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Sustainable desalination: how to produce sufficient water towards the future, while protecting the marine environment

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EXTENDED ABSTRACT

The population in the Middle East Gulf area is growing and with that the water demand. In a region with very little rainfall and almost no rivers, this presents a challenge. Over the past decades, groundwater has been used as a water supply for drinking water as well as agriculture, but in many places, the groundwater reserves have been depleted. Towards the future, the dependency on seawater desalination will become larger and some areas will completely depend on this source of produced water.

The total amount of desalination plants and their capacity has risen exponentially over the last few decades (Fig. 1), whereas the current production of desalinated water from reverse osmosis accounts for approximately 69% (~66 million m^3/d) of the global volume of desalinated water (~95 million m^3/d; [1]).

A clear trend from thermal desalination technologies (MSF, MED) to seawater reverse osmosis (SWRO) can be observed, globally and in the Middle East Gulf region specifically. This shift in technology also results in a trend in the market to decouple energy from water production. Power and desalination plants were commonly co-located in the past due to the use of thermal energy from the power production process for thermal desalination. However, an RO plant only uses electricity and can therefore be decoupled from the powerplant, both technically and economically.

The main difference between the different desalination technologies in relation to the marine environment is the type and amount of brine effluent these technologies produce. Thermal desalination typically has a larger brine flow (often with elevated temperature and slightly elevated salinity of about 10%). SWRO effluent typically has no elevated temperature, but strongly elevated salinity (of about 50% or more), but the discharge rate is much less. The SWRO effluent thus provides a smaller, denser effluent plume that could result in high salinity levels near the bed, if not properly diluted by the outfall (e.g., by a diffuser).

For sustainable desalination, it is important to be able to predict the effects on the environment of the discharged brine effluent when designing new desalination plants or planning plant capacity around the Gulf. Questions about this environmental impact play on different spatial and temporal scales and should be considered accordingly with suitable models and methodologies. Close to the desalination brine outfall, near field effects play an important role in the initial mixing of the effluent. Near field mixing models, like CORMIX and CFD are required to compute these non-hydrostatic effects accurately. However, these models use a simplified geometry and ambient flow conditions, relevant close to the outfall (typically about 100 m). Further away from the outfall, a far field model like Delft3D is required to predict the outfall plume dispersion and possible effects on the environment in more detail and to ensure a good, compliant outfall design. On an even larger scale, the combined effects of the desalination industry (i.e., multiple plants) should be considered, for example, on a Gulf-wide scale. Here, also the longer-term natural effects like evaporation, large-scale circulations and climate change effects play a role. Large-scale models, like the open Gulf Community Model (Fig. 2), are available to investigate and study long-term scenarios as input to a sustainable national desalination strategy.

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Here also important questions currently play in the Gulf region that are still subject to research: Does climate change have a larger impact on the Gulf's salinity or does the increasing desalination capacity have a larger impact? Our research shows that closer to desalination plants, an increase in capacity shows a larger impact and that in areas without brine discharges, climate change has the larger impact. On a Gulf-scale, differences average out more, but regional differences can be expected, as well as possible changes in circulations that could increase salinity and its variability in some regions, but also reduce salinity on average slightly in other areas. Knowledge from such research could also inform a sustainable desalination strategy and be downscaled to plant level again.

Back to the current market dynamics for desalination plants. It is a point of attention that independent water plants (built and operated by a consortium of partners for decades) are still granted the project at the lowest metre cube water price, rather than the most sustainable design and operation. It is a challenge, but also opportunity, for water companies to put projects on the market that demand the highest levels of sustainability (in conjunction with different stakeholders like environment agencies, local communities, looking at employment etc.) in addition to an economic preference. Steps are being made in the right direction and many innovations are being developed and tested that can promote this further, like sustainable outfall designs.

An example of such sustainable outfall designs could be an outfall that can double as an artificial reef. The impacts of brine discharges on the marine environment may not be as high as thought before according to our and Australian research, although it still needs careful consideration. Outfalls are often observed as covered with marine life, as being a hard substrate for life to settle on (Fig. 3). Outfalls (and intakes) could also be designed specifically with this (additional) function in mind [2].

Furthermore, not all sites around the World are equal and it is important to adopt site-specific and ecologically relevant criteria for a desalination brine outfall. Often mixing zone criteria are adopted from other parts in the world, with different ecosystems that could be either harmful to local ecosystems or be overly restrictive. Research is needed and useful to develop more relevant criteria that could be adopted by regulators and increase the sustainability of desalination in relation to the marine environment, while ensuring sufficient water for everyone in the future.

Keywords: Sustainable desalination; Seawater; Environment

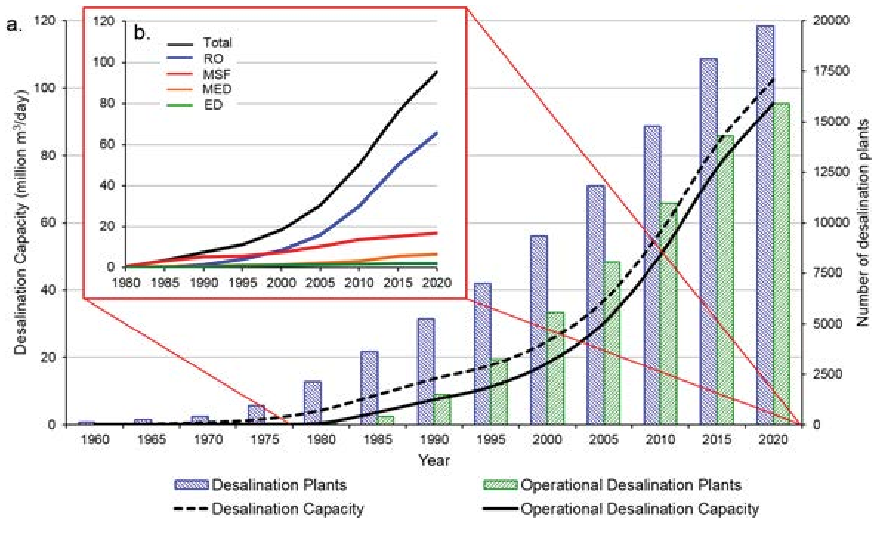

Fig. 1. Trends in global desalination by (a) number and capacity of total and operational desalination facilities and (b) operational capacity by desalination technology (Jones et al. [1]).

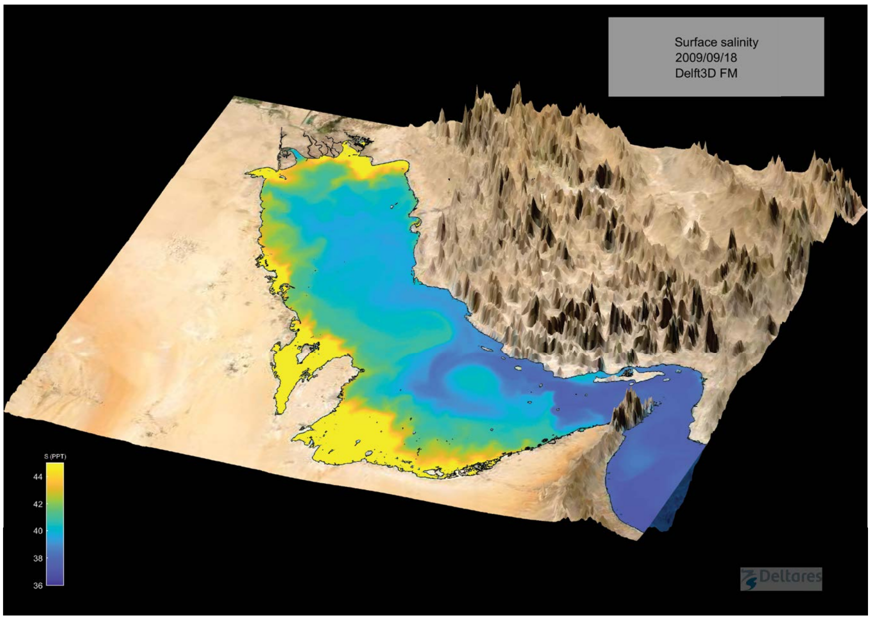

Fig. 2. Gulf-scale numerical modelling of the seawater salinity with the Delft3D-FM Gulf Community Model (https://www.agmcommunity.org/).

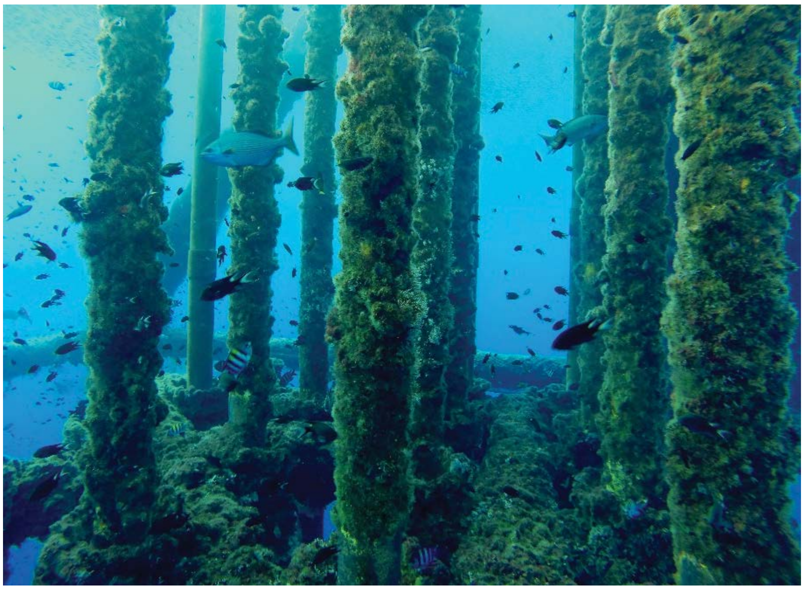

Fig. 3. Example of underwater structures functioning as habitats.

References

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