Journal of Environmental Science and Technology

ISSN 1994-7887

Journal of Environmental Science and Technology 4 (2): 158-171, 2011
ISSN 1994-7887 / DOI: 10.3923/jest.2011.158.171

Brackish Water Desalination is the Merely Potable Water Potential in the Gaza Strip: Prospective and Limitations

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ABSTRACT
Due to the increasing of salinity and nitrate in the groundwater aquifer, most of the water-relevant institutions in Gaza strip rely on brackish water desalination for drinking purposes. The study aims to evaluate the small-scale brackish water desalination plants in the Gaza strip and to highlight its environmental impacts. Samples of water from inlet and outlet for 43 local desalination plants were collected and analyzed in Water Laboratory of Palestinian Ministry of Health. Chloride, Ca and HCO_3^- were measured by Titration while EC, TDS and pH were determined using electrode and NO_3^- by spectrophotometer. Analyzed results have been compared with WHO standards, the parameters such as; TDS, Cl, Ca and NO_3 in the outlet were lower than WHO limits in most desalination plants. Results indicate that TDS concentration in most of desalination plants (outlet) ranges from 61-120 mg L^{-1}, while, Cl, Ca and NO_3 were ranged from 0-60, 0-30 and 0-60 mg L^{-1}, respectively. The variations of the chemical parameters are due to the variations of inlet water and instability of desalination efficiency. The monitoring of small-scale desalination plants is urgently needed to obtain the required safe chemical parameters. Meanwhile, more studies on the environmental impacts of desalination should be conducted in order to take the proper measures to protect the environment and the human health.

Key words: Gaza strip, reverse osmosis, brackish water, desalination, brine water, chloride, TDS

INTRODUCTION
Gaza Strip lies on the southwestern part of the Palestinian coastal plain. Its total area is 378 km^2 (UNEP, 2009) its length is approximately 45 km. Bounded by the Negev desert to the Southeast and the Sinai desert to the Southwest. Gaza is characterized by its desert nature. The average daily mean temperature ranges from 25°C in the summer to 13°C in the winter. Average daily maximum temperatures range from 29 to 17°C and minimum temperatures from 21 to 9°C in the summer and in the winter, respectively. The average annual rainfall varies from 450 mm $year^{-1}$ in the north to 200 mm $year^{-1}$ in the south (Daya, 2002). Regarding evaporation, maximum values of 140 mm $month^{-1}$ have been quoted for the summer, while relatively low pan-evaporation values of around 70 mm $month^{-1}$ were measured during the months of December and January. The daily relative humidity fluctuates between 65% in the daytime and 85% at night in the summer and between 60 and 80%, respectively in the winter (Daya, 2002).

Desalination provides a mean of upgrading brackish water (poor quality) to produce fresh water. This method has been practiced regularly for over 50 years and is a well-established means of water in many countries throughout the world (Semiat, 1999).

Gaza Strip suffering from depletion of available fresh water due to the over-pumping of the groundwater the only resource of domestic purposes. This problem became more severe by time as a result of sea water intrusion to the coastal aquifer, in addition to the infiltration of partially treated wastewater to the aquifer (Shomar, 2010; Qahman *et al*., 2009; PWA, 2003). The water demand in Gaza Strip is growing rapidly due the population growth and the willing of farmers to cultivate the poor land as a strategy toward poverty alleviation (Al-Najar, 2007). The high salinity of the water and other contaminants, in addition its bad health effect, undesirable tastes are motives to find new resource such as the desalination and quality improvement technology in addition to other means which are not included in the current research. The concentration of chemical pollutants, including nitrate and chloride have exceeded the standards recommended by WHO (MOH, 2009; Al-Najar and Adeloye, 2005; Daya, 2002) from most of the municipal wells. Due to the pointed shortage of water and the bad quality of groundwater, desalination plants were set up in the Gaza Strip. Reverse Osmosis (RO) systems reverse the natural process of solvent transport across a semi-permeable membrane from a region of lower solute concentration into one of higher solute concentration to equalize the free energies. In RO external pressure is applied to the high solute (concentrated) water to cause solvent (water) to migrate through the membrane leaving the solute (salts and other non permeates) in a more concentrated brine. Some membranes will reject up to 99% of all ionic solids and commonly have molecular weight cut off in the range of 100 to 300 Daltons for organic chemicals. RO processes can produce water in the range of 10 to 500 mg L^{-1} TDS (WHO, 2007).

Currently, there are six reverse osmosis desalination plants in the Gaza Strip owned and operated by the Palestinian Water Authority (PWA) local municipalities. In addition, there are many small desalination units owned and operated by private investors for commercial purposes. Nowadays there is a plan for a regional seawater desalination plant with a capacity up to 150,000 m^3/y (CMWU, 2009; Baalousha, 2005). According to the Palestininan Water Authority (PWA) and Coastal Municipal Water Utility (CMWU) plan, desalination seems to be the only feasible alternative for potable water source for the residents in the Gaza Strip. The desalinated water market has been developed by time; about 95% of the people in Gaza Strip depend on the small-scale brackish water desalination plants and home filter for drinking purposes (Abu-Amr and Mayla, 2010). There are more than 50 Brackish Water Desalination Plants (BWDPs) in Gaza Strip, more than 50% of these plants are unofficially registered and therefore no quality monitoring program is applied. The current research aims to evaluation the ground water quality in Gaza Strip in general and the inlet and outlet water quality for small-scale brackish water BWDPs comparing to the WHO standards. Various desalination techniques that are implemented in the Gaza Strip and the main environmental impacts will be essential concern in the current research.

MATERIALS AND METHODS

During the period from March 2009 to March 2010, samples of water from the inlet and outlet of the desalination plants in the Gaza Strip were collected for chemical water analysis such as pH, Total Dissolved Solids (TDS), Chloride, Nitrate and Calcium to evaluate the desalinated water quality in Gaza Strip. Ground water quality data of municipal wells were collected (ministry of health monitoring program) for the same period 2009/2010 to evaluate the ground water quality status during the research period. Chloride, Ca and HCO_3^- were measured by Titration while EC, TDS and pH were determined using electrode and NO_3^- by spectrophotometer. Samples analysis were conducted at the public health laboratory for foods and water at the Palestinian Ministry of Health for the monitoring program implemented by Water control department using the procedures described by the American Public Health Association, 1992. Results of desalination plants water quality (inlet and outlet) and the collected data were analyzed using software packages such as Microsoft office (Excel) and Statistical Package for Social Sciences (SPSS).

RESULTS AND DISCUSSION

Groundwater quality beneath The Gaza Strip Governorates: Total Dissolved Solids (TDS) and Cl used in the current research as an indicator of groundwater salinity contamination in Gaza Strip while Nitrate is used as an indicator of anthropogenic contamination of groundwater. High levels of chloride and TDS in the groundwater cause high salinity in the water supply (Al-Jamal and Al-Yaqubi, 2000). Table 1 summarize the average concentration of TDS, Cl and NO_3 for drinking water-wells in each Governorate of Gaza Strip within one year. The Average TDS Concentration ranges from 720 mg L^{-1} in the north to 2709 mg L^{-1} in Gaza Governorate. The Average chloride concentration ranges from 181 mg L^{-1} in the North to 772 mg L^{-1} in Gaza Governorate. Gaza city represent the main city in the Gaza Strip, so nearly half of Gaza Strip population reside in Gaza city. As a consequence water supply and demand are the highest, therefore more groundwater abstracted from the aquifer beneath the Gaza city. This accelerates the rapid sea intrusion which can be seen in the high concentration of TDS and chloride compared to the north governorates. The average concentration of Nitrate ranges from 97 mg L^{-1} in the north to 139 in Gaza Governorate. Similar investigation also emphasis the fact of nitrate pollution due to the infiltration of partially treated effluent and the excess use of nitrogen fertilizer to the groundwater (Shomar *et al.*, 2008) As shown in Table 1, the level of TDS, Cl and Nitrate were higher than WHO standards (1000, 250 and 50 mg L^{-1}, respectively) for the entire Gaza strip Governorates except the North Governorate which has a lower concentration of TDS than WHO standards.

Table 2 presents the percentages of drinking water wells that exceed WHO standards of TDS, Chloride and Nitrate. For TDS, about 49% of drinking municipal water wells were exceed the WHO standards (1000 mg L^{-1}). The percentage ranges from 4% in the north Governorate to 81% in Middle Governorates. Like TDS, the concentrations of Chloride in 58% of municipal water wells

Table 1: Average concentration of chemical parameters of the coastal aquifer beneath the five geographical governorates in Gaza Strip at the year 2009/2010

Governorate	No. of wells	Abstraction ($m^3 h^{-1}$)	TDS (mg L^{-1})	NO_3 (mg L^{-1})	Cl (mg L^{-1})
Rafah	17	1505	1196	114	429
Khan Younis	32	2470	1603	205	637
Middle	39	2308	1495	80	634
Gaza	44	4562	1696	139	772
North	32	3904	720	97	181
WHO standard	-	-	1000	50	250
Total	164	14749	-	-	-

were higher than WHO Standards (250 mg L^{-1}) and its ranges from 8% in the North to 94% in Middle Governorate.

The major source of salinity in Gaza Strip aquifer is derived from the flow of natural saline groundwater from the eastern part of the aquifer toward the Gaza Strip. The long-term reduction of the water table because of overexploitation has increased the water gradients and rate of lateral

Table 2: Chemical parameters (mg L^{-1}) for inlet of small-scale BWDPs in Gaza Strip (Brackish water wells)

Location	Plant name	pH	TDS	NO_3	Cl	Ca
North area	Hanneaf P.	7.56	2685	239.9	1362	334
	Al Rodwan P.	7.61	569	132.4	946	120
	Al Nile 2 P.	7.2	883	198.4	175	127
	Al Nile 1 P.	7.31	1109	316.8	287	146
	Al Rashead P.	7.59	819	120.6	189	103.7
	Al Karama P.	7.16	1469	131.3	527.3	116.6
	Yafa P.	7.4	1192	83.3	374.1	107
	Al Yasean P.	7.23	719	121.4	156.8	95.9
	Al Shahd P.	7.1	635	93	121.1	120
	Ammer Project P.	7.46	1102	139	349	118
	Al Barakah P.	6.52	785	197	106	105
More than WHO Standards		0 (0%)	5 (45%)	11 (100%)	6 (54%)	1 (9%)
Gaza	Al Qemma P.	7.05	731	160	147.4	100.7
	Industrial Estate P.	7.5	2976	38.3	1154	70.29
	Al Mannar P.	7.99	2294	48.05	872	54.12
	Al Rahmma P.	7.4	1556	113.5	516.3	84.71
	Al Holle P.	6	1922	270.3	537.8	152.7
	Al Sabbrah P.	6.24	1291	165.4	375	106
	Al Ferdawse P.	7.73	817	69.6	243.8	90.2
	Al Sakhrah P.	7.6	1612	156.7	517.3	138.2
	Al Qawther P.	6.74	704.3	26.7	217	68
	Al Zarka P.	7.34	3057	139	1190	131.3
	Beach Camp P.	7.25	1606	188.6	555.8	113.2
	Mekkah P.	7.2	1210	177.6	413.8	109.7
	Al Forrate P.	7.06	2740	42.1	1131	165
	Akwa P.	7.25	2727	24.4	1179	120
	Al Harazzen P.	6.61	521	296.7	537.8	167.5
More than WHO Standards		0 (0%)	11(73.3%)	10 (66.6%)	12 (80%)	0 (0%)
Middle	Al Forat P.	7.65	2615	30	1162	181
	Islamic Al Salah P.	7.1	2678	185	1083.2	106
	Al Ferdaws P.	7.2	3373	552.8	1150.9	97
	Al Zawaida P.	7.3	2260	124.7	872.5	108
	Al GanowP P.	7.4	2635	32.37	1062	137.8
More than WHO Standards		0 (0%)	5 (100%)	3 (60%)	5 (100%)	0 (0%)
Khan Younis	Al Sharqy P.	7.21	2846	212.8	1061	73.88
	Al Sharqeya P.	7.84	2740	188	928	66
	Al Saada P.	7.68	2418	320	817	132
	Khan Younis P.	7.6	2540	126.4	1048	136

Table 2: Continued

Location	Plant name	pH	TDS	NO_3	Cl	Ca
More than WHO Standards		0 (0%)	4 (100%)	4 (100%)	4(100%)	0 (0%)
Rafah	Al Forat P.	7.17	1773	297.8	681.2	75.2
	Zamzam P.	7.69	2077	191.5	735	138.2
	Al Salah Ass.	7.57	2263	242.3	756	104.5
	Al Salam P.	7.01	1637	151.4	532	53.6
	Abu Shaar P.	8.28	2207	373	747	72
	Al Raiian P.	7.9	1928	342.2	609	101.1
	Al Nile P.	7.77	2877	110	1103	124
	Rafah P.	7.66	2210	277.6	838	127
More than WHO Standards		0 (0%)	8 (100%)	8 (100%)	8 (100%)	0 (0%)

water flow toward Gaza Strip. Seawater intrusion has also resulted in salinization of groundwater in the western part of the aquifer (Qahman *et al*., 2005; Weinthal *et al*., 2005). Seawater intrusion and uplift the deep brine water are the direct consequences of over pumping and represent the greatest threats to municipal and agricultural water supplies in Gaza Strip. The lateral inflow of brackish water from the east is believed to be groundwater from the Eocene age rocks that underlie the coastal aquifer in the east and is therefore of natural origin (AL-Agha and EL-Nakhal, 2004). The relatively low values of chloride in the north and demonstrates the shallow nature of wells that are sampled. The increasing chloride trends in the Khan Younis municipal well field are demonstrated by the deeper wells.

In contrast to salinity, groundwater flowing from east has relatively low nitrate levels (Nassar *et al*., 2009). As shown in Table 2, about 79% of municipal wells in the Gaza Strip have nitrate concentrations that exceed WHO guidelines of 50 mg L^{-1}. The level of nitrate contamination has been rising so rapidly that most of Gaza's drinking water wells are no longer adequate for human consumption. Nevertheless, domestic wells continue to supply groundwater of poor quality to local communities for domestic use (Vengosh *et al*., 2002, 2005).

Chemical quality for inlet of small-scale BWDPs in Gaza Strip: About 43 desalination plants were distributing randomly in Gaza Strip Governorates. The source of inlet water for these plants mainly from groundwater abstracted by drilling boreholes in the site of this plants, which located in different governorates as shown in Table 1. pH values in inlet for all desalination plants aren't exceed WHO standards (6.5-8.5), while, its less than WHO limits for two plants in Gaza Governorate (6 and 6.2). For TDS concentration, about 5 plants (45%) out of 11 in the North Governorate were exceed WHO Limits (1000 mg L^{-1}), while in Gaza City TDS level was higher than WHO standards in 11 (73.3%) plants, the concentration of TDS was higher than WHO limits in the inlet water for all desalination plants in Middle governorate; 5 plants (100%), Khanyounis 4 (100%) and Rafah 8 (100%). The concentration of chloride for inlet water of 6 (54%) plants in the North Governorate were more than WHO standards (250 mg L^{-1}). while, in Gaza Governorate, the concentration level was exceeds WHO standards for inlet water of 12 (80%) desalination plants as shown in Table 2. Like TDS, the concentration of Chloride were higher than WHO standard for inlet water of all desalination plants in Middle governorate, Khanyounis and Rafah; 5 (100%), 4(100%) and 8 (100%), respectively. Its worth to mention that the percentages of desalination plants that higher than WHO limits for concentration of TDS and Chloride were increasing from the North to Rafah Governorate. The level of TDS, Cl and Nitrate were higher than WHO standard for the Gaza Strip except in the North Governorate the concentration of TDS were less than standards. Mayla and Amr 2010 declare the similar results. For Nitrate Concentration, the inlet water for most desalination plants in the North 11 (100%), Khanyounis 4 (100%) and Rafah 8 (100%) Governorates were higher than WHO standards, while the level of Nitrate for inlet water of plants in Gaza and Middle Governorates were higher than WHO standards in 10 (66.6%) and 3 (60%) of plants, respectively. Its reflects the contamination of groundwater by Nitrate due to the infiltration of partially treated wastewater. Generally, the Calcium concentration were not exceeds than WHO standards (200 mg L^{-1}) for inlet water in the most desalination plants for all Gaza Strip Governorates except one plants in the North.

Chemical quality for outlet of small-scale BWDPs in Gaza strip: To evaluate the desalinated water quality, Table 3 presents the results of chemical analysis for desalinated water from small-scale BWDPs in Gaza Strip. Generally, pH values were less than 6.5 in the most desalination plants in Gaza Strip except in some plants were fluctuates from 6.5 to 8.5. The Palestinian Recommendation for the pH value of the drinking water is between 6.5-8.5 and this value has healthy effects (PWA, 2000). The main purpose in controlling pH is to produce water in which corrosion and incrustation are minimized. These processes, which can cause considerable damage to the water supply system, result from complex interactions between pH and other parameters such as dissolved solids, dissolved gases, hardness, alkalinity and temperature. By keeping the pH below 8.5, the rate of chlorine disinfection is increased and the production of trihalomethanes is reduced. (WHO, 2003). The level of both TDS and Chloride aren't exceed the limits of WHO for all desalination plants, while in some plants the level of TDS and Chloride were less than 50 and 10 mg L^{-1}, respectively. For Nitrate concentration, 3 desalination plants out of 43 in Gaza Strip resulting an increasing of Nitrate level than WHO limits, while the other plants generally less than 38 mg L^{-1}. The level of calcium was not exceeds WHO standards moreover, the concentration of calcium for all desalination plants were less than 25 mg L^{-1} except in one plant in Gaza Governorate was 51 mg L^{-1}. A certain Ca^{2+} concentration is required in drinking water not only because it induces $CaCO_3$(s) precipitation, but also because of health reasons. Calcium is vital for human growth particularly for infants. Twenty percent of the recommended daily dosage arrives from drinking water (Kozisek, 2003). Most guidelines worldwide set the minimum Ca^{2+} concentration value at 20-25 mg Ca^{2+} L^{-1}.

Chemical parameters for inlet and outlet of small-scale BWDPs comparing with WHO standards: In order to achieve an obvious investigation and evaluate the efficiency of the small-scale BWDPs; chemical parameters of inlet and outlet of their plants have been compared with WHO standards .

As shown in Fig. 1, Generally, pH of inlet in most plants ranging within the acceptable WHO standards (6.5-8.5). While, pH of the outlet in most of their plants were less than WHO standards, as a result of lacking pH adjustment and clear control in desalination plants.

In Fig. 2 and 3, generally, there is a big gap between inlet and outlet concentrations of TDS and Chloride as a result to the high removal efficiency of desalination plants.

As shown in Fig. 4. Nitrate concentration for outlet of most plants is slightly lower than WHO standards, moreover, three plants produced a higher concentrations of nitrate than WHO standards. It is indicate that the efficiency of NO_3 is lower the that in case of TDS and Chloride.

Table 3: Chemical parameters (mg L^{-1}) for outlet of small-scale BWDPs in Gaza Strip

Location	Plant name	pH	TDS	NO_3	Cl	Ca
North area	Hanneaf P.	7.72	156.9	36.6	76.16	4.2
	Al Rodwan P.	6.44	48.98	20.64	15.77	6.5
	Al Nile 2 P.	5.99	59.77	20.6	14	7
	Al Nile 1 P.	5.92	58.28	20.1	21	6
	Al Rashead P.	6.14	54.6	12.3	28	7.8
	Al Karama P.	6.17	192	25.4	71.3	3.5
	Yafa P.	5.49	62	18	14.3	5.3
	Al Yasean P.	6.42	81	34.5	3.6	4.3
	Al Shahd P.	6.28	64	21.1	14.3	5.2
	Ammer Project P.	7.06	154	35	42	18
	Al Barakah P.	6.3	50	17	11	2
Gaza	Al Qemma P.	6.13	79.98	24.31	21.26	7.94
	Industrial Estate P.	8.2	246.8	4.997	102	11.88
	Al Mannar P.	6.92	83.45	5.22	35.86	14.76
	Al Rahmma P.	6.44	110.4	7.261	14.34	25.61
	Al Holle P.	6.08	124	25.56	35.86	19.7
	Al Sabbrah P.	6.32	104.2	28.7	28.68	8.4
	Al Ferdawse P.	7.7	80.48	19.7	28.68	8.4
	Al Sakhrah P.	7.4	121.2	21.3	31.04	7.8
	Al Qawther P.	5.52	79.42	11.4	14	9
	Al Zarka P.	5.66	108	9.9	35.6	2.6
	Beach Camp P.	6.3	109	20.8	42.8	2.2
	Mekkah P.	4.15	23.13	10.9	13.79	1.7
	Al Forrate P.	8.2	102.4	2.8	42.7	8.2
	Akwa P.	7.43	198.4	8.7	103	1
	Al Harazzen P.	7.12	184.1	50.24	131.4	51.17
Middle	Al Forat P.	8.34	92.07	2.6	35	7
	Islamic Al Salah P.	6.14	81	8.1	28.5	1.3
	Al Ferdaws P.	5	74	25.5	24.9	0.7
	Al Zawaida P.	6.3	116	7.9	44.8	1.4
	Al GanowP P.	6.4	87.36	4.84	39.3	5.4
Khan Younis	Al Sharqy P.	6.81	287.1	63.37	93.22	5.4
	Al Sharqeya P.	7.6	205	41	66	3
	Al Saada P.	7.71	236	49	70	10
	Khan Younis P.	6.9	142	8.4	65.6	10
Rafah	Al Forat P.	5.95	164.9	51.6	44.46	2.5
	Zamzam P.	8.22	116	25.6	28	14.7
	Al Salah Association	6.47	111	33.6	21	13
	Al Salam P.	6.1	288	42	98	5.2
	Abu Shaar P.	7.79	186	84	49	3
	Al Raiian P.	7.24	117	38.5	35	9.5
	Al Nile P.	6.4	129	9	42	8
	Rafah P.	6.3	85.1	31.5	31	8.5

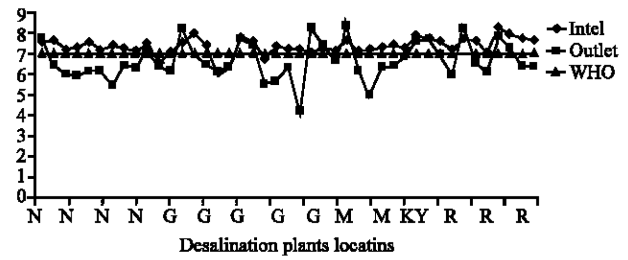

Fig. 1: pH concentration for inlet and outlet water of small scale desalination plants comparing with WHO limit

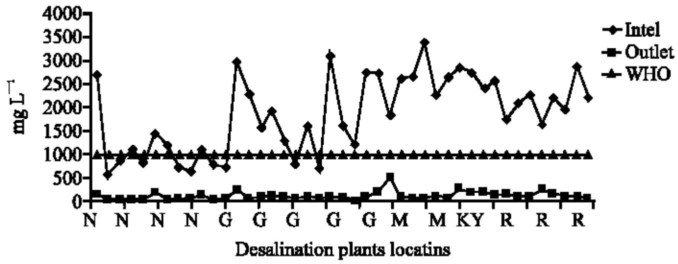

Fig. 2: TDS concentration for inlet and outlet water of small scale desalination plants comparing with WHO limit

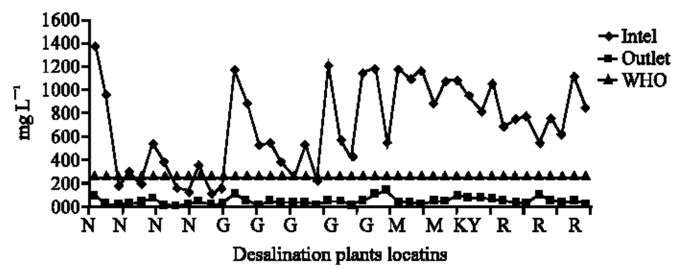

Fig. 3: Chloride concentration for inlet and outlet water of small scale desalination plants comparing with WHO limit

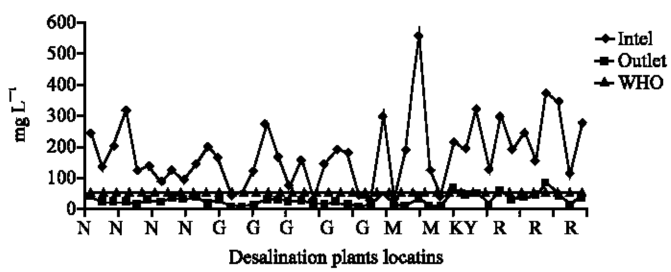

Fig. 4: Nitrate concentration for inlet and outlet water of small scale desalination plants comparing with WHO limit

This fact is not appropriate in case of Gaza strip which has a higher concentration of Nitrate in the groundwater aquifer, that motives to find other more efficient technologies in removing of NO_3 than

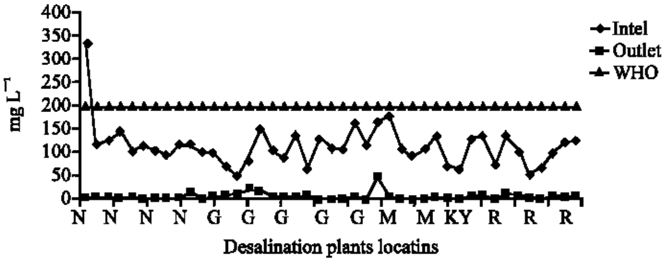

Fig. 5: Calcium concentration for inlet and outlet water of small scale desalination plants comparing with WHO limit

the actual technology, particularly in the regions that have a highest concentrations of NO_3. In addition, nitrate has more health impact than TDS and chloride specially if the blue babies is considered.

As shown in Fig. 5, there is an excessive removing of calcium element less than WHO standards (20-25 mg L^{-1}). In many of small-scale BWDPs in Gaza Strip it is clear that there is no any concerning of the concentration level of the calcium and any of other vital elements needed to the human growth particularly in case of infants. And there is no any official regulation or clear monitoring body to control water quality parameters for drinking proposes. The highest priority to offer good taste drinking water rather than healthy water.

Table 4 illustrates the Minimum, Maximum and Average concentration of chemical parameters for desalinated water of small scale desalination plants in Gaza Strip. Moreover, TDS concentration in desalinated water of small scale plants ranges from 23 to 521 mg L^{-1}. For chloride concentration, the minimum value was 3.6 mg L^{-1} and the maximum value was 130 mg L^{-1}. The level of Nitrate in desalinated water for all plants ranges from 2.6 to 84 mg L^{-1} and for Calcium concentration, the minimum level was 0.7 and the maximum was 51 mg L^{-1}. There is a big gab and obvious variation between the minimum and maximum values for all chemical parameters in desalinated water from desalinated plants due to the variations in inlet water quality and the variety of desalination efficiency of elements removing by using the small scale desalination plants. The concentration intervals for chemical parameters of desalinated water also interpreted in Table 4 and Fig. 1-5.

Total Dissolved Solids (TDS) comprises inorganic salts and small amounts of organic matter that are dissolved in water. The principal constituents are usually the cations calcium, magnesium, sodium and potassium and the anions carbonate, bicarbonate, chloride, sulphate and, particularly in groundwater, nitrate (WHO, 2003). Figure 6 shows that the intervals of TDS concentration for desalinated water from small scale plants in Gaza Strip. The highest intervals of TDS concentration showed from 61 to 90 and from 91 to 120 mg L^{-1}, respectively and the lowest interval was from 0 to 30 mg L^{-1}. Recent data on health effects associated with the ingestion of TDS in drinking water have not been identified; however, associations between various health effects and hardness, rather than TDS content, have been investigated in many studies. Water with extremely low TDS concentrations may also be unacceptable because of its flat, insipid taste. The WHO standard of chloride concentration in drinking water is 250 mg L^{-1}, The concentration intervals of chloride in desalinated water showed in Fig. 7, chloride concentration in the most desalination plants were ranges in the intervals from 0 to 30 and from 31 to 60 mg L^{-1}, respectively. Chloride is the most abundant anion in the human body and contributes significantly, along with its associated actions, to the osmotic activity of the extra-cellular fluid; 88% of the chloride in the body is extra-cellular.

Table 4: Minimum, maximum, average and concentration intervals for chemical parameters of small-scale BWDPs in Gaza Strip

				Intervals (mg L^{-1})						
Parameters	Min.	Max.	Ave.	> 200	151-200	121-150	91-120	61-90	31-60	0- 30
TDS	23	521	130	6	6	4	10	11	5	1
Cl	3.6	130	42	0	0	0	4	5	16	18
NO_3	2.6	84	24	0	0	0	0	1	12	30
Ca	0.7	51	8.3	0	0	0	0	0	0	43

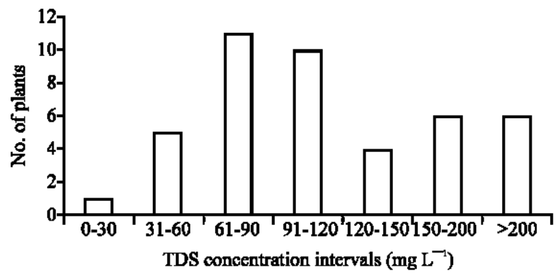

Fig. 6: TDS concentration intervals for desalinated water from small-scale BWDPs in Gaza Strip

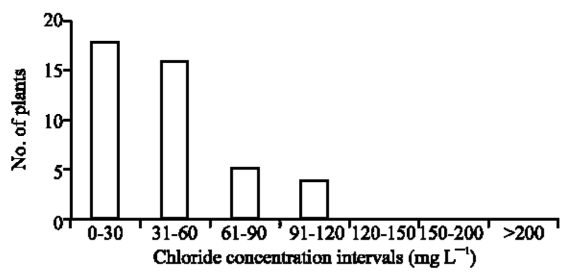

Fig. 7: Chloride concentration intervals for desalinated water from small-scale BWDPs in Gaza Strip

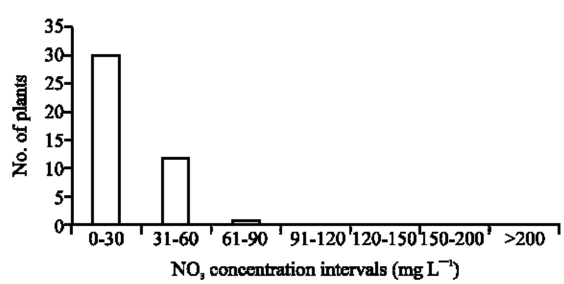

Fig. 8: Nitrate concentration intervals for desalinated water from small-scale BWDPs in Gaza Strip

A normal 70 kg human body contains approximately 81.7 g of chloride and 45 L of water. The taste threshold for chloride in drinking water is dependent on associated cation, but is usually within the range of 200-300 mg of chloride per litter (WHO, 1996).

Nitrate (NO_3) concentration intervals in desalinated water presents in Fig. 8, the concentration of nitrate in the majority outlet of desalination plants ranges in the interval from 0 to 30 mg L^{-1}. It has been well documented that, in some countries, water supplies containing high levels of

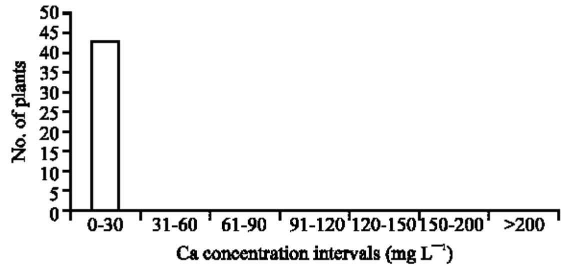

Fig. 9: Calcium Concentration intervals for desalinated water from small-scale BWDPs in Gaza Strip

nitrate have been responsible for cases of infantile methaemoglobinaemia and death. The extent of the world wide problem has been reviewed in a WHO document. It has been recommended that water supplies containing high levels of nitrate (more than 100 mg L^{-1}) should not be used for the preparation of infant foods, alternative supplies having low nitrate content, even to the extent of using bottled water, have been recommended (WHO, 1984).

Calcium is an essential part of the human diet. However, the nutritional value from water is likely to be minimal compared to that from other food sources. There is no health objection to high calcium content in water, the main limitations being made on the grounds of excessive scale formation. Figure 9 showed the concentration interval for calcium in desalinated water from small scale plants in Gaza Strip, the level of Calcium for all plants were ranging in the interval from 0 to 30 mg L^{-1}. WHO recommends a maximum level of 200 mg L^{-1} as Ca, even if there is no health-base guideline value recommended by WHO for water calcium. The taste threshold for the calcium ion is in the range 100-300 mg L^{-1}, depending on the associated anion. Studies presented that the optimal Ca/Mg ratio should not exceed 2:1 (Kozisek, 2003).

According to the WHO standards, potable water may contain different minerals up to a certain limit. In the Gaza commercial desalination plants and in the absence of quality control, the desalinated water has negligible amounts of several minerals such as calcium. It is reported that the produced water of these plants has less than 30 mg L^{-1} Ca and similarly other elements, Therefore, the produced water contains no elements that are needed for human health.

The disadvantages and the environmental impacts of small-scale BWDPs: Characteristics of effluent brine from desalination plants depend on the method of desalination. However, all desalination plants use chlorine, which is hazardous to the environment, to clean the pipes in the pretreatment process. In general, salt concentration of brine effluent is almost double that of seawater (seawater has about 35,000 ppm of salt concentration, while the brine has 46,000 to 80,000 ppm). Brine salinity measurements were at twice as high as these of the feed water. Both the high bacterial counts and salinity values may cause risky environmental changes in the Bay (coastal seawater) ecosystem especially on coral reefs, in fish aquaria, as well as to effect swimmers, snorkeller and scuba divers, Despite the high efficiency (100%) of the reverse osmosis membrane technology in removing seawater and brackish water salts, the investigated desalination systems were not satisfactory in producing bacteriologically- safe potable water, Furthermore, There is a possibility of having a highly contaminated fresh water source with bacteria other than the seawater, kitchen and/or swimming pool drains for example and it may also indicate a bad fouled condition of the running reverse osmosis membranes (Diab 2002). In such a case the reveres osmosis membrane become a source of contamination (Durham, 1997; Tua, 1996). In many cases reverse osmosis is the heart of a high water purity system. The very high load of pathogenic bacteria in the brine, such as Salmonella, Shigella, vibrio and Aeromonas are virulent against both human and fish (Diab *et al.*, 1995). It is clear that the bad environmental impacts on the studied ecosystem is expected, if not recognizable now it would be later (Diab, 2002).

RO membrane fouling is a complex phenomenon involving the deposition of materials on the membrane surface rather than plugging of the system. Scaling of RO membrane surfaces is caused by the precipitation of sparingly soluble salts from the concentrated brine (especially $CaCO_3$ and $BaSO_4$). A number of chemicals may be added to prevent membrane fouling. For example, sulfuric or hydrochloric acid is employed to reduce pH and prevent $CaCO_3$ precipitation. Sulfuric acid, while safer and less expensive than HCl, will increase the content of sulfate ions in the feed water and consequently the risk of $CaSO_4$ precipitation. The addition of polyphosphates or, more recently, polycarboxylates is employed for preventing $CaSO_4$ scaling (Morales and Barrufet, 2002).

In Gaza Strip small-scale BWDPs. Accordingly, effluent of these plants contains some chemicals like anti-scaling, surfactants, ferric chloride and acids, that may affect the environment if a proper dilution process not followed. The effluents of small-scale BWDPs which are also used in the Gaza Strip have characteristics totally different from that of groundwater. It has more calcium and magnesium besides other components. In the Gaza Strip, the effluents of these plants are not properly disposed. In all cases, the effluents are discharged in the nearby field and thus, it might lead to contamination of groundwater and leachate deposition may denigrate soil productivity. Besides commercial desalination plants, use of small RO units at home is very common in the Gaza Strip. The water produced by these units is generally not controlled or tested. In the absence of public awareness, people are using these RO units for a very long time without changing the membrane. As a result, the consumed water from the home units is rather unhealthy and might cause different diseases due to bacteria and virus accumulations.

Freshwater in the Gaza Strip coastal aquifer exists in the form of lenses which lie on more dense brackish water. These freshwater lenses are recharged by infiltration of rainfall and other minor sources (e.g., leakage from water system, sewer system). Over-pumping of freshwater causes upconing of brackish and saline water beneath. Although the desalination projects use brackish water beneath the fresh lenses as a feed, this has an adverse impact on the environment. Withdrawal of brackish groundwater might contribute to imbalance in the groundwater system, which is already very fragile. Continuous pumping of these dense layers of brackish groundwater might lead to lowering of water table above. The water table and transition zone between fresh and brackish/saline water will be changed. In coastal aquifers, like the case of the Gaza Strip aquifer, there is a saltwater boundary between the fresh groundwater and the seawater. The length of that boundary is highly dependent on the inflow and outflow of groundwater. In natural conditions, the length of the boundary is about tens to hundreds of meters. Extraction of groundwater causes an inland shift of this boundary, consequently affecting the freshwater–saline water balance. This balance is obviously disturbed in the Gaza Strip coastal aquifer. Given the high pumping rate, there is a strong evidence of seawater intrusion.

CONCLUSION

The groundwater beneath the Gaza Strip is unsuitable for drinking purposes; the low areas of chloride concentration has high nitrate concentration and vice versa. There are wide variations of water quality, therefore not all water in Gaza Strip need the same elements removal technology. The inlet water quality parameters in most plants are higher than WHO standards and Palestinian standards but the high desalination efficiency led to completely removal of essential elements that are essential to human health such as Calcium.

Using desalination as a source of water supply has many advantages. It seems that RO is the best choice in terms of quality of produced drinking water. However, the impact of these plants is not well investigated.

The environmental issue should be well discussed before implementing the small-scale or regional desalination plant. The relevant institutions should strictly control the private sector desalination units for commercial purposes to ensure that they consider environmental aspects. Currently, the brine of these inland units is disposed in the field, in the sewerage system or directly in the street. The quality of the produced water should be also monitored to ensure that it meets health requirements. Another important issue is the pumping of brackish water from the aquifer. It is true that this water is not potable, but it is located in layers beneath the underground freshwater. Depletion of these layers of brackish water could lead to lowering of the water table and intrusion of seawater affecting the unsaturated zone.

ACKNOWLEDGMENT

My deep grateful to the Al Azhar University, particularly the Institution of Water and Environment for giving me the real and appreciated opportunity to carry out the research and I wish to express my gratitude to Mr. Salem Abu Amr for his unlimited technical support and data analysis.

REFERENCES

Abu Amr, S. and Y. Abu Mayla, 2010. Integrated Water Resources Management Options in Gaza Strip. Whelfenston Center for Development, Washington DC.

Al-Agha, M. and H. El-Nakhal, 2004. Hydrochemical facies of groundwater in the Gaza Strip, Palestine/Facis hydrochimiques de leau souterraine dans la Bande de Gaza, Palestine. Hydrol. Sci. J., 49: 1-371.

Al-Jamal, K. and A. Al-Yaqubi, 2000. Prospect of Water Desalination in Gaza. Palestinian Water Authority, Gaza.

Al-Najar, H. and A.J. Adeloye, 2005. The effect of urban expansion on groundwater recharge as renewable resource in Gaza Strip. RICS, 5: 7-21.

Al-Najar, H., 2007. Urban agriculture and eco-sanitation: The strategic potential toward poverty alleviation in the Gaza Strip. RICS Res., 7: 9-22.

APHA, 1992. Standard Methods for the Examination of Water and Wastewater. 17th Edn., American Public Health Association, Washington, DC.

Baalousha, H., 2005. Desalination Status in the Gaza Strip and its Environmental Impact. Institute of Hydraulic Engineering and Water Resources Management, Aachen University of Technology Germany.

CMWU, 2009. Gaza emergency water project II. 2nd Quarter Report of Water Quality in Gaza Strip, Palestinian Authority, pp: 1-19.

Daya, N.A., 2002. Qualitative use of home reverse osmosis filters of some areas in Gaza strip. Hydrology Group For Water and Environmental. http://www.phg.org/publications.asp?i=19 andcat=5.

Diab, A.M., A. Dewedar and M. Zaki, 1995. Aeromonas hydrophyla and aeromonas sobria, a hygienic prospective in Lake Manzala, Egypt. Al-Azhar Univ. J. Microbiol., 11: 69-80.

Diab, A.M., 2002. Bacteriological studies on the potability, efficacy and EIA of desalination operations at Sharm El-Sheikh region, Egypt. J. Biological Sci., 2: 411-414.

Durham, B., 1997. Membrane pretreatment of reverse osmosis-long term experience on difficult water. Desalination, 100: 49-58.

Kozisek, F., 2003. Health significance of drinking water calcium and magnesium. Environ. Res. Section, 1: 219-227.

MOH, 2009. The status of health in Palestine 2008. Annual Report, Periodical Analysis for Drinking Wells, Palestinian Authority, Gaza Strip, pp: 40-47.

Mayla, Y.A. and S.S.A. Amr, 2010. Chemical and microbiological contamination of ground water in the Gaza Strip–Palestine. Proceedings of the 2nd Conference for Water Resources in Gaza Strip-the Reality and Evaluation, Institute of Water and Environment, Alazhar University, Gaza.

Morales, G. and M. Barrufet, 2002. Desalination of produced water using reverse osmosis. Production Operations, pp: 13-17. http://media.godashboard.com/gti/4ReportsPubs/4_7GasTips/Summer02/DesalinationOfProducedWater.pdf.

Nassar, A., K. Tubail and S. Afifi, 2009. Attitudes of farmers toward sludge use in Gaza Strip. Int. J. Environ. Technol. Manage., 10: 89-101.

PWA, 2000. Drinking water quality standards in Gaza Strip. Palestinian Authority, pp: 1-50.

PWA, 2003. Water resources and management issues. July Report 2003, Palestinian Authority, pp: 1-50.

Qahman, K., A. Larabi, D. Ouazar, A. Naji and A.H.D. Cheng, 2005. Optimal and sustainable extraction of groundwater in coastal aquifers. Stoch. Environ. Res. Risk Assess., 19: 99-110.

Qahman, K., A. Larabi, D. Ouazar, A. Naji and A.H.D. Cheng, 2009. Optimal extraction of groundwater in gaza coastal aquifer. J. Water Resour. Protect., 4: 249-259.

Semiat, R., 1999. Desalination: Present and Future. Israel Institute of Technology Amman, Jordan.

Shomar, B., K. Osenbruck and A. Yahya, 2008. Elevated nitrate levels in the groundwater of the Gaza Strip: Distribution and sources. Sci. Total Environ., 398: 164-174.

Shomar, B., 2010. Groundwater contaminations and health perspectives in developing world case study: Gaza Strip. Environ. Geochem. Health,

Tua, A., 1996. Desalination of Seawater by Reverse Osmosis: Experience in Malta. 3rd Edn., WHO., USA.

UNEP, 2009. Environmental assessment of the Gaza Strip 2009. Report of the Following the Escalation of Hostilities in December 2008-January 2009.

Vengosh, A., A. Marei, C. Guerrot and I. Pankratov, 2002. An enigmatic salinity source in the mediterranean coastal aquifer and Gaza Strip. Geochim. Cosmochim. Acta, 15A: A804-A804.

Vengosh, A., A. Marei, W. Kloppmann, Y. Livshitz and C. Guerrot, 2005. Tracing the origin of boron and salinity in the Gaza strip. Natural Contaminant Trans Boundary Flow in the Mediterranean Coastal Aquifer. Water Resources Research 41W010113WR003344.

WHO, 1984. Guidelines for Drinking Water Quality. Vol. 1, World Health Organization, Switzerland, Geneva,.

WHO, 1996. Guidelines for Drinking Water Quality. 2nd Edn., Vol. 2, World Health Organization, Geneva, Switzerland.

WHO, 2003. Guidelines for Drinking Water Quality. World Health Organization, Geneva.

WHO, 2007. Desalination for Safe Water Supply, Guidance for the Health and Environmental Aspects Applicable to Desalination. Public Health and the Environment, Geneva.

Weinthal, E., A. Vengosh, A. Marei, A. Guterrez and W. Kloppmann, 2005. The water crisis in the gaza strip: Prospects for resolution. Ground Water, 43: 653-660.