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Microbial Water Quality in Nablus District

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Dedication

To my beloved mother and family, dear sisters and all who gave me help and support throughout my life.

Acknowledgment

I would like to express my special thanks to Dr. Ansam Sawalha and Dr Issam Al-Khatib for their supervision. Without their endless support this work could not be achieved. At last, all my love to my dear sisters, there encouragement was my motivation.

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List of abbreviation

AWWA:	American Water Work Association.
ARIJ:	Applied Research Institute Jerusalem.
CDC:	Centers of Disease Control.
DBPS:	Disinfection byproducts.
DS:	Distribution System.
EPA:	Environmental Protection Agency.
FC	Fecal Coliform.
FCR:	Free Chlorine Residual.
HPC:	Hetrophic Plate Count
HAV	Hepatitis A Virus.
IPCS	International Programme on Chemical Safety.
MCL:	Maximum Contaminant Level.
NESC:	National Environmental Services Center.
PCBS:	Palestinian Central Bureau of Statistics.
PSI:	Palestinian Standard Instituation.
SRSVs:	Small Round Structured Viruses.
TC	Total Coliform.
THMS:	Trihalomethanes.
WHO:	World Health Organization.

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Abstract

The objective of this study was to evaluate drinking water quality to decide if drinking water is safe for drinking.

Data of microbial drinking water examination in Nablus district in the year 1997, 2000. 2001 and 2003 at Environmental Health Department, Ministry of Health were analyzed and studied for the microbial contamination in order to assess drinking water quality.

A total of 4031 samples were collected from the city, villages and camps in Nablus district and analyzed. Both the percentage of total coliform count and fecal coliform count (E-coli) were used as indicators for water quality, also the free chlorine residual was needed to be tested.

Both indicators gave percentage higher than the recommended as safe drinking water by the WHO and PSI. The percentage of total coliform count (n/ 100 ml) were 23% in 1997, 30.6% in 2000, 11.5% in 2001 and 10.3% in 2003. The percentage of fecal coliform count (n/ 100 ml) were 43.1% in 1997, 33% in 2000, 10.4% in 2001 and 12.4% in 2003.

Based on the percentage count of both indicators, a significant variation were observed on the quality of drinking water in areas studied. The percentage of total coliforms count (n/ 100 ml) were 13% in the city, 30.5% in villages and 18.7% in camps. While the percentage of fecal

coliforms count (n/ 100 ml) were 16% in the city, 29.9% in villages and 25% in camps.

The degree of contamination based on total coliform counts were the highest in Springs (86.8%), then rain fed cisterns (59.4%). While the percentage count of fecal coliforms were 64.4% in rain fed cisterns and 56.8% in the springs.

According to seasonal variations, a significant variation on the percentage count of total coliform were observed. The percentage of total coliform were high in Spring (24.4%) and in Summer (20.9%).

Chapter One

Literature Review

Chapter One

1 Introduction

Water is essential to sustain life, and without it life become impossible (WHO,1997). Water is an indispensable commodity, which should be easily accessible, adequate in quantity, free of contamination, safe, affordable and available throughout the year in order to sustain life (Al-Khatib *et al*., 2003). Since water is very important for life, it should be available to all livings; plants, animals, and human. Availability of water implies sufficient quantity and good quality. Adequate supply of quality water is essential to maintain good public and community health since protection of water resources from contamination is the first priority (Daud *et al*., 2001).

Water is one of the most important and sensitive issues in the Middle East, where increasing water deficiency and deterioration of the available water resources are imminent. A major issue is that water resources are very limited and do not meet the existing population's demands, as well as the generations to come. As such, water deficiency and contamination is an obvious and acute problem in Palestine (Al-Khatib *et al*., 2003).

Potable or drinking water is defined as having acceptable quality in terms of its physical, chemical, and bacteriological characteristics so that it can be safely used for drinking and cooking.

1.1 Nablus District

Nablus district is located in the northern part of the West Bank. It is bounded by Jenin and from the north; Tulkarm and from the west; Ramallah and Jericho from the south and the Jordan River from the east. The district is located between 394 m below sea level and 918 m above sea level (Applied Research Institute [ARIJ], 1996).

1.1.1 Topography

Nablus district can be divided into four parts:

1. Jordan valley.
2. The eastern slopes.
3. Mountain crests.
4. Western slopes.

The highest point in the district reaches 918 m above the sea level at Jabal Ibal, while the lowest elevation is 344 m below sea level at the southeast corner of the district (ARIJ, 1996).

1.1.2 Geographical Location

Nablus district is located at the northern latitude earth grid 32:12 and at the eastern latitude earth grid 35:16. It's about 110 km far away from Amman, 42Km from Mediterranean, 66 km from Jerusalem and Jenin and it is 550 m high above mean sea level (ARIJ, 1996).

1.1.3 Temperature

The geographical position of Nablus district in the northern part of West Bank gives it a comparatively a low temperature range. The average maximum temperature reaches 26^{o}C , and the average minimum temperature 8^{o}C (Nablus Municipality, 2002).

1.1.4 Population

The estimated total population of Nablus district is 332,299 for the year 2004, representing 8.75% of the total population of Palestine. Approximately 49.6% (164.852 of the population district live in rural area), 10.5% (349.58 live in refuges camp) 39.8% (132.489 live in the communities under municipality administration (Palestinian Central Bureau of Statistics (PCBS), 2003).

Table 1. Projected mid-year population for Nablus Governorate by locality 1997-2003.

Area	1997	1998	1999	2000	2001	2002	2003
Camps	26,101	27,096	28,157	29,279	30,574	32,018	33,480
Village	123,082	127,777	132,780	138,072	144,175	150,985	157,876
City	98,919	102,693	106,713	110,966	115,872	121,344	126,884
Total	248,102	257,566	267,650	278,317	290,621	304,347	318,240

(PCBS, 2003)

1.1.4 Humidity

It reaches its minimum value in May due to the high range between the maximum and minimum daily temperature, yet, it reaches its maximum percentage during Winter (Nablus Municipality, 2002).

1.1.5 Water Supply System in Nablus District

Nablus district depend on water –network supply systems (piped water) and house hold rainwater, cisterns and communal sources (un piped). The total towns and villages in Nablus district are sixty five. Thirty four of these communities with piped water and thirty one with un-piped water (Abu- Alian, 2001).

The Nablus Water network was constructed in 1934 with the supply of the city's water resources to Ras Al Ain, Al Qaryoun, and Am Al-Asal. It served the 22,000 inhabitants of the city as well as others in the area. As a major network, constructed with meters for all participants, the Nablus City Municipality later signed an agreement with landowners, making the above water resources the property of the Municipality. The resources continued to sufficiently serve the Old City until the fifties. Then it was expanded; major water reservoirs were built in and the first water pump (Al Qaryoun water pump) was added to the network, utilizing the Ain Dafna water resources to supply the eastern part of Nablus . In the early sixties, the water of Ain Bit Al-Ma was utilized (ARIJ, 1996)

Due to population growth following the improvement of health and social conditions and the enlargement of city limits to include the refugee camps of Blalata and Asker and the town of Rafidia, the available water resources did not meet the population needs. These realities prompted

Nablus City to explore new resources that would satisfy the increasing needs. ln 1966, the municipality dug a well in the area of Dir Sharaf (10 km west of Nablus). The well was operating by the end of the year at a capacity of 50 m^3 per hour (ARIJ,1996) .

There are four artesian wells operated by the municipality

1. Odala well
2. Al Badhan well
3. Al Far'a well
4. Deir Sharaf well

As for the drinking water Springs utilized by the Nablus municipality , they are :- (Nablus Municipality, 2004).

1. Dafna Spring
2. Ra's Al Ain spring
3. Ayn al Asal spring.
4. Al Qaryan spring.
5. Bayt Al Ma' Spring.

2 Literature Review.

1.2 Drinking Water Quality

The World Health Organization (WHO) (1996) guidelines present contaminant levels in drinking water. Specific guidelines are presented for permissible concentrations of (a) bacteria, viruses, and parasites; (b) chemicals of health significance including specific inorganic and organic constituents, pesticides, disinfectants, and disinfection byproducts; (c) radioactive constituents; and (d) substances and parameters in drinking water that may give rise to complaints from consumers (American Water Work Association [AWWA], 2002)

Water quality standards have been developed to minimize known chemical and microbial risks. The term "safe" drinking water does not mean risk free; it simply means risks are very small, at or below our ability to quantify them, or that water quality limits cannot be lowered further by economical water treatment processes (Szewzyk *et al.*, 2000)

All countries have their own legal drinking water standards. These prescribe which substances can be in drinking water and what the maximum amounts of these substances are. These standards are called maximum contaminant levels (MCL).

1.3 Microbial Quality of Water

WHO states in 1997 that the "infectious diseases caused by pathogenic bacteria, viruses and protozoa or by parasites are the most common and widespread health risk associated with drinking water."

Esrey *et al* (1998) surveyed 142 studies on 6 of the major waterborne diseases and estimated that in developing countries (excluding China), there were 875 million cases of diarrhea and 4.6 million deaths annually in the mid-1980s. According to the World Bank estimate, more than 3 million children below age 5 die annually from diarrhea diseases contracted through drinking water in the developing world (Gadgile, 1998).

1.3.1 Water-Borne Pathogens and Diseases

Microorganisms transmitted in water generally grow in the intestines and leave the body with faeces (AL-Kahah, 2000). They include bacteria, viruses, protozoa, and other organisms. Such pathogens are often found in water, frequently as a result of fecal matter from sewage discharges, leaking septic tanks, and runoff from animal (EPA, 2001b).

1.3.1.1 Bacteria

Bacteria are microorganisms often composed of single cells shaped like rods, spheres or spiral structures. Prior to widespread chlorination of drinking water, bacteria like *Vibrio cholerae*, *Salmonella typhii* and several species of *Shigella* commonly cause diseases such as cholera, typhoid fever and bacillary dysentery, respectively (Microbe world, 2002)

Salmonella

Salmonella is a Gram-negative rod-shaped, nonsporeforming organisms. There is a widespread occurrence in animals, especially in poultry and swine. Environmental sources of the organism include water, soil, insects, factory surfaces, kitchen surfaces, animal feces, raw meats, raw poultry, and raw seafoods (Centers of Disease Control [CDC], 2002).

S. typhi and the paratyphoid bacteria normally can cause septicemia or produce typhoid or typhoid-like fever in humans. They also cause salmonellosis, a disease with milder symptoms (CDC, 2002).

Salmonellosis is considered a fast infection. The organism grow and produce an endotoxin that cause the illness. Acute symptoms; Nausea, vomiting, abdominal cramps, minor diarrhea, fever, and headache. Chronic consequences; arthritic symptoms may follow 3-4 weeks after onset of acute symptoms. Incubation period: 6-48 hours (CDC, 2002).

Infective dose; As few as 15-20 cells; depending upon age and health of host, and strain differences among the members of the genus.

Duration of symptoms; Acute symptoms may last for 1 to 2 days or may be prolonged, again depending on host factors, ingested dose, and strain characteristics (CDC, 2002).

Campylobacter Jejuni

Campylobacter jejuni is a Gram-negative cylinder, curved, and motile rod. It is a microaerophilic organism, which means it requires law levels of oxygen. It is relatively fragile and sensitive to environmental stresses (e.g. 21% oxygen, drying, heating, disinfectants, acidic conditions). Because of its microaerophilic characteristics the organism requires 3 to 5% oxygen and 2 to 10% carbon dioxide for optimal growth conditions. This bacterium is now recognized as an important enteric pathogen. Surveys have shown that C. jejuni is the leading cause of bacterial diarrheal illness. It causes more disease than Shigella species (spp) and Salmonella spp. combined (CDC, 2003) .

Campylobacteriosis is the name of the illness caused by C. jejuni. It is also often known as campylobacter enteritis or gastroenteritis (CDC, 2003) C. jejuni infection causes diarrhea, which may be watery or sticky and can contain blood (usually occult) and fecal leukocytes (white cells). Other symptoms often present are fever, abdominal pain, nausea, headache and muscle pain. The illness usually occurs 2-5 days after ingestion of the contaminated water. Illness generally lasts 7-10 days, but relapses are not uncommon (about 25% of cases) (CDC ,2000). The infective dose of C. jejuni is considered to be small. Human feeding studies suggest that about

400-500 bacteria may cause illness in some individuals, while in others, greater numbers are required (CDC, 2003).

Diengaardt (2004) said in his study "Campylobacter spp., mainly C. coli and C. jejuni, are recognized as significant human bacterial pathogens, being responsible for increasing numbers of gastroenteritis cases worldwide. Several reports have indicated that environmental waters are potential reservoirs and transmitting vehicles for these bacteria.

Yersinia

The genus Yersinia is currently placed in the family Enterobacteriaceae. The cells of Y. entrocolitica are Gram- negative rods, motile at 25^{O}C but nonmotile in cultures grown at 37^{0} C. Certain strains of Y. entrocolitica cause acute gastroenteritis with diarrhea, but other human diseases caused by Y.entrocolitica are also known (WHO,1997).

The transmission of Y. entrocolitica from the natural reservoirs to humans has been the subject of much debate. Many domestic and wild animals are considered to be possible natural reservoirs of Y. entrocolitica such as shrews, hares, foxes, and beavers (CDC, 2003). But the ingestion of contaminated food and water is probably the most likely one. There is some evidence that pathogenic strains of Y. entrocolitica enter drinking water via contaminated surface water or as a result of pollution with sewage. Recent studies have shown that human pathogenic serotypes of Y. enterocolitica are present in sewage and polluted surface water (WHO, 1997).

One study indicated that 25% of Y. entrocolitica- positive samples were negative for both total and faecal coliforms. Other studies have shown a close relationship between faecal pollution and Y. entrocolitica isolation rates (WHO, 1997).

A special feature of Y. entrocolitica is their ability to grow at low temperatures, even at $4^{O}C$. Accordingly, these organisms can survive for long periods in water habitats. For example, Y. entrocolitica was detected in previously sterilized distilled water after over 18 months at $4^{O}C$. such long survival periods makes it difficult to determine the origin of contamination when Yersinia are detected (Anon, 2000) .

Shigella

Shigella are Gram-negative, nonmotile and nonsporeforming rod-shaped bacteria. Shigella rarely occurs in animals; principally a disease of humans and other primates such as monkeys and chimpanzees. The organism is frequently found in water polluted with human feces (CDC, 2000) Shigellosis (bacillary dysentery) is the name of the illness caused by Shigella (CDC, 2000).

Symptoms: Abdominal pain; cramps; diarrhea; fever; vomiting; blood, pus, or mucus in stools; tenesmus. Onset time: 12 to 50 hours after ingestion of contaminated water (CDC, 2000)

Infective dose: As few as 10 cells depending on age and condition of host. The Shigella spp. are highly infectious agents that are transmitted by the fecal-oral route (AWWA, 2000).

Vibrio Cholerae:

Motile, non-spore-forming, slightly curved Gram-negative rods with a single polar flagellum; they are both aerobic and facultatively anaerobic. (WHO, 1997).Cholera is the name of the disease caused by V.cholerae. Symptoms of Asiatic cholera may vary from a mild, watery diarrhea to an acute sever diarrhea, with characteristic rice water stools. Onset of the illness is generally sudden, with incubation periods varying from 6 hours to 5 days. (CDC, 2002).

Illness is caused by the ingestion of viable bacteria, which attack to the small intestine and produce cholera toxin. The production of cholera toxin by the attached bacteria results in the watery diarrhea associated with this illness (CDC, 2002).

Infective dose: approximately one million organisms must be ingested to cause illness. Death occurs from dehydration and loss of essential electrolytes (CDC, 2003).

Escherichia Coli (0157:H7)

Facultative Gram negative organism. It is a heterogeneous species comprising many different strains, the vast majority of which are not pathogenic (WHO, 1997). Most of strains are considered to be part of the normal microbial flora of gastro-intestinal tract of man and other warm-blooded animals. However, certain strains are pathogenic and cause characteristic diarrheal symptom such as E.coli 0157:H7 which was isolated in 1975 in USA (Atiya, 2003).

The diseases caused by the pathogenic E-coli range from mild diarrhea to haemorrhagic colitis characterized by blood-strained diarrhea usually without fever but accompained by abdominal pain. It is also a cause of the hemolytic uraemic syndrome, commonest in infants and young children, and characterized by acute renal failure and hemolytic anaemia (Anon, 2000).

Symptoms include abdominal pain, vomiting, anemia, thrombocytopenia, acute renal injury with bloody urine, seizure and pancreatitis (Atiya, 2003).

1.2.2.2 Opportunistic Pathogens.

Certain bacteria in drinking water deserve particular attention because they are opportunistic pathogens to humans, i.e. they are able to cause infections in susceptible persons. The most important organisms of this type are Legionella, Aeromonas, and Pseudomonas aeruginosa (Curriero, 2001).

Legionella

Gram negative, rod-shaped, non-spore forming bacteria that require L-cysteine for growth and primary isolation. Legionella infections can lead to two types of disease, namely Legionnaires disease (legionellosis) and non-pneumonic Legionnaires disease (Pontaic fever). (Curriero, 2001).

Legionellae are widespread in natural sources of water and may also be found in soil. They occur commonly in man–made water systems, particularly in hot water and cooling-water systems. Infection is the result of inhalation of aerosols that are small enough to penetrate the lungs and be retained by alveoli. The degree of risk depends on four key factors: (i) the density of the bacteria in the source, (ii) the extent of aerosol generation, (iii) the number of inhaled bacteria, (iv) the susceptibility of the exposed individual (WHO, 1997).

Legionellosis is a form of pneumonia with an incubation period usually of 3-6 days. Males are more frequently affected than females, and most cases occur in the 40-70 year age group. The fatality rate in untreated cases may be 10% or higher. The non-pneumonic form of the disease is milder, with a high attack rate, and symptoms similar to those of influenza: fever, headache, nausea, vomiting, aching muscles, and coughing (Curriero, 2001).

Pseudomonas Aeruginosa

Gram-negative rod. It can be recognized by its production of a blue green fluorescent pigment (pyocyanin), which in agar cultures, will diffuse into the medium., and they are aerobic. P.aeruginosa, however, is capable of growth at 41-42^0 C and the blue-green pigment (fluorescein) produced by other species of fluorescent pseudomonads found in water. It is also capable of growing anaerobically in stab cultures nitrate agar (WHO, 1997).

P. aeruginosa is commonly found in feces, soil water, and sewage. It is an opportunistic pathogen. Most of the illness in humans for which it is responsible are caused, not by drinking water, but by contact with it. Water containing these bacteria may also contaminate food, drinks and pharmaceutical products, causing them to deteriorate and to act as secondary vehicles for transmission (CDC, 2002).

The presence of this organism in potable water also indicates a serious deterioration in bacteriological quality and is often associated with complaints about taste, odor, and turbidity linked to low rates of flow in the distribution system and a rise in water temperature (WHO, 1997).

Mycobacterium

Rod-shaped bacteria with cell walls having a high lipid content; this enables them to retain certain dyes in staining procedures that employ an acid wash , and they are therefore often referred to as acid- fast bacteria (CDC, 2002).

All mycobacteria are characterized by slow growth (generation times under optimal circumstances 2-20 hours, but within this range they are slow dividers and rapid growers. Most pathogenic species are found among the slow growers which are not transmitted by water and have only human or animal reservoirs. Other mycobacterial species, often referred to as "atypical" have environmental reservoirs. Although many are considered to be nonpathogenic, several species are opportunistic pathogens for humans (WHO, 1997).

The environmental mycobacteria may cause a range of disease including tuberculous lung disease and disseminated infections which may also involve the skeleton (CDC, 2002).

1.2.2.3 Viruses

Viruses are infectious agents that can reproduce only within living host cells. Shaped like rods, spheres or filaments, viruses are so small that they pass through filters that retain bacteria. Enteric viruses,(such as hepatitis A, Norwalk virus, adenovirus and rotavirus) are excreted in the feces of infected individuals and may contaminate water intended for drinking. Enteric viruses infect the gastrointestinal or respiratory tracts, and are capable of causing a wide range of illness, including diarrhea, fever, hepatitis, paralysis, meningitis, and heart disease (AWWA, 1999).

Rotaviruses

Rotaviruses are classified with the Reoviridae family. They have a genome consisting of 11 double-stranded RNA segments surrounded by a distinctive two-layered protein capsid. Six serological groups have been identified, three of which (groups A, B, and C) infect humans (CDC, 2002).

Rotaviruse group A cause acute gastroenteritis, Infantile diarrhea, Winter diarrhea, acute nonbacterial infectious gastroenteritis, and acute viral gastroenteritis are names applied to the infection caused by the most common and widespread group A rotavirus (AWWA,1999).

Rotavirus gastroenteritis is a self-limiting, mild to severe disease characterized by vomiting, watery diarrhea, and low-grade fever. The infective dose is presumed to be 10-100 infectious viral particles. Because a person with rotavirus diarrhea often excretes large numbers of virus (108-1010 infectious particles/ml of feces), infection doses can be readily acquired through contaminated hands, objects, or utensils (CDC, 2002).

Group A rotavirus is endemic worldwide. It is the leading cause of severe diarrhea among infants and children, and accounts for about half of the cases requiring hospitalization. Over 3 million cases of rotavirus gastroenteritis occur annually in the U.S. In temperate areas, it occurs primarily in the winter, but in the tropics it occurs throughout the year (CDC, 2000).

Group B rotavirus, also called adult diarrhea rotavirus or ADRV, has caused major epidemics of severe diarrhea affecting thousands of persons of all ages in China (AWWA,1999).

Group C rotavirus has been associated with rare and sporadic cases of diarrhea in children in many countries. However, the first outbreaks were reported from Japan and England (AWWA ,1999).

Norwalk Virus Family:

Norwalk virus is the prototype of a family of unclassified small round structured viruses (SRSVs) which may be related to the caliciviruses. They contain a positive strand RNA genome The family consists of several serologically distinct groups of viruses that have been named after the places where the outbreaks occurred (CDC, 2002).

Common names of the illness caused by the Norwalk and Norwalk-like viruses are viral gastroenteritis, acute nonbacterial gastroenteritis, food poisoning (WHO, 1997).

The disease is self-limiting, mild, and characterized by nausea, vomiting, diarrhea, and abdominal pain, headache and low-grade fever may occur. The infectious dose is unknown but presumed to be low(WHO, 1997).

Hepatitis A

This virus (HAV) is classified with the enterovirus group of the Picornaviridae family. HAV has a single molecule of RNA .

Hepatitis A is usually a mild illness characterized by sudden onset of fever, malaise, nausea, anorexia, and abdominal discomfort, followed in several days by jaundice. The infectious dose is unknown but presumably is 10-100 virus particles (WHO, 1997).

Hepatitis A has a worldwide distribution; a bout 22,700 cases of hepatitis A representing 38% of all hepatitis cases (5-year average from all routes of transmission) are reported annually in the U.S. In 1988 an estimated 7.3% cases were foodborne or waterborne. HAV is primarily transmitted by person-to-person contact through fecal contamination, but common-source epidemics from contaminated food and water also occur, in addition to poor sanitation and crowding facilitate transmission (WHO, 1997).

The incubation period for hepatitis A, which varies from 10 to 50 days (mean 30 days), is dependent upon the number of infectious particles consumed. Infection with very few particles results in longer incubation periods. The period of communicability extends from early in the incubation period to about a week after the development of jaundice. The greatest danger of spreading the disease to others occurs during the middle of the incubation period, well before the first presentation of symptoms. Many infections with HAV do not result in clinical disease, especially in children. When disease does occur, it is usually mild and recovery is complete in 1-2 weeks. Occasionaly, the symptoms are severe and convalescence can take several months. Patients suffer from feeling chronically tired during convalescence, and their inability to work can cause financial loss (WHO, 1997).

Adenovirus

Enteric adenoviruses represent serotypes 40 and 41 of the family Adenoviridae. These viruses contain a double-stranded DNA. Common names of the illness caused by these viruses are acute nonbacterial infectious gastroenteritis and viral gastroenteritis (CDC, 2000).

Viral gastroenteritis is usually a mild illness characterized by nausea, vomiting, diarrhea, malaise, abdominal pain, headache, and fever. The infectious dose is not known but is presumed to be low (CDC, 2002).

1.2.2.4 Protozoa

Protozoan parasites are single-celled microorganisms that feed on bacteria found in multicellular organisms, such as animals and humans. Several species of protozoan parasites are transmitted through water in dormant, resistant forms, known as cysts and oocysts. According to the World Health Organization, Cryptosporidium parvum oocysts and Giardia lamblia cysts are introduced to waters all over the world by fecal pollution. (WHO,2002a). Protozoa parasites are sometimes called the "super bug". Giardia and Cryptosporidium are the more commonly known waterborne protozoa (AWWA,1999).

Giardia Lamblia

It is a single celled a prasitic animal, that moves with the aid of five flagella. In Europe, it is sometimes referred to as Lamblia intestinalis (WHO, 1997).

Giardiasis is the name of the illness caused by Giadia Lamblia .It is the most frequent cause of non-bacterial diarrhea in North America (CDC, 2002).

Human giardiasis may involve diarrhea within 1 week of ingestion of the cyst, which is the environmental survival form and infective stage of the organism (AWWA, 2002).

Normally illness lasts for 1 to 2 weeks, but there are cases of chronic infections lasting months to years. Chronic cases, both those with defined immune deficiencies and those without, are difficult to treat (AWWA, 2002).

Infectious Dose: ingestion of one or more cysts may cause disease, as contrasted to most bacterial illnesses where hundreds to thousands of organisms must be consumed to produce illness (CDC, 2002).

Cryptosporidium Spp.

A single-celled parasitic animal and an obligate intracellular parasite. The infective stage of the organism, the oocyst is 3 um in diameter or about half the size of a red blood cell. The sporocysts are resistant to most chemical disinfectants, but are susceptible to drying and the ultraviolet portion of sunlight. The species or strain infecting the respiratory system is not currently distinguished from the form infecting the intestines (WHO, 1997).

Cryptosporidiosis is the name of the illness caused by Cryptosporidium parvum ; (Intestinal, tracheal, or pulmonary). Intestinal cryptosporidiosis is characterized by severe watery diarrhea but may, alternatively, be asymptomatic. Pulmonary and tracheal cryptosporidiosis in humans is associated with coughing and frequently a low-grade fever; these symptoms are often accompanied by severe intestinal distress. Infectious dose; less than 10 organisms and, presumably, one organism can initiate an infection (CDC, 2002).

Joe (1998) indicated that Cryptosporidium is present in about 65% to 97% of the surface water in the U.S. Neither chlorine disinfectant nor standard water filtration systems fully remove this pathogen from drinking water.

Entamoeba Histolytica

It is a single celled parasitic animal. The active (trophozoite) stage exists only in the host and in fresh feces; cysts survive outside the host in water and soils and on foods, especially under moist conditions on the latter. When swallowed they cause infections by excysting (to the trophozoite stage) in the digestive tract (AWWA, 2000).

Amebiasis (or amoebiasis) is the name of the infection caused by E. histolytica (CDC, 2002).Infections that sometimes last for years may be accompanied by either 1) no symptoms, 2) vague gastrointestinal distress, 3) dysentery (with blood and mucus). Most infections occur in the digestive tract but other tissues may be invaded. Complications include 4) ulcerative and abscess pain and, rarely, 5) intestinal blockage. Onset time is highly variable. It is theorized that the absence of symptoms or their intensity varies with such factors as 1) strain of amoeba, 2) immune health of the host, and 3) associated bacteria and, perhaps, viruses. The amoeba's enzymes help it to penetrate and digest human tissues; it secretes toxic substances(CDC, 2002).

Infectious Dose: theoretically, the ingestion of one viable cyst can cause an infection (WHO, 1997). The most dramatic incident in the USA was the Chicago World's Fair outbreak in 1933 caused by contaminated drinking water; defective plumbing permitted sewage to contaminate the drinking water. There were 1,000 cases (with 58 deaths) (CDC, 2000) .

1.4 Microbial Indicators of Water Quality

One of the primary concerns of water authorities is to ensure that the drinking water they supply does not pose a health risk to consumers: The safety of drinking water is generally monitored in a number of ways:

I. Constituents of drinking water which can compromise human health can be measured directly (chemicals and microbes);

2 Barriers designed to protect water quality (such as catchments activities, filtration and disinfection) can be monitored; and

3. Indicators of water quality can be measured (Steven *et al.,* NHMRC, 2001).

The concept of coliforms as bacterial indicators of microbial water quality is based on the premise that because coliforms are present in high numbers in the faeces of human and other warm-blooded animals, if faecal contamination has entered drinking water, it is likely that these bacteria will be present even after significant dilution (NHMRC, 2001).

With exceptions, coliforms themselves are not considered to be a health risk, but their presence indicate that faecal contamination may have occurred and pathogens might be present as a result (WHO,1996).

Coliform was the term first used in the 1880s to describe rod-shaped bacteria isolated from human faeces. The coliform group of bacteria, is a functionally–related group which all belong to a single taxanonic family (Enterobacteriaceae) (NHMRC, 2001).

Of the coliforms normally present in the gut of warm-blooded animals, E coil is the most numerous and is also the only coliform which rarely grows in the environment (NHMRC, 2001).

It's widely acknowledged that the major threat to public health from drinking water is from microbiological contamination with human, and to a lesser degree, animal feces (NHMRC, 2001).

1.4.1 Total Coliforms (TC) and E-coli.

1- The coliform group are aerobic and facultatively anaerobic, gram-negative, nonspore forming, rod-shaped bacteria that ferment lactose with gas and acid production in 24 to 48h at $35^{O}C$ (Al-kahah, 2001).

2- The total coliform group of bacteria was originally used as a surrogate for E.coli (the name coming from "coli-form" or like), which in turn was considered to be faecal contamination (Byamukama, 2000).

3- The group include:

1. Klebsiella- may be found in feces and in the environment;

2. Escherichia- found always in human and other animal feces;

3- Enterobacter- found in feces and in the environment;

4- Serratia- found in the environment.

Coliforms can be classified into those of fecal or non-fecal origin. The fecal coliform group is reffered to as organisms that grow in the gastrointestinal tract of humans and of the warm blooded animals and include members of 3 genera: Escherichia, Klebsiella and Enterobacter.

4- the presence of E.coli is considered an appropriate and specific indicator of faecal pollution, uncertainty surrounds the use of total coliforms as health indicator (Byamukama, 2000).

1.4.2. Fecal Coliform (FC).

There is no minimum value for the tolerable level of pathogenic contamination of drinking water. WHO (1996) recommends that E. coli or thermotolerant coliforms must not be detectable in any 100-ml sample. Both WHO and USEPA recommend regular sampling of treated water supplies, and that not more than 5% of the samples in any 12-month period should test positive for E.coli or thermotolerant coliforms.

Australian drinking water guidelines (2000) indicated that "Detection of coliform bacteria in the absence of thermotolerant coliforms (or E-coli) may be tolerated providing it can be shown that the organisms do not indicate faecal contamination."

1.4.3 Other Less Commonly Used Bacterial Indicators.

1.4.3.1 Fecal Streptococci (Enterococci).

To increase the confidence of water quality results, especially when monitoring for faecal contamination, analysis for *enterococci* has been used. The *enterococci* are the group of bacteria most often suggested as alternative to coliforms, and interest in their use as a water quality indicator date back to 1900 when they were found to be common commensal bacteria in the gut of warm-blooded animals (Edberg, 2001).

The predominant intestinal enterococci are *E. fecalis, E. faecium, E. durans and E. hirae* . In addition, other enterococcus species and some species of streptococcus (namely *S. bovis*, and *S. equines*) may occasionally be detected. Generally, for water examination purposes Enterococcai can be regarded as indicators of fecal contamination, although some can occasionally originate from other habitats (Pinito *et al.*,1999).

Enterococci have a number of advantages as indicators over total coliforms and even E.coli including that they generally don't grow in the environment, and they have been shown to survive longer (WHO, 2000).

More recent research on the relevance of fecal streptococci as indicators of contamination showed that the majority of Enterococci (84%) isolated from a variety of contamination water sources were true fecal species (Pinto *el at.,* 1999).

1.4.3.2 Sulfite-Reducing Clostridia

C.perfringens are sulphite-reducing, spore-forming clostridia, which are hardly rod-shaped anaerobic bacteria. They spread widely through nature and have been isolated from the intestines of many animals. The spores produced by C. perfringens are very resistant to disinfection (Gray, 1997).

Spores of C. perfringens are largely of fecal origin and are always present in sewage. Their spores are highly resistant in the environment. Unlike many traditional indicator bacteria C. perfringens is present in higher concentration in the feces of animals such as dogs than humans and is generally lower or absent in other warm-blooded animals (Leeming *et al*, 1998). There is evidence to show that C. perfringens may be a suitable indicator for viruses and parasitic protozoa when sewage is the suspected cause of the contamination (Leeming *et al*., 1998).

Nonetheless C. perfringens is not generally considered a robust indicator of microbial water quality because they can survive and accumulate in drinking water systems and may be detected long after a pollution event has occurred and far from the source (WHO, 1996). Their preferred role is to aid identification of faecal contamination in the sanitary surveys (Gray, 1997).

1.4.3.3. Bacteriophages

Bacteriophages are viruses that infect bacteria while those that infect coliform are known as coliphages, or more generally, phages. Phages have been proposed as microbial indicators as they behave more like the human enteric viruses which pose a health risk to water consumers if water has been contaminated with human faeces (NHMRC, 2001).

1.5 Drinking Water Treatment

The treatment and distribution of water for safe use is one of the greatest achievements of the twentieth century (AWWA, 2002).

Meeting the goal of clean, safe drinking water requires a multi-barrier approach that include: (AWWA, 2002).

1. Protecting the source from contamination.
2. Appropriately treating raw water.
3. Ensuring safe distribution of treated water to consumer's tap.

The water treatment process involves a series of different steps. Some of the major steps include: (CDC, 2000).

1-Flocculation and coagulation (the joining of small particles of matter in the water into larger ones that can more readily be removed);

2-Sedimentation (the settling of suspended particles in the water to the bottom of basins from which they can be removed);

3-Filtration (the filtering or straining of the water through various types of materials to remove much of the remaining suspended particles);

4-Chemical disinfection.

Chlorination can be defined as the adding of chlorine to water in order to kill any dangerous bacteria that might be present (Daud *et al.*, 2001) During the treatment process, chlorine is added to drinking water as elemental chlorine (chlorine gas), sodium hypochlorite solution or dry calcium hypochlorite. When applied to water, each of these forms produce "free chlorine," which destroys pathogenic (disease-causing) organisms (AWWA, 2002).

In addition to controlling disease-causing organisms, chlorination offers a number of benefits including:

- Reduces many disagreeable tastes and odors;
- Eliminates slime bacteria, molds and algae that commonly grow in water supply reservoirs, on the walls of water mains and in storage tanks;
- Removes chemical compounds that have unpleasant tastes and hinder disinfection;
- Helps remove iron and manganese from raw water.

John Edward (2000) said "Drinking water quality can decay substantially within distribution systems. This decay is exhibited by decreases in disinfectant residuals and increases in bacterial counts, sometimes to levels that affect public health. The processes that influence water quality decay are complex and depend on many factors, and the raw water properties that influence these factors differ greatly with location".

Chlorination is usually performed at several stages of the treatment process. Prechlorination may be performed in the initial stages to combat the algae and other aquatic life that may interfere with the treatment equipment and later steps. The major chlorination stage, however, occurs as the final treatment step after the completion of the other major processes, where the concentration and residual content of the chlorine can be closely monitored (AWWA, 2002).

The Challenge of Disinfection Byproducts

National environmental services center (NESC) (2000) stated that "While protecting against microbial contamination is the top priority, water systems must also control disinfection byproducts (DBPs) and chemical compounds formed unintentionally when chlorine and other disinfectants react with natural organic matter in water. In the early 1970s, EPA scientists first determined that drinking water chlorination could form a group of byproducts known as trihalomethanes (THMs), including chloroform. High levels of these chemicals are certainly undesirable. Cost-effective methods to reduce DBPs formation are available and should be adopted where possible".

Epidemiological studies in Valencia Province of Spain showed that surface waters contain higher levels of human carcinogens than groundwater sources. The possible contaminants that might play such a role are the halogenated organic compounds produced by the chemical reaction between organic materials in water and chlorine used for disinfection. (Suarez *et al.,* 1994).

The International Programme on Chemical Safety (IPCS) (2000) reached the conclusions that; "Disinfection is unquestionably the most important step in the treatment of water for drinking water supplies. The microbial quality of drinking water should not be compromised because of concern over the potential long-term effects of disinfectants and DBPs. The risk of illness and death resulting from exposure to pathogens in drinking water is very much greater than the risks from disinfectants and DBPs".

Life magazine (1997) declared, “The filtration of drinking water plus the use of chlorine is probably the most significant public health advancement of the water treatment”.

The effectiveness of water treatment varies depending upon whether the waterborne contaminant is a bacteria, a virus or a protozoa parasite. Bacteria are the least troublesome and are generally removed by current water treatment processes. Diseases such as Salmonella, Typhus, Dysentery and other bacterial diseases are fairly well controlled, at least in developed countries, through effective water treatment procedures (Joe,1998).

Viruses present a greater challenge. They are generally harder than bacteria, although they too can be controlled, but with increased amounts of disinfectant. Viruses linked to waterborne disease have protein protective coats and are considered to be about 100 times more resistant to disinfectant than are bacteria (Joe, 1998).

Pathogenic protozoa parasites are the most problematic micro bacteria, it is the contaminant that poses the greatest risk to human health. Unlike bacteria and viruses, protozoa parasites are resistant to commonly used treatment procedures. During their life cycles, some species persist in an environmentally resistant cyst stage. They are considered to be about 10,000 to 50,000 times more resistant to disinfectant than are bacteria. Even water treatment by filtration may not do the job, since parasites such as Cryptosporidium are small enough to pass through filtration systems.

1.6 Objective of the Study.

To evaluate drinking water quality to decide if drinking water is safe for drinking and this by estimating the variations of bacterial quality of water samples by the years, areas, source, and seasons, the effect of chlorine disinfection and recommending of some solutions to the problem of water contamination.

Chapter Two

Methodology

Chapter Two

Methodology

Data about water quality which was used in this study was collected from Environmental Health Department, Ministry of Health (MOH) at Nablus district. The data was reviewed and revised with the help of environmental health department workers.

2.1 Types of collected samples.

The total of 4031 samples were collected during the period (1997-2003). They were collected from several areas and during different seasons.

2.1.1 Area of Collection.

3187 samples were collected from Nablus city, 427 from villages and 417 from camps.

2.1.2 The Sources of Samples.

550 were collected from restaurants, 60 from schools, 136 from sweetshops, 284 from springs, 180 from storage tanks, 153 from artesian wells, 128 from rain fed cisterns and 2540 from the water networks.

2.1.3 The Years of Taken Samples.

1153 samples were collected in 1997, 1357 in 2000, 602 in 2001 and 919 in 2003.

2.1.4 The Seasons of Taken Samples.

1440 samples were collected during spring, 1097 during summer,937 during Autumn and 553 during Winter.

* Spring: from 22/8 to 21/6; *Summer : from 22/6 to 21/9

*Autumn : from 22/9 to 20/12; *Winter: from 21/12 to 21/3

2.2 Sample Collection

Water samples were collected for routine tests of microbiological quality for public health issues by Environmental Health Inspectors. This was done to determine the degree of water safety and to take action by law to safe guard health of people.

Samples were held in sterile bottles and sent to Central Public Health Laboratories (CPHL) (a body of the MOH) in Ramallah city on the same day of collection. The Environmental Health Department workers usually test residual chlorine.

2.3 Receiving Samples at the Laboratory.

As soon as samples were received at; the time of collection and temperature are checked. Each sample is tested for total coliform and fecal coliform.

2.4 Detection of Total Coliform.

1- Filter 250 ml of bottled water or 100 ml of drinking or swimming pool water using membrane filter technique.

2- Place filter on m endo agar less media plates.

3- Incubate at 35-37 ^{o}C for 24 houres.

4- Count the number of colony forming units and report per 250 ml or per 100 ml.

2.5 Detection of Fecal Coliform.

1- Filter 100 ml of drinking water or 250 ml of bottled water or 250 ml of swimming pool water using membrane filter technique.

2- Place filter on m-Enterococcus agar less media plates.

3- Incubate at 35^{o} C for 48 houres.

4- Count the number of red colony forming units and report per 250 ml or per 100 ml.

2.6 Data Analysis

Data was coded and entered into the computer and analyzed using the statistical analytical system SPSS.

Chapter Three

Results

Chapter Three

Results

3.1 Distribution of Water Samples.

A total of 4163 water samples of different sources were reported from the records of Environmental Health Department, Ministry of Health during the period 1977-2003. samples were collected by Environmental Health Inspector from different area, different sources and different seasons as show in the following tables.

3.1.1 Distribution According to Years.

3.1.1.1 Concentration Free Chlorine Residual in the Years Studied.

Table (2) shows that the total percentage of chlorine conc sample below 0.2 ppm was 63.0%, the percentage differed from year to year. In 1997 it was 62.2%, 62.9% in 2000, 63.8% in 2001 and 69.5% in 2003.while 2.4% of the total sample was more than 0.8 ppm.

Table 2. Chlorine level in the years studied

Year	Chlorine conc (ppm) (%)			Total no of Samples (%)
	< 0.2 (%)	0.2-0.8* (%)	>0.8 (%)	
1997	327 (62.2)	194 (37.0)	4 (0.8)	525 (100)
2000	552 (62.9)	293 (33.9)	29 (3.2)	878 (100)
2001	136 (63.84)	75 (35.21)	2 (0.95)	213 (100)
2003	41 (69.5)	17 (28.8)	1 (1.7)	59 (100)
Total	1056 (63.0)	579 (34.6)	40 (2.4)	1675 (100)
P value	0.009			

Year	Chlorine conc (ppm) (%)			Total no of Samples (%)
	< 0.2 (%)	0.2-0.8* (%)	>0.8 (%)	
Chi square	16.992			

Note: 0.2-0.8 ppm the standard concentration of FCR (WHO, 1996).

3.1.1.2 Levels of Total Coliform (TC) in the Year Studied.

Table (3) shows that the highest percentage of TC contamination was in the year 2000 it was 12.8% in 4-50 count and 17.8% in 51-50000 count. While the lowest percentage of TC contamination was in the year 2003 which had 7.1% in 4-50 count and 3.2% in 51-50000 count.

Table 3. Level of Total Coliform (TC) and the years

Year	TC (count/ 100 ml) (%)			Total no of Samples (%)
	0-3 (%)	4-50 (%)	51_50000 (%)	
1997	888 (77.0)	137 (11.9)	128 (11.1)	1153 (100)
2000	942 (69.4)	174 (12.8)	241 (17.8)	1357 (100)
2001	533 (88.5)	51 (8.5)	18 (3.0)	602 (100)
2003	824 (89.7)	65 (7.1)	30 (3.2)	919 (100)
Total	3187 (79.1)	427 (10.6)	417 (10.3)	4031 (100)
P value	**0.0000**			
Chi square	**206.732**			

Table 4. WHO classification for TC contamination degree and treatment methods.

Total Coliform Count (N\100 ml)	Contamination Degree	Treatment Method
0-3	0	-
>3 - 50	1	Disinfection
>50- 50000	2	Agglutination ,filtration, disinfection
>50000	3	Special treatment

After: (Othman, 2000).

3.1.1.3 Levels of Fecal Coliform (FC) in the Year Studied.

Table (5) shows that the highest percentage of FC contamination was in the year 1997 it was 24.4% in 1-10 count, 10.0% in 11-100 count, 7.5% in 101-1000 count and 1.3% in > 1000 count . While the lowest percentage of FC contamination was in the year 2001 which had 6.7% in 1-10 count, 3.4% in 11-100 count and 0.3% in 101-1000 count.

Table 5. Fecal Coliform (FC) level in the year studied.

Year	FC (Count/ 100 ml) (%)					Total of Samples (%)
	0 (%)	1-10 (%)	11-100 (%)	101-1000 (%)	> 1000 (%)	
1997	91 (56.9)	39 (24.4)	16 (10.0)	12 (7.5)	2 (1.2)	160 (100)
2000	741 (67.0)	154 (13.9)	106 (9.6)	105 (9.5)	0 (0)	1106 (100)
2001	534 (89.6)	40 (6.7)	20 (3.4)	2 (0.3)	0 (0)	596 (100)
2003	818 (87.6)	71 (7.6)	36 (3.8)	9 (1.0)	0 (0)	934 (100)
Total	2184 (78.1)	304 (10.9)	178 (6.4)	128 (4.5)	2 (0.1)	2796 (100)
P value	0.000					
Chi square	59.436					

Table 6. WHO classification for fecal coliform counts and risk

FC(Count / 100 ml)	Risk
0	No risk
Greater than 0 to 10	Low risk
Greater than 10-100	Intermediate risk
Greater than 100-1000	High risk
Greater than 1000	Very high risk

After: (Othman, 2000).

3.1.2 Distribution According to Area.

3.1.2.1 Concentration of Free Chlorine in the Area Studied.

Table (7) shows that concentration of chlorine below WHO standard level differed from area to area, city had the highest percentage which was 77.1% then villages had 56.4% and camps had 23%. The percentage of chlorine >0.8 also differed from area to area, it was 2.4% in city, 2.4% in villages and 2.64% in camps.

Table 7. Chlorine level in the area studied

Area	**Chlorine conc (ppm) (%)**			**Total no of Samples (%)**
	< 0.2 (%)	**0.2-0.8 (%)**	**>0.8 (%)**	
City	603 (77.1)	160 (20.5)	19 (2.4)	782 (100)
Villages	418 (56.4)	306 (41.3)	17 (2.3)	741 (100)
Camps	35 (23.02)	113 (74.34)	4 (2.64)	152 (100)
Total	1056 (63.0)	579 (34.6)	40 (2.4)	1675 (100)
P value	0.000			
Chi square	192.685			

3.1.2.2 Levels of Total Coliform (TC) in the Area Studied.

Table (8) shows that villages had the highest level of TC contamination then camps and then city. It was 13.1% in villages, 9.35% in camps and 8.7% in city. These percentage when TC count 4-50. The same result when TC count 51-50000, it was and 17.5% in villages, 9.35% in camps and 4.4% in city.

Table 8. Level of Total Coliform (TC) in the area studied**.**

Area	**TC (count/ 100 ml) (%)**			**Total no of Samples (%)**
	0-3(%)	**4-50 (%)**	**51-50000(%)**	
City	1746 (87.0)	174 (8.7)	88 (4.3)	2008 (100)
Villages	1197 (69.5)	225 (13.1)	301 (17.4)	1723 (100)
Camps	244 (81.3)	28 (9.35)	28 (9.35)	300 (100)
Total	3187 (79.1)	427 (10.6)	417 (10.3)	4031 (100)
P value	**0.0000**			
Chi square	**207.279**			

3.1.2.3 Levels of Fecal Coliform (FC) in the Area Studied.

Table (9) shows that the highest percentage of FC contamination was in villages then camps, the percentages in villages was 11.8% in 1-10 count, 9.0% in 11-100 count and 9.1% in 101-1000 count. While the percentage of FC contamination in camps was 10.5% in 1-10 count, 9.1% in 11-100 count and 5.4% in 101-1000 count.

Table 9. Fecal Coliform (FC) level in the area studied.

Area	FC (Count/ 100 ml) (%)					Total of Samples (%)
	0 (%)	1-10 (%)	11-100 (%)	101-1000 (%)	> 1000 (%)	
City	1284 (84.0)	157 (10.3)	64 (4.2)	21 (1.4)	2 (0.1)	1528 (100)
Villages	735 (70.1)	124 (11.8)	94 (9.0)	95 (9.1)	0 (0)	1048 (100)
Camps	165 (75.0)	23 (10.5)	20 (9.1)	12 (5.4)	0 (0)	220 (100)
Total	2184 (78.1)	304 (10.9)	178 (6.4)	128 (4.5)	2 (0.1)	2796 (100)
P value	**0.000**					
Chi square	**52.848**					

3.1.3 Distribution According to Sources of Sampling.

3.1.3.1 Concentration Free Chlorine Residual and Sources of Samples.

Table (10) shows that first four sources with high percentage of chlorine concentration < 0.2 are school, spring, sweatshop and restaurant. The percentage was 100, 83.1, 82.8 and 79.0 respectively. While the first four sources with high percentage of chlorine concentration >0.8 are artesian well, storage tank, rain fed cistern and sweetshop. the percentage was 7.7, 6.5, 3.6 and 3.4 respectively.

Table 10. Chlorine level and sources of sampling.

Place of Sampling	Chlorine conc (ppm)			Total no of Samples (%)
	< 0.2 (%)	0.2-0.8* (%)	>0.8 (%)	
Restaurant	236 (79.0)	52 (17.5)	8 (2.6)	297 (100)
School	13 (100)	0 (0)	0 (0)	13 (100)
Sweatshop	24 (82.8)	4 (13.8)	1 (3.4)	29 (100)
Spring	54 (83.1)	11 (16.9)	0 (0)	65 (100)

Place of Sampling	Chlorine conc (ppm) < 0.2 (%)	0.2-0.8* (%)	>0.8 (%)	Total no of Samples (%)
Storage Tank	24 (77.4)	5 (16.1)	2 (6.5)	31 (100)
Artesian Well	30 (76.9)	6 (15.4)	3 (7.7)	39 (100)
Rain Fed Cistern	17 (60.7)	10 (35.7)	1 (3.6)	28 (100)
Water Network	656 (55.9)	491 (41.9)	26 (2.2)	1173 (100)
Total	1056 (63.0)	579 (34.6)	40 (2.4)	1675 (100)
P Value	**0.000**			
Chi Square	**106.548**			

3.1.3.2 Levels of Total Coliform (TC) and Sources of Samples.

Table (11) shows that spring had the highest percentage of TC contamination which was 26.1% of TC count 4-50 and 38.3% of TC count 51-50000, then in rain fed cistern the percentage was 13.3% of TC count 4-50 and 46.1% of 51-50000 TC count. Then in artesian well the percentage was 20.9% of 4-50 TC count and 7.9% of 51-50000 TC count.

Table 11. Level of Total Coliform (TC) and sources of sampling

Sources of Sampling	TC (Count/ 100 ml) (%) 0-3 (%)	4-50 (%)	51-50000 (%)	Total no of Samples (%)
Restaurant	453 (82.4)	71 (12.9)	26 (4.7)	550 (100)
School	46 (76.7)	3 (5.0)	11 (18.3)	60 (100)
Sweatshop	120 (88.2)	10 (7.35)	6 (4.45)	136 (100)
Spring	101 (35.6)	74 (26.1)	109 (38.3)	284 (100)
Storage Tank	142 (78.9)	18 (10.0)	20 (11.1)	180 (100)
Artesian Well	109	32	12	153

Sources of Sampling	TC (Count/ 100 ml) (%)			Total no of Samples (%)
	0-3 (%)	4-50 (%)	51-50000 (%)	
	(71.2)	(20.9)	(7.9)	(100)
Rain Fed Cistern	52 (40.6)	17 (13.3)	59 (46.1)	128 (100)
Water Network	2164 (85.2)	202 (8.0)	174 (6.9)	2540 (100)
Total	3187 (79.1)	427 (10.6)	417 (10.3)	4031 (100)
P Value	0.0000			
Chi Square	207.279			

3.1.3.3 Levels of Fecal Coliform (FC) and Sources of Samples.

Table (12) shows that rain fed cistern had the highest percentage of FC contamination which was 11.0% of FC count 1-10, 21.7% of FC count 11-100, and 32.6% of FC count 101-1000. Then in spring the percentage was 19.2% of FC count 1-10, 15.9% of FC count 11-100, and 16.6% of FC count 101-1000. Then in artesian well the percentage was 14.0% of FC count 1-10, 11.0% of FC count 11-100, and 2.0% of FC count 101-1000.

Table 12. Fecal Coliform (FC) level and sources of sampling

Sources of Sampling	FC (Count/ 100 ml) (%)					Total of samples (%)
	0 (%)	1-10 (%)	11-100 (%)	101-1000 (%)	> 1000 (%)	
Restaurant	315 (78.4)	57 (14.2)	21 (5.2)	9 (2.2)	0 (0)	402 (100)
School	28 (82.4)	3 (8.8)	2 (5.9)	1 (2.9)	0 (0)	34 (100)
Sweatshop	82 (81.2)	11 (10.9)	8 (7.9)	0(0)	0 (0)	101 (100)
Spring	116 (47.3)	47 (19.2)	39 (15.9)	43 (17.6)	0 (0)	245 (100)
Storage Tank	127 (84.7)	8 (5.3)	8 (5.3)	7 (4.7)	0 (0)	150 (100)
Artesian Well	73	14	11	2	0	100

Sources of Sampling	FC (Count/ 100 ml) (%)					Total of samples (%)
	0 (%)	1-10 (%)	11-100 (%)	101-1000 (%)	> 1000 (%)	
	(73.0)	(14.0)	(11.0)	(2.0)	(0)	(100)
Rain Fed Cistern	32 (34.7)	10 (11.0)	20 (21.7)	30 (32.6)	0 (0)	92 (100)
Water Network	1411 (84.4)	154 (9.2)	69 (4.1)	36 (2.2)	2 (0.1)	1672 (100)
Total	2184 (78.1)	304 (10.9)	178 (6.4)	128 (4.5)	2 (0.1)	2796 (100)
P Value			0.000			
Chi Square			78.639			

3.1.4 Distribution According to Season.

3.1.4.1 Concentration of Free Chlorine Residual According to Season.

Table (13) shows that highest percentage of chlorine concentration < 0.2 in Autumn which was 68.2% then Spring Summer and Winter, it was 63.4%, 61.0% and 60.4% respectively. The percentage of chlorine concentration > 0.8 was high in Summer then Autumn and Spring, it was 5.4%, 2.3% and 1.1% respectively.

Table 13. Chlorine level according to the season.

Season	Chlorine conc (ppm)			Total no of Samples (%)
	< 0.2 (%)	0.2-0.8 (%)	0.8 (%)	
Spring	453 (63.4)	254 (35.5)	8 (1.1)	715 (100)
Summer	296 (61.0)	163 (33.6)	26 (5.4)	485 (100)
Autumn	176 (68.2)	76 (29.5)	6 (2.3)	258 (100)
Winter	131 (60.4)	86 (39.6)	0 (0)	217 (100)
Total	1056 (63.0)	579 (34.6)	40 (2.4)	1675 (100)

Season	Chlorine conc (ppm)			Total no of Samples (%)
	< 0.2 (%)	0.2-0.8 (%)	0.8 (%)	
P value	0.009			
Chi square	33.499			

3.1.4.2 Levels of Total Coliform (TC) According to Season.

Table (14) shows that the highest percentage of TC contamination was in Spring and Summer. In Spring the percentage of TC contamination was 11.8% in 4-50 count and 12.4% in 51-50000 count. While in Summer it was 9.7% in 4-50 count and 11.2% in 51-50000 count.

Table 14. Level of Total Coliform (TC) and the season.

Season	TC (count/ 100 ml) (%)			Total no of samples (%)
	0-3(%)	4-50 (%)	51-50000(%)	
Spring	1092 (75.8)	170 (11.8)	178 (12.4)	1440 (100)
Summer	868 (79.1)	106 (9.7)	123 (11.2)	1097 (100)
Autumn	772 (82.4)	95 (10.1)	70 (7.5)	937 (100)
Winter	454 (82.1)	55 (9.9)	44 (8.0)	553 (100)
Total	3186 (79.1)	426 (10.6)	415 (10.3)	4031 (100)
P value	**0.0000**			
Chi square	**24.200**			

3.1.4.3 Levels of Fecal Coliform (FC) According to Season.

Table (15) shows that Spring and Summer had the highest percentage of FC contamination. In Spring it was 13.3% in 1-10 FC count, 7.0% in 11-100 FC count, 5.8% in 101-1000 FC count. In Summer the percentage of FC contamination was 10.6% in 1-10 count, 6.2% in 11-100 count, 5.0% in 101-1000 count and 0.2% in > 1000 count.

Table 15. Fecal Coliform (FC) level according to season.

Season	FC (Count/ 100 ml) (%)					Total of Samples (%)
	0 (%)	1-10 (%)	11-100 (%)	101-1000 (%)	1000 (%)	
Spring	724 (73.9)	130 (13.3)	69 (7.0)	57 (5.8)	0 (0)	160 (100)
Summer	626 (78.0)	85 (10.6)	50 (6.2)	40 (5.0)	2 (0.2)	1106 (100)
Autumn	524 (81.4)	62(9.5)	39 (6.1)	19 (3.0)	0 (0)	596 (100)
Winter	307 (84.1)	26 (7.1)	20 (5.5)	12 (3.3)	0 (0)	934 (100)
Total	2184 (78.1)	304 (10.9)	178 (6.4)	128 (4.5)	2 (0.1)	2796 (100)
P value	0.485					
Chi square	8.5					

Chapter Four

Discussion

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4.1 Level of Free Chlorine Residual, Total Coliform, Fecal Coliform in Years Studied.

There is a significant association between the level of free chlorine and the year studied. According to WHO and PSI standard the result of this study show that only 37% of the tested drinking water samples taken in 1997 have FCR within the standards and 33.4%, 35.2 %, 28.8% in 2001 , 2001 and 2003 respectively.

A significant relationship exists between each of total and fecal coliform with the year of the study. The year 2000 had the higher contamination with TC while the year 2003 had the least contamination. Fecal contamination appeared clearly in the year 1997 while the least FC contamination was in 2001.

There is problem in the collecting samples system, eg, in the year 1997 there were 1153 TC samples. While the number of TC samples were 1357, 602, and 919 in the years 2000, 2001, and 2003 respectively. And this affected data analysis results.

Such findings could be due to the fact that chlorine disinfection is very important for improving water quality; and this mean decrease in TC and FC contamination.

But this fact does not appear in this study, because most of analyzed samples were taken from sources, and in usual water in sources free from contamination, and contamination usually occurs after distribution.

This was shown clearly in the year 2000 where the results show that 62.9% of the tested drinking water have a concentration of FCR less than 0.2 (less than the standard) and in the same year TC contamination was 30.6% (low and intermediate risk of contamination). FC in the same year was also as high as 33% (high and intermediate risk of contamination).

4.2 Level of Free Chlorine Residual, Total Coliform, Fecal Coliform in the Area Studied.

The result showed that a significant association exist between each of the level of free chlorine residual, TC, FC in the area studied. This study show that 20.5% of the tested drinking water samples that were taken from the city have FCR within the standard limits, and 41.3% and 74.3% in villages and camps, respectively.

There is strong relation between CFR and fecal and total contamination, but this does not appear in this study because many of CFR tests were taken after wells owners in villages add chlorine to their wells.

The water taken from the villages have higher TC and FC contamination than water from the city and the camps. According to the survey which was conducted by ARIJ in 1995, the waste water network covers only 38% of Nablus district. Almost 70% of Nablus city is served by the sewage network. The remaining part of the city use cesspits to dispose their wastewater, or simply drain the wastewater in the nearby wadi. Open sewage channels are usually used in the refugee camps (ARIJ, 1996).

The sewage Network system consists of a total 60 Km of sewer lines. In Beit Eiba , the network covers only 40% of the village . Other villages, which are located near Nablus city, discharge their wastewater directly into Wadi Nablus (ARIJ, 1996).

The wastewater in the existing western sewage pipeline within the municipal boundaries discharges into wadi Nablus. On the eastern side of the district, the present pipeline ends at the location near the slaughter-houses where it is discharged into wadi Al-Sajoor. It then flows through wadi El Badan to the Jordan Valley. Thus the waste water either pollutes the aquifer through percolation or is used by farmers for irrigation in the adjacent villages (Nablus municipality, 2002).

Cesspits are one of the main methods presently used to dispose of wastewater in areas lacking sewage networks. Cesspits are most commonly used in the villages and camps, thus covering approximately 62% of Nablus district. The use of cesspits has led to negative consequences, for example, cesspits often leak or overflow and their waste needs to be pumped out. Many villages like Ejnesiniya, Yatma, Jit, Qabalan, Es Sawiya, Odala, and others, are suffering from leaking cesspits which threaten wells and springs (ARIJ, 1996).

Another alternative wastewater disposal method is open channels. Open channels are commonly used in refugee camps. Far'a camp is a good example, where the wastewater is collected in two open channels. The wastewater flows toward the southern part of the camp to Ein Shibli, where it meets the wastewater discharged from Nablus city. At that location, the raw wastewater flows outside the camp boundaries to be used for irrigating of various crops. Because the channels are uncovered, overflow of the drains is likely to occur during the Winter (ARIJ, 1996).

Another problem is solid waste, according to ARIJ survey, 60% of the waste is disposed of randomly near houses, or in open spaces on roadsides. Often the waste is dumped and this directly and indirectly cause water contamination.

The disposal of industrial, municipal and domestic waste water directly into streams is a major source of water pollution In Nablus district specifically in villages as Qussien, Asira Esh Shamaliya, Kafr Qallil, Ásira al Qibliya, Nisf Jbeil, and Qaryut. In these villages cesspits flood into the streets. This surface flow creates wet areas in the nearby lands which are hazardous for people living adjacent to them.

Most important, sewage sludge contains traces of many pollutants, toxic materials, organic waste material, pathogenic bacteria, viruses, and protozoa along with parasites, all of which could bring potential harm to human health. But the problem in the camps didn’t show clearly in this study because few numbers of tested drinking samples were taken from camps.

4.3 Level of Free Chlorine Residual, Total Coliform, Fecal Coliform and the Sources of Sampling

The results show that there is significant association between each of the level of free chlorine residual, TC and FC with the sources of sampling. Although there is differences in the numbers of tested drinking water samples which were taken from different places; it is clear that spring and rain fed cisterns had higher TC and FC contamination, while the water network was the least contaminated place. This indicates that such springs and rain fed sources were exposed to fecal contamination but network supply is chlorinated regularly.

But this fact does not appear in this study, because most of analyzed samples were taken from sources, and in usual water in sources free from contamination, and contamination usually occurs after distribution.

4.4 Level of Free Chlorine Residual, TC, FC and the Seasons

The study shows that percentage of FCR in the tested drinking water samples which was within the standard were the same in the four seasons but the results show that there is no significant relationship between FC and seasons.

The percentage of TC and FC were high in Spring and Summer. This may be due to high temperature which increase bacterial growth and in this seasons there is a shortage in water and this increases water-washed disease.

Bacteria grow faster at higher temperature, the growth rate slows dramatically at low temperatures (Murphy, 2000). Sunny climate improves the quality of drinking water because sunlight will destroy much of the fecal bacteria present in contaminated drinking water, this occur only if water contain sufficient oxygen (Reed, 1997).

There is also some evidence that heavy rainfall events may be followed by coliform re-growth in water distribution systems, presumably because of increased nutrients in water. However, the health significance of this observation is unclear as non-fecal coliforms in drinking water do not appear to be associated with disease in the community (Hunter, 2003).

The results show that there is no significant relationship between FC and seasons.

Most of the bacteriological parameters (colony, *Escherichia coli*, coliform, *fecal streptococcal*, and *Clostridium peifringens* counts) increased considerably during extreme runoff events. If relevant sources of parasitic contamination occurred in catchments areas, the concentrations of Giardia and Cryptosporidium will rise significantly (Kisternann *et al*., 2002).

Conclusion

Although there are several methods to eliminate disease-causing organism in water, chlorination is the most commonly used. It is important to add sufficient chlorine to the water to meet the chlorine demand and provide residual disinfection. An ideal system supplies free chlorine residual at concentration of 0.2-0.8 mg\ L.

The result of this study show that chlorinating of water resources was a major problem in the Nablus district. Many of the tested drinking water sample were not within the limits of Palestinian and International regulation for drinking water. Untreated or inadequately treated drinking water supplies is the greatest threat to public health, in Nablus district as it in the developing countries.

The political and economical situation restricts the efforts of MOH and other involved institutions to take action. The absence of clear lines of authority or overlapping between different governmental organizations, agencies and other sectors causing wastage of limited existing resources.

Recommendations

From the analysis of the previous results the following recommendations can be drawn.

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1.4 Limitations:

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بسم الله الرحمن الرحيم

جامعة النجاح الوطنية
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الجودة البيولوجية لمياه الشرب في محافظة نابلس

إعداد
ميسر لطفي عبد الفتاح الميناوي

إشراف
الدكتورة أنسام صوالحه
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قدمت هذه الأطروحة استكمالاً لمتطلبات درجة الماجستير في الصحة العامة بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس، فلسطين.

2004

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الملخص

الهدف من هذه الرسالة البحث في جودة المياه ومدى صلاحيتها للشرب وتحديد أثر تلوث المياه على صحة السكان في محافظة نابلس.

تم الحصول على معلومات الفحص البيولوجي لمياه الشرب في محافظة نابلس للسنوات 1997، 2000، 2001 و2003 من دائرة صحة البيئة – وزارة الصحة– تم تحليل هذه المعلومات ودراستها لتحديد جودة مياه الشرب.

تم تحليل 4031 عينة إحصائيا أخذت عشوائيا من منطقة الدراسة و التي تشمل (المدينة والقرى والمخيمات) في سنوات محددة وهي 1997، 2000، 2001 و2003. تم استخدام النسبة المئوية لكل من بكتيريا القولونيات وبكتيريا القولونيات الغائطية (الاشرسكية القولونية) كمؤشرات للتلوث في فحص المياه، كما تم فحص تركيز الكلور المتبقي في المياه كذلك.

دلت نتائج كل من مؤشران الفحص البكتيري أن معدلات التلوث خلال سنوات البحث ذات قيمة أعلى مما هو موصى به من قبل منظمة الصحة العالمية و دائرة المواصفات الفلسطينية للمياه الآمنة للشرب. حيث كانت النسبة المئوية لمعدلات القراءة لبكتيريا القولونيات (مستعمرة بكتيرية لكل 100 مل) 23% في سنة 1997، 30.6% سنة 2000، 11.5% سنة 2001، و 10.3% في سنة 2003. في حين كانت معدلات القراءة لبكتيريا القولونيات الغائطية

(الاشريكية القولونية) في سنوات البحث43.1، 33، 10.4، 12.4 (مستعمرة بكتيرية لكل 100 مل) على التوالي.

عند موازنة درجات التلوث غي مناطق البحث الثلاث (مدينة، قرية، مخـيم) باسـتخدام المؤشرات السابقة تبين وجود فرقا في مستويات التلوث و وجدت دلالة إحصائية واضحة حيـث كانت معدلات النسبة المئوية لبكتيريا القولونيات فـي ميـاه المدينـة 13% والقريـة 30.5% والمخيمات 18.6%بينما كانت النسبة المئوية لبكتيريا القولونيات الغائطية في نفـس المنـاطق 16%، 29.9%، 14.6% على التوالي.

فيما يتعلق بدرجة التلوث المقدرة بالاعتماد على بكتيريا القولونيات كانت النسبة أعلى ما يكون في الينابيع حيث بلغت 86.8% ثم مياه المطر حيث كانـت 59.4% وبالاعتمـاد علـى بكتيريا القولونيات الغائطية كانت نسبة التلوث في مياه الينابيع و مياه المطر 64.4%، 56.8% على التوالي.

عند مقارنة درجات التلوث مع فصول السنة تبين وجود فرقا ظاهرا غي درجات التلوث ووجدت دلالة إحصائية واضحة فكانت أعلى درجات التلوث قي فصلي الربيع حيث كانت النسبة المئوية لبكتيريا القولونيات 24.4% في فصل الربيع و20.9% في فصل الصيف.