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Assessment of Microbiological Characteristics of the Desalinated Water Used in Household Facilities in Gaza Strip

Mohammed Abudaya[1]* Ayman ELRamlawi[2] Samir Hararah[3]

1. University of Palestine, Engineering Faculty, PO box 1219, Rimal, Gaza, Palestine
2. Ministry of Health, Primary Health Care Directorate, Water Control Dept. Gaza, Palestine
3. Islamic university of Gaza, Science Faculty, PO. box 108, Rimal, Gaza, Palestine

- E-mail of the corresponding author: dr.m.abudaya@hotmail.com

Abstract

Access to safe water represents one of the most important basic human needs of the people of Palestine and is vital to a growing economy and a healthy population. Groundwater is the major source of water to the Palestinians. Nowadays, the water crisis in the Strip is multiplying. The objective of this research is to make an assessment of the desalination plants for the microbiological quality for both the inlet (groundwater) and the outlet water (product water) in the desalination plants. Samples from both the inlet and outlet water from 88 desalination plants have been collected by the researchers have been tested in the Palestinian Ministry of Health-The Public Health Laboratory for both Total Coliform and Fecal Coliform. The study proved that the current private desalination monitoring program by the concerned authorities should be developed, enhanced and intensified. The study also revealed that the current private desalination plants were established randomly and for commercial purposes without any previous planning. The results indicated that there is a high percentage of microbiological contamination in the outlet water (21.6%) and the inlet water (16.6%), which exceeded the WHO guidelines. The study concluded that large scale sea water desalination plants should be established to overcome the current water quality problems and the quantity shortage.

Keywords: Groundwater, contamination, reverse osmosis (RO), brackish water, desalination plants, Gaza Strip, Total Coliform (TC), Fecal Coliform (FC)

1. Introduction

Gaza strip suffers from many water problems such as shortage, scarcity, insufficiency, pollution and high salinity. The main source of water in Gaza Strip is the groundwater aquifer. Over pumping due to the increased demands of the high population in the Gaza Strip and low recharges from rainwater have limited the quantity of water available and have further contributed to the degradation of the water quality (Metcalf and Eddy, 2000 and, PHG. 2002). Unavailability of a proper sewage system, high distribution of septic tanks, old water networks, frequent interruption of water chlorinating and interruption of water supply play a major role in increasing the microbiological water contamination which lead to an increase in health risks of humans (El-Mahallawi, 1999). The people of the Gaza Strip depend on the groundwater for their agriculture, industries, and for household purposes like cooking, washing, cleaning and showering. Long-term overexploitation in the Gaza Strip and constraints by the Israeli occupation in using more groundwater have resulted also in decreasing the supply of tap-water which accompanies low and poor water quality. Furthermore, controlling and monitoring the quality (biological, chemical and physical) of the water wells and water distribution networks at the Gaza Strip are not always possible due to the constraints applied by the Israeli occupation either on the entry of the disinfectants and the instruments required for water quality assurance or sometimes on reaching wells that are located near to hot clash points. Therefore, due to the low reduced quantities, as

well as the poor deteriorating qualities of drinking water, the people of the Gaza Strip try to overcome these problems and find other solutions and sources which offer good safe drinking water, so they start to depend on the marketed desalinated water produced mainly by the reverse osmosis method. As a result, many special and governmental water desalination facilities or small plants were established to market the desalinated water for people in order to overcome the low and poor quality of groundwater. The limited data about microbiological and chemical water quality for the few past years in the Gaza Strip are not enough to be judged. However, recent reports by the Ministry of Health (MoH, 2010) mentioned that about 19% of groundwater, 27% of desalinated water and 20% of water network samples are microbiologically contaminated by Total Coliform while 13%, 14% and 12% by Fecal Coliform bacteria respectively. Monitoring and controlling programs of water quality in the Gaza Strip should be evaluated and developed.

Yassin et al. (1999) indicated that Gaza Strip suffers from many health problems due to the poor wastewater collection and treatment system. Microbiological and chemical quality is the most important aspect of drinking water in relation to water-borne disease. Suitable indicator bacteria of fecal contamination are Total Coliform, Fecal Coliform and Fecal Streptococci. Fecal pollution of drinking water may introduce a variety of intestinal pathogens (bacteria, viruses and parasites). Intestinal bacteria pathogens are widely distributed throughout the world, known to have occurred in the contaminated drinking water from the infiltration of raw wastewater to the groundwater. The percentage of Coliform contamination for water examined throughout a 12-month period should not exceed 5% (WHO, 1996). Transmission of waterborne diseases by a water supply has been accepted. The health care specialists are currently faced with the problems related to controlling the waterborne diseases that have shown a rapid increase in the past ten years. High parasitic infection rates were recorded among children in Gaza city with Giardia lamblia, Ascaris Lumbricoides and Entamoeba histolytica being the most frequent. The overall aim of this study is to assess the microbiological parameters of water produced and distributed by the common small and large desalination plants in the Gaza Strip.

2. Study area

The Gaza Strip is a part of the Palestinian coastal plain in the south west of Palestine in the Middle East, where it forms a long and narrow rectangle on the Mediterranean Sea. The Gaza Strip is about 1.33% of the total area of mandate Palestine. The Gaza Strip occupies an area of about 365 Km2; about 45Km long and 5-15Km wide. Gaza Strip is divided into five Governorates: 1) the North Governorate, comprising three towns: Jabalia, Bit Hanoun and Beit Lahia; 2) Gaza Governorate, 3) Mid-Zone contains 5 refugees camps: Deir Elbalah, Maghazi, Burij, Nuseirat and Zwaida, 4) Khanyounis Governorate, and 6) Rafah Governorate (Khalaf, 2005). Figure (1) shows the map of the study area.

Groundwater is considered the main source of fresh water and is of primary importance to the Palestinians in the Gaza Strip (Al-Agha, 1995). Moreover, the Palestinian Water Authority (PWA) purchases a big quantity of water from the Israeli water company Mekorot (PWA, Water supply report, 2012). Groundwater is recharged from several sources including rainwater, return from irrigation, sewage infiltration and seawater intrusion (PEPA, 1994). Pumped for people of the Gaza Strip, groundwater is mainly from municipal wells which are basically used as the main source of drinking water, while some people have opened their own wells in their homes. On the other hand, there are many wells used for agricultural purposes.

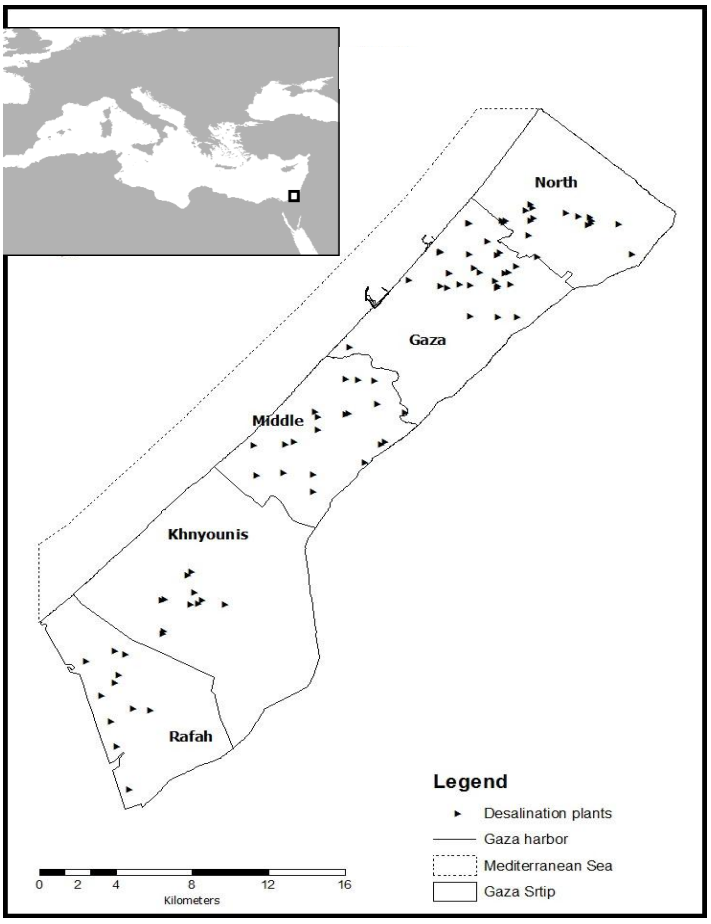

Figure 1 Study area and locations of desalination plants in Gaza Strip, a total of 88 plants are available.

3. Methodology

An experimental analytical study design has been used with a cross-sectional method for data collection and water sampling for microbiological analysis, where it depends on collecting samples from all small and large desalination units or facilities in the Gaza Strip. The microbiological results of groundwater and desalinated water were recorded, counted, and analyzed. The experimental design for this research has been chosen because it is simple and appropriate for this kind of public health study.

The samples of the study were taken from all the five governorates of the Gaza strip including groundwater and desalinated water samples. The samples collection lasted from the 1st Jan. until the middle of April 2011. Sampling was performed according to Standard Methods for the Examination of Water and Wastewater (20th edition, APHA, 1999). Procedures of sample collection were as described in the following sections. Non-reactive borosilicate glass bottles of 500ml were used to collect samples for microbiological examinations that had been cleansed and rinsed carefully, given a final rinse with deionized or distilled water, and sterilized 1210C for 15 minutes. For the chemical tests 1000ml plastic or pure polyethylene bottles were used. A sufficient amount of sodium thiosulfate (Na2S2O3) was added to all containers intended for the collection of desalinated water to eliminate residual chlorine toxic effect which kills Coliforms. Before collection of the samples, any external additions such as tap water filter or external pieces of plastic or rubber were removed so as to ensure no contamination of these accessories; the water was allowed to run for 2-3 minutes before collecting samples to insure that stagnant water flushed out of the plastic, rubber or steel pipes. The plastic or rubber pipes were sterilized with concentrated Sodium Hypochlorite (NaClO) by

immersing the pipe in the concentrated fluid for 2-3 minutes, while the steel one was flamed for one minute. After sterilization, the water was left for two minutes to cool the exit of water or to rewash the exit from the concentrated NaClO so as to guarantee that there is no killing for any microbes that might be present in the water which will be tested, and then the sample was collected in the prepared glass bottle and quickly closed tightly. The number of the sample was written on the label pasted on the bottle, while the name and the origin of the sample and the time were written down on the prepared paper sheet. Then the bottles were stored in the ice box (or sample transportation container) under a temperature up to 40C. Finally, the samples were transferred to the Public Health laboratory in order to perform the Total and Fecal Coliform tests during 2 to 6 hours.

Table 1: The number of samples from each governorate

Governorate	Desalination plants outlet water	Desalination plants inlet water	Total
North	17	17	34
Gaza	29	29	58
Middle	20	20	40
Khanyounis	11	11	22
Rafah	11	11	22
Total	88	88	176

3.1 Data analysis

Data were computer-analyzed using Excel and SPSS programs to calculate the bacteriological contamination percentage of water by Total and Fecal Coliform, comparing the water quality between desalination plants inlet water and desalination plants outlet water for each governorate in Gaza Strip according to international standards and guidelines.

4. Results

The current data on the Total and Fecal Coliform contamination in desalination plants outlet water, and desalination plants inlet water of the Gaza Strip were collected during the period of sampling from January, 2012 to April, 2012. The term 'contamination' is based on one colony forming per 100 ml (CFU) for the examined sample.

4.1 Contamination percentages of Total Coliform in desalinated water

Table 2 shows the Total Coliform (TC) percentages of Gaza Strip governorates in the desalinated water and inlet water. In the North governorate, 3 samples out of 17 samples were contaminated with a percentage of 18.4%. In Gaza governorate 4 samples out of 29 samples were contaminated while the contamination percentage was 13.8%. For the Middle governorate, the contaminated samples number was 4 out of 20 and the contamination percentage was 20%. The highest contamination percentages were recorded in Khanyounis and Rafah governorates with 27.3%. The number of contaminated samples was the same in both Khanyounis and Rafah and it was 3 samples out of 11 samples. In Gaza Strip, 17 samples out 88 were contaminated and the percentage was 19.3%. Figure 2shows the contamination percentages in the governorates and in the Gaza Strip.

Table 2 Contamination percentages of Total Coliform in the desalinated water in Gaza Strip Governorate

Parameter	Governorate	Desalinated water (Outlet) samples No.	Contaminated Samples No.	Contamination Percentage %
Total Coliform	North	17	3	17.6%
	Gaza	29	4	13.8%
	Middle	20	4	20.0%
	Khanyounis	11	3	27.3%
	Rafah	11	3	27.3%

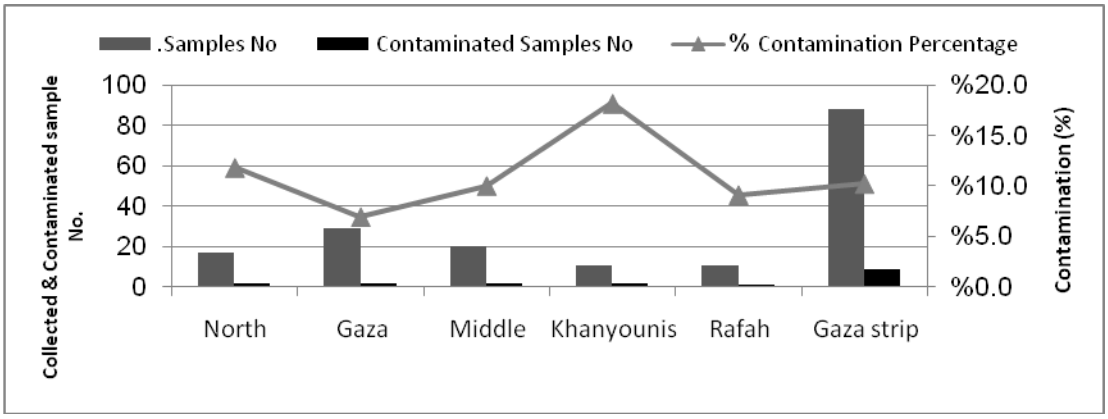

Figure 2 Contamination percentages of Total Coliform in the desalinated water in Gaza Strip governorates

4.2 Contamination percentages of Fecal Coliform in desalinated water

Table 3 summarizes the Fecal Coliform (FC) contamination percentages and the number of collected samples of the desalinated water in Gaza Strip governorates. Figure 3 shows the contamination percentages in Gaza Strip governorates.

Table 3 Contamination percentages of Fecal Coliform in the desalinated in Gaza Strip Governorate

Parameter	Governorate	Desalinated water samples No.	Contaminated Samples No.	Contamination Percentage %
Fecal Coliform	North	17	2	11.8%
	Gaza	29	2	6.9%
	Middle	20	2	10%
	Khanyounis	11	2	18.2%
	Rafah	11	1	9.1%

The contamination percentages of FC were lower than that of TC in Table. The highest contamination percentage was in Khanyounis (18.5%) and the number of the contaminated samples was 2 samples out of 11 samples, while the lowest percentage was recorded in Gaza (6.9%) with a contaminated sample of 2 samples out of 29 samples. In Rafah, the number of contaminated samples was 1 sample out of 11samples with a percentage of 9.1%. On the other hand, the Middle governorate recorded a percentage of 10% (2 samples out of 20 samples) and in the North

governorate the contamination percentage was 11.8% (2 samples out of 17 samples). The total contamination percentage of FC in Gaza Strip was 13.8% while the contaminated samples number of the desalinated water was 30 out of 227 samples.

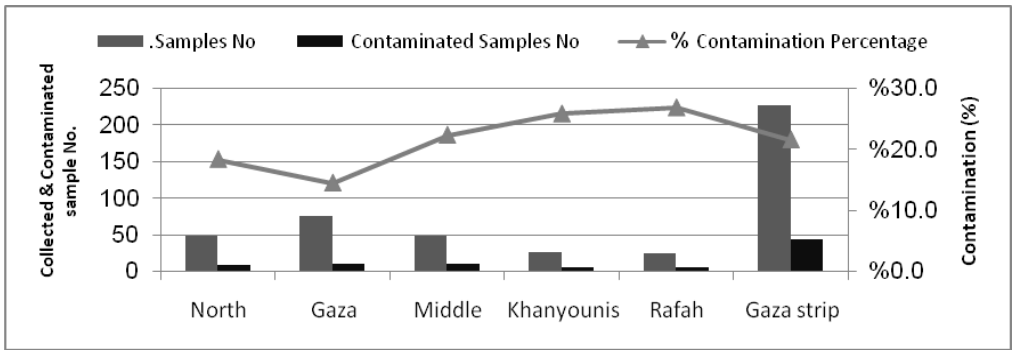

Figure 3 Contamination percentages of Fecal Coliform in the desalinated Gaza Strip governorates

4.3 Contamination percentages of Total Coliform in groundwater

Table 4 shows TC percentages of Gaza Strip governorates in desalinated water. In the North governorate, 3 samples out of 17 were contaminated and the contamination percentage was 17.6%. In Gaza governorate 4 samples out of 29 were contaminated and the contamination percentage was 13.8%. For the Middle governorate, the contaminated samples number was 3 out of 20 and the contamination percentage was 15%. The highest contamination percentages were recorded in Khanyounis and Rafah governorates with the same percentage of 18.2%, and the same number of samples and contaminated samples (2 samples out of 11). In Gaza Strip, 14 samples out 88 were contaminated and the percentage was 16.6%. Figure 4 shows the contamination percentages in the governorates and in the Gaza Strip.

Table 4 Contamination percentages of Total Coliform in the groundwater in Gaza Strip governorates

Parameter	Governorate	Groundwater (Inlet) samples No.	Contaminated Samples No	Contamination Percentage %
Total Coliform	North	17	3	17.6%
	Gaza	29	4	13.8%
	Middle	20	3	15.0%
	Khanyounis	11	2	18.2%
	Rafah	11	2	18.2%

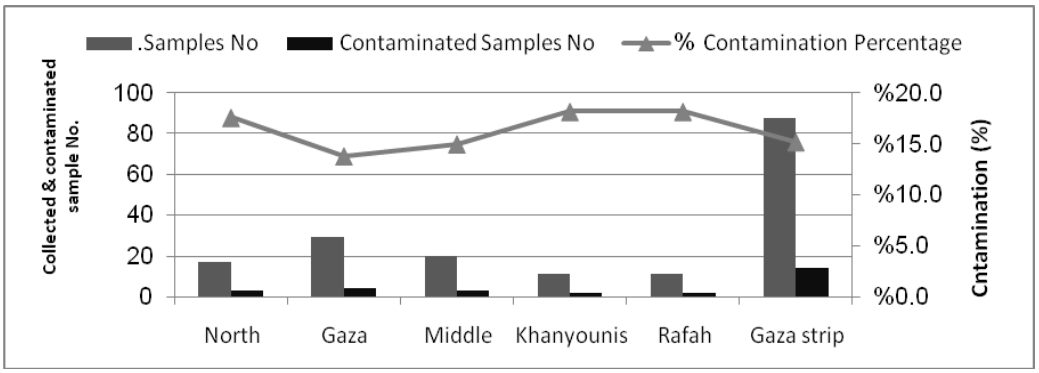

Figure 4 Contamination percentages of Total Coliform in the groundwater in Gaza Strip governorates

4.4 Contamination percentages of Fecal Coliform in the groundwater

Fecal Coliform contamination percentages in the groundwater (inlet) were slightly different than that of TC in the groundwater. Table 5 and Figure 5 summarize and show the collected and contaminated samples numbers and the contamination percentages of FC in Gaza Strip governorates. The lowest contamination percentage was recorded in the Middle governorate where 1 sample out of 20 was contaminated and the percentage was 5%, followed by Gaza governorate in which the percentage was 10.3% and the contaminated samples were 3 out of 29 samples. In the North, the percentage was 11.8% and 2 samples out 17 samples were contaminated.

Table 5 Contamination percentages of Fecal Coliform in the groundwater in Gaza Strip governorates

Parameter	Governorate	Groundwater (Inlet) samples No.	Contaminated Samples No	Contamination Percentage %
Fecal Coliform	North	17	2	11.8%
	Gaza	29	3	10.3%
	Middle	20	1	5.0%
	Khanyounis	11	2	18.2%
	Rafah	11	2	18.2%
	Gaza Strip	88	10	12.7%

However, the highest contamination percentages were recorded in Khanyounis and Rafah governorates. The percentage was the same in both governorates at 18.2%, and the same number of collected and contaminated samples was repeated at 2 out of 11 samples. Regarding the contamination percentage in the Gaza Strip, 10 samples out of 88 were contaminated and the percentage was 12.7%.

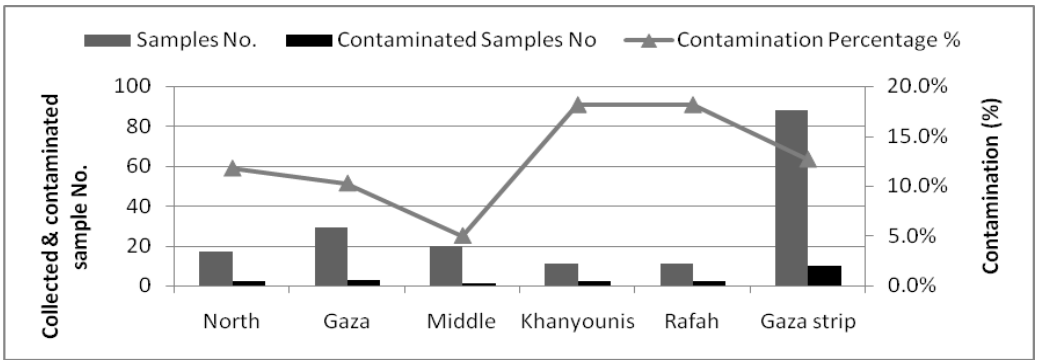

Figure 5 Contamination percentages of Faecal Coliform in the groundwater in Gaza Strip governorates

5.0 Discussion

5.1 Microbiological quality of the desalinated water and groundwater

The presence of the TC in the water system should be supported by testing of FC, since the presence of TC may be due to the colonization of a water system by non-fecal Klebsiella, Enterobacter or Citrobacter sp. (Geldreich, 1986). Therefore TC and FC tests should be simultaneously applied for testing water samples in order to exclude the contamination by environmental Coliforms. In the US, for example, all public drinking water systems are required to monitor for TC and FC bacteria under the Total Coliform Rule (EPA, 1989a). TC is a good indicator for contamination of water because most enteric bacteria pathogens die off very rapidly outside the human gut, whereas indicator bacteria such as E. coli will persist for periods of time (Ward et al. 1984). In addition, FC is a common indicator in vulnerable water systems.

The TC contamination percentage in the desalinated water in Gaza Strip was 19.3%, while in desalination plants' inlet water the percentage was 10.6%. However, the FC contamination percentages in the desalinated water and in the groundwater in the Gaza strip were 15.2% and 11.4% respectively. These percentages are considered very high if they are compared with the WHO guidelines for drinking water.

5.2 Contamination levels in the groundwater (desalination plants' inlet water)

Although the regulations of protecting the desalinated water and the groundwater from microbial contamination are very strict, the microbiological analysis for each governorate in Gaza Strip during the period of sampling from January, 2012 to April, 2012 revealed that TC and FC contamination in desalinated water and groundwater were generally higher than that of the WHO limit of 5%. The drinking water source and its delivery system (casing, pump, pipes and other appurtenances) must be free from fecal contamination, from either surface (e.g. waste infiltration) or subsurface (e.g. cesspools) source. In particular, the water must meet the guideline criteria of microbiological quality (WHO, 1996).

The level of TC and FC contamination in the groundwater in Khanyounis and Rafah governorates was the highest at 18.2% for both TC and FC in both governorates, whereas the wastewater network coverage was only 40%; in Rafah it was 70%. The lack of a wastewater network in Khanyounis has pushed people to use the absorbing wells and the septic tanks for the disposal of the raw wastewater. These ways of wastewater disposal cause a direct source of groundwater contamination through infiltration. However, in Rafah governorate, although the wastewater network coverage was 70%, the contamination level in the groundwater was high. Reasons for this high contamination level in Rafah could be due to the old and rickety wastewater network and old inefficient wastewater treatment plants. On the other hand, in Gaza governorate, the wastewater network coverage was 90%; however, the contamination level in the groundwater was almost the lowest between the Gaza Strip governorates for both TC and FC; it was 13.8% for TC and 10.3% for FC. The Middle governorate contamination level of the groundwater was also high at 15% for TC and 5% for FC; the problem of contamination in the Middle governorate could be due to the disposal of huge quantities of raw wastewater in the Wadi of Gaza passing through the Middle governorate. These huge quantities

were pumped from Gaza wastewater treatment plants through a direct line connected to the Wadi of Gaza. Moreover, the old wastewater network could cause an additional source of pollution. In the North governorate, the contamination levels were found at 17.6% and 11.8% for TC and FC respectively, although the wastewater network coverage was 80%. The old wastewater treatment plant in Bait Lahia located in the western part of the North governorate, and the huge daily received quantities of wastewater were largely contributing to the contamination of groundwater, besides the illegal wastewater absorption wells which may be considered as another source of contamination by wastewater.

Generally, the major factors contributing to the Coliform problem in Gaza Strip are: (1) sewage infiltration through incorrectly designed sewage systems or through cesspools and wastewater treatment facilities in Gaza Strip (Tubail K. M. et al. 2004, Yassin M. M., et al. 2002 and Sharif F.A., 2003); (2) interruption of water supply that may cause inverse pumping of wastewater or other contaminants from the surrounding system; this may be due to breakage in the distribution system, thus promoting bacterial biofilm growth, which is reported to develop in water distribution systems (Frias J et al. 2001, Lehtola MJ et al. 2004); (3) Improper maintenance of the distribution system and inadequate or interrupted disinfection (Yassin M. M. et al. 2006); (4) The continuous power cut-off in the groundwater pumping wells that causes negative pressure in the pipes during no pumping periods, which sucks polluted wastewater from the ground into the old leaky water pipes; (5) the bad management system of the wastewater sector in Gaza Strip.

Abu Mayla Y. et al. (2010) has mentioned that the main problem in Gaza Strip is the lack of spare parts and professionals to repair and maintain water distribution system. Leakage from nodes and joints, with interruption of water supply for many hours a day, increases the possibilities of wastewater seepage to the water network. In addition, the problems of network contamination are exacerbated due to the destruction of the infrastructure including water and wastewater networks by the Israeli militant activities.

5.3 Contamination levels in the desalinated water

The results showed that the contamination level in the Gaza strip with TC in the desalinated water was 19.3%, higher than that of the groundwater which was 15.2%. The contamination percentage of TC in the desalinated water was 13.8%; however, the FC percentage was 13.8% in the desalinated water. In the North governorate, the TC contamination percentage was 17.6% in the desalinated water. However, the FC percentage was found to be 11.8% in the desalinated water. The Middle governorate recorded high contamination levels for both TC and FC; the percentage of TC and FC was of 27.3% and 10% in the desalinated water respectively. In Khanyounis governorate, the contamination percentage for both TC and FC in the desalinated water was the highest. Regarding TC, the contamination percentage was 27.3% in the desalinated water, whereas the percentage of FC contamination was recorded at 18.2% in the desalinated. As for Rafah governorate, the TC contamination was very high and was 27.3% in the desalinated. However, the result of the FC contamination showed some difference and was recorded 9.1%.

Reasons why there are high contamination levels in the desalination plants may be due to: (1) The bad microbiological quality of the groundwater (inlet water); (2) The bad quality of the filters used in the RO desalination plants may play an important role in the formation of bacterial colonies inside the filter; (3) Most plants depend on ultraviolet radiation (UV) for water disinfection which are inactive against high levels of contamination; moreover, UV is unlike chlorine that leaves a remainder - free chlorine protects water from external source pollution; (4) The unqualified worker hose operating these plants may be considered as another cause of contamination; (5) Continuous damage in the chlorination pumps which lead to un-chlorinated or non-disinfected water; (6) The bad quality of the place containing the plant; (7) Non-compliance with health and environmental conditions and working without a license from the relevant authorities distorts the process of monitoring the quality of the product water.

Current deterioration in the quality of desalinated water in the Gaza Strip is not fortuitous but is an extension of the previous several years, as mentioned in the records of the MoH; the contamination percentage of the desalinated water quality for the year 2011 was 16.8%, while in the year 2010 it was 23.1% (MoH, 2011).

Many studies yield similar results with ours. Al-Khatib A. I. et al. (2009) has also found similar results to the current research results for desalinated water: desalinated water is prone to contamination due to the other methods by which it is distributed in Gaza Strip, namely, plastic containers, distribution tankers, filling taps at the desalination plants, and several other primitive methods, reported elsewhere. This manual handling of water significantly increases the

risk of water contamination, especially if proper hygienic practices are not followed by the handlers of water. Sadly, this strips the desalinated water of one of its main advantages, which is that it is microorganism-free as it permeates through the RO membranes. Abu Mayla Y. et al. (2009) reported that the data analysis of microbiological tests for the inlet and outlet of 22 plants show that the total contamination in inlet water is 41% for TC and 27.3% for FC while the total contamination percentages in outlet water were 45.5% for TC and 31.8% for FC.

Al Tartory Sh. (2009) found that 12 desalination plants' outlet water out of 20 were contaminated with TC bacteria, and 6 desalination plants' outlet water out of 20 were contaminated with FC bacteria. He also tested the water for Pseudomonas aeruginosa and fungi. Aish A. (2010) has recorded results which resemble ours and found that the level of bacterial contamination in the product water (desalinated water) was higher than that of the inlet water (groundwater), which may be attributed to the bad quality of filters that may play a significant role in the formation of bacterial biofilms inside the filters.

6.0 Conclusions

- The percentage of TC and FC contamination in the desalinated water and the groundwater generally exceeded WHO limit during the period of sampling.
- The contamination percentage in the desalinated water was higher than that of the groundwater for both Total Coliform and Faecal Coliform.
- The total contamination percentages in groundwater is 15.2% for the TC and 11.4% for the FC, while the total contamination percentages in outlet water was 19.3% for the TC and 13.8% for the FC; in some plants, the contamination by TC and FC in the inlet water is higher than that of the outlet water, but in other plants, the contamination level in outlet water is higher than that of inlet water.

7.0 Recommendations

- A monitoring program for the desalination plants includes chemical and microbiological analysis should be enhanced, developed and intensified for the evaluation of the product and distributed water.
- A strategy should be adopted to control the location of the small scale desalination plants' construction according to the groundwater quality to manage salinity problems in the Gaza Strip.
- Dependence on desalinated water should increase, which means that the desalination capacity of the current plants should be boosted or new plants should be built. This will reduce the water withdrawal rate from the coastal aquifer and allow it to rehabilitate itself and reduce its salinity. Moreover, this will guarantee a high quality water supply in the Gaza Strip. Distribution of desalinated water, then, should be totally done through the water network.
- Large seawater desalination plants should be established in order to decrease pumping water in the Gaza Strip aquifer.

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