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Microbiological Water Quality Assessment in Gaza Strip

by

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Abstract

Gaza Strip is located in a semi-arid region where deteriorating water quantity and quality are the main features. Attention has been paid on the assessment of chemical characteristics of groundwater in the Gaza Strip, while microbiological contamination is rarely investigated. Microbial quality of water was deteriorated for both water wells and networks in Gaza Strip during the period from 1999 to 2003. In addition to questionnaire interview (n=150), the current study examined the total and fecal coliforms contamination in water wells and distribution networks in Gaza Strip at monthly basis throughout the year 2003. The level of contamination was found to exceed that of WHO limit for both water wells and networks. However, the contamination percentages in networks were higher than that in wells. Giardiasis and diarrheal diseases showed positive strong correlations with fecal coliform contamination in water networks (r=0.8 and r=0.7, respectively) whereas a positive weak correlation was exhibited by hepatitis A (r=0.3). The numbers of interviewed people who mentioned to depend 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, a total of 12 (70.6%) had self reported waterborne diseases whereas 80 (60.0%) out of those who use to drink desalinated and home filtered water had such diseases (OR=1.6). The highest percentage of self reported diseases incidence 24 (77.4%) was found among persons who claimed that the age of municipal water networks is 5 years (OR=3.43). For sewage networks, the highest percentage of self reported diseases incidence 37 (62.7%) was found among persons who claimed that the age of sewage networks is more than 5 years (OR=1.29). The number of self reported infected persons 57 (77.0%) who reported the interruption of water supply for 2-3 days was the highest (OR=3.35). Self reported diseases incidence by sewage flood were found in 59 (69.4%) of questioned people in Gaza City (OR=2.2).

تقييم نوعية المياه الميكروبيولوجية في قطاع غزة

مستخلص

يعاني قطاع غزة من نقص حاد في مصادر المياه الصالحة للاستخدام الآدمـــي. أن معظـــم الدراسات الخاصة بالمياه ومصادرها اقتصرت على التلوث الكيميائي في حـــين ان التلـــوث الميكروبيولوجي وأثره على الإنسان لم يلق نفس الاهتمام علما" أن المقاييس الدوليـــة ومنهـــا منظمة الصحة العالمية اهتمت بالتلوث الميكروبيولوجي وحـــددت إعـــداد الكائنـــات الدقيقـــة (البكتيريا، الطفيليات، الفيروسات) المسموح بها في مياه الشرب.

اعتمدت هذه الدراسة على مجموعة القولونيات (TC) والقولونيات البرازية (FC) كمحـــدد لمستوى التلوث الميكروبيولوجي في كلا" من مياه الآبار والـــشبكات، إضـــافة إلـــى توزيـــع استبيان لنحو 150 شخص من الرجال والنساء بمستوى تعليمـــي مختلـــف لـــربط الإصـــابة بالأمراض المنقولة بالمياه مع وضع الشبكات، وتلوث مياه الآبار والشبكات.

أظهرت الدراسة أن التلوث الميكروبيولوجي في كلا" من مياه الآبار والشبكات يفـــوق القـــيم المسموح بها حسب معايير منظمة الصحة العالمية خلال السنوات من 1999 وحتـــى 2003. من الجدير بالذكر أن تلوث مياه الشبكات يفوق تلوث الآبار في كافة محافظات قطـــاع غـــزة وهذا يتفق مع نتائج الاستبيان والتي أظهرت أن معظم الإصابات(70.6%) في السكان الـــذين يفوق عمر شبكة المياه في مناطقهم عن 5 سنوات والـــذين يعتمـــدون علـــى ميـــاه البلديـــة (77.2%) في الشرب مقارنة مع مستخدمي مياه التحلية والفلاتر المنزلية (60.0%). تظهر الدراسة العلاقة الواضحة بين تكرار انقطاع مياه الشرب وطفح المياه العادمة مع تلوث ميـــاه الشبكات ومن ثم الإصابة بالأمراض المنقولة بالمياه (التهاب الكبـــد الوبـــائي A والجارديـــا والإسهال). كما أظهرت الدراسة علاقة واضحة بين حدوث طفح لمياه المجـــاري والإصـــابة بالأمراض المنقولة بالمياه فقد اظهرت ان معظم السكان (69.4%) الذين يحدث في منطقـــتهم طفح لمياه المجاري كانوا يعانون من أعراض الأمراض المنقولة بالميـــاه. نتـــائج التحاليـــل الإحصائية أظهرت علاقة قوية بين تلوث مياه الشبكات بمجموعة القولون البرازيـــة ومعـــدل الإصابة بالأمراض المنقولة بالمياه (التهاب الكبد الوبـــائي A ‏(r=0.3)، الجارديـــا (r=0.8)، الإسهال(r=0.7)) في قطاع غزة.

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Chapter (1)

Introduction

1.1 Background

Water and sanitation related diseases are major causes of illness and death among people in both rural and urban areas in many developing countries due to the lack for monitoring of both the resource and the convey systems. It has been estimated that as many as 80 % of all diseases in the world are associated with unsafe water (World Health Organization, WHO, 1993). Public health problems are existed in Gaza Strip due to poor wastewater collection/treatment system. Microbiological quality is the most important aspect of drinking water in relation to water borne disease. Suitable indicator bacteria of Fecal contamination are Fecal Coliform and Fecal streptococci. Fecal pollution of drinking water may introduce a variety of intestinal pathogens (bacteria, viruses and parasites). Intestinal bacteria pathogens are widely distributed throughout the world, those known to have occurred in the contaminated drinking water from the infiltration of raw waste water to the ground water. The percentage of Coliform contamination for water examined throughout 12- months period should not exceed 5% (WHO, 1996). Transmission of waterborne diseases by a water supply has been accepted. The health care specialists are currently faced with the problems related to controlling the waterborne diseases that have shown a rapid increase in the past ten years. High parasitic infection rates were recorded among children in Gaza City with *Giardia lamblia, Ascaris Lumbricoides* and *Entamoeba histolytica* are the most frequent (Yassin et al., 1999).

1.2 Statement of the problem

The main source of water in Gaza Strip is the groundwater aquifer, which has 3 components of recharge: rainwater, return flow from irrigation, the infiltration of wastewater and lateral inflow from Egypt and Israel. Overpumping and low recharges from rainwater have limited the quantity of water available and have further contributed to the degradation of the water quality (Metcalf and Eddy, 2000 and Palestinian Hydrology Group, PHG. 2002). As a consequence, seawater intrusion is clearly measured by chloride concentration as indicator (Palestinian Ministry Of Health, MOH, 2003). Unavailability of proper sewage system, highly distribution of septic tanks, old water networks, frequent interruption of water chlorinating and interruption of water supply play a major role in increasing the microbiological water contamination which led to increase health risk of human (El-mahallawi, 1999). There are limited data on microbiological water quality in Gaza Strip. However, recent report of Ministry of Health (MOH, 2003) mentioned that about 14% of samples are bacteriological contaminated by Total Coliform, 6% by Fecal Coliform and 6% by Fecal streptococcus bacteria. Monitoring and control programs of water quality need to be evaluated and developed.

1.3 Research objectives

The overall aim of the current study is to assess the microbiological water quality in both water wells and networks distribution system and its relation to human health in the Gaza strip. The research work is intended to achieve the following specific objectives:

1. Evaluation of water quality of water wells and networks distribution system of Total and Fecal Coliform contamination during 1999 to 2003 at annual basis.
2. Assessment of water quality of water wells and networks distribution system of Total and Fecal Coliform contamination at monthly basis during the year 2003.
3. Identification of the most common waterborne diseases in Gaza Strip.
4. Investigation of the relationship between Fecal Coliform contamination with waterborne diseases (Giardiasis, Hepatites A and Diarrheal diseases).
5. Evaluation of water situation and its relation to human health in Gaza Strip through questionnaire interview.

Chapter (2)

Study area

2.1 Geographical data

The Gaza Strip is a part of the Palestinian coastal plain in the south west of Palestine, where it forms long and narrow rectangle on the Mediterranean Sea. It is bordered by Egypt from the south, Negev desert from east and the green line from the north (Fig. I). The Gaza Strip occupies an area of about 365 Km^2; about 45 Km long and 5-15 Km wide. Gaza Strip is divided into five Governorates: 1) the North Governorate with Total area of about 60.98Km^2 and comprises three towns; Jabalia, Bit Hanon and Bit Lahia, 2) Gaza Governorate with Total area of 73.35 Km^2, 3) Mid Zone Governorate that presented a Total area of 56.22 Km^2 and has 5 refugees camps; Deir Elbalah, Maghazi, Burij, Nussirat and Zwaida, 4) Khanyounis Governorate with the Total area of 110 Km^2 and 6) Rafah Governorate with a Total area of 60.48 Km^2 (Khalaf, 2005).

2.2 Population

The population characteristics of the Gaza Strip are strongly influenced by political developments, which have played a significant role in the growth and population distribution of the Gaza Strip. About 1,364,733 of the Palestinian people live and work in Gaza Strip (Palestinian Central Bureau of Statistics, 2003). This figure classified the strip as one of the highest dense populated area in the world. The population is mainly concentrated in the cities, small villages and eight refugee camps that contain two thirds of population. The people of Gaza Strip are generally young, about 75% of the population is under 35 years.

2.3 Environmental situation

The environmental problems of Gaza Strip are huge. The abnormal situation is the results of the influx of a large number of the refugees and the 38 years of occupation which led to the significant degradation of the natural and human environment. Overpopulation has created adverse living conditions, influencing directly the quality of health and social well being of the population. In some situations, human and animal life is directly threatened and requires an immediate response. In others, adverse developments such as the unsuitability use of scarce resources like land, water and semi natural landscape may inhibit economic and social development of the area in the medium term. High economic cost may result if no immediate action is taken to control further degradation of the environment and reverse the negative developments.

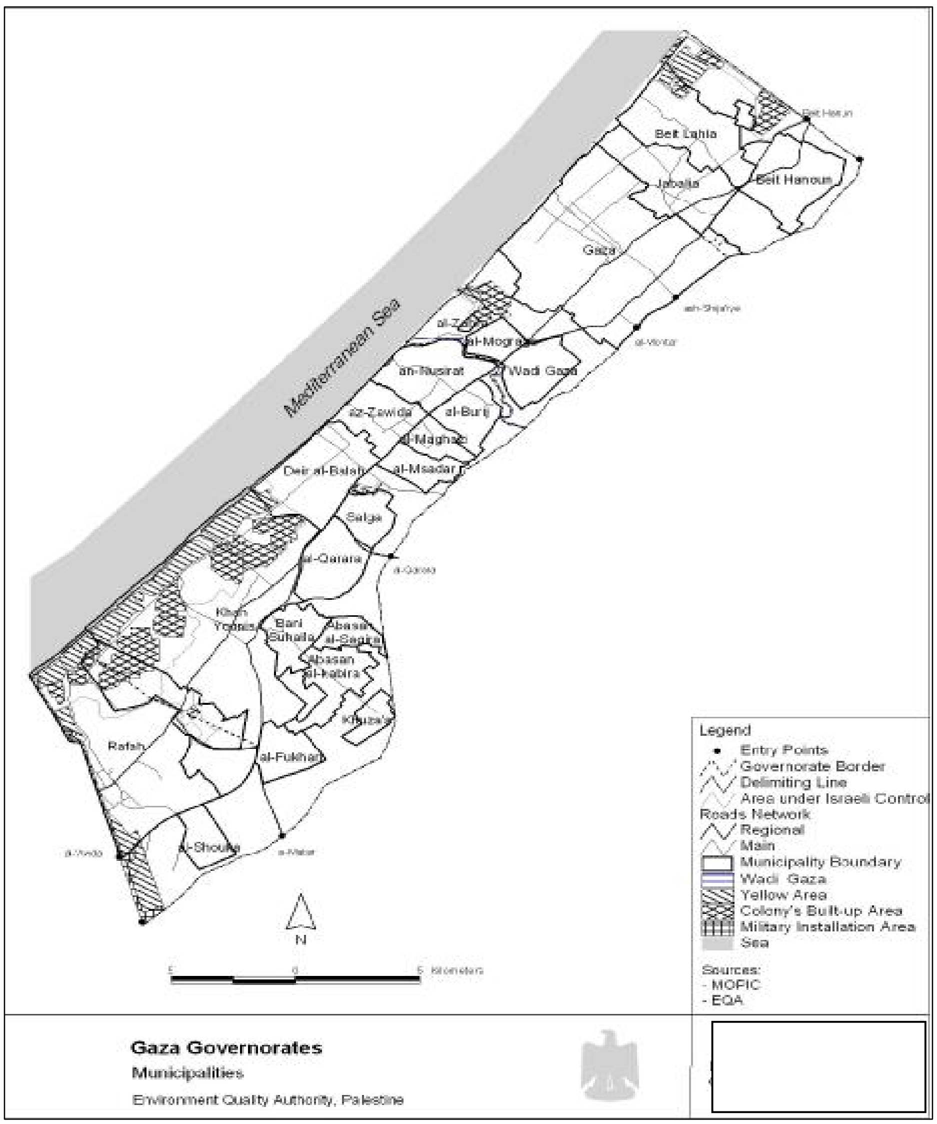

Fig. I: Location of Gaza Strip and distribution of Governorates and towns

Source: Ministry of Environmental Affairs (MENA), (1999)

2.4 Climate and rainfall

The Gaza Strip is located in the transitional zone between the arid desert climate of the Sinai Peninsula and the temperate and the semi-humid Mediterranean climate along the coast. The average daily mean temperature range from 25 ^{0}C in summer to 13 ^{0}C in winter. The average annual rainfall varies from 450 mm/year in the north to 200 mm/year in the south. Most of the rainfall occurs in the period from October to March, the rest of the year being dry (PHG, 2002).

2.5 Water recourses

There is no permanent surface water in Gaza Strip. However, the only form of the surface water is related to wadis. It has been reported that the wadis may carry substantial amounts of water for relatively short time during the rainy season. In particular, the wadi Gaza may transport a large amount of water. However, the floods may not occur every year and especially recently the floods of the Wadi Gaza have decreased as a result of the construction of dams and reservoirs on the upstream Israeli side. Groundwater is the main source of fresh water and is of primary importance to the Palestinian in the Gaza Strip (Al-Agha, 1995). Groundwater is recharged from several sources including rainwater, return from irrigation, sewage infiltration and seawater intrusion. (Palestinian Environmental Protection Authority, PEPA, 1994).

2.6 Water situation

The Total abstraction of Groundwater in Gaza Governorates is estimated to be 135 Mm^3/year (Tubail et al., 2004). Crop cultivation consumes is around two thirds of Groundwater pumped through more than 4000 wells located over all Gaza Governorates (Palestinian Water Authority, PWA, 2002). The remainder is used for industrial and domestic water supplies. The aquifer is continuously being over-exploited (Naciri and Ttlich, 2001). The gap between water demand and water supply is increasing with time as a result of rapid population growth in this small area (growth rate = 4.5%, PCBS, 2000). The water balance record reveals a deficit of about 45 Mm^3/year (Tubail et al., 2004). The quality of the Groundwater in Gaza Strip is generally poor; water quality is deteriorated due to infiltration of sewage, solid waste leaching and agricultural fertilizers. Water quality in Gaza failed to meet international guidelines. Chloride content ranges from 200 to 1000 mg/l, 77% of groundwater wells have nitrate concentrations greater than 50 mg/l, 44% greater than 100 mg/l, and 32% have Fecal Coliform (Lyonnasie, 1995). Microbiological pollution of water in the Gaza Strip is a serious problem. It may occur in water wells, distribution system and in the tanks at home (EL-Mahallawi, 1999). Many types of bacterial and viral pathogens were detected such as Fecal Coliform, *salmonella, clostridium, cholera*, hepatitis A virus and others. From time to another these pathogenic microorganisms could cause outbreaks of infectious diseases such as gastroenteritis (diarrhea) and enterocolitis (fever, diarrhea, vomiting). High parasitic infection rates were recorded among children in Gaza City with *Giardia lamblia, Ascaris Lumbricoides* and *Entamoeba histolytica* are the most frequent (Yassin et al., 1999 and Shubair et al., 2000).

2.7 Water supply and sanitary services characteristics in different Governorates of the Gaza Strip (Source PWA, 2002).

North Governorate

- 96% of the Total population is connected to water distribution system
- 78% of the population is connected to sewerage system
- The Governorate is served by wastewater treatment plant, but the continuous flooding of the existing wastewater treatment plant will increase the nitrate pollution of the ground water (NO_3 ranges from 60-230 mg/l).
- Around 10% of highly nitrate wastewater infiltrates to the ground water and 1% used for agriculture.
- The number of wells which were closed due to pollution are accounted for 6 wells
- The efficiency of water distribution system is moderate ranges from 54% to 71%.
- The durability of water supply ranges from 6-12 hrs a day

Gaza Governorate

- 98% of the Total population is connected to water distribution system
- 98% of the population is connected to sewerage system
- The Governorate is served by wastewater treatment plant, and around 15% of treated wastewater which has high level of nitrate infiltrates to the ground water and the rest discharge to the sea.
- The number of wells which were closed due to high level of pollution accounted for 2 wells. While most of the wells are over WHO limits. In some locations Cl concentration exceeds 1000 mg/l.
- The efficiency of water distribution system is 71%
- The durability of water supply ranges from 6-12 hrs a day.

Deir Al Balah Governorate

- 85% of the Total population is connected to water distribution system
- 75% of the population is connected to sewerage system
- Wastewater discharge to Wadi Gaza and create high pollution in the groundwater.
- The quality of water in all the wells are above WHO limits, therefore a desalination plants with capacity of 500 m^3 a day was installed.
- The efficiency of water distribution system is 65%
- The durability of water supply ranges from 3-6 hrs a day.

Khan Yunis Governorate

- 80% of the Total population is connected to water distribution system

- The Governorate has not sewerage collection system, therefore wastewater and the sludge evacuated by trucks and dump in open area
- High ground water pollution due to sewage sludge leaching and NO_3 ranges from 50 to 500 mg/l.
- The quality of water in all the wells are above WHO limits, therefore installation of desalination plants with capacity of 1200 m^3 a day was installed.
- The efficiency of water distribution system is 70%
- The durability of water supply ranges from 8-14 hrs a day.

Rafah Governorate

- 90% of the Total population is connected to water distribution system
- 85% of the population is connected to sewerage system
- The Governorate is served by wastewater treatment plant, but the wastewater treatment plant reaches to the full capacity.
- Groundwater pollution is noticeable due to flooding of the wastewater to the sandy dunes (NO3 ranges from 100 to 350 mg/l)
- The quality of water in all the wells is above WHO limits.
- The efficiency of water distribution system is 65%
- The durability of water supply ranges from 6-12 hrs a day.

Chapter (3)

Literature review

Water is essential to humans, animals and plants. Without water, life on earth would not exist. From the beginning of human civilization, people have settled close to water source, along rivers, beside lakes or near natural springs. Drinking water should be suitable for human consumption and for all usual domestic purposes including personal hygiene.

3.1 Microbiological water quality

Microbiological water quality is the most important aspect of drinking water. The microbial quality of drinking water and its relation to human health traditionally has been assessed by determining the presence or absence of enteric microbial pathogens directly or more commonly indirectly by the use of Fecal indicator bacteria (Martine, 1984). Bacteria in water are, in general, not present individually, but located as clump or in association with particulate matter. Each clump or particle may have bacteria associated with it (Jamie and Richard, 1996).

El-Zanfaly et al., 1989 analyzed water samples from the intakes of 10 water treatment plants at Greater Cairo for Total bacterial counts, Total Coliforms, Fecal Coliform and Fecal streptococci during 1984-1986. The Total bacterial counts ranged between 10^4-10^6, 10^3-10^6, and 10^3-10^5/ml during 1984, 85, and 86 respectively. Total Coliform density ranged between 0-10^3, 10- greater than 10^4, and 10^2- greater than 10^4/100 ml during 1984, 85, and 86 respectively. Although Fecal streptococci density does not exceed 10^3/100 ml in most cases, large numbers of samples are negative for Fecal streptococci.

Gaza Strip region constitutes a characteristic case of highly polluted coastal aquifer. This situation has developed due to hydrological stress as well as poor environmental management (Goldenberg and Melloul, 1994). Lyonnasie, 1995 reported that the quality of groundwater in Gaza Strip is poor; water quality is deteriorated due to infiltration of sewage, solid waste leaching and agricultural fertilizers. Water quality in Gaza failed to meet international guidelines. Chloride content ranges from 200 to 100 mg/l, 77% of groundwater wells have nitrate concentrations greater than 50 mg/l, 44% grater than 100mg/l, and 32% have Fecal Coliform.

El-Mahallawi, 1999 concluded that the bacteriological quality of the tap water and the roof tanks in Gaza Strip is hygienically not completely save. Total and Fecal Coliform in the roof tanks were higher than their relative sources especially in the dry period when the increase of temperature may enhance the bacterial growth rate in the roof tanks. For instance, 87% of the Total Coliform and 94% of the Fecal Coliforms samples of the tap water were met the WHO standards. Moreover, in the roof tanks 79% of the Total Coliforms and 85% of the Fecal Coliforms samples were met the WHO standards. It has been reported that the principal determinants of microorganisms growth in water are temperature, availability of nutrients, and lack of residual disinfectant. Nutrients may derive from the water body and/or materials in contact with water (WHO, 2002).

A study conducted by Melad (2002) showed various levels of microbial contamination in water samples from 20 groundwater wells located in the surrounding of the water treatment pond of Beith Lahia, Gaza Strip, over four seasons (April 2000 to March 2001).

Powell et al., 2003 assessed the microbial quality of groundwater collected from depth-specific intervals over a 15-month period within the Permo-Triassic Sherwood Sandstone aquifers underlying the cities of Nottingham and Birmingham, UK. Sewage-derived bacteria (thermotolerant Coliforms, faecal streptococci and sulphite-reducing clostridia) and viruses (enteroviruses, Norwalk-like viruses, coliphage) were regularly detected to depths of 60 m in the unconfined sandstone and to a depth of 91 m in the confined sandstone. Microbial concentrations varied temporally and spatially but increased frequency of contamination with depth coincided with geological heterogeneities such as fissures and mudstone bands.

A study in Lebanon was conducted over a period of 12 months to determine the effect of storage on the microbial quality of household storage tanks (500 L), which were of two main types galvanized cast iron and black polyethylene (Tokajian et al., 2003). The mean bacterial count increased significantly after 7 days storage in both tank types.

Nyati, 2004 surveyed microbiological and chemical quality of water supplies in the Bindura urban and peri-urban area in Zimbabwe over a three-year period from January 2000 to July 2003. In this study, thermotolerant (faecal) Coliform levels, Total aerobic bacterial counts and physicochemical profiles were determined for municipal and borehole water as well as water supplies to mining and squatter communities. Although municipal and mining compound water supplies were of satisfactory microbial and chemical quality, borehole water supplies showed a seasonal fluctuation, with higher Coliform counts in the wet season from November to March. Stream water supplies to a squatter camp in the peri-urban area consistently recorded Coliform levels >1,800/100 mL and Total aerobic plate counts of <2.8 x 10^6 CFU/mL.

A study carried out by Dana et al., 2005 quarterly for three years suggested that surface water quality in North Carolina, United States of America, can be degraded by human and animal Fecal waste sources and that best management practices as well as source water protection programs are needed to minimize waterborne microbe levels and risks to public health.

3.2 Microbial contamination of groundwater

Community groundwater supplies are routinely monitored for drinking water standard compliance and are generally free of contamination. Groundwater is better protected from the risk of microbial contamination than surface water because of the soil, which acts as a barrier above it. However, contamination of groundwater with such microorganisms was addressed.

Shallow wells and wells that do not have watertight casings can be contaminated by bacteria infiltrating with floodwaters and the flooding of wastewater sewer network through the soil near the well, especially in coarse-textured soils. While contamination of large public water supplies is uncommon, bacteria at levels well above what is considered acceptable often contaminate private wells. In addition, occasional accidents can create conditions resulting in bacterial contamination (Schmilz, 1984).

Chen (1988), reported significant nutrient and Fecal Coliform contamination of Lakes shore groundwater in northeast of New York state. The fate of wastewater effluents discharged had been investigated from 17 septic tanks disposal systems located near the shores of eight lakes. The depth of groundwater from discharge point of the sewage system was the main factor in influencing the pattern and severely of groundwater contamination. Bauder et al., (1991) examined private wells in Montana and reported that the contamination with Coliform bacteria was 40%.

Morz and Pillai, 1994 has tested bacterial population in the groundwater on the US-Mexico border in El Paso Country, Texas. From 73 domestic wells were sampled using a variety of selective media to determinate the extent of bacterial contamination of the groundwater, thirteen wells were contaminated by Fecal Coliform, whereas other wells contaminated by a variety of bacterial genera including some potential pathogens that normally would not be detected by standard methods of water testing.

Lieberman et al., (1995) has examined 30 public water supply wells judged to be vulnerable to Fecal contamination. These were sampled monthly for one year. The author reported that 24% of the wells were positive for cultivable viruses, more than 50% positive for Coliphages, 50% positive for *E. coli*, and 70% positive for *Enterococci*. These results indicated that multiple samples of a source were necessary to determine the contamination.

A study conducted by Appleyared (1996) showed that chemical and microbiological contamination extends about 1000m in a southerly direction from a site near Perth, Western Australia, in the direction of groundwater flow, from a plume of a disused liquid waste disposal. The plume is up to 600m wide and 5-40m thick. Chemical and microbiological analysis indicated that contaminated groundwater contained high concentrations of ammonia, iron and bacteria at levels that exceeded natural drinking water guidelines.

Chippaux et al., 2002 conducted a study on chemical and bacteriological groundwater pollution in Niamey, Niger. A Total of 22 wells and 24 bore-holes were selected on a geological and socio-economic basis. The superficial aquifers, located on each bank of the River Niger and connected to the wells, presented high levels of oxidizable nitrogen and bacteriological pollution (Coliform and faecal Streptococcus) which make the water unfit for human consumption. The deep aquifer, which supplies pumps, was also polluted but to a lesser degree. Faecal pollution increased after the rainy season. Powell et al., 2003 pointed out that rapid penetration of microbial contaminants into sandstone aquifers, not previously reported, highlights the vulnerability of sandstone aquifers to microbial contamination.

3.3 Sources of microbial water contamination

Contamination of groundwater with pathogenic microorganisms is generally believed to be a result of migration or introduction of Fecal material, either from humans or animals, into the subsurface. Fecal contamination can reach groundwater from many concentrated pond sources such as landfills, filled septic systems, leaking sewer lines and cesspools.

Blannon and Peterson, 1974 stated that sanitary landfills, if properly designed for the burial of sludge, avoid many of the problems associated with open dumping. However, if the impermeable liner of the bottom of the landfill is penetrated, there is a concern that solid waste leachate would leak into the surrounding groundwater or emerge from the site and contaminate surface and groundwater.

Nancy et al., 1985 declared that one of the most known reasons for problems with groundwater is the biological contamination by bacteria, viruses or parasites, which can seep into the aquifer from sources such as septic tank systems, leakage from fields spread with manure. Ray, et al., 1990 also mentioned that the major source of microbial contamination of groundwater and wells is improper disposal of domestic wastewater, particularly the use of cesspools, abandoned wells, or other subsurface excavations.

Sinton et al, 1997, examined Fecal Coliform in alluvial aquifer; microorganisms were introduced into the aquifer as a result of effluent irrigation. Microorganisms were detected at 60 and 445m downstream of the center of the irrigation strips. Using field data obtained from direct injection of microorganisms into experimental wells in the aquifer, authors developed a three-dimensional dispersion model of microbial transport in the subsurface. Such models will investigate and monitor groundwater contamination by pathogenic microorganisms.

Hectar et al. (1998) searched the relationship between land use and groundwater contamination in the suburban area of Mar del Plata in Argentine. They have identified three elements that endanger the quality of groundwater. Horticultural activity, urban solid waste disposal site, and sewage disposal on land. They have sampled fifty wells in an area of 175Km^2, all samples were analyzed for major ions were observed in the surrounding of the solid waste disposal area.

El-Mahallawi, 1999 stated that there are many anthropogenic activities and agricultural practices that pose a great hazard of chemical and microbiological pollution of groundwater in the Gaza Strip. These practices and activities include the lack of or inadequate sewage disposal methods, where 65% of the population uses uncontrolled infiltration boreholes, and the rest of the population use inadequate sewerage system resulting in by flooded lagoons in the sandy dunes (base grounded area) and streets all over the year. Recently, the situation is largely improved where more than 80% of population are connected to the sewage system (PWA, 2001).

Melad, 2002 analyzed water samples from 20 groundwater wells located in the surrounding of the wastewater treatment pond of Beith Lahia, Gaza Strip, over four seasons (April 2000 to March 2001). Total Coliform was isolated from 18 wells in winter seasons, and the count ranged between (1-130 cfu/100ml), from 17 wells in summer season and the count ranged between (2-130 cfu/100ml), (2-120 cfu/100ml), from 15 wells during spring season and recorded (1-110cfu/100ml) from 13 well during autumn season. Fecal Coliform recorded values ranged between (1-120 cfu/100ml) during winter season that obtained from 12 wells, while 11 wells during summer season had a values ranged between (1-120 cfu/100ml), and 8 wells in both spring and autumn season recorded counts ranged between (1-110 cfu/100ml) and (1-90 cfu/100ml), respectively.

Celico et al., 2004 analyzed the interaction between Enterococcus faecalis and the soil of a limestone aquifer to verify the influence of this interaction on the time dependence of groundwater contamination in southern Italy. Fecal bacteria because of the interaction between rocks having high permeability often contaminate the groundwater and microbial pollutants introduced into the environment by grazing and/or manure spreading. The microbial contamination of spring water in picnic areas located in high mountains can cause gastrointestinal illness. The transport of bacterial cells through soil samples was analyzed by simulating an infiltration event that was monitored in the study area. Comparison of laboratory results with data acquired in the field showed that discontinuous precipitation caused an intermittent migration of microorganisms through the soil and produced, together with dispersion in the fractured medium (unsaturated and saturated zones), an articulated breakthrough at the spring. The short distances of bacterial transport in the study area produced a significant daily variability of bacterial contamination at the field scale.

3.4 Microbial contamination of water distribution system

One of the more common ways in which drinking water supply systems are contaminated by sewage is through cross contamination of pipeline systems. Schmitz, (1984) pointed out that sanitary sewer lines should be separated from water lines by a minimum of 10 feet. If they cross each other, they should be separated by 18 inches with the water line above the sewer line.

Distribution systems are especially vulnerable to contamination when the pressure falls, particularly in the intermittent supplies of many cities in developing countries. In the distribution system environment, many bacteria reach the pipe walls and sediments where the fine conditions suitable for survival and possible growth. Bacteria may attach to the surfaces of pipes or particles by means of glycocalyx, which is composed of complex mucopolysaccharide material. The organisms may also respond to the low nutrient condition from disinfecting. Once attached to the pipe or sediment surfaces, the organisms benefit by the presence of other organisms and their capsular and glycocalyx materials, and possible by symbiotic interactions in which metabolites released by other organisms may be used as nutrients and vice versa. Biofilms develop in all aquatic ecosystems and water distribution systems are no exception (Nagy et al., 1983 and Donlan, et al., 1987).

In a published study of persistent Coliform problem in New Jersey, Coliforms were first isolated in June 1984 and have persisted at varying levels since that time (LeChevallier, et al., 1987). The water received conventional treatment (pretreatment, flocculation, clarification, filtration, and postdisinfiction). In studying this problem, investigators concluded that the plant met the Coliform standard. However, Coliforms were found in 193 of 500 (38.6 percent) of the distribution samples collected between May and August 1986 (Environmental Protection Agency, EPA, 1990).

Microbial contamination can occur as a result of the use of unsuitable materials for items coming into contact with water. Such materials include those used for washers, jointing and packing materials, pipe and tank lining compounds and plastic used in pipes, tanks, and faucets, all of which can deteriorate to form substances that support the growth of microorganisms (WHO, 1996).

Sibille et al., 1998 quantified the microbial communities (especially bacteria and protozoa) in two distribution networks in Franc, one of GAC water (i.e., water filtered on granular activated carbon) and the other of nanofiltered water. The nanofiltered water-supplied network contained no organisms larger than bacteria, either in the water phase (on average, 5 x 10^7 bacterial cells / liter) or in the biofilm (on average, 7 x 10^6 bacterial cells /cm^2). No protozoa were detected in the whole nanofiltered water-supplied network (water plus biofilm). In contrast, the GAC water-supplied network contained bacteria (on average, 3 x 10^8 cells /liter in water and 4 x 10^7 cells /cm in biofilm) and protozoa (on average, 10^5 cells /liter in water and 10^3 cells /cm^2 in biofilm).

In deir El-balah-Gaza strip, 8% of water distribution samples was contaminated by Total Coliform but Fecal Coliform was not detected in winter season. In summer season the percentage of samples contaminated by Total Coliform was 16% and 4% by Fecal Coliform (Elmahalawi, 1999).

Zacheus et al., 2001 studied the microbiological quality of soft pipeline deposits removed from drinking water distribution networks during mechanical cleaning in Finland. Drinking water and deposit samples were collected from 16 drinking water distribution networks located at eight towns in different parts of Finland. Soft pipeline deposits were found to be the key site for microbial growth in the distribution networks. The microbial numbers in the soft deposits were significantly higher than numbers in running water. The highest microbial numbers were detected in the main deposit pushed ahead by the first swab. The deposits contained high numbers of heterotrophic bacteria, actinomycetes and fungi. Also Coliform bacteria were often isolated from deposit samples.

Tokajian et al., 2003 conducted study in Lebanon over a period of 12 months to determine bacterial regrowth in a small network supplying the Beirut suburb of Naccache that had a population of about 3,000. The residential area, which is fed by gravity, is supplied twice a week with chlorinated water from two artesian wells of a confined aquifer. A significant correlation was detected between the turbidity and the levels of heterotrophic plate count bacteria (HPC) in the samples from the distribution network as well as from the artesian wells. Faecal Coliforms were detected in the source water but none in the network except during a pipe breakage incident with confirmed Escherichia coli reaching 40 CFU/100 mL. However, Coliforms such as Citrobacter freundii, Enterobacter agglomerans, E. cloacae and E. skazakii were repeatedly isolated from the network, mainly due to inadequate chlorination.

3.5 Indicators of microbial water quality and their standards

An indicator organism provides evidence of the presence or absence of pathogenic organisms that survives under similar physical, chemical, and nutrient conditions. Although it is now possible to detected the presence of many pathogens in water, the methods of isolation and enumeration are often difficult. It is therefore impractical to monitor drinking water for every possible microbial pathogen that might occur with Fecal contamination. Most international drinking water quality guidelines and standards include bacterial indicators as a measure of microbiological water quality, and for compliance reporting. The bacterial species chosen as indicators are indigenous to the intestines of warm-blooded animals and indicate the potential presence of dangerous pathogens that can cause human illnesses.

A single indicator or even a range of indicators is unlikely to be appropriate for every occasion and therefore it is useful to tailor indicator choice to local circumstances when translating international guidelines into national standards. Additionally, with the change in management paradigm, more indicators of process efficiency are required rather than reliance on the 'old-style' Fecal indicators (Nicholas, et al., 2001).

Several qualities that are desirable for a useful water quality indicator include universally present in the feces of humans and warm-blooded animals in large numbers, readily detected by simple methods, do not grow in natural waters and persistence in water and the extent to which they are removed by water treatment are similar to those of waterborne pathogens (Dutka, 1973; WHO, 1996 and Steven et al., 2001).

Coliform organisms have been recognized, as a suitable microbial indicator of water quality, largely because these organisms are easy to detect and enumerate in water.

They are defined as the group of bacteria that are Gram negative, aerobic or facultative anaerobic, nonsporforming rods that ferment lactose with the production of gas within 48 hours at 35^0C. They include *E. coli, Citrobacter, Enterobacter and Klebsiella* species (Kabler and Clark, 1960; Standard Methods for the Examination of Water, 1985 and Ericksen, et al., 1986).

As reported by the World Health Organization (WHO, 1996), the bacteriological quality of drinking water is controlled through the presence or not of bacteria that specifically indicate the presence of Fecal pollution. For All water intended for drinking, Fecal Coliform bacteria must not be detectable in any 100-ml sample. For treated water entering the distribution system Fecal and Total Coliform bacteria must not be detectable in any 100-ml sample. In the case of large supplies, where sufficient samples are examined, Total and Fecal Coliform bacteria must not be present in 95% of samples taken throughout any 12-month period

Lemke, et al., 1997 reported that bacteria are potentially useful indicators for water quality because of their species diversity and for their rapid response for changing environmental conditions. In addition, Bezirtzoglou et al., 1997, mentioned that organisms commonly used as bacterial indicators for Fecal pollution include the Coliform group of organisms.

Byamukama et al., 2000 determined Escherichia coli, Total Coliforms, Fecal Coliforms, and sulfite-reducing anaerobic spore formers from different polluted sites in a tropical environment in order to test for their indication ability for Fecal contamination in Uganda. Quantification of *E. coli* contamination with Chromocult Coliform agar proved to be efficient and feasible for determining Fecal pollutions in the investigated area within 24 h. The other microbial parameters showed a lower ability to differentiate sites and cannot be recommended for monitoring Fecal pollution in the studied tropical surface waters.

Hadas et al. 2000, conducted an interdisciplinary biological, physical and chemical approach to determine the distribution of bacteria and river alluvium at the mouth of Jordan river. Results from the distribution of FC analysis showed that the maximum longitudinal gradient was at the bar, so FC can be used as indicator of Fecal contamination coming from the river and entering the lake. FC varied accordingly to attenuation of flow velocity. At the entrance to the bar sedimentation was found to dominate, while dilution was the process dominating beyond the bar.

The two major international bodies, the United States Environmental Protection Agency (USEPA), and the European Union (EU) both include *E. coli* as a mandatory microbial indicator, and the USEPA regulates for Total Coliforms, via the Total Coliform Rule. With few exceptions, Coliforms themselves are not considered to be a health risk, but their presence indicates that Fecal pollution may have occurred and pathogens might be present as a result (Steven et al., 2001). In addition, indicator microorganisms have been used to suggest the presence of pathogens. However, we understand a myriad of possible reasons for indicator presence and pathogen absence, or vice versa (Nicholas, et al., 2001).

Bacteriological testing provides means for the detection and control of microbial pollution. Although modern microbiological techniques have the detection of pathogenic bacteria, viruses and protozoa in sewage and sewage effluents possible, it practical to attempt to routinely isolate them from drinking water. During waterborne outbreaks, pathogens are greatly outnumbered by normal intestinal bacteria, which are easier to isolate and identify. The presence of non-pathogenic Fecal indicator bacteria indicates that pathogenic enteric. If Fecal indicator bacteria are absent, pathogenic enteric bacteria are probably also absent. (Federal-Provincial-Territorial Committee on Drinking Water, FPTCDW, 2002).

While Coliforms are not disease producers, they are often found in association with other microbes that are capable of causing disease. Coliform bacteria are more hardy than many disease-causing organisms; therefore, their absence from water is a good indication that the water is bacteriological safe for human consumption. Fecal Coliform is often used as an indicator of the Fecal contamination of domestic water supply (Drinking Water Quality Report, 2002).

As Canada guidelines of microbial drinking water quality (FPTCDW, 2003): not more than 10% of samples from the distribution system in a given calendar month should show the presence of Total Coliform bacteria for public drinking water system. For semipublic and private drinking water supply system, no sample should contain Total Coliform bacteria. In non-disinfected well water, the presence of Total Coliform bacteria in the absence of *E. coli* indicates the well is prone to surface water infiltration and therefore at risk of Fecal contamination. In disinfected water systems, the presence of Total Coliform bacteria indicates a failure in the disinfecting process. In both disinfected and non-disinfected systems, Total Coliform detection may also indicate the presence of biofilm in the well or plumbing system. The degree of response to the presence of Total Coliform bacteria, in the absence of *E. coli*, may be site specific and can vary between jurisdictions.

The control of Fecal contamination in drinking water systems and sources where it occurs is of primary importance. Fecal-specific indicator bacteria are the parameters of first importance in monitoring Fecal pollution (WHO, 2004).

3.6 Health aspects of microbial water contamination

Infectious diseases caused by human and animal pathogens are the most common and widespread health risk associated with drinking water. Infectious diseases are transmitted primarily through human and animal excreta, particularly feces. If there are active cases or carriers in the community, then Fecal contamination of water sources will result in the causative organisms being present in the water. The use of such water for drinking or for preparing food, contact during washing or bathing and even inhalation of water vapor or aerosols may then result in new cases of infection and outbreaks of waterborne diseases. The pathogenic agents include bacteria; viruses and protozoa, which may cause diseases that vary in severity from mild gastroenteritis to severe and sometimes fatal diarrhea, dysentery, hepatitis, or typhoid fever. Most of them are widely distributed throughout the world.

From year 1971 to 1978 there were 224 outbreaks of waterborne diseases affecting 48,193 individuals in the United States (Craun, 1981). Almost half of these outbreaks occurred because of the contamination of groundwater. Overflow or seepage of sewage from septic tanks and cesspools was believed to be responsible for over 40 % of the outbreaks. However, the actual source of groundwater contamination was proved in only 17 % of the outbreaks (Wilson et al., 1983).

Bacteria associated with waterborne illness outbreaks include two types of pathogens, those present in water as a result of pollution and some aquatic organisms that appear to be indigenous to drinking water distribution systems. The pathogens acquired from polluted waters are of Fecal origin and are causes of gastrointestinal illness. Pathogens acquired from polluted waters include recently recognized species, such as *Campelobacter* and *Yersinia*, as well as classical enteric pathogens, such as *Salmonella* and *Shigilla*. Most outbreaks of drinking water-associated gastroenteritis have resulted from human Fecal pollution; however, animal Fecal pollution is being increasingly implicated in outbreaks (Craun, 1986).

Craun, 1988 declared that distribution system problems in U.S caused 16 % of waterborne diseases outbreaks and illnesses during the period 1971-1985. However, these figures represent only reported waterborne outbreaks; there may have been other similar outbreaks that went undetected and there have been many distribution problems that have not been epidemiologically investigated. Israel experienced high levels of waterborne disease in term of documented outbreaks; in the 1975-85 periods the rate was 18 times that of United States (Tulchinisky et, al., 1988).

Levine, et al., 1990 showed that the USA has experienced great number of reported water borne outbreaks, over 25 occurring between 1986 and 1988. In some of the outbreaks, water supplies had been contaminated with human sewage; in others, Fecal discharges from watershed animals were the suspected sources of the contamination. Surveys of such animals have shown very high *Giardia* prevalence in aquatic environments (Pach, et al., 1990).

In the United States, over the 2-year period 1989-90, 16 states reported 26 outbreaks due to drinking water, with illness occurring in 4,288 persons. Just over one half of the outbreaks had no organisms identified but were epidemulogically considered to be viral in origin (Craun, 1986).

Egoze, et al., 1991 reported that one large outbreak in 1985 with over 9,000 cases of shigellosis, 49 cases of typhoid fever, and 1 death occurred from an unchlorinated municipal water distribution system in Israel when one of the groundwater sources was contaminated by sewage from a nearby sewage pipe broken during road construction work.

The density of bacteria in drinking water should be controlled for the reasons. Certain bacteria in drinking water deserve particular attention because they are opportunistic pathogens to human. The isolation of shigella from drinking water indicates recent human Fecal contamination and in view of the extreme pathogenically of the organisms is of crucial public health significance (WHO, 1996).

Craun and Calderon (1997) reported 356 outbreaks from 1971 to 1994 caused by contaminated groundwater systems in USA, represent about 58% of the Total of all waterborne outbreaks. Community systems were involved in 32% of these outbreaks and 68% were attributed to non-community systems. Contamination of the groundwater source was considered responsible for 70% of these outbreaks and contamination of the distribution system for the rest 30%.

Drinking water plays a major role in the spread of intestinal protozoa pathogenic from humans, namely *Giardia intestinalis* and *Entamoeba histolytica*. Epidemic giardiasis associated with contaminated drinking water has been reported in the England (Jephcott, et al., 1986), Canada (Wallis, et al., 1986), Sweden (Neringer, et al., 1987), United Stets of America (Craun, 1990), Jordan (Nimri, 1994) and Gaza Strip (Yassin et al., 1999 and Shubair et al., 2000). The wide distribution of *Giardia* in human and animals, the uncertainty concerning cross-species infectivity, the resistance of the cysts to inactivation by disinfection, and experience with the outbreaks led the USA to develop regulations on the disinfection of all surface water supplies in the country

World Health Organization, 1996 reported that the viruses of greatest significance in waterborne transmission of infectious disease are essentially those that multiply in the intestine of humans and are excreted in large numbers in the feces of individuals. As sewage mixes with receiving water, viruses are carried downstream, remaining detectable for verifying periods of time, depending on the temperature, the degree to which they are adsorbed on to sediments, the depth to which sunlight penetrates into the water, and other factors.

Frost et al. 1996 revealed that inadequate disinfection for community groundwater systems was cited in 23% of outbreaks and lack of disinfection in an additional 20%. For non-community groundwater systems, these numbers were respectively 28% and 53%. Acute gastroenteric illness was the most common disease described in these outbreaks, accounting for 35%. When a disease agent has been identified with an outbreak, Shigella, hepatitis A virus, norwalk virus, Giardia lamblia, *Campylobacter* jejuni, and Cryptosporidium parvum have been implicated.

Macler and Merkle, 2000 showed that, up to half of our drinking water wells tests had evidence of Fecal contamination. Asignificant fraction of all waterborne disease outbreaks is associated with groundwater. An estimated 75.000 to 5.9 million illnesses per year resulting as groundwater contamination in the US. Mortality from these illnesses may be 1400-9400 per year.

The lack of sanitation in Niamey, Niger and the seepage of polluted matters from the superficial layers could explain this pollution. Eventually, the use of the groundwater could increase and constitute a major health risk for the majority of the inhabitants of Niamey (chippaux et al., 2002).

All cholera incidents recorded in 1999 and 2000 at the Provincial hospital were from peri-urban settlements and surrounding commercial farms while 1,045 to 2,632 cases of dysentery were also reported each year at the provincial hospital during the period 1997-2002 in Zimbabwe (Niaty, 2004).

Chapter (4)

Methodology

4.1 Data Collection

4.1.1 Collection and Reviewing of Literatures

Literatures were collected and reviewing for microbiological water quality, microbial contamination of groundwater, source of microbial water contamination, microbial contamination of water networks and health aspects of microbial water contamination.

4.1.2 Historical Data Collection

Data of bacteriological water quality (Total Coliform and Fecal Coliforms) for both water wells and networks distribution system throughout the year 1999 to 2003 in Gaza Strip were collected from the records of Palestinian Ministry of Health. Also data of the same parameters were collected at monthly basis during the year 2003. The incidence of waterborne diseases (Giardiasis, Hepatitis A, Diarrheal diseases, Entamibosis, Salmonillosis and Shigellosis) at monthly basis during the year 2003 were collected from the Department of Eidemiology, Palestinian Ministry of Health.

A Total of 128 drinking water wells distributed in all governorates of Gaza Strip were collected annually from 1999 to 2003, some wells were closed other were rehabilitated and/or new drilled during the same period (Annex 1). From networks, data were collected randomly form representative points for networks served water to consumers (Households, schools, Hospitals and clinics) (personal communication, MOH).

4.2 Bacteriological Examination of Collected Samples by MOH

The following media were used throughout the study for the growth, differentiation and detection of bacteria.

<u>Recovery and detection of Total Coliform</u>

M-Endo agar used for detection of Total Coliform bacteria. One hundred milliliter of water sample was filtered through 0.45 µ membrane filter. Membrane filter was pleaced onto M-Endo agar plate, and the plate was incubated at 37±0.2 ^{0}C for 24 hours. Colonies were counted under 10-25x magnification.

<u>Recovery and detection of Fecal Coliform</u>

M-FC agar used for detection of Fecal Coliform bacteria. One hundred mililiter of water sample was filtered through 0.45 µ membrane filter. Membrane filter was placed onto M-Fecal Coliform agar plate, and the plate was incubated at 44.5±0.2 ^{0}C for 24±2 hours. Colonies were counted under 10-25x magnification.

4.3 Questionnaire

4.3.1 Study Population

The target population was the residents of Gaza City. One hundred and fifty people were included in the current study. The estimated resident connected with municipal water networks in Gaza City was 90% (personal communication with the Municipality of Gaza, Palestinian National authority). The sample size was then determined on the basis of a formula for descriptive interviews, 1.96 S.E= $\{P(1-P)/N\}^{1/2}$ (Kuzma 1992), P=0.90 as the prevalence N= the desire sample size at C.I.95%. So, 1.96= $\{0.9(1-0.9)/N\}^{1/2}$ = 0.05, by calculation N our entire sample is 139 resident in Gaza City in addition to 11 pilot study samples to increase our sample size to 150 residents.

4.3.2 Questionnaire Validity and Pilot Study

The validity of the questionnaire was tested by eight specialists in the fields of water quality, microbiology, environment and public health. A questionnaire was piloted with 11 people included in the sample from the study area, and modified as necessary.

4.3.3 Questionnaire Information

The questionnaire was administered in Arabic language. English version of the questionnaire is also available (Annex 4). The questionnaire included information about the personal profile of the study population, various aspects of domestic water supply for the people who live in the study area, the use of roof water tanks and their situation, situation of wastewater networks system, occurrence of waterborne diseases and treatment and awareness of the study population towards drinking water in Gaza City. During the survey the interviewer explained to the people any of the questions that were not clear to them. The interviews were conducted only by one investigator himself. This will minimize the source of error or bias. Most 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 (Backestrom and Hursh-Cesar, 1981).

4.4 Data analysis

Data were computer analyzed using Microsoft Excel Program to calculate the bacteriological contamination percentage of water by Total and Fecal Coliform and comparing the water quality between wells and networks for each governorates in Gaza Strip according to international standards and guidelines. The incidence rate of waterborne diseases (Gardiasis, Hepatitis A and Diarrheal diseases) log rate regression/10,000 population by Fecal Coliform contamination percentage in water networks at monthly basis during the year 2003 in different governorates of Gaza Strip was plotted. Also, correlation was calculated to illustrate the conjunction between incidence rates of waterborne diseases and contamination percentages of water networks by Fecal Coliform. SPSS (Statistical Package for the Social Sciences) and EPINFO (Epidemiological Program Office) Statistical packages, cross tabulation and odds ratio were also applied to calculate all aspects of water and wastewater and its relation to human health according to results of the questionnaire variables.

Chapter (5)

Results

The current data on the Total and Fecal Coliform contamination in wells and water networks of Gaza Strip were collected from the records of the Palestinian ministry of health in the period from 1999 to 2003. The term contamination is based on one colony forming per 100 ml (CFU) for the examined sample.

5.1 Microbiological Contamination Level of Water Samples Collected from Water wells and networks distribution system during 1999 to 2003 at annual basis

The Total and Fecal Coliform contamination percentages in water samples collected from wells and water networks in the Gaza Strip from 1999 to 2003 are summarized in Table 1 and Figure 1. In wells the Total Coliform contamination varied between 8-12% throughout the five years of testing. For the Total Colifrom contamination of the water networks, the values slightly varied from 11 – 14% in the same period. These values exceeded that of the World Health Organization, WHO limit (5%). The Fecal Coliform contamination percentages in the wells were 8, 5, 5, 5 and 3% during the 5 years of examination, respectively. In water networks the level of contamination decreased from 10% to 5% in the year 1999 to 2000, and then account for 6% for each of the next three years. In general, the Total and Fecal Coliform contamination in water networks was higher than that in the wells in the Gaza Strip along the study period.

Table 1: Total and Fecal Coliform contamination percentages of water wells and networks in Gaza Strip from 1999 to 2003

Parameter	Source	Years														
		1999			2000			2001			2002			2003		
		S. no	C .s	C.%	S. no	C .s	C.%	S. no	C .s	C.%	S. no	C .s	C.%	S. no	C .s	C.%
# Total Coliform	wells	1683	203	**12**	1416	115	**8**	1462	177	**12**	1728	155	**9**	1274	111	**9**
	networks	4217	580	**14**	3858	432	**11**	3298	397	**12**	2790	335	**12**	2474	334	**14**
Fecal Coliform	wells	1614	129	**8**	1381	70	**5**	1462	75	**5**	1316	67	**5**	1272	32	**3**
	networks	3904	392	**10**	3795	193	**5**	2887	175	**6**	2557	153	**6**	2463	147	**6**

S. no: Number of the samples, **C .s:** Contaminated samples, **C%:** Contamination percentage, * no contaminated samples were detected, # Should not be exceeded than 5% (WHO Guideline).

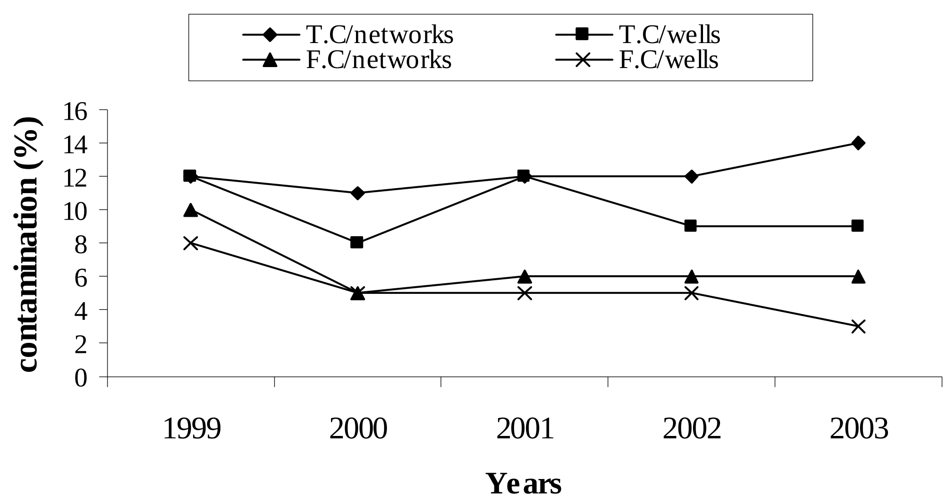

Fig 1: Total and Fecal Coliform contamination percentages in water wells and networks in Gaza Strip along the five years period from 1999 to 2003.

For better understanding, the contamination levels of both Total and Fecal Coliforms were investigated in each of the five Governorates of the Gaza Strip. Data shown in Table 2 and Figure 2 illustrate the Total and Fecal Coliform contamination percentages in water wells and networks in the Northern Governorate in the period from 1999 to 2003. The Total Coliform contamination percentages in the wells showed a decreasing trend started with 13% in the year 1999 and ended by 7% in the year 2003. In water networks the values of contamination accounted for 17, 14, 10, 12 and 13% for years 1999 to 2003, respectively. The Fecal Coliform contamination in the wells recorded decreasing values of 8, 4, 6, 4 and 3% throughout the 5 years of testing, respectively. In the networks such contamination has reduced from 13% in the year 1999 to around 6% in each of the next four years examined. It is obvious that the Total and Fecal Coliform contamination in the water networks was higher than that in the wells in the Northern Governorate along the study period.

Table 2: Total and Fecal Coliform contamination percentages in water wells and networks in the North Governorate from1999 to 2003

Parameter	**Source**	**Years**														
		1999			**2000**			**2001**			**2002**			**2003**		
		S. no	**C .s**	**C.%**	**S. no**	**C .s**	**C.%**	**S. no**	**C .s**	**C.%**	**S. no**	**C .s**	**C.%**	**S. no**	**C .s**	**C.%**
Total Coliform	wells	331	43	**13**	305	36	**12**	364	41	**11**	296	33	**11**	285	19	**7**
	networks	544	93	**17**	541	77	**14**	573	57	**10**	480	58	**12**	354	47	**13**
Fecal Coliform	wells	295	24	**8**	300	12	**4**	364	22	**6**	294	12	**4**	285	9	**3**
	networks	497	65	**13**	515	38	**7**	485	30	**6**	418	21	**5**	354	22	**6**

S. no: Number of the samples, **C .s:** Contaminated samples, **C%:** Contamination percentage, * no contaminated samples were detected

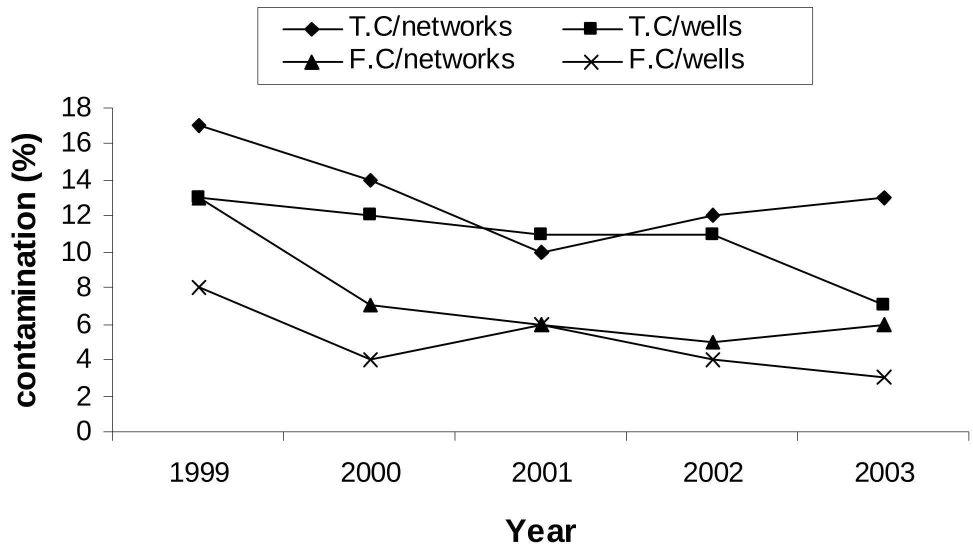

Fig. 2: Total and Fecal Coliform contamination percentages in water wells and networks in the North Gaza Governorate throughout 1999 to 2003.

The Total and Fecal Coliform contamination percentages in water wells and networks in Gaza Governorate from 1999 to 2003 are shown in Table 3 and Figure 3. The Total Coliform contamination in the wells varied from 6-13% along the five years examined with year 2001 represents the second high value (11%) after the year 1999 (13%). In water networks the values fluctuated from 12 to 20% throughout the study period, recording the highest percentage of 20% in the year 2001. Fecal Coliform contamination in the wells is reduced from 8% in the year 1999 to 2% in the year 2000, registering a reduction of 75%. Then, it increased to reach 6% in the next two years 2001 and 2002 and finally it decreased to be 2% in the years 2003. In networks, the Fecal Coliform contamination values were 12, 6, 11, 4 and 6% throughout the five years of investigation, respectively. Like in the Northern Governorate, the Total and Fecal Coliform contamination in water networks registered higher levels than that in wells in the Gaza Governorate during the five years study period.

Table 3: Total and Fecal Coliform contamination percentages in water wells and networks in Gaza Governorate from 1999 to 2003

Parameter	Source	Years														
		1999			2000			2001			2002			2003		
		S. no	C .s	C.%	S. no	C .s	C.%	S. no	C .s	C.%	S. no	C .s	C.%	S. no	C .s	C.%
Total Coliform	wells	826	108	**13**	810	50	**6**	872	97	**11**	1233	111	**9**	769	83	**11**
	networks	1504	225	**15**	1255	176	**14**	1349	270	**20**	1422	173	**12**	982	118	**12**
Fecal Coliform	wells	743	60	**8**	780	18	**2**	872	54	**6**	823	50	**6**	767	18	**2**
	networks	1393	170	**12**	1218	74	**6**	1288	144	**11**	1364	60	**4**	974	57	**6**

S. no: Number of the samples, **C .s:** Contaminated samples, **C%:** Contamination percentage, * no contaminated samples were detected

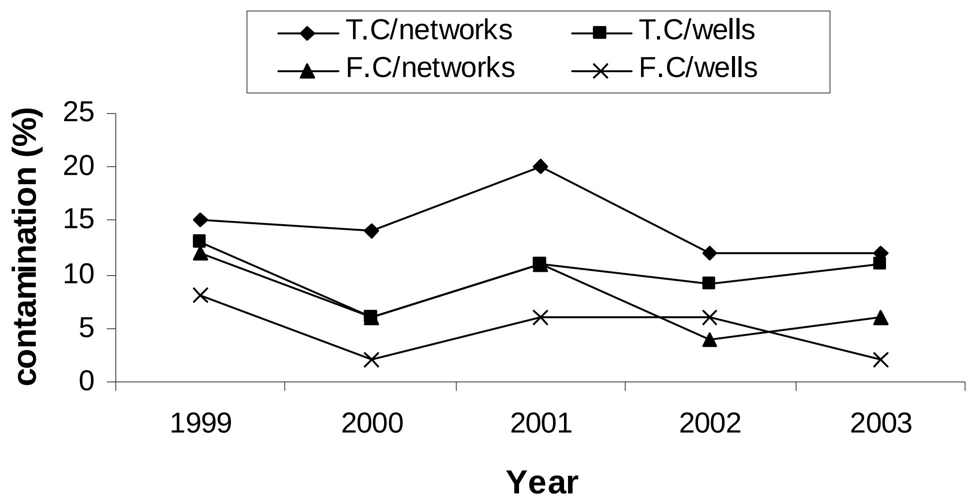

Fig. 3: Total and Fecal Coliform contamination percentages in water wells and networks in Gaza Governorate during the years from 1999 to 2003.

Mid Zone Governorate comprises most of the refugee camps, where sanitation services are the responsibility of United Nations Relief and Worker Agency (UNRWA) and the main municipalities. Table 4 and Figure 4 presented the Total and Fecal Coliform contamination percentages in wells and water networks in the Mid zone Governorate in the years from 1999 to 2003. There is a general increasing trend in the Total Coliform contamination in both wells and networks throughout the study period. The highest values of contamination in wells and networks were registered during the year 2001 (21 and 12%, respectively) whereas the lowest values were recorded in wells during the year 1999 (8%). The Fecal Coliform contamination in wells and networks in the year 1999 were 8 and 10%, respectively. In the wells the level of contamination then showed no clear trend recording values of 10, 3, 15 and 0% in the next four years, respectively. However, the zero value recorded in the year 2003 is a matter of debate particularly after 15% of contamination registered in the previous year 2002. In networks the contamination percentage of Fecal Coliform was considerably decreased to reach a value of 6% in the year 2000 i.e. 50% reduction within one year and then to 4% in each of the last three years tested.

Table 4: Total and Fecal Coliform contamination percentages in water wells and networks in the Mid zone Governorate from1999 to 2003

Parameter	**Source**	**Years**														
		1999			**2000**			**2001**			**2002**			**2003**		
		S. no	**C .s**	**C.%**	**S. no**	**C .s**	**C.%**	**S. no**	**C .s**	**C.%**	**S. no**	**C .s**	**C.%**	**S. no**	**C .s**	**C.%**
Total Coliform	wells	39	3	**8**	10	1	**10**	33	7	**21**	20	4	**20**	31	4	**13**
	networks	749	46	**15**	650	65	**10**	634	77	**12**	569	63	**11**	632	84	**13**
Fecal Coliform	wells	39	3	**8**	10	1	**10**	33	1	**3**	20	3	**15**	31	0	**0**
	networks	678	66	**10**	650	40	**6**	520	21	**4**	501	21	**4**	632	25	**4**

S. no: Number of the samples, **C .s:** Contaminated samples, **C%:** Contamination percentage, * no contaminated samples were detected

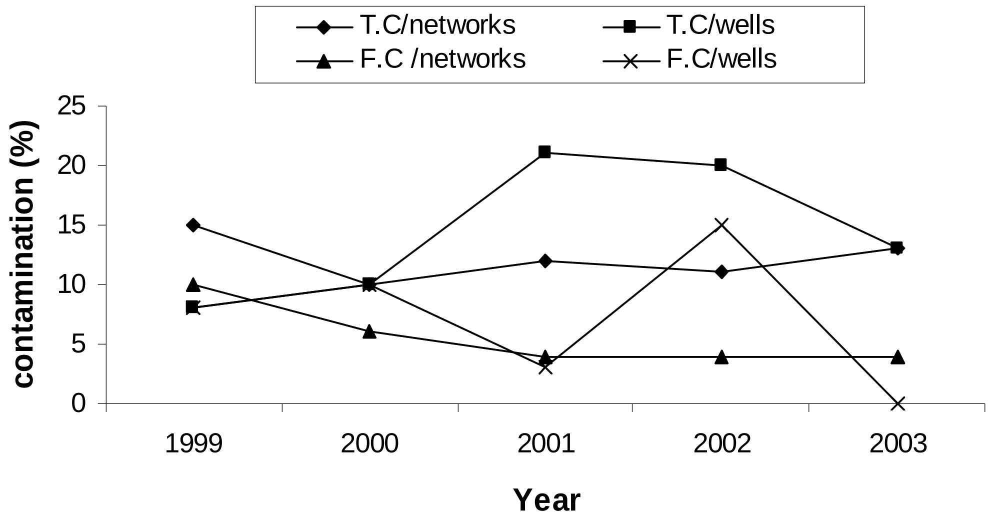

Fig. 4: Total and Fecal Coliform contamination percentages in water wells and networks in the Mid zone Governorate along the five years period from 1999 to 2003

Table 5 and Figure 5 show the Total and Fecal contamination percentages in water wells and water networks in KhanYounis Governorate from1999 to 2003. In wells the Total Coliform contamination was generally decreased recording percentages of 14, 8, 10, 0 and 0% in the years from 1999 to 2003, respectively. In contrast, such contamination in networks was generally increased with time showing percentage values of 16, 14, 13, 18, and 21 allover the interval year periods examined. Similar trend was registered for Fecal Coliform contamination in both wells and networks. The values of contamination were 10, 4, 7, 0 and 0% in wells and 11, 6, 7, 12 and 13% in networks during the five years of study. However, the zero values recorded in wells in the last two yeas (2002 and 2003) for both Total and Fecal Coliform contamination is a matter of discussion. It is clear that the Total and Fecal Coliform contamination in water networks in the Northern Governorate exceeded that in wells, particularly in the last two years.

Table 5: Total and Fecal Coliform contamination percentages in water wells and networks in KhanYounis Governorate from 1999 to 2003

Parameter	Source	Years														
		1999			2000			2001			2002			2003		
		S. no	C .s	C.%	S. no	C .s	C.%	S. no	C .s	C.%	S. no	C .s	C.%	S. no	C .s	C.%
Total Coliform	wells	221	34	**14**	53	4	**8**	30	3	**10**	0	0	**0****	27	0	**0***
	networks	1187	190	**16**	1133	157	**14**	543	72	**13**	168	30	**18**	339	71	**21**
Fecal Coliform	wells	192	18	**10**	53	2	**4**	30	2	**7**	0	0	**0****	27	0	**0**
	networks	1029	115	**11**	1133	72	**6**	464	33	**7**	153	18	**12**	329	41	**12**

S. no: Number of the samples, **C .s:** Contaminated samples, **C%:** Contamination percentage, * no contaminated samples were detected, ** No samples were collected to examine

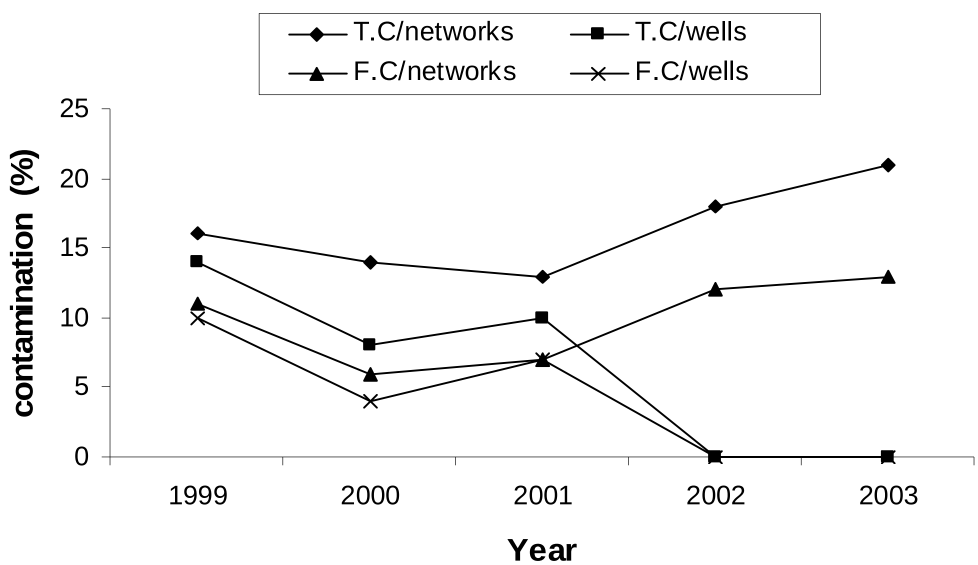

Fig. 5: Total and Fecal Coliform contamination percentages in water wells and networks in KhanYounis Governorate along the five years period from 1999 to 2003

The Total and Fecal Coliform contamination in wells and water networks in Rafah Governorate in the period from 1999 to 2003 is illustrated in table 6 and Figure 6. Total Coliform contamination in wells showed a decreasing trend with values of 11, 6, 6, 5 and 3% for years 1999 to 2003, respectively. In contrast, contamination values in networks increased slightly from 6% in the year 1999 to 8% in the year

2003. Fecal Coliform contamination level was found to be fluctuated in both wells and networks; showing values of 6, 4, 0, 2 and 3% in wells and 3, 1, 3, 5 and 1% in networks during the study years, respectively.

Table 6: Total and Fecal Coliform contamination percentages in water wells and networks in Rafah Governorate from1999 to 2003

Parameter	Source	Years														
		1999			2000			2001			2002			2003		
		S. no	C .s	C.%	S. no	C .s	C.%	S. no	C .s	C.%	S. no	C .s	C.%	S. no	C .s	C.%
Total Coliform	wells	266	30	**11**	238	14	**6**	163	10	**6**	179	9	**5**	162	5	**3**
	networks	233	14	**6**	279	12	**4**	199	12	**6**	151	12	**8**	167	14	**8**
Fecal Coliform	wells	345	22	**6**	238	10	**4**	163	0	**0***	179	4	**2**	162	5	**3**
	networks	307	10	**3**	279	6	**1**	130	4	**3**	121	6	**5**	147	2	**1**

S. no: Number of the samples, **C .s:** Contaminated samples, **C%:** Contamination percentage, * no contaminated samples were detected

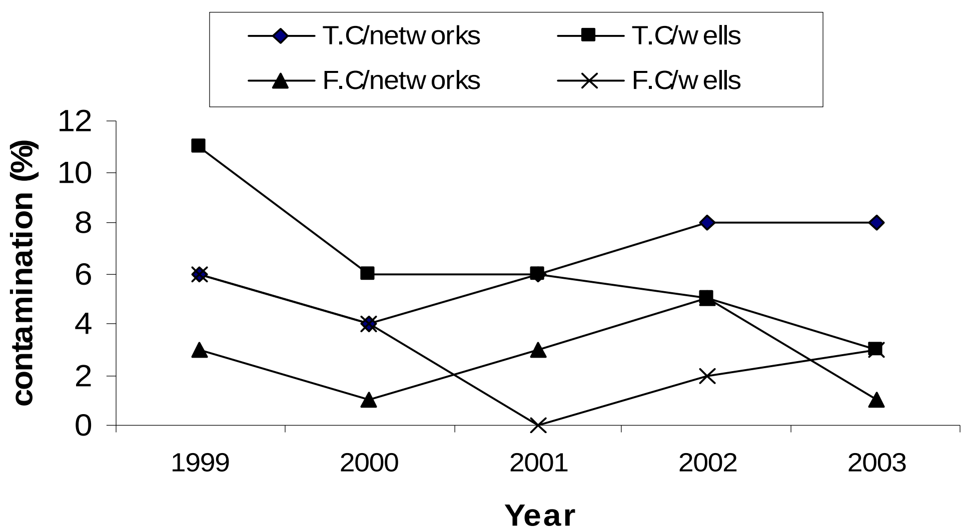

Fig. 6: Total and Fecal Coliform contamination percentages in water wells and networks in Rafah Governorate along the five years period from 1999 to 2003.

5.2 Microbiological Contamination Level of water Samples collected from Water wells and networks distribution system at monthly basis during the year 2003.

To provide us with the recent situation of the microbial water quality and to help to understanding the influence of season on the level of the microbial contamination in the Gaza Strip, the microbial contamination was investigated at monthly basis only along the year 2003. Table 7 and Figure 7 summarize the Total Coliform sample contamination examined for both water wells and networks at monthly basis throughout the year 2003 in the Gaza Strip. The monthly collected samples in term of population size fulfilled the minimum limit of samples according to monitoring program that was applied by the Palestinian ministry of health. In general, the percentage of Total Coliform contamination in wells is lower than that in networks allover the various months of the year. The contamination values vary from 0-17% and from 7-25% in wells and networks, respectively. Unlike wells, the level of Total Coliform contamination in the networks across the months of February, March, April, May, September, October and December is exceeded that of the WHO standard (5%). The highest contamination values for both wells and networks were recorded in the summer season (June, July and August). The ranges were 11-17% and 18-25% in wells and networks, respectively. However, high contamination percentages of 17 and 12% were detected in January, 2003 in wells and networks, respectively.

Table 7: Total Coliform sample contamination examined for water wells and networks at monthly basis throughout the year 2003 in the Gaza Strip.

	Wells			Networks		
Month	**S. no**	**C. s**	**C.%**	**S. no**	**C .s**	**C.%**
January	115	20	**17**	212	25	**12**
February	93	0	**0***	164	11	**7**
March	136	6	**4**	240	23	**10**
April	114	6	**5**	230	23	**10**
May	96	4	**4**	233	27	**12**
June	127	22	**17**	212	50	**24**
July	128	22	**17**	226	41	**18**
August	117	13	**11**	199	50	**25**
September	77	4	**5**	207	15	**7**
October	92	2	**2**	200	24	**12**
November	85	7	**8**	176	24	**14**
December	94	5	**5**	175	21	**12**
Total	1274	111	Aver. **9**	2474	334	**Aver. 14**

S. no: Number of the samples, **C .s:** Contaminated samples, **C%:** Contamination percentage, * no contaminated samples were detected

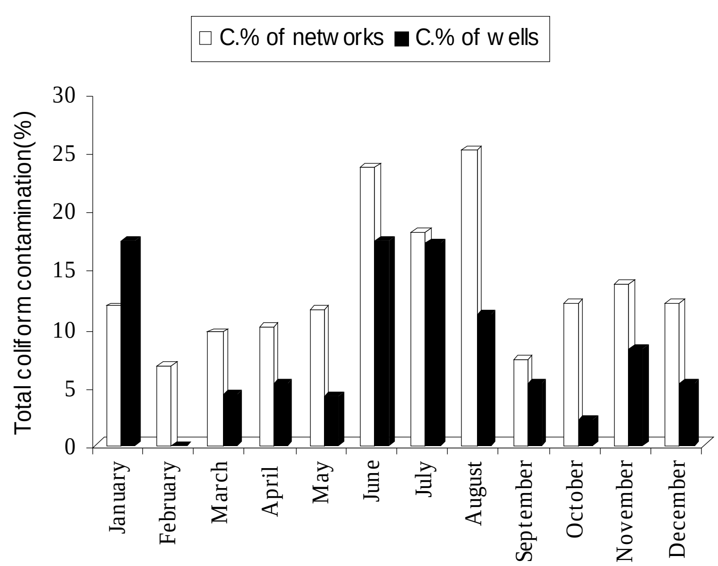

Fig. 7: Contamination percentages of water wells and networks by Total Coliform in Gaza Strip recorded monthly during the year 2003.

The Fecal Colifrom sample contamination recorded for water wells and networks at monthly basis during the year 2003 in the Gaza Strip is illustrated in Table 8 and Fig. 8. The collected monthly samples were considered to fulfill the minimum limit of samples according to monitoring program that was applied by the Palestinian Ministry of Health. According to the WHO standard, Fecal Coliform contamination is based on forming ≥1 colony per 100ml examined sample. Like Total Coliform, the Fecal Coliform contamination in the wells is generally lower than that in the networks. The range of Fecal Coliform contamination was from 0-7.9% in wells and from 2.9 to 10.9% in networks allover the 12 month-period of 2003. However, the level of contamination was generally exceeded that of the WHO standard except for wells in February and October where the examined samples were free of Fecal contamination. In general, higher Fecal Coliform contamination values in both water wells and networks were registered in summer and winter seasons compared to other seasons of the year 2003.

Table 8: Fecal Coliform sample contamination examined for water wells and networks at monthly basis throughout the year 2003 in the Gaza Strip.

	Wells			Networks		
Month	**S. no**	**C. s**	**C.%**	**S. no**	**C. s**	**C.% of**
January	115	4	**3.5**	212	7	**3.3**
February	93	0	**0***	164	6	**3.7**
March	136	2	**1.5**	223	7	**3.1**
April	114	2	**1.8**	215	11	**5.1**
May	96	1	**1.0**	233	19	**8.2**
June	127	4	**3.1**	212	11	**5.2**
July	126	10	**7.9**	226	20	**8.8**
August	117	4	**3.4**	199	18	**9.0**
September	77	1	**1.3**	207	6	**2.9**
October	92	0	**0***	194	11	**5.7**
November	85	1	**1.2**	176	12	**6.8**
December	94	3	**3.2**	175	19	**10.9**
Total	1272	32	**Aver. 2.5**	2436	147	**Aver. 6.0**

S. no: Number of the samples, **C .s:** Contaminated samples, **C%:** Contamination percentage, * No contaminated samples were detected

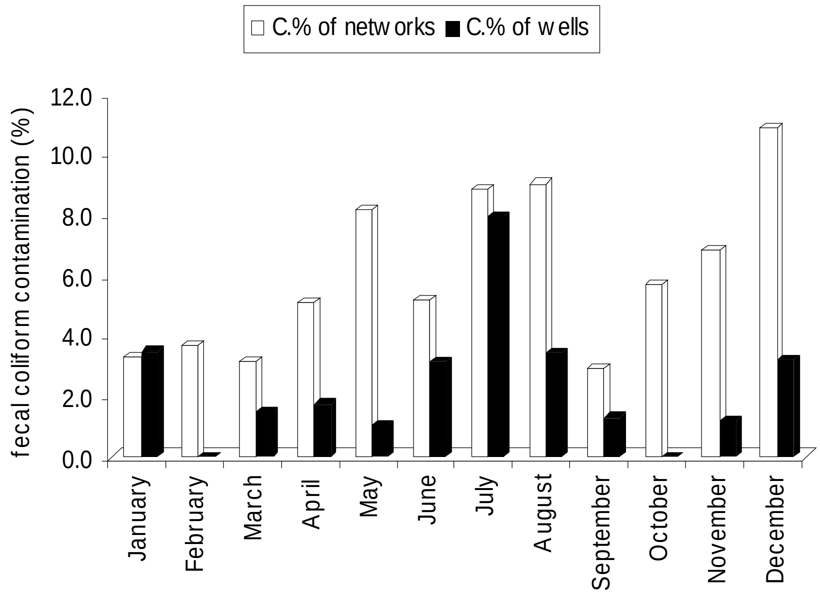

Fig. 8: Contamination percentages of water wells and networks by Fecal Coliform in Gaza Strip recorded monthly during the year 2003

Each geographically identified Governorate of Gaza Strip is considered for monthly investigation of microbial contamination over the year 2003. Data presented in Table 9 and Figure 9 showed the Total Coliform contamination in water wells and networks in the North Governorate throughout the 12 months of the year 2003. The level of contamination in wells was lower than that in networks fluctuating from 0-19% in wells and from 0 to 36% in the networks. Again relatively higher contamination values were detected in summer and winter months compared to the other ones of the year. Drop of Total Coliform contamination to zero values was recorded in February, March, May, October and November for wells and only in October for networks.

Table 9: Total Coliform sample contamination examined for water wells and networks at monthly basis throughout the year 2003 in the North Governorate

	Wells			Networks		
Month	**S. no**	**C .s**	**C.%**	**S. no**	**C. s**	**C.% of**
January	17	1	**6**	27	5	**19**
February	26	0	**0***	30	2	**7**
March	27	0	**0***	26	2	**8**
April	19	1	**5**	43	5	**12**
May	22	0	**0**	30	3	**10**
June	27	2	**7**	31	3	**10**
July	36	7	**19**	33	5	**15**
August	32	3	**9**	21	1	**5**
September	21	3	**14**	29	3	**10**
October	27	0	**0***	25	0	**0***
November	18	0	**0***	45	16	**36**
December	13	2	**15**	14	2	**14**
Total	285	19	**Aver. 7**	354	47	**Aver. 13**

S. no: Number of the samples, **C .s:** Contaminated samples, **C%:** Contamination percentage, * No contaminated samples were detected

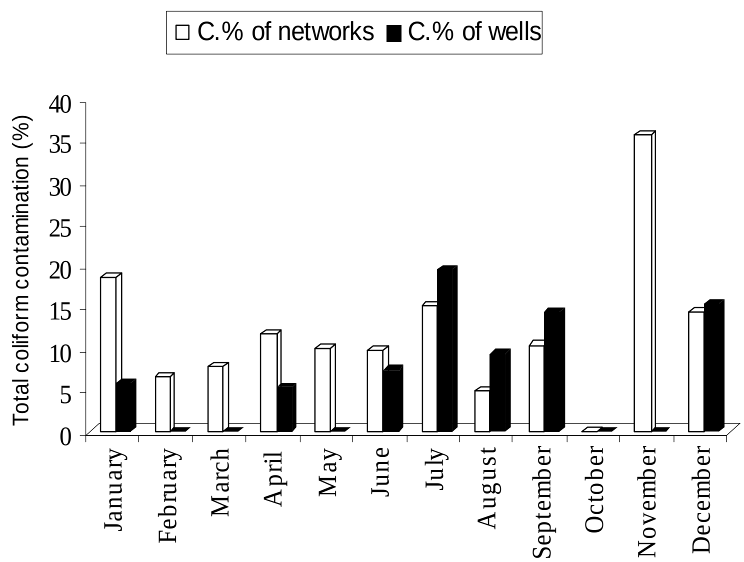

Fig. 9: Total Coliform contamination percentages in water wells and networks registered monthly in the North Governorate along year 2003

Table 10 and Figure 10 illustrate the Fecal Coliform contamination in water wells and networks registered at monthly basis throughout the year 2003 in the North Governorate. The contamination percentages in wells were generally found to be lower than that in networks. Fecal Coliform contamination in wells recorded 0% through January to May, then it increase in summer season recording values of 4, 17 and 3% in June, July and August, respectively. In September, the contamination value was 5% then dropped again to 0% in October, November and December. For water networks, the zero values were registered in June, August, October and December. However, July still displayed a high value of contamination (9%).

Table 10: Fecal Coliform sample contamination examined for water wells and networks at monthly basis during the year 2003 in the North Governorate

	Wells			Networks		
Month	**S. no**	**C .s**	**C.%**	**S. no**	**C. s**	**C.%**
January	17	0	**0***	27	1	**4**
February	26	0	**0***	30	1	**3**
March	27	0	**0***	26	2	**8**
April	19	0	**0***	43	4	**9**
May	22	0	**0***	30	3	**10**
June	27	1	**4**	31	0	**0***
July	36	6	**17**	33	3	**9**
August	32	1	**3**	21	0	**0***
September	21	1	**5**	29	1	**3**
October	27	0	**0***	25	0	**0***
November	18	0	**0***	45	7	**16**
December	13	0	**0***	14	0	**0***
Total	285	9	**Aver. 3**	354	22	**Aver. 6**

S. no: Number of the samples, **C .s:** Contaminated samples, **C%:** Contamination percentage, * No contaminated samples were detected

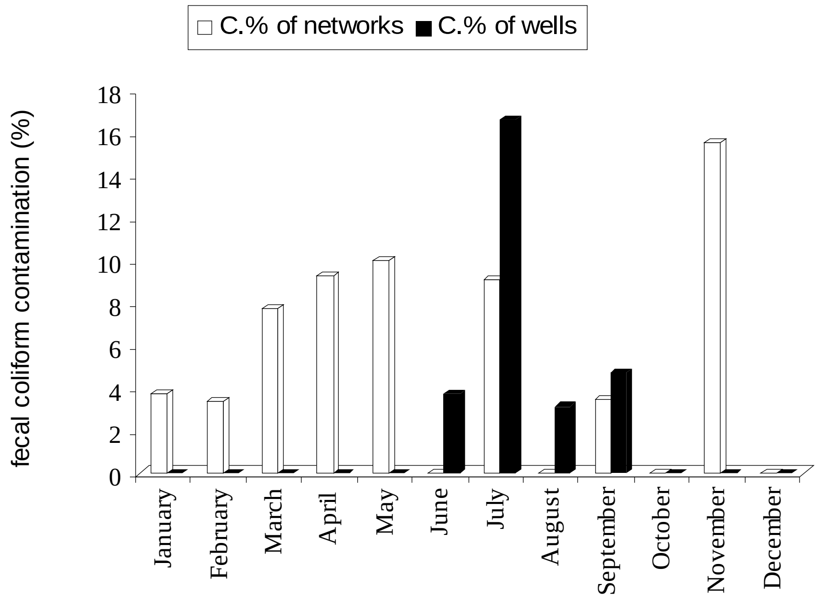

Fig. 10: Fecal Coli form contamination in water wells and networks in the North Governorate registered monthly along year 2003

Data shown in table 11 and Figure 11 represent the Total coli form contamination in water wells and networks recorded at monthly basis in Gaza Governorate during the year 2003. The number of analyzed sample was the highest as Gaza Governorate is the largest and with the highest population density compared to the other Governorates of the Gaza Strip. However, the number of collected samples represents the minimum limit. The level of Contamination ranged from 0 to 29% in wells and from 4 to 22% in networks. In wells, the percentages of Total coli form contamination registered for February, March, May, September and October were (0, 5, 4, 0 and 4%, respectively). In networks, such low levels of contamination were recorded in March and July (4%). On the other hand, the highest level of Total Coliform contamination in wells (29%) was registered in January and that for networks (22%) was registered in May. However, high level of contamination still registered for summer season particularly in networks except for July.

Table 11: Total Coliform sample contamination examined for water wells and networks at monthly basis during the year 2003 in Gaza Governorate

	Wells			Networks		
Month	**S. no**	**C. s**	**C.%**	**S. no**	**C. s**	**C.%**
January	80	23	**29**	128	16	**13**
February	60	0	**0***	44	6	**14**
March	110	6	**5**	106	4	**4**
April	80	12	**15**	93	10	**11**
May	56	2	**4**	93	20	**22**
June	86	8	**9**	108	20	**19**
July	59	9	**15**	105	4	**4**
August	62	9	**15**	42	9	**21**
September	33	0	**0***	70	4	**6**
October	56	2	**4**	91	13	**14**
November	42	5	**12**	35	4	**11**
December	45	7	**16**	67	8	**12**
Total	769	83	**Aver. 11**	982	118	**Aver. 12**

S. no: Number of the samples, **C .s:** Contaminated samples, **C%:** Contamination percentage, * No contaminated samples were detected

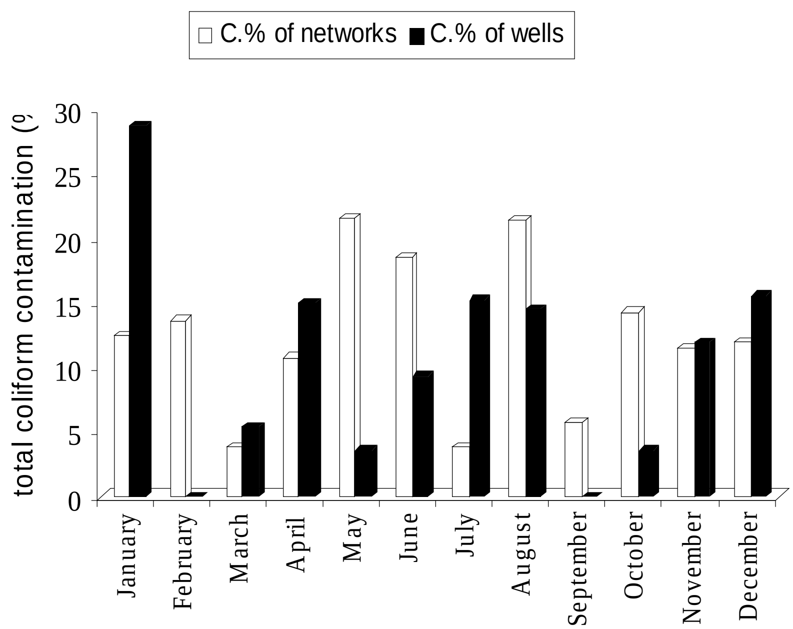

Fig. 11: Contamination percentages of water wells and networks by Total Coliform in Gaza Governorate registered monthly over year 2003

Table 12 and Figure 12 show the Fecal Coliform contamination in water wells and networks at monthly basis during the year 2003 in Gaza Governorate. The contamination percentages for wells (0-10%) were generally lower than that in networks (0-17%). In wells, the level of Fecal Coliform contamination was exceeding that of WHO standard except for February, April, May, September and October. For networks, the contamination values were generally exceeded that of WHO standard except for March. However, the highest Fecal Coliform contamination was registered in August for both water wells and networks (10 and 17 %, respectively).

Table 12: Fecal Coliform sample contamination examined for water wells and networks at monthly basis during the year 2003 in Gaza Governorate

	Wells			**Networks**		
Month	**S. no**	**C. s**	**C.%**	**S. no**	**C. s**	**C.%**
January	80	4	**5**	129	6	**5**
February	60	0	**0***	43	4	**9**
March	110	2	**2**	106	0	**0***
April	80	0	**0**	93	6	**6**
May	54	0	**0**	87	6	**7**
June	86	2	**2**	108	10	**9**
July	59	1	**2**	105	3	**3**
August	62	6	**10**	42	7	**17**
September	33	0	**0***	70	3	**4**
October	56	0	**0***	91	7	**8**
November	42	1	**2**	35	1	**3**
December	45	2	**4**	65	4	**6**
Total	767	18	**Aver. 2**	974	57	**Aver. 6**

S. no: Number of the samples, **C .s:** Contaminated samples, **C%:** Contamination percentage, * No contaminated samples were detected

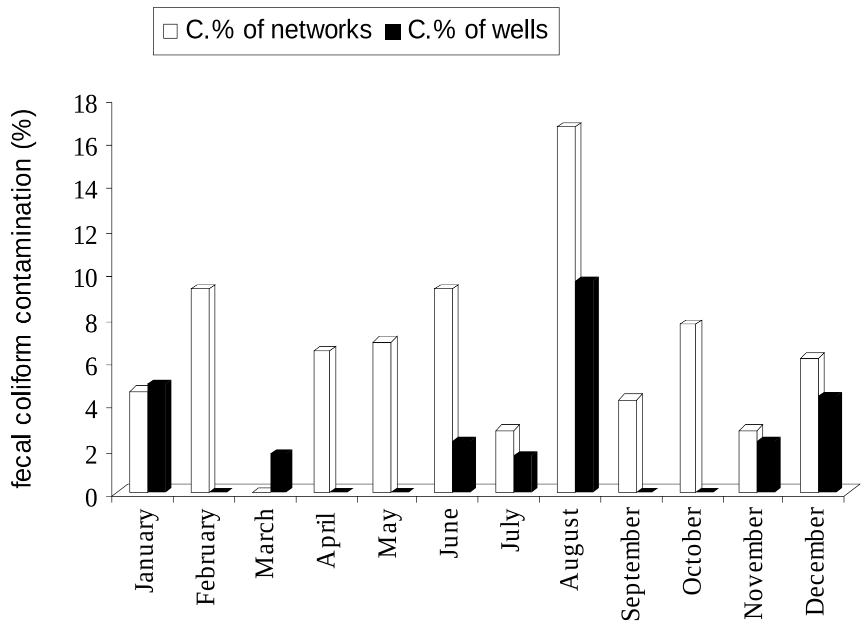

Fig.12: Contamination percentages of water wells and networks by Fecal Coliform in Gaza Governorate registered monthly over year 2003

The Total Coliform contamination in water wells and networks recorded at monthly basis along year 2003 in Mid Zone Governorate is illustrated in Table 13 and Figure 13. In contrast to networks, no samples were collected for examination from wells during the months of January, February, April and October, even the number of those collected during the other months does not meet the minimum limit of sample number implying a non representative contamination percentage for wells. In the networks, the Total Coliform contamination percentages fluctuate from 3-34% throughout the year 2003. The highest values were registered for summer season showing percentages of 18, 31 and 34 in June, July and August, respectively.

Table 13: The Total Coliform sample contamination examined for water wells and networks at monthly basis throughout the year 2003 in the Mid Zone Governorate

	Wells			Networks		
Month	**S. no**	**C .s**	**C.%**	**S. no**	**C .s**	**C.%**
January	0	0	**0****	54	2	**4**
February	0	0	**0****	36	1	**3**
March	2	0	**0***	62	2	**3**
April	0	0	**0****	61	6	**10**
May	3	1	**33**	45	6	**13**
June	1	0	**0***	76	14	**18**
July	4	0	**0**	62	19	**31**
August	1	0	**0***	56	19	**34**
September	7	2	**29**	53	4	**8**
October	0	0	**0****	38	2	**5**
November	7	1	**14**	20	2	**10**
December	6	0	**0***	69	7	**10**
Total	31	4	**Aver. 13**	632	84	**Aver. 13**

S. no: Number of the samples, **C .s:** Contaminated samples, **C%:** Contamination percentage, * No contaminated samples were detected, ** No samples were collected to examine

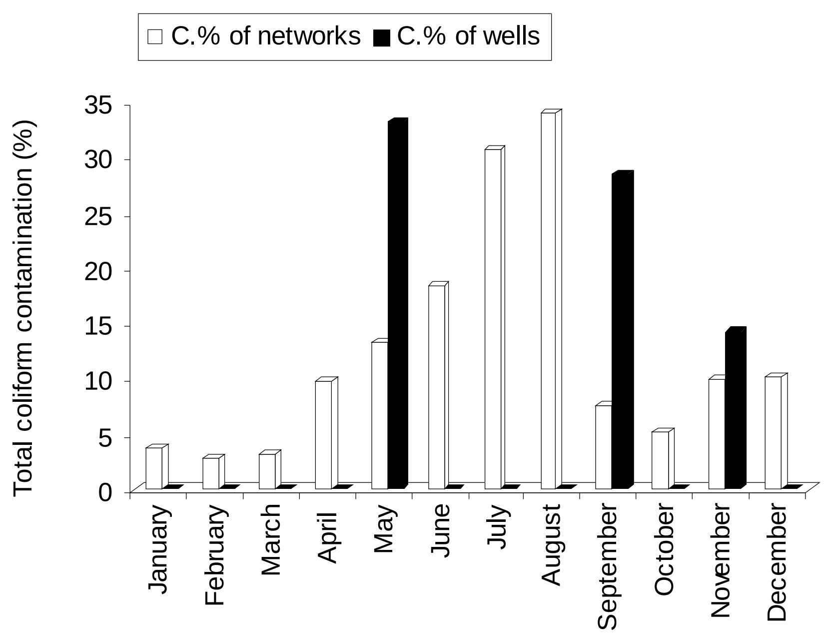

Fig. 13: Total Colifom contamination in water wells and networks in the Mid Zone Governorate recorded monthly throughout the year 2003.

The Fecal Coliform contamination in the water wells and networks recorded at monthly basis during the year 2003 in the Mid Zone Governorate is shown in Table 14 and Figure 14. No samples were collected for examination from wells during the months of January, February, April and October, even the number of those collected during the other months does not meet the minimum limit of sample number implying a non representative contamination percentage for wells. Consequently the 0% contamination in well throughout the year is questioned. For networks, the collected samples do meet the minimum limit for the sample number. The Fecal Coliform contamination percentages were generally exceeding that of WHO standard except for January, June and October. Again, July and August of the summer season registered the highest value (10 and 13%, respectively) of Fecal Coliform contamination in the networks.

Table 14: The Fecal Coliform sample contamination examined for water wells and networks at monthly basis throughout the year 2003 in the Mid Zone Governorate.

	Wells			Networks		
Month	**S. no**	**C. s**	**C.%**	**S. no**	**C. s**	**C.%**
January	0	0	**0****	54	0	**0***
February	0	0	**0****	36	1	**3**
March	2	0	**0**	62	1	**2**
April	0	0	**0****	51	4	**8**
May	3	0	**0***	54	1	**2**
June	1	0	**0***	77	0	**0***
July	4	0	**0***	62	6	**10**
August	1	0	**0***	56	7	**13**
September	7	0	**0**	53	2	**4**
October	0	0	**0****	40	0	**0***
November	7	0	**0***	20	1	**5**
December	6	0	**0***	67	2	**3**
Total	31	0	**Aver. 0***	632	25	**Aver. 4**

S. no: Number of the samples, **C .s:** Contaminated samples, **C%:** Contamination percentage, * No contaminated samples were detected, ** No samples were collected to examine

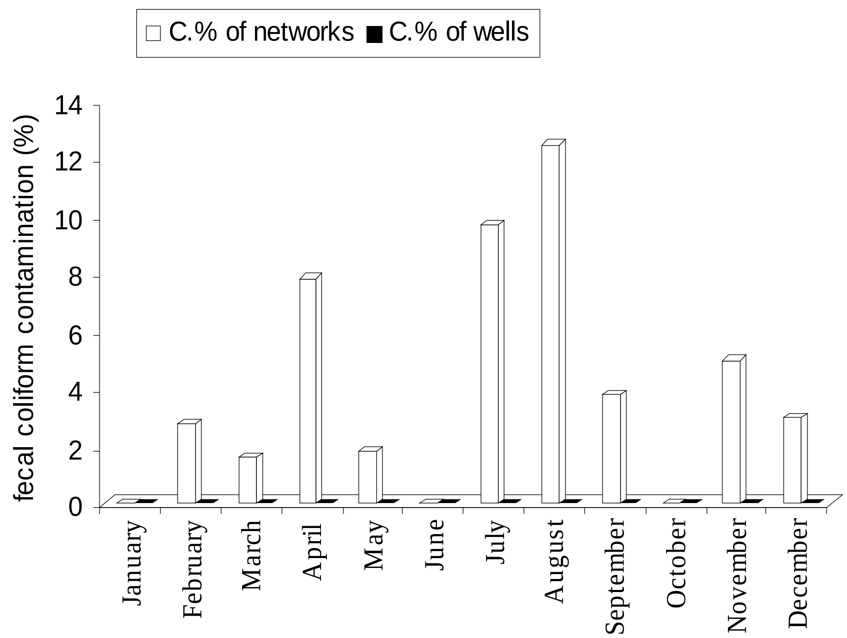

Fig. 14: Fecal Coliform contamination in water wells and networks in the Mid Zone Governorate recorded monthly throughout the year 2003

Table 15 and Figure 15 illustrate the monthly records of Total Coliform contamination in wells and networks through the year 2003 in Khan Younis Governorate. Unlike networks, no samples were collected from the wells during January, July, September, October and December. However, the number of the collected samples during the remaining months of the year were generally not meeting the minimum limit of sample number implying a non-representative contamination level in wells. Therefore the 0% contamination in wells allover the 12 month-period is questioned. Unlike wells, the minimum limit of sample number in the networks was fulfilled for most months of the year. No contaminated samples were registered during February, April and May. The Total Coliform contamination percentages in the remaining months of the year fluctuated from 5 to 44%. Although December is considered as the highest contaminated month (44%), high level of contamination were also registered in summer season showing values of 25, 30 and 29% in June, July and August, respectively.

Table 15: The Total Coliform sample contamination examined for water wells and networks at monthly basis throughout the year 2003 in Khan Younis Governorate.

	Wells			Networks		
Month	**S. no**	**C. s**	**C.%**	**S. no**	**C. s o**	**C.%**
January	0	0	**0****	25	2	**8**
February	1	0	**0***	7	0	**0***
March	10	0	**0***	25	4	**16**
April	1	0	**0***	8	0	**0***
May	3	0	**0***	6	0	**0***
June	4	0	**0***	12	3	**25**
July	0	0	**0****	81	24	**30**
August	4	0	**0***	77	22	**29**
September	0	0	**0****	28	2	**7**
October	0	0	**0****	30	5	**17**
November	4	0	**0***	22	1	**5**
December	0	0	**0****	18	8	**44**
Total	27	0	**Aver. 0 ***	339	71	**Aver. 21**

S. no: Number of the samples, **C .s:** Contaminated samples, **C%:** Contamination percentage, * No contaminated samples were detected, ** No samples were collected to examine

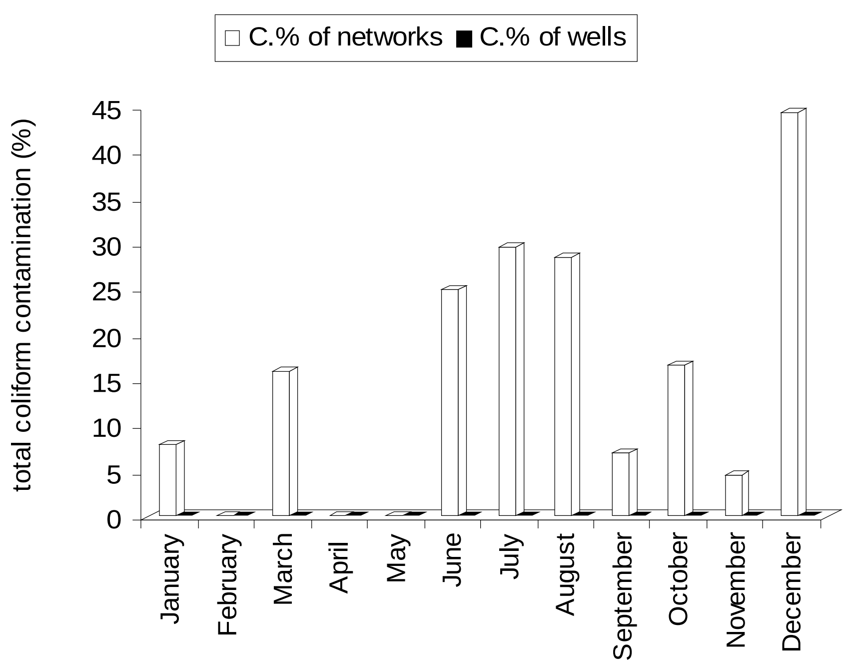

Fig. 15: Contamination percentages of water wells and networks by Total Coliform in Khan Younis Governorate recorded monthly during the 2003.

The Fecal Coliform contamination in wells and water networks registered at monthly basis in Khan Younis Governorate is presented in Table 16 and Figure 16. Like Total Coliform, there were no collected samples from the wells during January, July, September, October and December. In addition, the number of collected samples during the remaining months of the year did not generally meet the minimum limit. Hence the contamination level (0%) in wells is not representative. In networks, the number of collected samples was generally representative. No contaminated samples were detected in February, April, May and June. In the remaining months the Fecal contamination percentages exceeded that of WHO limit with fluctuation from 5 to 33%. Similar to that recorded for Total Coliform in the networks, the Fecal Coliform contamination was the highest in December (33%) followed by August and July (21 and 14%, respectively).

Table 16: Fecal Coliform sample contamination examined for water wells and networks at monthly basis throughout the year 2003 in Khanyounis Governorate.

	Wells			**Networks**		
Month	**S. no**	**C. s**	**C.%**	**S. no**	**C. s**	**C.%**
January	0	0	0**	25	2	8
February	1	0	0*	7	0	0*
March	10	0	0*	25	3	12
April	1	0	0*	8	0	0*
May	3	0	0*	6	0	0*
June	4	0	0*	12	0	0*
July	0	0	0**	71	10	14
August	4	0	0*	77	16	21
September	0	0	0**	28	1	4
October	0	0	0**	30	2	7
November	4	0	0*	22	1	5
December	0	0	0**	18	6	33
Total	27	0	Aver. 0*	329	41	Aver. 12

S. no: Number of the samples, **C .s:** Contaminated samples, **C%:** Contamination percentage, * No contaminated samples were detected, ** No samples were collected to examine

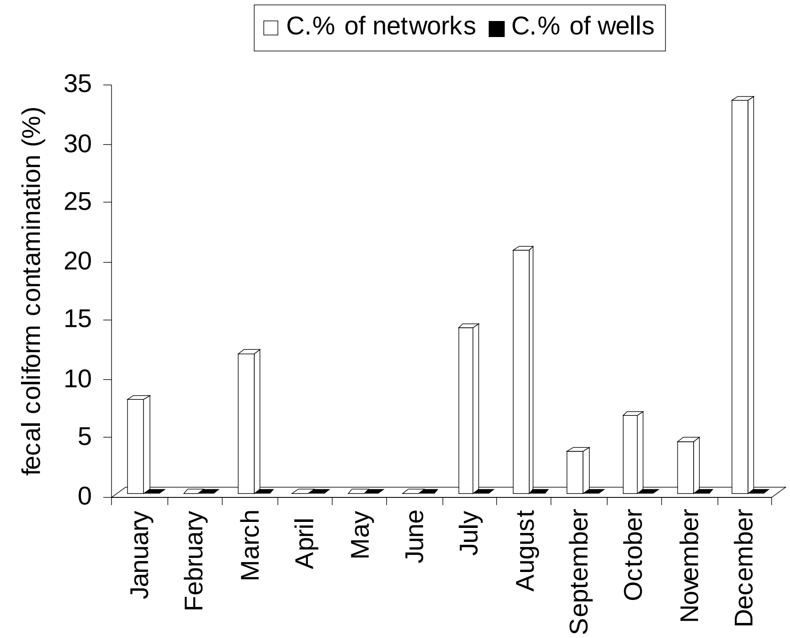

Fig. 16: Contamination percentages of water wells and networks by Fecal Coliform in Khan Younis Governorate recorded monthly during year 2003

Table 17 and Figure 17 showed the monthly records of Total Coliform contamination in wells and networks during the year 2003 in Rafah Governorate. No samples were collected from wells and networks in March. The number of samples collected from wells and networks in the rest of the year were generally representative. In wells, the contamination percentages are complying with the limit of WHO except for April, May, October and November. In the networks, the sample collected during January, September, October and December were found to be free of contamination. The highest Total Coliform contamination percentages in networks was registered in May (26%) followed by April (15%). June and July still showed high contamination percentages of 10 and 12, respectively.

Table 17: The Total Coliform sample contamination examined for water wells and networks at monthly basis throughout the year 2003 in Rafah Governorate.

	Wells			Networks		
Month	**S. no**	**C. s**	**C.%**	**S. no**	**C. s**	**C.%**
January	18	0	**0***	8	0	**0***
February	6	0	**0***	26	1	**4**
March	0	0	**0****	0	0	**0****
April	14	1	**7**	20	3	**15**
May	8	2	**25**	19	5	**26**
June	16	0	**0***	10	1	**10**
July	23	0	**0***	17	2	**12**
August	18	0	**0***	18	1	**6**
September	17	0	**0***	9	0	**0***
October	9	1	**11**	5	0	**0***
November	7	1	**14**	9	1	**11**
December	26	0	**0***	26	0	**0***
Total	162	5	**Aver. 3**	167	14	**Aver. 8**

S. no: Number of the samples, **C .s:** Contaminated samples, **C%:** Contamination percentage, * No contaminated samples were detected, ** No samples were collected to examine

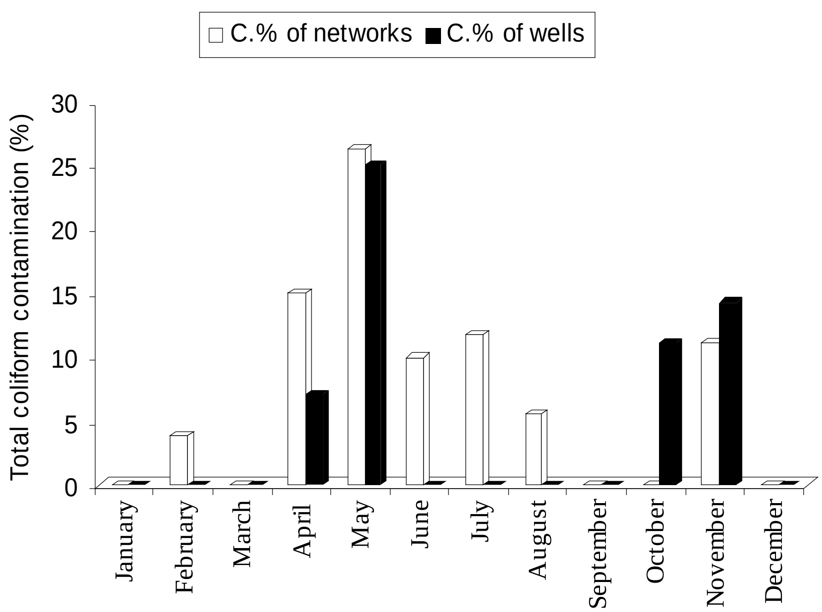

Fig. 17: Total Coliform contamination in water wells and networks in Rafah Governorate registered monthly over the year 2003

Fecal Coliform contamination registered at monthly basis for wells and networks during the year 2003 in Rafah Governorate is presented in Table 18 and Figure 18. No samples were collected from wells and networks in March. The number of samples collected from wells and networks in the rest of the year were generally representative. In wells, the values of Fecal Coliform contamination were found not to exceed the WHO limit except for April, May and June and December (14, 13, 6 and 4%, respectively). In the networks, Fecal Coliform contamination were found to comply with WHO standard except for May and August where the contamination values were 5 and 13%, respectively.

Table 18: The Fecal Coliform sample contamination examined for water wells and networks at monthly basis throughout the year 2003 in Rafah Governorate.

	Wells			**Networks**		
Month	**S. no**	**C .s**	**C.%**	**S. no**	**C .s**	**C.%**
January	18	0	**0***	8	0	**0***
February	6	0	**0***	26	0	**0***
March	0	0	**0****	0	0	**0****
April	14	2	**14**	20	0	**0***
May	8	1	**13**	19	1	**5**
June	16	1	**6**	10	0	**0***
July	23	0	**0***	17	0	**0***
August	18	0	**0***	8	1	**13**
September	17	0	**0***	9	0	**0***
October	9	0	**0***	5	0	**0***
November	7	0	**0***	9	0	**0***
December	26	1	**4**	16	0	**0***
Total	162	5	**Aver. 3**	147	2	**Aver. 1**

S. no: Number of the samples, **C .s:** Contaminated samples, **C%:** Contamination percentage, * No contaminated samples were detected, ** No samples were collected to examine

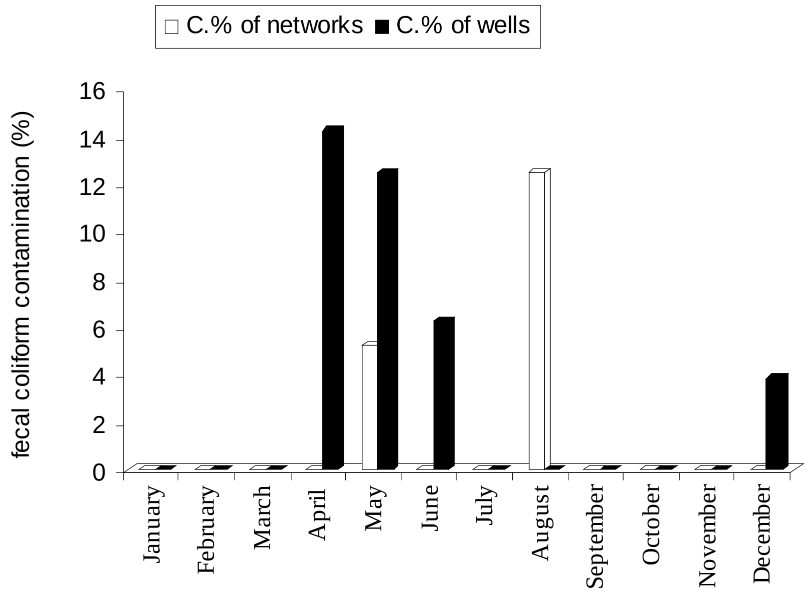

Fig. 18: Fecal Coliform contamination in water wells and networks in Rafah Governorate registered monthly over the year 2003

Comparison between the Total Coliform contamination in the wells and water networks of the five Governorates of Gaza Strip for the year 2003 is summarized in Table 19 and Figure 19. In the wells, the contamination percentages were exceeded that of the WHO limit in the North, Gaza and Mid Governorate showing values of 7, 11 and 13%, respectively. No contaminated samples were detected in Khan Younis Governorate. However, the number of the samples collected from Mid Zone and Kahn Younis Governorates during the year 2003 is questioned. In Rafah Governorate the contamination percentage was 3%. In the networks, the Total Coliform contamination was exceeded that of WHO limit for all Governorates. The highest level of contamination was registered for Khan Younis Governorate (21%) while the lowest level was recorded for Rafah Governorate (8%). The level of contamination in the North, Gaza and Mid Zone Governorates was accounted for 13, 12 and 13%, respectively.

Table 19: Comparison between the Total Coliform contamination in wells and water networks of the five Governorates of Gaza Strip for the year 2003

	Wells			Networks		
Governorates	**S. no**	**C. s**	**C.%**	**S. no**	**C. s**	**C.%**
North	285	19	**7**	354	47	**13**
Gaza	769	83	**11**	982	118	**12**
Mid Zone	31	4	**13**	632	84	**13**
Khan Younis	27	0	**0***	339	71	**21**
Rafah	162	5	**3**	167	14	**8**
Total	1274	111	**Aver. 9**	2474	334	**Aver. 14**

*No contaminated samples were detected

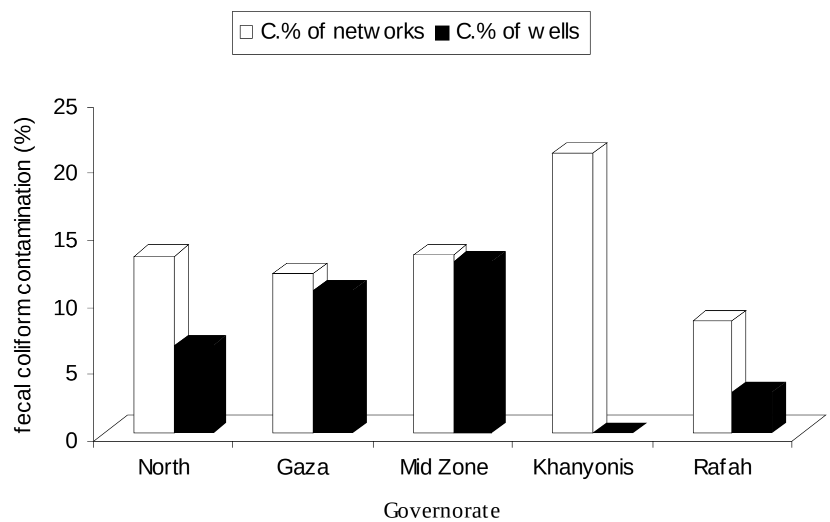

Fig. 19: Comparison between the Total Coliform contamination in wells and water networks of the five Governorates of Gaza Strip for the year 2003

Table 20 and Figure 20 summarize the levels of Fecal Coliform contamination in the wells and water networks of the five Governorates of Gaza Strip for the year 2003. In the Wells, the Fecal Coliform contamination was exceeded the WHO limit in the North, Gaza and Rafah Governorates showing percentages of 3, 2 and 3%, respectably. No contaminated samples were recorded in the Mid Zone and Khan Younis Governorates. However, the number of the samples collected from these twoGovernorates during the year 2003 is questioned. In the networks, the level of

Fecal Coliform contamination was exceeded the WHO limits for all Governorates. Like Total Coliform, the highest Fecal contamination in the water networks was registered in Khan Younis Governorate (12%) and the lowest level was recorded for Rafah Governorate (1%). The level of Fecal Coliform contamination in North, Gaza and Mid Zone Governorates were accounted for 6, 6 and 4%, respectively.

Table 20: Comparison between the Fecal Coliform contamination in wells and water networks of the five Governorates of Gaza Strip for the year 2003

	Wells			**Networks**		
Governorates	**S .no**	**C. s**	**C.%**	**S. no**	**C .s**	**C.%**
North	285	9	**3**	354	22	**6**
Gaza	767	18	**2**	974	57	**6**
Mid Zone	31	0	**0***	632	25	**4**
Khan Younis	27	0	**0***	329	41	**12**
Rafah	162	5	**3**	147	2	**1**
Total	1272	32	**Aver. 3**	2436	147	**Aver. 6**

* No contaminated samples were detected

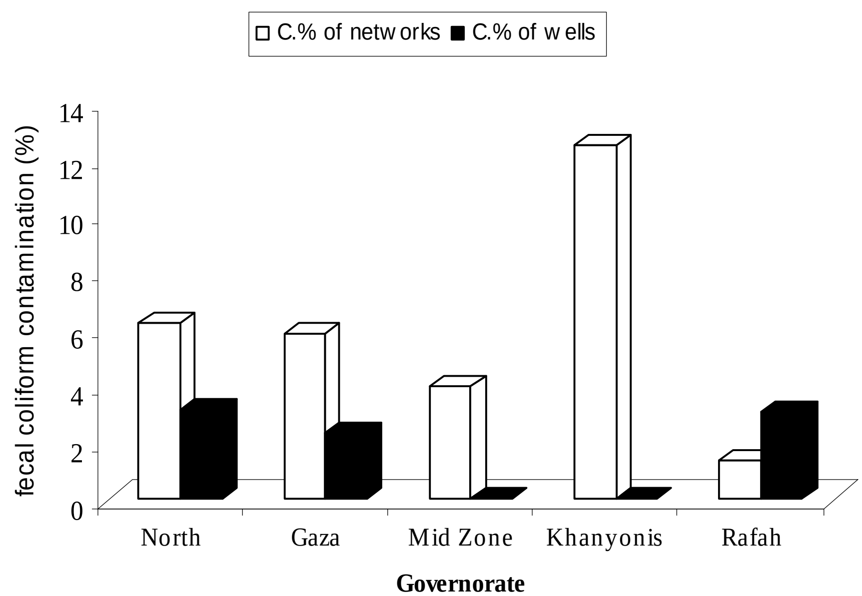

Fig. 20: Comparison between the Fecal Coliform contamination in wells and water networks of the five Governorates of Gaza Strip for the year 2003

5.3 Fecal Coliform contamination and waterborne diseases

Drinking water contaminated by pathogenic microorganism could be a source of waterborne diseases. Table 21 summarizes the incidence of various waterborne diseases collectd monthly from the records of Palestinian Ministry of Health in Gaza Strip throughout the year 2003. The registered waterborne diseases include: a) Parasitic diseases which are represented by Giardiasis, Entamabiasis and Ascariasis, b) Bacterial diseases which include salmonellosis and shigellosis, c) Diarrheal diseases which are mainly caused by parasites and to a lesser extent by bacteria and d) Viral diseases which is represented by hepatitis A.

Table 21 (a): Incidence of various waterborne diseases registered at monthly basis in Gaza Strip throughout the year 2003.

Month	Ascariasis	Entamabiasis	Giardiasis	Salmonellosis	Shigellosis	Hepatitis A	Diarrheal diseases
January	100	266	494	18	1	101	3108
February	79	237	257	42	2	123	3886
March	142	87	346	7	1	86	3399
April	169	306	456	5	2	99	3156
May	138	445	617	797	24	91	3870
June	171	769	780	149	5	61	5920
July	186	449	572	50	0	45	5763
August	138	462	478	53	0	22	3076
September	150	325	453	58	2	48	4878
October	172	1446	606	43	2	47	4450
November	84	311	324	109	0	41	3925
December	101	439	369	27	2	38	3903
Total	1461	5542	5752	1358	41	802	49334

Diarrheal diseases showed the highest incidence among waterborne diseases fluctuating from 3076 to 5920 throughout the year 2003. This is followed by Giardiasis incidence that varies from 257 to 780. For entamebiasis and Ascariasis the incidence fluctuated sharply from 87 to 1446 and 79 to 186, respectively over the year 2003. In general, the highest incidence for diarrheal and parasitic diseases was registered in June, July and October. The incidence of salmonellosis during the year 2003 fluctuated sharply from 5 to 797. No incidence cases of shigellosis were registered during July, August and November. However, the incidence of shigellosis in the remaining months varied from 1 to 24. In general, the highest incidence for bacterial diseases was found in May and June of the year 2003. The incidence of hepatitis A was found to be fluctuated from 22 to 123 over the study period with the highest incidence in February.

Table 21 (b): Incidence of various waterborne diseases registered at monthly basis in Gaza Governorates throughout the year 2003.

December	November	October	September	August	July	June	May	April	March	February	January	Months Gove.	Diseases
36	46	85	68	64	95	95	68	71	9	37	47	North	Ascariasis
33	12	53	45	37	40	35	30	58	31	25	27	Gaza	
6	9	13	11	7	9	10	7	12	7	8	10	Mid	
19	10	14	16	20	26	21	23	17	26	9	11	Khan Younis	
7	7	7	10	10	16	10	10	11	19	0	5	Rafah	
185	111	146	121	140	25	267	121	108	16	80	75	North	Entamabiasis
5	1	0	1	6	4	5	6	9	5	1	2	Gaza	
78	88	112	8	95	109	223	115	64	9	31	57	Mid	
101	45	1102	119	141	185	179	129	63	57	83	94	Khan Younis	
70	66	86	76	80	126	95	74	62	0	42	38	Rafah	
80	74	94	103	100	85	165	110	117	76	53	83	North	Giardiasis
135	113	197	152	185	223	323	162	207	127	92	109	Gaza	
66	62	101	80	68	100	142	82	36	30	11	213	Mid	
28	19	151	62	57	57	65	180	38	68	73	60	Khan Younis	
60	56	63	56	68	107	85	83	58	45	28	29	Rafah	
0	0	0	0	0	0	0	0	0	0	0	0	North	Salmonellosis
1	50	1	2	0	2	0	0	0	0	0	0	Gaza	
0	0	0	0	0	0	0	0	0	0	0	0	Mid	
0	19	0	0	0	0	0	0	0	0	0	0	Khan Younis	
0	0	0	0	0	0	0	0	0	0	0	0	Rafah	
0	0	0	0	0	0	0	0	0	0	0	0	North	Shigellosi
2	0	1	2	0	0	4	24	2	1	1	1	Gaza	
0	0	1	0	0	0	1	0	0	0	0	0	Mid	

0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**Khan Younis**	
0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**Rafah**	
5	**3**	**2**	**1**	**2**	**1**	**1**	**5**	**6**	**4**	**1**	**7**	**North**	**Hepatitis A**
16	**13**	**23**	**22**	**2**	**15**	**20**	**15**	**18**	**10**	**28**	**9**	**Gaza**	
3	**1**	**6**	**5**	**1**	**8**	**7**	**4**	**14**	**10**	**13**	**14**	**Mid**	
11	**21**	**11**	**12**	**10**	**7**	**13**	**37**	**34**	**35**	**42**	**50**	**Khan Younis**	
3	**3**	**5**	**8**	**7**	**14**	**20**	**30**	**27**	**27**	**39**	**21**	**Rafah**	
427	**504**	**447**	**592**	**52**	**858**	**937**	**967**	**553**	**822**	**441**	**413**	**North**	**Diarrheal diseases**
679	**881**	**987**	**1046**	**752**	**1508**	**1288**	**669**	**743**	**601**	**896**	**815**	**Gaza**	
979	**814**	**1034**	**1272**	**645**	**1432**	**1772**	**886**	**709**	**771**	**1197**	**361**	**Mid**	
1445	**1146**	**1129**	**1522**	**1243**	**1384**	**1234**	**856**	**771**	**671**	**791**	**940**	**Khan Younis**	
373	**580**	**853**	**446**	**384**	**581**	**689**	**492**	**382**	**534**	**561**	**579**	**Rafah**	

The level of Fecal Coliform contamination in water networks (%) is used as an indicator for water contamination by pathogens causing various waterborne diseases. Figure 21 illustrates the log rate regression/10,000 population of incidence of Giardiasis, hepatitis A and diarrheal diseases by Fecal Coliform contamination percentage in water networks examined at monthly basis during the year 2003 in Gaza Strip. The log rate regression for both diarrheal diseases and Giardiasis was steadily increased with Fecal Coliform contamination whereas that for hepatitis A was decreased over the year 2003. Gaiardiasis and diarrheal diseases showed a positive stronge correlation with Fecal Coliform contamination in drinking water networks in Gaza Strip (r =0.8 and 0.7, respectively) while a positive weak correlation was exhibited by Hepatitis A (r =0.3).

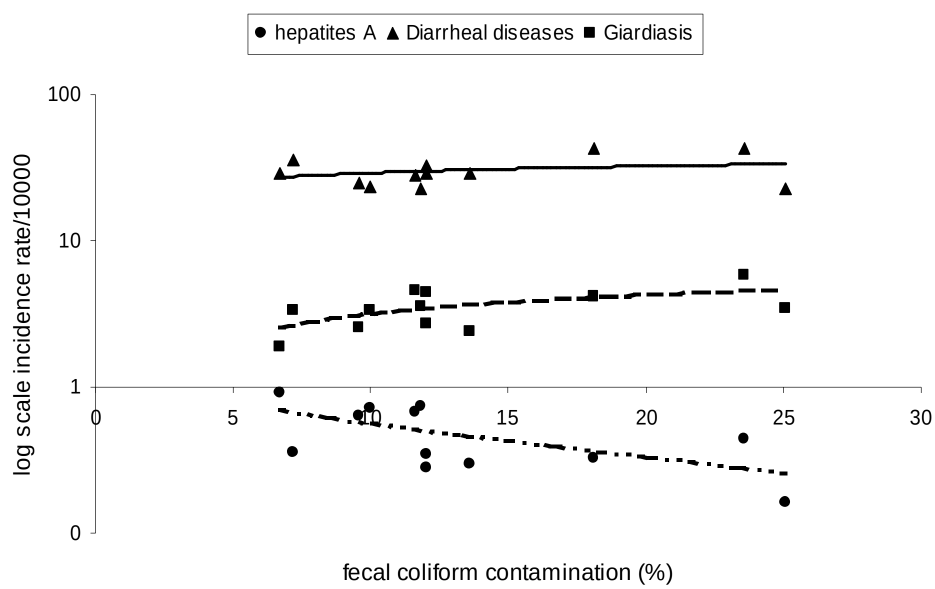

Fig. 21: Incidence of Giardiasis, Hepatitis and diarrheal diseases log rate regression/10,000 population by Fecal Coliform contamination percentage in water networks at monthly basis during the year 2003 in Gaza Strip.

For more detailed information, the incidence of the previously mentioned waterborne diseases and Fecal Coliform contamination in water networks in each Governorates of Gaza Strip during the year 2003 was investigated. Fig. 22 presents the rate of regression of incidence of Giardiasis, hepatitis and diarrheal diseases /10,000 population by Fecal Coliform contamination percentage in water networks in the North Governorate throughout the year 2003. The rates of regression for Diarrheal diseases and hepatitis A were steadily increased with Fecal Coliform contamination. On the other hands, the rate of regression for Giardiasis slightly decreased along the year 2003. Diarrheal diseases and Hepatitis A showed weak positive correlation with Fecal Coliform contamination in water networks (r =0.2). Giardiasis on the other hands was negatively correlated with Fecal Coliform contamination (r =-0.2).

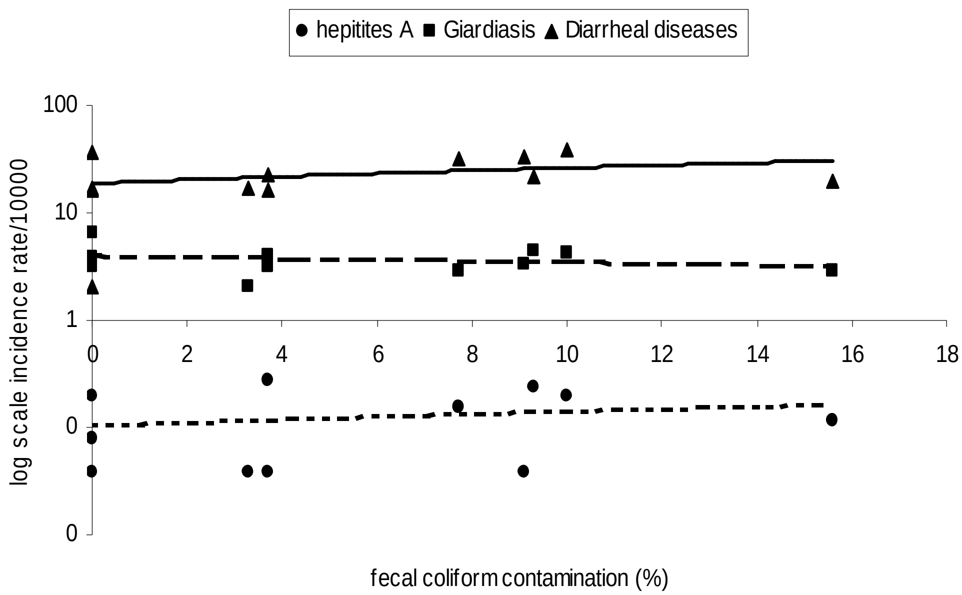

Fig. 22: Incidence of Giardiasis, Hepatitis and diarrheal diseases rate of regression/10,000 population by Fecal Coliform contamination percentage in water networks at monthly basis during the year 2003 in the North Governorate.

Fig. 23 showed the rate of regression for incidence of Giardiasis, hepatitis and diarrheal diseases /10,000 populations by Fecal Coliform contamination percentage in water networks in Gaza Governorate over the year 2003. The rate of regression of diarrheal diseases with Fecal Coliform contamination in water networks was slightly decreased while that of Giardiasis was increased. For Hepatitis A, the rate of regression was more or less constant along the year 2003. Giardisis was found to be strongly correlated with Fecal Coliform contamination in water networks (r =0.7) in

Gaza Governorate during the year 2003. However, weak correlation was shown for diarrheal diseases and hepatitis A during the same period of study (r =0.2 and 0.1, respectively).

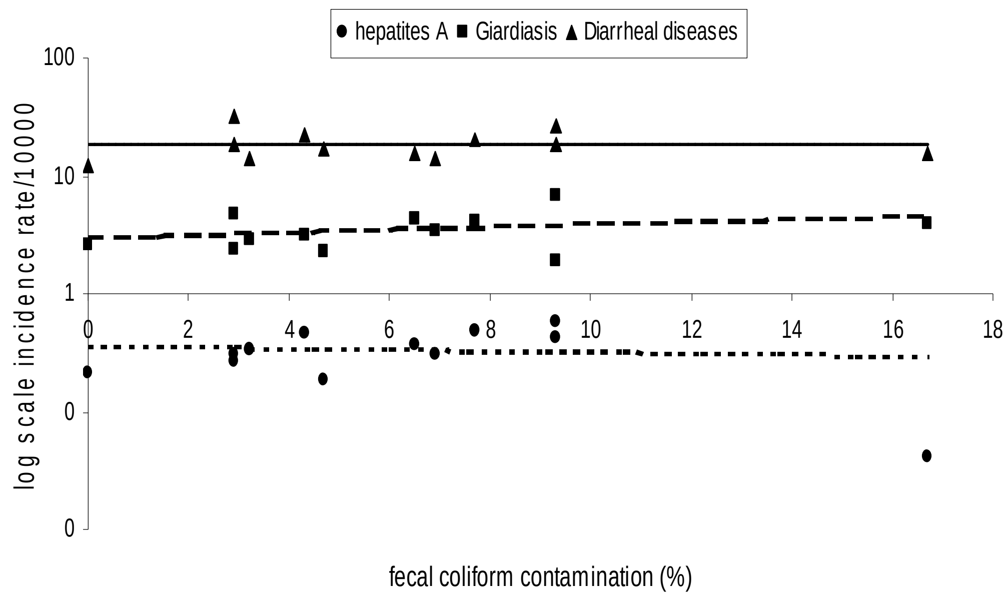

Fig. 23 Incidence of Giardiasis, Hepatitis and diarrheal diseases log rate regression/10,000 population by Fecal Coliform contamination percentage in water networks at monthly basis during the year 2003 in Gaza Governorate

Figure 24 demonstrated the rate of regression for incidence of Giardiasis, hepatitis and Diarrheal diseases/10,000 populations by Fecal Coliform contamination percentage in water networks in the Mid zone Governorate throughout the year 2003. The rate of regression of Diarrheal diseases with Fecal Coliform contamination was slightly decreased. This reduction was obvious in the case of Giardiasis and hepatitis A over the year 2003. There was inverse relationship between the incidence of the three diseases with Fecal Coliform contamination in water networks with negative correlation value of -0.1, -0.3 and –0.2 for Diarrheal diseases, Giardiasis and Hepatitis A, respectively during the year 2003.

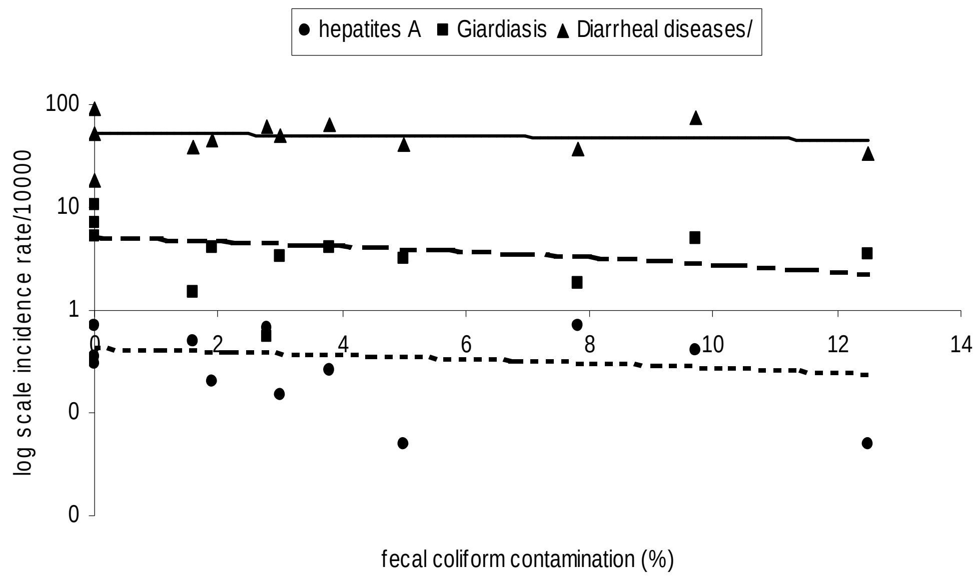

Fig. 24: Giardiasis, Hepatitis and Diarrheal diseases rate of regression/10,000 population by Fecal Coliform contamination percentage in water networks at monthly basis during the year 2003 in the Mid Zone Governorate.

Figure 25 illustrates the rate of regression for incidence of Giardiasis, hepatitis A and Diarrheal diseases /10,000 populations by Fecal Coliform contamination percentages in water networks in Khan Younis Governorate throughout the year 2003. The incidence rate of diarrheal diseases is decreased slightly along the year 2003. This decrease was clear in Giardasis and Hepatitis A during the same period of study. Diarrheal diseases showed relatively weak correlation with Fecal Coliform contamination in water networks (r =0.4). For Giardiasis and Hepatitis A the correlation was negative (r = -0.2 and –0.5, respectively) over the same period of study.

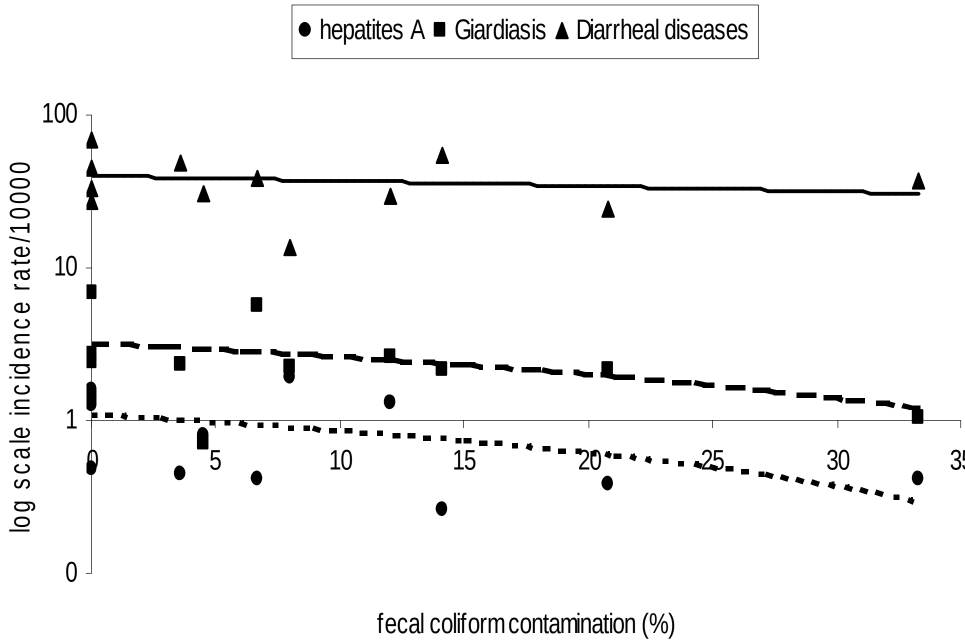

Fig. 25: Giardiasis, Hepatitis and diarrheal diseases rate of regression/10,000 population by Fecal Coliform contamination percentage in water networks at monthly basis during the year 2003 in Khan Younis Governorate.

Figure 26 presents the rate of regression for incidence of Giardiasis, Hepatitis A and diarrheal diseases /10,000 populations by Fecal Coliform contamination percentage in water networks in Rafah Governorate along the year 2003. The rates of regression for both diarrheal diseases and Hepatitis A with Fecal Coliform contamination were slightly decreasing during the year 2003. For Giardiasis, the rate of regression was nearly constant during the same period. Giardiasis and hepatitis A were weakly correlated with Fecal Coliform contamination in water networks (r=0.3 and 0.1m respectively) during the year 2003. However, negative correlation was recorded for diarrheal diseases (r= -0.3) during the same period.

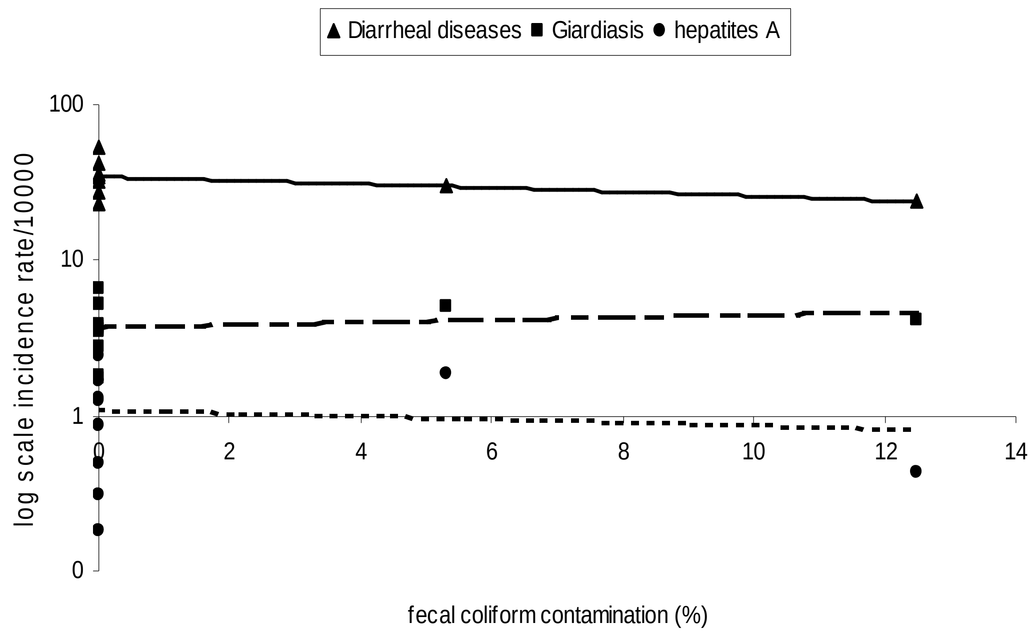

Fig. 26: Giardiasis, Hepatitis and diarrheal diseases rate of regression/10,000 population by Fecal Coliform contamination percentage in water networks at monthly basis during the year 2003 in Rafah Governorate.

5.4 water situation and its relation to human health

Questionnaire interview

The following data were collected by a questioner interview from one handed and fifty people living in Gaza City. Table 22 gives the personal profile of the study population. Their mean age was (34.4 ± 1.0). The age distribution showed that the highest count was for the age group of 21 to 30 years (41.3%) while the lowest 14 (9.3%) was for the age group of ≤20 years. Analysis of the educational status of the interviewed people showed that 110 (73.3%) had a university degree, 24 (16.0%) had finished secondary school, 10 (6.7%) had finished preparatory school, 3 (2.0%) had passed primary school, and 3 (2.0%) were illiterate. Regarding occupation, the majority of the interviewed people 101 (67.3%) were employee, 16 (10.7%) were workers and 33 (22.0%) were unemployed. A Total of 61 (40.7%) people have a family of 6 to 8 members followed by 46 (30.7%) who have 3 to 5 members and by 26 (17.3%) who have more than 8 members and finally 17 (11.3%) have 1 to 2 members.

Table 22: Personal profile of the study population (n=150)

Item	No.	%
Age mean (34.4 ± 1)		
≤ 20 years	14	9.3
21 - 30	62	41.3
31 - 40	31	20.7
41 - 50	24	16.0
>50	19	12.7
Occupation		
Employee	101	67.3
*Worker	16	10.7
Unemployed	33	22.0
Family number		
1 to 2	17	11.3
3 to 5	46	30.7
6 to 8	61	40.7
>8	26	17.3
Education		
illiterate	3	2.0
primary school	3	2.0
preparatory school	10	6.7
secondary school	24	16.0
university	110	73.3

*Agricultural, constructional and industrial workers

Table 23 summarizes the response of the study population (n=150) on various aspects of domestic water supply in Gaza City. A Total of 17 (11.3%) said that they depend on municipal water for drinking. However, 88 (58.7%) claimed that they depend on desalinated water followed by 45 (30.0%) who depend on home filters for drinking. For washing and bathing purposes, most people 148 (98.7%) admitted the use of municipal wells whereas only 2 (1.3%) used special wells. A Total of 51 (34.0%) of the study population reported that the local water networks aged >5 years, 31 (20.7%) claimed that the networks aged 5 years, 19 (12.7%) said that the water networks is 3 years old and only 10 (6.7%) stated that the water networks has been established since one year. However, 39 (26.0%) don't Know the age of the water networks.. The majority of people 143 (95.3%) reported interruption of water supply; 74 (51.1%) reported 2 to 3 days interruption, 34 (24.0%) reported one-day interruption and 33 (22.9%) reported more than 3 days interruption. Most of the interviewed people 104 (69.3%) reported the taste of chlorine in drinking water

Table 23: Response of study population (n=150) on the various aspects of domestic water supply in Gaza City.

Item	No.	%
Type of drinking water source		
municipal water	17	11.3
desalinated water	88	58.7
home filter	45	30.0
Washing and bathing water		
municipal wells	148	98.7
special well	2	1.3
Age of water networks (year)		
1	10	6.7
3	19	12.7
5	31	20.7
> 5	51	34.0
don't know	39	26.0
Interruption of water supply	143	95.3
Interruption interval (day)		
one	34	24.0
2 - 3 more	74	51.1
>3	33	22.9
Taste of chlorine	104	69.3

Table 24 presents information on the use of roof water tanks and their situation at homes in Gaza City. All the study population 150 (100.0%) reported the use of roof water tanks as a source of water supply in their houses. Most of them 149 (99.3%) used black plastic tanks while only 1 (0.7%) used white plastic tanks. Although 91 (60.7%) see suspensions, alga and settlements in the roof water tanks, 52 (34.7%) of the population clean them. However, most of the interviewed people 142 (94.7%) claimed that they closed their roof water tanks properly.

Table 24: Use of roof water tanks and their situation as reported by the study population (n=150) in Gaza City.

Item	**No.**	**%**
Use of roof tanks	150	100
Types of tanks		
black plastic	149	99.3
white plastic	1	0.7
Cleaning of water tanks	52	34.7
Suspension, alga and settlements observed	91	60.7
Closed water tanks	142	94.7

Table 25 illustrates the situation of wastewater networks system in Gaza City as reported by the interviewed people (n=150). Most of the population 146 (97.3%) are connected to the sewage networks system. On the other hand, 4 (2.7%) are not connected; 3 (2.0%) disposed wastewater in cesspools and 1 (0.7%) drainage wastewater in open area. A Total of 59 (39.3%) of the study population reported that the sewage networks aged >5 years, 28 (18.7%) claimed that the networks established since 5 years, 14 (9.3%) said that the sewage networks is constructed since one year and 11 (7.3%) stated that the sewage networks has been found since 3 years. However, 38 (25.3%) don't Know the age of the sewage networks. More than half of the population 85 (57.0%) reported sewage flood; 58 (68.2%) of them said that flood occur along summer and winter seasons, 22 (25.9%) stated that flood happen during winter and only 5 (5.9%) states that it happens in summer.

Table 25: Response of study population (n=150) on the situation of wastewater networks system in Gaza City.

Item	No.	%
Connected to sewage networks	146	97.3
No sewage networks		
cesspools	3	2.0
open area	1	0.7
Age of sewage networks (year)		
1	14	9.3
3	11	7.3
5	28	18.7
> 5	59	39.3
don't know	38	25.3
Sewage flood	85	57.0
summer	5	5.9
winter	22	25.9
summer and winter	58	68.2

Table 26 showed self reported waterborne diseases as claimed by the study population (n=150) in Gaza City. Self reported symptoms and diseases were claimed by 92 (61.3%) of the interviewed people; 45 (48.9%), 36 (39.1%), 6 (6.5%) and 5 (5.4%) reported diarrheal diseases and vomiting diarrheal diseases, vomiting and hepatitis A, respectively. Most of people 82 (89.1%) said that they received treatment; 46 (55.4%) of them received treatment at the hospital and Governmental clinics, 31 (37.3%) treated at home and only 6 (7.2%) visit special clinics for treatment.

Table 26: Self reported waterborne diseases and treatment as claimed by the study population (n=150) in Gaza City.

Item	No.	%
Occurrence of symptoms and diseases	92	61.3
Type		
Diarrheal diseases	36	39.1
Vomiting	6	6.5
Diarrheal diseases and vomiting	45	48.9
Hepatitis A	5	5.4
Treatment	82	89.1
location		
Home	31	37.3
Hospital and governmental clinic	46	55.4
Special clinic	6	7.2

Table 27 illustrates awareness of the study population (n=150) towards drinking water contamination in Gaza City. The interviewed people believed that water transmit diseases either through networks 139 (92.7%) or through roof tanks 109 (72.7%). When asked “Do you think that water in Gaza Strip is Suitable for drinking?” only 15 (10.1%) agreed. Forty three (28.9%) of the interviewed people participated in educational programs on the health impact of polluted water. Only 10 (6.8%) of the study population mentioned that some body visit them to explain water situation in their areas.

Table 27: Awareness of the study population (n=150) towards drinking water contamination in Gaza City.

Items	Yeas		No	
	No.	%	No.	%
Do you think that drinking water transmit diseases?	139	92.7	11	7.3
Do you think that water roof tanks transmit diseases?	109	72.7	41	27.3
Do you think that water in Gaza Strip is Suitable for drinking?	15	10.0	135	90.0
Have you been attended educational programs on the health impact of polluted water?	43	28.7	107	71.3
Does any body visit you to explain the water situation in your area?	10	6.8	140	93.2

Table 28 summarizes the relation between incidence of self reported waterborne diseases and various aspects of drinking water and sewage networks in Gaza City. The numbers of interviewed people who mentioned to depend 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 directly, a Total of 12 (70.6%) had self reported waterborne diseases whereas 80 (60.0%) out of those who use to drink desalinated and home filtered water had such diseases (OR=1.6). The highest percentage of self reported diseases incidence 24 (77.4%) was found among persons who claimed that the age of municipal water networks is 5 years (OR=3.43). For sewage networks, the highest percentage of self reported diseases incidence 37 (62.7%) was found among persons who claimed that the age of sewage networks is more than 5 years (OR=1.29). The number of self reported infected persons 57 (77.0%) who reported the interruption of water supply for 2-3 days was the highest (OR=3.35). Self reported diseases incidence by sewage flood were found in 59 (69.4%) of questioned people in Gaza City (OR=2.2).

Table 28: Summary of the relationship between the incidence of self reported waterborne diseases and different aspects of drinking water and sewage networks in Gaza City**.**

Item	**Total individuals**	**Self reported infection No. (%)**	*** OR (95% CI)**
Source of drinking water			
Municipal water	17	12 (70.6)	1.6 (0.5-4.75)
Filters and desalination	133	80 (60.0)	
Age of water networks (year)			
1	10	5 (50.0)	
3	19	13 (68.4)	2.17 (0.35 to 14.1)
5	31	24 (77.4)	3.43 (0.16 to 20.06)
> 5	51	24 (47.0)	0.89 (0.19 to 4.14)
Age of sewage networks (year)			
1	14	8 (57.2)	
3	11	5 (45.2)	063(0.09 to 4.04)
5	28	16 (57.2)	1.00 (0.23 to 4.4)
> 5	59	37 (62.7)	1.26 (0.33 to 4.74
Interruption of water supply (day)			
1	34	17 (50.0)	
2-3	74	57 (77.0)	3.35 (1.3 to 8.73)
>3	33	14 (42.4)	0.74 (0.25 to 2.15)
Sewage flood	85	59 (69.4)	2.2 (1.07 to 4.55)

* Odd ratio at Confidence Interval 95%

Chapter (6)

Discussion

The present study describes the microbial quality of groundwater wells and networks distribution system for all Governorates of the Gaza Strip. Specifically, the study aimed to 1) Evaluation of water wells and networks distribution system of Total and Fecal Coliform contamination during 1999 to 2003 at annual basis, 2) Assessment of water wells and networks distribution system of Total and Fecal Coliform contamination at monthly basis during the year 2003, 3) Identification of the most common waterborne diseases in Gaza Strip, 4) Investigation of the relationship between Fecal Coliform contamination with waterborne diseases (Giardiasis, Hepatites A and Diarrheal diseases) and 5) Evaluation of water situation and its relation to human health in Gaza Strip through questionnaire interview. The groundwater wells and water networks included in this study were selected in such away to cover all the possible source of drinking water purposes for all Governorates in Gaza Strip (Annex 1). The results of microbiological parameters examined include Total Coliform and Fecal Coliform.

Total Coliform is a good indicator for contamination of water because most enteric bacteria pathogens die off very rapidly outside the human gut, whereas indicator bacteria such as E. coli will persist for periods of time (Ward et al., 1984). In addition, Fecal Coliform is a common indicator in vulnerable water systems. In a study conducted in Indonesia, Geoffery et al. (1999) have showed that most of the 130 tested groundwater wells were heavily contaminated with Fecal Coliform. In another study on the relationship between land use and groundwater pollution in Argentina, Hectar et al. (1998) have reported that Fecal Coliform was detected in 60% of the 50 examined wells.

The presence of Total Coliform group in a water system should, be supported by testing of Fecal Coliform, since the presence of Total Coliform may be due to the colonization of a water system by non Fecal *Klebsiella, Enterobacter or Citrobacter sp*. (Geldreich, 1986). Therefore Total Coliform and Fecal Coliform tests should be simultaneously applied for testing water samples in order to exclude the contamination by environmental Coliforms. In United States, e.g., all public drinking water systems are required to monitor for Total and Fecal Coliform bacteria under the Total Coliform Rule (EPA, 1989a).

In spite of regulations to protect groundwater and the distribution system from microbial contamination, the annual bacteriological analysis of drinking water for each Governorate in the Gaza strip during the period from 1999 to 2003 revealed that the Total and Fecal Coliform contamination in wells and water distribution networks was generally higher than that of the WHO limit. The drinking water source and its delivery system (casing, pump, pipes and other appurtenances) must be free of Fecal contamination from either surface (e.g. waste infiltration) or subsurface (e.g. cesspools) source. Specially, the water must meet the guideline criteria of microbiological quality (WHO, 1996).

Melad, et al, 2002 mentioned that the infiltration of wastewater in Beith Lahia- Gaza Strip directly affects the microbial quality of groundwater. Beith Lahia has a very sever chemical and biological contamination problems due to the flooding of the existing wastewater treatment plant to the nearest sand dunes. The same problems are tangible in all the surrounding areas of wastewater treatment plant in Rafah. Khanyounis Governorate has no sewer system and the residents use cesspits which finally infiltrate to the groundwater.

Ray, et al., 1990: mentioned that disposal of domestic wastewater, particularly the use of cesspools, abandoned wells, or other subsurface excavations are the major source of microbial contamination of groundwater wells. Bacteria can enter wells from the space between the wall of the drilled well and the outside of the well casing in case of flooding. Generally, allover aquifers in Gaza Strip describe as an unconfined sandstone aquifer and shallow water table led to increasing percolation and infiltration of flooded wastewater to groundwater. Cracks occurring in some clay layers and lens may cause a direct injection of wastewater with highly microbial content to groundwater.

Although Gaza Governorate has an improved water supply system (wells and networks) compared to the other Governorates of the Gaza Strip (personal communication), Total Coliform contamination is still far exceed the WHO limit in most of the network tested samples. The contamination is also detected in the wells to a lesser extent. Increasing of Total and Fecal Coliform contamination in water networks than that in the wells for all Governorates in Gaza Strip led to increasing the reversal health impacts of persons who depend on the municipal water for drinking purposes. The main conveying system of water is the networks

The main problem in Gaza Strip is the lack of spare parts and professional to repair and maintain water distribution system. Leakage form nodes and joints, interruption of water supply for many hours a day increase the possibilities of wastewater seepage to water network. In addition, the problems of networks contamination will exacerbated due to the destruction of the infrastructure including water and wastewater networks by the Israeli militant activities. WHO, 1996 reported that deterioration of the bacteriological quality of water during distribution can occur and there where are a number of places contamination can be introduced. In addition many wells have damage chlorination units. Chlorination chemical compounds in many cases are not in the market due to the Israeli restriction and closure.

In general, the major factors contributing for Coliform problem in the distribution system may include:

1) improper operation and inadequate or interrupted disinfection and problem with system maintenance. El-Mahallawi (1999) concluded that the disinfection efficiency is not sufficient and the chlorination processes are not well implemented in most of the cases in Gaza Strip. PWA (2002) estimated that The efficiency of water distribution system in the governorates of the Gaza Strip ranges from 54 to 71%.

2) Dead-end and slow-flow areas of distribution system contribute highly to bacterial growth due primarily to the loss of disinfectant residual and its inhibitory effect on bacterial growth,

3) Available of sufficient nutrients in standpipe or storage reservoir that is not used for some period of time. It was indicated that in the drinking water of the Barcelona distribution system the factor that controls the growth of bacteria is organic carbon. Moreover, bacteria from the biofilm growing on the surface of the pipes may cause the problems of bacterial growth (Frias et al, 2001),

4) Cross contamination of pipeline systems. Schmitz, (1984) reported that Cross contamination of pipeline systems is one of the more common ways in which drinking water supply system is contaminated by sewage,

5) water main repairs and new main construction. Microbial contamination can occur as a result of the use of unsuitable materials for items coming into contact with water. Such materials include those used for washers, jointing and packing materials, pipe and tank lining compounds and plastic used in pipes, tanks, and faucets, all of which can deteriorate to form substances that support the growth of microorganisms (WHO, 1996) and

6) The hydraulic effect of high-flow rates and high pressure. This effect helps in shedding biofilm organisms from the pipe or sediment surfaces. Biofilms developed in all aquatic ecosystem and water distribution systems are no exception (Nagy et al., 1983 and Donlan et al., 1987). The impact of deteriorating pipes on water quality in the distribution network has not been considered. High pressure can also cause breaks in pipes when pressure fluctuates suddenly due to rapid changes in demand. Such fluctuation and interruption of water supply may cause an inverse pumping of wastewater or other contaminants from outer surrounding system when leakage and break existed in the distribution system. El-Mahallawi (1999) found that the percentage of the water losses in the distribution system is high. The average value is 37% of the supplied water in the Gaza Strip.

To provide us with the recent situation of the microbial water quality and to understand the influence of season on it, the level of microbial contamination in both water wells and networks was investigated at monthly basis throughout the year 2003 in the different Governorates of the Gaza Strip. In contrast to water networks, the number of collected samples from wells for Total and Fecal colfroms analysis in Mid Zone and Khan Younis Governorates during various months dose not meet the minimum limit of sample number implying a non representative contamination percentages, but at least it gives indication of contamination.

It is recommended that a minimum of four samples per month is to be examined for water supply systems. As a general guide, the World Health Organization (1996) recommends that one sample per 1000 persons served should be examined each month for supplies serving up to 100 000 persons. For supplies serving populations over 100 000, it is considered justifiable to reduce the sampling increment to one per 10000 persons per month (Annex 3). In systems serving populations of this size, the interval between successive samples will be very short. The samples should be taken at regular intervals throughout the month. In water supplies with a history of high-quality water production, it may be possible to reduce the number of samples taken for bacteriological analysis. Therefore, the water-monitoring program in Gaza Strip should be applied to increasing the monitoring of supplies and number of samples. However, the monitoring processes are restricted by the complexity of water distribution system (Ross, 2004). Chlorine residual tests should be made when bacteriological samples are taken. Samples should be taken at the point where the water enters the system and from representative points throughout the network, although not necessarily the same points on each occasion. If the water supply is obtained from more than one source, the location of sampling points in the distribution system should ensure that water from each source is periodically sampled. The majority of samples should be taken in potential problem areas: low-pressure zones, reservoirs, dead ends, areas at the periphery of the system farthest from the water source and areas with a poor previous record (FPTC, 2002).

The implemented water-monitoring program in Gaza Strip has no clear strategy for the number and location of the samples to be collected regarding to the population distribution and density. In addition to unqualified monitoring team, the existing political situation made it impossible to reach the southern and middle Governorates in regular manner. Moreover, the institutional overlapping and unclear mandate of municipalities, local communities and the ministry of health lead to confusion in the continuity of the monitoring program.

Monthly data registered throughout the year 2003 also showed that Total and Fecal Coliform contamination do exist in water wells and networks in different Governorates of Gaza Strip. This could be largely attributed to the fact that about two thirds of the population in Gaza Strip is deprived of sewage networks system and row wastewater is discharged into cesspools, open drain and vaults that may infiltrate of wastewater into the soils and sediments will carry the contaminant towards the water table (Al-Agha, 1995 and Yassin and Abd Rabou, 2002). This situation is now improved largely, except in Khanyounis, 78, 98, 75 and 85% of population is connected to sewer system in the North, Gaza, Mid Zone and Rafah Governorates, respectively (PWA, 2002). However, the level of contamination in networks was generally higher than that in wells in the most months of the year. This could be largely attributed to the major factors contributing for Coliform problem in the distribution system (previously discussed) while in some months of the year in the North and Gaza governorates the level of contamination in wells was higher than that in networks. This may refer to infiltration of wastewater. The infiltration of wastewater in Beith Lahia- Gaza Strip directly affects the microbial quality of groundwater (Melad, 2002).

Microbiological analysis of water wells and networks at monthly basis for all Governorates in Gaza Strip showed fluctuation in the level of Total and Fecal Coliform contamination throughout the year 2003. The highest level of contamination was generally observed in summer and winter seasons. Similar results were obtained by El-Mahallawi, 1999 and Isobe et al., 2004. Mertens et al., 1990 found that the absence or presence of Fecal Coliform in drinking water changed with season and varied between areas and between types of water source. Steets et al., 2003 suggested that there are seasonally varying roles for coastal lagoons in mediating Fecal Coliform contamination to coastal waters. During summer season high level of Total and Fecal Coliform contamination especially in networks refers to increasing of water supply interruption. This help the growth of biofilm bacteria inside the distribution system and then high pressure led to distribute such bacterial growth contamination allover the distribution networks. El-Mahallawi, (1999) pointed out that in summer season when water demand increases there is not enough water in the pipes to supply the community in Gaza Strip so the water is alternating distributed over the areas giving a chance for Total and Fecal Coliform contamination. During the winter season, storm water rainfall caused flood includes water, wastewater, animals manure and other contaminants with high microbial content. Flood moving from upstream to downstream meets to drinking water wells which located in the lower lands led to groundwater contamination as well as water networks. Heavy rainfall has been shown to allow significant vertical migration of indicator microorganisms and increasing Fecal pollution (Zyman and Sorber, 1988 and chippaux et al., 2002).

Water played a significant role in the transmission of human disease. Bacteria, viruses and protozoa that cause disease are known as pathogens. Fecal Coliform in water indicates that the water may contain one or more of these organisms that can cause human diseases. Moreover, an increase in the concentration of the indicator measure should increase the risk of illness (Timothy, 2003). Giardiasis, Entamabiasis, Ascariasis, Diarrheal diseases Hepatites A, Salmonilasis and Shegellosis are some of waterborne diseases registered in Gaza Strip during the year 2003. Also, these diseases can be transmitted to human by food.

The log rate of regression/10,000 population and correlation were achieved between waterborne diseases (Giardiasis, hepatitis A and diarrheal diseases) with Fecal Coliform contamination in water networks for each Governorate in Gaza Strip monthly throughout the year 2003. The rate of regression can help to understand the relation between variables while the correlation presents significant values, which illustrates the conjunction between two variables. Fecal Coliform contamination is used her as an indicator of pathogenic microorganisms (Bacteria, Viruses and Parasites) in the water networks distribution system which is the main conveying system of water supply to consumers (WHO, 1993 and Qi et al., 2004).

In Gaza Strip as a whole, a strong positive correlation was found for Giardiasis and diarrheal diseases with Fecal Coliform contamination in water networks whereas correlation with hepatitis A was relatively weak. Diarrhea was strongly associated with source of drinking water In Gaza Strip (Abu Mourad, 2004). However, weak positive and negative correlation was generally recorded between incidence of such diseases and Fecal contamination in water networks in each governorates of Gaza Strip except of Gaza Governorate were Giardiasis showed strong correlation. Giardiasis was reported to be prevalent in Gaza City (Yassin et al., 1999 and shubair et al., 2000). This may refer to :

1) unrepresentative number or missing of collected samples from water networks particularly in Khan Younis and Rafah Governorates during various months,

2) reported cases of diseases do not coincide with time of Fecal Coliform contamination tested at monthly basis for each Governorat i.e. symptoms appearance required time since disease exposure. This may be avoided in case of annual reporting for the Gaza Strip as a whole,

3) dependence of the calculations only on the people who reported that they received treatment in hospitals and Governmental clinics (55.4%) as indicated by the conducted questionnaire interview and

4) poor reporting of diseases incidence in the Gaza Strip. Awad (2001) reported that underreporting of infectious diseases remains a major problem in communicable disease surveillance in Gaza Strip. He recommended unification of the reporting forms between different health providers, increased involvement of health providers in reporting of infectious diseases and complete separation of surveillance and clinical activities in epidemiology departments.

In order to study the health impact of contaminated water on consumers a questionnaire was prepared. The questionnaire includes information about: the personal profile of the study population, various aspects of domestic water supply for the people who live in the study area, the use of roof water tanks and their situation, situation of wastewater networks system, occurrence of waterborne diseases and treatment and awareness of the study population towards drinking water in Gaza City. The role of the local community is highly appreciated during the course of this work. The participatory appraisal is a means of learning from and with the local people, and this helps us very much in conducting this part of the study. People in Gaza Governorate showed good intention to participate in the questionnaire interview. The low level of illiteracy recorded among the participants reflects a well-educated community. This will help in enhancing the level of awareness towards the health impact of contaminated water and in launching educational environmental programs in the future. The unemployment problem reported in the presence study indicated bad economical situation in Gaza Strip. Similar results were shown by Yassin et al., 2002. Most of the interviewed people was found to depend on desalinated water and home filters for drinking while small numbers of them depend on municipal water. This indicated that people in Gaza Strip seem to have good knowledge which is reflected in good practice. Their good Knowledge was apparent when the majority of them stated that the water in Gaza Strip is unsuitable for drinking. Palestinian Hydrology Group, PHG, (2002) reported that the quality of drinking water served to consumers in Gaza Strip is bad.

In general water and wastewater networks in Gaza Strip are in bad situation, old and need urgent development. This was clear when most of interviewed people reported that the age of water and wastewater networks were more than 5 years old. However, self reported symptoms was less in people claimed that the age of water networks >5 years old (OR= 0.89). This could be refer to improvement of water networks in the resent years. El-Mahallawi (1999) reported that in most of Gaza Governorates, the existing of water supply networks are very old and deteriorated. The water networks of most municipalities are physically separated from each other, making it impossible efficiently manage the whole sector (PWA, 2002). About half of the interviewed people reported 2 to 3 days water interruption. Drinking water supply in the Gaza Strip is still of insufficient quality and intermittent, with interruptions of supplies sometimes lasting for several days. (PWA, 2002), The shortage in water resources and the increased water demand by fast growing of the population in Gaza Strip (Tubail et al., 2004) forced the Palestinian water authority to do so. This led to suitable conditions of biofilm bacterial regrowth giving more chance for water contamination. PHG, 2002 reported that the quantity of water available in Gaza Strip is limited due to excessive exploitation, over pumping, and low rainfall.

Use of roof tanks for storage water is found to be a common practice in Gaza Strip due to frequent water interruption and increasing of water demand. Similar results were obtained by El-Mahallawi, 1999. However, most of the interviewed people admitted that they do not clean water tanks which give another chance for water contamination. Abu Mourad (2004) reported that diarrhea was strongly associated with the source of drinking water, a full-day water supply and cleaning of water tanks.

Data revealed that sewage flood occurred mostly during winter and summer seasons. This may contribute to microbial contamination of water wells and networks. Melad, 2002 reported that the infiltration of wastewater in Beith Lahia-Gaza Strip directly affected the quality of groundwater. Most of the interviewed people claimed the occurrence of waterborne diseases-related symptoms. Diarrheal diseases and vomiting were the most mentioned ones. The prevalence of parasitic and diarrheal diseases are common in Gaza Strip (Lasch et al., 1983; Yassin et al., 1999 and Shuobair et al., 2000). In addition, Abu Morad (2004) reported that the intestinal parasites were strongly associated with crowding, source of drinking water and the cleaning of water tanks in Nuseirat Refuge Camp of Gaza.

In their view, the people believed that the drinking water in Gaza Strip is unsuitable for drinking. In addition, most of them believed that drinking water and roof tanks transmit diseases. Not more than one third of the questioned people attended educational program on the health impact of polluted water or even they rarely visited by health educators or somebody to explain the situation of water in their areas. This necessitates raising of health educational level and awareness. Yassin et al., 2002 and Abu Morad, 2004 concluded that health education and environmental awareness are urgently needed in Gaza refugee camps.

Chapter (7)

Conclusion and recommendations

7.1 Conclusion

1. The annual level of Total and Fecal Coliform contamination in both water wells and networks was generally exceeded that of WHO limit in Gaza Strip during the years of 1999 to 2003.

2. Total and Fecal Coliform contamination percentages registered at monthly basis throughout the year 2003 were also exceeded the WHO limit in most Gaza Strip Governorates particularly in summer and winter seasons. However, the number of collected samples were not meet the minimum limit of sample number particularly in Mid Zone and Khan Younis Governorates implying no representative contamination percentages.

3. The level of Total and Fecal Coliform contamination in water networks was higher than that in wells in Gaza Strip Governorates.

4. The incidence of various waterborne diseases collected monthly from the records of Palestinian Ministry of Health in Gaza Strip throughout the year 2003 included: a) Parasitic diseases which are represented by Giardiasis, Entamabiasis and Ascariasis, b) Bacterial diseases which include salmonellosis and shigellosis, c) Diarrheal diseases which are mainly caused by parasites and to a lesser extent by bacteria and d) Viral diseases which is represented by hepatitis A.

5. A strong positive correlation was found for Gaiardiasis and diarrheal diseases with Fecal Coliform contamination in drinking water networks in Gaza Strip (r =0.8 and 0.7, respectively) whereas correlation with hepatitis A was relatively weak (r =0.3).

6. The questionnaire interviewed revealed that diarrhea diseases and vomiting were the most self reported waterborne diseases claimed by the interviewed people in Gaza City. Such diseases were more prevalent among persons who used municipal water than persons used desalinated water and home filtered for drinking. In

addition, people in Gaza Strip seem to have good knowledge toward contamination of drinking water which is reflected in good practice.

7.2 Recommendations

1. Implementation of protection system for water wells and networks.

2. Frequent maintenance of the sewage water networks to reduce wastewater flooding events and hence to minimize the spread of waterborne diseases.

3. Raise the monitoring level of all water resources near the source of pollution such as septic tanks, cesspools and wastewater treatment plants and decentralizing of monitoring program

4. Minimizing of the interruption intervals of water supply.

5. Establishment of data base program in the hospital and clinics for documentation of waterborne diseases incidence in addition to analysis of the local data and water pollution to limit the spread of such cases to residents.

6. Raising of public awareness programs should be developed.

7. further studies are needs for water contamination and its relation to human health

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