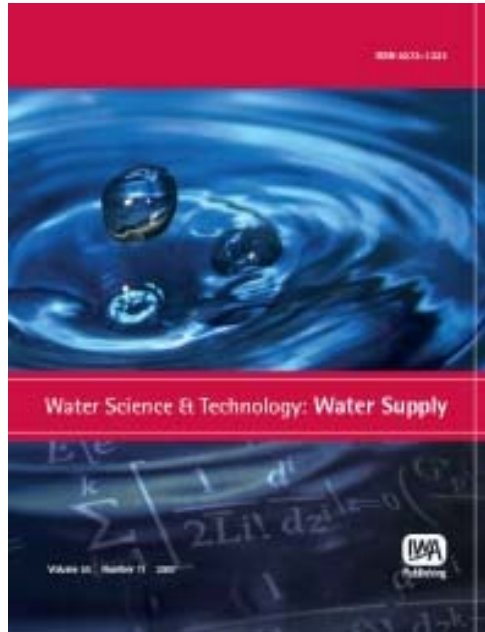


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A joint power and desalination plant for Sinai and the Gaza Strip

Raed Bashitialshaaer and Kenneth M. Persson

ABSTRACT

Desalination can be a cost-effective way to produce fresh water and possibly electricity. The Gaza Strip has had a complex hydro-political situation for many years. Gaza is bordered by the Mediterranean sea in the west, by Israel to the north and east and by Egypt in the south. Water and electricity consumption in the Gaza Strip is expected to increase in the future due to the increasing population. In this paper, a solution for Sinai and the Gaza Strip is suggested involving the building of a joint power and desalination plant, located in Egypt close to the border with Gaza. The suggested joint project would increase drinking water supply by 500,000 m³/d and the power supply by 500 MW, of which two thirds is suggested to be used in Gaza and one third in Sinai. The present lack of electricity and water in Gaza could be erased by such a project. But Egypt will probably gain more: more water and electricity for the future development of Sinai and Gaza; a significant value will be added to the sale of Egyptian natural gas; more employment opportunities for Sinai people; the domestic market for operation and maintenance of desalination plants can be boosted by the suggested project; Egypt may naturally and peacefully increase its cooperation with and presence in Gaza, which should lead to increased security. This type of project could also get international support and can be a role-model for cooperation and trust-building between neighbours.

Key words | desalination, environmental impact, Palestine-Gaza, power plant, water resources

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INTRODUCTION

The Gaza Strip is a small, densely populated area in the Middle East in which groundwater is the main source of water. Gaza has several water problems: inefficient water use by the agricultural sector, limited fresh water supply and high water demand, groundwater contamination and seawater intrusion. In the Gaza Strip area of Palestine, there is a large gap between water resources and demand. The citizens of the Gaza Strip have pursued several alternatives to increase water supply, including water desalination (house units) and use of bottled water and imported water (El-Nakhhal 2004). Annual water availability from the Gaza aquifer will decrease from 147 to 125 MCM/yr, i.e. almost 15%, based on assumptions of climate change between 2009 and 2030 (Al-juaidi *et al.* 2009).

The problems facing water sector projects development were due partly to deteriorating security conditions (Gray 2009). At present, maintenance is too difficult for the water sector and pipes and cement are for instance being

impounded for Gaza people, despite the pledge of \$4.5 billion dollars of aid money to rebuild Gaza which was made at the conference in Sharm el Sheikh held in March, 2009 (PCHR 2009). The inequality in access to water between Israelis and Palestinians is striking. In some rural communities Palestinians survive on 20 to less than 70 L per day, which is less than the minimum amount recommended by the WHO for emergency situations response of 100 L per day (WHO 2011).

In this study, a bench-mark analysis of seawater desalination was performed for reverse osmosis (RO) systems. A reverse osmosis desalination project to improve water quality and quantity was previously proposed (El-Nakhhal 2004). Desalination plants in the Gaza Strip area with a capacity of up to 150,000 m³/d have also been suggested, but very little has been implemented until now, partly due to political conditions (Baalousha 2006). To address this, the new desalination plant is suggested to be located in Egypt to serve two

areas, specifically specifically Gaza and Sinai. The current Israeli blockade of Gaza and restrictions on some of the materials and chemicals required for pre- and post-treatment make cooperation on the project with Israel almost impossible. Additionally, it is much cheaper to buy natural gas directly from Egypt.

Current situation in Gaza

The production capacity of the desalination plants in Gaza varies between 20 and 150 m³/d (Jaber & Ahmed 2004). There are four sources of drinking water, namely municipal water wells (50 MCM/yr), agricultural water wells (90 MCM/yr), water from an Israeli company 'Mekkorot' (5 MCM/yr) and brackish water reverse osmosis plants (4 MCM/yr) (El-Sheikh *et al.* 2003). The municipality located in the middle of Gaza (Dier Albalah) operates a RO plant using brackish groundwater, producing about 1,080 m³/d desalinated water with a recovery rate of 75%. There are two RO desalination plants located in Khanyunis City with a total production capacity of 2,760 m³/d (El-Sheikh 2004).

A small scale desalination plant was built in Gaza but the larger one which was suggested has not yet been built due to the many reasons listed above, not least the political issues. Even some of the small plants have been stopped and electricity production is limited in the Gaza Strip. This leaves most of the population in Gaza without electricity for up to 18 h per day and without water for more than 20 h per day. The current electricity demand in the Gaza Strip, according to the President's Office and the Gaza Power Generating Company (GPGC), is 215 MW but this increases to 225 MW during the winter months (UNOCHA 2006).

The current supply available to Gaza, which totals 184 MW, originates from three sources: Gaza Power Generating Company (GPGC) 60 MW (maximum), Israel Electrical Company (IEC) 107 MW and Egypt 17 MW. GPGC estimated that the maximum power generated from the power station did not exceed 60 MW while the potential of the original transformers was up to 140 MW (UNOCHA 2006).

Water prices

In general, the cost of water and source of energy is important for producing fresh water in low income and poor countries.

Akgul *et al.* (2008) studied different designs for Mediterranean sea water reverse osmosis (SWRO) membranes. The average unit costs of RO processes have declined from \$5.0/m³ in 1970 to less than \$1.0/m³ (at present approximately \$0.50/m³) (Zhou & Tol 2005). Large RO-plants have lower specific production costs despite location. The Ashkelon desalination plant, which is also located on the Mediterranean sea coast, has presented cost figures as low as \$0.52/m³ (Busch & Mickols 2004). Another example is the Perth desalination plant in Australia, which consumes only 3.7 kWh/m³ fresh water (Gary 2006).

El-Sheikh *et al.* (2003) reported that customers in Gaza are paying an average of \$0.25–0.50 per cubic meter for municipal water distribution and they will be able to pay 1.0 \$/m³ of the desalinated water in the distribution network because they already pay \$1.25 for 1 m³ desalinated seawater. The energy prices were calculated in the range of 6–9 cent/kWh electricity (Akgul *et al.* 2008). Egypt's natural gas sector is expanding rapidly with production of about 1.9 trillion cubic feet (Tcf) and consumption of 1.1 trillion cubic feet in 2008 (1,000 ft³ = 28.3 m³). According to the Oil and Gas Journal, Egypt's estimated proven gas reserves stand at 58.5 Tcf, the third highest in Africa, and Egypt continues to be an important supplier of natural gas to Europe and the Mediterranean region (U.S. Energy: last update June 2010).

Purpose

The purpose of this study is to make a bench-mark analysis of a seawater desalination plant for reverse osmosis with the aim of increasing water availability in Gaza and Sinai for a maximum number of people. This proposed project could minimise the cost of water and electricity and improve the other sectors, e.g. agriculture and industry. Another purpose is also to stress the importance of joint projects between countries of the Middle East, to reduce tensions, disputes and fighting, and to increase cooperation, mutual trust and security. With examples from Europe, the century long conflict between France and Germany was able to be settled by economic and political cooperation. In 1950, the Schuman declaration stated that 'Europe will not be made all at once, or according to a single plan. It will be built through concrete achievements which first create a de facto solidarity'. Through initial cooperation on coal and steel, the

countries gradually worked towards a position where they formed the EEC in 1957 and then the EU.

In 2010, 27 European countries cooperate closely within the EU and more European countries want to join. HRH Prince El Hassan bin Talal of Jordan has in several presentations, speeches and articles argued for the urgent need of a similar development within the Middle East countries. Bridging towards peace and trust between countries must be reached through concrete actions (HRH 2010a). In the opening of WOCMES 2010 in Barcelona, Spain, HRH Prince El Hassan bin Talal said that 'The need to promote cultural ties among Middle East nations must be stressed, and the importance of developing joint policies to enhance contact at various levels noted' (HRH 2010b).

STUDY AREA

An overview

Gaza has a semi-arid climate with a total area of about 365 km² and a population of 1.55 million with a growth rate of 3.2% (Al-juaidi *et al.* 2009). The Gaza Strip forms a transitional zone between the semi-humid coastal area in the north and the semi-arid Sinai desert in the south. The Gaza Strip is 40 km long and has an average width of

about 9 km. Its area is surrounded by the Negev desert, Israel, Egypt and the Mediterranean Sea (Figure 1). The Gaza Strip area is part of the Palestinian Autonomous areas according to the Oslo agreement that was signed by the USA, Egypt and Israel in 1993. Gaza is divided in five districts known as Gaza, North Gaza, Deir Al-Balah, Khan Younis and Rafah. The locations of the agricultural areas are also shown in Figure 1. Gaza is located on the western-most part of the shallow coastal aquifer that is exploited for municipal and agricultural water supply. The aquifer in the Gaza Strip is part of the coastal aquifer, which extends from Mt Carmel in the north to the Sinai desert in the south with a variable width and depth. The total area of the coastal aquifer is about 2,000 km² with 400 km² beneath the Gaza Strip (EXACT 1998).

Annual average rain in the Gaza Strip is between 200 mm (in the south) and 400 mm (in the north), which falls mainly in winter in which groundwater is considered as the main water source in Gaza (El-Nakhhal 2004). The evaporation rate is very high compared with rainfall. The average amount of open water evaporation is about 1,300 mm/yr (PBS 2000). Increased demands for water for domestic and agricultural use dry up most of the agricultural areas. Thus, water scarcity in Gaza is a significant problem and concerns have been highlighted in many studies. Immigration of Palestinian refugees after the 1948 Israeli-Arab war to the Gaza Strip, coupled

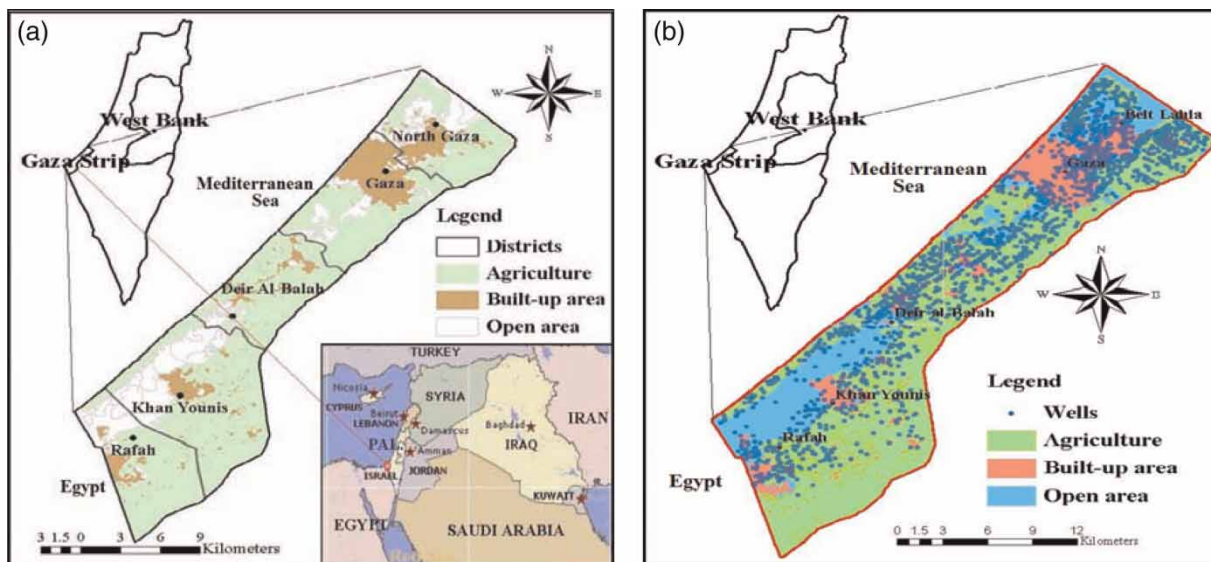


Figure 1 | Gaza Strip overall map for (a) districts and (b) agricultural areas (from: Al-juaidi 2009).

with the high fertility rate, increased the population of that Palestinian coastal land strip from 50,000 in 1948 to more than 1.5 M in 2009 (PBS 2000).

Water balance in Gaza

It is important to analyse the water balance in the Gaza Strip and to compare water supply with demand. In 2020, there will be more than 2 M Gazans, double the year 2000 population (PBS 2000), and the water demand could easily also double from 154 MCM/yr (Metcalf & Eddy 2000a, b). In Gaza there are no surface water resources except for an occasional water flow in Wadi Gaza during heavy rainfall, which temporarily occurs in two to three of the winter months. Another environmental problem is the infiltration of nitrates into the aquifer from the uncontrolled and excessive use of fertilisers by farmers in their irrigated fields to increase productivity.

Baalousha (2004) reported that the net average annual groundwater recharge comes from precipitation is about 43.3 MCM. Although the total amount of annual inflow to the Gaza aquifer is about 109 MCM as explained in the top part of Table 1, only part of this amount can be considered as a safe yield (about 60 MCM/yr). Table 1 (bottom) presents the general water balance in the Gaza strip among five different waters as inputs and outputs (Abu Zahra 2001). Based on PWA records, the domestic water demand for 2000 was 55 MCM. This domestic demand was predicted to increase to 182 MCM in 2020 (Metcalf & Eddy 2000a, b). Finally, water resources should thus be increased by 110–120 MCM/yr (330,000 m³/d) to meet this shortage.

Water quality in the Gaza strip

Of the approximately 50 L/capita/d of water delivered to the residents of the Gaza Strip, only about 13 L/capita/d meets WHO quality standards (PWA 2000). The problem of groundwater quality especially in Khanyounis city is rather complicated. Both NO₃ and Cl are major pollutants of the aquifer attributed to human use as well as the scarcity of the water resource (Al-Agha 2005). Maximum nitrate values of 433 mg/L and a mean of 166 mg/L have been measured, exceeding WHO standards (45 mg/L) (WHO 1996). The corresponding values have also been reported in the case of chloride, where the maximum value is about 1,290 mg/L,

Table 1 | Water balance in the Gaza Strip in 2000 and 2001

| Balance (Metcalf & Eddy 2000a, b) | Amount, MCM | |
|---|-------------|--------|
| <i>Inflow</i> | | |
| Recharge from rainfall | 43 | |
| Lateral inflow | 10 | |
| Irrigation return flow | 20 | |
| Saltwater intrusion | 11 | |
| Leakage of sewer system | 12 | |
| Leakage of water system | 13 | |
| Total | 109 | |
| <i>Outflow</i> | | |
| Municipal abstraction | 50 | |
| Agricultural abstraction | 80 | |
| Natural groundwater discharge | 11 | |
| Total | 141 | |
| Gaza Strip contribution to water balance | | |
| Hydrologic Parameter (Abu Zahra 2001) | Percentage | MCM/yr |
| Annual rainfall | 100 | 101 |
| Evapotranspiration | −52.5 | −53 |
| Surface run-off | −1.98 | −2 |
| Natural recharge | 45.5 | 46 |
| Return flow | 8.9 | 9 |
| Overall balance | | 55 |

and the mean value is 491 mg/L compared to the WHO standard of 250 mg/L (WHO 1996).

According to the PWA, more than 60% of the total amount of groundwater in the Gaza Strip aquifers is of bad quality and not potable according to WHO standards (PWA 1999). It is believed that fertilisers, in combination with the leached wastewater from septic tanks and non treated wastewater, are responsible for this high level of nitrate.

METHODOLOGIES

Proposal overview

Desalination projects are always related to a number of parameters and factors such as water scarcity, water quality, energy recovery, cost per cubic metre, capital cost, location,

land use, operations and maintenances as well as environmental impact. In general, any project has to meet at least the minimum requirements such as:

- Desalination plant allocation systems.
- Consumers income and economical acceptance.
- Availability of operational materials and chemicals in the area.
- Annual cost optimization including workers.
- Environmental impact analysis.
- Study different scenarios for comparison.
- Economic benefits of water use and net benefits of overall operations.

Figure 2 shows the border line between Egypt and Palestine as well as the end point along the Mediterranean Sea coastline. In Figure 2, the triangle on the south-west part of the map encloses possible locations for the proposed project within a 10 km area on and around the Mediterranean coast. It is suggested that the brine from the desalination plant first be mixed with the power plant cooling water and then discharged to the sea to minimise the impact. The closer the plant to the Gaza border, the cheaper it will be to distribute external power and water to the Gaza Strip.

The joint project will supply fresh water and electricity to the two areas with one third to the Egyptian part (Sinai) and two thirds to the Palestinian part (Gaza). The advantages are much greater than disadvantages and there are almost no disadvantages for the Egyptians. In this project Egypt will get their amount for free plus selling

natural gas, improving water quality and quantity, employee opportunities, materials and tools for repairing and chemicals for treatment. All these will be supplied by Egypt, and are seen as advantages for them.

Cost of labour is important and to have labor from Egypt is much cheaper than in Gaza for operation and maintenance because this project will be located on the Sinai coastline. There is also the matter of easy exchange of expertise from different countries to come to the Sinai area in order to train personnel. Currently, it makes much more sense to locate the project in Sinai, which is more accessible to visiting training and technical consultants, given the severely restricted access problems under the current Gaza blockade. It is not easy to compare the two countries' labour costs because they have different situations but taking them from Egypt is a good solution. On the other hand, workers in Gaza will be responsible for establishing pipeline connections and networks to all cities starting from the border and also for their maintenance.

Water transport examples

The transfer of water from Sinai to Gaza should not cause any problems. There are many practical examples of water transport from one city to another or from one country to another (see Table 2). Some calculations on transportation costs of water are presented in Zhou & Tol (2005). Comparison of these estimates to those of other studies suggests that Kally (1993) may have been overly pessimistic, but most of these studies suggest that the actual costs would have been higher (see Table 2). Kally's estimation is still used because his calculation takes account of not only horizontal distance but also vertical lifting cost. It is important to search for independent sources of energy that might be as cheap as Israeli pricing. A good alternative for energy supply to the power plant could be off-shore gas discovered in the sea close to Gaza (Baalousha 2006).

Alternatives water supply solution

Water transport

Water transport was one of the alternatives proposed to supply fresh water to Gaza people. As seen in Table 2,



Figure 2 | Proposed desalination and power plant projects in the study area (from: Google Earth 2009).

Table 2 | Cost of water transport to selected projects (Adapted from Zhou & Tol 2005)

| City, Country | Project name | Distance (km) | Amount, MCM | Cost \$/m ³ | Reference |
|------------------|--------------------------------------|---------------|-------------|------------------------|---|
| Gaza, Palestine | Nile to Gaza | 200 | 100 | 0.214 | Zhou & Tol (2005) |
| Northern Cyprus | Turkey to Northern Cyprus | 78 | 75 | 0.25–0.34 0.26 | Gruen (2000) Kally (1993) |
| Barcelona, Spain | Ebro to Barcelona | 900 | 1,000 | 0.36 0.52 | Uche <i>et al.</i> (2001) Kally (1993) |
| Colorado, USA | Colorado river to Phoenix and Tucson | 550 | 1,800 | 0.05 0.74 | Hahnemann (2002) Kally (1993) |
| Yangtze, China | Yangtze to China's north | 1,150 | 32 | 0.10–0.16 0.38 | Liu & Zheng (2002) Kally (1993) |

transport from the Nile to Gaza was suggested as one alternative by Zhou & Tol (2005), and is comparable with desalinated water. The transport cost per cubic metre is about \$0.214, cheaper than desalination but not possible now due to increased demand from the countries around the river.

Another solution was to entail connecting the West Bank and the Gaza Strip using a 60–70 km long pipeline of fresh water derived from Lake Tiberia (with Israeli permission) from the West Bank mountain aquifer and/or from the Israeli National Water Carrier. The solution was considered to be highly politically dependent and is now not possible because the lake's level has dropped in recent years due to drought. Some of the examples in Table 2 are successes and are already in operation.

Artificial recharge

Artificial recharging was previously planned as one possible solution for the Gaza aquifer, advocated in 1985 (Assaf & Assaf 1985) using floodwaters of Wadi Gaza and/or treated wastewater. There are many problems with this supply due to poor water quality in this Wadi and lack of wastewater collection. The annual volume of wastewater in the Gaza strip is about 13 MCM (CAMP 2001). Approximately 70–80% of the domestic wastewater produced in Gaza is discharged into the environment without treatment; either directly or through leakage. Also, there are about 18 different pipelines of wastewater discharged into the Mediterranean (UNEP 2003). Almost all wastewater treatment plants in the Gaza Strip do not function effectively. The flood water amount is approximately 2 MCM/yr

which does not meet the needs of Gaza, and decreases in precipitation and increases in the evaporation rate over Gaza are important.

Desalination

A large scale seawater desalination system set up in the Gaza Strip has been suggested previously (Assaf 2001). Solar plants have been suggested for desalination purposes. Three stages of a co-generation plant with a planned water capacity of 100 MCM/yr, a power capacity of 2.5 billion kWh/yr and a total panel area of approximately 13 km² have been proposed (Lubna *et al.* 2008). It was calculated that about 5 km² is required for the collector field to produce 1 TWh/yr of electricity (Trans 2004; Knies *et al.* 2005). The estimated total cost of this proposal is approximately \$1.1–1.3 billion, which is high compared to a joint project. The total land use would be huge and solar panels are expensive. Ghabayen *et al.* (2004) planned a desalination plant capacity of 140,000 m³/d to produce water quality at maximum 400 ppm TDS, at a recovery rate of 50%. Plant localization inside the Gaza Strip is unrealistic for three reasons: political problems, interior problems and energy availability.

In Gaza, there is no guarantee of a power supply to water projects. For example, no safe supply of operational and maintenance materials can be guaranteed. The interior situation in Gaza is characterised by lack of control of available water (chaos due to war) as well as leaks of information and technology. The energy availability and power supply functions most of the time despite the political problems.

RESULTS AND RECOMMENDATIONS

Unit and capital cost results

The reported average unit cost of seawater desalination production dropped significantly from 1955 to 2020 and will probably reach less than \$0.5/m³ in 2020, as shown in Figure 3. Four different technology types were studied and compared for long-term seawater desalination: membrane processes containing reverse osmosis (RO), thermal processes including multistage flash (MSF) evaporation, multiple effect (ME) evaporation and vapour compression (VC), see Figure 3. Bashitialshaaer & Persson (2010) extracted data from the International Desalination Association (IDA) yearbooks 2006–07, 2007–08, 2008–09 and 2009–10. These data were collected from 18 different projects mainly in the Middle East and some projects with similar intake concentration. The capital cost to produce 1 m³ of desalinated water per day was found to be about \$1080 (approx. \$1 million to produce 1,000 m³/d) (Bashitialshaaer & Persson 2010).

Also, the mean cost of production for 1 m³ was found to be about \$0.79 and the mean energy consumption

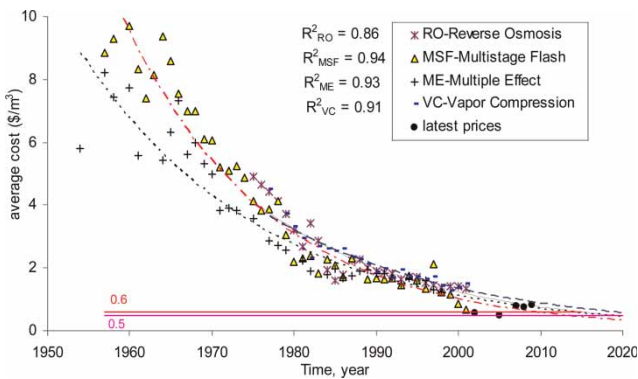


Figure 3 | Unit costs for seawater desalination 1955–2020 for four technologies.

Table 3 | Population, land area and population growth rate (U.S. Census 2008)

| Country or area | Population | | | Area km ² | Annual population growth rate |
|-----------------|------------|------------|-------------|----------------------|-------------------------------|
| | 1950 | 2008 | 2050 | | |
| Egypt | 21,197,691 | 81,713,517 | 127,563,256 | 995,450 | 1.79 |
| Israel | 1,286,131 | 7,112,359 | 10,828,462 | 20,330 | 2.13 |
| Palestine | 1,016,540 | 4,149,173 | 9,789,347 | 6,000 | 2.26 |
| West bank | 771,165 | 2,611,904 | 5,580,321 | 5,640 | 1.98 |
| Gaza Strip | 245,375 | 1,537,269 | 4,209,026 | 360 | 2.84 |

approximately 4.5 kWh/m³, for a raw water of Mediterranean Sea concentration. Building desalination and power plants in the same location has been practised in Israel, Saudi Arabia and the UAE to supply electricity to the desalination plant directly and the surplus to the power grid. It was found that the average cost of producing 1 Watt from the power plant is about \$1 (approx. \$1 million to produce 1 MW) (Bashitialshaaer & Persson 2010). In Table 3, population change, growth rate and land area for some countries in the Middle East are presented. The population growth rate for the Gaza Strip is very high, with a simultaneous increase in water requirements. The annual population growth rates over 100 years from 1950 and predicted for year 2050 were taken from the U.S. Census Bureau (2008).

The amount of fresh water needed for the Gaza Strip can be calculated from census and population progress data. If we consider a population of about 2 million living in Gaza in 2020 and that the daily fresh water requirement is about 100 l per capita, the water supply should be 200,000 m³/d. The expected electricity demand is about 350 MW. A combined water production and power plant will have a capital cost of about \$200 million in addition to the energy cost used for the desalination plant. The proposal put forward is to progressively reach up to 500,000 m³/d of desalinated water and about 500 MW electrical energy. The total amount will be distributed to the Gaza Strip in Palestine and Sinai in Egypt. It will also be possible in the future to transport any excess water from the Gaza Strip to the West Bank. The distance from the last point in the Gaza strip to the closest point on the West Bank is approximately 34 km.

The proposed project should be initiated as soon as possible. The final results and production distribution of the proposed desalination and power plants are presented in Table 4. This proposal is planned over five years but

Table 4 | Sample calculation for desalination and power plant proposal

| Date | Total capacity (m ³ /d) | Within project (kW) | Capital cost, \$ (million) | Gaza strip (m ³ /d) | Egypt Sinai (m ³ /d) |
|---------|------------------------------------|---------------------|----------------------------|--------------------------------|---------------------------------|
| 2010 | 0 | 0 | 0 | 0 | 0 |
| 2011 | 100,000 | 100,000 | 200 | 66,667 | 33,333 |
| 2012 | 200,000 | 200,000 | 200 | 133,333 | 66,667 |
| 2013 | 300,000 | 300,000 | 200 | 200,000 | 100,000 |
| 2014 | 400,000 | 400,000 | 200 | 266,667 | 133,333 |
| 2015 | 500,000 | 500,000 | 200 | 333,333 | 166,667 |
| Finally | 500,000 | 500,000 | 1,000 | 333,333 | 166,667 |

production could begin at the end of the first year, and then use generated income to fund subsequent development. Details on how to finance the investment need to be sorted out later, but this type of project is expensive, thus it might be more convenient to carry out the projects step by step. It is possible to get international support from donors such as the World Bank, SIDA and the European Union. If the investment can be financed, then the project schedule time can be made shorter.

Impacts and recommendations

Environmental effects: In the Gaza Strip, many households use desalination home units, resulting in a local production of brine that ends up in the sea and increases the salt concentration of the seawage water, making the process of wastewater reuse more difficult and costly (El-Nakhal 2004). In the absence of stability in the Gaza Strip, there are no regulations for desalinated water, thus there is very little control of the quality of desalinated water or the brine discharge. A safe supply of desalinated water should decrease the need for home units. With a RO-plant, less brine will be discharged on land in Gaza.

Maintenance impact: Low cost maintenance and operational processes need trained people to prevent damage to the RO membrane. In Egypt, it is possible to recruit qualified personnel and operation and maintenance costs here could be similar or lower than world prices.

Groundwater contamination: Small unit brine water is presently disposed of together with domestic wastewater in shallow drainage as well as in septic tanks, where it directly

infiltrates to the aquifers and affects the groundwater (El-Nakhal 2004). By supplying alternative drinking water, the need to extract groundwater decreases.

Land impact: The area of the Gaza Strip is small in relation to a large scale safe water supply from desalination plant projects. Implementation of this project away from the border of Gaza requires a pipeline and pumps with additional energy needs to transport the fresh water to the municipalities.

Energy impact: The cost of energy in desalination plants is about 30 to 50% of the total cost of the water produced. Comparison of the cost components of reverse osmosis for two different energy supplies reveals that energy costs constitute the largest part of the operating costs (70%) (Akgul *et al.* 2008). In addition, a power plant was established in the Gaza Strip consisting of six turbines, with a total production capacity of 136 MW when fully completed (Baalousha 2006). This plant is normally out of operation due to damaged parts and lack of appropriate maintenance. Already there is an electricity cooperation in operation between Egypt and Gaza governments. The most important incentives and advantages to Egypt are listed below:

- This project will increase water quality and quantities and electricity that will be available for the growing population of Sinai.
- Egyptian natural gas can be used in the project adding value to the gas sales.
- The plant will need staff. This gives employment opportunities for the people of Sinai.
- Materials, chemicals and tools for repairing and maintenance of the desalination plant will also be provided from Egypt, which will increase the domestic M&U market.
- Politically, this is an opportunity for Egypt to increase cooperation with and be more present in Gaza; this will lead to increased security around the border between Egypt and Gaza.

CONCLUSIONS

Clearly both the desalination and the power plant are vital in the Gaza Strip to supply water and electricity to the people. Desalination as a source of water supply has many advantages and few disadvantages. In the Gaza Strip,

sources of energy for desalination and power plant projects are very important in order to create an independent source of electricity, but nothing is secure in this situation. The people of Gaza lack infrastructure and rely on a clean water supply in order for their services to function normally. Although RO is a promising technology, highly professional people are required to operate the desalination plants.

Why Egypt? Locating the desalination and power plant in Egypt on the Mediterranean coast is a good solution for both Egyptians and the people of Gaza. From the current experience the cost of water and electricity will be lower than that from cooperation with Israel and the workers are also much cheaper. This proposal should improve agriculture as well as the socioeconomic and industry of both areas. More fresh water will be supplied to the people and more electricity will be supplied to industry that may increase production. The environmental issue must be studied in great detail before implementing the desalination plant project.

However, costs may be reduced by the use of natural gas to produce energy in the same location. The distribution of the produced water and electricity will be supplied one third for free to Sinai people for their land and natural gas usage. The rest of the outcome of this project from Gaza people will be used for repairing, maintenance and workers costs. One possible solution is to sell all the production from this project to Gaza-Sinai people in order to get back the capital cost in a few years and at the same time to pay-back the land rent, gas cost and repairing and maintenance. Only the progressive capital costs are needed to start this project, after which the project benefits must cover all expenses.

ACKNOWLEDGEMENTS

The authors would like to thank the Center for Middle Eastern Studies (CMES) at Lund University because this work was partly funded by them. Also we would like to acknowledge Prof. Ronny Berndtsson for his help and valuable time.

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First received 11 May 2011; accepted in revised form 12 September 2011