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Theme

Enhancing the solar still performance using nanoparticles of aluminum oxide at different concentrations

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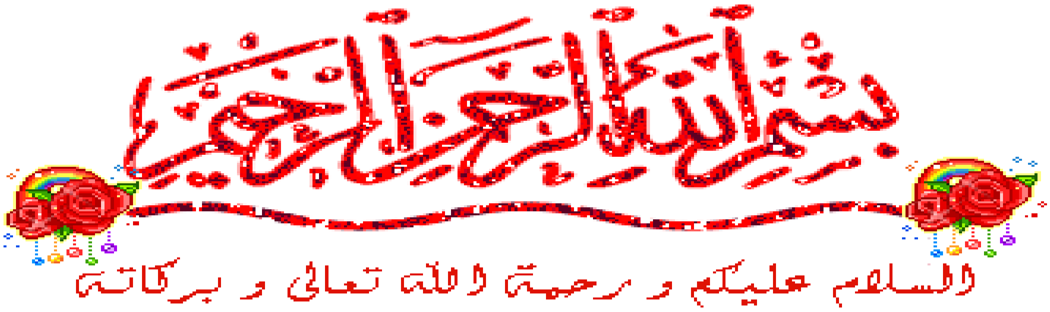

﴿وَقل رَّبِّ زِدْنِي عِلْماً﴾

(طه: ١١٤)

DEDICATED TO

To whom always gives the ability to decipher the impossible,

To the destiny maker, to you, my God, I offer you Hamdi and thank you, for the praise be to God, who definitely rules the truth and rewards every soul with what you seek

To the source of the tender that I planted in myself ambitious and persevering ...... my dear father

To the source of the tenderness that is draining ...... My dear mother

To my honorable Professor BENOUDINA

Belkheir, you have all the respect and thanks

for your contribution to the success of this work

To my dear friends

To my colleagues and colleagues

To those who are more honorable than us ... the martyrs of Palestine

I dedicate this research to you

Thanks and gratitude.

THANKS

The prophet Peace Be Upon Him said.

"He who did not thank people did not thank God"

After thanking God Almighty for his success in completing this humble research, I extend my sincere thanks to the dear parents who encouraged me to continue in the path of knowledge success

I extend my sincere thanks,

Jamil Al-Irfan, and His Highness the gratitude to the Supervising

Professor : BENOUDINA Belkheir

It also represented sincere thanks to the discussion committee

To English professor Mariam

thank you all

ملخص:

تعتبر مشكلة نقص المياه من المشاكل المؤرقة للكثير من دول العالم، خصوصا ان المياه عصب الحياة، فلا يمكن للزراعة والصناعة وغيرها من المشاريع الاخرى ان تزدهر وتنمو الا بوجود المياه، لذألك تعد المياه من اهم مكونات الطبيعة واكثرها طلبا. كحل لهده المشكل تقدم هده الدراسة طريقة بسيطة و غير مكلفة لتحلية المياه هي التقطير الشمسي, ان هذه الطريقة تعاني من عيب كبير و هو المردود الضعيف المقطر, ولرفع مردود المقطر الشمسي ارتئينا ان نضيف اوكسيد الالمنيوم (AL_2O_3) بتراكيز مختلفة على شكل مسحوق النانو , استعملنا في تجربتنا 3 مقطرات شمسية , المقطر الأول هو مقطر شاهد يحوي الماء فقط , المقطر الثاني يحمل تركيز 1 غ من اوكسيد الألمنيوم لكل 1 لتر ماء , الما المقطر الثالث فيحمل 2 غ اوكسيد الألمنيوم لكل لتر من الماء , كمية المياه المستعملة لكل مقطر هي 2,5 لتر, اثبتنا تجريبيا ان تقنية النانو تحسن من المردود المقطر بشكل مذهل وكانت النتائج كتالي: تحسن في الاداء ب 21٪ للمقطر دو تركيز 1 g/l و كذا 42٪ للمقطر دو تركيز 2g/l.مقارنة بالمقطر الشاهد.

كلمات مفتاحية: مقطر شمسي – فعالية - تقنية النانو- تبخر - تكاثف

Résumé :

Le problème de la pénurie d'eau est l'un des problèmes gênants de nombreux pays dans le monde, d'autant plus que l'eau est l'épine dorsale de la vie, de sorte que l'agriculture, l'industrie et d'autres projets ne peuvent prospérer et croître sans eau, de sorte que l'eau est l'une des composantes les plus importantes et les plus exigeantes de la nature. Pour résoudre ce problème, cette étude présente un moyen simple et peu coûteux de dessaler l'eau, qui est la distillation solaire. Cette méthode souffre d'un gros défaut, qui est le faible rendement. Dans notre expérience, on utilise trois distillateurs solaires, le premier distillateur est un distillateur témoin qui ne contient que de l'eau, le deuxième distillateur contient une concentration de 1 g d'oxyde d'aluminium pour 1 litre d'eau, le troisième distillateur contient 2 g d'oxyde d'aluminium pour 1 litre d'eau. La quantité d'eau utilisée pour chaque distillateur est de 2,5 litres. L'expériencea montré que la nanotechnologie améliore le rendement du distillateur de manière surprenante, et les résultats étaient les suivants: une amélioration des performances de 21% pour la concentration du 1g/l et également de 42% pour la concentration du 2g/ l par rapport au distillateurtémoin.

Mots-clés : distillation solaire, efficacité, nanotechnologie, évaporation, condensation

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LIST OF SYMBOLS

Symbol	**Designation**	**Unit**
Md	Mass flow of distilled water	Kg/s
Q Evp	Heat flux used for water evaporation	W/m^2
Lv	Latent heat of vaporization	J/kg.
G	Global solar radiation	W/m
S	glass surface	m^2
Q_{eau}	Thermal flux actually received by the body of water	W/m^2
Q	Amount of brackish water entering the still	Kg
Ni	Internalefficiency	%
Hv	Glass transmittance	/
He	Water transmission coefficient	/
Ae	Water absorption coefficient	/
Af	Absorption coefficient of the bottom of thedistiller	/
At	Fictitious absorption coefficient of the distiller	/
F.P.B	Gross performance factors	/
F.P.H	Hourly performance factors	/
Q_{re_vi}	Radiation heat flux between the water film and the glazing	W/m^2
Q_{ce_vi}	Thermal flow by convection between the water film and the glazing	W/m^2
Q_{evap}	Thermal flux by evaporation-condensation between the water film and the glazing Flux	W/m^2
Q_{rve_ciel}	Heat flux lost by the glass by radiation to the outside	W/m^2
Q_{cv_a}	Heat flow lost by convection through the glass to the outside	W/m^2
λv	Thermal conductivity of the glass	W/m.°C
δv	Glass thickness	M

$Q_{c.b\_e}$	Thermal flow by convection between the bottom of the tank and the water film	W/m^2
Pe	Power absorbed by the water table, itisnegligible for seawater	W
Q_{cd}	Heat flux lost by conduction of the tank	W/m^2
$Q_{c.d.b\_iso.i}$	Conductive heat flux between the tank and the thermal insulator	W/m^2
M	Mass of condensate	Kg
T_e	Water temperature	°C
T_v	Glass temperature	°C
$Q_{r.e.\_v}$	Coefficient of heat transfer by radiation between the water film and the glass	$W/m^2.°C$
ε_{eff}	Effective emissivity	/
Z	Constant by Stefan - Boltzmann	W/m^2K^4
ε_e	Glass emissivity	/
ε_v	Water emissivity	/
$h_{c.e\_v}$	Coefficient of heat transfer by convection between the water film and the glazing	$W/m^2.°C$
H_{evap}	Transfer coefficient by evaporation-condensation between the water film and the glazing	$W/m^2.°C$
P	Water vapor pressure	Pa
$h_{r.v\_ciel}$	Coefficient of heat transfer by radiation through the glass to the outside	$W/m^2.°C$
T_{ciel}	Sky temperature	°C
Ta	Ambient temperature	°C
V	Wind speed	(m/s)
$h_{c.b\_e}$	Coefficient of heat transfer by convection between the bottom of the tank and the water film.	$W/m^2.°C$

λ_f	Thermal conductivity of the fluid (water)	W/m^2.°C
Gr	Number of GRASHOFs	/
Pr	Number of PRANDTLs	/
Β	Coefficient of volumetric expansion of water.	1/K
Λ	Length of the absorbent tank.	M
Ρ	The density of water.	Kg/m^3
G	Acceleration.	m^2 /s
Μ	Dynamic viscosity.	Kg/m.s
T_b	Tank temperature.	°C
T_i	Insulation temperature.	°C
λ_b	Thermal conductivity of the tank.	W/m. °C
λ_{iso}	Insulation conductivity.	W/m. °C
δ_{iso}	Insulation thickness.	W/(m^2.K)
$h_{iso.e\_a}$	Coefficient of heat transfer by convection between the insulation and the outside air.	W/(m^2.K)
U_I	Overall coefficient of thermal losses of the insulation	J/(kg.K)
C_p	Specificheat	
C	SpecificHeatCapacity	
BF	Base fluid	
CNT	Carbon nanotube	
CVD	Chemicalvapordeposition	
DSSS	Doubleslope solar still	
FE-SEM	Fieldemission-scanning electron microscope	
FPC	Flat plate collector	
MWCNT	Multiwalledcarbon nanotube	
NF	Nanofluid	

NP	Nanoparticle	
PCM	Parabolictrough collector	
PV	Photovoltaic	
PW	Paraffinwaxihyytdd ‘’’’’’’’’’’’’’’’’’’’’’’’’’’’’’’’’’’’’’’’	
SSSS	Singleslope solar still	
TSS	Tubular solar still	

GENERAL INTRODUCTION

The world has experienced many crises and among these crises we find the water crisis. Various studies related to this issue indicate that water will become a crisis of the twenty-first century. The problem of environmental pollution and water pollution in particular poses a major challenge that threatens humanity in the twenty-first century .A Canadian activist "Maud Barlow" mentioned in her book "The Blue Charter" a set of disturbing data, and reviewed facts known to all, including international organizations, and from these data, about 80% of China's rivers, 90% of its underground water is polluted, and 65% of Bangladesh's water, 75% of Russia's surface water, 40% of the United States's rivers, and 46% of its lakes are polluted, and the numbers in the book also report that 700 million Chinese drink polluted water, and 75% of Pakistanis drink polluted water, and that more than 130 million in Latin America drink Polluted water, and that 75% of the population of this continent suffers from drought, and most of the people of Africa also drink polluted water, and 2 million Indian children die annually under the age of five due to water pollution.. Solar energy gradually occupies a great importance in meeting human daily energy needs. This type of energy has an appropriate price and environmental protection, and solar energy is one of the largest types of renewable energy used in water desalination.

There are many methods of desalination in the world, one of the most important methods of desalination of salty water is the use of nanotechnology, and this is what we discussed in our research. The aim of this topic is to employ nanotechnology to desalinate water and demonstrate its effectiveness in improving the yield of a simple solar distillery for different concentrations of nano powder (AL2O3).

This research contributes to the development of solar water desalination technology in Algeria, and to addressing the problem of drinking water scarcity

Our research contains 5 chapters divided as follows:

Chapter I: At the beginning, we touched on a historical note about solar distilleries and some global research done on solar distilleries. We also presented the principle of simple solar distillation and some types of solar distillers. We then touched upon information about theearth.

and the sun, and then we detailed the internal and external factors affecting the solar distillation process.

Chapter II: we refer to the geographical location of Ghardaia and its administrative division of the state, as well as its climate, geological structure, and water quality in it.

Chapter III: We first discussed the laws of solar radiation, in the end we conclude by studying the thermal equilibrium inside the solar distillery.

Chapter IV: We first discussed the definition of nanotechnology and its history, then we discussed the properties of materials in the nanoscale, the reasons for interest in nanotechnology, as well as the techniques for preparing nanomaterials. We also discussed some applications and uses of nanotechnology.

Finally, we concluded this chapter by studying the properties of nanofluids associated with heat transfer

Chapter V: Dedicated for analysis and discussion of results

Chapter I

generalities about solar distillation

Chapter I: generalities about solar distillation

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I-1 History:

Since prehistoric times, the sun has been drying food and evaporating seawater to extract salt; so, people started thinking to find ways to use this energy. During the nineteenth century, many attempts were made to convert solar energy into other forms that depended on the generation of vapor with low pressure. to run vapor machines

The scientist (Archimede) made the first breakthrough in the field of using solar energy by inventing glass material, where he was able to exploit it in the manufacture of lenses and mirrors to contribute to the exploitation of these solar radiation. It was the first actual exploitation of solar energy in the field of distillation by the English scientist (Harding) in 1872 in the North Chilean desert (LAS SALINAS). [1]

In the year 1950, research started heading towards improving the techniques of obtaining fresh water using solar energy, and using solar distillers, which have multiple types. Research is still underway in designing a study of new types of solar distillers. In 1965, Florida decided to build four solar distilleries. [2]

In 1980 Wibulswas and his group studied cylindrical solar distillers with vertical absorption and evaporation surfaces with a diameter of 0.1m and a height of 1m covered with a cylinder of 0.3m diameter and obtained daily productivity of up to **1.7 l / m^2** where the solar radiation rate was 17 MJ / m^{2}d. [2]

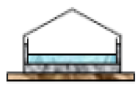
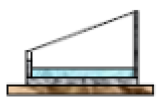
In 1987, the researcher (Kiatsiriroat) and his group presented an analysis of evaporation and absorption in the one-side distillates as well as the distillates with two sides covered with glass, the theoretical results were completely consistent with the practical results, then they simulated the performance of the distillator for a whole year and for different distances between the absorption surface and the glass cover .

In 1998 (A. EL-Sebaii) studied the factors affecting the productivity of the vertical solar distiller and found that the productivity increases with increasing wind speed (to some extent) and decreases with the increase of the distance between the absorbent surface and the glass cover . The productivity increases with increasing the distillation area down to **3.5m^2**[2]

In 2004, the researchers (M.Boukar and A. Harmim) studied the factors affecting the performance of the vertical solar distillers under desert climatic conditions, and they found that productivity depends closely on the intensity of the solar radiation and the temperature of the atmosphere and on the direction and obtained productivity ranging from **(0.5-2.3). l / m^2** [2]

In 2008 in the Egyptian city of Alexandria, the researcher (Kabeel) studied the performance of the filamen solar distillate. This distillate has a concave basin with four transparent covers forming a pyramid above the concave basin in order to increase the entry of solar radiation to it, where the average productivity **4l/m^2**and the system efficiency **38%.** [3]

The following Table is characterized by the development of the productivity of some distillates throughout history

The place where the achievement was made	Achieveme n f	Productivity L/ m^2 /j	Productivity L/jour	Solar radiation W/m^2	The shape used in the achievement
Muresk (Australia)	1966	4.03	2.2	246	
Coober (pedy)	1966	3.987	3.22	246	
Caiguna	1966	4.03	-	246	
Hamelin(pool)	1967	3.87	-	-	
Las Salinas(Chili)	1872	3.99	-	-	
Bhavnagar(India)	1965	-	1.5	-	
Aldabra(Ind.ocean)	1969	3.8	-	250	
Bakharden(USSR)	1969	4	1.75	-	
Shafrikan (USSR)	1970	4	1.75	-	
)NatvidadMexico)	1969	-	0.41	400	
Chakhmou(Tunisi a)	1967	1.8	0.75		
Mahdia	1968	5.23	4.48		
Haiti(Caribbean)	1969	4.03	0.81		

I-2- Definition of the solar distiller:

The solar distiller is a wooden box with a transparent glass cover that allows the transfer of solar radiation. This box contains an amount of salt water over a black base to absorb the largest amount of radiation. With the effect of radiation heat, the water temperature inside the box becomes higher than it surrounds, which helps to Water evaporated. The vapor rises and condenses on the inner surface of the glass, then collects in the channel of distilled water (Figure1-1). [5]

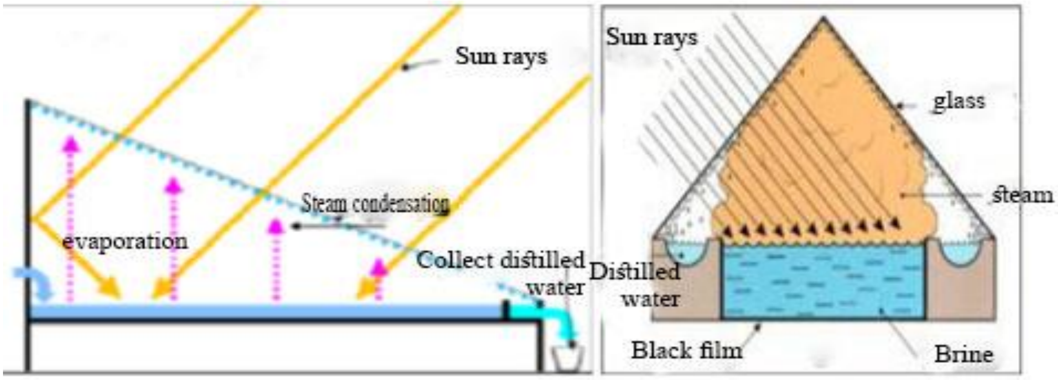


Figure I-1: The basic principle of simple solar distiller [5]

I-3 Some Scientific Research On Solar Distillers :

In 1984 (Attaseth) and his group manufactured two similar vertical distillers for the purpose of studying the effect of different glass and plastic covers on the rate of productivity, and they noticed that the productivity of the distilled glass cover is higher than in the case of plastic covers up to 10%. [2]

In 1994 at Brunel University in the city of Oxford in Britain, researchers presented (Mahdi and Smith) a design for a solar filament destiller using concentrated solar reflectors. The study was carried out in summer and winter and to show the effect of the reflector. The researchers concluded that the distillate's productivity in the summer without the reflector is greater than the productivity of thedestiller with reflector and the reverse state in the winter season as the productivity increases with the presence of the reflector more than in the absence of it. [3]

In the year 2000 (Tanaka), an applied study was carried out to design a set of rectangular cells with an inter-dimensional dimension between two 5mm plates. It also contains a piece of tissue attached to the hot plate of the cell. The solar distillator used is a single slope type. Theoretical results have concluded that if the number of cells increase the productivity . Theoretically, the proposed output reaches more than **15 kg/m^2/d** for 10 cells with an intermediate dimension of 5mm, for solar radiation of **22.4MJ / m^2 / d.** [4]

As a result of the increase in the rate of vapor trapped inside the solar distiller, which creates additional pressure,(El-Bahi) thought, to reduce the effect of this phenomenon by opening a small incision to pass the vapor to a second condensing room, reinforced with an additional condenser and a reflector of radiation, which gives him an advantage to improve the performance of the device. The daily production rate of this design is about **7 L/m^2 /d**, where its efficiency decrease to 70% when it works by adding the condenser, but it increases to 75% as soon as we abandon the condenser. [4]

Chaibi (2000) completed a numerical study on a greenhouse prepared for cultivation and containing a solar distiller directed towards the direction of solar radiation

This distiller consists of transparent materials for incident radiation. Through the authorized results, this proposed model is suitable for use in areas with a dry climate in order to adapt climatic conditions to help plants grow in areas that lack moisture, and distilled water can be produced for use in the watering process. The productive capacity obtained from this model is estimated about 1-1.6 kg/m/J, and therefore this model is among the proposed systems for the production of fresh water for use in irrigation of agricultural crops. [4]

Boukar and Harmim (2001) have experimentally demonstrated the efficacy of vertical solar distillers when using the evaporative water flow feature on a sponge cloth surface. The same research indicated that the rate of production doubles automatically with the increase in the temperature of the desert region and the increase in the temperature of the glass cover, as the study showed over a period of 4 months that the productivity of such a vertical distillate varies from 0.5 to22.3 kg / m^2. [4]

In 2006 in the Indian city of New Delhi, the researcher (Tiwari) studied the effect of water depth on the productivity of the solar distillate in the summer. Where he took the clear cover angle 30 ° and readings were taken for 24 hours for five different days and for five different depths of water in the distilled basin starting with a depth of 0.4 meters and ending with a depth of 0.18 meters. It was found that the productivity of the solar distillery decreases with increasing depth of water in the basin. [3]

In 2007 at Al-Balqa Applied University in Amman, the researcher, Badran, conducted an experimental study to improve the production of single slope distiller. Where the study was carried out on various factors such as painting the asphalt basin or spraying it and changing the depth of the water. This study found that productivity increases by 51% when asphalt coating and productivity increases by reducing the depth of the water in the distiller. Badran showed the effect of external conditions. At night, productivity is about 16% of daily production with solar radiation due to the difference between the heat bike for water and the outer cover. [3]

Bechki (2010) piloted a simple double-slope solar distiller in southern Algeria on the basis of partial shading of intermittent periods of one side of the glass cover in order to reduce its temperature and improve condensation performance. This work gave an improvement of 12% of daily output [4]

In 2011, the two researchers (Walke and Teltumbade) in the Indian city of Maharashtra presented an experimental study on single-slope solar distillers using various radiation absorbent materials in the inner basin where they used a rubber mat as well as black ink and sponge. It turned out that the rubber is more effective, followed by black ink, which was finally made of sponge. As we have shown through their studies, the internal heat is chosen over production, and they found that with increasing internal heat, production increases [3].

The main objective of his work (2011 Zeroual) was to enhance the daily yield of the simple double slope solar distiller by improving the performance of the condenser. This was accomplished by cooling one of its condensed surfaces. As a result, two series of experiments were carried out. In the first group, the northern cover was cooled with flowing water on its entire outer surface, so productivity increased by 11.8%. As for the second series, the northern glass temperature was lowered by setting intermittent shadows at intervals of (12:00 to 14:00), the improvement rate for this procedure was about 2.94%. (4)

I-4 Principle of solar distiller:

The principle of the solar distiller is the same as the principle of the natural phenomenon of solar distillation. When the solar radiation falls on the water (oceans, lakes and rivers), this water is heated and then evaporates and rises to the top. The vapor travels through the wind until it reaches a cooler place, joining together and clouds forming as rain or snow. The principle of the solar distiller is as follows: the water in the basin is heated by sunlight and evaporates, the resulting water vapor is transferred on the inner side of the cover at a temperature between the salt water temperature at the base and the surrounding temperature. The water droplets formed flow over the inner glass cover by its weight to the distilled water collection bowl (Figure I-1). [5]

I-5- Types of solar distillers:

I-5-1 simple distiller:

It is the most used distillater in the world. It contains a basin with a black-coated base for capturing the largest amount of solar radiation. This basin is filled with water and covered with a transparent glass. The glass cover should be tilted to condense the vapor in its inner part. The simple distiller is distinguished by its ease of construction and maintenance, as well as its small cost, but its main disavantage is its poor production of water for distilled water. [4]

I-5-1-1 Single slope distiller:

It is the simplest solar distiller ever. Any middle-level person can manufacture and maintain its components. See Figure I-2. [4]

The solar distillate consists of one of the following:

_wooden box-Glass cover- Water collecting tube-Water collecting vessel

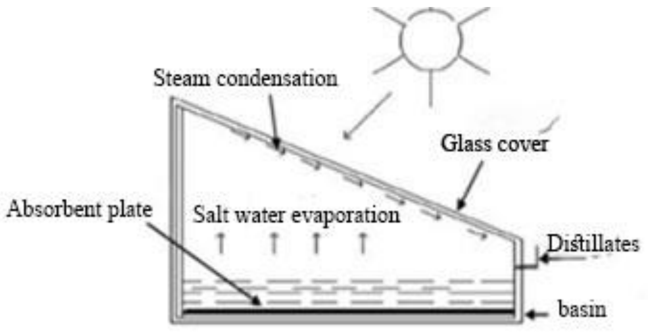


Figure I-2single slope distiller [4]

I-5-1-2 Double slope distiller:

It has the same principle as the single slope distiller, except that it has two covers, each one at an angle β Among its advantages is that one of the covers is directed to the sun and the other is directed to the shade to increase the area of solar radiation capture and to accelerate the condensation process . [4]

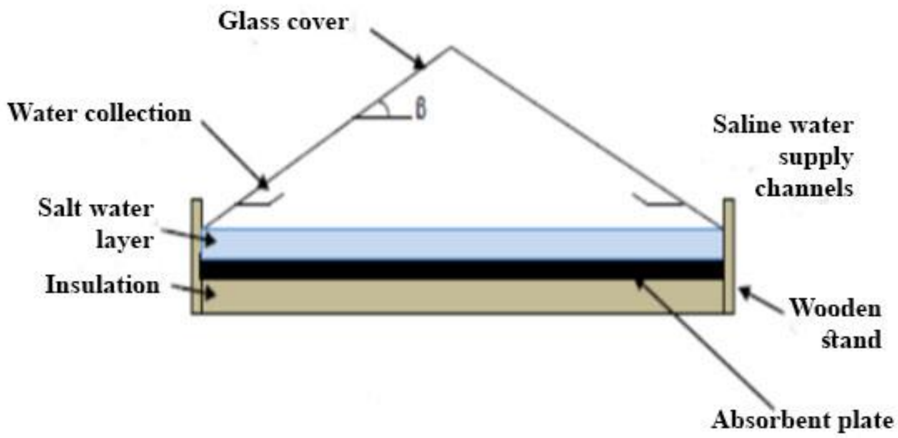


Figure I-3 double slope distiller [4]

I-5-2 Solar distiller Earth-Water:

A large quantities of moisture are stored in the ground to return to the atmosphere in dry areas during the hot season to complete the natural hydrogen cycle; For this, we use the solar distillater (Earth - Water) which resembles the double slope only replacing the black basin with Earth. [5]

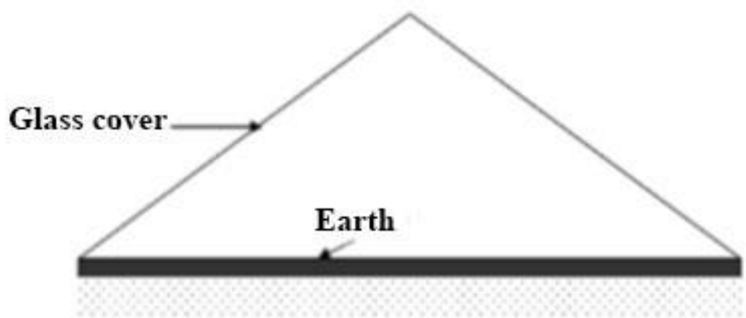


Figure I-4 solar distillerearth- water [5]

I-5-3 Spherical Solar Distillater :

The spherical solar distiller is in the form of a transparent ball made of glass inside it contains a circular basin that has a black color that works as a thermal radiation absorbent in which salt water is placed to evaporate and then the condensation of vapor to rise until it touches the inner surface of the glass and then collect at the bottom of the spherical shape and to make the inner glass transparent we use a scanner electrician. [4]

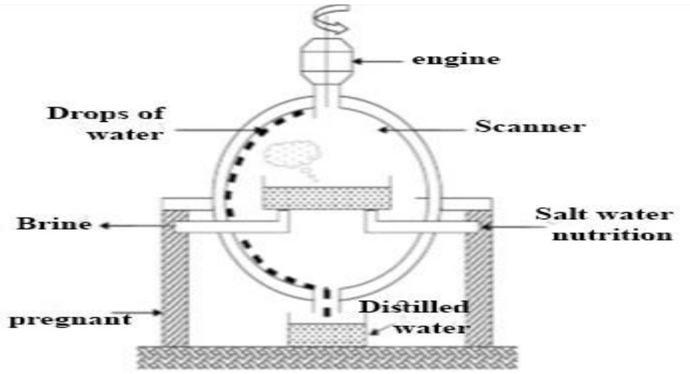


Figure I-5 : The spherical solar distillation [4]

I-5-4 Solar vertical distillation:

The vertical solar distillers consist of an aluminum absorption plate covered with a black cotton cloth. The distiller is feeded with salty water to be distilled from a main tank connected to the distiller by a plastic tube whose flow rate is controlled by parameters. Salt water is introduced into the vertical distiller through the tube in the upper channel with a specific depth in which the upper end of the black cotton cloth is to be saturated with wate. Due to gravity and water absorption of the cloth, the entire piece is wet with water, distributed almost evenly and subjected to vaporization, then the vapor condenses on the inner surface of the glass and the water is descended to the water collection channel (Figure I-6).

The excess water from evaporation collects in the lower channel where the lower end of the piece of cloth is located to help also wet the cloth from the bottom and its rise with the capillary properties feature. In addition, it comes out of the excess salty water exit tube attached to the lower channel. [5]

A) _Vertical solar distillers witn one side

(B) _ the vertical solar distiller, with two sides

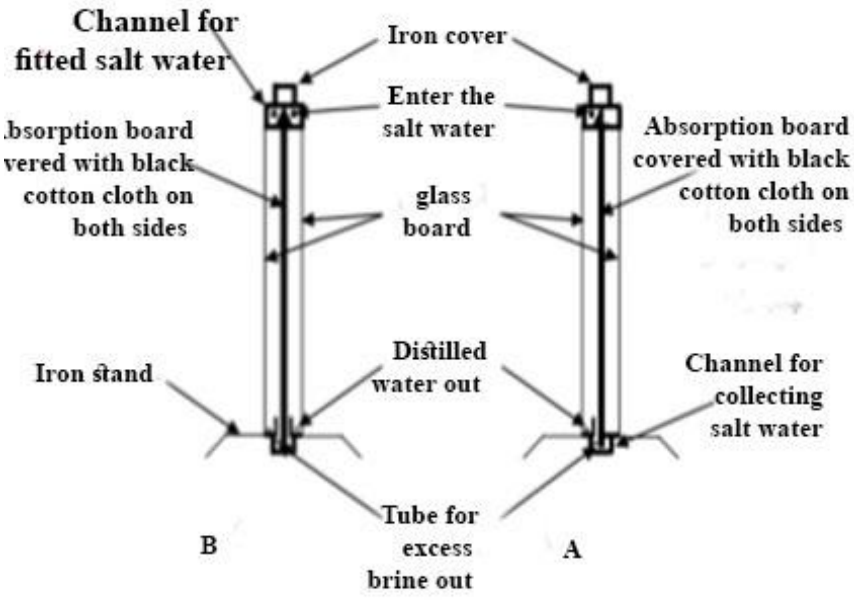


Figure 1-6 vertical solar distiller [5]

I-5-5 Other types:

The technological development has produced different types of distillates, all aiming to improve the efficiency, among them: multi-effect distillers - cylindrical solar distillers - a glass cover distillers - incandescent solar distillers - plastic solar distillers - stepped solar distillers - conical solar distillers

I – 6 Internal and external factors affecting the distillate's yield:

I-6-1 External factors:

I-6-1-1 Solar radiation intensity:

Solar radiation is among the most important factors affecting the work of the solar distiller. The source of this radiant energy is a tiny, weightless particle called photons that is responsible for exciting the electrons when they collide with the photovoltaic cells.

Several researches were carried out to study the effect of solar radiation on solar distillation, and the results obtained by (Safwat 2000 and Rahbar2012) prove without a doubt the significant increase of distilled water resulting with increased intensity of solar radiation. [6]

I-6-1-2 Wind speed:

Cooper, 1960, demonstrated that the distillation yield increased by 11.5% with an average wind speed 2.15m / s, while it increased by 1.5% for wind speed values in the range from 2.15 to up to 8.8 m / s and thus we could say that the excess wind speed has a slight effect on the distillation rate. [6]

I-6-1-3 Effect of ambient temperature:

Several studies have been done to find out the **effect of ambient temperature** on the efficiency of the solar distiller. The theoretical model proposed by (Malik1982) determined that in order to increase the **ambient temperature** by 5 ° C, there is a slight increase of 3% in the efficiency of the solar distiller. This result coincides with the work done by (ALHinan2002), that assured a rise in the ambient temperature by 10 ° C will improve the efficiency of the device by about 8.3%. [6]

1-6-1-4 Other factors:

In addition to wind speed Solar radiation intensity and ambient air temperature, there are other atmospheric factors such as ambient air humidity and the amount of rain that must be taken into account so that they change the thermal balance of the distiller.

I-6-2 Internal factors: [6]

I-6-2-1 The effect of the thermal insulation of the distiller body:

Solar distillation productivity depends largely on the efficiency of the used thermal insulation and this efficiency depends directly on the value of thermal insulation, so it is necessary to balance the value of thermal insulation with the value of distiller productivity. [6]

I-6-2-2 Effects of salty water depth in distiller base:

Several studies have sought to demonstrate the effect of the thickness of the water layer in the basin on daily production of distilled water. The authorized results confirm the decrease in the distillate yield as the thickness of the aquarium increases. [6]

I-6-2-3 Vapor leakage effect from distiller:

Vapor leakage from the distiller is one of the most important factors that leads to a significant reduction in distilled productivity, so it is recommended to place the lid on the distiller to prevent the leakage of water vapor from the distiller into the surrounding atmosphere, The best materials used for this purpose are silicon rubber material with permanent maintenance. [6]

I-6-2-4 Slope of glass on the horizontal surface:

The inclination of the glass plays an important role in the work of the solar distiller, so it is important to choose a lower tilt of the glass without causing the water to leak into the salt water basin. Empirical studies have confirmed that the optimum value of the inclination is between (10-50 °). [6]

I-7 The earth and sun:

I-7-1 The sun:

The sun is a gas ball with a diameter of about $1.39 * 10^9$ m, and its masses about $2 * 10^{30}$ kg, and its lifespan is about $4.6 * 10^6$ years. The average distance from Earth is 149,500,000 km. The sun is the seat of thermonuclear reactions that convert every 564 million tons of hydrogen every 560 million tons of helium, while the remaining 4 million tons are converted to energy in the form of radiation. The core temperature of the sun is about 10^7 k, and the surface temperature of the sun is 5760 k

I-7-2 The importance of solar radiation:

Solar radiation is the main source of energy in the atmosphere, as it contributes to more than 99.97% of the used energy in the atmosphere and on the surface of the Earth. As for the other sources of energy represented by the interior of the earth, the energy of stars, and the tides, they only contribute a small premium that does not exceed 0.03%. Solar energy is responsible for all processes that occur in the atmosphere, such as atmospheric disturbances, clouds, rain, wind, lightning, thunder, and others. The main cause of the continuous movement of the atmosphere and the variability of weather and its change are the differences that exist between one place and another in the abundance of solar energy. [7]

I-7-3 Nature of solar radiation:

The sun can be likened to a huge nuclear reactor in which energy is generated by the nuclear reactions whereby hydrogen atoms are converted into helium and the excess of the reaction generates energy, which is solar energy. The energy of the sun is in the form of different waves traveling at a speed of light estimated at about 300,000 km / s, and since the distance between the Earth and the sun is on average about 152 million km, the solar rays reach the surface of the earth approximately eight minutes after sunrise. [7]

The sun revolves around its axis from west to east once every 42,86 days, but the movement of the Earth in its orbit around the sun makes the length of this cycle relative to the surface of the earth 29,86 days. Shiny spots of various widths appear on the sun disk, known as sunspots. They are inflamed gas fountains or powerful hurricanes that erupt from the body of the sun in the space. [7]

The sun is made up of two main elements, which are hydrogen, whose rate is 81.76%, and helium, whose rate is 18.17%, while the proportion of other gases, represents only about 0.07%. [7]

Wavelengths of solar radiation are short wavelengths, while wavelengths of ground radiation ground radiation is called long-wave rays. Not all wavelengths of solar radiation are of equal length. Scientists have distinguished three different types of solar radiation

I-7-3-1 Thermal rays:

Also known as infrared ray, they are invisible rays whose wavelengths range from 750 nm to 0.1 mm . It is estimated at about 49% of the total solar radiation. The largest part of these rays contributes to raising the temperature of the Earth's surface and atmosphere, and as such has a great impact on climate studies. [7]

I-7-3- 2 Optical Rays:

It is a visual ray that is estimated at 34% of the total solar radiation, and its wavelengths range from 390 nm to 750 nm . In it, we can distinguish blue, red, yellow, green, and other rays that form by mixing them with light. This radiation is used by plants in the process of photosynthesis. [7]

I-7-3-2 UV ray:

Sometimes known as biological radiation. It accounts for 7% of the total solar radiation, which is short-wave radiation, the length of which ranges between 10-390 nm These rays are useful to humans when they reach them in small quantities, as they help to treat some diseases, especially rickets, due to their ability to form vitamin (D). These rays also have severe damage to humans and all living organisms, and they have an impact on the climate, and fortunately they do not reach Earth except a very small percentage because it is absorbed by the ozone gas, which is at an altitude of 35 km. The remainder of the solar ray, which is estimated at 10 %, will be in the form of It is in the form of X-waves, gama waves, and radio waves. [7]

I-7-4 Earth :

Earth is a rocky planet with a high density and mineral composition, and it revolves around the illuminating sun, which is considered the source of light and heat. The Earth is the third planet in terms of the distance that separates it from the sun, and this makes it at a suitable distance keeping its temperature within a moderate range, which allows water to be in its liquid state on its surface, and for life to flourish. The Earth is a planet that is covered by water bodies. The area of water bodies is 71% of the total land area. (8)

I-8- The effect of atmosphere components on solar radiation:

The air that creates the atmosphere is a barrier between the sun and the Earth's surface, as only a portion of the solar constant is allowed to reach the Earth's surface. The amount of solar radiation reaching the surface of the earth depends on the composition of the atmosphere. Whenever it is transparent and pure, that is, free of water vapor and clouds, the greater the energy reaching the surface of the earth, and this is why the radiative amount arriving to the surface of the earth under the pure atmosphere, such as deserts - is equal to 3/4 Total solar constant. The amount of solar radiation reaching the Earth's surface is in any case less than the amount of solar radiation reaching the top surface of the atmosphere. Three processes that can be exposed to solar radiation can be distinguished. [7]

I-8-1 Absorption:

Oxygen and nitrogen gas, which are more than 99% of the atmosphere, are good conductors of solar radiation, as they allow solar radiation to pass through without absorbing anything from it. As for the ozone gas, which is only a small percentage of the atmosphere, it is characterized by its great ability to absorb short-wave rays that are less than 0.3 micron long.The ozone layer absorbs a large part of the short-wave sunlight, especially ultraviolet radiation, and allows only a small portion of it to reach the surface of the earth. The solar radiation absorbed by ozone is estimated at 2%. Water vapor, which is concentrated in the lower atmosphere, absorbs between 6% and 8% of the solar radiation. Water vapor absorbes very well rays that range in length from 4 to 4,5 microns, and the rays that range in length from11-30 microns. As for dust particles, they absorb 3% of the solar radiation. Thus, it can be said that more than 12% of the solar radiation that passes through the atmosphere is absorbed by that atmosphere before it reaches the Earth's surface. [7]

I-8-2 Diffusion of radiation:

The refraction of radiation as it passes through the atmosphere results in its diffusion in all directions. The diffusion process is air particles, water vapor, dust particles, smoke, salts and other impurities suspended in the air.The percentage of diffused rays exceeds 9%of the total solar radiation, but that percentage varies greatly from place to place and from time to time depending on the difference in the degree of display and cloudiness. [7]

I-8-3 Reflection of radiation:

Clouds, water droplets suspended in the atmosphere, and other snow crystals and impurities play a large role in reflecting part of the solar radiation, but clouds are the main factor that reflects the greater part. Clouds that form in the Earth’s atmosphere reflect a large part of the sun’s rays. The amount of solar radiation reflected by clouds varies with the quality of clouds and their height. The solar reflection coefficient of cumulus clouds is greater than 90 %, and therefore, little direct solar radiation reaches the Earth’s surface on days when the sky is cloudy. However, thin and very high clouds reflect only a small percentage of the solar radiation heading to the surface of the Earth. [7]

I-9 Sun Tracking:

The position of the sun at every moment of the day and year is determined by two different coordinate systems. [9]

I-9-1 Tropical coordinates:

The movement of the sun is determined by two angles:

Declination δ and Hour angle ω [9]

I-9-1-1 Declination of sun

Declination of sun δ is the angle formed by the direction of the sun with the equatorial plane. It varies during the year between -23.45 ° and + 23.45 °. It is zero at the equinoxes (March 21 and September 21), The maximum is at the summer solstice (June 21) and the minimum at the winter summer solstice (December 21). (Figure I-8). [9]

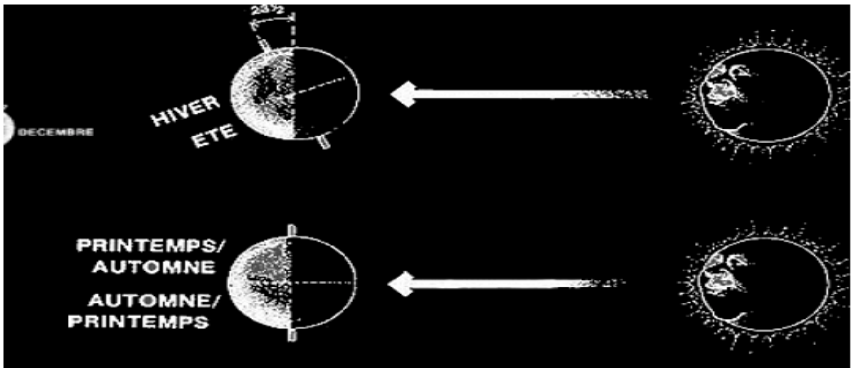


Figure I-7Declination of sun [9]

Many researchers have suggested formulas for calculating Declination, the following formula allows to do so accurately. [9]

$$\delta = (0.006918 - 0.399912\cos\Gamma + 0.070257\sin\Gamma - 0.006758\cos 2\Gamma + 0.000907\sin 2\Gamma - 0.002697\cos 3\Gamma + 0.00148\sin 3\Gamma)(\pi/180) \quad \textbf{(I-1)}$$

Γwhich is expressed in radians, is called the angle of the day and is given by :

$$\Gamma = \frac{2\pi(nj-1)}{365} \quad (\mathbf{I-2})$$

.

n_j is the number of the day per year, ranging from 1 to 365. (On January 1, nj = 1 and 31December, nj = 365). [9]

I-9-1-2 Hour angle of the sunω:

At any time, calculating time by grades is more practical than hours. The unit is an hourly angle (24 hours representing 360 degrees). The hour angle is the angle between the original meridian passing through the south and the projection of the direction of the sun on the equatorial plane, it measures the course of the sun in the sky. [9]

$$\omega = 15(12 - TSV).(Degre) \qquad (I - 3)$$

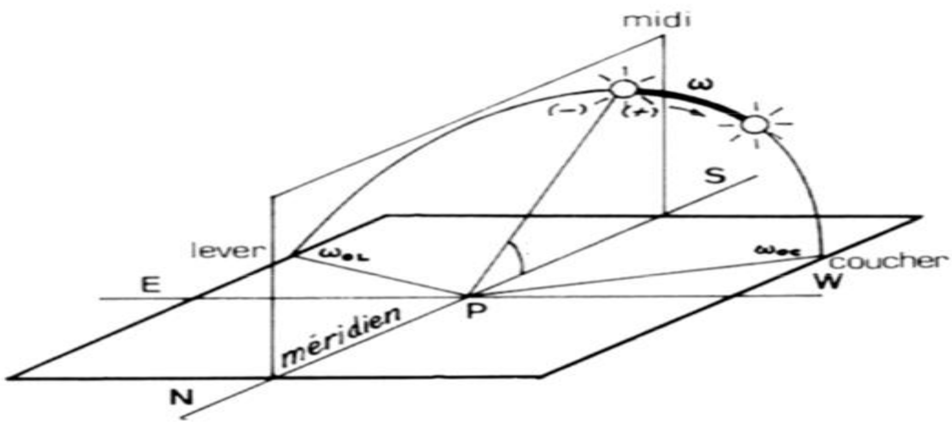


Figure I-8 Hour angle [9]

I-9-2 Horizontal coordinates:

The horizontal coordinate system is formed by the plane of the astronomical horizon and the vertical location. In this coordinate system, the coordinates are the height of the sun, 'h' and the azimuth a_z [9]

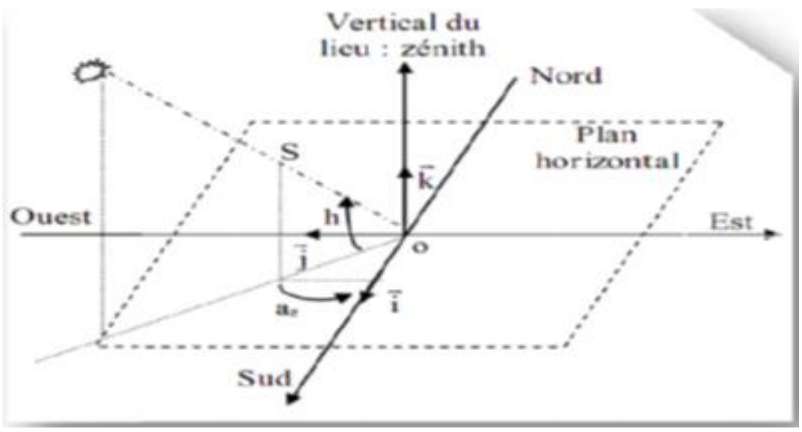


Figure (1-9) Horizontal coordinates [9]

I-9-2 -1 The height of the sun:

The height of the sun is the angle formed by the direction of the sun and its projection on the horizontal plane. It is particularly equal to 0 ° at the astronomical sunrise and sunset, its value is maximum at noon, in true solar time. The expression of the height of the sun is given by. [9]

$$\sin(h) = \cos(\delta)\cos(\varphi)\cos(\omega) + \sin(\varphi)\sin(\omega) \qquad \text{(I-4)}$$

φlatitude of the place ; declination of sun δ ;hour angle of the sunω

I-9-2 -2 Sun azimuth:

The azimuth of the sun is the angle between the projection of the direction of the sun on the horizontal plane and the direction south. [9]

$$\sin a_z = \frac{\cos\delta \sin\omega}{\cos h} \qquad (\text{I}-5)$$

It is zero at noon TSV and maximum at sunrise and sunset.

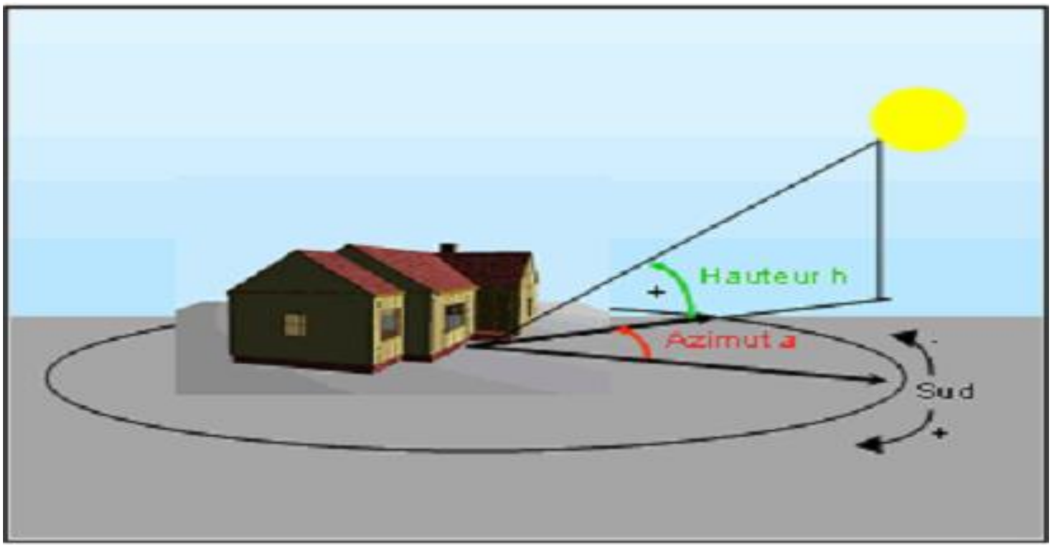


Figure 1-10 Sun azimuth [9]

I-9-3 Orientation of a plan

Any plane is defined by two angles (α, γ)

α: azimuth of the plane, this is the angle made by the projection of the normal on the horizontal plane and the direction of south.

γ: height of the plane, this is the angle made by the normal of the plane and its projection on the horizontal plane. Its value can be calculated by the equation: [9]

$$\gamma = 90^{o} - \beta \qquad (I-6)$$

β ': inclination of the plane, this is the angle between the plane and its projection on the horizontal plane.For a horizontal plane: β '= 0 and γ = 90º.

I-9-4 Angle of incidence of the sun's rays:

The angle of incidence of the solar beam with any plane of inclination and orientation (β ', γ) is the angle formed by the directional vector of the solar beam and the outgoing normal to the plane. [9]

For a south-facing plane

$$\cos(i) = \cos(\delta)\cos(\omega)\cos(\varphi-\beta) + \sin\delta\sin(\varphi-\beta) \qquad (I-7)$$

For a north facing plane

$$\cos(i) = \cos(\delta)\cos(\omega)\cos(\varphi-\beta) + \sin\delta\sin(\varphi+\beta) \qquad (I-8)$$

I-9-5 Tilt factor:

The hourly tilt factor is given by the equation: (9)

$$r_b = \frac{\sin(\delta)\sin(\varphi-\beta)+\cos(\delta)\cos(\varphi-\beta)\cos(\omega)}{\sin(\delta)\sin(\varphi)+\cos(\delta)\cos(\varphi)\cos(\omega)} \qquad (I-9)$$

The daily tilt factor is given by the equation:

$$R_b = \frac{[(\pi/180)w'_s]\sin(\delta)\sin(\Phi-\beta)+\cos(-\beta)sin w'_s}{[(\pi/180)w'_s]\sin(\delta)\sin(\Phi)+\cos(\delta)\cos(\Phi)sin(w'_s)} \qquad (I-10)$$

I-10 Solar Flux at Ground Level:

To be able to size a solar installation, it is necessary to know the amount of energy available. For a given plan, incident irradiation, called global irradiation, is the sum of three components. [9]

I-10-1 Direct irradiation :

which comes directly from the sun. This component is zero when the sun is hidden by clouds or by an obstacle (building, distant mask).

I-10-2 Diffuse irradiation:

which corresponds to the radiation received from the sky, except direct radiation.

I-10-3 Reflected irradiation :

which corresponds to the radiation reflected by the soil and the environment. This component is zero on a horizontal plane.

I-11 Characteristics and performance of destiller:

Several quantities are defined in order to characterize a solar destiller. Wedistinguishes: distillate production, conversion rate, efficiency, yield and performance [10]

I-11-1 Production and conversion rate:

The mass flow rate of distilled water is given by the following relationship:

$$\dot{m}_d = \frac{Q_{evap}}{L_v} \qquad (I-11)$$

The production of a solar still distillate represents the amount of distilled water produced, per square meter of evaporation surface and per day, it is calculated byintegrating the previous relationship in a time interval. [10]

We can also define a very important quantity, it is the conversion rate which represents the ratio between the amount of distilled water and the amount of brackish water entering the distiller either: [10]

$$\boldsymbol{Q} = \frac{\dot{m}_d}{\int_{tlc}^{tcs} \dot{m}dt} \qquad (\mathbf{I-12})$$

I-11-2 Overall efficiency:

The overall daily efficiency is the ratio between the amount of heat used for evaporation by the amount of incident global energy, which can be calculated by the following formula. [10]

$$\boldsymbol{\eta_g} = \frac{Q_{evapo}}{GS} = \frac{\dot{m}_d}{GS} L_v \qquad (\mathbf{I-13})$$

I.11.3 Internal efficiency

Internal efficiency is the ratio of the amount of heat used to evaporation per unit of time and the amount of energy actually absorbed by the salt water per unit of time, it is calculated by the following formula: [10]

$$\boldsymbol{\eta_i} = \frac{Q_{evapo}}{Q_{water}} = \frac{\dot{m}_d}{\alpha_t GS} L_v \qquad (\mathbf{I-14})$$

For an overall intensity G, the expression Q_{water} becomes

$$\boldsymbol{Q_{water}} = (\tau_v \alpha_e + \tau_v \tau_e \alpha_f) \qquad (\mathbf{I-15})$$

Then $\eta_i = \frac{\eta_g}{\alpha_t}$

τ_v glass transmission coefficient;

τ_e water transmission coefficient;

α_e water absorption coefficient;

α_f absorption coefficient of the bottom of the still;

α_t fictitious absorption coefficient of the distiller;

The coefficient α_t depends on the angle of incidence of the incident radiation with respect totheglass.

I-11-4 Performance:

In order to characterize a still more absolutely, we have been led to define the gross (F.P.B) and hourly (F.P.H) performance factors: [10]

FPH = Quantity of water produced after one hour/ amount of energy entered after one hour

FPB = Quantity of water produced after 24 hours/ Amount of energy entered after 24 hours

A un instant donné de la journée, le facteur de performance FP est donné par la relation :

$$\mathrm{FP} = \frac{\dot{m}_d}{\alpha_t G S} \qquad (\mathbf{I-16})$$

1-11-5 Yield:

This is the amount of water produced per unit of plan area per day.

The major disadvantage of this criterion is that it does not mention the solar energy which arrives on the distiller. (10)

The performance of a single distiller is :

$$\eta = \frac{\dot{m}_d}{G} \mathrm{h_{ev}} \qquad (\mathbf{I-17})$$

$h_{ev}$is Enthalpy of evaporation

Chapter II

Geographical characteristic of Ghardaia

Chapter II: Geographical characteristic of Ghardaia

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II-1 Geographical location:

The state of Ghardaia is located in the northerndesert of Algeria, 600 km south of the capital of Algeria, its total area is 86105 km², its extension fromnorth to south is 450 km and fromeast to west is 200 to 250 km, it rises at sea level by 640 m.Ghardaia's location is determined by longitude 3.6333 east and longitude 32.2667 north. Its borders are:

Laghouat and djelfa from the north, Elbeidh and Adrar from the west, Ouargla from the east and Tamanrasset from the south.

Ghardaia is the capital of Ghardaia, it is at 200 km from the capital of Laghouat, 200 km from the capital of Ouargla, 480 km from the capital of Adrar, 1400 km from the capital of Tamanrasset .It is crossed by National Road No. 1 linking between the Algerian capital and the charming big south. [11]

II-2 Administrative division:

Ghardaiaisdevided into 9 departments which is divided into 13 municipalities

1- Mitili department: It consists of two municipalities: Mutili, Sebsab

2- Al-Manea department: it consists of two municipalities: Al-Manea, Hassi Al-karah

3- Bannoura department: it consists of two municipalities: Al-Atef and Bannoura

4- The Mansoura department: it consists of two municipalities: Mansoura, HassiFahl

5- Ghardaia department: it consists of one municipality: Ghardaia

6 - Daya Bin Dahwa Department: which consists of one municipality: Daya Bin Dahwa

7 –Zilfana department: it consists of one municipality: Zelfana

8- Berian department: it consists of one municipality: Berian

9 - Al-Gerara Department which consists of one municipality: Al-Qarara

Figure II-1: An illustrative map of the province of Ghardaia [11]

II-3 Climate:

Ghardaia is characterized by a dry desert climate, where the annual rain fall is less than 100 mm The average annual rain fall is about 60 mm see Fig.II.2 .The average value of rain fall does not have much importance because the rain may decrease for several years, but two to three days of rain can bring 50 to 80 mm, which sometimes causes large floods with large flows which can reach 1000 m 3 / sec For 50 years.

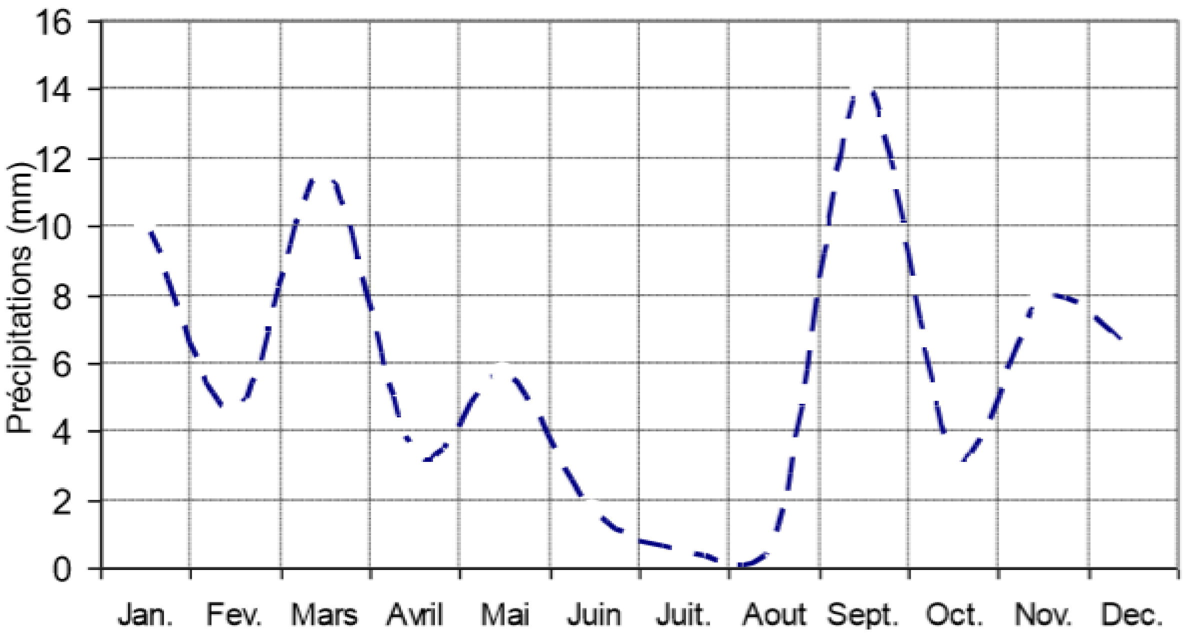

Fig.II.2 – Monthly precipitation (mm)(2014-2018) [11]

The temperatures in the winter is between (1 to 25 c°), while in the summer is between (18 -48 c°), and the weather is moderate between the spring and autumn seasons,the sky is clear most of the year. [12]

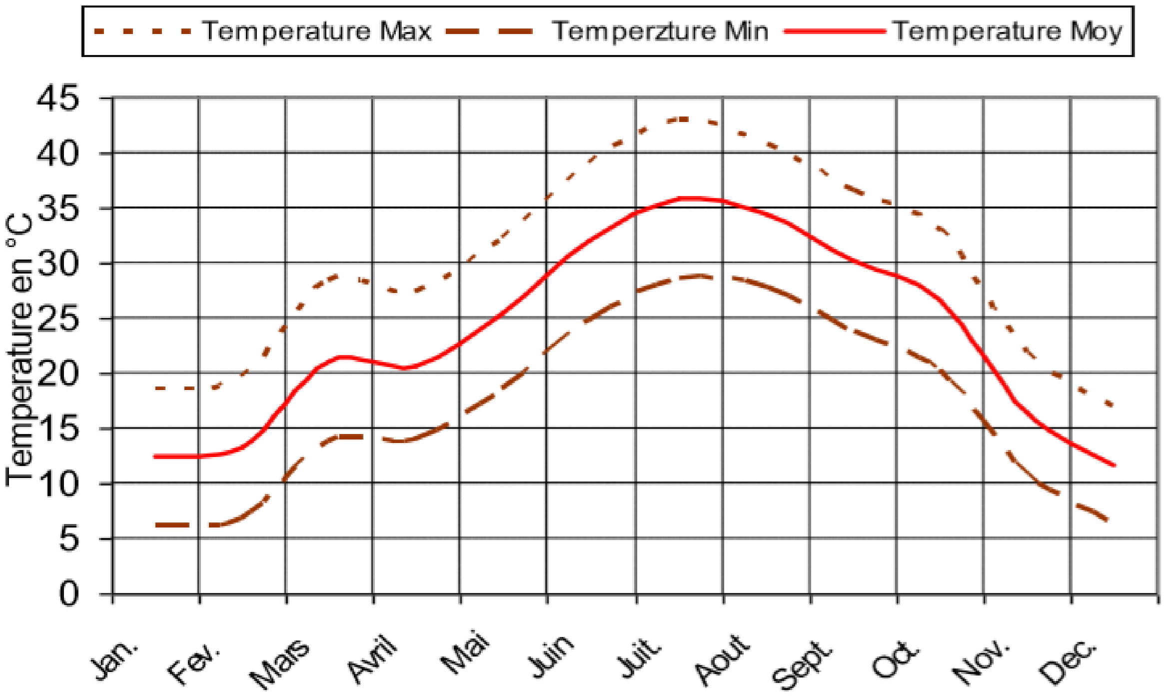

Fig.II.3 – Monthly temperature variations(2014-2018) [12]

The average annual rainfall is approximately 60 mm per year, as it is concentrated in the winter season, as the northwest winds blow in this season to the city, in addition to the southwest winds laden with sand in the spring, while in the summer, there are hot south winds known to the city By wind, Al-Shuhaili.

The strength of evaporation is large, reaching its maximum in July 432 mm, while the minimum observed during December 79.3 mm [12]

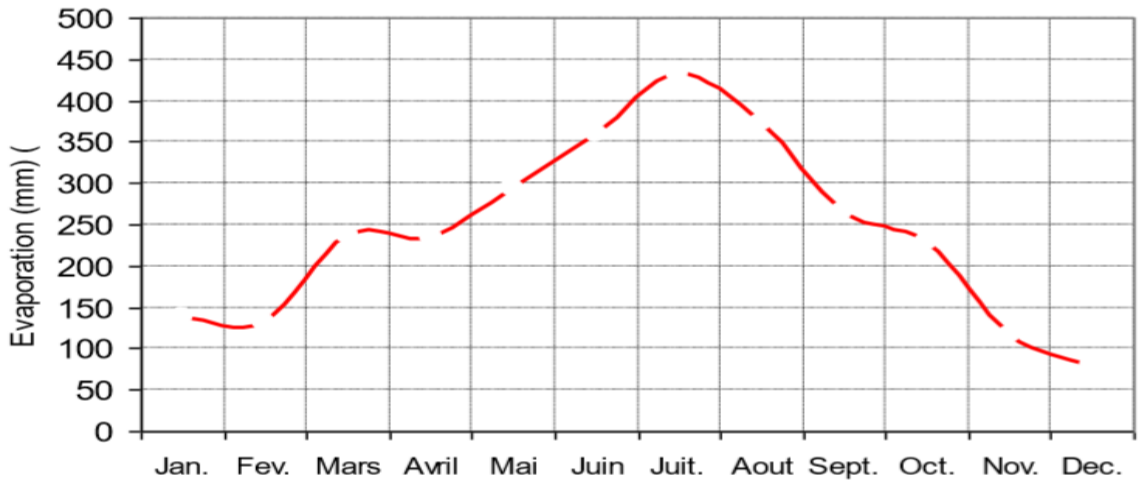

Fig. II.4 - Monthly variations in Evaporation (2014-2018) [12]

Table (II.1): Monthly average of various climatic factors (2014-2018) [13]

Humidity (%)	**Evaporation (mm)**	**Precipitation (mm)**	**Temperature (°C)**			
			T_{MOY}	T_{MAX}	T_{MIN}	**Months**
46	98.4	2.76	11.94	18.26	5.64	**Janfi**
44.2	116.8	5.52	13.48	20.3	6.9	**February**
30.6	183	0.84	17.04	24.38	10.48	**March**
31.8	246.2	1.8	22.1	30.62	14.1	**Avril**
28.2	303.4	4.12	26.96	35.18	19.25	**Mai**
24.4	320.4	1.86	30.8	38.88	22.65	**Joan**
18	376.6	0.2	34.96	42.36	27.54	**July**
31.6	324.6	6.66	33.95	40.64	26.52	**Ott**
36.2	247.4	10.98	29.48	36.6	22.32	**September**
8.28	186.2	3.22	23.42	30.74	16.74	**October**
48.6	118.2	4.26	16.56	23.24	10.32	**Nov**
57.4	81.8	1.76	12.24	18.34	2.26	**Dec**
33.77	216.9	8.8	22.84	29.96	15.72	

II-4 Geological aspect:

the wilaya of Ghardaia is located on the western borderd of the secondary sedimentary basin of the lower sahara. The outcrops are largely attributed to the Upper Cretaceous From the lithological point of view, these outcrops are of type;

• Greenish and variegated clays in the West and the Southwest attributed to the Cenomanian;

• Hard massive limestones; grayish white or center attributed or Turonian. limestones

• limestones marly and agile gypsous in the East, attributed to the Senonian

• reddishsand consolidated in the East and or northeastattributed or mio-plio Last Supper.

• Quaternary alluviumlining the bottom of s valley of the wadis [12]

II-5 The hydrology side

The main water resources of the wilaya are of underground origin .They are contained in two types of aquifers: the surface water tables with infero-flow and the deep-water table captive of the albian intermediate container -

Groundwater: they are sheltered in the alluviums of the valleys of the wadis of the region. supply and hydrological behavior are closely linked to rainfall. The depth of the water level varies between 10 and 30 m. these aquifers are collected mainly to irrigate the palm groves of the valleys, the chemical quality for consumption up stream, fluctuates and unfit for consumption down stream following their contamination by urban waters.

The Continental Intercalairetablecloth:. It represents the main water resource of the region, The aquifer is composed of sands, sandstones and sandy clays of Albian age.Depending on the region, it is collected at a depth ranging from 80 to 1000 m (fig.2.5)depending on the attitude of the zone and the variation in the thickness of the formations posterior to the **Continental Intercalairetablecloth**it is gushing and admits pressure at the head of the catching work in the zones of Zelfana, Guerrara, HassiFhel and HassiGara, pumped at depths ranging from 0.5m to 140m in the areas of Ghardaia, Metlili, Berriane, Sebseb, Mansourah and certain regions of El Menia.. [12]

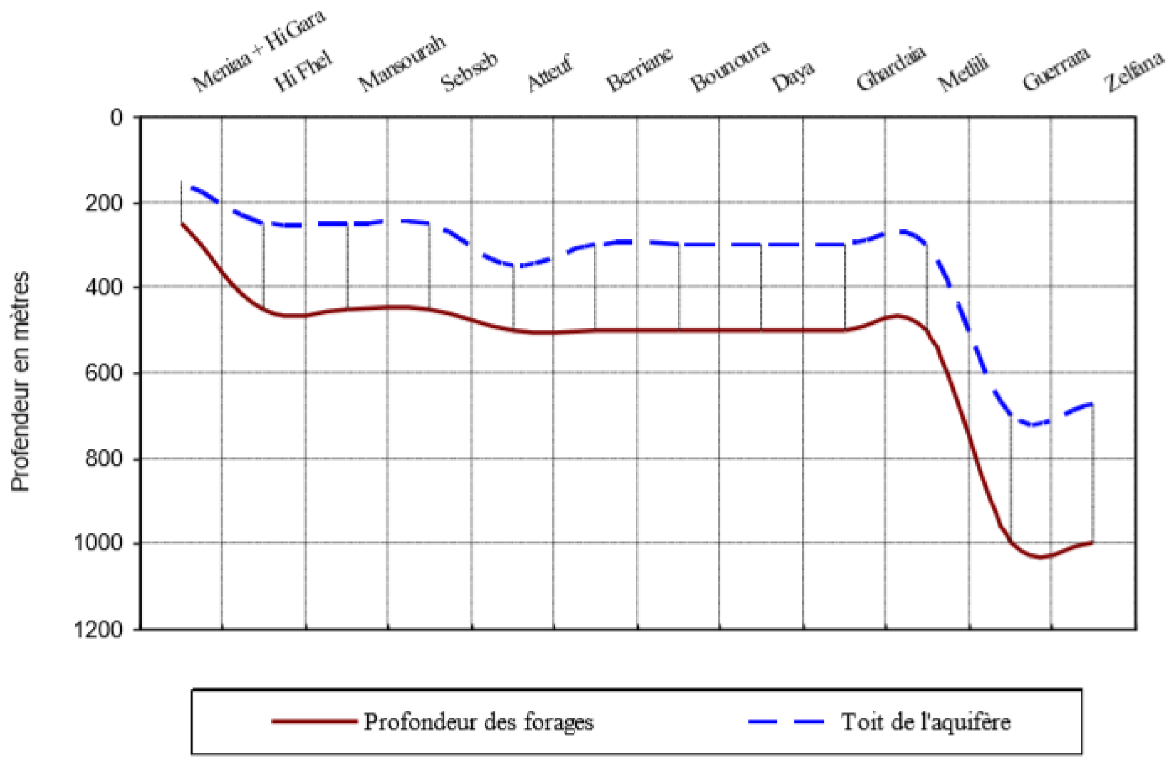

Fig.II.5– Variation of the roof and depth of the Albian aquifer [12]

II-6 Water quality:

From the consumption point of view the chemical analyzes of samples, presented in the comparative table **Table (II.2)** representing the different localities of the wilaya, show that the waters, except those of El Maniaa which are extremely sweet, are not too busy (RS variant between 1 and 1.8 / I) and present chemical facies of the sulfated magnesia typeand sometimes sulfated chlorinated magnesium see figure **II.6**. The comparison of the quantities of minerals continues in the waters of the region and national and WHO standards shows that these waters are good for consumption. [11]

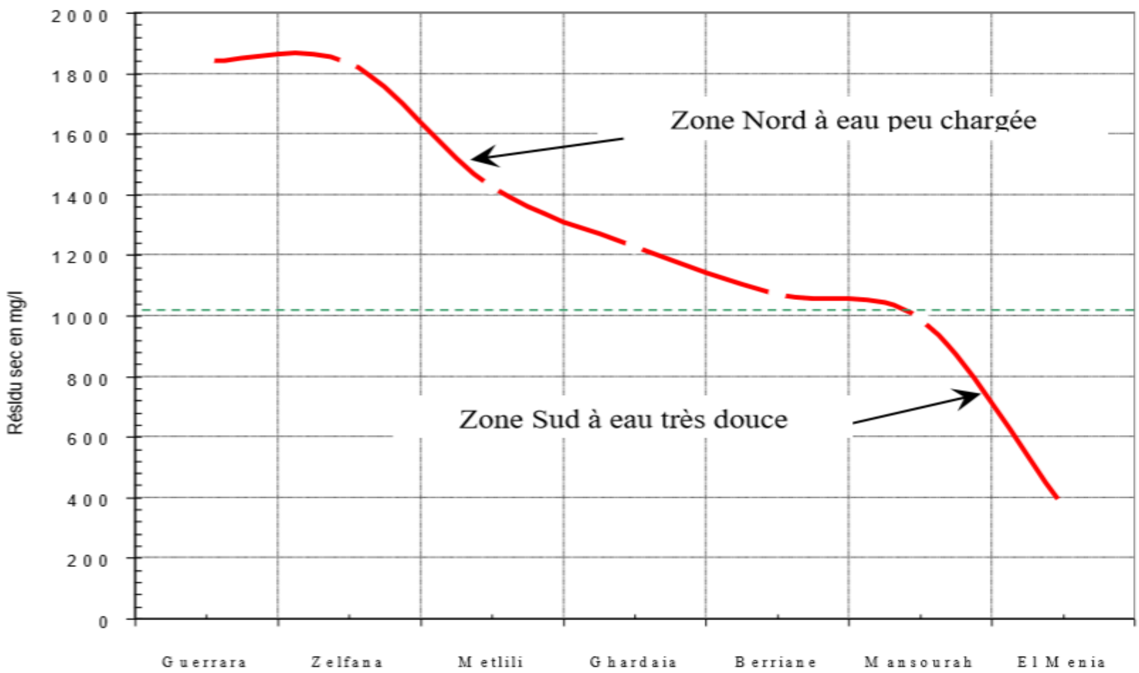

Fig.II.6 – Variation of dry residue across localities in the Wilaya [11]

Table (II.2):Comparison between regional water and national and WHO regulations (11)

Localités	Ca^{++}	Mg^{+}	Na^{+}	K^{+}	Cl-	SO_4-	HCO_{3-}	NO_{3-}	R.S
	mg/l								
Berriane	67	105	145	8	270	325	170	26	1068
Guerrara	98	170	212	16	470	536	140	21	1840
Ghardaia	21	149	145	13	265	400	128	10	1226
Zelfana	126	169	112	20	135	950	153	0	1832
Metlili	35	241	145	8	180	796	275	20	1424
Mansourah	60	110	132	7	230	305	163	21	987
El Menia	39	13	63	7	40	45	210	7	370
National standards	100	200	150	12	200	250	-	50	1500
WHO standards	100	250	200	-	250	400	-	44	2000

Chapter III

The physical phenomena associated with Soler distillation

Chapter III: The physical phenomena associated with soler distillation

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III-1 Introduction:

Energy has many different forms, the most important of which is thermal energy, which expresses how atoms are transported inside objects , The heat is classified as invisible properties, yet we can feel it around us through the phenomenon of the transition between bodies from the hotter body to the body with the lowest temperature until the two bodies become at the same temperature in order to reach the state known as thermal equilibrium between them. The science of heat transfer is the science that examines the methods of heat transfer between materials due to the difference in temperature and the nature of materials in terms of their resistance to heat transfer. The heat is classified as a type of energy that enters and exits a system.Theoretical study of distillation gives the relationship between the physical amounts, we find the heat transfer (conduction, load, radiation) .The main source of energy is the sun so that the radiation coming from it ensures the survival of the organisms and also enables the human to generate Thermal energy. [6]

III-2 Radiation Laws :

III-2-1 Definition of temperature :

Temperature is a physical property of matter that quantitatively expresses hot and cold. It is the manifestation of thermal energy, present in all matter, which is the source of the occurrence of heat, a flow of energy, when a body is in contact with another that is colder.

The heat is the energy produced from the material medium by the motion of its composite particles (molecules - atoms). These particles exchange heat energy, losing or gaining kinetic energy.The transfer of heat is the movement of the amount of heat from one point to another with a gradient of heat, and the transfer takes place regardless of the type of medium.

III-2-2 Forms of heat transfer :

III-2-2-1 Thermal conduction :

We consider a non-moving and homogeneous medium limited by two parallel plates having the same area between them there is a difference in temperature dT. A heat current is formed from the hot plate to the cold plate, [6]

This is the thermal power

$$\mathbf{Q} = \frac{dq}{dt} \qquad (\mathbf{III-1})$$

The thermal power is calculated by **first Fourier Law**:

$$\frac{dq}{dt} = -\lambda.\mathbf{S}.\frac{\mathrm{dT}}{dX} \qquad (\mathbf{III-2})$$

λ : Thermal conductivity measured (w/m.^{0}c)

III-2-2-2 Thermal Convection:

A-Natural convection :

The heat is carried by the load in the fluids (liquids and gases) due to the movement of the fluid and its mixing with each other by moving particles of matter from hot to cold places, carrying with them the heat where the particles of matter are free the movement. [6]

B-Forced convection:

In forced convection due to an external effect ,it moves on a surface that is higher or lower than it in a temperature. [6]

C- Newton'sLaw:

We consider a thermal fluid with a temperature T in a contact with a solid surface A ; its temperature is Ts ; there is a heat exchange between them (heat or cooling), a heat current dq/dT is given by Newton'slaw : [6]

$$\frac{dq}{\mathrm{dt}} = \mathbf{h}.\mathbf{A}(\mathbf{T}\infty - \mathbf{TS}) \qquad \textbf{(III-3)}$$

h : Represents The Convection Factor Thermique ; his unit is w/m$^{2°}$

III-2-2-3 Rayonnementthermique :

Rayonnementthermique is a method of heat tansfer. It does not require physical contact with each other. Heat is transmitted from its source of generation to the surrounding center. It may be solid, liquid, gas, or in the form of photons and electromagnetic waves,. [6]

- Stefan-Boltzman Law :

The Stefan–Boltzmann law, also known as Stefan's law, states that the total energy radiated per unit surface area of a black body in unit time (known variously as the black-body irradiance, energy flux density, radiant flux, or the emissive power), j*, is directly proportional to the fourth power of the black body's thermodynamic temperature T (also called absolute temperature).

The law of heat flow emitted from the transmitting surface as following: [6]

$$\mathbf{M = \varepsilon . \sigma . T^4} \qquad \mathbf{(III-4)}$$

M : Radiative emission of the transmitting surface W/m^2

ε : Emission factor for transmitting surface

σ ; Stefan-Boltzmann constant

$\sigma = 5.669 \,.\, 10^{8} (k^4 \cdot w/m^2)$

III-3 Energy study of the solar still

III-3-1 Introduction :

Since ancient times, it is known that the sun has enormous energy, and through the phenomenon of heating the basins, this great energy has been discovered so that the relationships that link the transmission of matter and heat give us an idea of the physical phenomena that occur in the solar distillation and the principle of its action. Based on these relationships, we can rely on the following : [6]

- Theoretical laws of heat transfer : we find thermal conductivity, convection and finally thermal radiation, in order to set the equations of thermal equilibrium
- Theoretical laws for mass transfer : molecular diffusion and convection, in order to set equations for mass balance and equations for the phenomena of evaporation and condensation.

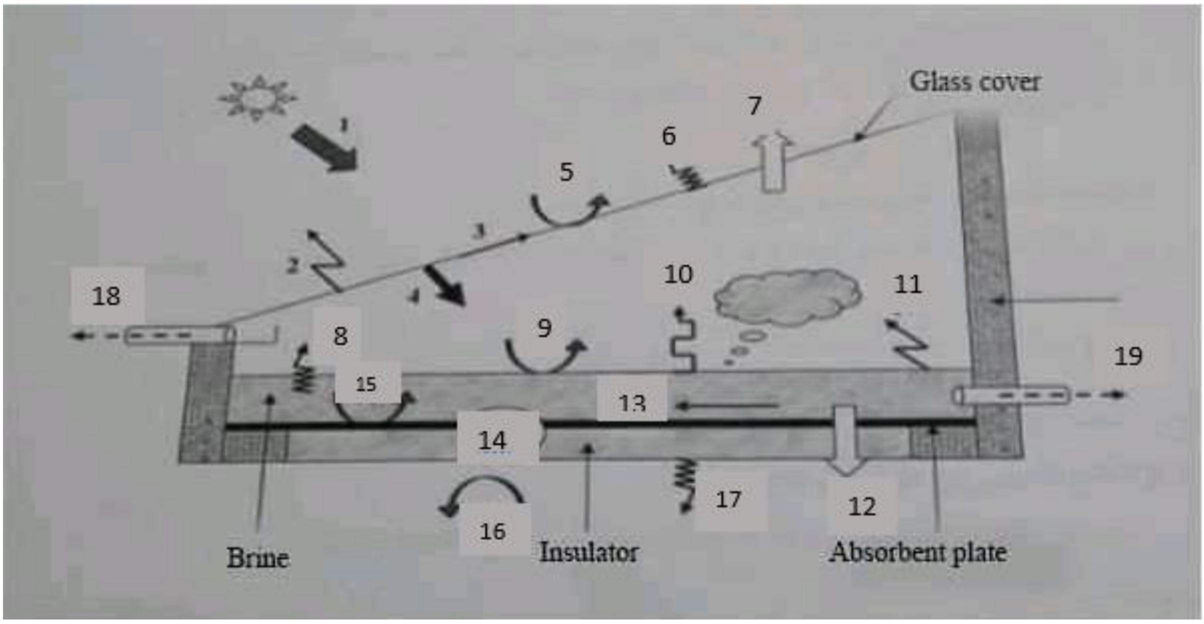
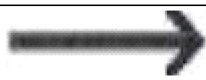
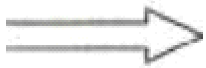
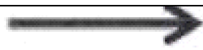


Figure III-1 : The most important thermal transfer in a simple slope distiller. [6]

Table (III-1) : Various transfers at the level of the solar distillery. [6]

Incident and transient solar radiation for glass.	
Thermal transfer with convection.	
Conductive heat by transfer.	
Heattransfer by radiation.	
The amountreflected	
Evaporatedamount.	
Absorbedamount.	
The amount lost in water.	

III-3-2 Heat Transfer at the solar distiller level:

When the distiller is exposed to radiation, it is exposed to heattransfers and flows. We will study on each level separately as follows : [6]

III-3-2-1 Transfers at the level of the glass cover :

As shown in Figure (III-4), we mention the transitions that occur through the glass cover as following**:** [6]

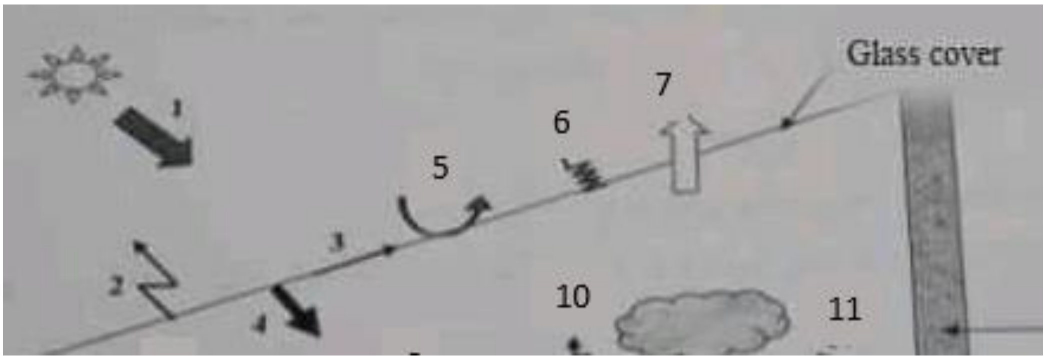


Figure (III-2): A drawing showing transitions at the level of the glass cover. [6]

1 - Solar radiation received by the glass:

It is the amount of radiation to which the glass cover is exposed. Solar energy supplied to the glass during the day and its relationship is as follows : [6]

$$G = \int qs(t)\mathrm{d}t \qquad (\mathrm{w/m^2}) \qquad (\mathbf{III-5})$$

2 - Reflected radiation on the glass level:

The rays contained on the glass do not absorb them all, but a small part of them is reflected, which gives the following statement (6)

$$Qr = pg\,G \qquad (\mathrm{w/m^2}) \qquad (\mathbf{III-6})$$

p_g : Reflection coefficient of glass.

3-The radiation absorbed by the glass:

Part of the incident solarenergy is absorbed by the glass cover.

and give as follows: [6]

$$Qa = \alpha gG \qquad (w/m^2) \qquad \textbf{(III-7)}$$

αg : Coefficient of absorption of the glass cover.

4. Radiation Transition of the Glass Cover :

The transparency of the glass that allows the passage of radiation received by the basin represents the largest part of this radiation, and it is given by the following words : [6]

$$Qt = \tau gG \qquad (w/m^2) \qquad \textbf{(III-8)}$$

τg : Pass coefficient for the glass cover

5. Convective heat transfer between the glass cover and the outer medium (air):

The movement of the outside air affects the heat flow of the mutual convection between the outer cover of the glass and the outer medium: [6]

$$Qc.ga = h\,c.ga(Tge - Ta) \qquad \textbf{(III – 9)}$$

h c.ga : Coefficient of convection

Tge : The temperature of the outer surface of the glass cover (k).

Ta : External temperature (air) (k).

6. Heat transfer by radiation between the glass cover and the outer medium (air):

The outer medium has an effect on the mutual radiation between the outer surface of the glass cover and the outer medium. [6]

$$\mathrm{Qr\ ga} = \varepsilon g \sigma \left(\mathrm{T}_{g\,ex}^{4} - \mathrm{T}_{Sky}^{4}\right) \qquad (w/m^2) \qquad \textbf{(III – 10)}$$

ε_g: Coefficient of emission of the glass cover.

T_{gex}^{4}:Glass cover temperature.

T_{Sky}^{4} : Planetarium temperature is given by the following phrase :

$$Tsky = Ta - 12 \qquad (k) \qquad \textbf{(III - 11)}$$

7-Thermal transfer by conduction between the outer medium and the innermedium.

The heat that the basin is exposed to from the inside can cross this glass by conducting through the glass surface [6]

$$Q_{cd} = \frac{\lambda g}{eg}\left(T_{g,i} - T_{g,e}\right) \qquad (w/m^2) \qquad \textbf{(III - 12)}$$

eg : Glass thickness.

λg : Thermal conductivity of the glass.

Tg, i : The internal surface temperature of the glass.

Tg, e : Temperature : the outer surface of the glass.

III-3-2-2 Transfers at the basin level :

The phenomenon of evaporation occurs on the level of boiling salt water. Condensation is a process in which water is transferred from the gaseous state to the liquid state, [6]

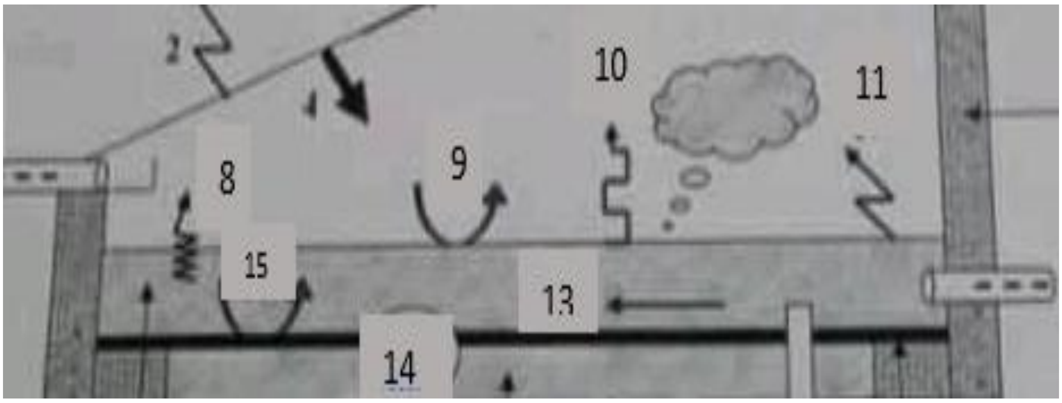


Figure (III-3): A drawing showing transitions in the middle of the basin.5.Heat transfer [6]

8-between salty water and glass cover :

The thermal transfer by mutual radiation between the salty water layer and the glass cover and its relationship are as following : [6]

$$Q_{r.w.g} = F_{wg}\sigma(T_w^4 - T_{g.i}^4) \qquad (w / m^2) \qquad \textbf{(III - 13)}$$

$F_{W.G}$: Form factor between the water layer and the glass cap.

T_w: Water temperature.

9. Heat transfer by natural convection inside the distiller (water and glass cover):

Convection thermal flow coincides with evaporation flow, and this is due to a rise in salt water temperature inside distilled and given by the following relationship. [6]

$$Q_{c.w.g} = h_{c.w.g}(T_w - T_{gi}) \qquad (w/m^2) \qquad \textbf{(III - 14)}$$

$h_{c.W.g}$:convection naturel coeficient.

T_{gi} Inner glass cover temperature.

10. Thermal flow due to evaporation :

The heat flux due to evaporation results from the movement of vapor from the salt water basin that condenses on the inner surface of the glass cover is given as follows: [6]

$$Q_{e.wg} = \dot{m}_w L_v \qquad (w/m^2) \qquad \textbf{(III - 15)}$$

11- Radiation reflected at the water level .

The radiation that crosses the glass cover towards the salt water inside the distillate is reflected in it and is given in the phrase: [6]

$$Q_{\rho w} = \rho_w \tau_g G \qquad (w/m^2) \qquad \textbf{(III - 16)}$$

ρ_w : Reflection coefficient

III-3-2-3 : Transfer at the bottom level of the distillate

Transitions occurring at the bottom level of the distillate as shown in Figure III-4

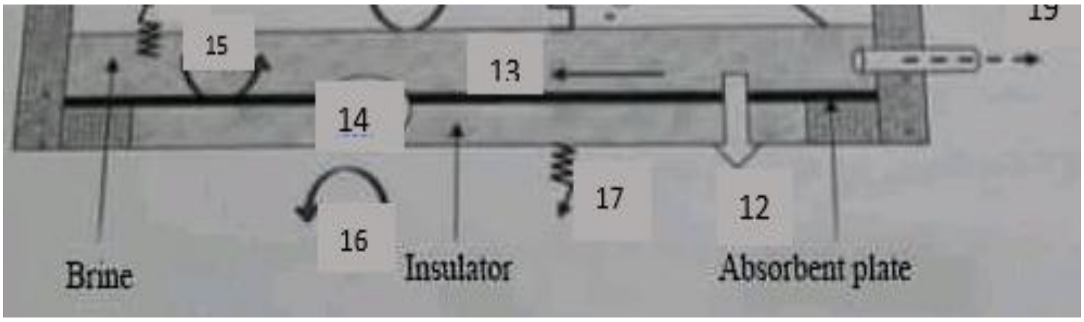


Figure III-4 : A drawing showing transitions at the bottom level of the distillate. [6]

12. Thermal loss through the absorbent plate :

There is an amount of heat lost through the absorbent plate and given as follows: [6]

$$Q_{cb} = \frac{\lambda b}{eb}(T_b - T_i) \qquad (w/m^2) \qquad \textbf{(III - 17)}$$

T_b : Absorbent surface temperature

T_i : Insulating temperature.

13.Heat absorbed by the salt ywater :

Sunlight that passes through the glass cover towards the salt water in the basin, one part is absorbed by water and the other part is absorbed by the absorbent plate and given as follows: [6]

$$Q_{aw} = a_w \tau_g G \qquad (w/m^2) \qquad \textbf{(III-18)}$$

α_w : Absorption coefficient of water.

14. Heat absorbed by the absorbent plate :

When heat passes through the glass cover towards the water in the basin, the absorbent plate absorbs a quantity of heat and its relationship : [6]

$$Q_{ad} = a_b \tau_w \tau_g G \qquad (w/m^2) \qquad \textbf{(III - 19)}$$

a_b :Absorbent plate absorption coefficient:

15. Convective heat transfer between water and absorbent plate:

The heat transfer by convection between water is caused by a difference temperature between them. And its phrase: [6]

$$Q_{c.wb} = h_{c.w}(T_{ab} - T_W) \qquad (w/m^2) \qquad \textbf{(III - 20)}$$

16. Convection heat transfer between the insulate and the outer medium:

The outer medium helps to heat exchange by convection between the insulator and the outer medium and is expressed as follows: [6]

$$Q_{c.ia} = h_{c.ia}(T_{ie} - T_a) \qquad (w/m^2) \qquad \textbf{(III - 21)}$$

17. Heat transfer by radiation between the insulator and the outer medium:

The heat transmitted by radiation between the insulator and the outer **medium**is given: [6]

$$Q_{r.ia} = \varepsilon_i \sigma (T_{ie}^4 - T_a^4) \qquad (w/m^2) \qquad \textbf{(III-22)}$$

III-3-2-4 Transitions at the level of insulators on bothsides of the distillate :

Among the transitions to which insulators are exposed to distillation are as follows:

18. Thermal loss with distilled water resulting:

Water carries a portion of the heat, exits from the distillation channel and writes with. [6]

$$Q_{out} = m_w c_{pw}(T_{dist} - T_a) \qquad (w/m^2) \qquad \textbf{(III - 23)}$$

19.Heat loss with feeding water :

The percentage that evaporates from distilled water from the water, which is compensated by a quantity of feed water until the heat is acquired to evaporate. This is called thermal loss, given as follows : [6]

$$Q_{in} = m_w c_{pw}(T_w - T_{fw}) \qquad (w/m^2) \qquad \textbf{(III-24)}$$

III-4 thermal balance simple solar distillers:

The thermal equations to which the solar distillate is exposed and written by : [6]

$$C_{PI}\frac{m_i}{S_i}\frac{dT_I}{dt} = \sum_{i=1}^{N} Q_{ij} \qquad (w/m^2) \qquad \textbf{(III-25)}$$

At the level of the outer face glass cover : [6]

$$C_{Pg}\frac{m_g}{S_g}\frac{dT_{ge}}{dt} = G + \rho_g G + \alpha_g G - Q_{rga} - Q_{cga} - Q_{cd} \quad (w/m^2) \qquad \textbf{(III-26)}$$

At the level of the gnner face of the glass cover : [6]

$$C_{Pg}\frac{m_g}{S_g}\frac{dT_{gi}}{dt} = Q_{ewg} + Q_{cwg} + Q_{rwg} - Q_{cd} \qquad (w/m^2) \qquad \textbf{(III-27)}$$

At the water surface level :

(III-28)

$$C_{Pw}\frac{m_w}{S_w}\frac{dT_w}{dt} = a_w \tau_g G + Q_{cwb} - Q_{ewg} - Q_{cwg} - Q_{rwg} - Q_{in} - Q_{ou} \quad (w/m^2)$$

At the level of the absorbent surface (absorbent plate):

$$C_{Pd}\frac{m_b}{S_b}\frac{dT_b}{dt} = a_b \tau_w \tau_g G - Q_{cb} - Q_{cwb} \qquad (w/m^2) \qquad \textbf{(III-29)}$$

Chapter IV

Nanotechnology and Solar Distillation

Chapter IV: Nanotechnology and Solar Distillation

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IV-1 Introduction:

Nanoscience and science are the sciences of small things in size such as atoms and molecules. The considered volume is in the order of a part of a billion meters (nanometers). Scientists have observed that in a small space (0.2 nm to 100 nm), called a nano scale, the properties of materials are very different from those in a larger space. The materials in the nanoscale give unique physical properties and we can exploited this phenomenon to produce unique devices and systems in their properties by controlling the shape and size in the nanoscale. Nanotechnology introduces a new challenge in science and engineering such as effective nanomaterials, nanoscale systems, systems Biological Nanomedicine and Medicine ..... [14]

IV- 2 Definition of Nanotechnology:

It is the production and use of compounds devices and systems by controlling the shape and size in the nanoscale, producing compounds, devices and systems that have at least one unique property. [14]

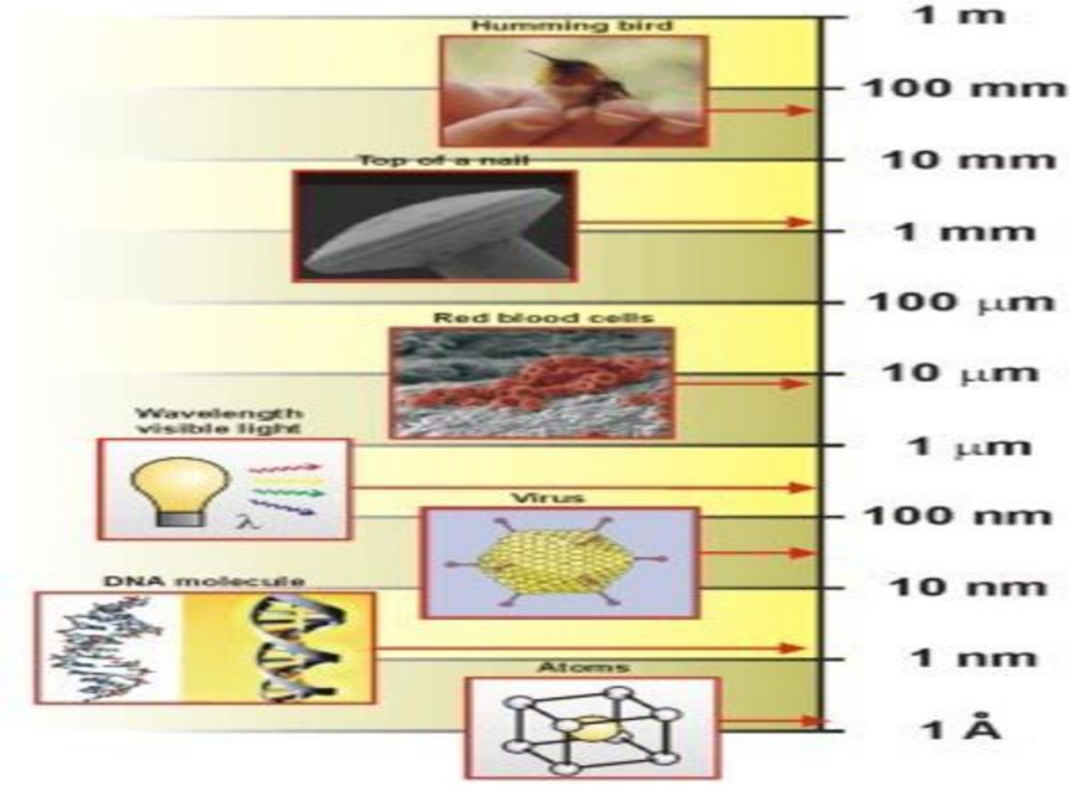

Figure IV 1 Illustration of nanoscale [14]

- The famous physicist (Richard Feynman) was the first to indicate the possibility of processing and controlling materials at atomic and molecular space in his famous lecture in 1959 in which he said the word famous

There is plenty of room at the bottom

But the word nano technology was not used until 1974 by the Japanese researcher Norio Taniguchi to mean the possibility of engineering materials at the nanoscale, and the forces that were pushing to minimize things came from electronic industries seeking to manufacture small electronic devices, on silicon chips, and used them in techniques to create nanostructures and devices In space (40-70 nm)

IV-3 History of nanotechnology:

Humans have used nanotechnology for thousands of years without knowing this term, so it was used in the manufacture of steel and rubber, all of which were based on random characteristics of the atomic volumes of these materials. And it is not possible to define a specific era to use this technique. Medieval glass makers mentioned that they were using colloidal nanoparticle gold granules in coloring. This supports the Roman King Cup of Icorges found in the British Museum since the fourth centure, and it contains particles of gold and silver nanoparticles Size, where the color of the cup is observed from green to dark red when exposed to a light source. American physicist Richard Feyman spoke in 1959 in a lecture he gave in front of the American Physical Society under the title (There is a wide area at the bottom), during which he explained that matter at infinitesimal levels (nanos now) and with a small number of atoms, behaves differently from its state when it is in big size. The perceptible, as he pointed out the possibility of finding ways to move the atoms and molecules of the material independently to reach the required size. The American mathematician Eric Drexler, the actual founder of this science, wrote in 1986 a book called The Genesis Engines, in which he laid out the basic ideas of nanoscience. Then, in 1991, a new physical phenomenon was discovered for the first time, which is nanotubes at NEC Electronic Industries in Japan by scientist Sumio Lijima, when he was studying the ash resulting from the electric discharge process between two electrodes of carbon using a high-efficiency electron microscope, and the result was that he found that carbon particles take An arrangement similar to the tubes inside each other.

Donald Pethion, a scientist in 1993 from IBM Computer Technology in the United States of America, was able to monitor single-layer nanotubes with a diameter of one tube of 12 nanometers, and the scientists set out after this in the field of nanotubes, so a team of Chinese scientists managed From observing the smallest nanotubes in the world, the diameter is only 0.5 nanometers, knowing that the lowest diameter of the smallest thing in theory is 0.4 nanometers.

The secrets of this technology and control of the world of nanomaterials have been known from 2003, while the industrial application stages of this technology started in 2004, when nanomaterials were used in the Malaysian rubber industry and the results were amazing. The mechanical properties of the rubber jumped from 12 to 20 times by adding simple parts from Nanomaterials. Nanotechnology has today received great attention due to its interconnected applications in many fields, including medical, military and computing. [15]

IV-4 Properties of materials in the nanoscale :

The properties of materials change very noticeably according to their nanoparticles components. Compounds consisting of granules in the size of nanostructures, whether they are ceramics or minerals, are much stronger than their percentages in the larger size. For example, metal with a grain size of about (10 nm) is more solid than ordinary metal with size of granules is measured in hundreds of nanometers, and this major change in the properties of materials in the nanoscale is caused by the following: [15]

IV-4-1 Relative increase in surface area:

Nanomaterials have a larger surface area when compared to the same mass of material produced in the larger space, and this makes the materials more chemical active and affects their strength or electrical properties. Sometimes the inert materials in the large space may be active when produced in the nanoscale, that is, when particles that have a size of 30 nm are smaller, only 5% of them are present on the surface, while the others with a size of 10 nm are located 20% of them on the surface, And the size of 3 nm of which 50% is present on the surface, and since chemical reactions take place at the surface, the nanomaterials are more active than their counterparts in the largest space. [14]

IV-4 -2 quantum effect:

Quantum effects begin to control the behavior of matter in the nanoscale, especially at the lower end, and affect the properties of electrical, magnetic and optical materials. [14]

IV-5 Reasons for interest in nanotechnology:

There are three main reasons for the interest in nanotechnology:

First: Research in nanoscience and technology that helps fill the void in our basic knowledge of matter. At the very least the nano scale atoms and molecules. We know something easy to use using the tools developed by traditional physics and chemistry

Secondly: The nanoscale phenomenon is promising with many applications and uses thatwill change the traditional concepts of manufacturing, health and treatment, energy and water, and will launch a stream of technologies, products and services create more many jobs. Examples include chemical synthesis using partially designed aggregation, detection of chronic diseases and cancer, treatment by interfering with cell components, tissue regeneration and deepening learning of neuropathy and cognitive processes, cleaning up environmental pollution and other applications and other uses.

Third: The beginning of the new industrial model and marketing of these technologies. Research programs in these countries began to take their path with great power and speed. They were announced in Japan in 2001, Korea 2001, Europe 2002, Taiwan 2002, and perhaps the first and most important of these programs is the National Initiative for Nanotechnology. Announced in the United States of America 2000. [14]

IV-6 Preparation Methods of Nano material

The size of the proposed minutes will be a reason for the type of technology used to build nanoparticles, in addition to the fact that the use is a critical work in the nature of the technology used, especially in the field of optical technologies and the medical field. There is a wide variety of technologies that possess the ability to produce nanostructures with varying degrees of quality and speed and cost. All of these technologies can be classified into two main categories, which are the upward path and the descending path, and the electrochemical method has been used. [16]

IV-6-1 Bottom-up Technology:

This method is based on the process of collecting and building nanoparticles from smaller particles (atoms and molecules) for the purpose of obtaining minutes of desired size and shape. It depends on the chemical reaction variables and the type of control systems used for each grouping reaction. Through the process of self-assembly of the atoms in which the atoms are arranged with a specific structure subject to their micro-nature. The modern semiconductor industry depends on the growth of crystals that give a good example of the method of self-assembly (self-growth). Growth to build nano-minute. [16]

IV-6-2 Bottom-Up Technology (descending method)

This method can be called metaphorically by cutting or segmenting (the process of converting substances of large sizes into smaller volumes and for the same physical mass) and it depends on the principle of eradication of atoms or molecules from the original materials with large sizes.

The use of thin films for materials is one of the common methods in this field for the production of nanomaterials and according to the required measurements, but it uses several other techniques in this method, especially the mechanical cutting technology and the superior engineering control technology.

The use of these technologies to obtain nanomaterials directly or manufacture them depends on Using microstructure materials. [16]

IV-6-3 Convergence of top-down and bottom-up techniques:

This technique could explain the relationship of convergence between the two previous techniques. Throughout seventy years of production, which is represented by the amount of development taking place with accurate dimensions and measurements used in this field since 1974 until 2010, where it is observed the evolution of methods and their diversity within the two technical range and convergence taking place Between them is a ratio of the measurements reached by comparison with the time needed for the growth and development of this field.

The control of the production to produce large minutes can occur through advanced chemical processes in this field. At present, the dimensions of control are represented either by the development of the existing preparatory methods, which leads to excitement and the generation of methods Hybrids for industrialization, or by using certain intermediate states to improve the quality of the nanoscale product and the economic costs associated with it, taking into account the environmental impact resulting from it and according to the permissible global standards. [16]

IV-7 Applications and uses of nanotechnology :

The strength of nanotechnology is represented in its capabilities to transfer and develop multiple technology and convert it into materials and installations device system that have applications and uses in all sectors and fields and works to solve the most important problems that the world suffers such as lack of water pollution and space exploration and others and the following below Nano Applications and Uses [14]

Biology, medicine and health : (wound dressings, early disease diagnosis and detection, drug delivery and cell imaging ...

Energy and Environment: (Solar Cells, Hydrogen Generation and Storage)

Storing electricity: (nanotechnology helps improve the efficiency of rechargeable batteries), using nanostructures to develop a super capacetor

The electronics industry: (nanoelectronics is the manufacture of current circuits and semiconductor devices of small (nanoscale) sizes with high efficiency. –

Scientists and researchers also used nanotechnology to desalinate water in various ways, in cludingus in nanoparticles in different thermal applications, as well as using nanofiltration to desalinate water.

IV-8 Heat transfer in nanofluids :

Upcoming applications for nanostructured systems include filtering drinking water, desalination, ultra pure water production, and industrial wastewater treatment. Nano fluid are stable suspensions of nanoparticles in a liquid Nanofluids contain up to 10 % of the nanoparticles, usually more than 10 % of the surfactant. Either oil or water is used as a carrier liquid, and the suspensions are designed in such a way as to block the brownish molecular motion that causes the precipitation of the particle. Some of the factors that must be analyzed before choosing nanoparticles are thermal conductivity, specific thermal power, density, fluid viscosity, safety, and compatibility with the base liquid. Nanotechnology improves the heat transfer of liquid working with solid nanoparticles. By combining nanoparticles, the physical physical properties of the working liquid such as thermal conductivity, viscosity, and heat transfer coefficient of the load are changed. [17]

IV-8-1 thermal conductivity:

Koo and Kleinstreuer proposed an equation to calculate the thermal conductivity of nanofluids. The thermal conductivity of nanofluidis a function of diameter of nanoparticles, volume fraction, nano particle temperature, and Brownian motion of the nanoparticles in the base fluid [17]

Koo and Klegnstreuer proposed an equatgon to calculate the thermal conductgvgty of nanoflugds

$$K_{nf} = \frac{K_P + 2K_{bf} + 2(K_P - K_{bf})\varphi}{K_P + 2K_{bf} - (K_P - K_{bf})\varphi} k_{bf} + 510^5 \beta\varphi\rho_{bf} C_{bf} \sqrt{\frac{k_B T}{\rho_p D}} f(T, \varphi) \qquad \mathbf{(IV-1)}$$

where

$$f(T, \varphi) = (-6.04\varphi + 0.4705)T + (1{,}722.3\varphi - 134.63) \qquad (IV-2)$$

Table IV-1 Some global experiences of nanotechnologydesalination [17]

Sl No	Author, reference & country	Solar still design	Base fluid	Nanofluid	Thermal conductivity of nano particle (W/m K)	Volume concentration	Observation in experiment
01	Sahota and Tiwari [18], India	DSS	Water	Al_2O_3	46	0.04%, 0.08%, and 0.12%	The productivityincreased by 16.83% due to Al_2O_3 nanofluids with the concentration of 0.12%.
02	Sahota and Tiwari [19], India	PVT FPC integrated with DSSS	Water	• Al_2O_3 • TiO2 •CuO	46.0 11 .8 17 .6	•0.063%-0.124% • 0.041%-0.108% • 0.082%-0.016%	CuOnanofluids have better ResultsthanAl$_2$O$_3$ and TiO2 nanofluids.
03	Sahota and Tiwari [20], India	DSS	Water	• Al_2O_3 • TiO2 •CuO	46 11.8 17.6	0.2%, 0.25%, and 0.3% for eachtype	The productivityis Al2O3 > TiO2>CuO.
04	Sahota et al. [21], India	DSS	Water	• Al_2O_3 • TiO2 •CuO	17 .6 17.6 46	0.044%–0.272% Foreach type	Annualenhancement of productivity: Al_2O_3: 19.10%; TiO2:10.38%; and CuO: 5.25%.
05	Kabeel et al. [22], Egypt	SSSS with external condenser	Water	•CuO • Al_2O_3	17.6 46.0	CuO: 0.02% Al2O3: 0.02%	CuO gave higherefficiency of 84.16% than Al_2O_3 nanofluids (73.85%).
06	Kabeel et al. [23], Egypt	SSSS with external condenser	Water	• Al_2O_3	46	0.2%	The nanofluidincreased the productivity by 116%.
07	Kabeel et al. [24], Egypt	SSSS with external condenser	Water	• Al_2O_3 • Cu2O	46 76.5	0.02%–0.2%	The productivityresults of Cu2O (φ = 0.16%) and Al_2O_3 nanofluids are 2,240 and 2,095 mL/m2/d, respectively.
08	Omara et al. [25], Egypt	Corrugatedwick solar still with reflector andfan	Water	• Al_2O_3 • Cu2O	46 76.5	1.97%	Corrugatedwick, reflector, and fanalong with Cu2O nanofluids enhanced the system productivity by 285.10%, and Al_2O_3 nanofluids by 254.88%.
09	Mahian et al. [26], Iran	SSSS with FPC	Water	• Cu • SiO2	400 1.4	1%–4% for both Types	Cu nanofluidsenhanced the evaporation more than SiO2 nanofluids.
10	Elango et al. [27], India	Sss	Water	• Al_2O_3 •ZnO • Fe2O3 • SnO2	46	0.05%–0.1% for all Types	Al2O3 nanofluidsenhanced productivity by 29.95%, SnO2 by 18.63%, and ZnO by 12.67%.
11	Madhu et al. [28], India	Sss	Water	• Al_2O_3 •CuO • Ti	29	0.2% for all types	Al_2O_3 nanofluids gave a yield of 4.03 kg/m2/d, CuO 2.25 kg/m2/d, and TiO2 2.17 kg/m2/d.
12	Saleh et al. [29], Egypt	Tss	Water	•ZnO	6	600 mg/100 mL (0.11%)	ZnOnanorodshapeenhanced the productivity by 38% and ZnOspherical shape by 30%.
13	Gupta et al. [30], India	Sss	Water	•CuO	.34–1.38	0.12%	The CuOnanoparticleproduced a Higherproductivity of 3,445 mL/ m2/d thanconventional still (2,814 mL/m2/d).
14	Gupta et al. [31], India	Sss	Water	•Cu2O	46		The productivity of with and without Cu2O nanofluidis 4,000 and 2,900 mL/m2/d, respectively
15	Abhinav and Harikumar [32], India	Sss	Water	• Al_2O_3	46	0.1%, 0.5%, 1.0%, and 1.5%	Al_2O_3 nanofluidsenhanced the Systemproductivity by 20%.

16	Navale et al. [33], India	Masonic solar still	Water	• Al_2O_3 •CuO	17.6	0.1%, 0.2%, and 0.3% for both types	CuOnanofluid with 0.3% Concentrationenhanced the Distillateproductivity by 89.42%, while Al2O3 by 45.19% (0.3% concentration).
17	Kabeel et al. [34], Egypt	Sss	Mixed with Blackp aint	•Cu2O	76.5	10%–40%	Productivityincreased by 25% compared with conventional solar still (CSS).
18	Sain and Kumawat [35], India	Sss	Mixed with Blackp aint	• Al_2O_3	46		Enhancedproductivity by 38.09%.
19	Sharshir et al. [36], China	SSS	Water	• Graphite flakes •CuO	129 17.6	0.125%–2%	Graphite-microflakesenhanced the productivity by 53.95% versus CuOnanofluids by 44.91%.
20	Chen et al. [37], China	SSS	Water	SiC	490	0.1%, 0.2%, 0.3%, and 0.4%	0.4% concentration enhanced thermal conductivity by 6%.
21	Gnanades on et al. [38], India	SSS	Water	MWCNT	2,000-3,000	-	Enhancedoverall system performance
22	Abdelal and Taamneh [39], Jordon	SSS	Water	MWCNT	2,000-3,000	-	-
23	Elfasakha ny [40], Saudi Arabia	SSS	Water	• Carbon • Fabrics • Graphene • CNT	-	Carbonfabrics 2.5%, Graphene 2.5%, CNT 2.5%, and CNT 5%.	CNT with 5% of weight concentration enhanced the productivity by 30%.
24	Elfasakha ny [41], Saudi Arabia	SSS	-	• Cu •Paraffinwax • Cu-Paraffin wax	387.6 0.172 0.226	2.2 kg of PW and 0.2%–4% Cu	The Cu-paraffin wax composites enhanced the system performance by 5%.
25	Easwara moorthy [42], India	SSS	-	•Paraffin wax • Al_2O_3 + PW	-	PW–2%wt Al_2O_3 and PW–4%wt Al_2O_3	Paraffin wax with-4%wt Al2O3 exhibitedbetter performance.
26	Chaichan and Kazem [43], Iraq	SSS		Paraffin wax + Aluminum powder		4.8 g of PW	PW with aluminumpowderenhanced the productivity by 21.19%.
27	Rajasekar and Easwara moorthy [44], India	SSS		Paraffin wax + Al_2O_3		15 kg of PW	The dailyefficiency of the Al_2O_3 + PW is 45% and PW alone 38%.

Kp: is the thermal conductivity of nanoparticle (W/m K),

Kbf ;is the thermal conductivity of the base fluid (W/m K),

φ ; is the volume fraction of the nanoparticles,

kB ; is the Boltzmann’s constant**,**

ρbf :is the density of the base fluid (kg/m3),

Cbf : is the specificheatcapacity of the base fluid (J/kg K),

knf ; is the thermal conductivity of the nanofluid and (W/m K),

T ;is the temperature (K).wherekBis the Boltzmann'sconstant,

Tis the temperature of nanofluid (K),

μ ; isdynamicviscosity of the nanofluids (kg/m/s), and dpisnanoparticlediameter (m).

IV-8-2 dynamic viscosity

Corcione [17] developed the correlation to calculate the dynamic viscosity of the nanofluids:

$$\frac{\mu_{nf}}{\mu_{bf}} = \frac{1}{1-34.87\left(\frac{d_p}{d_{bf}}\right)^{-3}\varphi^{1.03}} \qquad (IV-3)$$

where

dbf ;istheequivalentdiameter of the base fluid (m),

μnf; is the dynamicviscosity of the nanofluid (kg/m/s),

μbf; is the dynamicviscosity of the base fluid (kg/m/s),

dp; is the particlediameter,

φ ; is the volume fraction of the nanoparticle. Also,

$$d_{bf} = \left[\frac{6M}{N\pi\rho_{f0}}\right]^{1/3} \qquad (IV-4)$$

Where

M ;is the molecularweight of the base fluid,

N :is the Avogadro number,

ρ_{f0} ;is the mass density of the base fluid (kg/m3).

VI-8-3 volumic mass

Pac and Cho developed an empiricalequation to calculate the volumic mass of the nanofluid as given by: (17)

$$\rho_{nf} = \rho_p\varphi + \rho_{bf}(1-\varphi) \qquad (IV-5)$$

Where ρ**nf**is the volumic mass of the nanofluid (kg/m^3), **ρ**is the volumic mass density of the nanoparticle (kg/m^3), **φ**is the volume fraction, and **ρbf** is the mass density of the base fluid (kg/m^3).

IV-8-4 Specific heat capacity:

Pac and Cho [17] developed an empirical equation to calculate the specific heat of the nanofluid as given by:

$$C_{nf} = (1-\varphi)C_W + \varphi C_P \qquad \text{(IV-6)}$$

Where $\mathbf{C_{nf}}$is the specific heat capacity of the nanofluid (J/kg K), **φ**is volume fraction, $\mathbf{C_W}$ is the specific heat capacity of the water (J/kg K), and $\mathbf{C_p}$ is the specific heatcapacity of the particle (J/kg K).

The random motion of the nano particles in the base fluid is termed Brownian motion. The Brownian motion is described by the Brownian coefficient $\mathbf{D_B}$, which is governed by the Einstein–Stokes equation

$$D_B = \frac{K_B T}{3\pi\mu d_p} \qquad \text{(IV-7)}$$

Where **kBis**the Boltzmann's constant, **T** is the temperature of nanofluid (K), **μ**isdynamicviscosity of the nanofluids (kg/m/s), and $\mathbf{d_p}$isnanoparticlediameter (m).

Chapter V

The experimental study of solar distillation

Chapter V: The experimental study of solar distillation

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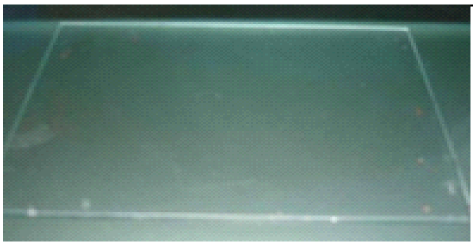
V-1 Introduction:

Humanity has long been suffering from a lack of drinking water. Researchers are trying to find final and economical solutions to this problem. Solar distillation seems the most economical solution to date, but the main drawback of this technique is its poor productivity. An improvement of this method is based on the fact of using nano particle at the level of the used distillers. In this study we will show the effect of the concentration of nano fluide present in the distiller on the productivity of the distillation . We have three destillers : the first is a conventional distiller without nano fluid 0g/l ; the second is a nano fluid distiller with a low concentrations of nano fluid 1g/l ; the third is an other nano fluid distiller with a high concentration of nano fluid 2g/l . The results of this experimental study have been showed an enhausement of the productivity of solar destillers (second and third), respectively, by high percentages (i.e. 21% and 42%)

V-2 Used materials and manufacturing steps:

V-2-1 Used materials:

The table V-1 shows the starting materials for making a single slope solar distiller

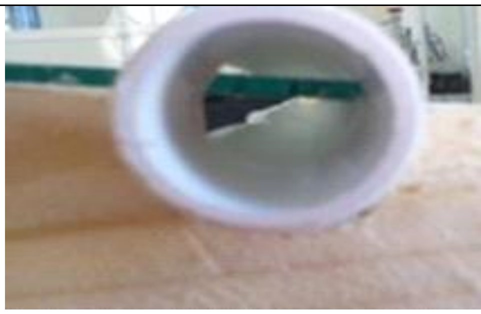
Dimensions,	, number,	, name	Images
L=50 cm **H_1 =14 cm** **H_2= 6 cm** **56 cm * 56 cm**	5**slabs**	**Wood box**	
50cm * 50 cm **3mmthikness**	**01**	Glass	

L=70cm **Diam=2.1cm**	**01**	**Tube**	
L=3.5 cm **Diam=3.6 cm** **Diam=2.6 cm**	**01**	Elbow at an angle of 90	
Diam=2.7 cm	**01**	**Plastic cover**	
	02	**Black silicone**	
	01	**Water balance**	

	01	thepolisher	
	01	**Black painttray**	
	01	abrush	
	01	**Oppression**	
	01	abottle	

V-2-2 Manufacturingsteps:

Box installation: Designs 04 panels of 14 Cm x 6 cm x 2 cm cut into pieces then we do Assemble it using special wood glue And attached to the fifth board screws, so their size will be 5 Cm x 50 cm and be placed in the base as shown in the corresponding image	
We drill two holes on the side panels With a drill, the hole is in a semicircle such that the tube can be fixed.	
inner coating of box: We paint the wooden box in black to absorb the most sunlight.	

Open the tube: 1/3 of the top of the tube is cut to assemble Condensed water drops from the glass cap .	
Insulator (silicone): We put the silicon on the sides and the base by the polisher so that we get a thin layer of insulator (silicon)	
Installation of elbow: We install the elbow at the end of the tube and then add a small tube at the other end to allow distilled water to transfer to the bottle.	
Positioning of the glass inside the tube : Insert the end of the glass cover into the plastic tube	

Finally, weget singleslopesolardistillers	

V-3 Measuring devices and tools used in the experiment :

V-3-1Multimeter device:

Figure V-1: Multimeter device:

V-3-2 piranometer:

It is a device to measure the intensity of the sun's radiation.

Figure V-2:piranometer:

V-3-3 Meter: PH device

Figure V-3: Meter: PH device

V-3-4 Conductivity measuring device

Figure V-4: Conductivitymeasuringdevice4

V-3-5 IncludedTube :

Figure V-5: IncludedTube:

V-4-Methodology:

V-4-1 General description:

We use distillers with single slope of the same size 50 * 50 cm with a thickness of 2.5 cm. The threedistillers are tinted in a black color to maximize thermal absorption. The condenser of the system consists of a commercial glass 50* 50cm with a thickness of 3mm and an inclination of with respect to the horizontal whichisequal to the atitude of the place of the experiment. Figure 1 represents the shemas of the usedconventional distiller. The conventional distiller isnamed (CD); the nano fluid distiller with low concentration of nano fluid (LND) finally the last distiller with high concentration of nano fluid named (HND) .

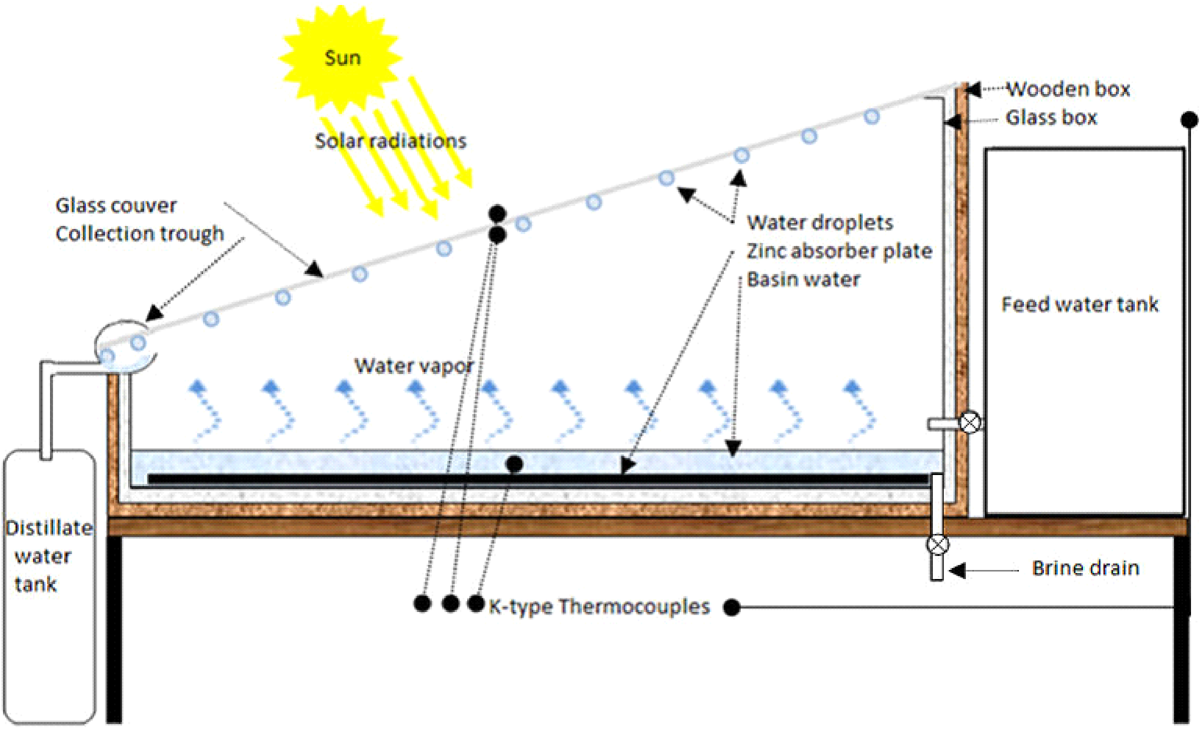


Figure V-6: Diagrams of the experimental setup

V-4-2 Place and time of experiment:

The place of the experimentis the city of Ghardaia in the south of Algeria. Ghardaia's location is determined by longitude 3.6333 east and longitude 32.2667 north and altitude 486m. The experimentwascarried out on 14/6/2020 From 9 a.m. to 6 p.m.

V-4-3 Meteriological conditions of the experiment:

Table 1 summarizes the meteorological conditions for the experiment.

Table 1 : Meteorological conditions on June 2020

Sunrise	05:41 am
Sunset	07:19 pm
Ambient temperature	26-35°C
Atmospheric pressure	101325 Pa

V-5 Result and discussion :

Twodistillers (HND) and (LND) are usedwhile the distiller C D isused as a witness distiller.

The experimentiscarried out on 2020/06/14 and begins at 8a.m. and ends at 6 p.m. The temperatureistakeneveryhour. The results are illustrated in the followingparagraphs.

V-5-1 Quality of obtained distilled water:

The quality of obtaineddistilled water isensured by measuring the PH and the conductivity of the usedwater before and after distillation, the measurementresults are collected in the following table.

Table V-2: Results of the analysis of the water used.

Distilled water (produced water)	Salty water (used water)
pH = 7.33	pH = 7.92
σ = 64 ɥs	σ= 3130 ɥs

V-5-2 Solar radiation and ambient temperature :

The day of the experience is sunny with no wind and no cloud. Solar radiation is the most important factor of solar distillation. The figure V-7 represents the evolution of the ambient temperature during the dayfrom 8 a.m. and until 6 p.m.

In the same figure we also represent the evolution of solar radiation during the day

The variation of the solar radiation and the ambient temperature have almost the same behavior. The minimum of solar radiation is recorded in the morning and the maximum of solar radiation (i.e., 1002 Wh/m^2) is reached around mid-day and then decreases in the afternoon. The maximum temperature is recorded during the period from 11 AM. To 4 PM and start todecrease in the afternoon.

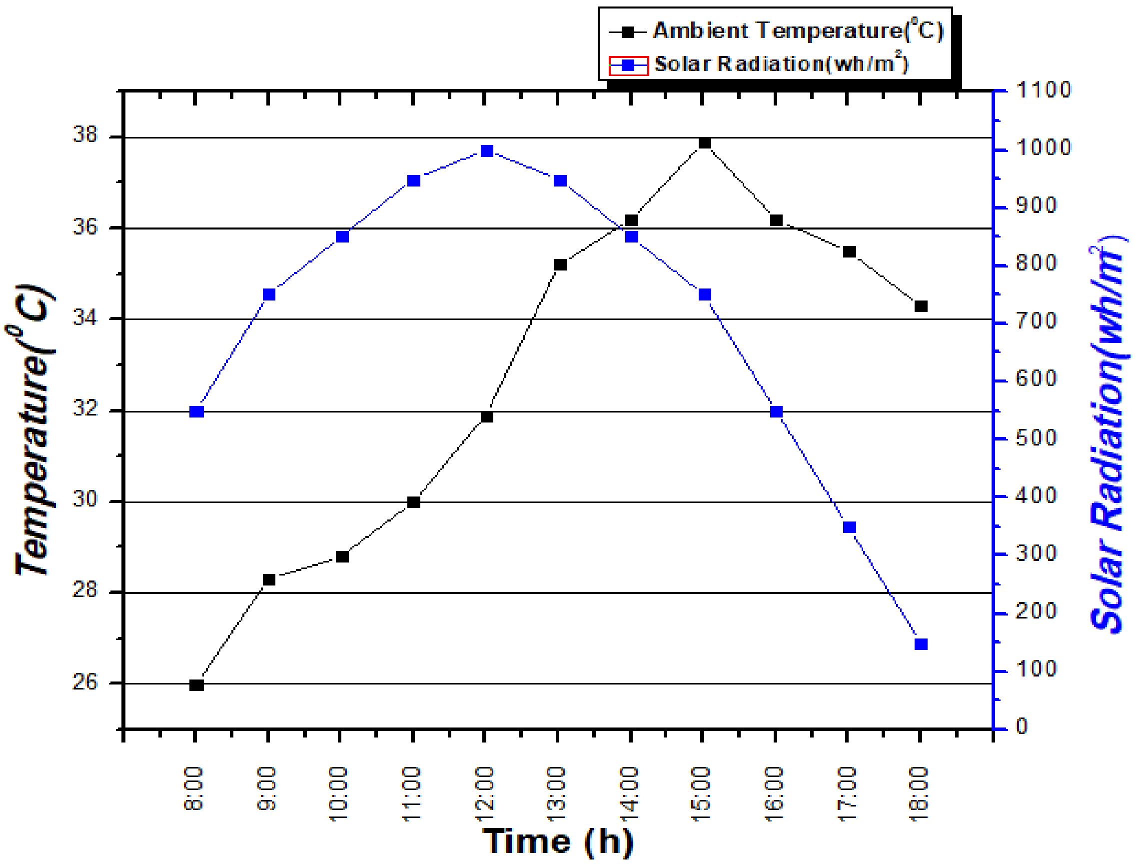


Figure V-7: Solar radiation and ambient temperature

V-5 -3 The variation of the basin salt-water temperatures

Figure V-8illustrate Comparisons between the basin salt-water temperatures and ntrenal glass temperature for each of the three solar destillers basins. The evaporation and the production rates are better in the nanofluid destiller than that of the conventional still for the following reason:

The water and internal glass temperatures of the aluminum oxide nanoparticles (2 g/ L) destiller are more than that of the conventional destiller (0 g/L Al_2O_3) by 0.5-4 °C, and 0-2 °C respectively. the water and internal glass temperatures of the nano fluid destiller (1 g/ L) are more than that of the conventional de (0 g/L Al_2O_3) by 0.5-6 °C , and 0-3 °C respectively.

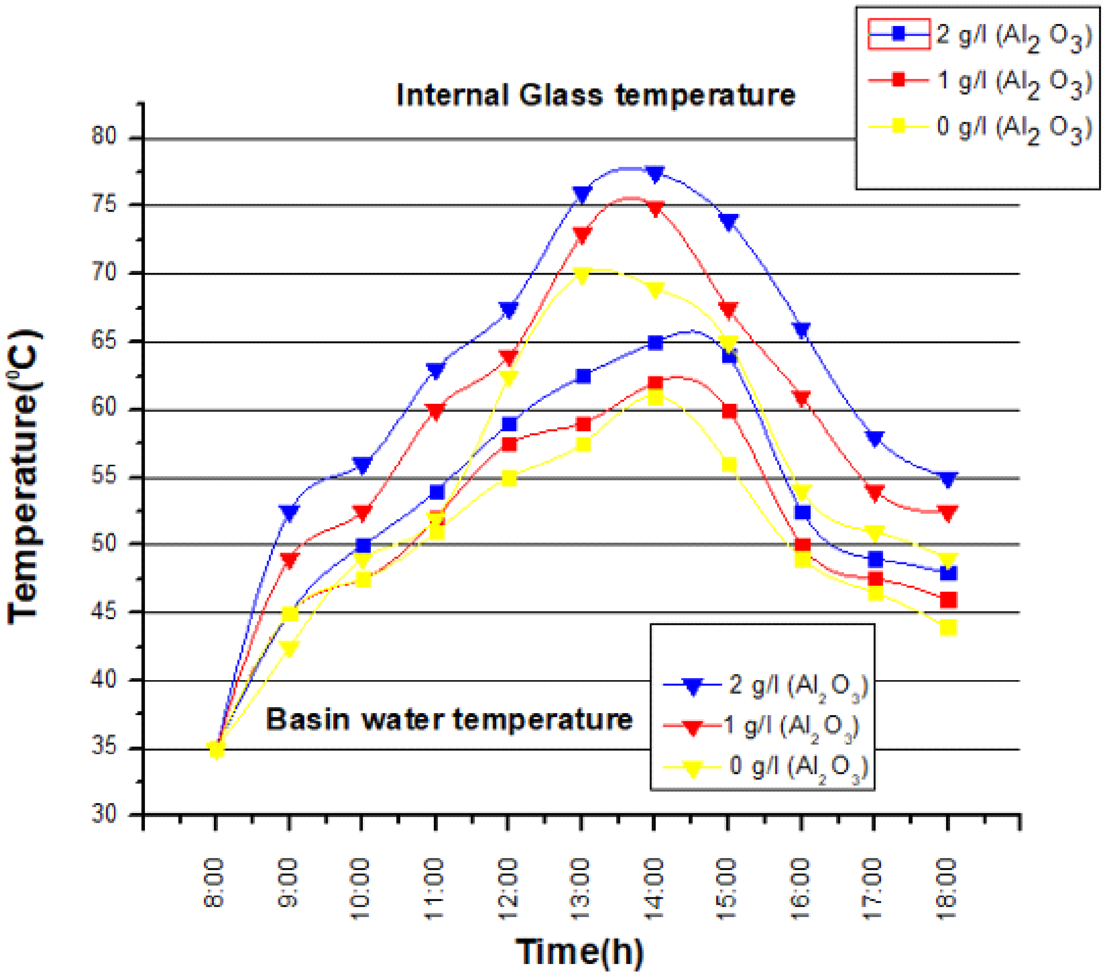


Figure V-8 The variation of the basin salt-water temperature

V-5-4 The variation of the hourly fresh water productivity

Figure V-9show that t fresh water he productivity of thr three destillersicreasses during the daytime and reaches the maximum value around the mid-day the decrease in the temperature gradually reduces the productivity rate in the afternoon period. The maximum productivity is recorded at the maximum temperature of the saline water (from 11 AM. to 4 PM. The effect of nanoparticle is very clear: In fact, the addition of nanoparticles in the basin surface increases the water temperature by increasing the heat transfer rate and as a result, the evaporation rate increases. If we use the aluminum oxide nanoparticles (1 g/ L) and (2 g/ L) the productivity of the nanofluid destillers are increased respectively by about 127 % and 174 % compared with the conventional one.

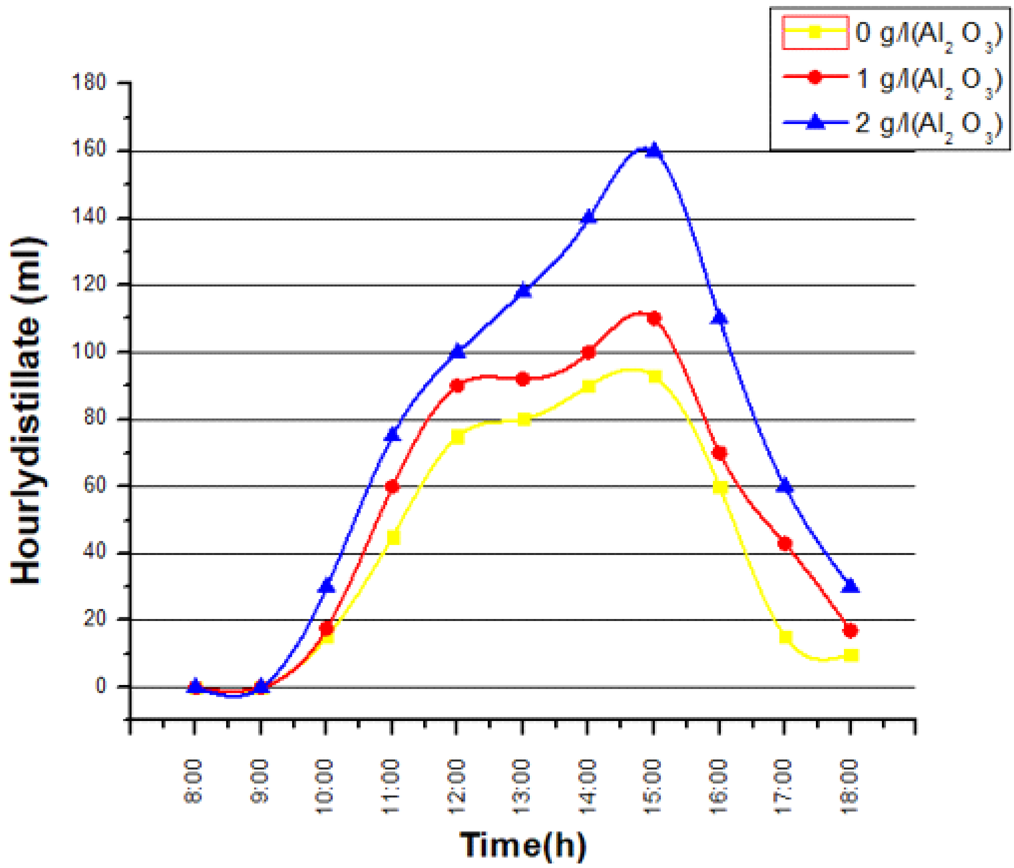


Figure V-9 The variation of the hourly fresh water productivity

GENERAL CONCLUSION

Solar distillation is one of the simplest techniques used in desalination, as it is a successful and inexpensive solution, especially for countries that suffer from a shortage of drinking water and enjoy a large solar energy. There are many factors that help to improve the solar distillation yield, including internal and external factors. Among the most important external factors are solar radiation, wind, ambient temperature and humidity. Among the internal factors, we mention the depth of the salty water and the leakage of water vapor from the distillery and the conditions of thermal insulation of the body and the angle of inclination of the glass cover. In addition to the problem of the lack of safe drinking water facing our region, there is also the problem of having a large percentage of lime in the water, which causes many diseases, including kidney stones, which causes many to pay money to buy clean water to drink, hence the idea of using the sunlight and providing drinking water with lowest cost by using simple solar distillers. But the most important problem facing the solar distillation technique is its low yield, and to overcome this problem we are adding nanotechnology to reduce the severity of this problem. We have accomplished 3 similar solar distilleries containing the same amount of water (5), under the same climatic conditions. The first box is a witness box without nano minutes. As for the second box, we added 1 g of nano powder (AL_2O_3) per one liter of water. box 3 we added 2 g of the same powder.

The experiment has passed in good climatic conditions, where we presented three solar distilleries to the sunlight from 8:00 to 18:00 pm under the same climatic conditions in order to give accurate and accurate results.

.Experience has shown that nanotechnology surprisingly improves the yield of the still, and the results were as follows: a performance improvement of 21% for the concentration of 1 g /l and also by 42% for the concentration of g 2 / l compared to the witness destiller.

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