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Assessment of Drinking Water Quality of Cisterns in Hebron City

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Abstract

The water quality of 100 cisterns in Hebron city- Palestine was studied through the period from December, 2007 till April, 2008. Water samples were collected directly from cisterns in two sterile glass bottles and tested for physical parameters (electrical conductivity, salinity, total dissolved substances, pH, temperature and turbidity), chemical parameters (alkalinity, chloride, total hardness, calcium, magnesium, ammonia and nitrate), microbiological parameters (total coliform(TC) and faecal coliform(FC)). All the results of physical parameters are within the acceptable limits of WHO, EPA and Palestinian standards except turbidity which exceed these limits in 24 % of the cases. The percentage of contamination of total coliform and faecal coliform was 95%, 57%, respectively. The chemical parameters exceed the standards by different percentages (calcium 47%, magnesium 32%), other parameters give results below the maximum contaminant levels. Sources of pollution of these cisterns were studied also by a questionnaire answered by the owner of the cistern. The rainwater is the source of contamination of cistern's water with both total and faecal coliform, the municipal water is the source of high hardness of the cistern's water, mixing between these two sources counter act the effect of each other. The presence of cesspits regardless of their level and distance from the cisterns has no statistically significant effect on the degree of contamination with both total and faecal coliform. The municipal sewerage flood weather it occurs in summer or winter and its frequency has no statistically significant effect on the degree of contamination.

No statistically significant relation between presence of animals at home, presence of trees around the cistern and degree of contamination with both TC and FC.

الخلاصة

تقييم جودة مياه آبار التجميع في مدينة الخليل- فلسطين

هذه الدراسة عبارة عن تقييم لجودة مياه آبار تجميع مياه الامطار (تحتوي على مياه بلدية ومياه شتاء) في مدينة الخليل التي تقع في جنوب الضفة الغربية من فلسطين. لقد تم تجميع مائة عينة من آبار مختلفة في مدينة الخليل وعملت عليها فحوصات مختلفة فيزيائية (درجة الحموضة, درجة الحرارة, التوصيل الكهربائي, نسبة الأملاح الذائبة, ونسبة العكورة) وكيميائية (نسبة عسر الماء, أملاح الكلورايد, الكالسيوم, المغنيسيوم بالإضافة إلى نسبة القاعدية, الامونيا والنترات) وجرثومية (القولونيات الكلية والبرازية).

نتائج الفحوصات الفيزيائية كانت ضمن الحدود المسموح بها من قبل منظمة الصحة العالمية، والمواصفات والمقاييس الفلسطينية, باستثناء نسبة العكورة التي تجاوزت هذه الحدود في 24%من العينات. نتائج الفحوصات الكيميائية تجاوزت الحدود المسموحة بنسب مختلفة (الكالسيوم 47% والمغنيسيوم 32%),بقية الفحوصات الكيميائية كانت نتائجها ضمن الحدود المسموح بها.

نسبة التلوث بالقولونيات الكلية والبرازية كانت 95% و 57% على الترتيب.

تمت دراسة مصادر تلوث هذه الآبار من خلال إجابة صاحب البئر على مجموعة أسئلة ضمن استبيان. لقد وجد أن مياه الشتاء هي مصدر التلوث لهذه الآبار، وأن مياه البلدية هي مصدر ارتفاع نسبة عسر المياه، وأن الخلط بين هذين المصدرين يخفف من تأثير كل منهما. إن وجود الحفر الامتصاصية بغض النظر عن مستواها أو بعدها عن البئر، ليس لها تأثير على مستوى التلوث بالقولونيات الكلية أو البرازية. كما أن فيضان مياه المجاري سواءً كان في الصيف أو الشتاء، ومهما كان عدد مرات الفيضان ليس له تأثير كذلك عل مستوى التلوث بالقولونيات الكلية و البرازية.

لا يوجد علاقة ذات دلالة إحصائية بين وجود حيوانات في المنزل وأشجار حول بئر التجميع وبين مستوى التلوث بالقولونيات الكلية والبرازية.

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Abbreviations

^{0}C	Degrees Celsius
EC	Electrical Conductivity.
EPA	Environmental Protection Agency.
FC	Faecal Coliform.
GIS	Geographical Information System.
HPCs	Heterotrophic Plate Counts.
L/c.d	Liter/ capita.day
Mg/L	Milligram/Liter.
MLC	Maximum Contaminant Level.
PSI	Palestinian Standards Institution
TC	Total Coliform
TDS	Total Dissolved Substances.
TH	Total Hardness.
WHO	World Health Organization.

Chapter One

1.1-Introduction:

Water is considered one of the most important and sensitive issues in the Middle East, where increasing water deficiency and deterioration of the available water are imminent. A major issue is that water resources are very limited and do not meet the existing population's needs (Al-Khatib et al., 2003).

An established goal of WHO and its Member States is that all people , whatever their stage of development and their social and economic conditions have the right to have access to an adequate supply of safe drinking water (WHO 1986, 1996, 1997).

In this context, safe refers to a water supply which is of a quality which does not represent a significant health risk, is of sufficient quantity to meet all domestic needs, is available continuously, is available to all the population and is affordable.

The most common and widespread danger associated with drinking water is contamination, either directly or indirectly, by sewage, by other wastes or animal excrement. If such contamination is recent, and if among the contributors there are carriers of communicable enteric diseases, some of the living causal agents may be present. The drinking of water so contaminated or its use in the preparation of certain foods may result in further cases of infection (WHO, 1984).

The objectives of this study are:

1-To asses the water physical, chemical and microbiological quality of cisterns in Hebron city.

2- To asses sources of water pollution.

3-To explore the perception of people towards water quality and water resources protection.

1.2– Study Area:

Hebron is the main city in Hebron District which is located in the southern part of West Bank of Palestine. Hebron city is located at a distance of 36 kilometers south of Jerusalem. The population about 173191 at mid – year 2007 (Palestinian Central Bureau of Statistics 2007).

Hebron has a Mediterranean climate, characterized by a relatively rainy season from November to April and very dry weather for the rest of the year, with hot, dry, uniform summers and cool, variable winters during which practically all of the precipitation occurs.

The average maximum & minimum temperature in summer is (26.6, 16.4) respectively and in winter is (12.1, 5.2), the total rainfall is (549mm), the relative humidity is (71.25%), (Palestinian Metrological Department, 2007).

The area of Hebron city is about 25 square kilometers, number of households is (17055), 65% of these households have cisterns with capacity ranges 91.4m^3. 85% of these households are connected to sewerage system (Table1.2) (Hebron municipality, GIS unit, 2007).

The stored water in cisterns is either rainwater, municipal water or mixed rainwater and municipal water from network.

The amount of harvested rainwater in Hebron District was estimated to be 1810595 m^3 per year (Abu-Dayyeh, 2005).

Table1.1-The monthly climatic averages in Hebron City, 2007.

Element	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec
Mean Max. Temp.	10.2	11.5	14.6	19.6	23.6	25.9	27.2	27.2	26.0	23.2	17.5	12.1
Mean Min.Temp.	4.0	4.7	6.5	9.9	13.2	15.8	17.0	17.0	15.9	14.0	9.9	5.6
Absolute Max. Temp.(C)	21.4	21.0	23.6	32.6	34.0	33.5	38.0	33.4	34.6	31.6	31.6	22.0
Absolute Min. Temp. (C)	-1.0	-3.0	-0.5	1.0	6.5	10.0	13.0	12.0	12.0	9.0	2.0	-0.4
Mean Temp. (C)	7.1	8.1	10.5	14.7	18.4	20.8	22.1	22.1	20.9	18.6	13.7	8.8
Mean Wind Speed (Km/h)	12.4	12.8	12.6	11.5	9.3	9.3	9.2	8.7	8.1	8.0	8.8	10.1
Pressure (mbar)	903	902	901	901	901	900	899	899	902	903	904	904
Mean Sunshine Duration (h/ day	4.7	4.8	6.4	8.1	9.0	8.3	9.6	10.9	10.3	9.8	7.0	4.7
Mean RH %	74	72	66	55	48	51	57	60	62	59	64	73
Total Rainfall (mm)*	133.6	141.6	91.7	25.4	4.7	0.5	0.0	0.0	1.6	14.6	66.7	115.5
Total Evaporation(mm)*	65	81	93	139	166	200	221	225	157	112	87	62
Total PET(mm)*	23	25	41	67	97	106	110	106	94	87	54	30
Max. Monthly Rainfall (mm)	351	335	194	235	37	10	0	0	21	65	220	334

* Monthly Total.

Source: Palestinian Metrological Department, 2007.

Table1. 2- Statistics about households in Hebron city, 2007.

Total number of household	17055
Number of household with cistern	11074
Number of household with cistern & connected to sewerage system	9412
Total volume of cisterns	1012135 m^3
Average volume of cistern	91.4 m^3
Percentage of household connected to sewerage system	85%
Percentage of household with cistern	65%

Source: Hebron Municipality, GIS Unit, 2007.

Source: Hebron Municipality, GIS Unit, 2007.
Figure 1.1 Location of Hebron city in the West Bank and in the regional map**.**

1.3 - Rainwater Characteristics:

Rainwater is valued for its purity and softness. It is free from disinfection by-products, salts, minerals, and other natural and man-made contaminants. Appliances last longer when free from the corrosive or scale effects of hard water. Users with potable systems prefer the superior taste and cleansing properties of rainwater (Texas Water Development Board, 2005). Once rain comes in contact with a roof or collection surface, it can wash many types of bacteria, molds, algae, protozoa and other contaminants into the cistern (Zhu et al., 2004 and Sazakli et al., 2007). Compared to roof-yard catchments, a land catchment system provides more flexibility for collecting water from a large surface area; however, the water quality was not as good as roof-yard systems did, but better than road catchment systems. Rainwater collected through land and road surfaces should only be used for irrigation instead of drinking. Greenhouses for vegetable cultivation are widely used to attain the highest benefit from rainwater harvesting (Zhu and Liu, 1998, Zhu et al., 2004). The quality of the harvested and stored rainwater depends on the characteristics of the individual area, such as topography, weather conditions and proximity to pollution sources (Va´squez et al., 2003; Evans et al., 2006), the type of the catchment area (Chang et al., 2004 and Zhu et al., 2004), the type of water tank (Dillaha and Zolan, 1985; Evison and Sunna, 2001) and the handling and management of the water (Pinfold et al., 1993; Evison and Sunna, 2001, Sazakli et al., 2007).

People are advised to boil rainwater before drinking and cooking and to use the suitable dosage of sodium hypochlorite for disinfecting. (Gordon et al., 1995 and Zhu et al., 2004).

It is recommended that the safe drinking water may only be harvested through the roof-yard catchment systems to ensure harvesting of good quality rainwater; collection processes should divert the very dirty runoff from the first few millimeters of rainfalls away from the cisterns to avoid contamination. Thus, the rainwater is only diverted into the cisterns after the catchment area has been washed off (Zhu et al., 2004).

1.4 - Cisterns Design and characteristic:

To design a rainwater harvesting system, the economic, social and cultural aspects of the location are taken into consideration with emphasis on the utilization of locally available unskilled laborers and indigenous building materials (Appan, 1999 and Zhu et al., 2004).

The size of cistern is dictated by several variables: the rainwater supply (local precipitation), the demand, the projected length of dry spells without rain, the catchment surface area, aesthetics, personal preference, and budget (Texas Water Development Board,2005). Cistern should meet the following basic requirements: ability to inhibit algae growth (opaque or painted dark), must never have been used to store toxic materials especially for potable systems, must be covered and vents screened to discourage mosquito breeding, accessible for cleaning (Texas Water Development Board,2005).

The recommended cistern structure looks quite deep in consideration of the continuous particulate sedimentation to reduce the effective cistern volume. An advantage of concrete cistern chambers is their ability to decrease the corrosiveness of rainwater by allowing the dissolution of calcium carbonate from the walls. Note that a thin layer of red clay must be tightly laid on the bottom of cisterns instead of packing concrete in order to minimize seepage losses and create proper conditions for the natural purification of stored rainwater through adsorption and biodegradation (Zhu et al., 2004).

1.5- Microbiological Aspects:

Microorganisms are present every where in our environment invisible to naked eye, vast numbers of these microbes can be found in soil, air, food and water. Humans are essentially free of microorganisms before birth, constant circumstances of exposure (e.g., breathing, eating, and drinking) quickly allow the establishment of harmless microbial flora in our bodies (EPA, 1991).

There are some organisms whose presence in water are nuisance but which are of no significance for public health, however they produce problems of turbidity, taste, and odor or appear as visible animal life in water, as well as being aesthetically objectionable. Some organisms naturally present in the environment and not normally regarded as pathogens may cause disease opportunistically (WHO, 2004).

The persistence of a pathogen in water is a measure of how quickly it dies after leaving the body. In practice, the numbers of a pathogen introduced on a given occasion will tend to decline exponentially with time, reacting in significant and undetectable levels after a certain period. A pathogen that persists outside the body only for a short time must rapidly find anew susceptible host (Pepper et al., 1991).

The persistence of most pathogens in water is affected by various factors of which sunlight and temperature are among the most important. Lifetimes are shorter at warmer temperatures. For example enteric viruses may be detected for up to 9 months at around 10^{0}C; their maximum period of detection at 20^{0}C is nearer to 2 months (Pepper et al., 1991).

The pathogens that may be transmitted through contaminated drinking-water are diverse. (WHO, 2004). A number of studies reviewed by Gould (1999) and Lye (2002) have identified various pathogens including *Salmonella*, *Shigella*, *Vibrio*, *Clostridium*, *Legionella*, *Campylobacter*, *Cryptosporidium* and *Giardia* spp. in samples taken from rainwater tanks(Heyworth, 2001), and *Aeromonas* spp.(Simmons et al.,2001)

1.5.1- Indicator Microorganisms:

The concept of using indicator organisms as signals of faecal pollution is a well established practice in the assessment of drinking-water quality. The criteria determined for such indicators were that they should not be pathogens themselves and should (WHO, 2004):

—be universally present in faeces of humans and animals in large numbers;

—not multiply in natural waters;

—persist in water in a similar manner to faecal pathogens;

—be present in higher numbers than faecal pathogens;

—respond to treatment processes in a similar fashion to faecal pathogens; and

—be readily detected by simple, inexpensive methods.

The three widely used bacterial indicators, total coliforms, E. coli and enterococci. These bacteria, which can be found in soils and other natural sources, originate in the feces of humans and warm blooded animals (Sazakli et al., 2007).

Since bacterial indicators do not give information relating to viruses and protozoa, and the methodologies applied to the direct detection of enteric viruses and protozoa are difficult and expensive, other indicators for these microorganisms are necessary (Me´ndez, 2004). To evaluate the virological quality of water, the use of bacteriophages as indicators has been proposed. Three groups of phages have been suggested: somatic coliphages, F-specific RNA bacteriophages and *Bacteroides fragilis* bacteriophages (IAWPRC 1991; Grabow 2001; Jofre 2002, and Me´ ndez, 2004). Nowadays standardized methods are available for the detection and enumeration of each of these groups (ISO 1995, 2000, 2001; EPA 2000). Data obtained with the standardized methods on their occurrence and densities in different types of water, including drinking water, are needed to evaluate the usefulness of phages for assessing water quality (Me´ ndez, 2004).

1.5.1.1 - Total Coliform bacteria:

Total coliform bacteria include a wide range of aerobic and facultative anaerobic, Gram-negative, non-spore-forming bacilli capable of growing in the presence of relatively high concentrations of bile salts with the fermentation of lactose and production of acid or aldehyde within 24 h at 35–37 °C. The total coliform group includes both faecal and environmental species. They can be used as an indicator of treatment effectiveness and to assess the cleanliness and integrity of distribution systems and the potential presence of biofilms (WHO, 2004).

Total coliforms are generally measured in 100-ml samples of water. A variety of relatively simple procedures are available based on the production of acid from lactose or the production of the enzyme b-galactosidase. The procedures include membrane filtration followed by incubation of the membranes on selective media (m-Endo) at 35–37 °C and counting of colonies after 24 h (WHO, 2004).

Total coliforms should be absent immediately after disinfection, and the presence of these organisms indicates inadequate treatment. The presence of total coliforms in distribution systems and stored water supplies can reveal regrowth and possible biofilm formation or contamination through ingress of foreign material, including soil or plants (WHO, 2004).

Total coliform is a non-specific indicator of fecal contamination and can originate from a number of different plant and soil sources (Strauss et al., 2001).

1.5.1.2- Faecal Coliform:

Faecal Coliform also known as thermotolerant coliform those are able to ferment lactose at 44–45 °C. *Escherichia coli* can be differentiated from the other thermotolerant coliforms by the ability to produce indole from tryptophan or by the production of the enzyme B-glucuronidase. *Escherichia coli* is present in very high numbers in human and animal(both mammals and birds) faeces and is rarely found in the absence of faecal pollution, although there is some evidence for growth in tropical soils (Rivera *et al.* 1988, Hunter, 2003). *Escherichia coli* is considered the most suitable index of faecal contamination. The theory was that if *E. coli* was present then so could pathogenic enteric bacteria such as *Shigella* and *Salmonella* spp. and detection should lead to consideration of further action, which could include further sampling and investigation of potential sources such as inadequate treatment or breaches in distribution system integrity. Despite recent concerns about the reliability of the organism as a marker of water safety, it is still the only species that almost all routine samples are tested for (Gleeson & Gray, 1997, Hunter, 2003, WHO, 2004). *Escherichia coli* are generally measured in100-ml samples of water. The procedures include membrane filtration followed by incubation of the membranes on selective media (m-FC) at 44–45 °C and counting of colonies after 24 h (WHO, 2004). Possible sources of elevated coliform counts include sewage discharges from municipal treatment plants and septic tanks, storm water overflows, and runoff from pastures and range lands (Hill et al., 2006).

1.5.4 - Microbiological Contamination of Cisterns:

The risk of microbiological contamination of drinking water during collection and storage in the home has long been recognized (van Zilj 1966; VanDerslice & Briscoe 1995 and Thomas et al., 2003). From a microbiological perspective, two separate modes of contamination of the roof catchment are likely: either via the direct activities of insects, birds and small mammals, or by atmospheric deposition of environmental organisms. The relative contributions of the two modes of contamination to the bacterial load of roof water should be considered. If atmospheric deposition is significant, variations in the composition from one rain event to the next would likely reflect the influence of weather. If the direct activity of animals is the major contributor, the influence of weather should be less apparent Thomas et al., 2003).

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In Spain rural water supplies with deficient treatment or no treatment accounted for the 47% of outbreaks attributed to water networks or rural areas, while 3% were linked to heavy rain episodes and the remainder to accidental deficiencies (Me´ ndez, 2004).

It has been estimated that 2% of *Campylobacter* infection (Eberhart-Phillips *et al*., 1997) in New Zealand, a total of 237 cases of illness notified to health authorities in 1998 were attributable to roof-collected rainwater consumption.(Simmons et al.,2001).

Legionella spp. are most commonly associated with growth in biofilms in pipes and distribution systems and are found in hot water systems. *Legionella* spp. are frequently isolated in home water systems (Marrie *et al*., 1994), it has previously been identified in roof-collected rainwater tanks (Broadhead *et al*., 1988, Simmons et al.,. 2001).

1.5.5 -Seasonal Variation of Microbiological Contamination:

Warm summer temperatures would be expected to accelerate multiplication of the bacteria in water, provided there is sufficient organic matter to support growth. E. coli and the enterococci do not multiply in water that is not heavily polluted with available nutrients. It is rather to be expected that warmer water temperatures would accelerate the decline of intestinal organisms (Rosenberg et al., 1968).

In warmer weather increased laundering and bathing would tend to bring more polluted water to the wells from the septic tanks (Rosenberg et al., 1968).

Possible explanations for the lower values of microbes in the winter are the lower temperature and the dilution due to the large amount of stored water, which do not favor the growth of microorganisms. Moreover, as sedimentation occurs into the water tank, most of the present bacteria co-migrate with the settleable particles (Sazakli, 2007).

Once the rain season begins, rain comes in contact with the catchment surfaces, from where it can wash many types of bacteria, algae, dust, leaves, bird droppings and other contaminants into the water tank, even though the first ‘‘heavy’’ rainfall is discarded, a practice followed globally (UNEP, 2002; Spinks et al., 2003; Villarreal and Dixon, 2005and Sazakli, 2007).

1.5.6 -Effect of water contamination on health:

Water is not an *agent* of disease, but a *medium* through which disease may be spread. When assessing the health risks of drinking rainwater, consider the path taken by the raindrop through a watershed into a reservoir, through public drinking water treatment and distribution systems to the end user (Texas Water Development Board, 2005). Under guidelines established by the World Health Organization (WHO), water intended for human consumption should contain no microbiological agents that are pathogenic to humans, 3cfu/100ml for Total Coliform and 0cfu/100ml for Faecal Coliform (WHO 1993). Microbial water quality may vary rapidly and widely. Short-term peaks in pathogen concentration may increase disease risks considerably and may also trigger outbreaks of waterborne disease. (WHO, 2004). A waterborne disease outbreak is defined as an outbreak in which epidemiologic evidence points to a drinking water source from which 2 or more persons become ill at similar times(Curriero et al.,2001).

Three factors primarily influenced the attack rate for infection: first, the level of contamination; second, the level of cyst viability and inactivation through chlorination; and third, the length of exposure to the population (Haas and Regli, 1991).

The most common waterborne pathogens and parasites are those that have high infectivity and either can proliferate in water or possess high resistance to decay outside the body. Viruses and the resting stages of parasites (cysts, oocysts, ova) are unable to multiply in water. Conversely, relatively high amounts of biodegradable organic carbon, together with warm temperatures and low residual concentrations of chlorine, can permit growth of *Legionella*, *V. cholera*, *Naegleria fowleri*, *Acanthamoeba* and nuisance organisms in some surface waters and during water distribution (WHO, 2004).

The microbiological safety of drinking water is assessed using surrogate indicator microorganisms. However, it has been suggested that over 30% of cases of waterborne gastroenteritis have their origin in drinking water that fulfils the legislated quality requirements based on bacterial indicators. In this situation the disease is caused by viruses and protozoa (Craun, 1996; Payment & Hunter, 2001; Anderson & Bohan, 2001, and Me´ ndez, 2004).

Contaminated drinking water, along with inadequate supplies of water for personal hygiene and poor sanitation are the main contributors to an estimated 4 billion cases of diarrhoea each year causing 2.2 million deaths, mostly among children under the age of five (WHO, 2000).

Waterborne pathogens and their significance in water supplies are illustrated in table 1.3.

Many consumers will link the presence of offensive tastes or odors with the possibility of a health risk (Jardine et al., 1999) though an unpleasant taste in water does not necessarily indicate that the water is unsafe to drink (Lou et al., 2007).

Table 1.3 Waterborne pathogens and their significance in water supplies. (Source: WHO. Guidelines for Drinking Water Quality, 2004).

Pathogen	Health Significance	Persistance In water Supplies(a)	Resistance To Chlorine(b)	Relative Infectivity (c)	Important Animal Source
Bacteria					
Burkholderia pseudomallei	Low	May multiply	Low	Low	No
Campylobacter jejuni, *C. coli*	High	Moderate	Low	Moderate	Yes
Escherichia coli –Pathogenic (d)	High	Moderate	Low	Low	Yes
E. coli – Enterohaemorrhagic					
Legionella spp.	High	Moderate	Low	High	Yes
Non-tuberculous mycobacteria	High	Multiply	Low	Moderate	No
*Pseudomonas aeruginosa*e	Low	Multiply	High	Low	No
Salmonella typhi	Moderate	May multiply	Moderate	Low	No
Other salmonellae	High	Moderate	Low	Low	No
Shigella spp.	High	May multiply	Low	Low	Yes
Vibrio cholerae	High	Short	Low	Moderate	No
Yersinia enterocolitica	High	Short	Low	Low	No
	High	Long	Low	Low	Yes
Viruses					
Adenoviruses	High	Long	Moderate	High	No
Enteroviruses	High	Long	Moderate	High	No
Hepatitis A	High	Long	Moderate	High	No
Hepatitis E	High	Long	Moderate	High	Potentialy
Noroviruses and Sapoviruses	High	Long	Moderate	High	Potentialy
Rotavirus	High	Long	Moderate	High	No
Protozoa					No
Acanthamoeba spp.	High	Long	High	High	No
Cryptosporidium parvum	High	Long	High	High	Yes
Cyclospora cayetanensis	High	Long	High	High	No
Entamoeba histolytica	High	Moderate	High	High	No
Giardia intestinalis	High	Moderate	High	High	Yes
Naegleria fowleri	High	May Multiplyf	High	High	No
Toxoplasma gondii	High	Long	High	High	No
Helminths					
Dracunculus medinensis	High	Moderate	Moderate	High	No
Schistosoma spp.	High	Short	Moderate	High	Yes

Note: Waterborne transmission of the pathogens listed has been confirmed by epidemiological studies and case histories. Part of the demonstration of pathogenicity involves reproducing the disease in suitable hosts. Experimental studies in which volunteers are exposed to known numbers of pathogens provide relative information. As most studies are done with healthy adult volunteers, such data are applicable to only a part of the exposed population, and extrapolation to more sensitive groups is an issue that remains to be studied in more detail.
A detection period for infective stage in water at 20 °C: short, up to 1 week; moderate, 1 week to 1 month; long, over 1 month. B. When the infective stage is freely suspended in water treated at conventional doses and contact times. Resistance moderate, agent may not be completely destroyed. C. From experiments with human volunteers or from epidemiological evidence. D. Includes enteropathogenic, enterotoxigenic and enteroinvasive. E. Main route of infection is by skin contact, but can infect immunosuppressed or cancer patients orally. F. In warm water.

1.6- Chemical Aspects:

The health concerns associated with chemical constituents of drinking-water differ from those associated with microbial contamination and arise primarily from the ability of chemical constituents to cause adverse health effects after prolonged periods of exposure. Table 1.5 illustrates water quality standard (Palestinian, EPA and WHO) for human consumption.

There are few chemical constituents of water that can lead to health problems resulting from a single exposure, except through massive accidental contamination of a drinking water supply. Moreover, experience shows that in many, but not all, such incidents, the water becomes undrinkable owing to unacceptable taste, odour and appearance (WHO, 2004). In situations where short-term exposure is not likely to lead to health impairment, it is often most effective to concentrate the available resources for remedial action on finding and eliminating the source of contamination, rather than on installing expensive drinking-water treatment for the removal of the chemical constituent and should be managed to ensure that scarce resources are not unnecessarily directed towards those of little or no health concern (WHO, 2004).
The probability that any particular chemical may occur in significant concentrations in any particular setting must be assessed on a case-by-case basis. The presence of certain chemicals may already be known within a particular country (the case of arsenic in groundwater in Bangladesh and West Bengal), but others may be more difficult to assess. Significant problems, even crises, can occur, however, when

chemicals posing high health risk are widespread but their presence is unknown because their long-term health effect is caused by chronic exposure as opposed to acute exposure. (WHO, 2004).

Chemicals are divided into six major source groups, as shown in Table 1.4. Categories may not always be clear-cut. The group of naturally occurring contaminants, for example, includes many inorganic chemicals that are found in drinking-water as a consequence of release from rocks and soils by rainfall, some of which may become problematical where there is environmental disturbance, such as in mining areas (WHO, 2004).

The parameters (pH, TDS, TH, alkalinity, free available chlorine, sulfate and ammonia-N) could influence drinking water flavor, while the turbidity and coliform group were measured due to esthetic and health concerns, respectively (Lou et al., 2007).

Table 1.4- Categorization of source of chemical constituents.

Source of chemical constituents	**Examples of sources**
Naturally occurring	Rocks, soils and the effects of the geological setting and climate
Industrial sources and human dwellings	Mining (extractive industries) and manufacturing and processing industries, sewage, solid wastes, urban runoff, fuel leakages
Agricultural activities	Manures, fertilizers, intensive animal practices and pesticides
Water treatment or materials in contact with drinking-water	Coagulants, DBPs, piping materials
Pesticides used in water for public health	Larvicides used in the control of insect vectors of disease
Cyanobacteria	Eutrophic lakes

Source: WHO. Guidelines for Drinking Water Quality, 2004

1.6.1 - Chemical Water Contamination

The chemical composition of rainfall samples contains different concentrations of chemical constituents depending on the amount of rainfall, direction of rain front, and the period between the precipitation events. The wind carried dust and soil plays an important factor in the chemistry of rainwater (Granat, 1972, Me´ ndez et al., 2004). Other factors that affect the chemical composition of rainfall samples includes the influence of the sea environment while the other can be attributed to human activities (agricultural sources, biomass burning-contribute at both local and subregional scale) as it consists of nitrites, ammonium and phosphates (Zunckel et al., 2003, Sazakli et al., 2007).

The variation of roof runoff quality seems to reflect differences in roofing materials, age and management, the surrounding environment, season, storm duration and intensity, and air quality conditions of the region (Chang et al., 2004).

Numerous studies of the chemical composition of urban rainwater and roof run-off (Bridgman, 1992; Bucheli et al., 1998; Forster, 1998 and Forster, 1999; Garnaud et al., 1999; Loye-Pilot and Morelli, 1988; Willey et al., 1988; Zhong et al., 2001) have demonstrated relationships between concentrations of chemical contaminants and proximity to contaminant sources (emissions), weather patterns, and atmospheric transport and deposition (Evans et al., 2006).

Al-Khashman (2005) investigated the chemical composition of wet atmospheric precipitation samples in the Eshidiya area in south Jordan. the results of this study suggest that the rainwater chemistry is strongly influenced by natural sources rather than anthropogenic and marine sources.

1.6.2 – Nitrate:

Public water supplies are routinely monitored for nitrate levels, and whenever these supplies exceed the nitrate standard, public notification via broadcast and print media is required. The current drinking water standard and health advisory level of 10 mg/L NO_3^{-N} (equivalent to 10 parts per million NO_3^--N or 45 parts per million NO_3^-) is based only on the non cancer health effects related to infantile methemoglobinemia (Kross et al., 1993). Concentrations over 3 mg/L nitrate nitrogen are usually considered indicative of anthropogenic pollution (Madison& Brunett, 1985, Kross et al., 1993).

The presence of nitrogen in the form of nitrates indicates older events of pollution and does not represent an immediate threat (Karavoltsosa et al., 2008). SO_4^{2-} and NO_3^- together represent the major ionic derivatives of industrial and traffic emissions (Evans et al., 2006).

Much of adults' nitrate intake may come from their diet, particularly green vegetables. With children, water intake is proportionately much more important, and often the dominant input (Kross et al., 1993).

The drinking water standard for nitrate was set primarily to prevent infant cyanosis, or methemoglobinemia (blue baby syndrome), a temporary blood disorder that reduces the ability of an infant's bloodstream to carry oxygen through the body which could have long-term developmental or neurological effects. (Kross et al., 1993).

Infants younger than 6 months are particularly sensitive to nitrate-induced methemoglobinemia because of many reasons: (1) they have a low capacity to reduce MetHb back to normal Hb (WHO, 1998); (2) they consume more water relative to their body weight than adults (US EPA, 1991), and thus have a higher relative exposure to nitrate when drinking formula or other drinks made with contaminated water; (3) a large proportion of Hb in infants is in the form of fetal Hb, which is more readily oxidized to MetHb than adult Hb (WHO, 1998); (4) the gastric environment in infants is more alkaline than in adults, providing optimal conditions for growth of bacteria that promote MetHb formation (WHO, 1996); and (5) gastroenteritis with vomiting and diarrhea, which is more common in infants than adults, enhances conditions for MetHb formation (ECETOC, 1988; Wright et al., 1999). (Sadeq et al., 2007). If excess nitrate concentration is determined, the well water should not be used in preparing infant formula or otherwise consumed by infants, particularly those less than 6 months of age (Kross et al., 1993).

Some evidence exists from epidemiological studies that high nitrate ingestion is involved in the etiology of human cancer. High nitrate levels in groundwater have been associated with increased rates of non-Hodglin's lymphoma in a Nebraska study. Boiling of water contaminated with nitrate is not effective and, in fact, actually increases the concentration of nitrate because of evaporation (Kross et al., 1993).

1.6.3 – pH

In many cases, the rain is acid with reported pH values starting at 4.17 (Mantovan et al., 1995, Chang et al., 2004). In this pH range, the leaching of various substances (metals) from the collection surfaces is promoted and deteriorates the quality of harvested rainwater (Sazakli et al., 2007). The pH values, ranging from 7.63 to 8.80, indicate that the rain is not acid. In this pH range, undesirable chemical reactions that may occur during the storage are eliminated (Zhu et al., 2004, Sazakli et al., 2007). The acidity in precipitation depends on the concentration of acid-forming ions, as well as, contractions of alkaline species which neutralize the acidity and the amount of rainfall (Al-Khashman, 2005). Such neutralization is frequently reported and attributed to NH_3 and/or carbonate materials. In Mediterranean area, carbonate particles were the most dominant neutralizing agents (Al-Momani et al., 1995, Tuncer et al., 2001). The neutralization by carbonate materials was usually reported in the region where composition of precipitation was strongly affected by high calcite content of Saharan dust (Losno et al., 1991; Loye-Pilot et al., 1986; Al-Momani et al., 1995, Al-Khashman, 2005).The ammonium compounds applied to soil can escape into atmosphere by means of gaseous NH_3 or as NH_4NO_3 and $(NH_4)_2SO_4$ particles. When ammonium was incorporated in rain, it can neutralize the acidity of rainwater (Al-Momani et al., 1995, Al-Khashman, 2005).

Additional H^+ ions that lower the pH values in wood shingle runoff may be accordingly released due to the weathering process of wooden material (cedar, red wood, or cypress in most cases) and the decomposition of wood-destroying fungi, lichens, mosses, debris, growing plants, insects, and other organic matter. On the contrary, composition shingles, painted aluminum, and galvanized iron roofs caused the pH of runoff to be significantly higher than the pH of rainwater (Chang et al., 2004).

1.6.4- Ammonia:

Ammonia in the environment originates from metabolic, agricultural and industrial processes and from disinfection with chloramines (WHO, 2004). Ammonia is highly soluble in water and has toxic and corrosive actions caused by its alkalinity (Millea, 1989, Swotinsky and Chase, 1990, Meulenbelt, 2007). The presence of ammonia in drinking water or food is often an indication of organic decomposition processes (Valentini et al., 2007).

Natural levels in groundwater and surface water are usually below 0.2 mg/liter, ammonia could cause taste and odour problems at concentrations above 35 and 1.5 mg/liter, respectively (WHO, 2004).

Ammonia contamination can also arise from cement mortar pipe linings. Ammonia in water is an indicator of possible bacterial, sewage and animal waste pollution. Toxicological effects are observed only at exposures above about 200mg/kg of body weight. Ammonia in drinking-water is not of immediate health relevance, and therefore no health-based guideline value is proposed (WHO, 2004).

Several methods have been developed to detect ammonia in water using either a flow injection analysis coupled with an amperometric/ potentiometric detection or colorimetric/spectroscopic methods. These methods are time consuming and often require elaborate preparation procedures. An interesting alternative method to detect ammonia involves the assembling of chemical sensors which can offer rapid, easy and efficient detection of ammonia (Valentini et al., 2007)

1.6.5- Chloride:

Chloride in drinking-water originates from natural sources, sewage and industrial effluents, urban runoff containing de-icing salt and saline intrusion (due to over pumping). Excessive chloride concentrations increase rates of corrosion of metals in the distribution system, depending on the alkalinity of the water. No health-based guideline value is proposed for chloride in drinking-water. However, chloride concentrations in excess of about 250 mg/liter can give rise to detectable taste in water (WHO, 2004) and corrosion effect in pipes (Karavoltsosa, et al., 2008).

Excess in chloride, sodium and conductivity indicate intrusion of seawater into the related aquifers due to the excessive extraction of water by pumping (Karavoltsosa, et al., 2008).

1.6.6- Hardness:

Hardness in water is caused by dissolved calcium and, to a lesser extent, magnesium. It is usually expressed as the equivalent quantity of calcium carbonate. Depending on pH and alkalinity, hardness above about 200 mg/liter can result in scale deposition, particularly on heating. Soft waters with a hardness of less than about 100 mg/liter have a low buffering capacity and may be more corrosive to water pipes (WHO, 2004).

Hard water interferes with almost every cleaning task, from laundering and dishwashing to bathing and personal grooming. Clothes laundered in hard water may look dingy and feel harsh and scratchy. Dishes and glasses may be spotted when dry. Hard water may cause a film on glass shower doors, shower walls, bathtubs, sinks, faucets, etc. Hair washed in hard water may feel sticky and look dull. Water flow may be reduced by hard water deposits in pipes. The amount of hardness minerals in water affects the amount of soap and detergent necessary for cleaning. (Skipton et al., 1996).

People preferred samples with higher total hardness and alkalinity to those with lower total hardness and alkalinity. Falahee and MacRae (1995) had similar findings that waters with low mineral content were liked least, and waters with higher mineral content were liked best (Lou et al., 2007).

1.6.7 - Total Dissolved Substances:

Conductivity and TDS are two separate measures of the same thing. They measure the presence of all anions and cations in drinking water. TDS does not specifically point to any health issues. Since some anions and cations are toxic (lead, arsenic, cadmium, nitrate, and others), a high measure of conductivity/TDS warrants getting a clear understanding of its cause (WHO, 2004).

1.6.8- Calcium and Magnesium:

Calcium and magnesium are known to occur naturally in water due to its passage through mineral deposits and rock strata and contribute to its total hardness (Karavoltsosa, et al., 2008).

The relationship between the cardiovascular mortality and the mineral content of drinking water was first described by Kobayashi (1957) in Japan and by Schroeder

(1960) in the United States (Sauvant and Pepin, 2002). The biological mechanism for a potential protective effect of hard drinking water has mainly been suggested to involve magnesium, which together with calcium is the main determinant of water hardness (Marx and Neutra, 1997; Rylander, 1996).

Calcium supplementation can reduce smooth muscle contractibility and tone and that this effect can be clinically manifested by a reduction in blood pressure and a reduction in the incidence of premature delivery (Yang et al., 2002). There is a significant protective effect of calcium intake from drinking water on the risk death from Acute Myocardial Infarction (Yang et al., 2006).

The scarcity of some base cations as calcium and magnesium in drinking water has been associated with cardiovascular diseases (Nerbrand et al., 2003; Kousa et al., 2006; Yang et al., 2006).Soft drinking water could provoke some physiological disorders in humans such as calcifications disorders (Driessens and Verbeeck, 1988) and magnesium deficiency can cause neuronal damage which could manifest as depression (Eby and Eby, 2006; Mora et al., 2008).

Cardiovascular disease (CVD) is among the main causes of mortality and morbidity in the industrialized countries (Thorn, 1993; Kuulasmaa et al., 2000). In order to better understand the determinants of CVD, particular attention has recently be given to environmental factors, such as weather, air pollution and especially the chemical quality of drinking water (Gyllerup et al.,1991a,b; Taylor, 1996; Lonn and Yusuf, 1999; Wilson,1999; Sauvant and Pepin,2002).

Several epidemiological studies have reported significant inverse associations between drinking water magnesium concentrations and mortality from coronary heart disease (Chiu et al., 2004).

1.6.9- Alkalinity:

Alkalinity is a measure of the capacity of water to neutralize acids, Alkaline compounds in the water such as bicarbonates, carbonates, and hydroxides remove H+ ions and lower the acidity of the water (which means increased pH). Measuring alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall or wastewater. Alkalinity in streams is influenced by rocks and soils, salts, certain plant activities, and certain industrial wastewater discharges. Total alkalinity is measured by measuring the amount of acid (e.g., sulfuric acid) needed to bring the sample to a pH of 4.2. At this pH all the alkaline compounds in the sample are "used up." The result is reported as milligrams per liter of calcium carbonate (mg/L $CaCO_3$), (EPA, 2006).

The alkalinity of rainwater is due to the high loading of particulate matter in the atmosphere (Khare et al., 2004). The suspended particulate matter that is rich in carbonate and bicarbonate of calcium buffers the acidity of rainwater(Al Obaidy and Joshi ,2006).If total anions \ total cations is less than 1, it indicates alkaline nature of rainwater and if greater than unity, it indicates the presence of free anions responsible for rainwater acidity(Al Obaidy and Joshi ,2006).

1.7 - Sources of Pollution:

Pollutants like gases and particles present in atmosphere may be dissolved and/or transported by the rain water and brought to the ground. Rainfall is one of the most effective ways of removing atmospheric pollutants. Storm water runoff is one of the major sources of diffuse pollution. It is responsible for the transport of sediment, nutrients, metals, oils and pesticides. Furthermore, storm water pollution can also have a profound effect on the ecological health of streams and reservoirs, and is one of the main reasons for ecosystem degradation (Qing-feng et al., 2007).

Non point sources of pollution are still the major water quality problems (Gannon et al., 1996, Griffith et al., 1999, Chang et al., 2004). Water pollution induced by storm runoff from different roofing materials is considered a non point source. Industrial emissions from petroleum refining, petrochemical production and forest products production can be another nonpoint source of rainwater pollution, (Chang et al., 2004).

Roof runoff is considered a potential source of non point pollution for two primary reasons. First, compounds contained in roofing materials may be leached into runoff, and airborne pollutants and organic substances, such as leaves, dead insects, and bird's wastes, are added to roofs by interception and deposition. Second, roof temperatures are much higher than temperatures of other surfaces, due to lower albedo, greater surface inclination to direct solar radiation, and less shading effects from surrounding trees (Chang and Crowley, 1993). Combining these constituents from rooftops with elements from precipitation deposition, chemical decomposition, and acid leaching make the quality of roof runoff a great concern for the household cistern system (Sharpe and Young, 1982, Ariyananda and Mawatha, 1999, Spinks et al., 2003 and Chang et al., 2004).

The roughness and cracks of wood shingle (created by tension, compression, shrinkage and weathering when exposed to sunlight and precipitation) roofs may trap water, which allows wood-rotting organisms to penetrate deeper into the wood, plants to grow, and organic matter to decay (due to heat energy from the sun, trapped moisture, and acid ions from rainwater), and provide homes to an array of insects and other organisms. The results are more ions released from the roof (they are often impregnated with preservative chemicals such as copper naphthenate, copper octoate, and zinc naphthenate, and fungi killing chemicals most notably zinc sulfate, copper sulfate, and zinc chloride), causing pH to be lowest and other water quality variables to be highest among the four roof types, especially Zn and EC (Chang et al., 2004).

Results of roof runoff studies have been variable. The variation reflects differences in roofing materials, industrial treatments, care and maintenance, age, climatic conditions, orientation and slope of roofs, and air quality of the region, (Chang et al.,2004).

The major sources of human and animal pathogens in the environment originate from animal feeding operations, decentralized wastewater treatment systems (e.g., septic tanks), wastewater treatment effluents, and treated sewage sludges(biosolids) (Gerba and Smith,2005). More than 150 microbial pathogens have been identified from all animal species that can be transmitted to humans by various routes (USDA, 1992;

USEPA, 1998). These organisms are *Campylo-bacter* spp., *Salmonella* spp. (nontyphoid), *Listeria monocytogenes*, *E. coli* O157:H7, *Cryptosporidium parvum*, and *Giardia lamblia*. Pathogens can be transmitted from animals to humans when manure is used as a fertilizer for food crops eaten raw and by storm water runoff from manured surface- to-surface waters or by its percolation to ground water (Gerba and Smith, 2005).

Poorly treated wastewater from on-site systems can contain parasites, bacteria, and viruses. Pathogens, too, can be transported for significant distances in groundwater or surface waters (Keswick and Gerba, 1980, Gerba and Smith, 2005).

Awadallah (2004) summarizes the factors affecting collected rainwater quality. The main factors are:

1- Any waste existing in the catchment area.

2- Penetration of sewage water from adjacent cesspit(s) into the cistern.

3- Sediments accumulated and not regularly removed year after year in the cistern.

4- Unreliable water quality, expected in case rainwater is finished and tanker-water is brought into the cistern (depending on the original source of tankered water, contaminated water is frequently supplied to consumers)

5- Insects breeding and waste entered in the cistern from the surface gate or the piping system left opened.

1.7.1 - Land Use:

Various types of land uses found in suburban areas have been linked to non point source pollution (to both surface and groundwater). In reality, the activities that occur on each land use type are the real pollution source. In general, urbanization can contribute to non point source pollution through the following activities: on-lot septic systems, nitrogen fertilizer use, and road salt application (Novotny, 1991, McGinty, 2003).

1.7.2 - Anthropogenic Practices:

The anthropogenic practices focused on for these land use types were solid waste landfill leachate, fertilizers from farmed land, leaching septic tanks, road deicing ($NaCl$, $MgCl$, and KCl), and water softening exchange(McGinty,2003).

Chloride and nitrate are the two most common indicators of anthropogenic activity. Chloride is an indicator of road salt application, especially when sodium concentrations are proportionally high. Nitrates are found in areas of septic use and nitrogen fertilizer application (McGinty, 2003).

1.7.3 - Septic systems:

Septic systems have been noted as one of the largest sources of pollution in the suburbs (along with construction erosion) through failing systems and subsurface movement of pollutants (Novotny, 1991). Septic systems have been cited as a major source of nitrogen to the groundwater as approximately only 10% of the nitrogen that processes through the septic tank is removed. Nitrate leaching can occur when home lawns are over watered after nitrate forms of nitrogen fertilizers are applied (Gold et al., 1990,). Additional contaminants that are associated with the presence of septic systems are potassium, sodium, and phosphate (Leidy and Morris, 1990; Shultz et al., 1995, McGinty, 2003).

1.7.4 - Environmental Factors:

Factors such as site characteristics, interval duration, and UV intensity would all impact on the survival of micro-organisms on the catchment surface and their viability in the run-off (Evans et al., 2006).

It should be remembered that inert release and airborne transport of micro-organisms from environmental sources/surfaces is dependent upon a number of variables, including bonding forces, wind shear forces and mechanical disturbances (Jones and Harrison, 2004). As a result, the minimum threshold wind speed required for uplift may vary over time, depending on surface conditions such as moisture content (Evans et al., 2006).

A large proportion of organic contaminants found in the harvested rainwater are associated with various sources of contamination. Organic compounds are introduced into the atmosphere as a result of evaporation from land surfaces, combustion of fossil fuels and emissions from industrial plants. These substances may be transported in the atmosphere for long distances and may pollute the rainfall in areas remote from the pollution sources. If using roads, fields and/or plastic film as the collection surfaces, rainwater can dissolve and wash any spilled petrol, pesticides and other chemicals from these surfaces, and show an increase in organic pollutants and phthalate esters (Zhu et al., 2004).

Runoffs from rural areas may contain pesticides, nutrients, and animal wastes. Roads are sources of many other substances, such as aliphatic, and aromatic compounds, PAH, fatty acids, ketones, phthalates. In particular, runoffs from roads may also contain petrochemical hydrocarbons in concentration of a few mg/l because of fuel leakage from vehicles of high-density traffic (Zhu et al., 2004).

Public outreach and education should be conducted to inform farmers about the importance of proper handling of fuels. Many individuals may not know that spillage of gasoline and diesel onto the yard surfaces can cause contamination of harvested rainwater, and would likely change their collection behaviors if they were aware of the potential consequences. For instance, the rainwater could be diverted into the cisterns after the catchment area has been washed off by the first millimeters of rain (Zhu et al., 2004). In addition to storm track pattern that may affect sources of airborne particulates (Hanson and Norton, 1982 and Chang and Crowley, 1993), other factors may include storm conditions such as rainfall amount, intensity, duration, and occurrence interval. Longer storm interval implies more airborne fallout and more weathering and deposition processes, resulting in more release of ions (Chang et al., 2004).

Acid rain and atmospheric aerosols are considered to be typical environmental pollution affecting human health, resulting in the deterioration of monuments, and the acidification of lakes and soil and natural equilibrium (Spanos et al., 2002, Al-Khashman, 2005).

There are two main sources that affect the composition of atmospheric particles and precipitation in the Mediterranean region. The first is the eolian dust transported from North Africa (Kubilay and Saydam, 1995, Al-Khashman, 2005) while the second is the pollution of aerosol transported from Europe (Bergametti et al., 1989; Gullu et al., 1998; Tuncer et al., 2001, Al-Khashman, 2005).

Chapter Two

2.0- Methodology:

2.1- GIS:

Using GIS as a tool, Hebron city was divided to 25 segments each one with an area of one square kilometer, The coordinate of the sampling sites was taken from GIS database of Hebron Municipality and the sampling sites map was created using Arc-View GIS version3.0 (Figure 2.1).

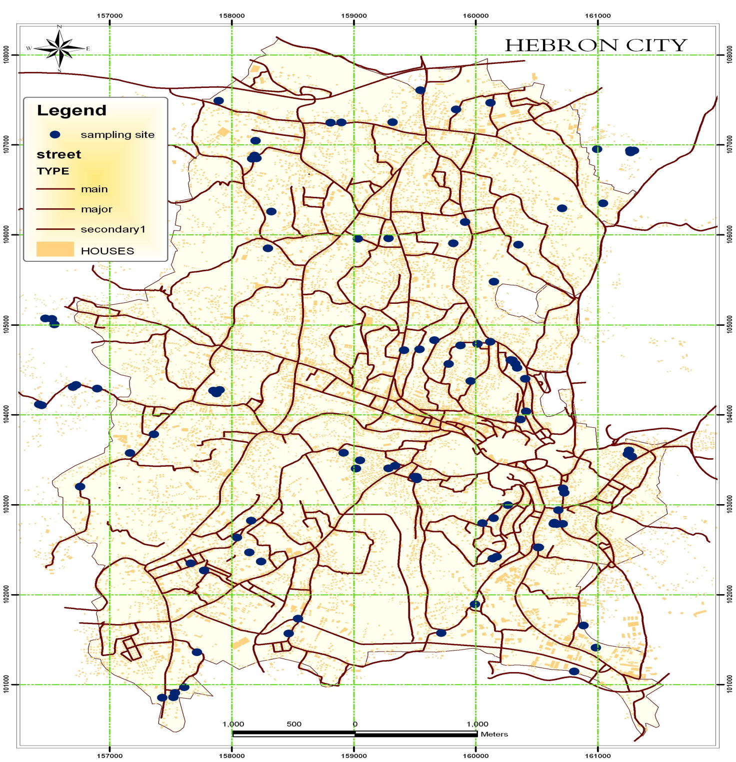

Figure 2.1 - Sampling Sites Map.(Source: Hebron Municipality, GIS Unit, 2008).

2.2- Questionnaire:

Semi structured questionnaire distributed to a representative sample of households from which water samples were collected. The owner of the house answered the questions in the questionnaire verbally and filled by the investigator and the one who can read and write was given the questionnaire and asked to fill it while we are taking the water sample to be gathered immediately to be analyzed later at the end of sampling (Appendix A).

The questionnaire included questions relating to the following:

(1) Personal profile of the owner of the house, such as age, and level of education.

(2) Various aspects of domestic water supply for the people who live in the study area, such as source of drinking water, age of cistern and its capacity.

(3) The use of roof for rainwater harvesting or others.

(4) Situation of wastewater networks system, such as connection to sewage network, use of septic tank or seepage pit, seasons of sewage flood, and how many times the sewage flood per year.

(5) Knowledge of the study population on drinking water contamination and their motivation towards water quality.

Most of the questions were one of two types: the yes/no question, which offers a dichotomous choice; and the multiple choice question, which offers several fixed alternatives. The questionnaire was modified and validated by the supervisor, no pilot study was done.

For analysis of the questionnaire the questions was divided to five categories as follows:

1- Owners of the houses personal data and water uses.

2- Cistern characteristics and sources of cistern water.

3- Cisterns sanitation.

4- Assessing cisterns water quality.

5- Environment surrounding the cisterns

The percentage of each sub item was calculated.

2.3- Sample size determination:

The sample size was determined as 100 by taking the population (number of houses which have cisterns) as 11074 houses, confidence interval as 95% and confidence level as 10% (Creative Research Systems, 2003).

2.4 - Water Sampling:

During the period from December 11, 2007 until April 22, 2008 one hundred water samples were collected (with a total of 15 sampling events on weekly basis from 3-12 samples each time) by the investigator from the households in Hebron city.

Samples were collected directly from the cistern at about half meter below water level into individual sterile 1000 ml glass bottles, or two sterile 330 ml glass bottles(labeled by number correspond to the number given to the questionnaire) and transported to the laboratory in a chilled-cold box (Abo-Shehada et al., 2004). The containers used were in accordance to the 18^{Th} edition of Standard Methods for the Examination of Water and Wastewater (Greenberg et al., 1992). Samples were collected in glass bottles that had been cleansed and rinsed carefully, given a final rinse with distilled water, and sterilized at 200^0C for two hours in dry oven.

2.5 - Samples Analysis:

At each sampling site, water temperature, electrical conductivity, total dissolved substances, pH, salinity and turbidity were measured in the field using EC 10 pH meter and CO150 conductivity meter and Hach 2100 P Turbidimeter (Hach Company, Loveland, Columbia-USA,1996) in accordance with Standard Methods for Examination of Water and Wastewater, 18Th edition, 1992 (Greenberg et al., 1992). Samples were then transported to the laboratory (Water Engineering Laboratory-Birzeit University, Birzeit-Palestine) within 24 hours after collection, samples are kept at 4^0C in refrigerator at night and in ice box during transportation from Hebron to Birzeit University. Laboratory analyses included measurements of chemical water quality (Alkalinity, Total hardness, Calcium, Magnesium, Chloride, Nitrate and Ammonia), and indicator organism concentrations (Total Coliform and Faecal Coliform). Summary of testing procedures for chemical and microbiological methods and physical parameters is illustrated in Tables 2.1 and 2.2 respectively.

2.5.1 - Membrane Filter Technique:

One hundred milliliter water samples were filtered through 0.45um pore size cellulose nitrate membrane for each Total Coliform and Faecal Coliform test. Then the membrane added to the corresponding culture media Petri dish with absorbent pad containing m-Endo and m-FC media respectively, the Petri dish was incubated at either 37^0C or 44^0C for 24hours (Beit Al-Maqdes company-Palestine and SanyoGallen KMB PLC- UK, 1995 respectively). (Greenberg et al., 1992).

Total Coliform as red colony with metallic sheen, and Faecal Coliform as blue were enumerated using membrane filtration technique after 24 hours of incubation at the corresponding temperature in incubators at 37^0C and at 44^0C The membrane filter technique is highly reproducible, can be used to test relatively large volumes of sample, and yields numerical results more rapidly than multiple – tube procedure. It is extremely useful in monitoring drinking water and a variety of natural waters. The MF technique has limitations, particularly when testing waters with high turbidity or non coliform bacteria. Total coliform give red colonies with metallic sheen within 24 hours at 35^0C on an Endo –type medium containing lactose. While faecal coliform will give blue colonies on m-FC medium. All red, pink, blue, white, or colorless colonies lacking sheen are considered non coliforms by this technique (Greenberg et al., 1992).

2.5.2- Titration Principle:

The principle of titration depend on the fact that gradual addition of titrable reagent to the sample which contains the analyte of choice, when all the analyte react with the reagent then the reagent reacts with the indicator and change its color to give the end point., for example in case of Chloride determination silver nitrate ($AgNO_3$) react with chloride until it is exhausted from the sample, then react with the indicator potassium chromate to give red color.

Table 2.1- Test methods for chemical and microbiological parameters (Greenberg et al., 1992).

Test	Method Name	Method Number	Method Principle
Total Coliform (TC)	Membrane filter technique.	9222B	Membrane Filtration
Fecal Coliform (FC)	Membrane filter technique.	9221E	Membrane Filtration
Chloride (Cl^-)	Argenometric Method	4500-Cl B	Titration with standard $AgNO_3$ and K_2CrO_4 as indicator.
Ammonia(NH_3)	Nesslerization	4500-NH3-C	Titration
Nitrate (NO_3)	Ultraviolet Technique	4500-NO3-B	UV Spectrophotometric screening
Calcium(Ca^{+2})	EDTA Titrimetric	2340C	Titration with EDTA and Murexide as indicator
Magnesium(Mg^{+2})	EDTA Titrimetric	2340 C	Difference between total hardness and Calcium.
Total Hardness	EDTA Titremetrc		Titration with EDTA and Eriochrome Black T as indicator
Alkalinity		2320 B	Titration with H2SO4 potentiometrically to PH 4.5

Table 2.2- Equipments used for testing physical parameters.

Tests	Equipment used
pH	Hach EC 10 pH Meter.
Temperature (Temp.)	Hach EC 10 pH Meter.
Electrical Conductivity(EC)	Hach CO150 Electrical Conductivity.
Salinity	Hach CO150 Electrical Conductivity.
Total Dissolved Substances(TDS)	Hach CO150 Electrical Conductivity.
Turbidity	Hach 2100 P Turbidimeter.

2.6- Data Entry & Analysis

Data were analyzed by computer using Statistical Package for Social Sciences (SPSS) version 13 and Microsoft Excel, 2003.

2.7- Quality Control:

To make sure that the contamination in the sample is related to the samples not to any other reasons such as media used .Two plates contains only the media (m-Endo & m-Fc media) and the membranes, then incubated as the samples which gives no growth.

For chemical testing standard samples of known concentration were tested in accordance with the samples which gives the desired results.

A sterile water sample (boiled for ten minutes) was put in sterile bottle (used for water sampling from the cistern) was taken to the field along with the samples and opened where ever the bottles for sampling was opened and stored and tested by the same procedure for Total and Faecal Coliform which gave negative result indicating that the cisterns was the source of contamination if present.

Chapter Three

3- Results and Discussion:

The following assumption was used to facilitate the data analysis, the not detectable result of ammonia was considered 0.1mg\L (the detection limit), and too many to count result of total coliform was considered as 2000.

3.1- Owner of the house personal data:

The average age of the owners of the cistern was 49 years (minimum 18 and maximum 81). Most of the people interviewed have elementary and secondary education (56%), (27%) respectively (Table 3.1). This is due to that most of the samples were collected between 9:30 AM and 1:30 PM, at this time only old people are present at home, and most of the people preferred to register the name of their fathers even they are not present. These results will not reflect the education level of people in Hebron city since the sample size is too small, and we are concerned to know the name of the owner of the house to create the sampling site map from Hebron Municipality database.

3.2 Sources of water in the cisterns.

To cope with the scarcity and irregulatory of water supply in Hebron city (low per capita daily water consumption 90 L/c.d) people seek to build cistern before building the house (different capacities according to economic status of the owner).

The percentages of sources of water in the cistern were Municipality water 20%, rainwater 22%and municipality and rainwater 53% as illustrated in Table3.2.

Table 3.1- Education and age levels of the cisterns owner at Hebron –Palestine, 2008.

Educational level of the cisterns owner at Hebron according to age.	Age						Total
	less than 20	20 - 30	31-40	41- 50	51-60	> 60	
Elementary	0	0	14	14	20	9	57
Secondary	3	6	4	7	2	4	26
Bachelor	0	0	1	5	1	1	8
Graduate	0	0	1	0	0	0	1
Diploma	0	0	0	1	0	1	2
Not educated	0	0	0	0	1	5	6
Total	3	6	20	27	24	20	100

Table 3.2 Sources of water in cisterns in Hebron – Palestine, 2008.

Source of water	Frequency	Valid Percent
Municipality water	20	20.0
Rainwater	22	22.0
All	5	5.0
Municipality & Rainwater	53	53.0
Total	100	100.0

The sources of rainwater were illustrated in Table 3.3, the highest percentages of rainwater sources in cisterns were house roof 68% which can be considered as a good practice because they can control it by cleaning before collecting rainwater (48% of people clean the house roof and discard the first flush of rainwater).

Yassin et al., 2006 in their study about assessment of microbiological water quality and its relation to human health in Gaza Governorate reported that 11.9% of population in Gaza city use municipal water for drinking purposes at home which is lower than the results reported in this study (20%), but the sources of drinking water in Gaza (municipal, desalinated, home filter) completely different from that used in Hebron city (municipal, rainwater, tanks, both municipal and rainwater, and all sources). The reason why people in Gaza don't use municipal water is that its origin is groundwater which is highly polluted. During the last few decades, groundwater quality has deteriorated to a limit that the municipal tap water became brackish and unsuitable for human consumption in most parts of the Gaza strip (El-Nakhal, 2004).

Sources of harvested rainwater in Germany are house roofs, courtyards and a one-way street with low traffic density which is less polluted Compared to high traffic density areas. Runoff from traffic areas contains higher pollutant concentrations than roof runoffs. These include abrasion from vehicle tires and brake linings, dripping losses, emission from engines, corrosion products as well as dust and dog and bird droppings (Nolde, 2007).

3.3 Cistern's Characteristics

46% of the cisterns in Hebron city has age more than 20 years which means that rainwater harvesting is an old practice (Figure 3.1), some of the people answered that some of the cisterns has an age over 100 years. Almost all of the cisterns have closed cover (96%) for the door which is located inside the house and has special key for protective purposes. Unfortunately in this study we did not ask about the level of the door of the cistern, however during field work i noticed that high percentage of cisterns doors located inside the house at the same level of the floor which is not closed well or cracks present at the boundary of the cover which leads to the seepage of floor cleaning water to reach the cistern which considered an important source of contamination.

Table 3.3 Sources of rainwater in cisterns in Hebron - Palestine, 2008.

Sources of rainwater in cisterns in Hebron	Frequency	Valid Percent	Cumulative Percent
House roof	68	68.0	68.0
House yard or garden	1	1.0	69.0
Street	2	2.0	71.0
Other	20	20.0	91.0
All (house roof, house yard and garden and street.))	1	1.0	92.0
House roof and house yard	5	5.0	97.0
House roof and street	2	2.0	99.0
House yard and street	1	1.0	100.0
Total	100	100.0	

34% of cisterns in Hebron city has a capacity more than 100 cubic meters,18% from 81 -100 cubic meters,16% has capacity between 61 -80 cubic meters and 17% from 20-40 cubic meters as illustrated in Figure 3.2**.**

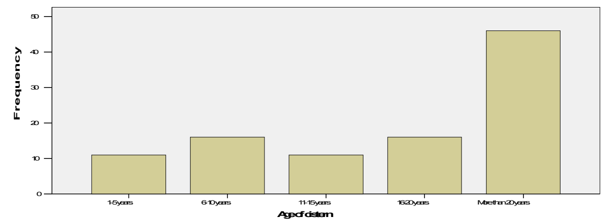

Figure 3.1- Frequencies of cisterns age in Hebron -Palestine, 2008.

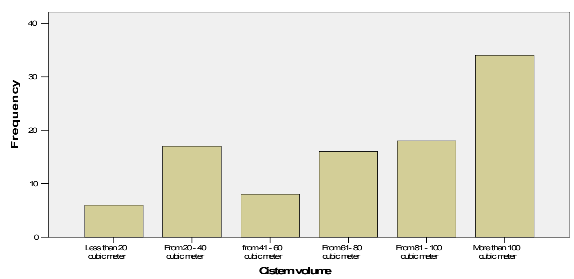

Figure 3.2-Frequencies of cisterns volume in Hebron -Palestine, 2008

3.4 Cisterns Sanitation Practices:

Cisterns sanitation practices includes, cleaning the cisterns, disinfecting the cisterns and actions taken before rainwater collections which includes cleaning the roof of the house, discarding the first flush of the roof and both cleaning the roof and discarding the first flush. The responses are summarized in Table 3.4

Table 3.4 Cistern's sanitation practices in Hebron – Palestine, 2008.

Question #	Questions	Answers	Percentages of respondents (%)
1-	Do you take any action before rainwater harvesting	Yes	73
		No	9
		Rainwater not collected	18
		Total	100
2-	If yes in V5,what are these actions	Clean house roof	23
		Discard first rainwater	3
		Both 1 and 2	48
		No action	26
		Total	100
3-	Do you treat cistern water in general	Yes	25
		No	75
		Total	100
4-	If yes for V7, How do you treat	Add Chlorine	12
		Add Kerosene	3
		Add Diesel	6
		Other	4
		No Treatment	75
5-	When did you clean the cistern last time	Not cleaned	14
		Less than one year	12
		1-5 years	53
		6- 10 years	17
		More than 10 years	4
		Total	100

Cleaning the cistern is a good practice in Hebron city, only 14% said that they did not clean their cisterns, some of them said that they did not clean because the cistern is used newly and it is already cleaned before starting to use it.

Although 128 subjects (61.2%) had seen suspensions, algae and settlements in their tanks, only 71 (34.0%) subjects had cleaned tanks. Almost two-thirds of the interviewees reported that they did not clean their tanks, which may increase the risk of water contamination and infection with water-related diseases (Abu Amr and Yassin, 2008).

Only 25% of people treat their cisterns in general while 75% don't, only 12% know the proper way of treatment practices by adding chlorine. 9% add either kerosene or diesel which is a common old practice not used any more nowadays as a proper treatment practice and not supported by any scientific evidence, but this practice may add unfavorable compounds that are carcinogenic, and leads to formation of trihalomethanes after addition of chlorine for disinfection. Disinfection by-products have been linked to cancer in animals or are suspected to have possible reproductive and development effects (Freuze et al, 2005).

86% of people used to clean their cisterns (82% within 1-10years, 4% more than 10 years) only 14% not cleaned it at all which indicate high level of awareness that the cistern should be cleaned regularly.

Regarding actions that were taken before rainwater collection, 23% clean the roof of the house, 3% discard the first rainwater flush, and 48% take the two actions together by cleaning the roof of the house and discarding the first flush of rainwater.

Al-Khatib & Orabi study about causes of drinking water contamination in rain-fed cisterns in three villages in Ramallah reported that 16.3 % disinfect their cisterns before use and 52.5% clean the house roof before collecting rainwater which is higher than the results of this study (12%, 48%) respectively.

Only 38% of those interviewed reported that they disinfected water prior to consumption by boiling in spite of the fact that public education programs had been promoting disinfection on all the islands (Dillaha and Zolan, 1985).

3.5 Cisterns water quality

Only 18% said that they test their cisterns, 82% did not test their cisterns before, the economical status of the people prevents them from testing their water, and many people agree to take samples from their cisterns when they know that the test is free of charge. 94% thank that their cistern's water was of good quality, 6% not.99% were concerned about the quality of their cistern's water, 1% not concerned, but this contradict with the behavior of people after we took the sample, only 10% of the interviewee call to know the results of their water (every one was given the business card of the author). 22% noticed things float at the surface of water, 78% didn't notice any thing. This can be explained because most of the people using lifting pump to take water from cistern and not through the door of the cistern directly. The same explanation can be given to (do you notice green spots on the sides of the cistern) where only 9% notice green spots at the sides of the cistern and 91% did not notice (Table3.5).

Yassin et al., (2006) in their study about assessment of microbiological water quality and its relation to human health in Gaza Governorate reported that only 10% of population in Gaza city think that water in Gaza strip is suitable for drinking while 90% think that it is not suitable, the same results reported by Abu Amr and Yassin, (2008) in Khan Yunis10.5%, 89.5% respectively. The situation in this study is almost reverse since 94% of people in Hebron city said that the water in their cisterns (regardless of its source) is suitable for drinking while only 6% think that it is not suitable.

Table 3.5 The percentages of cistern's water quality in Hebron –Palestine, 2008.

Question #	**Question**	**Answer**	**Percentage of respondents (%)**
1	do you test your cistern	Yes	18
		No	82
		Total	100
2	Do you think that the water is of good quality	Yes	94
		No	6
		Total	100
3	If you tested the water in your cistern, when was the last test	< 1 year	4
		1- 5 years	13
		> 10 years	1
		Total	18
4	Do you concern to have water of good quality	Yes	99
		No	1
		Total	100
5	Do you notice anything on the water surface	Yes	22
		No	78
		Total	100
6	Do you notice green color on the sides of the cistern	Yes	9
		No	91
		Total	100

Although 128 subjects (61.2%) had seen suspensions, algae and settlements in their tanks, only 71 (34.0%) subjects had cleaned the tanks. Almost two-thirds of the interviewees reported that they did not clean their tanks, which may increase the risk of water contamination and infection with water-related diseases (Abu Amr and Yassin, 2008).

3.6- Environment surrounding the cisterns:

The environment surrounding the cisterns was studied by asking the owner of the house, do you have animals or birds at home? Is there trees near the cistern?, Do you use the roof for clothes drying?, Do you gather the waste in the house yard?.

The responses are summarized in Table 3.6.

Table 3.6 The percentages of cistern's surrounding environment in Hebron-Palestine, 2008.

Question #	Question	Answers	Percentage of respondents (%)
1-	Do you have animals or birds at home	Yes Always	16
		Yes Sometimes	20
		No	64
		Total	100
2	Is there trees around the cistern	Yes	30
		No	70
		Total	100
3	Do you use the roof of the house for clothes drying in winter	Yes	64
		No	36
		Total	100
4	Do you collect the house wastes in the yard	Yes	30
		No	70
		Total	100

Al-Khatib & Orabi in their study about causes of drinking water contamination in rain-fed cisterns in three villages in Ramallah indicate that 42.3% of people have animals and birds in the house, 22.8% clean their cisterns within five years, and 26.3% they use the house roof for clothes drying in winter, which is higher than the results of this study (36 %) in case of presence of animals, but lower in the other two cases (65%, 64%) respectively, but they did not study the relation between the presence of animals and degree of contamination with both TC and FC (statistically not significant by One-Way ANOVA in this study) which is an important issue, but directly they conclude that it is a source of pollution.

3.7- House Sewerage system:

66% of the people in Hebron city have municipal sewerage systems, while 34% have cesspits. 16% have cesspits within 20 meters from the cistern, 18% have cesspits more than 20 meters away from the cistern. 30% have cesspits lower than the level of the cistern and 4% the same level.18% of the people never ever evacuate their cesspits but 8% evacuate it within one year and 8% within one to five years. 9% of the people who have sewerage system reported that they have flood (7% have floods less than four times, but 2% have it more than four times) while 57% reported that they don't have floods. The results of house sewerage system were illustrated in Table 3.7.

Yassin et al., (2006) in their study about assessment of microbiological water quality and its relation to human health in Gaza Governorate reported that 97.3% of population in Gaza city connected to sewerage system which is higher than the results reported in this study (66 %).

Al-Khatib & Orabi (2004) in their study about causes of drinking water contamination in rain-fed cisterns in three villages in Ramallah indicate that 60.1% of cesspits are higher than the level of the cistern which is higher than the results of this study (0%), but they did not study the relation between the presence of cesspits and degree of contamination with both TC and FC (statistically not significant by

One-Way ANOVA in this study) which is an important issue, but directly they conclude that that it is a source of pollution.

Yassin et al., (2006) in their study about assessment of microbiological water quality and its relation to human health in Gaza Governorate reported that 56.7% of population in Gaza city has flood in their sewerage system (5.9% in summer, 25.9% in winter and 68.2 % in winter and summer), almost the same results reported by Abu Amr and Yassin, (2008) in Khan Yunis 57.6%, 66.9% respectively. These results are higher than the results reported in this study that flood in sewerage occur in (9%) in Hebron city.

Table 3.7 Responses of study population about house sewerage system in Hebron-Palestine, 2008.

Variables	Frequencies	Percentages %
Sewerage system		
Municipal	66	66
Cesspit	34	34
Septic Tank	0	0
Level of Cesspit with respect to cistern		
Higher	0	0
Lower	30	30
Same Level	4	4
Distance between Cesspit and cistern		
< 20 meters	16	16
> 20 meters	18	18
Occurrences of Sewage Flood from sewage network		
Yes	9	9
No	57	57

3.8 Cistern's Water Usage:

The cistern's water usages for different purposes are illustrated in Figure 3.4. Seventy-nine percent of those interviewed indicated that rainwater catchment system (RWCS) water was used exclusively for drinking and/or cooking purposes. Ninety-five percent of those interviewed reported they also used other sources of water but only 14% of these secondary sources were used for drinking (Dillaha and Zolan, 1985).

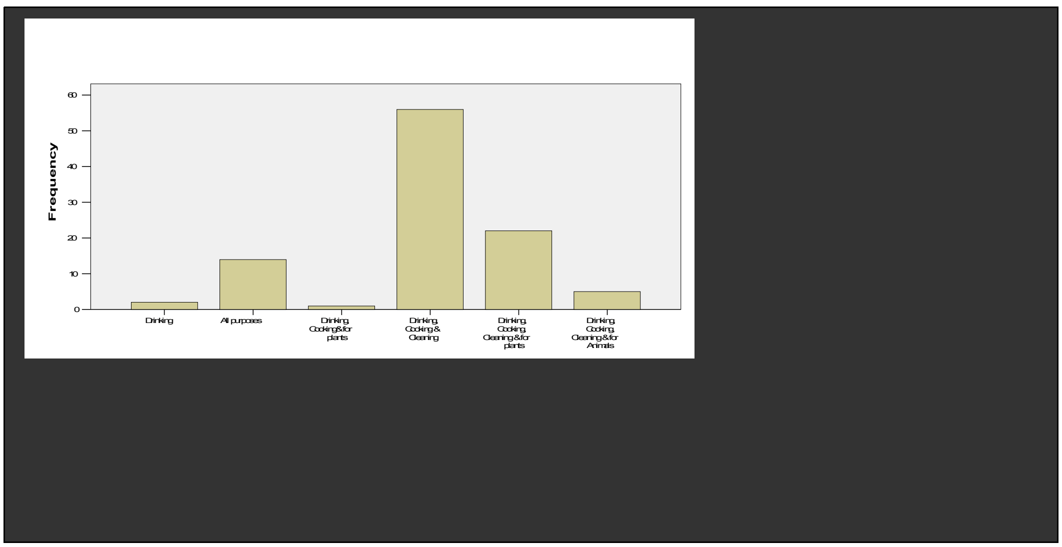

Figure 3.3 Different purposes of water usage from cisterns in Hebron-Palestine, 2008

Cistern systems are the primary source of water in the U.S. Virgin Islands. Over 80% of the residents in St Thomas, St Croix and St John use cisterns combined with a rainwater roof catchment system to supply water for drinking and washing (Crabtree et al., 1996).

Harvested rainwater in Germany used for toilet flushing, garden watering and household laundry (Nolde, 2007).

3.9 – Contamination with Total and Faecal Coliform

The percentage of contamination of cisterns in Hebron city by total coliform and faecal coliform was 95% and 57% (maximum contaminant level is 0-3 colonies per 100 ml and 0 colonies per 100 ml) respectively. These results are higher than the results obtained in three villages in Ramallah district by Al-Khatib and Orabi (2004) (87%) for Total Coliform, but lower regarding Faecal Coliform (100%). In other study conducted by Al-Khatib et al, (2003) about drinking water quality in Tulkarm District- Palestine, they found that only 34% of samples were contaminated with Total Coliform and 9.2% contaminated with Faecal Coliform. The high results of this study may be attributed to collection of rainwater which increases the degree of contamination. Also the results of this study are higher than results obtained by Abo-Shehada et al, (2004) of cisterns in Bani-Kenanah District –Northern Jordan, 49% for Total Coliform and 17% for Faecal Coliform. Canadian private water supplies may pose a risk to public health; numerous studies report such water supplies in excess of the minimal acceptable standards for microbial and chemical contamination, and an estimated 45% of all waterborne disease epidemics in Canada involve non-municipal systems, largely in rural or remote areas (Yassin et al., 2006).

Crabtree et al., (1996) in their study about microbiological quality of cisterns in Virgin Islands of USA reported that fifty-seven percent of the samples were positive for total coliforms and 36% were positive for fecal coliforms which are lower than the results of this study.

No significant correlation between Total Coliform and Faecal Coliform counts (Sperman's correlation coefficient =0.178). The number of positive total coliform and its relation to range of contamination, degree of contamination and treatment procedure are illustrated in table 3.8. Distribution of cistern's contamination with Faecal Coliform and degree of risk

Table 3.8- Number of positive total coliform for water from cisterns and its relation to range of contamination, degree of contamination and treatment procedure in Hebron- Palestine, 2008.

Range of TC	Degree of Contamination *	Number of positive samples (%)	Treatment Procedure
0 -3	0	5 (5%)	
4 - 50	1	17 (17%)	Chlorination only
51 – 50000	2	78 (78%)	Flocculation, Sedimentation then Chlorination
>50000	3		Very high contamination, need special treatment

*(Al-Khatib, 2004).

Table 3.9 Distribution of cistern's water contamination with Faecal Coliform and degree of risk in Hebron –Palestine, 2008.

Range of FC	Degree of Contamination *	Number of positive samples (%)
0	No Risk	43 (43%)
1 – 10	Simple Risk	33 (33%)
11 – 100	Moderate Risk	24 (24%)
101 – 1000	High Risk	0 (0 %)
> 1000	Very High Risk	0 (0 %)

*(Al-Khatib, 2004).

3.10- Chemical Water Quality:

The water quality standards (maximum contaminant levels) of Palestinian, EPA and WHO for different parameters were illustrated in Table 3.10.

3.10.1 Physical Parameters

The descriptive statistics (minimum, maximum, average and standard deviation) for the physical parameters were illustrated in table3.11.

Table 3.10 Water quality standards for human consumption (Modified after Shalash, 2006).

Parameter	**Palestinian Standards**	**EPA Standards**	**WHO Standards**
pH	6.5 – 8.5	6.5 – 8.5	6.5 – 8.5
Electrical Conductivity	NA*	1000	2000
Salinity	NA*	1.0	NA*
Total Dissolved Substances	1000	500	1000
Turbidity (NTU)	5	0.3 – 1	5
Total coliform (cfu/100ml)	< 3	<_5% of samples per month	0
Faecal Coliform (cfu/100ml)	0	0	0
Alkalinity	400	NA*	NA*
Calcium (Mg/L)	100	100	100
Chloride Mg/L	250	250	250
Total Hardness (Mg/L as CaCO3)	500	NA*	NA*
Magnesium	100	100	100
Ammonia	NA*	NA*	NA*

Nitrate	50 (as NO3)	10 (as N)	45 (as NO3)

*Not available

The pH values of cistern's water ranges from 7.32 to 8.97 with a mean value of 8.11, at this pH value the water is alkaline so unfavorable reactions will not occur (Zhu et al., 2004). 45% of pH values are within the range of 7.6 – 8.0, 49% within the range 8.1 – 8.5 and 4% of cases are higher than 8.5 which is the higher limit established by Palestinian and WHO standards. 65% of municipality water are within the range of 7.6 – 8.0 and 35% are within the range of 8.1 – 8.5, no results of municipality water exceeds the maximum limits of the Palestinian and WHO standards. 27.3% of rainwater are within the range of 7.6- 8.0, 68.2 % are within the range of 8.1 – 8.5, 4.5% of rainwater exceeds the maximum limits of the Palestinian and WHO standards.5.8% of mixed municipality and rainwater exceeds the maximum limits of the Palestinian and WHO standards(Table 3.12).

Table 3.11 The descriptive statistics for water quality parameters in water of cisterns in Hebron – Palestine, 2008.

Parameters	Minimum	Maximum	Mean	Std. Deviation
PH	7.32	8.97	8.1154	0.27586
Temp	9.80	26.00	16.7818	3.44482
EC	129.00	802.00	449.5152	184.33656
Salinity	0.10	0.40	0.2182	0.08848
TDS	62.00	384.00	216.1818	89.88228
Turbidity	0.34	113.00	7.4461	16.49146
TC	0.00	2000.00	1031.3200	914.59220
FC	0.00	98.00	8.8000	16.62480
Nitrate	1.50	7.00	4.1790	1.23151
Ammonia	0.00	13.30	1.3994	2.56667
Chloride	13.40	134.00	42.2680	21.88612
Calcium	16.00	172.00	94.6400	42.10701
Magnesium	0.00	212.00	64.6000	51.56892
TH	20.00	292.00	159.2000	86.11385

Alkalinity	16.0	346.0	154.790	68.8549

There is a significant difference between the sources of rainwater and pH, but no significant difference between sources of water in the cistern and pH; this is evident from the results of Pearson's Chi-Square Asymp. Sig. (2- sided) of 0.03 and 0.530 respectively,(Table 3.13).

Table 3.12 Percentages of sources of water in cisterns according to pH ranges in Hebron- Palestine, 2008.

Sources of water	pH Ranges			
	7.1 –7.5	7.6 – 8.0	8.1 – 8.5	> 8.5
Municipality water	0%	65 %	35%	0%
Rainwater	0%	27.3%	68.2 %	4.5 %
Mixed Municipality and Rainwater	1.8 %	46.2%	46.2%	5.8%

Table 3.13 The results of Chi- Square and P values for water quality parameters when cross tabulated with both sources of water in cisterns and sources of rainwater.

Test	Sources of water in cistern		Sources of Rainwater	
	Chi- Square	P values	Chi- Square	P values
pH	8.045	0.530	34.815	0.030
Temperature	22.278	0.035	42.865	0.036
Electrical Conductivity (EC)	62.936	0.000	66.221	0.000
Salinity	62.268	0.000	41.973	0.004
Total Dissolved Substances (TDS)	52.008	0.000	45.364	0.002
Turbidity	8.234	0.221	20.289	0.121
Nitrate (NO3)	7.681	0.053	6.134	0.524
Ammonia (NH3)	17.265	0.008	13.230	0.508
Chloride (CL)	22.712	0.001	7.424	0.970
Calcium (Ca)	35.071	0.000	23.919	0.047
Magnesium (Mg)	30.650	0.000	28.206	0.013
Total Hardness	39.624	0.000	28.004	0.014
Alkalinity	58.882	0.000	36.607	0.019

The results of temperature, electrical conductivity, salinity and total dissolved substances are below the maximum contaminant levels established by Palestinian and WHO standards.

The turbidity results of cistern's water ranges from 0.34 to 113 NTU with a mean value of 7.44 NTU(Table 3.11). 50% of the turbidity results are below 2 NTU, 25% are between 2- 5 NTU and 24% are more than 5 NTU which exceeds both Palestinian and WHO standards. The possible causes of these high results are, some of the samples are collected while it is raining and water are entering the cistern so the whole water are mixed and some of the samples are collected during holidays so the physical parameters not tested onsite but tested later after 24hours of storage in refrigerator at 4°C, at this temperature the solubility of dissolved substances decrease so the turbidity increased. This fact was confirmed in other sampling batch in which the turbidity was tested on site and repeated after almost 24 hours of storing at 4°C which gave high results. 10% of municipality water, 31.8% of rainwater and 25% of mixed municipality and rainwater exceed the maximum limits of Palestinian and WHO standards.

There is significant correlation between electrical conductivity and total dissolved substances at 0.01 level (Pearson's correlation coefficient = 0.951). There is significant correlation between turbidity and both Total and Faecal Coliform at levels 0.01and 0.05 (Pearson's correlation coefficient 0.280, 0.215) respectively (Table 3.14).

Collecting the house wastes in the house yard, presence of green spots at the sides of the cistern, presence of floating things at the surface of the cistern's water, increases the turbidity of the cistern's water.

Awadallah, (2004) in his study about the water quality of 30 cisterns in Hebron District and Dawod in Ramallah and Qalqilya. They reported only the averages of physical parameters and nitrate, but they didn't create any percentages when their results exceeds the WHO and Palestinian standards.

Table 3.14a Pearson correlation coefficients between water quality parameters of cisterns in Hebron-Palestine, 2008.

Correlations

		PH	Temp	EC	Salinity	TDS	Turbidity	TC	FC
PH	Pearson Correlation	1	.125	-.349	-.324	-.352	-.153	.238	.171
Temp	Pearson Correlation	.125	1	-.152	-.196	-.143	-.353	-.237	.087
EC	Pearson Correlation	-.349	-.152	1	.937	.990	-.384	-.300	-.270
Salinity	Pearson Correlation	-.324	-.196	.937	1	.936	-.268	-.311	-.263
TDS	Pearson Correlation	-.352	-.143	.990	.936	1	-.373	-.321	-.276
Turbidity	Pearson Correlation	-.153	-.353	-.384	-.268	-.373	1	.137	-.031
TC	Pearson Correlation	.238	-.237	-.300	-.311	-.321	.137	1	.224
FC	Pearson Correlation	.171	.087	-.270	-.263	-.276	-.031	.224	1
Nitrate	Pearson Correlation	.182	.023	.398	.323	.342	-.321	-.030	.026
Ammonia	Pearson Correlation	-.175	.161	.352	.289	.396	-.092	-.180	-.200
Chloride	Pearson Correlation	.274	-.160	.713	.669	.704	-.235	-.228	-.120
Calcium	Pearson Correlation	.160	.092	.611	.585	.608	-.288	-.031	-.141
Magnesium	Pearson Correlation	.005	.108	.459	.418	.425	-.391	-.057	-.127
TH	Pearson Correlation	-.074	.017	.572	.536	.551	-.375	-.049	-.145
Alkalinity	Pearson Correlation	-.385	.080	.800	.803	.798	-.320	-.217	-.319

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

3.10.2 Ammonia and Nitrate

The results of nitrate ranges from1.5 to 7.0 mg/L with a mean value of 4.2 mg/L(table 3.11), 24% of nitrate results in the cisterns are below 3 mg/L and 76% are within the range from 3 to 10 mg/L.

None of the results exceeds the Palestinian and WHO standards of 10 mg/L as nitrate nitrogen. Concentrations over 3 mg/L nitrate nitrogen are usually considered indicative of anthropogenic pollution (Madison& Brunett, 1985, Kross et al., 1993). The results of ammonia ranges from 0.0 to 13.3 mg/L with a mean value of 1.4mg/L 65% of the results are below 0.2 mg\L, 6% are between 0.2 – 1.5 mg/L and 29% are more than 1.5 mg/L. 15% of municipality water and 9.1% of rainwater has ammonia results more than 1.5 mg/l. No maximum contaminant level established by Palestinian Authority and WHO Standards.

Figure 3.4 illustrates the results of ammonia and nitrate in cisterns in Hebron city.

Table 3.14 b Pearson correlation coefficients between water quality parameters of cisterns in Hebron-Palestine, 2008.

Correlations

		Variables						
Variables	Statistics	Nitrate	Ammonia	Chloride	Calcium	Magnesium	TH	Alkalinity
PH	Pearson Correlation	.132	.175	-.274**	-.160	.005	-.074	-.385**
Temp	Pearson Correlation	-.023	.161	-.160	-.092	.103	.017	-.080
EC	Pearson Correlation	.398	.352**	.713**	.611**	.459**	.572**	.800**
Salinity	Pearson Correlation	.323	.289**	.669**	.585**	.418**	.536**	.803**
TDS	Pearson Correlation	.342	.396**	.704**	.608**	.425**	.551**	.798**
Turbidity	Pearson Correlation	-.321	-.092	-.235*	-.288**	-.391**	-.375**	-.320**
TC	Pearson Correlation	-.030	.180	-.228*	-.031	-.057	-.049	-.217*
FC	Pearson Correlation	.026	.200*	-.120	-.141	-.127	-.145	-.319**
Nitrate	Pearson Correlation	1	.151	.284**	.275**	.432**	.392**	.285**
Ammonia	Pearson Correlation	.151	1	.254*	.117	-.216*	-.073	.224*
Chloride	Pearson Correlation	.284	.254*	1	.200*	.147	.185	.511**
Calcium	Pearson Correlation	.275	.117	.200*	1	.689**	.901**	.562**
Magnesium	Pearson Correlation	.432	-.216*	.147	.689**	1	.935**	.405**
TH	Pearson Correlation	.392	-.073	.185	.901**	.935**	1	.517**
Alkalinity	Pearson Correlation	.285	.224*	.511**	.562**	.405**	.517**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

No significant correlation between nitrate and ammonia. No significant relation between sources of water, rainwater and nitrate, this is evident from the results of

Pearson's Chi-Square Asymp. Sig. (2- sided) of 0.053, 0.524 respectively (Table 3.13).

Using the house roof for clothes drying in winter, presence of floating things at the surface of the cistern's water, treating the cistern's water in general, increases the level of ammonia in the cistern's water. Occurrence of flood of sewerage system decreases the level of ammonia in the cistern's water, these conclusions are drawn from the results of T test between the variables and water quality parameters, where the mean difference is positive indicate there is increase in the results while negative difference in the means indicate decrease in the results of water quality parameter compared.

The results of nitrate of this study are consistent with two studies of water quality of cisterns in West Bank (Awadallah,2004 and Dawod,2008) that no results of nitrate exceeds the Palestinian and WHO standards of 10mg/L NO_3^- -N.

The case is completely different in Gaza Strip where high percentages of wells are contaminated with high level of nitrate (almost 90% of the sampled wells had levels of NO_3^- above the World Health Organization's standard). Manure and septic effluents are the main sources of NO_3^- in the groundwater of Gaza followed by sludge and synthetic fertilizers (Shomar et al., 2008).

Nitrate, due to its high water solubility, is possibly the most widespread groundwater contaminant in the world, imposing a serious threat to drinking water supplies and promoting eutrophication. Nitrate from such sources can be introduced into surface and groundwater systems via runoff and infiltration (Liu et al., 2005).

In Saudi Arabia 5% and 11% of tank water supplied to houses have nitrate and ammonium values higher than the WHO standards (Alaa El-Din et al., 1994).These results are higher than the results of this study which is 0% for both nitrate and ammonia.

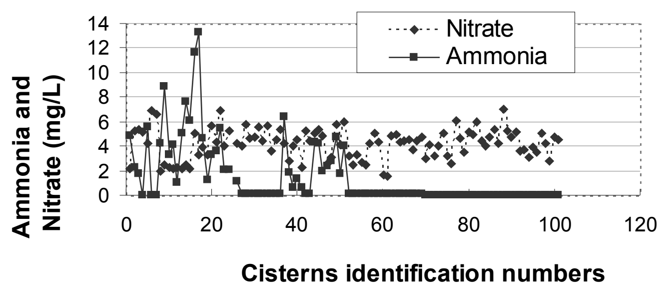

Figure 3.4 Plot of the results of ammonia and nitrate in cisterns in Hebron-Palestine, 2008.

3.10.3 Chloride

The results of chloride ranges from 13.4 to 134 mg/L with a mean value of 42.3 mg/L , 70% of the results between 0 – 50 mg/L, 28% between 51 – 100 mg/L, and 2% between 101 – 150 mg/L. No results exceeds the Palestinian and WHO standards of 250 mg/L.

There is weak, negative, and significant correlation between chloride and Total Coliform. Weak, positive significant correlation between chloride and nitrate at level 0.05 and 0.01(Pearson's correlation coefficient -0.228, 0.284) respectively (Table 3.14).

The results of chloride in cisterns are low which indicate no intrusion of wastewater to cisterns; this is supported by good construction of cisterns in Hebron city. The concrete may protect the reservoir better from being contaminated with the wastewater leaking from the adjacent seepage pit (Abo-Shehada et al., 2004). Chloride at concentrations above 250mg/L gives salty taste to water, which is objectionable to many people (Sawyer, 1994, Shalash, 2006).

70% of municipality and 95.5% of rainwater chloride results lies between 0 -50 mg/L which indicate that there is no intrusion of wastewater to the cisterns from nearby sewerage system or cesspits.

There is a significant relation between sources of water in general and chloride level in the cisterns (Pearson's Chi-Square Asymp. Sig. (2- sided) of 0.001), but there is no relation between rainwater and chloride level (Pearson's Chi-Square Asymp. Sig. (2-sided) of 0.917) (Table 3.13).

3.10.4 Alkalinity

The results of alkalinity ranges from 16 to 346 mg/L with a mean value of 154.8 mg/L, 24% of the results ranges between 0 – 100 mg/L, 53% between 101 – 200 mg/L , 22% between 201 – 300, and only 1% of results over 300mg/L.

77.3 % of rainwater alkalinity below 100 mg/L but decrease to 11.3 % when mixed with municipality water. 50% of municipality water alkalinity ranges from 201 – 300 mg/L which decreases to 20.8 % when mixed with rainwater, this indicate that municipality water of groundwater origin has alkalinity higher than rainwater.

There is a significant relation between source of water in general, sources of rainwater and alkalinity (Pearson's Chi-Square Asymp. Sig. (2- sided) of 0.000, 0.019) respectively (Table 3.13).

There is negative correlation between alkalinity and pH (Pearson's correlation coefficient -0.331) at 0.01 level (Table 3.14). A correlation coefficient is a number between -1 and 1 which measures the degree to which two variables are linearly related. If there is perfect linear relationship with positive slope between the two variables, we have a correlation coefficient of 1; if there is positive correlation, whenever one variable has a high (low) value, so does the other. If there is a perfect linear relationship with negative slope between the two variables, we have a correlation coefficient of -1; if there is negative correlation, whenever one variable has a high (low) value; the other has a low (high) value. A correlation coefficient of 0 means that there is no linear relationship between the variables (Easton and McColl, 2008).

3.10.5 Total Hardness, Calcium, and Magnesium

As clear from table 3.15, 26% of cistern's water in Hebron city is soft, 25% is moderately hard and 49% are hard. The results of total hardness ranges from 20 to 292 mg/L with a mean of 159.2mg/L. No results exceeds the Palestinian and WHO standards of 500 mg/L as $CaCO_3$.

90% of municipality water is hard, this percentage decrease to 56.6% when mixed with rainwater, in contrary 54.5% of rainwater is soft and decrease to 17% when mixed with municipality water.

Table 3.15 Sawyer and McCarty (1967) classification of water based on hardness and percentages of total hardness in Hebron–Palestine, 2008 (modified after Shalash, 2006).

Class of Water	Hardness as CaCO3 (Mg/L)	Number of Samples (%)	Water Type
I	0 – 75	26 (26%)	Soft
II	75 – 150	25 (25%)	Moderately Hard
III	150 – 300	49 (49%)	Hard
IV	> 300	0 (0%)	Very Hard

The Box- and- Whisker plot was used to compare the results of total hardness of different sources of water in cisterns (Figure 3.6). From the figure it is clear that municipality water has highest results of hardness followed by mixed water then the rainwater.

There is a significant relation between source of water in general, source of rainwater and level of total hardness (Pearson's Chi-Square Asymp. Sig. (2- sided) of 0.000, 0.014) respectively (Table 3.13).

The results of calcium ranges from 16 to 172 mg/L with a mean of 94.6. 47% of the results exceed the Palestinian and WHO standards of 100 mg/L (85% of municipality water and only 4.5% of rainwater).

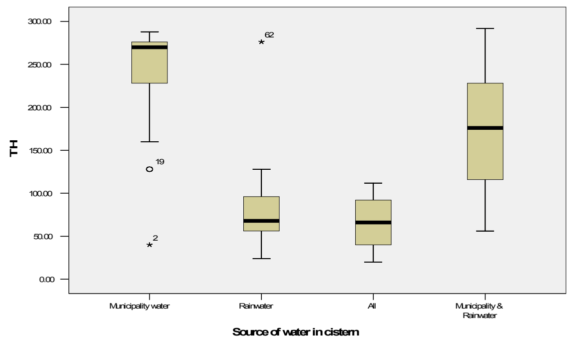

Figure 3.5 Box- and- Whisker plot for total hardness of source of water in cisterns in Hebron-Palestine, 2008. The boxes indicate the lower and upper quartiles and the central line is the median. The points at the ends of the ‘‘whiskers’’ are the 2.5% and 97.5% values.

High percentage of calcium and magnesium exceeds the Palestinian and WHO standards which may have negative impacts on the people's health, however several studies indicate that there is a protective effect of calcium level against many diseases, unfortunately these studies did not specify this level, when it has protective effect and when it will be harmful.

There is a significant relation between both source of water and rainwater and calcium level (Pearson's Chi-Square Asymp. Sig. (2- sided) of 0.000, 0.047) respectively (Table 3.13).

The results of magnesium ranges from 0.0 to 212 mg/L with a mean value of 64.6 mg/L. 32% of the results exceeds the Palestinian and WHO standard of 100 mg/L(70% municipality water ,4.5% rainwater).

There is a significant relation between both source of water in general, source of rainwater and magnesium level (Pearson's Chi-Square Asymp. Sig. (2- sided) of 0.000, 0.013) respectively (Table 3.13).

The acceptable concentrations of calcium and magnesium are 100 mg/L, above these concentrations; water becomes hard for some industrial and domestic uses. High concentrations of magnesium are laxative and cause abdomen problems (Shalash, 2006).

The percentages of physical, chemical and microbiological parameters that exceeds the Palestinian and WHO maximum contaminant levels are summarized in Figure 3.6 below.

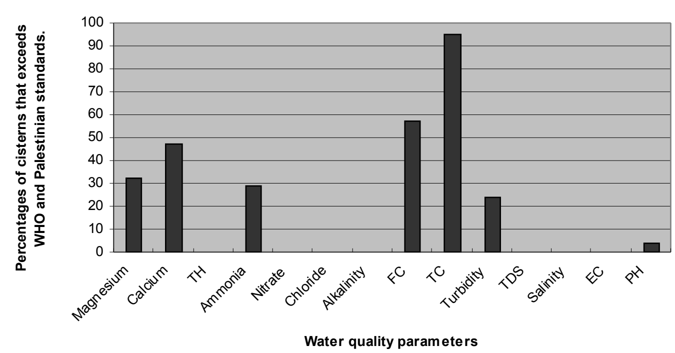

Figure 3.6 Percentages of physical, chemical and microbiological parameters that exceeds Palestinian and WHO standards in Hebron-Palestine, 2008.

Ziadat,(2005) in his study about impact of storage tanks on drinking water quality in Al-Karak Province-Jordan reported that none of the chemical parameters tested

(calcium, magnesium, chloride, sodium, potasium, bicarbonate, sulphate, nitrate, pH and electrical conductivity) exceed the WHO and Jordanian standards.

El-Fadaly et al., (2000) in their study about chemical and microbiological analyses of certain water sources and industrial wastewater samples in Egypt reported that all the chemical parameters tested(electrical conductivity, alkalinity, hardness, sulphate, pH, TDS, and chloride) have values within the limitation of either national or international standards. Same results also reported by AbdelKarem and Hassan, (2000) in their study about quality assessment of Egyptian water supplies and disinfecting using ultraviolet radiation.

3.11- Sources of contamination

3.11.1 Contamination of sources of cistern's water and rainwater.

From the cross tabulation between source of water (in general) in cisterns and level of contamination with Total Coliform we found that 15% of people who use municipality water only don't have contamination with Total Coliform (0-3 colonies per 100 ml of water) while this percentage decrease to3.8% when municipality water mixed with rainwater(Table 3.16) which indicate that the rainwater is the source of Total Coliform, this conclusion is supported also by the percentage of contamination increase with the increase of degree of contamination.

From Table 3.16, 55% of cisterns which use only municipality water have no contamination with Faecal Coliform while 45.3% of cisterns which use mixed municipality and rainwater have no contamination (0 colonies of FC per 100ml of water). Total coliform can come from environmental sources, reproduce in paper pulp plants and other environments, and is often found in the absence of fecal contamination (Payment, & Hunter, 2001).

The source of water played a significant role in water pollution. Reservoirs receiving chlorinated water from the public source were free from contamination. The possibility of contamination increased when the chlorinated water was mixed with rainwater inside the reservoir (Rabi' and Abo-Shehada 1995). It is worthy to say that cisterns in which only municipal water is collected in it is free of contamination from both Total Coliform and Faecal Coliform (3%). These results consistent with other study done in Jordan by Rabi' and Abo-Shehada (1995).

Table 3.16-Created from cross tabulation between source of water in cistern and level of contamination with Total and Faecal Coliform in Hebron – Palestine, 2008.

Water Sources	% of **non** contaminated Cisterns with TC	% of **non** contaminated Cisterns with FC
Municipality	15	55
Municipality & rainwater	3.8	45.3
House roof rainwater	3	41.8

3% and 41.8% of cisterns which use the house roof as a source of rainwater not contaminated with Total Coliform and Faecal Coliform respectively, while the cisterns which use other sources are contaminated with Total Coliform and Faecal Coliform in different degrees. These results indicate that the house roof is best source of rainwater which can be controlled by cleaning and discarding the first flush of rainwater (48% of people in Hebron city clean the house roof and discard the first flush of rainwater).

In this study we did not ask the people how they clean the house roof and for how many times did they clean so we couldn't conclude about the best way of cleaning and for how many times. Collecting water from a surface washed once or twice at the beginning of the winter season is not enough to ensure the safety of the rainwater (Rabi' and Abo-Shehada 1995), this practice did not prevent further contamination of the collecting surface dirt, animal and bird droppings, so the use of an efficient filter on the collecting surface may reduce the rate of contamination (Abo-Shehada et al., 2004).

The increase in percentage of contamination may be attributed to runoff (study was done during winter) of dirt and animal droppings, also the water not stayed in the cistern for long time before testing to give enough time for the natural process to occur. The quality of rainwater stored in a cistern is potentially improved with time. The investigation has found that rainwater is a valuable water resource if it has been stored in a cistern for half a year or, even longer (Zhu et al., 2004).

The difference in percentages between sources of water in general and level of contamination of both TC and FC is not statistically significant since the values of Pearson's Chi-Square Asymp. Sig. (2- sided) is higher than 0.05.

The degree of contamination of sources of cistern's water in general and sources of rainwater with Total and Faecal Coliform are illustrated in Appendix G.

3.12- Risk Factors and degree of contamination

From the cross tabulation between the risk factors and degree of contamination with TC and FC we found that the percentage of contamination when this factor is applied (Yes) and when it is not used(No), then we apply the Chi-Square test to know whether the difference in percentage is statistically significant or not. The results are summarized in Table 3-17. Same results we get when T-test was applied. The risk factors includes, treatment water in cistern in general, taking an action before rainwater harvesting, presence of animal or birds at home, presence of trees around the cistern, presence of floating things on water surface or green spots on the sides of the cistern, using the roof of the house for clothes drying in winter, door of the cistern is open or not and collecting wastes in the house yard.

Taking any action before rainwater harvesting has did not decrease the percentage of contamination with Total and Faecal Coliform, and has no effect on the level of turbidity, nitrate, chloride and ammonia, but treatment of the cistern (in general) has significant effect on the degree of contamination with Total coliform but not with Faecal Coliform. The presence of animals in the house and trees around the cistern did not increase the percentage of contamination with both TC and FC, this relation between presence of animals and trees and degree of contamination with TC and FC is statistically not significant, this is evident from Pearson's Chi-Square Asymp. Sig. (2- sided) is 0.377, 0.827 respectively (Table 3.17).

Birds are the most common source of pollution on roofs. They can, however be prevented from landing by putting wires low over the roof surface. Leaves, conifer needles, and pollen will, together with soot and dust, create a constant problem for the cistern user. Trees that are close to the house can be advantageously removed (Johanson and Seifert, 1989).

Table 3.17 Risk factors for cistern contamination with Total and Faecal Coliform in Hebron-Palestine, 2008.

Risk Factors		% +ve TC	% +ve FC	Df	X^2	P
Do you treat cistern in general	Yes	87	47.8	3	7.692	0.053
	No	97.3	59.5	2	2.291	0.318
Do you take any action before	Yes	95.8	59.7	6	7.554	0.273
rainwater harvesting	No	100	44.4	4	1.596	0.809
Door of the cistern is open	Yes	100	66.7	6	20.97	0.002
	No	95.8	56.8	4	3	0.830
Do you have animals or birds	Yes	93.7	56.2	6	1.481	0.377
at home	No	96.8	54	4	6.427	0.827
Is there trees around the cistern	Yes	96.6	57.6	3	1.497	0.638
	No	94.3	55.7	2	1.697	0.952
Do you notice any thing float at	Yes	95.5	40.9	3	0.099	0.706
the surface of water	No	94.8	61	2	1.396	0.118
Do you notice green spots at the	Yes	100	55.6	3	4.277	0.737
sides of the cistern	No	94.4	56.7	2	1.266	0.989
Do you use the roof for clothes	Yes	96.8	50	3	0.022	0.259
drying in winter	No	91.7	66.7	2	4.021	0.100
Do you collect the house wastes	Yes	93.1	44.8	3	4.601	0.536
in the yard	No	95.7	60.9	2	2.180	0.318
					2.294	

The results of df, x^2 and P in the first row of each risk factor are for TC and the second one is for FC.

Abo-Shehada et al (2004) reported a significant relation between the presence of animals at home and degree of contamination with Cryptosporidium parvum, presence of cesspits within radius of 15 meters and degree of contamination with *E.Coli*

There is no effect of presence of floating things and green spots at the surface and sides of the cistern and the percentage of contamination with TC, but the presence of floating things at the water surface increase the percentage of contamination with FC and this difference is statistically significant, presence of green spots at the sides of the cistern has no effect on the degree of contamination with FC.

Using the house yard for waste collection did not increase the percentage of contamination with both TC and FC. Using the house roof for clothes drying in winter has no effect on the percentage of contamination with TC, but has effect on the percentage of contamination with FC (Yes 50%, No 66.7%)and this difference in percentages is statistically significant when tested with T- test.

The results of this study indicate that the source of FC in Hebron cisterns may be environmental factor (atmospheric deposition of airborne microorganisms) since no statistically significant relationship between degree of contamination with FC and presence of trees around the cistern was found (source of bird droppings), presence of animals at home, using the house roof for clothes drying in winter (improperly cleaned clothes),and collection of wastes in the house yard. these results are consistent with the results of (Evans et al., 2006) who concluded that airborne micro-organisms represented a significant contribution to the bacterial load of roof water at Newcastle (on the east coast of Australia), and that the overall contaminant load was influenced by wind velocities, while the profile (composition) of the load varied with wind direction.

The door of the cistern weather it is open or closed has a significant effect on the degree of contamination with Total Coliform at p level 0.002, but not with Faecal Coliform (Pearson Chi-Square asymp.sig.is 0.830) (Table 3.17).

3.13- One - Way ANOVA

One- Way ANOVA statistical test was applied on some of the questionnaire variables and the degree of contamination with TC and FC, turbidity, nitrate, and chloride. Taking an action before rainwater harvesting has effect on the degree of contamination with FC (statistically significant between and within groups), but has no effect on the degree of contamination with TC. Discarding the first rainwater has significant effect on the degree of contamination with FC, while cleaning the house roof has no effect, this result support the conclusion that the source of FC is atmospheric deposition. In this study i did not ask about the characteristics of the house roof to study its effect on the water quality. Chang et al., (2004) concluded that roofs can be a non point source of water pollution. However, results of roof runoff studies have been variable. The variation reflects differences in roofing materials, industrial treatments, care and maintenance, age, climatic conditions, orientation and slope of the roofs, and air quality of the region.

The roof surface should not contain tar or lubricants, asbestos cement plate and sod roofs. Roof covering materials that are normally useful as collection surfaces include tile, concrete, or slate shingles, aluminum, and corrosion-proofed steel. Plastic materials can also be used as a coating material or as a separate cover. (Johanson and Seifert, 1989).

The effect of house roof cleaning on the quality of cisterns water was discussed in section 3.11.1 of this chapter. From the results of this study i cannot specify time to be the best time for cistern cleaning to be repeated regularly (which has the least degree of contamination) since the time of cleaning has no significant effect on the degree of contamination with FC, but has relation with TC and there is no relation within groups of time and FC contamination. A cistern needs to be cleaned at least every five years. This might be needed more often where blowing dust, leaves and fireplace or stove ash fall on the roof. Inspecting and cleaning the gutters, downspout, roof washer and filter will help to keep a cistern cleaner (Taraba et al., 1990). Cleaning of the cistern is usually done by using a stiff brush, water, and baking soda. Finally, wash the area with amounts of clean water. Careful cleaning of the collection area (the roof and downspouts) along with a good intake filter and cold storage can lengthen the time between the cleaning (Johanson and Seifert, 1989).

Treatment of cistern's water with chlorine, kerosene or diesel has no effect on the degree of contamination with both FC and TC. Testing, cleaning and age of the cistern has no effect on the degree of contamination with both TC and FC.

Door of the cistern weather it is opened or closed has significant effect on the degree of contamination with TC (opened 100% contamination and 95.85% contaminated when it is closed, this difference is statistically significant) (Table 3.17). According to the Jordanian standards of cistern's design for rainwater harvesting, the door of the cistern should be raised at least 30 centimeters from the level of the floor (JISM, 2008). No Palestinian standards of cistern's design for rainwater harvesting.

The sewerage system of the house weather it is municipal or cesspit has no effect on the degree of contamination with both TC and FC. but it has effect on the turbidity (32.8% of the houses which has sewerage system has turbidity more than 5 NTU but only 8.8% of the houses which has cesspits has turbidity more than 5 NTU)

(Table3.18).

Table 3.18 Results of cross tabulation between house sewerage system and its effect on the degree of turbidity of cisterns in Hebron – Palestine, 2008.

Sewerage system of the house	Turbidity			Total
	< 2	2 - 5	> 5	
Municipal sewerage	29	14	21	64
	45.3%	21.9%	32.8%	100.0%
Cesspit	20	11	3	34
	58.8%	32.4%	8.8%	100.0%
Total	49	25	24	98
	50.0%	25.5%	24.5%	100.0%

Presence of cesspits in the houses of Hebron city statistically has no effect on the degree of contamination with both TC, FC, turbidity, nitrate and chloride regardless of the level of cesspit and distance between the cesspit and cistern so i cannot recommend a distance which will be the least distance between the cesspits and cistern that considered safe and born no risk of contamination with Total and Faecal Coliform. According to the Jordanian standards of cistern's design for rainwater harvesting, the cistern should be away from any nearby cesspit at least 15 meters (JISM, 2008).

The municipal sewerage system flood weather it occurs in summer or winter has its effects on the degree of contamination with TC and the results of chloride. The number of floods (how many times it will occur per year) has no effect on the degree of contamination with both TC and FC, but has effect on the results of chloride level, since the major source of chloride in water is sea water or wastewater.

Chapter Four

4-Conclusions and recommendations

4.1- Conclusions:

High percentages of cisterns are contaminated with either Total(95%) or Faecal Coliform(57%) or both of them, so the cisterns should be chlorinated especially those who used rainwater only.

High percentages of cisterns exceeds the Palestinian and WHO standards of calcium(47%) or magnesium(32%) or both.

The rainwater is the source of contamination of cistern's water in Hebron city, while the municipal water is the source of high hardness. Mixing the two sources together counter act the effect of each other.

The source of Faecal Coliform in cistern's in Hebron city seems to be environmental factor (atmospheric deposition) since the presence of trees around the cistern, presence of animals in the house and presence of cesspits (possible sources) has no significant effect on the degree of contamination with FC.

The design of the cisterns in Hebron is of good quality so the presence of cesspits around the cisterns and municipal sewerage flood has no effect (statistically no significant difference by One Way-ANOVA) on the degree of contamination by Total and Faecal Coliform.

4.2- Recommendations

1**-** To cope with the scarcity of water supply in Hebron city the local government should stimulate the people to build cisterns by providing them some financial support and make presence of cistern in the house necessary for house accreditation by the municipality**.**

2- The door of the cistern weather it is inside or outside the house should be raised over the surface of the floor to prevent the contamination of it from the seepage of water from the surrounding into it especially water of cleaning.

3- There should be no trees over the cistern to prevent the reach of birds dropping and trees' leaves into the cistern.

4- The cistern volume should be large enough to gather as much water to cope with the scarcity of water supply especially in summer.

5- Cleaning the house roof should be performed properly more than one time using detergent and chlorine to decrease the degree of contamination since the rainwater is the source of contamination of cistern's water.

6- Harvested rainwater should be chlorinated after every heavy rainfall episode because the water harvested is used continuously.

7- Cistern's water should be tested at least one time every year, if contamination detected, cistern should be retested after two weeks of chlorination.

8- Cisterns should be cleaned frequently, at least every five years (from results of this study, I cannot recommend specific time for cleaning (no significant difference between time of cleaning and degree of contamination with Total and Faecal Coliform).

9- Further studies are required to assess the water quality of cisterns in Hebron city (e.g rainwater quality collected before reaching the ground and cistern's water quality in dry season).

10- Education of the people through mass media or brochures about the sources of cistern's contamination and the possible ways of decreasing it.

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Appendices

Appendix A: The questionnaire distributed at the owner of the houses in Hebron city, Arabic language.

جامعة بيرزيت، كلية الدراسات العليا
معهد الدراسات المائية والبيئية

بسم الله الرحمن الرحيم

هذا الاستبيان وضع لاغراض البحث العلمي من قبل الباحث عادل السلايمه لدراسة مصادر تلوث آبار تجميع المياه في مدينة الخليل

الاسم (اختياري)

V1	العمر
V2	المستوى التعليمي 1- أساسي 2- ثانوي 2 بكالوريوس 3- دراسات عليا. 5- دبلوم 6- أمي
V3	مصدر المياه في البئر 1- مياه بلدية 2- مياه شتاء 3- تنكات 4- غير ذلك حدد ----------
V4	ما هي مصادر مياه الشتاء 1- سطح المنزل 2- ساحة المنزل أو الحديقة 3- الشارع 4- غير ذلك حدد --------------------
V5	هل تتخذ إجراءات محددة قبل تجميع مياه الأمطار؟ 1- نعم 2- لا
V6	إذا كان الجواب نعم، فما هي هذه الإجراءات؟ 1- تنظيف سطح المنزل 2- التخلص من مياه اول شتوة 3- الاثنين معا 4- غير ذلك حدد ----------------------
V7	هل يتم معالجة مياه البئر بشكل عام؟ 1- نعم 2 - لا
V8	إذا كان الجواب نعم، فكيف تتم المعالجة؟ -------------
V9	متى تم فحص مياه البئر آخر مرة؟ قبل ------------
V10	متى تم تنظيف البئر آخر مرة؟ قبل ------
V11	ما هي استخداماتك لماء البئر؟ (يمكن أن يكون الجواب أكثر من خيار) 1- للشرب 2- لسقي الحيوانات 3- لري المزروعات 4- للطهي 5- لتنظيف البيت 6- غير ذلك حدد ---------------
V12	اذكر عمر البئر بالتقريب ....
V13	ما هو حجم بئر التجميع لديك ....
V14	هل باب بئر التجميع 1- مفتوح 2- مغلق 3- شبك 4- غير ذلك حدد ------------
V15	هل تعتقد أن المياه التي تستعملها من البئر صالحة للشرب 1- نعم 2- لا
V16	هل أنت مهتم للتأكد من جودة المياه التي تستعملها 1- نعم 2 - لا
V17	ما هي وسيلة الصرف الصحي التي تستعملها في المنزل: 1- مجاري عامة 2- حفرة امتصاصية 3- حفرة صماء (لا تسرب المياه العادمة)

V18	في حالة استعمال حفرة امتصاصية اذكر بعدها عن البئر بالمتر ----------
V19	هل مستوى الحفرة الامتصاصية 1- أعلى من مستوى البئر 2- أهبط من مستوى البئر 3- نفس المستوى
V20	متى تم نضح الحفرة الامتصاصية آخر مرة؟ قبل ---------
V21	في حالة استعمال المجاري العامة، هل يحدث فيضان للمجاري 1- نعم 2- لا.
V22	إذا كانت الإجابة نعم . هل يحدث الفيضان في 1- الصيف 2- الشتاء 3- غير ذلك
V23	ما هي عدد المرات التي يحدث فيها الفيضان سنويا ....
V24	هل تقوم بتربية حيوانات او طيور اليفة في المنزل 1- نعم دائما 2- أحيانا 3- لا
V25	هل يوجد أشجار قريبة من بئر التجميع 1- نعم 2- لا
V26	هل تلاحظ شوائب عائمة على سطح مياه البئر 1- نعم 2- لا
V27	هل تلاحظ اخضرار على جوانب البئر 1- نعم 2- لا
V28	هل يتم استعمال سطح المنزل في الشتاء لغرض نشر الغسيل 1- نعم 2- لا
V29	هل يتم تجميع النفايات في ساحة المنزل 1- نعم 2- لا

Appendix B: Table of percentages of water quality parameters and water sources percentages that exceeds the Palestinian and WHO standards.

Parameter	% that exceeds MCLs	% of municipality	% of rainwater

		water	
PH	4	0	4
EC	0	0	0
Salinity	0	0	0
TDS	0	0	0
Turbidity	24	10	32
TC	95	85	100
FC	57	45	68
Alkalinity	0	0	0
Chloride	0	0	0
Nitrate	0	0	0
Ammonia	29	15	9.1
TH	0	0	0
Calcium	47	85	4.5
Magnesium	32	70	4.5

Appendix C: Pearson's Chi-Square Asymp. Sig. (2- sided) values for different water quality parameters and its relation to sources of water and rainwater.

Parameter	Pearson's Chi-Square Asymp. Sig. (2- sided), **sources of water**.	Pearson's Chi-SquareAsymp. Sig. (2- sided), **sources of rainwater**
PH	0.530	0.030
EC	0.000	0.000
Salinity	0.000	0.004
TDS	0.000	0.002
Turbidity	0.221	0.121
TC	0.363	0.817
FC	0.417	0.395
Alkalinity	0.000	0.019
Chloride	0.001	0.917
Nitrate	0.053	0.524
Ammonia	0.008	0.508
TH	0.000	0.014
Calcium	0.000	0.047
Magnesium	0.000	0.013

Appendix D: Example of cross tabulation result between sources of water, sources of rainwater and water quality parameter.

Source of water in cistern * TC Cross tabulation

Source of water in cistern		TC				Total
		0 - 3	4 - 50	51 - 1000	1000 - 2000	
Municipality water	Count	3	5	5	7	20
	% within Source of water in cistern	15.0%	25.0%	25.0%	35.0%	100.0%
Rainwater	Count	0	2	9	11	22
	% within Source of water in cistern	0.0%	9.1%	40.9%	50.0%	100.0%
All	Count	0	1	2	1	4
	% within Source of water in cistern	0 .0%	25.0%	50.0%	25.0%	100.0%
Municipality & Rainwater	Count	2	9	15	27	53
	% within Source of water in cistern	3.8%	17.0%	28.3%	50.9%	100.0%
Total	Count	5	17	31	46	99
	% within Source of water in cistern	5.1%	17.2%	31.3%	46.5%	100.0%

Appendix E: Example of one way ANOVA on the relation between some of the variables of the questionnaire and water quality parameters that is affected with wastewater intrusion to cistern's water.

ANOVA

Water Quality Parameters		Sum of Squares	df	Mean Square	F	Sig.
Turbidity	Between Groups	3.372	3	1.124	1.670	0.179
	Within Groups	63.251	94	0.673		
	Total	66.622	97			
TC	Between Groups	5.599	3	1.866	2.404	0.072
	Within Groups	73.754	95	0.776		
	Total	79.354	98			
FC	Between Groups	5.260	3	1.753	2.867	0.041
	Within Groups	58.093	95	0.612		
	Total	63.354	98			
Nitrate	Between Groups	0.095	3	0.032	0.151	0.929
	Within Groups	19.985	95	0.210		
	Total	20.081	98			
Chloride	Between Groups	0.366	3	0.122	0.459	0.712
	Within Groups	25.290	95	0.266		
	Total	25.657	98			

Appendix F Plots of water quality parameters against identification numbers of cisterns in Hebron – Palestine, 2008.

Figure F-1 Plot of water quality results (PH,Temperature and Nitrate) of different cisterns in Hebron –Palestine,2008.

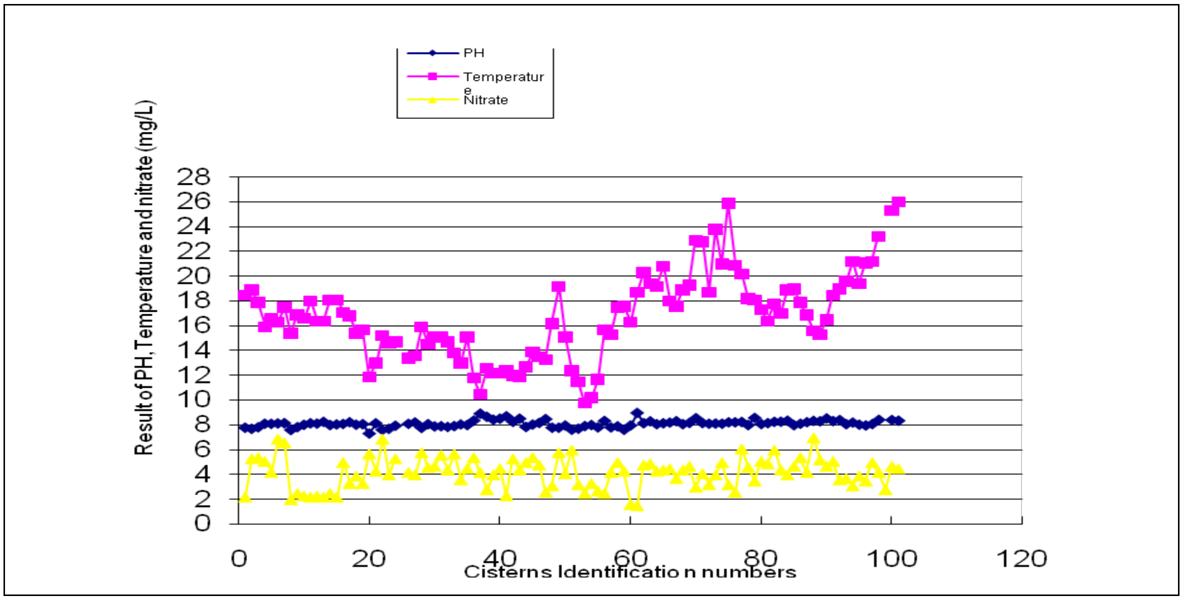


Figure F-2 Plot of water quality results (Calcium,Magnesium and Total Hardness) of different cisterns in Hebron –Palestine,2008.

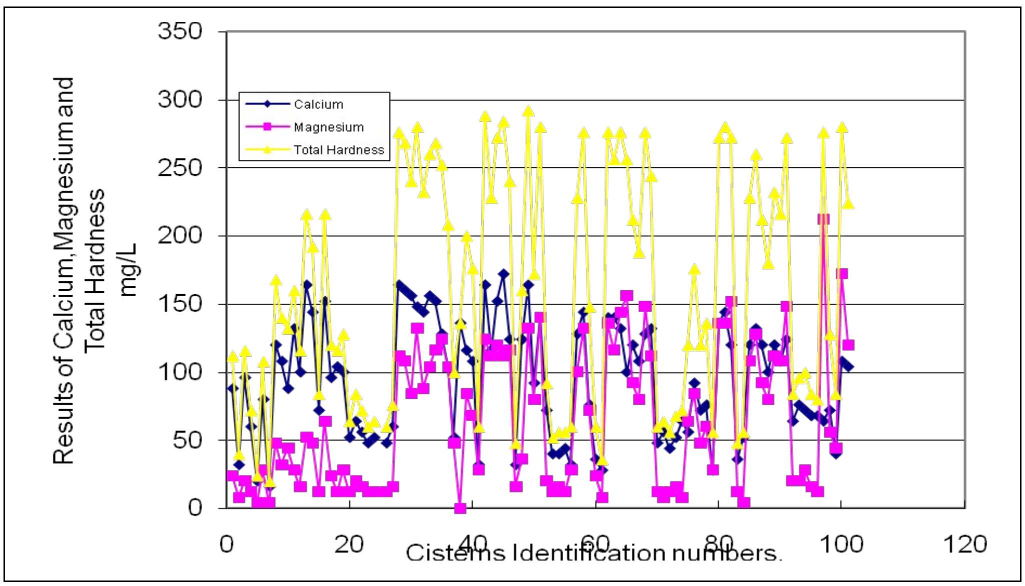


Figure F-3 Plot of water quality results (Alkalinity and Chloride) of different cisterns in Hebron –Palestine,2008.

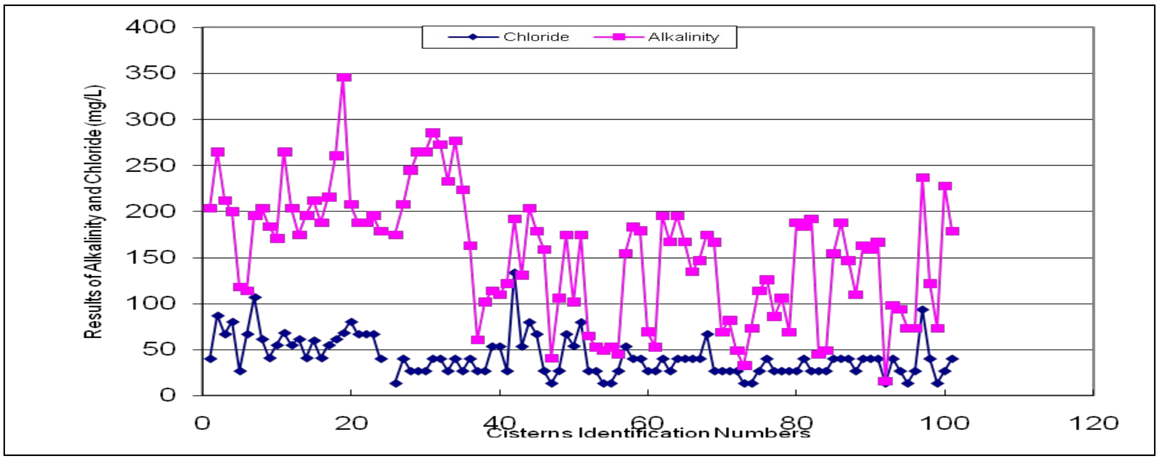


Figure F-4 Plot of water quality results (Electrical Conductivity and Total Dissolved Substances) of different cisterns in Hebron –Palestine,2008.

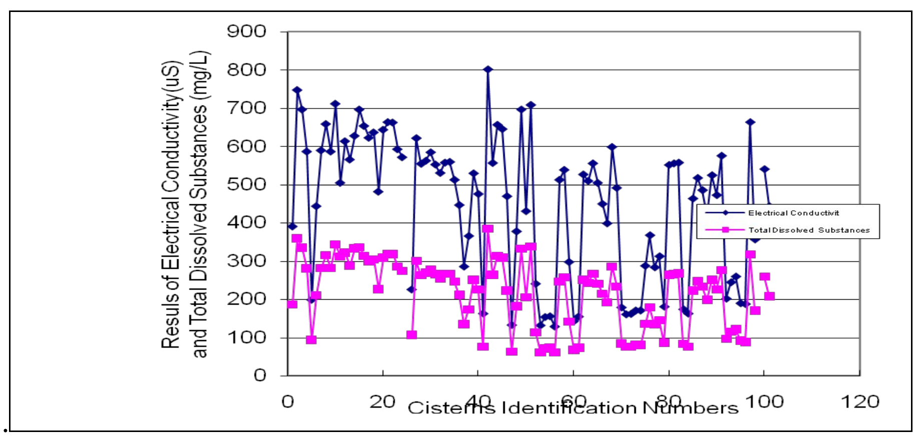


Figure F-5 Plot of water quality results (Total Coliform) of different cisterns in Hebron –Palestine,2008.

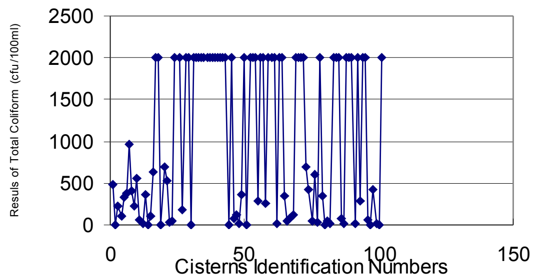


Figure F-6 Plot of water quality results (Faecal Coliform) of different cisterns in Hebron –Palestine,2008.

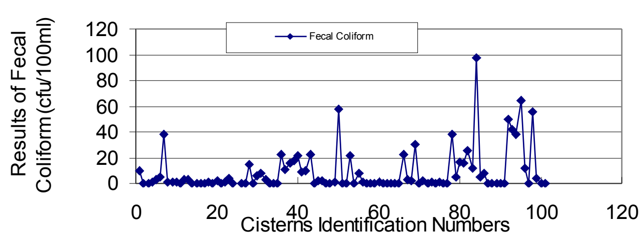
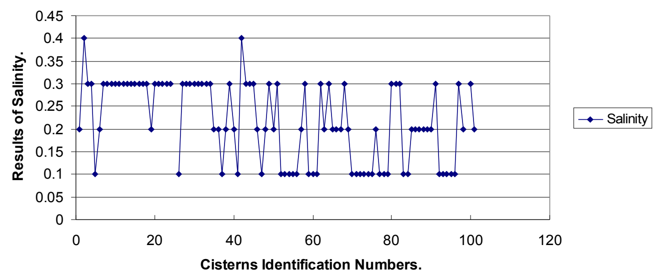


Figure F-7 Plot of water quality results (Salinity) of different cisterns in Hebron –Palestine,2008.



Appendix G: The degree of contamination of sources of cistern's water in general and sources of rainwater with Total and Faecal Coliform.

Figure G-1 Sources of water in cisterns levels of contamination with TC.

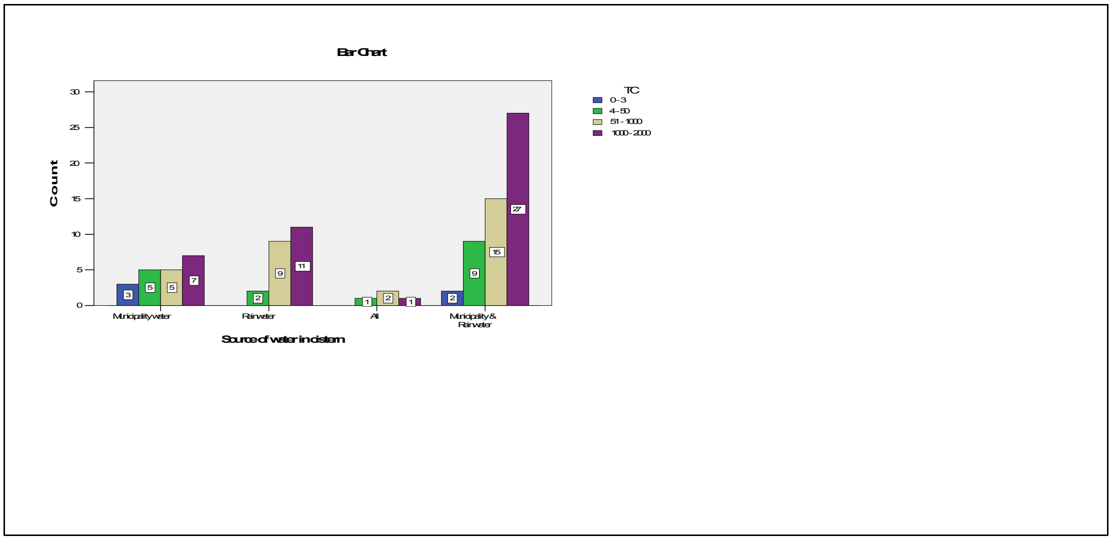


Figure G-2 Sources of water in cisterns levels of contamination with FC.

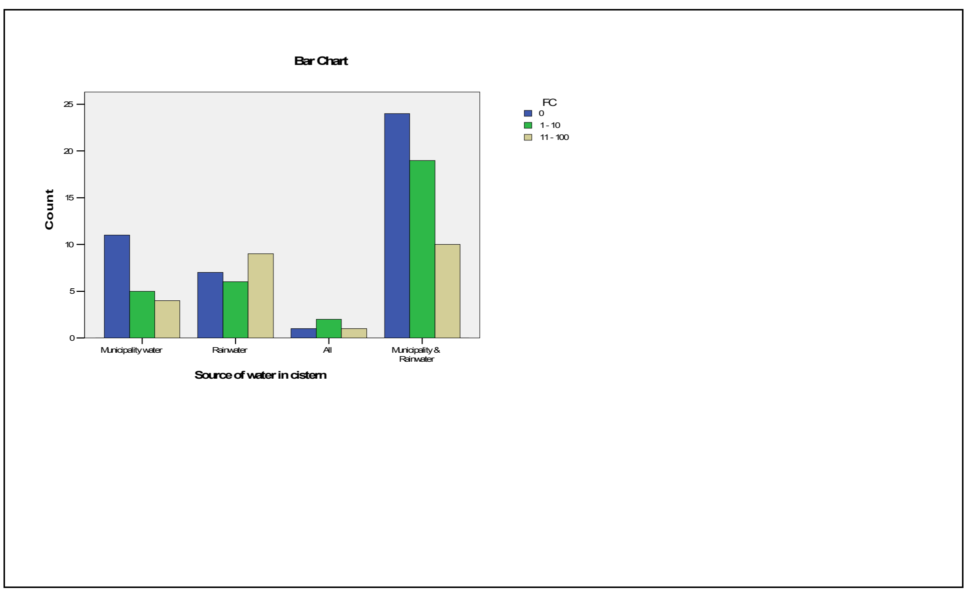


Figure G-3 Sources of rainwater in cisterns levels of contamination with TC.

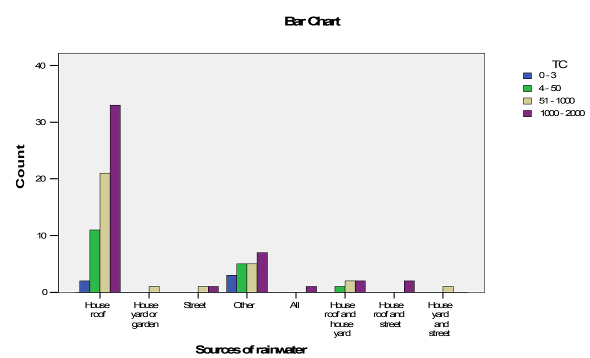


Figure G-4 Sources of rainwater in cisterns levels of contamination with FC.