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Evaluation of Microbiological Quality of Desalinated Water at Gaza City Schools, Palestine

Zeyad H. Abu Heen Osama K. Haneya
Department of Environment & Earth Sciences, Islamic University of Gaza, Palestine

Abstract
Gaza Strip is an elongated strip located at southeastern coast of Palestine with total area of about 365 km^2 with approximately 40 km long and the width varies from 8 km in the north to 14 km in the south. Gaza City is the biggest cities in Gaza Strip and has an area of approximately 55km^2 with about 500,000 people forms about 30% of total Gaza strip residence. The Area has very limited water resources. Groundwater is the main source for domestic, industrial and agricultural purposes. Over abstraction of the groundwater leaded to sea water intrusion which increases salinity of the groundwater by time. Water resources are deteriorating in terms of quantities and quality which led to establish small business scale desalination plants to treat and distribute desalinated water by trucks for most of Gaza strip areas and schools. The aims of this research are to check if there is microbiological contamination at desalinated water at Gaza City schools, to determine the source of contamination if any, and to determine the difference between drinking water microbiological quality between schools moderated by Ministry of High Education (MOHE) and schools moderated by United Nations Relief and Works Agency (UNRWA). Some of 130 school buildings have been selected and the data evaluated for the periods from the year 2009 to 2011. Results indicated significant microbiological contamination in the desalination plants inlet and in schools water tanks. The origin of this contamination is believed to animal origin. About 50.0% of monitored schools at East Directorate, 83.3% of monitored schools at West Directorate and 60.0% of monitored schools at UNRWA were contaminated. Contaminated schools after follow-up has decreased, it were 16.7% at East, 50% at West and 40% at UNRWA schools.
Keywords: Gaza Strip, Palestine, Contamination, Desalination plants.

1. Introduction

Gaza Strip is an elongated strip located at southeastern coast of Palestine with coordination of Latitude N 31° 26' 25" and Longitude E 34° 23' 34". The area is bounded by the Mediterranean in the west, the 1948 cease-fire line in the north and east and by Egypt in the south. The total area of the Gaza strip is 365 km^2 with approximately 40 km long and the width varies from 8 km in the north to 14 km in the south (UNEP, 2003). Gaza Strip is divided geographically into five governorates: Northern, Gaza, Middle Zone, Khan Yunis, and Rafah as shown in Figure (1). The Gaza Strip is located in a semi-arid zone. The annual rainfall rate in the area ranges from 200 mm in the south to 400 in the north. The strip has very limited water resources. Groundwater is the main source for domestic, industrial and agricultural purposes. Over abstraction of the groundwater leaded to sea water intrusion which increases salinity of the groundwater by time. Water resources are deteriorating in terms of quantities and quality.

Gaza city has total area of approximately 55km^2. According to the latest statistical census at 2007, Gaza city was and still hold the largest population of about 500,000 people in year 2011 (PCBS, 2007), which form about 30% of total Gaza strip residence (MOLG, 2010). Gaza city has a total number of 252 schools located at 152 building described as shown in Table 1(MOHE, 2011).

2. Statement of the Problem and Study Objectives

Gaza strip residents use ground water wells as main source of water which suffers from deterioration of water quality rather than water scarcity. This situation led to establish small business scale desalination plants to treat and distribute desalinated water by trucks for most of Gaza strip areas and schools. Treated drinking water is provided by desalination plants which should enhance the quality of all water properties. Water analyses indicate that 10% of Inlet water samples were contaminated by Total Coliform (TC) and 5% of water samples were contaminated by Fecal Coliform (FC). The study showed that 25% of product water samples were contaminated by Total Coliform, and about 15% of water samples were contaminated by Fecal Coliform (Aish, 2010).

Some of desalinated drinking water delivered to Gaza city schools could be contaminated biologically; therefore desalination plants maybe a source of contaminated water. Otherwise contamination maybe caused at distribution trucks or at school sites; and it could be human or non-human origin. To achieve this evaluation study, the following objectives were selected:

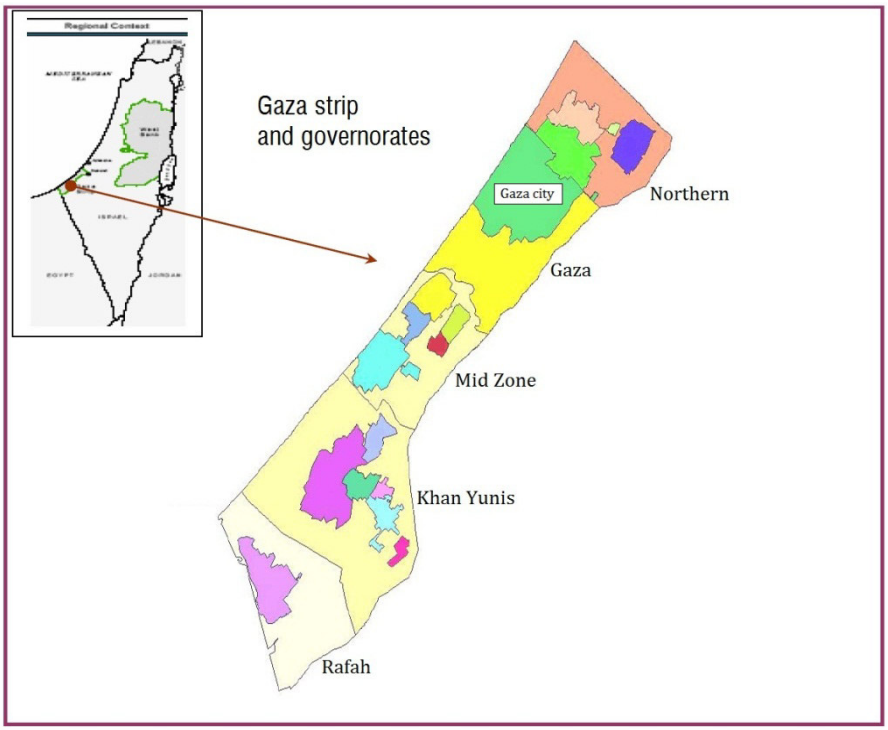

Figure1. Location map of the studied area.

Table 1. General information about schools at Gaza city according to different directorates

Directorate	East Gaza	West Gaza	UNRWA	Private	Total
Number of schools	85	81	64	22	252
Number of school (as building)	46	55	29	22	152
Number of students	51,000	49,000	55,000	8,000	163,000

- Check if there is microbiological contamination at desalinated water at Gaza city schools using available historical data.
- Determine the source of contamination if any.
- Determine the difference between drinking water microbiological quality between schools moderated by Ministry of High Education (MOHE) and schools moderated by United Nations Relief and Works Agency (UNRWA).

3. Study design and methodology

Figure (2) summarizes the study design and its objectives. The methodology to achieve the objectives is detailed as follows:

- Objective-1: historical data from Ministry of Health (MOH) and UNRWA's Special Environmental Health Program (SEHP) were used. Total and Fecal Coliform analysis for several school years were obtained. The data were sorted, verified and organized, and then frequencies had been calculated.
- Objective-2: consists from two parts. The first aims to tracking contamination point source, several tools were used to check which place of desalinated drinking water (plant, trucks and school tanks) is responsible of being source of contamination. The second part aims to determining contamination origin, which believed to be human or non-human. A special designed research tool were used which depends on selection the most prober contaminated schools (depending on historical data) and check their positivity for contamination then apply FC/FS ratio to contaminated schools.
- Objective-3: frequencies comparisons between east Gaza schools, west Gaza schools and UNRWA schools in Gaza were applied on data gathered from school tanks analysis, school tanks checklist and students questionnaire, to compare between different directorates.

4. Drinking water microbiological contamination in Gaza Strip

Few studies have discussed the problem of microbiological quality of drinking water which has deteriorated in Gaza strip. Abu Amr and Yassin (2008) and Yassin et. al (2006) assessed total and faecal coliform contamination in water wells and distribution networks over the past 7 years, and their association with human

health in in Gaza Strip and in Khan Yunis Governorate. They concluded that the contamination percentages were higher in networks than in wells and exceeded the World Health Organization standards. Diarrheal diseases were strongly correlated with faecal coliform contamination in water networks. Sharif (2003) found various concentrations of total and fecal coliform in water samples from 20 groundwater wells located in the surrounds of the wastewater treatment plant of Beit Lahia, north of Gaza Strip. El-Mahallawi (1999) detected total and fecal coliform contamination of tap water and roof tanks in Deir El-Balah, Gaza Strip, where disinfection processes were not fully implemented. Actually, bacterial contamination of drinking water has been reported in developing and some developed countries (Zacheus et al. 2001; Rifaat, 2007 and Liguori et al. 2010).

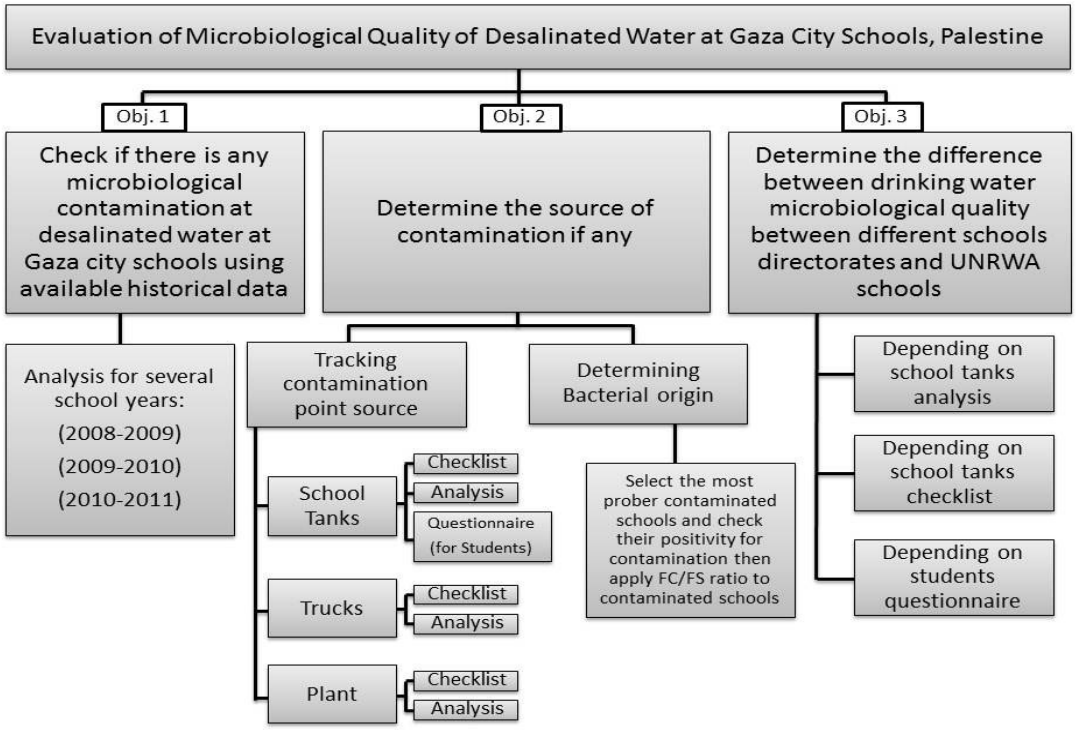

Figure 2. Study design and its objectives

Detection of bacterial indicators in drinking water indicates the probability of presence of pathogenic organisms that are likely to be the source of waterborne diseases. Some of these diseases could be fatal (Macler and Merkel, 2000). The presence of giardiasis was reported in various countries and epidemic was associated with contaminated drinking water (Azizullah et al. 2007; Castro -Hermida et al. 2008 and Karanis et al. 2006). Outbreaks of bacterial and viral diseases have also been recorded (Viau et al. 2011 and Vivancos et al. 2010). Intestinal parasites and diarrhea are prevalent in the Gaza Strip (Abu Mourad, 2004).

5. Sampling collection and procedure

The possible locations for microbiological contamination of the drinking water of the selected schools are: the desalination plant which provides drinking water; delivery trucks which distribute drinking water for schools and school tanks which serve drinking water for school students.

Historical data were obtained from the Palestinian Ministry of Health (MOH) which monitors desalinated drinking water at Gaza strip Schools, mainly those following Palestinian National Authority. The data were available for total coliform and fecal coliform results from studying season 2008-2009 to 2010-2011. At studying season 2010-2011, UNRWA started a health monitoring program for its schools. The samples of three sites were collected, and then delivered quickly to MOH laboratory to conduct TC and FC analyses. Sampling was performed according to Standard Methods for the Examination of Water and Wastewater, 20th edition.

A special checklist was designed to evaluate desalination plant, delivery trucks and schools tanks. Most of checklist questions were yes/no questions. General characteristics of each checklist are described in Table (2).

A questionnaire was conducted for 425 school students at 17 schools in Gaza city. The total return and accepted forms were 417. The questionnaire survey was designed to test student acceptance for hygienic proprieties of water available at their schools. Sample size was chosen to accept margin of error 5% at

confidence level 95%, considering response distribution is 50% (Raosoft, 2004). The minimum recommended sample size is 384 students.

Table 2. General characteristic of the used checklists

	desalination plant checklist	delivery trucks checklist	schools tanks checklist
Sample size	1	3	28
No. of questions	15	12	13

6. Results and discussion

6.1 Microbiological quality of desalinated water at Gaza City schools

The total schools number as building is 130 schools and this number considered as population. There was not any increase at schools building at the few last years (2008 to 2011) because of scarcity of building materials due to the Israeli siege on Gaza strip. Table (3) summarizes the microbiological quality of desalinated water at Gaza city schools at studying years (2008-2011).

Table 3. Microbiological quality of desalinated water at Gaza City schools at studying years (2008-2011)

School year	2008-2009		2009-2010		2010-2011	
Total school No.	130		130		130	
	Freq.	%	Freq.	%	Freq.	%
Monitored schools	23	17.7	93	71.5	118	90.8
Contaminated schools (before follow-up)	14	60.9	41	44.1	34	28.8
Contaminated schools (after follow-up)	7	30.4	19	20.4	29	24.6
No. of follow-up	8		31		7	
Average delay of follow-ups (days)	37.6		74.3		97.3	

The monitoring program provided the number of contaminated schools. MOH inform these schools and order them to clean and disinfect the drinking tanks. This process recommends follow-up procedures. The (follow-up) term means the returning back process to re-sample the contaminated tank to make sure that the drinking water at the contaminated school is microbiologically safe. The delay in follow-up process is mean to how many days passed until the re-sampling process take place. The average delay of follow-ups in days can be calculated by calculating the arithmetic mean of all delaying number.

Inspection of table (3) reveals that:

1. Monitored schools percentage has increased at the last three studying years from 17.7% at 2009, to 71.5% at 2010 and to 90.8% at studying year 2011. This refers to the increase of the local authorities' awareness to microbiological awareness.
2. Contaminated schools percentage has decreased at the last three years from 60.9% to 44.1% and to 28.8% respectively.
3. The number of contaminated schools after follow-up is less than the number of contaminated schools before follow-up. Also, it is noticed that increasing of monitored schools lead to the decreasing of contaminated schools, because the monitoring process encourage the school department to keep the drinking water in tank as clean as possible.
4. The percentage of contaminated schools after follow-up was 30.4% at studying year 2009, decreases to 20.4% at studying year 2010 and increased to 24.6% at studying year 2011. The reason for the higher contamination in year 2011 more than the previous years may refer to the decrease in fellow-ups times and to the increase in average delay of follow-ups as shown from the table (3).

6.2 Source of contamination determination

The source of contamination could be one of the following sources: desalination plant inlet; desalination plant outlet: delivery trucks and school's tank. Results are listed in tables (4, 5, 6 and 7).

Table 4. Desalination plant inlet analysis result

Location	Total coliform	Fecal coliform	Fecal strep.	Status
Inlet	30	5	N/A	contaminated
Inlet	N/A	0	0	clean

Table 5. Desalination plant outlet analysis result

Location	Total coliform	Fecal coliform	Status
Outlet	0	0	clean

Table 6. Delivery trucks analyses result

Truck No.	Total coliform	Fecal coliform	Status
1	0	0	clean
2	0	0	clean
3	0	0	clean

Table 7. Schools tanks analyses result

Test date	Visited schools No.	Status		
		clean	Contaminated freq.	Contaminated %
07-05-2011	7	7	0	0.0%
08-05-2011	10	7	3	30.0%
14-05-2011	11	10	1	9.1%
Total	28	24	4	14.3%

Inspection of the above tables shows that the inlet of the desalination plant was contaminated, but the outlet of the same plant was not contaminated. It could be due to the presence of UV disinfection unit in the desalination plant. Four of total twenty eight schools tanks (14.3%) were contaminated. If the source of contamination was from the plant or the trucks, we would found all or most of school tank contaminated. This indicates that the contamination source of desalinated drinking water at schools is the schools themselves. There should be a special cause for contamination in each school.

To delineate the different factors and elements that could be responsible for school tank contamination, school tank checklist and student questionnaires were prepared. The results are presented in Tables (8 and 9).

The tables showed that only 46.4% of schools tanks were well closed. The open hole of the water tank could be a source of contamination. However, table (9) illustrates that the student behaviors are the main source of contamination.

Throwing the wastes into the water discharger pool play the main reason (70.5%), followed by blowing into water taps and discharged pool clogging (47.7%). The absent of the upper cover of tank hole plays an important factor for contamination (28.6%) where birds standing on tank's upper hole which may lead to a serious cause of animal bacterial origin.

6.3 Determining Bacterial Origin

Tables (10 and 11) show the results of bacterial origin determination process. The first test was made to locate contaminated drinking water as shown in Table (10) for about 28 selected schools. The second test was made to calculate FC/FS ratio for the contaminated schools (14.3%) as shown in Table (11).

Table (11) illustrates that FC/FS ratio for Jamal Abdul Nasser School and Males of Al Falah School is zero. FC/FS ratio for Hiteen School is less than 0.03. And FC/FS ratio for Abdel Fattah Hamoud School is less than 0.02. According to Edwards et al. (1997), the FC/FS ratio for human bacterial origin waste is >4.0 and FC/FS ratio for animal bacterial origin waste is <0.7. This means that the bacterial origin of contamination in the contaminated schools in Gaza city is assumed to be animal.

Table 8. Comprehensive table of health suitability of drinking water tanks at Gaza city schools

No.	Question		%
1.	Is the tank made from stainless steel?		100.0
2.	Is the tank well closed?		46.4
3.	Is the pipe which supply taps safely higher than the bottom of tank?		60.7
4.	Is the tank being emptied?		50.0
5.	Is end to end disinfection process being applied when filling-up the tank?		14.3
6.	Is the tank being disinfected?		57.1
7.	What is the period of disinfection?	Weekly	18.8
		Monthly	56.2
		Annual	25.0
8.	Is free chlorine used as matter of disinfection?		87.5
9.	Is a drainage hole installed specially for cleaning?		96.4
10.	Is the tank located in an appropriate site?		64.3
11.	Does the water in tank have residual chlorine?		14.3
12.	Is there any agency conduct periodic test for water?		92.9
13.	How often they conduct periodic test?	Weekly	11.5
		Monthly	42.3
		Annual	46.2

Table 9. Student questionnaire of schools tanks results

Question No.	Freq. yes answers	%
1. Did you see anyone throw waste in tank's upper hole?	54	12.9
2. Did you see any waste in water discharger pool?	294	70.5
3. Did you notice that discharger pool is clogged?	199	47.7
4. Did you notice someday that there is no cover for tank?	49	11.8
5. Did you notice birds standing on tank's upper hole?	14	28.6[a]
6. Did you see anyone blowing into water taps?	199	47.7

[a] The percentage calculated according (yes) answers at question number 4.

Table 10. FC/FS ratio for contaminated schools at Gaza city

No.	School name	Directorate	1st test	TC[a]	FC[a]	2nd test	FC[b]	FS[b]	FC/FS ratio[b]
1	(A)Jamal Abdul Nasser	East Gaza and UNRWA*	08/05/2011	3	0	22/05/2011	0	>100	0
2	(B)Hiteen	East Gaza	08/05/2011	2	1	22/05/2011	3	>100	<0.03
3	(C)Abdel Fattah Hamoud	East Gaza	08/05/2011	8	3	22/05/2011	2	>100	<0.02
4	(D)Males of Al Falah	UNRWA	14/05/2011	3	1	22/05/2011	0	>100	0

*UNRWA has rented the second studying period of this school from MOHE.
[a] result for first test, [b] result for second test

6.4 Differences between drinking water microbiological quality between different schools directorates

Differences will be stated between three schools directorates (East, West and UNRWA) according to drinking water microbiological quality. A Summary of the comparison results are listed in Table (12). Inspection the table reveals the following conclusions:

- Follow up processing improved the water quality at the water school tanks. Decreasing of the contaminated schools is observed after follow up for all the directorates (East, West and ANRAWA).
- An Improvement of water quality is observed for all the directorates by time (from 2009 to 2011) which supports the importance of follow up processing to improve the water quality at the contaminated school water tanks.

Table 12. A Summary of the comparison results between different school directorates.

Factor	2008-2009			2009-2010			2010-2011		
	East	West	UNRWA	East	West	UNRWA	East	West	UNRWA
Total school No. (130 as total) %	35.4	42.3	22.3	35.4	42.3	22.3	35.4%	42.3%	22.3%
Contaminated schools before follow-up (%)	50.0	83.3	60.0	59.1	31.2	n/a	23.8	20.8	56.5
Contaminated schools after follow-up (%)	16.7	50	40	15.9	25	n/a	19.0	15.1	n/a

- The table shows that in year 2009 East directorate school is the best, followed by ANRWA School then West directorate schools. Whilst in year 2010 the East directorate schools are the best, followed by the west directorate. In year 2011 the West directorate school is the best followed by the East directorate schools.

7. Conclusion

1. The microbiological safety of desalinated drinking water at Gaza city schools has improved in the last three studying years (2009 to 2011).
2. Monitored schools number has increased at the last three studying years from 17.7% at 2009, to 90.8% at studying year 2010-2011. Frequency of contaminated schools has decreased at the same period from 60.9% to 28.8%. Contaminated schools number after follow-up is less than the number before follow-up process.
3. Due to the weakness of monitoring program of desalinated drinking water there was a high contaminated schools ratio. This ratio had been lowered after follow-up process activation.
4. The well maintenance of the desalination plant leads to keep the product of the plant safe and well accepted. When the inlet of the plant was contaminated the UV unit helped to kill the source of contamination, and the chlorination process insures the safety of the plant product.
5. The point source of microbiological contamination in Gaza city schools are the schools themselves. While the desalination plant and delivery trucks are clean, because the plant ensures to meet most of drinking water

safety guidance.

6. Due to analyses results, the bacterial origin of contamination at desalinated drinking water in Gaza city schools is animal bacterial origin.

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