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Etude de la performance d'un distillateur solaire à cascade

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Résumé

La consommation d'eau douce ne cesse d'augmenter à travers le monde. Selon les estimations des Nations Unies, la demande excédera l'offre de 40% d'ici 2030. La croissance démographique dans le monde, les changements climatiques et la pollution de l'environnement ne sont que quelques facteurs responsables de l'augmentation constante de la pression qui s'exerce sur les réserves hydriques. La pénurie croissante de l'eau peut être réduite grâce à l'utilisation d'équipements de dessalement solaire, fournissant ainsi de l'eau potable pour la consommation humaine, l'évaporation et la condensation sont les principes de base de son fonctionnement. Ces systèmes peuvent être fabriqués avec des matériaux que l'on trouve facilement sur le marché local et ne nécessitent absolument aucun entretien ni aucun coût permanent. Les différents modèles des distillateurs solaires sont utilisés pour augmenter l'efficacité et la productivité du distillat. Notre étude consiste à une réalisation et une conception numérique d'un distillateur solaire à cascade, les résultats trouvés sont satisfaisants et meilleurs par rapport à un distillateur simple, nous avons observé une augmentation plus importante de la température de l'eau, passant de 25°C à 46°C sur la même période. De plus, nous avons constaté une humidité relative de l'air à l'intérieur de notre distillateur à cascade des variations significatives de l'humidité relative selon les axes x et z, mettant en évidence l'influence du changement de phase évaporation-condensation. Les résultats obtenus fournissent des informations précieuses pour la conception, l'optimisation et la mise en œuvre de distillateurs solaires, contribuant ainsi au développement de technologies durables de production d'eau potable.

Mots clés : eau, pollution, dessalement, distillateurs solaires, optimisation.

Study of the performance of a solar cascade distiller

Abstract

Consumption of fresh water continues to increase around the world. According to United Nations estimates, demand will exceed supply by 40% by 2030. Global population growth, climate change and environmental pollution are just a few factors responsible for the constant increase in the pressure exerted on water reserves. The increasing scarcity of water can be reduced through the use of solar desalination equipment, thereby providing potable water for human consumption; evaporation and condensation are the basic principles of its operation. These systems can be made with materials that are easily found in the local market and require absolutely no maintenance or ongoing costs. The different models of solar stills are used to increase the efficiency and productivity of the distillate. Our study consists of a realization and a digital design of a solar cascade distiller, the results found are satisfactory and better compared to a simple distiller, we observed a greater increase in the water temperature, going from 25 °C to 46°C over the same period. Additionally, we found significant variations in relative humidity along the x and z axes in the relative humidity of the air inside our cascade distiller, highlighting the influence of the evaporation-condensation phase change. . The results obtained provide valuable information for the design, optimization and implementation of solar stills, thus contributing to the development of sustainable technologies for the production of drinking water.

Key Words*:* water, pollution, desalination, solar stills, optimization.

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1-INTRODUCTION

Algeria is ranked among the 13 African countries which suffer the most from lack of water. (National Meteorological Office) [2] and also classified among the water-poor countries and very close to a crisis situation. [1]. The largest solar deposit in the Mediterranean basin is located locally in Algeria. The Mediterranean basin is afflicted with poor physical and hydro-climatic characteristics which make it difficult to use solar energy for uses such as desalination. Solar distillation of brackish water and seawater can provide potable water, especially in dry or semi-arid regions, on a household or even a small town scale. The city of Annaba is supplied mainly from two water transfer systems from the Cheffia and Mexa dams in the city of El Tarf, ensuring the needs of 84% of the population. The remaining 16% is supplied by independent systems. But the drop in the level of the Cheffia dam has significantly affected the food supply of part of the population of Annaba. The Cheffia dam with a capacity of 155 million m3 is currently 10% full and is intended to supply the great Annaba via the Chaiba treatment station (Sidi Amar), the Mexa and Bougous dams are respectively at a filling rate of 76% and 55%. [2].

In isolated places where sunlight is abundant and thanks to the use of solar desalination equipment, we can offer a simple and economical solution for producing clean water, this is the solar distiller, it is a still device that uses thermal energy from sunlight for water distillation based on evaporation and condensation phenomena. Solar energy is used to heat liquid water to evaporate it and produce steam then the steam is allowed to condense on an inclined glass lid. The condensate is then collected as drinking water. With this in mind, we present the creation and digital design of a solar cascade still. According to an analysis of the thermal behavior of the distiller, the production of distilled water depends on the incident solar energy, the absorbent surface, the ambient temperature and wind speed [2].

MATÉRIELS ET MÉTHODES

Solar still is an insulated, airtight basin containing brackish water and covered with a transparent material. The basin is usually made of galvanized iron sheet and the top cover is usually made of transparent glass or plastic. The glass lid is tilted and a drain pan is placed at the base of the tilted glass lid to collect the distillate. The operating principle of solar still is exactly the same as the hydrological cycle found in nature. The sun's rays falling on the transparent glass cover pass through it and strike the inner surface of the basin. The interior surface of the pool is blackened so as to absorb most of the radiation. The salt water contained in the pool heats up and begins to evaporate. The vapors begin to rise, leaving behind salt and impurities. When the steam reaches the inclined glass cover, it condenses on the inner surface of the glass and the condensed water flows by gravity into the collecting channel. Distilled water is then extracted from the system for direct use illustrate in the Fig.1 - [3].

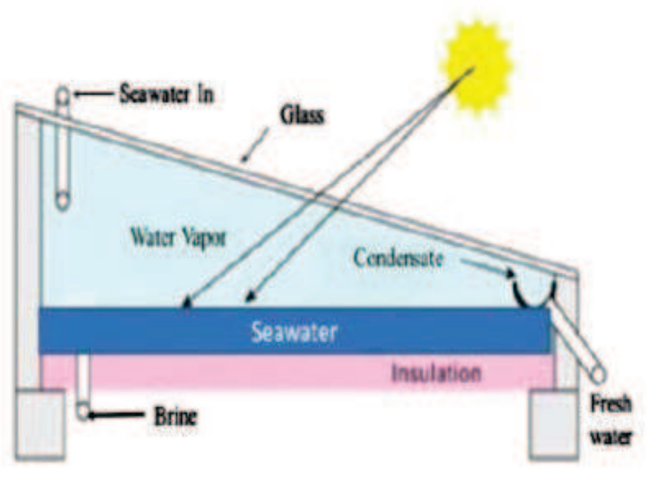

Fig. 1 - Principle operating of solar stills.

Parameters influencing the operation of a distiller

There are a lot of types of parameters influencing the solar still;

a)External parameters[4]**:**

• Geographic parameters:
- Longitude
- Latitude

Nawel. Nedjah et al.,/IJWSET -JISTEE, Vol. (viii), Issue 2, Decembe 2023, pp. 89-95

- The height of the sun
• Weather parameters:
- Wind speed: The convective effect on the face of the window plays an important role such that the speed intervenes in the convective exchange between the external face and the external environment.
- The intensity of solar radiation: This is the essential factor in this study. It is a radiant energy of short lengthwave (0.17 to 4 µm).
- Ambient temperature: The value of this temperature helps us determine the thermal exchanges between theexternal face and the external environment.
- Cloud intermittency: The amount of solar energy received by a surface depends on the nature of the sky, i.e. the passage of clouds reduces the average effective absorption.

b)Internal parameters [5]**:**

• Construction parameters:
- The cover: The glass cover must: transmit the maximum amount of solar radiation, opaque to infrared, non-hydrophobic, and it must resist attacks from wind and particles solid.
- The distance between the evaporation surface and the condensation surface: Studies have shown when the distance between the brine and the glass decreases, the performance of the distiller increases.
- Insulation of the distiller: Insulation is important to eliminate thermal losses (heat transfer with the outside environment).
- Level height of the water mass: The thickness of the water is very important in the solar distillation procedure; more than the thickness is low; more than the production is high.

• Position parameters:
- The orientation of the distiller: The orientation of the distiller depends on its operation during the day. Three operating modes can be determined depending on the time of day:
  - Operation throughout the day: South orientation.
  - Operation during the morning: East orientation.
  - Operation during the afternoon: West orientation
- The location of the distiller: The location is also linked to the geometric parameters and is taken into consideration the location; it must not contain any type of obstacle which would prevent solar radiation from reaching the collection surface.
- The inclination: It depends on the operation of the distiller during the year:

c) Brine parameters:

- The thickness of the brine to be distilled: This parameter plays an important role in production, when the thickness is low the production is high, if the thickness is large the distillation will be hard.
- Brine temperature: When the brine temperature increases, a white deposit is observed on the surface free from water due to the formation of insoluble carbonates in the brine.
- The quality of water which feeds the distiller: Research has shown when the concentration increases, the production of the distiller decreases.

d) Optical parameters:

- Emissivity
- Absorptivity
- Reflectivity
- Transitivity

e) Thermo-physical parameter:

- Thermal conductivity
- Specific heat
- Kinematic viscosity.
- Dynamic viscosity.

Operation of a solar cascade still (see the Fig. -2):

The principle of distillation is the same in all distillers but the shape of each distiller plays a very important role. The distillation system operates on two scientific principles: evaporation and condensation. The absorber in this system is a cascade, black-bottomed container, filled with seawater and topped with transparent glass. The amount of heat that comes from solar radiation is absorbed by the black material which will accelerate the rate of evaporation and because of the waterfall shape of the absorber the water heats up more quickly. The production is high when the mass of water evaporated is low. The condensed steam forms water droplets [4], [5].

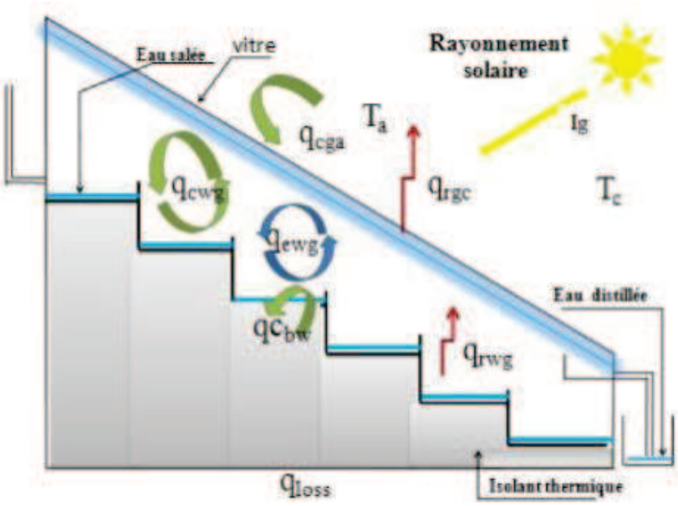

Fig. 2 - Principles operations of solar cascade still [5].

Digital design of a solar cascade still

This part of our work is devoted to the digital design of a solar cascade still using SolidWorks software. We describe the key stages of the design, starting with the creation of an accurate 3D model of the still. We will explore SolidWorks features used to integrate specific parameters, simulate thermal performance, and optimize the design. Numerical modeling will allow us to visualize and evaluate different configurations of the solar cascade still, providing a valuable guide for the realization of a physical prototype [6], [7]. The following Fig.3- describes the design by SolidWorks of solar cascade still:

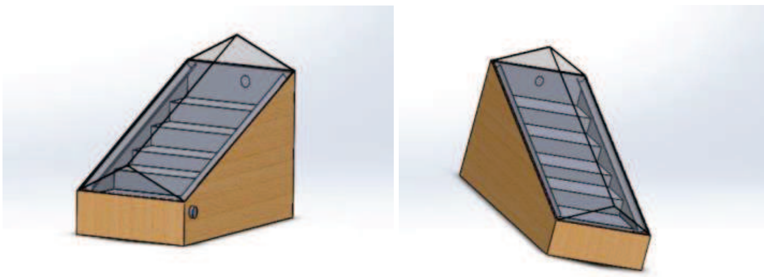

Fig.3- Solar cascade still

RÉSULTATS ET DISCUSSION

Mesh geometry

In our case, we chose a triangular geometry, because it offers better calculation results in terms of meshing. This meshing step makes it possible to divide the continuous medium into a finite number of elements, thus facilitating subsequent calculations, the following fig.4- describe the mesh geometry.

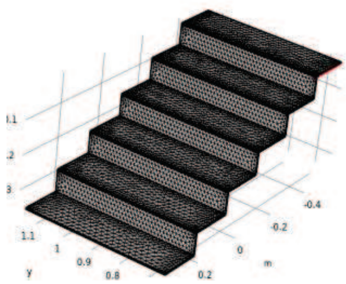

Fig.4- Mesh geometry

Temperature distribution

In the case of the solar cascade still, the simulations revealed a variation in water and air temperature inside the system over a period of 12 hours. During this period, the water temperature gradually increased from 25°C to 46°C.

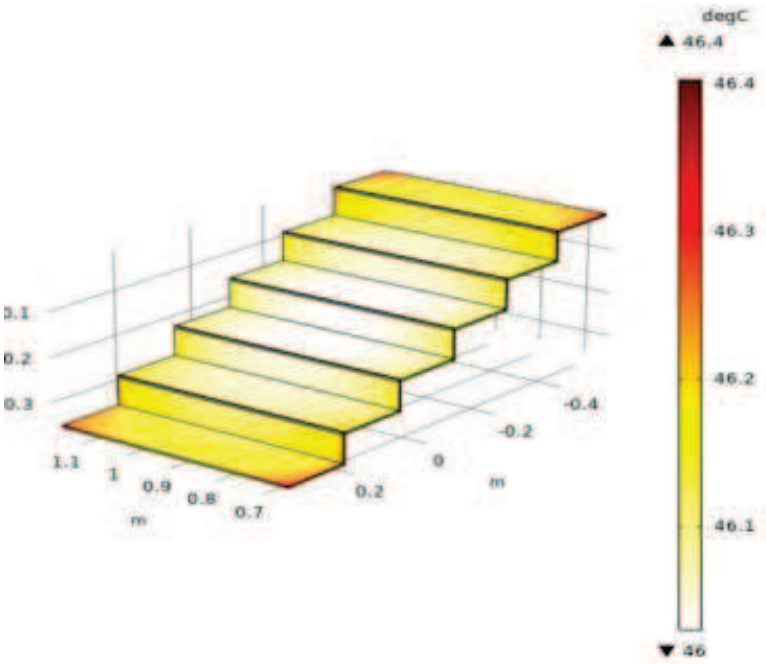

Fig.5- Water temperature distribution(3D OUTLINES)

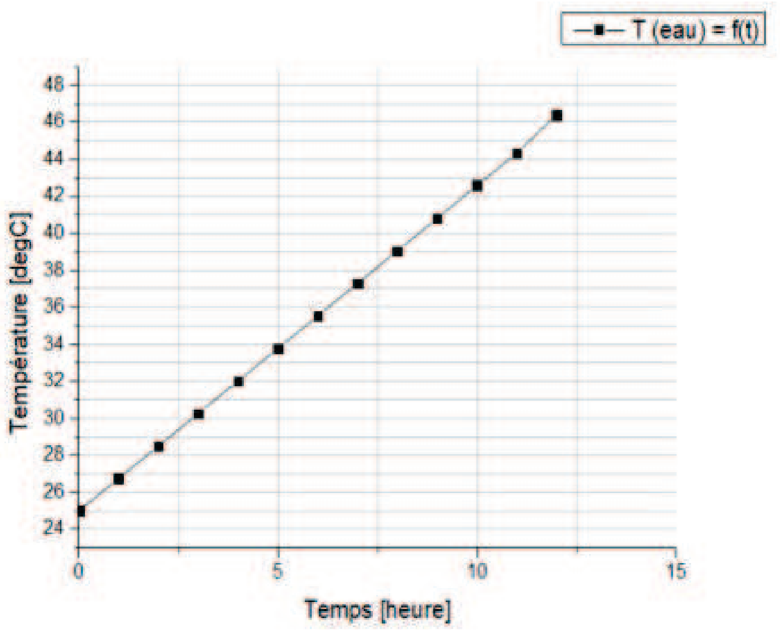

Fig.6- Evolution of water temperature as a function of time

The rise in water temperature is the result of successive exposure to the different heat capture zones of the cascade distiller. Each stage of the distiller helps increase the temperature of the water as it flows through the system. This gradual increase in temperature promotes water evaporation and the production of water vapor at higher temperatures, which is essential for distillation.

Air temperature distribution

Concerning the air inside the distiller, we also observed a significant temperature variation (figure 0 10 a, b and c). The air temperature also varies from 24°C to 47°C during the 12 hours of simulation.

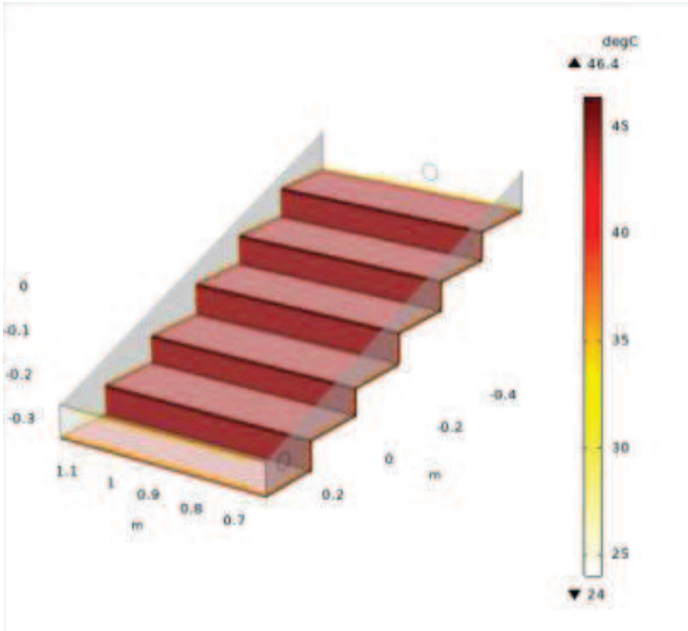

Fig.7- Air temperature distribution inside the distiller

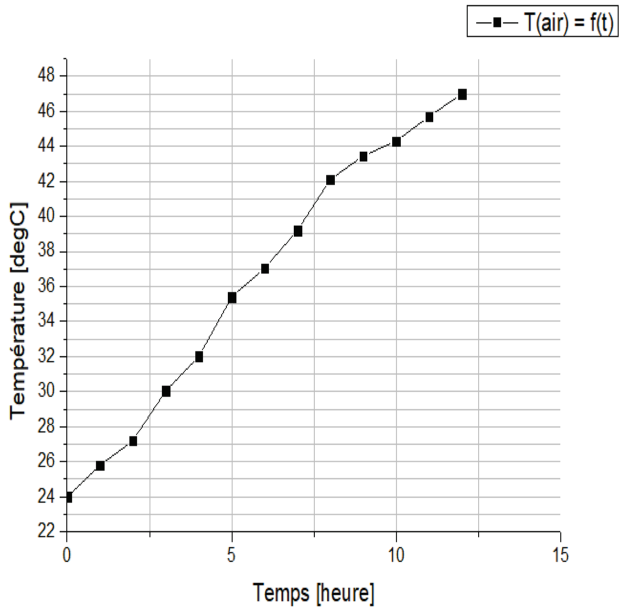

Fig.8 Evolution of Air temperature as a function of time

CONCLUSION

The approach adopted in this work is distinguished by its focus on the digital design of the distiller using SolidWorks software and the simulation of thermofluidic phenomena inside the distiller using COMSOL Multiphysics software. This combined methodology allowed us to analyze in detail the performance of the distiller and to interpret the results obtained in a solar cascade still, we saw a greater increase in water temperature, from 25°C to 46°C over the same period. This increased significant increase can be attributed to the cascade effect, which improves heat absorption and promotes a faster increase in water temperature.

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