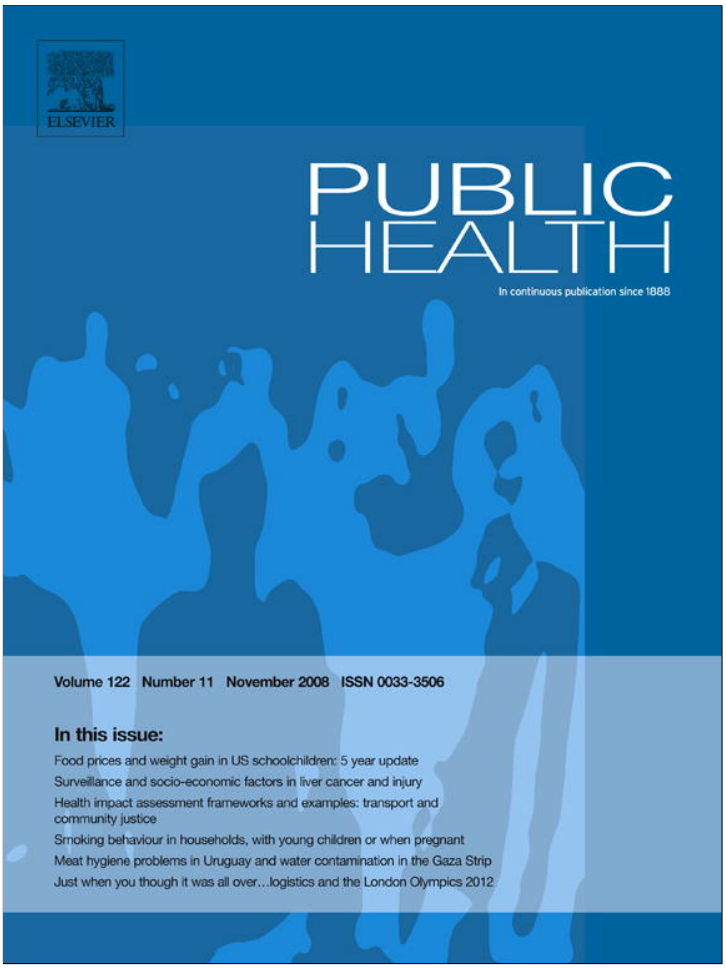

Public Health (2008) **122**, 1275—1283

ELSEVIER

PUBLIC HEALTH
www.elsevierhealth.com/journals/pubh

Original Research

Microbial contamination of the drinking water distribution system and its impact on human health in Khan Yunis Governorate, Gaza Strip: Seven years of monitoring (2000—2006)

S.S. Abu Amr[a], **M.M. Yassin**[b,*]

[a]*Water Control Department, Environmental Health Directorate, Palestinian Ministry of Health, Palestinian Territory*
[b]*Faculty of Medicine, Department of Physiology, The Islamic University of Gaza, Palestinian Territory*

Received 30 October 2007; received in revised form 8 January 2008; accepted 22 February 2008
Available online 9 June 2008

KEYWORDS
Total and faecal coliforms;
Water distribution system;
Human health;
Gaza Strip

Summary *Objective:* To assess total and faecal coliform contamination in water wells and distribution networks over the past 7 years, and their association with human health in Khan Yunis Governorate, Gaza Strip.
Study design: Historical data and interview questionnaire.
Methods: Data were obtained from the Palestinian Ministry of Health on total and faecal coliform contamination in water wells and distribution networks, and on the incidence of water-related diseases in Khan Yunis Governorate. An interview questionnaire was conducted with 210 residents of Khan Yunis Governorate.
Results: Total and faecal coliform contamination exceeded the World Health Organization's limit for water wells and networks. However, the contamination percentages were higher in networks than in wells. Diarrhoeal diseases were strongly correlated with faecal coliform contamination in water networks ($r = 0.98$). This is consistent with the finding that diarrhoeal diseases were the most common self-reported diseases among the interviewees. Such diseases were more prevalent among subjects who drank municipal water than subjects who drank desalinated or home-filtered water (odds ratio = 2.03). Intermittent water supply, insufficient chlorination and sewage flooding seem to be associated with self-reported diseases. Residents in the Gaza Strip have a good level of knowledge about drinking water contamination, and this is reflected in good practice.
Conclusions: Water quality has deteriorated in the Gaza Strip, and this may contribute to the prevalence of water-related diseases. Self-reported diseases among

*Corresponding author.
E-mail address: myassin@mail.iugaza.edu (M.M. Yassin).

doi:10.1016/j.puhe.2008.02.009

interviewees in Khan Yunis Governorate were associated with source of drinking water, intermittent water supply, insufficient chlorination, sewage flooding and age of water networks.

Introduction

The Gaza Strip is a plain coastal strip located in an arid to semi-arid region. The annual average rainfall varies from approximately 400 mm in the north to 200 mm in the south. Most of the rainfall occurs between October and March, with the rest of the year being dry. The total surface area of the Gaza Strip is 360 km^2, where approximately 1.5 million Palestinian people live and work.[1] Groundwater is the only source of drinking water for almost all of the population in the Gaza Strip. However, the quantity and quality of drinking water have deteriorated over the past two decades. The aquifer is continuously overexploited to meet the demand of the rapidly growing population.[2] The drinking water distribution system is relatively old and requires frequent maintenance. Interruption of the water supply and use of roof tanks are common in the Gaza Strip, and the sewage system is improbably designed.[3]

Although the microbiological quality of drinking water has deteriorated in the Gaza Strip, few studies have discussed the problem. Total and faecal coliform contamination of tap water and roof tanks were detected in Deir El-Balah, Gaza Strip, where disinfection processes were not fully implemented.[4] Various concentrations of total and faecal coliforms have also been found in water samples from 20 groundwater wells located in the surrounds of the wastewater treatment facility of Beit Lahia, Gaza Strip.[5] Recent work revealed that total and faecal coliform contamination exceeded the World Health Organization's (WHO) limits for water wells and networks in Gaza Governorate, Gaza Strip. However, the contamination percentages were higher in networks than in wells.[6] Bacterial contamination of water wells and networks has been reported in developed and developing countries.[7–9]

Detection of bacterial indicators in drinking water indicates the presence of pathogenic organisms that are likely to be the source of waterborne diseases. Such diseases could be fatal.[10,11] Epidemic giardiasis associated with contaminated drinking water has been reported in various countries.[12–15] Outbreaks of bacterial and viral diseases have also been recorded.[16,17] Intestinal parasites and diarrhoea are prevalent in the Gaza Strip.[18,19]

This work was conducted in Khan Yunis Governorate, one of the five governorates of the Gaza Strip. The aim was to assess microbial contamination of the drinking water distribution system and its impact on human health over the past 7 years (2000–2006). The objectives of this study were: (1) to evaluate total and faecal coliform contamination levels in water wells and distribution networks in Khan Yunis Governorate between 2000 and 2006; (2) to examine the possibility of finding an association between faecal coliform contamination and water-related diseases; and (3) to study the water situation and its relationship with human health in Khan Yunis Governorate.

Study area

The Gaza Strip is divided geographically into five governorates: Northern; Gaza; Mid Zone; Khan Yunis; and Rafah. Khan Yunis Governorate is the largest in the Gaza Strip with a total area of approximately 112 km^2, and an estimated population of 280,000.[20] It comprises Khan Yunis city and its camp, and five villages. Around 85% of the total population are connected to the water distribution system. The efficiency of the water distribution system is approximately 70%, and the water supply is available from 8 to 14 h/day.[21] A sewage network has been established in Khan Yunis Governorate recently. However, this only serves 25% of the population and it is not yet operational, so many people are still using cesspools.[22] This contributes to groundwater pollution due to sewage sludge leaching. Nitrate levels in the range of 50–460 mg/l have been recorded in the water wells of Khan Yunis Governorate.[23]

Methods

Data collection

Data on total and faecal coliform contamination in water wells and distribution networks in Khan

Yunis Governorate over the past 7 years were obtained from the records of the Water Control Department, Palestinian Ministry of Health. According to the records, water samples were collected each year (2000–2006) from 27 drinking water wells distributed in Khan Yunis Governorate. For networks, samples were collected at random from representative points serving water to consumers (households, schools, hospitals and clinics). Total and faecal coliform analyses were undertaken in the laboratory of the Palestinian Ministry of Health using the procedures described by the American Public Health Association.[24] The bacteriological media used were prepared according to Difco.[25] Data on the incidence of water-related diseases in Khan Yunis Governorate, including amebiasis, giardiasis, ascariasis, diarrhoea, hepatitis A, typhoid fever, salmenollosis and shigellosis, from 2000 to 2006 were obtained from the Department of Epidemiology, Ministry of Health.

Interview questionnaires

The target population was the residents of Khan Yunis Governorate. It is estimated that 85% of residences are connected to the municipal water networks in Khan Yunis Governorate (personal communication with Khan Yunis Municipality). The sample size was determined in order to achieve 95% confidence limits of 5% maximum error of the estimate, when the prevalence is 85%.[26] This led to a required sample size of 196 residents. To allow for non-response, the sample size was increased to 210 residents. The questionnaire was validated by six specialists in the fields of water quality, microbiology, environment and public health. Questionnaires were completed by one of the authors (who had a Masters degree in water resources management) during a face-to-face interview. Most of the questions were one of two types: yes/no questions, which offer a dichotomous choice; and multiple choice questions, which offer several fixed alternatives.[27] A questionnaire was piloted among 12 residents from the study area who were not included in the sample, and was modified as necessary to improve reliability. The questionnaire included questions relating to the following: (1) personal profile of the study population, such as age, occupation and level of education; (2) various aspects of domestic water supply for the people who live in the study area, such as source of drinking water, age of water network in the area, interruption of water supply and taste of chlorine in water; (3) the use of roof water tanks and information about them (i.e. types of tanks used and their cleaning); (4) the sewage collection system in the area and seasons when sewage flooding occurs; (5) occurrence of water-related diseases and treatment; and (6) knowledge about drinking water contamination in Khan Yunis Governorate.

Data analysis

Data were analysed using Microsoft Excel to calculate the bacterial contamination percentage by total and faecal coliforms for water wells and networks in Khan Yunis Governorate. The incidence rates (log rate regression/1000 population) of giardiasis, hepatitis A, ascariasis, amebiasis and diarrhoeal diseases were plotted against faecal coliform contamination percentage in water networks for 2000–2006 in Khan Yunis Governorate. In addition, correlations (r value) between incidence rates of such diseases and contamination percentages of water networks by faecal coliforms were calculated. Statistical Package for the Social Sciences[28] and EPI-INFO software were also used.[29] Simple distribution of the study variables, cross tabulation and odds ratio (OR) were also applied.[30,31]

Results

Total and faecal coliform contamination in water wells and networks: 2000–2006

Table 1 shows that the percentages of total coliform contamination fluctuated from 0% to 22% in wells and from 8% to 25% in networks during the 7 years under study. Faecal coliform contamination ranged from 0% to 7% in wells, and from 0% to 12% in networks. In general, total and faecal coliform contamination levels were higher in networks than in wells, and these levels exceeded the WHO standards ($\leq$5% for total coliforms and 0% for faecal coliforms) in most cases.

Faecal coliform contamination and water-related diseases

The incidence rates of various water-related diseases in Khan Yunis Governorate for 2000–2006, obtained from the records of the Epidemiology Department, Palestinian Ministry of Health, are listed in Table 2. The percentage contamination in water networks was used as an indicator for water contamination by pathogens causing such diseases.[32] The regression rate of diarrhoeal diseases and hepatitis A was increased with faecal coliform

Table 1 Contamination percentages of total and faecal coliforms in water wells and networks in Khan Yunis Governorate from 2000 to 2006.

Parameter	Source	Year																			
		2000			2001			2002			2003			2004			2005			2006		
		n	CS	C(%)	*n*	CS	C(%)	*n*	CS	C(%)	*n*	CS	C(%)	*n*	CS	C(%)	*n*	CS	C(%)	*n*	CS	C(%)
Total coliform	Wells	53	4	8	30	3	10	0	0	0*	27	0	0**	18	4	22	61	7	11	76	7	9
	Networks	1133	157	14	543	72	13	168	30	18	339	71	21	179	45	25	270	29	11	426	34	8
Faecal coliform	Wells	53	2	4	30	2	7	0	0	0*	27	0	0**	5	0	0**	61	0	0**	76	4	5
	Networks	1133	72	6	464	33	7	153	18	12	329	41	12	189	0	0**	243	9	4	426	23	5

n, number of collected samples; CS, contaminated samples; C(%), contamination percentage.
0*, no samples were collected; 0**, no contaminated samples were detected.

contamination, compared with a decrease in amebiasis, giardiasis and ascariasis from 2000 to 2006 (Fig. 1). Diarrhoeal diseases were found to be strongly correlated with faecal coliform contamination in water networks ($r = 0.98$) in Khan Yunis Governorate in 2000–2006 (Table 3). For amebiasis and giardiasis, the correlation values were 0.41 and 0.40, respectively. However, weak correlations were shown for ascariasis and hepatitis A during the same period of study ($r = 0.18$ and 0.05, respectively).

Interview questionnaire

The mean age of participants in the study sample was 32.3 ± 1.0 years. Most of the interviewees ($n = 146$, 69.2%) had a university degree. In total, 126 (60.0%) subjects had more than five children and 64 (30.5%) were unemployed.

Table 4 summarizes the responses of the interviewees on various aspects of the domestic water supply. Only 29 (13.8%) subjects said that they drank municipal water. However, 118 (56.2%) claimed that they drank desalinated water, and 63 (30.0%) drank home-filtered water. Regarding the age of the water networks in the area, 69 (32.9%) subjects reported that the water networks had been established over 5 years ago, 38 (18.1%) said that they were 4–5 years old, 32 (15.2%) said that they were 2–3 years old, and 17 (8.1%) said that the water networks had been established for 1 year. Most subjects ($n = 200$, 95.2%) reported interruption of the water supply; 105 (52.5%) reported interruptions of 2–3 days, 48 (24.0%) reported interruptions of more than 3 days, and 47 (23.5%) reported interruptions of 1 day. More than half of the subjects ($n = 155$; 73.8%) said that they could taste chlorine in drinking water.

Almost all subjects ($n = 209$, 99.5%) reported the use of roof water tanks in their homes; 208 (99.5%) used black plastic tanks and only one (0.5%) used a white tank (Table 5). Although 128 subjects (61.2%) had seen suspensions, algae and settlements in their tanks, only 71 (34.0%) subjects had cleaned the tanks. In addition, 199 (95.2%) interviewees claimed that they closed their water tanks properly.

As mentioned earlier, a sewage network has been established in Khan Yunis Governorate recently. However, it only serves 25% of the population, and is not yet operational. As such, the majority of subjects ($n = 189$, 90.0%) reported that they disposed of wastewater in cesspools and nine (4.3%) drained wastewater in an open area (Table 6). More than half of the interviewees ($n = 121$, 57.6%) reported sewage flooding, and

Table 2 Incidence of various water-related diseases in Khan Yunis Governorate as obtained from records of the Department of Epidemiology, Ministry of Health for 2000–2006.

Year	Hepatitis A	Salmonellosis	Shigillosis	Typhoid fever	Diarrhoea	Ascariasis	Amebiasis	Giardiasis
2000	368	49	1	54	951	484	1432	998
2001	187	1	1	142	2455	599	2217	1615
2002	272	0	5	106	2764	384	2185	1234
2003	283	19	0	177	3520	212	1308	688
2004	129	0	0	635	2882	280	1257	638
2005	481	6	0	974	4239	176	1884	683
2006	607	9	0	577	5430	47	1146	534

most ($n = 81$, 66.9%) said that flooding occurred in both the winter and summer seasons.

Self-reported diseases were claimed by 132 (62.9%) of the interviewees; 68 (51.5%), 49 (37.1%), nine (6.8%) and six (4.5%) reported diarrhoeal diseases and vomiting, diarrhoeal diseases, vomiting and hepatitis A, respectively (Table 7). Most of the interviewees ($n = 120$, 90.9%) said that they had received treatment; 64 (53.3%) had received treatment at the hospital and governmental clinics, 46 (38.3%) had been treated at home and only 10 (8.3%) had visited special clinics for treatment.

Table 8 shows subjects' awareness about contamination of drinking water. The majority of interviewees ($n = 196$, 93.3%) believed that drinking water transmitted diseases. Also, 151 (71.9%) subjects believed that this was true for roof tanks. When asked 'Do you think that water in Gaza Strip is suitable for drinking?', only 22 (10.5%) subjects agreed. Fifty-eight (27.6%) subjects had taken part in educational programmes about the effect of polluted water on health. Only 17 (8.1%) subjects mentioned that somebody had visited them to explain the local water situation.

The relationships between incidence of self-reported diseases and various aspects of drinking water and sewage in Khan Yunis Governorate are summarized in Table 9. The number of interviewees who drank municipal water and desalinated/home-filtered water were 29 (13.8%) and 181 (86.2%), respectively. Twenty-two of 29 (75.9%) subjects who drank municipal water had self-reported diseases, compared with 110 of 181 (60.8%) subjects who drank desalinated or home-filtered water (OR = 2.03). The highest incidence of self-reported diseases ($n = 28$, 73.7%) was found among subjects who reported that the municipal water networks were 4–5 years old (OR = 1.96). For interruption of the water supply, the highest incidence ($n = 82$, 78.1%) of self-reported diseases was found among subjects who reported interruptions of 2–3 days (OR = 4.61). Self-reported diseases were more common among subjects who

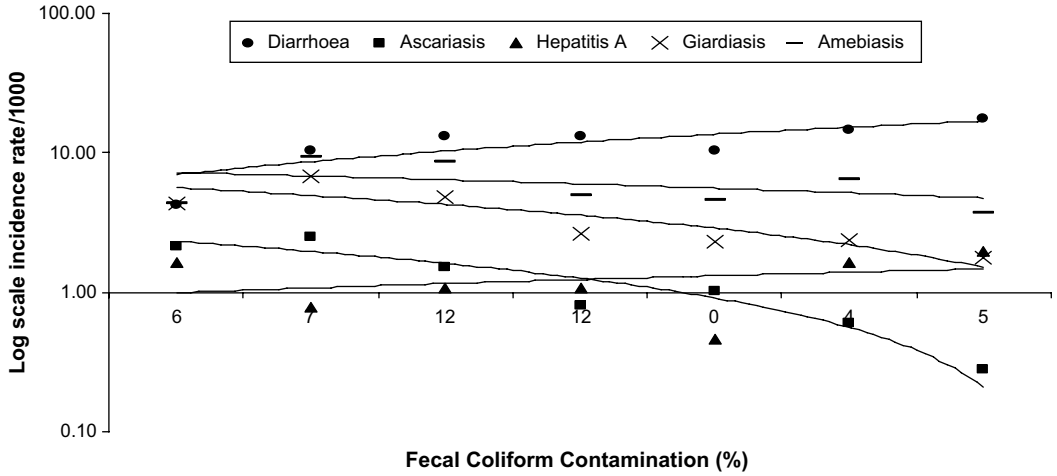

Figure 1 Incidence rates (log rate regression/1000 population) of giardiasis, hepatitis A, ascariasis, amebiasis and diarrhoeal diseases and faecal coliform contamination percentages in water networks from 2000 to 2006 in Khan Yunis Governorate.

Table 3 Correlation of water-related diseases with faecal coliform contamination in water networks of Khan Yunis Governorate for 2000–2006.

Diseases	*r*-value
Amoebiasis	0.41
Giardiasis	0.40
Ascariasis	0.18
Diarrhoeal diseases	0.98
Hepatitis A	0.05

claimed not to taste chlorine in water ($n = 43$, 78.2) compared with subjects who did (OR = 2.66). Eighty-seven (71.9%) subjects self-reported disease incidence by sewage flooding (OR = 2.45).

Discussion

In addition to the questionnaire interviews, this work presents data obtained from the drinking water monitoring system applied by the Palestinian Ministry of Health for the past 7 years in Khan Yunis Governorate, Gaza Strip. Coliform organisms, used in this study as indicators for water contamination, are the most commonly used indicators for monitoring water quality.[32,33]

In general, the total coliform levels in water wells and networks in Khan Yunis Governorate for 2000–2006 were higher than the WHO limit (≤5%).

Table 4 Responses of study population ($n = 210$) on various aspects of domestic water supply in Khan Yunis Governorate.

Variable	Frequency	%
Source of drinking water		
Municipal water	29	13.8
Desalinated water	118	56.2
Home-filtered water	63	30.0
Age of water networks (years)		
0–1	17	8.1
2–3	32	15.2
4–5	38	18.1
>5	69	32.9
Don't know	54	25.7
Interruption of water supply	200	95.2
Interruption interval (days)		
1	47	23.5
2–3	105	52.5
>3	48	24.0
Taste of chlorine	155	73.8

Table 5 Use of roof water tanks and their status as reported by the study population ($n = 210$) in Khan Yunis Governorate.

Variable	Frequency	%
Use of roof tanks	209	99.5
Types of tank		
Black plastic	208	99.5
White plastic	1	0.5
Cleaning of water tanks	71	34.0
Suspension, algae and settlements observed	128	61.2
Closed water tanks	199	95.2

The contamination levels for faecal coliforms, were also higher than the WHO standard (0%), except in 2003–2005 for wells and 2004 for networks.[32] However, coliform contamination was generally higher in networks than in wells throughout the study period. The percentage contamination is likely to be representative because the number of collected samples was dependent on the population size, the quantity of water supplied and the frequent monitoring of the water source over a definite period. Accordingly, the percentage increase in contamination will increase the risk to human health. It is worth mentioning that no samples were collected from wells in 2002 due to military activities of the Israeli army in the area. Heavily contaminated water networks and groundwater wells have been registered for total and faecal coliforms, particularly in developing countries.[34,35]

Coliform problems in Khan Yunis Governorate may be attributed to several causes:

(1) Sewage infiltration through widely used cesspools and winter and summer flooding. Cesspools and sewage flooding contributed largely to drinking water contamination.[6,36,37]

Table 6 Sewage system in Khan Yunis Governorate as reported by the study population ($n = 210$).

Variable	Frequency	%
Connected to sewage networks	0	0
Cesspools	189	90
Open area	9	4.3
Don't know	12	5.7
Sewage floods	121	57.6
Summer	6	5.0
Winter	34	28.1
Winter and summer	81	66.9

Table 7 Self-reported diseases and treatment as claimed by the study population ($n = 210$) in Khan Yunis Governorate.

Variable	Frequency	%
Reported disease	132	62.9
Type		
Diarrhoeal diseases	49	37.1
Vomiting	9	6.8
Diarrhoeal diseases and vomiting	68	51.5
Hepatitis A	6	4.5
Treatment	120	90.9
Location of treatment		
Home	46	38.3
Hospital and governmental clinic	64	53.3
Special clinic	10	8.3

(2) Interruption of the water supply that may cause inverse pumping of wastewater or other contaminants from the surrounding system. This may be due to breakages in the distribution system, thus promoting bacterial biofilm growth. Biofilms have been reported to develop in water distribution systems.[38,39] The interruption interval of water supply can exceed 3 days in Khan Yunis Governorate. Water shortages and increased water demand by a fast-growing population in the Gaza Strip has forced the Palestinian Water Authority to interrupt the supply.

(3) Age and improper maintenance of the distribution system despite the relatively adequate disinfection. The water networks are >5 years old in many areas. The authors did not test the level of chlorine in drinking water, but approximately two-thirds of the interviewees reported that they could taste chlorine in drinking water. It was concluded that the chlorination process was not fully implemented in the Gaza Strip.[4]

Roof tanks for water storage, especially black plastic tanks, are commonly used in the Gaza Strip including Khan Yunis Governorate. Such practice is attributed to frequent water interruption and increased water demand, particularly in the summer. Almost two-thirds of the interviewees reported that they did not clean their tanks, which may increase the risk of water contamination and infection with water-related diseases. It has been shown that intestinal parasites and diarrhoea were strongly associated with cleaning of water tanks in the Gaza Strip.[19]

An increase in the regression rate and a strong correlation between diarrhoeal diseases and faecal coliform contamination in water networks means that diarrhoeal diseases are still prevalent and may even have increased in Khan Yunis Governorate. Diarrhoeal diseases were the most common self-reported diseases among the interviewees. A similar result was reported in Nuseirat refugee camp in the Mid Zone Governorate, Gaza Strip.[19] The relatively weak correlation found for amoebiasis, giardiasis and ascariasis implies involvement of other sources for such diseases, as well as drinking water contamination. Although most of the study sample reported treatment in hospitals, governmental clinics and special clinics, diarrhoea is still one of the leading causes of morbidity among the population in the Gaza Strip.[40]

Residents in the Gaza Strip seem to be aware of the poor quality of water, which is reflected by a small scale of dependency on municipal water for drinking. Most residents stated that water in the Gaza Strip is unsuitable for drinking. Home reverse osmosis filters are being used increasingly to overcome the poor quality of drinking water served to consumers in many areas of the Gaza Strip.[41]

More than two-thirds of the interviewees had not attended an educational programme about the effects of polluted water on health. Visits by health educators or somebody to explain the local water situation were rare. Despite this, most subjects reported that water in the Gaza Strip is unsuitable for drinking, and that drinking water

Table 8 Knowledge of the study population ($n = 210$) about drinking water contamination in Khan Yunis Governorate.

Question	Yes		No	
	Frequency	%	Frequency	%
Do you think that drinking water transmits diseases?	196	93.3	14	6.7
Do you think that water roof tanks transmit diseases?	151	71.9	59	28.1
Do you think that water in the Gaza Strip is suitable for drinking?	22	10.5	188	89.5
Have you attended an educational programme on the health impact of polluted water?	58	27.6	152	72.4
Has anyone visited you to explain the water situation in your area?	17	8.1	193	91.9

Table 9 Summary of the relationship between the incidence of self-reported diseases and different aspects of drinking water and sewage networks in Khan Yunis Governorate.

Variable	Frequency	Self-reported disease		OR (95% CI)*
		n	%	
Source of drinking water				
Municipal water	29	22	75.9	
Desalinated or home-filtered water	181	110	60.8	2.03 (0.77–5.54)
Age of water networks (years)				
0–1	17	10	58.8	
2–3	32	21	65.6	1.34 (0.34–5.3)
4–5	38	28	73.7	1.96 (0.5–7.75)
>5	69	35	50.7	0.72 (0.22–2.37)
Interruption of water supply (days)				
1	47	21	44.7	
2–3	105	82	78.1	4.61 (2.06–10.4)
>3	48	20	41.7	0.88 (0.36–2.16)
Taste of chlorine	155	89	57.4	0.32 (0.17–0.81)
No taste of chlorine	55	43	78.2	2.66 (1.24–5.8)
Sewage flooding	121	87	71.9	2.45 (1.32–4.54)

*Odds ratio at 95% confidence interval.

and water from roof tanks transmit diseases. This good level of knowledge is reflected in good practice as shown earlier. Their knowledge may stem from the existing water crises in the Gaza Strip; filtered water is sold in the Gaza Strip through water tank vehicles or local shops.

The finding that self-reported diseases were more common in subjects who drank municipal water may support the previously mentioned data on water contamination. Rehabilitation of municipal water pipelines over 5 years old and chlorination could minimize such self-reported diseases. Again, an intermittent water supply and sewage flooding seem to contribute to these diseases.

Conclusions

Total and faecal coliform contamination in water wells and networks generally exceeded the WHO limits in Khan Yunis Governorate. However, the level of contamination was higher in networks than in wells, and seems to occur mainly in the winter and summer seasons. A strong correlation ($r = 0.98$) was found between diarrhoeal diseases and faecal coliform contamination in drinking water networks. The questionnaire revealed that diarrhoeal diseases were the most common self-reported diseases in Khan Yunis Governorate. Such diseases were more prevalent among subjects who drank municipal water compared with subjects who drank desalinated or home-filtered water (OR = 2.3). An intermittent water supply, insufficient chlorination and sewage flooding seem to contribute largely to self-reported diseases.

Recommendations

Establishment of a proper sewage network system in Khan Yunis Governorate is a high priority. Regular maintenance of water networks is necessary to reduce breakages in pipelines. Interruption of the water supply should be minimized. Regular cleaning of water roof tanks and proper implementation of water disinfection are recommended.

Ethical approval

Helsinki Committee in the Gaza Strip, Ref. No. 64.

Funding

None declared.

Competing interests

None declared.

References

1. Palestinian Central Bureau of Statistics. *Projected mid-year population in the Palestinian territory by governorate (2001–2006)*; 2006.

2. Naciri A, Ttlich G. Policy guidelines for wastewater management in the Gaza Strip. *Potential of wastewater reuse in the Gaza Strip*; 2001. pp. 1—2.
3. Nashashibi M, van Duijl LA. Wastewater characteristics in Palestine. *Water Sci Technol* 1995;**32**:65—75.
4. El-Mahallawi KM. Assessment and improvement of drinking water quality in the Gaza Strip: case study: application of a computer model of the Deir El-Balah Network. MSc thesis. Delft; 1999.
5. Sharif FA. Impact of a wastewater treatment facility on wells waters in Beit Lahia, Gaza Strip. *Islamic Univ J* 2003;**11**:15—25.
6. Yassin M, Abu Amr S, Al-Najar H. Assessment of microbiological water quality and its relation to human health in Gaza Governorate, Gaza Strip. *Public Health* 2006;**120**:1177—87.
7. Dowidar A, Yosef YA, Merdan AI, Abdel-Monem MH, Diab AM. Bacterial contamination of water wells in wadi el-Sheikh area, in southern Sinai. *J Egypt Public Health Assoc* 1990; **65**:119—34.
8. Mroz Jr RC, Pillai SD. Bacterial populations in the groundwater on the US—Mexico border in El Paso County, Texas. *South Med J* 1994;**87**:1214—7.
9. Zacheus OM, Lehtola MJ, Korhonen LK, Martikainen PJ. Soft deposits, the key site for microbial growth in drinking water distribution networks. *Water Res* 2001;**35**:1757—65.
10. Egoz N, Shmilovitz M, Kretzer B, Lucian M, Porat V, Raz R. An outbreak of *Shigella sonnei* infection due to contamination of a municipal water supply in northern Israel. *J Infect* 1991;**22**:87—93.
11. Macler AB, Merkel CJ. Current knowledge on groundwater microbial pathogens and their control. *Hydrogeol J* 2000; **8**:29—40.
12. Sullivan PS, DuPont HL, Arafat RR, Thornton SA, Selwyn BJ, el Alamy MA, et al. Illness and reservoirs associated with *Giardia lamblia* infection in rural Egypt: the case against treatment in developing world environments of high endemicity. *Am J Epidemiol* 1988;**127**:1272—81.
13. Develoux M, Alarou A, Mouchet F. High prevalence of giardiasis in an urban population in Niger. *J Trop Med Hyg* 1990; **93**:355—6.
14. Tay J, Ruiz A, Schenone H, Robert L, Sanchez-Vega JT, Uribarren T, et al. Frequency of intestinal protozoosis in the Mexican Republic. *Bol Chil Parasitol* 1994;**49**:9—15.
15. Nimri LF. Prevalence of giardiasis among primary school children. *Child Care Health Dev* 1994;**20**:231—7.
16. Tulchinsky TH, Burla E, Halperin R, Bonn J, Ostroy P. Water quality, waterborne disease and enteric disease in Israel, 1976—92. *Isr J Med Sci* 1993;**29**:783—90.
17. Frost FJ, Craun GF, Calderon RL. Waterborne disease surveillance. *J Am Water Works Assoc* 1996;**88**:66—75.
18. Yassin MM, Shubair ME, AL-Hindi AI, Jadallah SY. Prevalence of intestinal parasites among school children in Gaza City, Gaza Strip. *J Egypt Soc Parasitol* 1999;**29**:365—73.
19. Abu Mourad TA. Palestinian refugee conditions associated with intestinal parasites and diarrhoea: Nuseirat refugee camp as a case study. *Public Health* 2004;**118**:131—42.
20. Palestinian Central Bureau of Statistics. *Small area population, revised estimates 2004—2006*; 2006.
21. Palestinian Water Authority. *Water resources and management issues* (*Gaza Strip/Palestine*); 2002.
22. Yassin MM, Tubail KM, Al-Dadah JY. Towards strategies for pollution control on the use of wastewater effluent in sustainable agriculture in the Gaza Strip. *WRSTSD* 2008;**5**: 66—78.
23. Palestinian Ministry of Health, Water Control Department. *Evaluation of drinking water quality in Gaza Strip*; 2006.
24. American Public Health Association. *Standard methods for the examination of water and wastewater*. Washington, DC: APHA; 1992. pp. 55—61.
25. Difco. *Dehydrated culture media and reagents for microbiology*. Michigan: Difco Laboratories; 1985.
26. Hogg RV, Tanis EA. *Probability and statistical inference*. 5th ed. Englewood Cliffs, NJ: Prentice-Hall; 1997. pp. 326—35.
27. Backestrom C, Hursh-Cesar G. *Survey research*. 2nd ed. London: Macmillan; 1981. pp. 128—40.
28. Statistical Package for the Social Sciences (SPSS, Version 11.0). Chicago, IL; 1999.
29. *Epidemiological Program Office (EPI-INFO, Version 6.04)*. Atlanta, GA: WHO-CDC; 2001.
30. Kirkwood BR. *Essential for medical statistics*. London: Blackwell Scientific Ltd; 1988. pp. 94—105.
31. Kuzma WJ. *Basic statistics for health science*. 2nd ed. Mountain View, CA: Mayfield Publishing; 1992. pp. 171—91.
32. World Health Organization. *Guidelines for drinking water quality*. 2nd ed., vol. 2. Geneva: WHO; 1996.
33. Ashbolt N, Grabow W, Snozzi M. *Water quality: guidelines, standards and health, indicators of microbial water quality*. London: IWA Publishing; 2001.
34. Brick T, Primrose B, Chandrasekhar R, Roy S, Muliyil J, Kang G. Water contamination in urban south India: household storage practices and their implications for water safety and enteric infections. *Int J Hyg Environ Health* 2004;**207**:473—80.
35. Massone HE, Martinez DE, Cionchi JL, Bocanegra E. Suburban areas in developing countries and their relationship to groundwater pollution: a case study of Mar del plata, Argentina. *Environ Manage* 1998;**22**:245—54.
36. Rail CD. *Groundwater contamination: contamination, sources and hydrology*, vol. 1. CRC Press; 2000. p. 36.
37. Rhode Island Department of Environmental Management, Office of Water Resources, USA. *Frequently asked questions: cesspools and the Rhode Island Cesspool Act of 2007*; 2007.
38. Frias J, Ribas F, Lucena F. Effects of different nutrients on bacterial growth in a pilot distribution system. *Antonie Van Leeuwenhoek* 2001;**80**:129—38.
39. Lehtola MJ, Juhna T, Miettinen IT, Vartiainen T, Martikainen PJ. Formation of biofilms in drinking water distribution networks, a case study in two cities in Finland and Latvia. *J Ind Microbiol Biotechnol* 2004;**31**:489—94.
40. Awad R, Abu Arquob O. *The status of health in Palestine*. HMIS-MOH; 2000. p. 2001.
41. Palestinian Hydrology Group for Water and Environmental Resources Development. *Quality use of home reverse osmosis filters of some areas in Gaza Strip*; 2002.