An-Najah National University
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BACTERIAL QUALITY OF DRINKING-WATER IN RAINFED CISTERNS AND ROOF STORAGE TANKS IN BEIT LEED AND SAFARINE VILLAGES

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ABSTRACT

Three hundred drinking water samples were collected from two storage systems (cisterns and roof storage tanks), 150 sample from each. The samples were collected during the summer season from June to October 1999 from two villages (Beit Leed and Safarine) in the district of Tulkarm. Average counts for both total coliform and thermotolerent coliform *E. coli* were used as indicators for water quality based on membrane filtration technique.

Both indicators gave average counts higher than that recommended as safe drinking water by the WHO. Total coliform counts were 16.1 and 12 CFU/100ml water in cisterns and roof storage tanks respectively, while average counts of thermotolerent coliform *E. coli* were 7.0 and 5.4 CFU/100 ml water for cisterns and roof storage tanks respectively. Roof storage tanks showed lower average counts for both indicators.

A comparison between old style and forced concrete cisterns showed a significant difference in favour of rain forced concrete cisterns using both indicators. Average counts for total coliform and thermotolerent coliform *E. coli* in old style cisterns were 17.6 and 7.9 CFU/100ml water respectively, while in forced concrete cisterns were 8.7 and 3.1 CFU/100ml water respectively.

Based on the average counts for both indicators no significant variations were observed on the quality of drinking water in the studied villages. Variations in both average counts for both indicators were with significant values with respect to different selected regions especially for Beit Leed center.

The degree of contamination based on total coliform counts in both storage systems were similar and the majority were with first degree of contamination according to the WHO classification. Based on thermotolerent coliform *E. coli* with respect to the risk levels, both storage

systems were within low and intermediate risk levels according to WHO classification.

A noticeable decrease in both indicators is clear up to a distance of 22 meter and above between cesspits and cisterns, however, variations up to 28 meters were of no significant values according to our findings with respect to total coliform count and thermotolerent coliform *E. coli*.

Neither cesspits' levels nor animal razing seems to have further effect on the contamination and risk levels compared to the findings on households with no histories with animal razing or having cesspits within the same level or uphill to cisterns. Our findings regard cisterns age indicate a significant increase in both indicators reflecting an increase degree of contamination and risk levels with increased cisterns age. Average counts of total coliform were 7.6 CFU/100ml water for age group greater than 0 to 9 compared to 57 CFU/100ml water for age group more than 90 years, however, thermotolerent coliform *E. coli* counts were 7.9 CFU/100ml water for age group greater than 0 to 9 compared to 31 CFU/100ml water for age groups more than 90.

CHAPTER I

INTRODUCTION

1.1 Introduction

Water is essential to sustain life, and its satisfactory supply must be made available to consumers. Efforts should be made to achieve a drinking water quality as high as practicable. Protection of water supplies from contamination is the first line of defense, and the source protection is the best method of ensuring safe drinking-water [1].

Water sources must be protected from contamination by human and animal waste, which can contain a variety of bacterial, viral, protozoal pathogens and helminth parazites. Failure to provide adequate protection and effective treatment will expose the community to the risk of out breaks of intestinal and other infectious disease. The greatest microbial risks are associated with ingestion of water that contaminated with human and animal excreta [1].

The recognition that faecally polluted water can lead to spread of microbial infections has lead to the development of sensitive methods for routine examination to ensure that water intended for human consumption is free from faecal contamination, although it is now possible to detect the presence of many pathogens in water, but the method of isolation and enumeration are often -complex and time consuming, it is therefore impracticable to monitor drinking water for every possible microbial pathogens [1].

A more logical approach is the detection of organisms normally presents in the faces of human and other warm-blooded animals as indicator of faecal pollution.

The materials dissolved or suspended in water give each source a distinctive character and its related to the ability to dissolve inorganic materials which it contacts. Many organic materials dissolve or become colloids in contact with water.

Water doesn't exist as monomolecular H_2O. It is one of the most difficult substances to obtain in a pure state due to its ability to dissolve materials in contact with it as well as its ability to support microbial life[2].

Water quality includes biological, chemical and physical aspects. Conditions that may cause variations in water quality are climatic, geographic, geologic conditions, season of year, resource management, and diurnal variation [2].

The most sources of water pollution are human waste from sewage, farm manure, and agrochemical, such as: pesticides and fertilizers. The pollution of water has two types of sources:

- Point sources: sources of pollution that are situated at one location, often a specific outlet (discharge) pipe.
- None point sources: those that don't come from one specific location, instead they come from many small sources (It is usually caused by water that flows over land to water sources) [2].

Water rapidly absorbs both natural and man-made substances, as a result to this the water will becomes unsuitable for drinking without treatment. Important categories of substances which can be considered undesirable in excess and effect the water quality were [2, 11]:

1- Coloure: This is due to the presence of dissolved organic matter from peaty soils, or the mineral salts of iron and manganese.

2- Suspended matter: This is like a fine mineral and a plant material that is unable to settle out of water.

3- Turbidity: This is a measure of the clarity, or transparency, of the water cloudiness can be caused by numerous factors such as particles in suspension, high bacteria concentration.

4- Pathogens: These can be viruses, bacteria, protozoa or other types of pathogenic organisms that can adversely affect the health of the consumer. They can arise from animal or human wastes which will contaminate the water sources.

5- Taste and odures: Unpleasant taste and odours are due to a variety of reasons such as contamination by waste water, excessive concentration of certain chemicals, decaying vegetation, stagnant conditions due to the lake of oxygen in the water and the presence of certain algae.

6- Harmful chemicals: There is a wide range of toxic and harmful organic and inorganic compounds which can occur in water resources. These are absorbed from the soil or occur due to contamination from sewage and industrial wastewater. Water contamination is not only from the resources themselves but also can be happened during treatment, distribution, storage and within the consumers' home.

1.2 Water resources in the West Bank and Gaza Strip

The occupied territories and Israel are depending on the same water resources. Water sources are originating from the rain and they are comprising ground water and surface water [3].

Since Israeli occupation of the West Bank and Gaza Strip in the year 1967, Israel has been exploiting the natural Palestinian resources, especially water. Israel has issued several military rules for the water in the West Bank, to diminish the Palestinian control on these resources in order to prevent them from exploiting such resources, for example prohibit drilling of new groundwater wells [2].

It is well documented that the total annual water consumption of the Palestinians in the West Bank and Gaza Strip (with a population of nearly 2.5 million) is 250 million m^3 (mcm), which gives an average of 100/m^3/capita/year). While the annual Israeli consumption (with a population of nearly 5 million) is 2 milliard m^3 which gives an average of 400m^3/capita/year, which is four times as much as the Palestinian individual consumers [3]. The Palestinian water experts are demanding that

Palestinian share in water should be increased from 250 million m^3 to 450 million m^3; i.e. 75% of annual water production, while, at present, it doesn't exceed 40%. This, in addition to giving the Palestinians the full rights to drill groundwater wells in Palestine [4].

1.2.1 Water supply systems In the West Bank

After the Israeli occupation in 1967, the West Bank has administratively divided into eight districts, namely: Jenin, Tulkarın, Ramallah, Nablus, Jerusalem, Bethlehem, Hebron and Jerico. These districts depend on: water-net work supply systems (piped water) and house hold rainwater; cisterns and communal sources (unpiped water) [5]. Table 1.1 shows water supply systems in various districts.

Table 1.1. Cities and villages with piped and unpiped water system.

No.	District	No. of cities and villages	Cities and villages with piped water	Cities and villages with unpiped water
1	Jenin	76	34	42
2	Tulkarm	78	41	37
3	Nablus	65	34	31
4	Ramallah	99	87	12
5	Bethlehem	59	39	20
6	Hebron	114	46	68
7	Jericho	13	9	4
	Total	504	290	214

Out of 504 listed cities and villages with the various districts, 214 villages are without piped water supply system, which comprize 42% of the total number of cities and villages which contain about 30-35% of the total population [5].

Most of these villages rely on the following systems for their water supply: Household rainwater (cistern), and communal sources as wells, springs and canals. Where communal sources are used, water is transported to homes by tankers and animals.

At present most of out-water network supply depends on, private wells (35.8%), Mekorote systems (27.6%) and West Bank department wells or springs (36.6%) [5].

The use of water in the West Bank is mainly for domestic, agriculture and industrial purposes. The total pumped quantities of water among these, from wells, springs and Mekorote resources are about 30-31 mcm/year, 22 mcm from wells, 4.5 mcm from springs and 4-5 mcm from mekorote [5]. The number of wells in the West Bank that are used for domestic is 41 and they are distributed in the different districts as shown in table 1.2.

Table 1.2. Number of domestic wells in West Bank and their owner ship in various districts.

No.	District	West bank water department	Municipalities	Village council	Local water department
1	Jenin	3	3	-	-
2	Tulkarm	1	7	6	-
3	Nablus	1	4	-	-
4	Ramallah	2	-	-	4 JWU*
5	Bethlehem	5	0	0	1 BWA**
6	Hebron	2	2	-	-
	Total	14	16	6	5

*JWU: Jerusalem Water Undertaking.
** BWA: Bethlehem Water Authority.

The average daily consumption of water for domestic and industrial sector in the West Bank was estimated [5] as follows: 100-120 litter/capita/day in cities, 70-90 litter/capita/day in towns, and 40-60 litters/capita/day in villages.

1.2.2 Water Supply systems In Tulkarm district

In 1997, the Palestinian National Authority divided the West Bank area into 11 districts, by considering Qalqillia, Salfeit and Tubas as new districts. Based on this new division, several villages, that were belonged to Tulrakm district were transferred and connected to both Salfeit and Qalqillia district. According to this, the number of villages was reduced form 78 to 42 villages with a total population number of 129,000 [6]. Out of 42 villages within this district only 25 are connected to water network system and the rest still dependent on private systems (cisterns). It is worth note, that most areas with water network systems are also have private water supply systems (cisterns).

1.2.3 Water Supply Systems in Beit Leed and Safarine villages

These villages are situated in the eastern part of Tulkarm city. They are about 15-18 km far from the city, both are dependent on cisterns water supply. However, Beit Leed, was partially connected to a water network systems in 1993 and the number of households that are connected now is 502 households out of 786. The remaining households are still depending completely on private sources and mainly rain fed cisterns. On the other hand, all newly connected households still have their own cisterns supply.

The population of Safarine village still depend upon rain fed cisterns[6].

Table 1.3 shows population, buildings, cisterns, cesspits and other services in Beit Leed and Safarine villages.

Table 1.3. Population, buildings, cisterns, cesspits, and other services in Beit Leed and Safarine villages

Village	No. of building	No. of Building Connected With Electricity Network	No. of Cesspit	No. of Cisterns	No. of Population	No. of Building Connected to water network
Beit Leed	786	640	675	1024	4412	502
Safarine	130	122	122	170	744	-

1.3 Cisterns

Cisterns are artificial reservoirs for collecting and storing rainwater from impermeable area. For a long time, Palestinians have been constructing cisterns to collect and store the rainfall from the roofs of their houses. These days, and in spite of the availability of water distribution systems in most cities and villages of the West Bank, the people continue collecting rain water in water cisterns, and this is due to the lack of continuos network water supply systems in addition to the limited winter season.

Harvested rainwater have been used for domestic and irrigation purposes, and it constitutes favorable alternative source of water. Due to the cost consideration and the limitation in current water supplies, with respect to quantity and quality, cistern of rainwater have started to attract attention as available and important source of water. Evidences in these respects are clear from the directed special programs of several Non Governmental Organizations (NGO's), such as, Palestinian Hydrology Groups.

Many cisterns, especially those that were constructed more than 50 years ago, have a pear shape that is usually pasted with a relatively thin layer of cement. Currently, cisterns are designed and built with international standards and most municipalities encourage rain forced concrete cisterns of various shape and size. Cisterns are usually equipped with overflow system and their openings are securely covered in order to prevent the entry of pollutants that may contribute to water contamination. Electrical pumps are usually used to pump water from a cistern to small-galvanized metal reservoirs (roof storage tank).

In respect to the economical aspects, construction cost of cisterns depends on soil texture and the type of the cistern (rainforced, old style)[7].

In general, constructions of cisterns are socially acceptable, relatively cheep, environmental safe, and don't require special permissions[7].

Possible sources that affect the bacterial quality of water in cisterns include, presence of cesspits, the distance between cesspits and cisterns, the level of cesspits with respect to the cisterns, animal razing, water sources (catchment area), age of cistern, washing of cisterns, styles of cisterns and treatment methods. To search for these possible sources a questionnaire was used (see annex I).

1.4 Roof storage tanks

A storage tank is commonly used to ensure water availability for the family needs. A storage tank is made of metal, plastic or asbestos with volume range (1-2) m^3. Most roof storage tanks are supplied with secure covers and usually fitted on metal stands.

1.5 Water Diseases and Microbial Water Quality Indicators

1.5.1 Water diseases

In general water pathogens are discrete and often clumped or adherent to suspend solid objects, thus acquiring an infective dose cannot be predicted from their average concentration in water. Infection usually depends upon the invasiveness and virulence of such pathogens, as well as the immune status of the individual and when an infection is established, pathogens multiply. Unlike chemical agents, the dose response of pathogens is not cumulative. Due to the above mentioned facts, water intended for human consumption should be free of any pathogenic agents[1].

Table 1.4 shows the health significance, properties of orally transmitted pathogens though contaminated water [1].

Table 1.4. Orally transmitted water born pathogens and their significance in water supply

Pathogen	Health Significance	Resistance to chlorine [a]	Relative Infective Dose [b]
Bacteria			
- *Campylobacter jejuni*	High	Low	Moderate
- Pathogenic *E. coli*	High	Low	High
- *Salmonellae typhi*	High	Low	High
- Other salmonellae	High	Low	High
- *Shegella* spp.	High	Low	Moderate
- *Vibrio cholerae*	High	Low	High
- *Yarsinia enterocolitica*	High	Low	high (?)
- *Pseudomonas aeruginosa*	Moderate	Moderate	High (?)
- *Aeromonas* spp.	Moderate	Low	High (?)
Viruses			
- Adenoviruses	High	Moderate	Low
- Enterviruses	High	Moderate	Low
- Hepatitis A	High	Moderate	Low
- Hepatitis non A, non B	High	Moderate	Low
- Hepatitis E	High	?	Low
- Norwalk viruses	High	?	Low
- Rotavirus	High	?	Moderate
- Small round viruses	Moderate	?	Low (?)
Protozoa			
- *Entamoeba histolytica*	High	High	Low
- *Giardia intestinalis*	High	High	Low
- *Cryptosporidium parvum*	High	High	Low
Helminths			
- *Dracunculus medinensis*	High	Moderate	Low

[a] Resistance to chlorine: 1- low: agent completely destroyed. 2- Moderate: agent may not be completely destroyed. 3- (?) not known or uncertain.

[b] Dose required to cause infection in 50% of healthy adults.

Infectious diseases caused by pathogenic bacteria, viruses and protozoa or by parasites are the most common and widespread health risk associated with drinking water. Infectious diseases are transmitted through human-animal excreta, particularly faeces. The presence of active cases or carriers in the community strongly indicates faecal contamination of water sources. The use of such water for drinking, food preparing, washing, bathing, or even inhalation, of water vapour or aerosols, may result in infection [1].

1.5.2 Agents of significance

Agents of significance are those of high health significance, opportunistic, nuisance and toxins of cyanobacteria.

1- Agents of High Health Significance:

Agents of high health hazard are those that cause serious risk for disease when ever present in drinking water and these include:

a. Bacterial agents, such as: *Salmonella spp, Shegilla spp, Pathogenic E. Coli, Vibrio Cholerae, Yersinia, Enterocolytica and Campylobacter spp.*

b. Viral agents, such as: *Adenoviruses, Enteroviruses, Hepatitis A, Hepatitis non A, Non B, Hepatitis E, Norwalk virus, Rotavirus and small round viruses.*

c. Protozoal agents, such as: *Entamoeba histolytica, Giardia intestinalis and Cryptosporidium parvum.*

d. Helminths agent, such as: *Drocunculus medinesis.*

Most of these pathogens are widely distributed worldwide, and their elimination has a high priority [1, 11].

2. Opportunistic Pathogens:

They are naturally occurring microorganisms that are present in the environment and are not normally and regarded as nonpathogenic agents, however, they are able to become pathogenic under certain circumstances such as, impaired local or general defense mechanisms, such as elderly or the very young, patients with burns or extensive wounds, or those with acquired immunodeficiency syndrome.

Such agents include: *Pseudomonas aeruginosa, Flavobacterium, Acinetobacter, Klebsiella, Serratia, Aeromonos, Legionella, Naegleria fowleri and Acanthameeba spp* [1].

3- Nuisance Organisms:

Diverse organisms that have no public health significance but are undesirable as they may produce turbidity, taste odour, or appear as a visible animal life in water. Presence of such organisms indicates a defective state of water, such organisms include Sulfur and Iron Bacteria that may cause corrosion of metals [1].

4- Toxins from cyanobacteria:

Blooms of cyanobacteria (blue-green algae) usually occur in lakes and reservoirs. They are able to produce different toxins depending upon species. These include hepatotoxins, neurotoxins and Lipopoly saccharides[1, 11].

1.5.3 Environmental Classification of Water-Related Diseases Transmission

Water related diseases include those caused by various pathogenic microorganisms associated with water such as: viruses, bacteria, protozoa and helminthes, those related to chemical contaminates of water (flouride, heavy metals, and nitrate), and those classified as noncommunicable disease, due to lack of sufficient water for hygiene [1].

Water related diseases transmission are classified into the following categories:

1- Water-Borne diseases:

Caused by pathogens present in drinking water, the source of these pathogens is the excreta and sewage, examples of these: Typhoid, Cholera, Shigellosis, Giardiasis, and Hepatitis viruses [9].

2- Water-washed diseases:

Caused by lack of adequate volumes of water, such as Trachoma, Scabies and other skin and eye infections [9].

3- Water-Based diseases:

Cause by warms where the pathogen spends part of its life cycle in one or more intermediate aquatic host such as: *Schistosomiasis (Bilharzia)* [9].

4- Water related insect vector diseases:

Spread by insects which either breed in water such as Malaria or bite near water such as African trypanosomiasis [9].

1.5.4 Persistence and Infective Dose of Water Pathogens

After leaving their host, pathogens gradually lose viability and their ability to infect. Their rate of decay is usually exponential and become undetectable after a certain period. Pathogens with low persistence must rapidly find a new host and they are more likely to be spread by person contact rather than by drinking contaminated water. Because faecal contamination is usually dispersed rapidly in water the most common waterborne pathogens and parasites are those that have high ineffectivety or possess high resistance to decay out side the host body.

Persistence is affected by several factors of which temperature is the most important. Decay is usually accelerated by increasing temperature of water and may be mediated by the lethal effects of ultraviolet radiation sunlight acting near the water surface [9]. Table 1.5 shows the persistence time of some excreted pathogens in fresh water at 20 - 30°C [10].

Table 1.5. The usual persistence time of excreted pathogens in fresh water at 20 - 30°C.

Type of pathogen	Survival time in days in fresh water
Viruses Enteroviruses	< 50
Bacteria	
- Faecal coliforms	< 30
- Salmonella spp.	< 30
- Shigella spp.	< 10
- *Vibrio cholera*	< 5
Protozoa	
- *Entamoeba Histolytica cysts*	<15
Helminthes	
- *Ascaris Lumbricoides eggs*	Many months

Infective dose determines the number of organisms needed to produce either a clinically apparent infection or intestinal colonization in human subjects (dose required to cause infection in 50% of healthy adults). Experimental studies of infectivity provide relative information, but it is doubtful whether the infective doses obtained are relevant to natural infections. Water borne transmission of the pathogens has been confirmed by epidemiological studies and case histories. Ingestion large numbers of pathogens on a single occasion of contaminated drinking water is relatively small and this is mainly due to the fact that enteric pathogens cannot normally multiply in water and they also have the tendency to disperse.

If polluted water is permitted to contaminated food, bacterial pathogens can multiply to produce very large doses and hence, infection through such contaminated food will be more serious [1].

1.5.5 Microbial Water Quality Indicators

Faecal indicator is the most sensitive and specific way for assessing water hygiene quality. The major indicator organisms of faecal pollution are *Escherichia coli* the thermotolerent, total coliform bacteria, faecal streptococci, sulfite reducing colostridia and colliphages.

Indicator organisms must fulfill the following criteria: Universally presented in high numbers in the faeces of humans and warm-blooded animals, readily detectable by simple methods, should not grow in natural water and their persistence in water and that removal degree in treatment are similar to those of water borne pathogens. The criteria described above, for an ideal faecal indicator, are not expected to be met by any single organism, however, many of them are fulfilled by the thermotolerent coliform *E. coli,* thus thermotolerent coliform *E. coli* is considered as the first choice indicator [1, 9].

Thermotolerent coliform defined as the group coliform organisms that are able to ferment lactose at 44-45°C, they include the genus Escherichia and to alesser extent species of *Klebsiella, Enterobacter and Citrobacter*. Organisms other than *E. coli* may originate from organically enriched water, such as industrial effluents, from decaying plant materials and soil. For this reason, the often-used term faecal coliform is a misleading concept [1]. The concentration of thermotolerent coliform organisms is, under most circumstances, directly related to that of *E. coli* and their use in assessing water quality is considered acceptable for routine purpose.

E. coli is a member of the family Enterobacteriaceae, and characterized by possession of the enzymes β-galactosidase and β-glucuronidase. It grow at 44-45°C, ferments lactose and mannitol with production of acid and gas. Primate the intestine are normal rich for *E. coli*, thus, it is expected to be abundant in human and animal faeces and may attain concentration in fresh faeces up to 10^9 colonies per gram. It is found in sewage, treated effluents, and all natural waters and soils that are subjected to recent faecal contamination. Recently, *E. coli* is reported to be found and multiply in tropical waters that are not subjected to faecal pollution [15].

Finally, presence of thermotolerent coliform *E. coli* bacteria in water is indicative for faecal contamination and therefore, it is considered as indicative of a health risk [15].

WHO classified contamination of drinking water based on thermotolerent coliform *E. coli* count into five risk levels according to the count of thermotolerent coliform *E. coli* CFU/100 ml [1, 8]. WHO classification is shown in table 1.6.

Table 1.6. WHO classification for *E. coli* counts and risk

Count /100 ml	Risk
0	No risk
Greater than 0 to 10	Low risk
Greater than 10 to 100	Intermediate risk
Greater than 100 to 1000	High risk
> 1000	Very high risk

Total coliform organisms have long been recognized as a suitable indicator of drinking water quality, as they are easy to detect and enumerate in water. The term coliform organisms refer to a group of gram-negative, rod shaped, non-spore former bacteria, capable of aerobic and facultative anaerobic growth in presence of bile salts. They are also able to fermint lactose and posses β-galactosidose gene [1].

Traditionally coliform bacteria were regarded to belong to the genera: *Escherhica, Citrobacter, Klebsialla and Enterobacter.* However, modern taxonomical methods consider this group as a hetrogeneous group that include lactose fermenting bacteria, such as: *Enterobacter cloacae* and *Citrobacter freundii.* Organisms belonging to this group can be found in faeces, soil, decaying plant material, and in drinking water rich in nutrients. Thus, it is presence in water, as coliform bacteria could be due to other sources rather than faecal contamination. A good example for this is the finding of *Serratia fonticola* species in water [1, 9].

The existence both of non-faecal coliform bacteria that fit the definitions of coliform bacteria, and of lactose negative coliform bacteria

(*Sallmonella, Shegilla)* limits the applicability of this group as indicator of faecal pollution. However, this test is useful for monitoring microbial quality of treated supplies, specially when coliform organisms are found in the absence of thermotolerent coliform organisms and for determining the contamination degree and treatment method.

Based on total coliform count the WHO classified contaminated drinking water into four degrees, and accordingly treatment of such water depends on its degree of contamination [11]. Table 1.7 shows this classification.

Table 1.7. WHO classification for contamination degree and treatment methods

Total coliform count	Contamination Degree	Treatment method
0 – 3	0	-
Greater than 3 to 50	1	Disinfection
Greater then 50 to 50,000	2	Agglutination, filtration, disinfection
> 50,000	3	Special treatment

When monitoring water quality, total coliform bacteria should not be detected, its presence indicates inadequate treatment, post treatment contamination or the presence of excessive nutrient.

1.6 Methods of Bacteriological Analysis

Methods that are used for bacteriological analysis are:

1- Multiple tube method.

2- On site testing method.

3- Presence-absence test.

4- Membrane-filtration method (MF).

The preferred methods for assessing water quality, using as indicators the members of total coliform group and thermotolerent coliform group are the membrane filtration technique and the multiple tube fermentation technique. Both are quantitative method with high levels of sensitivity and they can be used to evaluate all types of waters including treated drinking waters and untreated drinking waters [15].

Membrane-filtration gives a direct count of total coliform and thermotolerent coliform present in a given sample water. The method is based on filtration of known water volume through a cellulose membrane filter with uniform pore diameter of 0.45μm.

Bacterial filtrates retained on the surface of the membrane filter were inoculated on selective differential culture media and incubated at appropriate required temperature for each specific bacterial isolate [8].

Volume of water samples to be filtered will depend on the type of water. In case of surface water and water from cisterns and roof storage tanks the sample volume (0.1-100 ml) [8]. Volumes less than 10 ml should be added to the filtration apparatus after addition of at least 10 ml of sterile diluent to ensure adequate dispersal across the surface of the membrane filter [8]. (see table 1.8)

Table 1.8. Typical sample volume for membrane filtration analysis

Sample type	Sample volume (ml)
1- Treated drinking water	100
2- partially treated drinking water	10 - 100
3- Protected source water or ground water	10 - 100
4- Surface water and water from open wells	0.1 - 100

1.7 Current Status of Water Supply and Quality in Palestine

Over the past 15 years several attempts were made in order to determine quality of drinking water in various locations of the Wet Bank and Gaza Strip. Most of these studies were based on total coliform and thermotolerent coliform count.

A study by Smith C. (1985) at cisterns of Abushkdaydim village [16]. Indicates that the average quality of 75 cistern in village was 5.01CFU of faecal coliform/100 ml, the average of faecal coliform concentration in cisterns where electric pump was used was 2.61 CFU of faecal coliform/100ml, while in cisterns where buckets were used for removal of water was 7.61CFU/100 ml.

A study by Birzeit University Community Health Unit (1990) on water quality in the West Bank [16]. Presents a brief definition of clean drinking water, the concentration of faecal coliform is used as indicator for the level of water pollution in cistern, the result shows that cisterns which were fed by water originated from streets had more that 100 faecal coliform/100 ml, while cisterns which were fed from home yards had less level of faecal coliform pollution. Cisterns which are located at distance of more than 50 meters from sewage soakage pits had 50% less pollution than cisterns which are located at a shorter distance from soakage pits.

In general one can deduce from such studies that the quality of drinking water in cisterns is affected by several factors, it is below the required intentional levels and is unfit with the WHO standers.

1.8 Aims of the Study

The current study aims at:

1- Evaluating the bacterial quality of drinking water in cisterns and roof storage tanks, based on total coliform and thermotolerent coliform *E. Coli*.

2- Determining the degree of water contamination and the associated risk levels according to WHO standards.

3- Searching for possible sources of water contamination in the studies sides.

CHAPTER II

METHODOLOGY

2.1 Sample collection

Samples were taken from 150 households during summer season from June to October 1999, two samples were collected from each household; one from the cistern and the other from the roof storage tank. Two hundred samples were collected from Beit Leed and 100 samples were collected from Safarine. Both villages were divided to five regions: Center, east, west, south and north, and equal samples were collected randomly from each region.

Two bacteriological tests were done on each sample. First test is to measure the average count of total coliform, and the second is to measure the average count of thermotolerent coliform *E. coli*.

Water samples were collected in 250ml glass bottles previously sterilized by autoclave at 121°C for 20 minutes. Separate samples were collected from cisterns and roof storage tanks using WHO recommendations as follow:

Cisterns samples were collected using a clean-weighted bottles tied to a clean string, the bottles were slowly and carefully lowered to prevent touching the side of cisterns. The bottles were completely immersed in the water below the surface-avoiding disturbance of the sediments and were filled, the bottles were then immediately covered tightly by caps.

Samples from roof storage tanks were collected either using outlet taps (if available) or the outdoor of the roof storage tanks. In case of tap collection, taps were cleaned and opened at maximum flow one to two minutes before sample collection [8]. While in case of outdoor collection, bottles were held from the lower part and immersed to a depth of about 20cm, with its mouth upwards.

Samples were immediately placed in a light roof insulated box containing ice packs and they were then transferred to the lab within two hours of collection. Samples where either analyzed immediately or stored at -4°C until testing [8]. Samples were tested at the laboratory of the Union of Palestinian Medical Relief Committees.

2.2 Sample filtration and culture media

A 100ml water sample was used. Samples were filtered on a cellulose membrane filter with uniform pore diameter 0.45μm purchased from Micron Separations Inc, West Borough, MA 01581, Catalog no. E04 WG047S4, Lot no. 98941. Bacterial filtrates retained on the surface of the membrane filter were inoculated on a petredishes using a selective deferential culture media.

At present several media can be used for the examination of coliform organisms by the membrane filtration method and all are based on lactose fermentation principle [12]. In this study Eosin methylene blue agar (EMB) media was used, this media is made of peptone 10gm, methylene blue 0.065gm, lactose 5gm, distilled water 1 litter, sucrose 5gm, dipotassium 2gm, agar 13.5gm, eosin 0.4gm, final pH=7.2 and was purchased from Oxoid ltd., Basingstoke, Hampshire, England, lot/ch.-B: 134 59771.

EMB is a differential plating medium that can be used in the isolation and detection of the coliform bacilli from specimens with mixed bacteria. The aniline dye (eosin and methylene blue) inhibit gram positive and fastidious gram-negative bacteria. They also combine to form a precipitate at acid pH. Thus, serving an indicator of acid production [12].

Reaction and interpretation of bacterial growth on EMB agar media, typical strong lactose-fermenting colonies: notably *E. coli* produce colonies that are green black with a metalic sheen, however, week ferminters including *Klebsiella, Enterbacter, serratia* and *Hafnia*, produce purple colonies within 24-48 hours and non lactose ferminter including *Proteus, Salmonella,* and *Shegilla*, produce transparent colonies [12].

The colonies of total coliform and thermotolerent coliform bacteria were identified from there characteristics on the media, and enumerated, and the results were expressed in numbers of Colony-Forming Units (CFU)/100 ml of water [8]. Data was analyzed by using the statistical program Spss.

CHAPTER III

RESULTS

3.1 Bacterial quality of drinking water in cisterns and roof storage tanks

Data presented in table 3.1 shows the average count for total coliform and thermotolerent coliform *E. coli* in both storage systems.

Table 3.1. Average counts of bacterial indicators in cisterns and in roof storage tanks

Water source	Average count	
	Total Coliform	Thermotolerent *E. coli*
Cisterns	16.1	7.0
Roof storage tanks	12.0	5.4

The average count for total coliform in cisterns was 16.1 CFU/100 ml water and in roof storage tanks was 12.0 CFU/100 ml water. The average count of thermotolerent coliform *E. coli* in cisterns was 7.0 and in roof storage tanks was 5.4 CFU/100 ml water. Figure 3.1 shows graphical presentation of these data.

The observed differences in average counts of total coliform, between cisterns and roof storage tanks were significant with *P*-value of 0.002, and the differences in average counts of thermotolerent coliform *E. coli* between cisterns and roof storage tanks were significant with *P*-value of 0.049.

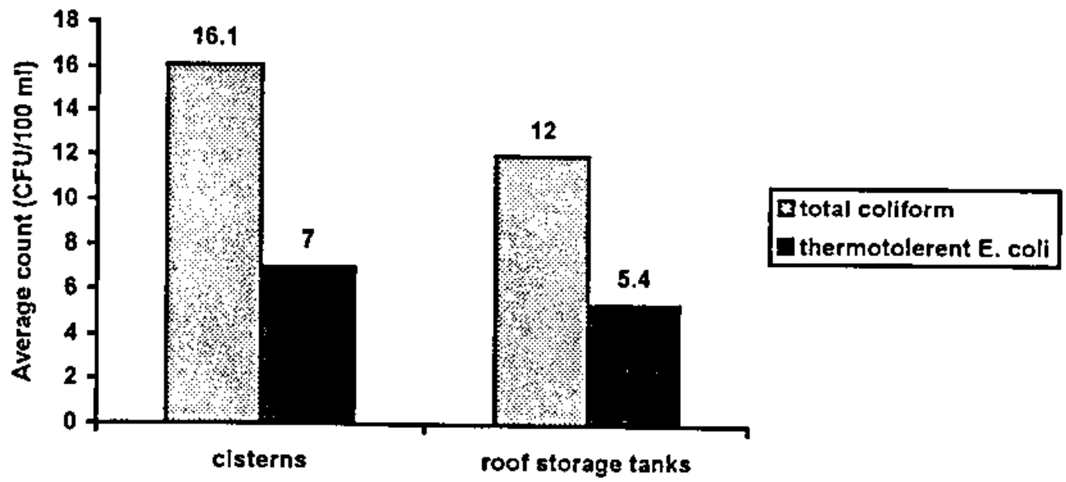

Fig. 3.1. Average count of Bacterial indicators in cisterns and in roof storage tanks.

3.2 Bacterial quality of drinking water in cisterns style

Data presented in table 3.2 shows the average count for total coliform and thermotolerent coliform *E. coli* in forced concrete cisterns and cisterns that is pasted with a relatively thin layer of cement (old style).

Table 3.2. Average counts of bacterial indicators in forced concrete and old style cisterns

Cisterns	Average count		
	No. of cisterns	Total Coliform	Thermotolerent *E. coli*
Old style	124	17.6	7.9
Forced concrete	26	8.7	3.1

The average count for total coliform in old style cisterns was 17.6 CFU/100 ml water and in rain forced was 8.7 CFU/100 ml water. The average count of thermotolerent coliform *E. coli* in old style cisterns was

7.9 and in forced concrete was 3.1 CFU/100 ml water. Figure 3.2 shows graphical presentation of these data.

The observed differences in average counts of total coliform thermotolerent coliform *E. coli* between old style and forced concrete were significant with *P*-values of 0.001 and 0.005, respectively.

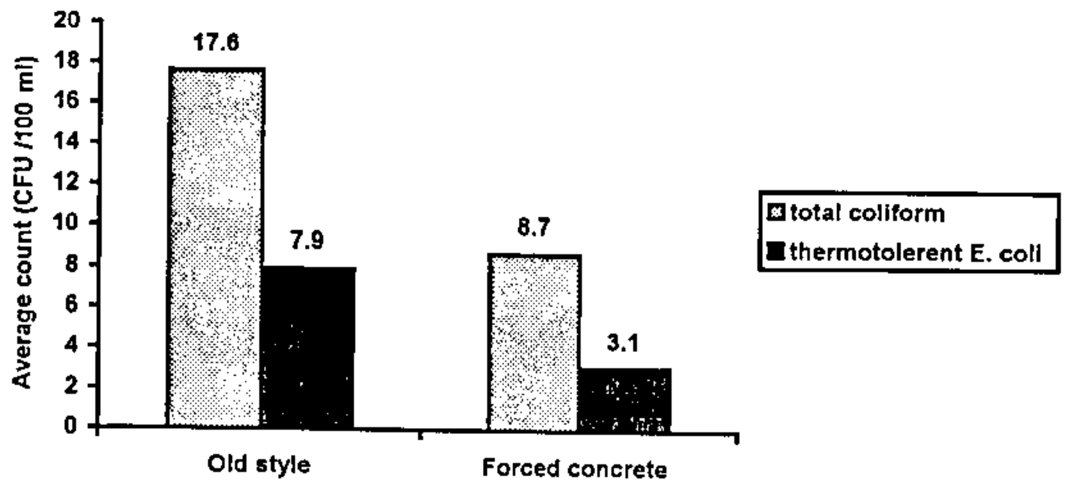

Fig. 3.2. Average count of Bacterial indicators in both cisterns' styles.

3.3 Bacterial quality of storage systems in Beit Leed and Safarine villages

Data presented in table 3.3 shows total coliform and thermotolerent coliform *E. coli* average counts in storage systems of the studied villages.

Table 3.3. Average counts of bacterial indicators in storage systems of Beit Leed and Safarine villages

Bacterial indicator / Village	Total coliform		*E. coli*	
	Cisterns	Roof storage Tanks	cisterns	Roof storage Tanks
Beit Leed	16.2	12	6.5	4.6
Safarine	15.8	12	8.3	5.1

The average count of total coliform in cisterns of Beit Leed and Safarine villages was 16.2 and 15.8 CFU/100ml water respectively, while that in roof storage tanks was the same in both villages 12 CFU/100ml water. The average count of thermotolerent coliform *E. coli* in cisterns of Beit Leed and Safarine villages was 6.3 and 8.3 CFU/100ml water, while that in roof storage tanks was 4.6 and 5.1 CFU/100ml water, respectively. Figures 3.3 and 3.4 show graphical presentation of these data.

Differences in average counts of total coliform in cisterns and roof storage tanks in both villages were of no significance with *P*-values of 0.825, 0.981 respectively. The differences in average counts of thermotolerent coliform *E. coli* in cisterns and roof storage tanks in both villages were of no significance with *P*-values of 0.191, 0.27 respectively.

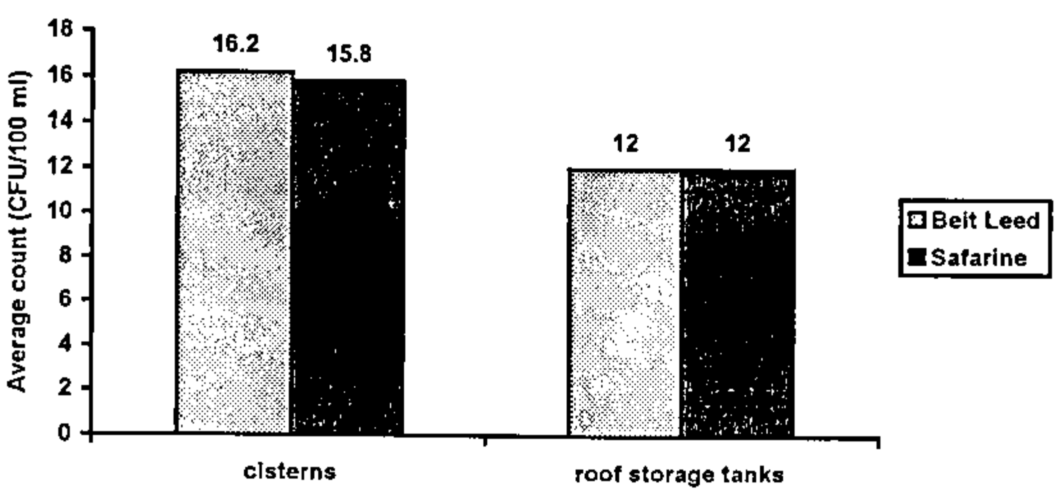

Fig. 3.3. Average count of total coliform in cisterns and roof storage tanks for Beit Leed and Safarine villages

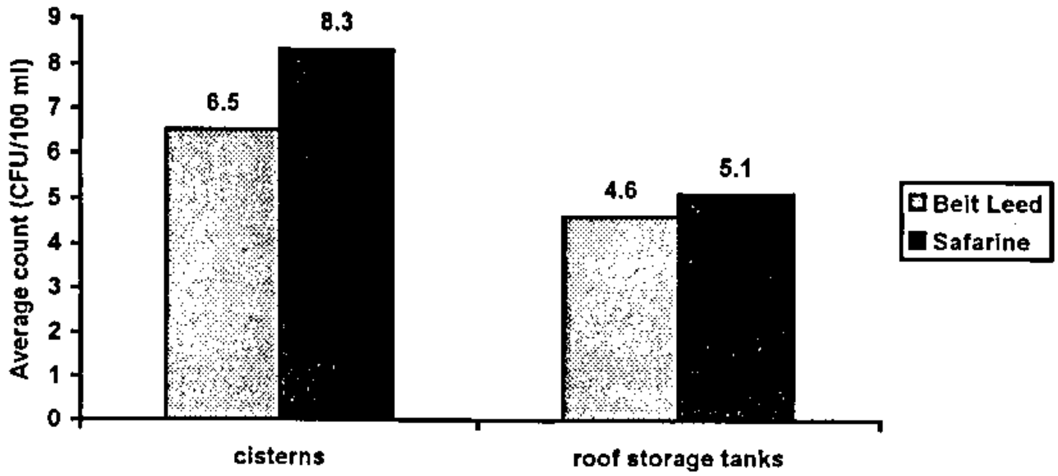

Fig. 3.4. Average count thermotolerent coliform E. coli in cisterns and roof storage tanks for Beit Leed and Safarine villages

3.4 Bacterial quality of storage systems in various regions of Beit Leed and Safarine villages

Data presented in table 3.4 represents regional variations in total coliform and thermotolerent coliform *E. coli* in both storage systems in the studied villages.

Table 3.4. Average count of bacterial indicators in various selected regions of Beit Leed and Safarine villages

Village	Region	Total coliform		*E. coli*	
		Cisterns	Roof storage tanks	Cisterns	Roof storage tanks
Beit Leed	South	14.8	10.3	5.1	4.0
	East	12.8	10.6	3.6	2.4
	North	16.3	12.9	6.5	5.5
	West	12.5	8.5	4.2	2.9
	Center	24.8	17.9	13.0	8.3
Safarine	South	13.9	10.9	8.7	5.3
	East	21.5	17.1	12.5	7.2
	North	11.0	9.1	5.7	3.3
	West	11.0	8.3	5.2	2.2
	Center	21.5	15.1	9.4	7.5

3.4.1 Variations in the average count of total coliform in cisterns of Beit Leed's regions.

The average count of total coliform in cisterns of Beit Leed's regions were 14.8, 12.8, 16.3, 12.5, and 24.8 CFU/100ml water for the south, east, north, west, and center of the village respectively. Differences in total coliform count were statically significant with *P*-value of 0.006. Multiple comparisons, using Least Significant Deference (LSD) test between various regions of Beit Leed were shown in table 3.4.

Table 3.5. LSD test for total coliform in cisterns of various regions of Beit Leed

Region	South	East	North	West	Center
South	-	1.95	-1.55	2.25	-9.95*
East	-	-	-3.5	0.3	-11.9*
North	-	-	-	3.8	-8.4*
West	-	-	-	-	-12.2*
Center	-	-	-	-	-

* Significant on the level (0.05).

Differences between the village center and other regions south, east, north and west were statically significant with *P*-values of 0.007, 0.001, 0.02 and 0.001 respectively, on the other hand differences among other regions were of no significance.

3.4.2 Variation in the average count of total coliform in roof storage tanks of Beit Leed's regions

The average count of total coliform in roof storage tanks of Beit Leed's regions were 10.3, 10.6, 12.9, 8.5 and 17.9 CFU/100ml water for the south, east, north, west, and center of the village respectively. Differences in total coliform count were statically significant with *P*-value of 0.014. Multiple comparisons, using Least Significant Deference (LSD) test between various regions of Beit Leed were shown in table 3.5.

Table 3.6. LSD test for total coliform in roof storage tanks of various regions of Beit Leed

Region	South	East	North	West	Center
South	-	-0.35	-2.7	1.75	-7.65*
East	-	-	-2.3	2.1	-7.3*
North	-	-	-	4.45	-6.95*
West	-	-	-	-	-9.4*
Center	-	-	-	-	-

* Significant on the level (0.05).

Differences between the village center and other regions south, east, north and west were statically significant with *P*-values of 0.008, 0.011, 0.049 and 0.001 respectively, on the other hand differences among other regions were of no significance. Figure 3.5 shows graphical presentation for total coliform in both storage systems among various selected regions in Beit Leed's village.

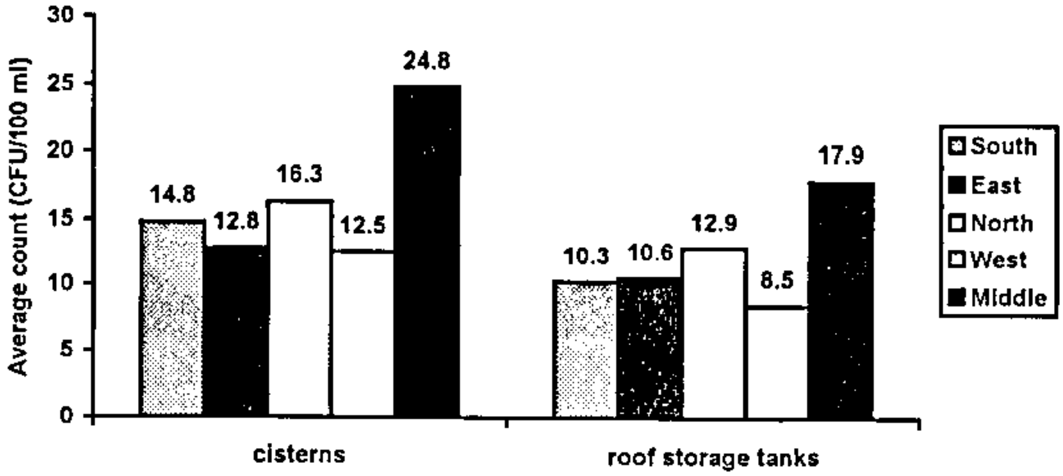

Fig. 3.5. Average count of total coliform in cisterns and roof storage tanks of Beit Leed's regions

3.4.3 Variation in the average counts of thermotolerent coliform *E. coli* in cisterns of Beit Leed's regions

The average count of thermotolerent coliform *E. coli* in cisterns of Beit Leed's regions were 5.1, 3.6, 6.5, 4.2 and 13.0 CFU/100ml water for the south, east, north, west, and center of the village respectively. Differences in thermotolerent coliform *E. coli* were statically significant with *P*-value of 0.001.

Multiple comparisons, using Least Significant Deference (LSD) test between various regions of Beit Leed were shown in table 3.7.

Table 3.7. LSD test for thermotolerent coliform E. coli in cisterns of various regions of Beit Leed

Region	South	East	North	West	Center
South	-	1.6	-1.35	0.9	-7.9*
East	-	-	-2.95	-0.7	-9.5*
North	-	-	-	2.25	-6.55*
West	-	-	-	-	-8.8*
Center	-	-	-	-	-

* Significant on the level (0.05).

Differences between the village center and other regions south, east, north and west were statically significant with *P*-values of 0.0001, 0.0001, 0.003, 0.0001 respectively, on the other hand differences among other regions were of no significance.

3.4.4 Variations in the average counts of thermotolerent *coliform E. coli* in roof storage tanks of Beit Leed's regions

The average count of thermotolerent coliform *E. coli* in roof storage tanks of Beit Leed's regions were 4.0, 2.4, 5.5, 2.9 and 8.3 CFU/100ml water for the south, east, north, west, and center of the village respectively. Differences in thermotolerent coliform *E. coli* were statically significant with *P*-value of 0.003. Multiple comparisons, using Least Significant Deference (LSD) test between various regions of Beit Leed were shown in table 3.8.

Table 3.8. LSD test for thermotolerent coliform E. coli in roof storage tanks of various regions of Beit Leed

Region	South	East	North	West	Center
South	-	1.65	-1.45	1.2	-4.2*
East	-	-	-3.1	-0.45	-5.85*
North	-	-	-	2.65	-5.75*
West	-	-	-	-	-5.4*
Center	-	-	-	-	-

* Significant on the level (0.05).

Differences between the village center and other regions south, east, north and west were statically significant with *P*-values of 0.011, 0.001, 0.009 and 0.001 respectively, on the other hand differences among other regions were of no significance. Figure 3.6 shows graphical presentation of thermotolerent coliform in both storage systems among various selected regions in Beit Leed's village.

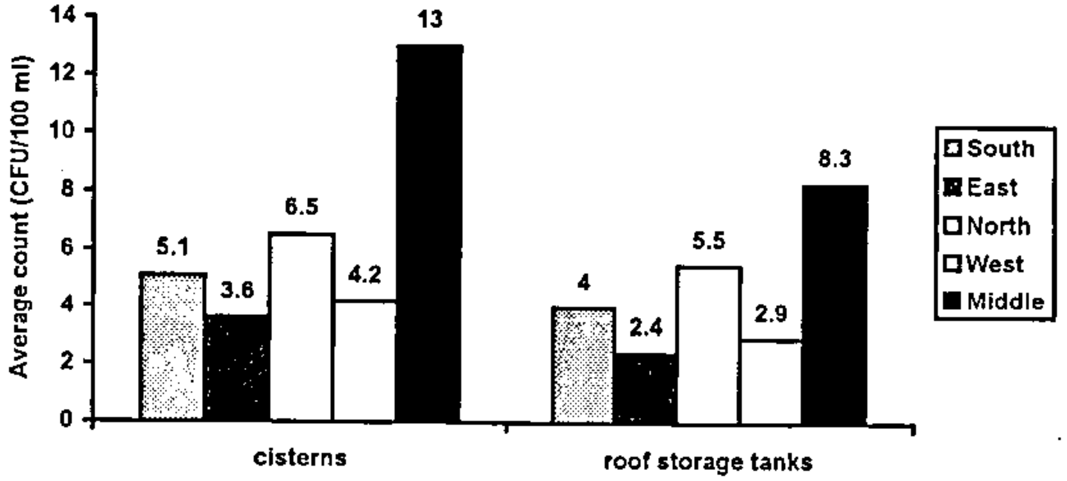

Fig. 3.6. Average count of thermotolerent coliform E. coli in cisterns and roof storage tanks of Beit Leed's regions

3.4.5 Variations in the average count of total coliform in cisterns and roof storage tanks of Safarine's regions

The average count of total coliform in cisterns and roof storage tanks were 13.9, 21.5, 11.0, 11.0, 21.5 and 10.9, 17.1, 9.1, 8.3, 15.1 CFU/100ml water for the south, east, north, west, and center of the village respectively. Figure 3.7 shows graphical presentation of these data.

Differences in the average count of total coliform in both storage systems among various regions were of no significance with *P*-values of 0.171 in cisterns and 0.274 in roof storage tanks.

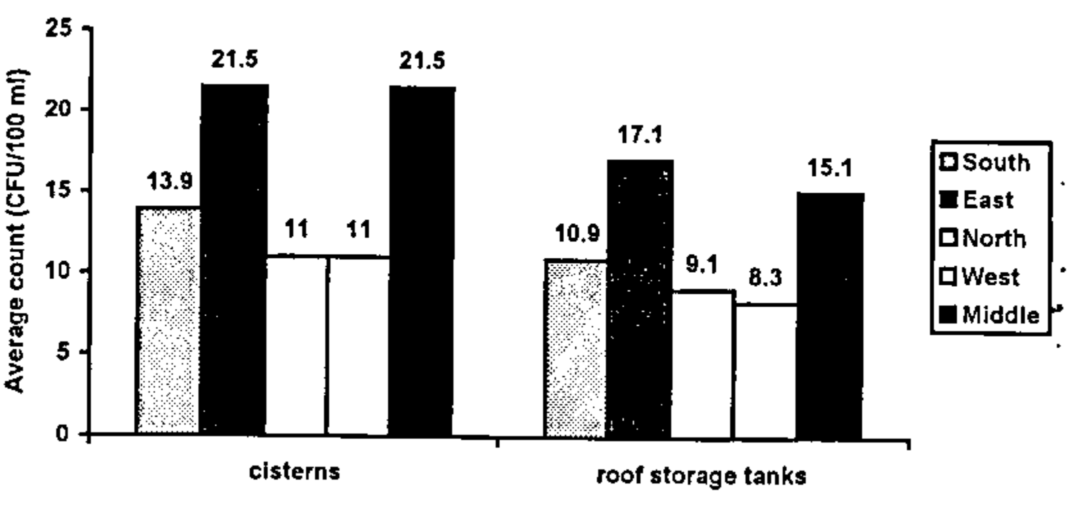

Fig. 3.7. Average count of total coliform in cisterns and roof storage tanks of Safarine's regions

3.4.6 Variation in the average count of thermotolerent coliform *E. coli* in cisterns and roof storage tanks of Safarine's regions

The average count of thermotolerent coliform *E. coli* in cisterns roof storage tanks were 8.7, 12.5, 5.7, 5.2, 9.4 and 5.3, 7.2, 3.3, 2.2, 7.5 CFU/100ml water for the south, east, north, west, and center of the village respectively. Figure 3.8 shows graphical presentation of these data.

Differences in the average count of thermotolerent coliform in both storage systems among various regions were of no significance with *P*-values of 0.324 in cisterns and 0.326 in roof storage tanks.

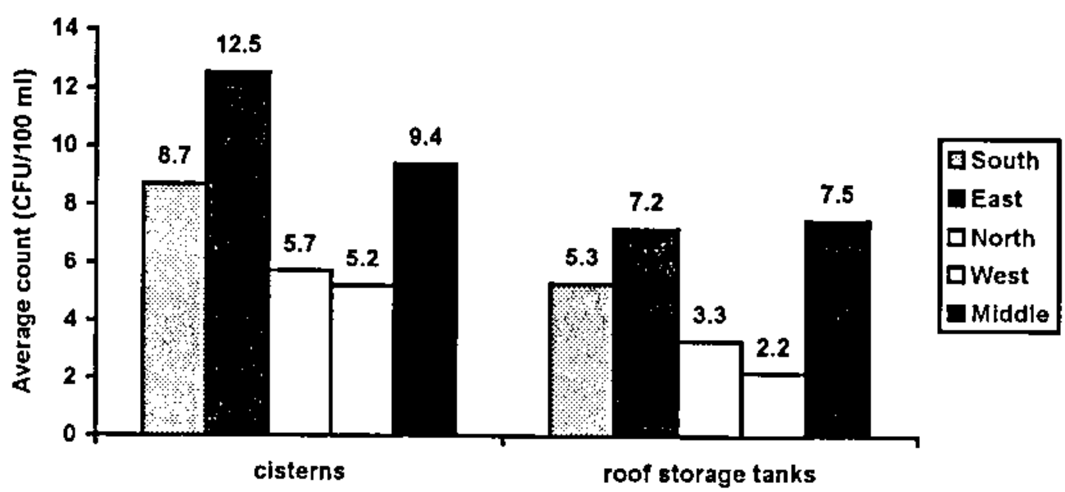

Fig. .3.8. Average count of thermotolerent coliform E. coli in cisterns and roof storage tanks of Safarine's regions

3.5 Degree of contamination in storage systems

Table 3.9 shows the results in both storage systems in the selected villages, according to the WHO classification for the degree of contamination, with respect to total coliform count.

Table 3.9. Distribution of cisterns, roof storage tanks according to contamination degree

Total Coliform Count	Contamination Degree	No. of Cisterns	Percentage (%)	No. of roof storage tanks	Percentage (%)
0 - 3	0	8	5.3	19	12.7
3 - 50	1	136	90.7	129	86.0
50 - 50,000	2	6	4.0	2	1.3
> 50,000	3	0	0	0	0
Total	-	150	100	150	100

Data presented in table 3.9 shows that eight cisterns (5.3%) and 19 roof storage tanks (12.7%) were free of contamination, (degree 0). One hundred and thirty six cisterns (90.7%) and 129 roof storage tanks (86.0%) were in the first degree of contamination. Six cisterns (4.0%) and 2 roof storage tanks (1.3%) were with the second degree of contamination. None of the studied storage systems were within the third degree of contamination. Figure 3.9 shows graphical presentation of these data.

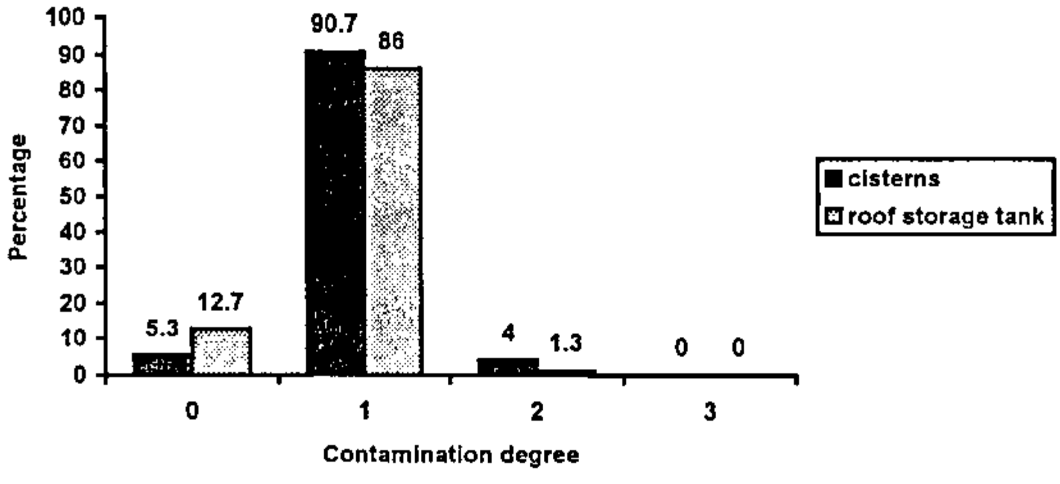

Fig. 3.9. Distribution of cisterns and roof storage tanks according to contamination degree

3.6 Contaminated storage systems as potential risk factor for human

Table 3.10 shows the findings in both storage systems in selected villages, according to WHO classification for risk levels of contaminated water, with respect to thermotolerent coliform *E. coli* count.

Table 3.10. Distribution of cisterns and roof storage tanks with respect to *E. coli* count and risk levels

E. coli Count/100 ml	Risk*	Cisterns		Roof storage tanks	
		Number	Percent (%)	Number	Percent (%)
0	No risk	9	6	29	19.3
0 - 10	Low risk	103	68.7	91	60.7
10 - 100	Intermediate risk	38	25.3	30	20.0
100 - 1000	High risk	0	0	0	0
> 1000	Very high risk	0	0	0	0
Total	-	150	100	150	100

* Risk as defined by WHO.

Data presented in table 3.10 shows that 9 cisterns (6.0%) and 29 roof storage tanks (19.3%) were free of contamination (no risk). One hundred and thirty cisterns (68.7%) and 91 roof storage tanks (60.7%) were with low risk level. Thirty-eight cisterns (25.3%) and 30 roof storage tanks (20.0%) were with an intermediate risk level, and none of these storage systems show high or very high risk level. Figure 3.10 shows graphical presentation of these data.

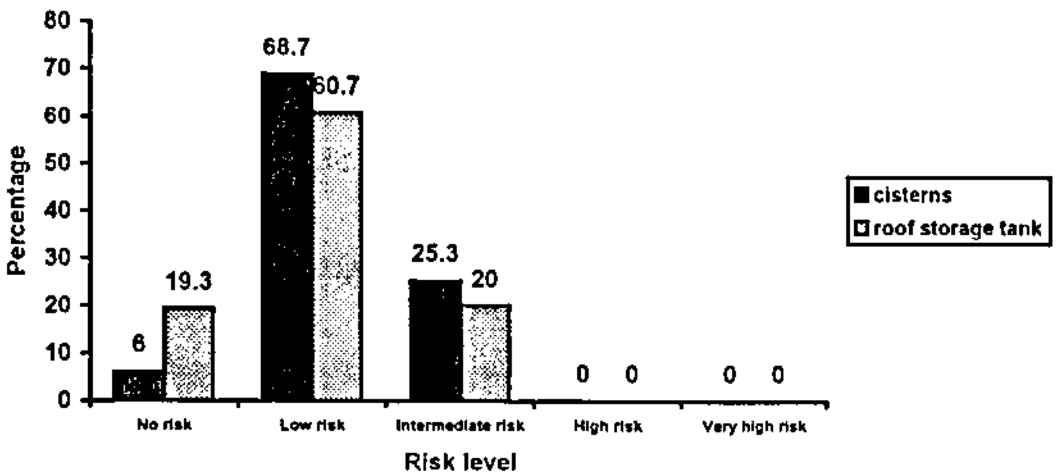

Fig. 3.10. Distribution of cisterns and roof storage tanks with respect to *E. coli* count and risk level

3.7 Factors that affect water quality in cisterns and roof storage tanks

3.7.1 Distance between the cesspits and cisterns in every household

Table 3.11 shows the association between average count for total coliform, thermotolerent coliform *E. coli* and distances between cesspits and cisterns.

Table 3.11. Association between average counts for bacterial indicators and distances between cesspits and cisterns

Distance in Meters	No. of Cisterns	Percent (%)	Average count	
			Total coliform	*E. coli*
7 - 9	10	6.7	16.9	6.5
10 - 12	53	35.3	17.0	7.8
13 - 15	46	30.7	15.8	7.0
16 - 18	22	14.7	16.2	6.9
19 - 21	13	8.7	15.0	6.5
22 - 24	4	2.7	8.5	2.5
25 - 27	1	0.7	4	1.0
28 - 30	1	0.7	21	12

A noticeable decrease in both indicators is clear up to a distance of 22 meters and above, however, this was not the case for a single cistern where both indicators were significantly higher average counts. Figure 3.11 shows graphical presentation of these data.

The results indicate that the distance of the cesspits had no significant effect on the average count of total coliform and thermotolerent coliform *E. coli* in cisterns with *P*-values of 0.73, 0.841 respectively.

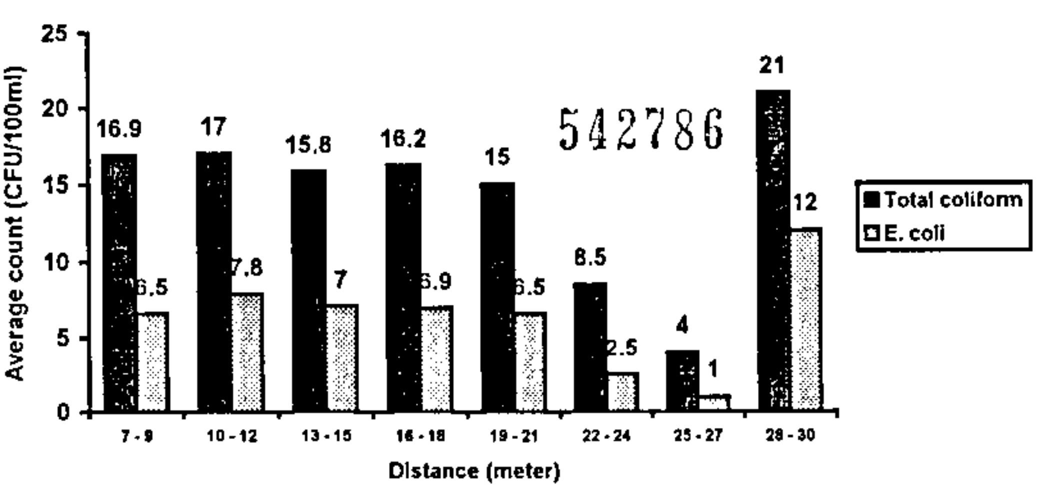

Fig. 3.11. Average count of bacterial indicators according to cesspits' distance

3.7.2 Cesspits' level with respect to cisterns' level in every household

Data presented in table 3.12 shows the association between average counts for total coliform, thermotolerent coliform *E. coli* and cesspit's levels with respect to cisterns.

Table 3.12. Association between average counts for bacterial indicators and levels of cesspits with respect to cisterns

Cesspits level	No. of cisterns	Percentage (%)	Average count	
			Total coliform	*E. coli*
Uphill	48	32	17.0	7.6
The same	41	27	16.3	7.0
Downhill	61	41	14.6	6.6
Total	150	100	-	-

According to collected data 40 cisterns (32.0%) were located downhill. The average count of total coliform and thermotolerent *E. coli* was 17 and 7.6 CFU/100 ml water, respectively. Forty one cisterns (27.0%) were located at the same level of cesspits. The average count of total coliform and thermotolerent coliform *E. coli* was 16.3 and 7.0 CFU/100 ml. Sixty one cisterns (41.0%) were located uphill. The average count of total coliform and thermotolerent coliform *E. coli* 14.6 and 6.6 CFU/100 ml respectively. Figure 3.12 shows graphical presentation of these data.

Differences in total counts for total coliform and thermotolerent coliform *E. coli* were of no significance with *P*-values of 0.675 and 0.861 respectively.

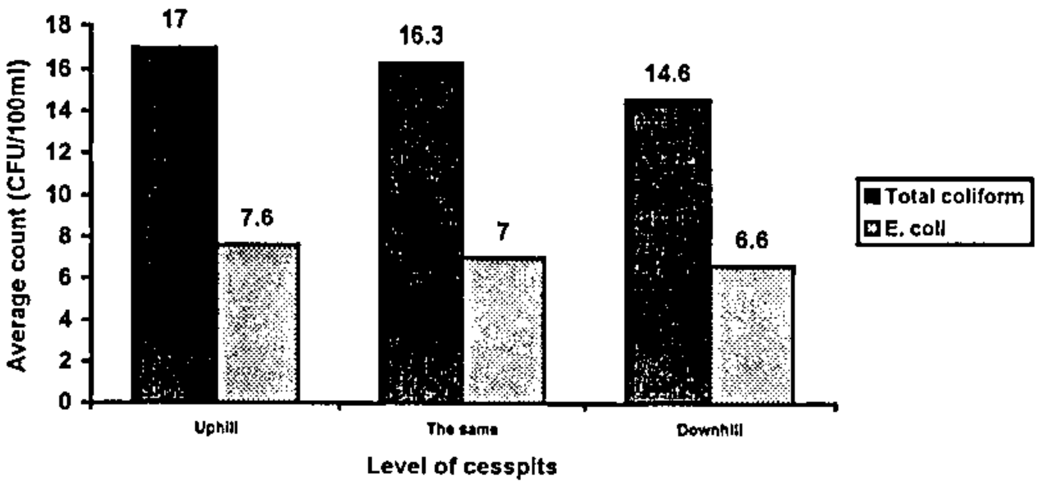

Fig. 3.12. Average count of bacterial indicators according to cesspit levels

3.7.3 Animal razing

Data presented in table 3.13 shows the association between average counts of total coliform, thermotolerent coliform *E. coli* and animal razing in every household.

Table 3.13. Numbers, percentages of cisterns according to animals' razing in households

Animal razing	No. of Cisterns	Percentage (%)	Average count	
			Total coliform	*E. coli*
Yes	40	26.6	19.3	9.0
No	110	73.4	15.7	6.8
Total	150	100	-	-

According to collected data, 40 cisterns (26.6%) were found near animal keeping areas. The average count of total coliform and thermotolerent coliform *E. coli* was 19.3 and 9.0 CFU/100 ml water, respectively. On other hand 110 cisterns (73.4%) were with no close animal keeping areas. The average count of total coliform and thermotolerent coliform *E. coli* was 15.7 and 6.8 CFU/100ml water.

Razing animals in households had no significant effect on the average count of total coliform and thermotolerent coliform *E. coli* with *P*-values of 0.250 and 0.172.

3.7.4 Cisterns' age

Data presented in table 3.14 shows the association between the average count for total coliform, thermotolerent coliform *E. coli* and cisterns' age.

Table 3.14. Distribution of cisterns according to their age and the average count of bacterial indicators

Age (years)	No. of cisterns	Percentage (%)	Average count	
			Total coliform	*E. coli*
1 - 9	47	31.3	7.6	2.9
10 - 19	47	31.3	13.1	4.9
20 - 29	23	15.3	19.3	8.3
30 - 39	18	12	24.3	10.9
40 - 49	4	2.8	26.6	11.0
50 - 59	4	2.8	39.5	21.0
60 - 69	3	2.1	40.7	25.0
70 - 79	2	1.4	48.5	28.0
80 - 89	1	0.7	54.0	28.0
90 - 99	1	0.7	57.0	31.0

The presented data clearly indicates significant increase in the average count for total coliform with *P*-value of 0.001 and thermotolerent coliform *E. coli* with *P*-value of 0.000 with increased cisterns' age. Both indicators were with unacceptable average counts according to WHO standards. Figure 3.13 shows graphical presentation of these data.

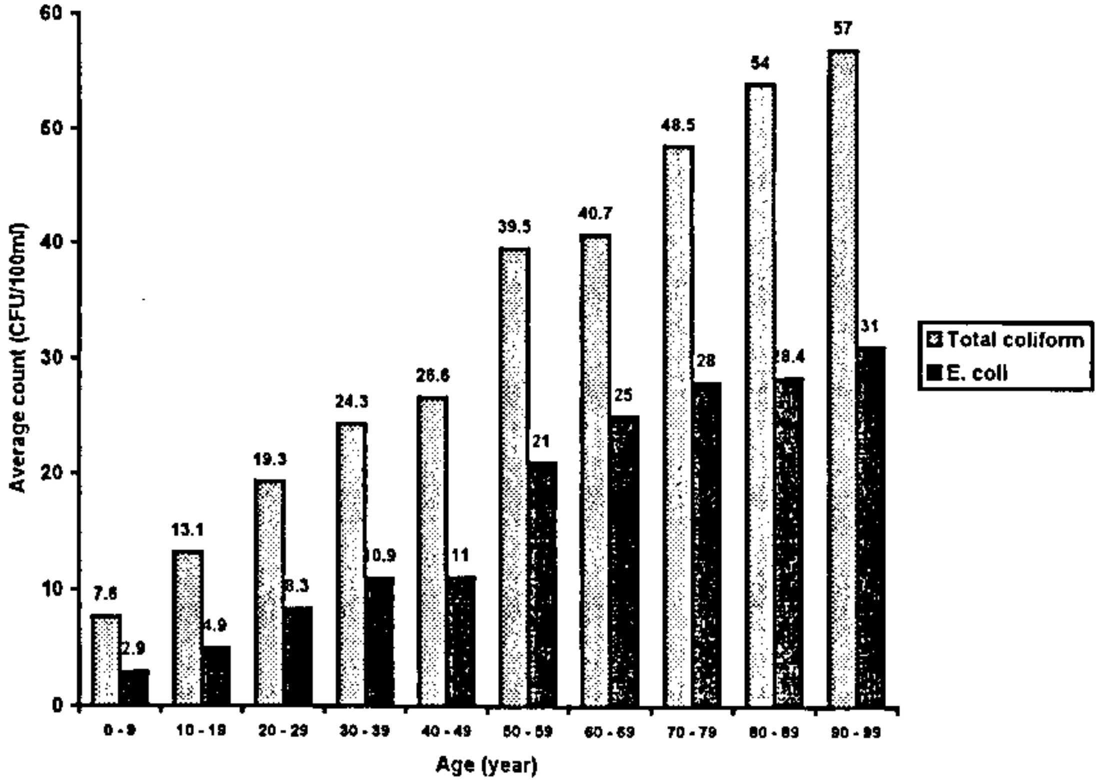

Fig. 3.13 Average count of bacterial indicators according to the cisterns' age

CHAPTER IV

DISCUSSION AND CONCLUSIONS

4.1 Average counts of Total Coliform and Thermotolerent Coliform *E. coli* in Cisterns and in Roof Storage Tanks

Average counts of total coliform in cisterns and roof storage tanks water was 16.1 and 12 CFU/100 ml water respectively (see table 3.1). According to international standards set by WHO, these values were higher than the safe limit which is 0 -3 CFU/100 ml water. Such findings could be due to the fact that, non of the studied storage systems were treated by any of the used disinfectants for this purpose. On other hand such storage systems are hardly clean, thus leading accumulation of deposits rich nutrients which in turn facilitate bacterial growth.

Average counts of thermotolerent coliform *E. coli* in cisterns and roof storage tanks water were 7 and 5.4 CFU/100 ml water respectively (see table 3.1). According to the international standards set by WHO, these values were higher than the safe limit which is 0.0. The finding of higher average counts of thermotolerent coliform *E. coli* in the studied storage systems, strongly indicate that such systems were exposed to faecal contamination. Behind such findings in the studied villages is the improper sewage disposal (cesspits) [8]. All included households do not have sewage networks for sewage water disposal and they rely on cesspits that are usually designed to serve single household, these cesspits required digging into grounds which increase the risk of water contamination. The risk of contamination depends on the soil permeability and drainage capacity, in impermeable and poor drainage capacity soil, frequent hypersaturation and flooding will occur, while in permeable and high drainage capacity soil rapid filtration through the soil will occur, especially during the rainy seasons. Both hypersaturation of cesspits and rapid filtration of wastewater result in contamination of these cisterns [13].

Differences for both indicators were significant between cisterns and roof storage tanks water. Both indicators were with much lower values in roof storage tanks water compared to cisterns water (see table 3.1). This is an expected observation as water surface often contains greater number of total coliform and thermotolerent coliform *E. coli* (see sampling methods in cisterns). On the other hand pumped water to roof storage tanks is usually from deeper areas that is usually deprived of O_2 , which is limiting growth factor for bacterial indicators [2]. Another possible explanation is the exposure of storage tanks water to high temperature especially during the summer season [9].

4.2 Average counts of total coliform and thermotolerent coliform *E. coli* in forced concrete and old style cisterns

A comparison between old style and forced concrete styles for both indicators was in favour of forced concrete style as both indicators were with lower average values compared in the old style cisterns (see table 3.2), these differences were statically significant. Such finding is more clearly due to the impermeability of the forced concrete compared to that thin pasted layer in the old style cisterns. Another possible explanation is that most forced concrete storage systems are usually designed and located in areas that are usually protected from flooded rainwater.

4.3 Bacterial quality of storage systems water in Beit Leed and Safarine villages

Table 3.3 represents a comparison for both storage systems in the studied villages. The findings for both indicators were similar and differences in average counts were with no significant values. Our finding strongly indicates that both villages are suffering from contamination of these water sources. Economical, cultural, life styles, land uses, sewage systems and geographical nature similarities are behind the finding of very similar average count values for both indicators.

4.4 Bacterial quality of storage systems in various selected regions of Beit Leed and Safarine villages

Regional variations for both storage systems for each village were observed regarding both indicators. These variation were statically significant and in favour of Beit Leed village center (see table 3.5-3.8), however, variations were of no significant value in Safarine village. Such finding is most likely due to the fact that Beit Leed village center represents the old village and cisterns on this region are much older in age than those in the other regions. Another fact is that the village center in more crowded compared to other regions.

4.5 Degree of contamination in storage systems

Estimation of the degree of contamination was based on the WHO classification (see table 3.4), which strongly indicates that (90.7%) of the cisterns and (80.0%) of roof storage tanks were with first degree of contamination. Only (5.3%) of cisterns and (12.7%) of roof storage tanks were free of contamination. According to WHO recommendation, such contamination degree is hazardous to human health and therefore, both systems required treatment that involve the regular use of disinfectant (chlorine) [8]. Whether chlorine in our storage systems is going to be effective or not, will depend on water turbidity levels and the pH [1, 14].

Cisterns and roof storage tanks that were with second degree of contamination (4.0%, 2.0%) can be treated with agglutination, filtration and disinfection, such cisterns were the oldest with an average age of 70.3 years. Proper maintenance and rehabilitation for such cisterns are essential and they are classified as unfit for human consumption.

4.6 Contaminated storage systems as potential risk factor for human health

Based upon WHO classification, the majority of our storage systems are within low and intermediate risk levels as shown in table 3.10. An increase in the risk level is an indicator of increase levels of faecal contamination, thus our findings indicates that the majority of our storage systems were exposed to faecal contamination. Whether this situation is mainly due to cesspits or other sources require farther investigation. Annual reports by the Palestinian Ministry of Health (see annex ii) regarding water borne disease shows an alarming number of cases indicative of bad water quality.

4.7 Factors that affect water quality in cisterns and roof storage tanks

4.7.1 Cesspits distance

Cesspits (improper sewage systems) are usually accused in water contamination. Thus, cisterns should be located a safe distance from all surrounding cesspits and other sources of pollution. The safe distance should be determined from the time taken by contaminants to travel from their source to the source of drinking water, this will depend on local condition of the area and influenced by geographical conditions, hydrological conditions, quantity of faecal matters likely to be discharged and land use and ownership. Our findings with respect to distance and level of contamination based on average counts of both indicators show clearly that high average counts for both indicators were associated with distance up to 22 meters away from cesspits. Both indicators showed noticeable decrease on their average counts in cisterns far away from cesspit 22 meter and above (see table 3.11). Such findings are in agreement with our previous result in both the degree of contamination and the risk levels. As we mentioned earlier it seems to be, that it is very difficult to specify a safe minimum distance, as this will depend on the slope of the land as well as the soil texture.

4.7.2 Cesspits levels

According to WHO recommendation, cesspits should be located downhill cisterns, such situation is difficult to apply depending on the geographical nature of the studied villages. Our findings regarding cesspits' levels in association with cisterns and average counts for both indicators showed no significant variation (see table 3.12). Both, the degree of contamination and risk levels were very similar at all levels. This can be explained by the fact that cisterns are not uniformly distributed and several cesspits might surround a single cistern.

4.7.3 Animal razing

Animal razing is another possible source of water contamination, especially during the rainy seasons as flooding is sometimes seepaging to cisterns. Association between animal razing and water contamination is clear as both indicators showed higher average counts in households with history of animal razing in the living vacinity compared to those with no history of animal razing (see table 3.13).

4.7.4 Cisterns age

As expected cisterns with increased age are most likely to develop many thicker sedimentation layers that in true will increase food sources and turbidity. These factors are most likely to have a positive effect on bacterial growth, thus influencing average counts of bacterial indicators. On the other hand, with increased age one expect to have more cracks especially in the upper part of the cisterns allowing more seepage of contaminants from adjacent sources. Our finding is in agreement with the above mentioned factors, as both indicators showed higher average counts with increased age (see table 3.14).

Conclusions and Recommendations

As a result of limitation in current supplies of water in the West Bank, cisterns are used as alternative source of water. Cisterns have a large risk of bacteriological and chemical contamination, from the water flowing of the ground surface during the rainy seasons, due to the existence of large number of contaminant sources in the rural area such as cesspits, animal farms, solid wastes and agrochemical. Contaminated cisterns are not recommended for use as water supply when a more satisfactory source is available, but if the satisfactory source is not available cisterns should be protected and treated from all sources of contamination.

The current study recommended that:

1- Effective physical protection for cisterns should be done to prevent the entrance of a surface drainage or contaminants. Such as:

   a. Secure cover

   b. Concrete apron around the cistern head, at least 2 meters in diameter should be above the soil level and sloped towards the drainage channel.

   c. Surface drainage ditch located uphill from the cistern to intercept surface water run off and carry it away from the cistern.

2- Rainwater should be collected from clean catchment area such as house roofs. House roofs should be cleaned completely from the contaminants and debris which have been accumulative on the roof and the gutters. It is therefore, recommended that the water running of the roof after the first storm of the season and preferably for the first five to ten minutes afterwards or until it run cleaned [8].

3- Mesh should be placed between guttering and the down pipe to prevent the entry of debris (to reduce turbidity).

4- Cisterns should be emptied and cleaned completely from the water of the previous year to remove the sediments and to keep the water turbidity in acceptable range.

5- The wall of cisterns should be covered with a thick layer of cement in old cisterns style to prevent the entry of contaminants from the adjacent soil.

6- Municipalities should encourage the construction of Forced concrete cisterns.

7- Monitoring the quality of the cisterns water by means of periodic checks for bacterial contamination by standard methods.

8- Water should be pumped from cisterns to houses by electric pumps and not by buckets or other manual containers.

9- Roof storage tanks should be covered with a secure cover to prevent the entry of debris, contaminants and to restrict access by children and animal.

10- Roof storage tanks should be provided with a tap for withdrawal of water.

11- Roof storage tanks should be inspected, cleaned and disinfected at least once a year if the water comes from a protected source, but if the water is not cleaned the tank will require more frequent cleaning, the frequency depending on the water quality [8].

12- When a household storage tank and pipes for drinking water are installed they should ideally filled with water containing 50 mg/liter of chlorine and left to stand overnight, so that the system is disinfected before use [8].

13- The cesspits and other pollutants sources should be located downhill of cisterns where ever possible and this based on the topography, subsurface geology, land ownership and land use.

14- The sewage disposal systems (cesspits) should be replaced by sewage net systems.

15- A minimum safe distance for all potentially pollutant activity should be fixed during the planning stage for the water source.

16- Suitable treatment process should be done to protect the consumer from pathogens and impurities that may be offensive or injurious to human health.

17- Treatment process should take into account the quality and the nature of the water supply sources. The method and intensity of treatment must depend on the degree of contamination and risk level of the water source.

18- Comprehensive hygiene educational programs should be developed and implemented, to ensure that the community:

a. Is aware of the importance of water quality and its relation to health and of the need for safe water supplies.

b. Accepts the importance of surveillance and the need for the community response.

19- Local water supply legislation should be developed and implemented, the drinking water quality legislation should clearly provide for the possibility of regional difference in standards and for differences between large urban and the small community (rural) supplies.

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Annex I

The Questionnaire

This questionnaire was used to search for possible sources of drinking water contamination in cisterns. It consists of two parts:

Part I: General information

Village name: ---------------------- Region: ----------------------------

Part II: questions

1- How old is the cistern? -- years.

2- Is there animal keeping area in the household? Yes ☐ No ☐

3- Is there a cesspit in the household? Yes ☐ No ☐

4- Are the disinfectant materials used? Yes ☐ No ☐

5- Is the water of the previous seasons removed out from the cisterns?
Yes ☐ No ☐

6- How many times is the well cleaned after its construction? --------Times.

7- How far is the cesspit from the cistern? -------------------- Meters.

8- The level of the cesspit in contrast with the level of the cistern is:
Uphill ☐ Same ☐ Downhill ☐

9- What are the sources of water that supply the cisterns (catchment area)?

10- What is the style of the cistern. (old style ☐ forced concrete ☐)

Annex Two

Water related diseases in Palestine in 1998*

Diseases	West Bank	Gaza Strip	Total
Hepatitis A	1558	712	2270
Malaria	1	4	5
Typhoid, Paratyphoid	33	66	99
Amoebiasis Trophozite	414	5176	5590
Giardiasis Trophozite	0	3303	3303
Shigellosis	965	15	980

* Ministry of health-Palestine

الملخص

الخواص البكتيرية لمياه الشرب في آبار الجمع والخزانات السطحية في قريتي بيت ليد وسفارين

أجريت هذه الدراسة في قريتي بيت ليد وسفارين خلال فصل الصيف لعام ١٩٩٩ على ١٥٠ عينة من آبار الجمع و١٥٠ عينة أخرى من الخزانات السطحية، حيث تم تحليل هذه العينات باستخدام طريقة غشاء الترشيح Membrane filtration method، وذلك عن طريق فحص مؤشرات التلوث المستخدمة في فحص المياه وهي بكتيريا Total coliform وبكتيريا Thermotolerent coliform *E. coli*.

دلت نتائج كل من مؤشرات الفحص البكتيري أن معدل التلوث في كل من آبار الجمع والخزانات السطحية ذات قيم أعلى مما هو موصى به من قبل منظمة الصحة العالمية للمياه الآمنة للشرب. حيث كانت معدلات القراءة لبكتيريا Total coliform ١٦,١ و ١٢,٠ مستعمرة بكتيرية لكل ١٠٠مل ماء في كل من الآبار والخزانات السطحية على التوالي. في حين كانت معدلات القراءة لبكتيريا Thermotolerent coliform *E. coli* ٧ و ٥,٤ مستعمرة بكتيرية لكل ١٠٠مل ماء في كل من آبار الجمع والخزانات السطحية على التوالي، حيث كان التلوث في للخزانات السطحية لكلا المؤشرين أقل منه في آبار الجمع، وكانت الفروق في التلوث بين الخزانات السطحية وآبار الجمع دالة إحصائيا.

وفي دراسة مقارنة ما بين الآبار المعدة على الطريقة التقليدية القديمة (الآبار المغطاة بطبقة رقيقة من الأسمنت) وخزانات الجمع الإسمنتية المسلحة، تبين وجود فروقات ذات قيم إحصائية دالة ولصالح الخزانات الإسمنتية باستخدام كلا المؤشرين من البكتيريا سابقة الذكر، حيث كانت معدلات Total coliform في آبار الجمع ذات النمط التقليدي القديم هي ١٧,٦ مستعمرة بكتيرية لكل ١٠٠مل ماء مقارنة مع ٧,٩ مستعمرة بكتيرية لكل ١٠٠مل ماء في الخزانات الإسمنتية، بينما كانت معدلات Thermotolerent coliform *E. coli* في الآبار التقليدية القديمة ٨,٧ مقارنة مع ٣,١ مستعمرة بكتيرية لكل ١٠٠مل ماء في الخزانات الحديثة.

عند مقارنة درجات التلوث بين بيت ليد وسفارين باستخدام المؤشرات السابقة تبين أن الفروقات بين مستويات التلوث في كل من القريتين متشابهة وليست ذات دلالة إحصائية، في

الفروقات في كلا المؤشرين المستخدمين ذات قيم إحصائية دالة في المناطق المختلفة ضمن القرية الواحدة، وكانت هذا الاختلافات متميزة في مركز قرية بيت ليد.

فيما يتعلق بدرجة التلوث المقدرة بالاعتماد على Total coliform في كل من آبار الجمع والخزانات السطحية كانت درجات التلوث متشابهة، حيث وقعت غالبية الآبار والخزانات السطحية ضمن الدرجة الأولى من التلوث حسب معايير منظمة الصحة العالمية، أما فيما يتعلق بعامل الخطورة والمقاس بالاعتماد على thermotolerent coliform *E. coli* فقد صنفت كل من آبار الجمع والخزانات السطحية على أنها ضمن درجات الخطورة المتدنية والمتوسطة، وذلك حسب معايير منظمة الصحة العالمية.

بينت الدراسة فيما يتعلق بدرجة التلوث والبعد ما بين الآبار وحفر الامتصاص ضمن الوحدات السكنية أنه لا توجد أية فروقات في معدلات قراءة كلا المؤشرين ولغاية ٢٢ متر، في حين لوحظ انخفاض واضح في معدلات كلا المؤشرين ما بعد ٢٢ متر مع العلم بأن هذه الفروقات ذات قيم إحصائية غير دالة، أما بالنسبة لمستوى الحفرة الامتصاصية وتربية الحيوانات في الوحدة السكنية وتأثيرها على تلوث آبار الجمع، لم يكن لهذه العوامل أي تأثيرات إضافية على درجة التلوث حيث كانت الفروقات غير دالة إحصائيا في كل من الوحدات السكنية التي وقعت فيها الحفر الامتصاصية سواء على مستوى الآبار أو أعلى منها، أو كان فيها أماكن لتربية الحيوانات مقارنة مع الوحدات السكنية التي كانت فيها الحفر الامتصاصية منخفضة عن مستوى الآبار ولا يوجد فيها أماكن لتربية الحيوانات.

دلت نتائج هذه الدراسة على وجود فروقات دالة إحصائيا في ما يتعلق بأعمار آبار الجمع ودرجة التلوث لكلا المؤشرين، لقد تراوحت معدلات التلوث بالإعتماد على Total coliform ما بين ٧,٦ إلى ٥٧ مستعمرة بكتيرية للآبار من الفئة العمرية من ٠-٩ سنوات، وللآبار من الفئة العمرية ٩٠ سنة فما فوق على التوالي. في حين تراوحت معدلات التلوث بالاعتماد على Thermotolerent coliform *E. coli* ٢,٩ مستعمرة بكتيرية للآبار من الفئة العمرية من ٠-٩ سنوات لكل ١٠٠مل ماء و ٣١ مستعمرة بكتيرية لكل ١٠٠مل ماء للآبار من الفئة العمرية أكثر من ٩٠ سنة.