(Re)thinking Desalination: Solution or Driver of Problems?

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Abstract

The impact of water desalination on sustainability is a topic of much debate and research. While desalination can provide a reliable source of water in regions where freshwater is scarce, it has several sustainability challenges. First, desalination is an energy-intensive process that requires copious amounts of electricity or fossil fuels, which can contribute to climate change and air pollution. Second, desalination facilities discharge a highly concentrated brine solution into the ocean, which can harm marine life and ecosystems. Third, the construction and operation of desalination plants can have negative impacts on local communities and their livelihoods, including displacement, loss of access to traditional fishing grounds, and increased water rates. Fourth, desalination can create a false sense of security and may encourage unsustainable practices such as overconsumption, land-use changes, and water-intensive industries. Therefore, desalination's sustainability depends on carefully considering environmental, social, and economic factors and adopting best practices to mitigate its negative impacts. In two parts, this paper first addresses various dimensions of desalination as a technological process and its impact on society. In the second part, we look at the impact of desalination on other sustainable development goals and their sub-targets listed in the agenda 2030. The paper concludes by identifying areas for future research on desalination.

INTRODUCTION

The impact of water desalination on sustainability is a topic of much debate and research. While desalination can provide a reliable source of water in regions where freshwater is scarce, it has several sustainability challenges. First, desalination is an energy-intensive process that requires copious amounts of electricity or fossil fuels, which can contribute to climate change and air pollution. Second, desalination facilities discharge a highly concentrated brine solution into the ocean, which can harm marine life and ecosystems. Third, the construction and operation of desalination plants can have negative impacts on local communities and their livelihoods, including displacement, loss of access to traditional fishing grounds, and increased water rates. Fourth, desalination can create a false sense of security and may encourage unsustainable practices such as overconsumption, land-use changes, and water-intensive industries. Therefore, desalination's sustainability depends on carefully considering environmental, social, and economic factors and adopting best practices to mitigate its negative impacts.
In two parts, this paper first addresses various dimensions of desalination as a technological process and its impact on society. In the second part, we look at the impact of desalination on other sustainable development goals and their sub-targets listed in the agenda 2030. The paper argues that while desalination is a significant solution for water shortage in arid and other water-scarce regions, an overreliance on desalination can create new vulnerabilities which are detrimental to global sustainable development.

DESALINATION AS A TECHNOLOGICAL PROCESS

Desalination technology is often viewed as a dependable, and viable solution, to the mounting demand for freshwater to meet the needs of our ever-growing global population. Presently, 300,000,000 people, representing over 150 countries, depend on desalinated water for their water needs (Panagopoulos, A. and Haralambous, K.J., 2020). Considering this reality, can there be any doubt regarding the benefits desalination provides in the minds of those in need of this technology? For countries that have traditionally faced water shortages due to climate or geographical impacts, desalination seems to be a tremendous solution to remedy their water deficiencies. This is why large desalination factories are being built in places like the Arabian sea coasts to turn sea water into freshwater, to be pumped out to thirsty populations, and to a lesser extent, meet the irrigation needs of countries suffering from chronic water shortages. It is for this reason many governments have adopted desalination as the perfect technology in meeting their freshwater needs.

DESALINATION TECHNOLOGY CURRENTLY BEING USED

According to the "Journal Of Contemporary Water Research And Education", there are mainly three methods used for water purification in the desalination process (Younos, T. and Tulou, K.E., 2005). Lately, there has been a fourth more recent technology that can be added to the first three now being used (Youssef, P.G., Al-Dadah, R.K. and Mahmoud, S.M., 2014). These technologies are as follows:

1. Membrane Technology

This technology involves using four forms of membranes (Microfiltration Ultrafiltration, Nanofiltration and Hyperfiltration) along with electrodialysis located along the side of the membranes. The intake pump pushes polluted water through these membranes to filter out various chemicals, salts, etc in the water in order to purify the water (Younos, T. and Tulou, K.E., 2005). These membranes must constantly be monitored and cleaned to maintain their effectiveness and replaced when needed.

2. Thermal Technology

This technology uses evaporation and condensation as distillation to filter out contaminants found in water. It can also use freezing components as a way to filter contaminants as well. Though it is an effective method for water purification it is highly energy intensive desalination technique.

3. Chemical Technology

This form of desalination is activated through chemicals that produce ion – exchange and can "adjust pH, control scale, remove particulates, prevent biological fouling, clean and remineralize the highly purified product streams. Specialized chemistry is also required to synthesize the reverse osmosis (RO) membranes (Challener, 2022)."

4. Adsorption Technology

for cleaning water there is a fourth method of desalination now being studied called adsorption technology. "In this technology an adsorbent material with high affinity to water like silica gel can be used to separate the water from the salts. (Youssef, P.G., Al-Dadah, R.K. and Mahmoud, S.M., 2014)" This is a promising development that has yet to catch on thus it is yet to be taken

on as a fourth, viable solution for desalination (Antonyan, M., 2019). Some desalination plants use all of the above in combination to clean its water.

CHALLENGES TO CURRENT METHODS OF DESALINATION

Now that we know how desalination works it is important to study how these technologies impact our world. Though desalination might appear to have great potential in bringing fresh water to a growing global population, living in a world in which 97% of world water resources are salt water, all is not well. There is much at stake when it comes to desalination. On the surface, desalination technology might seem to be the perfect solution for providing much needed water resources to population groups living in dry climates. However, upon closer examination of desalination technology, there are some concerns to be aware of, especially in the following five areas:

1. Energy Consumption

Desalination is an energy-intensive process that requires large amounts of electricity or fossil fuels. Since the energy needed to power large desalination plants are extensive it creates a large ecological impact in contributing to climate change and air pollution. This negative environmental footprint will only grow greater with the continual increase in reliance upon desalination technology. The math is simple. The more we grow this technology, the more pollution we create. This increase in pollution will have a negative impact on climate change, that in turn, will be a driver of increased CO2 emissions. This will lead to climate related droughts and elongated dry seasons creating a greater demand for water produced from desalination plants.

Recently, there have been attempts to use green energy to power desalination plants however, as of now, this form of energy has been unreliable due to its limited availability, its intermittency, and its lack of capacity to provide the large amount of energy needed to power up the desalination factories. Until we can develop more efficient green energy options, conventional energy will continue to be used in desalination which will result in more pollution.

2. Environmental Harm

It is important to know that desalination is not only used for saltwater treatments but is also used to treat water from other sources including urban and industrial wastewater, as well as brackish water from aquifers (Fernández-Torquemada, Y., Carratalá, A. and Sánchez Lizaso, J.L., 2019). The large amount of CO2 emissions because of the energy used to treat these forms of water are not the only source of environmental harm as the desalination process also pollutes sea water. Marine life and ecosystems are harmed by desalination when the toxic waste of brine, created during the refining process, is dumped back into the ocean. When it comes to other water sources, such as industrial wastewater; “the desalination process yields reject water containing high concentrations of toxic substances. Discharging reject water with toxic substances into the marine environment could lead to substantial environmental problems.” Even the use of the intake of water into desalination plants causes harm to the environment as marine life is often killed when water is drawn into the plants for desalination (Williams, J., 2022). These factors have a domino effect all thew way down to the local fishermen who might have once fished near these plants, but can no longer do so, due to the environmental harm they spew out.

Though there have been some scientific and technological advancements made to help mitigate the amount of toxic waste produced from desalination more must be done. The high price for

this kind of cleaning technology, accompanied by the number of hours, and regulations needed in monitoring toxic waste, is a problem. Considering these challenges, the environment will continue to pay the price of desalination until we are able to come up with a more affordable way to treat toxic waste produced from desalination plants. As of now, desalination will continue to destroy the ocean habitats through the dumping of brine and toxic chemicals into the land and oceans.

3. Social Costs

Without knowledge of environmental concerns because of desalination it is easy for people to have a false sense of security in benefitting from its technology. The belief of a never ending, abundance of water, can encourage people to take on unsustainable practices, such as overconsumption, and wasteful practices, within water - intensive industries.

The idea that desalination is the solution for all our water problems is a popular message politician have used in countries that once respected water as a valuable resource to be managed well. In Israel, this false message of never-ending water supply was used to garner political support for the government in power. In 2010 and 2011 the ruling party sent false messages that essentially told its population that Israel no longer had to worry about water management because desalination has now solved the past problems the nation once had with water shortages. “For the first time in the state’s 60 – year history, policymakers and officials were telling the population that their supply – side management was a permanent solution to this historically omnipresent challenge.” (Wieczorek, C., 2020). Unfortunately, these types of bold, and blatantly false statements, are tempting for politicians to us for political advantage. The results are tragic. People, who once were very proficient in conserving water due to their respect for its scarcity, were given permission from the powers that be, to abuse this important and threatened resource. With the false belief that there are no limits on water availability industries will no longer need to regulate their usage of water. People will also take advantage of water and overconsume its usage which will put added pressure on desalination plants to pump out more water resulting in net – zero – gain. Instead of droughts being the cause for the need for more water, wasteful water practices by people will increase water demand from desalination plants. This human problem will mean that more energy will be used to power desalination increasing its CO2 impact while also emitting more toxic waste into the ocean resulting in a hugely negative and growing environmental impact (See Diagram Below). This short-term gain for political points will only result in long - term pain for the future of Israel and the planet.

4. Political Ramifications

Desalination can possibly be an incentive for countries to work together to produce clean water. A good example of this is seen in how some people are pushing desalination as a potential peacemaker between Israel, Jordan, and Palestine. The group: “EcoPeace” are calling these nations to sign a “Green Blue Deal” as they understand that; “Israel and Palestine have coastlines suitable for desalination, while Jordan has huge potential for solar energy generation but lacks a coastline, thereby creating potential for mutually beneficial water/energy transfers among the three countries. The Green Blue Deal envisaged by EcoPeace is based on the principal of "harnessing the sun and the sea to create region-wide desalinated water and energy security for all." However, as of now, this has not happened.

Though desalination could be a means to bring cooperation between nations as seen in the proposal “EcoPeace” is calling for in the Middle East, the opposite is true as well. Desalination

can also cause nations to become more independent, and thus break ties with one another, because they can use desalination technology for economic dominance over other nations. In the above case, Israel's access to its desalination plants; "could be read as an attempt to transform Palestinians into paying water customers while simultaneously disavowing their claims to a greater share of the Jordan River." (Williams, J., 2022).

5. Operational Impact

In conclusion to this section, it is important to acknowledge that as the rush to build desalination plants continues to go unabated as a solution to water shortages, people are often overlooked. The water treatment industry is currently worth over $12.4 billion dollars annually, and it is growing. With this kind of money in play it is important to not allow this growing market to overpower the potential negative impacts it can have on local communities. We have already covered the huge energy consumption, environmental harm, social costs, and potential political ramifications from desalination that are present day concerns. All these factors can be placed into a fifth category of concern which is the operational impact desalination has on the average person. As we move forward in healthy water management, we must measure both the negative impacts of desalination along with the positive effects. This balance must not be disregarded through the tyranny of the urgent, or by greed to make money. Nor should there be a complete rejection of desalination without considering the importance access to fresh water is for people who live with water insecurity. Progressive balance must be practiced so that we can discover cleaner desalination technology. In this case the old saying of "do not throw out the baby with the bath water" makes sense even if the bath water polluted.

DESALINATION AND THE SDGs

While countries with access to primarily saltwater bodies embrace the advent of desalination for its ability to tackle the issue of scarcity, the impacts of this technology are questionable. To better understand the impacts of desalination processes on the environment, poverty, economics, and the quality of life felt by its constituents, this section will assess the relationships between several sustainable development goals. Through the perspective of the SDGs, it will be deduced that there are far greater negative impacts than positive. Here we focus on four SDGs:

- SDG 6 (Ensure availability and sustainable management of water and sanitation for all)
- SDG 7 (Clean energy)
- SDG 10 (Reduce inequality among and within countries)
- SDG 12 (Responsible production and consumption)

SDG 6 – Clean water and sanitation for all

In our view, the most relevant SDG towards the topic of desalination is SDG 6. While desalination offers a viable solution towards *increasing* the quantity of water received and used by a population, its sustainability and ability to uphold equity is suspect. Firstly, in areas where freshwater bodies exist, but are dredged or nearing the end of their lifecycle, desalination will be offered as a solution as opposed to encouraging populations to reduce their per-capita-water consumption (Badr, 2021). This unsustainable practice of providing a technocratic solution to problems often driven by human consumption is ignorant of the natural boundaries and limitations of withdrawing water from the earth. Through foreboding the process of encouraging and offering solutions to reduce water-consumption, a lifestyle of water-overconsumption among populations will persist. Secondly, in a study done by Jones et al., (2019) aimed towards

understanding the environmental consequences of desalination, it was concluded that the process of desalination is detrimental towards the environment. The wastage left behind from the filtration of salt-water, brine, and its disposal is costly and harmful to the environment it may be dumped in (Jones et al., 2019). Jones et al., (2019) calculated that 51.3 billion M^3 of Brine, or 50% more than the total amount of desalinated water, is produced. Brine disposal and management is costly, and instead countries resort towards dumping the waste back into its bodies of water (Jones et al., 2019) harming the wildlife that exists within the water. As a result of the significantly larger share of waste caused by desalination versus the amount of desalinated water produced, the *sustainability* of the desalination process is absent. Desalination plants are also responsible for poorer air qualities in cities, increases in noise pollution, and the damaging of marine biodiversity due to poor disposal methods (Moossa et al., 2022).

SDG 7 – Clean Energy

The massive energy consumption needed for desalination processes is unsustainable and may further degrade the environment. In the Middle East alone, despite desalination providing just 3% of the water supply, desalination processes contributed to 5% of total energy consumption in the region (Walton, 2019). Furthermore, desalination in the middle east is done using massive amounts of fossil fuels as they employ the fuel-based thermal desalination for their needs (Walton, 2019). The unsustainable energy consumption, paired with unsustainable disposal practices of the desalination processes are harmful towards the environment and are not sustainable.

SDG 10: Reduce inequality within and among countries.

Though desalination has been effective in providing formerly water-scarce regions with access to abundant water from salty seas, if managed incorrectly, the process of desalination and its provisioning may further reinforce inequities. In a case study by Ajami et al., (2020), the inequitable impacts felt by the Mexican border communities caused by the introduction of desalination are outlined. With the introduction of easily deployable desalination methods around the San Quintin Valley of Mexico, a large number of small-medium sized agricultural firms had begun operating and expanding their production (Ajami et al., 2020). As a result of the increased agricultural production, reliant on desalination, salt-water began to leak into the groundwater reserves the community had been previously reliant on (Ajami et al., 2020). The Mexican government had provided subsidies to the producers and attracted a population of Indigenous communities to migrate and work for the growing companies- reliant on desalinated water. However, the cost of water for the local communities had increased due to the transition away from groundwater withdrawal and towards desalinated water, placing the new migrants and already-established communities to incur increased financial hardships (Ajami et al., 2020). This serves as an effective example of the inequities which may occur if the growing reliance on desalinated water is not managed effectively.

SDG 12 - Responsible Consumption and production

The acceptance of desalination as a process to provide for human water-consumption needs is unsustainable towards the goal of reducing consumption and production. Furthermore, an indicator of SDG is as follows: *"Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production"* (United Nations, Department of Economic and Social Affairs). The advent and rapid adoption and reliance of desalination in nations with scarce access to water are not in line with

this indicator. A study by Moossa et al., (2022) on the water consumption patterns of Gulf-cooperation Council (GCC) nations, driven by desalination processes, supports this claim. Moossa et al., (2022) identifies, through the employment of a life-cycle analysis method, that the cumulative environmental degradation caused by the operations of a desalination plant far outweighs the benefits or amount of water received by a population. While there are other alternatives to desalination for the provisioning of water, desalination remains the most favored option of governments due to its low economic cost- this however is at the expense of long-term environmental impacts. Furthermore, the management of wastage is done poorly, but cheaply at the expense of environmental consequences (Moossa et al., 2022).

Due to the scarcity of freshwater reserves, countries in the Middle East have become dependent on desalination to provide for their water-consumption needs. The excessive reliance on desalination, an often easily deployable method of producing water for consumption, has created an illusion of abundance (Banat et al., 2021). As the residents are not in a position to perceive the negative consequences of desalination outlined in the sections above, they are detached from viewing their desalinated water as a scarce and environmentally exhaustive good (Banat et al., 2021).

Conclusions

Following from the above it is not easy to evaluate the net impact of desalination on sustainability. While desalination has several positive impacts on society, the environment, and the economy, it also has significant negative impacts that should be considered. Perhaps, the most significant benefit of desalination is that it provides a reliable source of freshwater that is not subject to fluctuations in weather patterns. Desalination is an especially critical water source in arid regions, where rainfall is limited, and freshwater resources are scarce (Shafi et al., 2019). The availability of a reliable and constant supply of freshwater enables communities to develop and thrive, reducing the impact of water scarcity on agriculture, industry, and daily life.

Desalination also has a positive impact on the environment by reducing the reliance on groundwater sources, which can be depleted or contaminated. Consequently, desalination reduces the pressure on freshwater ecosystems and preserves them for future generations. The use of desalinated water can also reduce the demand for energy-intensive water transportation, which can have a significant carbon footprint (Global Water Intelligence, 2018). In addition to its environmental benefits, desalination also has economic advantages. The use of desalinated water can support the growth of industries that require a reliable source of freshwater, such as agriculture, manufacturing, and tourism. Desalination can provide an opportunity for economic growth by creating jobs in the desalination industry and related sectors (IDA, n.d.). However, desalination has serious negative impacts too especially in context of the UN sustainable development goals (SDGs). The biggest among these is the negative impact marine ecosystems. The high concentration of salt in the brine, which is released back into the ocean after the process, can have negative effects on marine life and ecosystems (Global Water Forum, 2018).

Additionally, desalination can have a negative impact on SDG 7, which aims to ensure access to affordable, dependable, sustainable, and modern energy for all. Desalination is an energy-intensive process that requires copious amounts of electricity to operate, so directly impacting SDG 13 (Climate Change) as well. In some regions, the cost of energy required for desalination is too high, making it unaffordable for low-income communities (World Bank, 2019). This can create an energy equity issue, where wealthier communities have access to clean drinking water, while low-income communities do not (SDG 10). Desalination can also have a negative

impact on SDG 6, which aims to ensure availability and sustainable management of water and sanitation for all. While desalination can provide a reliable source of freshwater, it is often costly and may not be financially viable for all communities. In some cases, alternative solutions such as rainwater harvesting, or wastewater recycling may be more sustainable and affordable (Global Water Forum, 2018).

In conclusion, while desalination offers several positive impacts on society, the environment, and the economy, it also has some negative impacts on the SDGs. Desalination has the potential to harm marine ecosystems, can create an energy equity issue, may not be financially viable for all communities, and requires copious amounts of energy that contribute to greenhouse gas emissions. Alternative solutions should be explored to ensure that the benefits of desalination are balanced against.

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