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Desalination as a Source of Freshwater

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Nominated by: Dr. Rebecca Teed

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Author notes:
Converting seawater to fresh, potable water through desalination is an exciting yet complex process. Drinkable seawater can bring water security around the globe, but desalination plants are expensive, inefficient, and environmentally hazardous. Like so many other climate-related crises, water security will come down to advancements in clean, sustainable energy that can make desalination plants clean and sustainable. Research on this topic was challenging, but learning about the mechanics and challenges of desalination was fascinating.

Faculty notes:
Jacob Pensky's article deals with technology we use to make saltwater drinkable. Drought-stricken coastal communities need desalination plants, especially as Earth's climate warms, but they are expensive and energy-intensive. This article describes ways to reduce the environmental and monetary costs.
Desalination as a Source of Freshwater

Freshwater is becoming more of a rare commodity every day, especially in areas experiencing rising sea levels and drought. Both of these stressors have significant effects in coastal areas. Sea level rise, in particular, can flood and contaminate underground aquifers, which are one of the most common sources of freshwater around the world. This means that regions in need of water may have to turn to Earth’s vast saltwater oceans, which is where desalination comes in. Desalination is the process in which salt is removed from seawater to produce freshwater that is fit for human consumption. Because of the sheer volume of saltwater on Earth, the scarcity of freshwater would not be a concern if clean and efficient desalination were achieved. Still, visions of transcontinental pipelines sending clean, potable seawater to every corner of the Earth will likely not be realized anytime in the near future. Desalination needs to be a reliable source of freshwater as rising sea levels are damaging underground aquifers in populous coastal areas, but it will not be until plants are run with clean, sustainable energy that allows for proper management of hazardous reject brine.

The brine left over from the desalination of salt water is a primary reason why it is not a reliable source of freshwater. Desalination “brine” refers to the salt that is left over after being removed from salt water. When salt is removed from water during desalination, it is often released back into the body of water that it came from, along with other harmful contaminants like chlorine, copper, and other heavy metals that are used during the filtration process. This brine has an extremely high salinity that can be almost twice as much as the body of water it is being deposited into (Ihsanullah et al., 2021). This poses a major threat to species that have become acclimated to a certain salinity level. Also, desalination plants need to heat the water to high temperatures for it to be properly filtered, especially in multi-stage flash and multi-effect distillation processes. Naturally, the reject brine from these plants has a much higher temperature than the surrounding water. Seagrasses are often the most vulnerable in high-salinity, high-temperature discharge areas, as the abnormally high salinity inhibits their ability to conduct photosynthesis (Sánchez-Lizaso et al., 2008). Because they are a primary producer, seagrasses have a significant effect on the surrounding ecosystem.

The reject brine from desalination is a difficult burden to shake, but there are techniques that, if further developed, can help mitigate the harmful environmental effects. One of these techniques is to recover the brine and recycle it for various other uses. For example, instead of releasing the brine back into the source, it can be released in areas where it can benefit the natural environment. Saltwater brine can be used to restore brackish wetland ecosystems (Rodríguez-DeLaNuez et al., 2012). For species that are adapted to saline environments, the addition of saltwater brine can provide nutrients that become limited during drought. This method is very useful because it allows the brine to be disposed of as-is without any extra treatment. However, finding areas that will benefit from the brine can be challenging, and if desalination becomes more prevalent as freshwater becomes scarcer, the amount of brine that needs to be managed will only increase. To make the brine easier to dispose of in different areas, its chemical composition can be altered. Specifically, harmful metals can be recovered to make the brine less hazardous (Bello et al., 2021). Metal recovery has gained tremendous popularity in recent years, primarily due to the economic benefits of recovering certain metals, with magnesium being one of the most abundant and valuable (Zhang et al., 2021). The technology for metal recovery is still relatively unreliable and expensive, but it presents a promising upside as a way to manage harmful brine from desalination plants.

In addition to environmentally hazardous byproducts, desalination plants are expensive and require a great deal of energy to function. Many plants still rely on fossil fuels like natural gas to
operate, which contributes to the climate change that is making freshwater so scarce. There are two main categories of desalination plants: membrane filtration and thermal distillation. The primary process in a membrane filtration plant is reverse osmosis, which essentially just pushes water through a membrane at high pressure to filter out impurities. Thermal distillation includes two different processes that share many similarities. These processes are multi-stage flash (MSF) and multi-effect distillation (MED). MED involves sending water through different stages, each at a decreasing temperature and pressure, to evaporate the freshwater. MSF also relies on evaporation, but it does so by flashing the water with high temperatures at each stage to evaporate small portions of the water each time. Membrane filtration processes are cheaper than thermal distillation processes, as the cost to construct a reverse osmosis plant that can process 50,000 cubic meters of water per day was estimated to be around 74 million USD in 2008, while an MSF plant of the same size was estimated to cost 149.5 million USD (Wittholz et al., 2008). Thermal distillation plants are more expensive because they require both electricity and thermal energy, while membrane filtration only requires electricity (Al-Karaghouli et al., 2013). However, thermal distillation can have a higher capacity for freshwater production once built. If they could be reliably run with clean, sustainable energy sources like solar, wind, and even hydroelectric, thermal distillation plants could be the most cost-efficient method of obtaining fresh water. The great energy costs mean that if they are run on fossil fuels, the environmental harm caused by the carbon emissions will outweigh the benefits of desalinated water.

Desalination needs an abundant source of clean energy if it is going to be of use to humanity in the future. The construction and operation of plants depend on having a large amount of energy, as does managing their hazardous reject brine. Possible sources include solar, wind, and nuclear energy. However, hydroelectric energy could serve as the most viable option for clean, efficient desalination, though it remains quite unproven (Bundschuh et al., 2021). This is because desalination plants are going to be constructed in coastal areas where hydroelectric power plants can also thrive. This proximity allows the facilities to work hand in hand to provide energy to produce clean water. One of the few real-world applications pairing hydropower with desalination is in Eagle Mountain, California, where the two facilities work together to protect the quality of the groundwater in the area (Saulsbury, 2020). This partnership provides energy for both desalination and the management of reject brine around the plant.

Along with addressing the energy needs of desalination, the Eagle Mountain site is focused on improving groundwater quality, which is one of the main reasons why desalination will be such an important technology in coming years. Temperatures are rising worldwide. This means that sea levels are also rising due to the melting of ice sheets. As seawater rises onto land, it makes its way into the freshwater underground aquifers that are relied upon for drinking water in coastal areas. Naturally, this flooding damages the quality of the water in the aquifers. If sea levels continue to rise, the damage to aquifers will only worsen. Another source of freshwater will need to be found, and desalination will have to be that source.

The world needs clean drinking water, as natural sources of freshwater, like lakes, rivers, and underground aquifers, have been put in jeopardy by human-caused climate change. Desalination has a great deal of promise when it comes to dealing with this lack of water, but high energy costs and harmful reject brine hold it back from being a primary source of freshwater. The expansion of renewable energy sources like hydroelectric power could be the catalyst that allows desalination to thrive, but until then, desalination is still a work in progress.
References


