Realization and Study of Desalination Prototype Assisted by Solar Energy

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Abstract: *Southern Morocco is considered a water-scarce area, with many cities having limited access to water. Water quality is an additional stress affecting the available water supply. In these semi-arid to arid regions of our country, there is a significant saline load in groundwater. The treatment of these water sources at potable levels requires desalination. The desalinization of water by solar energy seems to be the most appropriate technical means to solve the global problem of the shortage of fresh water in the arid and sub-Saharan zones. This technique will provide a new source of irrigation and supply, particularly in those countries far from the ocean and experiencing significant water stress. This work presents the preliminary results of an autonomous prototype of desalination assisted by solar energy. This article aims to realize and study an autonomous prototype of small-scale desalination and subsequently the feasibility and development of another prototype of large-scale solar desalination. Finally, the preliminary results obtained by this prototype are encouraging and will allow us to consider a large-scale prototype that can be compared to technologies based on other sources of energy, from a point of view, cost range, expected and actual production of supply water.*

1 INTRODUCTION

Access to drinking water is one of the major issues of the coming decades. Research on desalination technologies with high energy efficiency must therefore be particularly active.

ation in isolated site.

The development of an economically viable autonomous water desalination system using solar energy to produce distilled water and irrigation water for such areas is central to this study. Large areas of southern Morocco depend strongly on drilling water or wells. In many rural and agricultural areas, access to well water has a constraint is that the water has a high salt concentration.

However, many rural areas in southern Morocco that don't have reliable access to drinking water are located in geographical areas where annual levels of solar radiation are high and groundwater saline is available. Current saltwater treatment technologies consume a lot of energy. Solar distillation is one of the technologies that does not require electricity for the production of desalinated water. This article aims to realize and study an autonomous prototype of small-scale desalination and subsequently the

This paper presents a autonomous prototype desalination simultaneously producing desalinated water and concentrated brine that can be used to produce Lithium for the drums. The electrical energy is provided by photovoltaic panels, which gives our system a permanent autonomy for the possibility of implant

development of another prototype of large-scale solar desalination, thereafter, to study the feasibility and profitability of the substitution of the fuel energy used in desalination plants by renewable energy.

2 DESALINATION PROCESS

The conventional desalination process requires large amounts of energy, either in the form of waste heat or in the form of grid electricity. Conventional electricity sources in the network are not available in many rural areas in these areas. However, many communities in southern Morocco that do not have reliable access to drinking water are located in geographical areas where annual levels of solar radiation are high and groundwater saline is available.

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The development and optimization of solar distillation designs had to meet the objectives of our study, from viewpoints, durability and performance while providing sufficient volumes of unpolluted water.

3 WATER POTENTIAL IN SOUTHERN MOROCCO

The Sahara Basin has the lowest mobilized renewable resources, with a total of 19 Mm^3 (25Mm^3 taking into account unconventional resources). Renewable resources are mainly groundwater (68%). (Agoussine, 2003).
The water potential of the Sahara Basin is well below the scarcity threshold with 161 m^3 per inhabitant per year.

3.1 Surface Waters

The average annual surface waters amounts from 50 to 60 Mm^3 per year, an average of 115 m^3 per inhabitant, a level well below the national average of 604 m^3 per inhabitant. The mobilized surface waters are entirely resources regularized by the dams and amount to 2 Mm^3, (Agoussine, 2004).

3.2 Groundwater

The most important aquifers in the Sahara basin are the Foum El Oued water table, the deep Paleogene aquifer and the deep Lower Cretaceous aquifer.
The deep water table of the lower Cretaceous is the most important in the basin by its extension. Its geology and power have allowed the constitution of a considerable underground water reserve at the basin level. The deposit consisting of whitish sands and red sandy clays has large variations in depth, lithology, productivity and quality. The underground potential of this aquifer amounts to 13 Mm^3, (Jellali, 1995).

4 THE QUALITY OF WATER RESOURCES

4.1 Surface Water and Drilling

The quality of the drilling water and boreholes are generally average with a salinity that varies between 2 and 3g/L in the center of the basin. However, this salinity is variable in the basin, the water is brackish towards outcrops to the east (3 to 5g/L) and becomes even more salty towards the west to reach high salinities in the region of Akhfenir-Dcheira, Lamsid (up to 30g/L), (Agoussine, 2004).

4.2 Groundwater Quality

The deep water table of Paleogene covers an area of 50000 km^2. The productivity of boreholes that capture the aquifer varies between 5 and 40 L/s, water quality is acceptable in the south (2 to 3g/L) in the region of Dakhla, Bir Gandouz and bad in the north (6 to 10 g/L), (Jellali, 1995),(Agoussine, 2004).
Renewable water resources remain constant as demand for water increases. In southern Morocco, a large percentage of those without access to drinking water live in rural and semi-arid areas. The scarcity of water is, however, exacerbated by the poor water quality of surface and groundwater resources.
Many southern communities that don't have reliable access to water are located in areas where groundwater has a significant salt load, (Table 1). These geographical areas have high levels of annual solar radiation.

Table 1: Groundwater and brackish water potential in southern Morocco, (Jellali, 1995).

Nappes	Potential in Mm^3
Tarfaya	10
Foum El Oued	4
Cretaceous inf and sup of Sahara	13
Moyenne vally Daraa	60
TOTAL	87

5 DEGREE OF SALINITY

Salinity refers to the total of non-toxic inorganic compounds dissolved in water, measured by total dissolved solids (TDS) and electrical conductivity (Ce). Electrical conductivity is measured in mS / cm and is related to TDS. TDS is defined as all compounds dissolved in water that carries an electrical charge.
Salinity is mainly reflected by the atoms: Na, Ca, Mg, SO_4, Cl and K. Humans tolerate moderate salinity (SDT)<1g/L. At MDT levels above 3g/L, fatal intestinal and kidney damage may occur. The high salt content also has a negative aesthetic effect on drinking water (bad taste).

Table 2: Degree of salinity in underground and brackish water in southern Morocco, (Jellali, 1995).

TABLECLOTHS	SALINITY (g/L)
Tarfaya	3,5
Foum El Oued	3 á 8
Cretaceous inf and sup of the sahara)	2 á 3
Moyen Vally Daraa	0,5 á 16

The treatment of salinity, groundwater and brackish water at potable levels requires desalination. Two main groups of desalination technologies exist: thermal technologies and membrane technologies reverse osmosis. The conventional desalination process requires large amounts of energy, either in the form of waste heat or in the form of grid electricity. Conventional electricity sources in the network are not available in many areas of southern Morocco.

6 POTENTIALITY IN TERMS OF SUNSHINE RATE

Most of the southern regions of Morocco average more than 6500 hours of sunshine a year, and average solar radiation levels are between 4,7 and 5,5 kWh/m^2 in one day, (Ministry in charge of the environment, 1998).
Solar energy can be used to provide the energy needed for a desalination process in the form of thermal energy or electricity.

7 DEVELOPMENT OF THE PROTOTYPE

Solar desalination systems require adaptation to local conditions such as water demand, groundwater quality, ambient conditions, and access to maintenance equipment. The design had to be robust to withstand outdoor use, with minimal supervision and maintenance and a maximum volume of desalinated water. Since the system is intended for remote rural areas, only solar energy would be used without any external electrical requirements for the components.
The proposed prototype will be based on solar-assisted desalination, this implies an increase in the temperature in the groundwater due to the solar energy absorbed in the solar panels and a subsequent heat transfer to the groundwater in the evaporation tank. In turn the heated water evaporates at the air-water interface which increases the humidity of the air, the humid air is cooled to condense in clean water, in other words desalinated.

The design shown in this work is a new configuration for a small-scale modular solar desalination system adapted to local conditions in the southern regions of Morocco. Energy autonomy is the main feature of this prototype that uses desalination technology.
The pumping process powered by photovoltaic cells and the distillation process powered by solar thermal panels. To achieve these objectives, a solar desalination technique has been developed. The design therefore represents a new configuration for a small scale modular solar desalination system adapted to local conditions in the southern regions of Morocco.

7.1 Presentation of the Prototype

The solar field will consist of approximately 10m2 of flat solar photovoltaic panels producing 2KWc/day, necessary to supply all the pumping processes and for the compressor and two flat thermal solar panels to heat the saline water. With a power of about 110Wc per panel.

The solar panels were assembled in a north-facing array tilted at 20 degrees to compensate for the ecliptic's tilt. This will ensure that the solar radiation input angle will be perpendicular in summer and will be optimal on solar panels for most of the year to ensure maximum radiation transfer into the system. Figure 1.

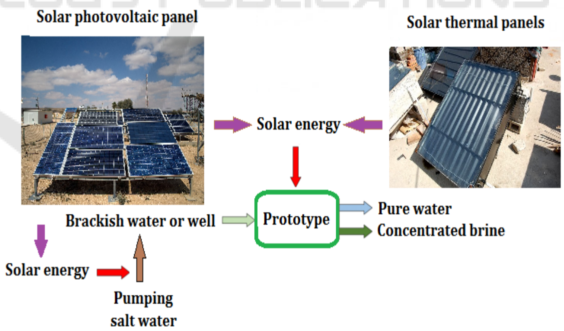

Figure 1: Diagram of the prototype.

The design of the prototype is in the form of a cylindrical tank volume 10l, with several funnels. The saline pumped from the well enters the evaporation tank at room temperature and will be heated by the PV panel fluid flowing through the copper coils inside the evaporation tank.
The heat exchanged at the saline water will heat the water between 70 °C and 88 °C during the winter, causing evaporation and the formation of steam. Figure 2.

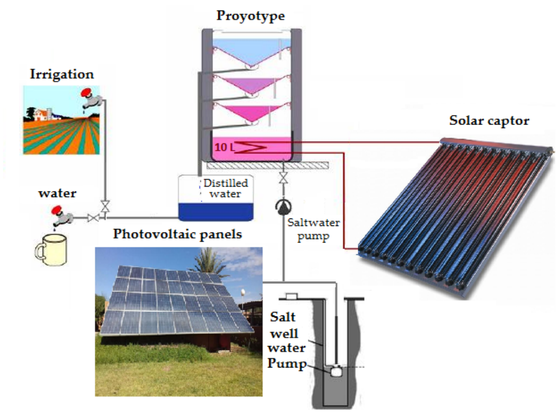

Figure 2: Diagram of the assembly of the prototype.

This laboratory scale prototype (see figure 3).exploits both heat and light emitted by the sun to produce an average of 1,5l per 5 hours of fresh water in winter.

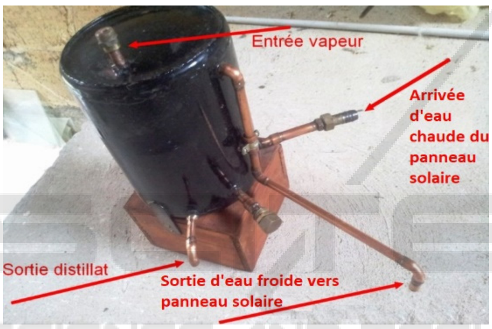

Figure 3: Real prototype.

7.2 Parameters Affecting the Prototype Output

The productivity of this solar desalination prototype will be affected by the ambient operating conditions. These include ambient temperature, solar insolation, wind speed and panel cooling temperature, well water depth, solar panel orientation, and supply water temperature.

8 MICROCLIMATE STUDY METHODOLOGY

The solar desalination prototype is installed in winter at the Guelmim High School of Outdoor Technology. The experimental setup will include:

- The solar desalination prototype (evaporation tank with funnels, condensation part, PV panels, 12V circulation pumps);
- PT100 temperature probes for different operating points of the prototype (evaporation tank, condensation zone, photovoltaic panels, sun and shade) with a data logger set to measurements at 1 minute intervals;
- A weather station that is available at school for ambient measurements at a recording interval of 5 minutes.

The temperature profile as well as the ambient conditions (sun and shade temperature, wind speed, wind direction, wind chill temperature and precipitation) were recorded for a typical winter study month and took the average.

The data recorded by the weather station located at the following GPS coordinates: (29°00'07.1"N10°05'00.3"W)/(29.001981,-10.083422) were downloaded during the month of November and stored in Excel format, so that we can identify them with well water desalinated by the prototype. Conductivity and pH measurements were also recorded all day for one month.

9 RESULTS AND DISCUSSION

Figure4, shows the average temperature measurements of a winter month in ambient conditions throughout the day. This curve shows that the average solar temperature reaches a maximum of 32°C around 15:00.

The average cooling temperatures of the panels were slightly higher than the temperature of the sun (sensor exposed directly to solar radiation) before the first half-days of midnight at 14:24 min and lower after 15:00.

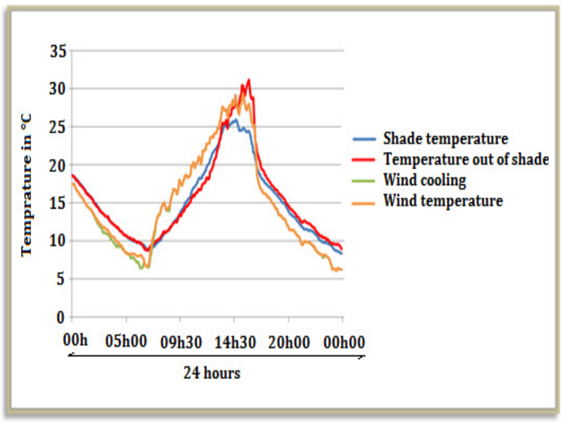

Figure 4: The average per day during the temperature measurements of the month of November.

Figure 5 shows the average gust and wind velocity measurements for a winter study month in ambient conditions throughout the day. This curve shows that the average wind speed is about 3.5Km/h/day. The wind tornado profiles show fluctuations throughout the day, this may influence the performance of the panels and consequently the volumes of the distillates obtained.

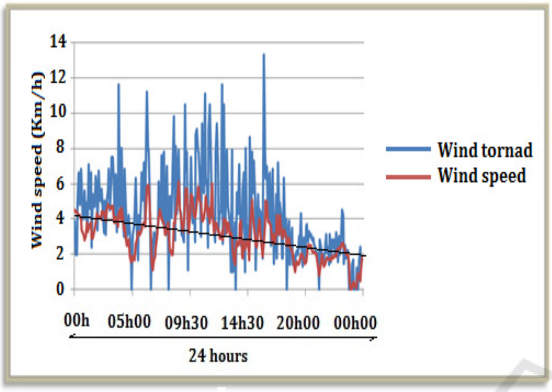

Figure 5: Velocity profile for 24 hours.(The average wind speeds during the month of November).

Figure 6 represents the average temperature profiles of a month of study, for different points of operation of the prototype for a day, measured by PT100 temperature probes, at the levels of (solar panels, sensor measures solar radiation, temperature shade, evaporation tank, condensation tank).

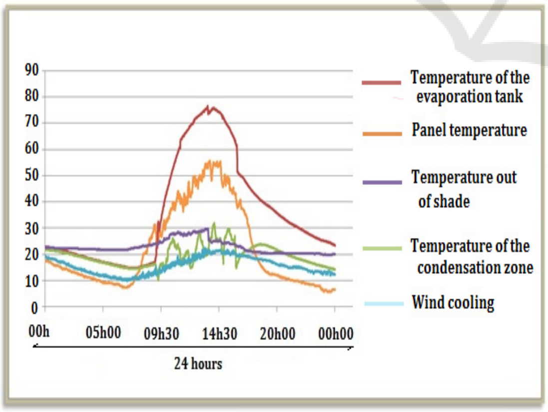

Figure 6: Temperature profile measured at different points of the prototype for 24 hours. (Average temperature of the month of November).

There is a good correlation between the highest average temperatures in the evaporation reservoir and those of the average ambient temperatures measured by the weather station.

The average temperatures in the evaporation tank reach 60°C between 12h00 and 15h30 correspond to the average ambient temperature between 20 and 30°C. It has also been noted that the average temperature in the evaporation vessel is delayed compared to the average temperature of the panels until 09:30, after which it increases steadily up to a maximum temperature around 70°C to 80°C, between 13:30 and 14:00.

The initial warm-up period (up to 09:00) is necessary for the equilibrium conditions to be reached in the solar panels before the circulation pumps are automatically activated by a microcontroller.

The warm-up time required to heat the salt water is relatively short with temperatures rising to 30°C in 15 minutes and 60°C in 120 minutes after activation of the circulation pumps by the microcontroller.

We also note that when the circulation pumps stopped around 15:30, the temperature of solar panels decreases regularly which causes the significant drop in temperature in the evaporation tank. Some temperature drops observed in the evaporation vessel correspond to an increase in wind speed and a decrease in ambient temperature.

The initial volumes of distillate produced will also be low since most of the heat required for evaporation is taken from the water itself. To maintain the temperature of the water, heat must be provided. In order for the molecules of a liquid to evaporate, they must be located near the surface and have sufficient kinetic energy to overcome the intermolecular forces in the liquid phase.

Only a small proportion of the molecules meet these criteria, so that the rate of evaporation is limited. Since the kinetic energy of a molecule is proportional to its temperature, evaporation occurs more rapidly at higher temperatures. As rapidly moving molecules escape, the remaining molecules have lower average kinetic energy and the temperature of the liquid decreases. Energy is used to break bonds that hold water molecules, which is why water evaporates easily at the boiling point at 100°C, but evaporates much more slowly at the freezing point.

Net evaporation occurs when the rate of evaporation exceeds the rate of condensation. The average flow rates of distillates vary between 3 ml/min and 6ml/min reached between 12:00 and 15:30, until 16:00, from 16:00 there is a sharp decline in the production rate, figure 7.

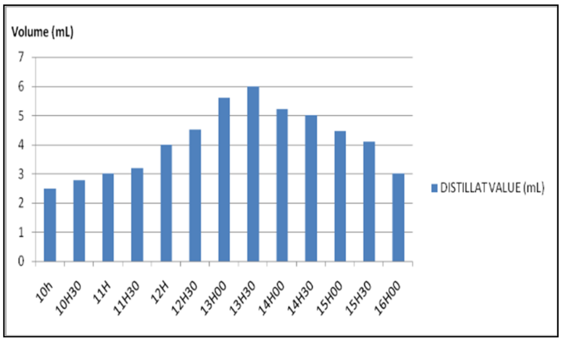

Figure 7: Maximum volume of distillate recovered between 10:00 and 16:00.

Although the following study is taken from well water, average electrical conductivity (eCm) was measured for a few days in November, the latter decreasing daily from 0.33 mS/cm to 0.04 mS/cm during the day, the best quality being produced at the end of the afternoon. The PH also drops almost every day between 11:00 and 15:30 from 8 to 6.4.

10 CONCLUSION

According to this preliminary study of the prototype presented, it has been found that there is a good correlation between the highest temperatures in the evaporation tank and those of the ambient temperatures measured by the meteorological station. The initial volumes of distillate produced will be small because most of the heat required for evaporation is taken from the water itself. This prototype produces an average of 1,5 liters/day of desalinated water in winter, or 45 liters/month using 300 liters of salt water. Based on encouraging preliminary results showing satisfactory drinking water production ratios, there are many opportunities to improve the efficiency of our prototype.
This future combination will allow us to increase the volume of treated saltwater by studying a large-scale prototype, the latter can be compared to technologies based on other sources of energy, from the point of view, range of expected costs and actual production of supply water and this while minimizing the amount of brine produced.

REFERENCES

M. Agoussine, "The various aspects of hydrology in arid and semi-arid regions - the case of south-east Morocco"; Earth & Life, Rabat, p.70, 2003.

Mr AGOUSSINE, Mr El Mehdi Saidi & Brahim IGMOULLAN, «Recognition of the water resources of the Ouarzazate basin (South-East Morocco)»; Bulletin of the Scientific Institute, Rabat, Earth Sciences Section, No. 26, 81-92, 2004.

Mr. JELLALI, "Development of water resources in Morocco"; Directorate General of Hydraulics, Ministry of Public Works, 1995.

Mr. Agoussine, L. Bouchaou, "The major problems of water management in Morocco. Drought ", p.2, p.15, pp.187-194, 2004.

Water and Climate Change in the Maghreb" book produced under the UNDPFEM project RAB 94G31: Ministry in charge of the environment-Morocco, P. 45, 1998.