Regional Programme
Energy Security and Climate Change
Middle East and North Africa

KONRAD ADENAUER STIFTUNG

Desalination and Its Impact on the Mediterranean Ecosystem

Bdredin Suliman, Hussam Hussein, Salma Daoudi

KAS-REMENA Policy Paper Series No. 1 / 2024

kas.de/remena

Executive Summary

Desalination plants have seen significant growth throughout the world due to their capacity to meet growing needs for freshwater. Desalination has also been recognized as a vital resource in regions facing water shortages, mainly arid coastal regions, and islands. Given the demographic and environmental challenges associated with unequal and insufficient distribution of water resources in the Mediterranean region, the latter has emerged as a key hub for the utilization of desalination processes and strategies. By diversifying water sources and lowering dependency on conventional sources like rivers and aquifers, it has been argued that this technology may bring positive impacts on society. Desalination has also contributed to economic growth, enabling the tourism, industrial, and agricultural sectors to thrive in previously water-stressed areas. However, the expansion of desalination has not been without challenges.

High energy consumption, environmental concerns, including disposal of concentrated brine back into the sea are some of the issues that require careful management. Desalination processes' energy consumption currently leads to a high dependence on fossil fuels and contributes to greenhouse gas emissions. While advancements in desalination technology, including reverse osmosis and renewable energy integration, are continuously improving efficiency, reducing costs, and minimizing environmental impact, such as impacts on fishing activities, coastal tourism, etc, they have yet to fully mitigate these challenges. Managing water supply strategies of Mediterranean countries, including the role of regional cooperation, is a key point to reduce desalination's environmental impacts.

Introduction

The process of purifying brackish or seawater by removing salt and pollutants, called desalination, has become a key technical response to the water scarcity challenge in arid and semi-arid regions. Desalination has emerged as a significant technical solution to provide a source of freshwater in regions where such resources are limited, and hence increase the availability of clean potable water, for either drinking, agricultural, or industrial purposes. There are two major technologies used within this framework: membrane desalination and thermal desalination. The first technique uses a specific membrane filter to generate desalinated water, whereas the second boils or evaporates seawater to produce water vapor that, when condensed, produces liquid water that is salt-free.

In the middle of the 20th century, large-scale desalination for the production of drinkable water began. The Key West Desalination Plant in Florida, USA, which started operating in 1957, was the first sizable desalination facility built employing thermal-based distillation. Desalination has since acquired recognition as a viable solution to the problem of water scarcity in arid and water-stressed areas. Table 1 below lists some of the largest desalination facilities worldwide, showing an important concentration of the largest desalination plants in the Middle East, where the top 10 desalination facilities are located.

Table 1: The 10 biggest desalination plants worldwide (Aquatech, 2021)

	Country	Desalination Plant	Capacity (m^3/day)
	Saudi Arabia	Ras Al Khair	1,036,000
2	United Arab Emirates	Taweelah	909,200
	Saudi Arabia	Shuaiba 3	880,000

4	Saudi Arabia	Jubail Water and Power Company (JWAP)	800,000
	United Arab Emirates	Umm Al Quwain	682,900
6	United Arab Emirates	DEWA Station M Dubai	636,000
	Israel	Sorek	624,000
8	Saudi Arabia	Jubail 3A IWP	600,000
	Israel	Sorek 2	570,000
10	United Arab Emirates	Fujairah 2	591,000

The expansion of desalination has not been without challenges. High energy consumption, environmental concerns, and the disposal of concentrated brine back into the sea are some of the issues that require careful management. Indeed, desalination produces brine, which is a byproduct that includes concentrated salts and other compounds and stands as an energy intensive process as reverse osmosis and thermal distillation technologies must meet high-pressure requirements. Nevertheless, advancements in desalination technology, including reverse osmosis and renewable energy integration, are continuously improving efficiency, reducing costs, and minimizing environmental impact.

In the Mediterranean region, characterized by a diverse range of countries and climates, freshwater supplies are scarce and water demands are high. As such, desalination has been adopted to help alleviate water scarcity, particularly in coastal areas where freshwater resources are limited, as shown in Figure 1. There are numerous desalination plants located throughout the Mediterranean region's diverse countries. Spain, Italy, Israel, Cyprus, Algeria, and Malta are some of the countries with sizable desalination capacity.

Desalination in the Mediterranean

The Regional Context of Water Scarcity

Suffering from a heightened vulnerability to climate change and its repercussions on socio-economic and political stability, the Mediterranean basin is projected to experience a significant decrease of freshwater supply and water stress over the next decades. The region's water demand is expected to double or even triple by 2050 (UNEP, 2023). The situation is particularly pressing in the Middle East and North Africa, where high levels of expected population growth exceed current capacity to meet rising water demand. Water scarcity in the region, compounded by severe droughts, food crises, and internal displacement, has been the source of disputes and conflicts at both the inter and intra-state levels. The lack of regional cooperation on water issues and the nationalization of projects, including dams, has stifled the potential of the Middle East and North Africa to reduce the risks of water stress and conflict (Selim, 2021).

However, Mediterranean Europe also grapples with shrinking water supplies and rising demand, calling into question the sustainability of conventional water resources (Barker, 2002). Spain, for instance, has experienced significant prolonged periods of drought over the last decades, leading to the shrinking of available water resources in river basins. Estimates from the Ministry of Ecological Transition (2021) reveal that 74% of the country is vulnerable to desertification, a risk that weighs on about 20% of the entire European territory.

Desalination Activities to Meet Water Demand

The subsequent imbalance between demand and supply stemming from these vulnerabilities across the Mediterranean region has prompted states to reassess their water policies and envision new solutions and technologies to alleviate water scarcity vulnerabilities (de Waal et al., 2023). This has rendered desalination an essential component of the region's water supply portfolio, prioritizing the immediate response to water needs and sometimes overlooking the economic and environmental costs associated with this particular technology. There are over 21,000 desalination plants worldwide, a large concentration of which operate in Africa, the Middle East, and Southern Europe (IFRI, 2022). The Mediterranean region boasts one of the highest concentrations of desalination plants in the world, with countries like Spain leading in desalination capacity. Spain has about 800 desalination plants with a production capacity of 5 million m3, most of which is used for drinking, agricultural, and industrial purposes (Wilson, 2023), and is considered to be a pioneer in the process of water desalination, both regionally and internationally. Similarly, Malta, as a small island nation lacking renewable water resources, is one of the few states able to produce more desalination water than what is withdrawn for human use (Jones et al., 2019). Generally, European Mediterranean countries are not only well integrated in the desalination market, but they are also rapidly expanding their shares in the regional desalination market. The latter stands as both extremely competitive and strategic, given the diminishing supply and security of traditional water resources and management policy options. Due to its vast potential, but limiting high-capital intensity, the industry is still concentrated in the hands of a few firms strategically positioned to maximize efficiency and output capacities. Veolia and Engie, two French companies, emerge for instance as strategic actors in desalination, covering parts of the Middle East and Africa's desalination industries (IFRI, 2022).

North African and Arab Mediterranean countries are indeed home to not only the largest desalination plants, but also to major desalination project plans. The industry continues to expand, with countries such as Morocco and Egypt, planning to significantly expand their desalination capacity in the few coming years. The Egypt 2030 Strategy includes the launch of at least 142 desalination plants, with the aim of reaching a capacity of 6.4 million m3/day in 2050 (IFRI, 2022). A new flagship project is also expected to launch in Jordan by 2028. The Aqaba-Amman Water Desalination and Conveyance Project aims to extract water from the southern part of the Red Sea at the Gulf of Aqaba to undergo desalination treatment before being transported to the city of Amman and its nearby regions. It is estimated the project will supply about 300 million m3 of water annually to address and relieve water scarcity (European Investment Bank, 2023).

Challenges amidst Opportunities

While the process of desalination has helped bolster local and national water production capacities, significant ecological, economic, and political obstacles are hampering its sustainability. In fact, desalination comes with large technical infrastructural projects, making them less sustainable and adaptable to future changes, and resulting in technical solutions – increase of water supply in the system – often disincentivizing demand management solutions (Shannon, et al., 2008). Moreover, desalination plants require substantial initial financial capital, require significant resources for construction and maintenance, and can lead to habitat disruption and directly impact local ecosystems (Le Quesne et al., 2021).

Furthermore, desalination requires high amounts of energy, a resource that is expensive in the Mediterranean region, which generally relies on energy imports (with some exception for energy rich countries such as Algeria, Egypt, and Israel), and therefore subject to market fluctuations and geopolitical tensions disrupting supply chains, despite attempts to transition to renewable energy sources, a process that also requires costly initial investments and costs. Accounting for the high energy consumption of desalination demonstrates that desalinated water is more costly than other water sources. The region's energy demand and carbon emissions are influenced by the high energy needs of desalination operations. For the generation of power, the Mediterranean region mainly relies on fossil fuels like natural gas and oil, which increases greenhouse gas emissions.

These issues have been further compounded by the lack of regional cooperation frameworks to establish joint industrial and production projects, especially in the Middle East and North Africa where concerns over the water and energy sector are enmeshed in geopolitical and local socio-economic tensions. Additionally, instability in major countries in the region such as Libya, Syria, and the Israeli-Palestinian conflict, have disrupted the development of large-scale desalination projects on the Mediterranean coast and raised concerns about the water inequities that could result from technology monopolies, all while also limiting opportunities for shared energy projects. Besides, escalation of geopolitical tensions translates in rising infrastructural vulnerabilities, with most countries fearing threats directed towards their desalination infrastructure. Oil spillage or nuclear waste could for instance represent severe risks unintentionally jeopardizing water supplies, while direct sabotage, attacks, or shelling from external powers would intentionally trigger large-scale humanitarian and water crises (Bulloch & Sarwish, 1996). This also pertains to possible renewable energy sources and plants, vulnerable to changing geopolitical dynamics.

The energy sources dedicated to desalination are therefore not only economically relatively expensive compared to conventional water sources, but they also have a higher carbon footprint. Indeed, in addition to the economic costs and challenges mentioned above, the Mediterranean region also faces environmental challenges associated with desalination. The discharge of brine into the sea can have adverse effects on marine ecosystems. The extensive usage of desalination requires sizeable energy resources, which raises carbon emissions, and the release of brine back into fragile marine ecosystem may have negative ecological effects (Sharifinia et al., 2019). Desalination facilities discharge concentrated brine streams that are heavy in salt and other chemicals that were extracted during the desalination process. When brine is released back into the ocean, or the sea the surrounding flora and fauna are disrupted and salinity levels rise, with negative externalities for marine ecosystems. One of the essential impacts of desalination as observed in the Arab Gulf for instance, is marine pollution, whereby "building desalination plants, up-taking seawater, and discharging untreated brine back into the sea adversely affects the biodiversity of the marine ecosystems" (Hosseini et al., 2021, 1).

Desalination can also negatively impact the fish population in the Mediterranean in different ways. During the seawater intake process for desalination, fish and other marine species may be captured or impacted; fish populations may be harmed or killed as a result. Chemicals employed in the desalination process may be released, increasing the risk of harm to marine life; in fact, "the fishing pressure in the Mediterranean Sea shows a fishing mortality rate that is on average 5 times higher than the target and for some specific stocks, up to 12 times higher than the biologically sustainable level" (The Blue Economy in the Mediterranean, 32). The feeding and spawning habits of fish may also be impacted by changes in water flow and salinity brought on by desalination facilities, which may have an effect on the distribution and catch rates of targeted species. Finally, desalination facilities frequently draw seawater from coastal regions where fishing takes place, resulting in less seawater being available for fishing-related uses like cleaning, storing, and maintaining boats.

Continuous research and environmental monitoring are essential to reduce the detrimental effects of desalination (Shenker et al., 2020). Desalination technology and process advancements can also result in less energy being consumed and more effective water production (Tal et al., 2019). In this way, it has been argued that desalination can maintain sustainable water management, protecting water resources and ecosystems for future generations, by continuously enhancing desalination techniques. It is also worth noting that the concentration of desalination capacities in wealthiest countries and the leading role played by limited strategic industrial actors translates severe disparities in the ability to sustainably respond to pressing water needs equally. The high initial investment costs required to build the plants and the high energy costs incurred by the desalination process itself, stand as stark obstacles to the weaker economies in the Mediterranean attempting to relieve water shortages.

Policy Implications and Recommendations

While desalination has been considered as a viable solution to address the challenge of water scarcity in arid and semi-arid regions such as the Mediterranean, it comes also with environmental externalities, as shown above. In order to mitigate such externalities, the following measures can be adopted:

- ***Promote international cooperation frameworks and agreements:*** Since desalination plants represent a capital-intensive investment, international financial and economic cooperation can enhance the economic viability of these projects and improve their efficiency. International agreements can also promote the exchange of technology and knowledge, thereby accelerating technological advancements and contributing to the establishment of shared best practices. Finally, environmental regulatory frameworks are needed to establish and enforce proper regulations to mitigate the environmental externalities of desalination and their impacts on local, regional, and international ecosystems.

- ***Strengthen regional cooperation:*** Cooperation between Mediterranean countries can result in the creation of standardized plans, ideal procedures, and laws for sustainable desalination. Some existing frameworks provide a foundation for tackling common issues including the sustainable management of water resources and the mitigation of the negative effects of desalination and have been effective in providing a platform for policy makers from the Mediterranean region to meet and discuss, share best practices, and empower youth from the region, as well as on science diplomacy (Elistania et al., 2019). One of these existing frameworks that could be further strengthened and built upon, is the Regional Marine Pollution Emergency Response Center for the Mediterranean Sea (REMPEC) that was established in 1976 by the Barcelona Convention for the Marine Environment and the Coastal Region of the Mediterranean and the Mediterranean Action Plan (MAP), the first regional program of the United Nations Environment Program. It provides a precise understanding of the state of the Mediterranean marine and coastal environment while emphasizing the need for cooperation to address challenges faced by the Mediterranean, including desalination plants' impacts. REMPEC has been effective in organizing capacity building trainings, national and regional workshops, and best practices across the Mediterranean region.

- ***Promote sustainable water management:*** The proper management of already available water resources must be prioritized, with a focus on water demand management at the national and local levels. This entails promoting national strategies focused on the sustainability of water resources, effective water usage technology, water conservation practices, and spreading knowledge about sensible water consumption among people and businesses. Measures should also be implemented to ensure an equitable access to clean and reliable water sources, by reducing access disparities and ensuring vulnerable communities are not marginalized.

- ***Strengthen environmental impact assessments (EIA):*** Continuous assessment of biological indicators, marine ecosystems, and water quality can help to identify future problems and guide adaptive management measures (Zhang et al., 2020; Soliman etal., 2022). EIA helps determine potential environmental consequences and risks related to desalination projects. This evaluation considers variables like water intake and output, energy use, and any potential effects on marine ecosystems (Khan et al., 2016). While EIAs are been used in the Mediterranean region, we must ensure that their results are always seriously being taken into account to adapt to current strategies and upcoming plans for new desalination projects.

- ***Implement effective brine disposal management:*** Monitoring and modeling strategies, along with dilution and dispersion measures, can assist to reduce the effects of brine flow on coastal areas (Zubair et al., 2021). In order to reduce the impact of desalination on marine life, diffusers for brine discharge and proper intake systems could be used (Siddiqui et al., 2019; Ghribi, 2023).

- ***Invest in technological innovation:*** Supporting research and development to improve desalination procedures could help make them more environmentally friendly and mitigate related challenges and concerns. This would also warrant encouraging collaborations between researchers, decision-makers, and industry experts. Technology breakthroughs should be supported in order to improve desalination procedures, with an emphasis on developments that boost productivity and minimize environmental impacts. Desalination will become a more accessible and financially viable alternative if research and development are funded to reduce its costs and energy requirements (Qadir et al., 2021). An example would be for instance promoting rainwater harvesting: In this method, rainwater is collected and stored for use in non-potable household applications or irrigation. During dry spells, it can ease the strain on freshwater resources and act as a backup water source. (Aladenola et al., 2021).

About the authors

Bdredin Suliman is currently majoring in Politics and International Relations studies at Sciences Po Paris, with a focus on the Mediterranean, Middle East and North Africa geopolitics. He expanded his perspective during an exchange year at Tokyo University of Foreign Studies in Japan, exploring International and Area Studies. His studies are complemented by hands-on experience, including internships at a city town focusing on international relations and education. Additionally, he dedicates time to tutoring students across various disciplines – languages, history, and more – in diverse school settings. Inspired by this, he is set to pursue a Master's in Diplomacy and Global Governance, driven by a passion for understanding global dynamics and contributing to diplomatic solutions.

Dr Hussam Hussein is the Executive Director of Partnerships for Development at the Royal Scientific Society (RSS) of Jordan, and a Research Associate in Water Diplomacy at the University of Oxford. His research focuses on the role of discourses in shaping water policies in the Middle East, on transboundary water governance and critical hydropolitics, and on issues related to the political economy of water. Before joining RSS, Dr Hussein worked as a Lecturer in International Relations at the University of Oxford, at the World Bank as a private sector development analyst, and at the European Parliament. He holds a PhD in international development from the University of East Anglia, studied Diplomacy and International Relations at the University of Trieste (Gorizia), Middle Eastern studies at SOAS - University of London, and European Interdisciplinary Studies at the College of Europe.

Salma Daoudi is a researcher and Dphil candidate in International Relations at the University of Oxford, specializing in international security and global health, with a regional focus on the Middle East and North Africa. Her research primarily revolves around the weaponization of health, water, and humanitarian aid in Syria, refugee access to healthcare, and the consequences of political violence on health. She has previously worked as a researcher and policy analyst, focusing predominantly on human security in asymmetric warfare, the security-development nexus, and more broadly MENA geopolitics. Salma has graduated in International Studies from Al Akhawayn University, Morocco, and in International Relations and Politics from the University of Cambridge, United Kingdom, as a Gates Cambridge Scholar.

References

Aquatech. (2021). Does size matter? Meet ten of the world's largest desalination plants. Retrieved from https://www.aquatechtrade.com/news/desalination/worlds-largest-desalination-plants

Aladenola, O. O., Adekola, O., & Ogunjuyigbe, A. S. O. (2021). Rainwater harvesting techniques and their potential for water supply augmentation in arid and semi-arid regions: A review. Journal of Water Process Engineering, 39, 101835. DOI: 10.1016/j.jwpe.2020.101835

Arab News (2020), Why thirsty Arab region needs sustainable desalination tech.

Bulloch, J., & Darwish, A. (1996). Water wars: Coming conflicts in the Middle East. Gollancz.

Barker, M. (2002). Desalination activity rising on Mediterranean coast. Retrieved from https://www.waterworld.com/wastewater/article/16201227/desalination-activity-rising-on-mediterranean-coast

de Waal, D., Khemani, S., Barone, A., & Borgomeo, E. (2023). The Economics of Water Scarcity in the Middle East and North Africa: Institutional Solutions. World Bank Publications.

Djoher, A. (2020). Desalination Projects in Algeria : What Are the Environmental and Economic Issues of Seawater Desalination. Environment and Ecology Research, 59-69. DOI: 10.13189/eer.2020.080301

Dosoretz C. G., et al. (2018). Environmental Implications of Seawater Desalination: The Israeli Experience. Environmental Science & Technology, 52(7), 3479-3486.

Elistania, E., Nurmeiga, F., & Permadi, A. (2019). Strategy To Strengthen Cooperation Between The European Union And The Mediterranean Countries Through The Union For Mediterranean (UfM). Global: Jurnal Politik Internasional, 21(2), 242-261.

European Investment Bank. (2023). Quenching Jordan's thirst. Retrieved from https://www.eib.org/en/stories/aqaba-amman-water-desalination-jordan

Ghribi, M. (2023). The role of science diplomacy in strengthening cooperation between the two shores of the Mediterranean.

Hosseini, H., Saadaoui, I., Moheimani, N., Al Saidi, M., Al Jamali, F., Al Jabri, H., Ben Hamadou, R. (2021).Marine health of the Arabian Gulf: Drivers of pollution and assessment approached focusing on desalination activities. Science Direct, Marine Pollution Bulletin 164.

Ibrahim, H.D., Eltahir, E. A. B. (2019). Impact of brine discharge from seawater desalination plants on Persian/Arabian Gulf salinity.

IFRI. (2022). The Geopolitics of Seawater Desalination. Retrieved from https://www.ifri.org/en/publications/etudes-de-lifri/geopolitics-seawater-desalination

Jones, E., Qadir, M., van Vliet, 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

Le Quesne, W. J. F., Fernand, L., Ali, T. S., Andres, O., Antonpoulou, M., Burt, J. A., Dougherty, W. W., Edson, P. J., El Kharraz, J., Glavan, J., Mamiit, R. J., Reid, K. D., Sajwani, A., & Sheahan, D. (2021). Is the development of desalination compatible with sustainable development of the Arabian Gulf? Marine Pollution Bulletin, 173, 112940. https://doi.org/10.1016/j.marpolbul.2021.112940

Ministry of Ecological Transition. (2021). Climate change adaptation plan 2021-2030.

Qadir, M., Wichelns, D., Raschid-Sally, L., & McCornick, P. G. (2020). Water management in agrarian societies: An introduction. In Water management, agriculture and the environment in a changing world (pp. 1-16). Routledge. DOI: 10.4324/9780429277779-1

Selim, A. (2021). Regional Water Cooperation in the Middle East and North Africa: Transitioning from Conflict to Stability. Retrieved from https://www.washingtoninstitute.org/policy-analysis/regional-water-cooperation-middle-east-and-north-africa-transitioning-conflict

Semiat R. (2017). Energy Issues in Desalination Processes. Environmental Science & Technology, 51(5), 2452-2461.

Shannon, M. A., et al. (2008). Science and technology for water purification in the coming decades. Nature, 452, 301-310.

Sharifinia, M., Afshari Bahmanbeigloo, Z., Smith, W.O., Yap, C.K., Keshavarzifard, M. (2019) Prevention is better than cure: Persian Gulf biodiversity vulnerability to the impacts of desalination plants.

Shenker M., et al. (2020). Brine Disposal from Seawater Desalination Plants: A Review. Desalination, 477, 114235.

Siddiqui, A., Kaci, M., & Al-Yamani, F. (2109). Impacts of seawater desalination on marine organisms: A critical review. Environmental Science and Pollution Research, 26(6), 5139-5153. DOI: 10.1007/s11356-018-3977-2

Soliman, M. N., Guen, F. Z., Ahmed, S. A., Saleem, H., & Zaidi, S. J. (2022). Environmental Impact Assessment of Desalination Plants in the Gulf Region. In Water-Energy-Nexus in the Ecological Transition: Natural-Based Solutions, Advanced Technologies and Best Practices for Environmental Sustainability (pp. 173-177). Cham: Springer International Publishing.

Tal A., et al. (2019). Energy implications of seawater desalination in Israel. Applied Energy, 242, 1487-1498.

The Blue Economy in the Mediterranean (2017), Union for the Mediterranean

UN-Water. (2013). Water cooperation for a water-secure world. United Nations. Retrieved from https://www.unwater.org/publications/water-cooperation-for-a-water-secure-world/

UNEP. (2023). Climate change in the Mediterranean. Retrieved from https://www.unep.org/unepmap/resources/factsheets/climate-change

Wilson, J. (2023). Drought-struck Barcelona quenches thirst with costly desalination. Retrieved from https://www.independent.co.uk/news/spain-ap-barcelona-water-europe-b2347563.html

Zhang, C., Lin, J., & Hong, H. (2020). Impacts of seawater desalination on coastal ecosystems: A review. Environmental Science and Pollution Research, 27(2), 1059-1074. DOI: 10.1007/s11356-019-06320-2

Zubair, S.M., Linares-Rueda, A., & Al-Rasheed, M. (2021). Desalination brine management in coastal areas: Review and recommendations. Science of the Total Environment, 763, 144081. DOI: 10.1016/j.scitotenv.2020.144081

Konrad-Adenauer-Stiftung e. V.
Regional Programme Energy Security and Climate Change
Middle East and North Africa (KAS-REMENA)

Veronika Ertl
Director
veronika.ertl@kas.de

kas.de/remena