Assessment of microbiological water quality and its relation to human health in Gaza Governorate, Gaza Strip

Maged Mohammed Yassin*, Salem S. Abu Amr, Husam M Al-Najar

Department of Biology, The Islamic University of Gaza, Jamal Abd El Naser Street, Gaza, Palestinian Territory

Received 22 August 2005; received in revised form 1 July 2006; accepted 14 July 2006
Available online 10 October 2006

Summary Objective: To assess the contamination level of total and faecal coliforms in water wells and distribution networks, and their association with human health in Gaza Governorate, Gaza Strip.

Methods: Data were obtained from the Palestinian Ministry of Health on contamination of total and faecal coliforms in water wells and distribution networks, and on the incidence of water-related diseases in Gaza Governorate. An interview questionnaire was conducted with 150 residents of Gaza.

Results: The contamination level of total and faecal coliforms exceeded that of the World Health Organization (WHO) limit for water wells and networks. However, the contamination percentages in networks were higher than that in wells. Giardiasis was strongly correlated with faecal coliform contamination in water networks ($r = 0.7$) compared with diarrhoeal diseases and hepatitis A ($r = 0.3$ and $0.1$, respectively). Diarrhoeal diseases were the highest self-reported diseases among interviewees in Gaza city. Such diseases were more prevalent among people using municipal water than people using desalinated water and water filtered at home for drinking (OR = 1.6). Intermittent water supply and sewage flooding seemed to contribute largely to self-reported diseases. People in Gaza Strip have good knowledge on drinking water contamination, and this is reflected in good practice. Conclusions: Water quality has deteriorated in Gaza Strip. This may contribute to the prevalence of water-related diseases. Self-reported diseases among interviewees in Gaza City were associated with source of drinking water, intermittent water supply, sewage flooding and age of water, and wastewater networks.

© 2006 The Royal Institute of Public Health. Published by Elsevier Ltd. All rights reserved.

*Corresponding author. Tel.: +970 8 2823311; Fax: +970 8 2863552.
E-mail address: myassin@mail.iugaza.edu (M.M. Yassin).

0033-5306/$ - see front matter © 2006 The Royal Institute of Public Health. Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.puhe.2006.07.026
Introduction

The Gaza Strip has no permanent surface water. However, Wadi Gaza transports water into the Mediterranean Sea for relatively short periods of time during the rainy season. The entire population is completely dependent on groundwater for agricultural, industrial, and domestic water supplies. The aquifer is continuously over-exploited. Interruption of water supply and use of roof tanks are common in Gaza Strip. The sewage system is incorrectly designed.

The microbiological water quality has deteriorated in the Gaza Strip. Despite this, few studies have addressed the problem. The bacteriological quality of the tap water and the roof tanks in Deir El-Balah, Gaza Strip, are not hygienically safe. Total and faecal coliforms in roof tanks are higher than their relative sources. Various levels of total and faecal coliforms have also been found in water samples from 20 groundwater wells located in the surround of the wastewater treatment pond of Beith Lahia, Gaza Strip. Bacterial contamination of water wells and networks has been reported worldwide.

Microbiological quality is the most important aspect of drinking water in relation to waterborne diseases. Detection of bacterial indicators in drinking water means the presence of pathogenic organisms that are the source of waterborne diseases. Such diseases could be fatal. Epidemic giardiasis associated with contaminated drinking water has been reported in different countries, including neighbouring ones. Outbreaks of bacterial and viral diseases have also been recorded. Intestinal parasites are prevalent in Gaza Strip.

The present study was carried out in Gaza Governorate, one of the fifth Governorates of the Gaza Strip. The aim was to assess the microbiological water quality in water wells and the network distribution system, and its relation to human health in Gaza Governorate. The objectives of this study were to answer the following research questions: (1) what is the contamination level of total and faecal coliforms in water wells and networks distribution system from the years 1999 to 2003? (2) what is the contamination level of total and faecal coliforms in water wells and network distribution system broken down each month during the year 2003? (3) is there an association between faecal coliform contamination and water-related diseases? and (4) what is the water situation and its relation to human health in Gaza Governorate?

Study area

The Gaza Strip is a part of the Palestinian coastal plain located in an arid to semi-arid region. It is bordered by Egypt from the south, the green line from the North, Nagev desert from the East and the Mediterranean Sea from the West. The total surface area of the Gaza Strip is 360 km², where about 1,443,737 Palestinian people live and work. This figure classifies the Gaza Strip as one of the most densely populated area in the world. The Gaza Strip is divided geographical into five Governorates: Northern, Gaza, Mid Zone, Khan Younis and Rafah. The annual average rainfall varies from 400 mm in the north to about 200 mm in the south of the strip. Most of the rainfall occurs in the period from October to March, the rest of the year being dry. Gaza Governorate occupies an area of 73.35 km², and its population has been estimated to be 507,448 people. It comprises Gaza City, the main city in the Gaza Strip and one of the main refugee camps, the Beach Camp. Around 95% of the total population is connected to the water distribution system. The efficiency of water distribution system ranges from 54% to 71%, and the durability of water supply ranges from 6 to 12 h a day. The Governorate is served by Gaza wastewater treatment plant, and around 95% of the total population is connected to the sewage network system. The plant is heavily overloaded and the actual flow far exceeds the design flow, resulting in frequently blocked pipes and flooded manholes.

Methods

Data collection

We obtained data on total and faecal coliform contamination for water wells and networks distribution system in Gaza Governorate from 1999 to 2003 from the records of the Palestinian Ministry of Health. Monthly records of the same indicator parameters for the year 2003 were available. According to records of the Palestinian Ministry of Health, water samples were collected for each year (1999–2003) from 27 drinking water wells distributed in Gaza Governorate. For networks, samples were collected randomly from representative points serving water to consumers (households, schools, hospitals and clinics). Total and faecal coliforms analyses were carried out in the laboratory of the Palestinian Ministry of health using the procedures described by the American Public Health Association. The bacteriological media...
used were prepared according to the Difco Manual.\textsuperscript{25} Data on the incidence of water-related diseases in Gaza Governorate, including giardiasis, ascariasis, amebiasis, diarrhoea, hepatitis A, typhoid fever, shigellosis and salmonellosis per month during 2003 were also obtained from the Department of Epidemiology, Ministry of Health.

**Interview questionnaires**

The target population was the residents of Gaza city. The estimated resident connected with municipal water networks in Gaza city is 90\% (personal communication with Gaza Municipality). The sample size was determined in order to have 95\% confidence limits of 5\% maximum error of the estimate, when the prevalence is 90\%.\textsuperscript{26} This led to the required sample size of 138 residents. To allow for a no-response expectation, the sample size was increased to 150 residents. The questionnaire was validated by eight 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 of water resources management) during a face to face interview. Most of the questions were one of two types: the yes/no question, which offers a dichotomous choice; and the multiple choice question, which offers several fixed alternatives.\textsuperscript{27} A questionnaire was piloted among 10 residents not included in the sample from the study area, and modified as necessary for improving 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, and interruption of water supply; (3) the use of roof water tanks and information about them (i.e. types of tanks used and their cleaning); (4) situation of wastewater networks system, such as connection to sewage network, age of sewage network in the area and seasons of sewage flood; (5) occurrence of water-related diseases and treatment; and (6) knowledge of the study population on drinking water contamination in Gaza city.

**Data analysis**

Data were analysed by computer using Microsoft Excel Program to calculate the bacterial contamination percentage by total and faecal coliforms for water wells and networks in Gaza Governorate. Incidence was plotted of giardiasis, hepatitis A and diarrhoeal diseases log rate regression/10,000 population by faecal coliform contamination percentage in water networks on a monthly basis during the year 2003 in Gaza Governorate. Also, correlation (r value) was calculated to illustrate the conjunction between incidence rates of such diseases and contamination percentages of water networks by faecal coliform. Two statistical packages were also used: Statistical Packages for the Social Sciences ‘SPSS’\textsuperscript{28} and Epidemiological Information ‘EPI-INFO’.\textsuperscript{29} Simple distribution of the study variables, the cross tabulation and odds ratio were also applied.\textsuperscript{30,31}

**Results**

**Contamination of total and faecal coliforms in water wells and networks from 1999 to 2003**

As indicated in Table 1, total coliform contamination percentages in wells fluctuated from 6\% to 13\% during the 5 years under study. In water networks, the values fluctuated from 12\% to 20\%. Faecal coliform contamination in wells ranged from 2\% to 8\%, whereas, in networks, it ranged from 4\% to 12\%. It is obvious that total and faecal coliform contamination levels exceeded the World Health Organization (WHO) limit (\(\leq 5\%\) for total coliform and free for faecal coliform), and these levels were generally higher in water networks than in wells.

**Contamination of total and faecal coliforms in water wells and networks each month during 2003**

Table 2 shows that the level of total coliform contamination fluctuated from 0\% to 29\% in wells and from 4\% to 22\% in networks during various months of the year 2003. Unacceptable levels (> 5\%) of contamination in wells were registered in January, April, July, August, November, and December (29\%, 15\%, 15\%, 15\%, 12\%, and 16\%, respectively). In networks, such values were registered in January, February, April, May, June, August, October, November, and December (13\%, 14\%, 11\%, 22\%, 19\%, 21\%, 14\%, 11\%, and 12\%, respectively). This implies that total coliform contamination in both wells and networks occurred mainly in winter and summer seasons. Table 3 shows that faecal coliform contamination in wells (0–10\%) was generally lower than that in networks (0–17\%). In wells, the level of contamination exceeded the WHO standard except for February,
April, May, September, and October. For networks, the WHO acceptable limit was registered only for March. As with total coliform, faecal coliform contamination in both wells and networks seems to occur mainly in winter and summer seasons.

**Contamination of faecal coliform and water-related diseases**

Incidence of various water-related diseases in Gaza Governorate obtained from the records of Palestinian Ministry of Health throughout the year 2003 is instead of are listed in Table 4. The percentage contamination in water networks was used as an indicator for water contamination by pathogens causing such diseases. The rate of regression of diarrhoeal diseases was slightly reduced with faecal coliform contamination, compared with an increase in Giardiasis (Fig. 1). For hepatitis A, the rate of regression was more or less constant along the year 2003. Giardiasis was found to be strongly correlated with faecal coliform contamination in water networks ($r = 0.7$) in Gaza Governorate during 2003. However, a weak correlation was shown for diarrhoeal diseases and hepatitis A during the same period of study ($r = 0.3$ and $0.1$, respectively).

**Interview questionnaire**

The average age of participants in the study sample was $34.4 \pm 1.0$ years. Most of the interviewees ($n = 110; 73.3\%$) had a university degree, reflecting a well-educated community. A total of 33 (22.0\%) were unemployed.

The response of the study population on various aspects of domestic water supply is summarized in Table 5. Only 17 (11.3\%) people said that they drank municipal water. However, 88 (58.7\%) claimed that they depended on desalinated water followed by 45 (30.0\%) who depended on home filters for drinking. For washing and bathing purposes, most people ($n = 148; 98.7\%$) admitted using municipal wells. A total of 51 (34.0\%) people reported that the water networks had been established over 5 years ago, 31 (20.7\%) said that they were 4–5 years old, 19 (12.7\%) said that they were 2–3 years old, and only 10 (6.6\%) stated that the water networks has been established for a year. Most people ($n = 141; 94.0\%$) reported interruption of water supply; 74 (52.5\%) reported 2–3 days' interruption, 34 (24.1\%) reported an interruption of 1 day, and 33 (23.4\%) reported interruption of more than 3 days. About half of the people ($n = 74; 49.3\%$) said that they tasted chlorine in drinking water.
As indicated in Table 6, all people 150 (100.0%) reported the use of roof water tanks as a source of water supply in their homes; 149 (99.3%) of them used black plastic tanks, whereas only one (0.7%) used a white tank. Although 91 (60.7%) saw suspensions, algae and settlements in the tanks, 52 (34.7%) people cleaned them. In addition, 142 (94.7%) interviewees claimed that they closed water tanks properly.

Most people (n = 146; 97.3%) said that their homes were connected to the sewage networks system (Table 7), whereas four (2.7%) were not connected; three (2.0%) disposed wastewater in cesspools and one (0.7%) drained wastewater in an open area. A total of 59 (39.3%) people reported that the sewage network had been established over 5 years ago, 28 (18.7%) estimated between 4 and 5 years ago, 14 (9.3%) said that the sewage network was constructed 1 year ago, and 11 (7.3%) stated 2–3 years. More than half of the interviewees (n = 85; 56.7%) reported flooding of sewage, and most (n = 58; 68.2%) said that flood occurred in winter and summer seasons.

As shown in Table 8, self-reported diseases were claimed by 92 (61.3%) of the interviewees; 45
(48.9%), 36 (39.1%), six (6.5%) and five (5.5%) reported diarrhoeal diseases and vomiting, diarrhoeal diseases, vomiting and hepatitis A, respectively. Most people (n = 83; 90.2%) said that they received treatment; 46 (55.4%) received treatment at the hospital and governmental clinics, 31 (37.4%) were treated at home and only six (7.2%) visited special clinics for treatment.

Table 9 presents data on peoples’ knowledge on drinking water contamination. Most people (n = 139; 92.7%) believed that drinking water transmitted diseases. Also, 109 (72.7%) people believed that this was true for roof tanks. When asked ‘Do you think that water in Gaza Strip is suitable for drinking?’ only 15 (10.0%) agreed. Forty-three (28.7%) people participated in educational programmes on the effect of polluted water on health. Only 10 (6.7%) people mentioned that somebody visited them to explain the water situation in their areas.

The relation between incidence of self-reported diseases and various aspects of drinking water and sewage networks in Gaza city is summarized in Table 10. The number of interviewees who depended on municipal water and on desalinated and home filtered water for drinking were 17 (11.3%) and 133 (88.7%), respectively. Out of 17 people who used to drink municipal water, 12 (70.6%) had self-reported diseases, whereas 80 (60.2%) out of those who use to drink desalinated and home filtered water had such self-reported diseases (OR = 1.6). The highest percentage of incidence of self-reported diseases (n = 24; 77.4%) was found among people who claimed that the age of municipal water networks was 4–5 years (OR = 3.43). For sewage networks, the highest incidence 37 (62.7%)
was found among people who claimed that the age of sewage networks was over 5 years (OR = 1.26).
Self-reported diseases among people who reported the interruption of water supply for 2–3 days (n = 57; 77.0%) was the highest (OR = 3.35). Fifty-nine (69.4%) of the interviewees self-reported disease incidence by sewage flood (OR = 2.2).

**Discussion**

Data collected in this study were based on historical data obtained from drinking water monitoring system applied by the Ministry of Health and questionnaire interview held in Gaza city. Coliform organisms, used in this study as indicators for water contamination, are the most commonly used indicators for monitoring water quality.\textsuperscript{32,33}

Bacteriological analysis of drinking water in Gaza Governorate during the period 1999–2003 revealed higher levels of total and faecal coliforms in water wells and networks than that of the WHO limit (<5% for total coliform and free for faecal coliform).\textsuperscript{32} However, coliform contamination in water networks was higher than that in wells throughout the study period. The percentage contamination will 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 in a definite period. Accordingly, percentage increase in contamination will increase the risk on human
The major factors contributing to the coliform problem in Gaza Strip in general, and in Gaza Governorate in particular, may include: (1) sewage infiltration through incorrectly designed sewage systems or through cesspools and wastewater treatment facilities in Gaza Strip;\(^{23,36,37}\) (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. Biofilms were reported to develop in water distribution systems.\(^ {38,39}\) The interruption interval of water supply may exceed 3 days in Gaza Governorate as shown from the questionnaire interview; (3) improper maintenance of the distribution system and inadequate or interrupted disinfection. The efficiency of water distribution system in Gaza Governorate ranges from 54\% to 71\%.\(^ {22}\) We did not test the level of chlorine in drinking water, but, from the questionnaire interview, almost half of the interviewees in Gaza city reported that they did not taste chlorine in the drinking water. It was concluded that disinfection was inefficient, and the chlorination processes was not well implemented in most of the cases in Gaza Strip.\(^4\) In addition to factors 2 and 3, cross-contamination of pipeline systems may contribute to higher levels of total and faecal coliforms, particularly in developing countries.\(^ {34,35}\)

### Table 9  Knowledge of the study population (n = 150) on drinking water contamination in Gaza city

<table>
<thead>
<tr>
<th>Question</th>
<th>Frequency</th>
<th>%</th>
<th>No</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you think that drinking water transmit diseases?</td>
<td>139</td>
<td>92.7</td>
<td>11</td>
<td>7.3</td>
<td></td>
</tr>
<tr>
<td>Do you think that water roof tanks transmit diseases?</td>
<td>109</td>
<td>72.7</td>
<td>41</td>
<td>27.3</td>
<td></td>
</tr>
<tr>
<td>Do you think that water in Gaza Strip is suitable for drinking?</td>
<td>15</td>
<td>10.0</td>
<td>135</td>
<td>90.0</td>
<td></td>
</tr>
<tr>
<td>Have you been attend educational programmes on the health impact of polluted water?</td>
<td>43</td>
<td>28.7</td>
<td>107</td>
<td>71.3</td>
<td></td>
</tr>
<tr>
<td>Does any body visit you to explain water situation in your area?</td>
<td>10</td>
<td>6.7</td>
<td>140</td>
<td>93.3</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Odds ratio at 95\% confidence interval

### Table 10  Summary of the relationship between the incidence of self-reported diseases and different aspects of drinking water and sewage networks in Gaza city

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency</th>
<th>Self-reported disease</th>
<th>OR (95% CI)(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source of drinking water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Municipal water</td>
<td>17</td>
<td>12</td>
<td>70.6</td>
</tr>
<tr>
<td>Filters and desalination</td>
<td>133</td>
<td>80</td>
<td>60.2</td>
</tr>
<tr>
<td>Age of water networks (year)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–1</td>
<td>10</td>
<td>5</td>
<td>50.0</td>
</tr>
<tr>
<td>2–3</td>
<td>19</td>
<td>13</td>
<td>68.4</td>
</tr>
<tr>
<td>4–5</td>
<td>31</td>
<td>24</td>
<td>77.4</td>
</tr>
<tr>
<td>&gt;5</td>
<td>31</td>
<td>24</td>
<td>47.1</td>
</tr>
<tr>
<td>Age of sewage networks (year)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–1</td>
<td>14</td>
<td>8</td>
<td>57.1</td>
</tr>
<tr>
<td>2–3</td>
<td>11</td>
<td>5</td>
<td>45.5</td>
</tr>
<tr>
<td>4–5</td>
<td>28</td>
<td>16</td>
<td>57.1</td>
</tr>
<tr>
<td>&gt;5</td>
<td>59</td>
<td>37</td>
<td>62.7</td>
</tr>
<tr>
<td>Interruption of water supply (day)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>34</td>
<td>17</td>
<td>50.0</td>
</tr>
<tr>
<td>2–3</td>
<td>74</td>
<td>57</td>
<td>77.0</td>
</tr>
<tr>
<td>&gt;3</td>
<td>33</td>
<td>14</td>
<td>42.4</td>
</tr>
<tr>
<td>Sewage flood</td>
<td>85</td>
<td>59</td>
<td>69.4</td>
</tr>
</tbody>
</table>

\(^a\)Odds ratio at 95\% confidence interval

The interruption interval of water supply may exceed 3 days in Gaza Governorate as shown from the questionnaire interview; (3) improper maintenance of the distribution system and inadequate or interrupted disinfection. The efficiency of water distribution system in Gaza Governorate ranges from 54\% to 71\%.\(^ {22}\) We did not test the level of chlorine in drinking water, but, from the questionnaire interview, almost half of the interviewees in Gaza city reported that they did not taste chlorine in the drinking water. It was concluded that disinfection was inefficient, and the chlorination processes was not well implemented in most of the cases in Gaza Strip.\(^4\) In addition to factors 2 and 3, cross-contamination of pipeline systems may contribute to higher levels of total and faecal coliforms, particularly in developing countries.\(^ {34,35}\)
coliform contamination registered for water networks. It was reported that cross-contamination of pipeline systems is one of the more common ways in which drinking water supply system is contaminated by sewage.\textsuperscript{40}

Seasonal variation of total and faecal coliform contamination in wells and networks found in the year 2003 in Gaza Governorate, with the highest contamination levels in winter and summer seasons, is in accordance with that reported by others.\textsuperscript{41,42} Gaza strip lacks proper collection and drainage systems for rain water. During the winter season, rainfall caused flood, including water, wastewater, animal manure, and other contaminants with high microbial contaminant that moved to lower lands leading to groundwater contamination as well as water networks. Rainfall has been shown to increase faecal pollution.\textsuperscript{43} In the summer season when water demand increases, there is insufficient water in the pipes to supply the community in Gaza Strip, so the water distribution alternates over the areas, thus promoting total and faecal coliform contamination.

An increase in the rate of regression and a strong correlation of giardiasis with faecal coliform contamination in water networks means that giardiasis is still prevalent and even increased as a water-related disease in Gaza Governorate. Giardiasis was reported to be prevalent in Gaza Strip.\textsuperscript{19} The weak correlation found for diarrhoeal diseases and hepatitis implies involvement of other sources for such diseases, beside drinking water contamination. Whatever the cause, diarrhoea is prevalent as indicated by the records of the Ministry of Health. Diarrhoeal diseases were the most self-reported diseases among the interviewees in Gaza city. Although more than half of the study sample reported treatment in hospitals, governmental and special clinics, diarrhoea is one of the leading causes of death among the population in Gaza Strip.\textsuperscript{44}

Dependence of a small number of people on municipal water for drinking indicates that people in Gaza Strip seem to have good knowledge of water quality, which is reflected in good practice. Their good knowledge was apparent when most of them stated that water in Gaza Strip is unsuitable for drinking. It was reported that the quality of drinking water served to consumers in Gaza Strip is bad.\textsuperscript{21} In general, water and wastewater networks in Gaza Strip are old and need urgent development. This was clear when most of the interviewee reported that the age of water and wastewater networks exceeded 5 years. Drinking water supplied in the Gaza Strip is insufficient and intermittent, with interruptions of supplies sometimes lasting for several days as indicated by the interviewees. The shortage in water resources and the increased water demand by a fast-growing population in the Gaza Strip has forced the Palestinian Water Authority to interrupt the supply. With inadequate disinfection, such practice could lead to suitable conditions for biofilm bacterial regrowth, thus increasing the possibility of water contamination.

Use of roof tanks for water storage is a common practice in Gaza Strip owing to frequent water interruption and increased water demand, particularly in the summer season. Not cleaning the tanks as admitted by most of the interviewed people may give a chance for water contamination. It was shown that intestinal parasites and diarrhoea were strongly associated with cleaning of water tanks in Gaza Strip.\textsuperscript{45}

Winter and summer sewage flood reported by people may contribute to microbial contamination of water wells and networks throughout wastewater infiltration. Such finding coincides with the previously mentioned data that total and faecal coliform contamination in both wells and networks in Gaza Governorate seems to occur mainly in winter and summer seasons.

Less than one-third of the interviewees attended an educational programme on the effects of polluted water on health. They were less frequently visited by health educators or somebody to explain the water situation in their areas. Despite this, most people reported that water in Gaza Strip is unsuitable for drinking, and that drinking water and water from roof tanks transmit diseases. This good knowledge is reflected in good practice as shown earlier. Their knowledge may stem from the existing water crises in Gaza Strip; home filters are increasingly recognized and filtered water is being sold in Gaza Strip through water tank vehicles or in local shops.

The finding that self-reported diseases were higher in people who used to drink municipal water may support the previously mentioned data on water contamination. Rehabilitation of municipal water pipelines aged over 5 years may lower such self-reported diseases. Again, intermittent water supply and sewage flood seem to contribute to these diseases.

Conclusions

Total and faecal coliform contamination in both water wells and networks generally exceeded that of WHO limit in Gaza Governorate. However, the
level of contamination in networks was higher than that in wells, and it seems to occur mainly in winter and summer seasons. A strong correlation \((r = 0.7)\) was found for giardiasis with faecal coliform contamination in drinking water networks, whereas correlation with diarrhoeal diseases and hepatitis A were relatively weak \((r = 0.3 \text{ and } 0.1, \text{ respectively})\). The questionnaire revealed that diarrhoeal diseases were the most self-reported diseases claimed by the interviewees in Gaza city. Such diseases were more prevalent among people who used municipal water than people who used desalinated water and home filtered for drinking \((\text{OR} = 1.6)\). Intermittent water supply and sewage flood seem to contribute largely to self-reported diseases.

**Recommendations**

Frequent maintenance of water and wastewater networks is needed to reduce breakage of pipelines and wastewater flooding events. Interruption of water supply should be minimized. Frequent cleaning of water roof tanks and proper implementation of water disinfection are recommended.

**Acknowledgement**

Many thanks to all members of the team in the Environmental Health Directorate, Palestinian Ministry of Health for their help in data collection. Special thanks to Dr. Yehia Abed and Dr. Fayez El-Bahtity for their valuable suggestions in data analysis.

**References**


