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Solar Desalination

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1. Introduction

Water is life in all its forms. All living organisms contain water: the body of a human being is composed of approximately 60% of water, a fish of 80%, plants between 80 and 90%. Water is necessary for the chemical reactions that occur in living cells and is also in the middle of this water that these cells are formed. Water is essential to sustainable food production as well as all living ecosystems; human development is based entirely on the hydrological cycle.
Water covers about 70% of the globe area. Furthermore, 97% of this water (salty, non-potable and unsuitable for irrigation) is located in the oceans. Freshwater is only 3% of total water on our planet. In this low percentage, rivers and lakes are 0.3%, while the rest is stored in the polar caps and glaciers.
Freshwater tanks are very unevenly distributed on the surface of the globe. While Western countries for example have the chance to have huge reserves which will renew each year to feed a population that acknowledges a low population growth for most. Many tropical and island countries lack sufficient water, however suffer rampant demographic growth and know an extremely bad supply difficulties. Arid regions are in a situation of severe water stress and simply a drought to decimate the weaker populations and livestock.
We fought for the strategic islands or for black gold, we will fight soon for «blue gold" if everyone does not share its resources, and does not reduce consumption and losses.
Drinking water demand is also growing more and more, and the inadequacy of this water can be considered to be a danger that continued to disturb the humanity until our days (and in the future), causing thus disruption or even a braking of economic activities and a deterioration of living standards [1, 2]. Similarly this lack can be linked directly to 80% of diseases affecting the world's population and 50% of cases of infant mortality [3]. All these data so eloquent drew our attention on the need to search other sources of drinking water.
On the other hand, and worldwide distribution of drinking water is not commensurate with the needs of each region. This is manifested by finding a surplus of water in regions, while others have chronic shortages. For the latter, the desalination of brackish or sea water is becoming the inevitable solution.
Furthermore, in addition to the vital need for water, human beings live also have a crucial need for energy. This is particularly true for human beings who consume increasing energy not only for food, dress, heat, move, entertainment and treat, but also for product all manufactured objects quantities.

The quality of life of the world population largely depends on energy at its disposal, not only in quantity but also in quality. It is determined by the choice of modes of production, distribution and consumption. Resolve the crucial energy in the world by providing men energy that they need on their housing and production sites is certainly a factor of peace.

In these circumstances, made to find a source of energy other than those of fossil energies and responding to environmental requirements, seems crucial. In this context, renewable energy have a certain interest and, in particular, solar energy.

Desalination processes fall into two categories; a distillation processes (requiring a phase change, vaporization/condensation) and in the other hand the membrane processes (membrane separation).

For its operation, the distillation process requires, for much part, the thermal energy for heating salty water. For seawater, for example, 100-50. 10^3 kcal per m^3 of water's produced following the performance of the unit. In addition, this thermal energy must be provided at a relatively low temperature, between 120 and 60 ° C according to the technology adopted. The heat source can be provided, in the case of a coupling solar, by solar flat plate or concentrator collectors.

The usually used processes which are likely to be coupled to solar energy are:

- Direct solar distillation greenhouse is a strictly a solar process.
- Classical distillation processes such as Multi-stage flash, multiple-effects, vapour compression process.

Solar energy can be converted from appropriate converters to other forms of energy such as electrical, mechanical, thermal, etc. In the thermal energy conversion there are two modes of conversion: at low temperature, where heating fluid temperature remains below 100 ° C [4-7] and at average and high temperature when it exceeds 100 ° C. For the first case, this level of temperature is reached by means of a flat plate collector, while in the second case, a concentrator collector is required [7, 8]. Several types of collectors were made until today we quote:

- conical concentrator,
- spherical concentrator,
- cylindro-parabolic concentrator and
- parabolic concentrator.

The process of solar distillation is used to distill brackish/saline water by using solar energy. The systems involved in solar distillation operate under two modes: passive and active.

Many prototypes of solar stills have been constructed and experimented by various researchers. A solar distillation system may consist of two separated devices - the solar collector and the distiller - or of one integrated system. The first case is an indirect solar desalination process, and the second one is a direct solar desalination process. Many small-size systems for direct solar desalination and several pilot plants of indirect solar desalination have been designed and implemented [9-11].

2. Desalination processes

These are separation processes that rely on a technique or technology for transforming a mixture of substances into two or more distinct components. The purpose of this type of process is to purify the saline water of its impurities.

The principle of a separation process is to use a difference of properties between the interest compound and the remaining mixture. When the difference property will be greater, the separation is easy. So the choice of the separation process starts with a good knowledge of the mixture composition and properties of different components. The desalination processes are divided into two main categories: on the one hand, the distillation process (which requires a phase change, evaporation / condensation) and on the other hand the membrane processes (filtration).

The most current techniques of desalination are thermal distillation - for the treatment of great volumes of water (55 000 m^3/jour) – and the membranes technology: electrodialysis and reverse osmosis. The ability of treatment with membrane technology can be adapted according to the intended use (the great plants have a capacity of more than 5000 m^3/day, the averages plant between 500 and 5000 m^3/day, while that small installations have a maximum capacity of 500 m^3/day).

It is noticed that these processes use thermal energy and / or electrical energy and consequently are consumer's energy and pollutants. The energy, conventional methods commonly used, can be of solar origin either a partial or total depending on production capacity and in this way we minimize significantly the consumption of energy while protecting the environment. Future research in this area is oriented toward the maximum utilization of solar energy, which is free and clean, or through technological innovation and/or improvements on conventional methods.

2.1 Solar thermal distillation

For their operation, the distillation processes require for much of the thermal energy for heating salt water. Furthermore, this thermal energy must be supplied at a relatively low temperature, between 60 and 120 ° C. Heat can be provided in the case of the use of solar energy by solar flat plate or concentrator collector according to working conditions.

The processes most commonly used and which are likely to be coupled to a source of solar energy are:

- The direct solar greenhouse distillation is a properly solar process.
- The conventional distillation processes such as multi-stage flash, multi-effects, vapor compression

2.1.1 Direct solar greenhouse distillation

This process consists in heating water directly by the solar radiation in a closed enclosure covered with glazing. The produced vapor, which condenses on the colder glazing and slightly inclined, east collects in the form of condensed in gutters. The principle is very simple, reliable and does not require any maintenance. But its output is relatively weak, 4 to 6 liters/day.m^2 [12, 13]. They are however two types of manufacturing distillers, they can be built either:

- In the form of modular product, it is usually a tray (plastic, metal, wood ...) isolated from below and covered with a glass top. Several distillers can be fed simultaneously to form a distillation unit. The number of distillers depends on the desired produced water capacity. This model is used only for very small product capacities, a few liters per d. It is practical when the need for distilled water is not very important (laboratory analysis, auto park ...).

They are however several variants include plat distillers, cascading wick, with multiple effects, spherical ... etc.

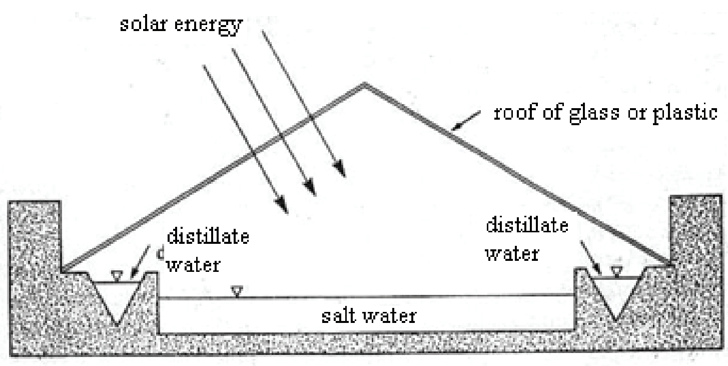


Fig. 1. Solar distillation by greenhouse effect.

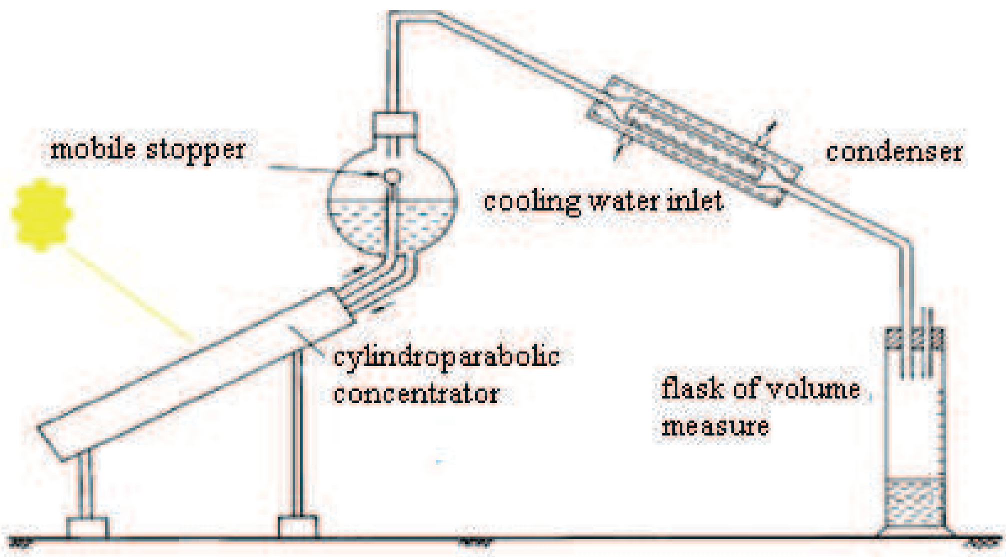


Fig. 2. Solar distiller with cylindroparabolic concentrator

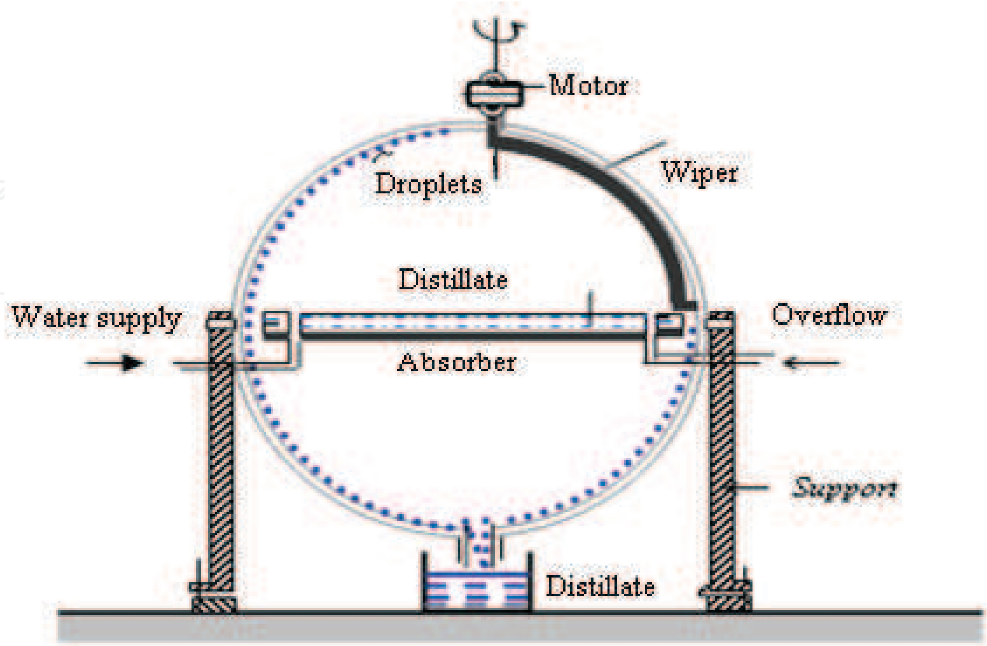


Fig. 3. Spherical solar distiller with sweeping

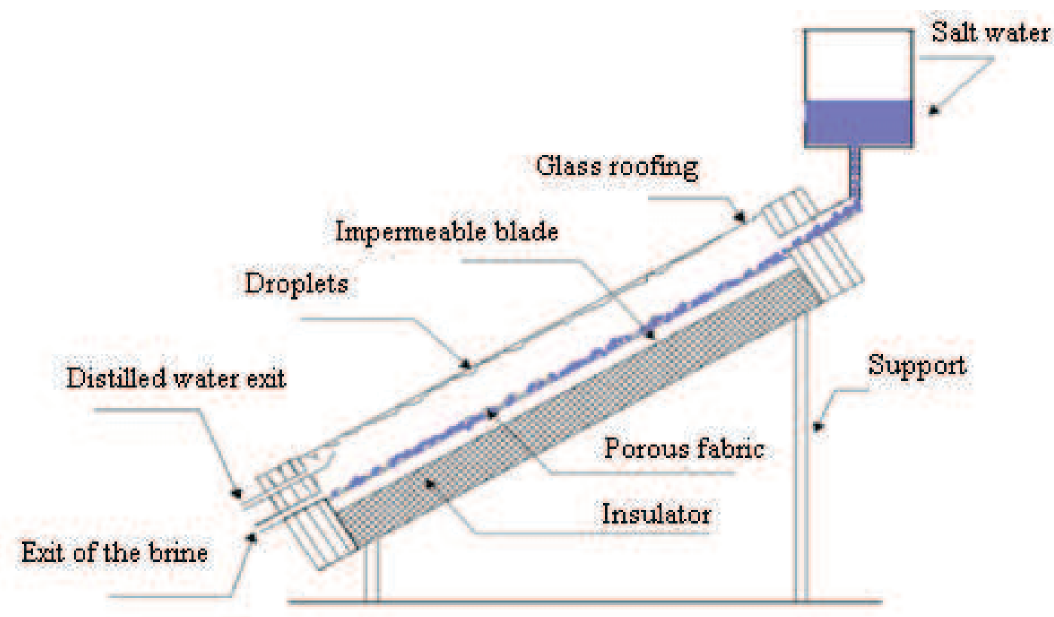


Fig. 4. Solar distiller with wick

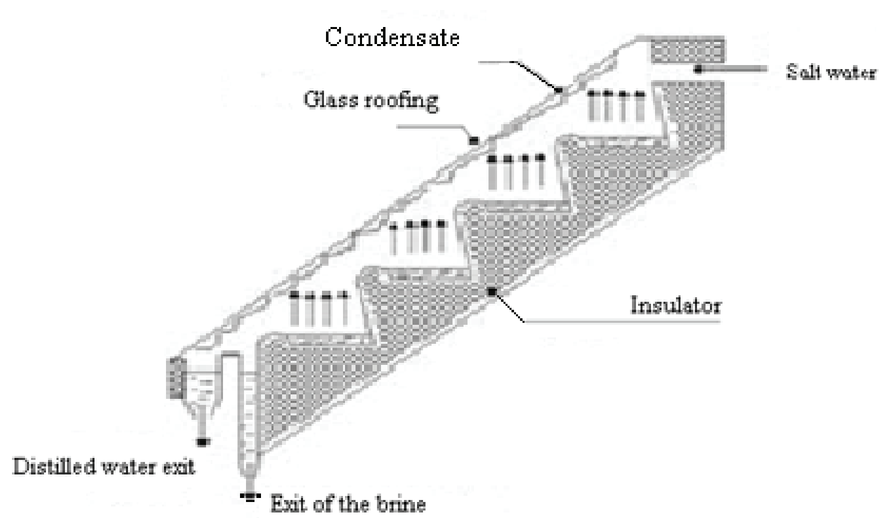


Fig. 5. Solar distiller with cascade

- When the needs are greater and to increase the production of fresh water, we can juxtapose several distillers or build a distiller of large surface. The first construction of this type of distillers was held in 1872 at Las Salinas (Chile) with an area of 4700 square meters and a production of 23 m^3 / d of fresh water [14]. In Tunisia, a desalination plant was built in 1929 near Ben Gardanne to support French military troops [15]. The first large pools (439 and 1300 m^2) were built during the 60s in the regions of Chakmou and Mahdia. Their daily production is respectively 0.57 and 4.48 m^3 [14, 16, 17].

The theoretical analysis is based on the heat balance of the distiller who allows to determine its output according to the various parameters.

2.1.2 Distillation with multi-stage flash (MSF)

This process usually profitable only for large capacity (several hundreds of thousands of m^3), is not flexible and presents difficulties of setting in mode for a solar application. The number of effects depends on the pressure difference that exists between the first and last stage. It is noticed that the contribution of thermal energy can be completely or partially solar and this is function of the desired production.

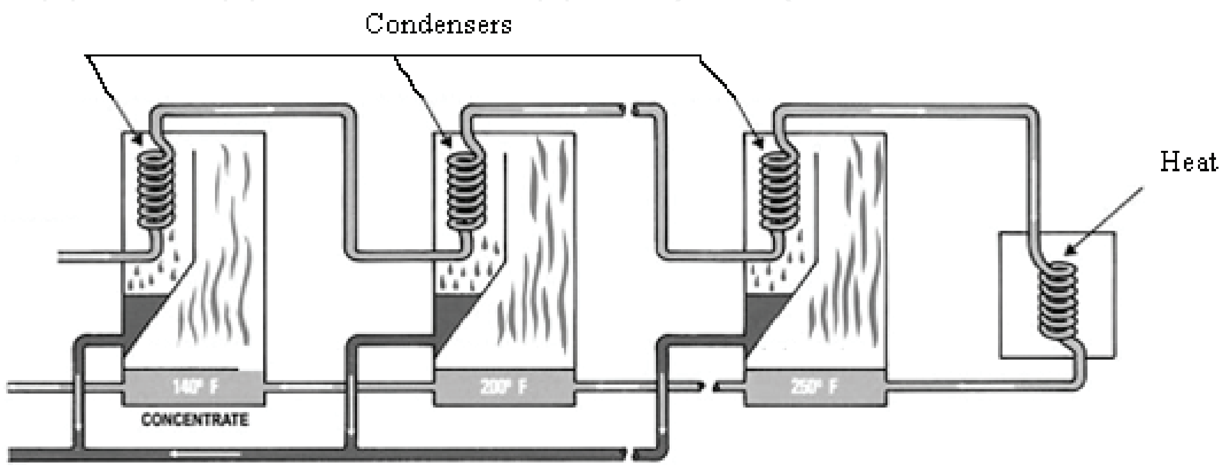


Fig. 6. Multi stage flash distiller

2.1.3 Distillation by vapour compression

It is a process involving a series of evaporators; however, its performance is improved by recycling vapor from the last effect (at the lowest heat) by compressing and then used as heating steam to the first effect. This method can use solar energy as heat source, but requires more energy to compress vapor. This is done either with a supercharger (mechanical compression) or a steam ejector (thermal compression)

2.1.4 Distillation by multiple effects

In this category, there are two processes: some use vertical tubes, the other horizontal tubes. The advantage goes to the horizontal tubes for low pumping power used and a global coefficient of heat exchange important.

An example of multiple effect distillers is shown in Fig. 7 [14].

This distiller is composed of a series of vertical and parallel plates, a storage tank for hot water and a solar panel. The first plate is heated by hot water circulating in the pipe welded at its left part. The last plate is cooled by circulating salt water in a tube in contact with it. After that, the heated salt water supplies distributors at the top and right side plates. These distributors provide a falling film flow along them. The contribution of energy provided by hot water at the first stage, will give rise to the formation of a quantity of steam in the right side of this plate. The steam is condensed in the left side of the plate after evaporating a quantity of water falling film flowing on the right side of this plate and so on. The condensate is collected at the bottom of the plates.

The storage tank allows the multiple effect process to operate during periods of absence or insufficient solar radiation. Hence the advantage of this system compared to those using solar energy directly.

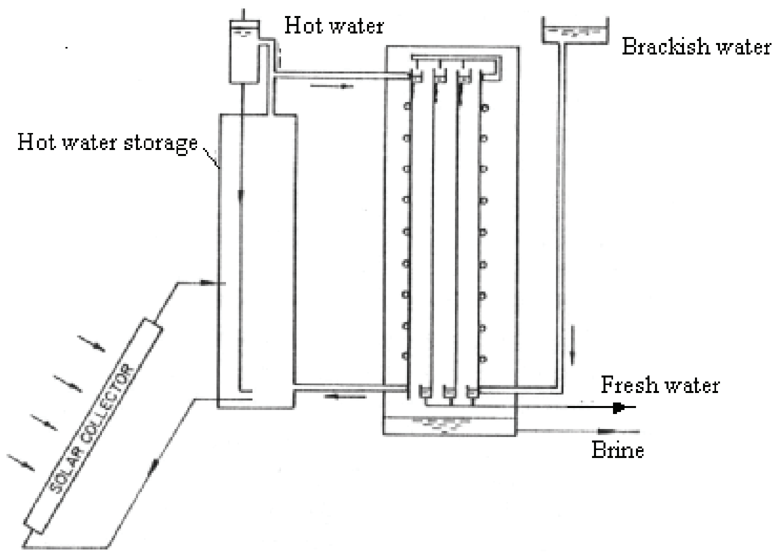


Fig. 7. Multiple effects solar distillation.

It should be noted that the multiple effect solar distillation at atmospheric pressure cannot always compete with one single effect. Thus, several studies have been conducted to improve the performance of these distillers. Among these works, there are those that replace the flat-plate by parabolic concentrator in order to produce steam for the initiation of multiple effect distillation [14].

2.2 Solar membrane processes

The main membrane processes used in the field of desalination are electrodialysis and reverse osmosis.

2.3 Electrodialysis

This process requires, for its operation, the application of an electric field between a cathode and an anode to allow the migration of the ions (positive and negative) through the membranes. It is a large consumer of energy, which makes its solar application possible, only for brackish water of very low salinity.

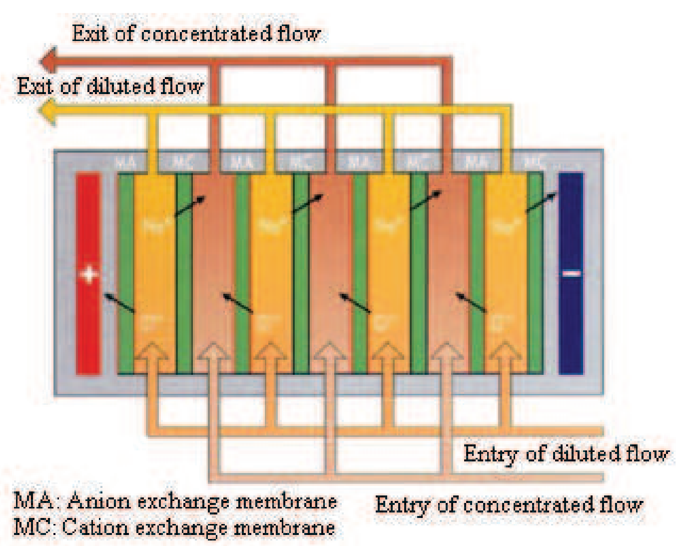


Fig. 8. Electrodialysis desalination process

2.4 Reverse osmosis

The principle of this process is to move under the influence of pressure, pure water through a semi permeable membrane which has the characteristic of retaining the salts dissolved in water. So we need the necessary energy to supply a high pressure pump, which can be provided economically (for small plants) by a photovoltaic generator or an aerogenerator.

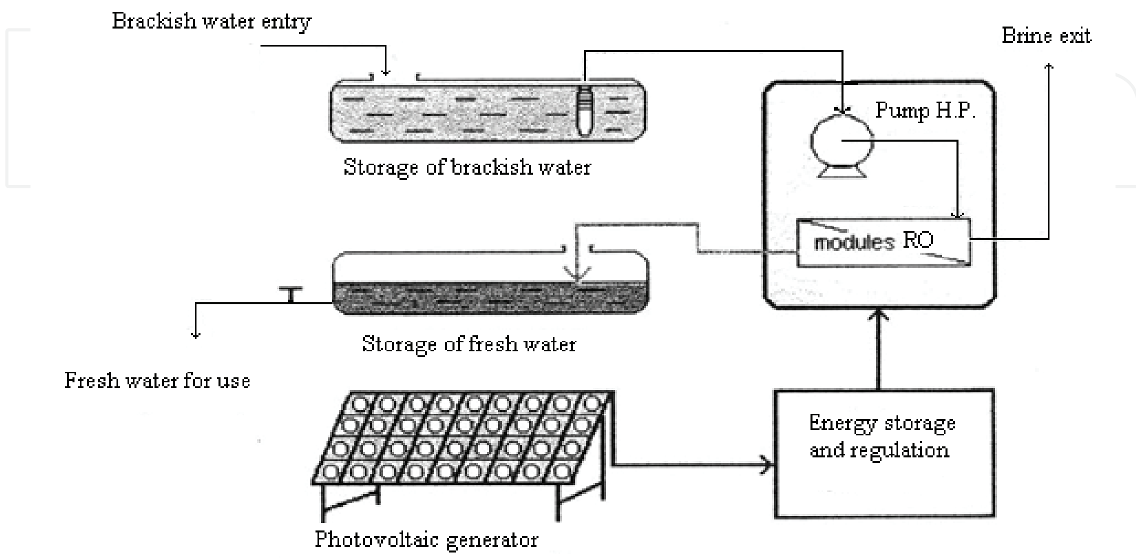


Fig. 9. Reverse osmosis desalination process

A certain number of units are in operation worldwide, and the results obtained through various studies and experiments make its application very encouraging.

2.5 Vacuum membrane distillation

Membrane distillation is a relatively recent process. This process uses hydrophobic porous membranes to separate a solution physically. The process driving force corresponds to the pressure and temperature variation between the two sides of membrane. The principle of separation by the membranes distillation is based on the balance liquid/vapour which controls the selectivity of the process [18].

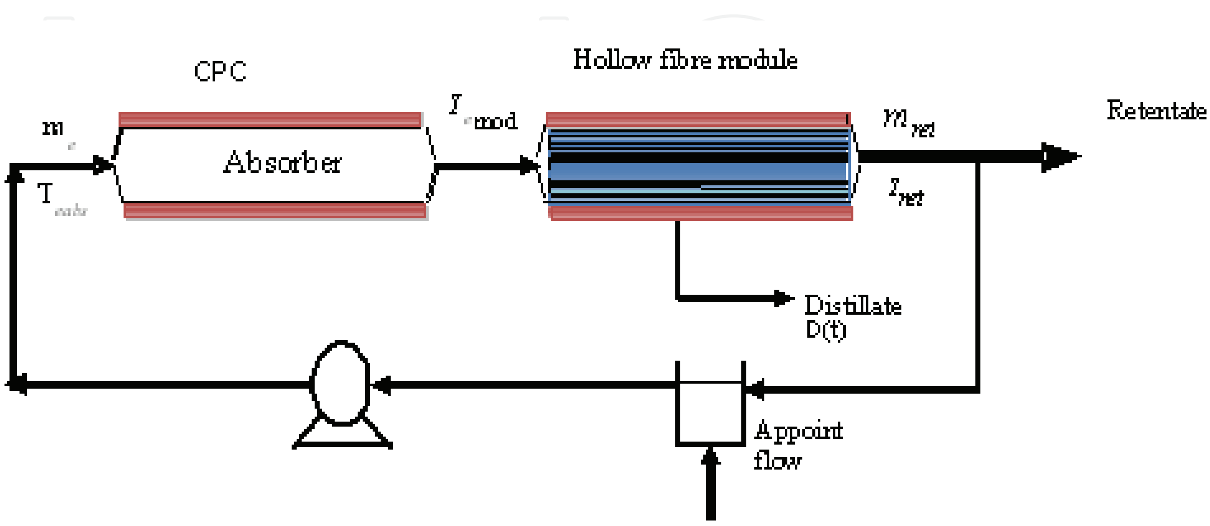


Fig. 10. Diagram of the desalination unit

The principal interests of membrane distillation compared to the conventional distillation process are the great contact specific area due to the installations compactness's, the modularity and the possibility of automating the process easily.

Among the membrane distillation techniques we are interested to the vacuum membrane distillation (VMD). It is an evaporative process which uses a hydrophobic porous membrane, whose function is to separate and put in contact a liquid and a gas phase [19]. This process is interesting for the seawater desalination. The analysis of the operating conditions shows that the parameters keys are a relatively low temperature and pressure. Moreover, the process coupling vacuum membrane distillation with a source of energy (solar or geothermal) could compete with reverse osmosis [20].

An example of a solar vacuum membrane distillation (SVMD) is represented on the figure 1. It is composed by a solar desalination system in series with a tank which receives seawater. This one feed by retentate flow and a auxiliary flow

3. Solar energy

The solar energy received at the ground level is very abundant and far exceeds the energy requirements of the current world population. It is free and accessible to all by its decentralized appearance. It reaches the user without hazardous waste or pollution risk.

3.1 Different forms of solar radiation

During the passage of solar radiation by the atmosphere, some is absorbed (UV and X rays), another part is dispersed by air molecules or suspended particles (dust). This gives rise to diffuse solar radiation. The remaining part arrives directly at the surface of the ground and constitutes the direct radiation. The total solar radiation is made of direct and diffuse radiation.

3.2 Solar constant

It is the total energy sent by the sun to the limit of the terrestrial atmosphere on a perpendicular surface to the radiation. The average value selected is of 1353 W/m^2 [21].

3.3 Evaluation of solar radiation reaching the collector

Several mathematical models have been developed to measure the solar irradiance at the collector. Among these models are cited that of EUFRATE which is based on the synthesis work of PERRIN DE BRICHAMBAUT, KASTEN and HAY. This model uses the factor of disturbance of LINKE (TL), latitude and declination [22]. Because the concentrators do not collect the diffuse radiation [21], we will be interested in this part only to the direct radiation.

The various equations describing the EUFRAT model are:

3.3.1 Correction of the earth-sun distance (r)

$$r = 1 + 0{,}034 \cos(0{,}986j - 2) \tag{1}$$

3.3.2 Estimation of the disturbance factor of LINKE (TL)

$$TL = 1{,}6 + 16\beta A + 0{,}5 \ln(P/100) \tag{2}$$

The disturbance coefficient of Angström (βA) varies according to the sky type. The following table illustrates this variation:

Type of the sky	βA
Major blue	0,02
Pure blue	0,05
Light blue	0,10
Milky blue	0,20
Whitish	0,50

Table 1. Angström disturbance coefficient βA.

In the same way, the factor TL can be estimated by geographical area with the help of the equation:

$$TL = TO + u\cos(0{,}986j) + v\sin(0{,}986j) \tag{3}$$

The TL value must be corrected according to altitude (-0,35 par 1000 m).

Zone		TO	u	v
Mediterranean	coast	3,25	-1,1	-0,15
	inside	3,15	-0,5	-0,05
Atlantic		3,25	-0,7	-0,15
Continental		3,75	-0,2	-0,05
Great agglomerations		4,05	-0,5	-0,10

Table 2. Values of the coefficients TO, u et v.

3.3.3 Equation of time (Et) [21]

$$Et = 0{,}123\,(t + 87) - \frac{1}{6}\sin(2(t + 10)) \tag{4}$$

$$t = 0{,}988\,[\,D + 30{,}3\,(\,M - 1\,)\,] \tag{5}$$

3.3.4 Real solar time (TSV)

$$TSV = TU + \frac{Lo}{15} + Et \tag{6}$$

3.3.5 Hour Angle (ω)

$$\omega = 15\,(TSV - 12) \tag{7}$$

3.3.6 Declination (δ)

$$\delta = 23{,}45\sin(0{,}986j - 80) \tag{8}$$

3.3.7 Height or the angle between the direction of the sun with its projection (γ) [23]

$$\sin(\gamma) = \sin(\delta)\sin(La) + \cos(\delta)\cos(La)\cos(\omega) \tag{9}$$

3.3.8 Optical way (AM)

$$AM = \frac{(1 - 0,1 .z))}{\sin(\gamma)} \tag{10}$$

3.3.9 Direct solar irradiance received on a normal surface with the rays (E)

$$E = Bo\ r\ \exp\left[\frac{-AM\ TL}{0,9\ AM + 9,4}\right] \tag{11}$$

Bo = 1367 W/m².

3.4 Conversion of solar energy

Solar energy can be converted using appropriate converters in other forms of energy such as electrical, mechanical, thermal, etc.. In this case, we are interested to the thermal conversion. We distinguish then two conversion modes: at low temperature, where the fluid temperature to heat remains below 100 ° C and at medium and high temperature when it exceeds 100 ° C. For the first case, the temperature level is achieved by means of a flat plate collector, whereas in the second case, a concentrator collector is required.
Several types of concentrators have been made to this day which we quote:

- the conical concentrator,
- the spherical concentrator,
- the cylindro-parabolic concentrator and
- the parabolic concentrator.

This last which will be the subject of this study, was used for a long time, because it ensures an high level of temperature and power [24]. A parabola is the whole of the points located at equal distance from a line fixes D, called director of the parabola, perpendicular to axis (OZ), passing by the X-coordinate (- F) and the focal point F (fig.11). Any luminous ray parallel with axis (OZ) will be deviated by the reflective surface of the paraboloid towards the point F of X-coordinate (F) representing the focal distance. The equation giving the focal distance (F) is [25]:

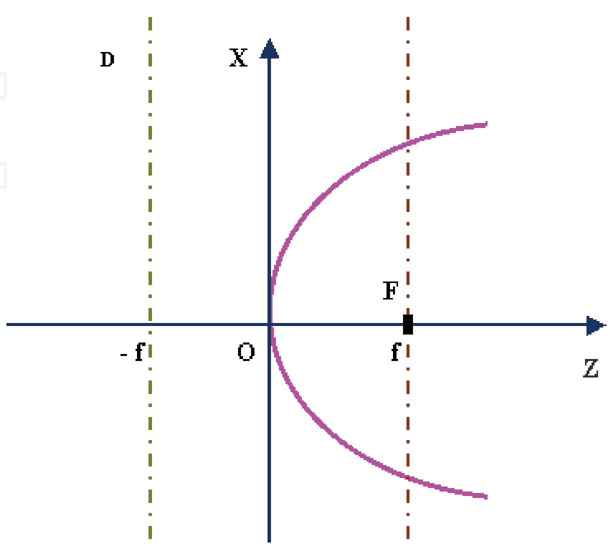


Fig. 11. Status of the paraboloid from the director D and demonstration of the focus F.

$$f = \frac{a}{4tg(\frac{\Phi o}{2})} \quad (12)$$

The depth of the paraboloid (Po) is given by:

$$Po = \frac{a^2}{16f} \quad (13)$$

3.4.1 Concentration of the solar radiation

a. Geometrical concentration (Cg)

The geometric concentration is defined as the ratio between collector area (S) of the concentrator obtained by orthogonal projection of the pupil surface on a perpendicular plane to the incident radiation and surface receptor (s) of the converter [26]. To determine the equation of the geometric concentration factor, we proceed as follows: Consider a paraboloid which approaches the stigmatism (small diameter of the paraboloid and low angle of incidence [27]), in I point, it receives a conical light beam of angle ε (fig.12).

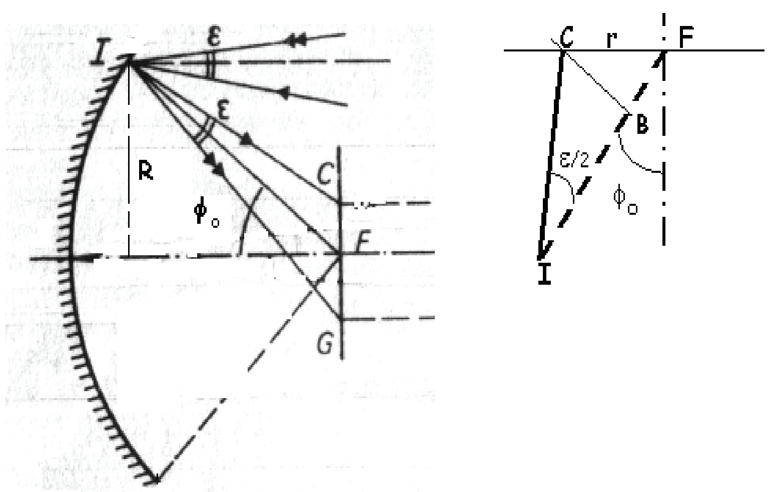


Fig. 12. Image of a solar beam on the focal plane[21].

As defined, the expression of the geometric concentration factor is presented in the following form:

$$C_g = \frac{S}{s} = \frac{\pi R^2}{\pi r^2} \quad (14)$$

When we replace (r) and (R) by their expression in equation (14), we find:

$$C_g = \frac{\sin^2(2\varphi_o)}{4tg^2(\varepsilon/2)}(1+tg(\varphi_0)tg(\frac{\varepsilon}{2}))^2 \quad (15)$$

b. Effective geometrical concentration (Cge)

The effective geometrical concentration (Cge) is the ratio between the surface of pupil (So) and the absorbing surface (so) [5]. In the case of a pointed concentrator with a flat absorber, the effective geometric concentration is equal to the geometric (Cg = Cge).

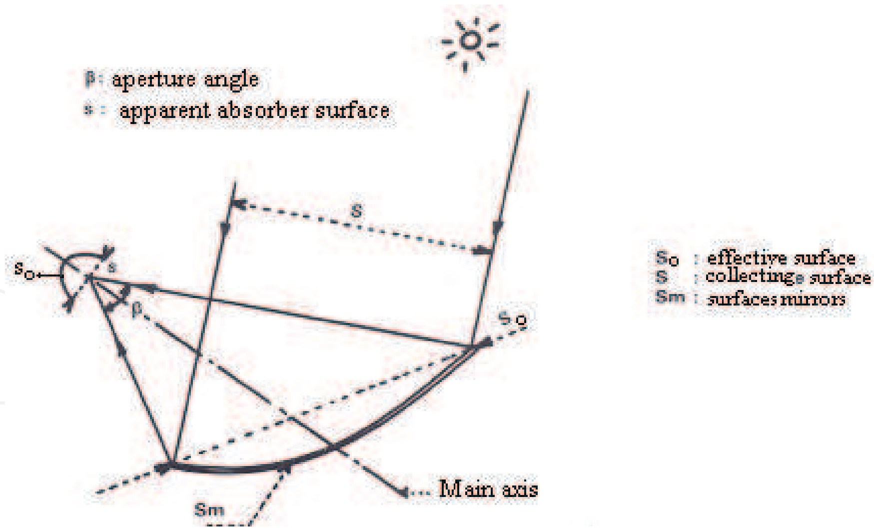


Fig. 12′. Diagram of a mirror concentrator

3.4.2 Heat balance of a concentrator

The heat balance of a solar concentrator in permanent pattern is the following:

$$Pa = Pu + Pe \quad (16)$$

The power of absorbed radiation can be calculated by:

$$Pa = ECgs\rho\gamma\tau\alpha \quad (17)$$

The coefficient of interception is given by the following equation [28,29]:

$$\gamma = 1\text{-}\exp\left[-820\left(0{,}7\frac{r}{f}\right)^2(1+\cos(\varphi_o))\right] \quad (18)$$

If we consider that on the level of the absorber we have only one transfer of energy without phase change, the useful power [30] will be:

$$Pu = qc(T_S\text{-}T_e) \quad (19)$$

The heat losses of the converter are given by:

$$Pe = Cps(T_{moy}\text{-}T_a) \quad (20)$$

The average temperature T_{moy} of the absorber is expressed according to the exit and inlet temperatures of the coolant and the temperature gradient heat transfer between the absorbing surface and the coolant ΔT. This is given by the following expression:

$$T_{moy} = \frac{T_s + \frac{T_s + T_e}{2}}{2} + \Delta T \quad (21)$$

Substituting Pa, Pu and Pe in equation (22) by their expressions, we find:

$$ECgs\rho\tau\alpha\gamma = q_c c_c(T_S\text{-}T_e) + Cps(0{,}25(3Ts+Te)+\Delta T\text{-}T_a) \quad (22)$$

The instantaneous global efficiency of the concentrator η_g is determined by:

$$\eta_g = \frac{P_u}{C_g s E} \quad (23)$$

By replacing P_u by $EC_g s\rho\tau\alpha\gamma$ - $Cp(T_{moy}-T_a)s$ in equation (23), we obtained:

$$\eta_g = \alpha\rho\tau\gamma - Cp\,\frac{(T_{moy} - T_a)}{C_g E} \quad (24)$$

We note here, that when the geometric concentration is higher, the instantaneous global efficiency is better. The instantaneous internal efficiency η_i of the concentrator is:

$$\eta_i = \frac{P_u}{P_a} \quad (25)$$

After replacement of Pu and Pa by their expression we obtained:

$$\eta_i = 1 - Cp\,\frac{(T_{moy} - T_a)}{EC_g\rho\alpha\tau\gamma} \quad (26)$$

a. Conductance of the thermal losses [23,30,31]

The thermal losses are located for a concentrator on the level of the absorber. These losses are by convection and radiation on the illuminated face and by conduction on the no enlightened face. The conductance of the thermal losses is given by the following equation:

$$Cp = hr + hcv + har \quad (27)$$

b. Exchange coefficient by conduction

The coefficient of exchange by conduction is given by:

Absorber cavity shape

$$h_{ar} = \frac{s_0\,\lambda_{ar}\,(T_{moy} - T_{ar})}{s\,e\,(T_{moy} - T_a)} \quad (28)$$

Absorber plane shape

$$h_{ar} = \frac{\lambda_{ar}\,(T_{moy} - T_{ar})}{e\,(T_{moy} - T_a)} \quad (29)$$

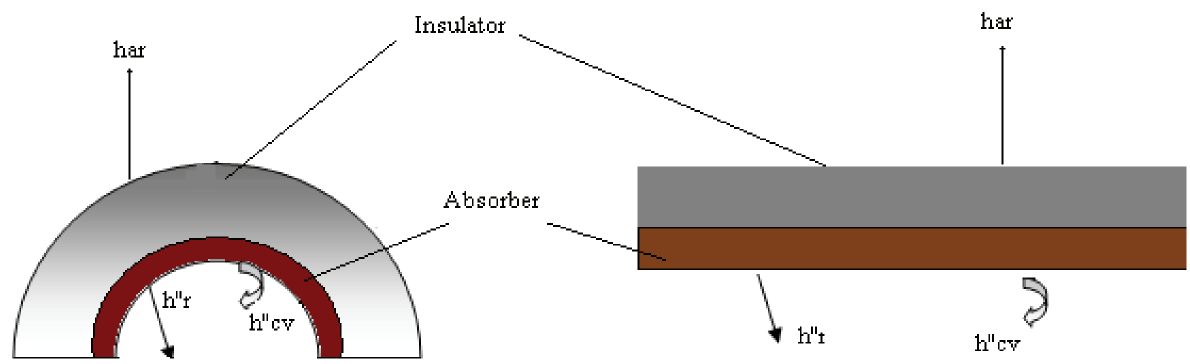
c. Exchange coefficients by radiation and convection

The exchange coefficients by radiation and convection are given following the case where the absorbing surface is protected or not.

Unprotected absorbent surface on the enlightened face. (fig. 13)

The following diagram shows the case of an unprotected absorber.
In this case, the coefficient of exchange by radiation is given by the following expression for the two shapes of the absorber:

$$h_r'' = \varepsilon_a\,\sigma\,\frac{(T_{moy}^4 - T_v^4)}{(T_{moy} - T_a)} \quad (30)$$



a / cavity shape b / plane shape

Fig. 13. Unprotected absorber.

For an absorbing surface with $100 < T_{moy} < 500°C$, the exchange coefficient by convection is given by:

Absorber cavity shape

for $0 < V < 4$ m/s

$$h''_{cv} = 7{,}5 + 4V \quad (31)$$

for $4 \le V < 40$ m/s

$$h''_{cv} = 7{,}3V^{0{,}8} \quad (32)$$

Absorber plane shape

for $0 < V < 4$ m/s

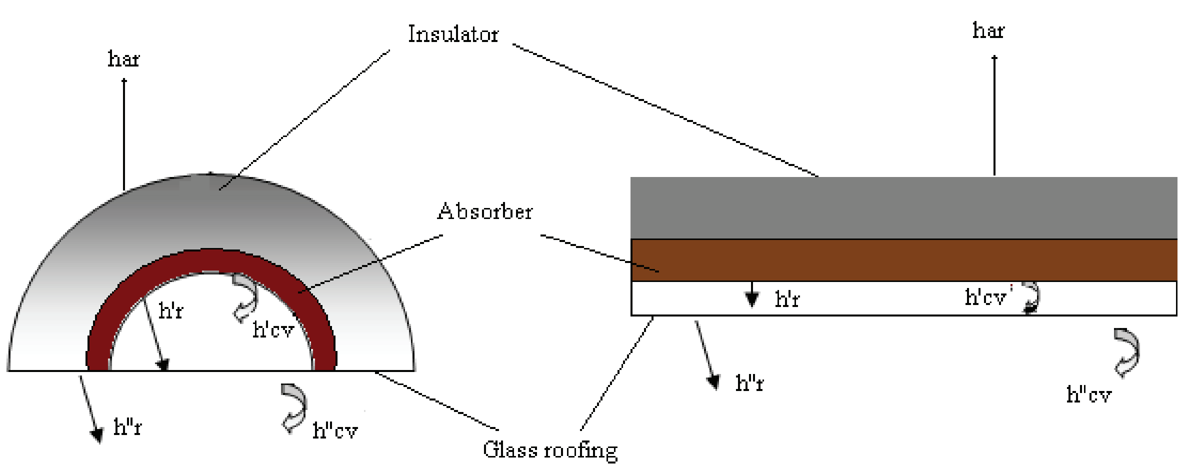
$$h''_{cv} = 2{,}2(T_{moy} - T_a)^{0{,}25} + 4V \quad (33)$$

for $4 \le V < 40$ m/s

$$h''_{cv} = 7{,}5V^{0{,}8} \quad (34)$$

Protected absorbing surface : greenhouse effect- (figure 14)

In this case, we have partial conductances presented in the following diagram:



a / cavity shape b / plane shape

Fig. 14. Protected absorber (greenhouse effect).

The expressions which give these conductances are the following ones:

Absorber cavity shape

$$h'_r = \varepsilon_{ac}\, \sigma \frac{(T^4_{moy} - T^4_{cmoy})}{(T_{moy} - T_{cmoy})} \quad (35)$$

With

$$\varepsilon_{ac} = \frac{1}{\frac{1}{\varepsilon_a} + \frac{1}{\varepsilon_c} - 1}$$

$$h'cv = 3{,}30\ W/m^2°C \quad (36)$$

$$h''_r = \frac{\varepsilon_a\, \sigma\, (T^4_{cmoy} - T^4_v)}{(T_{cmoy} - T_a)} \quad (37)$$

$$h''cv = 7{,}5 + 4V \quad (38)$$

for $0 < V < 4$ m/s

or

$$h''cv = 7{,}3V^{0{,}8} \quad (39)$$

for $4 \leq V < 40$ m/s

Absorber plane shape

$$h'_r = \varepsilon_{ac} \sigma \frac{(T^4_{moy} - T^4_{cmoy})}{T_{moy} - T_{cmoy}} \quad (40)$$

$$h'cv = 1{,}1\,(T_{moy} - T_{cmoy}) \quad (41)$$

$$h''_r = \varepsilon_a\, \sigma \frac{(T^4_{cmoy} - T^4_v)}{(T_{cmoy} - T_a)} \quad (42)$$

$$h''_{cv} = 2{,}2\,(T_{moy} - T_a)^{0{,}25} + 4V \quad (43)$$

For $0 < V < 4$ m/s

or

$$h''_{cv} = 7{,}5\, V^{0{,}8} \quad (44)$$

For $4 \leq V < 40$ m/s

The expression of the resulting coefficient of exchange for the front face is given by:

$$hr + hcv = \frac{1}{\frac{1}{h'r + h'cv} + \frac{1}{h''r + h''cv}} \quad (45)$$

3.4.3 Example

The thermal conversion of solar energy by means of solar concentrators makes it possible to reach high temperatures able to boil the salted water with pressures higher or equal to the atmospheric one. In order to test these concentrators in the brackish water desalination field, Chaouachi and al. have designed, dimensioned and built in their laboratory a small solar desalination unit equipped with a paraboloid concentrator.

The experimental device shown in Fig. 1, is composed of a solar parabolic collector type. The support of the parabolic concentrator is made of molded fiberglass with 1.8 m in dish aperture diameter. This dish surface was covered with rectangular stainless steel sheet segments with a thickness of 1 mm [32,33]. The obtained reflecting surface presents some imperfections due to the imperfect attachment of the sheets to the mother dish. The absorber is mounted at its focus, which is shaped like a cylindrical vase, with a receiving surface of 0.013 m2 and a geometric concentration of 195. This absorber is completely insulated except the part lit by the solar rays reflected by the parabolic surface. The sun tracking mechanism for this solar distiller has two axes according to previous research [8,9] and it is a manual system. The brackish water supply to the absorber is kept continuous in order to keep a constant volume of water in the absorber. The steam produced passes in a coil condenser where it is condensed. The cooling water circulates with counter flow in the shell and with a salt water flow of 40 L/h. Condensation is made inside the horizontal copper tubes and it is out of film. In the same way, it works at the atmospheric pressure and it is followed by a stage of under-cooling.

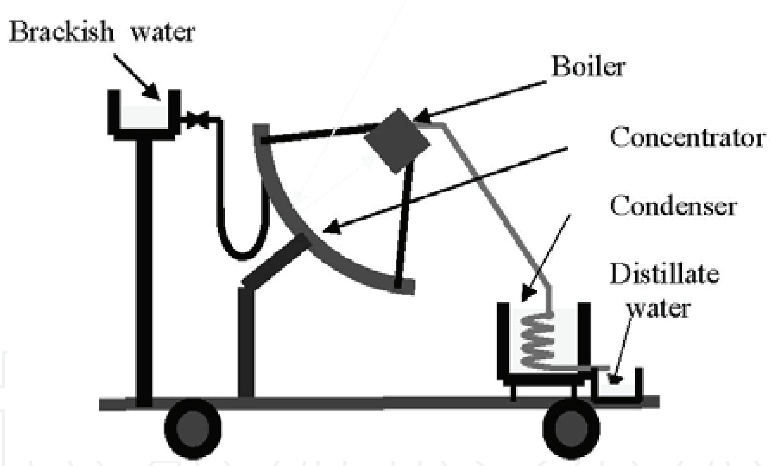


Fig. 15. Experimental device.

The capacity of production can reach 4,5 l/m^2.day.

4. Conclusion

The lack of drinking water, exhaustion and the high cost of energy and pollution problem, encourage us to find appropriate solutions to meet these challenges. The desalination of brackish or sea water using renewable energy such as solar energy represents a promising way. Future research in this area is oriented toward the maximum utilization of solar energy, which is free and clean, or through technological innovation and/or improvements on conventional desalination processes.

Nomenclature

Capital letters :

Cp	Apparent conductance of heat loss (W/m²°C).
D	Day of the month
La	Latitude (degree).
Lo	Longitude (degree).
M	Number of months
P	Vapour pressure (Pa)
Pa	Incident power of absorbed radiation (W/m²)
Pe	Power of heat loss (W/m²)
Pu	Useful power (W)
R	Radius of the pupil surface (m)
S	Collecting area (m²)
T	Temperature (K)
TU	Universal Time (h)
V	Wind speed (m/s)

Small letters:

a	Aperture diameter of the paraboloid (m).
c	The specific heat (J/kg°C).
e	Thickness of the insulation on the back of the absorbers (m).
f	Focal or friction factor.
h	Exchange coefficient (W/m²°C).
h′	Internal heat transfer coefficient (W/m²°C).
h′′	External heat transfer coefficient (W/m²°C).
qc	Mass flow of coolant (kg/s).
R	Radius of the absorber or correction of the earth-sun distance (m).
so	Surface receptor (m²).
s	Collecting surface (m²)
z	Altitude (km).

Greek letters

ϕo	Aperture Half angle of the paraboloid (degree).
α	Absorption coefficient of the absorber (%).
ε	The angle of a conical light beam (degree).
εa	Emissivity of the absorber (%).
εc	Emissivity of the cover (%).
εac	Apparent emissivity of the system (%).
λ	Thermal Conductivity (W/m°C).
ρ	Reflection coefficient of the paraboloid (%).
σ	STEFAN-BOLTZMANN constant.
τ	Transmittivity of the cover (%).
ω	Hour Angle (degree).

Indices :

a	Absorber or ambient.
ar	Rear wall insulation.

cmoy	Average cover.
moy	Average absorber
cv	Convection
r	Radiation.
s	Fluid outlet of the concentrator.
v	Steam or vault surrounding.

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The book comprises 14 chapters covering all the issues related to water desalination. These chapters emphasize the relationship between problems encountered with the use of feed water, the processes developed to address them, the operation of the required plants and solutions actually implemented. This compendium will assist designers, engineers and investigators to select the process and plant configuration that are most appropriate for the particular feed water to be used, for the geographic region considered, as well as for the characteristics required of the treated water produced. This survey offers a comprehensive, hierarchical and logical assessment of the entire desalination industry. It starts with the worldwide scarcity of water and energy, continues with the thermal - and membrane-based processes and, finally, presents the design and operation of large and small desalination plants. As such, it covers all the scientific, technological and economical aspects of this critical industry, not disregarding its environmental and social points of view. One of InTech's books has received widespread praise across a number of key publications. Desalination, Trends and Technologies (Ed. Schorr, M. 2011) has been reviewed in Corrosion Engineering, Science & Technology – the official magazine for the Institute of Materials, Minerals & Mining, and Taylor & Francis's Desalination Publications. Praised for its “multi-faceted content [which] contributes to enrich it,” and described as “an essential companion...[that] enables the reader to gain a deeper understanding of the desalination industry,” this book is testament to the quality improvements we have been striving towards over the last twelve months.

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