Potabilization of water with zero-liquid discharge using low temperature solar thermal energy

Corentin Koninck, Vincent Goetz, Driss Stitou

Potabilization of water with zero-liquid discharge using low temperature solar thermal energy

Corentin Koninck, Vincent Goetz, Driss Stitou

PROMES-CNRS UPR 8521, PROcess Material and Solar Energy, Rambla de la Thermodynamique, 66100 Perpignan, France. corentin.koninck@promes.cnrs.fr

Access to drinking water is a major issue for the 21st century on a global scale. This vital resource is still inaccessible to 2 billion people, due to the absence or inefficiency of sanitation facilities, which affects 2.3 billion people in the inter-tropical zone. Biological micro-organisms (bacteria, viruses, protozoa and helminths) present in poorly sanitised water are the cause of waterborne diseases and mortality [1]. Various water treatment techniques exist to address these problems: chemical treatments such as chlorination or ozonation that require the use of chemical consumables, and physical treatments (membrane filtration) or thermal treatments (pasteurisation) that require energy consumption [2]. The present study aims to evaluate the latter two water treatment techniques exploiting solar thermal energy, which can be easily delivered by conventional solar collectors at low temperature (60-80°C), in order to develop a simple, robust process that is suitable for remote sites with an abundant solar resource that are isolated from sewerage networks.

The first part of the study deals with the evaluation of a thermo-hydraulic process implementing an ultra/nano filtration membrane, powered by solar thermal energy (Fig. 1). In this process the thermal energy is directly converted into hydraulic energy by a Rankine type thermodynamic cycle (ORC) to allow the pressurization of the water to be treated by the membrane filtration process. The hydraulic energy of the produced concentrate is recovered to pre-pressurise the water to be treated and thus improve the energy efficiency of the process [3].

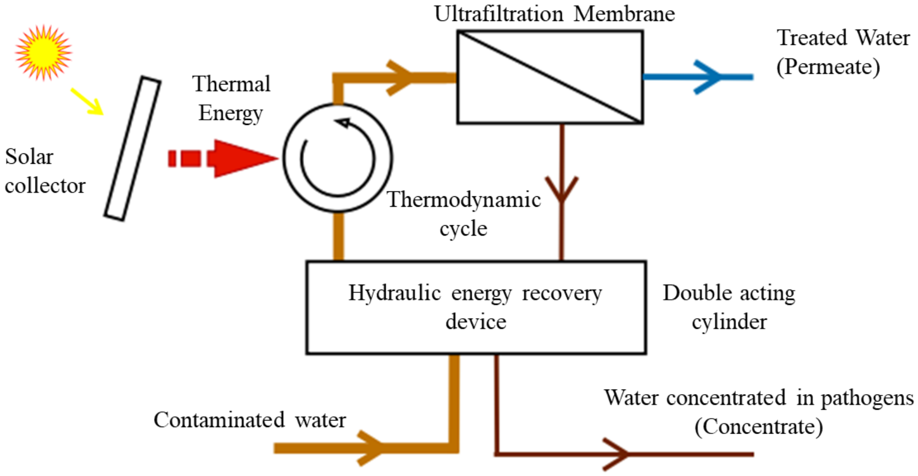

Fig. 1. Block diagram of the membrane filtration process

The second part of the study is dedicated to a pasteurisation process using solar thermal energy. This continuous process, presented by the fig. 2, consists of heating the water to be treated and maintaining its temperature in a reservoir for a given period of time to kill the pathogens. At the output of the process, a heat exchanger is implemented to recover the thermal energy of the pasteurised water to preheat the water to be treated, thus improving the energy performance of this process.

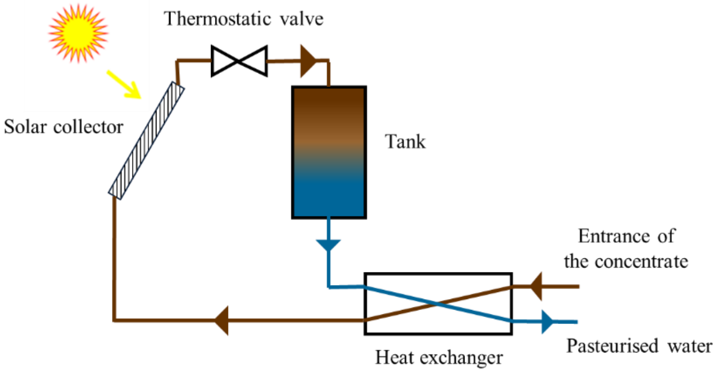

Fig. 2. Diagram of the pasteurisation process

A simplified steady-state modelling of these two solar processes has allowed us to estimate their performances in terms of daily treated water production and specific energy consumed. Thus, it would be possible to obtain during the summer season a daily production of treated water of about 1.2 m^3/m^2 of installed solar collector for the thermo-hydraulic membrane filtration process and of about 0.45 m^3/m^2 for the solar pasteurisation process. The specific energy consumed by each of the processes, related to the solar irradiation, is respectively 4.5 kWh_{solar}/m^3 and 13 kWh_{solar}/m^3. These first interesting results showed the relevancy of these two processes from an energy point of view and also their technological feasibility: the filtration process, which nevertheless discharges an effluent highly concentrated in pathogens has a very interesting energy performance in contrast to the pasteurisation process which however does not discharge any effluent (all the water is treated).

The third part of this study is naturally focusing on the feasibility and the performance evaluation of the coupling of these two processes to obtain a hybrid solar process for the full treatment of contaminated water with zero discharge: the concentrated water leaving the membrane process is then treated downstream by the solar pasteurisation process (Fig. 3). The performance of such an association obtained in a first evaluation is very promising: the daily production and the specific energy consumption have values between those of the membrane filtration process alone and those of the pasteurisation process (0.8 $m^3/day.m^2$ and 6.5 kWh_{solar}/m^3) with the great advantage of eliminating completely all pathogens present in the contaminated water. In addition, this hybrid process has comparable performances as those obtained by solar ultrafiltration processes using photovoltaic solar panels, in which the water is pressurized by electrical pump.

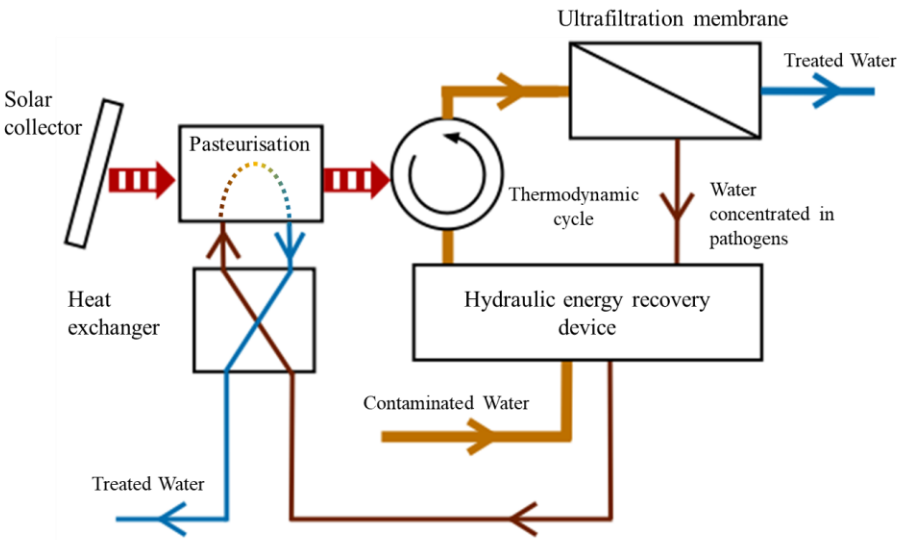

Fig. 3. Block diagram of the hybrid process

[1] Gadgil A., Drinking water in developing countries, 1998
[2] Bennett, Anthony. « Drinking water: Pathogen removal from water – technologies and techniques », 2008
[3] Clément Lacroix et al., Solar-driven thermos-hydraulic process for reverse osmosis desalination, 2018