

SHATAT et al.

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SUSTAIN WATER, SANITATION AND HYGIENE SERVICES**Water desalination in the Gaza Strip: Al Salam RO brackish
water desalination plant case study***Mahmoud Shatat, Karen Arakelyan, Omar Shatat, Tim Forster & Ashraf Mushtaha*

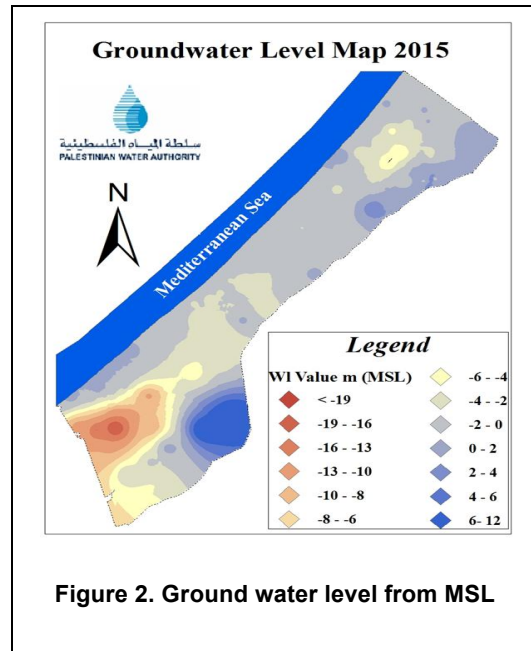
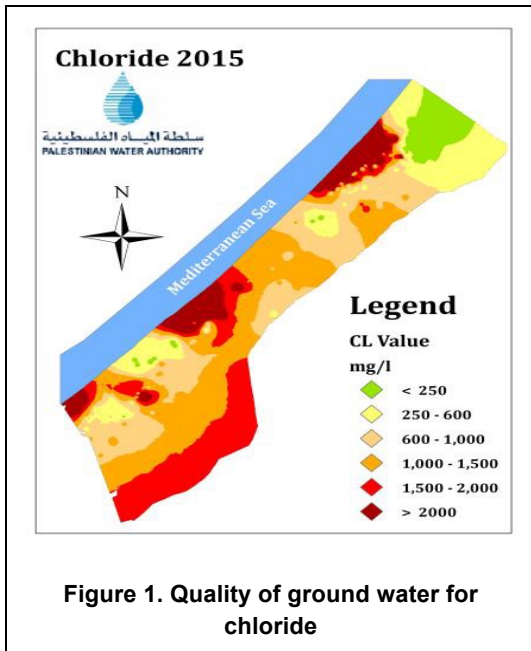
PAPER 2821

Ongoing deterioration of the water supply of the Gaza strip poses a difficult challenge for water planners and sustainable management of the coastal aquifer. The aquifer is currently overexploited, with total pumping exceeding total recharge. In addition, anthropogenic sources of pollution threaten the water supplies in major urban centres. Many water quality parameters presently exceed World Health Organisation (WHO) drinking water standards. The major documented water quality problems are elevated chloride (salinity) and nitrate concentrations in the aquifer. Up to 95 per cent of Gaza's population source their drinking water from 154 public or private producers, whose production and supply chain result in the potential contamination of up to 68% of drinking water supplies, exposing nearly 60% of the population to severe public health risks. This paper presents the details of the implementation of a medium scale brackish water desalination plant constructed in eastern Rafah – Gaza by Oxfam and its partner the Coastal Municipalities Water Utility.

Introduction

Many countries around the world, especially developing countries and countries in the Middle East region and the Gaza strip in particular, suffer from a scarcity of fresh water. The population of the Gaza Strip is expected to increase to 2.1 million by 2020; with the UN reporting that Gaza will no longer be habitable if major reconstruction is further delayed (UNRWA, 2015). One of the most affected service sectors is water, where poor water quality and high levels of water demand are increasingly leading to water scarcity, as highlighted by the Palestinian Water Authority (PWA) (*Water Resources Status Report, 2015*). Groundwater is the only water resource in the Gaza Strip and the total annual extraction from the coastal aquifer by water wells is about 200 Mm³, whilst it receives an annual average recharge of 80 - 110 Mm³/year, mainly from rainfall, lateral ground water flow, leakages from networks and wastewater collection basins. More than 45% of the available groundwater is being severely exploited for agricultural irrigation, whilst the remaining is used for domestic water supply and industry. As a result, it is estimated that there is an annual cumulative deficit of water of about 90 - 110 Mm³/year. Meanwhile the groundwater quality is deteriorating rapidly as can be seen in Figure 1. There is high salinity of chloride concentrations and total dissolved solids (TDS) exceed WHO recommended standards. The PWA's recent water resources report reveals that there is a rapid and massive decline in the level of groundwater below the mean sea water level (MSL), causing seawater intrusion. The water measurements demonstrate that there is large cone of depression in Rafah city that reaches 19 m below mean sea level (MSL) as illustrated in Figure 2. This is considered the maximum groundwater level declination in the Gaza strip. Urgent measures to address the prevailing water crisis in the Gaza Strip are being considered by the PWA to secure safe water for the people of the Gaza Strip. Due to the high salinity of water wells close to the Mediterranean coastal line of the Gaza strip territory and the need to overcome both water scarcity and salinity a medium term solution of spot pointing the eastern water wells of Rafah has been initiated. A Reverse Osmoses (RO) brackish water desalination plant has been constructed in order to benefit 22,000 inhabitants of Al Salam District. Oxfam has worked with the Coastal Municipalities Water Utility (CMWU). The overall aim of the plant is to enhance the water quality and quantity supplied to eastern districts of Rafah city whilst reducing the very high levels of extraction from

wells in the western region. The project included the drilling and equipping of the new reverse osmoses plant.



Rafah water supply system

The domestic municipal water supply and piped distribution system of Rafah served around 174,498 inhabitants in 2003. By 2016, it was serving around 213,124 inhabitants, using ground water extracted from the coastal aquifer. Table 1 shows the historical and current abstracted water quantities in the Rafah governorates. It can be seen that water demand has significantly increased in Rafah governorate from 5.5 to 8.82 Mm³ within 13 years. Overall system efficiency has been about 65%. This dramatic increase in users has severely affected the quality of ground water, which will be discussed in the next section.

Items	2003	2004	2005	2016
Total Municipal Water Production(Mm3)	5.5	6	6.4	8.82
Total Municipal Water Consumption(Mm3)	3.6	3.8	4	5.78
Efficiency	65%	63%	62.5%	65.5%
Assumed Total Agricultural Water Production(Mm3)	16.2	14.8	18	20
Total Water Abstracted (Mm3)	21.7	20.8	24.4	28.82
Per Capita Per Day (L/C/D)	93 ⁽¹⁾ - 60 ⁽²⁾	95 ⁽¹⁾ - 61 ⁽²⁾	97 ⁽¹⁾ - 61 ⁽²⁾	112 ⁽¹⁾ - 73 ⁽²⁾

(1) Computed value according to abstracted water (2) Computed value according to consumed water

Water quality

The aquifer water quality monitoring program and hydrological studies carried out by PWA water resources department shows less deterioration of water quality for water wells located at the eastern of the Gaza strip far away from the coastal line with mild brackish water. This makes the construction of RO brackish water desalination plant more feasible. Figure 4 shows the water quality of water wells in Rafah in addition to El Barazil water well highlighted in the circle which is being used to feed in Al Salam desalination plant.

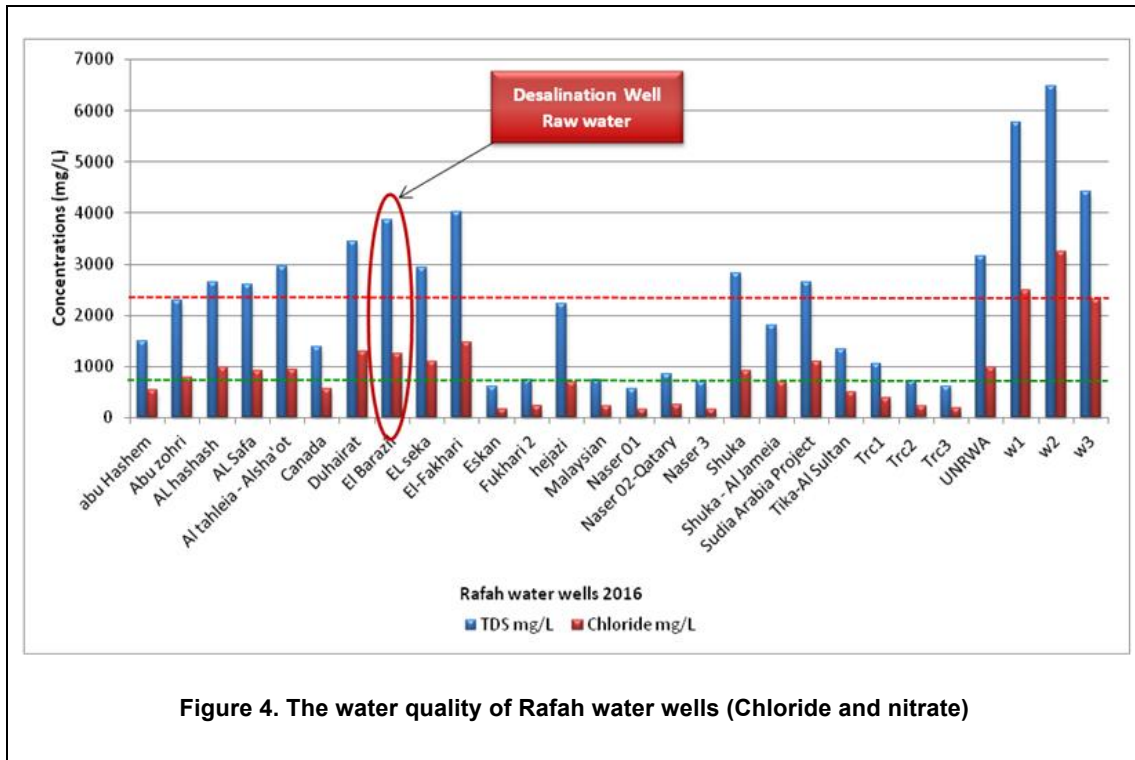


Figure 4. The water quality of Rafah water wells (Chloride and nitrate)

The quality of the municipal water wells is also monitored through the Ministry of Health (MoH) laboratory by taking a water sample from each municipal well twice a year. Figure 4 illustrates the TDS and chloride contaminants in the water well in Rafah; as it can be seen, the average TDS concentration in the water well is about 2,270 mg/l.

Geographical location and climatic situation

2.1 Study area

The Al Salam brackish water desalination plant is located in the southern part of the Gaza Strip on the eastern coast of the Mediterranean Sea where it forms a long and narrow rectangle, approximately 45 km in length and 8 km wide, giving a total area of about 378 km². A desert area, it is bounded by the Negev Desert to the south east and the Sinai Desert to the south west.

It is one of the most densely populated areas in the world with an average density of approximately 4,300 inhabitants/km². Most of its people are refugees who fled their homes in areas now controlled by Israel in the 1948 and 1967 Arab–Israeli wars (The World Fact Book 2015). It is expected that the population density will exceed 5,835 inhabitants/km² by 2020 (UNCT, Gaza in 2020).

Climate, rainfall and environment

The Gaza Strip is located in the transitional zone between the arid desert climate of the Sinai Peninsula and the temperate and the semi-humid Mediterranean climate along the coast. The average daily mean temperature ranges from 25°C in summer to 13°C in winter. Average daily maximum temperatures range from 29°C to 17°C and minimum temperatures from 21°C to 9°C in the summer and winter respectively.

The average annual rainfall varies from 450mm/year in the north to 200mm/year in the south (EQA 1999). The major environmental problem in the Gaza Strip is deteriorating water quality through salinisation and pollution resulting from a deficit in the water balance. This problem covers the fresh groundwater in the shallow aquifer underlying the Gaza Strip. The major indicators for deterioration are increases in salinity (chloride) and nitrate concentration (Water Quality report).

Selection of the water desalination plant location

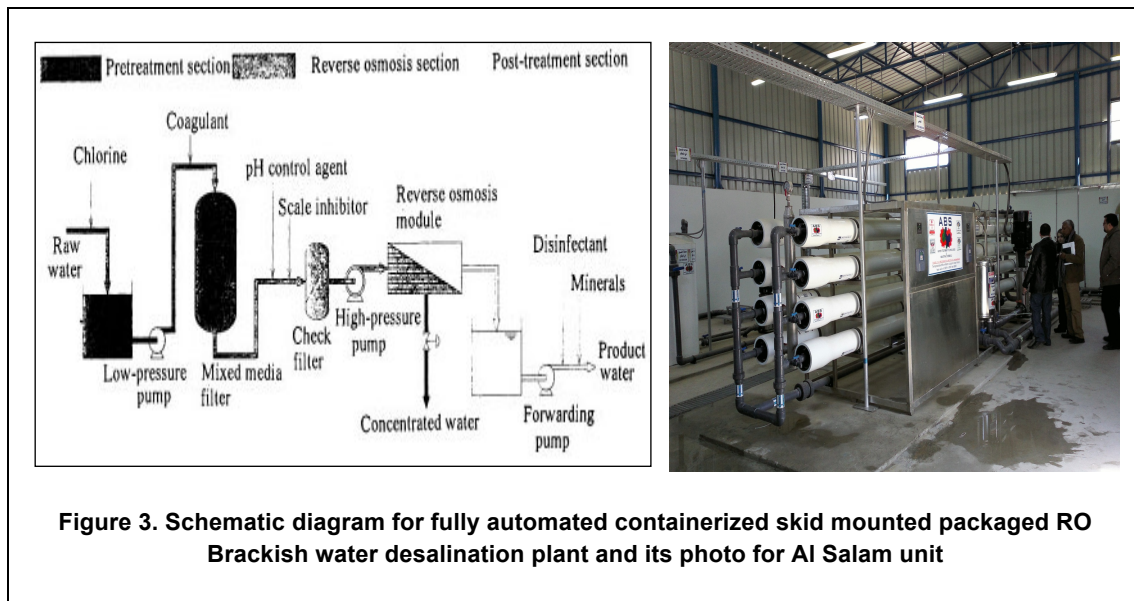
The plan location was determined in collaboration with the Palestinian Water Authority according to the master plan and the equitable distribution plan issued by the Coastal Municipalities Water Utility (CMWU). Additional reasons considered are as follows:

- The RO plant is located at eastern part of Rafah away from the other cluster of wells that suffer from high drawdown. The construction of this RO plant will offer the possibility of resizing the high discharge water wells and reducing the daily operating hours for each of them.
- No additional water network installations will be needed in addition to the RO plant.
- The location is close to an electricity utility and has drain facilities for brine rejection.
- The project will eliminate the need for carried lines to feed the eastern areas which will provide a positive impact in reducing pumping costs and reducing leakage from the main carrier lines.

Project components and process

The project activities included water well drilling and plant construction along with all associated electromechanical and civil works. In addition to that, a local booster pump with a 30m³ water tank was constructed to blend the desalinated pure water with a certain percentage of brackish water and to then to pump this water into the adjacent domestic water distribution network. Figure 3 illustrates the different water desalination process and their components. This includes pre-treatment, the RO section and the post treatment process.

Raw water of total maximum TDS of around 3,000 – 4,000 p.p.m. and chloride concentration around 1,300 p.p.m. is drawn from the new brackish water well. This then passes through the raw water tank and is pumped through a multimedia filter by a raw water pump through to 4" diameter stainless steel mesh screen and 5-micron cylindrical cartridge filter as illustrated in Figure 4.



Chemical pre-treatment of the raw water to control the Alkalinity (pH) of the raw water is controlled by a fully automated hydrochloric acid 33% dosing system linked with a pH monitoring meter.

Following the pre treatment process the raw water is pumped through the RO membranes to generate the permeate water with 78% system efficiency. Brine from the treatment plant is discharged via a gravity system through a 6" UPVC pipeline from the desalination plant to the main manhole, and from there to the sea through the existing gravity pipeline.

The quantity of permeate water from RO membrane is about 50m³/hour.

The unit also is fully equipped with an anti-scaling chemical treatment and a controlled backwashing process, including residual chlorine monitoring program for both inflow and out flow water of the designated plant. Figure 3 shows the installed RO desalination plant.

Results and discussions

Result of water quality tests for desalination plant (raw water from well, permeate water after RO and feed water after blending)

The Brackish Water Desalination Unit receives the feed water from a new municipal well named El Barazil (as circled and shown in Figure 4) with a total capacity of approximately 70m³/h brackish water.

Table 2 shows the characteristics of the desalination plant including flow rates ,quantities of feed water and distributed feed water. The mechanical and electromechanical equipment of the reverse osmosis unit itself has been designed for a maximum capacity of 50 m³/h.

The desalinated water (about 1,200 m³/d after a blending process with almost the same quantity of water supplied by another water scheme) is being pumped through the existing water networks, to supply drinking water to some 22,000 people (less than 500 p.p.m. Chlorides and nitrate concentration less than 70 p.p.m.).

Water flow rates										
Water Well M ³ /hr	Feed Water M ³ /hr	Permeate Water M ³ /hr	Brine Water M ³ /hr	Blending Water M ³ /hr	Total Feed Water M ³ /hr	Efficiency of RO %	Mobile Tankers M ³ /day	Public Taps M ³ /day	Flow Rate at HHs L/sec	Beneficiaries People
72,0	67,0	53,5	13,5	5,0	58,5	78	50,0	10,0	0,13 – 0,14	22000

Evaluation of chemical water quality of effluent water from desalination plants

The constructed desalination plant consists of different filters (sand filter, carbon filter, Antecedents, RO filter). The main filter of the desalination plants is a Reverse Osmosis filter. This filter is very effective; purifying 99% of the contaminating elements found in the raw water supply (Toray, 2017). The most important factor determining the success of the filters is the inlet water quality. However, as of March 2017, the quality of the water produced in the plant is within WHO limits for water quality as it can be seen in Figures 5 & 6.

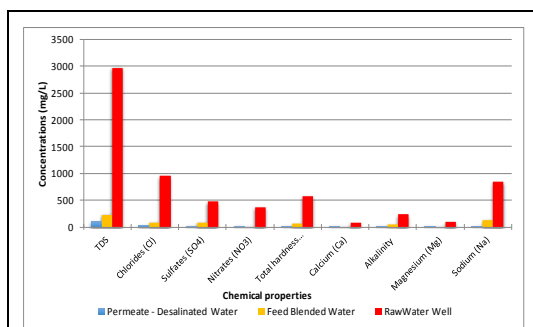


Figure 5. Water quality of desalinated, raw water and feed blended water

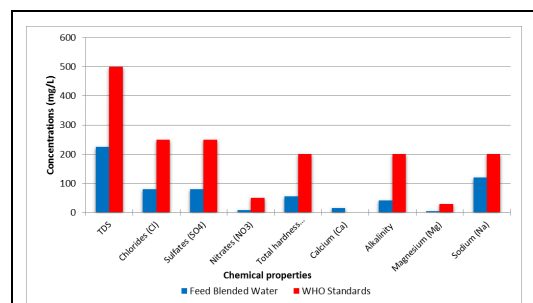


Figure 6. Water quality parameters of desalinated, water and WHO standards

The quality of the desalinated water and blended water has been laboratory tested. The RO plant is designed and constructed to produce fresh water and to distribute it through the water distribution network to the community. For this purpose the distributed water has been monitored and controlled to match WHO guidelines for drinking water and in particular to not exceed 250 p.p.m. for chloride and 50 p.p.m. for nitrate as it can be seen in Figure 5.

Microbiological water quality

An important aspect of drinking water is the microbiological quality. It is of particular significance because many types of disease can be transmitted to humans via pathogenic microorganisms or parasites in drinking water. Pathogenic organisms are highly dangerous to human health (Gray, N. F. 1994). The water quality analysis showed 100% of biological contaminant removal.

Financial aspects

The financial model and analysis for all incurred costs shows that the water produced costs no more than 1.6/m³ New Israel Shekel (NIS) which is less than the unit price of water supplied by the Israel Mekorot water company (priced at NIS 2.9 /m³ (CMWU 2017).

Operation and maintenance and staff training

The operation, management and maintenance of the RO unit has been assigned to the CMWU, which is already managing all the medium-scale desalination units in the Gaza Strip and has the required expertise and trained staff to keep the RO plant well-maintained and fully operational.

Sustainability

The desalination plant and its associated sustainability have been ensured through different aspects. The Brackish water RO unit has a lifespan of at least 20 years, if well-maintained and operated. The plants have so far been operated for 5 years by the CMWU, who have 20 years of experience of operating and managing such units.

The sustainability of a potable water supply for the target communities has also been enhanced by an extensive awareness raising programs. A increase consumption and utilization culture has been built among women, children and youth; creating a feeling of ownership for the water system and the infrastructure. This has helped promote keeping the RO units in good condition, both during and after the programme intervention. In addition, the target youths, mothers and children were encouraged to share the information they receive with as many people as possible to raise their social responsibility in terms of water provision.

Conclusion

The treatment of saline water is proving to be an important source of fresh water and is contributing to tackling global water scarcity issues, especially in the Gaza strip. The rapid deterioration of the available water resources in the Gaza strip had encouraged the PWA and CMWU to adopt desalination as a non-conventional water resource in order to cover the massive shortfall in fresh water. The installation of Al-Salam desalination plant has achieved the following outcomes:

- Improved water supply quality to the Al-Salam targeted communities (22,000 inhabitants) in terms of quality and quantity. The blended feed water is within WHO standards for drinking water.
- Reduction in the incidence of hygiene-related and water-borne diseases through integrating the RO unit's provision with hygiene and public health promotion, helping consumers to increase their awareness on water-borne diseases and how to prevent them.
- Reduction of malnutrition level, diarrhoea and anaemia by improving the quality of drinking water supply.

Empowerment of women, youth and children role in promoting a better water culture. It was easier to create a new generation with a positive water culture than to modify an existing one.

- Finally a collective cooperation and coordination among PWA, CMWU, International agencies and local communities was established to promote the use of brackish water medium scale desalination plants in order to tackle the water crises in the Gaza strip for the short-term solution and until the central desalination plant has been constructed.

Acknowledgement

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Notes

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