Greywater treatment or desalination for drinking water supply? A life cycle perspective

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Highlights:

- Greywater is a potential potable water source in areas with water scarcity, because of continuous availability and large volume.
- Electricity, sludge management and chemicals use are main contributors to LCA-impacts for wastewater treatment.
- Electricity, activated carbon and chemicals use are expected to contribute to higher LCA-impacts than membranes components for advanced water treatment.

Keywords: source-separation; potable water; brackish water; LCA

INTRODUCTION

Surface water (rivers, lakes) and groundwater have traditionally been the primary sources for drinking water supply, either directly or through municipal treatment and distribution systems. In coastal regions with limited freshwater resources, desalination has become a suitable choice. However, its high energy requirements (Lee & Jepson, 2021) have prompted city planners seek other options. Domestic wastewater, constantly produced at the household level where drinking water demand exists, presents another alternative. Greywater, the fraction generated from bathtubs, showers, sinks and washing machines, constitutes up to 60-75% of the total domestic wastewater volume (Isaksson et al., 2023). The lower faecal (and nutrient) content and relatively large volumes make greywater an attractive water source. Furthermore, EU countries will be required to promote the reuse of treated wastewater from all treatment plants in the coming years, especially in water-stressed areas (EU, 2024), making this water source more realistic.

This study compares different alternatives for drinking water production in a new residential area facing water scarcity. The environmental impact of brackish water desalination (with reverse osmosis, Alternative A) and advanced treatment of greywater (B) and mixed wastewater (C) are compared following a life cycle analysis approach (Fig.1). The results can be used by planners and decision-makers interested in diversifying the water supply and understanding the environmental burden of different water supply systems to implement the options with smallest impacts.

METHODOLOGY

Life cycle assessment methodology was followed according to the ISO 14040:2006 standard (ISO 14040, 2006), which includes the definition of goal and scope, the life cycle inventory, life cycle impact assessment and the interpretation. The Environmental Footprint 3.1 method was used for the analysis, along with the SimaPro 9.5.0.1 software and the EcoInvent v3 database.

The functional unit was the production of one m^3 of potable water. To ensure comparability and that the alternatives fulfilled the same function, the treatment of wastewater was also included in the system boundaries (Fig. 1), as the greywater alternative provided both drinking water and wastewater treatment. The system boundaries comprised the construction and operational phase, from water intake to treated effluent discharge and sludge disposal (farmland application) (Fig. 1). The distribution network was excluded.

RESULTS AND CONCLUSIONS

The preliminary findings indicate that electricity production has a major influence in all the alternatives. The Swedish electricity mix is dominated by hydro and nuclear power and has relatively low global warming potential compared to other European countries (Swedish Energy Agency, 2022), so higher impacts can be expected in countries with more dependence on fossil fuels. The sludge management, and the use of chemicals such as iron chloride (precipitant) are also major contributors to the environmental impacts of the wastewater treatment (Fig. 1). The choice of precipitant appears to be a hotspot in the analysis, with iron chloride having higher impacts than iron sulfate, another common precipitant. The alternative with advanced greywater treatment includes activated carbon for micropollutants removal (Fig. 1), whose extraction and production contributes considerably to global warming and resources depletion (Selvarajan, 2020). Electricity use is the main contributor for the desalination process by far, although brackish water desalination uses less energy and has lower CO_2 emissions than seawater desalination. Chemicals for cleaning the membranes, such as sodium hydroxide, also contribute, but to a much lesser extent. The hypothesis presuming that advanced greywater treatment would result in lower environmental impacts compared to desalination remains to be tested.

Water infrastructure has a long lifetime, challenging the transition to more sustainable water systems because of the strong locks-in (Franco-Torres et al., 2020). It is therefore important that the environmental impacts of the different alternatives are considered before the long-term investments are made. Moreover, source-separating wastewater systems such as greywater-blackwater separation accrue costs for some actors (e.g. water utility), but generate benefits for others (e.g. society at large, agricultural sector), which are difficult to account for in a life cycle approach and further challenge their implementation in practice (Lennartsson et al., 2019). A broader methodological approach such as multi-criteria analysis could further account for the aspects that are not quantifiable in a life cycle analysis.

FIGURES

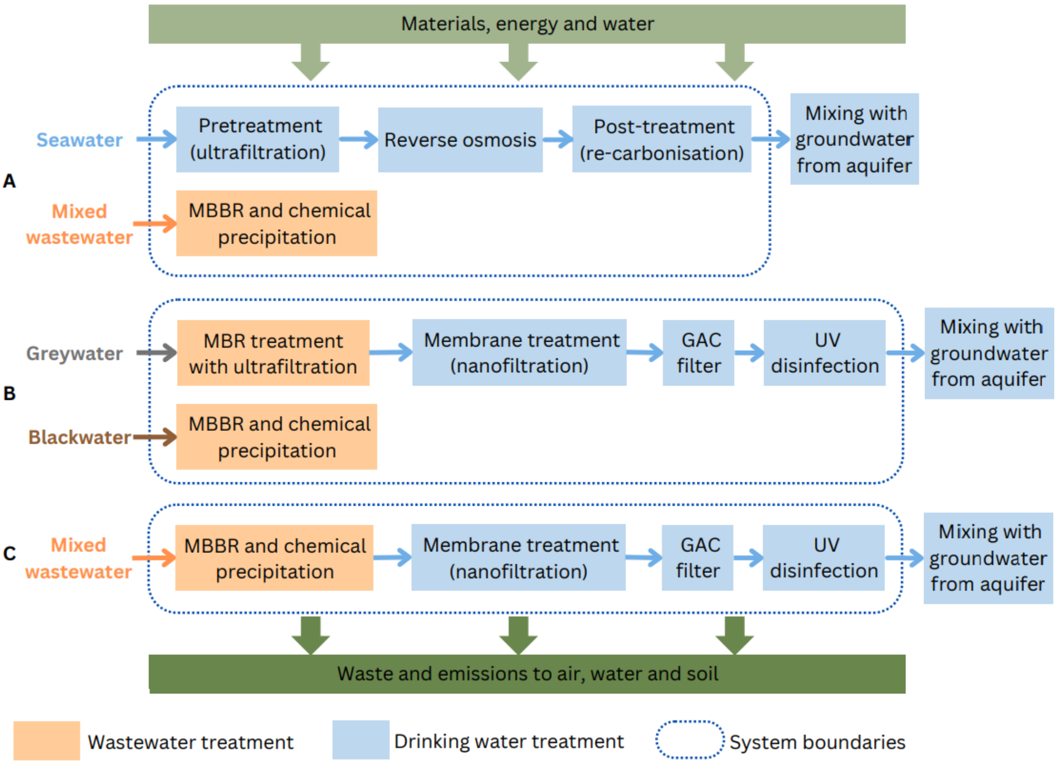

Fig 1. Overview of the three main alternatives (A–C) for potable water production including wastewater treatment, and corresponding system boundaries.

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REFERENCES

Franco-Torres, M., Rogers, B. C., & Harder, R. (2020). Articulating the new urban water paradigm. Critical Reviews in Environmental Science and Technology. https://doi.org/10.1080/10643389.2020.1803686

Isaksson, F., Herrmann, I., & Kvarnström, E. (2023). *Greywater reuse for different purposes in Sweden*. Technical report, Luleå University of Technology, Sweden.

ISO 14040, 2006. Environmental Management - Life Cycle Assessment - Principles and Framework: International Standard 14040. International Standards Organisation, Geneva. (2006).

Lee, K., & Jepson, W. (2021). Environmental impact of desalination: A systematic review of Life Cycle Assessment. *Desalination*, *509*, 115066. https://doi.org/10.1016/j.desal.2021.115066

Lennartsson, M., McConville, J. R., Kvarnström, E., Hagman, M., & Kjerstadius, H. (2019). Investments in innovative urban sanitation - Decision-making processes in Sweden. *Water Alternatives*, *12*(2), 588–608.

Selvarajan, S. (2020). *Cradle-to-Gate LCA of Water Treatment Alternatives A case study performed for Norrvatten's future waterwork expansion*. MSc thesis, KTH Royal Institute of Technology.