Simulation of the performance of three desalination systems

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The increase in demand for water is driven by several factors, such as population growth, rapid urbanization, the intensification of industrial activities and climate change, which put increasing pressure on available water resources (Omerspahic *et al.*, 2022). As a result, it is imperative to look for innovative solutions, explore sustainable alternatives and more efficient processes to ensure water security on a global scale, namely through seawater desalination.

Seawater desalination plays a crucial role in increasing the supply of drinking water, given the predominance of salt water on the planet (Shemer *et al*., 2023). This process generally uses water with high salinity, like sea water, to which energy is applied in the form of heat, electricity, or hydraulic pressure (Elsaid *et al*., 2020). However, this process results not only in the production of drinking water, but also in greenhouse gas emissions and waste discharge - brine, a solution highly concentrated in salts, which represents an environmental problem if not properly managed (Glosson, 2023; Mavukkandy *et al*., 2019). A Schematic of the desalination process is presented in Figure 1 (Ghernaout, 2020 and Fontana *et al*., 2023).

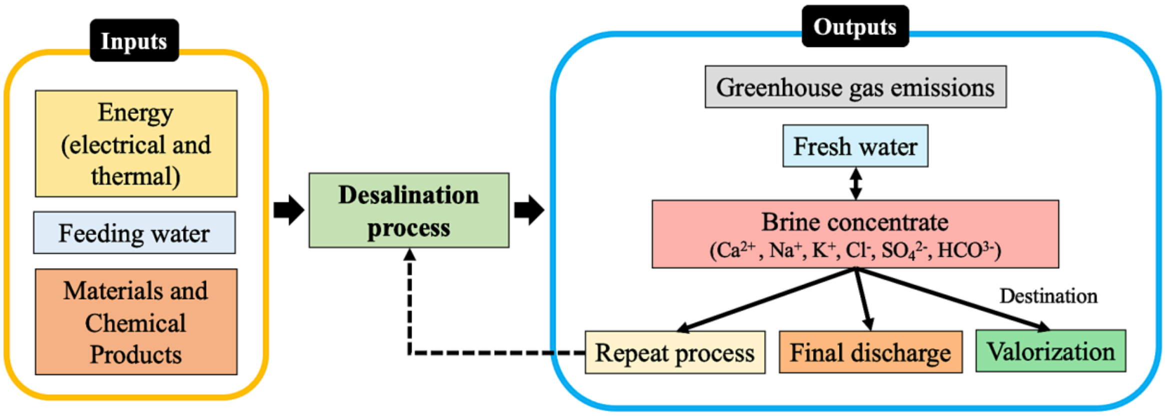

Figure 1. Schematic of the desalination process (Adapted from Ghernaout, 2020 and Fontana *et al*., 2023)

Faced with this scenario, two critical issues arise: the destination of the rejected brine and its proper management. To address the challenges associated with brine discharges, the concept of zero discharge was developed as a solution to maximize the production of high-quality drinking water while reducing the liquid waste generated during the desalination process (Omerspahic *et al.*, 2022). This method allows for the additional recovery of water, as well as making it possible to recover valuable raw materials present in the rejected brine, such as magnesium, calcium, boron, sulphate, strontium, calcium carbonate, sodium chloride and bromine (Fontana *et al*., 2023; Omerspahic *et al*., 2022). These recovered raw materials have a wide range of applications, both internally, by re-introducing brine into the desalination process, and externally, in various industries, including food, cosmetics, pharmaceuticals, agriculture and construction (Fontana *et al*., 2023; Ghernaout, 2020).

Currently, seawater desalination can be carried out by thermal processes such as Multi-Stage Flash Distillation (MSF) and Multi-Effect Distillation; by membranes such as Reverse osmosis (RO), Electrodialysis or Nanofiltration; or emerging processes such as hybrids (Elsaid *et al*., 2020). There are numerous types of processes for desalinating seawater, but little attention has been paid to the discharge of desalination by-products and their effects on the ecosystem (Omerspahic *et al*., 2022).

The most common method for brine disposal is to ensure efficient brine dispersal at the outfall (Fontana *et al*., 2023). However, given the growing number of desalination plants around the world, there is a need to explore more suitable and efficient methods capable of recovering water and eliminating excess salts for other purposes by reducing and/or eliminating brine in an environmentally friendly way and with reduced environmental impacts (Jones *et al.,* 2019).

The aim of this study is to investigate the most effective method of desalinating seawater to produce drinking water, considering production performance, energy consumption, as well as the associated environmental impacts and operating costs, through numerical modeling of three desalination systems - RO, MSF and a hybrid RO/MSF - in different scenarios. The aim is also to explore the interactions between environmental factors such as weather conditions, feed water temperature and current velocity in the different processes. It is hoped to identify the most effective desalination method, taking into account efficiency in the production of drinking water and the minimization of environmental impacts, especially in relation to the management of rejected brine.

The simulation will be carried out in a software, considering the specific characteristics and real data obtained from a desalination plant in Portugal as a case study.

This study is still under development. However, in the future, it will contribute to the development of more sustainable practices in the desalination process, guaranteeing the supply of drinking water for the current and future population, since the results obtained can be applied to other coastal regions facing similar challenges.

References

Elsaid, K., Kamil, M., Sayed, E. T., Abdelkareem, M. A., Wilberforce, T., & Olabi, A. (2020). Environmental impact of desalination technologies: A review. *Science of The Total Environment*, 748, 141528. https://doi.org/10.1016/j.scitotenv.2020.141528.

Fontana, D., Forte, F., Pietrantonio, M., Pucciarmati, S., & Marcoaldi, C. (2023). Magnesium recovery from seawater desalination brines: A technical review. *Environment, Development and Sustainability*, *25*, 13733–13754. https://doi.org/10.1007/s10668-022-02663-2.

Ghernaout, D. (2020). Desalination Engineering: Environmental Impacts of the Brine Disposal and Their Control. *Open Access Library Journal*, 7, 6777, 1-17. https://doi.org/10.4236/oalib.1106777.

Glosson, G. (2023). *Simulating and Optimizing a Zero-Waste Wave-To-Water Desalination System,* M.S. thesis, East Carolina University. Available on: http://hdl.handle.net/10342/12843.

Jones, E., Qadir, M., VanVliet, M. T. H., Smakhtin, V., & Kang, S. (2019). The state of desalination and brine production: A global outlook. *Science of the Total Environment*, 657, 1343–1356. https://doi.org/10.1016/j.scitotenv.2018.12.076.

Mavukkandy, M. O., Chabib, C. M., Mustafa, I., Ghaferi, A. A., & AlMarzooqi, F. (2019). Brine management in desalination industry: From waste to resources generation. *Desalination*, 472(114187). https://doi.org/10.1016/j.desal.2019.114187.

Omerspahic, M., Al-Jabri, H., Siddiqui, S. A., & Saadaoui, I. (2022). Characteristics of Desalination Brine and Its Impacts on Marine Chemistry and Health, With Emphasis on the Persian/Arabian Gulf: A Review. *Sec. Marine Pollution*, 9. https://doi.org/10.3389/fmars.2022.845113.

Shemer, H., Wald, S., & Semiat, R. (2023). Challenges and Solutions for Global Water Scarcity. *Membranes*, 13(6), 612. https://doi.org/10.3390/membranes13060612.