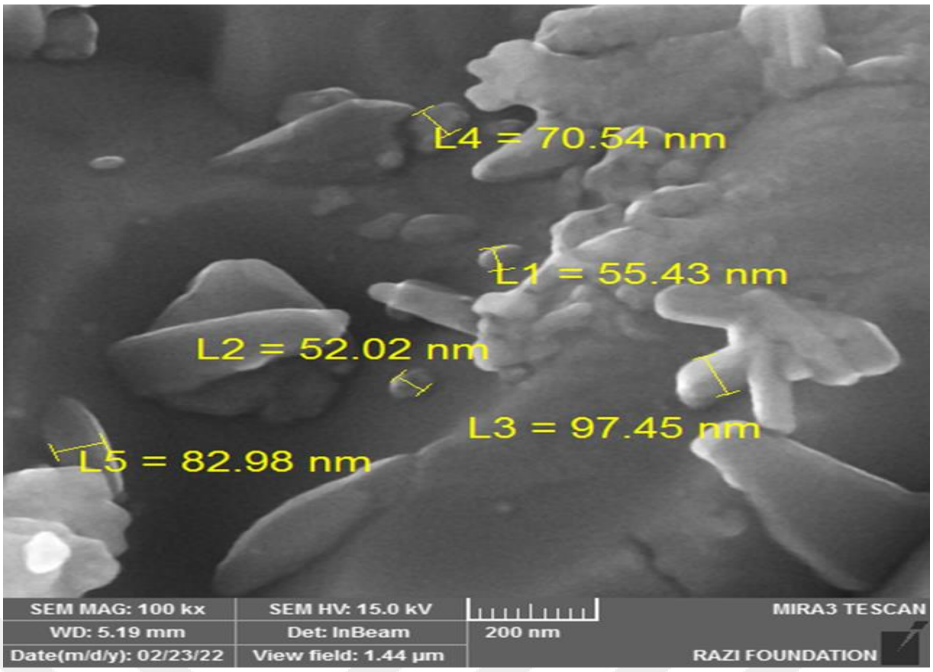

Figure 3.21 Morphology of Cuo Nanoparticles At 200nm

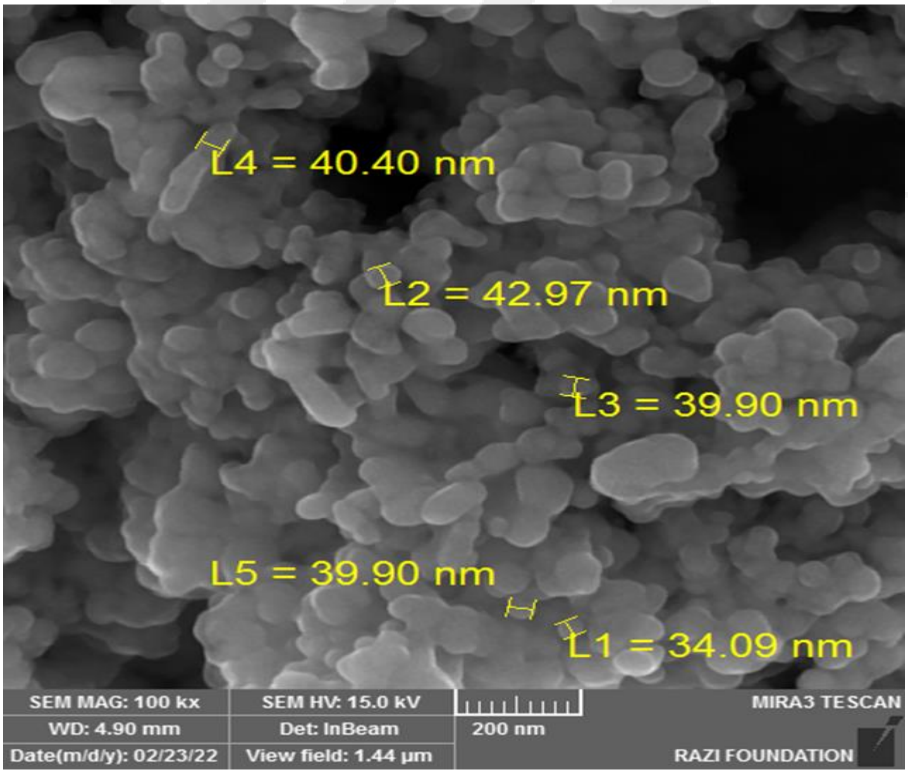

Figure 3.28: Morphology of Al2O3 Nanoparticles At 200nm

4. RESULTS AND DISCUSSION

4.1 INTRODUCTION

In this study, experiments 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 18:00 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).

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.

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 CuO and AL2O3. The particle size of these nanomaterials is about 30nm, the purity is 99.8%, the concentration of use is 1%, 4%, and 7%, and the water depth is 1cm, 4cm, and 7cm.

4.2 EVAPORATION ENHANCEMENT

4.2.1 Nanomaterials

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 an 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 aluminium panel.

Initially, the nanomaterials AL2O3 and CuO with two concentrations of 1% 4%, and 7% in 1 cm water depth were used. All results obtained were obtained within two days per nanomaterial, as well as a comparative study between conventional (CSS) and modified (MSS) solar stills. The figures below show all the results observed from the experimental work and a discussion of AL2O3 and CuO nanomaterials, respectively.

4.2.1.1 Aluminum Oxide (AL2O3) nanomaterials

Figure 4.1. shows the effect of a 1% concentration of AL2O3 nanomaterials 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 2-3 pm, then drop to a minimum at 3-6 pm. This behaviour 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 (2) shows the amount of productivity for 1,4 and 7% concentrations.

4.2.1.2 Copper Oxide (CuO) nanomaterials

As shown in the Figures 4.2. the temperature of the water can be observed to increase over time. The average temperature of water increased when CuO nanomaterials were introduced into the MSS basin. This result shows that copper oxide has higher thermal conductivity and density compared to aluminium oxide. In addition, copper oxide has the highest productivity, as shown in Table (3).

Figure 4.3 and figure 4.4 show the effect of using nanomaterials on the rise in water temperature.

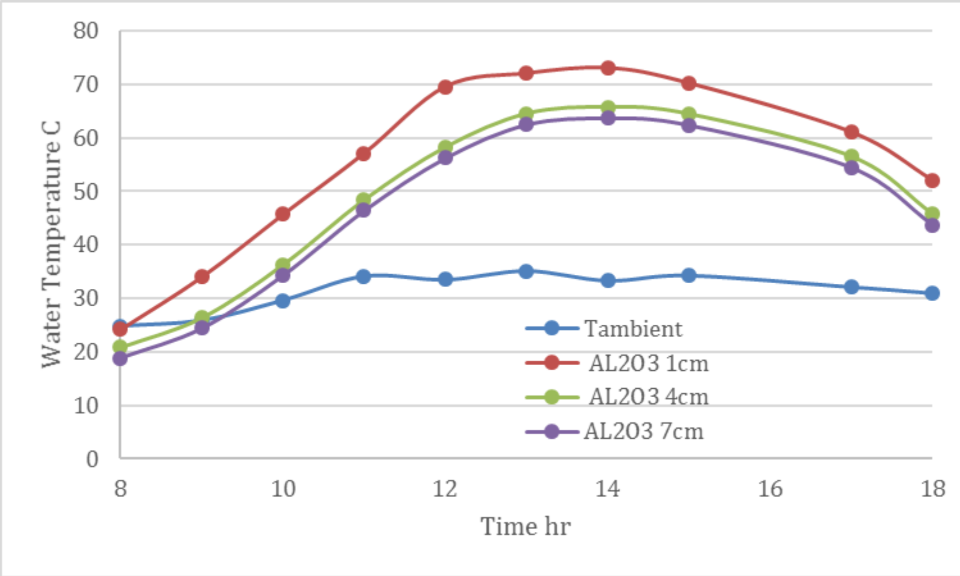

Figure 4.1: Water Temperature Distribution for MSS At Φ=1% Of Al2O3 Nanomaterial At 1,4 And 7 Cm Water Depth

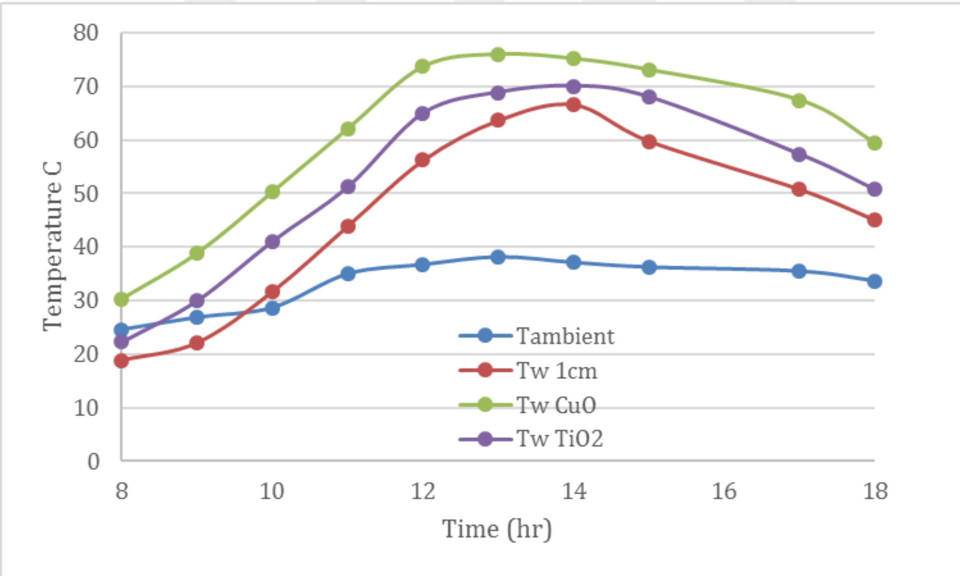

Figure 4.2: Water Temperature Distribution For MSS At Φ=1% Of Cuo Nanomaterial At 29/5/2022 At 1 Cm Water Depth

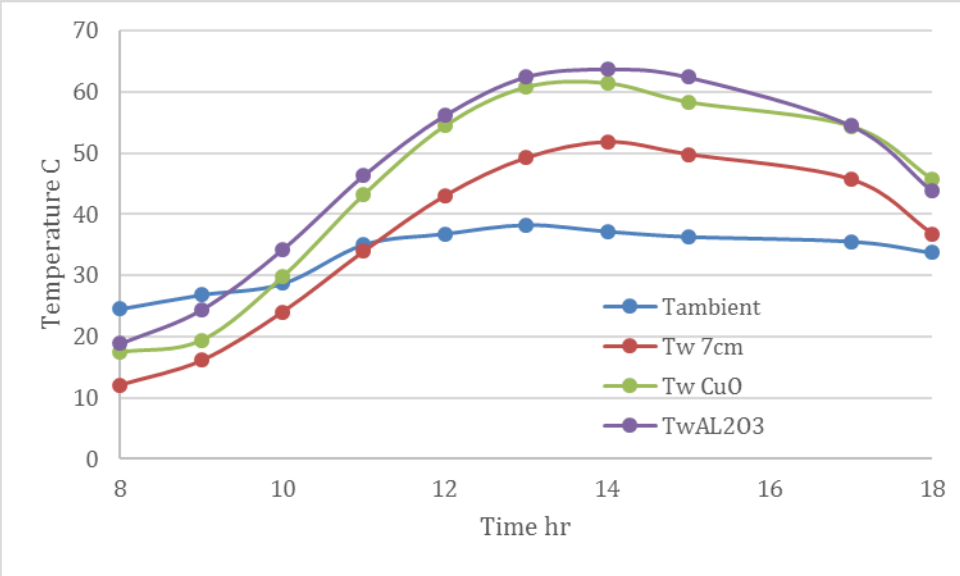

Figure 4.3: Water Temperature Distribution for MSS At Φ=1% Of Cuo Nanomaterial At 2/6/2022 At 7 Cm Water Depth

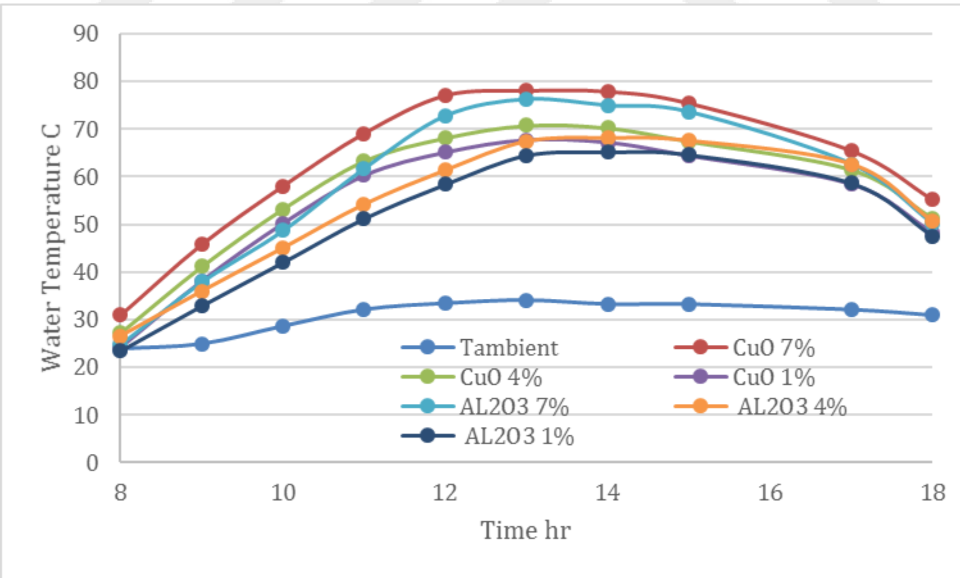

Figure 4.4: Water Temperature Distribution for MSS At Φ=1,4 And 7% Of Cuo and Al2O3 Nanomaterial At 4cm Water Depth

The productivity of CSS and MSS is Registered in Table (2). It was revealed that MSS was more productive than CSS two days at a time. The productivity of MSS increased by about

20% to 52% when increasing the concentration of Al2O3. 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 Two Days At Ø=1%, 4%, And 7% Of AL2O3 Nanomaterial.

Concentration	Date	Daily productivity (ml/day)		Daily productivity rise
		CSS	**MSS**	
1%	2/7/2022	450	540	20%
4%	6/7/2022	470	640	36%
7%	8/7/2022	460	700	52%

Table (3) shows the productivity of solar stills "CSS and MSS" when CuO nanomaterials were used at 1% to 7% concentrations. It was revealed that productivity increases when CuO nanoparticles are higher than Al2O3. However, it is observed that the increase in productivity decreases with the lowest heat capacity and thermal conductivity of titania compared to alumina.

Table 4.2: Accumulated Daily Productivity of CSS And MSS For Two Days At Ø=1%, 4%, And 7% Of Cuo Nanomaterial.

Concentration	Date	Daily productivity (ml/day)		Daily productivity rise
		CSS	**MSS**	
1%	7/7/2022	490	610	25%
4%	8/7/2022	500	710	42%
7%	10/7/2022	520	820	58%

5. CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

In this chapter, we will present the results and analyse these results, as the results show the effect of water depth and nanotechnology in regards to the efficiency of acrylic pyramidal solar still, see fig 5.1. show a diagram of a component of pyramidal, Where a laboratory experiment was carried out on a solar still and the productivity was calculated for one day in the absence of using nanoparticles with paint, and the productivity was recalculated with the use of nanoparticles (AL2O3) with the black-coloured aquarium paint at concentrations of 1%, 4% and 7% with a change of water depth of 1 cm, 4 cm, and 7 cm, respectively, then the calculations were made again with the use of nanoparticles (Cuo) with the black-colored aquarium paint at concentrations of 1%, 4% and 7% with a change of water depth of 1 cm, 4 cm and 7 cm, respectively.

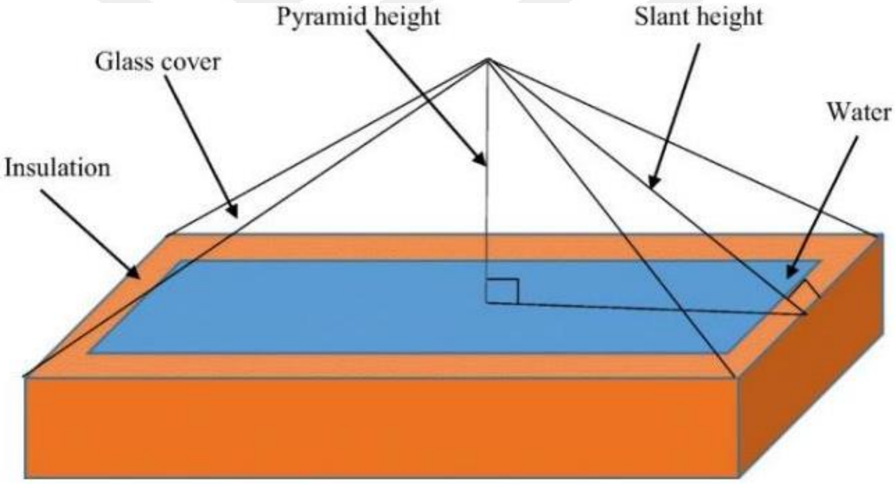

Figure 5.1: Diagram of Components of Pyramidal Still

Then compare the results if nanotechnology is not used, and then with two different types of nanoparticles, namely (Cuo, AL2O3), with changing the depth of the water, to determine the effect of changing the depth of the water with the black coating of the aquarium supported by nanoparticles, see Figure 5.2. which shows the components The laboratory device used in the experiment, which is a pyramidal solar still.

Figure 5.2: Tools and Materials Used in The Experiment**.**

5.2 RESULT AND DISCUSSION

the results in Table No. (2) shows that when (AL2O3) particles were added to the paint of the black-painted basin, and when the concentration of (AL2O3) was 1% on the first day of the experiment, the amount of distilled water in Solar Stills (CSS) and Modified Solar Stills (MSS), was 450 ml per day and 540 ml per day Respectively, The results show an improvement in productivity by 20% in favor of(MSS), when the concentration of (AL2O3) was 4% on the first day of the experiment, the amount of distilled water in Solar Stills (CSS) and Modified Solar Stills (MSS), were 470 ml per day and 640 ml per day Respectively, The results show an improvement in productivity by 36% in favor of(MSS), when the concentration of (AL2O3) was 7% on the first day of the experiment, the amount of distilled water in Solar Stills (CSS) and Modified Solar Stills (MSS), were 460 ml per day and 700 ml per day Respectively, The results show an improvement in productivity by 52% in favor of(MSS).

Table 5.1: Accumulated Daily Productivity of CSS And MSS For Two Days At Ø=1%, 4%, And 7% Of AL2O3 Nanomaterial.

Concentration	**Date**	**Daily productivity (ml/day)**		**Daily productivity rise**
		CSS	**MSS**	
1%	**2/7/2022**	**450**	**540**	**20%**
4%	**6/7/2022**	**470**	**640**	**36%**
7%	**8/7/2022**	**460**	**700**	**52%**

the results at Table No. (3) shows that when (cuo) particles were added to the paint of the black-painted basin, and when the concentration of (cuo) was 1% on the first day of the experiment, the amount of distilled water in Solar Stills (CSS) and Modified Solar Stills (MSS), was 490 ml per day and 510 ml per day Respectively, The results show an improvement in productivity by 25% in favor of(MSS), when the concentration of (cuo) was 4% on the first day of the experiment, the amount of distilled water in Solar Stills (CSS) and Modified Solar Stills (MSS), were 500 ml per day and 640 710 ml per day Respectively, The results show an improvement in productivity by 42% in favor of(MSS), when the concentration of (cuo) was 7% on the first day of the experiment, the amount of distilled water in Solar Stills (CSS) and Modified Solar Stills (MSS), were 520 ml per day and 820 ml per day Respectively, The results show an improvement in productivity by 58% in favor of(MSS).

Table 5.2: Accumulated Daily Productivity of CSS And MSS For Two Days At Ø=1%, 4%, And 7% Of Cuo Nanomaterial

Concentration	**Date**	**Daily productivity (ml/day)**		**Daily productivity rise**
		CSS	**MSS**	
1%	**7/7/2022**	**490**	**610**	**25%**
4%	**8/7/2022**	**500**	**710**	**42%**
7%	**10/7/2022**	**520**	**820**	**58%**

By comparing the results, it is clear that:

a. The use of nanoparticles in paint, whether (CUO or AL2O3) is better in solar stills (MSS)than (CSS), As shown in Figure 5.3. the maximum water temperature in the distillates (MSS) is higher than that in the distillates (CSS), whether in the case of using (cuo) in painting the basins or using (AL2O3) at all concentrations and different depths.

b. The use of nanoparticles in paint improves productivity more than paint without nanoparticles see figure 5.3- 5.4. Where the maximum temperature of the water reaches 68c and the maximum temperature of water 65c in the case of not using nanoparticles, while in the case of using nanoparticles the maximum temperature of the water reaches 73c.

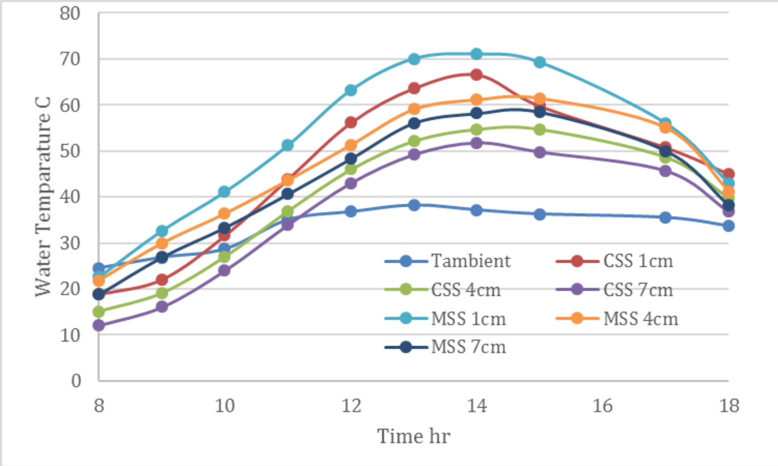

Figure 5.3: Water Temperature Distribution for CSS And MSS On 24/5/2022 For Ambient with Nanoparticles At 1,4 And 7 Cm.

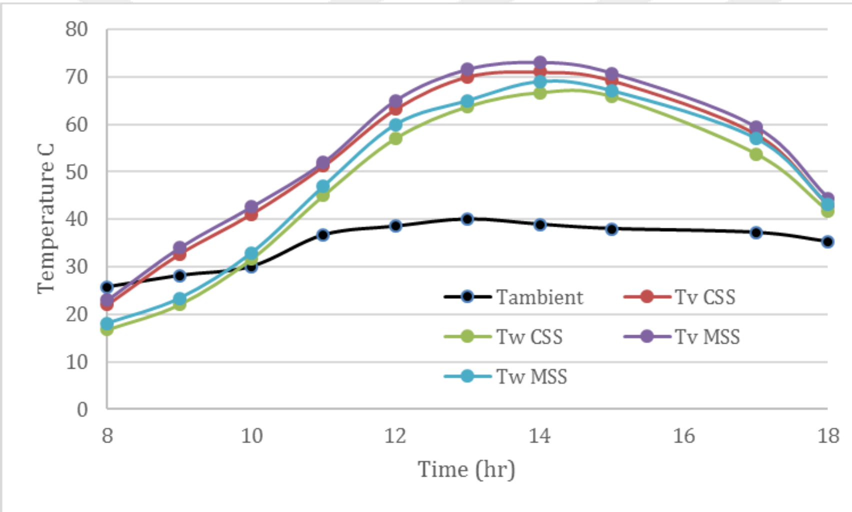

Figure 5.4: Temperature Distribution for CSS And MSS At 22/4/2022 For Ambient, Vapor Temperature, And Water Temperature Without Nanomaterials.

c. The use of nanoparticles (cuo)in the painting process gives the same results as the use of nanoparticles (AL2O3), see fig 5.5. Where, in the case of using (cou), the maximum temperature of the water reaches 66c, but in the case of using (AL203), the maximum temperature reaches 66 c, That is, using either (cuo) or (AL2O3) as nanoparticles, with paint, gives approximately the same thermal efficiency, because the temperature of the water in the basin in the first case or the second case is the same 66c, but The values vary very slightly.

However, according to Table No. (2) and (3), the productivity of water in the case of using (cuo) exceeds (AL2O3) , But the increase is not large.

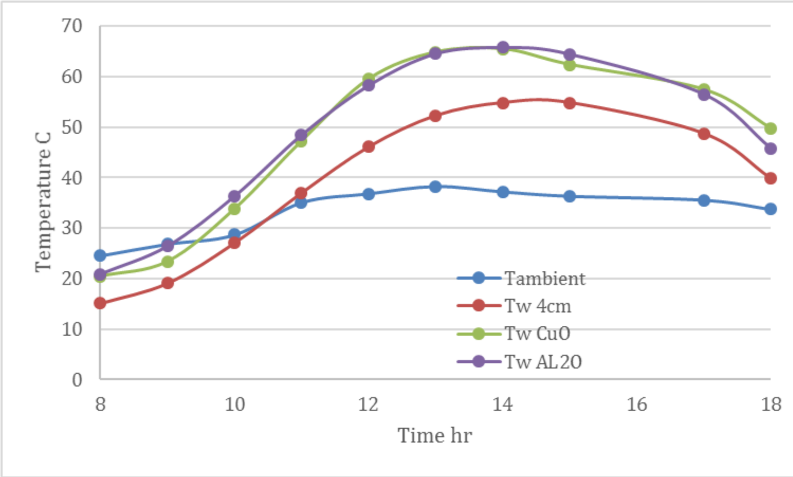

Figure 5.5: Water Temperature Distribution for MSS At Φ=1% Of Cuo Nanomaterial At 1/6/2022 At 4 Cm Water Depth

d. When see Figures 5.6. and Figure 5.7. are the effect of changing the depth of the water in the aquarium from 1 cm to 4 cm and then 7 cm in the case of using (cuo) and (AL2O3), respectively, we find that in the case of (CUO) the temperature has changed Water from 76 Celsius to 65 Celsius, then to 60 Celsius, and in the case of (AI2O3) the water temperature has changed from 74 Celsius to 64 Celsius and then to 60 Celsius, but with the change of water depth from 1 cm to 4 cm, the improvement in productivity was noticeable. But when the depth was changed to 7 cm, the improvement in productivity was very slight.

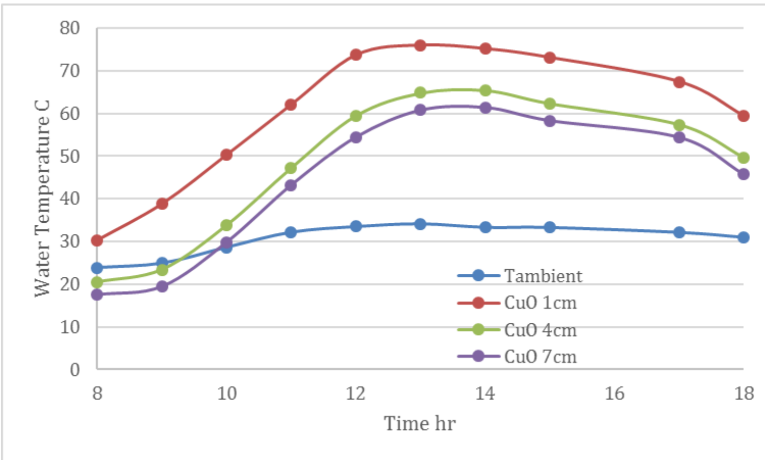

Figure 5.6: Water Temperature Distribution For MSS At Φ=1% Of Cuo Nanomaterial At 1,4 And 7 Cm Water Depth

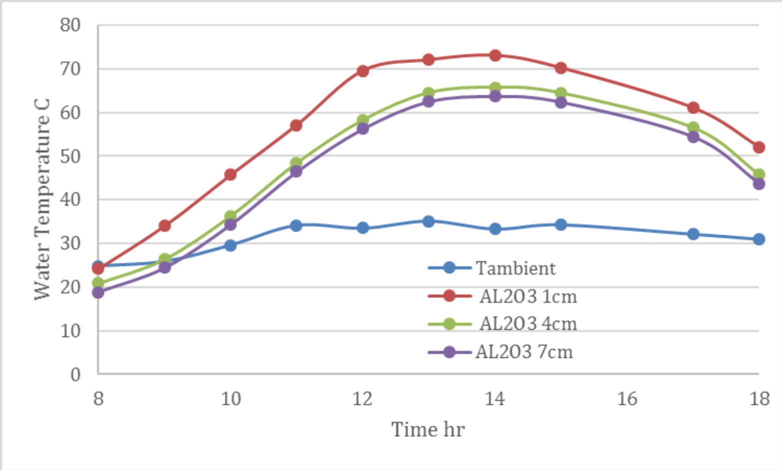

Figure 5.7: Water Temperature Distribution For MSS At Φ=1% Of Al2O3 Nanomaterial At 1,4 And 7 Cm Water Depth

5.3 CONCLUSION

Through the previous results, we can conclude that the using of nanotechnology is very important to improve the performance of solar stills, whether by raising thermal efficiency or increasing productivity Also, changing the depth of the water leads to a noticeable improvement in productivity to a certain extent, but after that, the improvement is slight and then becomes unnoticeable after that, in addition to the following conclusions:

a. The use of nanoparticles in paint improves productivity more than paint without nanoparticles.

b. The use of nanoparticles (cuo)in the painting process is better than the use of nanoparticles (AL2O3).

c. The use of nanoparticles in paint, whether (cuo or AL2O3) is better in solar stills (MSS)than (CSS), the maximum water temperature in the distillates (MSS) is higher than that in the distillates (CSS), whether in the case of using (cuo) in painting the basins or using (AL2O3) at all concentrations and different depths.

d. The effect of changing the depth of the water in the aquarium in the case of using (cuo) and (AL2O3), respectively, the improvement in productivity was noticeable. But when the depth was changed to 7 cm, the improvement in productivity was very slight.

5.4 SUMMARY

We can summarize all the previous studies on improving the performance of solar stills by adding nanomaterials to the coating of the coating basins and changing the depth of the water indicating that the use of nanotechnology and increasing the depth of water in the basins leads to improving the thermal performance of solar stills and increasing productivity significantly with the use of Nanotechnology, but with the change in the depth of the water, the improvement in productivity is noticeable up to a certain depth, after which the improvement is slight. In full agreement with the results and laboratory experiment we conducted in this research, the results of this research proved that the use of nanotechnology in coating basins for solar still leads to raising their thermal efficiency and increasing production, in addition to that it proved that adding some nanoparticles to coating materials is better than some other types, such as the preference of using copper oxide over aluminium oxide, And the preference for the performance of some distillates such as (MSS) over some other distillates, such as (CSS) in the case of using nanotechnology in coating the basins of the solar stills, In the end, we can make it clear that this study can be used as an important reference for researchers and scholars in the field of raising the efficiency of solar stills and increasing their production.

REFERENCES

[1] X. Xu, W. L. Daniel, W. Wei, and C. A. Mirkin, "Colorimetric Cu2+ detection using DNA-modified gold-nanoparticle aggregates as probes and click chemistry," *Small*, vol. 6, no. 5, 2010, doi: 10.1002/smll.200901691.

[2] J. E. Hulla, S. C. Sahu, and A. W. Hayes, "Nanotechnology: History and future," *Human and Experimental Toxicology*, vol. 34, no. 12. 2015, doi: 10.1177/0960327115603588.

[3] E. Amstad, S. Zurcher, A. Mashaghi, J. Y. Wong, M. Textor, and E. Reimhult, "Surface functionalization of single superparamagnetic iron oxide nanoparticles for targeted Magnetic resonance imaging," *Small*, vol. 5, no. 11, 2009, doi: 10.1002/smll.200801328.

[4] B. Wadgaonkar *et al.*, "Evaluation of the effect of water-uptake on the impedance of dental resins," *Biomaterials*, vol. 27, no. 17, 2006, doi: 10.1016/j.biomaterials.2006.01.045.

[5] R. J. Aitken *et al.*, "A multidisciplinary approach to the identification of reference materials for engineered nanoparticle toxicology," *Nanotoxicology*, vol. 2, no. 2, 2008, doi: 10.1080/17435390802109177.

[6] D. Quigley, C. L. Freeman, J. H. Harding, and P. M. Rodger, "Sampling the structure of calcium carbonate nanoparticles with metadynamics," *J. Chem. Phys.*, vol. 134, no. 4, 2011, doi: 10.1063/1.3530288.

[7] Y. Wu, W. Yang, C. Wang, J. Hu, and S. Fu, "Chitosan nanoparticles as a novel delivery system for ammonium glycyrrhizinate," *Int. J. Pharm.*, vol. 295, no. 1–2, 2005, doi: 10.1016/j.ijpharm.2005.01.042.

[8] Z. S. Abdel-Rehim and A. Lasheen, "Experimental and theoretical study of a solar desalination system located in Cairo, Egypt," *Desalination*, vol. 217, no. 1–3, 2007, doi: 10.1016/j.desal.2007.01.012.

[9] P. Vishwanath Kumar, A. Kumar, O. Prakash, and A. K. Kaviti, "Solar stills system design: A review," *Renewable and Sustainable Energy Reviews*, vol. 51. 2015, doi: 10.1016/j.rser.2015.04.103.

[10] T. Arunkumar, R. Jayaprakash, A. Ahsan, D. Denkenberger, and M. S. Okundamiya, "Effect of water and air flow on concentric tubular solar water desalting system," *Appl. Energy*, vol. 103, 2013, doi: 10.1016/j.apenergy.2012.09.014.

[11] R. Sathyamurthy *et al.*, "Exergy and energy analysis of a tubular solar still with and without fins: a comparative theoretical and experimental approach," *Environ. Sci. Pollut. Res.*, vol. 29, no. 5, 2022, doi: 10.1007/s11356-021-16065-w.

[12] M. Bhargva, A. Yadav, H. M. Abd-ur-rehman, and S. Shakir, "CFD Applied to the Analysis of the Operation of a Solar Still Pyramidal-type CFD Applied to the Analysis of the Operation of a Solar Still," 2022, doi: 10.1088/1742-6596/2307/1/012002.

[13] M. E. H. Attia, A. E. Kabeel, M. Abdelgaied, and A. R. Shmouty, "Enhancing the hemispherical solar distiller performance using internal reflectors and El Oued sand grains as energy storage mediums," *Environ. Sci. Pollut. Res.*, vol. 29, no. 15, pp. 21451–21464, 2022, doi: 10.1007/s11356-021-17367-9.

[14] D. Ferreira, P. Pereira, and R. Fangueiro, "Multifunctional Fibrous Structures Based on Graphene Nanoplatelets , Chitosan and Natural Fibres," vol. 1069, no. June, p. 2019, 2019.

[15] D. Rim, L. Wallace, S. Nabinger, and A. Persily, "Reduction of exposure to ultrafine particles by kitchen exhaust hoods: The effects of exhaust flow rates, particle size, and burner position," *Sci. Total Environ.*, vol. 432, 2012, doi: 10.1016/j.scitotenv.2012.06.015.

[16] B. Madhu *et al.*, "Exergy Analysis of Solar Still with Sand Heat Energy Storage," *Appl. Sol. Energy (English Transl. Geliotekhnika)*, vol. 54, no. 3, 2018, doi: 10.3103/S0003701X1803009X.

[17] Z. M. Omara, A. S. Abdullah, A. E. Kabeel, and F. A. Essa, "The cooling techniques of the solar stills' glass covers – A review," *Renewable and Sustainable Energy Reviews*, vol. 78. 2017, doi: 10.1016/j.rser.2017.04.085.

[18] E. J.I, “Comparative evaluation of rectangular and pyramid-shaped solar stills using saline water,” *Int. J. Phys. Sci.*, vol. 7, no. 31, 2012, doi: 10.5897/ijps11.1503.

[19] L. Et, A. Usoo8673059b2, D. P. Leta, and M. Bordelon, “Application Data Provisional application,” 2011.

[20] M. C. C. da Silva, M. L. Sens, C. Soares, and C. O. de A. Neto, “Potabilização de água por processo de destilação solar direta para residências isoladas,” *Acta Sci. - Technol.*, vol. 36, no. 1, 2014, doi: 10.4025/actascitechnol.v36i1.18737.

[21] M. Bhargva and A. Yadav, “Productivity augmentation of single-slope solar still using evacuated tubes, heat exchanger, internal reflectors and external condenser,” *Energy Sources, Part A Recover. Util. Environ. Eff.*, pp. 1–21, 2019.

[22] V. Velmurugan, K. J. Naveen Kumar, T. Noorul Haq, and K. Srithar, “Performance analysis in stepped solar still for effluent desalination,” *Energy*, vol. 34, no. 9, 2009, doi: 10.1016/j.energy.2009.04.029.

[23] T. Peng, L. Huajun, H. Yang, and C. Yan, “Synthesis of SrAl2O4:Eu, Dy phosphor nanometer powders by sol-gel processes and its optical properties,” *Mater. Chem. Phys.*, vol. 85, no. 1, pp. 68–72, May 2004, doi: 10.1016/j.matchemphys.2003.12.001.

[24] A. Madhlopa and C. Johnstone, “Numerical study of a passive solar still with separate condenser,” *Renew. Energy*, vol. 34, no. 7, 2009, doi: 10.1016/j.renene.2008.12.032.

[25] H. N. Panchal, “Enhancement of distillate output of double basin solar still with vacuum tubes,” *J. King Saud Univ. - Eng. Sci.*, vol. 27, no. 2, 2015, doi: 10.1016/j.jksues.2013.06.007.

[26] N. Baig, I. Kammakakam, W. Falath, and I. Kammakakam, "Nanomaterials: A review of synthesis methods, properties, recent progress, and challenges," *Materials Advances*, vol. 2, no. 6. 2021, doi: 10.1039/d0ma00807a.

[27] A. A. Elnazer, E. M. M. Seleem, S. A. M. Zeid, I. S. A. Ismail, H. A. Bahlol, and S. A. Salman, "Hydrochemical evaluation of the quaternary aquifer and its suitability for different purposes at south Al Waqf city, Qena, Upper Egypt," *Groundw. Sustain. Dev.*, vol. 12, 2021, doi: 10.1016/j.gsd.2020.100517.

[28] H. I. Z. Al-sudani, "Salinity Pollution of Groundwater in South of Iraq," no. 27, 2019.

[29] S. W. Sharshir *et al.*, "Improving the solar still performance by using thermal energy storage materials: A review of recent developments," *Desalin. Water Treat.*, vol. 165, 2019, doi: 10.5004/dwt.2019.24362.

[30] Y. Taamneh, A. M. Manokar, M. M. Thalib, A. E. Kabeel, R. Sathyamurthy, and A. J. Chamkha, "Extraction of drinking water from modified inclined solar still incorporated with spiral tube solar water heater," *J. Water Process Eng.*, vol. 38, 2020, doi: 10.1016/j.jwpe.2020.101613.

[31] A. K. Hussein, L. Kolsi, O. Younis, D. Li, H. M. Ali, and M. Afrand, "USING of NANOTECHNOLOGY CONCEPT to ENHANCE the PERFORMANCE of SOLAR STILLS - RECENT ADVANCES and OVERVIEW," *J. Eng. Sci. Technol.*, vol. 15, no. 6, pp. 3991–4031, 2020.

[32] O. A. Nashmi, A. A. Mohammed, and N. N. Abdulrazzaq, "Investigation of Ozone Microbubbles for the Degradation of Methylene Orange Contaminated Wastewater," *Iraqi J. Chem. Pet. Eng.*, vol. 21, no. 2, 2020, doi: 10.31699/ijcpe.2020.2.4.

[33] O. Mahian, A. Kianifar, S. Zeinali, D. Wen, and A. Z. Sahin, "CLOETENS XXVIIIe Congr??s Francais de M??decine ?? Bruxelles.," *Scalpel (Brux).*, vol. 104, no. 41, 1951.

[34] K. V. Modi, S. R. Maurya, J. H. Parmar, A. B. Kalsariya, and P. B. Panasara, "An experimental investigation of the effectiveness of partially and fully submerged metal hollow-fins and jute cloth wick-fins on the performance of a dual-basin single-slope solar still," *Clean. Eng. Technol.*, vol. 6, 2022, doi: 10.1016/j.clet.2021.100392.

[35] Z. Tian *et al.*, "Prediction of rheological behavior of a new hybrid nanofluid consists of copper oxide and multi wall carbon nanotubes suspended in a mixture of water and ethylene glycol using curve-fitting on experimental data," *Phys. A Stat. Mech. its Appl.*, vol. 549, 2020, doi: 10.1016/j.physa.2019.124101.

[36] L. Wang, G. Chen, C. Zhang, Y. Wang, and R. Sun, "Application of loop-mediated isothermal amplification combined with lateral flow dipstick to rapid and sensitive detection of Alexandrium catenella," *Environ. Sci. Pollut. Res.*, vol. 27, no. 4, pp. 4246–4257, 2020.

[37] K. Velmurugan *et al.*, "A Review of Heat Batteries Based PV Module Cooling—Case Studies on Performance Enhancement of Large-Scale Solar PV System," *Sustainability (Switzerland)*, vol. 14, no. 4. 2022, doi: 10.3390/su14041963.

[38] D. R. Mishra and A. K. Tiwari, "Effect of coal and metal chip on the solar still," *J. Sci. Tech. Res.*, vol. 3, no. 1, pp. 1–6, 2013.

[39] G. N. Tiwari, H. N. Singh, and R. Tripathi, "Present status of solar distillation," *Sol. Energy*, vol. 75, no. 5, 2003, doi: 10.1016/j.solener.2003.07.005.

[40] A. Krnac, M. Araiz, S. Rana, J. Velardo, and A. Date, “Investigation of direct contact membrane distillation coupling with a concentrated photovoltaic solar system,” in *Energy Procedia*, 2019, vol. 160, doi: 10.1016/j.egypro.2019.02.143.

[41] N. Binti, M. Azezs, and K. B. W. A. N. Yusof, “EVALUATION OF PERFORMANCE FOR BASIN WITH BLACK SOIL AND SEA SAND LAYER IN PRODUCING POTABLE,” no. May, 2014.

[42] M. T. Chaichan and H. A. Kazem, *Generating electricity using photovoltaic solar plants in Iraq*. 2018.

[43] W. S. Choong, Z. Y. Ho, and R. Bahar, “Solar Desalination Using Fresnel Lens as Concentrated Solar Power Device: An Experimental Study in Tropical Climate,” *Front. Energy Res.*, vol. 8, no. October, pp. 1–8, 2020, doi: 10.3389/fenrg.2020.565542.

[44] S. Abdallah, M. Nasir, and D. Afaneh, “Performance evaluation of spherical and pyramid solar stills with chamber stepwise basin,” *Desalin. Water Treat.*, vol. 218, 2021, doi: 10.5004/dwt.2021.27009.

[45] Q. Zhang, R. H. Gangupomu, D. Ramirez, and Y. Zhu, “Measurement of ultrafine particles and other air pollutants emitted by cooking activities,” *Int. J. Environ. Res. Public Health*, vol. 7, no. 4, 2010, doi: 10.3390/ijerph7041744.

[46] S. M. Taheri Mousavi, F. Egelioglu, and M. Ilkan, “Experimental and numerical study of the effect of various design configurations on the thermal performance of solar still desalination,” *Energy Sources, Part A Recover. Util. Environ. Eff.*, 2020, doi: 10.1080/15567036.2020.1826018.

[47] A. Kianifar, S. Zeinali Heris, and O. Mahian, “Exergy and economic analysis of a pyramid-shaped solar water purification system: Active and passive cases,” *Energy*, vol. 38, no. 1, 2012, doi: 10.1016/j.energy.2011.12.046.

[48] K. Sampathkumar, T. V. Arjunan, P. Pitchandi, and P. Senthilkumar, “Active solar distillation-A detailed review,” *Renewable and Sustainable Energy Reviews*, vol. 14, no. 6. 2010, doi: 10.1016/j.rser.2010.01.023.

[49] A. Saleh, J. A. Qudeiri, and M. A. Al-Nimr, “Performance investigation of a salt gradient solar pond coupled with desalination facility near the Dead Sea,” *Energy*, vol. 36, no. 2, 2011, doi: 10.1016/j.energy.2010.12.018.

[50] H. Akter, H. O. R. Howlader, A. Nakadomari, M. R. Islam, A. Y. Saber, and T. Senjyu, “A Short Assessment of Renewable Energy for Optimal Sizing of 100% Renewable Energy Based Microgrids in Remote Islands of Developing Countries: A Case Study in Bangladesh,” *Energies*, vol. 15, no. 3, 2022, doi: 10.3390/en15031084.

[51] P. Calvo, C. Remuñán-López, J. L. Vila-Jato, and M. J. Alonso, “Novel hydrophilic chitosan-polyethylene oxide nanoparticles as protein carriers,” *J. Appl. Polym. Sci.*, vol. 63, no. 1, 1997, doi: 10.1002/(SICI)1097-4628(19970103)63:1<125::AID-APP13>3.0.CO;2-4.

[52] A. Kumar, Priyam, H. Meena, J. Prakash, L. Wang, and G. Singh, “Recent advances on semiconducting nanomaterials-ferroelectric liquid crystals nanocomposites,” *J. Phys. Condens. Matter*, vol. 34, no. 1, 2022, doi: 10.1088/1361-648X/ac2ace.

[53] R. Chand, G. C. Rana, and A. K. Hussein, “Effect of suspended particles on the onset of thermal convection in a nanofluid layer for more realistic boundary conditions,” *Int. J. Fluid Mech. Res.*, vol. 42, no. 5, 2015, doi: 10.1615/InterJFluidMechRes.v42.i5.10.

[54] P. U. Parikh, Ruchir, “Solar distillation system with nano particle: a review,” *PDPU J. Energy Manag.*, vol. 3, no. 1, pp. 29–35, 2018.

[55] S. S. Tuly, M. S. Islam, R. Hassan, B. K. Das, and M. R. I. Sarker, “Investigation of a modified double slope solar still integrated with nanoparticle-mixed phase change materials: Energy, exergy, exergo-economic, environmental, and sustainability analyses,” *Case Stud. Therm. Eng.*, vol. 37, no. July, p. 102256, 2022, doi: 10.1016/j.csite.2022.102256.

[56] B. Gupta, P. Shankar, R. Sharma, and P. Baredar, “Performance Enhancement Using Nano Particles in Modified Passive Solar Still,” *Procedia Technol.*, vol. 25, 2016, doi: 10.1016/j.protcy.2016.08.208.

[57] L. Sahota and G. N. Tiwari, “Effect of nanofluids on the performance of passive double slope solar still: A comparative study using characteristic curve,” *Desalination*, vol. 388, 2016, doi: 10.1016/j.desal.2016.02.039.

[58] M. S. Kumar and G. Kumawat, “Performance Enhancement of Single Slope Solar Still Using Nano-Particles Mixed Black Paint,” *Adv. Nanosci. Technol. An Int. J.*, vol. 1, no. 1, pp. 55–65, 2015.

[59] “Effect of climatic, design and operational parameters on the yield of a simple solar still,” *Fuel Energy Abstr.*, vol. 44, no. 2, 2003, doi: 10.1016/s0140-6701(03)90659-x.

[60] A. Y. Hashim, “A new design of a single slop double-basin solar still(SSDBS),” *J. Basrah Res.*, vol. 37, no. 2, 2011.