BACTERIOLOGICAL QUALITY EVALUATION OF BOTTLED WATER SOLD IN THE GAZA STRIP, PALESTINE

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ABSTRACT

The purpose of this paper is to investigate the bacteriological quality of bottled waters and compare it with those determined in small scale of (RO) desalination companies in the Gaza Strip. However the number of imported and domestic bottled waters is limited in Gaza Strip. Eleven brands of imported bottled waters from West bank, Egypt, Jordan and Israel and four brands of locally packing bottled waters were microbiologically analyzed within two hours of purchase at a local supermarket. Viable bacterial count was estimated on quarter-strength Plate Count Agar (1/4 PCA) incubated at 22°C for 72 hours. The number of counted bacteria was in 50% of locally bottled waters over the permitted safe stander in Palestine, 36.4% of imported bottled water brands were also over this level. Beside the estimation of total bacterial count in indigenous and imported bottled waters, EMB Agar was used for detection of total coliform as well as for thermotolerant coliform in these different brands of bottled waters. The presence of total coliform bacteria was detectable in 75% of locally bottled waters and in 45.4% of imported brands. Thermotolerant coliform bacteria were respectively detected in 75% of indigenous and in 27% of imported bottled waters.

Keywords: Gaza Strip, Bottled water, Water quality

1. INTRODUCTION

Gaza Strip is a narrow strip along the Mediterranean Sea as shown in Fig. 1. It is around 40 km long while its width varies from 7 to 12 km. Its area is around 365 km^2 and has a population around 1.6 million, PCBS [1]. In general, Gaza Strip is known to have serious water problems ranging from quality problems to expected shortage of water supplies not only for agricultural and industrial usage but also for drinking. A major reason for this crisis is because the Palestinians lack the control over their water resources, Abu Zahra [2]. It is to be noted here that groundwater is the only significant source for water to meet the demand in Gaza Strip. The entire population is completely dependent on groundwater for agricultural, industrial, and domestic water supplies, Weinthal *et al*. [3].

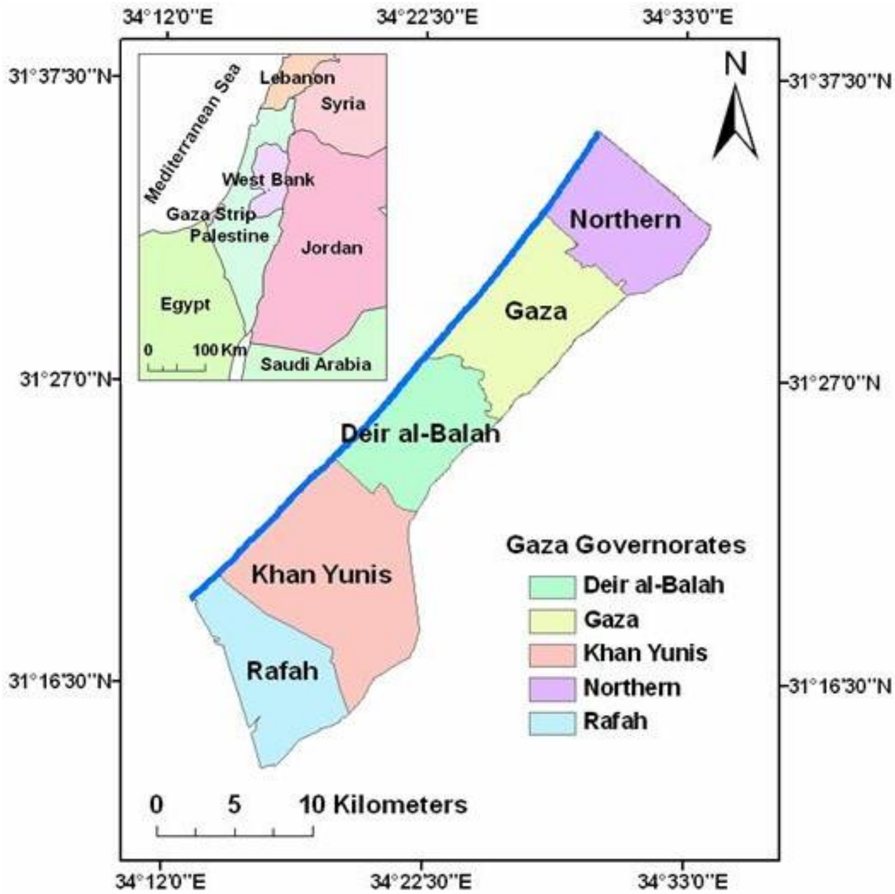

Fig. 1: Location map of the Gaza Strip

The two common problems with drinking water quality in Gaza Strip are the presence of high level of both nitrates and chlorides, where 150 wells supply the population with drinking water. About 90% of wells having NO_3^- concentrations that is several times higher than the World Health Organization (WHO) [4] standards, which is 50 mg/l. In some wells, the level of nitrates in drinking water may exceed 300 mg/l which is 6 times that allowed by WHO, while the level of chlorides may exceed the WHO standards by 4–5 times, Shomar *et al*. [5].

The above two problems are mainly attributed to wastewater, agricultural fertilizers, pesticides and industrial pollutants. These pollutants may directly penetrate to the groundwater reservoir through pores in rocks or indirectly by decomposition which increases the salts in the wells and thus deteriorates water quality. Based on Palestinian Water Authority records, the domestic water demand for the year 2000 was 55 million m^3, which is expected to increase to 182 million m^3 in the year 2020, Metcalf & Eddy [6]. The agricultural water demand was about 90 million m^3 in year 2000. However, agricultural water demand is not expected to increase because of the dramatic decrease in agricultural land due to rapid urbanization. Also it is planned to change the crop pattern to reduce the water demand. Therefore, the projected agricultural water demand in the year 2020 is about 80 million m^3. Table 1 shows the current and projected water demand for the period from 2000 to 2020 according to the Palestinian water authority.

Table 1. Prediction of water demand and water input in the Gaza Strip (million m^3)

Year	Population	Agricultural demand	Domestic and Industrial demand	Total demand	Input to the aquifer	Deficit
2000	1,167,359	91	55	146	109	37
2005	1,1472,333	92	100	192	131	61
2010	1,871,144	88	125	213	137	76
2015	2,241,206	86	152	238	145	93
2020	2,617,823	80	182	262	155	107

Metcalf & Eddy, [6]

One of the major options for resolving the water problems is the utilization of desalination technology for both sea and brackish water, Al-Jayyousi & Mohsen [7]. More than 90% of the population of the Gaza Strip depends on desalinated water for drinking purposes, Al-Agha & Mortaja [8]. There has been dissemination of many small scale brackish water desalination companies in the Gaza Strip (private RO plants). Chemical and bacteriological qualities of this small scale of (RO) desalination plants were determined in previous study, Aish [9]. The second option is the consumption of bottled waters, both Indigenous and imported bottled waters.

Like other developing and developed countries, the increase in consumption of bottled waters in Gaza is referred to the general believe that the bottled water is safe and free of bacteria and other impurities, Tamagnini & Gonzalez [10]. Additional to the consumption of bottled waters by adults, it was ideal for infant's formula preparation, Warburton *et al*. [11]. A lot of studies about the microbiological status of bottled waters have been carried out in different countries like Canada, Taiwan , UK, Trinidad, India, and Brazil (Warburton *et al*. [12]; Tsai & Yu [13]; Arnas & Sutherland 1999 [14]; Bharath *et al*.[15]; Jeena *et al*.[16] & Da Silva *et al*.[17]. However, several studies demonstrated the fact that bottled water is not in generally safe and clean of microbes as assumed. Warburton *et al*. [18] &, [19] proved that more than 30% of bottled waters at the Canadian market had aerobic colony count that exceeded the standard level.

In Gaza Strip there is no sufficient information about the microbiological quality of bottled drinking water, so we begin with our present study to describe the bacteriological quality of four brands of locally bottled waters and eleven brands imported from West bank, Egypt, Jordan and Israel, consumed in Gaza.

The microbiological analyses were performed through conventional routine methods according to Palestinian and EC standards, [20] & [21] (Table 2) on the following microbiological parameters: Heterotrophic Plate count at 22 ºC, Coliform bacteria at 35 ºC and thermotolerant Coliform bacteria at 44 ºC. Finally we compared our results and the results achieved in the study of small scale of (RO) desalination plants, Aish [9] with Palestinian and European Standards .

Table 2. Palestinian and European Drinking water standards comparative table

Parameter	**Palestinian standard**	**European standard**
Colony count at 22 ºC	≤ 100 CFU ml^{-1}	100 CFU ml^{-1}
Total coliform	0/ 100 CFU ml-1	0/ 100 CFU ml^{-1}
Thermotolerant coliform	0/ 100 CFU ml^{-1}	0/250 CFU ml^{-1}

2. MATERIALS AND METHODS

2.1 Indigenous and imported bottled water

Triplicate of fifteen types of available bottled waters in Gaza strip were collected from different markets. (Table 3)

Table 3. Indigenous and imported bottled water

	Brand	Locality of bottled water	Label on bottled water
Indigenous bottled water	**A**	Gaza	Natural Drinking Water
	B	Gaza	Natural Mineral Spring Water
	C	Gaza	Natural Drinking Water
	D	Gaza	Mineral Water
Imported bottled water	**E**	West bank	Natural Mineral Water
	F	Jordan	Natural Drinking Water
	G	Jordan	Natural Drinking Water
	H	Jordan	Pure Natural Water
	I	Egypt	Pure Natural Water
	J	Israel	Pure Natural Water
	K	Israel	Natural Mineral Water
	L	Israel	Natural Mineral Spring Water
	M	Israel	Pure Natural Water
	N	Israel	Natural Mineral Water
	O	Israel	Natural Mineral Water

2.2 Sampling

Triplicate of fifteen types of available bottled waters in Gaza strip were purchased from different market, transported within 2 hours into laboratory and heterotrophic plate count (HPC) were performed as well as the determination of total coliform and thermotolerant coliform contamination.

2.3 Heterotrophic plate count

Microbial colony count were determined by decimal dilution in sterile saline (0.9% sodium chloride), started with nil dilution until $1x10^{-5}$. A volume of 100 µl of each dilution were plating on Plate Count Agar (PCA; himedia, India) at quarter-strength (1/4 PCA) (Armas & Sutherland 1999). Duplicate plates for each dilution of the three bottles for the fifteen brands were plating on 1/4 PCA and incubated at 22ºC for 3 days.

2.4 Detection of coliform and thermotolerant coliform bacteria

Coliform and thermo tolerant coliform bacteria were enumerated by using of membrane filter techniques. A volume of 100 ml and 250 ml of the different brands were filtered through a 0.45 µm-pore size membrane filters (Schleicher & Schuell, Germany). The membrane filters were placed on Eosin methylene blue agar (EMB agar, himedia, India). EMB agar with membrane filters for detection of coliform bacteria were incubated by 35ºC for 24 hour, while EMB plates for detection of thermotolerant coliform bacteria were incubated by 44.5ºC for 48 hour.

3. RESULTS AND DISCUSSION

3.1 Enumeration of bacteria

The results of HPC are shown in Table 4. The Table shows the viable bacterial number in the fifteen brand of bottled waters (4 indigenous and 11 imported).

Table 4. Heterotrophic plate count (CFU ml^{-1}) in fifteen brands of indigenous and imported bottled water sold in Gaza

Heterotrophic plate count (cfu ml^{-1}) on 1/4 PCA at 22ºC								
	Brands	**cfu ml^{-1}**	**cfu ml^{-1} (d)**	**cfu ml^{-1}**	**cfu ml^{-1} (d)**	**cfu ml^{-1}**	**cfu ml^{-} 1(d)**	**Average**
Indigenous bottled water	**A**	$3x10^3$	$1.2x10^3$	$1.4x10^3$	$1.1x10^3$	$1.3x10^3$	$4.3x10^3$	$2.05x10^3$
	B	$1.x10^1$	0	$1.5.x10^1$	0	$1.x10^1$	0	5.8
	C	$9x10^1$	$1.2x10^2$	$7x10^1$	$2x10^2$	$8x10^1$	$9x10^1$	$1.08x10^2$
	D	$1.x10^1$	0	$1.x10^1$	$2.5.x10^1$	0	$2.x10^1$	$1.08x10^1$
Imported bottled water	**E**	0	0	0	0	0	0	0
	F	$4x10^1$	$2x10^1$	$2x10^1$	$5x10^1$	$4x10^1$	0	$2.8x10^1$
	G	$7x10^2$	$5.8x10^2$	$1.8x10^2$	$2x10^2$	$3x10^2$	$1.2x10^2$	$3.5x10^2$
	H	$2x10^2$	$2.6x10^2$	$3x10^2$	$2.1x10^2$	$3.6x10^2$	$4x10^2$	$2.9x10^2$
	I	$1.4x10^1$	$1x10^1$	0	0	$1.9x10^2$	$7x10^1$	$4.7x10^1$
	J	0	0	0	0	0	0	0
	K	$2x10^3$	$2.7x10^3$	$1.5x10^3$	$1x10^3$	$7x10^2$	$1.5x10^3$	$1.6x10^3$
	L	$7x10^2$	$5x10^2$	$4.2x10^2$	$3.6x10^2$	$8x10^2$	$9x10^1$	$4.8x10^2$
	M	0	0	0	0	0	0	0
	N	0	0	0	0	0	0	0
	O	0	0	0	0	0	0	0

Two brands (50%) of the indigenous bottled waters were over the Palestinian standard for bottled drinking water. Brand A has average bacterial count of about 2000 CFU ml^{-1}, which is significantly above the 100 cfu ml^{-1} Palestinian standard [20], whereas the average bacterial count in brand C exceeded the Palestinian standard with average count of 108 cfu ml$^{-1.}$ Bacterial colony count in brand B and D was with about 6 and 11 cfu ml^{-1} under the maximum level permitted in Palestine. About Thirty six percent of imported bottled water was also over the maximum level legally permitted in Palestine. Brands G, H, K, and L, with bacterial count of 350, 290, 1600 and 480 cfu ml^{-1} . Brand F and I have average bacterial count under the Palestinian standard, 28 and 47 cfu ml^{-1} respectively, whereas in the other brands E, J, M, N and O no bacteria were detected after 3 days of incubation at 22 ºC.

3.2 Enumerations of coliform and thermotolerant coliform bacteria

Table 5 illustrates the number of coliform bacteria detected in 100 ml of the examined sample. Three of the four indigenous brands (75%) showed contamination with coliform bacteria. Brand A, C and D of indigenous bottled waters showed a positive result for the present of coliform with average count of about 14.5, 6.3 and 3.5 colonies in 100 ml. In Brand B was no coliform bacteria detected in 100 ml of filtered samples. Five of the eleven imported bottled waters (45.45%) showed a positive result for the present of coliform. In brand F, G, H, I and M was the coliform titer in 100ml filtered samples over the Palestinian legally permitted level. In brand E, J, K, L, N and O were no coliform bacteria detected. According to Palestinian drinking water standards, the legally permitted level of total coliform and thermotolerant coliform bacteria in 100 ml of drinking water is equal zero.

Table 5. Number of coliform bacteria detected in 100 ml of the examined sample

Number of coliform bacteria detected in 100 ml of the sample								
	Brands	**Colonies number**	**Colonies number (d)**	**Colonies number**	**Colonies number (d)**	**Colonies number**	**Colonies number (d)**	**Average**
Indigenous bottled water	**A**	12	23	12	16	11	13	14.5
	B	0	0	0	0	0	0	0
	C	5	7	6	5	8	7	6.3
	D	3	4	4	1	2	7	3.5
Imported bottled water	**E**	0	0	0	0	0	0	0
	F	5	7	4	3	0	0	3.2
	G	13	14	11	16	17	11	13.7
	H	10	8	4	0	6	4	5.3
	I	17	11	6	4	8	2	8
	J	0	0	0	0	0	0	0
	K	0	0	0	0	0	0	0
	L	0	0	0	0	0	0	0
	M	1	1	0	2	0	2	1
	N	0	0	0	0	0	0	0
	O	0	0	0	0	0	0	0

d= duplicate measurement

The results for detection of thermotolerant coliform bacteria in indigenous and imported bottled waters are mentioned in table 6. 75% of indigenous brands showed contamination with thermotolerant coliform bacteria. Brand A, C and D of indigenous bottled waters showed a positive result for the present of thermotolerant coliform. In Brand B, no thermotolerant coliform bacteria war detected in 250 ml of filtered samples. Brand G, H and I of imported bottled waters (27.27%) showed a positive result for the present of thermotolerant coliform bacteria. In brand E, F, J, K, L, M, N and O were no thermotolerant coliform bacteria detected.

Table 6. Number of thermotolerant coliform bacteria detected in 250 ml of the examined samples

Number of thermotolerant coliform bacteria detected in 250 ml of the examined samples								
	Brands	**Colonies number**	**Colonies number (d)**	**Colonies number**	**Colonies number (d)**	**Colonies number**	**Colonies number (d)**	**Average**
Indigenous bottled water	**A**	7	18	10	13	5	6	9.8
	B	0	0	0	0	0	0	0
	C	2	2	0	1	2	0	1.2
	D	2	2	1	0	2	3	1.7
Imported bottled water	**E**	0	0	0	0	0	0	0
	F	0	0	0	0	0	0	0
	G	5	1	0	3	6	1	2.7
	H	6	2	1	0	2	3	2.3
	I	2	1	0	1	0	2	1
	J	0	0	0	0	0	0	0
	K	0	0	0	0	0	0	0
	L	0	0	0	0	0	0	0
	M	0	0	0	0	0	0	0
	N	0	0	0	0	0	0	0
	O	0	0	0	0	0	0	0

d= duplicate measurement

3.3 Comparison between bacteriological quality of bottled and RO desalinated water

The Comparison between bacteriological analysis of bottled and RO desalinated water regard total and thermotolerant coliform bacteria in examined samples showed that the bacterial contamination in RO desalinated water was relatively lower than those detected in bottled waters sold in Gaza Strip as shown in table 6. More Experiments should be done to verify this comparison.

Table 7. Bacteriological quality of small-scale reverse osmosis desalination plants and bottled water

Source	**Parameter**	**Sample No.**	**Contamination %**
OR desalinated water Bottled water	Total Coliform	20 15	25 53.3
OR desalinated water Bottled water	Fecal Coliform	20 15	15 40

4. CONCLUSIONS

Bottled water is widely available in both developed and developing countries. The crisis situation and the severe shortage in water supplies in Gaza consider as a major reason for the increase in consumption of bottled waters in Gaza Strip. We examined 15 different brands of indigenous and imported bottled waters and used the quarter strength agar for the heterotrophic plate count, which is more suitable for recovery of microorganisms in bottled waters than full strength agar. The presence of bacteria in the investigated bottles indicated a serious contamination in different brands of the examined bottled waters.

The present descriptive study has demonstrated that an aerobic bacterial count as well as total coliform and thermotolerant coliform count exceeds the standards permitted in Palestine as well as the European drinking water standard. Such results are not to be ignored, especially with the fact, that several waterborne pathogens like *Escherichia coli* O157:H7 are harmful to human health and have high mortality rate. The contamination percentage of total coliform and fecal coliform bacteria in small-scale reverse osmosis (RO) desalination plants was lower than those detected in bottled waters, so that desalinated water can provide a partial solution for the water problems in the Gaza Strip with more microbiological safety than bottled waters consumed in Gaza Strip. However more Experiments should be done to verify this comparison.

We recommended especially the local companies to focused on and improve the microbiological quality of bottled waters. We think this should be done in cooperation with the Palestinian water authority and ministry of health.

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