

Use of Photovoltaic Energy in the Distillation and Purification of Water: Design of a Prototype



Kamilia Mounich, Aicha Wahabi, and Mohamed Chafi

Abstract Globally, the demand for good quality drinking water is growing. Indeed, the desalination and purification of sea water require lots of treatments. This paper presents the theoretical study and practical realization of a system that consists to solve the issue of water anti-calcification. Softening is the technique used to remove TH from water (due to the presence of alkaline earth salts: carbonates, sulfates, and chlorides of calcium and magnesium). This system will provide soft water, free of alkaline earth salts and heavy metals such as arsenic, lead, cadmium, nickel, mercury, chromium, cobalt, zinc, and selenium and which are highly toxic even in minor quantities. Hence, the principle of magnetic induction was studied as a key milestone to solve the calcite deposit into the canalization. This phenomenon creates strong magnetic fields that cause mineral ions (especially calcium carbonate) to agglomerate and neutralize with each other before the water is heated to reach then the final step which is the pass-through activated carbon filter.

Keywords Sea water distillation · Heavy metal · Water softener · Softener device · Limestone deposit · Anti limestone magnet

1 Introduction

Faced with a certain water crisis that is beginning to be felt and triggered the alarm all over the world, in addition to the economic constraints of sustainable development, appropriate solutions must be formulated to prepare for this challenge which threatens the survival of humanity. Morocco has considerable saline water resources and a large solar period throughout the year. It is necessary to use desalination technology by exploiting the available green energy [1]. This solution is a reliable way to produce drinking water. However, it should be noted that this method is economically reliable only for small units whose daily volume of drinking water varies from a few cubic meters to tens (or even hundreds) of drinking water per day [2].

K. Mounich (✉) · A. Wahabi · M. Chafi
LIPE, Higher School of Technology, Hassan II University, Casablanca, Morocco

The following study is focused on the practice of small processes. For large capacities, the combination of desalination processes with renewable energies requires high investment costs and the reliability of such systems is not always guaranteed [3].

The desalination process is divided into two main categories: firstly, the distillation processes (which require a phase change, evaporation/condensation) and secondly, the membrane processes (filtration), which consist to eliminate heavy Metals and bad taste from water thanks to filtration phenomenon [4, 5].

The best and most cost-effective method to ensure that is using a filter with multiple stages with activated carbon based as used in this experiment.

2 Process Working Principle

2.1 Materials and Methods

The study was conducted on a laboratory-scale distiller. It is consisting of a heat source (heating element) and a 750 ml container of sea water and a 6 mm diameter copper tube formed into 7 turns, a cooling fan powered through a 3.7 V lithium battery which in turn is charged through a 5 V, 12 W photovoltaic panel controlled by an SG09 servo motor, 4 LDR and an Arduino Nano Atmel Atmega 328p board. The freshwater passes through an anti-lime magnet to resolve the deposit of calcite in the pipeline and five steps activated carbon filter using gravity and absorption phenomenon (Fig. 1), and then to the final container to collect fresh water.

The five steps filter activated carbon-based offer a significant result in terms of water purification such as removing heavy metals, bad taste, and other deposits. This filter is a combination of five materials: Activated carbon, Anthracite, Sand, Garnet, and Gravel. Activated carbon and the Anthracite filters use minimal bonding agents and have superior contaminant reduction and performance capability.

Also, sand filtration technology can homogenize wastewater containing heavy metals. Thanks to the continuous flushing system, the resistance and flow rate of the filter bed are always stable and self-disciplined, providing stable output and steady-state operation. However, the Gravel layer was found to be very effective for the removal of sediment and heavy metals, even as the system clogged over time. In addition, the pores of the Garnet are small enough to allow the passage of liquid but too small to allow the passage of certain contaminating particles, which are filtered from the fluid.

2.2 Process and Theoretical Measures

The synoptic diagram (Fig. 2) describes the operating principle of the desalination system equipped, on the one hand, with a mechanism which supplies thermal energy

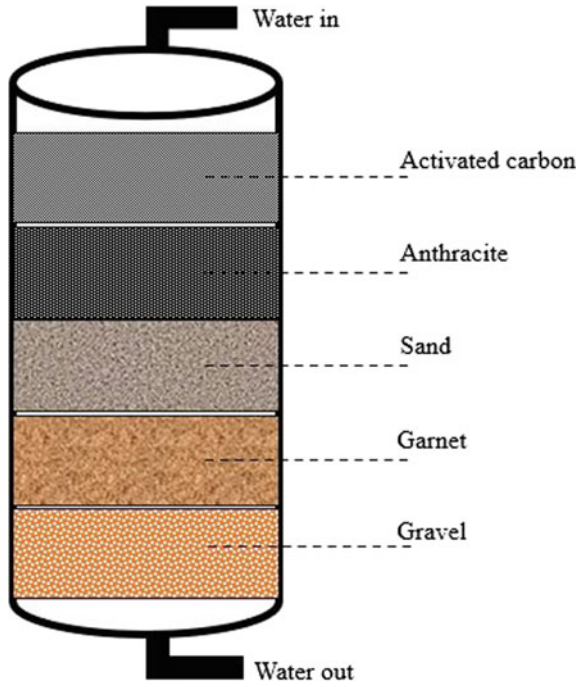


Fig. 1 Multiple steps filter (activated carbon-based)

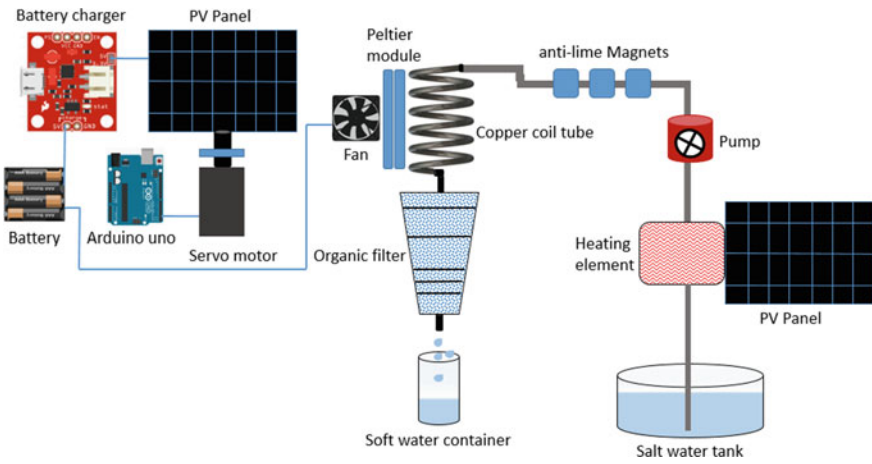


Fig. 2 Sea water distiller, purifying schema

Table 1 Taste of water with different concentrations of TDS

TDS level in parts per million (ppm)	Evaluation
Between 50 and 150	Excellent for drinking
150–250	Good
250–300	Fair
300–500	Poor
Above 1200	Unacceptable

through photovoltaic panels, and on the other hand, with a sub-system composed of two parts: the use of anti-lime magnets [4] to eliminate lime deposits in the pipes and the use of 5-stage filters based on activated carbon and other absorbent materials in order to eliminate the presence of heavy metals [5].

The permanent magnet processes generate a constant magnetic field: They are to be distinguished from electromagnetic processes which are at the origin of a variable magnetic field, catalytic processes, or systems at the origin of turbulent regimes.

These processes act on the calcium carbonate and facilitate its crystallization in a non-encrusting form they prevent the formation of scale.

Magnetic lime scale devices are placed in series on the pipe; the devices generate the magnetic field through which the water passes.

The water purity measurement is done using the TDS meter (Total Dissolved Solid) [6] (Table 1).

The experience showed a value of 10,600 ppm in saline water sampling measured by TDS before starting the heating. Hence, according to EPA (Environmental Protection Agency), this value is health-harming as it's over the limits. So, the TDS measurements taken on the final recipient showed a value of 90 ppm, which is within EPA limits.

2.3 *Electronic Components*

In order to enable this project, the electronic part is necessary to drive results. The diagrams (Fig. 3) show the wiring and essential electronic components. In fact, the electric power is ensured by the photovoltaic panel to all electronic items. The type of photovoltaic panel is monocrystalline 12 V 80 W.

The Arduino Nano card controls the servo motor movement via four LDR, then moves the photovoltaic panels in the direction of the sun (sun follower) to catch a maximum of solar rays. The battery 7.4 V is under charge permanently to ensure the cooling system fan power supply. A Peltier module was added to guarantee a perfect cooling of the solenoid copper tube.

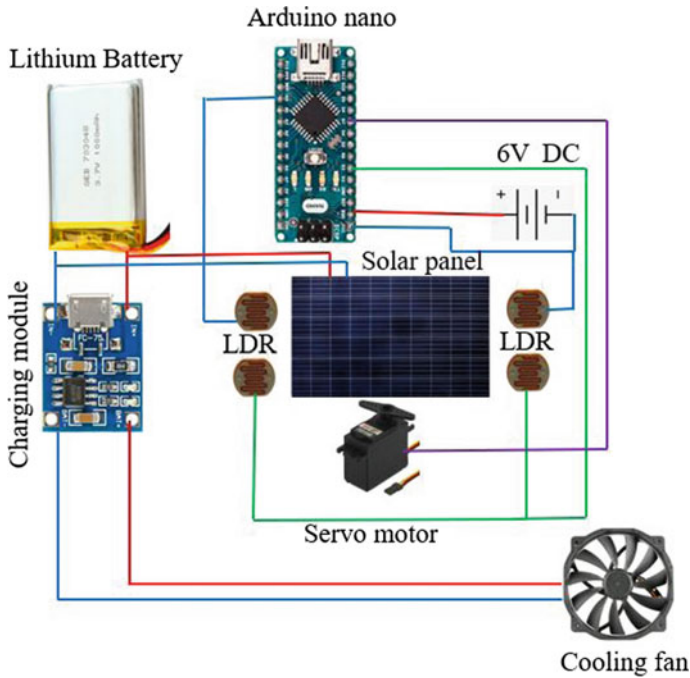


Fig. 3 Electronics schema

2.4 Magnetic Anti-lime Scale Device

Revolutionary anti-lime scale and anti-magnetic scale solution works without chemical additives, without maintenance, and current. This very powerful magnetic field prevents the formation of limestone and other deposits and cleanses pipes and equipment from old limestone encrustation.

The presence of limestone nanocrystals suspended in the water causes indeed a natural phenomenon of limestone erosion. The water that has become depleted in available calcium and carbonate ions begins to behave like rainwater: it seeks to become loaded with mineral salts. In other words, the principle is simple and effective; these magnets create a magnetic field that modifies the polarization of the mineral salts suspended in the water, thus preventing the formation of scale inside the water pipes (Fig. 4).

2.5 Grouping of Photovoltaic Cells

We have coupled two photovoltaic panels in parallel. A parallel mounting of two cells increases the generator output current. In a group of identical cells connected

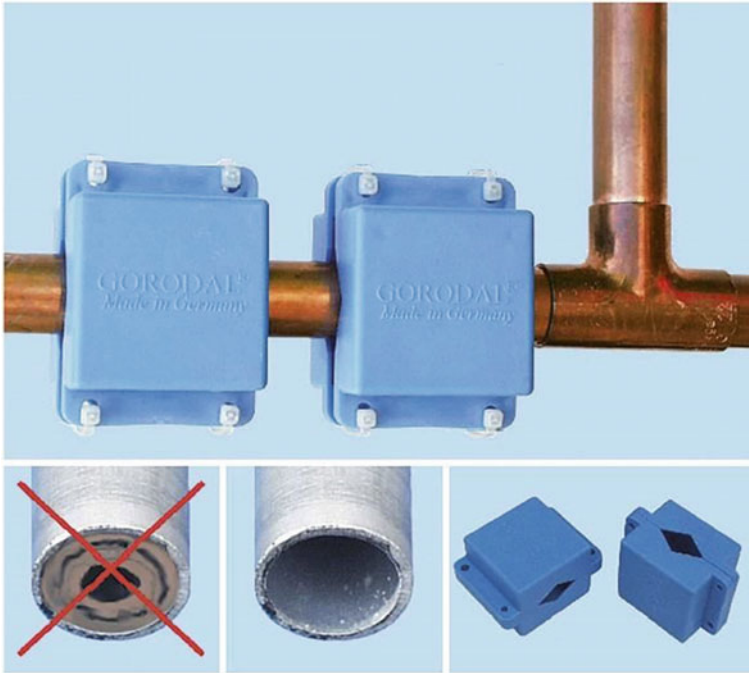


Fig. 4 Anti-lime magnet (calcium build up)

in parallel, the cells are subjected to the same voltage and the characteristic resulting from the grouping is obtained by adding the currents (Fig. 5). Equation (1) in turn summarizes the electrical characteristics of a parallel association of N_p cells.

$$V_1 = V_N \text{ and } I_T = I_1 + I_N \text{ (} N \text{ is PV cells number)}$$

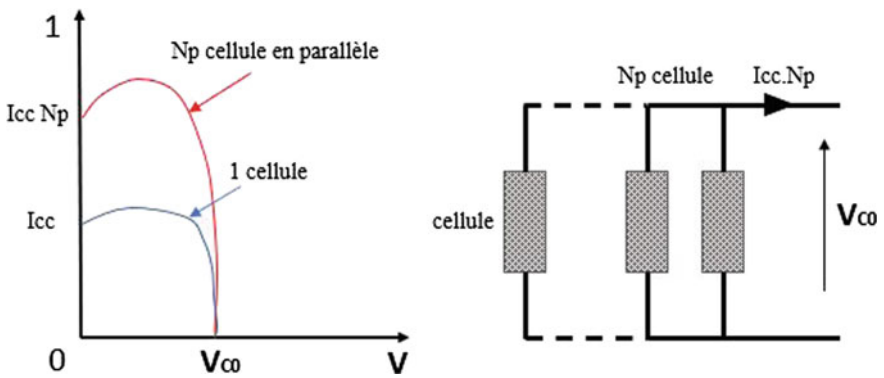


Fig. 5 Characteristic result from a grouping of N_p cells in parallel

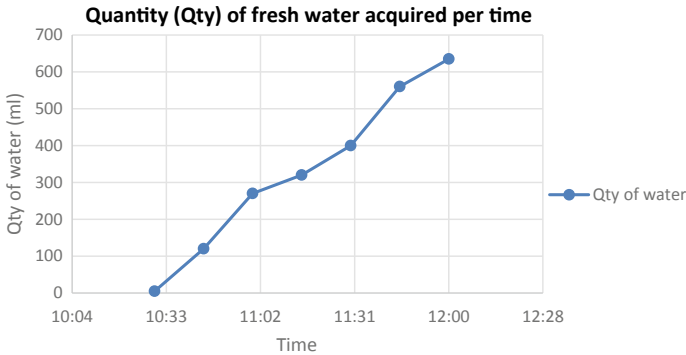


Fig. 6 Quantity of fresh water (ml) acquired per time

$$I_T = I_{\text{total}} \quad (1)$$

3 Results and Discussion

The day of September 9th, 2021, was chosen to perform the experience, which is characterized by strong sunshine throughout the day with a maximum temperature around 33 °C, specify that the time of the first drop was detected at 10:30 a.m. and the total amount of distillate collected until 12 p.m. is equal to 645 ml. The time between the first drop and the total quantity of collected fresh water is around 120 min (Fig. 6).

As mentioned before, the first fresh drop was collected at 10:28 even the condensation begin earlier as the water take several times to pass through the five stages of the filter. As the process progress, the quantity of water increase to reach finally around 640 ml at mid-day.

Among the results done, the biochemical test of the fresh water coming from the filter with the TDS device, and we had in Fig. 7.

4 Conclusion

It is well known that the scarcity of water is an object of both nature matter and human responsibility. The huge need for fresh water requires the exploitation of all available green energy such as solar energy, and at the same time take benefit that nature offers in terms of organic filters to provide fresh drinkable water for all needy areas. Indeed, this will not only gives alternatives but also will stop harming our planet by using fossil fuel.

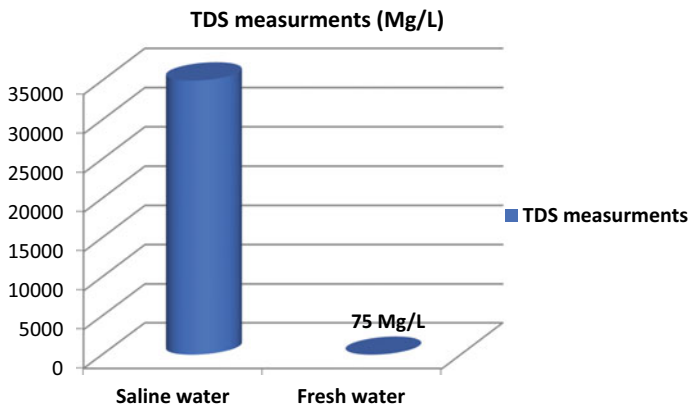


Fig. 7 Salt measurement TDS

Electromagnetic and magnetic techniques are a good solution to decrease the rate of heavy metals treatments because these non-invasive and cheap techniques do not need chemicals added to the water. There are various theories about the effects of these techniques. Other papers affirm that an electromagnetic field favors the formation of crystals within the fluid instead of in the pipes, and for this reason, the scale would not form. These techniques can increase or decrease turbulence in the fluid, promoting the aggregation or disaggregation of ferromagnetic and diamagnetic colloids. In addition, studies conducted at the University of Alicante have seen an orientation of the crystals formed after the application of an electromagnetic treatment that did not occur without treatment. It has also been observed in other studies that after the application of the magnetic treatment, the diffusion coefficients of the sodium, magnesium, and calcium ions increased and those of the anions decreased [7].

The filtration and absorption system provides a wide utilization in wastewater treatment. Nowadays, many prototypes of filters are available, competitive cost, easy to build, and efficient. As this research showed the benefits of a mixture of all absorbents material (Activated carbon, Anthracite, sand, Garnet, and Gravel), lots of the study demonstrated the strong influence of additions on the removal of heavy metals from saline water by using 5 layers filter, which varied according to the type of heavy metal.

The anti-lime magnet is fixed permanently in the water pipe, which gives autonomy and performance to the system. However, the treatments of different types of wastewater present a challenge. In fact, all types of water treatment will not be covered by a single filter, which gives the perspective to work on the filter change over or develop a filter that gathers all the characteristics that allow a standard filtration.

References

1. Mounich, K., Wahabi, A., Chafi, M.: Water-purifying distiller with a cooling system controlled by a photovoltaic panel. In: Motahhir, S., Bossoufi, B. (eds.) *Digital Technologies and Applications. ICDTA 2021. Lecture Notes in Networks and Systems*, vol. 211. Springer, Cham (2021)
2. Carr, W.J., Levin, B.H., Dissinger, M.L.: Water drinking and air drinking: some physiological determinants. *Psychon. Sci.* **13**, 23–24 (1968)
3. Esmaeilion, F.: Hybrid renewable energy systems for desalination. *Appl. Water Sci.* **10**, 84 (2020)
4. Delyannis, A.A., Delyannis, E.A.: Distillation processes. In: O. Sauerstoff. *Oxygen (System-Nr. 3)*. Springer, Berlin, Heidelberg (1974)
5. Rajczykowski, K., Loska, K.: Stimulation of heavy metal adsorption process by using a strong magnetic field. *Water Air Soil Pollut.* **229**, 20 (2018)
6. TDS and PH meter: <https://www.safewater.org/french-fact-sheets/2017/2/9/tds-ph>. Accessed 2021/11/01
7. Martínez Moya, S., Boluda Botella, N.: Review of techniques to reduce and prevent carbonate scale. Prospecting in water treatment by magnetism and electromagnetism. *Water* **13**, 2365 (2021)