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Presented by

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Realization of a reduced model of a water distillation station by solar energy: Case study in Africa for Consumption or Irrigation

Defended on 05/09/2019 Before the Following Committee:

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DEDICATIONS

I want to dedicate to my dear parents(MOHAMED ANOUAR & NAJOUAR), but no dedication will be witness to my deep love, my immense gratitude and my greatest respect, for I could never forget the tenderness and the devoted love with which they have always surrounded me since my childhood.

My sister **Sabrine**, my grandmother, my uncles, **RIADH ZLITNI**, **Lotfi** and **Arbi HATTAB**, my aunts **SAIDA** and **SAYDA**, my cousins and all my family for their moral support.

finally, to all the families **Zlitni** and **Hattab** who are the source of my encouragement, to all the people who gave me encouragement and took the trouble to support me during this training

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ABSTRACT

This study concerns the use of clean energy for technical purposes; so we were interested in a simple technique for desalination of seawater, in this case, the distillation by solar radiation.

At the beginning of the study we focused on different solar distillation processes with theoretical description of the phenomenon.

Subsequently, we defined, in general, the radiation in Algeria, before proceeding directly to the practical part of solar distillation by the use of a prismatic glass test bench.

The prototype used at a distillation capacity of 20 litters, it can be moved to the place deemed appropriate, and is equipped with temperature and humidity sensor transmitting the measurement to an Arduino Uno allowing to display the results on an LCD screen or recorded on PC.

Thus, after sampling of seawater, tests and measurements were made on the prototype, placed in a sunny spot near the University of PAUWES, followed by laboratory analysis and discussion of the results.

The various measurements and analyses carried out have demonstrated that the prototype is suitable for the distillation of brines, the salinity level analysed indicates that distilled water is even good for domestic consumption.

Key word: clean energy, solar distillation, radiation in Algeria, prismatic glass test bench, temperature and humidity sensor, salinity level, domestic consumption.

RESUMÉ

Cette étude concerne l’utilisation d’énergie propre à des fins techniques. Nous nous sommes donc intéressés à une technique simple de dessalement de l’eau de mer, en l’occurrence la distillation par rayonnement solaire.

Au début de l’étude, nous nous sommes concentrés sur différents procédés de distillation solaire avec une description théorique du phénomène.

Par la suite, nous avons défini, d’une manière générale, le rayonnement en Algérie, avant de passer directement à la partie pratique de la distillation solaire par l’utilisation d’un banc d’essai en verre prismatique.

Le prototype utilisé avec une capacité de distillation de 20 litres, peut être déplacé vers le lieu jugé approprié et est équipé d’un capteur de température et d’humidité transmettant la mesure à une carte Arduino Uno permettant d’afficher les résultats sur un écran LCD ou enregistré sur PC.

Ainsi, après avoir eu des échantillons de l’eau de mer, des tests et des mesures ont été effectués sur le prototype placé dans un endroit

ensoleillé près de l’université de PAUWES, suivis d’une analyse en laboratoire et d’une discussion de vérification des résultats.

Les différentes mesures et analyses effectuées ont montré que le prototype était adapté à la distillation des saumures. Le niveau de salinité analysé indique que l’eau distillée est même prêt à la consommation domestique.

Mot clé: énergie propre, distillation solaire, rayonnement en Algérie, banc d’essai en verre prismatique, capteur de température et d’humidité, niveau de salinité, consommation domestique.

ملخص

تتعلق هذه الدراسة باستخدام الطاقة النظيفة لألغراض الفنية ؛ لذلك كنا مهتمين بتقنية بسيطة لتحلية مياه البحر ، وفي هذه الحالة ، التقطير باإلشعاع الشمسي في بداية الدراسة ركزنا على عمليات التقطير الشمسية المختلفة مع وصف نظري للظاهرة بعد ذلك ، حددنا ، بشكل عام ، اإلشعاع في الجزائر ، قبل االنتقال مباشرة إلى الجزء العملي من التقطير الشمسي باستخدام طاولة اختبار الزجاج المنشورية النموذج األول المستخدم بسعة تقطير 20 الرل يمكن نقله الى المكان الدي يعتبر مناسبا و مجهزا بمستشعر درجة الحرارة و الرطوبة ينقل القياس الى بطاقة اردوينو اونو مما يسمح بعرض النتائج او تسجيلها على جهاز الكمبيوتر شاشة ال سي دي وهكذا ، بعد أخذ عينات من مياه البحر ، أجريت اختبارات وقياسات على النموذج األولي ، وضعت في بقعة مشمسة بالقرب من جامعة باوس و تليها التحليل المخبري و منقاقشة النتائج.

أظهرت القياسات والتحاليل المختلفة التي أجريت أن النموذج األولي مناسب لتقطير المحاليل الملحية ، ويشير مستوى الملوحة الذي تم تحليله إلى أن الماء المقطر مفيد لالستهالك المنزلي.

الكلمة ألساسية: الطاقة النظيفة ، التقطير الشمسي ، اإلشعاع في الجزائر ، منضدة اختبار الزجاج المنشورية ، مستشعر درجة الحرارة والرطوبة ، مستوى الملوحة ، االستهالك المحلي

Sommaire

CHAPTER ONE: INTRODUCTION

1.1.Introduction:

In this part, an overview of the distillation by solar energy process as a solution to the scarcity of potable water if we compare the increase of global water consumption by the freshwater that can be mobilized.

1.2.Background information:

One of the most abundant resources on earth is the water whereas three-fourth of the earth's surface is occupied by water but very few of them can be used for drinking water purpose.

The geography science indicates that about 97% of earth's water is saltwater in the oceans and only 3% is fresh water which is existed in the poles (in the form of ice), ground water, lakes, and rivers [1].

Unfortunately, 70% of this small 3% is inaccessible due to glaciers and permanent snow cover. Also, 30% of the entire freshwater is underground and just a little more than 0.25% of freshwater is in human access which is comprised of lakes and rivers [2].

Nowadays, global water consumption has increased compared to the amount of freshwater due to population growth [3], incorrect water usage, and management problems of the usable water resources that can be mobilized, aggravating the situation of access to water that has become one of the major challenges of this century that humanity must quickly recover.

According to united not access to clean drinking water; water scarcity defines as a lack of sufficient water resources. Today, the availability of drinking water is the prime requirement for all [4].

So, having a better understanding of existing water resources is crucial to filling this gap. Oceans are an inexhaustible reserve, other reserves such as brackish water are too salty to be directly consumable and they are also exploitable.

In the context of Algeria, it has limited natural resources, irregular and very unevenly distributed. With the exception of the fossil waters of the Sahara, natural hydraulic resources are mainly located in the north of the country.90% of the total surface flow is in the littoral region, the remaining 10% is shared between the highlands and the Saharan basins [5].

Specifically in Tlemcen, quality indicators were measured and differences were quantified in assessing the state of the water supply network, managers in the organization as well as subscribers were surveyed; and finally corrective and preventive measures were then taken to ensure continuous operation and sustainability of the service.

The results showed that the drinking water supply in the urban group of Tlemcen was characterized by an insufficient production which could not cover the actual needs. Water was provided to the districts twice per week only for a few hours [6].

Adding to this, there was a 50% water loss during transport as a consequence of steel pipeline corrosion, poor quality workmanship, and a lack of proper maintenance and renewal of the conduits.

One way to overcome, or at least reduce, this problem is desalination of brackish water and seawater [7].

Faced with challenges, Algeria has followed a conventional water resources planning and even the use of unconventional water resources, including seawater distillation which has become an increasingly urgent need and a solution imposed to meet these growing needs and to relieve pressure on local resources.

In the last decade, Algeria has carried out a dozen desalination plants along its shoreline, which almost of all use osmotic filtration and are intended for large-scale drinking water supply significant flows produced by stations [8].

Of course, nothing seems easier than imitating nature, it is enough to distil sea water to extract fresh water, that is to say produce water vapor by boiling the water. Sea water and recover the fresh water by condensation of the steam.

Thus, desalinate seawater or brackish water to obtain freshwater is one of the solutions to mitigate the problem of water scarcity, which means that more and more states have access to water.
As a result, water desalination is experiencing rapid development and is currently required in some water-scarce areas [9].
Desalination processes require energy for separation of salt from brackish water or seawater. The intense rising of desalination systems consumes lots of energy which cause environmental pollution due to the use of fossil fuels.
Renewable systems are a desirable selection to replace with fossil fuels energy base systems for preventing harmful effluent and environmental problems [10].
However, solar energy is a free and a clean source of the energy compared to fossil energy.
In the context of Algeria, the average annual solar radiation is 19.13 MJ/m2 per day, which has a high technical and economic potential for solar power exploitation with about 170 TWh per year. Using that great energy in water distillation is promising technology.
In this paper, we will study the distillation by solar radiation of sea water, for the water supply of the small agglomerations of the littoral, as well as the beaches in summer period.
Fresh water production using desalination technologies [11] driven by renewable energy system is a reasonable solution to the water scarcity in Tlemcen's remote areas marked by the lack of potable waters.
To show the importance of the subject and its role in mitigating problems of water supply of hamlets and beaches in summer, in this work, we carried out the distillation test using a prototype of solar distillation.

1.3. Scope of the study:

Distilled water is very useful water in industries, houses and agriculture field.
So this research will provide the facility in the village also general people can setup small equipment on the roof of the building and get distil water continuous basis. This research will provide the growth of the small scale industries in the village side in Tlemcen.

1.4. Objectives of the study:

The work objective is to design a portable water distillation system, which depends on thermal solar energy on the daytime.
The important objectives to distillate seawater are:

1- Provides people with potable water (clean & fresh drinking water).
2- Provides water to the agricultural industry.
3- Water quality is safe (not dangerous or hazardous to any living thing).
4- Uses tried-and-tested technology (the method is proven and effective).
5- Helps preserve current freshwater supplies.
6- Unlimited ocean water as source.
7- Independent of changing factors.
8- Plants are safely located.
9- Help with habitat protection.

1.5. Conclusion:

In this part, we spoke about the problem of fresh water's lack specifically in Algeria Tlemcen and we gave the solution that is water distillation by solar energy.

CHAPTER TWO: LITTERATURE REVIEW

2.1.Introduction:

In this part, we are mentioned the critical analysis of existing knowledge on the water distillation project, the author and publisher.

2.2.Review on the past study:

Nature uses solar energy to desalinate ocean water by means of the rain cycle. In the rain cycle, sea water gets heated (by solar irradiation) and humidifies the air which acts as a carrier gas. Then the humidified air rises and forms clouds. Eventually, the clouds 'dehumidify' as rain. The man-made version of this cycle is called the humidification dehumidification desalination (HDH) cycle.

The main drawback of the solar still is that the various functional processes (solar absorption, evaporation, condensation, and heat recovery) all occur within a single component. By separating these functions into distinct components, thermal inefficiencies may be reduced and overall performance improves. This separation of functions is the essential characteristic of the HDH system. For example, the recovery of the latent heat of condensation, in the HDH process, is affected in a separate heat exchanger (the dehumidifier) wherein the seawater, for example, can be preheated. The module for solar collection can be optimized almost independently of the humidification or condensation component.

The HDH process, thus, promises higher productivity due to the separation of the basic processes Pr. M.Zamen & al [12] Authors evaluates multistage technique to improve the efficiency of the solar HD process through mathematical programming method. Also it is concluded that according to modeling results and construction cost. A two stage process is the most suitable choice for fresh water production. This unit could be designed as a combined system for simultaneously fresh water and hot water production. The Pr. Lixi Zhang & al [13] they were introduced a solar desalination process using air humidification and dehumidification. In order to increase the output of freshwater, multi-technologies are adopted; the double-pass solar air heater and tubular solar collector are used to heat the air and seawater respectively. The air is humidified by bubbling in the seawater pool, and dehumidified in the inorganic heat pipe condenser the researcher of M. Abd Elkader [14] found the principle of desalination in every stage is based on evaporation to and condensation from a closed natural convection air loop in a thermal insulation box. A three stage multi-effect humidification (MEH)- dehumidification process with energy storage system, the experimental test results showed that, the increase of seawater mass flow rate through the system from 0.1 liter/s to 0.13 liter/s increases the productivity of the system by 10 %. It can be seen from the results also that the use of energy storage increases the productivity by 13.5%. The researcher of Shaobo Hou & al [15] the solar evacuated tube collector is employed in the desalination system, multi-effect humidification dehumidification desalination (HDD) process is plotted, and then the water rejected from multi- effect HDD process is reused to desalinate in a basin-type unit further. The researcher of Javier Leon & al [16] solar seawater desalination using parabolic trough solar collectors coupled with conventional Multi-Effect Desalination plants.

However, and besides significant achievements in the process energy efficiency, by the development and implementation of a double-effect absorption heat pump, the technology cannot yet compete in cost reduction with conventional thermal distillation.

Solar still is a device to desalinate impure water like brackish or saline water. It is a simple device to get fresh distilled water from impure water, using solar energy as fuel, for its various applications in domestic and industrial sectors. The basic concept of using solar energy to obtain drinkable fresh water from salty [17], brackish or contaminated water is really quite simple.

2.3.Conclusion:

In this section, most resources are from the past eight years using citations that are nine years and older only when necessary and for historical purposes.

CHAPITER THREE: METHODS
PART ONE: DESALINATION AND DISTILLATION

3.1.Introduction:

Problems related to water are many very various. Fresh water is a precious resource that is often in short supply. Other reserves such as brackish water or seawater where water is plentiful are too salty to be directly consumable and they are also exploitable. The only problem is that salt water and industrial machinery do not make good companions [18].

However, desalination can remove the sodium chloride, minerals, and impurities from the water and make it a viable resource that can be used to keep your operations flowing.

There is therefore no simple solution to meet his demand in any country. There are many methods of desalination including, ion exchange, and membrane [19] removal of marine or brackish water is a process that allows the extraction of salt to make it drinkable.

3.2.Desalination:

Desalination can be defined as any process that removes salts from water. Desalination processes may be used in municipal, industrial, or commercial applications. With improvements in technology, desalination processes are becoming cost-competitive with other methods of producing usable water for our growing needs [20].

3.2.1. Definition of desalination:

There are multiple methods of desalination including distillation, ion exchange, and membrane removal.

Using distillation, te water is heated until it boils. As it boils, the water vapor rises until it reaches the top of the distillation container. There, the vapor condenses as it is cooled and collected into a vat or cooling pond. Since the salt is heavier than air, it remains within the distillation container [21].

Running salt water between an anode and a cathode separates the sodium chloride from the solution. Ion exchange is highly effective at removing other impurities and is among the oldest desalination methods still in use [22].

3.2.2. Desalination technologies:

A desalination process essentially separates salt water into two parts [23]:

- That has a low concentration of salt (treated water or product water)
- With a much higher concentration than the original feed water, usually referred to as brine concentrate or simply as “concentrate”.

The two major types of technologies that are used around the word for desalination can be broadly classified as either thermal of membrane.

Both technologies need energy to operate and produce fresh water. Within those two broad types, there are many processes using different techniques [24].

The major desalination processes are identified in the diagram below:

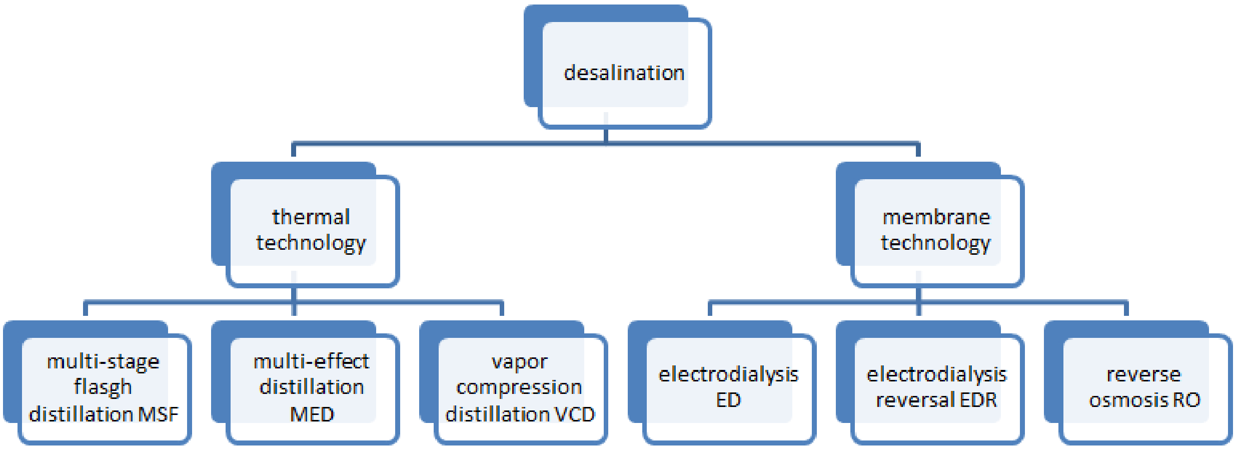

Figure 3-1: Diagram of desalination process

3.2.2.1. Thermal technologies:

Thermal technologies, as the name implies, involve the heating of saline water and collecting the condensed vapor “distillate” to produce pure water.
Thermal technologies have rarely been used for brackish water desalination, because of the high costs involved.
They have however been used for seawater desalination and can be sub-divided into three groups:

- Multi-Stage Flash Distillation MSF.
- Multi-Effect Distillation MED.
- Vapor Compression Distillation VCD.

a. Multi-Stage Flash Distillation MSF:

This process involves the use of distillation through several “multi-stage” chambers. In the MSF process, each successive stage of the plant operates at progressively lower pressures. The feed water is first heated under high pressure, and is led into the first “flash chamber”, where the pressure is first heated under high pressure, and is led into the first “flash chamber”, where the pressure, is released, causing the water to boil rapidly resulting in sudden evaporation or “flashing”. This “flashing” of a portion of the feed continues in each successive stage, because the pressure at each stage is lower than in the previous stage. The vapor generated by the flashing is converted into water by being condensed on heat exchanger tubing that run through each stage. The tubes are cooled by the incoming cooler feed water. Generally, only a small percentage of the feed water is converted into vapor and condensed [25].
Some MSF plants can contain from 15 to 25 stages, but are usually no larger than 15 mgd in capacity. MSF distillation plants can have either a “once-through” or “recycled” process. In the “once-through” design, the feed water is passed through the heater and flash chambers just one and disposed of, while in the recycled design, the feed water for cooling is recycled. Each of these processes can be structured as a “long tube” or “cross tube” design. In the long tube design, the feed water for cooling is recycled. Each of these processes can be structured as a “long tube’ or “cross tube” design. In the long tube design, tubing is parallel to the concentrate flow, while in the cross tube design, tubing is perpendicular to the concentrate flow.
MSF plants are subject to corrosion unless stainless steel is used extensively [26].
Most of those plants have been built overseas, primarily in the Middle East, where energy resources have been plentiful and inexpensive.

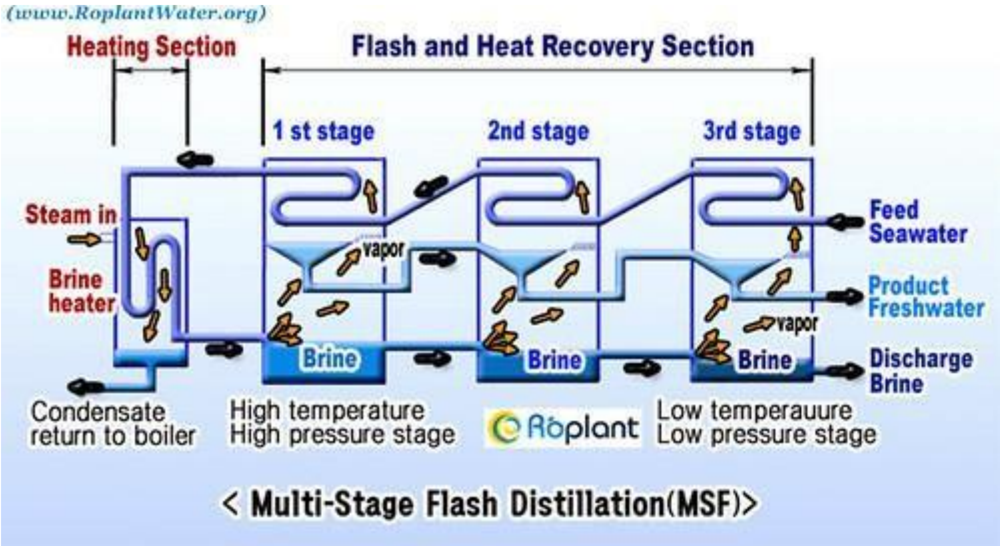

Figure 3-2: Diagram of desalination process

b. Multi-Effect Distillation MED:

Multi-effect distillation MED occurs in a series of vessels “effects” and uses the principles of evaporation and condensation at reduced ambient pressure.

In MED, a series of evaporator effects produce water at progressively lower pressures.

Water boils at lower temperatures as pressure decreases, so the water vapor of the first vessel or effect serves as the heating medium for the second, and so on. The more vessels or effects there are, the higher the performance ratio. Depending upon the arrangement of the heat exchanger tubing, MED units could be classified as horizontal tube, vertical tube or vertically stacked tube bundles.

Stream from the power plant is directed to the evaporators in the desalination units. Product water is obtained as condensate of the vapor from each vessel.

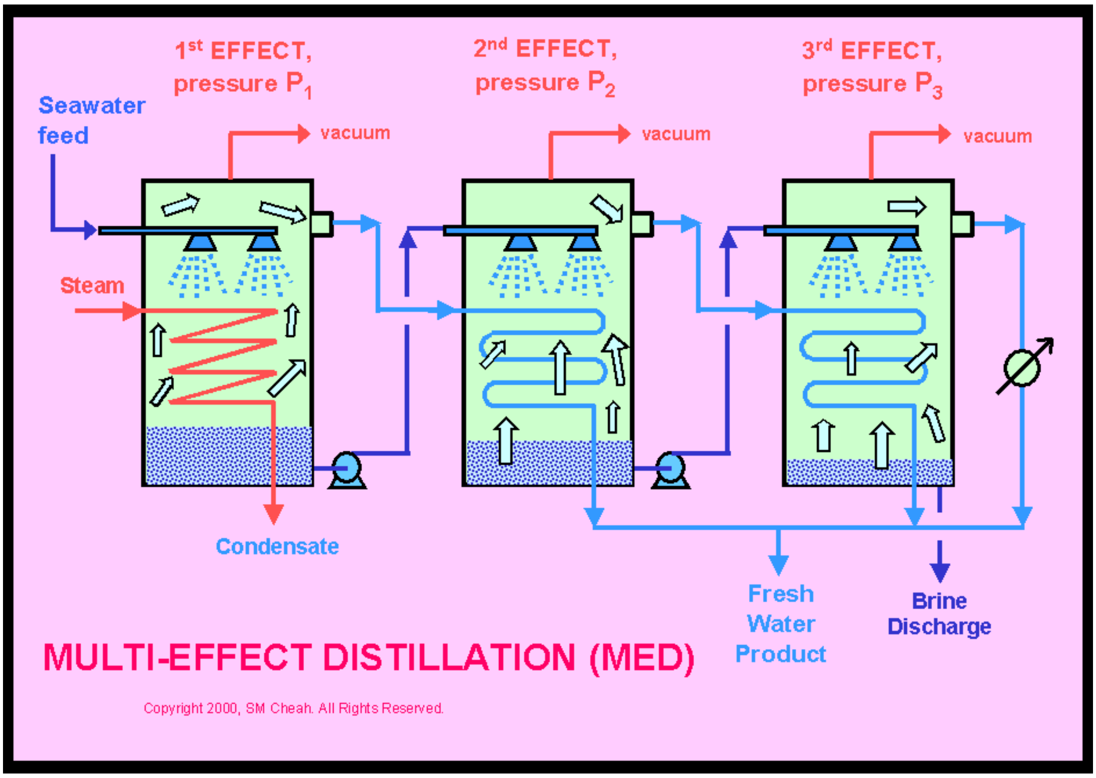

Figure 3-3: Multi-Effect Distillation MED

c. Vapor Compression Distillation VCD:

The vapor compression distillation VCD process is used either in combination with other processes such as the MED, or by itself.

The heat for evaporating the water comes from the compression of vapor, rather than the direct exchange of heat from steam produced in a boiler.

Vapor compression VC units have been built in a variety of configurations.

Usually, a mechanical compressor is used to generate the heat for evaporation. The VC units are generally small in capacity, and are often used at hotels, resorts and in industrial applications.

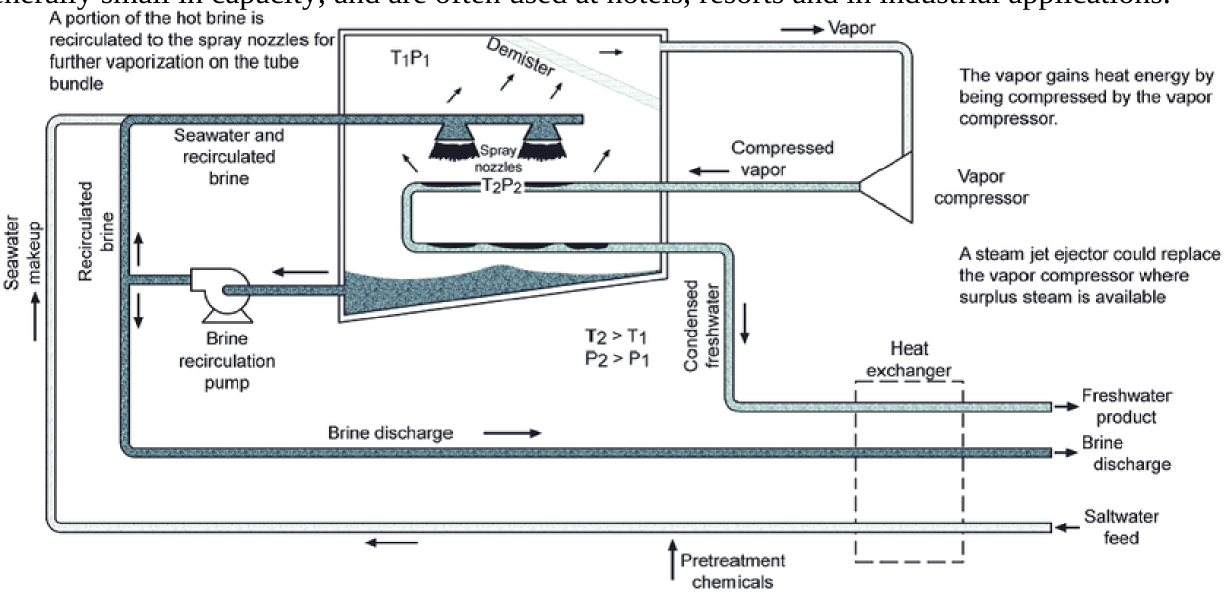

Figure 3-4: Vapor Compression Distillation VCD

3.2.2.2. Membrane technologies:

Membrane technologies can be subdivided into two broad categories:

- Electrodialysis ED.
- Electrodialysis Reversal EDR.
- Reverse Osmosis RO.

a. Electrodialys ED:

Electrodialysis ED is a voltage-driven membrane process. An electrical potential is used to move salts through a membrane, leaving fresh water behind as product water.
Although, ED was originally conceived as a seawater desalination process, it has generally been used for brackish water desalination.
ED depends on the following general principles [27]:

- Most salts dissolved in water are ions, either positively charged "cations", or negatively charded "anions".
- The ions migrate toward the electroldes with an opposite electric charge, since like poles repel each other and unlike poles attract.
- Suitable membranes can be constructed to permit selective passage of either anions or cations.

In a saline solution, dissolved ions such as sodium "+" and chloride "-" migrates to the opposite electrodes passing through selected membranes that either allows cations or anions to pass through "not both".
Membranes are usually arranged in an alternate pattern, with anion-selective membrane followed by a cation-selective membrane.
During this process, the salt content of the water channel is diluted, while concentrated solutions are formed at the electrodes [28].
Concentrated and diluted solutions are created in the spaces between the alternating membranes, and these spaces bound by two membranes are called cells.
ED units consist of several hundred cells bound together with electrodes, and is referred to as a stack. Feed water passes through all the cells simultaneously to provide a continuous flow of desalinated water and a steady stream of concentrate "brine"from the stack.

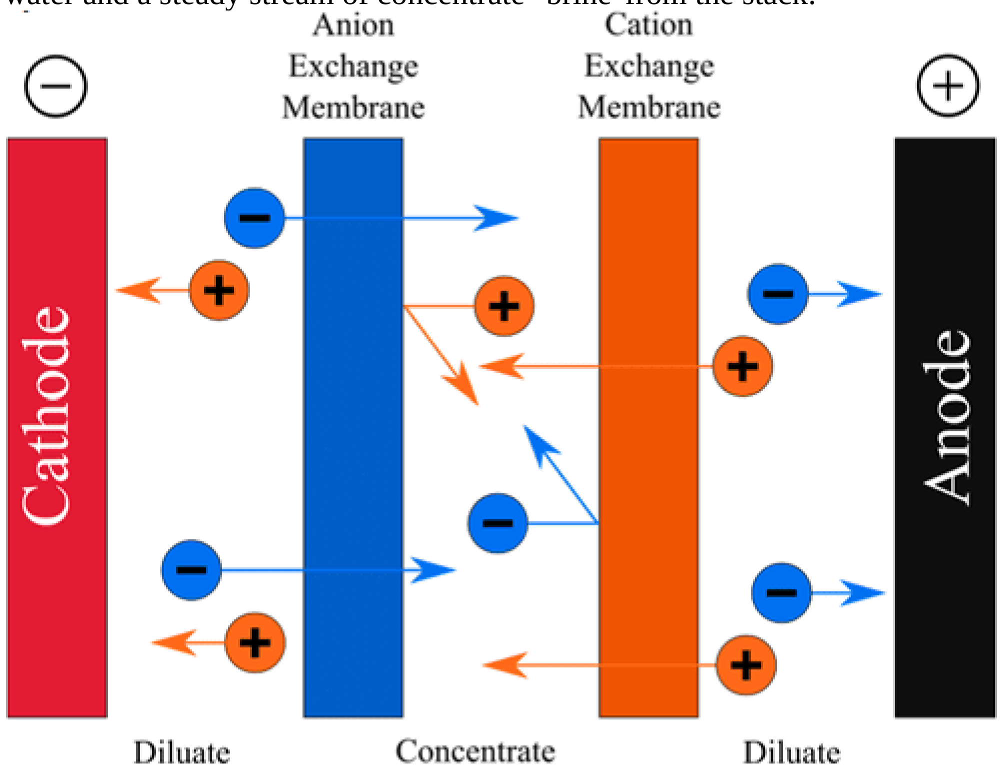

Figure 3-5: Electrodialysis ED

b. Electrodialysis Reversal EDR:

An Electrodialysis Reversal EDR unit operates on the same general principle as an ED unit, except that both the product and concentrate channels are identical in construction.

At intervals of several times an hour, the polarity of the electrodes is reversed, causing ions to be attracted in the opposite direction across the membranes.

Immediately following reversal, the product water is removed until the lines are flushed out and desired water quality restored:

The flush takes just a few minutes before resuming water production. The reversal process is useful in breaking up and flushing out scales, slimes, and other deposits in the cells before they build up. Flushing helps in reducing the problem of membrane fouling [29].

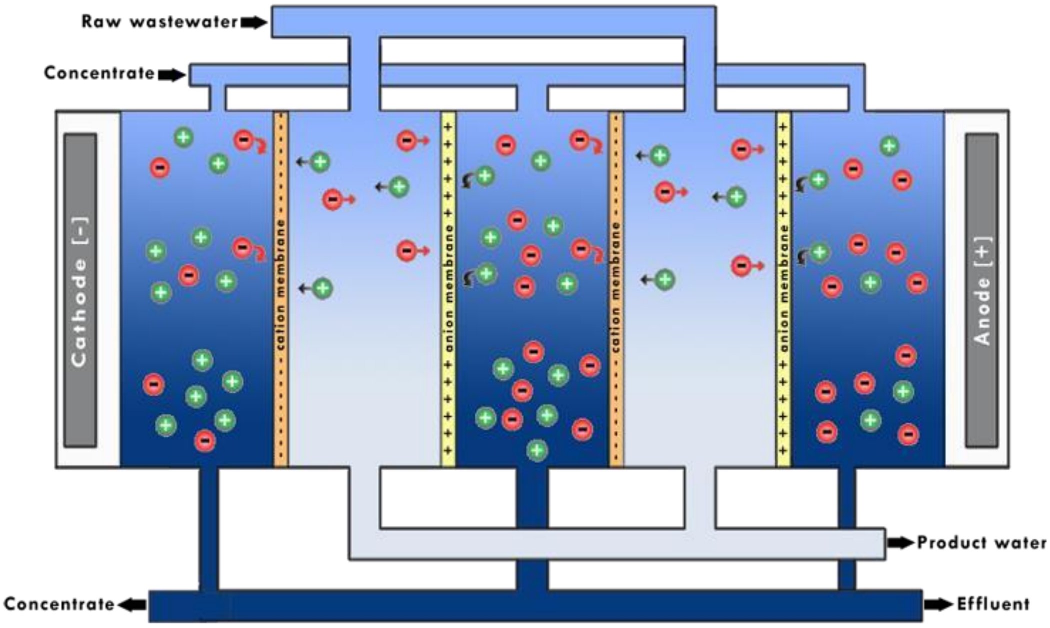

Figure 3-6: Electrodialysis Reversal EDR

c. Reverse Osmosis RO:

The Reverse Osmosis RO process uses pressure as the driving force to push saline water through a semi-permeable membrane into a product water stream and a concentrated brine stream.

Nano-filtration “NF” is also a membrane process that is used for removal of divalent salt ions such as Calcium, Magnesium and Sulphate.

On the other hand, RO is used for removal of Sodium and Chloride. RO processes are used for desalinating brackish water and seawater [30].

Osmosis process is a natural phenomenon by which water from a low salt concentration passes into a more concentrated solution through a semi-permeable membrane. When pressure is applied to the solution with the higher salt concentration solutions, the water will flow in a reverse direction through the semi-permeable membrane, leaving the salt behind. This is known as the Reverse Osmosis process of RO process.

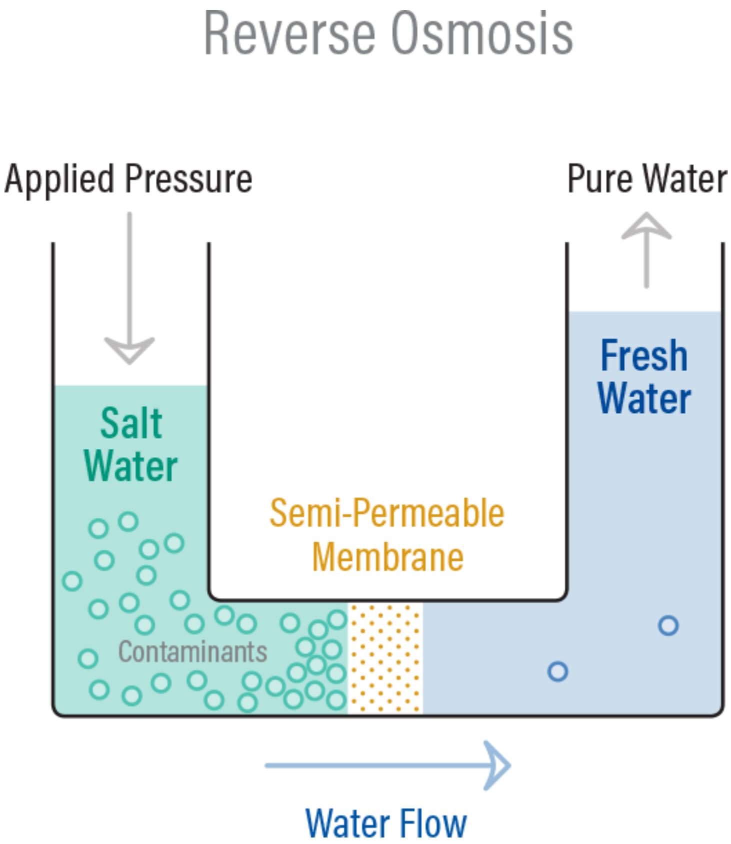

Figure 3-7: Reverse Osmosis RO

The Reverse Osmosis desalination plant is shown below:

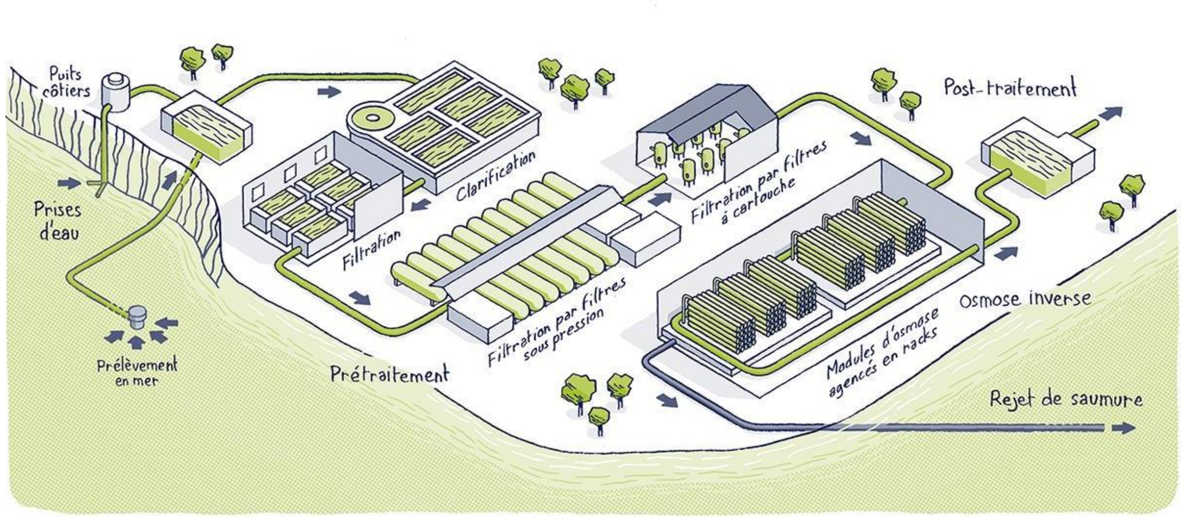

Figure 3-8: Reverse Osmosis desalination plant

The desalination plants are built according to the needs and the type of water to be treated. These plants incorporate innovative technologies to optimize processes, reduce operating costs and environmental impacts.

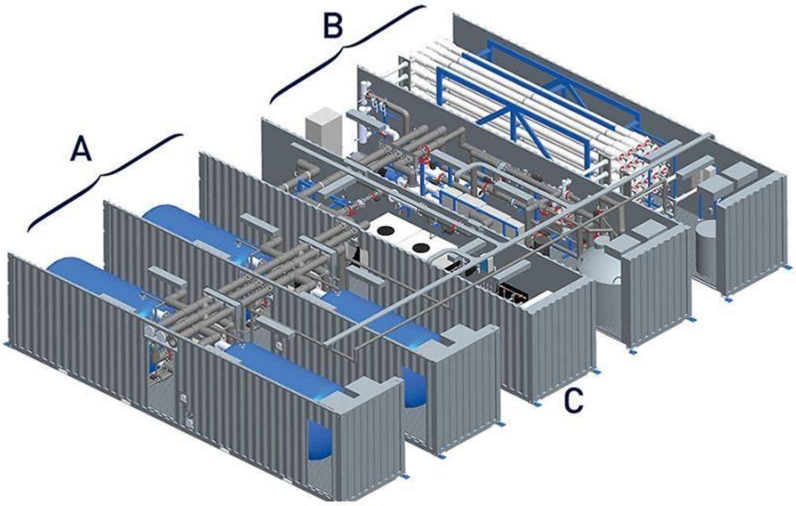

Figure 3-9: Module in containers with a cumulative capacity adapted to the desired production volumes

Each module with an individual production capacity consists of five containers:

- Zone A: Pre-treatment on bilayer filters “2 containers”.
- Zone B: Reverse Osmosis RO membrane treatment “2 containers”.
- Zone C: final treatment + feed pump“1 container”.

An RO desalination plant essentially consists of four major systems:

- **Pre-Treatment System:**

Pre-treatment is very important in RO because the membrane surface must remain clean. Therefore, all suspended solids must be first removed, and the water pre-treated so that salt precipitation or microbial growth does not occur on the membranes. Pre-treatment may involve conventional methods such as a chemical feed followed by coagulation/flocculation/sedimentation and san filtration, or pre-treatment may involve membrane processes such as microfiltration “MF” and ultrafiltration “UF”. The choice of a particular pre-treatment process is based on a number of factors such as feel water quality characteristics, space availability, RO membrane requirements, etc [31].

- **High-Pressure Pumps:**

High pressure pumps supply the pressure needed to enable the water to pass through the membrane and have the salt rejected. The pressures range from about 150 psi for slightly brackish water to 800 – 1,000 psi for seawater [31].

- **Membrane Systems:**

The membrane assembly consists of a pressure vessel and a semi-permeable membrane inside that permits the feed water to pass through it.

RO membranes for desalination generally come in two types: Spiral wound and Hollow fiber.

- **Spiral Wound:**

Spiral Wound elements are actually constructed from flat sheet membranes. Membrane materials may be made of cellulose acetate or of other composite polymers. In the spiral wound design, the membrane envelope is wrapped around a central collecting tube.

The feed water under pressure, flows in a spiral path within the membrane envelope, and pure desalinated’ water is collected in the central tube [31].

As a portion of the water passes through the membrane, the remaining feed water increases in salt content.
A portion of the feed water is discharged without passing through the membrane. Without this discharge, the pressurized feed water would continue to increase in salinity content, causing super-saturation of salts. The amount of feed water that is discharged as concentrate ranges from about 20 percent for brackish water to about 50 percent for seawater [32].

- **Hollow Fiber:**

Hollow Fiber design places a large number of hollow fiber membranes in a pressure vessel. The pressurized saline water is introduced into the vessel along the outside of the hollow fibers.
Under pressure, desalinated water passes through the fiber walls, and flows in the hollow fibers for collection. This type of design is not as widely used now as the spiral wound membranes for desalination.

- **Post-treatment:**

Post-treatment consists of stabilizing the water and preparing it for distribution. The post-treatment might consist of adjusting the pH and disinfection.
If the desalinated water is being combined with other sources of water supply, it is very important to ensure similar water quality characteristics in both water sources [31],

3.2.3. Advantages and disadvantages of desalination:

3.2.3.1. Advantages:

- Desalination cans also be used to provide a cost-effective alternative to unreasonable water prices. These prices usually occur in regions where water isn't plentiful and drought conditions make setting up operations difficult.
- Desalination is not a new concept, and it has been used around the globe in varying degrees for thousands of years. Coupled with modern technology and knowledge of filtering techniques, desalination is highly viable throughout the world.
- Desalinated water is often cleaner than many freshwater sources that the process is used to remove not only sodium chloride but many other impurities.
- Desalination water helps to protect vital machinery from mechanical breakdowns that impurities can damage the equipment. This advantage can reduce operational maintenance costs and extend the lifespan of equipment [33].

3.2.3.2. Disadvantages:

- Desalination consumes a large amount of energy that the opponents to desalination have pointed out that it is not feasible due to the fact that it requires a significant amount of energy to operate. The distillation process requires millions of gallons of saltwater to be boiled at high temperatures before it is potable.
- Desalination cost is high: Desalination plants can be expensive to build and to operate, which may not include equipment and worker training. They can also be expensive to maintain and these costs are affected by the energy price changes. Some studies say that 'desalinated water is five times more expensive to harvest than freshwater, making it too costly for the average consumer'.
- Desalination consumes a large amount of energy that the opponents to desalination have pointed out that it is not feasible due to the fact that it requires a significant amount of energy to operate. The distillation process requires millions of gallons of saltwater to be boiled at high temperatures before it is potable.
- Desalination's environmental impact can be high: while desalination plants can help to stop species endangerment, it is also possible that they can have a negative environmental impact. Chlorine and other chemicals are often added to the water during

processing and left behind with the brine which, if dumped back into the ocean, will bring many harmful substances with it. It can also cause stress and damage to animals that are not used to highly saline water [34].

3.3.Distillation:

Distillation is a physical method of separating mixtures depending upon the difference in the boiling point of the component substances. In simple words, the working principle of distillation is to heat a mixture at a specific temperature, collect the hot vapor, and condense to separate the component substance. In short, a highly volatile compound is separated from a less-volatile compound by using distillation.

Today, it is one of the most popular technic implemented for purification and separation of a mixture.

In this study, solar distillation refers to the evaporation of aquatic solutions by means of solar energy and to the simultaneous condensation of the vapor, created by the activity of solar thermal energy [35].

3.3.1. Few types of distillation:

There are several methods of distillation depending on the procedure and the instrument setup. Following are the common types:

3.3.1.1. Simple distillation:

In this process the simple distillation involves heating the liquid mixture to the boiling point and immediately condensing the resulting vapors.

Simple distillation is used for a mixture in which the boiling point of the components differs by at least 158°F (70°C).

This method is best for separating a liquid from a solution. It is also followed for the moistures contaminated with no-volatile particles (solid or oil), and those that are nearly pure with less than 10% contamination.

For example, if you want to separate water from a salt solution, simple distillation would be great for this. It works like this:

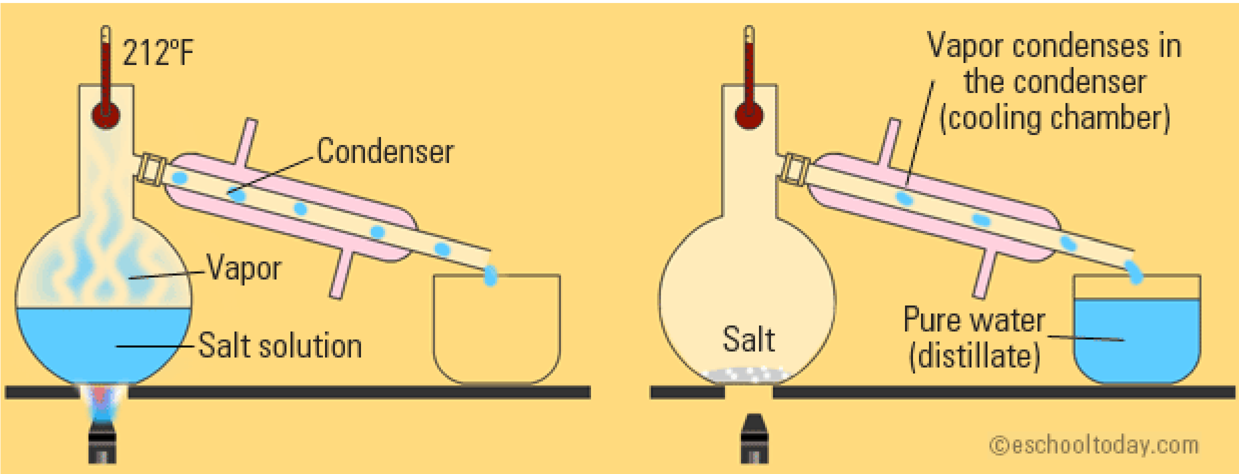

Figure 3-10: Simple distillation

- A beaker of the salt solution is heated to the boiling point of the liquid.
- As it boils, the liquid turns into vapor (gas).
- The vapor is directed through tubes (condenser) connected to another beaker.
- As the vapor goes through the tube, it is cooled down by running cold water around the tubes.

- This forces the temperature of the vapor to fall, causing the gas to turn into liquid again (condensation).
- The liquid is pure at this point, as it is free from salt.
- The process continues until all the liquid in the solution turns into vapour, leaving the salt residue.

3.3.1.2. Fractional distillation:

Fractional distillation is used when the boiling points of the components of a mixture are close to each other, as determined using Raoult's law. A fractionating column is used to separate the components used a series of distillations called rectification. In fractional distillation, a mixture is heated so vapour rises and enters the fractionating column. As the vapour cools, it condenses on the packing material of the column. The heat of rising vapour causes this liquid to vaporize again, moving it along the column and eventually yielding a higher purity sample of the more volatile component of the mixture [36].

The equipments required to perform a fractional distillation on a mixture is listed below:

- Round-bottom flask or distilling flask
- A source of heat, which can be a fire or a hot baht
- Receiving flask to collect the condensed vapours
- Fractioning column
- Thermometer to measure the temperature in the distilling flask
- Condenser
- Standard Glassware

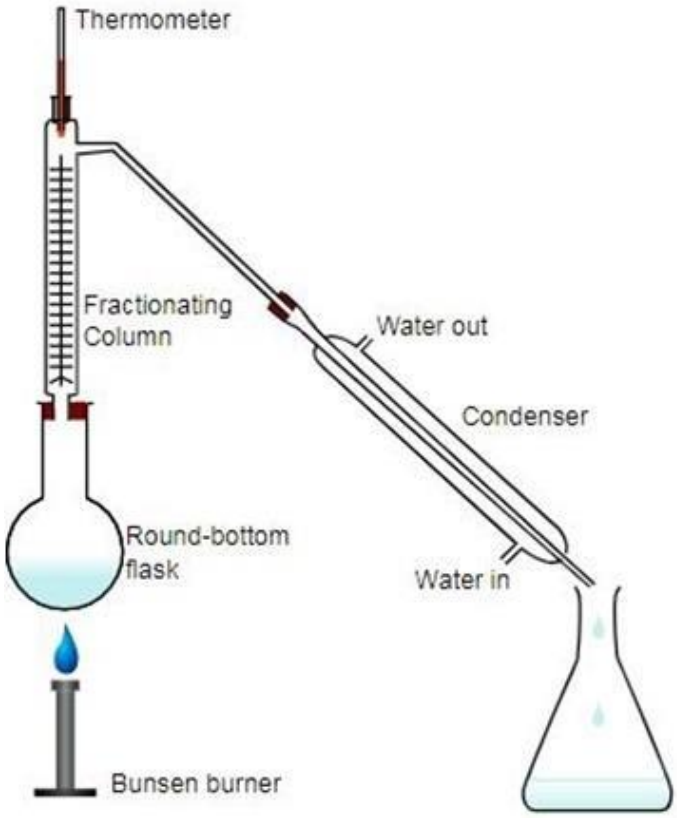

Figure 3-11: Fractional distillation

This method is more effective and easy to use process, compared to simple distillation method. It is, however, comparatively expensive than any other types of distillation. Fractional distillation is used for the alcohol purification and gasoline purification in petroleum refining industries. It is commonly used condensers in laboratories include Liebig condensers and Graham condensers [37].

3.3.1.3. Steam distillation:

Steam distillation id often used to separate heat-sensitive components in a mixture. In this process, steam is added to the mixture to vaporize some of it. The process establishes a high heat-transfer rate without the need for high temperatures.

This vapour is cooled and condensed into two liquid fractions. Sometimes the fractions are collected separately, or they may have different density values, so they separate on their own.

The process of steam distillation is used to obtain essential oils and herbal distillates from several aromatic flowers/herbs [38].

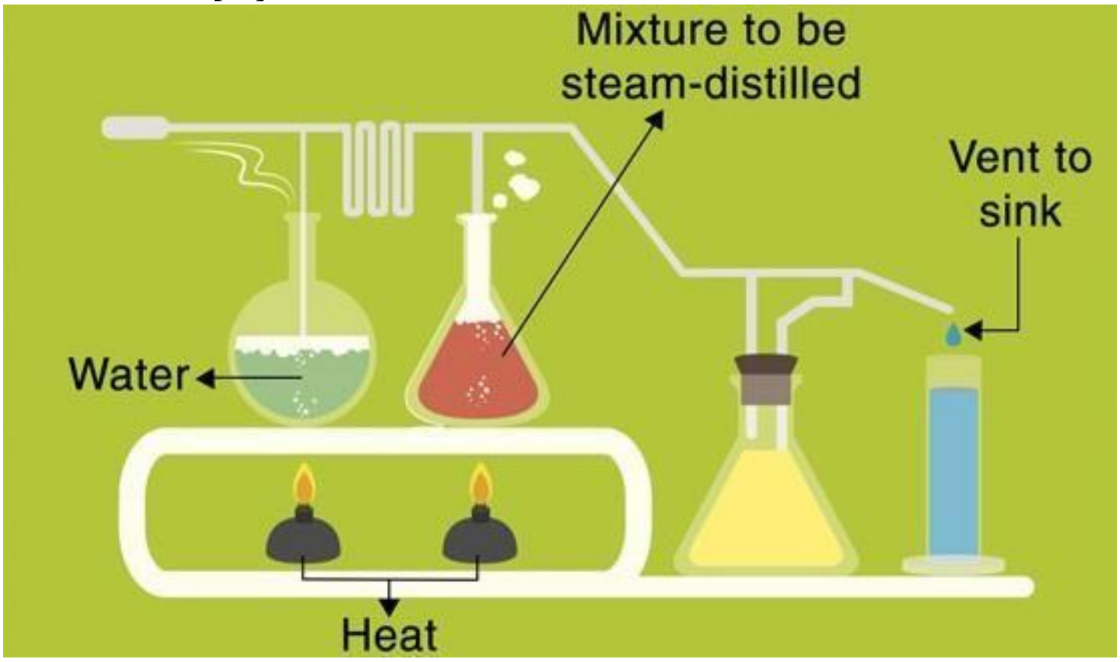

Figure 3-12: Steam distillation

The advantage of steam distillation over simple distillation is that hte lower boiling point reduces decomposition of temperature-sensitive compounds.

The process requires some initial training and skill to operate the equipment. It also requires periodic maintenance.

Steam distillation is the preferred method used for large-scale to isolate essential oils, fats, waxes, and perfumes. It is also used for “steam stripping” in petroleum refineries and to separate commercially important organic compounds, such as fatty acids [39].

3.3.1.4. Vacuum distillation:

Vacuum distillation is a special method of separating compounds that have high boiling points. The lowering of the pressure enables the component to boil at lower temperatures. In order to boil these compounds, heating to high temperatures is an inefficient method. Once the vapour pressure of the components is equal to the surrounding pressure, it is converted into a vapour.

Otherwise, the process is similar to other forms of distillation. Vacuum distillation is particularly useful when the normal boiling point exceeds the decomposition temperature of a compound.

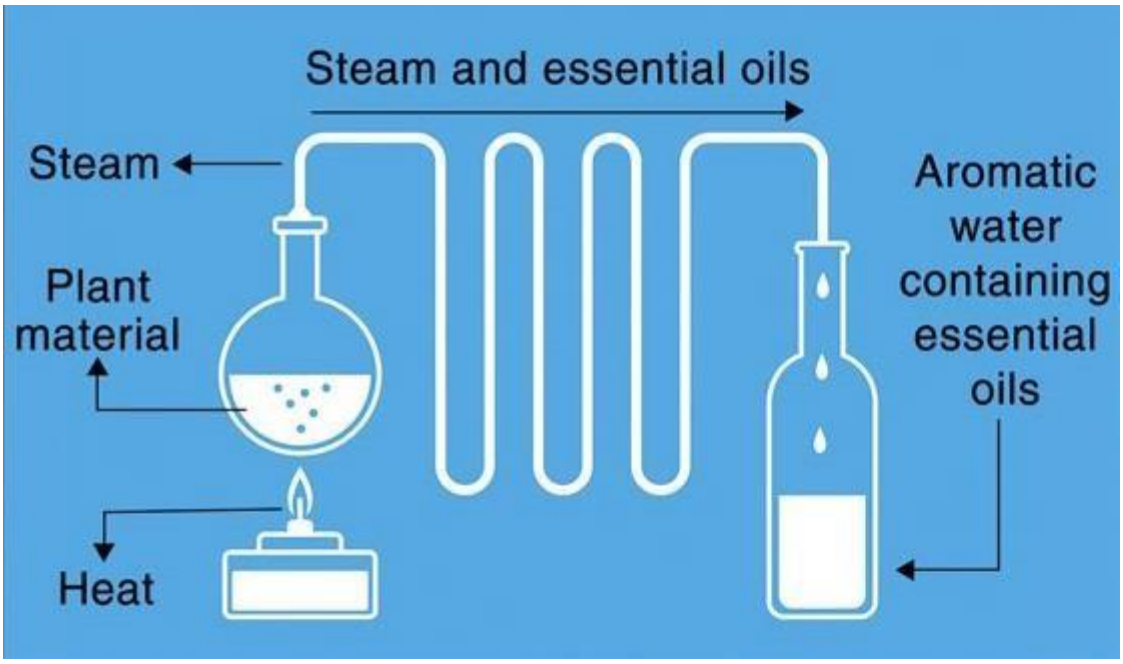

Figure 3-13: Vacuum distillation

For the separation of some aromatic compounds, vacuum distillation is used along with steam distillation. When vacuum distillation is combined with fractional distillation method, components of a mixture get separated very easily.
Vacuum distillation can be conducted without heating the mixture, as is usually followed in other distillation types.

3.3.1.5. Short path distillation:

Short path distillation is used to purify a small quantity of a compound that is unstable at high temperatures. This is done under lowered pressure levels and generally involves the distillate traveling a very small distance before being collected (hence the name 'short path'). The reduced distance traveled by the distillate in this method also reduces the wastage along the walls of the apparatus.
In short path distillation, the separated compounds are condensed immediately, without traveling to the condenser. The condenser is configured in a vertical manner, between the heating flask and the collecting flask.
Similar to vacuum type, the pressure is maintained below the atmospheric pressure. Thermal sensitive compounds cans also be separated by following short path distillation.
This method is mainly used for the separation of organic compounds with high molecular weight, especially in the pharmaceutical industries. It is also used for processing edible oils and fats.
Another method of classifying distillation is based on the amount of compound fed to the columns. There are two types of distillation columns namely, batch and continuous [40].
In the batch column method, the feed to the column is provided in batch-wise manner. The distillation process gets carried out when a batch of feed is introduced to the column.

In the continuous column method, the feed to the column is introduced continuously without any interruptions. A continuous operation is used commonly in the industrial applications.

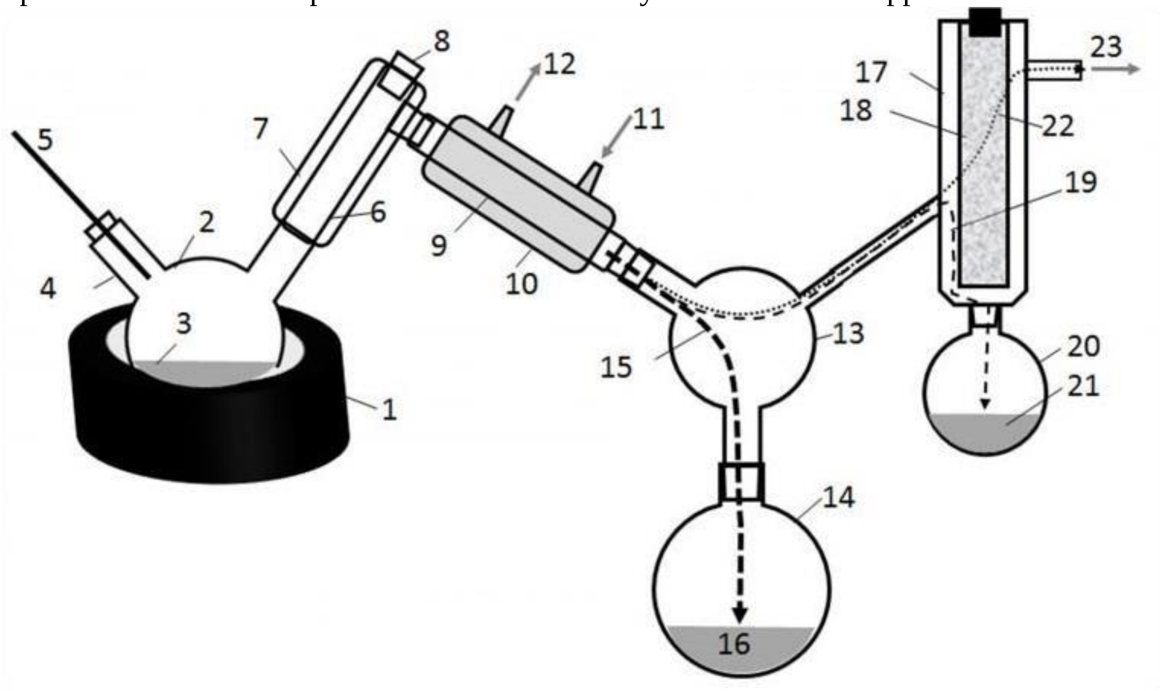

Figure 3-14: Short path distillation

- Setting up a clean short path distillation system using the following equipment: heating/receiving flask – round bottom flasks, distillation head, distribution condensers, short path distillation head.
- The liquid is placed to be distilled in the heating flask [41].
- A vacuum is pulled below 5 Torr.
- Heating the system: Make sure the large flask no more than ½ full on a hot plate at around 180 – 200° Celsius. This will heat up the large beaker.
- The temperature is varied to get a steady flow of distillate through the condenser, but not so much where it is violently boiling through the head.
- The collection flask is changed when the main body is flowing through the condenser but avoid cross contaminating the fractions.
- The collection flask is changed when the potency is decreasing and collects the residual tails.
- As the run completes, the glassware is cleaned and is set it up for another pass.

3.3.1.6. Zone distillation:

Zone distillation is a distillation process in long container with partial melting of refined matter in moving liquid zone and condensation of vapour in the solid phase at condensate pulling in cold area.

When zone heater is moving from the top to the bottom of the container then solid condensate with irregular impurity distribution is forming.

Then most pure part of the condensate may be extracted as product.

The process may be iterated many times by moving the received condensate to the bottom part of the container on the place of refined matter.

The irregular impurity distribution in the condensation increases with number of repetitions of the process.

3.3.2. Utilisation of diagram:

The diagram allows us to determine the boiling temperature (or condensation) of a homogeneous mixture, the composition of the first bubbles (of first drops), which of the two species is the most volatile, the nature of the distillate and the residue.

3.3.2.1. Case of simple distillation:

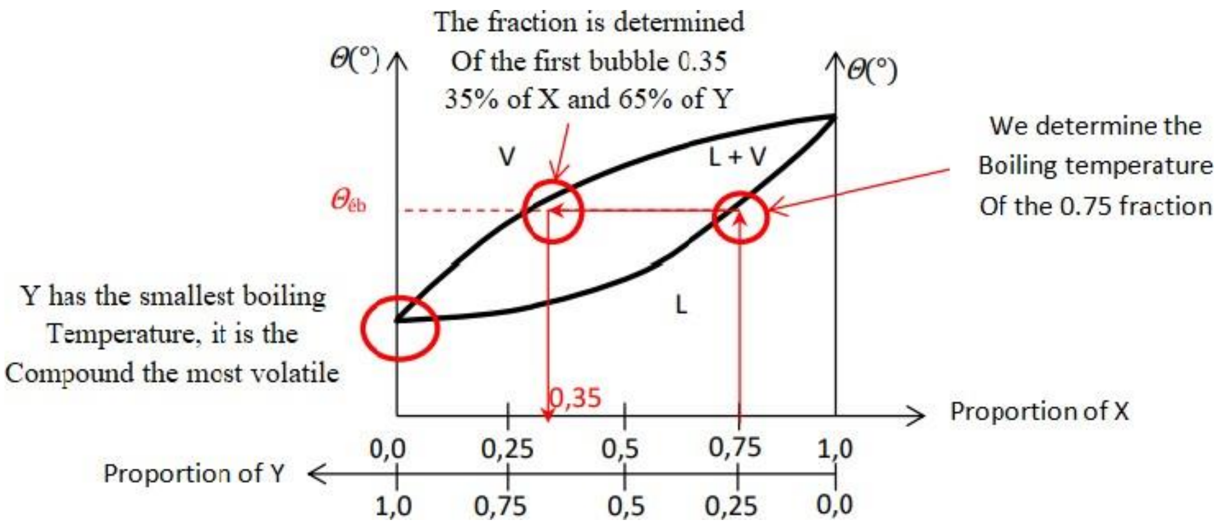

Figure 3-15: Simple distillation diagram [36]

3.3.2.2. Case of fractional distillation:

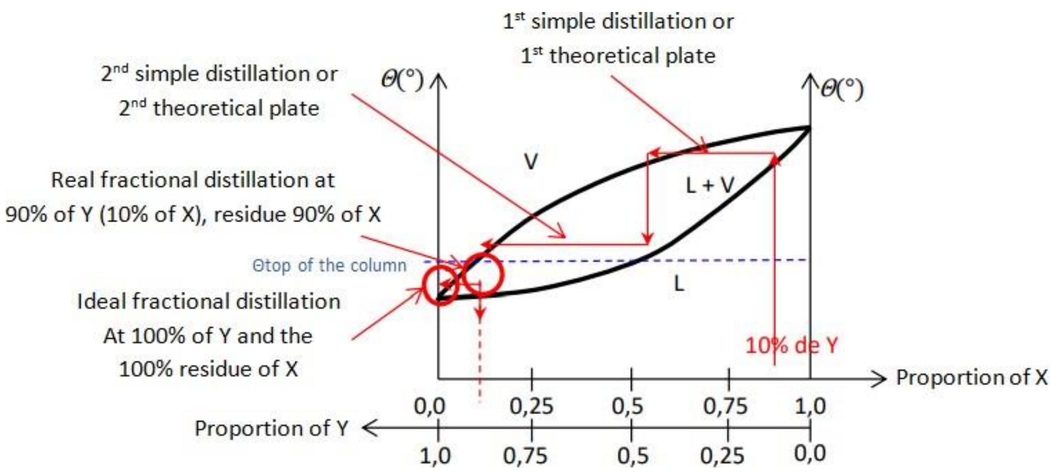

Figure 3-16: Fractional distillation diagram

We called separator power of a distillation system, the number of simple distillation sequence (Called theoretical plate). The boiler alone corresponds to a separating power.

The separating power of the distillation column = separating capacity of the distillation system- that of the boiler is here: 2-1 = 1.

In reality, the distillation is a function of the temperature at the top of the column, the lower it is the lower the can reach a 100% distillate.

3.3.3. Advantages and disadvantages of distillation:

Like all systems, solar water distillation has advantages and disadvantages, they are listed below:

3.3.3.1. Advantages:

The advantages of the solar water distillation are listed below [43]:

- It produces water of high quality.
- Negligible Maintenance.
- This process can purified any type of potable water.
- No electricity is required to operate this system and does not involve any moving parts to operate.
- Minimum wastage of water.
- Can purify water from virtually any source, including the ocean.
- Relatively inexpensive therefore accessible to a wide range of people
- Easy to use interface
- Intuitive setup and operation
- Provides clean drinking water without the need for an external energy source.
- Reasonably portable and compact.

3.3.3.2. Disadvantages:

- Rate of distillation is usually very slow ‘6 litres of water per sunny day’.
- It is not suitable for larger consumptive needs.
- The materials required for the distiller may be difficult to obtain in some areas.
- If not correctly used, the distillation process can be a potential source of environmental pollution ‘high concentrations of salts and pollutants’.
- Solar energy is only available during the day.

3.4. Conclusion:

Out of the five main types, simple and fractional distillation types are the two widely used methods that are applied even today in petroleum-refining industries, laboratories, and chemical factories.

PART TWO: DIFFERENT FORMS OF RENEWABLE ENERGY, SPECIFICALLY SOLAR ENERGY

4.1.Introduction:

Renewable energy is becoming an increasingly important issue in today's world. In addition to the rising cost of fossil fuels and the threat of climate change, there have also been positive developments in this field which include improvements in efficiency as well as diminishing prices.

4.2.Definition of renewable energy:

Renewable energy is a specific type of energy production that uses different types of energy resources that are obtained naturally from the environment and renewed continually. These energies are quickly becoming inexpensive as well as efficient, and that includes solar, biomas, wind, hydropower, geothermal, etc [44].

A long time ago, this energy is not used much due to their cost. But some of the energy sources are smart financial choices for hospitals, business, and homes.

Renewable energy is very beneficial due to their partial negative ecological impact when contrasted to fossil fuels. This means that renewable are increasingly displacing fossil fuels in the power sector, offering the benefit of lower emissions of carbon and other types of pollution. But not all sources of energy marketed as renewable are beneficial to the environment. Biomass and large hydroelectric dams create difficult trade-offs when considering the impact on wildlife, climate change, and other issues.

Particularly, solar energy is the best option for the house owners who want to reduce their environmental track while conserving money.

Renewable energy has increased the demand for alternative energy and accelerated the transition towards cleaner, more sustainable methods of electrical power.

However, it is important to note that are many kinds of it: solar, wind, tidal, power, etc. that each one has it own share of advantages and disadvantages [45].

4.3.Different forms of renewable energy [46] :

There are different forms of renewable energy. Following are the common types:

4.3.1. Solar energy:

This form of energy relies on the nuclear fusion power from the core of the sun. this energy can be collected and converted in a few different ways.

The range if from solar water heating with solar collectors or attic cooling with solar attic fans for domestic use to the complex technologies of direct conversion of sunlight to electrical energy using mirrors and boilers or photovoltaic cells.

Solar power can be used directly for heating and producing electricity or indirectly via biomass, wind ocean thermal, and hydroelectric power. Energy from the gravititational field can be harnessed by tidal power, and the internal heat of the Earth can be tapped geotermally.

Unfortunately these are currently insufficient to fully power our modern society.

4.3.2. Wind energy:

The movement of the atmosphere is driven by differences of temperature at the Earth's surface due to varying temperatures of the Earth's surface when lit by sunlight. Wind energy can be used to pump water or generate electricity, but requires extensive areal coverage to produce significant amounts of energy [47].

4.3.3. Hydroelectric energy:

This form uses the gravitational potential of elevated water that was lifted from the oceans by sunlight. It is not strictly speaking renewable since all reservoirs eventually fill up and require very expensive excavation to become useful again.
At this time, most of the available locations for hydroelectric dams are already used in the developed word [48].

4.3.4. Biomass:

Is the term for energy from plants. Energy in this form is very commonly used throught the word. Unfortunately the most popular is the burning of trees for cooking and warmth. This process releases copious amounts of carbon dioxide gases into the atmosphere and is a major contributor to unhealthy air in many areas. Some of the more modern forms of biomass energy are methane generation and production of alcohol for automobile fuel and fueling electric power plants [49].

4.3.5. Hydrogen and fuel cells:

These are also not strictly renewable energy resources but are very abundant in availability and are very low in pollution when utilized. Hydrogen can be burned as a fuel, typically in a vehicle, with only water as the combustion production [50]. This clean burning fuel can mean a significant reduction of pollution in cities. Or the hydrogen can be used in fuel cells, which are similar to batteries, to power an electric motor. In either case significant production of hydrogen requires abundant power. Due to the need for energy to produce the initial hydrogen gas, the results in the relocation of pollution from the cities to the power plants. There are several promising methods to produce hydrogen, such as solar power, that may alter this picture drastically.

4.3.6. Geothermal power:

Energy left over from the original accretion of the planet and augmented by heat from radioactive decay seeps out slowly everywhere and every day. In certain areas the geothermal gradients (increase in temperature with depth) is high enough to exploit to generate electricity. This possibility is limited to a few locations on Earth and many technical problems exist that limit its utility. Another form of geothermal energy is Earth energy, a result of the heat storage in the earth’s surface. Soil everywhere tends to stay at a relatively constant temperature, the yearly average, and can be used with heat pumps to heat a building in winter and cool a building in summer. This form of energy can lessen the need for other power to maintain comfortable temperature in buildings, but cannot be used to produce electricity.

4.3.7. Other forms of energy:

Energy from tides, the oceans and hot hydrogen fusion are other forms that can be used to generate electricity. Each fo these is discussed in some detail with the final result being that each suffers from one or another significant drawback and cannot be relied upon at this time to solve the upcoming energy crunch.

4.4. Solar energy:

Solar energy is any type of energy generated by the sun.
It is created by nuclear fusion that takes place in the sun. Fusion occurs when protons of hydrogen atoms violently collide in the sun’s core and fuse to create a helium atom.
It would be interesting to know some notions about radiation solar energy (characteristic, coordinated, nature….), the different physical processes that will be subject to this radiation [51].

4.4.1. Source of solar radiation [52]:

The main source of energy that we have is the sun, which is about 150 million kilometers from the earth; it emits iso-tropically a radiation that can to be assimilated, as a first approximation, to that of a black body (perfectly emissive and perfectly absorbent) at 5800°k. This radiation spreads in space form electromagnetic wave, it reaches the earth after about eight minutes of its emission. The 98% of the energy emitted is in the wavelength band between o.25 and 3μm.

4.4.2. The sun's coordinate [53]:

The sun is considered to produces as constant amount of energy. At the surface of the Sun the intensity of the solar radiation is about 6.33 x 10^7 W/m^2 (note that this is a power, in watts, per unit area in meters). As the sun's rays spread out into space the radiation becomes less intense and by the time the rays reach the edge of the Earth's atmosphere they are considered to be parallel.

4.4.2.1. The solar constant and irradiance incident:

The solar constant I_{SC} is the average radiation intensity falling on an imaginary surface, perpendicular to the sun's rays and at the edge of the Earth' atmosphere [54].

The word' constant' is a little misleading since, because of the Earth's elliptical orbit the intensity of the solar radiation falling on the Earth changes by about 7% between January 1st, when the Earth is nearest the sun, and July 3rd, when the Earth is furthest from the sun.

A yearly average value is thus taken; the most used I_{SC} value is that adopted by the World Meteorological Organization 'OMM' in October 1981 with an uncertainty of 1%, the solar constant equals:

$$I_{SC}=1367\ W/m^2$$

Even this value is inaccurate since the output of the sun changes by about ±0.25% due to Sun spot cycles.

The solar radiation intensity falling on a surface is called irradiance or insolation and is measured in W/m^2 or kW/m^2.

The solar constant can be used to calculate the irradiance incident on a surface perpendicular to the Sun's rays outside and the Earth's atmosphere on any day of the year (i.e. as the distance between the Sun and Earth changes thought the year):

$$I_0= I_{SC}\left[1+0.034 \cos\left(2\pi \frac{n}{265.25}\right)\right]$$

Where:

I_0 = extraterrestrial (outside the atmosphere) irradiance on a plane perpendicular to the Sun's rays (W/m^2).

I_{SC} = the solar constant is 1367 W/m^2.

n = the day of the year such that for January the 1st, n=1.

Most solar power calculations use I_0 as a starting point because, for any given day of the year it is the maximum possible energy obtainable from the Sun at the edge of the Earth's atmosphere. The figure below shows the variation in I_0 over the course of a year, the dashed line shows the value of the solar constant I_{SC}:

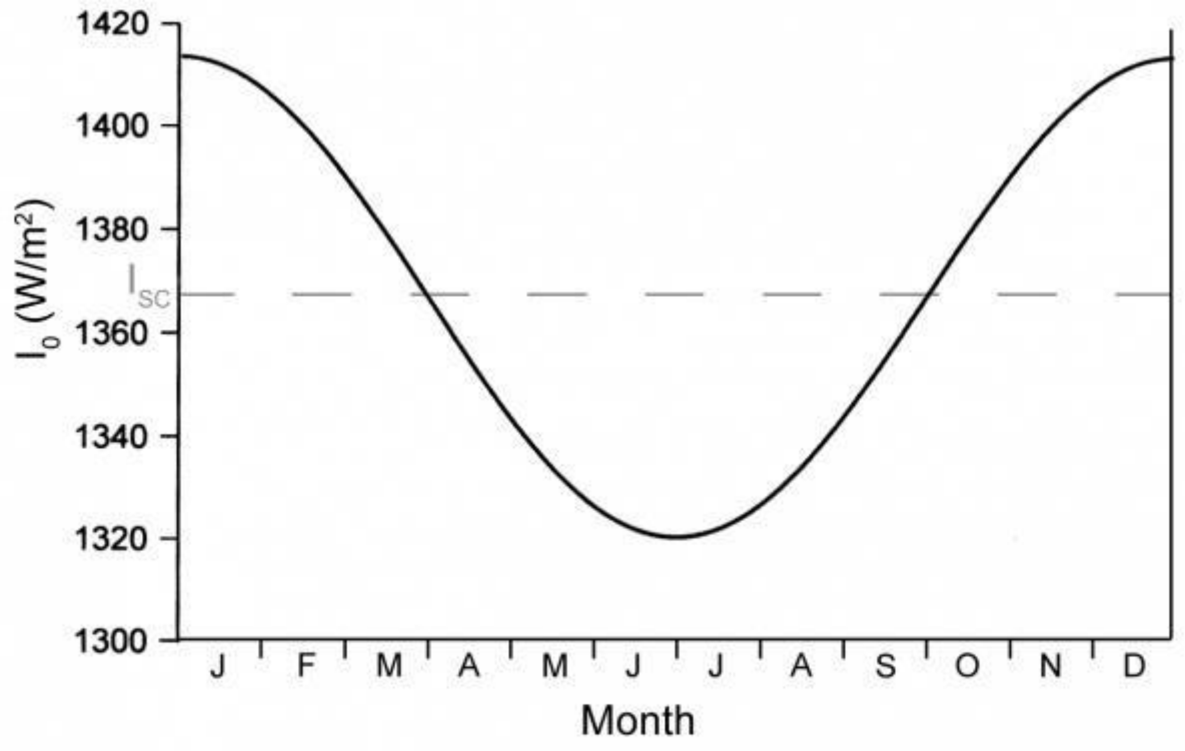

Figure 4-1: The variation in I0 over the course of a year

The value of I_0 is the same no matter where you are on the Earth's surface, however not all points on the Earth's surface are perpendicular to the Sun's rays. A useful quality to calculate is the solar irradiance incident on an imaginary surface that is parallel to horizontal plane on the Earth's surface. The irradiance on such a surface is smaller than I_0 because of the cosine effect and is the maximum amount of solar energy that could be collected on a horizontal plane at the Earth's surface if the atmosphere did not scatter and absorb any radiation [55].

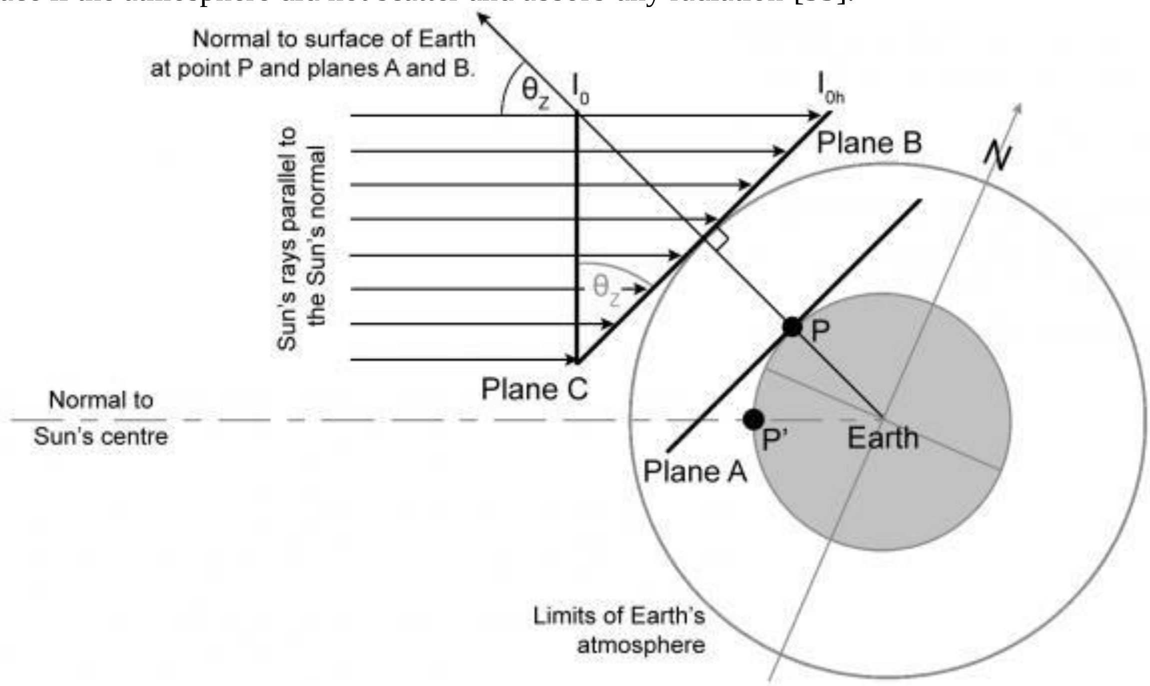

Figure 4-2: The cosine effect

This figure shows three plane surfaces:

- Plane A, a horizontal plane at the point P on the Earth's surface,
- Place B, a surface parallel to plane A but on the edge of the Earth's atmosphere, often referred to as the horizontal plane,
- Plane C, a surface perpendicular to the Sun's rays, often referred to as the normal plane.

I_0 is the irradiance intensity on the normal plane and the irradiance intensity on the horizontal plane can be calculated from:

$$I_0 = \cos\theta_z$$

Where:
θ_z: the solar zenith angle.
I_{0h}: the extraterrestrial irradiance intensity on a horizontal plane.
θ_z is also the angle of incidence of the Sun's rays on a horizontal plane.
Note that since cosine values fall between 1 and -1, I_{0h} will never be greater than I_0 and $I_{0h} = I_0$ at point P' where $\cos\theta_z = 1$ ($\theta_z = 0°$).

4.4.2.2. Solar irradiation:

Just to be confusing the intensity of solar radiation is called irradiance and is measures in the units of power per unit area (W/m^2 of kW/m^2) however, the total amount of solar radiation energy is called irradiation and it is measures in the units of energy per unit area (J/m^2). Irradiation is given the symbol H.
Where:
H_0: the total daily amount of extraterrestrial radiation on a plane perpendicular to the Sun's rays.
H_{0h}: the total daily amount of extraterrestrial radiation on a plane horizontal to the Earth's surface.
Note that these planes are considered to rotate with the Earth so that H_0 and H_{0h} are daily values, and the planes are shaded at night.

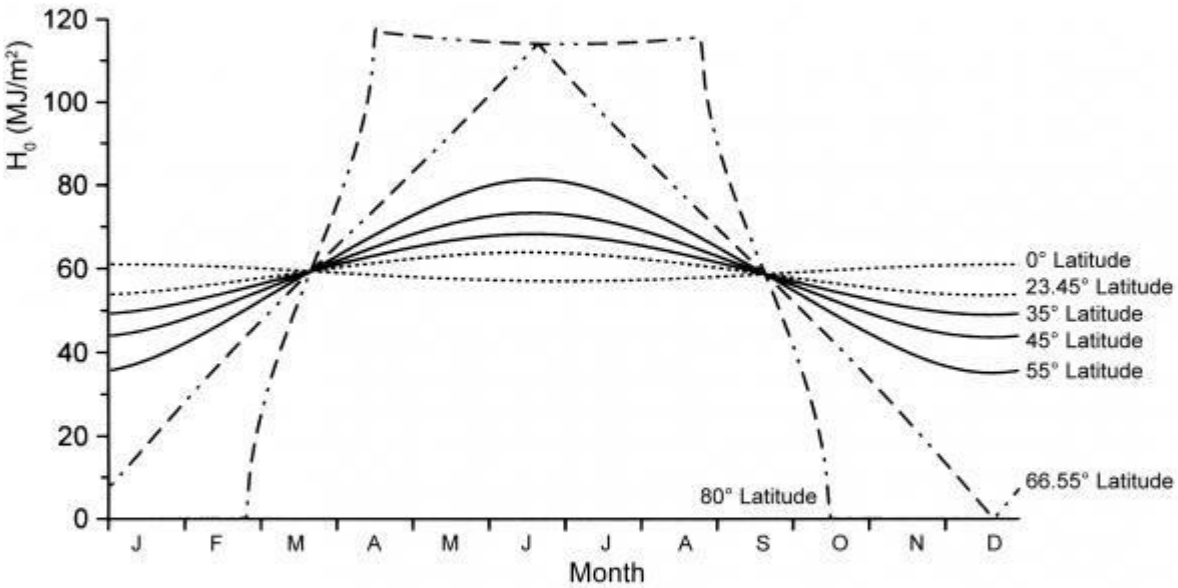

Figure 4-3: the total daily amount of extraterrestrial irradiation on a plane perpendicular to the Sun's rays H0 for different latitudes

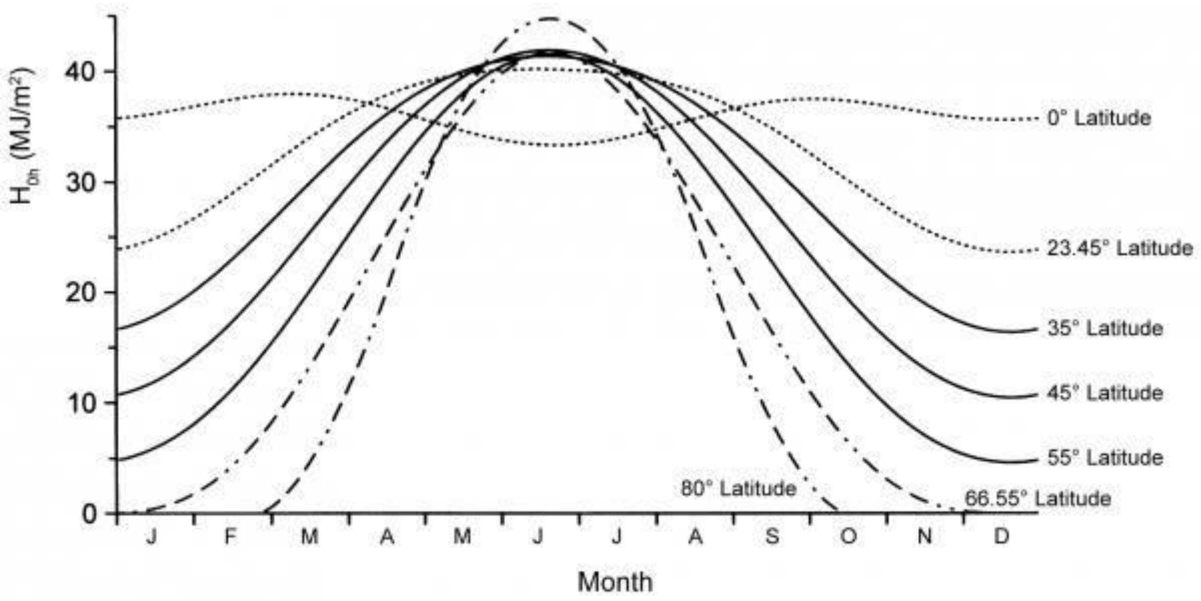

Figure 4-4: the total daily amount of extraterrestrial irradiation on a plane horizontal to the Earth's surface H0h for different latitudes

Figures 3 and 4 show how the values of H_0 and H_{0h} vary throughout the year in the northern hemisphere.
Note that for any given day the value of H_0 changes from latitude to latitude despite the value of I_0 being constant for all latitudes. This occurs because the length of the day's changes and the effects is most obvious inside the Arctic Circle where much of the year is either 24 hours of darkness or 24 hours of daylight.

4.4.2.3. Solar reflection:

The amount of energy reflected, scattered and absorbed depends on the amount of atmosphere that the incident radiation travels through as well as the levels of dust particles and water vapour present in the atmosphere. The latter is difficult to judge but the distance travelled through atmosphere by incident radiation depends on the angle of the Sun.

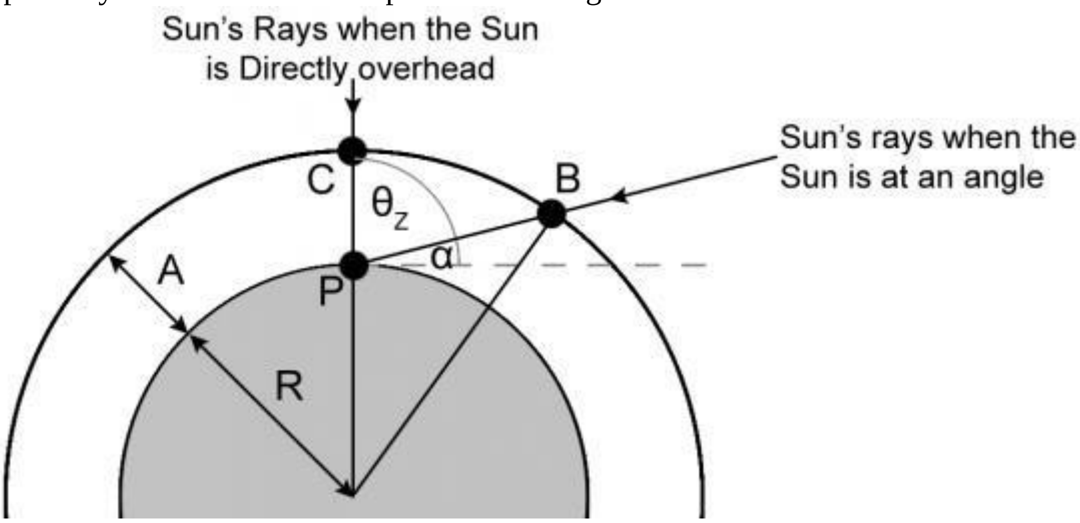

Figure 4-5: the distance travelled through the atmosphere by the Sun's rays

The distance travelled through the atmosphere by the sun's rays incident on the earth is accounted for by a quantity called air mass AM.

$$\text{Air mass} = \frac{\text{path length travelled}}{\text{vertical depth of the atmosphere}}$$

$$AM = \frac{BP}{CP} = [(\frac{R}{H}\cos\theta)^2 + 2\frac{R}{H} + 1]^{1/2} - (\frac{R}{H})\cos\theta_z$$

Where:
R: the radius of the Earth, taken to be 6370 km.
H: thickness of atmosphere, taken to be 7991 km (although it is considerably thicker at the equator than the poles).
For angles θ_z<70°:

$$AM \approx \frac{1}{\cos\theta z} = \sec\theta_z$$

Therefore outside the earth's atmosphere AM=0, when the Sun is directly overhead θ_z = 60°, AM =2.
AM is normally taken to be an average of 1.5 for a clear sunny day and this value is used for the calibration of solar cells.

4.4.2.4. Rough estimates of the solar energy available at the earth's surface:

The solar constant is the average extraterrestrial insolation at the edge of the atmosphere:

$$I_{SC} = 1367 \text{ W/m}^2$$

The Earth presents a disc of area nR² to the Sun; therefore the total amount of extraterrestrial insolation incident on the Earth is I_{SC} x nR^2
This value is then divided by half the surface areas of the Earth, $4nR^2/2$, which give 684 W/m², the average insolation incident on unit area of the earth facing the Sun.
Note that solar panels are calibrated assuming that there is 1000W/m² available.

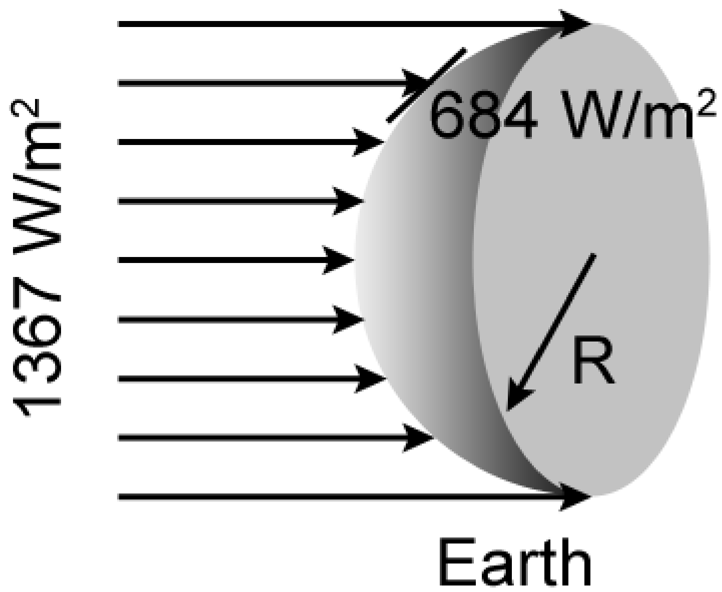

Figure 4-6: Radiation estimation

A rough estimate of the irradiation incident per unit area H of the Earth's surface can be made if we assume that 30% of the sun's energy is lost in the atmosphere and that the day is an average of 12 hours long at any location:

$$H = 07 \times 684 \times 12 = 5.75 \text{ kWh/day}$$

Or if we assume that the Sun is only at an appreciable strength for an average 6 hours in the day (as is likely in more northerly latitudes):

$$H= 07\times 684\times 6 = 2.88 \text{ kWh/day}$$

4.4.2.5. Calculation of solar angles:

These equations should be used keeping all of the angles in radians even though with some of the equations it does not matter whether degrees or radians are used.

a. Declination angle [56]:

Another way to view the motion of the Earth around the Sun is to consider the Earth as stationary and plot the apparent motion of the Sun throughout the course of one year, such a view is called the “celestial sphere” and is shown in figure 7.

In this model the sun moves around the ecliptic and the earth’s equator is projected onto the celestial sphere as the celestial equator.

The variation in the declination throughout the year is clearly seen in figure 7, where the declination angle is the angle between the lines joining the centre of the Earth to the ecliptic and the celestial equator.

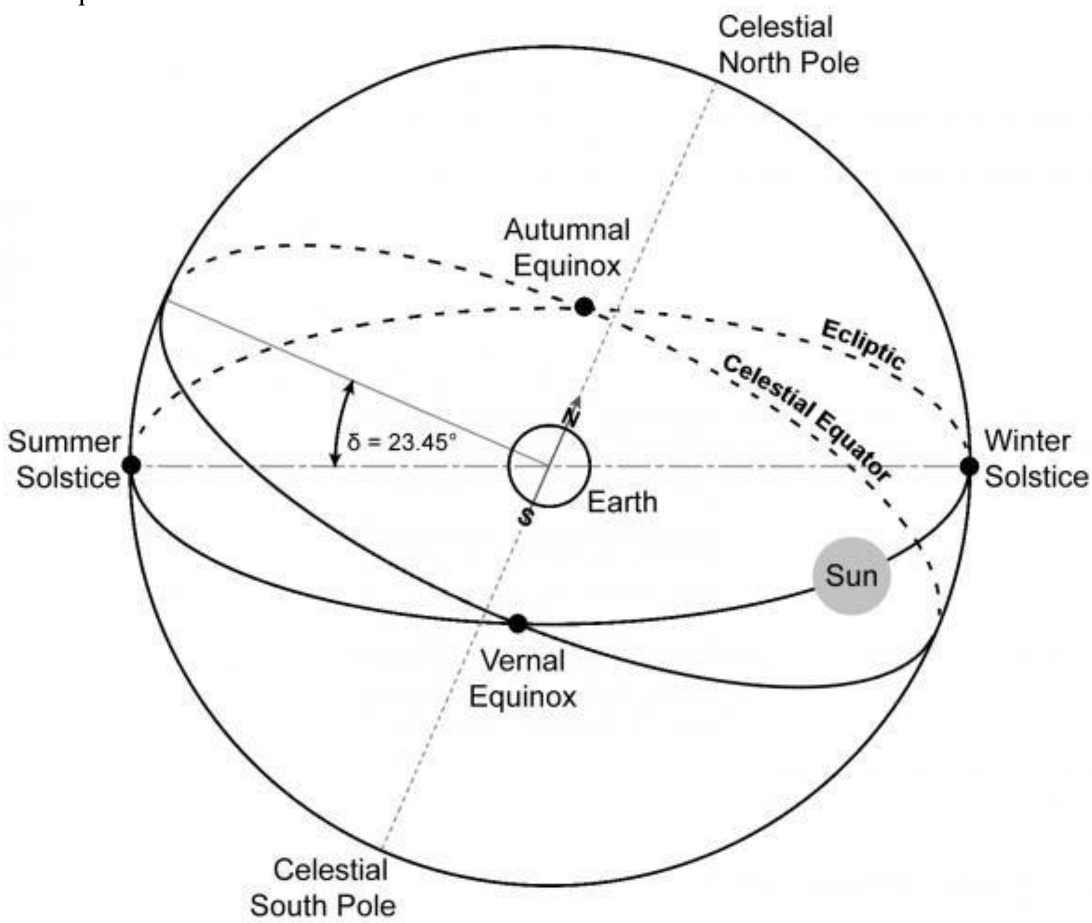

Figure 4-7: the celestial sphere

The equation used to calculate the declination angle in radians on any given days is:

$$\delta = 23.45 \frac{\pi}{180} \sin \left[2\pi \left(\frac{284+n}{36.25}\right)\right]$$

Where:

δ: is the declination angle (rads), which is at a maximum at the solstices and zero at the equinoxes.

n: the day number, such that n=1 on the 1st January.

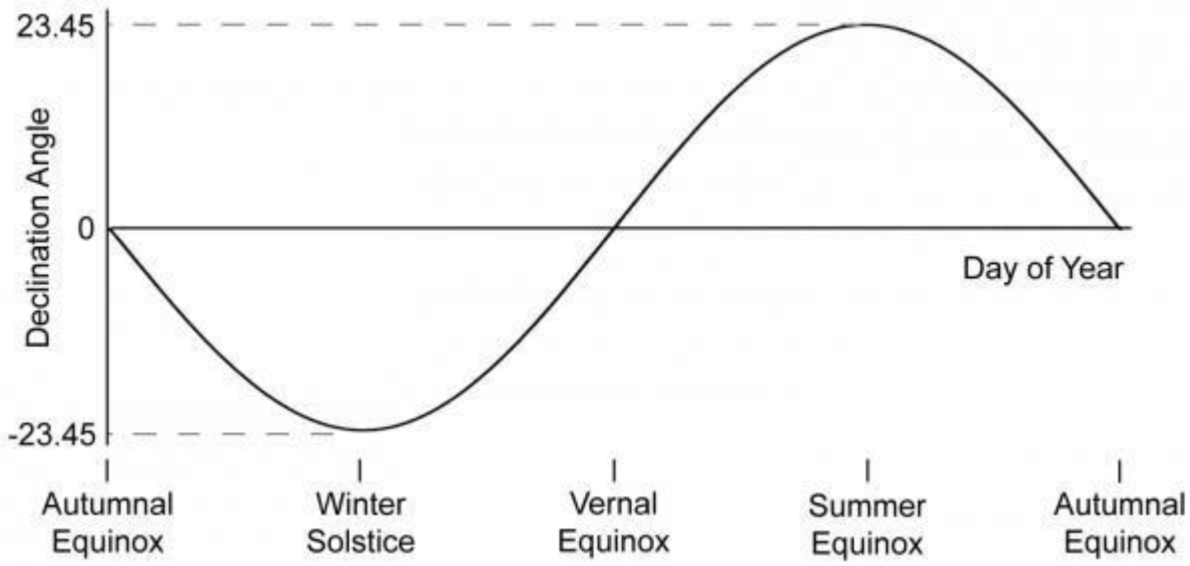

Figure 4-8: The variation in the declination angle throughout the year

The declination angle is the same for the whole globe on any given day.
Figure 8 shows the change in the declination angle throughout a year. Because the period of the Earth's complete revolution around the sun does not coincide exactly with the calendar year the declination varies slightly on the same day from year to year.

b. The hour angle [57]:

The hour angle is described in figure 24 and it is positive during the morning, reduces to zero at solar noon and becomes increasingly negative as the afternoon progresses, two equations can be used to calculate the hour angle when various angles are known.
Note that δ changes from day to day and α and A change with time throughout the day:

$$\sin\omega = -\frac{\cos\alpha \sin A_z}{\cos\delta}$$

$$\sin\omega = \frac{\sin\alpha - \sin\delta \sin\varphi}{\cos\delta \cos\varphi}$$

Where:
ω: the hour angle. α: the altitude angle.
A_z: the solar azimuth angle. δ: the declination angle.
φ: observer's latitude.
Note that at solar noon, the hour angle equals zero and since the hour angle changes at 15° per hour, it is a simple matter to calculate the hour angle at any time of day.
The hour angles at sunrise and sunset ω_s are very useful quantities to know.
Numerically, these two values have the same value. However, the sunrise angle is negative and the sunset angle is positive. Both can be calculated from:

$$\cos\omega_s = -\tan\phi \tan\delta$$

This equation is derived by substituting α=0
ω_s can be used to find the number of daylight hours N for a particular day using the next equation, where ω_s is in radians:

$$N = \frac{2\omega s}{15} \times \frac{180}{\pi}$$

Note that there are always 4380 hours of daylight per year everywhere on the globe.

If a surface is tilted from the horizontal, the sun may rise over its edge after it has risen over the horizon.
Therefore the surface may shade itself for some of the day.
The sunrise and sunset angles for a titled surface ω_s facing the equator are given by:

$$\cos\omega' = -\tan(\phi-\beta)\tan\delta$$

Where:
β: the angle of inclination of the surface from the horizontal.
This equation may give the sunrise angle for the tilted surface that indicates that the sun rises over the edge of the surface before it has appeared over the horizon.
This situation is obviously wrong and a check must be made to find the actual sunrise angle over the tilted plance ω_0:

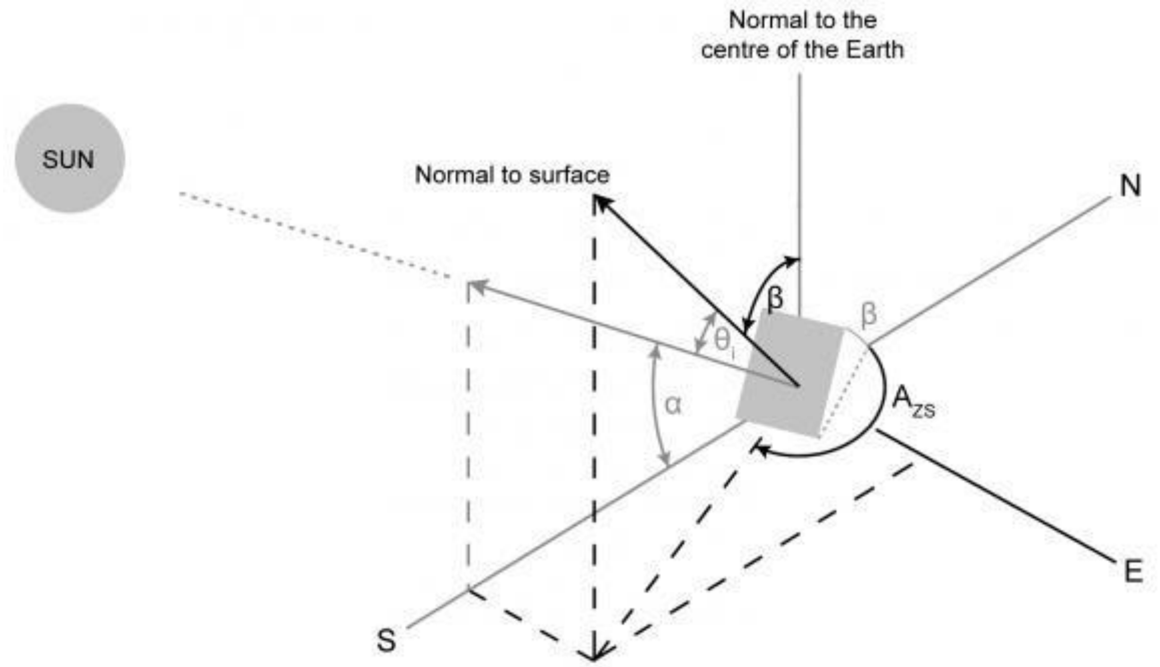

Figure 4-9: A tilted surface that is not facing the equator

Note that for a titled surface facing the equator, the sunrise and sunset angles are still numerically equal with the sunrise angle being positive and the sunset angle being negative.
When a surface is inclined from the horizontal but not facing the equator, calculating the sunrise and sunset angles over the edge of the surface are complex.
Such a surface is shown in figure 9, for such a surface the sunrise and sunset angles will not be numerically equal and the following procedure must be followed:

$$\omega'_s = \cos^{-1}\left[\frac{ab\pm\sqrt{(a^2-b^2+1)}}{a^2+1}\right]$$

Where:

$$a = \frac{\cos\varphi}{\sin A_{zs}\tan\beta} + \frac{\sin\varphi}{\sin A_{zs}} = \tan\delta\left[\frac{\cos\varphi}{\tan A_{AZ}} - \frac{\sin\varphi}{\sin A_{AZ}\tan\beta}\right]$$

The equation of ω'_s gives two solutions because of the negative or positive sign, one is the sunset angle and the other is the sunrise angle. Then c_0 is checked as before:

$$\omega_0 = \min\{\omega s, \omega''_s\}$$

c. More solar angle:

More angles are defined by considering the path of the sun across the sky when viewed from point P on the surface of the Earth.

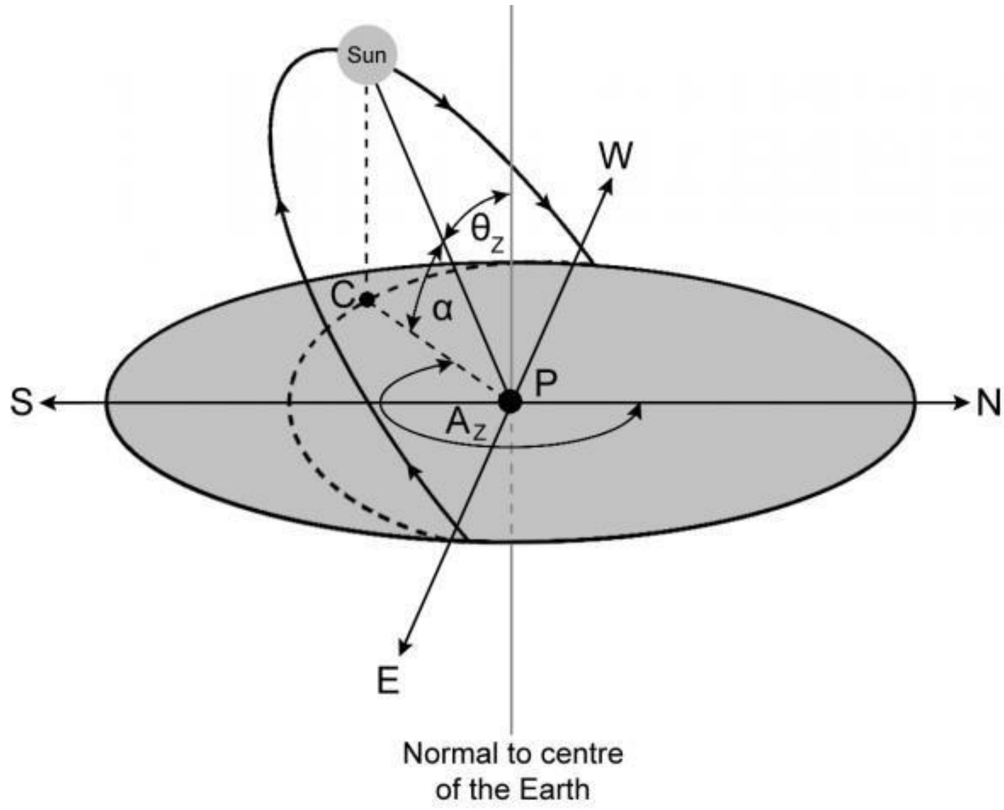

Figure 4-10: the zenith angle θZ, the altitude angle α and the azimuth angle AZ of the Sun when viewed from point P

This figure shows the solar zenith angle θ_Z, the solar altitude angle α and the solar azimuth angle A_Z.
The height of the Sun in the sky at any time can be descried as either α° from the horizon or θ_Z° from a normal running though point P from the centre of the Earth so that $\alpha + \theta_Z = 90°$.
The compass position of the Sun is given by A_Z.
Figure 10 show A_Z measured from due north, so that it equals 180° at solar noon. An alternative method can be used that measures from due south so that $A_Z = 0°$ at solar noon, negative when the sun is east from this point (i.e.in the morning) and positive when the Sun is west of this point (i.e. in the afternoon).

d. The altitude angle:

The altitude angle α can be calculated from:

$$Sin\alpha = \sin\delta \sin\phi + \cos\delta \cos\omega \cos\phi$$

e. The azimuth angle:

The azimuth angle A_Z can be calculated from the following equation:

$$Sin\alpha = \frac{\sin\phi \cos\delta}{\sin\theta_Z} = \frac{\sin\phi\cos\delta}{\cos\alpha}$$

The azimuth angle at sunrise A_{SR} can be calculated from:

$$SinA_{SR} = -\sin\omega S \cos\delta$$

f. Angle of incidence:

The angle of incidence θ_i of the sun on a surface tilted at an angle from the horizontal β and with any surface azimuth angle A_{ZS} in figure 9 can be calculated from when A_{ZS} is measured clockwise from north:

$$Cos\theta_i = \sin\delta \sin\phi \cos\beta + \sin\delta \cos\phi \sin\beta \cos A_{ZS} + \cos\delta \cos\beta \cos\omega - \cos\delta \sin\beta \cos A_{ZS} \cos\omega - \cos\delta \sin\beta \sin A_{ZS} \sin\omega$$

This equation can be simplified in a number of instances, when the surface is flat (i.e. horizontal):
$\beta = 0$
$\cos\beta = 1$
$\sin\beta = 0$
Therefore this previous equation becomes:

$$\cos\theta_i = \cos\theta_Z = \cos\delta \cos\phi \cos\omega + \sin\delta \sin\phi$$

When the surface is tilted towards the equator (facing south in the northern hemisphere):

$$\cos\theta_i = \cos\delta \cos(\phi-\beta) \cos\omega + \sin\delta \sin(\phi-\beta)$$

Note that if $\theta_i > 90°$ at any point the Sun is behind the surface and the surface will be shading itself.

4.5.Renewable energy in Algeria [58]:

Algeria plays a key role in world energy markets as a leading producer and exporter of natural gas and liquefied natural gas.

Algeria is amongst the top five and the top ten countries in the world for natural gas and oil production respectively. Indeed, Algeria relies heavily on hydrocarbons, with 94% of energy currently coming from natural gas, representing 50% of the national GDP. Recent studies suggest that about 5% to 1% comes from wind and solar energy. This dire status of renewable energy in Algeria exists despite a favourable geographical location which offers one of the highest solar potentials in the world. Algeria resides within the solar belt of the world, where it is estimated that 6 hours of solar energy from the world deserts can meet the annual global energy demands [59].

The energy usage in Algeria between three sectors, industrial, transport, and residential and services are 24%, 33% and 43% respectively.

Algeria's energy mix in 2010 was almost exclusively based on fossil fuels, especially natural gas 92%. However the country has enormous renewable energy potential, mainly solar, which the government is trying to harness by launching an ambitious Renewable Energy and Energy Efficiency Program [60].

The Program consistz of generating 22,000 MW of power from renewable sources between 2011 and 2030, of which 12,000 MW will be meant for domestic consumption and the rest for export. The Program is focused on developing and expanding the use of renewable resources, such as solar, wind, biomass, geothermal and hydropower, in order to diversify energy sources and promote sustainable development of the country [61].

Around 60 solar photovoltaic plants, concentrating solar power plants, wind farms as well as hybrid power plants are to be constructed within the next ten years. Algeria has also joined the Desertec Indusrial Initiative, which aims to use Sahara solar and wind power to supply 15 per cent of Europe's electricity needs by 2050 [62].

4.5.1. Solar energy:

On account of its geographical location, Algeria holds one of the highest solar potentials in the world which is estimated at 13.0 TWh per year. The country receives annual sunshine exposure equivalent to 2,500KWh/m^2. Daily solar energy potential varies from 4.66 KWh/m^2 in the north to 7.26 KWh/m^2 in the south.

Pilot projects for the construction of two solar power plants with storage of a total capacity of about 150MW each, will be launched during the 2011-2013 period. These will be in addition to the hybrid power plant project of Hassi R'Mel with a total power capacity of 150 MW, including 25 MW in solar.

Four solar thermal power plants with a total capacity of about 1,200 MW are to be constructed over the period of 2016 to 2020.

The Hassi R'Mel integrated solar combined cycle power station is one of world's first hybrid power stations. The plant combines a 25 MW parabolic trough concentrating solar power array, covering an area of over 180,000m^2, in conjunction with a 130 MW combined cycle gas turbine plant, so cutting carbon emissions compared to a traditional power station. The gas turbine and stream cycle are fired by natural gas, with the steam turbine receiving additional solar-generated steam during the day. The plant began electricity production in June 2011.

Figure 4-11: one of the world's first hybrid solar power plant is located at Hassi R'Mel

4.5.2. Wind energy:

Algeria has promising wind energy potential of about 35 TWh/year. Almost half of the country experience significant wind speed. The country's first wind farm is being built at Adrar with installed capacity of 10MW with substantial funding from state-utility Sonelgaz. Two mor wind farms, each of 20 MW, are to be developed during 2014-2013. Studies will be led to detect suitable sites to realize the other projects during the period 2015-2030 for a power of about 1700 MW.

Mean wind data for 64 stations, 48 of which are located in Algeria and 16 in neighbouring countries has been used to establish the wind energy map of Algeria at a height of 10m. It is found that the wind speed varies between 1 and 6 m/s. The windy regions are located at the west south of Algeria, in the Sahara. Statistical analysis of the date for 21 stations located at various topographic locations in Algeria have been carried out and the daily and yearly variations of wind speed have been estabilished. The Weibull parameters and power density of the stations have been determined using the hybrid Weibull distribution. Finally, wind speeds obtained in Algeria prove that it is interesting to set up some wind systems for agricultural applications.

4.5.3. Biomass Energy:

Biomass is a general term used to refer to all types of animal and plant material including municipal solid waste, animal and industrial residues, agricultural and forestry crops/residues, and sewage. These materials can be burned or digested to produce heat and electricity. A common example is the burning of wood for heating purposes. Biomass material can be taken through either a gasification process to produce gases or a pyrolysis process to obtain bio liquids. The gases and liquids can liquids can then be used as fuel to fire power plants.

Algeria has large areas of unused land that can be exploited to grow wheat, corn, soybeans and sugarcane to create biofuels e.g. in the form of ethanol and biodiesel. Growing these plants can be done over land not used for food crops to minimise any impact on food production and prices, whilst producing biofuel that can be sold. Potential tensions rising from conflicts over land-use can be further reduced through appropriate policies and approaches to land-use

management. In 2006, an Algerian biotech company, Nakheel, announced plans to produce bio-methanol as a transport fuel using non-edible waste fruits from the large date industry in the country. This initiative was the first of its kind in the Arab world, driven by the fact that 20% of all dates produce is not suitable for consumption, thus providing substantial amounts of potential biomass. However, it has not been possible to verify whether this initiative remains operational or not. In an excellent article that won the 2013 Algerian Paper for the Year Award in Biological Sciences, reserchers Acourene and Ammouche have demonstrated the possibility of producing bioethanol from date wastes. Potentially, this bioethanol can be used as a fuel additive in petrol engines. Their results show that there is a basis for further biomass development in Algeria not only of biofuel production but also for other useful chemicals such as citric acid.
Solid waste is the best source of biomass potential in the country. According to the National Cadastre for Generation of Solid Waste in Algeria, annual generation of municipal wastes is more than 10 million tons. Solid wastes are usually disposed in open dumps or burnt wantonly. In recent time, they are starting to use recycled jutebags to minimize the impact of solid wastes Other perhaps unexpected possibilities for exploiting biomass include using municipal waste to create landfill gas and produce electricity when burned in large combustion engines, and using unwanted materials such as recycled vegetable oil and grease from restaurants to make biofuels. Miscanthus, which is a tall grass that can grow to heights of more Thant 3.5m in one growing season, has a rapid growth rate, high yield per acre, and low mineral content, making it yet another excellent candidate for producing biofuels. Miscanthus Grows well on barren land, and so does not compete for land used for food crops. Last but not least, Algae, which can possess up to 40 of its weight as oil, are also a promising source for biofuel production and can naturally grow in many aquatic environments. Algae can be harvested in photo-bioreactors, or in large scale nurseries;

4.6.Conclusion:

Energy is the basic necessity for all of us leads a normal life on the earth. Solar energy is considered the main resource, which is very worldwide, abundant and never lasting, free of cost and environment friendly. This type of energy offers a real alternative to consumption of fossil fuels with a low environmental impact and a high potential for cost reduction.

PART 3: PROTOTYPE USED FOR DISTILLATION

5.1.Introduction:

As we are interested in the type of treatment the sea water into portable water by solar distillation, we had the reflection on a distillation system integrating solar energy.

That said, in this chapter, we will describe the model of the prototype that we used, as well as the stages of its realization.

The bench of distillation is composed of several organs, to which we present in this part the detailed description of each one

5.2.Choice of the type of prototype to be made:

Some types of distillers were made and developed for water treatment, in our case we had the reflection for a prismatic greenhouse-like distiller as an experimental prototype, as described at first chapter, as well as the benefits it presents [63].

5.3.Advantages and disadvantages of this type of distillation:

5.3.1. Advantages [64]:

The reason for which we opted to use this type of prototype of distillation because it presents some advantages such as:

- It is a simple and modern distiller frequently used to get the fresh water from the salt water.
- Its cost price is less expensive due to the use of clean solar energy.
- Installation of the pilot unit is simple and easy.
- The intensity of solar radiation inside the seawater distillation tank is a meteorological factor that changes according to the geographical position and seasonal fluctuations. It has a direct influence on the amount of heat received by the water in the tubes placed on the roof, thus contributing to the increase of its sensible heat.
- The absorption of solar energy leads to a substantial increase in the water vapor tension necessary for the humidification of the air.
- A high value of the relative humidity corresponds to a high value of the condensate flow.

5.3.2. Disadvantages:

However, this prototype has some disadvantages, judged not too important as:

- A decrease in the relative humidity which it is reflected by a consequent increase in the amount of non-condensable gas (air), which by its presence constitutes a barrier on the wall of the condenser tube, thus activating the condensation phenomenon. This explains the gradual reduction in condensate flow during the night.
- A need to save energy is the desire to provide new water resources.
- Limited efficiency in a well-defined territory where high temperatures are present.

However, these drawbacks are almost the same for other types of prototypes.

5.4.Sizing of the prototype:

The prototype we used is mainly composed of four organs : glass prismatic part, steel tray mounted on a sliding table, distiller feed table and distilled water recovery part.

5.4.1. Sizing the prism:

The glass cover intervenes essentially by its nature and its prismatic form, as it transmits the maximum of solar radiation. It must be non –hydrophobic and it must also resist the attacks of wind and solid particles.

Our prism was made in such way that it absorbs the maximum of solar radiation, however the complication of the calculation of the angle of solar radiation on a sloping surface, as well as the lack of sunshine data pushed us to s press on certain works indicating the best inclinations with respect to the sunshine rays, in this case the angle varying between 45° and 85°.
So in our case, we chose a glass angle of 70°, this angle allows an optimum capture of solar radiation, in addition it promotes an adequate flow drops of water evaporated on the walls.
The prism to a square base with a width of 71.1 cm, a height of 70 cm, and a crest width of 10 cm realized for the stable maintenance of the prism. It is also equipped with mirrors to increase the effect of radiation on the tray, installed in the lower part of the prism, on a height of 10 cm in the vertical part and 12 cm in the inclined part.

Figure 5-1: Sizing of the glass prism

5.4.2. Sizing of the tank and the absorber:

The role of the absorbent tray is to absorb the maximum of global solar radiation and transmit the heat produced by this absorption to the brine. Studies in this field indicate that the absorbing surface can be constructed of several materials (wood, metal, concrete, synthetic material or ordinary glass).
The choice of the materiel of the absorbing surface or black tank depends on its thermal inertia, resistance to oxidation by water and mineral deposits.
In our case, we designed a black steel absorber tray, which we welded black thick 4mm.
The tray has a square shape, its width is 55cm, and its height of 10 cm and it is mounted on lifting table.
The tank is equipped with a water level measurement rule, it can contain a maximum capacity of 30 liters of salty or salty water.

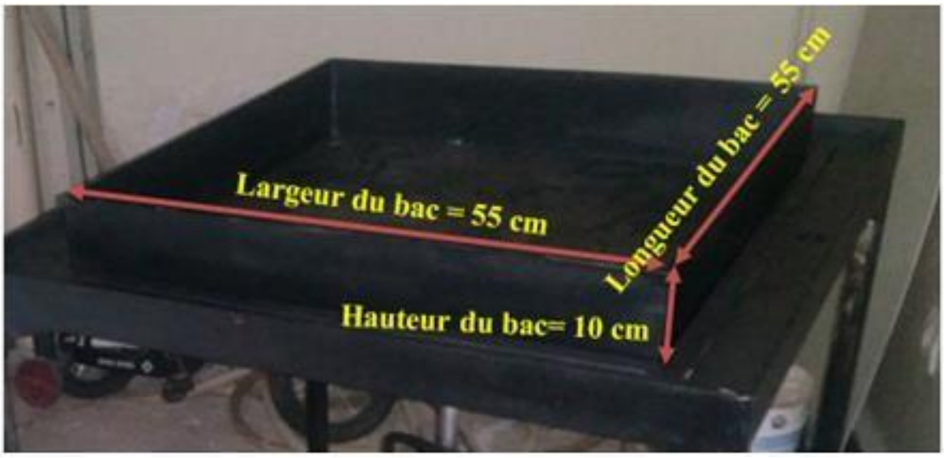

Figure 5-2: Sizing of absorber tank

5.4.3. Support and lifting table:

Our prototype is designed according to a sliding system, in fact, the tray is welded on a lifting platform by a lever following the table, and it can show and descend with an optimal distance for its maintenance.
The prism is held on the square table of 1.20m height and 72cm wide, the tray is introduced into the prism to a height of 10cm, where it will be blocked by the rib of the tray with those of the table.

Figure 5-3: Support and lifting table

5.4.4. Design of the desiccated water evacuation system:

The distilled water evaporates and flower through the walls of the prism on a 70° sloppe to accumulate at the flow channels with slopes of 1% oriented towards the lowest point, where it is located the permeate evacuation building.
The ortifice is linked to a distilled water storage zone by a 10mm pipe whose capacity of the permeate recovery tank is 20 liters.

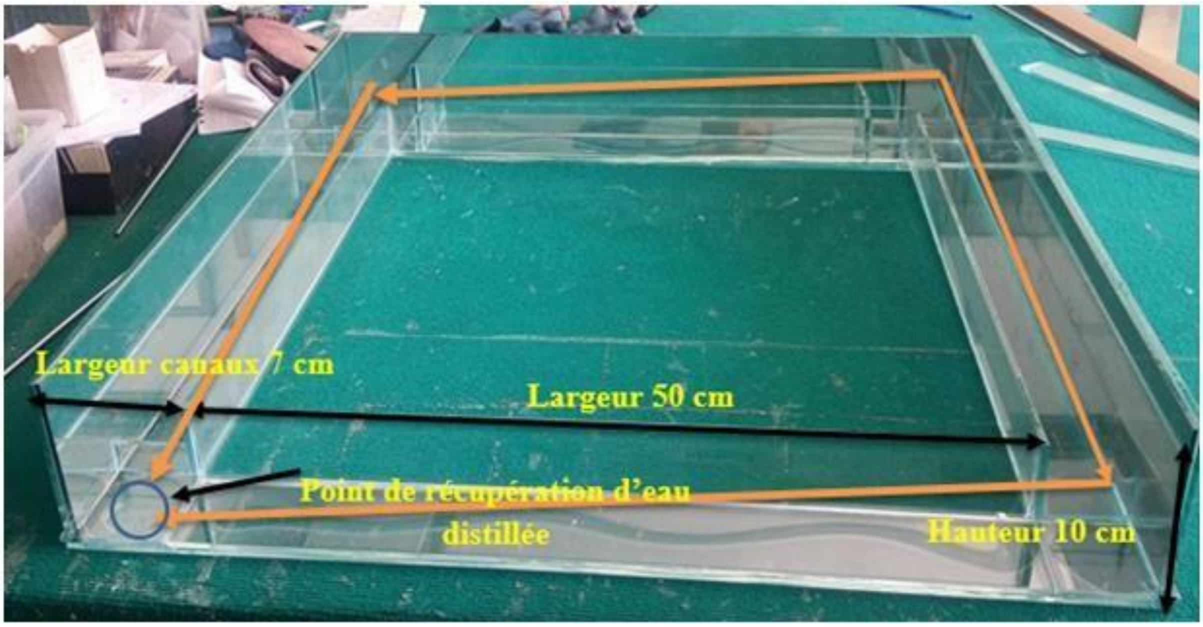

Figure 5-4: Permeate evacuation system

5.4.5. Design of the permeate recovery system:

At the moment when the sea water distils the humidity, it becomes more and more elevated, the vapor condenses at the head of the prism and on the walls of the other.

Figure 5-5: Condensation of steam at the top of the prism and on the walls

The condensed fresh water is then collected and brought to the walls, then it flows through the channels to the point of recovery of distilled water and brought by storage conduct in the reservoir of fresh water recovered.
After having distilled the sea water, the tank must be rinsed and cleaned so that the experience can be repeated under better conditions.

Figure 5-6: Prototype and permeate evacuation system

5.4.6. Basin feeding system by brine:

The steel tank is fed by a 20-liter capacity bucket with a valve and placed on a wooden support higher than the tank (2.4M), allowing it to be fed directly by a flexible pipe through the prism.
The feed is equipped with a float which is positioned at the constant water level in the tank.

Figure 5-7: Prototype and feeder system of the tank

5.4.7. Insulation system:

The insulation system is used to keep the heat and minimize the heat loss in the tank.
For this, we used the polyester as insulation, having a thickness of 4cm, on the windows of the base of the prism and on the windows inclined of 12 cm, as well as around the tank.

Figure 5-8: Prototype and insulation system

5.4.8. Measuring system:

To study the performance of our distiller, it is essential to carry out certain measures considered as principal in the distillation, it is necessary to know:

- The temperature of the air.
- The temperature of the water in the tank.
- The temperature of the condensed air in the prism.
- The temperature in the prism.

5.4.8.1. Electronic components and sensors:

To take the necessary measures for distillation, it is necessary to install sensors and temperature probes and a humidity sensor:

- Outside temperature sensor of the air “LM34”, this one must be equipped with a capacitor.
- Humidity sensor, which must be endowed with resistance.
- Two watertight sensors of water and steam “TP 100” also with resistance.

Temperature sensor:

Figure 5-9: Temperature sensor LM35 with capacitor

Humidity sensor:

Figure 5-10: Humidity sensor

Temperature of steam sensor:

Figure 5-11: Sensors for steam's temperature LM35 and water with a float

5.4.8.2. Reading values:

A set of temperature and humidity values are transmitted as an electronic signal to a card called "Arduino Uno" which reads the values of each signal using a program.

In our case, we wrote the program for reading the data and displaying it directly on an LCD screen.

5.4.8.3. Arduino Uno card:

The Arduino Uno card is a programmable ATmega328 microcontroller for operating components (motor, LED…). It has "ports" allowing for example to connect to a computer or to feed.
The Arduino Uno card is the centerpiece of any electronic circuit.

Figure 5-12: Arduino Uno card

The installation of sensors on the Arduino Uno card board:

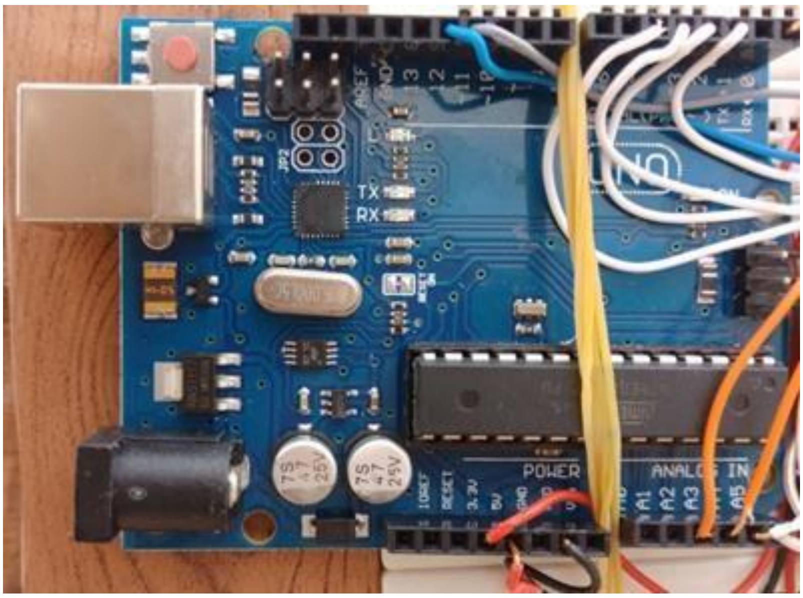

Figure 5-13: Installation of sensors on the Arduino Uno board

It is equipped of:

- 14 inputs/outputs (which 6 provide PWM output).
- 6 analog inputs.

- A crystal at 16 MHz.

- USB connection.
- A power jack.
- An ICSP header.
- A reset function.

To use it, simply connect it to a computer with a USB cable, or feed it with an external power supply or batteries. Values can be stored in a database in Excel, as they can be displayed on a screen.

Values can be stored in a database in Excel, as they can be displayed on a screen.

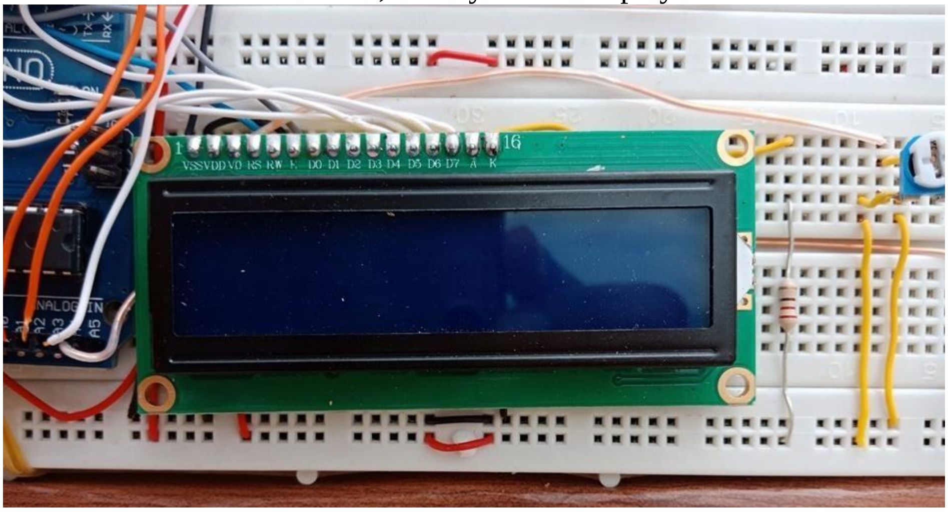

Figure 5-14: LCD display screen, image regulator, resistance and card cabling

Programming language interface on the Arduino Uno board:

Figure 5-15: Programming language interface on the Arduino Uno board

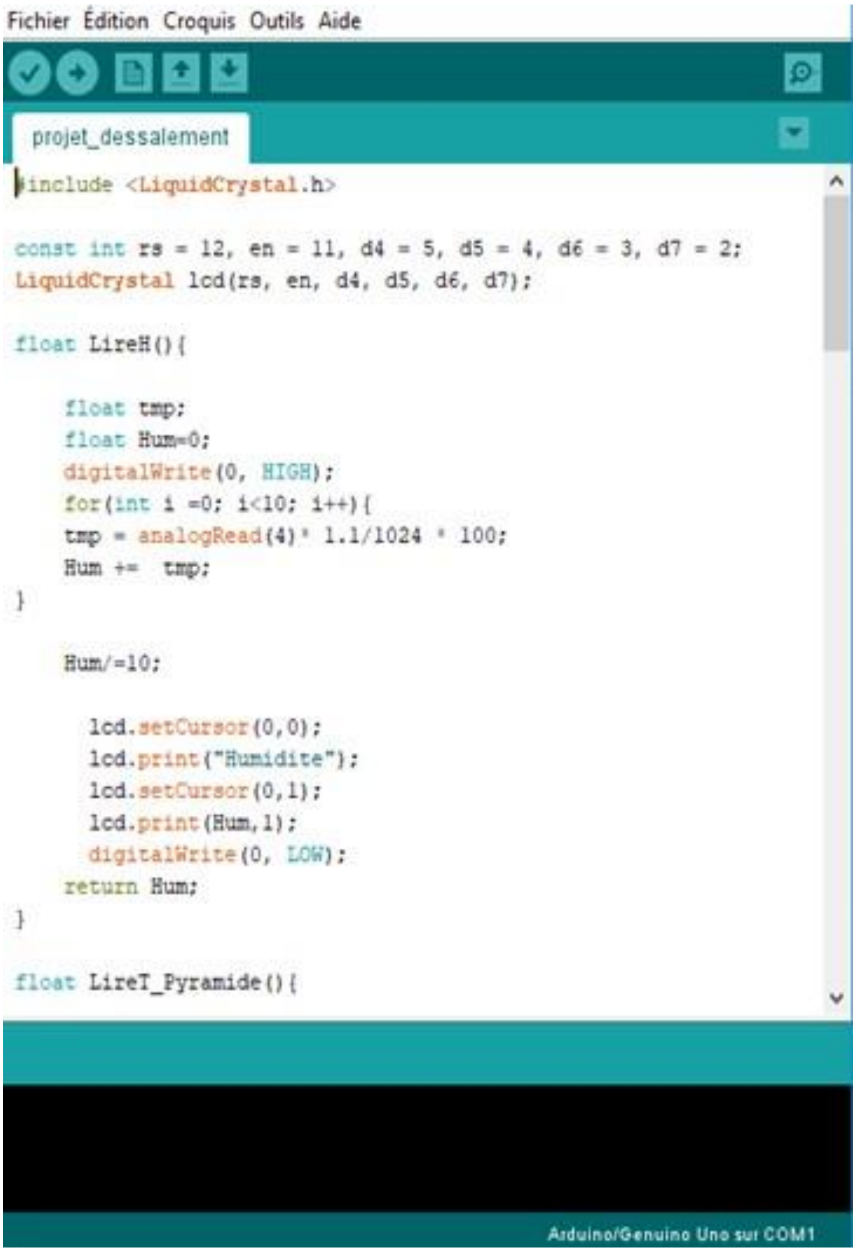

Figure 5-16: Program for transferring data signals and their display

CHAPTER FOUR: RESULTS AND DISCUSSIONS

6.1.Introduction:

In this chapter, we proceeded to the practical side by using our prototype of water distillation. First, we did the analysis of the seawater that we took, by determining its salt concentration.
In parallel, between May 12 to June 06, 2019; we proceeded to hourly measurements, between 9h and 17h, we fed the tank by the brine and to the parameters of the air temperatures, the steam and the tank, the humidity, and volumes of distilled water and raw water in the tank.
Subsequently, we performed the analysis of distilled water in the laboratory by measuring the salinity level.
Finally, this chapter also contains a detailed interpretation of the values of the parameters and the results obtained.

6.2.Analysis and discussion of sea-water:

We analyzed the seawater at the level of the water treatment laboratory, of the department of hydraulics between the period of May 12th and June 6th 2019 using certain material and by proceeding to the following procedure:

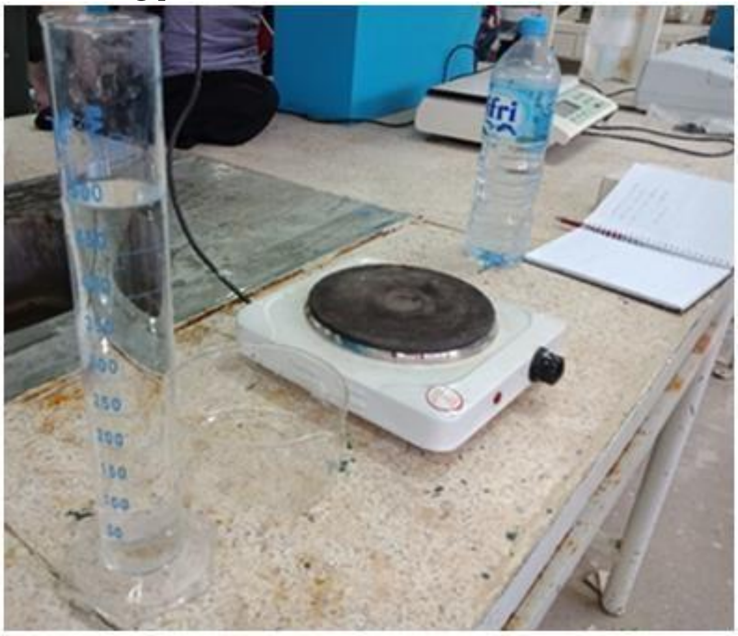

Figure 6-1: Equipment used

- Collection of a 1 liter of salt water sample.
- Measurement of the net weight of the container m0=259g.

Figure 6-2: Weight of the container

- Measurement of the weight of the container with 1 liter of salt water m1=1392g.
- Heating salt water with thermal agitation for 2 hours to evaporate salt water before steaming, so as not to steal the water by oven.


Figure 6-3: Brackish water heating

- Place the container, which is almost dry in the oven, for 24 hours with a temperature of 107°C.

Figure 6-4: The oven

- Measurement of the weight of the container after 14h: m2 = 294g.
- Measurement of the weight of salt: m3 = m2 –m0.

Figure 6-5: Salt weight after heating by the oven

The results obtained in the laboratory on the salinity of the sampled seawater indicated that the salt concentration is:
M3 = 35g/l

6.3.Setting of seawater's prototype and measurements:

In parallel with the measurement of the salinity, we proceeded to fill our test bench with the seawater sample, after which we began the measurements and analysis according to the following procedure:

- Fill the tank until 6.5 cm of height, the equivalent of a volume of nearly 20 liters.

Figure 6-6: Brackish water level in the tank

- Time reading of the values of the three temperatures (air, tank, steam),
- Time reading of the value of the moisture of the prism,
- Hourly reading of the brackish water level in the tank;
- Measurement of the level of the distillate in the recovery tank ,
- Daily measurement of the salinity rate by the TDS meter, it gives us an indication of the portability of the water according to the degree of salinity contained in the distillate.

Figure 6-7: The TDS meter

6.4.Results of parameters measured from the prototype:

CHAPTER FOUR

After placing our model at the terrace of the laboratories of the faculty of technology, we immediately filled the tank with a quantity of 20 liters and immediately after taking the hourly measurements of the various parameters following the procedure described, between May 30 and June 3, 2019.

The set of values we have measured daily and every hour in the table below:

Date	hour	H_{bench} (cm)	V_{bench} (ml)	$V_{distilled}$ (ml)	$T°_{aire}$	$T°_{Bench}$	$T°_{Vapor}$	Humidity	TDS (ppm)
30 - May	9h00	6,44	175,5	137	21,2	23,1	23,1	6,5	181
	10h00	6,42	234	180	22,6	26	26	8,6	
	11h00	6,42	247	190	23,6	26,3	26,3	13,6	
	12h00	6,38	364	280	26,1	27,4	27,4	21,9	
	13h00	6,35	455	350	27,1	27,6	27,6	22	
	14h00	6,29	637	490	27,3	27,9	27,9	25,1	
	15h00	6,20	916,5	705	26,3	28,9	28,9	26,4	
	16h00	6,14	1079	830	24,3	27,9	27,9	29,8	
	17h00	6,10	1202,5	925	23,1	27	27	29,4	
31 st May	9h00	6,3	1436,5	1105	21,3	22,3	22,4	8	127
	10h00	5,97	1599	1230	24,8	25	25	13,4	
	11h00	5,94	1703	1310	26,4	27,4	27,4	28,3	
	12h00	5,90	1826,5	1405	29,5	30,1	30,1	28,5	
	13h00	5,85	1963	1510	28,4	28,5	28,6	29,3	
	14h00	5,82	2054	1580	28,8	29	29	29,5	
	15h00	5,80	2132	1640	29,1	29,3	29,3	29,8	
	16h00	5,73	2327	1790	27,8	30,3	30,3	30,9	
	17h	5,	2450	1885	25,	29,5	29,5	30,3	

	00	69	,5		2				
	9h00	5,42	3276	2520	20,7	21,6	21,6	7,4	
	10h00	5,36	3445	2650	22,3	24,3	24,3	9,6	334
	11h00	5,31	3601	2770	24,1	25,7	25,7	14,1	
3rd	12h00	5,27	3718	2860	25,6	27,4	27,4	21,4	
June	13h00	5,22	3887	2990	27,2	28,3	28,2	23,7	
	14h00	5,19	3965	3050	26,9	27,9	28	29,6	
	15h00	5,12	4186	3220	27,7	27,9	28	29,6	
	16h00	5,06	4355	3350	27	27,7	27,7	29,7	
	17h00	5,03	4446	3420	26,1	27,7	27,8	27,1	
	9h00	4,79	5187	3990	24,4	25,2	25,2	6,9	
	10h00	4,73	5343	4110	27,9	28,1	28,1	8,7	424
	11h00	4,68	5499	4230	28,9	30,2	30,2	12,1	
4th -	12h00	4,61	5707	4390	29,8	30,3	30,3	23,4	
June	13h00	4,58	5798	4460	30,3	32	32	25,3	
	14h00	4,55	5889	4530	30,5	33,8	33,9	29,8	
	15h00	4,49	6071	4670	30,0	34	34,1	30,4	
	16h00	4,47	6136	4720	30	33,5	33,5	30,7	
	14h00	4,38	6409	4930	29,3	32,3	32,3	28,1	

Table 6-1: Results of collected samples between 30 May and 4 June 2019

6.5.Discussions of the results of the prototype measures:

In this section, we discuss the results obtained by varying certain parameters with each other as a function of the measurement time, namely:

CHAPTER FOUR

- Discussion of internal temperature variations of the prism.
- Discussion of the variation of the internal temperatures with that of the air.
- Discussion of the variation of the internal temperature with the humidity of the prism.
- Discussion of the volume of distillate obtained as a function of internal temperatures.

- Discussion of the volume of distillate obtained as a function of internal temperatures.

6.5.1. Variations of the internal temperatures of the prism:

We initially compared the internal temperatures of the prism, namely the temperature of the water in the tank and that evaporated. The variations are illustrated in the following curves:

- **The 1st day is May 30, 2019:**

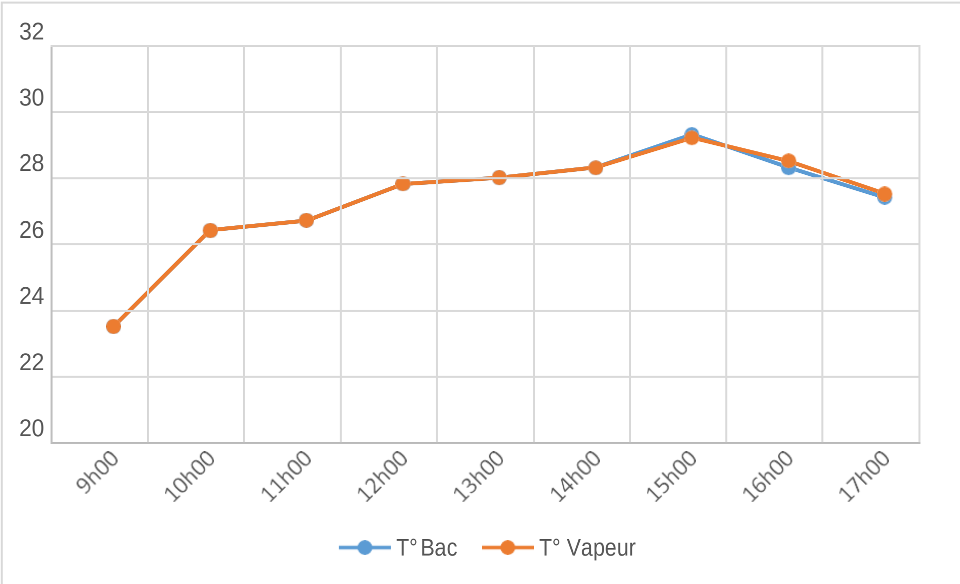

Figure 6-8: Curve of temperature evolution of the tank and steam according to the time : May 30, 2019

- **The 2nd day is June 2, 2019:**

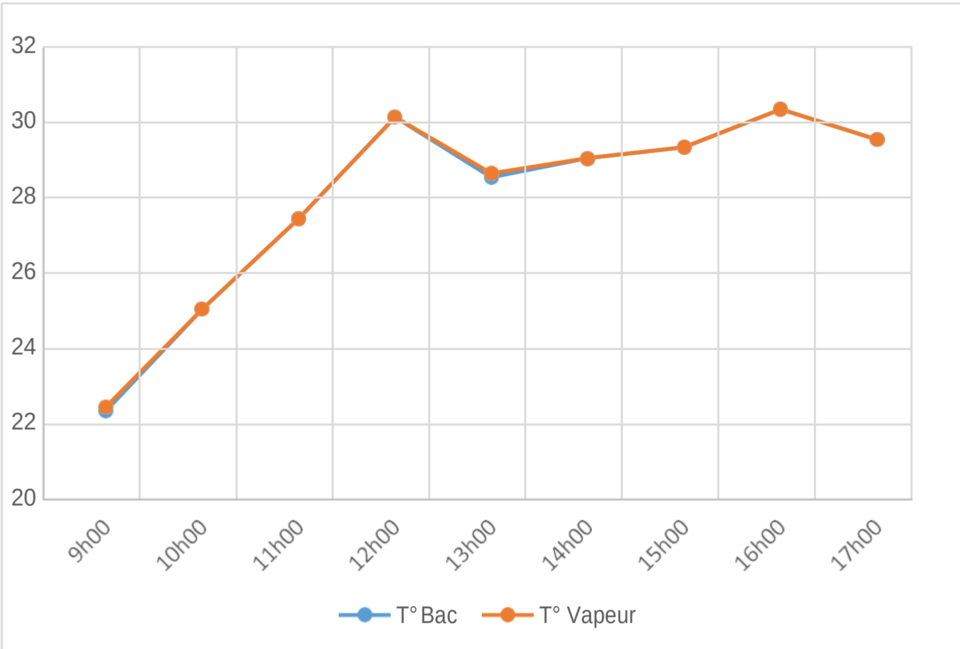

Figure 6-9: Curve of temperature evolution of the tank and steam according to the time : June 2, 2019

- **The 3rd day is June 3, 2019:**

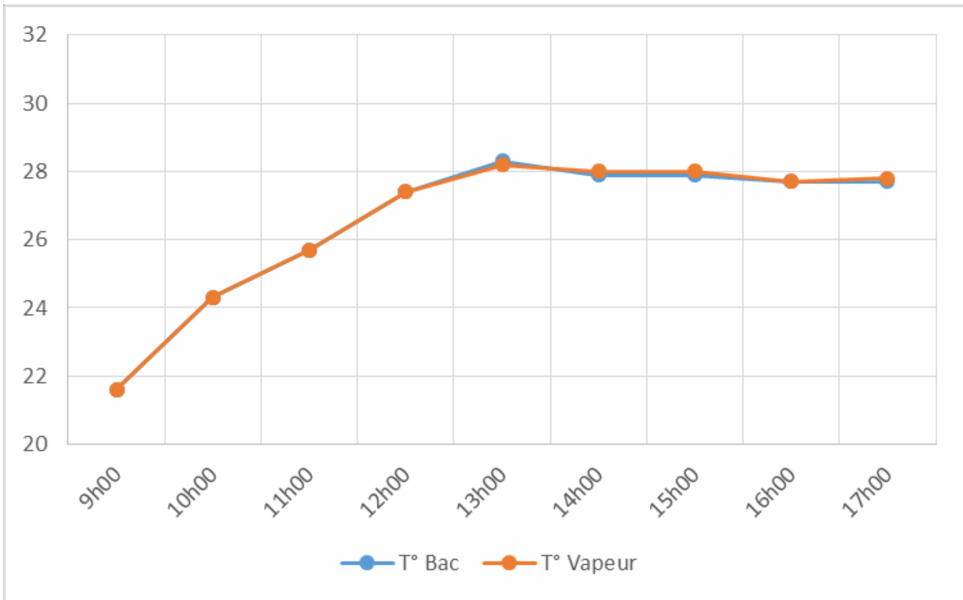

Figure 6-10: Curve of temperature evolution of the tank and steam according to the time June 3rd, 2019

- **The 4th day is June 4, 2019:**

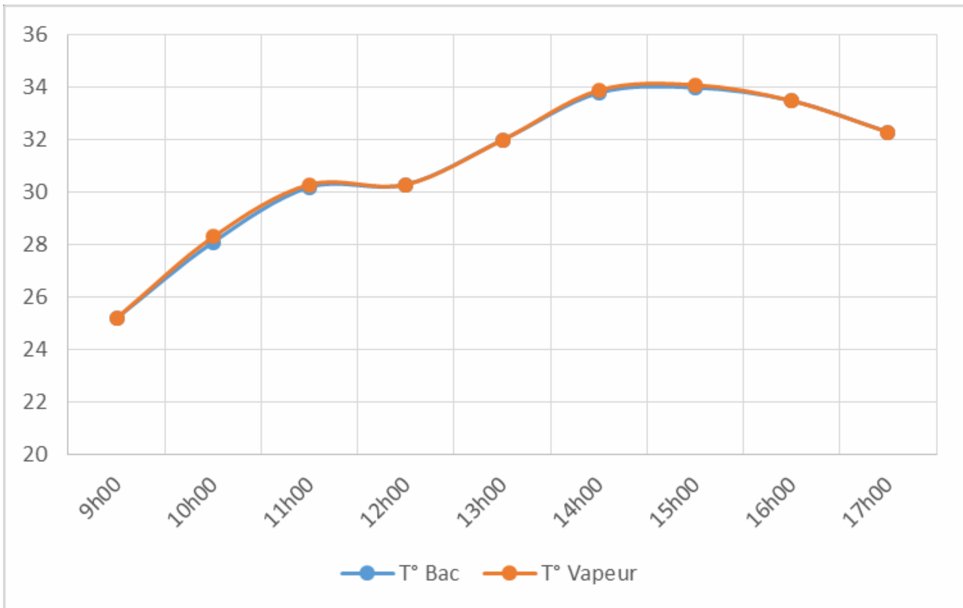

Figure 6-11: curve of temperature evolution of the tank and steam according to the time: June 4th, 2019

Figures 6-8, 6-9, 6-10 and 6-11 show that the curves of the two temperatures, either water in the tank or steam in the prism, are superimposed on each other, which indicates that the water temperature inside the prototype is virtually the same.

6.5.2. Variation of the internal temperatures with that of the air:

In view of the fact that the temperatures inside the prism are practically identical, we have reduced our hourly and daily comparison analysis to the temperature of the air with that of steam only, since this directly concerns the distilled water. The variations are illustrated in te following curves:

- **The 1st day is May 30, 2019:**

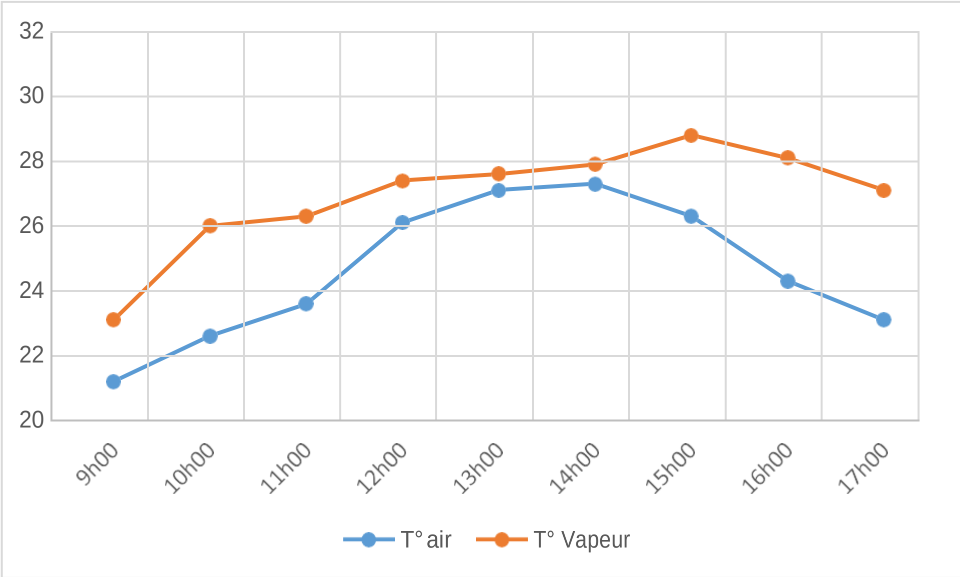

Figure 6-12: Curve of evolution of the air and steam temperatures according to time : May 30, 2019

- **The 2nd day is June 2, 2019:**

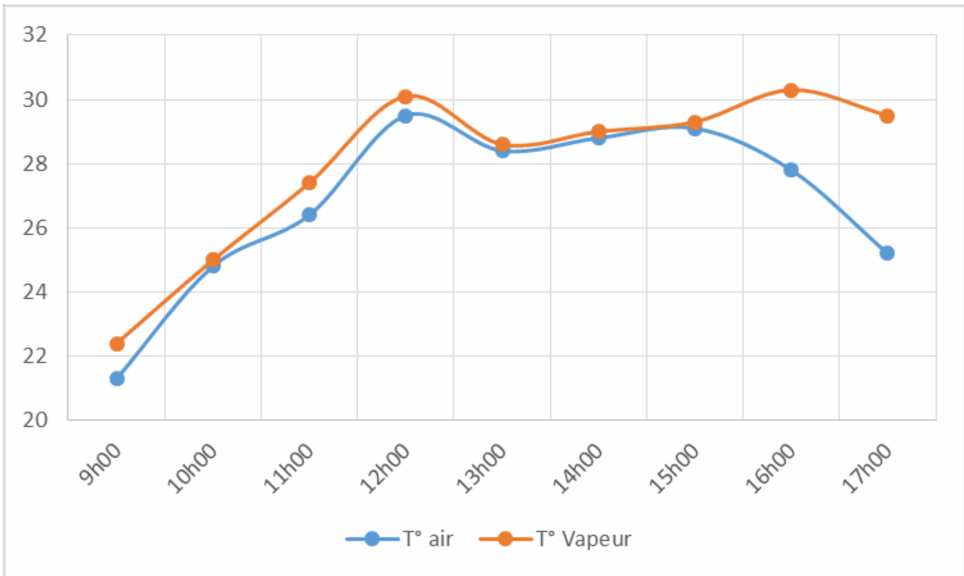

Figure 6-13: Curve of evolution of the air and steam temperatures according to time : June 2, 2019

- **The 3rd day is June 3, 2019:**

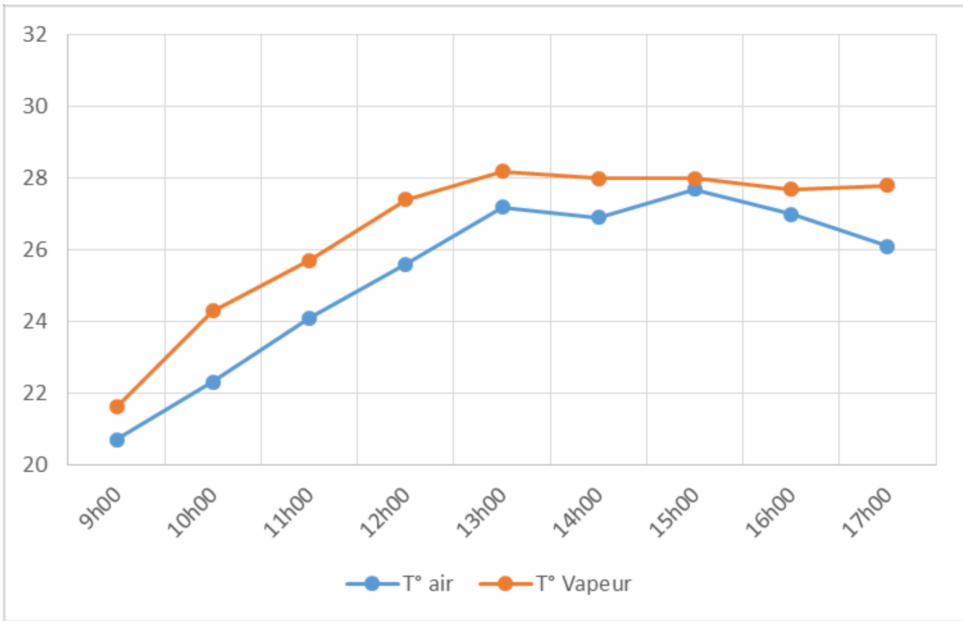

Figure 6-14: Curve of evolution of the air and steam temperatures according to time: June 3, 2019

- **The 4th day is June 4, 2019:**

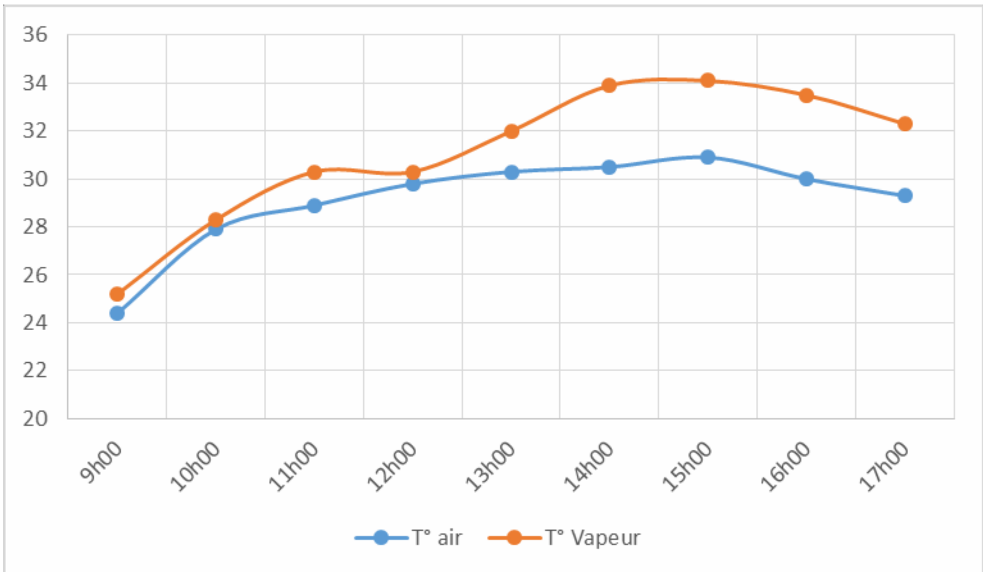

Figure 6-15: Curve of evolution of the air and steam temperatures according to time: June 4, 2019

Figures 6-12, 6-13, 6-14 and 6-15 show that the two temperatures follow almost the same pace, the temperature of the evaporated water is always higher than that of the air, and therefore the temperature of the water in the bench, reflecting the reflective role of the mirrors we had the reflection of putting on the walls of the prism.
We also noticed that the air temperature decreases from 15h, against that of the value remains high given the significant condensation of water vapor, clearly visible in the prism.

6.5.3. Variation of the internal temperature with the moisture:

We also made the hourly and daily comparison at steam temperature with that of humidity in order to know the important interaction between these two parameters. The variations are illustrated in the following curves:

- **The 1st day is May 30, 2019:**

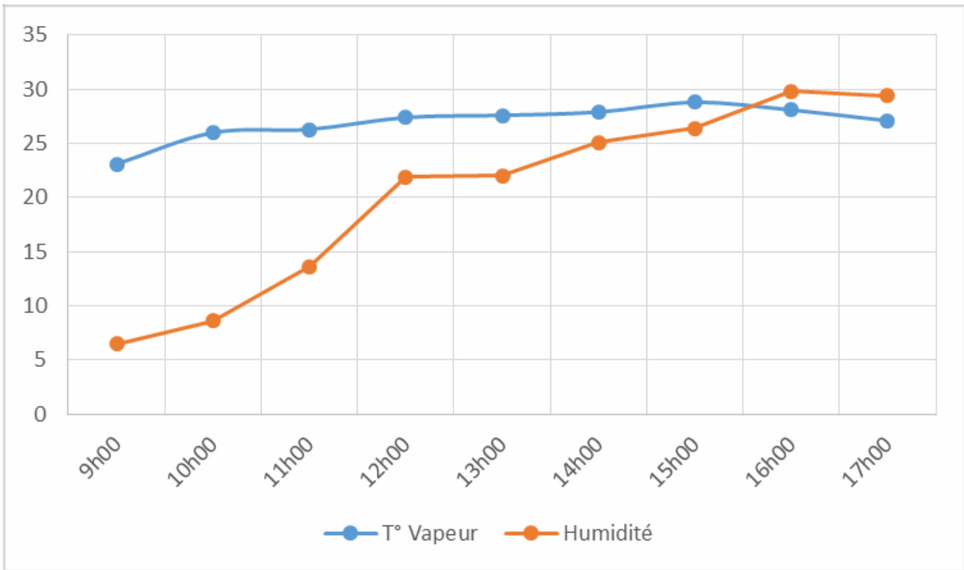

Figure 6-16: Evolution curve of vapor temperature and humidity as a function of time: May 30, 2019

- **The 2nd day is June 2, 2019:**

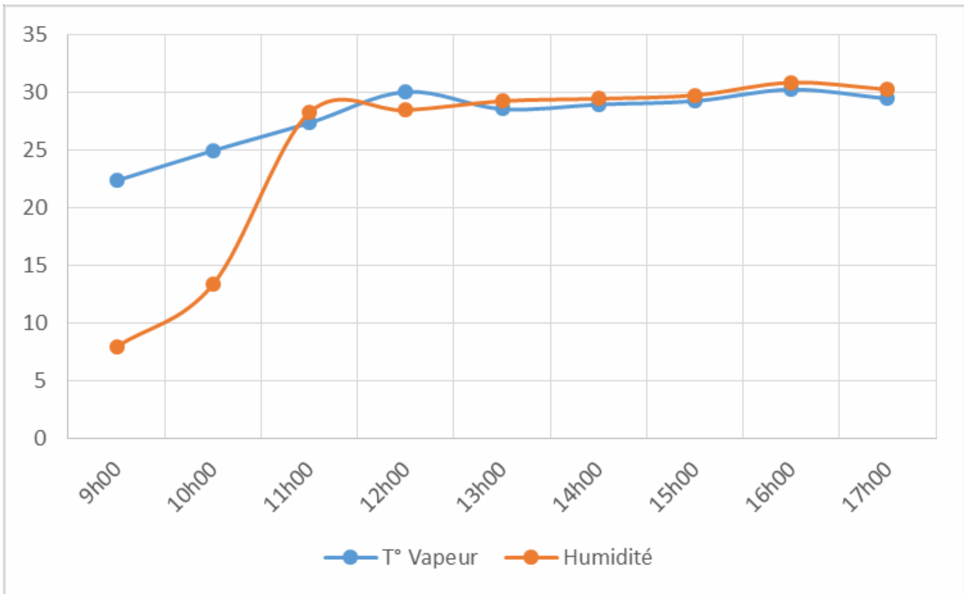

Figure 6-17: Evolution curve of vapor temperature and humidity as a function of time: June 2, 2019

- **The 3rd day is June 3, 2019:**

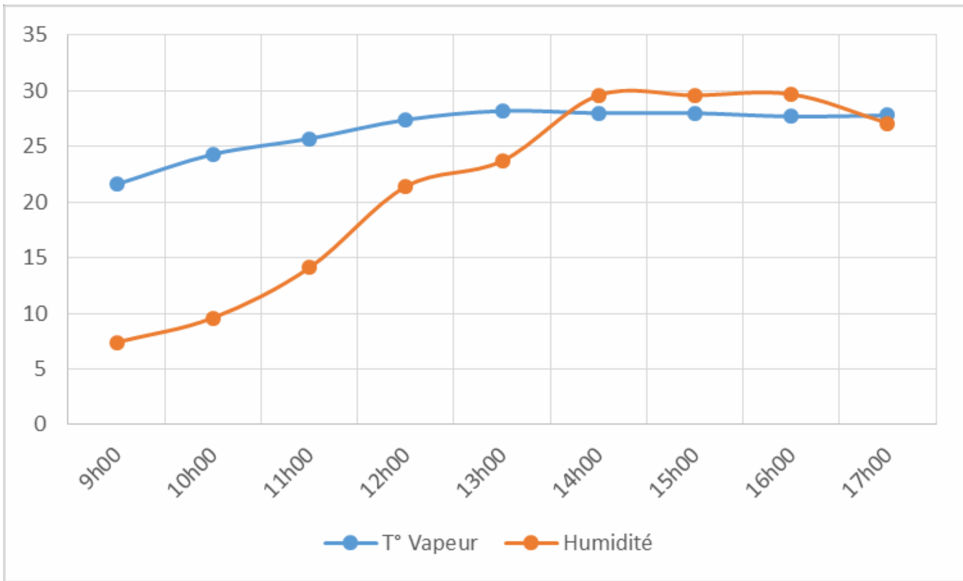

Figure 6-18: Evolution curve of vapor temperature and humidity as a function of time: June 3, 2019

- **The 4th day is June 4, 2019:**

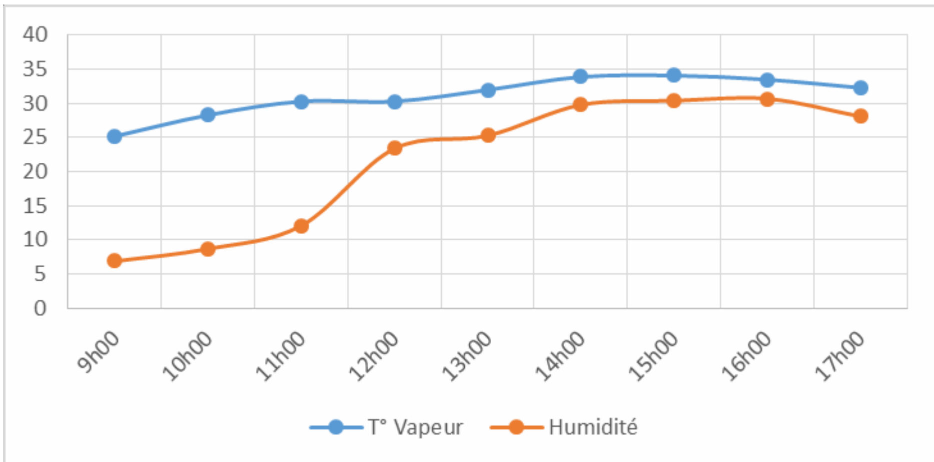

Figure 6-19: Evolution curve of vapor temperature and humidity as a function of time: June 4, 2019

Figures 6-16, 6-17, 6-18 and 6-19 illustrate the relationship between moisture following that of temperature.
Indeed, in the early morning we noticed that the humidity increases timidly with respect to the temperature, it is practically at around noon that the humidity approaches the temperature curve and is kept practically constant, this is strongly due to the concentration of vapor condensation at the end of the day.
The percentages of variation confirm this discussion, by the fact that at the beginning of the day there is a humidity evolution not exceeding 30% between 9h and 12h, whereas between 12h and 9h the percentage increase humidity is more than 220%, then a stabilization of the variation in the afternoon does not exceed 20%.

6.5.4. Distilled volume based on the internal temperatures:

We considered that the comparison between the internal temperature of the prism (that of the water vapor) as a function of the distilled volume, is important to clarify the link between these two parameters. The variations are illustrated in the following curves:

- **The 1st day is May 30, 2019:**

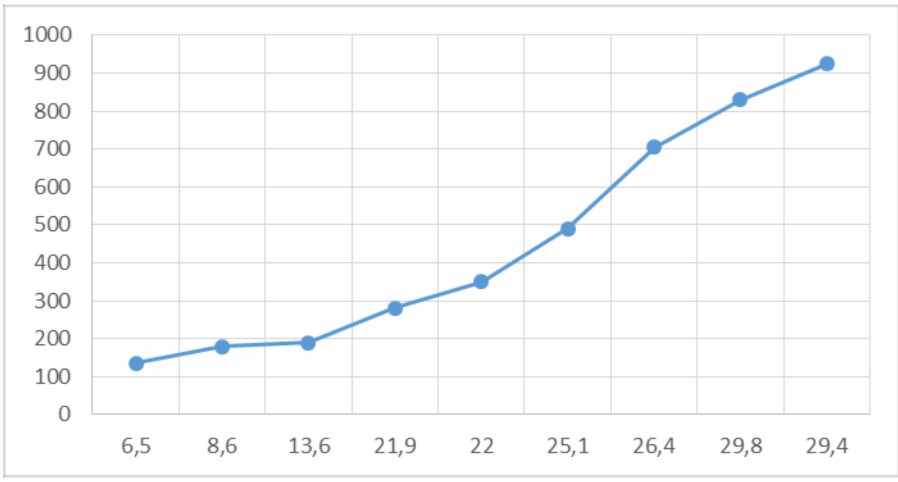

Figure 6-20: Cumulative curve of the distilled volume according to the humidity: May 30, 2019

- **The 2nd day is June 2, 2019:**

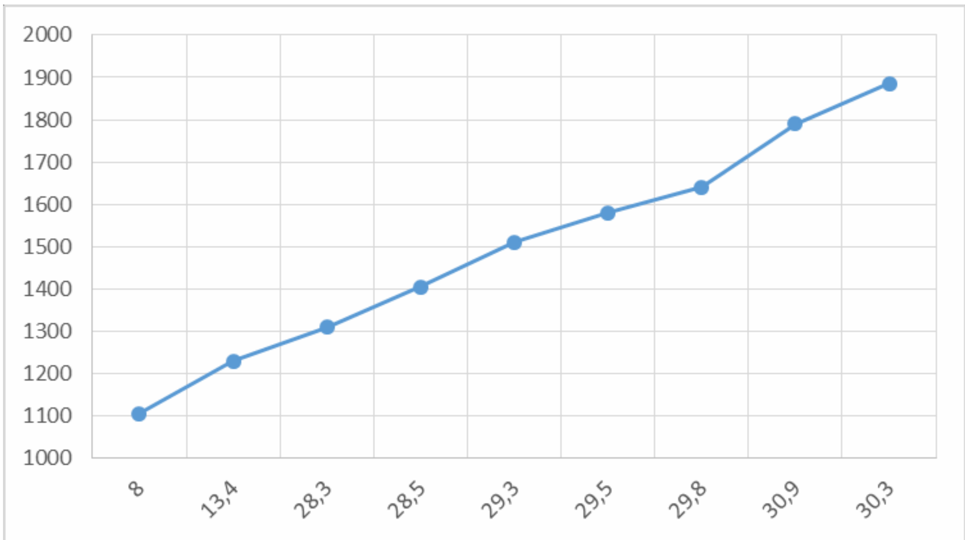

Figure 6-21: Cumulative curve of distilled volume as a function of humidity: June 2, 2019

- **The 3rd day is June 3, 2019:**

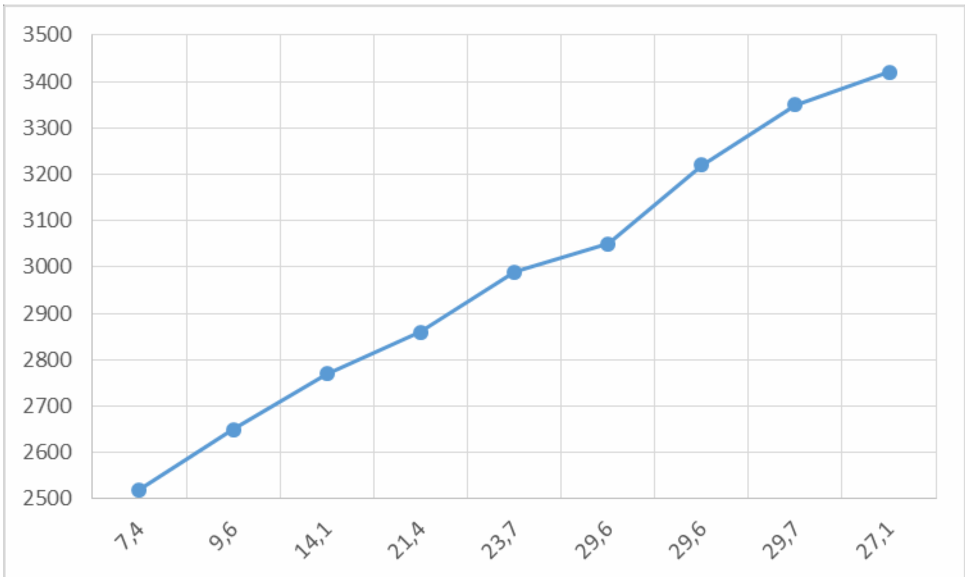

Figure 6-22: Cumulative curve of distilled volume as a function of humidity: June 3, 2019

- **The 4th day is June 4, 2019:**

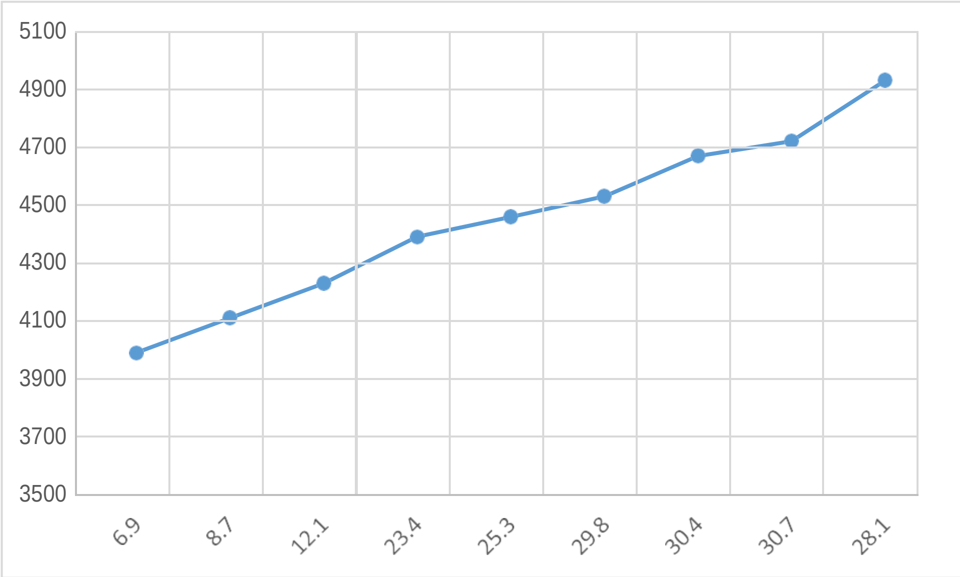

Figure 6-23: Cumulative curve of distilled volume as a function of humidity: June 4, 2019

The figures 6-20, 6-21, 6-22 and 6-23 show the evolution of the volume of distilled water as a function of humidity from May 30 to June 04, 2019.
It is clear that the variation is linear during the measurement period. We notice that as moisture increases, drops of water form on the walls, and slide to accumulate in the permeate reservoir, for all the curves we noticed that the slope of the straight lines reaches 70% per hour.

6.5.5. Distilled volume based on internal temperatures:

It is also useful to compare the variation between moisture and distilled volume to clarify the relationship between these two parameters. The variations are illustrated in the following curves:

- **The 1st day is May 30, 2019:**

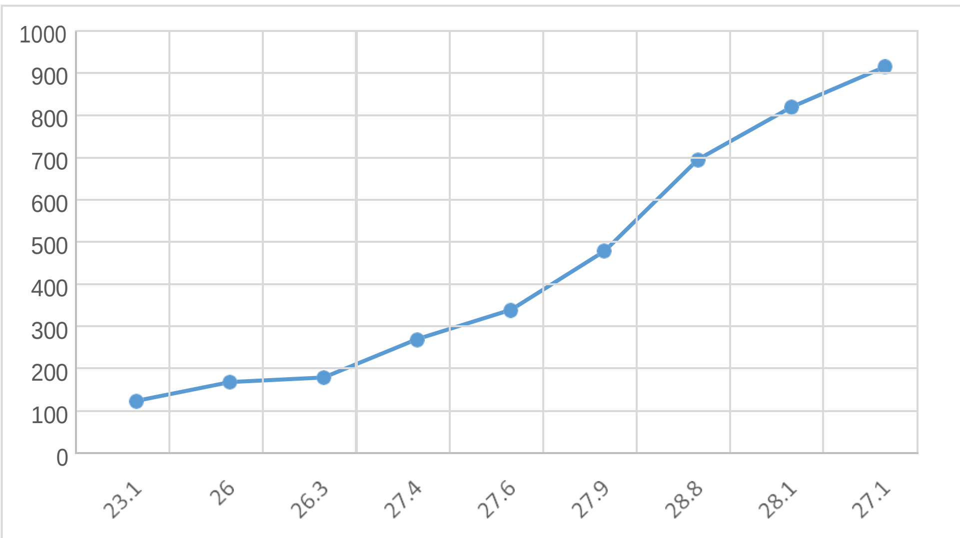

Figure 6-24: Cumulative curve of the distilled volume as a function of the vapor temperature : May 30, 2019

- **The 2nd day is June 2, 2019:**

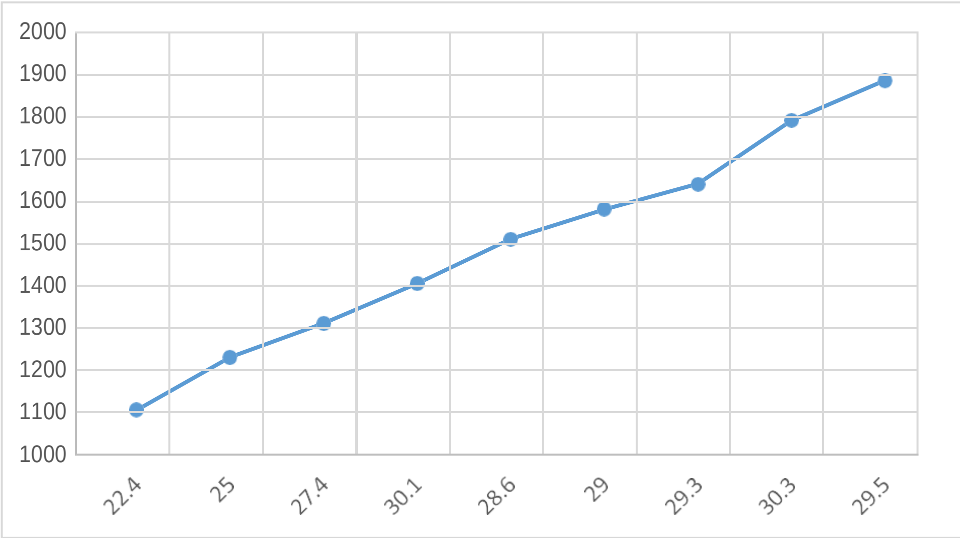

Figure 6-25: Cumulative curve of the distilled volume as a function of the vapor temperature: June 2, 2019

- **The 3rd day is June 3, 2019:**

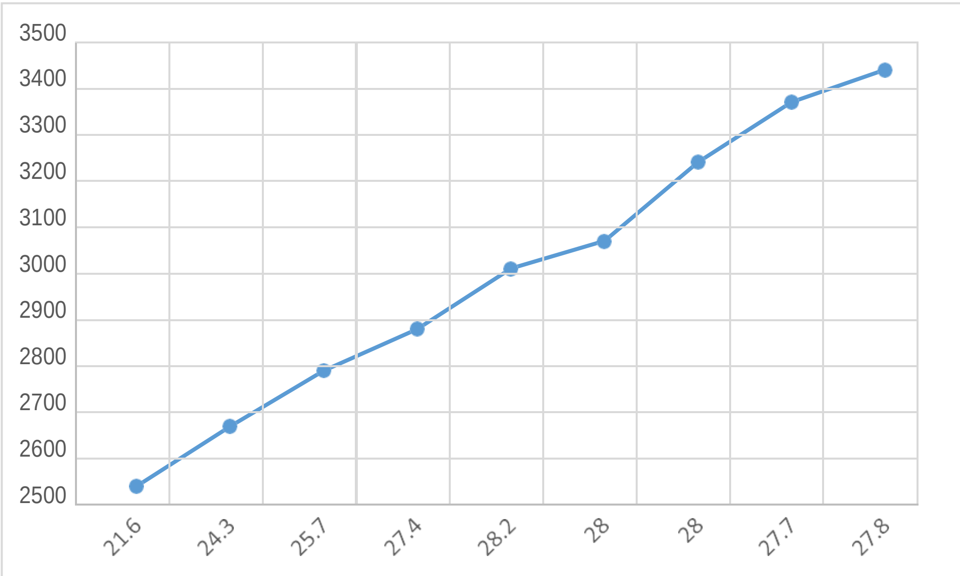

Figure 6-26: Cumulative curve of the distilled volume as a function of the vapor temperature: June 3, 2019

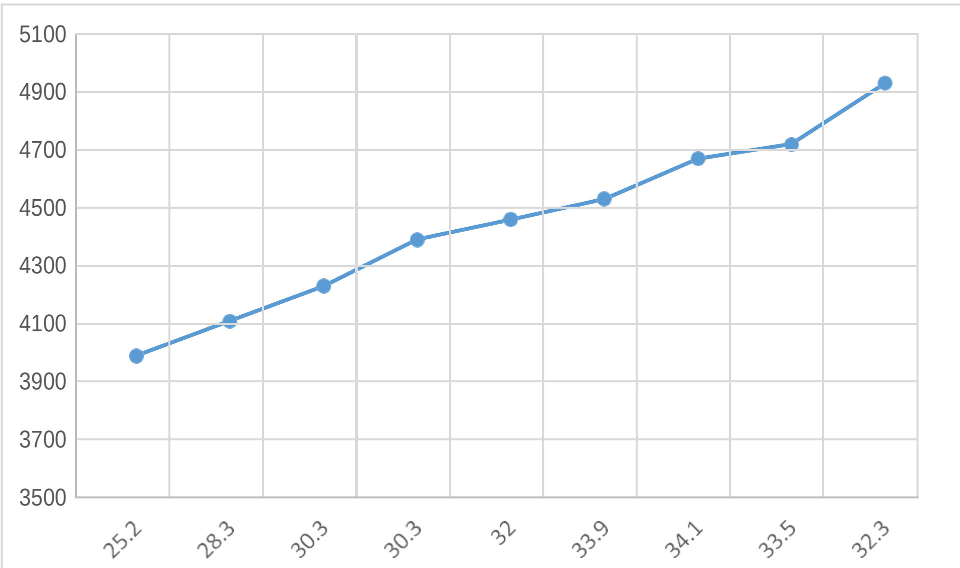

Figure 6-27: Cumulative curve of the distilled volume as a function of the vapor temperature: June 4, 2019

Figure 6-24, 6-25, 6-26 and 6-27 show that the evolution of the volume of distilled water as a function of the vapor temperature, during the measurement period, is also linear with slopes exceeding 80% which explains as the vapor temperature affects the volume; as long as kit is high, the volume becomes larger.

6.6. Discussions of permeate analysis results:

We have also performed permeate analysis to conform or affirm its salinity and /or of our distiller is functioning properly.

For this, we took samples directly from the solar distiller outlet (figure below), which we analyzed at the treatment laboratory using the same approach as the analysis of the salinity of the daily accumulated.

Figure 6-28: taking distilled water for analysis

The results obtained on the raw water and distilled water analysis show that the salt concentration of the distilled water is totally equal to zero, the values measured by the TDS-put indicate that the salt content in the permeate is between 181 and 434 ppm, which places our distilled water in the drinking water flow.

6.7. Conclusion:

In this chapter, we tested our prototype, after analyzing the seawater whose salinity result was 35g/l, we made variations between the different parameters observed along the duration of experiment, we found that the link is very clear between all the temperatures, the humidity and the distilled volume, this one increases according to the increase of the temperature and the humidity in the course of the day.

The analysis of the distillate clearly demonstrates that the model we have designed is well adopted for distilled seawater and may even be intended for domestic consumption as it has been indicated by the TDS-put.

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

7.1.Summary:

In this study we are interested in the supply of drinking water by desalination of seawater, focusing on one of the simplest treatment processes, in this case, and solar distillation.
In addition, this work includes a dimensioning engineering part, allowing to distil the water directly captured from the sea, in the region of El-Bekhata, for the water supply the summer population of this beach, as well as the hamlet of El-Bekhata.
Our experimental distillation project was placed on the terrace of the laboratories of the technology faculty of Tlemcen, on which we carried out between May & June 6, 2019 different temperature and humidity measurements
The various measurements and analysis carried out have demonstrated that the designed prototype is suitable for brine distillation; the analyzed salinity indicates that distilled water is good for domestic consumption.
On this fact we have developed a model of a prismatic prototype composed of three essential compartments.
The first compartment that we used is the glass prism, it is the most important element of the prototype, we conceived it in the form of a pyramid with square base so that it absorbs the maximum of solar energy some be the direction of the sun. In the lower part, we have provided windows facing inward to increase the reflection of solar radiation in the tank to brine. We have also developed a brine reception and distillate reception system, as well as the installation of measurement tools.
The second part of the model is the so-called elevating table, on which the distillation prism is placed, but also this on we used it to allow the tray containing the brine to slide with a lever towards the inside and outside the prism with a locking system with the table once the base of the tray reaches the lower limit of the prism, this system will allow the maintenance and control of the tray without touching the prism. In fact, the bottom has a square shape, which we made in black steel to absorb the maximum of solar radiation, and isolate from the outside by polyester to ensure its thermal insulation and keep the heat inside, when-the maximum volume that can accommodate this tray is 30.
The third, very important part of the prototype, concerns the different measuring tools, it is a set of sensors and electronic probe that we have installed on the prototype to carry out mainly the measurement of the moisture of the prism and the different temperatures (air, brine, steam). These measurement components we have stalled by resistors and amplifiers all connected on an electronic table to transmit the date to the Arduino Uno card, it-self is placed on the table, is allowed following the computer program that we established display the measured values on an LCD screen or transmits them to a computer as database.

7.2.General conclusion of the project:

Energy is the basic necessity for all of us leads a normal life on this beautiful earth. Solar energy technologies and is usage are very important and useful for the developing and under developed countries to sustain their energy needs. The use of solar energy in distillation process is one of the best applications of renewable energy. The solar stills are user friendly to the human being in the nature.
Solar energy is abundant and never lasting, free of cost and environment friendly. Solar distillation is the best solution for small communities who facing problems with lack of fresh water. Solar still is good for operation, maintenance and repair. Solar still have good chanced to

success in Algeria. The improvement in solar still distillation due to the use of several ways i.e. sponges, gravels, dyes etc.

In this study, we are interested in the supply of drinking water by solar distillation of seawater. To achieve this, we have scanned several bibliographical references dealing with different theoretical and practical studies on desalination techniques and the application of solar energy for the treatment of seawater.

In this case, we are thus focused in this work on one of the simplest treatment processes, solar distillation.

To better understand this phenomenon of solar distillation, we have found it useful to use a reduced model of solar distillation, on which different analysis and measurements can be carried out.

Indeed, we took samples of the seawater, which we initially analyzed the salinity in the water treatment laboratory, whose value was 35g/l, we then filled the tank of our distiller by near 20 L of water and we have during all the period of test carried out hourly measurements of the temperatures and the internal humidity of the prism.

We have found that temperatures and humidity are highest between midday and 16thn that the variation of the temperatures of the tank is internal vapor of the prism are virtually identical, they have the same pace of the hourly variation of the external temperature of the air, that the humidity varies according to the variation of the temperature, this one is also at its maximum between noon and 16h, whose mist is visibly clear in the prism with the formation of the drops of water distilled on these walls, this which gives every hour a new volume of distilled water.

Laboratory analysis of the distillate salinity shows that it is completely free of salinity, which has been confirmed by Salinity analysis (TDS) on different samples of the permeate, which indicates that our distilled water can be clean for consumption. That said, the model we used has demonstrated its significant performance only in a short time of measurement and in a climate not very sunny.

On the basis of the results we obtained, we decided to enrich our work by the projection of an engineering project aimed at distilling seawater to feed a summer population as well as some houses.

For that, our choice was on the region of EL-Bekhata that the analysis of its physical environment indicated well that it presents a favorable place for this type of projects. Thus we set up a micro solar distillation installation to connect to a treatment station by filtration on sand and active charcoal, and a small disinfection work, this station feeds by repulsing a water stain of 25m” allowing the supply of electromechanical equipment is powered by solar energy using photovoltaic panels.

Finally, our project has two components, in this case, a research component on the phenomenon of solar distillation of seawater and salt water, of which the model that we have used constitutes an adequate and favorable experimental bench for the different experimental experiments. On the other hand, and engineering component, where the location of this type of project in certain beaches remains a very profitable economic investment for the population around these beaches of the summer population.

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