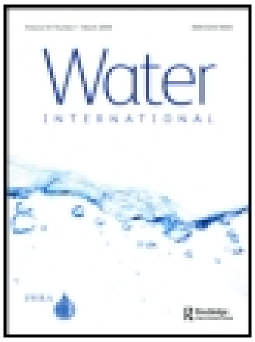

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VIEWPOINT

The challenges of reverse osmosis desalination: solutions in Jordan

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ABSTRACT
Desalinating water through reverse osmosis is becoming more economically affordable. Identifying the challenges in adopting desalination technology may help countries address water security concerns. In this article, we examine these challenges and present some of the solutions implemented in the Kingdom of Jordan, such as the creation of a cooperative water project to reduce financial investment and transportation costs and the coupling of renewable energy to desalination technology. Reverse osmosis desalination can play a role in promoting regional cooperation.

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Introduction

Economic growth and climate change are putting increasing pressure on freshwater sources (Beisheim, 2013). Seawater desalination, as an alternative to conventional sources, offers a chance to relieve this pressure and meet rising water demands. By 2040, according to the International Energy Agency (IEA, 2017), desalination will be 13 times more developed than in 2014. The technology is expected to change the fate of countries facing water scarcity, especially where the economy is growing dependent on water, such as the Kingdom of Jordan, whose case will be discussed in this article. Desalination has seen its costs decrease with the introduction of new methods and new sources of energy. Technologies such as membrane desalination with reverse osmosis (RO) are becoming more affordable, and more efficient regarding energy consumption. Most methods, including thermal and RO, are powered by oil or natural gas, with high energy costs (4–8 kWh/m^3 for the former and 3.5–5 kWh/m^3 for the latter; World Bank, 2012). In the Middle East and North Africa, a region with unequal access to large sources of hydrocarbons, some countries, especially the Gulf countries, are able to use these sources to power large-scale desalination plants (Greenlee, Lawler, Freeman, Marrot, & Moulin, 2009; International Renewable Energy Agency [IRENA], 2012). The region's high sun exposure and wide-open desert spaces make it suitable for solar-powered desalination plants. Until now, this alternative to fossil fuel sources remains expensive, even though technological progress is being made to reduce costs. But cost reductions for membrane-based desalination are also progressing, meaning that fossil-fuel power is likely to remain the first option in the short

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term (IEA, 2017). Until recently, most of desalination plants have been located where energy is available in significant amounts and at a very low price, with only 1% of desalinated water powered by renewable energy (IRENA, 2012). But renewables are a growing power alternative for energy-importing countries such as India and China, where the demand for desalination is on the rise (IRENA, 2012).

Two main techniques for water desalination are currently commercially viable. Thermal desalination uses heat to vaporize freshwater. Membrane desalination uses high pressure to separate freshwater from seawater or brackish water through a membrane. Today, the dominant desalination processes in use worldwide are based on RO (membrane technology) and multi-stage flash techniques (thermal technology) (IRENA, 2012). The feasibility of each depends on specific conditions such as water quality and type, energy cost, and the technical resources of the country or the region (Amer, Adeel, Böer, & Saleh, 2017; IRENA, 2012). Only RO will be discussed in this article, as thermal desalination techniques are mostly used in the Gulf countries and do not apply to Jordan.

This study identifies the financial and environmental challenges RO desalination can face, as well as the existing strategies. Considering this, we then review the recent progress in membrane desalination in the Kingdom of Jordan by examining the and the proposed Red Sea–Dead Sea Canal of Israel and the Palestinian Authority. Desalination on any scale is a turning point in the water sector, as it creates new sources of water and therefore more flexibility in countries where economic development often means increasing water consumption.

Reverse osmosis desalination: state of the art

Global context of reverse osmosis desalination use

As of 2019, RO technology is the most widely used technique worldwide, accounting for more than half of global desalination capacity. However, implementing the technology on a scale large enough to meet growing water needs is not possible everywhere. Despite its lower energy consumption than thermal techniques, building RO desalination plants still requires substantial financial investments. Small desalination plants, sometimes at a very local level, can help provide water to a few households or a community. Local initiatives with renewable-energy-powered desalination plants are blooming in countries such as India and Brazil (Gabbrielli, 2017). Rural areas or islands, where there is no other water supply, are also turning to small-scale RO desalination. For example, many of the desalination plants in the Caribbean area use RO systems (Caribbean Environmental Health Institute, 2006). Medium-scale desalination facilities are also being used at a regional or municipal level in countries such as Jordan and Egypt to provide new sources of water to cities and regions. Large-scale desalination is still mostly used in developed countries which are able to bear the costs. In Israel, a pioneer in RO desalination, more than half of municipal water supply is from desalination. Such large-scale plants can be built in developing countries with the help of international funds, as in Jordan, with the proposed Red Sea–Dead Sea Canal (RSDSC) analyzed in this article. Along with the increase in RO desalination, a rise in the use of renewable energy to power desalination plants has been observed. Solar

Table 1. Financial and environmental challenges faced by reverse osmosis desalination.

Financial challenges	Construction: plant size Operation: type of feed water; energy source; plant size Maintenance
Environmental challenges	Brine CO_2 emissions

energy use is expanding, especially in arid and semi-arid regions. In the Middle East and North Africa, for example, the potential energy per square kilometre from solar radiation is equivalent to the energy produced by 1–2 million barrels of oil (World Bank, 2012).

Challenges

Despite its rising utilization, desalination by RO is facing financial and environmental challenges (Table 1). The environmental challenges are likely to increase in number and diversity as this technology spreads. The nature of these challenges can vary by country and by characteristics of the feed water. They can also vary over time.

Financial challenges

Due to the high financial capital required to build the facilities, the construction and operation of desalination facilities represent one of the main challenges. In 2008, a review of water desalination cost literature established three different elements varying the cost (in $\$/m^3$) of desalinated water: the type of feed water (seawater or brackish), the energy source, and the plant size (Professor David Katz, personal communication, Haifa University, July 2017; Karagiannis & Soldatos, 2008). Of the three, the energy cost has the largest influence on the cost of desalinating water. Therefore, the economic feasibility of building a desalination plant depends on the local availability or the energy cost (Zejli, Bouhelal, Benchrifa, & Bennouna, 2002). When comparing the costs of desalination using the different technologies, one must use similar local conditions. Regarding the type of feed water, the investment cost per unit of production capacity is higher for seawater RO facilities than for brackish water RO facilities. Desalinating the less salty brackish water takes less energy than desalinating seawater. Some countries are therefore more inclined to desalinate brackish water, for example the Palestinian Authority (Katz, personal communication, July 2017). On the other hand, brackish water is limited, unlike seawater, which in practical terms is unlimited. Thus, for the long term, desalination from seawater may be a more secure investment.

Some site-specific aspects also affect the cost of desalination, such as plant size, feed-water transportation to the plant, freshwater delivery, and brine disposal (IRENA, 2012). Regarding operation and maintenance costs, a study directed by Al-Karaghouli and Kazmerski (2011) showed that RO desalination plants have higher maintenance and operation costs than multi-stage flash desalination plants, but thermal desalination plants have higher capital costs. Conducted in 2011, the study estimated investment costs for a new desalination plant at between USD 800 and USD 1500 per unit of capacity (m^3/d). While the costs can vary considerably depending on local conditions such as interest rates, material prices and labour cost, Al-Karaghouli and Kazmerski estimated the yearly average operation and maintenance costs at about 2–2.5% of the investment. Despite significant reductions in the overall desalination costs over the past years, only high- and middle-income countries can afford large-scale desalination technology; it remains too expensive for most low-income countries. In average conditions, the typical production cost of conventional desalination facilities powered by fossil fuels is USD 1–2/m^3 in average conditions, and around USD 0.5/m^3 under favourable conditions (Moilanen & Mroueh, 2010).

Environmental challenges

Even if the urgent need for non-conventional solutions has been acknowledged, the high energy consumption and related CO_2 emissions of desalination keep certain experts from advocating the technology. Membrane desalination is presented by its advocates as consuming less energy than thermal desalination. In some countries, membrane desalination plants are powered by natural gas, which produces only 20% of the CO_2 emissions, compared to coal power plants (Tenne, 2010). RO desalination still faces multiple environmental challenges, such as energy consumption and brine disposal. But steps can be taken to reduce its environmental footprint. For example, energy consumption can be reduced by reusing waste heat or by keeping the membranes clean (to reduce the pressure needed to push water through them). Regarding brine disposal, discussions are ongoing in the scientific and political fields. For now, the brine is mostly discharged into the sea or diluted into open spaces, which raises ecosystem concerns. Some desalination companies offer chemical-free desalination, which means there is minimal impact (D'Souza, 2017). Increasing desalination capacity will require sustainable solutions for brine recycling and disposal to avoid further environmental degradation (Gude, Nirmalakhandanb, & Deng, 2010).

Desalination strategies

Though solutions are very country-specific, we take a closer look at several financial and environmental strategies, which are summarized in Table 2. Only strategies relevant to desalination in Jordan are reviewed in this section.

Financial strategies

International funding sources

As mentioned, the building, operating and maintaining of large-scale desalination plants is a costly operation which low- and middle-income countries often cannot afford. In some cases, external actors can play a role in developing desalination capacity in these countries. Consolidating peace or political stability is an important driver of such involvement. International funding can take multiple forms. External financial can help towards the construction of the plant itself, through financial donations, such as

Table 2. Categories of strategies to reduce the financial and environmental costs of desalination.

Financial strategies	International plants (construction, operation, maintenance) International funding (construction, operation, maintenance)
Environmental strategies	Renewable energies alternatives (operation)

the EU funding of the Southern Gaza plant. This facility, despite issues in the provision of electricity to power the plant, currently provides safe, clean drinking water for 75,000 inhabitants of Gaza. Plans for another large-scale desalination plant, together with the appropriate supply and distribution infrastructure, have been confirmed by all major stakeholders, including the European Commission, the European Investment Bank, the Islamic Development Bank and the World Bank. This second desalination facility should stabilize the costal aquifer and secure its water supply (State of Palestine Authority, 2018). Loans are also a possible way of financing a project, as with the Kuwait Fund's financing of four desalination plants in Egypt. Financial contributions can also fund a feasibility study, as did the World Bank for the RSDSC. The project aims at enhancing interdependence and cooperation in the region, as well as saving the Dead Sea and improving stability in the Kingdom of Jordan. In summary, the types of external actors involved in financial strategies to develop desalination can vary.

Binational desalination opportunities

Binational desalination plants are an increasing solution for riparian actors. These facilities reduce the cost of desalination systems. They also increase the interdependence and cooperation between actors, and they help overcome environmental regulations which might be stricter in one country than in another. In this context, states share the construction, operation and maintenance costs of the desalination technology, which is essential in the water supply strategy of multiple water-scarce countries. For instance, Mexico and the US have turned to desalination as part of their water security strategy. One of the solutions to these common water challenges is the development of binational desalination systems (Wilder et al., 2016). These facilities could increase water supply and benefit people, especially the major populations centres which are on the US side. The water would be desalinated in Mexico, but most of it would be transported across the North American border. Still, in spite of the need for new water supply, critical environmental concerns exist regarding desalination, and economic and environmental consequences may interrelate in other ways in these transboundary settings (Wilder et al., 2016). Therefore, as the aim of these binational plants is to reduce the cost of technological issues in seawater desalination, their implementation requires taking into account the numerous non-technological attributes of desalination facilities, including environmental, social, legal, financial, institutional and political aspects.

Environmental strategies

Alternative energy sources

Coupling renewable energy sources with RO desalination facilities is an expanding technique. The use of alternative sources of energy has made membrane technology more cost-competitive, more environmental friendly and more efficient, raising great interest in further development (Lenntech, 2015). Its use for desalination, such as off-grid solar photovoltaic, grid-connected wind turbines and solar water heating, has turned into an attractive solution (Kalogirou, 2005). Given the high energy consumption of saline feed-water, the combination of photovoltaic with RO (PV-RO) is considered one of the most promising technologies (Thomson & Infield, 2002), especially in small-scale facilities where other technologies are less competitive (Herold, Horstmann, Neskakis, &

Plettner-Marliani, 1998; Herold & Neskakis, 2001). PV-RO systems for brackish water desalination are also on the market (Thomson, Miranda, & Infield, 2002). The different implemented technologies depend on the locally available energy sources. For example, regions such as the Middle East and North Africa have abundant solar energy, while coastal and island communities have abundant wind energy. Remote regions and islands with low population density and poor infrastructure for freshwater and electricity transmission and distribution could therefore make use of locally available renewable energy resources as a cost-effective solution (IRENA, 2012).

According to figures from the report on desalination of the Euro-Mediterranean Regional Programme for Water Management (European Union, 2008), less than 1% of desalination capacity is based on renewable energy sources; of this, 62% is based on RO, and the rest on thermal processes such as multi-stage flash and MED. The same report shows that solar photovoltaics is the most widely used source (43%), followed by solar thermal and wind energy. Despite their intermittence, a correctly implemented desalination technology powered by renewable energy could provide the right economic solution while respecting environmental requirements. The decision-making process to evaluate the cost-effectiveness and technical feasibility of a specific situation has to assess several factors, including the available renewable energy, the location, plant capacity and size, type of feed-water input and fresh-water output, and the electricity available in the grid. Decision makers have also to take into account post-production factors such as operation and maintenance requirements, feed-water transportation, and costs that can occur in the pre-treatment phase. As with fossil-fuel-powered facilities, the effectiveness of the combination will depend largely on the size of the plant, with some better suited to large-scale applications (European Union, 2008).

The Middle East and North Africa is one of the most arid regions in the world where renewable-energy-powered desalination is on the rise due to its high solar energy potential. While most of the existing renewable-powered desalination plants are small, the region now also has now a few medium-size plants. Saudi Arabia is building the world's largest solar photovoltaic desalination plant in Al Khafji using novel nano-membrane technology. Three stages are planned to reach a production capacity of 60,000 m^3 per day (Water Technology, 2015). The kingdom is currently using 1.5 million barrels of oil per day to power its desalination facilities, which provide 50–70% of the country's drinking water (Thomson et al., 2002). India, Brazil, Cyprus, Egypt, Jordan, Turkey and other countries are also implementing desalination plants powered by renewable energy (IRENA, 2012). The use of renewable technologies in desalination processes implies technical, economic and organizational issues to provide a constant energy supply. Large low-cost sources of renewable energy, plus energy storage technologies, are necessary to alleviate the variable nature of renewables. On the economic side, there is a need to attract private companies to invest in renewable-powered plants by singling out niche markets and crafting proper policy frameworks (Papapetrou, Wieghaus, & Biercamp, 2010). Good cooperation and integration are needed between companies in the energy sector and companies in the water sector (Papapetrou et al., 2010). In developing countries, barriers such as training staff to run the plants, and investment and operation costs, need to be addressed (IRENA, 2012).

Desalination in Jordan

Like other countries in arid and semi-arid regions, Jordan is facing severe water shortage (El-Quosy, 2009); it is among the most water-scarce countries worldwide (Economic and Social Commission for Western Asia, 2005). With booming demography, refugee intake and climate change, water scarcity is expected to increase (Government of Jordan, 2007). In 2014, according to the World Bank (2018), Jordan had 77 m^3 of annual freshwater per capita, far below the Falkenmark 'absolute scarcity' threshold of 500 m^3 per capita per year. Unlike some of its neighbouring countries, such as Israel and Saudi Arabia, Jordan has not been able to produce alternative sources of water. Jordan has therefore increased the pressure on its natural sources to meet the water demand, and aquifers and surface waters are now facing over-extraction. Desalination might help (Economic and Social Commission for Western Asia, 2009), but Jordan does not have large stocks of crude oil to power desalination at a relatively low price. Typically, the fluctuations in crude oil prices (increasing the cost of desalinating water) and the cost of transportation are preventing Jordan from investing in large-scale desalination. A potentially affordable way to power these plants is solar energy, since Jordan benefits from high insolation (Qiblawey, Banat, & Al-Nasser, 2011). Jordan's average insolation on a horizontal surface is approximately 5e7 kWh/m^2 per day, one of the highest in the world (Mohsen, 2007). The country is therefore turning to renewables to power desalination plants, especially on a small scale. RO technology, which consumes less energy than thermal desalination, can be coupled to the use of renewables, such as solar energy. Jordan, with its two different plant scales, a medium-sized desalination plant and the RSDSC, is an interesting case study to analyze two different ways of facing the financial and environmental challenges of seawater desalination.

Water resources in Jordan

Though Jordan is experiencing intense water shortage, water management in this semi-arid region has not been a priority until recently, especially with irrigation (EcoPeace, 2014). In a country where refugees make up one-third of the population, access to water is a key factor for stability and development. Jordan has 15 surface water basins and 12 groundwater basins (Ministry of Water and Irrigation of Jordan, 2013). In 2013, the Jordanian Ministry of Water and Irrigation estimated annual water availability at 892 million cubic metres (MCM). According to the ministry, 79% of this 892 MCM came from renewable freshwater sources: 239 MCM (28%) from surface water (of which 50 MCM comes from Israel under the 1994 peace treaty) and 433 MCM (51%) from renewable groundwater. The other 21% was divided between non-renewable aquifer groundwater (75 MCM, or 9%) and treated wastewater (102 MCM, or 12%) (Fanack Water, 2016a). Several of Jordan's natural sources of water are shared, including the Jordan River basin, with its effluents, and the Disi aquifer (Mohsen, 2007). Israel, Syria and Jordan, all riparian states of the Lower Jordan River, have been diverting most of its tributaries for agriculture and domestic purposes, reducing inflow to less than 2% of historical rates (EcoPeace, 2010). Inadequate development and pollution are also threatening the river. Israeli, Jordanian and Palestinian sewage, untreated or poorly treated, is discharged into the river either directly, or indirectly through open sewers

(EcoPeace, 2010). The river is also contaminated with agricultural and fish pond effluents and diverted saline water. The extreme diversion of the Lower Jordan River is also a primary cause of the severe decline of the Dead Sea (EcoPeace, 2010). Over the last few decades, the water levels have fallen from −397 m in 1968 to −432 m as of the beginning of 2018. At the same time, a third of the sea surface area has dried out, increasing the salinity even further (EcoPeace, 2011). In addition to unsustainable rates of extraction, the drilling of wells, the high agricultural water demand in the region, and the exploitation and over-evaporation of the sea by large chemical industries have added to its rapid decline. Regarding the Disi aquifer shared with Saudi Arabia, in 2013 Jordan completed a pipeline extracting water from the groundwater source, the Disi Water Conveyance Project (Fanack Water, 2016b). In 2015, Saudi Arabia and Jordan signed an agreement over the aquifer. Despite its minimalist approach, the treaty is noteworthy as until today it is the one of the very few agreements on a comprehensive management regime for a transboundary aquifer. On top of water mismanagement, over-extraction and water contamination, climate change is predicted to have an important impact on the region. Less rainfall and higher average temperatures are expected to reduce the amount of water infiltrating into the groundwater sources (Al-Omari, Salman, & Karablieh, 2013). Furthermore, with higher evaporation rates (resulting from the higher temperatures), greater domestic and agricultural demand is expected (Menzel, Reichert, & Weiss, 2007). Socio-economic development is predicted to exacerbate these patterns. The combination of higher water demand for domestic and agricultural purposes and lower water resources availability represents a threat to socio-economic development. The improvement of water management in all sectors and the development of new water sources are some of the few solutions available to Jordan to overcome its water shortage and face the alarming effects likely to follow from climate change (Menzel et al., 2007).

Financial and environmental strategies for desalination in Jordan

Jordan is facing two main problems regarding desalination. First, it has a very limited access to the sea. Second, its portion of shoreline is distant from most of its population, which is in the centre of the country (Mohsen, 2007). The capital, Amman, has a great demand for water but is more than 300 km from the shoreline, making water transportation from Aqaba to the centre of the country very costly. This partly explains why small-scale desalination facilities have been built on the coast, providing freshwater only to the local population. Nonetheless, with the worsening water shortage, there has been a regional agreement to face the problem, and with the financial help of international bidders, to build a larger desalination plant. This plan has been implemented in the context of cooperation and hydro-diplomacy to allow water swaps with Israel (Rabadi, 2016). To date, the desalination of either brackish water or seawater in Jordan has been very limited. In terms of seawater, Jordan has access to a very short shoreline on the Gulf of Aqaba, far from the main population centres. In addition, these centres of population are at high elevations, implying a costly pumping system (World Bank, 2004). Brackish water resources, on the other hand, are spread around the country. A few brackish water desalination plants have therefore been built, such as in the Jordan Valley. They deliver water destined largely for irrigation use (World Bank, 2004).

The Aqaba desalination plant

In April 2017, the Jordanian Ministry of Water started operating its first seawater desalination plant. The plant is on the Gulf of Aqaba, about 25 km south of the centre of Aqaba City. Implemented on the principle of build-operate-transfer, the public–private partnership allows the Jordanian state to recover its investment after an agreed period of time. The Jordanian water treatment company, AquaTreat, has provided all engineering, construction and technology inputs. With a capacity of 15,000 m^3 per day, the plant is based on a conventional system of microfiltration, ultrafiltration, and RO (MF-UF-RO) (Water, Desalination and Reuse, 2017). It is expected to meet Aqaba's water demand until 2035. The plant is entirely powered by renewable energy. Solar energy generates electricity for the plant, along with the reuse of emitted methane gas. According to the Jordanian minister of water and irrigation, the plant provides a similar amount of water (5 MCM/y) to the conveyance project transporting water from the Disi Aquifer to Amman (*Jordan Times*, 2017). The Jordanian-built-and-operated plant is considered by the authorities a first step in a desalination revolution, clearing the way for the RSDSC project.

The first phase of the RSDSC project

As mentioned, large desalination plants represent a certain investment for developing countries that lack financial capacity. The water crisis in Jordan has brought international attention to the region's water shortage situation. In this context, the RSDSC, as mentioned earlier, is under negotiation. The main purpose of this joint initiative is to provide freshwater to Amman and the north of Jordan. The project also has three other objectives: preventing the complete depletion of the Dead Sea; desalinating water on a large scale to get an affordable price; and building a symbol of peace and cooperation in a conflictual region (World Bank, 2013). Connecting the Dead Sea to the Mediterranean Sea or the Red Sea has been discussed for centuries. It became clearer with the peace agreement between Israel and Jordan in 1994 and the creation of a plan for integrated development (El-Anis & Smith, 2013). In May 2005, an agreement to conduct a feasibility study was signed after the Palestinian Authority joined the talks. The World Bank agreed to commission the study, which was released in 2013. The draft presented assessments of the environmental and social impacts of the project, as well as a study of more than 20 alternatives (Aggestam & Sundell, 2014). In December 2013, a memorandum of understanding was signed at the World Bank headquarters on the will of the three parties to start the implementation of Phase I of the project. Within these terms, Israel has agreed to sell 20–30 MCM/y to the Palestinian Authority (Rabadi, 2016). In February 2015, Jordan and Israel signed a bilateral agreement, stating the modalities of the cooperation for every stage of the project, as well as management and procedures (Rabadi, 2016). The project presents a water-swap agreement between Israel and Jordan that reduces the cost of water per cubic metre (Rabadi, 2016). In the first stage, seawater will be extracted from the Red Sea and transported through pipelines to a desalination plant in Aqaba. The plant will produce around 65–80 MCM of desalinated freshwater per year. Of this, 35–50 MCM will be sent to Israel as part of the water swap agreement, while 50 MCM will be sent from Israel to northern Jordan. What is left will be supplied to the Aqaba region. Annually, 110–220 MCM of seawater and brine will be

Table 3. Financial and environmental strategies to the cost of desalination in Jordan.

Aqaba desalination plant	Renewable energies alternatives (operation), fully operated and financed by Jordanian entities
First phase of the Red Sea–Dead Sea Canal	International plants (construction, operation, maintenance), agreement between Israel, Jordan and Palestine International funding, feasibility study by the World Bank

released into the Dead Sea (Rabadi, 2016). In Phase I of the project, the desalination plant will be entirely located in Jordan. With the pilot project accepted, Jordan will therefore sell the water desalinated in Aqaba to Israel, while the Israeli authorities will sell water from the north of Israel to Jordan.

The is managed and funded on the national/private level (*Jordan Times*, 2017). The RSDSC is on a more regional and international level, with international financial help and the agreement between Jordan, Israel and the Palestinian Authority following the memorandum of understanding signed in 2013. The different strategies are presented in Table 3.

Conclusion

As reviewed in this article, Jordan has used various ways to reduce the costs of desalination for its two main seawater desalination facilities. With a capacity of 5 MCM/y, the is expected to provide water to the municipality of Aqaba until 2035. On a small scale, the facility has a great impact on the area unserved by the Disi pipeline. With the implementation of the first phase of the RSDSC project, desalinated water is expected to alleviate the pressure on existing sources and allow greater allocation of these to other sectors. In an arid/semi-arid region where water shortage is linked to instability, these new supplies of water meet the increasing domestic and agricultural demands resulting from booming demographic patterns and the socio-economic development of the country. From a political point of view, as water is seen as a public service that has to be provided by the State, RO desalination gives the Jordanian authorities a tool to allocate cheap and good-quality water to the population.

Regarding the impact of desalination on regional cooperation, the RSDSC project is impacting regional transboundary resources management and the hydro-diplomacy between the actors involved. For instance, it has generated water-swap deals between Israel and Jordan and between Israel and the Palestinian Authority. Funded by international donors, it is seen as a joint initiative to promote cooperation among the three riparian entities. While desalination creates a certain flexibility for the desalinating country, projects such as the RSDSWC aim to create interdependency between actors to promote cooperation and regional stability.

RO desalination has the potential to change the politics of water supply. With fast-growing populations, some countries have now the possibility to alleviate water scarcity in a context where this resource is essential to socio-economic development and agriculture. By creating new sources of freshwater and increasing water supply, RO desalination can have economic, political and social benefits. But on the environmental level, further research is necessary, as the ecological footprint of the desalinating method remains under-studied.

The two most important developments for the democratization of RO technology are the increasing use of renewable energy to power the facilities and cooperative water projects to share their financial burden. The example of desalination in the Kingdom of Jordan shows that both developments are feasible if large amounts of renewables are available and there are institutions to facilitate the negotiation of the cooperative regional projects. Looking at the pace at which the technology is evolving and being improved, the use of RO will probably spread in the coming years. The larger challenge facing cooperative international transboundary water management is the institutions that govern the demand side.

Disclosure statement

No potential conflict of interest was reported by the authors.

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