An-Najah National University

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Assessing Water Quality of Harvested Rainwater in Tubas Governorate and Evaluation of Local Public Awareness Regarding Water Pollution

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Dedication

I dedicate this work with my deep sense of gratitude and appreciation to my dear parents, who always been there, with unconditional love, encouragement and patience.

To my dear sisters (Ro'a, Rana, and Fatima), my brothers (Ali, Anas, Bara', and Yahya).

To my lovely friend khaled and to all friends who support us in one way or another.

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Thanks are also expanded to my mother, my sisters, my brothers, my dear friends, and for everybody who supported me during the achievement of this thesis, may God bless them with health, happiness, and the realization of their dreams.

الإقرار

أنا الموقع أدناه، مقدم الرسالة التي تحمل العنوان:

Assessing Water Quality of Harvested Rainwater in Tubas Governorate and Evaluation of Local Public Awareness Regarding Water Pollution

أقر بأن ما اشتملت عليه هذه الرسالة إنما هو نتاج جهدي الخاص، باستثناء ما تمت الإشارة إليه حيثما ورد، وأن هذه الرسالة ككل أو أي جزء منها لم يقدم من قبل لنيل أي درجة علمية أو بحث علمي أو بحثي لدى أي مؤسسة تعليمية أو بحثية أخرى.

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.

Student's Name:	**اسم الطالب:**
Signature:	**التوقيع :**
Date:	**التاريخ:**

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List of Abbreviations

°C	Degree Celsius
RW	Rainwater
RWH	Rainwater harvesting
WHO	World Health Organization
PS	Palestinian Standards
WESI	Water and Environmental Studies Institute
ARIJ	Applied Research institute / Jerusalem
UNICEF	United Nations Children's fund
Cfu	Colony Forming Unit
mg/l	Milligram per liter
Cm	Centimeter
TC	Total Coliform
FC	Fecal Coliform
m^3	Cubic Meters
MS	Mass Spectrometry
µs	Micro Siemenes
NTU	Nephelometric Turbidity Unit
TDS	Total Dissolved Solids
EC	Electrical Conductivity
B.C	Before Christ
PCBS	Palestinian Centeral Bureau of Statistics

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Abstract

This study was conducted to assessing the quality of collected rainwater in rainwater harvesting systems for drinking purposes, in conjunction with determining the levels of people's awareness and their related behaviors that lead to water pollution in Tubas governorate. Forty-seven samples of water were collected randomly from tested cisterns at 11different areas. All samples were analyzed for physical parameters (pH, electrical conductivity, total dissolved solids, and turbidity), chemical parameters (alkalinity, chloride, total hardness, calcium, magnesium, potassium, sodium, sulfate, phosphate, and nitrate), and microbiological parameters (total coliform (TC) and fecal coliform (FC)).

The obtained results compared with the Palestinian standards (PS) and world health organization (WHO) standards for drinking water. Through the sample analyzing, all the results of physiochemical parameters were within the accepteable limits of PS and WHO standards except (17%) of pH results, (2%) of total dissolved solids results, (4%) for turbidity results, (30%) for Potassium results, (28%) for Phosphate results and (21%) for Magnesium results. The percentage of contamination with total coliform and fecal coliform was (98%, 92%), respectively.

The characteristics of cisterns and sources of pollution were studied by a questionnaires answered by the owners of the cisterns, according to the information collected by the questionnaire the most significant sources of pollution were according to the presence of plants and trees near the cistern which consist (66%), while the storage of the first storm of rainwater in the cistern consist (53%), storage the rainwater of the previous season in the cistern (34%), and almost (24%) due the lack of cleaning the catchment area before the beggning of the rain season.

The assessment of the public awareness through the study area indicate that (58%) of the cisterns owners do not have any knowledge about the potential contaminants of the cisterns, in addition, the absence of environmental or health awareness for citizens about water pollution during the study area, and (70%) of cistern's owner preferred the awareness-raising meetings as appropriate ways to promote environmental awareness on issues related to water pollution.

The overall results for analyzing the random samples through the study area indicate to a high contamination level, especially for microbial parameters. In general these study aim to identifying the current characteristics and conditions of RWH systems and the main causes of pollution in the study area cisterns, also to assessing cisterns water quality in the study area according to local and international standards, and propose the best available tools for raising local citizens' awareness. In addition, the study will explore the best incentive practices which will be able to motivate local citizens toward better practices regarding water pollution.

Chapter One
Introduction

1.1 General Background

Water forms more than two-thirds of earth's surface which is estimated to be about 1,386 million cubic kilometers. However, 97.5 % of the total amount of water is salty water, and nearly 2.5 % is fresh water (Shiklomanov, 2000).

The main sources of water supply that are used to meet population need are surface water which represented in the river, lake, wetland and oceans, and groundwater. Drinking water should be safe for drinking, cooking, irrigation, and washing, it must meeting the physical, chemical, and biological standards when supplied from confirmed resources to meet the demand of consumers in good quality (Zuane, 1997).

As the numbers of the population keep going increase, the pressure on the earth's water resources increasing hugely. High consumption leads to a global pollution problem (Dehghani et al., 2015)

Water is considered as one of the most sensitive and susceptible issues in the whole world in general and in the Middle East countries in particular, where deficient of water resources and the decadence of the available water are impending (Al-Khatib et al., 2003). Assessing the water quality according to the set of standards reference guide, which is used to evaluate water quality related to safe drinking water to people and for their health (Ertud and Mirza, 2010).

Most of the countries in the Middle East are suffering from the lack of efficiency in managing water resources which are leading to degrading the environment and adversely affecting the social life of the individuals. Water demand exceeds the sustainable supply for people, and the situation will be more precarious in the future with increasing the numbers of population and increasing the living standards (Abu-Taleb and Mareschal 1995).

Palestine is suffering from water scarcity and pollution. The major water resources available to the Palestinians in the West Bank are the West Bank Aquifers which are located under the West Bank and are recharged by its rainfall. Due to political complications and Israeli Occupation, Palestinians are not allowed to use more than 15% of their groundwater and are denied access to the Jordan River (Haddad ,1998). According to the World Health Organization (WHO), the minimum amount of water needed per capita per day is estimated about one hundred liters for drinking and households needs. However the average domestic water consumption is 62 liters per capita per day in the West Bank. This is significantly below the per capita domestic water delivery in other countries in the world (World Bank Group, 2018).

The arid and semi-arid Middle East countries such as Palestine are suffering from limited resources of water. The public awareness is now focusing on alternatives such as rainwater catchment systems as supplementary water sources with multi-purpose functions. Rainwater harvesting considered as one of the most favourable choices for providing clean water in the face of expanding the water deficiency and the rapid increasing for demand in the rural areas (Abusafa et al., 2012)

Rainwater Harvesting (RWH) is one of the most ancient practices used in the world to overcome water supply needs (Campisano et al., 2017). It is a technique used for collecting and storing rainwater from the catchment area (rooftops, land surfaces, and road surfaces) by using uncomplicated techniques such as tanks and cistern as well as more compounded techniques such as underground check reservoir (Abdulla and Al-Shareef, 2006).

To ensure the efficiency of RWH systems to meet the need of water supply, it should be sufficient to face the individual's demand, so the catchment area has to be suitable for collection and the rainwater collection efficiency is as high as possible. The collection area should be clean to avoid water contamination to ensure high water quality (Zhu, 2015).

In Palestinian rural areas and some urban areas, RWH is considered as a favorable option to supply water for different purposes such as drinking, irrigation and domestic use. About 32% of Palestinian population still favor RWH as an alternative to collect water in the winter in the cisterns, to be used later in the dry summer months (Almur, 2016).

RWH systems have various advantages such as: i) it provide a safe source of water because rainwater is comparatively clean and safe and can be used for several purposes without any processing, ii) collecting rainwater process is done at the place of water use and water could be used at the same site where it is gathered and stored, iii) negative environmental impacts are fewer than big water reservoirs, and iv) cheap and easily accessible technology is used for harvesting rainwater through the system. Rainwater harvesting is also considered as the fundamental source of water for daily use in different regions during periods of drought in arid and semi-arid regions (Lo and Gould, 2015). However, RWH system has several disadvantages which includes i) the limited supply of water, which is limited by the amount of rainfall, catchment area size and storage capacity of the cistern, ii) also rainwater may be polluted by animal or bird droppings or air pollutants so the quality of water will be affected. In addition, the regular maintenance and continuous cleaning of the cistern is often complicated (Worm, 2006).

1.2 Problem Statement:

Despite the high dependence on RWH system as water supply for drinking or irrigation and other purposes, there is an absence of knowledge about the significance of quality control in these systems. Therefore it is important to re-evaluate the RWH system considering the sources and types of contamination beside the level of public awareness which are related to the sources of pollution in the cisterns.

1.3 Significance of the Study:

This research helps to identify the sources of contamination of cisterns and determine it’s water quality which affects the safe use, that in turn lead to adjust the practices of people to get high quality of water resource supply.

1.4 Research Objectives:

The general objective of the intended study is to assess the quality of water in cisterns in Tubas governorate for drinking purposes. In addition, the study aims to achieve the following specific objectives:

- Identifying the current characteristics and conditions of RWH systems and determining the main causes of pollution in the study area cisterns that directly affecting the water quality.
- Assessing cisterns water quality in the study area according to local and international standards.
- Determine the levels of people's awareness and their related behaviors that lead to water pollution and determine and propose the best available tools for raising local citizens' awareness. In addition, the research will explore the best incentive practices which will be able to motivate local citizens toward better practices regarding water pollution.

1.5 Thesis Organization

The thesis is summarized in six chapters. After this chapter, the thesis proceeds as follows:

- **Chapter 2:Literature Review**

This chapter discusses the several studies conducted on RWH systems, brief information about the water quality of physiochemical and microbial parameters and different case studies which are related to assessing the public awareness towards water pollution in cisterns.

- **Chapter 3: Study Area**

This chapter shows the characterization of the study area such as geography, topography, population, water resources and climate.

- **Chapter 4: Methodology**

This chapter presents the overall methodology which includes: questionnaire distribution, water sampling, and the physiochemical and biological analysis which were adopted to get the results.

- **Chapter 5: Results and Discussion**

This chapter presents the result obtained including the analysis of questionnaires and the obtained laboratory data, and interprets what the results mean.

- **Chapter 6: Conclusion and Recommendations**

This chapter includes a critical explanation covering the results of the study, and the most important recommendations.

Chapter Two

Theoretical Background

2. 1 Rainwater Harvesting System

2.1.1 History of Rain Water Harvesting

Thousands of years ago people have tried to survive in arid and semi-arid regions, by managing vital, scarce water resource. Water harvesting methods formerly developed are nowadays receiving renewed attention because they can contribute to increased water supplies for domestic use, agriculture and for other proposes (Fink and Ehrler, 1978).

RWH as many techniques used nowadays is not new. It was invented and used in 4500 B.C in the area of the Middle East by the people of Ur (in ancient Iraq) and also latest by the Nabateans. On the other hand, the development in the technology in the last century has made it possible to use artificial means for increasing runoff from precipitation so increasing the quantity and quality of collected rainwater for use (Sivanappan, 2006).

2.1.2 Rain Water Harvesting Techniques

Rainwater harvesting is a technique used for collecting and storing rainwater from rooftops and yards by conventional methods such as tanks and cistern. Water harvesting systems provide an ideal solution for supplying water to the small and large sites in order to meet their needs. RWH process has been developed over the time to be used as reliable integrated approach during summer days (Abdulla and Al-Shareef 2009 ; Moglia et al., 2016).

The suitable design and evaluation of (RWH) system is required to enhance the system performance and the stability of the water supply. The main parameters of an RWH system design are rainfall, catchment area, collection efficiency, cistern capacity and water demand (Mun and Han, 2012).

2.1.3 RWH system characterization:

RWH systems are applied in arid and semi-arid regions where rains fall is intermittent. In addition to the systems implementation, the storage of rainwater is considered as integral part of water harvesting (Fink et al., 1979)Moreover, a small-scale techniques are related to the catchment area, volume of storage, and construction costs (Boers and Ben-Asher,1982).

2.1.4 Basic components and principles technique of RWH system:

RWH system consists from three basic components which include (Worm, 2006):

1. Catchment area (roof surface) which is used to collect rainwater.
2. Delivery system to transport the rainwater from the catchment area to the cistern (storage tank) which include gutters and drainpipes.
3. The cistern (storage tank or reservoir) where water is stored until it used.

The main part of the RWH system is the rainwater cistern, where the collected rainwater is stored and treated. Also, the catchment area which is the building rooftop, but other catchment surfaces (normally those closely associated with the building) can be connected to the cistern, gutters, downpipes, and the pump if it used (Campisano et al., 2017).

Collection of rainwater can be categorized into roof-based and land-based. In land-based the rainwater is collected from the land surface and stored in the cistern while in the roof- based the rainwater is collected from the rooftops runoff water which has been prepared for RWH in good quality for drinking and other purposes (Al-Salaymeh, 2008).

During the rainy season, rainwater runoff is transferred to the cistern by the collection system (usually a system of gutters and downpipes) and stored in order to utilize it in indoor or outdoor use. The rainwater cistern is usually connected with a separate pipe to taps for rainwater use. One or more pumps are generally adopted to ensure appropriate pressure head for the different uses (Abbasi, 2011).

2.1.5 RWH Systems Uses:

RWH system supplying a source of drinking water, using water for domestic demands as cleaning and flushing, garden irrigation and other outdoor uses such as car washing. However, the main goal of using RWH system is reducing the consumption of drinking water from centrally supplied sources (Campisano et al., 2017).

The basic factors that could be taken into account for RWH construction are (Bisoyi, 2006):

- Rainfall pattern, intermittent or falling uniformly through the seasons.
- Topography and the nature of the area, whether urban or rural area, arid or semi-arid area and drought or flood area.
- The quantity and intensity of the rainfall.
- Characterization of the soil if permeable or impermeable.

2.1.6 Advantages and Disadvantages of RWH system:

The main advantages of rainwater harvesting systems are; providing a high water quality supply if collected from clean roof-yard systems and cost-effectiveness due to the use of local materials during construction. In addition, RWH systems are also often situated at an accessible and convenient distance from the households where it is reducing operation and maintenance problems and running costs. Relatively limited technical knowledge is required and it is easily understood, and the RWH technique is usually found to be economically, socially and environmentally acceptable. On the other hand the RWH systems disadvantages are mainly related to the limited supply and uncertainty of rainfall. The quality of rainwater may be affected by air pollution, dirt and contaminated organic matter or by animals and birds droppings. In addition, the collected rainwater could cause nutritional deficiencies because it is mineral-free water and people prefer to drink water rich in minerals (Zhu et al., 2004; Abdulla and Al-Shareef, 2006; Sazakli et al., 2007).

2.2 Rainwater Harvesting Characterization

RWH offers considerable potential as an alternative water supply, the main worries is about the purity of harvested rainwater compared to other sources of water (Zhu et al., 2004).

Rainwater harvesting and utilization are considered as an alternative sources in the absence of contaminants and pollution. different external pollution sources affect water quality such as microbiological pathogens or chemical contaminants (Simmons et al., 2001).

The harvested and stored rainwater quality depend on the characteristics of the rain harvesting area including the topography, the exposure to pollution sources, the type of the catchment area, the type of the cistern and the handling with water (Al-Salaymeh, 2008).

Acceptable water quality occurs when it does not have a bad taste or smell and color, there are no microorganisms such as bacteria present that may cause contamination lead to diseases and there is no levels of chemicals exceeded the global or local standards that would cause harm to human health (Mosley, 2005). The quality of the water indicates to the chemical, physical and biological criteria of water. Human activities and natural processes affect water quality which can create a significant risk for human health (Almur, 2016).

The significant scientific parameters which affect water quality used in this study are discussed later.

2.2.1 Physiochemical Water Quality Parameters

The physiochemical quality parameters of water have less attention in water contamination scope rather than microbiology parameters. This is related to the ability of the chemical component to cause adverse health effects after prolonged periods of exposure while the microbial contamination could cause the immediate health problem (Radaideh et al., 2009; De Kwaadsteniet et al., 2013).

A good impression of water quality status is assessed when the physiochemical properties are used. The changes in physical characteristics like temperature, pH, turbidity and chemical elements of water such as nitrate and phosphate provide precious information on the quality of the water and the sources of the variations and their impacts on the human health (Mustapha, 2008)

The major sources of contamination that could affect physiochemical composition of water may occur naturally such as rocks, soils and the effects of the geological setting and climate or by human activities such as industrial and agricultural activities which include mining, manufacturing and processing industries, using of manures and fertilizers, also the intensive animal practices and pesticides (WHO, 2004).

The physiochemical parameters could affect water quality in term of color, taste and smell; water is usually a colorless liquid. Colors can originate from the decomposition of organic matter and leakage of contaminate from sewage, while the taste is classified in three groups of sweet, medium and brackish. Taste in water can be detected by different factors, such as decomposing organic matter, living organisms, iron, mixing industrial waste and the smell in water classified into three classifications of slight smell, no smell and fast smell (Mohsin et al., 2013).

2.2.1.1 pH

pH is the parameter that measures the acidity or basicity of water. It is expressed as the negative logarithm of the hydrogen ions concentration in the solution. It ranges from 0 (very acidic) to 14 (very alkaline) (EPA, 2001). Water with a pH of 7 is considered as neutral while lower than 7 is referred to as acidic and it tends to be toxic and greater than 7 is known as basic and it is turned into bitter taste. pH is considered the most important parameter in determining the corrosive nature of water, so low pH values give high levels of corrosion (Mohsin et al., 2013).

According to PS and WHO standards pH of water should be 6.5 to 8.5 in drinking water (WHO, 2004). Most of chemical reactions are influenced by the pH, which is positively correlated with E.C and total alkalinity (Gupta et al., 2009). On the other hand the pH values control the behavior of other significant parameters of water quality such as ammonia toxicity, chlorine disinfection efficiency, and metal solubility (EPA, 2001)

2.2.1.2 Electrical Conductivity

The electrical conductivity of water is the ability of water to conduct an electric current. In general, the EC is actually used to measure the ionic process of a solution that allow it to transmit current (EPA, 2001; Mohsin, et al., 2013). These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and carbonate compounds (Miller et al., 1988).

As this parameter is related to the ionic content of the sample, it reflects the amount of dissolved solids concentration and salinity in water (TDS). TDS is calculated from a conductivity measurement, by multiplying EC with a TDS factor. This TDS factor depends on the type of solids dissolved in water so it can be changed depending on the water source. Standard Methods for the Examination of Water and Wastewater accepts a TDS factor of (0.55-0.7). This factor must be identified for each water body (EPA, 2001; Eaton et al., 2005).

TDS is originated from sewage and wastewater leakage. Therefore, the TDS parameter is considered as one of the signs to determine the quality of the water (Patil et al., 2012).

Conductivity has a significant correlation with ten parameters such as TDS, pH value, temperature, alkalinity, total hardness, calcium, total solids, chemical oxygen demand, chloride and iron concentration of water (Kumar and Sinha, 2010).

According to the WHO standards, EC value should not exceed 2000 µs/cm, while according to the PS the EC value should not exceed 1500 µs/cm. In addition, the TDS should not exceed 500mg/L in drinking water according to the PS and WHO standards.

2.2.1.3 Turbidity

Turbidity is considered as a good parameter of the water quality, which measure the degree to which the water loses its transparency due to the presence of suspended particulates, by measuring the ability of light to pass through water, the more total suspended solids in the water, the higher degree of turbidity (Bellingham, 2009). Turbidity is measured in Nephelometric Turbidity Unit (NTU) (EPA, 2001).

Turbidity makes the water seem to be cloudy or muddy. The presence of suspended and dissolved matter such as clay, silt, organic matter, algae, plankton, sewage solids, organic acids, and other microorganisms can make the water more turbid (Rasmussen et al., 2005)

In terms of water quality, the temperature of water is increased and dissolved Oxygen is decreased by high levels of. It will also inhibit photosynthesis by blocking sunlight. Also an increase in turbidity can also indicate increased erosion of water body (Rahmanian et al., 2015).

Turbidity measurement is considered a significant issue for determining the type and level of treatment and disinfection needed (WHO, 2004). Suspended particles can be attached on the surface of bacteria and other microbes such as protozoa and viruses, which protect them from disinfection. Turbid water due to the presence of organic or inorganic material cannot be easily disinfected, as the suspended particles will hide these microorganisms. These microbes contribute to waterborne diseases (Langland and Cronin, 2003; Dawood, 2008).

2.2.1.4 Hardness

Hard water is a natural property of water caused by dissolved compounds of calcium and magnesium, and sometimes with other divalent and trivalent metallic elements. The main natural sources of hardness in water are dissolved polyvalent metallic ions from sedimentary rocks, seepage, and runoff from soils (WHO, 2010).

The significant problems caused by water hardness are; preventing soap from lathering by causing the development of an insoluble curdy precipitate in the water, therefore the amount of hardness affect the amount of soap and detergent for cleaning, and it is responsible for most scaling of deposition in pipes and water heaters. Also, the hardness of water may be associated with the incidence of heart diseases (Al-Salaymeh, 2008; WHO, 2010).

Hardness is usually expressed as the equivalent quantity of calcium carbonate (mg/L $CaCO_3$) and according to the PS and WHO standards its value should not exceed 500 mg/L $CaCO_3$ in drinking water (EPA, 2001; WHO, 2004).

2.2.1.5 Calcium

Calcium is very important for human cells physiology and bones and a sufficient intake is important for normal growth and health. The maximum daily need of calcium is (1 - 2) grams and comes especially from dairy products (EPA, 2001; Mohsin et al., 2013).

Despite the potential health benefits of calcium abundance, there are a significant problems associated with hardness. Insufficient intakes of calcium have been correlated with increased risks of osteoporosis, hypertension and stroke, nephrolithiasis (kidney stones), colorectal cancer, coronary artery disease, insulin resistance, and obesity (EPA, 2001; WHO, 2009).

According to the PS and WHO standards calcium value should not exceed 100 mg/L for drinking water (WHO, 2004).

2.2.1.6 Magnesium

Magnesium is considered as the major component of geological formations, one of the most abundant elements on the earth layer, also the fourth most abundant cation in the body and natural constituent of water. It is important need for the proper functioning of living organisms and found in minerals such as dolomite, magnesite etc. Magnesium play a significant role with calcium for increasing the water hardness; also it could affect hypertension, coronary heart disease, and metabolic syndrome (Yang and Chiu, 1999; EPA, 2001; WHO, 2009).

According to WHO standards magnesium value should not exceed 100mg/L for drinking water (WHO, 2004).

2.2.1.7 Alkalinity

Alkalinity is a measure of the capacity of the water to neutralize acids and its called buffer capacity (water ability to resist pH change after the addition of acids and bases) (EPA, 2001).

Alkalinity is the presence of one or more ions in water including hydroxides, carbonates, and bicarbonates. The moderate concentration of alkalinity is preferable in most water supplies to stable the corrosive effects of acidity. However, excessive quantities may cause a number of problems. Alkalinity can be affected by rocks, soils, salts, and industrial wastewater discharge (EPA, 2001; Mohsin et al., 2013).

High alkalinity of water need a higher free residual chlorine level at the end of the contact time for sufficient disinfection chlorination which may be ineffective above pH 9 (WHO, 2004). Alkalinity is measured as milligrams per liter of calcium carbonate mg/L ($CaCO_3$) and according to the WHO standards the alkalinity value should remain belwo 400 mg/L $CaCO_3$ (WHO, 2004; Dawood, 2008).

2.2.1.8 Chloride

Chloride exists in all natural waters in different concentrations varying very widely where it is distributed as salts of sodium (NaCl), potassium (KCl), and calcium ($CaCl_2$) (EPA, 2001; WHO, 2004).

Chloride originate from either natural sources such as decomposition of soil and rock formations and sea spray, or from sewage and industrial effluents, urban runoff and saline intrusion waste discharges, sewage contains large amounts of chloride, as do some industrial effluents (Al-Salaymeh, 2008).

Chloride does not create a significant health hazard to human and the main consideration is in relation to palatability (gives salty taste to water). But high chloride concentration damage metallic pipes and structures as well as damage growing of the plants (EPA, 2001; Karavoltsos et al., 2008). According to the PS and WHO standards chloride value should not exceed 250 mg/L for drinking water (WHO, 2004).

2.2.1.9 Sodium

Sodium is always present in natural waters, it is originated from rocks and soils, and sewage and industrial effluents. Concentrations of sodium compound in water varied depending on geological conditions and wastewater contamination (EPA, 2001).

Sodium is not considered to be harmful. The human body needs sodium in order to maintain blood pressure, control fluid levels and for normal nerve and muscle function. However, the excessive intake leads to hypertension. According to the PS and WHO standards sodium value should not exceed 200 mg/L for drinking water.

2.2.1.10 Potassium

Potassium, which is highly reactive with water, occours in all natural water. It is necessary for body functions where it is found in human and animal tissues and in plants cells (Mohsin et al., 2013).

Potassium is a fundamental component of many pesticides and fertilizers, so the critical issue is correlated with leakage of potassium compounds into water sources when fertilizers are used. In addition, the presence of a high concentration of potassium refers to contaminants that are associated with the presence of leakage from the septic system (EPA, 2001; Al-Salaymeh, 2008). According to the PS the potassium value should not exceeded 12 mg/L and according to the WHO standards it should not exceeded 5 mg/L for drinking water.

2.2.1.11 Nitrate

Nitrate is naturally occurring ions that are part of the nitrogen cycle. The decomposition of organic materials releases ammonia where this ammonia oxidizes to form nitrate (WHO, 2003).

Nitrate can reach to the water supply as a consequence of agricultural activity according to the excess application of inorganic nitrogenous fertilizers and manures, also from sewage and industrial effluents and from leakage of wastewater of septic tanks (Scholefield et al., 1993; WHO, 2003).

Nitrate is considered one of the most important parameters of water quality. The significant health concern regarding nitrate is the formation of methemoglobinemia, which is called (blue-baby syndrome). Nitrate is reduced to nitrite in the stomach of infants, and nitrite is able to oxidize hemoglobin (Hb) to methemoglobin (metHb), which is unable to transport oxygen around the body (Kross et al., 1993; Dawood, 2008).

In addition, high level of nitrate may cause dangerous health effects such as cancer, hypertension, increased infant mortality, central nervous system birth defects, , spontaneous abortions, infections diabetes, and changes to the immune system (WHO, 2003; Fewtrell, 2004).

According to the PS and WHO standards nitrate value should not exceed 10 mg/L as (NO_3 – N) in water to be used for drinking water.

2.2.1.12 Phosphate

Phosphate is present in natural water in different forms of organic and inorganic phosphate including orthophosphate, metaphosphate (or polyphosphate) and organically bound phosphate. Each compound contains phosphorous in a different chemical arrangement (Carr and Neary, 2008; Singh, 2013).

Natural decomposition of rocks and minerals, excess using of pesticides and fertilizers, corrosion and deposition of chemicals, sewage effluents and industrial discharges all of these sources leading to increasing the phosphate concentrations in water supplies (Singh, 2013).

In most water supplies phosphorous is known as limiting nutrient. High concentration of phosphorous promots excessive algae and aquatic vegetation growth which leads to eutrophication of the aqueous system, where it causes water pollution. Such polluted water cannot be recommended even for irrigation (Rao and Prasad, 1997; Singh, 2013).

According to national standards, phosphate value should not exceed 2 mg/L in water to be used for drinking water. The high concentration level of phosphate may damage the kidney and could cause osteoporosis (Bricker, 1972; WHO, 2004).

2.2.1.13 Sulfate

Sulfate occurs naturally in water by the dissolution of salts of sulfuric acid and abundantly found in almost all water bodies (Darbi et al., 2003).

High concentration of sulfate could be related to oxidation of pyrite (Iron sulfide) which resulted from decomposition of sedimentary rocks, industrial drainage, and sewage effluents etc (Mohsin et al., 2013).

sulfate ions present in water in high concentrations may cause temporary and acute effects on humans and animals, including diarrhea. According to the PS and WHO standards, sulfate value should not exceed 200 mg/L in water to be used for drinking water, high concentrations of sulfate ions in water may cause temporary and acute effects on humans and animals, including diarrhea (Backer et al., 2001; WHO, 2004).

2.2.2 Microbial water quality parameter

Contaminated drinking water is a major source of pathogenic microorganisms. The microbial contamination of water supplies present a significant risk to human health (Ashbolt, 2004). The quality of drinking water is a significant issue correlated with health worldwide because water quality has a major impact on health, both through outbreaks of waterborne disease and by contributing to the background rates of disease (Fewtrell and Bartram, 2001; WHO, 2004).

The health risk of infection from drinking polluted water related to the high numbers of pathogenic microorganisms which detected in the contaminated water. However, some microorganisms are naturally present in the water and not normally regarded as pathogens but it may causes disease opportunistically (EPA, 2001; WHO, 2004).

Microbial water pollution caused by pathogens is a serious problem espicially if the concentrations of pathogens from faecal contamination are high and the number of several potential pathogens is large (Moe and Rheingans, 2006; Sharma et al., 2012).

The pathogens may be transmitted into drinking water by different ways such as untreated wastewater, leaching of manure, stormwater runoff, and domestic or wildlife animal feces (Almur, 2016). The pathogenic microorganisms transmitted through water depend on several factors such as the tendency of the microorganism to survival in water and the dose required for susceptible individuals response to the infection (dose-response). Also, the period between the excretion of a pathogen and it's becoming infective to human or other organisms, and microorganisms ability to multiply in an environment (Smith et al., 2013).

The persistence of a pathogen in water is a measure of how rapidly it dies after leaving the body. Actually, the numbers of pathogens introduced will tend to decrease exponentially with time, reacting insignificant and undetectable levels after a particular period. The persistence of the pathogen outside the body for a short time make it trying to rapidly find an anew susceptible host. The persistence of different microorganisms in water is affected by several factors such as sunlight and temperature (Al-Salaymeh, 2008; Pepper et al., 2011).

Collected and stored rainwater in any harvesting system may contain microbial contamination which are derived from the fecal material deposited on catchment area by insects, birds and small mammles and atmospheric deposition environmental organisms (Geldreich et al., 1968).

Contamination of rainwater with microorganisms necessitates developing precise and credible tests on harvested rainwater to evaluate its quality for human consumption, this lead to the development of the concept of indicator organisms as signals of fecal pollution (Dawood, 2008).

2.2.2.1 Indicator Microorganisms

This practice became a developed and accepted practice in the assessment of drinking water quality. The criteria determined for each indicator were that they should not be pathogens themselves and should be as the follows (WHO, 2004):

- The organisms must be universally present in feces of humans and animals in large numbers.
- The organisms most not multiply in natural waters.
- The organisms must persist in water in a similar manner to fecal pathogens.
- The organisms must be present in higher numbers than fecal pathogens.
- The organisms must respond to treatment processes in a similar fashion to fecal pathogens.
- The organisms must be readily detected by simple, inexpensive methods.

Common indicator bacteria include: Total coliform bacteria, fecal coliform, enterococci, and enterococci. In this study total caliform bacteria and fecal coliform bacteria were measured to assess the microbial water quality.

2.2.2.2 Total Coliform Bacteria

Coliform bacteria is a common bacteria in the environment and it is generally harmless. It includes a wide range of aerobic and facultatively anaerobic, Gram-negative, non-spore-forming bacilli and it is rod-shaped. Coliform bacteria susceptible to growing in high concentration environments of bile salts with the fermentation of lactose and production of acid or aldehyde within 24 hours at 35–37 °C (WHO, 2004).

TC bacteria are commonly present in the environment, in soil or vegetation, as well as the intestines of mammals, including humans. Coliform bacteria are improbable to cause illness, however, their presence in drinking water indicates that pathogenic microorganisms could be found in water (WHO, 2004).

TC is a large group of several categories of bacteria, which include; Fecal coliform, which is a type of TC that exist in feces and Escherichia coli (E. coli) , which is a subgroup of fecal coliform (WHO, 2004).

TC can be used as a parameter of treatment effectiveness and to assess the purity and safety of distribution systems. TC should be absent directly after disinfection, and the presence of these microorganisms indicates inadequate treatment (WHO, 2008).

2.2.2.3 Fecal Coliform Bacteria

Fecal Coliform bacteria is also known as thermotolerant coliform bacteria which is a subgroup of TC bacteria that is presents in the intestines and feces of people and animals. FC bacteria is capable to grow at 44.5 °C, also has the ability to ferment lactose at 44–45 °C and has a short life span compared to other bacteria groups (WHO, 2008).

In general, FC does not create a significant health risk to humans, but it indicates the presence of other disease-causing microorganisms, such as those that cause cholera, typhoid, and dysentery. However, fecal coliform is commonly tested in surface and groundwater and it is considered as an indicator of contamination of sewage waste (Dawood, 2008).

E. coli is a subset of the fecal coliform group that can ferment lactose at higher temperatures also produce indole from tryptophan. Coliform bacteria were regarded as belonging to the genera Escherichia, Citrobacter, Klebsiella and Enterobacter, but the group is more heterogeneous and includes a wider range of genera, such as Serratia and Hafnia. The total coliform group includes both faecal and environmental species (WHO, 2004; Smith et al., 2013).

According to the WHO standards the number of TC bacterial colonies allowed is up to 3 cfu/100 while FC colonies is not allowed to appear in the drinking water (WHO, 2004).

2.3 Statistical Analysis

Several statistical methods have been adopted to analyze collected data which makes it easier, the hypothesis testing, the confidence interval, and Grubbs test are used to analysis the results which obtained by analyzing the questionnaire and the physicochemical and microbial analyzing.

2.3.1 Confidence interval on the mean of a normal distribution, variance unknown

There are different random samples with unknown mean μ and unknown variance σ, the random variable :

$$T = \frac{\overline{X} - \mu}{S - \sqrt{n}}$$

Has a t - distribution with n-1 degrees of freedom, where:

$\overline{x}$: the sample mean of a random sample of size n

S: standard deviation of the sample.

n: number of samples.

μ: the mean of the sample.

If the mean and standard deviation of the random sample are (X,s) respectively from a normal distribution with unknown variance σ^2, a **100 (1-α)% confidence interval on μ** is given by :

$$\overline{X} - t_{\alpha/2,\,n\text{-}1}\,{}^{s}/_{\sqrt{n}} \leq \mu \leq \overline{X} + t_{\alpha/2,\,n\text{-}1}\,{}^{s}/_{\sqrt{n}}$$

Where $t_{\alpha/2, n-1}$ is the upper $100\alpha/2$ percentage point of the t - distribution with n-1 degrees of freedom.

The mean of a normal distribution can be simply find by using the suitable lower or upper confidence limit from the last equation above and replacing $t_{\alpha/2,\, n\text{-}1}$ by $t_{\alpha,\, n\text{-}1}$(Montgomery and Runger, 2010).

2.3.2 Hypothesis Testing

many problems need to determine which one of different competing statements about several parameters is true. The statements are called hypotheses, and the decision-making procedure is called hypothesis testing, as well as, there is a significant connection between hypothesis testing and confidence intervals.

The formal definition of a statistical hypothesis is known as a statement about the parameters of one or more populations.

Null hypothesis

A null hypothesis is a type of hypothesis used in statistics that proposes that no statistical significance exists in a set of given observations. The null hypothesis attempts to show that no variation exists between variables or that a single variable is no different than its mean. It is presumed to be true until statistical evidence nullifies it for an alternative hypothesis. This hypothesis is denoted by H_o.

Alternative hypothesis

The alternative hypothesis reflects that there will be an observed effect of the experiment. In a mathematical formulation of the alternative hypothesis, there will typically be an inequality. This hypothesis is denoted by H_1.

The hypothesis-testing process depends on using the data in a random sample from the population of interest. If the data is constant, the hypothesis will be rejected; however, if this information is inconsistent with the hypothesis, the hypothesis is false. This decision process can lead to either of two wrong conclusions :

- Type I Error, it is define as the error which rejecting the null hypothesis (H_o) when it is true.
- Type II Error, it is define as the error which failing to reject the null hypothesis when it is false.

Because our decision is based on random variables, probabilities can be associated with the type I and type II errors.

Probability of Type I Error and it is called the significance level is denoted by the Greek letter α.

$$\alpha = P(type\ \mathrm{I\ Error})$$

A commonly used process in hypothesis testing is to use a type I error or significance level of $\alpha = 0.05$, this value has improved through experiments, and may not be suitable for all cases(Montgomery and Runger, 2010).

2.3.3 *P*-Value

The *P*-value is known as the smallest level of significance that could lead to rejection of the null hypothesis H_o with the specified data, in other words, the *P*-value is the observed significance level(Montgomery and Runger, 2010).

All hypothesis tests ultimately use a p-value to weigh the strength of the evidence. The p-value is a number between 0 and 1 and interpreted in the following way:

- A small p-value (typically ≤ 0.05) indicates strong evidence against the null hypothesis, so you reject the null hypothesis.

- A large p-value (> 0.05) indicates weak evidence against the null hypothesis, so you fail to reject the null hypothesis.

2.3.4 Tests on the Mean of A Normal Distribution,Variance Unknown

If X_1, X_2 ,....., X_n are differant random samples with unknown mean μ and unknown variance σ^2, the random variable is :

$$T = \frac{\overline{X} - \mu}{S - \sqrt{n}}$$

By considering testing the hypotheses

H_o :μ=μ_o

H_1: μ≠μ_o

We will use the **test statistics**:

$$T_o = \frac{\overline{X} - \mu_o}{S - \sqrt{n}}$$

If the null hypothesis is true, T_o has a t distribution with (n – 1) degree of freedom. When the distribution of the test statistic is known, H_o is true and this is often called the null distribution, also the P-value could be calculated from this test statistics (Montgomery and Runger, 2010).

The null hypothesis is attempting to find evidence against in the hypothesis test, if it obtained a small enough p-value which is lower than the level of significance alpha, the null hypothesis will be accepted. If the p-value is greater than alpha, the null hypothesis will be rejected.

2.3.5 Contingency Table Tests

Samples could be classified according to different criteria, It is important to know whether the different methods of classification are statistically independent. The data will arrange in rows and columns in the contingency table to determine if the methods of classification are independent or not.

Contingency table also called two-way table, which is used to show the relationship between different categorical variables. the contingency table considers as a special type of frequency distribution table, where two variables are shown simultaneously.

Testing the hypothesis that the row and column methods of classification are independent. If we reject this hypothesis, we conclude there is some interaction between the two criteria of classification. The exact test procedures are difficult to obtain, but an approximate test statistic is valid for a large number of samples(Montgomery and Runger, 2010).

2.3.6 Grubbs's test

Grubbs's test depends on the assumption of normality, it detects an outlier value of the given samples. This outlier is plot out from the dataset and the test is repeated until no outliers have appeared. However, various repeats modify the probabilities of detection, and the test should not be used for sample sizes of a small number of samples ($n<6$)(Grubbs, 1950).

Grubbs's test is defined for the hypothesis:

H_o: There are no outliers in the data set.

H_a: There is exactly one outlier in the data set.

If p-value ≤ 0.05 it indicates there is an outlier value , so you reject the null hypothesis and accept the alternative hypothesis.

Grubbs test statistic is defined as:

$$G = \frac{\max\limits_{i=1,\ldots,N} |Y_i - \bar{Y}|}{s}$$

with $\bar{Y}$ and s denoting the sample mean and standard deviation, respectively. The Grubbs' test statistic is the largest absolute deviation from the sample mean in units of the sample standard deviation.

Chapter Three
Literture Review

3.1 Previous Studies

Different studies and researches have been conducted to identify the quality of water in the cisterns of the rainwater harvesting system, some of these studies are presented below:

Al-Salaymeh (2008) in his study showed that the water quality for a 100 cistern as a sample in Hebron city in Palestine. The samples were tested for physical, chemical, microbiological parameters. And sources of pollution of these cisterns were studied also by a questionnaire answered by the owner of the cistern. All of the results of physical parameters are within the acceptable limits of WHO, EPA, and PS except turbidity. The percentage of contamination according to the microbial parameters of TC and FC was (95%, 57%) respectively. The results of chemical parameters are within the acceptable limits except calcium and magnesium which exceeded the standards by different percentage (47%, 32%) respectively, the other parameters give results below the maximum contaminant levels, the main objective of the study was assessing the quality of drinking water of cistern in the study area (Hebron city).

Abusafa et al. (2012) studied the assessment of contamination risk of water in rainwater harvesting cisterns to ensure the water quality in Palestinian territories. In this study, 106 cisterns were sampled in 11 villages within 3 districts in the northern West Bank; Jenin, Nablus and Tulkarem, and 176 cistern owners were surveyed. The results indicate that the nitrate concentration and TDS was acceptable to the Palestinian standards, while most the cisterns contained FC, exceeding 8000 CFU/ml in many cases. The cisterns owners' responses indicate a set of wrong practices, which lead to contamination risks. different therapeutic measures have been proposed to mitigate these risks.

Almur (2016) studied the assessment of the quality of rainwater harvesting cisterns for drinking purposes at Sharawiya rural area in Tulkarem - Palestine. Fifty water samples were collected to analyze for physiochemical, microbial parameters (FC and TC), and some heavy metals (Ag ,Cr, Be, Cu, Cd, Co, Ni, Ba, Mn, Al, Zn, Pb, and Fe). The results data of tested physiochemical parameters were within acceptable limits of PS and WHO standards except (4%) of results of nitrate and turbidity, (2%) of alkalinity, (EC) and Ca^{+2} results, and (28%) of Mg^{+2} results exceeded the PS and WHO standards. The percentage of microbiological contamination with TC and FC was (86%, 80%), respectively. All heavy metals were within PS except the iron (Fe) which (33%) of results exceeded the limits. In addition, 100 questionnaires were distributed on the owners of the cisterns in the study area to identify the cisterns characteristic and sources of contamination and their practices which could lead to contamination risk of drinking water. This study aimed to raise public awareness for cistern owners about the best management to get high quality of drinking water from the RWH system.

Dawod (2008) evaluated the quality of water and the health risks which correlated with using untreated rainwater harvested for drinking purposes through roof catchment systems from Qalqilia and Ramallah districts in the West Bank, Palestine. Twenty one water samples were collected and analyzed and tested for microbial and chemical parameters. The potential health risk could occur was determined based on chemical and physical results.

Physical and chemical rainwater parameters were mostly within the WHO standards. In General, tested samples in summer season included higher levels of TDS, salinity and EC compared to samples that were collected and tested in the winter season.

The results also indicate a high percentage of microbial contamination which affects water quality especially if water is to be used for drinking purposes. The chemical parameters are acceptable for HRW samples tested from Qalqilia and Ramallah regions, while the microbial parameters indicate that collected rainwater should be disinfected before being used for drinking purposes.

De Kwaadsteniet et al.(2013) studied the quality of the water, which is being contaminated from anthropogenic sources, agricultural and industrial activities. Domestic rainwater harvesting system, which includes the collection and storage of rainwater from the catchment area, is implemented worldwide as a sustainable source of water. This study used the chemical and microbial parameters for testing rainwater harvesting, with a focus on sources of chemical pollution and major microbial contamination associated with the water source.

Also, he discussed the disease correlated to consumption and utilization of HRW and their health risks and the possible methods which can use for disinfection the harvested rainwater.

Abdulla et al. (2009) showed the evaluation of the importance of rainwater roof harvesting systems for domestic supply in Jordan. The study was conducted to assess the quality of the HRW from the roofs of the houses, the study for the cisterns rainwater quality carried out in Amman and Irbid cities by using chemical and microbial parameters. Also studied the different patterns and design considerations of roof water harvesting systems. In addition, they estimated the maximum amount of rainwater, which may be collected in cisterns using roof catchment systems, and how to improve the quality and quantity of harvested rainwater have been provided.

The present study examines and assesses the quality of water in a cisterns which are used for drinking purposes in the study area, in conjunction with the evaluation of the public environmental awareness, and what are the factors underpinning the pollution of water and what are the approaches will using to reducing it in Tubas governorate as a case study.

This study seeks to provide opportunities for accumulating scientific knowledge within the perspective of a developing country and then urges to promote a policy agenda in the water management system, taking international development into consideration.

Chapter Four
Study Area

4.1Geographical Location

The Governorate of Tubas is located at northeastern side of the West Bank; it is bounded by Nablus Governorate to the west, Jericho Governorate to the south also Jenin Governorate and Armistice Line (1948 borders) to the north and Jordan valley to the east. It is located to the west of Jordan River and south of Bissan plain. Its overall area estimated approximately 440 km^2, which forms eight percent of the Palestinian territories area. It is characterized as a moderately elevated area where its highest elevation reaches up to 495 m over the Sea level at Aqqaba and the lowest high reaches 182 m beneath the sea level at Khirbet Tell el Himma (ARIJ, 2006).

Three localities of them are administrated by municipality councils, six localities managed by village councils and the others are managed by project committees in addition to one refugee camp. The largest locality in Tubas Governorate by area is Tubas city, while the smallest locality by area is Al Far'a Camp (PCBS, 2011).

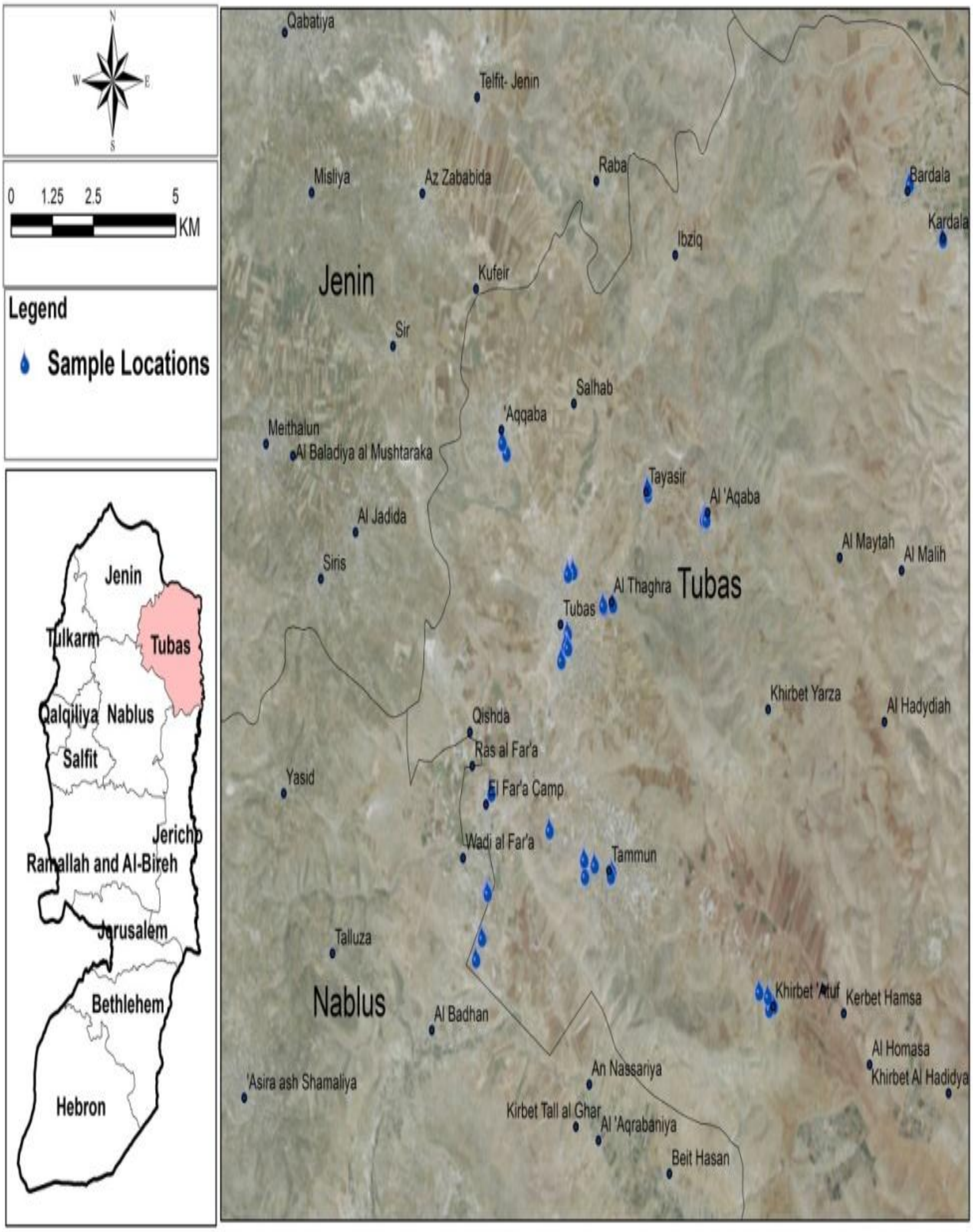

Figure (1) : Geographic Location of Tubas Governorate

The communities located in Tubas governorate are arranged in the Table 1.

Table (1): the communities localized in Tubas governorate.

The Nature of localities	Locality Names
Localities managed by municipality councils.	Tubas city, Tammun and Aqqaba
Localities managed by village councils.	Tayasir, Ras al Far'a, Wadi al-far'a, Kardala, , Bardala, 'Ein el Beida
Refugee Camp.	Al-Far'a Camp
Localities managed by project committees.	Al Farisiya, Al Malih, Al-Hadidiya, Khirbet 'Atuf, Kh ar Ras al Ahmar, Kh Kishda, Al 'Aqaba, Kh Ebziq,Khirbet Humsa, Kh tell el Himma, Khirbet Yarza, Kh Salhab Al Thaghra

Tubas is consider as one of the main agrarian areas in the West Bank and an important source for animal grazing due to the land fertility, and availability of water, where approximately 47% of the Governorate lands are agricultural lands and nearly 37% of the Governorate lands are forests, grazing land, and natural vegetation (ARIJ, 2006).

4.2 Climate and Annual Rainfall

The dominant climate of the study area is the Mediterranean, semi-arid climate, according to the geographic location of Tubas governorate characterized by dry warm in summer and cold rainy in winter (Issa, 2016). The average annual temperature in the governorate is 21°C, and the average annual humidity is 56 % while the average annual rainfall is 329mm (varies between 180 mm in the east to 440 in the west and also varies from one year to another), which is showing in figure 2 for the average annual rainfall map for the West bank and figure 3 for the isoheytal map.

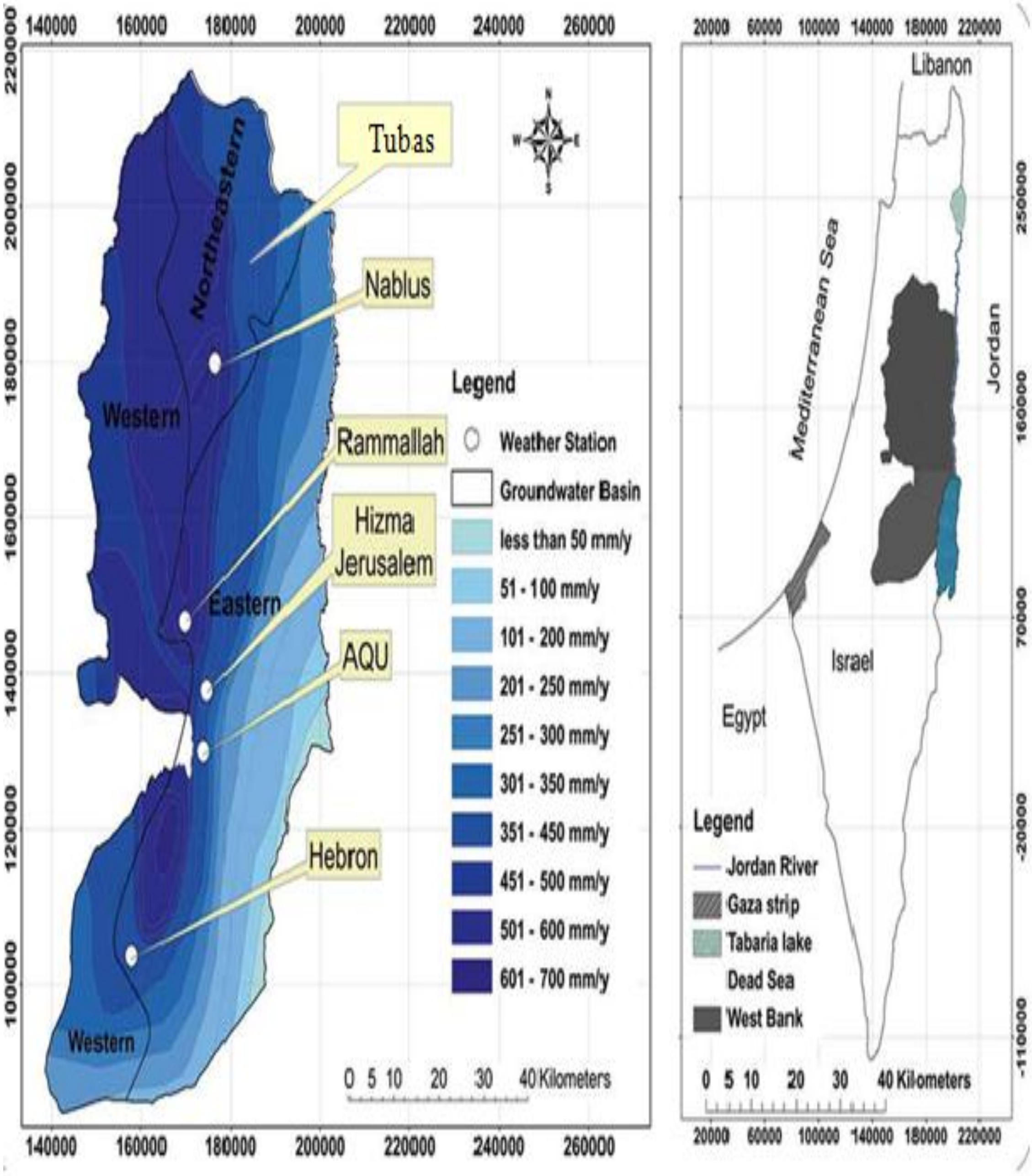

Figure (2): The Average annual rainfall (mm/year) distribution in the West Bank. Palestinian Water Authority, 2006. Ramallah, Palestine.

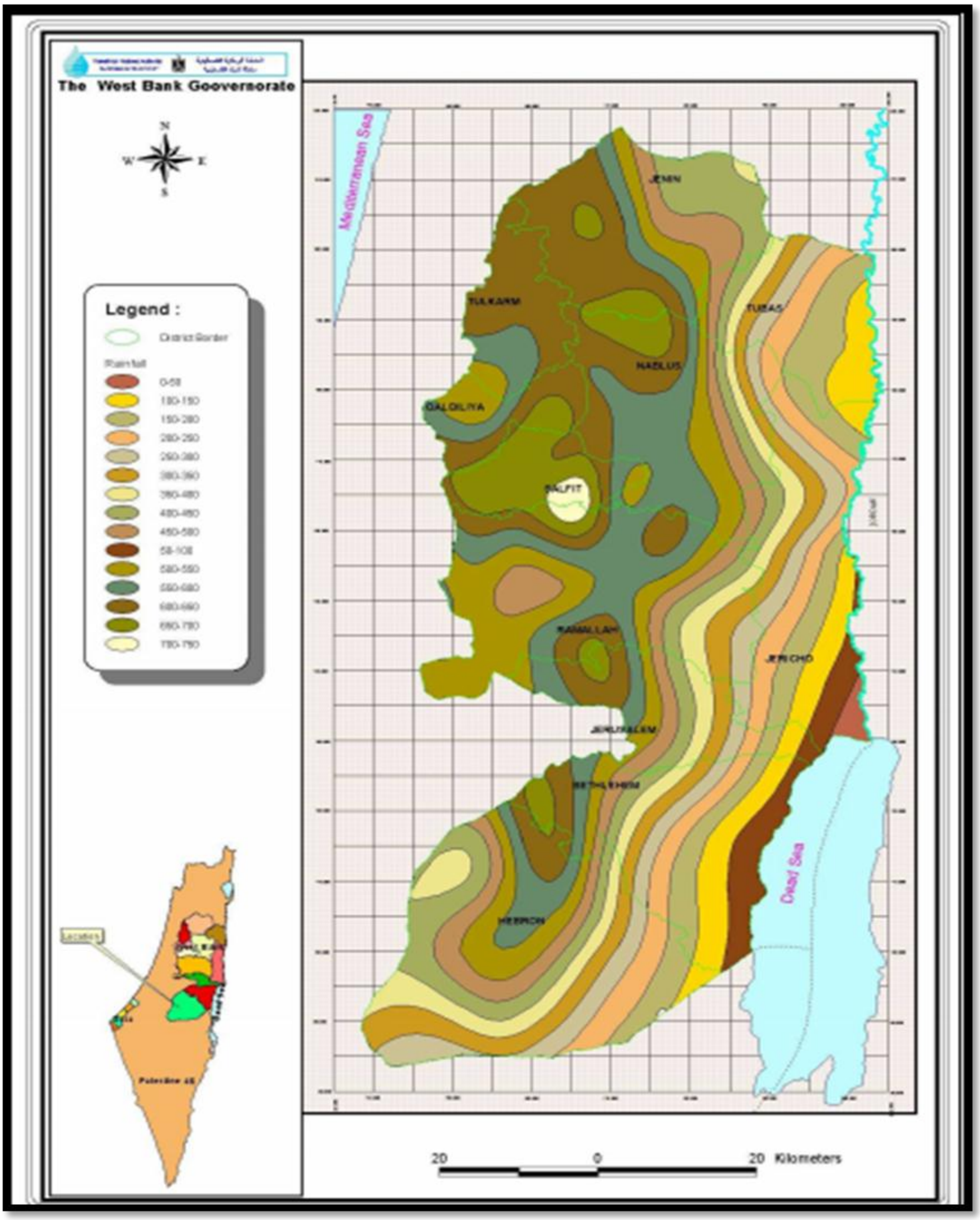

Figure (3): The Isoheytal Map of the West Bank. Palestinian Water Authority, 2012. Ramallah, Palestine.

4.3 Population

The total population of Tubas governorate is (60,399) which is about 1.3 % of the total population of the Palestinian Territory (PCBS, 2017). The population of Tubas Governorate distributed over 23 localities, one locality is urban area (Tubas city), one locality is a refugee camp (Al Far'a Camp) and 21 localities are rural areas (ARIJ, 2006).

4.4 Water Resources

Tubas governorate overlies the Eastern aquifer and a small part located in the Northeastern aquifer. Water resources in Tubas governorate are found as groundwater wells, springs, and additional amounts were supplied mainly through Israeli occupation company (Mekrot). Tubas governorate has only two main water supplying wells; the old well of Tubas municipality with has capacity declining to less than 15 cubic meters per hour (PWA, 2012), and Tammun well that was recently drilled by Palestinian Water Authority (Salameh, 2015).

In Tubas Governorate two main projects for water supply had been completed by (PWA). The first one was the construction of water lines (Fara'a refugee water camp line) and the other one was the construction of water wells (Tammun well, tanks, poster, electronic panel, and vertical well pump) (PWA, 2012). The number of communities in the governorate is 23, including 12 communities that do not have water networks. These communities depend mainly on tankers for transporting water from nearby wells and springs. Tubas governorate has about 21 wells used basically for agricultural purposes and one well used for domestic purposes, which is Tubas water project (PWA, 2012).

4.5 The sanitation system

The collection and treatment of wastewater in the Tubas Governorate is poorly developed. This is also generally status in the West Bank with only a few wastewater treatment plants in operation to date. In the study area, sanitation mainly consists of cesspits or septic tanks that are emptied by private tanker trucks, for further disposal in dedicated or, often, illegal disposal sites. No collection network has ever been operated in the study area (PCPS,2011)

Chapter Five
Methodology

Introduction

To accomplish thesis objectives the research starts with identifying the research problem and selecting the study area. After that, it proceeds with collecting data about the study area in terms of geography, topography, climate, sources of water population and nature of the area, etc. Hypotheses were formed based on the previous literature and theory review, and then questionnaires were prepared to collect the needed data which helps to achieve the objectives of the study.

Water samples were collected parallel to the distribution of questionnaire among the households whom the samples were collected from their cisterns. The collected water samples were analyzed at the Water and Environmental Studies Institute (WESI) labs at An-Najah National University, then the chemical and biological results were compared with global and local standards.

Collected data were analyzed by (XLSTATE18 software, MS- Excel software program, and Minitab 18 software program).

Finally based on the results collected and accessed, some recommendations were recorded is conclude of the thesis.

Overall methodology followed in this study is summarized in Figure (2)

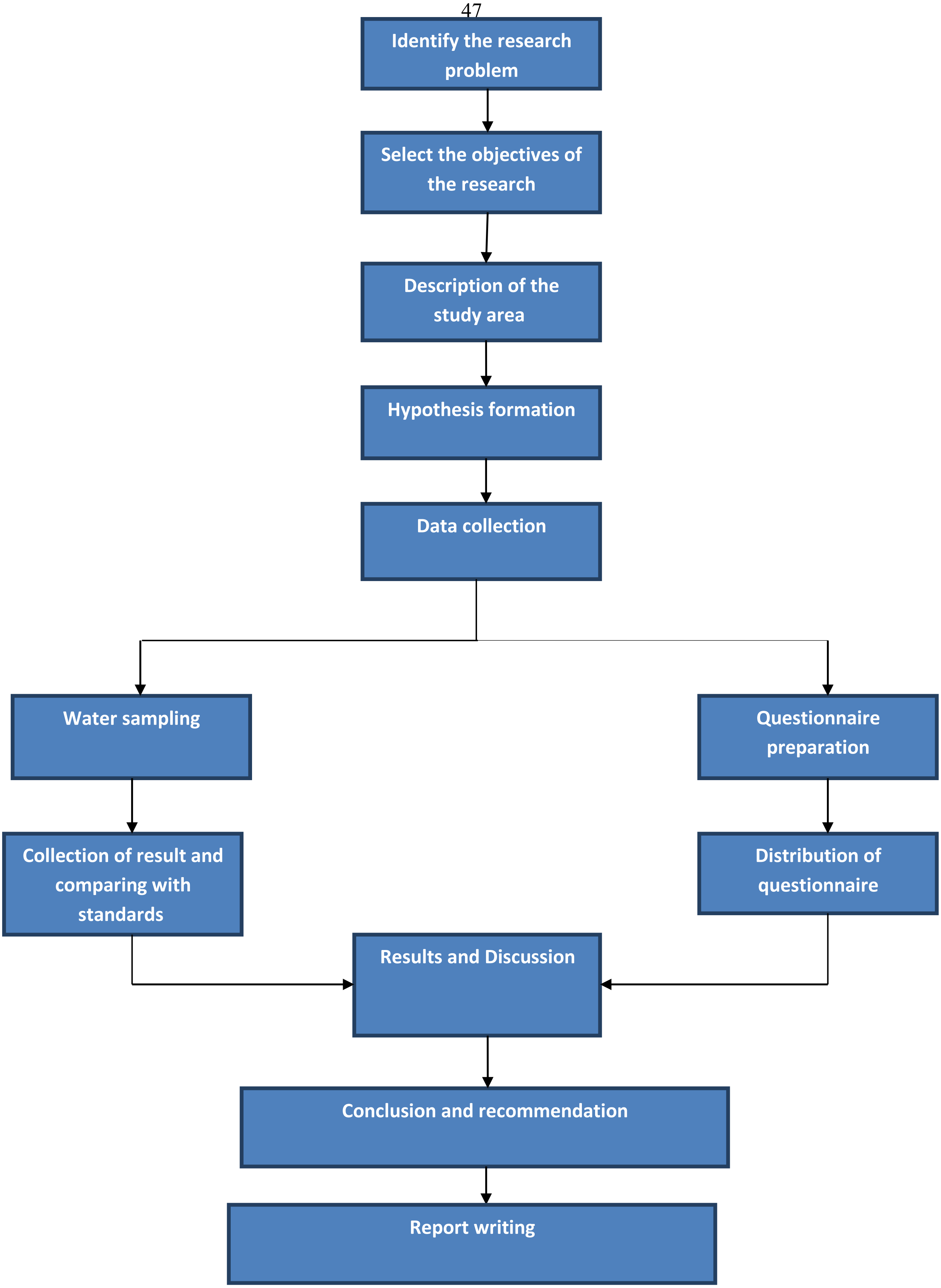

Figure (4): Overall Research Methodology

5.1 The questionnaire

A questionnaire was prepared to assess the awareness of the participants regarding the quality of water in rain harvesting system in the study area to achieve the objectives of the study.

Forty seven same structured questionnaires were distributed to a representative sample of households from which water samples were collected among the study area in Tubas governorate. The owner of the cistern answered the questions in the questionnaire, which was gathered immediately to be analyzed later at the end of sampling.

The questionnaire consists of four sections which include:

1. The first section included questions about social variables of the owner of the cistern such as gender, age, educational level and number of individuals using the cistern.
2. The second section included questions about the cistern characteristics such as age, capacity, and shape of cistern, environment surrounding the cisterns, the water supply system and waste water disposal system in the study area.
3. The third section included questions to assess the behavior of individuals who own the cistern.
4. The fourth section included questions to assess the environmental awareness of individuals about the water pollution.

   A sample of the questionnaire can be found in Appendix (A).

5.2 Samples design and distribution

Samples were collected randomly from 47 cisterns at selected sites from 11 rural areas and 1 urban area in the in Tubas Governorate (Table1) during the period from July 26, 2018 until August 16, 2018, this period where the collecting of rainfall is stopping, and the collected water from the rainy seasons is using as a source of water, also the microbial growth is will be more active according to the increasing of the surrounding temperature. Figure (3) shows the spatial distribution of cisterns which samples were collected.

One and a half liter samples were collected from the cisterns either manually or by an electric pump and then filled in sterile clean plastic bottle for microbial and physiochemical analysis. Then each bottle of sample was labeled .Samples that collected were transferred directly in the same day to the laboratories of Water and Environmental Studies Institute (WESI) of An-Najah National University for analysis. Samples distribution from each site in Tubas Governorate are shown in table (2) and described spatially in figure (3).

Table (2): the distributed samples from each site in the Tubas Governorate

Name of area	No. of Samples
Al'Aqaba	4
Al Thaghra	4
Aqqaba	4
Bardala	1
Kardala	1
Khirbet Atouf	4
Ras al-far'a	1
Tammun	9
Tayasir	4
Tubas	10
Wadi al-far'a	5

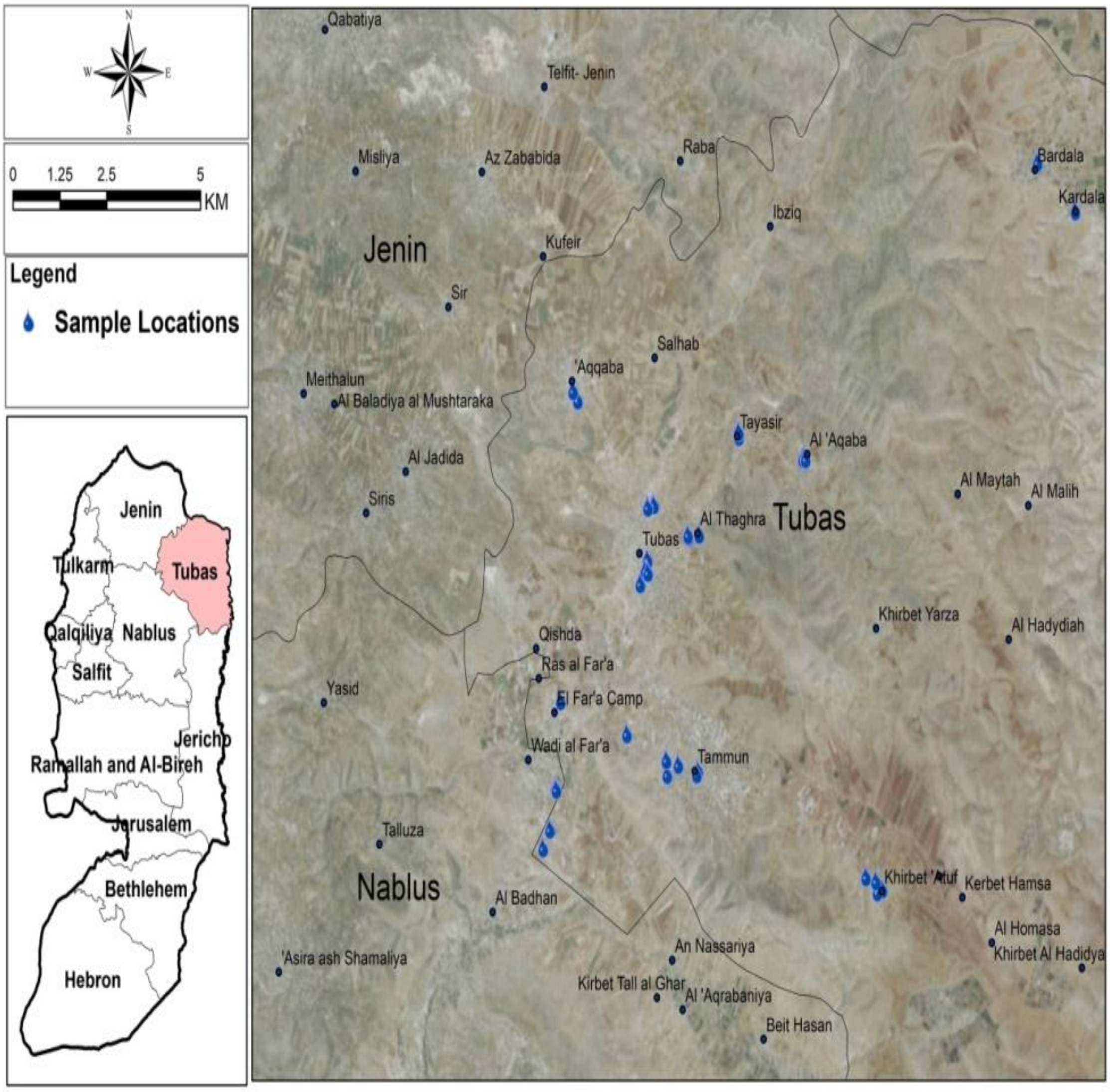

Figure (5): the spatial distribution of cisterns from which samples were collected.

5.3 Water Quality Analysis

The collected samples were analyzed according to chemica, physical, and microbial parameters. The laboratory analysis included measurements of (pH, Total Dissolve Solids, Turbidity, Nitrate, Chloride, Hardness, Calcium, Magnesium, Bicarbonate, Sulfate, Phosphate) and the microbial analysis which included (Fecal coliform and Total Coliform).

5.3.1The chemical parameter analysis

Chemical analysis includes measuring of main anions such as:

- Nitrate, which measured by two methods. Most of the samples were tested using Hanna Colour Meter and the others were tested by the Hanna Nitrate-Nitrogen Portable Photometer by using a specific reagent added to the samples.
- Sulfate and phosphate were measured using HACH spectrophotometer by using a specific reagent added to the measured sample.
- Chloride ion was analyzed by titration with silver nitrate using potassium chromate indicator.
- Bicarbonate was analyzed by titration with sulfuric acid and using Phenolphthalein as indicator.
- Calcium and hardness were analyzed by titration with EDTA (Ethylene Diamine Tetra Acetic Acid) using Eriochrome Black T (EBT) indicator, in the case of measuring Ca ions, the concentration of Ca ions calculated by titrating the samples with EDTA and adding drops of sodium hydroxide to precipitate the Mg ions and left the Ca ions. The second titration was to calculate the total hardness which equals to the sum of Ca and Mg ions.
- Sodium and potassium cations were analyzed using flame photometer.

5.3.1.1 Titration method

Titration method is a common method of quantitative analysis which is used to determine the concentration of known reactant. Titration technique depends on gradual addition of reagent to the sample which contains the analyte of choice. When all the analyte react with the reagent then the reagent reacts with the indicator and changes its color to give the end point. For example in case of Bicarbonate determination, sulfuric acid reacts with bicarbonate until it is exhausted from the sample and then react with Phenolphthalein the indicator to give pink color, the other titration methods were used shown in the table (3) .

Table (3): Chemical methods for testing samples in laboratory (Greenberg et al., 1992).

Test	Method Name	Method Principle
Chloride	Argenometric Method	Titration with standard $AgNO_3$ and K_2CrO_4 as indicator.
Bicarbonate	Titration method	Titration with sulfuric acid and using Phenolphthalein as indicator.
Calcium	EDTA Titrimetric	Titration with EDTA and Murexide as indicator
Magnesium	EDTA Titrimetric	Difference between total hardness and Calcium.
Total Hardness	EDTA Titrimetric	Titration with EDTA and Eriochrome Black T as indicator

5.3.2 The physical parameter analysis

The physical analysis including the pH, Total Dissolve Solids, Turbidity, Electrical conductivity was testing by using different lab apparatus showed in table (4) in addition to other apparatus for chemical analysis.

Table (4): The apparatus used for testing physical parameters.

Tests	Apparatus used
pH	pH-meter
Electrical conductivity (EC)	Electrical conductivity meter
Total dissolve substances (T.D.S)	Electrical conductivity meter
Turbidity	Turbidimeter
Nitrate	Nitrate meter (colorimeter)
Sulfate and Phosphate	Spectrophotometer
Sodium and Potassium	Flame photometer

5.3.3 The microbial analysis

In addition to the previous physicochemical analysis, the samples were tested for microbial analysis which including total coliform bacteria and fecal coliform bacteria using filter membrane method.

5.3.3.1 Filter membrane method

Filter membrane method is an effective, accepted method for testing fluid samples for microbiological contamination. It is a common method used in laboratories(Li and Liu, 2019). First 100 ml of samples were filtered immediately through 0.45 micron pore size cellulose nitrate membrane for each Total Coliform and Fecal Coliform test. In addition 1ml of tested sample diluted in 100 ml of distilled water and filtered for Total Coliform test. Then the vacuum is applied and the sample is drawn throw the filter membrane. After that filter membrane is incubated in the identical culture media Petri dish, then it is transferred into incubator at the proper temperature of 37°C and for the appropriate time period of approximately 24 hours to allow the growth of bacteria into colonies, then colonies were counted. Total Coliform were identified as red colony with metallic sheen, and Fecal Coliform as blue colony.

5.4 The local and global standards for drinking water

The obtained water analysis results were collected and arranged to be compared with global and local drinking water standards. For example the standards which were used in this study including the World Health

Organization standards (WHO, 2004) and Palestinian standards (PS, 2004; 2005). Table (5) shows the physiochemical and microbial water quality parameters with WHO and PS standards.

Table (5): WHO and PS standards of drinking water(PSI 2004; WHO 2004)

Parameter	PS standards	WHO standards
pH	6.5-8.5	6.5-8.5
TDS (mg/L)	Up to 500	Up to 500
Turbidity (NTU)	5	5
Nitrate (mg/L)	45	50
Chloride (mg/L)	Up to 250	Up to 250
Hardness (mg/L) $CaCO_3$	500	Up to 500
Calcium (mg/L)	Up to 100	Up to 100
Magnesium(mg/L)	Up to 100	Up to 100
Bicarbonate (HCO_3) (mg/L)	600	-
Sulfate (mg/L)	200	200
Phosphate (mg/L)	2	-
Sodium (mg/L)	200	200
Potassium (mg/L)	12	5
Fecal coliform colonies (CFU/100ml)	0	0
Total coliform colonies (CFU/100ml)	<3	3

Chapter Six

Results and Discussion

This chapter shows the obtained results of the physicochemical analysis, microbial analysis, the questionnaire analysis, and the statistical analysis which were applied to the obtained results from lab testing and questionnaire analysis. In addition, it will discuss the causes of contamination, and the expected health risk for the available pollutant. Also, it will explain statistically the relations between different variables, and the exceeded parameters for the tested samples.

All of the obtained results are consider as the best tool to set the recommendations which helping for developing the current situation

6.1 Personal data of the owners of the cisterns

Samples were collected from 47 cisterns, most of the owner of the cistern are male(85%)of the total samples, the average age of the owners of cisterns was from 41 years to 60 years which consist approximately 49% of total samples.

Most of the people interviewed have elementary and secondary education (36%), (28%) respectively. According to the collected data by questionnaires the most ratio of the of individuals using the cistern in each cistern was from 1 to 10 persons which estimated by 87% of the total samples.

6.2 Cistern Characterization and Conditions

This section include the description of characteristics and features of the cisterns in term of age, shape, size, capacity, construction material, source of water type, the surrounding environment, type of wastewater disposal system, water uses, elevation difference between cistern and wastewater disposal system, the presence of plants and animals near the cistern and other factors that affect water quality of cisterns.

6.2.1Age of cistern

According to the collected data by questionnaires, the results show about more than half of samples (51%) have an age of (0-20) years. Also (2.13%) have an age of (81-100) years, also (2.13%) for cisterns their age over 100 years. Figure (4) show the cistern age in the study Area.

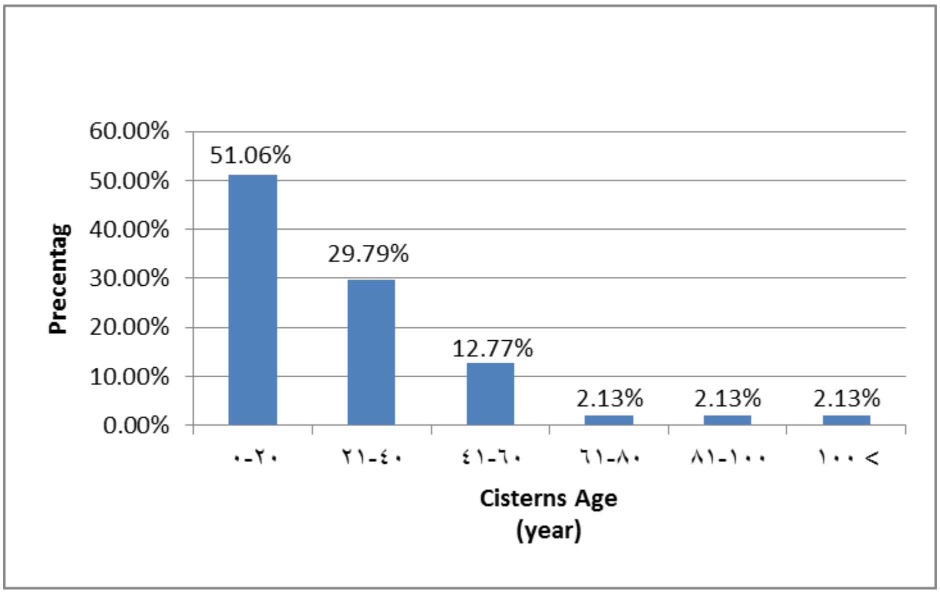

Figure (6): Age of the tested cisterns in Tubas Governorate

6.2.2 The shape of the Cistern

The shape of the cistern either be cubic or pears like, the ratio of the cubic cistern in the study area was(28%) while the ratio of pears like shape was (72%). The cistern size should be suitable to store the sufficient amount of water for using it as needed, the cistern size is depending on the depth and capacity, which is related to them in direct relation.

6.2.3 The Depth of the Cistern

The results show that the highest percentage of cistern (55%) has a depth from (6-10) meters, followed by the depth from (0-5) meters which were (36%). Figure (5) show the depth of cistern in the study area.

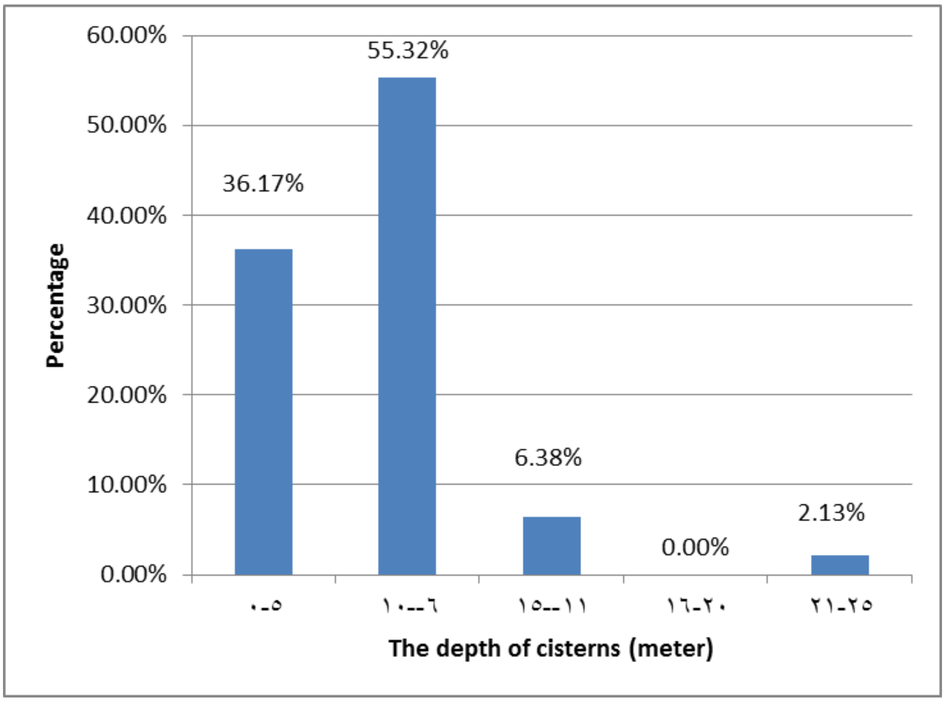

Figure (7): The depth of the tested cisterns in Tubas Governorate

6.2.4 Cistern capacity

The results show that (36%) of the cistern have a capacity less than 30 cubic meters also the same percentage obtained for the capacity between (30-50) cubic meter, and (28%)for cistern with more than 50 cubic meter capacity.

6.2.5 Construction Material

The results show that (92%) of people using cement as construction material so this indicates that cement is the most common construction material and it is considered one of the best materials used in cisterns and the most suitable for insulation conditions. (92%) of cistern were using a metal door while the rest samples using a wooden door to close the cistern.

6.2.6 Source of Water supply

The results show that (89%) of cistern depend on rainwater only as water supply while the rest of cistern using a mix of municipal water and rainwater.

6.2.7 Catchment Area of the Cistern

The results show that most of the cisterns using the roof of the houses as catchment area (89%) of cisterns, while the others using the yard of the houses to catch rainwater.

6.2.8 The water extraction method from the cistern

The extraction of water either be manually or by a pump, through the study area (55%) of the owners of the cisterns were using a pump to extract water from the cistern while(45%) were extracting the water manually.

6.2.9 The cistern location at home

The location of cistern is affect the water quality so the location of cistern should be away from any septic tank or any sewage disposal system to avoid contamination of water in the cistern, in the study area (55%) of cistern are located in the yard of the house, while (30%) of cistern located in the lower construction and (15%) located close to the house.

6.2.10 Waste Water Disposal System

The results showed that septic system is the main wastewater system used in the study area, which represents (87%) of total samples, while about (13%) are using the cesspit tanks as wastewater system, and it has been observed absence of public sanitary services systems through the study area. The level of elevation of cistern according to wastewater system is summarized in the table (6) below :

Table (6): The cistern level according to wastewater system.

The level of elevation of cistern according to wastewater system	Percentage
The cistern level higher than wastewater system	72%
In the same level	11%
The cistern level lower than wastewater system	17%

6.2.11 Water Uses

The results show that 64% of the cisterns owner in the study area using the water in an intermittent way while the others using it continuously. 55% of the owner of the cistern in the study area are using water for drinking and food preparation, and 28% using it for agriculture purposes, table 7 explained, in particular the using of water during the study area:

Table (7) :the purposes of using cistern water

Water Using Purposes	Percentage
Drinking and food preparation	55%
Agricultural purposes	28%
Cleaning purposes (domestic cleaning)	6%
Other purposes such as using it for ranching	9%
Don’t used water in the cistern	2%

6.2.12 The existence of plants, animals, and livestock near the well

Table (8) summarizes some information about the presence of plants or trees and animals near the cistern.

Table (8): The percentages of the presence of animal or plant near the cistern.

Factor	Answer	Percentage (%)
The presence of pets and animals in house	Yes	17
	No	83
The presence of plants and trees near the cistern (agricultural activities)	Yes	66
	No	34

6.3 Effect of cistern owners behavior on water quality

The results of questionnaire analysis indicate that the behaviors of cisterns owners affecting on the water quality of cisterns such as cleaning the cistern before collection and storing rainwater, flushing the first storm away and water disinfection of cistern or periodic testing of water quality in specialized laboratories. Table (9) summarizes some information about the cisterns owners behaviors that can affect the water quality and their sanitation practices.

Table (9): Factors that affect the water quality of cistern

Factors	Answer	Percentage (%)
Cleaning the catchment area before rainwater harvesting	Yes	6
	Often	70
	Occasionally	11
	No	13
Periodic cleaning up of cistern	Yes	45
	Often	47
	Occasionally	0
	No	8
Disposal of rainwater in the cistern of the previous season	Yes	47
	Often	9
	Occasionally	10
	No	34
Flushing the first storm away	Yes	47
	No	53
Examination of water quality by laboratory analysis	Yes	13
	No	87
Water disinfection of cistern	Yes	13
	Often	17
	Occasionally	32
	No	38
Using water from the cistern	Directly	57

directly or pumped it for the tank and then used it	Pumped it then used	43
Ensuring that cisterns door is securely closed	Yes	96
	No	4
There is periodic maintenance for the cistern	Yes	38
	Often	17
	Occasionally	23
	No	22

6.4 Assessing the public awareness of cisterns owners regarding water pollution of the RWH system.

42% of the cisterns owner have knowledge about the contaminants that may contaminate the cistern while the rest answers show that they had no information about the contamination of RW in cisterns. In addition according to the results of analyzing the questionnaire, it has been shown that there is no environmental or health concerns about citizens by the competent authorities about water pollution during the study area .

Based on the results obtained by the questionnaires in the section of assessing the awareness of the cisterns owners about the methods that can be used from their point of view to reduce contamination, most of the answers were cleaning the surface of the house or the house yard and the entryway of the cistern also cleaning the cistern itself, keeping the door closed tightly and disinfected the rainwater in the cistern by chlorine.

The results show that (70%) of cistern's owner preferred the awareness-raising meetings as appropriate way to promote environmental awareness on issues related to water pollution while (19%) preferred the distribution of awareness leaflets and brochures and the rest favored using social media as appropriate way.

And for the ability of individuals to attend awareness-meetings, (75%) of the cisterns owner in the study area they have a desire to attend meetings to raising their public awareness about water pollution.

6.5 Analytical testing of physicochemical and microbial parameters of the tested cisterns in Tubas Governorate.

6.5.1 The descriptive statistics of physicochemical and microbial water quality

The descriptive statistics such as; minimum, maximum, average and the standard deviation) of physicochemical and microbial water quality parameters tested cisterns in the study area are shown in the table (10).

Table (10): The descriptive statistics of physicochemical and microbial water quality .

Parameters	Confidence level (95%)	Minimum	Maximum	Average	Std. deviation
pH	0.12	8.04	8.29	8.17	0.42
TDS	30.12	196.46	256.69	226.58	102.57
Turbidity (NTU)	0.96	0.68	2.59	1.64	3.26
Nitrate (mg/L)	1.88	6.05	9.83	7.95	6.43
Chloride (mg/L)	5.25	31.94	42.45	37.20	17.89
Hardness (mg/L)	12.80	101.6	127.28	114.48	43.59
Calcium (mg/L)	3.16	31.9	38.24	35.08	10.77
Magnesium (mg/l)	10.6	68.8	90.00	79.4	35.6
Alkalinity (mg/L)	13.47	73.18	100.13	86.66	45.89
Sulfate (mg/L)	6.50	15.39	28.41	21.91	22.17
Phosphate (mg/L)	0.55	0.63	1.73	1.18	1.88
Sodium (mg/L)	3.35	16.57	23.29	19.94	11.44
Potassium (mg/L)	1.15	3.69	6.00	4.85	3.93
Fecal Coliform colonies(cfu/100ml)	384.88	148.77	918.54	533.66	1310.85
Total Coliform colonies(cfu/1ml)	227.79	383.56	839.16	611.36	775.85

Table (11): Average results of analytical testing of physicochemical and microbial parameters of the tested cisterns in Tubas Governorate with PS and WHO standards of drinking water.

Name of area	No. of sample	Parameters														
		pH	EC	TDS	Turbidity	Hardness	Ca^{2+}	Mg^{2+}	Alkalinity	Cl^{-1}	Na^{+1}	K^{+1}	NO_3^{-1}	PO_4^{-1}	SO_4^{-1}	FC	TC
Tubas	10	8.2	347.2	222.2	3.2	96.3	33.77	62.53	77.5	32.31	19.8	7.2	7.1	1.5	21.7	200.1	218.6
Tammun	9	8.2	324	210.6	1.9	114.8	35.5	79.3	95.1	33.8	20.7	3.3	6.1	1.4	18.7	429.6	623.1
Aqqaba	4	7.8	406.2	264	0.5	164.97	47.2	117.77	167.3	37.7	22.5	2.3	6	0.12	2.4	303.8	515.5
Tayasir	4	8.1	308.5	200.5	1.6	110.8	31.6	79.2	90.5	30.1	15.1	5.6	4.6	0.11	25.8	49.5	788.75
Ras al Far'a	2	7.9	340	221	0.75	100.65	39.3	61.35	107.7	26.3	22.9	3.8	4.5	1.68	19.3	169.5	457.5
Wadi al-far'a	4	8.15	288.3	184.5	1.3	83.6	31.5	52.1	60.1	30.1	12.2	7.5	8.3	2.08	10.2	2017.5	1790
Kardala	1	8.74	312.3	203	0.46	125	32	93	76	44.5	24.1	6	22.4	2.13	23.3	23	2000
Bardala	1	7.8	471.1	306.2	0.42	183	60	123	75	79.2	53	2	23	0.14	129.1	0	0
Khirbet 'Atuf	4	8.06	460.7	299.5	1.7	134.5	37.9	96.6	67.3	65.6	28.3	6	15.5	0.14	29.95	893.75	525
Al 'Aqaba	4	8.2	265.5	172.6	0.8	79.1	22.65	56.45	41.8	28.6	10.8	4.25	3.4	0.25	19.87	188.25	127.5
Al- Thaghra	4	8.47	421.6	274.03	0.43	145.8	34.22	111.58	92	44.1	18.5	2	10.4	2.8	24.9	15.25	288.3
Standards	PS	6.5-8.5	1500	500	5	500	100	100	400	250	200	12	50	2	200	0	3
	WHO	6.5-8.5	2000	500	5	500	100	100	-	250	200	5	45	-	200	0	3

The obtained results of the tested water cisterns for physicochemical and microbial parameters that were showing in tables (10) and (11) discussed in some details to determine if the obtained results are acceptable for drinking purposes and comparing it with the local and global standards.

6.5.1.1 Physicochemical Water quality

6.5.1.1.1pH

According to analyzing results regarding pH value, the obtained value range between 8.04 and 8.29 with a mean value of 8.17. This refers to the basicity of harvested rainwater. 17% of total samples their pH value exceeded the Palestinian and WHO standards limits. while the other samples have pH in the standards range.

Higher pH levels have been observed in rainwater stored in cisterns could be related to the construction material of the cistern especially if it constructed from cement (De Kwaadsteniet et al., 2013), leaching of calcium carbonate from the concrete walls of the cistern affecting on pH value of stored rainwater in the cistern, using cement as construction materials could be the main causes of raising the pH value(Zhu et al., 2004). Also it could be due to the presence of alkaline particles, which had accumulated on the catchment area such as organic rubbish, clays and mineral particles(Abusafa et al., 2012).

6.5.1.1.2 TDS

The total dissolve solids (TDS) values were in the range (196.46mg/L and 256.69 mg/L), and with mean value of 226.58 mg/L.

Almost (2%) of all sampled cistern exceeded the limits of Palestinian and WHO standards while the rest of samples are within the desirable limits of the standards.

TDS can be obtained by multiplying the EC value by a factor which is usually between(0.55 and 0.75). TDS measure the existence of all anions and cations in drinking water. TDS is not very critical for health issues, high TDS value could be related to the leak of salts from rocks and soils or pesticides and fertilizers to the stored rainwater in the cistern (Al-Salaymeh, 2008).

6.5.1.1.3 Turbidity

The turbidity results range between 0.68 NTU and 2.59 NTU with a mean value of 1.67NTU, (4%) of total samples there turbidity value are more than (5NTU) which exceedes the PS and WHO standards.

The high value of turbidity related to the appearance of suspended particles in the water such as algal growth inside and around the cistern and it could be caused by the existence of different materials, organic or inorganic(Hauser, 2002).

6.5.1.1.4 Nitrate

The results of nitrate value range between 6.05 mg/ L and 9.83 mg/L with a mean value of 7.95 mg/L. No results exceeded the PS and WHO standards.

6.5.1.1.5 Chloride

The results of chloride value range between 31.94 mg/L and 42.45 mg/L with a mean value of 37.20 mg/L. 85% of result range between 0-50 mg/L (very low concentration) and no results exceeded the PS and WHO standards.

6.5.1.1.6 Hardness

The results of hardness range between 101.6 mg/L and 127.28 mg/L with a mean value 114.48 mg/L. No results exceeded the PS and WHO standards.

Table (12) shows the classification of water based on hardness of water in cistern at Tubas Governorate(UNICEF, 2008):

Table (12): The classification of water based on hardness of water in cistern at Tubas Governorate

Classification	Hardness as $CaCo_3$ (mg/L)	Percentage of samples
Soft	0-60	4%
Moderately Hard	61-120	62%
Hard	121-180	23%
VeryHard	> 180	11%

6.5.1.1.7 Calcium

The results of calcium range between 31.19mg/L and 38.24mg/L with a mean value of 35.08 mg/L. No results exceed the PS and WHO standards .

6.5.1.1.8 Magnesium

The results of magnesium range between 68.8mg/L and 90mg/L with a mean value of 79.4mg/L .Results show that (21%) of tested samples exceed the PS and WHO standards, high concentration of magnesium in drinking water causes a significant health effect which could affect on hypertension and could cause abdomen problem(Yang and Chiu, 1999).

High concentration of Calcium and Magnesium increasing the hardness of water, hardness is a property of water that is not a health concern, but it can be a discomfort. Hard water can cause mineral accumulation in pipes and water cisterns, and poor performance of soaps and detergents(Lanz and Provins, 2016).

6.5.1.1.9 Alkalinity (as Bicarbonate)

The results of alkalinity range between 73.18 mg/L and 100.13mg/L with a mean value of 86.66 mg/L. No results of alkalinity exceed the Palestinian standards.

6.5.1.1.10 Sulfate

The results of sulfate range between 15.39mg/L and 28.41 mg/L with a mean value of 21.91mg/L. The values of sulfate do not exceeded the PS or the WHO standards.

6.5.1.1.11 Phosphate

The results of phosphate range between 0.63 mg/L and 1.73 mg/L with a mean value of 1.18mg/L. Results show that (28%) of tested samples exceeded the PS while the same percentage of tested sampled nearly have no phosphate and the rest samples are in the range of standards limits.

Excessive concentration of phosphorus in water is usually known as limiting nutrient, which causes water pollution by promoting the algae growth and chlorophyll levels (Leidy and Morris, 1991).

High concentration of phosphate could be related to the leakage of wastewater from wastewater disposal system used in the house especially if the septic system using as a wastewater disposal system, or from sewage leak, animal waste, soil erosion and fertilizers used (Sharpley et al., 1994).

6.5.1.1.12 Sodium

The results of sodium range between 16.57 mg/L and 23.29 mg/L with a mean value of 19.44 mg/L. No results of sodium exceed the PS and WHO standards.

6.5.1.1.13 Potassium

The results of potassium range between 3.69 mg/L and 6 mg/L with a mean value of 4.85 mg/L. Results show that (30%) of tested samples exceeded the PS while (4%) of total samples exceededed the WHO standards.

High concentration of potassium is considered as a contaminate associated with the presence of septic system or it related to the pesticides and fertilizers used (Al-Salaymeh, 2008).

6.5.1.2 Microbial Water Quality

6.5.1.2.1 Fecal coliform

The results of the FC tests show that most of the results have coliforms contamination, (92%) of results exceeding the PS and WHO standards and contaminated by FC colonies.

6.5.1.2.2 Total Coliform

The result of TC tests show that most of the results have coliforms contamination, (98%) of results exceeding the PS and WHO standards.

The tested samples considered heavily contaminated with microbes and should disinfected before using for different purposes.

Table (13): Range of Fecal Coliform with percentage of contaminated cisterns and degree of contamination (WHO, 2004) .

Fecal Coliform			
Range (cfu/100mL)	**Number of positive samples**	**Percentage (%)**	**Degree of contamination**
0*	4	8	No Risk
1-10	9	19	Simple Risk
11-100	18	39	Moderate Risk
101-1000	12	26	High Risk
>1000	4	8	Very High Risk

*: within the limits of PS and WHO standards.

The results indicate the highest percentage of risk for FC tests for the third degree of contamination (39%) that have FC range between(11-100) (cfu/100ml) which is classified as" Moderate Risk" and followed by the fourth degree of contamination (26%) that have FC range between (101-1000) (cfu/100mL) which classified as" High Risk "

Table (14): Range of Total Coliform with percentage of contaminated cisterns and degree of contamination (WHO, 2004).

Total Coliform			
Range (cfu/ml)	**Number of positive samples**	**Percentage (%)**	**Degree of contamination**
0 - .03*	1	2	No Risk
0.04 -0.5	0	0	Simple Risk
0.51-100	14	30	Moderate Risk
101- 500	15	32	High Risk
>500	17	36	Very High Risk

*: within the limits of PS and WHO standards.

The results indicate that the highest percentage of risk for TC tests for the fifth degree of contamination (36%) that have TC more than 500 (cfu/ml) which is classified as" Very High Risk", and followed by the fourth degree of contamination (32%) that have TC range between (101-500) (cfu/ml) which classified as" High Risk ".

The measured FC and TC count in this study are more than repoted in a similar study of (Almur, 2016). Also it is considered more than count the similar study of (Al-Salaymeh, 2008) for FC and TC and more count for FC for the study of (Abusafa et al., 2012) in different cities in Palestinian territories.

In other study prepared by (Al-Khatib et al., 2003) about drinking water quality in Tulkarm District- Palestine, they found that only 34% of samples were contaminated with TC and 9.2% contaminated with FC where the results obtained in this study for FC and TC are more count than the results of the study of (Al-Khatib et al., 2003).

(Crabtree et al., 1996) in their study about the detection of microbiology quality in cistern water in the U.S. Virgin Island, the results of contaminatin by FC and TC was 36% and 75% respectively. Their results are lower than the results of this study.

In additation for the study of (Lee et al. 2010) about comparison of the microbiological and chemical characterization of harvested rainwater and reservoir water the result was 91.6% and 72% for TC and FC respectively which are lower than the results of this study.

The high presence of FC and TC amounts in RHW system exceeding the limits of local and global standards leads to significant contamination and high risk affecting on the health issues. The contamination may be contributed to several reasons of contamination of collecting surface by animal and bird droppings, withdrawing water manually which increasing the human contact with water and the presence of animals at home (Abo-Shehada et al., 2004).

Also, it could be related to the growth of plants and trees around the cisterns, store the first storm of water, there is no cleaning for the catchment area and cisterns, and using the house yard as catchment area and the presence of water disposal system close the cistern (Almur, 2016).

6.6 Potential sources of contamination of tested cisterns

By assessing the obtained results of the microbial analysis with their identical questionnaire in the study area, It turns out the most significant sources of contamination that increasing the coliforms contamination in the cisterns which are concluded in the table (15)

Table (15): Actual causes of contamination and the percentage of affected cisterns

Causes of Contamination	**Percentage of affected cisterns**
Using a septic tank as a disposal wastewater system close to the cistern.	87%
Do not disinfect the cistern by adding disinfectant as chlorine .	77%
The level of a wastewater disposal system is higher than the cistern level..	72%
The shape of the cistern (pear-shaped). (Are more likely to enter contaminants than the cube-shape) which it is related to the ability of isolating of the cistern and their constructions material.	70%
The presence of plants and trees around the cistern.	62%
There is no any periodic maintenance for the cistern.	55%
Store the first storm of rainwater.	53%
There is no any disposal process for rainwater in the cistern of the previous season.	44%
Extraction the water from the cistern manually.	47%
Not cleaning the collection surfaces and the catchment area.	44%
The presence of animals in home close to the cistern.	17%

Table (15) indicate that the wastewater disposal system affect the quality of RHW in cistern in the highest percentage (87%) especially if the wastewater disposal system is close to the cistern and at a higher level than the heigh of the cistern and there is a leakage of contaminated water that reaches the cistern water .

Also the individual's actions and behaviors which regarding to the absence of using the disinfectant such as chlorine which increasing the potential of contamination (77%), where the disinfectants reduce contamination by reducing the microbial growth.

The shape of the cistern has a significant effect water quality (70%) especially if it pear-shaped (ancient shape of cisterns), as this shape is more susceptible to contamination because it is not completely isolated, and contaminate can leak into water inside but it is characterized as that it has a higher capacity than the cube-shape.

The presence of plant and trees around the cistern is considered as one of the major causes of contamination (62%). Trees grow close to the cistern could pollute the surface of water by fallen leaves and flowers or by the dirt of animals and birds that can live on these trees, also trees root could be extended and penetrate the wall of cisterns, resulting in cracks around the cisterns and thus allow the contaminants to enter into the cistern and affect on water quality (Almur, 2016).

In addition, the store of the first storm of water affect adversely of water quality which it considers one of the major sources of RWH contamination, which it is responsible for the transport of microbes sediment, metals, and pesticides. Thes contaminate can be transferred into the cistern during the initial period of rainfall (Chen et al., 2007).

Extraction the water continuously increasing the human contact with surface water of cistern and it will transfer pollutant to the cistern so it considers one of the significant sources of contamination, in the other hand cleaning the cisterns and catchment area, and disposal of rainwater of the last season decreasing the potential of contamination and microbial growth of cistern water.

6.7 The exceeded samples of physicochemical and microbial water quality parameters analysis

Some of physiochemical and microbial parameters exceeded the PS and WHO standards limit such as pH (17%), TDS (2%), Turbidity (4%), Mg^{+2} (21%), PO_4^{-1} (28%), k^{+1}(30%) according to the PS, FC(92%) and TC (98%), which are represented in figure (6).

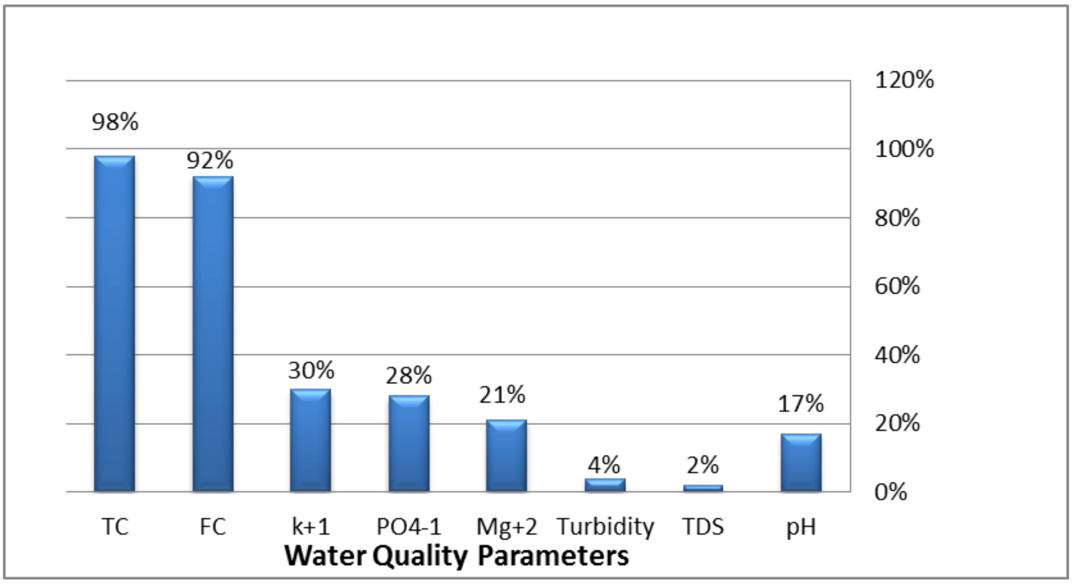

Figure (8): The percentage of Physiochemical and microbial parameters which exceed the PS and WHO standards of water drinking.

6.8 Cause – Effect Analysis for the Tested Cisterns that Exceeded the PS and WHO Standards

The potential causes and effects for the obtained results which exceeded the PS and WHO standards are shown in table (16).

Table (16): Cause – Effect Analysis for the Parameters that Exceeded the PS or WHO Standards

Parameter	Standard value	Percentage of contaminated cisterns	Significant causes of contamination found in the study sample
pH	6.5 – 8.5	17%	The high alkalinity of these water samples could be due to the concrete walls of some cisterns that increase the pH value of water to the alkaline range.
TDS	500	2%	-Due to the presence of inorganic dissolve salts,leaked from sewage and wastewater system, rocks or soils and pesticides or fertilizers to the stored rainwater in cisterns - Due to the high evaporation rates in summer which increase the concentrations of dissolved ions with a small amount of water left in most of the cisterns at this time which correlated to increasing water demand in the summer season.
Turbidity	5	4%	Due to the appearance of suspended particles in the water such as algal growth inside and around the cistern and it could be caused by the existence of different materials, organic or inorganic leaked to the cisterns.And its related by the cisterns age, which turbidity value incraese with increasing the cistern's age.
Mg^{+2}	100	21%	Due to the erosion of rocks and the construction material of cistern (cement) which it present in form of magnesite.
PO_4^{-1}	2*	28%	Due to leakage wastewater from wastewater disposal system used in the house especially if the septic system is using as a wastewater disposal system , or from sewage leak . Presence of plants and trees and using fertilizers . Presence of animals. (animals waste leak to the cistern)
K^{+1}	12*	30%	Due to the lekage wastewater from the wastewater system

			Due to the pesticides and fertilizers used for trees and plants.
FC and TC	FC: 0	FC: 92%	Storing the first storm and do not cleaning the cistern and catchment area Presence of trees near the cisterns Non isolated cisterm related to pear-shape
	TC: 3	TC: 98%	

*: related to PS –

6.9 The significant health risk for exceeded physiochemical parameters of water quality.

The significant health risk for exceeded physiochemical parameters of water quality are illustrated in the following table(EPA, 2001).

Table (17): The significant health risk of the physicochemical parameters of water quality which exceeded the PS or the WHO standards.

Parameters	Health Significant
pH	Increasing the pH affect the mucous membrane, creat a bitter taste and increase the corrosion
TDS	Principally affects on organoleptic implications, which are the aspects of food, water or other substances that an individual experiences via the sensesincluding taste, sight, smell, and touch , increasing the corrosion of cistern's construction material, and gastrointestinal irritation
Turbidity	This parameter gives an indication of the presence suspended matter, living microorganisms, and hence it is a reflection of the diseases causing by bacteria.
Mg^{+2}	Magnesium is influence on health indirectly by: Increasing the total hardness of water with Calcium (total hardness is taken to comprise the calcium and magnesium concentrations expressed as mg/L $CaCO_3$). Hard water can cause mineral buildup in plumbing, pumps and pipes, and poor performance of soaps and detergents. Causes diarrhea (has a laxative effect) if it related to sulfate "Epsom Salts".
PO_4^{-1}	Stimulate the microbial growth, which lead to causing diseases and Rancidity Mold growth
K^{+1}	There are no implications of toxicity but could cause carcinogenic disease if found as Potassium Bromate compound.
FC and TC	pathogenic microbes can result in potentially serious illness and possibly death. FC presence is an indicator of contamination of sewage waste.

6.10 Hypothesis testing

To test the hypothesis that cisterns owners behaviors and actions in addition to the cistern characteristics and conditions and usage patterns are behind its water pollution in the study area, a statistical analysis (t-test) was conducted to investigate the significant correlations between the indicators associated with cistern's owner personal data, cistern characteristics and its surrounding environment, utilization pattern and the public awareness of cistern's owners. The correlation was tested based on data collected from all cisterns sampled.

The significance level for each of the independent variables is shown in Table(18), statistically, a significant correlation could be assumed if the p-value was equal or less than 0.05, or if the observed value of chi-square greater than the critical value of chi-square.

As shown in table (18), the significant correlation appears between six independent variables which their p-value is less than 0.05, these variables include the correlation between "education level vs. knowledge about causes of pollution" and "education level vs. appropriate ways to promote environmental awareness on issues related to water pollution", the correlation between "last time of cleaning the cistern vs. Knowledge about causes of pollution", in addition to the correlation between "uses of water vs. adoption cisterns water as an alternative source" also the correlation about "knowledge about causes of pollution vs. the knowledge about the effective methods of water treatment" and the correlation about the "periodic examination of water quality by the municipality vs. treatment cistern's water in general".

However, the weak correlations (p-value > 0.05) appeared for the remaining variables such as the correlation between "gender vs. knowledge about causes of pollution" because most of the owners of cisterns are males

(85%) so actually there is no real effect of gender on the causes of pollution, and the correlation between "age vs. the knowledge about causes of pollution" because most of the owners cistern (49%) with age period from (41-60)years old this indicates that most of the cistern's owner is older, and the correlation between "education level vs. the ability of individuals to attend awareness-meetings" because (64%) of cistern's owner in the study area have elementary and secondary education level so there is no any positive attitudes towards pollution problems .

Table (18): t-test for hypothesis testing between the different correlations.

Type of relation	p-value	(Observed value)	(Critical Value)
Gender and knowledge about causes of pollution	0.33	0.95	3.8
Age and knowledge about causes of pollution	0.25	4.1	7.8
Education level and knowledge about causes of pollution	0.74	1.95	9.5
Age and knowledge about causes of pollution	0.221	11.87	16.9
Education level and knowledge about causes of pollution	0.053	20.89	21.03
Age and periodic maintenance for the cistern	0.199	12.27	16.9
Uses of water and Adoption cisterns water as an alternative source	0.003	15.86	9.5
periodic maintenance for the cistern and suffering from water borne disease	0.93	0.449	7.82
Disposal of rainwater in the cistern of the previous season and suffering from water borne disease	0.605	1.85	82..7
Cistern's shape and suffering from water borne disease	0.739	0.111	3.84
Continuous water using and suffering from water borne disease	0.287	1.13	3.84
knowledge about causes of pollution and the knowledge about the effective methods of water treatment	0.010	11.27	7.82
The last time of cleaning the cistern and knowledge about causes of pollution	0.033	13.75	12.6
Examination of water quality by laboratory analysis and knowledge about causes of pollution	0.764	5.75	16.92
Examination of water quality by laboratory analysis and the knowledge about the effective methods of water treatment	0.859	0.762	7.82
appropriate ways to promote environmental awareness on issues related to water pollution and the ability of individuals to attend awareness-meetings	0.797	5.42	16.92
Education level and appropriate ways to promote environmental awareness on issues related to water pollution	0.010	31.88	26.29
Education level and the ability of individuals to attend awareness-meetings	0.361	13.12	21.026
Periodic examination of water quality by the municipality and treatment cistern's water in general	0.003	25.172	16.92
Ensuring that cisterns door is securely closed and the presence of algae or any type of contamination on the water surface in the cistern	0.036	8.55	7.82
knowledge about causes of pollution and the presence of environmental awareness for individuals in the study area	0.17	9.066	12.59
Using water from cistern directly and suffering from water borne disease	0.903	0.015	3.84

The results are shown in the table (18) emphasize on the impact of cisterns owner behaviors in the study area and the quality of water collected in the cistern, also on the suitable ways should be used to promote the public awareness about water pollution, as mentioned previously (70%) of cistern's owner preferred the awareness-raising meetings as appropriate ways to promote environmental awareness on issues related to water pollution and (75%) of them have a desire to attend meetings to raising their public awareness about water pollution.

6.11 The Outlier Value Test

Table (19) below shows the results of Grubbs' Test of outer values for samples which collected in the study area, the results of testing (pH, Nitrate, and Calcium) show that no outliers values for these parameters.

The TDS outlier value has appeared in the sample in kherbet Atuf, which it exceeded the PS and WHO standards, the outlier TDS value could be related to the leak of salts from rocks and soils or pesticides and fertilizers to the cistern, the same sample indicate that has outlier value for chloride test, which it does not exceed the PS and WHO standards, the appearance of chloride outlier value associated with Sodium, which it is also consider an outlier value for the same sample. the high concentration of Sodium related to the decomposition of construction materials of the cistern.

The turbidity outlier value found in a sample in Tubas city which it exceeded the PS and WHO standards, the reasons of outlier value of sample related to the appearance of suspended particles (algae) in the water inside and around the cistern.

The outlier value of Hardness test and Bicarbonate test appear for the sample in the cistern in Aqqaba, the hardness and bicarbonate values do not exceeded the limits of the standards, the high concentration of hardness and bicarbonate of this sample could be related to erosion of rocks and the construction material of cistern (cement and lime paste).

The outlier value of Sulfate test was for sample from the cistern in Bardala, the concentration of sulfate do not exceed the standards, the high concentration could be related to the excessive using of pesticides near the cistern which could leak to the stored water in the cistern, while the outlier value of phosphate was for sample in cistern in Al- Thaghra, which it is not exceeded the PS and WHO standards, but the high concentration of phosphate for this sample could be related to the leakage wastewater from wastewater disposal system used in the house.

The outlier value of potassium test was for the sample from the cistern in Tubas city which it exceeded the PS and WHO standards, the high concentration of potassium could be related to the excessive use of pesticide and fertilizers near the cistern.

The outlier value of FC was for the sample of cistern in Wadi Al-far'a which it exceeded the standard, the high contamination of this sample could be related to several reasons contamination of collecting surface by animal and bird droppings, withdrawing water manually which increasing the human contact with water and the presence of animals and plants at home live close to the cistern, while the outlier value of TC was for the other sample in Wadi al-far'a which it also exceeded the PS and WHO standards the main causes of contamination of this sample related to store the first storm of water and did not cleaning the catchment area .

Table (19): The Outlier Values for the Chemical and Biological Parameters for samples through the Study Area.

Variables	No.of sample	Mean	Standard Deviation	Min	Max	P	Availability of outlier	Outlier value
pH	47	8.1717	0.4241	7.4700	9.3400	0.195	No	-
T.D.S	47	226.6	102.6	64.7	649.7	0.000	Yes	649.67
Turbidity	47	1.638	3.262	0.220	19.900	0.000	Yes	19.9
Nitrate	47	7.946	6.430	0.000	25.960	0.164	No	-
Chloride	47	37.20	17.89	16.60	100.00	0.008	Yes	100
Hardness	47	114.48	43.60	56.00	250.00	0.049	Yes	250
Calcium	47	35.08	10.77	16.00	66.60	0.102	No	-
Bicarbonate	47	86.66	45.89	26.60	238.30	0.021	Yes	238.30
Sulfate	47	21.91	22.17	0.00	129.07	0.000	Yes	129.07
Phosphate	47	1.184	1.883	0.020	11.000	0.000	Yes	11
Sodium	47	19.94	11.44	6.00	56.00	0.040	Yes	56
Potassium	47	4.852	3.931	1.000	23.100	0.000	Yes	23.10
faecal coliform colonies(cfu/10)	47	534	1311	0	6000	0.000	Yes	6000
total coliform colonies (cfu/1ml)	47	611	776	0	3400	0.005	Yes	3400

Chapter Seven
Conclusion and Recommendations

7.1 Conclusion

Natural conditions, as well as human activities significantly affect the quality and safety of harvested rainwater. This study aims to evaluate the quality of harvested rainwater in cisterns in Tubas governorate as a case study in conjunction with assessing the public awareness of the owner of cisterns about water pollution issue. Based on the results, the following points can be concluded.

1. The results in the study area show that (92%) of the analyzed samples contains fecal coliform while (98%) contains total coliform, therefore the collected rainwater is unsuitable for drinking purposes and could create a significant health risk.
2. The results indicate that some of the cisterns have a high concentration of chemicals which exceeded the PS and WHO standards such as potassium (3 %), phosphate (28%), magnesium (21%), turbidity (4%), TDS (2%), and pH (17%).
3. The research results show that the main sources of contamination of cisterns in the study area are related to the presence of plants and animals around the cistern, the shape of the cistern (pear-shaped), the level of a wastewater disposal system is higher than the cistern level, which could leak wastewater to the cistern.

4. The shape of cisterns, the construction material and the site of cisterns in the houses in addition to the location of the catchment area influence significantly the quality of harvested rainwater
5. The malpractices of cisterns owner affect directly the quality of collected rainwater in the cisterns which include; the absence of cleaning the collection surfaces and the catchment area. using a septic tank as a disposal wastewater system close to the cistern, do not disinfect the cistern by adding disinfectant, there is no any dispose of processes for rainwater in the cistern of the previous season, also do not dispose of the first storm of rainwater and there is no any periodic maintenance for the cistern.
6. The results show that there is no environmental or health awareness for citizens by the competent authorities about water pollution through the study area.
7. The results show that most of cisterns owner preferred the awareness-raising meetings as appropriate ways to promote environmental awareness on issues related to water pollution.

7.2 Recommendations

1. The municipality should encourage people to build cisterns in their houses by providing them some financial support and guide them to keep the water clean and out of contamination to face the deficiency of water supply.
2. Rainwater harvesting system should be cleaned periodically starting from the catchment area and ending in the cistern where water is stored.

3. Cisterns door should be well closed tightly to avoid entering pollutants and sunlight to reduce the growth of microbes organisms such as algae or the entry of animals and insects into the cistern.
4. There should be no trees over and close to the cistern to prevent the birds dropping and trees' leaves from reaching into the cistern
5. The shape of cistern should be cubic because it is more isolated and less leaking than the pear shape.
6. All of the outlier value of samples which exceeded the national or the global standards should be studied from the competent authorities such as Directorate of Health to find the main causes of current pollution and to limit the hazards potential could occur.
7. Catchment area should be soft and flat to avoid entrapment of pollutant on the surface of the catchment area.
8. The catchment area should be completely clean and should using a disinfectant such as chlorine to decrease the contamination.
9. Cisterns should be isolated and located away from the disposal wastewater system, and higher than the elevation of any wastewater disposal system in the home.
10. The construction material for the cistern must be water tight and not decomposing greatly and rapidly with time. In addition, the inside surface must not give off substances that make the water unsuitable for drinking. Traditionally, poured concrete systems have been the rule, but lately prefabricated systems made of plastic or glass fiber–reinforced polyester are popular, which it is considered more isolated than cement and concrete.

11. Choosing of the insulation material as the construction material of the cistern should be carefully and precisely, to avoid the hazards and the health problem of the insulation material especially in the case of using a material containing polystyrene and other dangerous manufactured material which is considered as cancerogenic and non-eco-friendly.
12. The first rainwater storm must not be stored and should be disposed of it away.
13. Cistern's water should be tested at least one time every year. If contamination detected, cisterns should be disinfected to avoid the contamination, and cistern should be retested after two weeks of chlorination.
14. The harvested rainwater can be used for irrigation purposes if it is unsuitable for drinking purposes depending on TDS and water salinity, where if the concentration of TDS in harvested rainwater is less than 450 mg/L, it indicates their suitability for irrigation purposes, so it not affected the crop yield and deteriorate soil fertility.
15. The public awareness should be raised for people about water pollution issue in general and the cisterns owners particularly by preparing awareness-raising meetings also by the distribution of awareness leaflets and brochures and by using social media, T.V, and newspapers to arrange guidelines for people to reduce the pollution and to promote a policy agenda in the water management system, taking international development into consideration.

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Annexes

Annexes A: The questionnaire which distributed for the cisterns owners in Tubas Governorate

جامعة النجاح الوطنية

كلية الدراسات العليا

تحية طيبة وبعد،

أخي المواطن، أختي المواطنة

تقوم الباحثة بإجراء دراسة لغاية إتمام متطلب رسالة ماجستير بعنوان :

تقييم جودة مياه الأمطار المحصودة في محافظة طوباس ودراسة مستوى الوعي البيئي للسكان المحليين بخصوص تلوث المياه.

حيث تهدف هذه الدراسة لتقييم جودة مياه الأمطار المحصودة في آبار الجمع في محافظة طوباس تبعاً للمعايير العامة وتحديد مصادر التلوث بناء على النتائج المخبرية، إضافة لتقييم الوعي البيئي المتعلق بقضية تلوث المياه لدى المواطنين في المنطقة المراد دراستها.

يرجي المساعدة في تعبئة البيانات بكل مصداقية ووضوح مع العلم بأن كافة البيانات المجموعة لن تستخدم إلا لغاية البحث العلمي شاكرين جهودكم .

الباحثة :
عهد عباس

اسم المنطقة :	
رقم العينة:	
القسم الأول : البيانات الاجتماعية	
1. الجنس	ذكر أنثى
2. العمر	1-20 21-40 41-60 61-80 80<
3. المستوى التعليمي	إعدادي ثانوي دبلوم بكالوريوس دراسات عليا
4. عدد الأفراد المستخدمين للبئر	0-10 11-20 21-30 31-40 41-50
القسم الثاني : البيانات المتعلقة بالبئر	
5. عمر البئر	0-20 21-40 41-60 61-80 81-100 أكثر من 100 عام
6. عمق البئر (بالمتر)	0-5 6-10 11-15 16-20 21-25
7. سعة البئر (بالمتر المكعب)	أقل من 30 من 30-50 اكثر من 50
8. شكل البئر	مكعب إجاصي
9. المواد المستخدمة في بناء البئر	إسمنت شيد غير ذلك (حدد ....)
10. مصدر المياه	مياد الأمطار مياه البلدية مياه الأمطار والبلدية غير ذلك
11. الشكل الذي يتم ادخال المياه للبئر بواسطته	من خلال مجرى متصل بسطح البيت من خلال مجرى من ساحة البيت
12. هيكلية باب البئر	باب حديدي باب خشبي باب على شكل شبك لا يوجد باب
13. طريقة استخراج المياه من داخل البئر	يدوي من خلال مضخة
14. طبيعة وسيلة الصرف الصحي في المنزل	حفرة امتصاصية حفرة صماء

	مجاري عامة
15. مستوى البئر بالنسبة للحفرة الامتصاصية	اعلى منه نفس المستوى أقل منه
16. موقع البئر في المنزل	في ساحة المنزل أسفل المنزل قريب من المنزل
17. هل استخدام مياه البئر بشكل مستمر او متقطع ؟	مستمر متقطع
18. بماذا يتم استخدام مياه البئر ؟	1-للشرب واعداد الطعام 2-للاستخدام المنزلي كالتنظيف 3- لسقي المزروعات 4- لايتم استخدامها 5-غير ذلك
19. هل يتم اعتمادها كمصدر بديل للشرب في حال انقطاع مياه البلدية	نعم لا
20. هل يتم تربية أي انواع من الحيوانات او المواشي بالقرب من البئر ؟	نعم لا
21. هل هناك تواجد للنباتات بالقرب من البئر	نعم لا
القسم الثالث : تقييم سلوكيات الأفراد الذين يمتلكون البئر	
22. هل يمكن اعتبار مياه البئر كمصدر بديل للمياه التي يتم تزويدها من البلدية	نعم غالبا أحيانا لا يتم استخدامها
23. هل يتم التأكد من اغلاق باب البئر بإحكام وشكل دائم	نعم غالبا أحيانا لا
24. هل هناك صيانة دورية للبئر ؟	نعم غالبا أحيانا لا
25. هل يتم التخلص من مياه السنة السابقة قبل تعبئته في الموسم الجديد ؟	نعم غالبا أحيانا لا
26. هل يتم تخزين مياه أول نزول للمطر في بداية الموسم داخل البئر	نعم لا
27. هل يلاحظ وجود أي شوائب او عوالق نامية على باب البئر او تطفو على سطح المياه	نعم غالبا أحيانا لا
28. متى كانت اخر مرة تم فيها تنظيف البئر ؟	في بداية الموسم قبل عدد محدد من السنوات (.....) لم يتم تنظيفه من قبل
29. هل يتم تنظيف المداخل ومكان سقوط الامطار وتجميعها وجريانها التي تؤول بوصول الامطار الى البئر (سطح البيت مثلا)	نعم غالبا أحيانا لا

30. هل سبق وان قمتم بعمل فحوصات مخبرية لاختبار جودة المياه التي تم تجميعها	نعم غالبا أحيانا لا
31. هل هناك سلوكيات معينة تقومون بها قبل البدء بعمليات جمع المياه	
32. هل يتم استخدام المياه بشكل مباشر من البئر ام يتم ضخها الى الخزان ؟	يتم استخدامها بشكل مباشر يتم ضخها للخزان ومن ثم يتم استخدامها
33. هل سبق وعانى احد افراد الأسرة من أي اضطرابات من امراض متعلقة بالمياه بعد استخدامه لمياه البئر ؟	نعم لا اذا نعم ما هي الاجراءات المتبعة من قبلكم
34. هل هناك فحوصات دورية من قبل البلدية للآبار ؟	نعم غالبا أحيانا لا
35. هل يتم معالجة مياه البئر بشكل عام عن طريق اضافة المعقمات مثل الكلور ؟	نعم غالبا أحيانا لا
القسم الرابع: تقييم الوعي البيئي للأفراد	
36. هل لديكم أي معرفة او دراية بمسببات التلوث التي ممكن التي قد تلوث البئر ؟	نعم لا
37. هل هناك طرق معينة من وجهة نظركم يمكن استخدامها لمعالجة مياه البئر ؟	نعم لا اذا نعم ما هي الطرق المتبعة من قبلكم ؟
38. اذا شعرتم بوجود تلوث ما هي الطرق التي يتم اللجوء اليها للتخلص منه ؟	
39. هل هناك توعية بيئية وصحية بخصوص قضايا تلوث المياه في منطقتكم	نعم غالبا أحيانا لا
40. برأيك ما هي الطرق الأنسب لنشر الوعي البيئي بخصوص القضايا المتعلقة بتلوث المياه	إقامة لقاءات توعوية توزيع منشورات توعوية بواسطة السوشال ميديا بواسطة الجريدة، التلفاز، المذياع أو أي من وسائل الاعلام غير ذلك، أذكر (...)
41. هل لديكم القابلية لحضور الفعاليات التوعوية المتعلقة بقضايا تلوث المياه	نعم غالبا أحيانا لا

Annexes B: Water quality analysis data

Name of area	No. of sample	pH	T.D.S	Turbidity	Nitrate	Chloride	Hardness	Calcium	Bicarbonate	Sulphate	Phosphate	Sodium	Potasium	faecal coliform colonies(cfu/100ml)	total coliform colonies(cfu/1ml)
Tubas	1	8.53	158.12	0.71	7.974	25	83.3	30.3	95.6	0.3	0.06	19.8	2.5	320/100	800/ml
	2	7.9	282.07	0.73	2.215	40	150	46.6	155.3	14	0.06	29	3.1	85/100ml	260/ml
	3	9.34	231.82	0.43	6.202	25	79.75	23.3	118.6	56.87	0.5	45.2	23.1	4/100ml	19/ml
	4	9.05	193.63	3.95	16.4	25	100	39.3	118.3	1.25	0.21	24.2	6.03	7/100ml	350/ml
	5	8.18	176.21	2.47	6.2	27	66.6	23.3	53.3	0.6	2.32	10	5.7	1/100ml	67/ml
	6	7.91	239.2	0.45	4.6	32.8	83.3	30	45.7	36.81	2.59	20	9.1	30/100ml	$6*10^{2}$ /ml
	7	7.87	296.81	19.9	12	39.8	116.6	40	62.8	49.51	3.22	25	11.8	19/100ml	115/ml
	8	7.69	191.62	0.97	10.5	33.3	66.6	25	26.6	2.36	2.26	7	3.5	21/100ml	72/ml
	9	7.89	251.25	0.87	4.8	38.6	133.3	46.6	69.2	28.1	1.79	10	3.4	37/100ml	$5*10^{2}$ /ml
	10	7.88	201.67	1.31	0	36.6	83.3	33.3	30	27.3	1.89	8	3.8	121/100ml	$8*10^{2}$ /ml
Tammun	1	8.08	158.12	0.5	4.43	16.6	93.3	30.6	112	0.33	0.02	13.9	3.6	900/100ml	$11*10^{2}$ /ml
	2	8.22	202.34	0.4	4.873	29.16	116.7	40	108.3	17.11	0.07	20.1	2.4	156/100ml	118/ml
	3	8.54	215.74	0.8	8.417	25	110	36.6	115.3	19.35	0.09	23.3	7.8	38/100ml	44 /ml
	4	7.82	251.25	0.37	4.873	33.3	133.32	45.2	116.7	26.4	0.14	23.5	4.2	8/100ml	2/ml
	5	8.03	162.14	0.49	2.7	52	150	40	105	12.14	2.36	18.3	2.1	15/100ml	53/ml
	6	7.98	117.05	0.24	3.6	30.5	80	20	54	7.46	1.33	11.5	1.6	10/100ml	$3*10^{2}$ /ml
	7	8.78	145.26	11.8	7.6	20	100	35	60.2	35.13	2.4	13	1.8	165/100ml	$28*10^{2}$ /ml
	8	8.63	154.77	1.06	3.2	29.4	100	32	68.5	40.02	2.29	23.1	5.1	21/100ml	61/ml
	9	7.89	488.43	1.82	15.5	68.5	150	40	115.8	10.7	4.29	40	1.2	19/100ml	44/ml
Aqqaba	1	7.58	180.9	0.23	4.43	25	116.6	40	131.7	0.16	0.04	19.1	2.1	13/100ml	175/ml
	2	7.72	394.63	0.7	15.52	55	250	49	238.3	8.1	0.12	30.5	2.1	$7*10^{2}$ /100ml	230/ml
	3	7.99	134.9	0.4	2.215	21.8	93.3	33.3	89.3	0.39	0.07	9.5	2.2	4/100ml	570/ml
	4	7.96	345.72	0.68	1.972	48.8	200	66.6	209.8	0.83	0.28	30.7	2.8	null	3/ml
Tayasir	1	8.88	122.8	2.05	0.886	21.8	93.3	26.7	78.3	12.87	0.17	9.2	4.7	7/100ml	230/ml
	2	7.47	319.6	3.44	9.303	45.8	166.7	46.6	166.6	38.17	0.07	24.6	6.8	50/100ml	350/ml
	3	8.4	131.99	0.49	2.215	17.67	66.6	20	40.3	25.52	0.08	10.2	5.2	18/100ml	80/ml

	4	7.78	227.8	0.46	5.859	35.2	116.6	33.3	76.6	26.8	0.12	16.3	5.6	27/100ml	640/ml
Al 'Aqaba	1	8.32	183.58	0.31	8.42	28.3	90	29.3	48.6	21.32	0.13	12	3	230/100ml	80/ml
	2	8.28	138.82	0.91	2.66	22.83	56.6	20	28.3	17.54	0.19	10	4	$33*10^2$ /100ml	$13*10^2$ /ml
	3	8.26	222.44	1.52	0	39.3	103.3	25.3	54.6	22.07	0.53	12	5	$5*10^2$ /100ml	160/ml
	4	8.03	145.6	0.56	2.66	23.8	66.67	16	35.6	18.55	0.14	9	5	4/100ml	$7*10^2$ /ml
Al-Thaghra	1	8.62	259.96	0.3	12.4	45.8	150	37.7	110	13.89	11	20	1	$10*10^2$ /100ml	270/ml
	2	7.95	282.74	0.46	7.08	44.5	100	22.6	65.6	11.75	0.06	21	2	120/100ml	100/ml
	3	8.81	182.24	0.66	5.32	20.5	100	36.6	41.6	41.2	0.04	8	3	120/100ml	140/ml
	4	8.5	371.18	0.28	16.83	65.7	233.3	40	150.8	32.9	0.19	25	2	160/100ml	120/ml
Khirbet 'Atuf	1	7.47	261.3	0.36	13.73	30.5	100.5	33.6	79.6	12.38	0.14	15	10	$60*10^2$ /100ml	$15*10^2$/ml
	2	8.14	222.13	3.4	15.95	83.3	133.3	37.3	33.3	16.64	0.19	9	7	64/100ml	$14*10^2$/ml
	3	8.25	64.72	1.34	6.202	48.7	120.8	30.3	96.6	24.72	0.06	33	3	$20*10^2$ /100ml	860/ml
	4	8.4	649.67	1.64	25.96	100	183.3	50.6	59.7	66.09	0.15	56	4	$50*10^2$ /100ml	$20*10^2$/ml
Wadi al-far'a	1	7.74	225.12	1.85	6.5	28.8	83.3	30	61.6	15.68	3.35	13	10	6/100ml	$34*10^2$/ml
	2	8.59	145.52	0.22	1.6	26.6	66.6	25.3	62.6	9.77	1.07	12	14.1	23/100ml	$18*10^2$/ml
	3	8.36	261.97	1.54	19.8	39.8	128.5	50.3	82.8	15.5	2.73	18	4	null	100/ml
	4	7.62	252.59	0.8	5.1	27.6	120.3	46.6	105.4	28.48	3.16	23	4.3	36/100ml	$11*10^2$/ml
	5	7.93	105.19	1.53	5.4	25	56	20.6	33.3	0	1.19	6	1.9	$37*10^2$ /100	$13*10^2$ /ml
Ras al Far'a	1	8.21	189.44	0.71	3.987	25	81	32	110	10.15	0.2	22.9	3.4	null	21/ml
Kardala	1	8.74	203.01	0.46	22.4	44.5	125	32	76	23.3	2.13	24.1	6	23/100	$20*10^2$/ml
Bardala	1	7.86	306.19	0.42	23	79.2	183	60	75	129.07	0.14	53	2	null	null

جامعة النجاح الوطنية

كلية الدراسات العليا

تقييم جودة مياه الامطار المحصودة في محافظة طوباس ودراسة مستوى الوعي البيئي للسكان المحليين بخصوص تلوث المياه

إعداد

عهد محمد عباس

إشراف

د. محمد السيد

د. عبد الحليم خضر

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

2019

تقييم جودة مياه الامطار المحصودة في محافظة طوباس ودراسة مستوى الوعي البيئي للسكان المحليين بخصوص تلوث المياه

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الملخص

تهدف هذه الدراسة لتقييم جودة مياه الأمطار في آبار الجمع المنزلية لأغراض الشرب في محافظة طوباس، بالمزامنة مع تقييم الوعي البيئي للسكان المحليين بخصوص قضايا تلوث المياه .

تم أخذ 47 عينة بشكل عشوائي من 11 منطقة مختلفة ضمن محافظة طوباس وأجريت لها بعض الفحوصات المخبرية التي تتضمن درجة الحموضة، الموصلية الكهربائية، البايكربونات، العسر الكلي، الكلورايد، المغنيسيوم، الكالسيوم، الصوديوم، النيترايت، الصوديوم، الفوسفات، الكبريتات، البوتاسيوم، القاعدية، العكورة، بالإضافة للفحوصات المايكروبية حيث شملت فحص وجود القولونات الكلية والبرازية.

لقد أظهرت النتائج التي تم الحصول عليها بعد التحاليل الفيزيائية و الكيميائية والمايكروبية أن هناك تجاوزاً للمعايير المحلية والعالمية، بحيث تجاوزت جميع نتائج العينات للتحاليل الفيزيائية المعايير المحلية والعالمية ، إذ تجاوزت 17 ٪ من العينات المعايير الفلسطينية ومعايير منظمة الصحة العالمية لمياه الشرب لدرجة الحموضة،2% من العينات تجاوزت المعايير بالنسبة لمجموع المواد الصلبة الذائبة في المياه، وكذلك 4% من العينات بالنسبة للتعكر.أما بالنسبة للتحاليل الكيميائية فتجاوزت نتائج التحاليل المعايير بنسب مختلفة كالتالي (البوتاسيوم 30 ٪ ، الفوسفات 28 ٪ ، المغنيسيوم 21 ٪) ، بينما كانت نسبة تلوث القولونيات الكلية والبرازية (98٪ ، 92٪) ، على التوالي. تمت دراسة خصائص آبار الجمع ومصادر التلوث بواسطة استبيانات تم الإجابة عليها من قبل أصحاب الآبار أنفسهم، ووفقًا للمعلومات التي تم جمعها وتحليلها من خلال

الاستبيانات ، كانت أهم مصادر التلوث هي وجود النباتات والأشجار بالقرب من الآبار بنسبة (66٪) ، وكذلك تخزين مياه الأمطار الأولى في بداية الموسم بحيث تكون محملة بالغبار والملوثات والمايكروبات بنسبة (53 ٪) ، بالإضافة الى الاحتفاظ بمياه الأمطار التي تم تجميعها في الموسم السابق داخل البئر بنسبة (34 ٪) ، ويعزى حوالي (24 ٪) من أسباب التلوث الى عدم تنظيف منطقة تجميع المياه ومداخل البئر قبل تخزينها.

وبالنسبة لنتائج التقييم المتعلقة بدراسة مستوى الوعي البيئي للأفراد ضمن منطقة الدراسة فقد أشارت النتائج إلى أن (58%) من أصحاب الآبار ليس لديهم معرفة أو دراية حول الملوثات التي تؤول الى تلوث آبارهم بالإضافة إلى فقدان الاهتمام والوعي البيئي من قبل الجهات المختصة ضمن المنطقة التي تمت دراستها ، وكما أن (70%) من أصحاب الآبار فضلو اللقاءات التوعية من قبل الجهات المختصة كوسيلة لرفع الوعي البيئي وزيادة الثقافة العامة بخصوص قضايا تلوث الماء وكيفية التعامل مع هذه المشكلة.

النتائج بشكل عام تشير الى وجود تلوث فعلي والذي بدوره يؤثر سلباً على صحة الإنسان مسبباً مخاطر صحية تهدد حياة الأفراد حيث أن أهم مسببات التلوث هي الممارسات الخاطئة في عملية حصاد مياه الأمطار وتخزينها لأغراض الشرب الناتجة عن غياب الوعي البيئي لدى الأفراد ملَاك الآبار .

تهدف هذه الدراسة بشكل عام إلى تحديد الخصائص والظروف الحالية والأسباب الرئيسية للتلوث لآبار الجمع التي تم دراستها خلال منطقة الدراسة، وكذلك تقييم جودة مياه الأمطار في الآبار التي تم دراستها وفقًا للمعايير المحلية والدولية ، واقتراح أفضل الأدوات والأساليب المتاحة لرفع الوعي البيئي المتعلق بقضايا تلوث المياه للمواطنين المحليين. بالإضافة إلى ذلك، تهدف هذه الدراسة بشكل عام لتوفير الفرص لتجميع المعرفة العلمية ضمن إطار دولة نامية ومن ثم تعمل على تعزيز جدول أعمال للسياسات في نظام إدارة المياه ، وذلك بهدف رفع الوعي العام لأصحاب الآبار للقيام بأفضل الممارسات لجمع وتخزين مياه الأمطار مع الأخذ بعين الاعتبار الحصول على أفضل جودة من مستوى المياه المستخدمة لأغراض الشرب.