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Assessing Water Quality of Cisterns in Sha'rawiya Area "Tulkarm Governorate" for Drinking Purposes

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Dedication

This thesis is dedicated with all respect, love and gratitude to:

My **dear father** and my **lovely mother** who always lightened my life with their love and care, and always encouraged and gave me an endless support, may God bless them.

My **beloved sisters** (Lina, Sherin, Alaa', and Doha).

My **beloved brothers** (Samer, Abdelqader, and Yosuf).

My **beloved fiancé** (Tariq)

For their support, love and encouragement.

My **friends** who always wish the best to me.

All people in my life who touch my heart.

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Saja Almur

الإقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Assessing Water Quality of Cisterns in Sha'rawiya Area "Tulkarm Governorate" for Drinking Purposes

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Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

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Date: **التاريخ:** ٣/٣/٢٠١٦

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List of Abbreviations

ºC	Degree Centigrade
ARIJ	Applied Research Institute/ Jerusalem
B.C	Before Christ
CEHI	Caribbean Environmental Health Institute
CFU	Colony Forming Unit
cm	Centimeter
EC	Electric Conductivity
EPA	Environmental Protection Agency
FC	Fecal Coli form
GEMS	Global Environmental Monitoring System
HSE	Health Service Executive
ICP	Inductively Coupled Plasma
Km/hr	Kilometer per Hour
m^3	Cubic Meters
m^3/yr	Cubic Meters per Year
mg/L	Milligram per Litter
mm	Millimeter
MS	Mass Spectrometry
µS	Micro Siemens
NHDES	New Hampshire Department of Environment Services
NTU	Nephelometric Turbidity Unit
PCBS	Palestinian Central Bureau of Statistics
PMD	Palestinian Meteorological Department
PS	Palestinian Standards
PWA	Palestinian Water Authority
RWH	Rainwater Harvesting
TC	Total Coli form
TDS	Total Dissolved Solids
UNEP	United Nations Environment Programme
UNICEF	United Nations Children's Fund
WESI	Water and Environmental Studies Institute
WHO	World Health Organization

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Abstract

This study was undertaken to assess the quality of rainwater harvesting (RWH) cisterns for drinking purposes at Sha'rawiya rural area. Fifty water samples were collected from tested cisterns at 12 rural areas. All samples were analyzed for physiochemical parameters (pH, EC, TDS, alkalinity, hardness, turbidity, Ca^{+2}, Mg^{+2}, K^{+}, Na^{+}, Cl^{-}, NO_3^{-}, SO_4^{-2}, PO_4^{-2}, and HCO_3^{-}), microbial parameters (TC and FC), and some heavy metals (Ag, Al, Ba, Be, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) using standard procedures. The results were compared with Palestinian standards (PS) and world health organization (WHO) standards of drinking water. Among the analyzed samples, all results of tested physiochemical parameters were within acceptable limits of PS and WHO standards except (4%) of NO_3^{-} results, (4%) of turbidity results, (2%) of alkalinity results, (2%) of electric conductivity (EC) results, (2%) of Ca^{+2} results, and (28%) of Mg^{+2} results exceeded the PS and WHO standards. The percentage of contamination with TC and FC was 86%, 80%, respectively. All heavy metals were within PS except the iron (Fe) in which (33%) of results exceeded the permissible limits. Cistern characteristics and sources of contamination were studied by

the distribution of 100 questionnaires along the study area. The highest percentage of contamination sources: (78%) was detected due to the presence of trees around the cistern, and storage of the first storm of rainwater in the cistern. Almost (36%) of contamination was due to withdrawing water manually.

In general, the obtained results of water quality parameters show that some parameters have values higher than standards especially the microbial parameters (TC and FC), this explained the unsuitable use of RWH systems for direct drinking purposes without disinfection processes. This is an indication of contamination hazards and weak drinking water treatment practices in the study area, which in turn have an important effect on human health. Based on total dissolved solids (TDS) as a salinity hazard, the obtained results indicate the possibility to use RWH for irrigation purposes. This study therefore, recommends the responsible authorities to raise public awareness for cistern owners about the best practices to collect and store rainwater, and to take appropriate corrective measures to get high water quality for drinking purposes.

CHAPTER ONE

INTRODUCTION

1.1 Background

Water is the most valuable natural resource on earth, and it is necessary to support and sustain life. While earth is very rich in water that is estimated at about 1400 billion m^3, only 14 billion m^3 is available for human use (UNEP and CEHI, 2009). The quantity of the world's water will continue to decrease as the human population and water consumption have both rapidly increased, which lead to water shortage as a sensitive problem in the world (Worm and Hattum, 2006; UNEP, 2002). Therefore, access to safe and reliable source of water is still a major life priority and fundamental health issue for the entire world (WHO, 2003).

The main sources of water supply that are used in the world to satisfy population needs include surface water, groundwater, and rainwater (alternative water supply source). The common technique used to collect and store rainwater that falls on a catchment area which is directly connected to cistern for future use is called rainwater harvesting (RWH) (Kloss, 2008).

RWH is one of ancient techniques used by Nabateans and other people of the Middle East around 4500 B.C. (Sivanappan, 2006). Today this technique is still used in many countries in response to challenges associated with the provision of clean water supplies for securing water demands, especially the marginal areas which are not served by municipal water supply networks (UNEP and CEHI, 2009). Nevertheless, RWH is a major source for domestic uses in areas that have water networks but still use rainwater as supplementary source (Radaideh et al., 2009).

RWH is considered as the simplest means of water supply to solve the water scarcity problem, traditionally in arid and semi-arid areas as in

Palestine (Al-Salaymeh et al., 2011; Nolde, 2011; Warm and Hattum, 2006).

In Palestine, RWH is one of the feasible options of freshwater supply. In spite of access to the municipal potable water supply, about 32% of local people in Palestine still favor rainwater in getting their drinking, cooking, and agricultural needs (Abusafa et al., 2012).

Adoption of RWH systems has several advantages, such as it promotes water supply, provides safe, clean, and reliable water for drinking purposes, and reduces soil erosion and floods. Moreover, this technique is economically feasible solution especially with rising water cost, and is environmentally sound option (Balasubramanya, 2006; Nodle, 2011; UNEP, 2002).

However, RWH has some disadvantages. For instance, the main disadvantage of this system is the supply is limited by the amount of rainfall and the size of the catchment area and cistern. Cistern can be breeding grounds for mosquitoes when not adequately sealed, and rainwater can be contaminated by air pollution, animal or bird droppings, insects, dirt and organic matter which may result in health risks (UNEP and CEHI, 2009; Warm and Hattum, 2006).

1.2 Problem Statement

Although cisterns in some rural areas are used for drinking purposes, there are some potential sources of contamination, which threaten water quality of such cisterns; among which are:

1. The contaminated surfaces, which is drained into the cisterns (e.g., roofs, yards, etc.).

2. The seepage from cesspits to cistern in some cases where the distance between cistern and cesspit is close.

This situation has compelled the dire need to assess water quality of such cisterns for drinking purposes.

1.3 Research Statement

This research will help to determine the water quality in cistern, by identifying the contamination sources of cisterns, and analyzing the parameters of microbial and physiochemical water quality. That in turn leads to adopt the best practices and measures to collect and store water in cisterns to get high water quality for drinking purposes.

1.4 Research Objectives

This research aims at assessing the quality of water in cisterns in Sha'rawiya area for drinking purposes. In light of the above, the following objectives are achieved:

1. Determine the main contamination sources of cisterns.
2. Identify the cisterns characteristics and conditions, which are in direct relation with cisterns water quality, by distribution of questionnaires among owners.
3. Assess cistern water quality in Sha'rawiya rural areas according to local and international standards.
4. Identify people acceptance for the use of cisterns for drinking purposes.

1.5 Thesis Organization

This thesis is organized as follows: Chapter one provides a brief introduction about the research, problem statement, research statement, and the main objectives. Chapter two provides brief gatherings from the literature include some characteristic about RWH system, brief information about water quality aspect for both physiochemical and microbial parameters, basic components and principal of RWH system, and different related case studies. Chapter three presents the characterization of study area in term of geography and topography, climate, water resources, and population. Chapter four presents the overall research methodology include the questionnaires, water sampling, water quality analysis, and water quality data analysis. Chapter five presents analysis the questionnaires and the obtained laboratory data. Chapter six presents the conclusions and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Rainwater Harvesting Characterization

The rainwater is abundant in the world but it is unevenly distributed, occurs in few months each year to become a common source of fresh water in many regions (Sivanappan, 2006). The rainwater is pure and free from minerals, salts, and human or natural contamination (Al-Salaymeh, 2008). Nevertheless, rainwater can dissolve heavy metals and other pollutants from catchment area and cisterns (WHO,1993).

RWH quality and its impact on human health is an important issue for people who use such water. The quality of this water is affected by environmental and atmospheric pollution, catchment area, collection methods, type of construction material, and human activities (Al-Salaymeh et al., 2011). Therefore, the quality of rainwater is acceptable when water meets the standards (no microbial contamination, no chemical contamination, and no bad taste, smell or color) (Mosely, 2005).

The quantity of rainwater that can be harvested depends on four basic factors: the frequency and intensity of rainfall in the area, the catchment area (e.g. rooftops), the amount of water losses through evaporation and runoff, and the volume of a cistern (González, 2012). In addition to that, leakage (or seepage) from cisterns could be another source of water losses.

2.2 Water Quality Aspects

Clean, safe, and adequate water is essential to survival of all living organisms on the world, basic human right, alleviating poverty, and important to human health. Nevertheless, quality of world's water is still threatened as population grows rapidly, industrial and agricultural activities expand, and climate change threatens to cause a major change of the hydrologic cycle (UNEP, 2010).

Water quality refers to physical, chemical, and biological characteristics of water (Ertuo and Mirza, 2005). A wide range of human activities and natural processes can affect the water quality. Poor water quality can cause risk to human health and ecosystem, reduce the quantity of safe water for drinking and other purposes, and limit the socioeconomic development (UNEP, 2010). Therefore, human consumption of drinking water requires the water free from any source of contamination, and do not contain any potential risk to health over lifetime of consumption (WHO, 2006).

The scientific significance of the physiochemical and microbial parameters, which are in direct relation to water quality evaluation used in this study, is discussed below.

2.2.1 Physiochemical Water Quality Parameters

The health concerns associated with physiochemical components of drinking water have received less attention than microbial contamination, due to the ability of physiochemical components to cause adverse health effects as a consequence of prolonged exposure, unlike the microbial contaminants that can cause immediate health risk. However, the physiochemical quality of drinking water cannot be taken for granted to assess water quality (EPA, 2012; Kwaadsteniet et al., 2013; UNICEF, 2008; WHO, 1993, 2006).

The physiochemical compositions of collected rainwater may be affected by many factors that may occur naturally by rocks or soils, location, and weather conditions, or may occur by human activities such as agriculture, industries, and urban activities (Radaideh et al., 2009).

The common physiochemical parameters that determine the quality of collected rainwater include (pH, total dissolved solids (TDS), hardness, alkalinity, chlorine, and sulfate) these parameters could affect water flavor, while the turbidity could affect the aesthetic characteristics of water (Al-Salaymeh, 2008).

There are thousands of chemicals that can cause health problems in drinking water. Therefore, WHO lists guideline values for nearly 200 chemicals, ranging from naturally occurring arsenic and fluoride to synthetic chemicals result from industrial activities. Nevertheless, only a relatively small number are likely to pose real threats in drinking water (UNICEF, 2008). Assessment of the adequacy of the physiochemical quality of drinking water relies on comparison of the results of water quality analysis with standard values (WHO, 1993).

The following table illustrated all physiochemical parameters which are tested in this study with their health significant.

Table (1. 1)Tested Physiochemical Water Quality Parameters and their Health Significant (EPA, 2001)

Parameters	Health Significant
pH	Affects mucous membrane, bitter taste, and increase corrosion
Electric Conductivity	High conductivity increases corrosive nature of water
Hardness	Poor lathering with soap
Turbidity	Higher level of turbidity is associated with disease causing bacteria's
Nitrate	Effect on Infants below the age of six months Symptoms include shortness of breath and blue-baby syndrome
Chloride	Eye/nose irritation, stomach discomfort. Increase corrosive character of water
Phosphorus	stimulate microbial growth
Alkalinity	High alkaline water may unpalatable to consumers
Sodium	Causes hypertension if taken in excess
Sulfate	Excess sulfate has a laxative effect, especially in combination with magnesium and/or sodium.
Total Dissolved Solids	Undesirable taste, gastrointestinal irritation, and increase corrosion or incrustation

2.2.1.1 pH

The pH is one of the most important water quality parameter, it is a measure of acidity or basicity of water, specifically it is defined as the negative logarithm of the hydrogen ion concentration of a solution (EPA, 2001). The pH is measured on a logarithmic scale of 0 (very acid) to 14 (very alkaline), with 7 being neutral. In addition, pH is affected by temperature (WHO, 1996), rocks and soils, organic acid (from decaying leaves and other sources), and human-induced acid from acid rains (NHDES, 2011).

The pH values of water can provide important information about many physiochemical and biological conditions (Bellingham, 2009; NHDES, 2011), and govern the behavior of several other important parameters of water quality such as ammonia toxicity, chlorine disinfection efficiency, and metal solubility (EPA, 2001). The pH is considered as one of the major factors vital in determining water corrosivity; in general, lower pH gives higher level of corrosion (WHO, 1996).

For rainwater harvesting, pH is affected by the catchment area, and cisterns types and conditions (Awadallah et al., 2011). The pH value suitable for drinking water is preferable to be 6.5-8.5 (EPA, 2001; WHO, 1996).

2.2.1.2 Electrical Conductivity

The electrical conductivity (EC) is the ability of water to conduct an electrical current by the dissolved ions (EPA, 2001), measured in microsiemens per centimeter (mS/cm) (Poe, 2000).

The measurements of EC reflect the amount of total dissolved solids (TDS) and salinity in water. TDS can be obtained by multiplying the EC value by a factor which is usually between 0.55 and 0.75. This factor must be identified for each water body (Bellingham, 2009; WHO, 1996).

The concentration or number of ions, mobility of the ion, oxidation state (valence), and temperature of the water, these factors can determine the degree to which water will carry an electrical current (WHO, 1996).

EC can indicate groundwater seepage or a sewage leak. The values of EC will increase if there is an increase in the concentration of pollutants in water. EC is affected by the presence of inorganic dissolved solids, such as chloride, nitrate, sulfate, and phosphate anions, or sodium, magnesium, calcium, iron, and aluminum cations (UNEP, 2012).

The permissible value of EC for drinking water is 2000 µs/cm (WHO, 2004).

2.2.1.3 Hardness (Calcium and Magnesium)

Hardness is a natural characteristic of water, which is used to express the properties of highly mineralized water, due to the presence of multivalent metal ions usually calcium and magnesium cations expressed as mg/L $CaCO_3$ (EPA, 2001; Esguerra et al., 2011; UNICEF, 2008; WHO, 1993, 2011).

The main natural sources of hardness in water are dissolved polyvalent metallic ions from sedimentary rocks, seepage and runoff from soils (WHO, 2011).

Hard water can be unacceptable to consumers, and requires more soap to produce the lather. The amount of hardness in water affects the amount of soap and detergent necessary for cleaning. Very soft water is undesirable in public supplies because it is more likely to be corrosive in metal pipes, and increases levels of heavy metals such as cadmium, copper, lead and zinc in drinking water, also may be associated with the incidence of heart disease (EPA, 2001; Esguerra et al., 2011; UNICEF, 2008).

2.2.1.4 Turbidity

Turbidity is a measure of water clarity or the amount of suspended particles in water, by measuring the ability of light to pass through water (Bellingham, 2009; Poe, 2000). Algae, suspended materials, sewage solids, clay particles, silt and sand washing, and organic matter particles can cloud the water making it more turbid (EPA, 2001). High turbidity can cause increased water temperature because suspended particles absorb more heat and can prevent light from penetrating the water, accordingly, dissolved oxygen and photosynthesis will be affected (Poe, 2000).

This parameter is very important because it affects both acceptability of water to consumers, and the efficiency of treatment processes (EPA, 2001; WHO, 1997). Turbidity is measured in Nephelometric Turbidity Units (NTUs) (Poe, 2000).

2.2.1.5 Nitrate

Nitrate ion (NO_3^-) is the common form of nitrogen in natural water (Bellingham, 2009). Nitrate in the soil is soluble and readily leached into groundwater and surface water, therefore nitrate leaching must be controlled to protect or improve water quality (Madison and Brunett, 1985; Schepers et al., 1991).

Plant decay, animals' debris, and igneous rock, are natural sources of nitrates in water. On the other hand, a major artificial source of nitrate in water arise from the excessive applications of nitrogen containing fertilizers, leaching of septic tanks, and human waste discharge (Bellingham, 2009; HSE-EPA, 2010; WHO, 1993).

High level of nitrate in water may cause hypertension, increased infant mortality, central nervous system birth defects, stomach cancer, reproductive or development effects, congenital malformations, and methemoglobinemia or blue baby syndrome (Bourne, 2001; Fedkiw, 1991; Kross et al., 1993; Spalding and Exner, 1993; Weigman and Kroehler, 1990).

Nitrate pollution will cause eutrophication in water where algae and other plankton growth and consume the oxygen, eutrophication is usually the result of nitrate and phosphate contamination and is a significant reduction of water quality (Bellingham, 2009).

According to international and local guidelines, nitrates should remain below 10 mg/L (as NO_3 - N) in water to be used as a drinking water supply.

2.2.1.6 Chloride

Chloride (Cl^-) occurs in all natural waters in widely varying concentration. Chloride gains access to drinking water in many ways from natural and anthropogenic sources, such as sewage and industrial influent, urban runoff containing de-icing salt, saline intrusion, landfill leachates, leaches from weathering of rocks, and animal feeds (WHO, 1996, 2006). Treatment processes in which chlorine or chloride is used may considerably increase chloride in water (WHO, 1996).

Chloride in reasonable concentration is not harmful to humans. Nevertheless, chloride concentration more than 250 mg/L gives salty taste to water, which is objectionable to many people. Moreover, increases rates of corrosion of metals in the distribution system, depending on the alkalinity of the water (WHO, 2006).

2.2.1.7 Phosphorus

Phosphorus is one of the nutrients that are essential to plants and animals. Phosphorus is present in natural waters primarily as phosphates, which can be separated into inorganic and organic phosphates, Phosphorus in water is usually measured as total phosphorus, total dissolved phosphorus, and soluble reactive or orthophosphorus (UN GEMS, 2006).

Under natural conditions phosphorus is typically scarce in water, but the human activities, have resulted in excessive loading of phosphorus into many freshwater systems that are usually known as limiting nutrient. This can cause water pollution by promoting excessive algae growth and chlorophyll levels, which can decrease oxygen levels and make water unattractive. This case is defined as eutrophication phenomenon (MPCA, 2007; NHDES, 2011).

Phosphorus can indicate the presence of pollution from many sources such as septic systems, sewage, animal waste, fertilizer, and soil erosion (NHDES, 2011). Phosphorous can enter a water system from the natural weathering of minerals and rocks, atmospheric deposition, and as runoff from agricultural areas (Bellingham, 2009; UN GEMS, 2006).

Phosphorus parameter may be chosen over phosphates because in most water systems, the total phosphorus concentration correlates well to other water quality parameters particularly algae growth and chlorophyll (Bellingham, 2009).

2.2.1.8 Alkalinity

Alkalinity is a chemical measurement the ability of water to neutralize acids. Alkalinity is also measures the buffering capacity of water or its ability to resist changes in pH upon the addition of acids or bases (EPA, 2001).

"Alkalinity in most natural waters is due to the presence of carbonate (CO_3^-), bicarbonate (HCO_3^-), and hydroxyl (OH^-) anions. However, borates, phosphates, silicates, and other bases also contribute to alkalinity if present" (EPA, 2006). This property is important when determining the suitability of water for irrigation and when interpreting and controlling wastewater treatment processes. Alkalinity can be affected by rocks, soils, salts, plant activities, and wastewater discharges (EPA, 2006). Alkalinity is usually reported as equivalents of calcium carbonate ($CaCO_3$). Drinking water alkalinity values should remain below 400 mg/L $CaCO_3$ (EPA, 2006).

2.2.1.9 Heavy Metals

Heavy metals are sometimes called trace elements (Salem et al., 2000), which are individual metals and metal compounds that resulting threat to human health.

There are over 50 elements that can be classified as heavy metals, 17 of which are considered very toxic and can cause damaging effects even at low concentration (Mohod and Dhote, 2013). Heavy metals in water occur only in trace levels but are more toxic to the human body. They enter water by natural and anthropogenic sources, such as weathering or rocks and minerals, industrial discharge, sewage effluents, and soil erosion (Morais et al., 2012).

Heavy metals in drinking water related to human poisoning are lead (Pb), iron (Fe), cadmium (Cd), copper (Cu), zinc (Zn), chromium (Cr), etc. (Mohod and Dhote, 2013). The human body needs these elements in small amounts, but they can be toxic in excess doses (Mohod and Dhote, 2013).

2.2.2 Microbial Water Quality Parameters

WHO considers most serious public health risk related with drinking water supplies is microbial contamination (WHO, 2004). Microbial water quality may vary rapidly and widely (WHO, 1993). Low-level concentration of pathogen (disease-causing microorganisms) may increase disease risks significantly and may cause outbreaks of waterborne diseases. Results of water quality testing for microbes are not normally available on time to inform management action and prevent the supply of unsafe water (WHO, 1993).

Most of the microbes will be harmless, but the safety of water will depend on reducing the presence of pathogenic bacteria, viruses, protozoa, and helminthes that can cause many health problems (UNICEF, 2008). These pathogens are introduced into water by untreated wastewater, leaching of manure, storm water runoff, and domestic or wildlife animal's feces (WHO, 2012).

The persistence of most pathogens in water is affected by various factors such as sunlight and temperature (WHO, 2006, 2011).

Rainwater collected and stored in cisterns may contain high levels of microbes from one or more sources, like atmospheric deposition, and pollution from activities of insects, birds, and some mammals (Al-Salaymeh, 2008).

The microbial tests give significant information about the catchment area, cistern design and construction, the efficiency of treatment process, indicate fecal contamination, and reflect the degree of pathogenic risk (Amin and Han, 2011; WHO 1996, 1997).

In this study total coliform bacteria and fecal coliform bacteria is measured to assess the microbial water quality.

2.2.2.1 Indicator Organisms

Testing for all possible pathogens to assess water quality for drinking purposes is complex, impractical, time-consuming, and expensive. For these reasons, indicator organisms are used for monitoring the presence of pathogenic organisms in drinking water that are hard to detect and to measure change in water quality (Kwaaelsteniet et al., 2013; UNEP, 2000).

The best indicator organism should correlate with health hazards associated with one or several given types of pollution sources (APHA et al., 1998), the requirements for a real indicator organism are as follows (Cabelli, 1977; UNICEF, 2008; WHO, 2006):

1. The organism must be exclusively of fecal origin and consistently present in fresh fecal waste.
2. The organism must occur in greater numbers than the associated pathogen, to provide an accurate density estimate.

3. The organism must not proliferate in the environment (water).
4. The organism must be resistant to disinfectants and environmental stresses.
5. The organism persists for a greater length of time than the pathogen.
6. Reliable, and inexpensive methods should exist for the detection, enumeration, and identification of the indicator organism.

Because the methods are not available to culture or count all pathogenic organisms that might be present in water, indicator bacteria (coliform bacteria) are usually chosen as an indicator. While viruses and protozoa are not used as indicators because of difficulties of in isolating them and detecting their presence in water (UNEP, 2000).

Indicator bacteria are present in the environment and feces of all warm-blooded animals and humans. These bacteria are usually harmless, more plentiful, and easier to detect pathogens (Wilhelm and Maluk, 1998).

Bacterial pollution can result from runoff from feedlots and pastures, septic tanks and sewage plants, waste of animals and wild birds, excessive use of manure and fertilizers (Wilhelm and Maluk, 1998).

Tests used to indicate the presence of pathogenic organisms include those for total coliforms (TC), fecal coliforms (FC), or Escherichia coli (*E. coli*) specifically. Nevertheless, the organisms most often used are fecal indicators. If testing detects coliform bacteria in a water sample, the source of contamination must be identified and restore safe drinking water (UN GEMS, 2006).

2.2.2.2 Total Coliform Bacteria

Total coliform (TC) is a group of bacteria that include a wide range of aerobic and facultative anaerobic, Gram-negative, non-spore-forming bacilli (WHO, 1997, 2004, 2006). These bacteria are 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 hours at 35–37˚C (WHO, 1997, 2004, 2006). TC are commonly found in environments such as soil and vegetation, as well as the intestines of mammals (WHO, 1997, 2004, 2006). TC are not likely to cause illness, and should be absent immediately after disinfection. Nevertheless, their presence indicates the possible presence of pathogenic bacteria, which in turn indicates inadequate treatment, and assesses the safety of distribution systems (WHO, 1997, 2004, 2006).

In some cases, pathogenic microbes can result in potentially serious illness and possibly death (WHO, 1997, 2004, 2006). To reduce the probability of being exposed to waterborne pathogenic bacteria the drinking water standard for total coliform is set at zero CFU/100 mL (WHO, 1997, 2004, 2006).

2.2.2.3 Fecal Coliform Bacteria

Fecal coliform (FC) is a subset of total coliform bacteria that are able to grow at 44.5 °C, and naturally found in the intestines of all endothermic animals and humans. They have a relatively short life span compared to other coliform bacteria (NHDES, 2010; WHO, 1997). Their presence is an indicator of contamination of sewage waste (NHDES, 2010; WHO, 1997).

The most specific indicator of fecal contamination is *E. coli* which is a subset of the total coliform group that can ferment lactose at higher temperatures (WHO, 2006). This is a species within the fecal coliform group, which originates only in the intestines of animals and humans (WHO, 2006). As with other fecal coliform, they have a relatively short life span compared to non-fecal coliform bacteria (WHO, 2006). Their presence indicates a strong likelihood that human or animal wastes are entering the water system (WHO, 2006). The WHO drinking water guidelines recommend zero E. coli or fecal coliform forming units (CFU's) per 100mL for all drinking water supplies (WHO, 2004).

2.3 Basic Components and Principles of RWH System

All RWH systems comprise of components for transporting rainwater through pipes or drains that are fixed at the edge of sloping roofs for storage of harvested water in cisterns (UNEP, 2012). The common components of RWH system are a collection system (catchment area), and a storage system (cistern) (Worm and Hattum, 2006).

The catchment area of a RWH system is defined as the surface that directly receives rainfall and diverts it to cisterns (Patil and Patil, 2006; Sharma, 2010).

The practice of collecting rainwater can be classified in to two categories: land-based and roof-based. Land-based RWH occurs when runoff from land surface is collected in cisterns. Roof-based RWH refers to collecting rainwater runoff from rooftops that collect rainwater of good quality for drinking purposes rather than other practices (Al-Salaymeh et al., 2011; Nolde, 2011).

RWH system can be categorized according to size, nature of catchment area, and location (urban versus rural) (UNEP, 2012).

The rooftop of a RWH system is the main catchment area at houses level that is commonly used for domestic purposes as the water source is close to people, requires a minimum energy and cost to collect, and easily to control and maintain (Dhoble and Bhole, 2006). The amount and quality of harvested rainwater in this system depends upon the rooftop area, intensity of rainfall, and type of roofing material (Dhoble and Bhole, 2006). Gould and Petersen-Nissen (1999), showed that the best roof-based RWH system has been done by using a rooftop made of material that allows for the water flow quickly and efficiently without any sticking to the rooftop.

The rooftop is considered as one of the determinants of the rainwater quality and source of the contamination, which occur when rainwater falls on a contaminated catchment and mix with dirt, debris, or bird dropping. To reduce the contamination degree, the first amount of rainfalls after a dry period should be diverted away from a cistern (Crowley, 2005). In addition, the materials used for building rooftop should be acceptable for use in direct contact with rainwater (suitable for drinking purposes), non-toxic to human, and should not leach contaminants or cause unacceptable taste or odor, and discoloration (WHO, 2006).

There are many factors to be taken into consideration for RWH practices (Bisoyi, 2006):

- Location and topography of the area – whether arid and semi-arid area, drought and flood area, or urban and rural area.
- Rainfall pattern – whether rainfall is distributed uniformly through the year, or intermittent.
- Intensity of rainfall.
- Soil characteristics – whether the soil is impermeable or permeable.

2.4 Cistern Design and Characterization

Not all RWH cisterns are well-designed, poorly built cisterns cause poor water quality that may pose a risk to human health. Design and application of RWH system from the catchment surfaces and cisterns to the suppliers will support the rainwater quality with very low contaminants level (WHO, 2006). There are three main characteristics to determine the cost and performance of a cistern: cistern size, location, and construction material.

A cistern must be designed to store a sufficient amount of rainwater to meet people's needs, that can be achieved by determining the size of the cistern correctly. The correct sizing of a cistern is critical in order to ensure that the owners have a sufficient storage capacity to hold enough water at minimum construction costs (Worm and Hattum, 2006). Thus, there are parameters to be considered in the determination of the size of the cistern. The criterion includes: the total quantity of rainfall available for use (supply), the catchment area available for collecting rainfall, the daily rainwater requirements (demand), and economics (Young and Sharpe, 1984).

The location of a cistern should be near the site where the water will be used, but away from any septic tanks or any sewage disposal facilities to avoid the contamination of water in the cistern (Young and Sharpe, 1984).

The cisterns can be constructed from many types of materials. The material for the cistern walls must be able to resist the soil and soil water pressure from outside when cistern is empty (Worm and Hattum, 2006). The choice of materials depends on its local availability, cost, and ability to resist soil and water pressures (Worm and Hattum, 2006). For instance, the reinforced concrete material is the best because of their ability to decrease corrosiveness of rainwater (Al-Salaymeh, 2008; Young and Sharpe, 1984).

The requirements that should be achieved in the cistern design (Al-Salaymeh, 2008; Worm and Hattum, 2006): protect the water quality (safe and non-toxic storage material), easy to clean, proper cover and ventilation to avoid mosquito breeding, sufficient structural strength, and must be away from direct sun to inhibit algae growth.

2.5 Previous Studies

There are many researches and studies, which have been done to study the water quality in cisterns, some of these studies are presented below:

Abusafa et al. (2012) studied the utilization and contamination risk of drinking water from rainwater-harvesting cisterns in the Palestinian Territories. Their objectives were to evaluate the water quality and contamination risk in RWH cisterns in northern West Bank region. In this study, 106 cisterns were sampled, and 176 cisterns owner were surveyed. The resulted data indicate that the nitrate concentration and TDS reading was acceptable to Palestinian standards, but most the cisterns contained fecal coliform above 8000 CFU/mL, and also the cisterns owner responses indicated that the contamination risk resulted from mismanagement and wrong practices.

Achadu et al. (2013) studied the assessment of stored harvested rainwater quality and impact of storage media in Wukari, North-Eastern Nigeria. Their objectives were to monitor the quality of stored rainwater in cisterns, tanks and reservoirs receiving rainwater in Wukari, to assess its suitability for potable and domestic uses. Other objective to evaluate the quality of rainwater collected and stored in different storage media to make sure their impacts on harvested rainwater quality. In this study physicochemical and microbiological analyses of the samples were carried out using standard methods, some of these parameters included pH, TDS, EC, acidity, trace and heavy metals. The study showed that all stored rainwater samples tested positive for fecal coliform were excess the WHO standards for drinking water, while the trace and heavy metals in the water samples were within the WHO standards except for copper and iron levels in metal tanks. Also this study indicated that the plastic tank and cistern constructed concrete tanks are the most suitable storage media. In addition, the harvested rainwater may not suitable for direct drinking, without treatment, but could be used for other purposes.

Amin and Han (2011) studied the microbial quality variation within a rainwater storage tank and the effects of first flush in rainwater harvesting system. The main objectives of this study were to monitor the microbial quality variation within couple of cisterns and the effects first flush removal on microbial quality of rainwater. The selected sample were collected from cisterns before and after treatment were analyzed for TC, FC, Escherichia coli, and Heterotrophic plate count, additionally some physicochemical parameters were also examined. Results showed that first flush of rainwater was highly contaminated which was contributing towards microbial contamination of stored rainwater, these result indicate that the collected rainwater from rooftop catchment after removal of first amount of rainfall is suitable for drinking purposes with very little treatment.

Barnes (2009) studied the assessment of rainwater harvesting in Northern Ghana. His objective was to assesses the current state of rainwater harvesting in the Northern Region of Ghana and makes recommendations regarding if and how rainwater harvesting could be used to address pure home water's goal of reaching 1 million people in the next five years with safe drinking water. In this study, three principal aspects of the water supply were considered: quality, quantity, and cost. Bacteriological water quality was tested to determine the level of risk. The rainwater supplies showed improved bacteriological quality over alternative sources, including dugout water and even piped water, which ranged from low (1 to 10 E. coli CFU/100mL) to intermediate risk (10 to 99 E. coli CFU/100mL), while other water sources showed a higher level of mean contamination. Unit cost per cubic meter was calculated for surveyed rainwater harvesting systems in Northern Ghana. The unit cost of water from these designs ranged between approximately $\$1/m^3$ and $\$10/m^3$.

Radaideh et al. (2009) studied the assessment of harvested rainwater quality for domestic uses, Jordan. Their objectives were to evaluate the quality of rainwater collected and stored in the cisterns of four governorates in northern Jordan. The ninety samples of harvested rainwater were collected and analyzed for chemical parameters (pH, alkalinity, Hardness, Turbidity, TDS, chemical oxygen demand (COD), NO_3^-, NH_4^+, PO_4^{-2}, Pb, Fe, and Cr) and microbial parameters (TC, FC, and *E. coli*). Results indicate that water quality in these cisterns varies depending on location, catchment area, and the availability of public sewer system. It was concluded that collected rainwater is unsuitable for drinking purposes while it could be used for irrigation within houses.

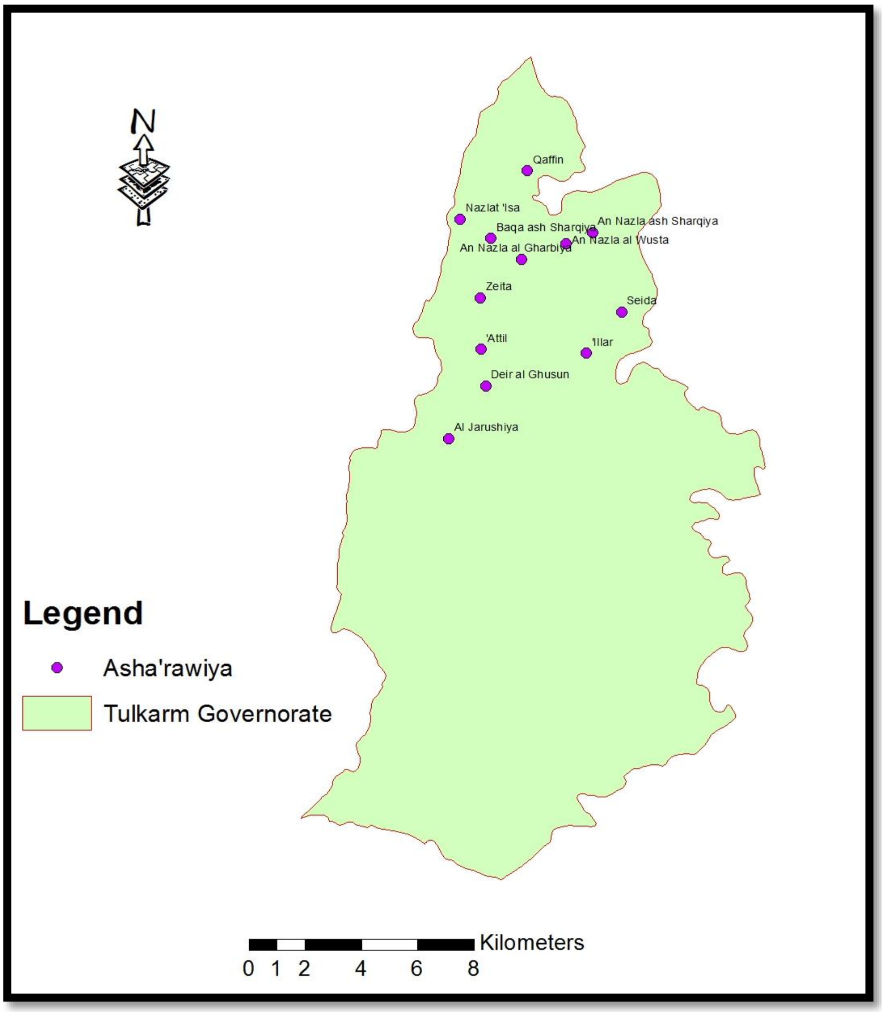
Al-Salaymeh (2008) studied the assessment of drinking water quality of cisterns in Hebron city, Palestine. His objectives were to identify the water quality of 100 cisterns in the city for drinking purposes, by testing physical, chemical, and microbiological parameters. In addition, the study was subjected to determine the sources of pollution of these cisterns by using a questionnaire. The assessment results showed that all physical parameters (EC, salinity, TDS, pH, temperature and turbidity) were within acceptable limits of WHO, EPA, and PS of drinking water, except turbidity. The percentage of contamination of TC and FC were 95% and \ 57% respectively. The chemical parameters exceed the standards by different percentages (e.g., calcium 47%, magnesium 32%); other parameters were within the limit.

CHAPTER THREE

STUDY AREA

3.1 Geography and Topography

Sha'rawiya rural area is part of Tulkarm governorate, which is located in the eastern part of the coastal plain of Palestine at the confluence of latitude 32.19 north and longitude 35.01 east (PMD, 2011). Sha'rawiya includes Al-Jarushiya, Attil, Baqa Ash-Sharqiya, Deir Al-Ghusun, Illar, Nazla Al-Gharbiya, Nazlet Isa, Nazla Wusta, Nazla Al-Sharqeyiaa, Qaffin, Seida, and Zeita, as shown in Figure 1**.** The nearest village to Tulkarm city is Al-Jarushiya at a distance of 5 Kilometers, Qaffin is considered as the farthest one at a distance of 23 Kilometers. The total area of these rural areas was estimated at 86.1 km^2 (PCBS, 2007).



Figure(2. 1): A Map of Sha'rawiya Area

Topographically, these rural areas lie on the western slopes of the West Bank, which are characterized by gentle slopes and have average ground surface elevation at about 350 meters above mean sea level (ARIJ, 1996). Also there are many agricultural plains surrounding these rural areas that have abundant production. These areas are mainly cultivated with fruit trees, vegetables, and field crops.

3.2 Climate

The climate of the study area is a semi-arid, characterized by cold wet winter from October to May, and moderately dry hot summer from June to September (PWA, 2011).

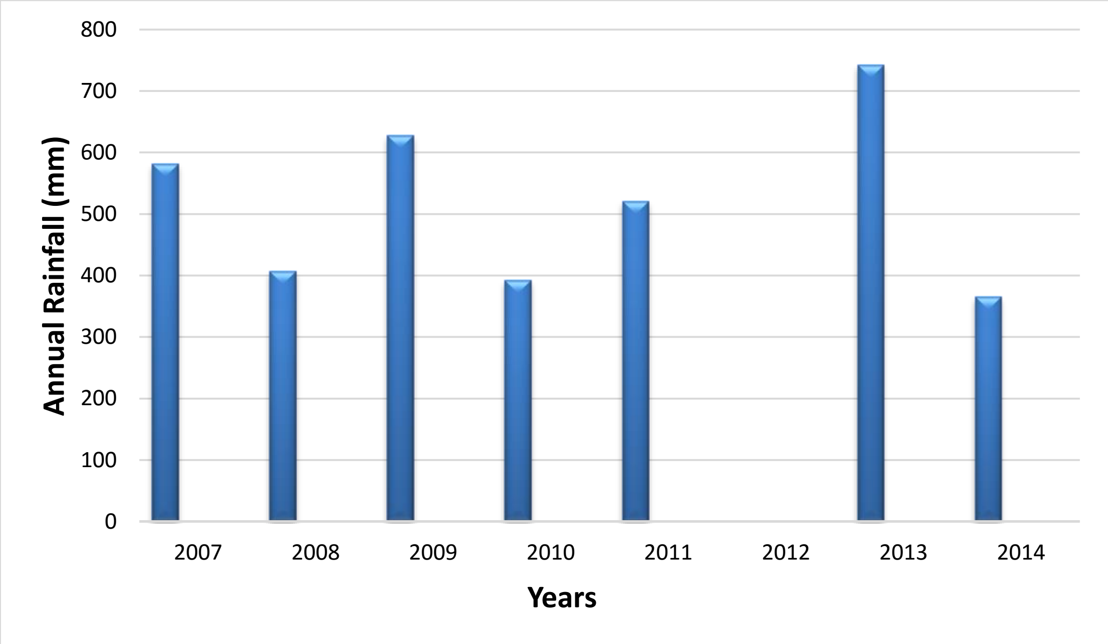
The average temperature ranges between (8-16˚C) in winter and between (17-30˚C) during the summer (PMD, 2011). The coldest month of the year is January with an average minimum temperature of about (8˚C), while August is the warmest month of the year with an average maximum temperature of about (29˚C) (PMD, 2011). The annual average relative humidity in these rural areas ranges between (50%-70%) (PMD, 2011).

Winds prevailing in these rural areas are southwestern and southeastern wind with mean annual speed of 3.4 km/hr (PMD, 2011). In addition, these rural areas are exposed to hot dry Khamsin, which is saturated with dust and sand during the spring and summer seasons (ARIJ, 1996).

The rainy season in these rural areas usually starts in October and continues through May. In winter (December - February) almost 70% of annual rainfall occurs, while 30% of annual rainfall occurs in the fall (September - November). December and January are normally the wettest months.

Rainfall in June and September is rare and comes to negligible amounts. July and August have no rain at all (ARIJ, 1996).

The spatial rainfall variation is uneven, and these rural areas receive different amounts of rainfall (PWA, 2011). Annual rainfall in these rural areas ranges between 500 and 600 mm (PCBS, 2007). Figure 2 shows the average annual rainfall of Tulkarm station for the period of (2007 – 2014) (PCBS, 2014).



Figure(2. 2): Annual Rainfall of Tulkarm Station (PCBS, 2014)

3.3 Water Resources

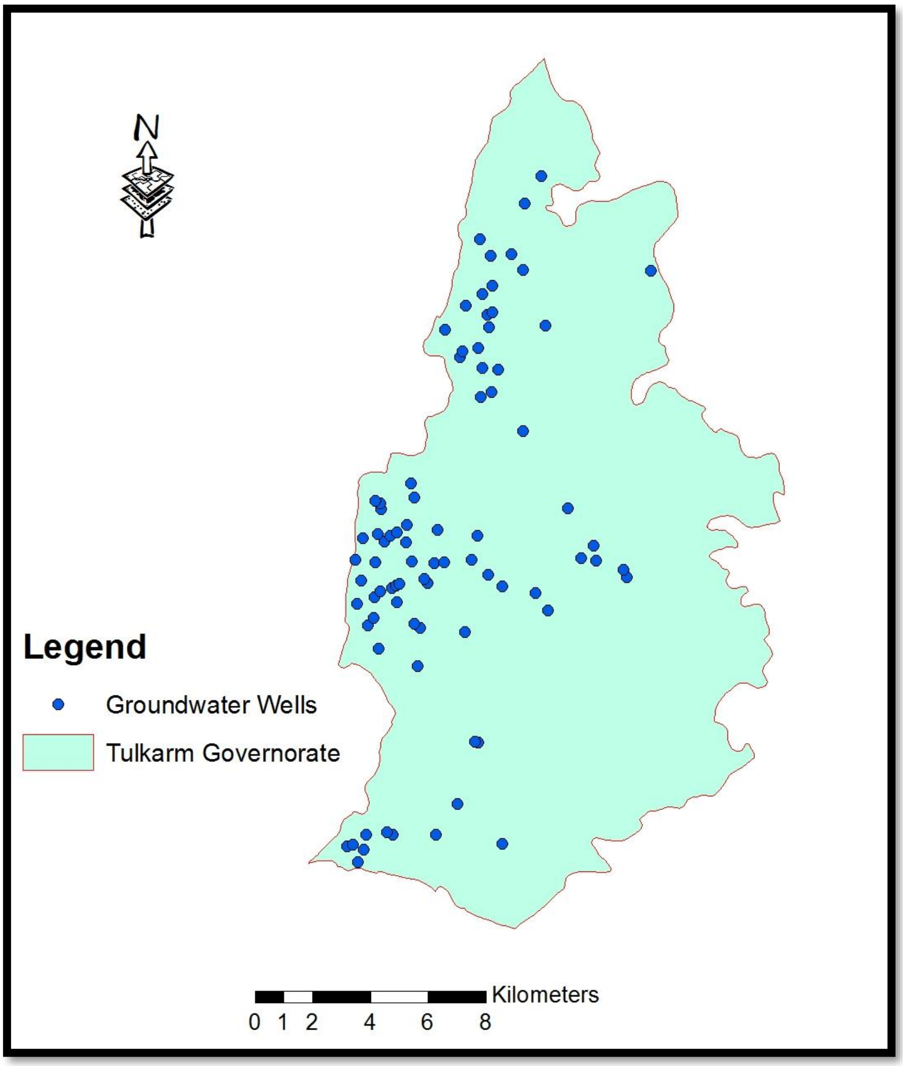
The West Bank has three principal groundwater aquifers: Western aquifer basin, Northeastern aquifer basin, and Eastern aquifer basin. These aquifers providing more than 90% of fresh water supply for various purposes (PWA, 2011). The total annual replenishable water in these aquifers is estimated at 700 million m^3 (ARIJ, 1996).

The Sha'rawiya area is located above the Western aquifer basin, where the total annual recharge is estimated at about 362-400 million m^3 (PWA, 2011). From which only 25 million m^3 are being used by Palestinians while the remaining (340-430 million m^3) are unfairly controlled and used by Israelis (PWA, 2011). In Sha'rawiya area, groundwater wells are the major source of water for both domestic and agricultural uses. In addition to the rainwater harvesting as a supplementary source. There are about 19 groundwater wells in the study area, which are distributed as presented in Table 2 (B. Khader, Personal communication, 2 August, 2015).

Table(2. 1): Distribution of Wells in the Study Area Until 2015

Community	**Attil**	**Nazlet Isa**	**Nazla AlSharqiya**	**Nazla Al Gharbiya**	**Deir Al-Ghusun**	**Qaffin**	**Illar**	**Baqa Ash Sharqiya**	**Zieta**
Number of wells	5	1	1	1	1	1	4	3	2
Discharge (m^3/yr)	260	90	70	130	100	N. A	340	450	200

Figure 3 shows the location of wells in Tulkarm Governorate, where the study area is located.



Figure(2. 3): Location of wells in Tulkarm Governorate

The study area is totally served by water distribution networks. Furthermore, the majority of the area lacks wastewater collection system as such, cesspits are being used for wastewater disposal in the area, which threaten the groundwater quality in the area (PWA, 2011).

3.4 Population

According to the PCBS (2007), the population, area, and total number of households in the Sha'rawiya rural areas are estimated as presented in Table3.

Table(2. 2): Population, area, and households of Sha'rawiya Area (PCBS, 2007)

Rural Areas	Area (km^2)	Population	No. of Households
Al-Jarushiya	2	932	183
Attil	13	9038	1720
Baqa Ash Sharqiya	4.2	4101	762
Deir Al-Ghusun	13	8242	1578
Illar	18.5	6190	1142
Nazla AlGharbiya	2.3	937	156
Nazlet Isa	4.2	2334	440
Nazla AlWusta	1.5	340	74
Nazla Al-Sharqiyaa	5	1514	277
Qaffin	10	8387	1587
Seida	6	2929	568
Zieta	6.4	2852	560

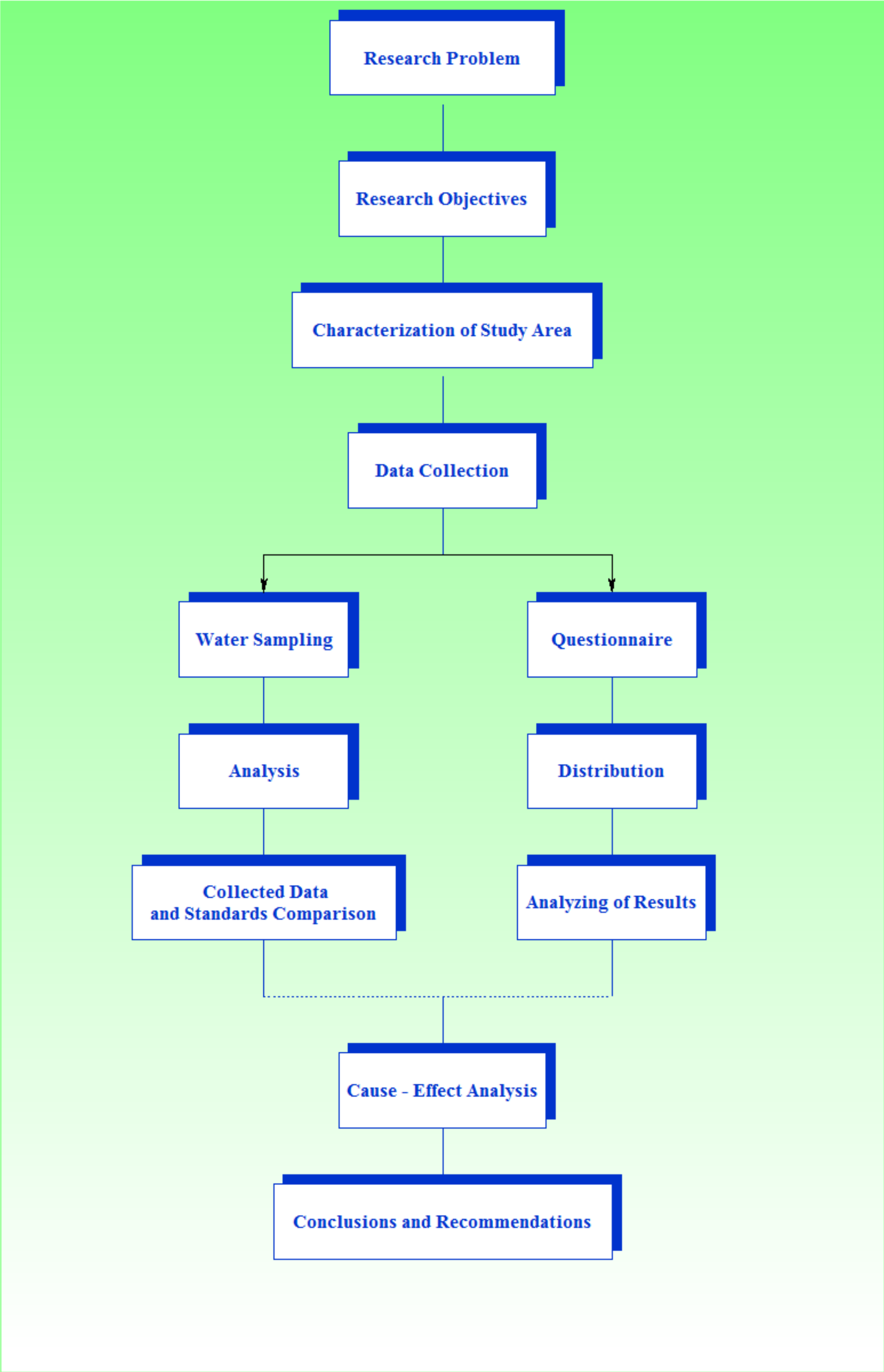
The per capita average water supply in Tulkarm Governorate was about 76 Litter/capita/day (l/c/d) (these amount doesn’t meet WHO standards, 100 l/c/d) and an average consumption rate of 46 l/c/d (PWA, 2010). The current total domestic water needs are estimated at approximately 9 million m^3 more than the currently available quantities (approximately 5 million m^3) (PWA, 2010). This shows a clear annual water deficit of about 4 million m^3 per year (PWA, 2010). To bridge the supply demand gap, the local communities are being use RWH system to satisfy their daily needs in an economically feasible solution.

CHAPTER FOUR

METHODOLOGY

4.1 Introduction

To achieve the research objectives of this study, initially the research problem and objectives were identified. Characterization of the study area included geography and topography, climate, water resources, and water resources. Data collection in this study was conducted by distributing questionnaires among the residents and by water sampling form cisterns. The collected data by questionnaires were analyzed using MS-Excel software. The collected water samples were analyzed at the Water and Environmental Studies Institute (WESI) of An-Najah National University, and the resulted data was compared with local and international standards. Finally, some conclusions and recommendations were identified. The overall methodology followed in this study is summarized in Figure 4.



Figure(3. 1): Overall Research Methodology

4.2 The Questionnaires

The questionnaire was designed to contain appropriate questions to get useful information that help to achieve some of the study objectives.

One hundred semi structured questionnaires were distributed among the residents in Sha'rawiya rural area, fifty of these questionnaires were distributed to a representative sample of houses from which water samples from cisterns were collected, while the rest were distributed randomly. The size of questionnaires was estimated according to the number of population at each rural area in the study area.

The questionnaire consisted of five parts:

1. The first part included socio-demographic data through questions about age, educational, and marital status of respondents.
2. The second part included questions about water supply system, and wastewater disposal system in the study area.
3. The third part included questions about the type of RWH system used in the house at the study area.
4. The fourth part is about characteristics and conditions of cisterns in terms of age, source of water, water quality, surrounding environment, sanitation practices, and disinfection methods and frequency.
5. The fifth part contained questions about knowledge of people in the study area on possible contamination sources of water in cistern and their practices to maintain good water quality.

The main types of questions were the Yes/No questions, and the multiple-choice questions. Cistern owners answered the questions in the questionnaire, then the data were collected and analyzed using the Ms-Excel.

4.3 Water Sampling

Due to budget analysis limitation only fifty water samples were collected in this study. These sample were collected randomly from only 50 cisterns at visited sites of 12 rural areas in Sha'rawiya rural area during the period from May 2, 2015 until June 2, 2015. Samples were collected either manually or mechanically by using electric pump and stored in both sterile plastic bottles with a secure cap for microbial analysis (with a volume of 0.5 Liter) and clean plastic bottles for physiochemical analysis (with a volume of 1.5 Liter). Each bottle was labeled by the same number given to the corresponding questionnaire. The collected samples kept at low temperatures (4˚C) at night and then transported to the laboratories of WESI of An-Najah National University for analysis within 24 hours after collection.

4.4 Sample Size Determination

The number of samples from each rural area of Sha'rawiya area was estimated according to the population number in that area as presented in Table 4.

Table(3. 1):Number of Samples from each Site at Sha'rawiya Area

Rural Areas	No. of Samples
Al-Jarushiya	1
Attil	9
Baqa Ash Sharqiya	5
Deir Al-Ghusun	9
Illar	6
Nazla Al-Gharbiya	1
Nazlet Isa	3
Nazla Al-Wusta	1
Nazla Al-Sharqiyaa	2
Qaffin	7
Seida	3
Zieta	3
Total	**50**

4.5 Water Quality Analysis

The collected water samples were tested for physiochemical and microbial parameters. The laboratory analyses included measurement of physiochemical water quality (pH, TDS, Hardness, Calcium, Magnesium, Nitrate, Sulfate, Chloride, Sodium, Bicarbonates, Phosphate, turbidity, Carbonate, Electrical Conductivity, and Heavy Metals) and the indicator organism concentrations (Fecal Coliform and Total Coliform).

The equipment used for testing parameters are pH-meter, Electrical Conductivity meter, Spectrophotometer, Nitrate-meter (colorimeter), Flame photometer, turbidimeter, and ICP-MS for heavy metal.

The testing procedures for physiophysiochemical and microbiological methods are summarized in Table 5.

Table(3. 2): Laboratory Methods for Testing Physiochemical and Microbial Parameters (Greenberg et al., 1992)

Test	Method Name	Method Principle
Chloride (Cl^-)	Argenometric method	Titration with standard $AgNO_3$ and K_2CrO_4
Calcium (Ca^{+2})	EDTA Titrimetric	Titration with EDTA and Murexide as indicator
Magnesium (Mg^{+2})	EDTA Titrimetric	Difference between total hardness and Calcium
Hardness	EDTA Titrimetric	Titration with EDTA and Eriochrome Black T as indicator
Bicarbonate (HCO_3)	Titration method	Titration with H_2SO_4 and Bromogresol green as indicator
Carbonate (CO_3)	Titration method	Titration with H_2SO_4 and Phenolphthalein as indicator
Total Coliform (TC)	Membrane filter technique	Membrane Filtration
Fecal Coliform (FC)	Membrane filter technique	Membrane Filtration

The two main methods are used for analysis in the laboratory:

4.5.1 Membrane Filtration

Membrane filtration (MF) is a very commonly used method in laboratories. In this method a water sample (typically 100 ml) is filtered through a sterile membrane filter with pore size 0.45 microns, then a vacuum is applied and the sample is drawn through the membrane filter. All coliform bacteria are retained on or within the filter, the membrane is then incubated in a suitable selective nutrient medium in Petri dish. Then it is transferred to an incubator at appropriate temperature for a suitable time to allow the growth bacteria into colonies then the colonies will be counted. The results are reported in number of colony-forming unit (CFU) per 100 mL. Total coliform gives red colonies with metallic sheen within 24 hours at 35˚C on Endo-type medium containing lactose, while fecal coliform gives blue colonies within 24 ± 2 hours or less at 44.5˚C on m-FC medium. Generally, in this technique may produce pink, blue, white, or colorless colonies with a metallic sheen, in this case they are considered non-coliform. The MF technique is preferred for water testing rather than Multiple-tube procedure because it permits analysis of larger samples in less time, and gives numerical results more rapidly. Nevertheless, this technique has some limitations as it is inappropriate for testing turbid water, which can clog the membrane or prevent growth of target bacteria on the filter (APHA, et al. 1998; NHDES, 2011; UNICEF, 2008; WHO, 1997).

4.5.2 Titration Method

A titration is a laboratory method of quantitative analysis used to help determine the concentration of an unknown substance, when done correctly and carefully.

A titration is a process in which a measured volume of a solution is added to a reaction mixture until the titration end-point is identified by the development of color resulting from the reaction with an indicator, by the change of electrical potential or by the change of pH value (WHO, 1993).

4.6 Water Quality Data Analysis

Because of the negative public health impacts of unsafe water, local and national government agencies have established drinking water quality standards. The water sources must meet or exceed standards to assess the acceptance of water quality for drinking purposes, and to ensure supply of clean and safe water for human consumption.

In this study, the obtained water quality results were compared with drinking water standards. For instance, the standards of both the World Health Organization (WHO, 2004), and Palestinian Standards (PS, 2004, 2005), Table 6 shows some heavy metals with PS of drinking water. As well Table 7 provides the physiochemical water quality parameters together with PS and WHO standards.

Table(3. 3): Heavy Metals with PS of Drinking Water (PS, 2004, 2005)

Heavy Metals	**PS Standards (mg/L)**
Aluminum (Al)	0.2
Barium (Ba)	0.3
Beryllium (Be)	>0.001
Cadmium (Cd)	0.005
Chromium (Cr)	0.05
Cobalt (Co)	0.1
Copper (Cu)	1
Iron (Fe)	0.3
Lead (Pb)	0.01
Manganese (Mn)	0.1
Nickle (Ni)	0.05
Silver (Ag)	0.01
Zinc (Zn)	5

Table(3. 4): PS and WHO Standards of Physiochemical Drinking Water Quality (PS, 2004, 2005; WHO, 2004)

Parameters	PS Standards	WHO Standards
pH	6.5-8.5	6.5-8.5
Sulfate (SO_4) (mg/L)	200	200
Nitrates (mg/L) (as NO_3-N)	Up to 10	Up to 10
Chloride (mg/L)	Up to 250	Up to 250
Hardness (mg/L $CaCO_3$)	500	Up to 500
Sodium (mg/L)	200	200
Calcium (mg/L)	Up to 100	Up to 100
Magnesium (mg/L)	Up to 100	Up to 100
Bicarbonates (HCO_3) (mg/L)	600	-
Alkalinity	400	-
TDS (mg/L)	Up to 500	Up to 500
Phosphate (PO_4) (mg/L)	2	-
Electrical Conductivity (EC)	1500	2000
Turbidity (NTU)	1.0	-
FC (CFU/100ml)	0	0
TC (CFU/100ml)	< 3	3

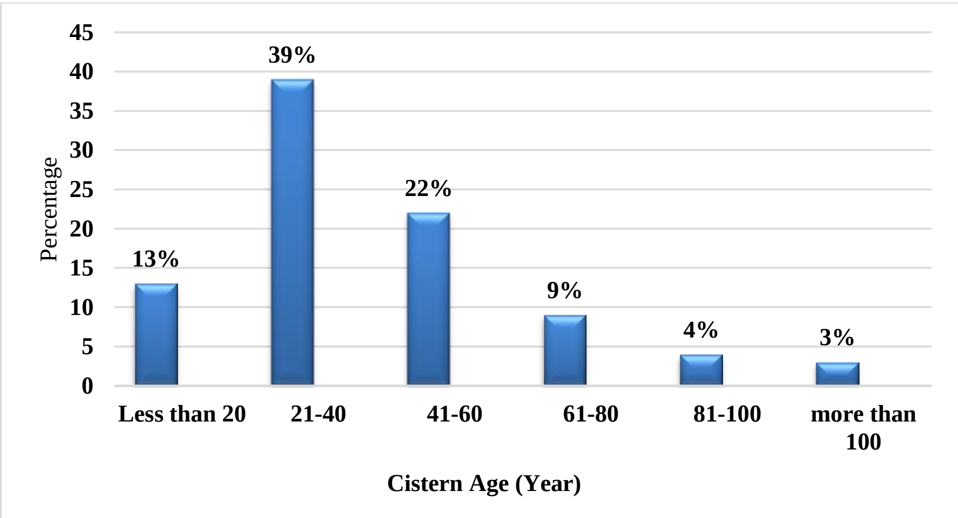
CHAPTER FIVE
RESULTS AND DISCUSSIONS

5.1 Cisterns Characterization and Conditions

This section describes the characteristics of cisterns in terms of age, size, source of water, type of catchment system, construction material, surrounding environment, water uses, type of wastewater disposal system, elevation difference and distance from wastewater disposal system, and other factors that affect water quality of cisterns.

Age of Cisterns

Results indicate about (39%) of cisterns in Sha'rawiya area have age between (20-40) years. Also (3%) of cisterns has an age over 100 years that is an evidence the RWH is practiced in the study area long time ago. Figure 5 illustrated the cistern age in Sha'rawiya area.



Figure(5. 1): Age of Cisterns in Sha'rawiya Area

Source of Water Supply

The sources of water in cisterns are (83%) rainwater, (2%) municipal water, and (10%) mix of municipal water and rainwater. Some people (5%) fill their cistern from springs.

Catchment System

The highest percentage of catchment system used in the study area were rooftop catchment systems at about (80%). This type can be considered as a perfect practice to collect rainwater with good quality because the possibility to clean it and flush the first storm away is easy. This area is also located away from some sources of contamination such as flooding of wastewater disposal system, trees, and animals, in comparison with house yards that are exposed directly to contaminated sources. Table 8 illustrated the type of catchment systems used in the study area.

Table(5. 1): Type of Catchment System used in Sha'rawiya Area

Type of catchment system	Percent (%)
Rooftop	80
House Yard	7
Rooftop + House Yard	6
Other	7

Cistern Size

The cistern size should be sufficient to store enough amount of water to meet people's need during dry periods. The majority of cisterns in the study area (54%) have a size exceeding 50 m^3, (32%) has a size between 30 m^3 and 50 m^3, while fewer (14%) is of small size (less than 30 m^3).

Water Uses

Moreover, the results indicate that the majority of cisterns (55%) are being used for drinking and cooking purposes, while (19%) of cisterns is used for agricultural and cleaning purposes, and (26%) is used for all purposes. The high percentage of water used for drinking and cooking purposes indicates the importance to draw attention and awareness of local people about water quality and contamination sources to reduce potential health risks.

Construction Material

The results reported that (93%) of cisterns are constructed of cement material which means that cement is a common material used to construct cisterns in Sha'rawiya area. As this material is considered as the best available material to store water in cisterns of good quality.

Wastewater Disposal System

The results also showed that cesspits (89%) are the main wastewater disposal system used in Sha'rawiya area, while about (11%) of houses are being served by public sanitary services system or septic tanks.

Factors Affect the Water Quality of Cisterns

The questionnaires analysis indicates the microbial contamination in cisterns may occur when contaminants from wastewater disposal system seep into cisterns through cracks and pose threats to water quality of cisterns. This could be due to absence of public sanitary services in most of Sha'rawiya area. This situation will be worse and the risk of contamination will increase if the elevation of a wastewater disposal system is higher than the elevation of cisterns.

Table 9 summarizes some information about the cistern owners' awareness to factors that can affect the water quality of cisterns and their sanitation practices, and the surrounding environment of cisterns.

Table(5. 2): Factors that Affect the Water Quality of Cisterns

Factors	Answer	Percentage (%)
Cleaning collection surfaces before rainwater harvesting	Yes	94
	No	6
Using the collection surface for laundry purposes	Yes	30
	No	70
Flushing the first storm away	Yes	29
	No	71
Withdrawing water manually	Yes	24
	No	76
Cleaning up of cistern	Yes	17
	No	83
Water disinfection of cistern	Yes	19
	No	81
Presence of pets at house	Yes	19
	No	81
Presence of trees around cistern	Yes	70
	No	30

5.2 Suitability of RWH for Drinking Purposes

As shown in Table 9 there are many factors that affect the water quality in tested cisterns at Sha'rawiya area. Therefore, RWH quality should be evaluated to make sure that the RWH meets drinking water standards and acceptable for drinking purposes to protect health of all people who use it.

Table 10 presents the obtained results of tested physiochemical and microbial parameters to assess water suitability for drinking purposes, by comparing the obtained results of the tested cisterns with PS and WHO standards.

Table(5. 3): Average Results of Analytical Testing of Physiochemical and Microbial Parameters of the Tested Cisterns in Sha'rawiya Area with PS and WHO Standards of Drinking Water.

Rural Area	No. of Samples	Parameter														
		pH	EC	Cl^-	Hardness	Ca^{+2}	Mg^{+2}	Na^+	PO_4^{-2}	TDS	Turbidity	Alkalinity	NO_3^-	SO_4^{-2}	TC	FC
Al-Jarushiya	1	7.1	229	17.9	100	33.6	66.7	10.4	0.03	164.5	0.2	84.0	1.8	19.4	2000	276
Attil	9	7.5	401	45.8	140.7	37.9	102.7	23.7	0.08	179.7	1.4	120.6	21.9	23.3	759	256
Baqa Asharqiya	5	7.4	236	27.9	130.8	37.1	93.7	15.8	0.03	163.8	0.2	107.6	10.3	26.4	1451	64
Deir AlGhusun	9	7.6	211	25.3	93.5	26.5	65.1	11.9	0.1	135.4	1.3	76.7	16.2	22.8	137	1
Illar	6	7.6	169	23.2	100.3	27.7	72.6	9.5	0.08	108.3	0.6	67.3	17.0	25.9	1275	27
Nazla Gharbiya	1	7.5	207	19.9	88.0	27.2	60.8	17.7	0.03	132.4	0.07	80.0	7.3	4.8	200	15
Nazlet Isa	3	7.7	452	45.9	192.1	49.4	142.7	30.1	0.1	228.6	0.2	164.6	13.0	60.5	246	39
Nazla Sharqiya	2	7.4	288	34.4	146.1	42.0	104.0	16.3	0.1	184.6	0.2	123.0	10.6	13.6	3050	580
Nazla Wusta	1	7.2	250	26.9	120.1	37.6	82.4	14.7	0.05	160.0	0.15	100.0	16.8	20.4	3800	300
Qaffin	7	7.4	343	34.7	137.7	43.9	99.5	18.3	0.2	219.9	0.8	118.5	15.7	36.6	1741	66
Seida	3	7.2	199	18.9	78	25.3	52.6	11.9	0.1	127.5	0.1	69.3	7.6	39.1	2100	129
Zeita	3	7.3	304	37.9	113.3	34.1	79.2	20.8	0.3	194.5	0.5	94.6	18.0	31.9	883	640
Standards	PS	6.5-8.5	1500	250	500	100	100	200	2	500	5	400	50	200	3	0
	WHO	6.5-8.5	2000	250	500	100	100	200	-	500	5	-	45	200	3	0

Some descriptive statistics (minimum, maximum, average, and standard deviation) of physiochemical and microbial water quality parameters of the tested cisterns in Sha'rawiya area are presented in Table 11.

Table(5. 4): Descriptive Statistics of Physiochemical and Microbial Water Quality

Parameters	Minimum	Maximum	Average	Std. Deviation
pH	7.1	8.5	7.5	0.2
Chloride (mg/L)	14.9	182.9	32	27
Alkalinity (mg/L)	8	414	99	65.1
Nitrate (mg/L)	1.8	71.6	16	13.2
Calcium (mg/L)	13.6	101.8	35	18.5
EC (µs/cm)	114.3	1569	287	222
Hardness (mg/L)	44	410	121	68
Magnesium (mg/L)	28.8	308.5	87	52.8
Phosphate (mg/L)	0	0.7	0.1	0.1
Sodium (mg/L)	6.5	91	17	13.5
Sulfate (mg/L)	0.05	113.6	28.5	20.9
TDS (mg/L)	73.1	408.9	169.7	81.5
Turbidity (NTU)	0.2	9	0.8	1.6
TC (CFU/100ml)	0	6900	1139	-
FC (CFU/100ml)	0	2000	149	-

The obtained results of physiochemical and microbial parameters of the tested water in cisterns that presented in the Table 10 and Table 11 were discussed in some details to determine if the obtained results were complying with standards to use water for drinking purposes.

5.2.1 Physiochemical Water Quality

pH

Table 12 shows that, regarding pH values of water in cisterns, the obtained values range between 7.1 and 8.5 with a mean value of 7.5. This indicates the basicity of harvested rainwater. The majority of samples have pH values within 7-7.5. No results of tested samples exceed the limits of WHO and PS.

The elevated values of pH could be attributed to the type of construction material. For instance, the leaching of calcium carbonate from the concrete walls of the cisterns which contain cement material could be considered as the main cause for increasing the pH values in some cisterns (Zhu et al., 2004).

Chloride

The chloride results range between 14.9 and 182.9 mg/L with a mean value of 32.08 mg/L. No results exceed the PS and WHO standards.

The highest percentage (90%) of chloride ranges between 0 – 50 mg/L (very low concentration). These percentage indicates the chloride not reacts with metal pipes or construction material of cisterns which may increase level of metals in water (i.e., increase its corrosivity) (WHO, 1996).

Nitrate

The results of nitrate range between 1.8 and 71.6 mg/L with a mean value of 16.03 mg/L. About (4%) of results exceeds the PS and WHO standards. This is may be due to excessive agricultural practices with an increased use of agro-chemicals (e.g. fertilizers and pesticides) close to the cisterns, or due to the age of cisterns. Old cisterns are more vulnerable to leakage of contaminants from wastewater disposal system into cisterns water through the cracks.

Turbidity

The turbidity results of cisterns water range between 0.2 and 9 NTU with a mean value of 0.8 NTU. Almost 4% of turbidity results are more than 5 NTU which exceeds both PS and WHO standards. Water that has higher values of turbidity appears cloudy or opaque that might be attributed to the presence of suspended particles in water. In addition, algal growth inside and around cisterns increased turbidity values. High turbidity can cause increased water temperature because suspended particles absorb more heat and can also prevent light from penetrating into water (Poe, 2000).

Alkalinity

The results of alkalinity range between 8 and 414 mg/L with a mean value of 99 mg/L. Results show that alkalinity exceeds PS in only (2%) of the samples. This is due to the use of lime paste in cisterns construction (old practices), which could be contributed to the leaching calcium carbonate from the cistern walls (lime paste) into water.

Phosphate

The results of phosphate range between 0 and 0.7 mg/L, with a mean value of 0.1 mg/L. Results indicate that about (6%) of samples has 0 mg/L of phosphate, and no results exceed PS.

Sulfate

The sulfate results range between 0.05 and 113.6 mg/L, with a mean value of 28.5 mg/L. No results of sulfate exceed PS and WHO standards.

Hardness

The results of hardness range between 44 and 410 mg/L, with a mean value of 121 mg/L. No results exceed PS and WHO standards. As shown in Table 12 the majority of cisterns (58%) have moderately hard water.

Table(5. 5): Classification of Water Based on Hardness of Water in Cisterns at Sha'rawiya Area (UNICEF, 2008)

Classification	Hardness as $CaCO_3$ (mg/L)	Percentages of Samples
Soft	0 – 60	10%
Moderately Hard	61 – 120	58%
Hard	121 – 180	18%
Very Hard	>180	14%

Calcium and Magnesium

The results of calcium range between 13.6 mg/L and 101.8 mg/L, with a mean value of 35.0 mg/L. Results indicate that about (2%) of results exceeds the PS and WHO standards. The magnesium results range between 28.8 mg/L and 308.5 mg/L, with a mean value of 78.0 mg/L. Results show that (28%) of tested samples exceed the PS and WHO standards. High concentration of magnesium has a laxative effect and may cause abdomen problems (Shalash, 2006).

High concentration of calcium and magnesium will increase the hardness of water, which may have adverse impacts on the people's health (WHO, 2009).

TDS

The total dissolved solids (TDS) values were in the range of 73.1 mg/L and 408.9 mg/L, with a mean value of 169.7 mg/L. For all sampled cisterns the TDS values were within the desirable limits of PS and WHO standards.

EC

The EC values were in the range of 114.3 µs/cm and 1569 µs/cm, with a mean value of 287 µs/cm. Results show that EC values exceed the PS and WHO standards in about (2%) of the tested samples. This is due to the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, phosphate anions, sodium, magnesium, calcium, and iron cations. Moreover, using the lime paste in construction of cisterns may easily allow the seepage from wastewater disposal system into cisterns, resulting in higher values of EC because of the presence of chloride, phosphate, and nitrate in wastewater (UNEP, 2012).

Sodium

The results of sodium range between 6.5 mg/L and 91 mg/L, with an average value of 17 mg/L. No results exceed the PS and WHO standards.

Heavy Metals

The ICP-MS instrument which is available at WESI was used to detect the presence and concentration of heavy metals in water. As such, silver (Ag), aluminum (Al), Ba (Barium), Be (Beryllium), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), lead (Pb), zinc (Zn), were analyzed for most of the tested cisterns.

The PS for heavy metals, the average values, and ranges of these heavy metals are presented in Table 13.

Table(5. 6): The Average Concentration and Ranges of Heavy Metals with PS

Heavy Metals	Average (10^{-3} mg/L)	Range (10^{-3} mg/L)	PS (mg/L)
Ag	0.03	0.005 – 0.15	0.01
Al	28.4	4.5 – 75.0	0.2
Ba	56.1	11.9 – 275.7	0.3
Be	0.0007	0.00 – 0.017	>0.001
Cd	0.2	0.004 – 1.25	0.005
Co*	0.2	0.08 – 0.65	0.1
Cr	7.5	3.2 – 25.6	0.05
Cu	3.2	0.5 – 17.6	1
Fe	492	176.6 – 1965.9	0.3
Mn	2.9	0.3 – 23.3	0.1
Ni	3.1	1.05 – 21.3	0.05
Pb	0.7	0.05 – 12.6	0.01
Zn	52.9	0.7 – 1276.2	5

*** The source is (USEP, 2008)**

As shown Table 13, all heavy metals were within acceptable limits, expect the iron (Fe) which exceeds the PS. Iron in RWH results from rusting of gutters or roof, but it is unlikely to cause any health problems, although it may be unacceptable to consumers (Mosely, 2005).

5.2.2 Microbial Water Quality

The microbial analysis presented in Table 10 shows that most of results of tested samples for TC and FC had coliform contamination. As shown in Table 14 (86%) and (80%) of samples exceeded WHO and PS limits for TC and FC, respectively. Hence, the tested water is considered heavily contaminated with microbes and needs to be disinfected before human consumption.

Table(5. 7): Rang of TC and FC with Number of Contaminated Cisterns

TC		FC	
Range (CFU/100mL)	**Percent (%)**	**Range (CFU/100mL)**	**Percent (%)**
0-3	14	0	20
4-100	34	1-10	30
101-2000	28	11-100	28
>2000	24	101-4000	22
Total	**100**	**Total**	**100**

The measured FC counts in this study are less than reported in by a similar study of (Al-Salaymeh, 2012), while the measured TC counts in this study are higher.

One of the recent studies was in South Korea (Lee et al., 2010) resulted in 92% (higher than this study) and 72% (lower than the results this study) of water samples were positive for TC and FC, respectively.

The elevated microbial contamination may be contributed to several reasons, among which are presence of pets at home, presence of trees around cistern, using rooftop for laundry purposes, withdrawing water manually, store first storm of rainwater, not cleaning the collection surfaces, presence of wastewater disposal system close to cistern, using house yard as a catchment system, and the elevation of cistern is lower than the elevate of the wastewater disposal system.

By compared the obtained results of microbial analysis of water samples with their corresponding questionnaires, the sources of contamination and the percentages of contaminated cisterns are concluded in the Table 15.

Table(5. 8): Potential Sources of Contamination and the Percentages of affected Cisterns

Source of Contamination	Percentage (%)
Store the first storm of rainwater	78%
Presence of trees around cistern	78%
Withdrawing water manually	36%
Using rooftop for laundry purposes	32%
Presence septic tanks close to cistern water	30%
Presence of animals and birds at home	22%
Cistern level lower than wastewater disposal system	20%
Using house yard as catchment system	14%
Not cleaning the collection surfaces	4%

Table 15 indicates that the major sources (78%) of contamination affect cistern and water quality are the presence of trees around cisterns, and the storage of the first storm of rainwater.

Trees affect water quality by several ways. Trees roots may penetrate to the cisterns wall, resulting in cracks around the cistern that allows the pollutants to diffuse into the cistern through the cracks and deteriorates water quality. In addition, trees are considered as a suitable habitat for insects and birds, which may contaminate the cisterns water by their feces, and trees may cause floating things on surface of water by falling leaves and flowers in cisterns.

First storm is considered as one of the major factors that contaminated the water in cisterns, because it carries a relatively large amount of pollutants from the atmosphere (Yaziz et al., 1989). In addition, contaminants such as debris, dust, dirt, bird and rodent feces, insect, and leaves accumulate on catchment area (rooftops or house yard) during summer period. These contaminants can be transferred into the cisterns during the initial period of rainfall (Abusafa et al., 2012; Mosely, 2005).

Degree of contamination with TC and FC (WHO, 1993, 1996), and number of non-compliant samples, are illustrated in Table 16.

Table(5. 9): Degree of Contamination with TC and FC and Number of Non-Compliant Samples (WHO, 1993, 1996)

Range of TC (CFU/100mL)	0-3	4-50		51-50000	>50000
Degree of Contamination	0	1		2	3
Number of Non-Compliant Samples	6	12		32	0
Range of FC (CFU/100mL)	**0**	**1-10**	**11-100**	**101-1000**	**>1000**
Degree of Contamination	No Risk	Simple Risk	Moderate Risk	High Risk	Very High Risk
Number of Non-Compliant Samples	10	16	13	9	2

These results indicate that most of cisterns (64%) have TC ranges between 51 and 50000 (CFU/100 mL) with a second degree of contamination. Only 32% of cisterns contain FC between 1 and 10 (CFU/100 mL) that classified as a simple risk. However, 4% of samples reported as a very high risk of contamination with more than 1000 CFU/100 mL of FC.

5.3 Potential of Using RWH for Irrigation Purposes

All obtained results indicate that the harvested water is heavily contaminated with microbial contamination, so it becomes unsuitable for direct drinking purposes. For this reason, the RWH for drinking purposes should be treated by adding some disinfecting agents as chlorine before being used for drinking purposes.

While the quality of water in cisterns is not good enough for direct drinking purposes without treatment, further assessment was conducted to assess water quality in cisterns for irrigation purposes.

In general, the presence of chemical substances in irrigation water may reduce crop yield and deteriorate soil fertility. In most irrigation systems, the primary water quality concern is salinity levels, since salts can negatively affect both soil structure and crop yield (Fipps, 2013).

The TDS and EC usually measure water salinity. Sodium hazard is usually expressed in terms of the sodium adsorption ratio (SAR), which is calculated from the ratio of sodium to calcium and magnesium. The assessment of the water from the study area for irrigation purposes is based on TDS values, which is referred to the total salinity and is expressed in parts per million (ppm) or in the equivalent units of milligram per liter (mg/L).

According to TDS values, the irrigation water can be classified as shown in Table 17 (Miller and Gardiner, 2001).

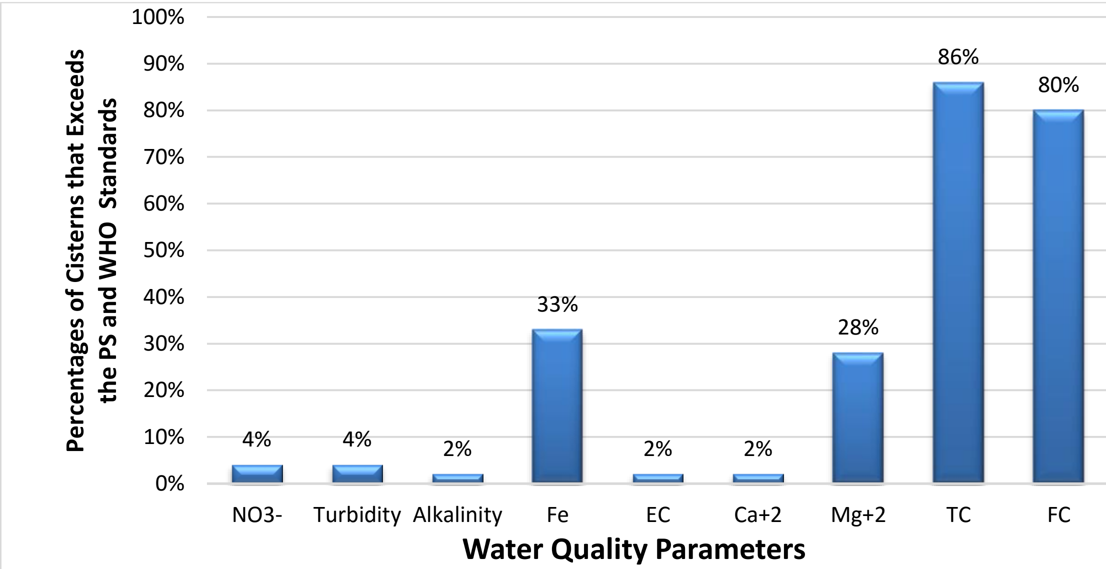
Table(5. 10): General Guidelines for Assessment of Salinity Hazard of Irrigation Water

	Limitation		
TDS Values (mg/L)	None	Moderate	Severe
	<450	450-2000	>2000

From Table 18, all water samples contain TDS values less than 450 mg/L, which indicates their suitability for irrigation purposes.

5.3 Cause – Effect Analysis

Figure 6 summarized the physiochemical and microbial water quality parameters that exceed the both PS and WHO standards.



Figure(5. 2): Percentages of Physiochemical and Microbial Parameters that Exceed the PS and WHO Standards of Drinking Water

As shown in Figure 6 the percentages of physiochemical and microbial water quality parameters, which are exceeds the PS and WHO standards are NO_3^- (4%), turbidity (4%), alkalinity (2%), EC (2%), Ca^{+2} (2%), Mg^{+2} (28%), Fe (33%), TC (86%), and FC (80%).

The cause-effect analysis for these parameters is summarized in Table 18.

Table(5. 11): Cause-Effect Analysis for Parameters that Exceed the PS and WHO Standards

Parameters	Standard value	The values of the samples that exceeds standard	General causes (EPA, 2001; Patil et al., 2012; WHO, 2003, 2011)	Actual causes found in the studied samples
NO_3^-	45	(58.2, 64.9) mg/L	(1) Agricultural activity (including excess application of fertilizers and manures) (2) From wastewater treatment (3) From oxidation of nitrogenous waste products in human and animal excreta, including septic tanks.	(1) The cistern age (increased algal growth and turbidity) (2) Excessive agricultural practices with increased using of agrochemical (as pesticide and fertilizers) (3) wastewater disposal system close to cistern
Turbidity	5	(5.3, 9) NTU	(1) Soil runoff (2) Total suspended particles (3) Sewage solids	(1) Presence of suspended particles on the surface of water (2) Algal growth inside and around the cistern
Alkalinity	400	414 mg/L	(1) Due to dissolved gases (CO_2) (2) From calcium carbonate ($CaCO_3$) leached from rocks and soil	(1) Using lime material in construction of cistern that lead to leaching $CaCO_3$ to water
EC	2000	1569 µs	(1) Due to different dissolved salt and inorganic solids	(1) The presence of inorganic dissolved solids

				(2) Use lime material in construction old cisterns
Ca^{+2}	100	101.8 mg/L	(1) The erosion of rocks, such as limestone and dolomite, and minerals, such as calcite and magnesite	(1) Due to $CaCO_3$ as a major constitute of cement material that used in construction cistern
Mg^{+2}		(105, 125, 138, 213, 308, 193, 102, 102, 201, 101, 106, 167, 172) mg/L		
Fe	0.3	(0.4, 0.46, 0.48, 0.5, 0.57, 0.6, 0.65, 0.8,1.6, 1.9) mg/L	(1) dissolve from iron pipes which are used for water distribution.	(1) Rusting from gutters and roofs
TC	3	Range (4 – 6900) CFU/100 mL	(1) From runoff (2) Septic systems (3) Animals (4) Poor cistern construction (5) Trees around cistern	(1) Presence of trees around cisterns (2) Store the first storm of rainwater
FC	0	Range (1 – 2000) CFU/100 mL	(1) From runoff (2) Septic systems (3) Animals (4) Poor cistern construction (5) Trees around cistern	(1) Presence of trees around cisterns (2) Store the first storm of rainwater

Table 18 shows the common sources of chemical contamination of cistern water. The contamination is mainly due to the old age of cisterns which were constructed in the past by using lime material, and also due to poor waste disposal systems that run close to the cistern. In addition, this table reveals the common sources of microbial contamination of cistern in the study area. As shown, the microbial contamination is caused by the presence of trees around cistern, and by storing the water from the first storm of rainwater.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The research aims at assessing the quality of harvested rainwater in cisterns in Sha'rawiya rural area for drinking purposes. Based on the obtained physiochemical and microbial results, the following can be concluded.

1. The results indicated that the collected rainwater is highly contaminated with microbes, therefore it becomes unsuitable for drinking purposes. As such, people using these cisterns for drinking purposes may subject to health problems in the absence of disinfection unit.
2. The comparison between the obtained results and the PS and WHO standards showed that most of physiochemical water quality parameters are within the desirable limits. However, alkalinity, turbidity, EC, nitrate, iron, calcium, and magnesium values exceeded the desirable limit.
3. This research showed that the quality of harvested rainwater is strongly affected by the type of catchment area. The rainwater harvested from rooftops has a better quality than the rainwater harvested from the house yard.
4. The influence of construction material type on harvested water was investigated. It was found that cistern built with cement has a better water quality than those built with lime.
5. The research results showed that the major sources of contamination of cisterns in Sha'rawiya rural area are the presence of trees around cisterns, and storing of the first storm of rainwater.
6. Cistern users do not get enough information on the best ways to build and maintain the rainwater harvesting system.

7. Finally, the research showed that the harvested rainwater might be used for irrigation purposes, depending on TDS values to assess salinity hazard of irrigation water.

6.2 Recommendations

Taking into account the above conclusions, the following can be recommended:

1. Cisterns should be covered well to keep out sunlight and contaminants from entering them, to minimize algae growth, and to eliminate the potential risk for any mosquito breeding.
2. Cisterns should be cleaned periodically.
3. Guideline for local people regarding the cleaning of RWH systems (e.g. pipes, rooftops) have to be developed.
4. Rooftops should be smooth enough to prevent entrapment of contaminants on the surface.
5. Tree branches overhanging the rooftops should be trimmed out to prevent leaves and birds dropping from falling onto the roof.
6. Cisterns must be located away and at a higher elevation than any close wastewater disposal system.
7. The first rainwater storm must not be stored and should be flushed away.
8. While cistern water is heavily contaminated with microbes, it is recommended that cistern water should be disinfected before drinking by boiling water or adding chlorine or other kind of disinfection treatment units.

References

- Abusafa, A., Arafat, H., Abu-Baker, M., and Khalili, K., (2012). **"Utilisation of Drinking Water from Rainwater-harvesting Cisterns in the Palestinian Territories: Assessment of Contamination Risk."** Int. J. Environment and Waste Management, Vol. 9, Nos. 3/4, 358-371.
- Achadu, O. J., Ako, F. E., and Dalla, C. L., (2013). **"Quality Assessment of Stored Harvested Rainwater in Wukari, North-Eastern Nigeria: Impact of Storage Media."** Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT). Volume 7, Issue 5 (Nov. - Dec. 2013), PP 25-32
- Al-Salaymeh, A., (2008). **"Assessment of Drinking Water Quality of Cisterns in Hebron City."** Master thesis of science in Institute for Water Studies, Birzeit University, Ramallah, Palestine, 4-19
- Al-Salaymeh, A., Al-Khatib, I., and Arafat, H., (2011). **"Towards Sustainable Water Quality Management of Rainwater Harvesting Cisterns in Southern Palestine."** Springer Science + Business Media B. V. 2011, Water Resource Manage, 25:1721-1736.
- Amin, T., and Han, M. Y., (2011). **"Microbial Quality Variation within a Rainwater Storage Tank and the Effects of First Flush in Rainwater Harvesting (RWH) System."** Australian Journal of Basic and Applied Sciences, 5(9): 1804-1813.
- APHA, AWWA, WEF (1998). **"Standard Methods for Examination of Water and Wastewater."** 20th Edition, American Public Health Association, Washington, D.C., USA

- ARIJ (Applied Research Institute - Jerusalem), (1996). **"Environmental Profile for the West Bank, Volume 8: Tulkarm District."** ARIJ, Jerusalem.
- Awadallah, W., Cancelliere, G., and Fulgoni, F., (2011). **"Monitoring of the Water Quality Stored the Rainwater Harvesting Cisterns."** Final Report. Palestinian Hydrology Group in partnership with GVC. Hebron Governorate, Palestine.
- Balasubramanya, N., (2006). **"Harvested Rainwater for Drinking, Rainwater Harvesting and Water Management."** National Seminar on ***Rainwater Harvesting and Water Management*** 11-12 Nov. 2006, Nagpur. 16-19.
- Barnes, D., (2009). **"Assessment of Rainwater Harvesting in Northern Ghana."** Master Thesis of Engineering in Civil and Environmental Engineering at the Massachusetts Institute of Technology.
- Bellingham, K., (2009). **"Physicochemical Parameters of Natural Water."** Steven Water Monitoring System, Inc., www.stevenwater.com
- Bisoyi, Er., (2006). **"Rain Water Harvesting - *An ultimate need in 21st Century*.**" National Seminar on ***Rainwater Harvesting and Water Management*** 11-12 Nov. 2006, Nagpur. 105-110.
- Bourne, A., (2001). **" Assessing the Contamination of Risk of Private Well Water Supplies in Virginia."** Master thesis of science in Biological systems engineering, Virginia Polytechnic Institute and State University. Blacksburg, Virginia.

- Cabelli, V. J., (1977). **"Indicators of Recreational Water Quality."** in Hoadley, A.W., and Dutka, B.J., (Eds.), Bacterial indicators/health hazards associated with water, American Society for Testing and Materials, ASTM STP 635, p. 222– 238.
- Crowley, B., (2005). **"Neighborhood Level Analysis of Rainwater Catchment in Portland, OR."** Master thesis of science in Portland State University.
- Dhoble, R., and Bhole, A., (2006). **"Review of Rainwater Harvesting in India."** National Seminar on ***Rainwater Harvesting and Water Management*** 11-12 Nov. 2006, Nagpur. 159-170.
- EPA (Environmental Protection Agency), (2001). **"Parameters Water Quality Interpretation and Standards."** Environmental Protection Agency, Ireland.
- EPA (Environmental Protection Agency), (2006). **"Volunteer Estuary Monitory- A Methods Manual."** 2nd Edition. Washington, DC.
- EPA (Environmental Protection Agency), (2012). **"Monitoring and Assessing Water Quality-Volunteer Monitoring."** United State Environmental Agency, Washington, D.C.
- Ertuo, K., and Mirza, I., (2005). **"Water Quality: Physical, Chemical, and Biological Characteristics."** Nova Science Publishers.
- Esguerra, A., Madrid, A., and Nillo, R., (2011). **"Rainwater Harvestin, Quality Assessment and Utilization in Region I."** E-International Scientific Research Journal, Volume 3, Issue 2, Don Mariano Marcos Memorial State University Bacnotan, La Union.

- Fedkiw, J., (1991). **"Nitrate Occurrence in U.S. Waters (and Related Questions): A Reference Summary of Published Sources from an Agricultural Perspective."** USDA.
- Fipps, G., (2013). **"Irrigation Water Quality Standards and Salinity Management Strategies."** Texas A&M AgriLife Extension, The Texas A&M University System, U.S Department of Agriculture.
- HES-EPA (Health Service Executive in conjunction with the Environmental Protection Agency) (2010). **"Nitrates in Drinking Water."**.
- González, A., (2012). **"Study to Analyze the Viability of Rainwater Catchment from Roofs for Its Reuse in Tegucigalpa, Honduras."** Master Thesis of Science, Colorado State University. Fort Collins, Colorado.
- Gould, J. and Nissen-Petersen, E., (1999). **"Rainwater catchment systems for domestic supply – design, construction and implementation."** Intermediate Technology Publications, London.
- Greenberg, A., Clesceri, L., and Eaton, A., (1992). **"Standard Methods** for Examination of Water and Wastewater." 18th edition. American Public Health Association. Washington, D.C.
- Kloss, C., (2008). **"Managing wet weather with green infrastructure municipal handbook- Rainwater Harvesting Policies."** Environmental Protection Agency.

- Kross, C., Hallberg, G., Bruner, D., Cherryholmes, K., and Johnson, J., (1993). **"The Nitrate Contamination of Private Well Water in Iowa."** American Journal of Public Health, 83(2):270-272.
- Kwaadstenient, M., Dobrowsky, P., Deventer, A., Khan, W., and Cloete, T., (2013). **"Domestic Rainwater Harvesting: Microbial and Chemical Water Quality and Point-of-Use Treatment Systems."** Springer Science+Business Media Dordrecht 2013. Water Air Soil Pollution. 224:1629.
- Lee, J. Y., Yang, J. S., Han, M., and Choi, J. (2010). **"Comparison of the microbiological and chemical characterization of harvested rainwater and reservoir water as alternative water resources. Science of the Total Environment."** 408, 896–905.
- Madison, R. J. and Brunett. J., (1985) "Overview of the Occurrence of Nitrate **in Ground Water of the United States."** USGS water supply paper #2275. P.P 93-105.
- Miller, R. W., and Gardiner, D., (2001). **"Soils in our environment."** 9th edition. Prentice Hall-Inc., Upper Sddle River, New Jersey.
- Mohod, Ch., and Dhote, J., (2013). **"Review of Heavy Metals in Drinking Water and their Effect on Human Health."** International Journal of Innovative Research in Science, Engineering and Technology. Volume 2. Issue 7: 2992 – 2996.
- Morais, S., Costa, F., and Pereira, M., (2012). **"Heavy Metals and Human Health."** Environmental Health - Emerging Issues and Practice, Prof. Jacques Oosthuizen (Ed.). 227-264.

- Mosely, L., (2005). **"Water Quality of Rainwater Harvesting Systems."** SOPAC Miscellaneous Report 579, 3-4.
- MPCA (Minnesota Pollution Control Agency). (2007). **"Phosphorus: Sources, Forms, Impact on Water Quality – A General Overview."** 520 Lafayette Rd. N., St. Paul, MN 55155-4194.
- NHDES (New Hampshire Department of Environment Services), (2010). **"Interpreting the Presence of Coliform Bacteria in Drinking Water."** Environmental Fact Sheet. New Hampshire Volunteer River Assessment Program. State of New Hampshire.
- NHDES (New Hampshire Department of Environment Services), (2011). **"Interpreting VRAP Water Quality Monitoring Parameters – Chemical Parameters."** New Hampshire Volunteer River Assessment Program. State of New Hampshire.
- Nolde – Khoury, N., (2011). **"Rainwater Harvesting."** Zero-M & Trade Association operating and rainwater harvesting e.V. Germany.
- Patil, K., and Patil, G., (2006). **"Rainwater Harvesting Techniques."** National Seminar on ***Rainwater Harvesting and Water Management*** 11-12 Nov. 2006, Nagpur. 10-14.
- Patil. P., Sawant. D., and Deshmukh. R., (2012). **"Physico-chemical parameters for testing of water – A review."** International Journal of Environmental Science. Volume 3, No.3, 1194 – 1207.
- PCBS (Palestinian Central Bureau of Statistic), (2007). **"The Population, Housing and Establishment Census–2007."** Press

Conference on the Preliminary Findings, (Population, Buildings, Housing Units and Establishments), Ramallah, Palestine.

- PCBS (Palestinian Central Bureau of Statistic), (2014). **"Statistical Yearbook of Palestine 2014."** No. 15. Ramallah, Palestine.
- PMD (Palestinian Meteorological Department), (2011). **"Climate Bulletin 2011."** Ministry of Transport, Meteorological Authority, Palestine.
- Poe, K., (2000). **"Water Quality and Monitoring - A river is the report card for its watershed."** Alan Levere, Connecticut Department of Environmental Protection.
- PSI (Palestine Standards Institute), (2004). "**The Second Working Draft of the Amended Drinking Water Standard."** Ramallah, Palestine.
- PWA (Palestinian Water Authority), (2010). **"Water Supply Report 2010."** Ramallah, Palestine.
- PWA (Palestinian Water Authority), (2011). **"Annual Water Status Report 2011."** Ramallah, Palestine.
- Radaideh, J., Al-Zboon, K., Al-Harahsheh, A., and Al-Adamat, R., (2009). **"Quality Assessment of Harvested Rainwater for Domestic Uses."** JJEES 2009.June.1; volume 2, ISSN 1995-6681,26-31.
- Salem, H., Eweida, A., and Azza, F., (2000). **"Heavy Metals in Drinking Water and their Environmental Impact on Human Health."** Cairo University, Egypt. 542-556.

- Schepers, J., Martin, D., Watts, D., and Ferguson. R., (1991). **"Integrated Water and Nitrogen Management." Nitrate contamination: exposure, consequence, and control."** University of Nebraska-Lincoln, USA. P.P:163-171.
- Shalash, I., (2006). **"Hydrochemistry of The Natuf Drainage Basin Ramallah/ West Bank."** Master thesis, Faculty of Graduate Studies, Birzeit University, Birzeit, West Bank, Palestine.
- Sharma, R., (2010). **"Rainwater Harvesting at N.I.T. Rourkela."** National Institute of Technology, Rourkela. 12-14.
- Sivanappan, R., (2006). **"Rainwater Harvesting Conservation and Management Strategies for Urban and Rural Sectors."** National Seminar on ***Rainwater Harvesting and Water Management*** 11-12 Nov. 2006, Nagpur. 1-5.
- Spalding, R., and Exner, M., (1993). **"Occurrence of Nitrate in Groundwater - A Review."** Journal of Environmental Quality. 22(3):392-402.
- UNEP (United Nations Environment Programme), (2000). **"Implementation Guidance for Ambient Wate Quality Criteria for Bacteria."** Office of water, Washington, DC.
- UNEP (United Nations Environment Programme), (2002). **"Rainwater Harvesting and Utilization."** Newsletter and Technical Publications.
- UNEP (United Nations Environmental Programme), (2010). **"Clearing the Water."** A focus on water quality solutions. Nairobi, Kenya.

- UNEP (United Nations Environmental Programme), (2012). **"Monitoring and Assessing Water Quality – Volunteer Monitoring."** United States Environmental Protection Agency. Washington. D.C.
- UNEP and CEHI (United Nations Environment Programme and Caribbean Environmental Health Institute), (2009). **"Rainwater: Catch it while you can: Handbook for Rainwater Harvesting for the Caribbean."** United Nations Environment Programme, Kenya
- UNICEF (United Nations Children's Fund), (2008). **"UNICEF Handbook on Water Quality."** 3 UN Plaza, New York, NY.
- UN GEMS (United Nations Environmental Programme Global Environmental Monitoring System), (2006). **"Water Quality for Ecosystem and Human Health."** 2nd Edition. International Institute-PAS-European Regional Centre for Ecohydrology u/a UNESCO IAP water programme, Canada.
- Weigman, D. L. and Kroehler, C. J., (1990). **"Threats to Virginia's Groundwater."** VPI & SU: Virginia Water Resources Research Center. USA.
- Wilhelm, L.J. and Maluk, T.L., (1998). **"Fecal Indicator Bacteria in Surface Waters of Santee River Basin and Coastal Drainage."** Fact Sheet FS-085-98 FS-085-98, The US Geological Survey (USGS), South Carolina.

- World Health Organization (WHO), (1993). **"Guidelines for drinking-water quality: recommendations."** 2nd edition, Vol. 1. Geneva, World Health Organization.
- World Health Organization (WHO), (1996). **"Guidelines for Drinking Water Quality: Health Criteria and Other Supporting Information."** Vol.2. Geneva.
- World Health Organization (WHO), (1996). **"Water Quality Assessments - A Guide to Use of Biota, Sediments and Water in Environmental Monitoring."** Second Edition. F & FN Spon. London.
- World Health Organization (WHO), (1997). "**Guidelines for Drinking Water Quality**: **Surveillance and Control of Community Supplies**." 2nd ed. Vol. 3. Geneva.
- World Health Organization (WHO), (2003). **"Right to Water."** 20 Avenue Appia, 1211 Geneva 27, Switzerland.
- World Health Organization (WHO), (2004). **"Guidelines for Drinking-water Quality."** Vol.1: 3rd ed., China.
- World Health Organization (WHO), (2006). **"Guidelines for Drinking-water Quality."** 3rd ed., Geneva.
- World Health Organization (WHO), (2009). **"Calcium and Magnesium in Drinking-water: Public health significance.**" 20 Avenue Appia, 1211 Geneva 27, Switzerland.
- World Health Organization (WHO), (2011). **"Guidelines for Drinking – Water Quality."** 4th ed., 20 Avenue Appia, 1211 Geneva 27, Switzerland.

- World Health Organization (WHO), (2012). **"Animal Waste, Water Quality and Human Health."** Edited by Al Dufour, Jamie Bartram, Robert Bos and Victor Gannon. IWA Publishing, London, UK.
- Worm, J., and Hattum, T., (2006). **"Rainwater Harvesting for Domestic Use."** ICCO and AIDEnvironment, 35-44.
- Yaziz, M. I., Gunting, H., Sapari, N., and Ghazali, A. W., (1989). **"Variations in rainwater quality from roof catchments."** Water Research, 23, 761–765.
- Young, S. E., and Sharpe, W. E., (1984). **"Rainwater Cisterns Design, Construction, and Water Treatment."** The Pennsylvania State University, Special Circular 277.
- Zhu, K., Zhang, L., Hart, W., Liu, M., and Chen, H., (2004). **"Quality issues in harvested rainwater in arid and semiarid Loess Plateau of northern China."** Journal of Arid Environments, 57, 487–505.

Annexes

Annexes A: The Questionnaire Distributed Among Houses in Sha'rawiya Area

Annexes B: Water Quality Data

Annexes A: The Questionnaire Distributed Among the Houses in Sha'rawiya Area.

جامعة النجاح الوطنية

كلية الدراسات العليا

أختي الفاضلة... أخي الفاضل...

تحية طيبة وبعد,

تقوم الباحثة بإجراء دراسة لمتطلب رسالة ماجستير بعنوان:

تقييم جودة مياه آبار الجمع لأغراض الشرب في منطقة الشعراوية

حيث تهدف هذه الدراسة لتحديد جودة مياه آبار الجمع ومدى ملائمتها لأغراض الشرب, ومعرفة مصادر تلوث هذه الآبار ان وجدت.

يرجى التكرم بتعبئة هذه الاستبانة بكل دقة وموضوعية, مع العلم أن المعلومات التي ستقدمونها لن تستخدم إلا لأغراض البحث العلمي.

شاكرين لكم حسن تعاونكم

الباحثة

سجى المر

المنطقة:		
رقم العينة:		
الجزء الأول: البيانات الاجتماعية		
.1	العمر	
.2	المستوى التعليمي	
.3	عدد أفراد الأسرة	
الجزء الثاني: خصائص الآبار ووصف للبيئة المحيطة		
.4	عمر البئر	
.5	مصدر المياه في البئر	1. مياه أمطار 2. مياه بلدية 3. مياه امطار+ مياه بلدية 4. غير ذلك حدد ....
.6	سعة البئر	1. اقل من 30م^3 2. (30-50) م^3 3. أكثر من 50 م^3
.7	المادة المستخدمة في البناء	1. اسمنت 2. شيد 3. غير ذلك حدد ....
.8	المنطقة المغذية للبئر	1. ساحة المنزل 2. سطح المنزل 3.غير ذلك حدد..........
.9	وسيلة الصرف الصحي المستخدمة في المنزل	1. حفرة امتصاصية 2. حفرة صماء 3. مجاري عامة
.10	مستوى البئر بالنسبة للحفرة الامتصاصية	1. أعلى 2. نفس المستوى 3. أقل
.11	هل توجد أشجار قريبة من منطقة البئر	1. نعم (حدد.......................) 2. لا
.12	هل تقوم بتربية حيوانات أو طيور أليفه بالمنزل	1. نعم 2. لا
.13	هل هناك احتمالية تجميع بعض النفايات المنزلية بالقرب من البئر	1. نعم 2. لا اذا كانت الاجابة (نعم): هل يتم ازالتها قبل الموسم المطري: 1.نعم 2.لا
.14	هل تلاحظ شوائب عائمة على سطح مياه البئر	1. نعم 2. لا
.15	هل تلاحظ اخضرار على جوانب البئر	1. نعم 2. لا
.16	هل باب البئر	1. مفتوح 2. مغلق 3. شبك 4. غير ذلك حدد..................
.17	هل يتم استخدام البئر بشكل مستمر خلال العام	1. نعم (حدد: 1. شرب 2. زراعة) 2. لا

.18	في حال استخدام مياه البئر للشرب كيف يتم استخدامها	1. بشكل مباشر 2. يتم ضخها للخزان ومن ثم استخدامها إذا كانت الإجابة رقم (2): - هل يعقم الخزان باستمرار: 1.نعم 2.لا - هل الخزان مغلق: 1.نعم 2.لا
.19	طريقة سحب الماء من البئر	1. يدوي 2. مضخة كهربائية
.20	هل سبق أن تعطل مصدر المياه من البلدية	1.نعم 2. لا إذا كانت الإجابة (نعم): هل يتم استخدام مياه البئر كمصدر بديل للشرب: 1.نعم 2.لا
الجزء الثالث: مدى التزام السكان بالعوامل التي تحد من تلوث مياه الآبار		
.21	استعمال السطح لأغراض الغسيل في الشتاء	1. نعم 2. لا
.22	هل يتم تنظيف سطح المنزل قبل موسم المطر	1. نعم 2. لا
.23	هل يتم التخلص من المياه المتبقية في البئر قبل الموسم الجديد	1. نعم 2. لا
.24	هل يتم معالجة مياه البئر بشكل عام	1. نعم 2. لا إذا كان الجواب نعم, كيف تتم المعالجة ....
.25	هل تتخذ إجراءات محددة قبل تجميع مياه الأمطار	1. نعم 2. لا إذا كان الجواب نعم, ما هي الإجراءات المتبعة ....
.26	هل يتم التخلص من مياه الشتوة الأولى	1. نعم 2. لا
.27	هل سبق وان قمتم بعمل فحوصات لنوعية مياه البئر	1. نعم (ما هي النتيجة.................................) 2. لا
.28	متى تمت آخر عملية تنظيف للبئر	
الجزء الرابع: أمور مرتبطة بتحديد جودة مياه آبار الجمع		
.29	هل عانى أحد أفراد الأسرة من الأمراض المتعلقة بالمياه (عند استخدام مياه البئر)	1.نعم 2. لا
.30	هل سبق أن لاحظتم تغير في أحد خصائص مياه البئر (اللون, الطعم, الرائحة)	1. نعم (حدد.........................) 2.لا

Annex B: Water Quality Data

		Parameters														
		pH	EC	Cl^-	Hardness	Ca^{+2}	Mg^{+2}	Na^+	PO_4^{-2}	TDS	Turbidity	Alkalinity	NO_3^-	SO_4^{-2}	TC	FC
Standards	PS	6.5-8.5	750	250	500	100	100	200	2	500	5	400	50	200	< 3	0
	WHO	6.5-8.5	2000	250	500	100	100	200	-	500	5	-	45	200	3	0
Attil	1	7.7	618	89.9	270.2	56.9	213.3	37.4	0.06	395.5	1.2	160	66.8	36.2	1943	6
	2	7.6	225	26.9	94	26.4	67.6	15.1	0.1	144	0.1	72	12.5	28.7	1800	160
	3	7.1	196	16.9	84	28.0	56.0	9.8	0.0	125.4	0.1	74	13.9	13.1	500	86
	4	7.7	241	17.9	112.1	36.8	75.2	10	0.04	154.2	0.0	98	11.9	2.2	70	36
	5	7.4	1569	182.9	410.3	101.8	308.5	91.1	0.06	308.5	0.1	414	71.6	113.6	3	0
	6	7.1	139.7	16.9	50	13.6	36.4	9.8	0.1	89.4	2.5	52	3.9	1.65	0	0
	7	7.9	232	19.9	60	19.2	40.8	18.2	0.0	148.4	0.04	80	10.5	5.3	4	1
	8	7.8	206	19.9	92	27.2	64.8	13.2	0.1	131.8	0.1	68	4.0	0.05	15	11
	9	7.4	188	20.9	94	32.0	62.0	9.5	0.3	120.3	9	68	2.7	9.3	2500	2000
Nazla Gharbiya	1	7.5	207	19.9	88	27.2	60.8	17.7	0.03	132.4	0.07	80	7.3	4.8	200	15
Nazla Wusta	1	7.2	250	26.9	120.1	37.6	82.4	14.7	0.05	160	0.1	100	16.8	20.4	3800	300
Nazla Sharqyia	1	7.3	266	31.9	142.1	40.8	101.2	14.6	0.2	170.2	0.04	124	3.1	14.2	3200	560
	2	7.5	311	36.9	150.1	43.2	106.8	18.0	0.06	199.0	0.4	122	18.1	13.1	2900	600
Nazlet Isa	1	7.4	494	44.9	236.2	68.9	167.3	29.2	0.2	314.3	0.4	176	21.5	94.7	19	1
	2	7.7	297	33.9	116.1	28.0	88.0	22.0	0.09	190.0	0.1	100	13.1	32.6	191	30
	3	8.0	565	58.9	224.2	51.3	172.9	39.1	0.2	361.6	0.2	218	4.6	54.3	528	87
Baqa Al-Sha'prqyia	1	7.5	463	50.9	274.2	72.9	201.3	27.6	0.01	296.3	0.3	224	22.6	19.6	37	24
	2	7.4	187	31.9	132.1	34.4	97.7	18.2	0.0	181.1	0.2	110	10.6	27.7	6900	240
	3	7.4	187	19.9	88	27.2	60.8	12.9	0.09	119.6	0.1	72	6.4	31.1	37	7
	4	7.5	156.3	16.9	74	24.0	50.0	7.5	0.01	100.0	0.2	62	5.8	21.9	27	1
	5	7.5	191	19.9	86	27.2	58.8	13	0.05	122.2	0.2	70	6.3	32.1	255	50
Deir Al-Ghusun	1	7.6	127.4	23.9	60	21.6	38.4	7.0	0.1	81.5	0.2	62	15.9	9.4	86	1

	2	7.2	148	20.9	68	16.0	52.0	7.0	0.1	94.7	0.08	58	15.7	19.3	38	2
	3	7.4	304	34.9	140.1	42.5	97.6	20.1	0.5	194.5	0.5	112	24.6	26.5	10	0
	4	8.5	162.1	19.9	66	16.8	49.2	6.6	0.04	103.7	0.7	25	21.8	34.6	300	1
	5	7.6	338	46.9	162.1	36.8	125.2	21.1	0.08	216.3	5.3	126	14.6	21.0	14	3
	6	7.8	247	25.9	90	25.6	64.4	18.1	0.02	158.0	0.3	80	15.6	24.2	0	0
	7	7.0	226	16.9	116.1	40.0	59.6	6.5	0.05	144.6	4.5	104	10.4	23.6	212	0
	8	7.8	170	18.9	84	23.2	60.8	7.3	0.05	108.8	0.4	60	8.7	26.9	1	0
	9	8.0	183	19.9	56	16.8	39.2	14.1	0.06	117.1	0.4	64	19.2	20.2	571	1
Al-Jarushiya	1	7.1	229	17.9	100	33.6	66.4	10.4	0.03	146.5	0.2	84	1.8	19.4	2000	276
Illar	1	7.3	226	29.9	152.1	46.5	105.6	10.1	0.19	144.4	0.3	130	20.4	22.3	0	0
	2	7.4	114.3	17.9	98	22.4	75.6	6.5	0.06	73.1	0.2	40	19.2	18.4	74	22
	3	7.9	143.5	16.9	86	18.4	67.6	10.4	0.02	91.8	0.7	50	13.6	40.9	69	13
	4	7.7	171	22.9	98	28.0	70.0	11.2	0.13	109.4	1.9	70	10.3	27.3	105	0
	5	7.7	170.6	26.9	88	29.6	58.4	11.1	0.07	109.1	0.3	60	26.6	29.8	3600	1
	6	7.4	191	24.9	80	21.6	58.4	8.0	0.02	122.2	0.2	54	12.0	17.0	3800	128
Seida	1	7.3	140	14.9	44	15.2	28.8	10.0	0.02	89.6	0.2	58	5.7	15.9	0	0
	2	7.1	211	18.9	94	32.0	62.0	10.1	0.2	135.0	0.1	78	4.5	44.0	2500	6
	3	7.3	247	22.9	96	28.8	67.2	15.6	0.09	158.0	0.03	72	12.7	57.6	3800	380
Zeita	1	7.3	225	27.9	86	28.0	58.0	13.2	0.1	144	0.4	60	25.2	30.0	112	5
	2	7.5	184	20.9	62	20.8	41.2	12.7	0.2	117.7	0.1	60	13.5	14.6	27	9
	3	7.2	503	64.9	192.1	53.7	138.4	36.5	0.7	321.9	1.2	164	15.5	51.2	2510	1906
Qaffin	1	7.7	639	81.9	226.2	92.9	173.2	33.7	0.3	408.9	3.6	212	36.5	24.8	4	0
	2	7.4	342	36.9	142.1	40.0	102.0	25.1	0.3	218.8	0.2	122	5.3	34.5	2800	80
	3	7.5	369	36.9	150.1	48.1	102.0	21.3	0.3	236.1	0.4	128	12.0	55.2	1500	7
	4	7.3	343	24.9	164.1	52.1	112.0	11.6	0.3	219.5	0.6	130	18.0	50.7	2000	52
	5	7.3	215	18.9	78	16.8	61.2	13.4	0.09	137.6	0.2	70	16.7	32.6	1900	270
	6	7.4	249	24.9	104	28.0	76.0	11.3	0.04	159.3	0.9	88	10.1	35.3	3900	1
	7	7.6	249	18.9	100	29.6	70.4	11.7	0.2	159.3	0.2	80	11.3	23.5	85	54
Range		7.0-8.5	114.3 -1569	14.9-182.9	44-410.3	13.6-101.8	28.8-308.5	6.5-91.1	0-0.78	73.1-408.9	0.2-9	8-414	0.8-71.6	0.05-113.6	0-6900	0-2000
Average		7.5	287	32.0	121.6	35	87	17	0.13	169.7	0.8	99.3	16	28.5	1139	149

جامعة النجاح الوطنية

كلية الدراسات العليا

تقييم جودة مياه آبار الجمع لأغراض الشرب في منطقة الشعراوية "محافظة طولكرم"

إعداد

سجى أسعد المر

إشراف

د. سمير شديد

د. عبد الرحيم أبو صفا

قدمت هذه الأطروحة استكمالا لمتطلبات الحصول على درجة الماجستير في العلوم البيئية بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس – فلسطين

2016

تقييم جودة مياه آبار الجمع لأغراض الشرب في منطقة الشعراوية " محافظة طولكرم"

إعداد
سجى أسعد المر
إشراف
د. سمير شديد
د. عبد الرحيم أبو صفا

الملخص

لقد هدفت هذه الدراسة لتقييم جودة المياه في آبار الجمع المنزلية لأغراض الشرب في منطقة الشعراوية والتي تضم 12 منطقة ريفية. حيث تم عمل فحوصات كيميائية وميكروبية لبعض آبار الجمع في منطقة الدراسة، وتم أخذ (50) عينة وأجريت لها بعض الفحوصات المخبرية التي تتضمن درجة الحموضة، الموصلية الكهربائية، البايكربونات، الكلورايد، العسر الكلي، الكالسيوم، المغنيسيوم، النيترايت، الكبريتات، الصوديوم، الفوسفات، العكورة، القاعدية، الحديد، البوتاسيوم، القولونيات الكلية والبرازية، وبعض العناصر الثقيلة.

لقد أظهرت النتائج أن معظم العناصر الكيميائية التي تم فحصها ضمن المعايير المسموح بها للشرب محليا وعالميا مع وجود بعض العناصر التي تجاوزت الحد الأقصى المسموح بالنسب التالية النيترايت (4%)، العكورة (4%)، القاعدية (2%)، المغنيسيوم (28%)، الكالسيوم (2%)، و الحديد (33%). وكذلك تم الكشف عن التلوث الميكروبي بالقولونيات الكلية والبرازية التي تجاوزت نسبتها المعايير المسموح بها بمقدار 86%، 80% على الترتيب.

لقد تمت دراسة خصائص الآبار ومصادر تلوثها من خلال توزيع (100) استبانة على أصحاب الآبار ومن خلال تحليل الإجابات تم التوصل إلى أن المصدر الرئيسي للتلوث بنسبة (78%) يعزى لوجود أشجار بالقرب من البئر وعدم التخلص من مياه الشتوة الأولى، في حين (36%) من نسبة التلوث تعزى لسحب المياه من البئر يدويا المنزل كمصدر لتجميع مياه المطر.

وفي نهاية الدراسة تم التوصل إلى عدم إمكانية استخدام مياه الجمع لأغراض الشرب بشكل مباشر وبدون معالجة نظرا لارتفاع نسبة الملوثات الميكروبية، في حين يمكن استخدامها لأغراض الري.