Physico-Chemical and Microbiological Assessment of Desalination Plants in Gaza City, Palestine

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Abstract
Gaza Strip is an area suffers from sharp deterioration in the water situation (both in terms of quality & quantity) due to high growth of population, rain shortage, sea water intrusion, industrial and agricultural activities. The bad situation leads to establish many commercial desalination plants, in order to contribute in the solution of water problems.The goal of this study is to assess the effects of desalination plants by analyzing the desalinated water chemically, bacteriology and physically.The results indicated that there is growth in the number of desalination plants in the last seven years, about half of the desalination plants located in the west of Gaza City. All of these plants depend on private wells as water source but there were large number of these wells not closed and also not protected well.It was found that 70 % of the desalination plants located in inappropriate sites (near facilities like schools, factories...). The pipe of discharge was fixed well in 72% of the trucks and the location of the generator was suitable in 76% of the trucks. Brine water disposal in 63% of the plants was in sewage. Most of the desalination plants were not disinfect the tanks, while 40.7% of the plants add chlorine to the water tanks.
There is no any problem in the physiochemical parameters of the desalinated water where all the samples were according to the WHO standards. The problems were present in the brackish water, where all the samples have physiochemical parameters higher than the WHO standards. There was bacteriological contamination in 27% of the plants with FC, while 28.3% were contaminated of E coli bacteria because of the absence of disinfection.
Keywords: Water, contamination, desalination, Palestine

1. Introduction

Gaza Strip suffers from a sharp deterioration in drinking water resources (both in quality &quantity) due to many factors such as location (arid to semi-arid), growth of population, occupation, agricultural activities and untreated wastewater. Baalousha (2005) reported that the projected water demand will be sharply increased from 213 MCM in the year 2010 to 262 MCM in the year 2020.The deficit will be increased from 76 MCM in the year 2010 to 107 MCM in the year 2020.

According to PWA (2012and 2013), average decline of groundwater in Gaza Strip up to about 50 cm annually, rate of sea water intrusion of groundwater in Gaza Strip up to about 40m/year. Currently the estimated deficit in water balance in Gaza Strip is about 80-100 MCM. Per capita consumption in Gaza Strip about 80 l/p/d that is half recommended by WHO (150 l/p/d). Occupation country stealing about 50 MCM from (Wadi Gaza water, groundwater flow normally from the eastern region and water traps).

Aish (2010) concluded that in the year 2005 approximately 150 MCM/y of water was pumped from about 4100 wells, 60 MCM were pumped for domestic and industrial and 90 MCM for irrigation.

In addition, Gaza Strip suffer from a sharp deterioration in water quality, according to CMWU (2010), 65% of wells contaminated with nitrate, 57%contaminated with chloride, water tests have shown some wells with high values of fluoride (EWASH, 2010). Moreover, Abu El-Naeem et al., (2008 and 2009) showed that most of the groundwater is unsuitable for domestic uses because polluted wells increased from (72%) to (78.5%) and (85.5 %) through the three stages 1994/1995, 1999/2000 and 2003/2004 respectively.

Al-Yaqubi, (2006) showed that the major water quality problems are high salinity and high nitrate concentration in the aquifer. According to (PWA, 2012) Nitrate concentration in the municipal wells ranges from 50 to more than 300 mg/l. 21.5 % of them had Nitrate concentration less than 50 mg/l (WHO allowable limit) while the remaining (73.5%) exceeds the WHO nitrate level as shown in figure (a). In addition, Chloride concentration in the municipal wells ranges from 250 to more than 5000 mg/l. 25% of them had chloride concentration less than 250 (WHO allowable limit) while the remaining (75%) exceeds the WHO chloride level as shown in figure (2).

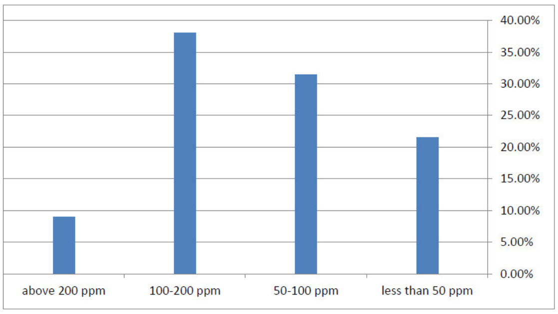

Figure (1): Nitrate concentrations of domestic municipal wells in Gaza Strip (PWA, 2013).

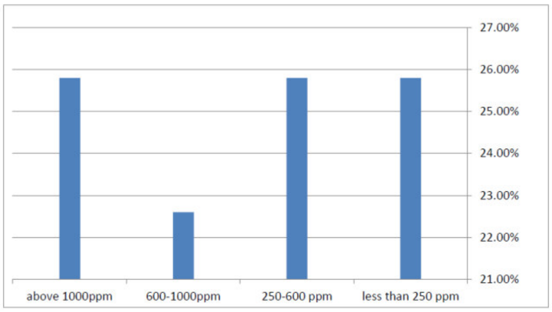

Figure (2): Chloride concentrations of domestic municipal wells in Gaza Strip (PWA, 2013).

Gaza Strip is located on the eastern coast of the Mediterranean Sea. It is bounded from the south by Egypt, from the east and the north by historical Palestine, and from the west by the Mediterranean Sea. The total area of Gaza strip is 365 km^2, with approximately 45 km long and the width varies from 8 km in the north to 14 km in the south (PCBS, 2014).Gaza Strip is divided geographically into five governorates: North, Gaza, Middle area, Khanyounis, and Rafah as shown in Figure (3).

According to (PCBS, 2014) the number of estimated population in the Gaza Strip is about 1,760,037. This number representing about 38.3% of the population of the Palestinian territories. Gaza governorate ranked first in terms of population between the governorates of Gaza, where a population of about 570 thousand people, including 13.3% of the total population in the Palestinian territories.

The main objectives of this study are to evaluate the quality of desalinated water resultant from the desalination plants, by determining the physio-chemical characteristics of the resultant desalinated water and to check the presence of microbiological contamination,

Groundwater is the only source of water in Gaza Strip. In the absence of other significant water resources in the Gaza Strip, the groundwater aquifer is considered the main water supply for all kind of human usage, which is currently facing a serious challenge in terms of quantity and quality. The available water quantities for the population in the Gaza Strip are inadequate due to the over-exploitation of the natural aquifer, and the water quality falls will before the accepted international guidelines for potable resources, which pose a risk on the public health of more than 1.7 million people living in the Gaza Strip. In addition, the population is expected to grow at the rate of around 3.5% per year, and the domestic water demand is projected to grow from 91 million cubic meters per year (MCM) to more than 199 MCM in year 2035.

This understanding necessitates a characterization of the utilizable quantities and the corresponding qualities. Both of over pumping and low rainfall lead to intrusion of sea water into the aquifer that in turn lead to continuous and increased deterioration of drinking water qualities. This phenomenon has created an urgent demand for improving drinking water quality. Because there were no major desalination plants, small desalination plants became the solution. In 1998, the first desalination plant was established and many other plants were established later that lead to total number of about 89 plants functioning now a days (MOH, 2011). Ministry of Health, municipalities and water authority all take partial parts in monitoring of desalination plants, yet not at the needed level.

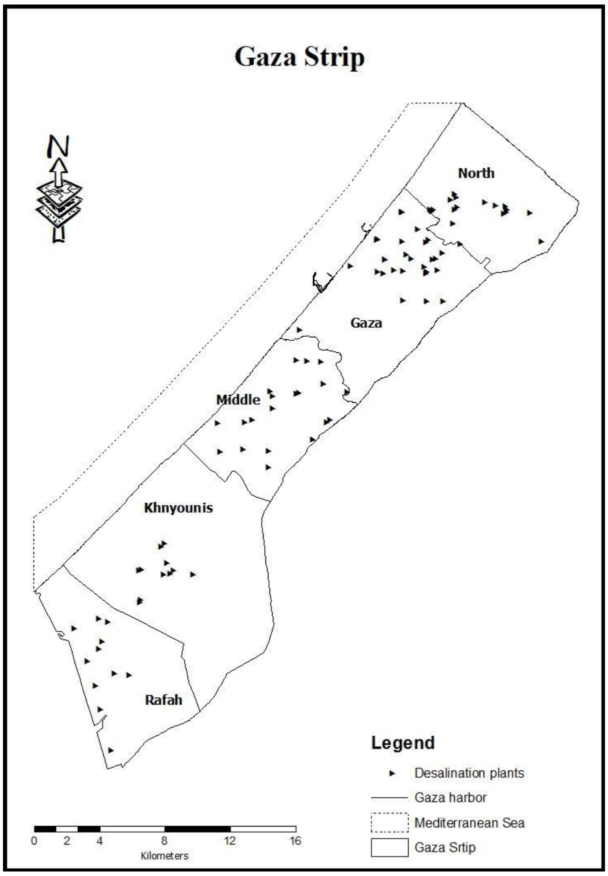

Figure (3): Distribution of the desalination plants in Gaza Strip. A total of 88 plants are available in Gaza Strip (CMWU, 2013).

2. Materials and Methods

Collection of the water samples was conducted in Gaza City, during the period from 20-10-2012 to 1-12-2012. The chemical (chloride, fluoride, nitrate, TDS and EC) and microbiological (fecal coliform, E coli) analysis were conduct in the laboratories of environmental and earth science department at the Islamic University, some measures (pH) were conducted in the field. After that the questionnaire was applied to collect the required information about the plants from 1-12-2012 to 30-1-2013, SPSS software was used to analyze the collected data. In Gaza City there are about 30 desalination plants, 27 desalination plants were targeted in this study. The total number of samples were collected and analyzed was 162 sample for chloride, fluoride and nitrate tests as the following: 81 samples were collected from the brackish water of the 27 desalination plants which targeted in the study, a sample were collected in each visit, where three visits were implemented for each plant, the total number of the collected brackish water samples become 81. The same was done for the desalinated water samples. Also 81 samples were collected to bacteriological analysis (FC, E coli) for the brackish water, and 81 samples from the desalinated water were collected to conduct the mentioned bacteriological tests. Sampling process was achieved according to Standard Methods for the Examination of Water and Wastewater 20th edition (APHA, 1999). The following points were taken into account:

250 ml plastic bottles were used to collect samples for chemical analysis. The bottles have been cleansed and rinsed very well with a final rinsed of distilled water and sterilized. While 100 ml sterilized plastic cups were used for bacteriological examinations, a cup of 100 ml also used to the measures that have been taken in the field.

The samples were collected from the tap which connected to the desalinated water tank in the desalination plant. The tap was opened in order to let water run to waste for 2-3 minutes, after that the tap was closed to apply disinfection (inside and outside) using 70% Ethanol then was disinfected again by flame for a minute. After that water was run for additional 2-3 minutes. Then water flow was reduced to permit filling bottle without splashing. While the sample is collected, air space was left in the 24cup to facilitate mixing by shaking. Samples package was delivered in ice box to the laboratory immediately or in less than 6 hours.

The results were coded numerically in order to entering on excel table, the entered data was checked and reviewed, after that the excel software was used to analyze some data, the SPSS was used also to analyze some data.

3. Results and Discussion

The goal of the research is to evaluate the desalination plants in Gaza City by analyzing the desalinated water chemically, physically and bacteriology

3.1Physico-chemical Characteristics of Water

The summary of the analytical results of both brackish and desalinated water in the study area is presented in Table (1), which shows the average maximum, minimum, mean and standard deviation values for the parameters. Also the table (2) shows a comparison of physico-chemical properties of brackish and desalinated water samples with Palestinian and (WHO) drinking water standards.

Table 1. Physico-chemical properties of brackish and desalinated water samples.

Parameter	Type of water	Values from collected samples			
		Minimum	Maximum	Mean	Std. Deviation
EC	Brackish	230	6720	3051.6	1650
	Desalinated	35	475	158.7	116
pH	Brackish	6.8	8	7.6	0.34
	Desalinated	6.3	7.8	6.8	0.37
TDS ppm	Brackish	760	3700	1871.8	741.18
	Desalinated	45	210	110	38.39
CL ppm	Brackish	128	1205	594.5	311.11
	Desalinated	25	100	47.6	20.51
NO_3 ppm	Brackish	75	310	173.6	62.95
	Desalinated	11.5	90	29.4	14.49
F ppm	Brackish	2.10	7	4.4	1.38
	Desalinated	0.3	2	0.5	0.30

Table 2. Comparison of physico-chemical properties of brackish and desalinated water samples with Palestinian and (WHO) drinking water standards.

Parameter	Type of water	Values from collected samples				Standards	
		Min	Max	Mean	Std. Deviation	WHO	Local
EC µs/cm	Brackish	230	6720	3051.6	1650	1200 µs/cm	1500 µs/cm
	Desalinated	35	475	158.7	116		
pH	Brackish	6.8	8	7.6	0.34	6.5-8.5	6.5-9.5
	Desalinated	6.3	7.8	6.8	0.37		
TDS ppm	Brackish	760	3700	1871.8	741.18	1000 ppm	1000 ppm
	Desalinated	45	210	110	38.39		
CL ppm	Brackish	128	1205	594.5	311.11	250 ppm	600 ppm
	Desalinated	25	100	47.6	20.51		
NO_3 ppm	Brackish	75	310	173.6	62.95	50 ppm	70 ppm
	Desalinated	11.5	90	29.4	14.49		
F ppm	Brackish	2	7	4.4	1.38	1.5 ppm	1.5 ppm
	Desalinated	0.3	2	0.5	0.30		

3.1.1 Electric Conductivity

Brackish and desalinated water EC analysis is shown in figure (4). According to the results; the values of EC in most of the plants are higher than the Palestinian standards (1500µs) and higher than the WHO standards (1200 µs). This reflects the bad quality of the water that supplied by the municipality and the need of the desalination processes.

The values of EC for the desalinated water range from 35 - 475 µs\cm. This reflects that the desalination process produce unbalanced water because these values less than the recommended standards. Also this means that there is a need for a uniform standard for all the desalination plants. Also there is a big difference between the values of EC before and after desalination process, this reflects high efficiency of desalination plants.

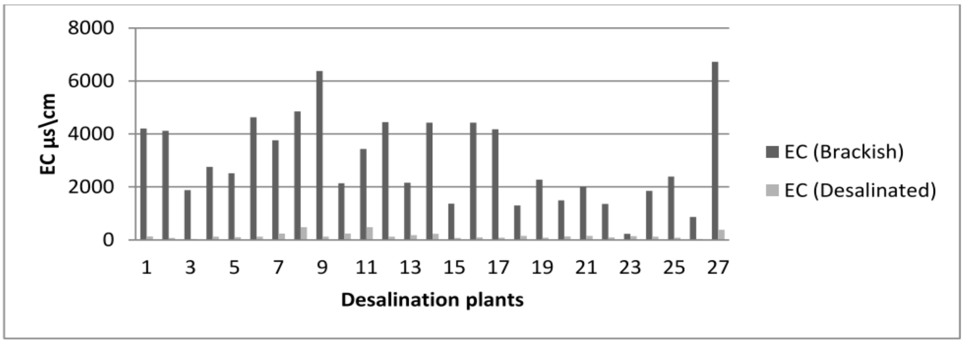

Figure (4): EC values for brackish and desalinated water.

3.1.2 pH value

According to (WHO 1996), the pH of water is a measure of the acid–base equilibrium and, in most natural waters, is controlled by the carbon dioxide–bicarbonate–carbonate equilibrium system.

In this study, the pH values for all brackish water samples are within the recommended standards (6.8-8) as in the tables above. But after the desalination process the values of pH of the desalinated water became less (6.3-7.8), this is due to the removal of elements. But the values of pH in both brackish and desalinated water samples are within the recommended standards. The differences of pH values of desalinated water reflect the need to uniform standards for all the desalination plants (Figure 5).

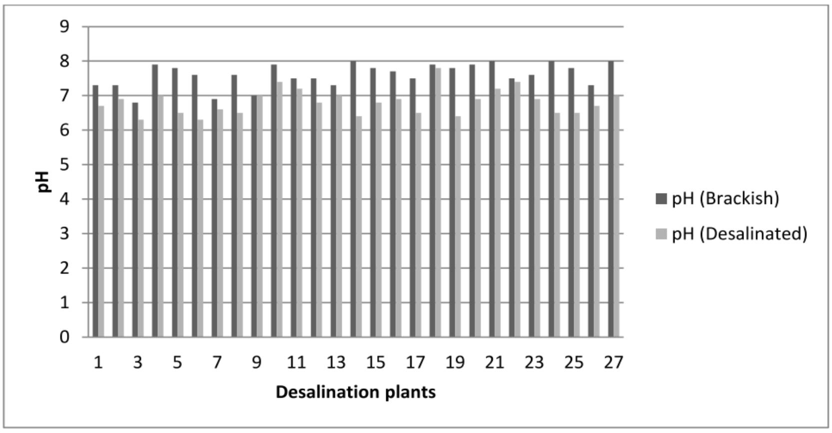

Figure (5): pH values for brackish and desalinated water.

3.1.3 Total Dissolved Solids (TDS)

Figure (6) shows the results analysis for the TDS. According to the data analysis results, the TDS for brackish water for most of the plants (93%) is higher than the recommended standards (1000 ppm), while the rest (7 %) of the samples are less than 1000 ppm. But the data result analysis of the TDS for the desalinated water is within the accepted range, the TDS ranges from (45-210 ppm). This reflects the absence of the uniform standards that should exist, and all the desalination plants must adhere to them. Also this reflects high efficiency of desalination process.

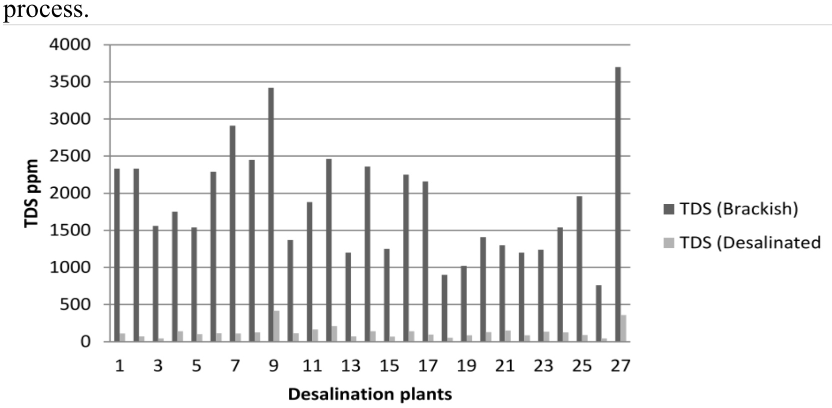

Figure (6): Total Dissolved Solids (TDS) values for brackish and desalinated water.

3.2 Chemical Parameters

3.2.1 Chloride

The result analysis of chloride concentrations are shown in the figure (7).The majority of Cl concentrations for brackish water range between 128-1205 mg/l. This may be due to the sea water intrusion and to continuous pumping (PWA, 2013). Also this can show the differences of chloride concentrations in the different areas in Gaza city. The concentrations of Cl for the desalinated water ranges between 25-100 mg/l. This means that they are in compliance with the recommended standards for drinking water, because all of the samples are under the Palestinian and WHO recommended standards. The difference in chloride concentrations between brackish and desalinated water samples reflects the high efficiency of desalination plants, while the differences in chloride concentrations in the desalinated water reflects the need for uniform standards to all the plants.

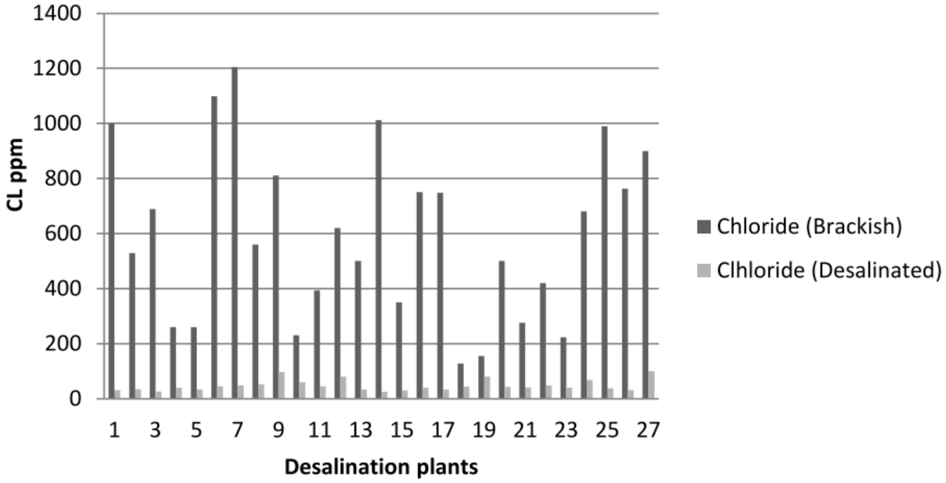

Figure (7): Concentrations of chloride (Cl) for brackish and desalinated water.

3.2.2 Nitrate

The nitrate concentration of brackish water in all the desalination plants is higher than the Palestinian and WHO recommended standards. As in the figure (8), the NO_3 concentrations range from (75-310 mg/l). The high concentrations of NO_3 in brackish water in Gaza City believed to be due to the extra use of chemical fertilizers in agriculture and of wastewater treatment process (WHO, 2013). According to the data result analysis for the desalinated water samples, nitrate concentrations are under the recommended standards in all the plants, except the plant (27), the nitrate was 90 ppm. This may due to the location of this plant (near a basin for collecting water in Alsheikh redwan area).

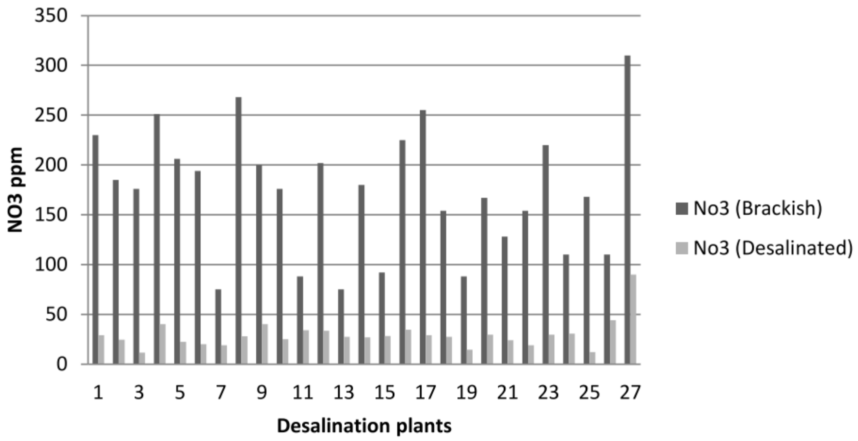

Figure (8): Concentrations of NO_3 for brackish and desalinated water.

3.2.3 Fluoride

Fluoride concentrations for both brackish and desalinated water are shown in the figure (9). Fluoride concentrations for all the brackish water samples are higher than the recommended (1.5 ppm). They range from (2.1-7.0 ppm). Fluoride concentrations of all desalinated water samples are less than the recommended standards (1.5 ppm). Except the plant (27) due to its location as mentioned.

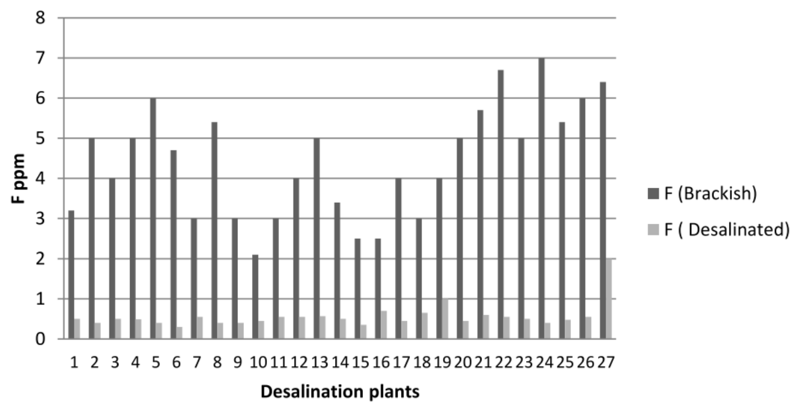

Figure (9): Concentrations of F for brackish and desalinated water.

3.3 Bacteriological Properties

Table (3) shows the results of bacteriological analysis of the targeted desalination plants. The first test shows that (37 %) of inlet of the targeted desalination plants are contaminated of Fecal coliform bacteria, while (18.5 %) are contaminated with E coli bacteria. The second test shows that (33%) of inlet of the targeted desalination plants are contaminated of Fecal coliform bacteria, while (18.5%) are contaminated with E coli bacteria. The third test shows that (29.6%) of inlet of the targeted desalination plants are contaminated of Fecal coliform bacteria, while (14.8%) are contaminated with E coli bacteria. This may be because the source of the water bores are not closed well and not protected from the sources of contamination (Albattnigi, 2015). The table shows that (22%) of outlet of the targeted desalination plants are contaminated of Fecal coliform bacteria. In addition, (29.6%) are contaminated with E coli bacteria. The second test shows that (29.6%) of outlet of the targeted desalination plants are contaminated of Fecal coliform bacteria. Moreover, (29.6%) are contaminated with E coli bacteria. The third test shows that (29.6%) of outlet of the targeted desalination plants are contaminated of Fecal coliform bacteria, and (25.9 %) are contaminated with E coli bacteria.

Table 3: A snapshot of the Excel table which was used to show the microbiological contamination of desalination plants.

Plant	Date of the test	FC(In)	FC(Out)	E-coli(In)	E-coli(Out)	Plant	Date of the test	FC(In)	FC(Out)	E-coli(In)	E-coli(Out)	Plant	Date of the test	FC(In)	FC(Out)	E-coli(In)	E-coli(Out)
1	20-10-2012	0	0	0	0	1	10/11/2012	0	0	0	0	1	01/12/2012	0	0	0	0
2	20-10-2012	1	0	0	0	2	10/11/2012	0	0	0	0	2	01/12/2012	0	0	0	0
3	20-10-2012	3	0	0	0	3	10/11/2012	6	0	0	0	3	01/12/2012	1	0	0	0
4	20-10-2012	0	0	0	0	4	10/11/2012	0	0	0	0	4	01/12/2012	0	0	0	0
5	20-10-2012	0	0	0	0	5	10/11/2012	0	0	0	0	5	01/12/2012	0	0	0	0
6	20-10-2012	2	7	1	2	6	10/11/2012	5	1	3	1	6	01/12/2012	5	2	2	2
7	20-10-2012	1	0	0	0	7	10/11/2012	1	0	0	0	7	01/12/2012	1	0	0	0
8	20-10-2012	0	0	0	0	8	10/11/2012	0	0	0	0	8	01/12/2012	0	0	0	0
9	20-10-2012	0	0	0	0	9	10/11/2012	0	0	0	0	9	01/12/2012	0	0	0	0
10	20-10-2012	2	2	0	1	10	10/11/2012	4	1	0	1	10	01/12/2012	3	1	2	1
11	20-10-2012	0	0	0	0	11	10/11/2012	0	0	0	0	11	01/12/2012	0	0	0	0
12	20-10-2012	0	6	0	4	12	10/11/2012	0	6	0	4	12	01/12/2012	0	1	0	2
13	20-10-2012	0	2	0	1	13	10/11/2012	0	2	0	2	13	01/12/2012	0	2	0	1
14	20-10-2012	6	2	0	1	14	10/11/2012	2	1	0	3	14	01/12/2012	3	1	0	0
15	20-10-2012	0	0	0	0	15	10/11/2012	0	0	0	0	15	01/12/2012	0	0	0	0
16	20-10-2012	0	0	0	0	16	10/11/2012	0	0	0	0	16	01/12/2012	0	0	0	0
17	20-10-2012	0	0	0	0	17	10/11/2012	0	0	0	0	17	01/12/2012	0	0	0	0
18	20-10-2012	4	0	2	0	18	10/11/2012	1	0	1	0	18	01/12/2012	4	0	2	0
19	20-10-2012	0	0	0	0	19	10/11/2012	0	0	0	0	19	01/12/2012	0	0	0	0
20	20-10-2012	0	0	0	0	20	10/11/2012	0	0	0	0	20	01/12/2012	0	0	0	0
21	20-10-2012	0	0	0	0	21	10/11/2012	0	0	0	0	21	01/12/2012	0	0	0	0
22	20-10-2012	0	9	0	2	22	10/11/2012	0	5	0	2	22	01/12/2012	0	9	0	2
23	20-10-2012	0	2	0	0	23	10/11/2012	0	0	0	0	23	01/12/2012	0	0	0	0
24	20-10-2012	0	0	0	0	24	10/11/2012	0	0	0	0	24	01/12/2012	0	0	0	0
25	20-10-2012	21	0	10	0	25	10/11/2012	14	0	6	0	25	01/12/2012	0	0	0	0
26	20-10-2012	6	9	4	3	26	10/11/2012	2	1	3	1	26	01/12/2012	4	2	2	1
27	20-10-2012	7	2	1	0	27	10/11/2012	8	1	2	0	27	01/12/2012	3	1	1	0

4.0 Conclusions

Bacteriological contamination was detected in 29.6% of the selected desalination plants in Gaza City with FC, and 25.9% were contaminated of E coli bacteria because of the absence of disinfection. All of the desalination plants depend on private wells. There were large numbers of these wells not closed well and protected well from contamination. Three quarter of the desalination plants were established in the last seven years. The desalination plants in Gaza city used 2378.5 M3/D of brackish water, to produce 1626M3/D desalinated water, with efficiency of 68.9%. There are no any problems in the physiochemical parameters of the desalinated water. All the samples were according to the WHO standards, the problems were present in the brackish water where all the samples have physiochemical parameters higher than the standards.

5.0 Recommendations

All desalination plants must have a system for disinfection for the tanks and for the desalinated water. Water sources and wells in desalination plants should be well closed. The competent authorities must implement monitoring programs for the plants and for delivery trucks.

6- Acknowledgments

Authors would like to express their deep gratitude to the Middle East Desalination Research Center (MEDRC) and to Palestinian Water Authority (PWA) for their donation to facilitate this research.

References

Aish, A., (2010). "Water Quality Evaluation of Small Scale Desalination Plants in the Gaza Strip, Palestine". Submitted to 14th. International Water Technology Conference IWTC-2010 Cairo – Egypt, March 21-23.

American Public Health Association (APHA), (1999). "Standard Methods for the Examination of Water and Wastewater", 20th ed. American Public Health Association, Washington DC.

Albattnigi, M., S. (2015) "Impact of Desalination Plants on Surrounding Environment and Public Health in Gaza City, Palestine. Msc thesis, Islamic University of Gaza, Palestine

Al-Yaqubi, A., (2006). "Sustainable Water Resources Management of Gaza Coastal Aquifer, Palestine".2nd International Conference on Water Resources and Arid Environments (2006). 26-29 November 2006. Organizer: King Saud University.

Baalousha, H., (2005). "Desalination Status in the Gaza Strip and Its Environmental Impact". Desalination 196,

1–12.
Coastal Municipalities Water Utility (CMWU). (2013). Annual Report on Water Status in the Gaza Strip. Summary about Water and Wastewater Situation in Gaza Strip. Gaza.
El-Naeem, M., Abu Heen, Z. and Tubail, K., (2008). "Groundwater Problems Resulting from Heavy Pumping in North Governorates of Gaza Strip (1999-2004) " . Twelfth International Water technology Conference (IWTC 2008), Alexandria, Egypt (27-30) March, 2008.
El-Naeem, M., Abu Heen, Z. and Tubail, K.,(2009). "Factors behind Groundwater Pollution by Nitrate in North Governorates of Gaza Strip (1994-2004)". Thirteenth International Water Technology Conference, IWTC 13 2009, Hurghada, Egypt.
EWASH.(2010). "WASH Cluster Opt Monthly Situation Report". No 28. pp. 3-6.
Palestinian Central Bureau of Statistics. (2014). "Estimated Population in the Occupied Palestinian territories.
Palestinian Ministry of Health (MoH), (2011). Water Control Department, Gaza, Palestine. Annual report of Environmental Health Directorate.
Palestinian Water Authority. (PWA). (2013). Evaluation of Groundwater Part B Water Quality in the Gaza Strip Municipal Wells".
World Health Organization. (WHO). (1996). ―Chloride in Drinking Water‖. Guidelines for drinking-water quality, 2nd ed. Vol. 2. Health criteria and other supporting information, World Health Organization, Geneva.

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