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M.Sc. Program in Water and Environmental Engineering

Heavy Metals in Harvested Rainwater Used for Domestic Purposes in Rural Areas (Yatta, Hebron as a Case Study)

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The thesis was prepared under the main supervision of Dr. Nidal Mahmoud and has been approved by all members of the Examination Committee

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Member ....

Date of Defense: 7/10/217

The findings, interpretations and the conclusions expressed in this study don't express the views of Birzeit University, the views of the individual members of the MSc committee or the views of their respective.

Dedication

To my parents,

To my brothers and sisters,

To my late uncle and aunts,

To all those who contributed to this work

Love you all

Fathi Anabtawi

February, 2018

Acknowledgements

My appreciation for the accomplishment of this study is directed to Dr. Nidal Mahmoud for his continuous support and guidance of this thesis, and to the members of the committee, Dr. Issam Al-Khatib and Dr. Rashed Al-Sa'ed, who were an important part in the success of the work.

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Abstract

Rainwater harvesting is considered one of the most important water resources in the Palestinian countryside. Many studies in Palestine and around the world indicate that there is a probability that this harvested rainwater be contaminated with different pollutants, of which is "Heavy Metals", which are considered the most dangerous pollutants of drinking water. In this research, the study area chosen for the study was Yatta town in Hebron city. 75 water samples were collected from 75 cisterns in a number of neighborhoods in Yatta. An analysis for the samples was made in the laboratory of Al-quds university to test the existence of a number of heavy metals namely, Pb, Cr, Mn, Co, Ni, Cu, Zn and Cd.

The results were compared with the WHO and Palestinian limits for drinking water quality. Considering the metals Mn, Co, Cu and Cd. Neither of the samples exceeded any of the two limits. For the metals Pb, Cr, and Ni, two samples exceeded both limits. For the metal Zn, one sample exceeded the WHO limit only.

Sources of pollution by heavy metals of the harvested rainwater were identified by means of a questionnaire distributed on the households. Statistical analysis was made to identify sources of contamination by heavy metals by connecting the questionnaire factors, which are considered possible sources of heavy metal contamination, and the laboratory results. The results showed that except for nickel and the sources of water in the cistern factor, there is no direct relationship between the questionnaire factors and the existence of heavy metals beyond local and international limits. Based on the questionnaire and literature: Possible sources of lead and zinc are the roof, storage tanks, distribution systems and plumbing; possible sources of chromium are road dust, asbestos brakes and anthropogenic activities occurring around the house; a possible sources of nickel is leaching from metals in contact with harvested rainwater such as pipes and fittings which are used to collect the harvested rainwater.

Also, an assessment of the potential health risks due to contamination of the harvested rainwater by heavy metals was made for all the samples that exceeded either WHO limit or the Palestinian limit or both. The Chronic Daily Intake (CDI) and the Health Risk Index (HRI) were calculated. The assessment was made for both adults and children. The results showed that all the samples are considered safe (HRI <1), which means that there are no potential health risks on consumers.

مقدمة

تعد مياه الأمطار من أهم مصادر المياه في الريف الفلسطيني وخاصة في منطقة الخليل نظرا لشح المياه الكبير فيها . تشير العديد من الدراسات الى احتمالية تلوث مياه الامطار المحصودة بعدة ملوثات، من أخطرها المعادن الثقيلة . سوف نستهدف في هذه الرسالة منطقة يطا في مدينة الخليل. 75 عينة جمعت من 75 بئر في أحياء يطا . تم تحليل جميع العينات في مختبر جامعة القدس. تم تحليل العينات بناء على وجود المعادن الثقيلة التالية : الرصاص، الكروم، المنغانيز، الكوبالت، النيكيل، النحاس، الخارصين والكادميوم.

قورنت النتائج بالمواصفة الفلسطينية وبمواصفة منظمة الصحة العالمية لمياه الشرب . بالنسبة لعناصر المنغنيز، الكوبلت ، النحاس والكادميوم ، لم تتجاوز أي من العينات المواصفتين. بالنسبة لعناصر الرصاص ، الكروم ، والنيكيل ، تجاوزت عينتان كلتا المواصفتين . أما بالنسبة لعنصر الخارصين ، تجاوزت عينة واحدة مواصفة منظمة الصحة العالمية فقط.

تم تحديد مصادر التلوث بالمعادن الثقيلة المحتملة من خلال استبيان وزع على أصحاب البيوت. تم اجراء تحليل احصائي لتحديد مصادر التلوث بالمعادن الثقيلة من خلال ربط عوامل الاستبيان التي تعتبر مصادر محتملة لتلوث المعادن الثقيلة مع نتائج المختبر. أظهرت النتائج أنه فيما عدا عنصر النيكيل وعامل مصادر المياه في البئر، لا توجد علاقة مباشرة بين معاملات الاستبيان ووجود المعادن الثقيلة خارج حدود المواصفات المحلية والعالمية.

بناء على الاستبيان والأدبيات، مصادر الخارصين والرصاص المحتملة هي الأسطح، خزانات المياه وأنظمة توزيع المياه . وبالنسبة لمصادر الكروم المتوقعة فهي غبار الطرق، فرامل الأسبستوس والأنشطة البشرية التي تحصل حول المنزل . أما بالنسبة لمصادر النيكل المتوقعة، فهي الأنابيب التي تجمع بها المياه.

كما تم عمل تقييم للمخاطر الصحية المحتملة بسبب تلوث مياه الأمطار المحصودة بالمعادن الثقيلة لجميع العينات التي تجاوزت حد منظمة الصحة العالمية أو الحد الفلسطيني أو كليهما. تم حساب الاستهلاك اليومي المزمن (CDI) ومؤشر المخاطر الصحية (HRI)، وقد أجري التقييم لكل من البالغين والأطفال. وأظهرت النتائج أن جميع العينات تعتبر آمنة (HRI <1)، مما يعني أنه لا توجد مخاطر صحية محتملة على المستهلكين.

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List of Abbreviations

Pb	Lead
Cr	Chromium
Mn	Manganese
Co	Cobalt
Ni	Nickel
Cu	Copper
Zn	Zinc
Cd	Cadmium
DRWH	Domestic Roof Water Harvesting
U.S. EPA	United States Environmental Protection Agency
RBCs	Red Blood Cells
IARC	International agency for Research on Cancer
WHO	World Health Organization
Pak EPA	Pakistan Environmental Protection Agency
PCBS	Palestinian Central Bureau of Statistics
ARIJ	Applied Research Institute-Jerusalem
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
ORS	Octapole Reaction System
CDIs	Chronic Daily Intake of Metals
HRIs	Health Risk Indexes of Metals
PWA	Palestinian Water Authority

Chapter One

Introduction

1.1 Background

Water is a vital substance in the environment (Shal *et al*., 2012), and its contamination with heavy metals is considered a worldwide environmental problem (Muhammad *et al*., 2011; Pejakov *et al.*, 2014). Heavy metals are elements with atomic weights between 63.546 and 200.590 g/mol and density more than 4.0 g/cm³ and they exist in water in colloidal, particulate and dissolved forms (Adepoju-Bello *et al*., 2009). There are 35 metals of concern due to occupational and residential exposure to them; of which 23 are heavy metals: antimony, arsenic, bismuth, cadmium, cerium, chromium, cobalt, copper, gallium, gold, iron, lead, manganese, mercury, nickel, platinum, silver, tellurium, thallium, tin, uranium, vanadium and zinc (Ferner, 2001). Small amounts of these elements are common in our environment and diet and are necessary for good health, but large amounts of any of them may cause acute or chronic toxicity. It is known that heavy metals are toxic to human beings if present in high concentrations. Human activities have resulted in an increase in the concentrations of heavy metals in the environment. For example, anthropogenic activities (e.g., industry, agriculture) increase the contents of heavy metals in different environmental matrices, e.g., water, soil, air, vegetables, fruits, fish, etc. (Abderahman and Abu-Rukah, 2006; Adekunle *et al.*, 2007; Chen *et al.*, 2007; Batayneh, 2010). Health risks of heavy metals include reduced growth and development, cancer, organ damage, nervous system damage, and in extreme cases, death (Roberts, 1999; Dupler, 2001).

Heavy metals are important pollutants to water: groundwater, surface water, and harvested rainwater (Chen *et al.*, 2007; Batayneh, 2010). Many studies were conducted around the world to test the presence of a number of heavy metals including Cr, Mn, Co, Ni, Cu, Zn, Cd, Pb and Fe. For example, the occurrence of the metals Aluminum, Arsenic, Cadmium, Lead, Chromium, Mercury, Copper, Cobalt, Iron, Manganese, Selenium, Molybdenum, Vanadium, Antimony, Nickel and Zinc in drinking water from source to consumption in Kermanshah- Iran was tested in Kermanshah University of Medical Sciences, the results showed that the amount amount of Aluminum, Iron and Manganese exceeded national standards and guidelines recommended by the World Health Organization (WHO) (Pirsaheb *et al.*, 2013). Another study was conducted by University of Peshwar in Pakistan to assess the health risks of heavy metals and their source allocation in drinking water of Kohistan region, northern Pakistan. The heavy metals of concern were (Cu, Co, Cr, Mn, Ni, Pb, Zn and Cd). However, the results showed that there are no potential health risks on consumers when compared with Pakistan Environmental Protection Agency (Pak EPA) and WHO limits (Muhammad *et al.*, 2011).

An assessment of rainwater quality from rainwater harvesting systems in terms of heavy metals contamination was made in Ontario, Canada (Despins *et al.*, 2009). Another study in Melbourne was made to study the occurrence of the metal lead and other heavy metals that are considered common contaminants of rainwater tanks. The results showed that the concentrations of the metals aluminum, cadium, iron and zinc were found at levels exceeding acceptable health levels (Magyar *et al.*, 2008).

Rainwater harvesting is a common practice in the West Bank, especially in the south where there is water scarcity. In these areas and during winter, the rainwater is collected from the roofs of the houses and stored in cisterns and thus, there is a high probability that this water is contaminated with heavy metals coming mainly from dust and roof materials (Mosley, 2005).

1.2 Problem definition

Nowadays, water pollution is one of the most important environmental problems around the world (Chen *et al.*, 2007; Batayneh, 2010). Among the wide variety of contaminants affecting water supplies, heavy metals deserve specific attention regarding their high toxicity even at low concentrations (Marcovecchio *et al.*, 2007). The source of heavy metals in water could be natural (weathering and erosion of bed rocks and ore deposits) or anthropogenic (mining, industries, use of wastewater in irrigation and agricultural activities) (Ahmet *et al.*, 2006; Chanpiwat *et al.*, 2010; Muhammad *et al.*, 2010). Heavy metals may contaminate the surface water and groundwater resulting in deterioration of drinking and irrigation water quality (Krishna *et al.*, 2009), and therefore, they are considered as severe pollutants owing to their toxicity, persistence and bioaccumulative nature in the environment (Pekey *et al.*, 2004).

In the countryside of Palestine, and especially in Hebron district, people depend a lot on rainwater harvesting techniques due to the scarcity of water. Therefore, there is a high probability that this water be contaminated with many pollutants that affect water quality, of which the most dangerous are heavy metals.

It is evident that studying and determining heavy metals in water (ground, surface, harvested rain) is an important issue for human health and environment, however and according to the best of our knowledge, there are few studies in Palestine conducted for the analysis of heavy metals in water, e.g., harvested rainwater.

1.3 Objectives

Harvested rainwater, used for domestic purposes in south West Bank, is the main focus of this research. Rural areas in Hebron, mainly different neighborhoods of Yatta area were selected as the study area, as many of them are not connected to water distribution networks, experiencing a shortage of water, and thus resorting to rainwater harvesting techniques (PWA, 2011).

The main objectives for this research are:

1. To study the occurrence of different heavy metals (Pb, Cr, Mn, Co, Ni, Cu, Zn and Cd) in harvested rainwater collected in rainfed cisterns from Yatta area (West Bank, Palestine).
2. To identify sources of pollution by heavy metals of the harvested rainwater.
3. To assess the potential health risks due to contamination of harvested rainwater used for drinking by heavy metals.

Chapter Two

Literature Review

2.1 Introduction

Water is one of the basic factors required for the survival of all living organisms on Earth, including human beings. However, water scarcity in many countries around the world is recognized as one of the main causes of poverty. Currently, more than one billion people globally do not have access to adequate volumes of clean drinking water, and thus they tend to find alternative ways and techniques to provide them with additional sources of water (UNESCO, 2005). One of the most common techniques used among the world is Domestic Roof Water Harvesting (DRWH) systems (Zhu *et al.*, 2004).

Rainwater harvesting is the capture, diversion and storage of rainwater and conserving rainfall from a surface (catchments) to be used later in various purposes including landscape irrigation, drinking and domestic use, aquifer recharge and storm water abatement.

Roof catchment system depends on three components: (PWA, 2003)

1. The collection area: which is the individual rooftop on the house.
2. The conveyance system: which is a series of gutters or pipes that convey the water to the storage facility (cisterns).
3. The storage facility itself.

The amount of water that can be collected depends on the catchments' area, the amount of rainfall and the storage volume (PWA, 2003). Figure 1 shows a schematic diagram of a rainwater harvesting system.

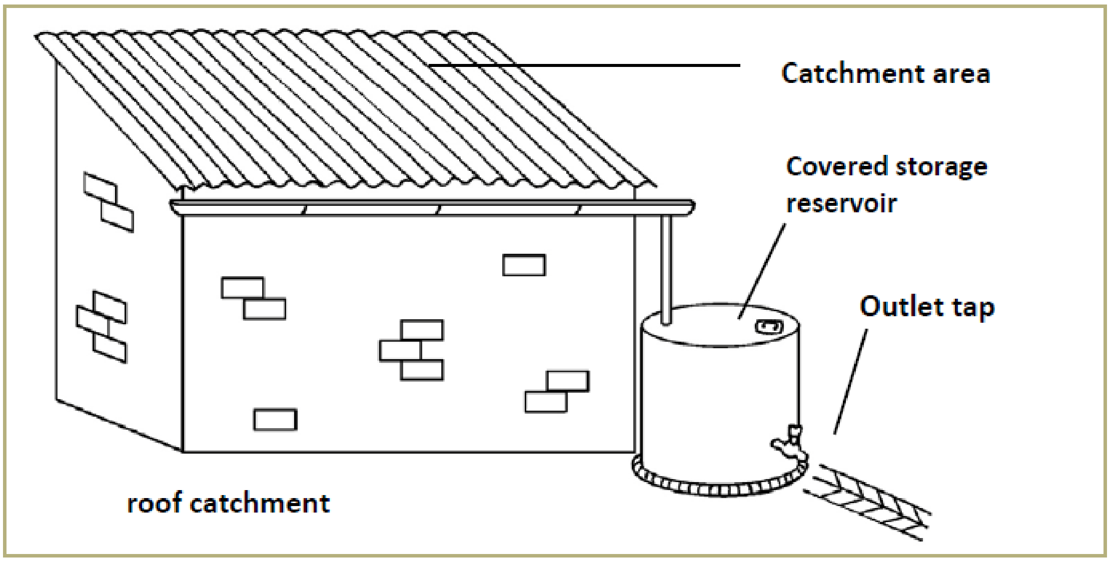

Figure 1: Rainwater Harvesting System, (ClimateTechWiki).

2.1.1 Advantages and disadvantages of rainwater harvesting

Advantages of rainwater harvesting include (Krishna, 2003; ARCSA, 2015):

- ✓ The water is free; the only cost is the cost of collection and use.
- ✓ The end use of harvested water is located close to the source, eliminating the need for complex and costly distribution systems.
- ✓ Rainwater provides a water source when groundwater is unacceptable or unavailable.
- ✓ Rainwater is sodium free.
- ✓ Rainwater is superior for landscape irrigation.
- ✓ Rainwater harvesting reduces flow to storm water drains and also reduces non-point source pollution by reducing flooding, erosion and the contamination of surface water with sediments, fertilizers and pesticides in rainfall runoff.
- ✓ Rainwater harvesting saves money by reducing consumers' utility bills.

Disadvantages of rainwater harvesting include (Krishna, 2003; ARCSA, 2015):

- ✓ The success of rainwater harvesting depends upon the frequency, the amount of rainfall and on the surface of the roof; therefore, it is not a dependable water source in dry weather and prolonged drought.
- ✓ Low storage capacities will limit rainwater harvesting, as the system may not be able to provide water in a low rainfall period. Increased storage capacities add to the construction and operating costs and thus making the technology economically unfeasible.
- ✓ Health risks may arise; as cisterns can be a breeding ground for mosquitoes.
- ✓ Cisterns and storage tanks may be unsafe for small children if proper access protection is not provided.
- ✓ Harvested rainwater is mineral-free, which may cause nutritional deficiencies.

2.2 Contamination of harvested water with heavy metals

Harvested water used for many purposes may be contaminated by many pollutants. Among various pollutants, heavy metals are always one of big concerns due to their severe toxicities, so that they have been included in "Blacklist" by the United States Environmental Protection Agency (U.S. EPA) (Jomova and Valko, 2011). When these heavy metals enter into the human body, they could easily bind to vital cellular components and accumulate in organisms, resulting in a series of diseases and disorders (e.g., cancers, osteomalacia, kidney malfunction, etc.) (Boyd and Johri, 2010). As the first step of water pollution prevention, accurate and rapid monitoring of the heavy metals is vital. Ideally monitoring methods are expected to identify point sources of pollutants and the variation of non-point sources of pollutants in the environment.

2.2.1 Sources of heavy metals

One of the main sources of heavy metals in harvested rainwater is the roofing material. The roofing material may be a source or sink influencing heavy metal concentrations in the harvested rainwater. Storm water runoff collects a variety of pollutants (e.g. excess nutrients, metals, hydrocarbons and pesticides) that may leach from traditional roofing materials or may be introduced onto roofs through wet and dry deposition. Pollutants in this runoff can subsequently enter into municipal sewage treatment systems or natural water systems (including rainwater harvesting systems) (Köhler *et al.*, 2002; Berndtsson *et al.*, 2009). A study characterized six proposed green roof substrates and found that under simulated conditions in a green house, most of the substrates released elevated concentrations of Pb and Cd into the runoff (Alsup *et al.*, 2010). Also, a study at Nacogdoches, Texas, America was made to test roof runoff quality, the aim of the study was to see the effect of the roofing material on the water quality. Four different roofing materials (wood shingle, composition shingle, painted aluminum, and galvanized iron) were tested. The results showed that runoff quality from wood shingles was the worst (Chang *et al*., 2004).

The first flush of runoff water occurring at the beginning of the storm contains a high proportion of the pollutant load, including heavy metals. The main reason of having this high proportion is the deposition and accumulation of pollutant material to the roof during dry periods, wind removes some of the heavy metals accumulated from atmospheric fallout. Rainwater not only adds a variety of chemicals and contaminants to the roofing system, the acidic nature of the rainwater will react with compounds retained in or by the roof and cause many elements in the roof-runoff to leach out, also, the high temperature of the roofing material may accelerate chemical reactions and organic decomposition of the materials and compounds that have accumulated on the topping of the roofs (Che *et al*., 2001; Spinks *et al*., 2003).

Other sources of heavy metals are mineral particles from ground surface, components originating from industrial emissions, vehicle emissions and fuel combustion products emitted to the atmosphere (Shirasuna *et al.*, 2006; Walna and Kurzyca, 2009; Ki *et al.*, 2011). For example, a study in Melbourne showed that rainwater tanks are contaminated with lead and other heavy metals at levels exceeding drinking water guidelines, the study included the investigation of six pilot roofs (glazed tiles, pre-painted steel, and 55% aluminum-zinc coated roofs with and without lead flushing) and tanks revealed that lead flushing significantly contributed to the lead content in the tank water which was up to 50 times the recommended Australian Drinking Water Guidelines (ADWG). Concentrations of Al, Cd, Fe and Zn were beyond the allowed limits too (Magyar *et al*., 2008).

2.3 Effects of heavy metals on health

Heavy metals in nature are not usually hazardous to the environment and human health, as the amounts of them are not significant; furthermore some heavy metals are required at low concentrations as catalysts for enzyme activities in human body. Some of these metals are vital to keep up life such as Calcium, Magnesium, Potassium and Sodium, which are necessary for common body functions and others including Cobalt, Copper, Iron, Manganese, Molybdenum and Zinc are needed at low concentrations as catalysts for enzyme activities). However, if the level of these elements are elevated to higher than the normal ranges, they cause malfunction and result in toxicity to human body. (Tuzen and Soylak, 2006; Adepoju-Bello *et al.*, 2009; Kaplan *et al*., 2011).

2.3.1 Interference of heavy metals in human body

Heavy metals possess serious effects on human health and might cause various symptoms depending on the type and amount of the metal involved (Adepoju-Bello *et al.*, 2005). Their toxicity is made by forming complexes with proteins where they contain carboxylic acid (−COOH), amine ($-NH_2$) and thiol (−SH) groups. These modified biological molecules lose their proper functions and consequently lead to breakdown or cell death. As heavy metals combine with these groups, they inhibit vital enzymes or may disturb the formation of some proteins necessary for catalytic functions of enzymes. In addition, some of these heavy metals can incite the production of harmful radicals and result in the oxidation of biological molecules (Anyakora and Momodu, 2010).

Common heavy metals that human beings are exposed to include: Aluminum (Al), Cadmium (Cd), Chromium (Cr), Lead (Pb), Mercury (Hg), Copper (Cu), Zinc (Zn), Iron (Fe), Nickel (Ni) and Cobalt (Co).

The effects of these heavy metals on human bodies and their functioning are discussed in detail in the following sections.

Aluminum

Al is considered one of the most hazardous trace metals found in drinking waters, as it is both toxic and carcinogenic. Also, it is associated with Alzheimer's and Parkinson's diseases and senile and pre-senile dementia. Long term exposure to the concentration of 50 mg/L can cause skin damages (WHO, 2001).

Cadmium

Cd exposure can cause both chronic and acute health effects in living organisms (Barbee and Prince, 1999). The chronic effects include kidney damage, skeletal damage and itai-itai (ouch-ouch) diseases (Jarup *et al.*, 2000; Nordberg *et al.*, 2002). Also, Cd may cause hypertension, arteriosclerosis and cancer (WHO, 1998; Bartin *et al.*, 2006). Municipal solid waste incinerators are a major source of Cd (Özsoy and Örnektekin, 2009). The abrasion of automobile tyres and the manufacturing and dumping of Cd batteries may be other sources of Cd emissions (Mugica *et al.*, 2002). Maximum acceptable concentration for Cd is recognized to be 3 µg/L or 5 µg/L by World Health Organization and Environmental Protection Agency (EPA) respectively (WHO, 2001; EPA, 2002).

Chromium

Cr is a trace metal essential for humans and animals, but in higher concentrations especially in the more toxic Chromium (VI) valence state, it will impair human health as it may be involved in pathogenesis of some diseases such as lung and gastrointestinal cancers (Dayan *et al.*, 2001). Also, Cr at high concentrations may cause liver and kidney problems (Knight *et al.*, 1997; Loubieres *et al.*, 1999; Strachan *et al.*, 2010). The allowed WHO limit for Cr is 50 μg/L (WHO, 2011).

Lead

Pb is a toxin and probably a human carcinogen (Bakare-Odunola, 2005). Pb may cause chronic health risks, including headache, irritability, abdominal pain, nerve damages, kidney damage, blood pressure, lung cancer, stomach cancer and gliomas (Steenland *et al.*, 2000, Mortada *et al.*, 2001; Jarup, 2003). As children are more susceptible to Pb toxicity, their exposure to high levels of Pb causes severe health complexities such as behavioral disturbances, memory deterioration and reduced ability to understand, while long-term Pb exposure may lead to anemia (Jarup, 2003). WHO identified 10 μg/L as the maximum permissible limit for Pb in drinking water (WHO, 2011). At higher concentrations, Pb can cause permanent brain damages.

Mercury

Hg is poisonous to human beings and might be associated with deterioration of mental status and disorders of speech, hearing, vision and movement. Hg may result in autoimmunity in which immune system of the body attacks its own cells. This might cause the development of joint diseases and malfunction of kidneys, cardiovascular system and neurons. Maximum allowable limit of Hg in drinking water by WHO is 6 μg/L (WHO, 2011).

Copper

Cu (II) is one of the most common heavy metals in water. Small amounts of Cu are needed for normal body growth and function, such as physiological functions of living tissue and regulation of many biochemical processes. However, abundant levels of Cu in drinking water can be neurotoxic and result in mental diseases such as Alzeheimer's disease (Dieter *et al.*, 2005). Industrial and domestic activities may be the main source of Cu in the environment. The allowable limit of Cu in drinking water according to the WHO is 2000 μg/L (WHO, 2011).

Zinc

Sufficient amount of Zn is important for normal body functions. Its deficiency can lead to poor wound healing, reduced work capacity of respiratory muscles, immune dysfunction, anorexia, diarrhea, hair loss, dermatitis and depression. However, high concentrations of Zn cause toxicity and the latter causes a sideroblastic anemia (Strachan *et al.*, 2010). The main source of zinc in natural waters may be galvanized pipes. Local contamination from vehicle components such as metal oxidation or tyre degradation might be additional potential sources of Zn emissions (Ball *et al.*, 1991, Loranger *et al.*, 1996). WHO recommends a value of no more than 3000 μg/L in drinking water (WHO, 2011).

Iron

Industrial and domestic activities are the main sources of Fe in groundwater. High Fe content results in very unpleasant taste of drinking water and also produces brown precipitate of ferric hydroxide, which can lead to severe microbiological problems in pipelines. In many manufacturing processes, particularly in the textile, paper and food industries, the Fe content should be kept to a minimum level (WHO, 2011).

Nickel

Nickel could enter the water system through mining, manufacturing activities, and through leaching from e-wastes. Ni-sulfate and Ni-chloride ingestion can cause severe health problems, including fatal cardiac arrest (Knight *et al.*, 1997). The allowed amount of Ni by WHO is 70 μg/L (WHO, 2011).

Manganese

Manganese in trace amounts is needed for physiological functions of living tissue, as well as for regulation of many biochemical processes inside the human body. However, high concentrations of Mn in drinking water can cause mental diseases such as Alzheimer's and Manganism (Dieter *et al.*, 2005). Also, high Mn contamination in drinking water also affects the intellectual functions of 10-year-old children (Wasserman *et al.*, 2006). The WHO limit for Mn in drinking water is 500 µg/L (WHO, 2011).

Cobalt

Co is one of the required metals and it is needed for normal body functions as a metal component of vitamin B_{12} (Strachan *et al.*, 2010). However, high intake of Co via consumption of contaminated food and water can cause abnormal thyroid artery, polycythemia, over-production of red blood cells (RBCs) and right coronary artery problems (Robert *et al.*, 2003). WHO recommends a value of no more than 10 µg/L (WHO, 2011).

2.3.2 Heavy metals and cancer risk

Worldwide, cancer is considered a significant health care problem, and it is considered the second most cause of death. Genetic features play an important role in many types of cancer, however, environmental factors including human's lifestyle, eating habits, and exposure to chemicals play an important role in most types of cancer (Boyle and Levin, 2008). According to WHO, environmental factors are responsible for more than 70% of cancer cases. Many heavy metals are considered carcinogenic according to the classification of WHO and the International Agency for Research on Cancer (IARC), e.g., cobalt, mercury, lead, arsenic, nickel, cadmium, beryllium, chromium and others (Changrajith and Dissanayake, 1999; IARC, 2012). For example, many studies showed that people who drink water containing high levels of arsenic have higher risks of bladder, kidney, lung, colon, liver and skin cancer (American Cancer Society, 2013). Also, cadmium is known to cause kidney, prostate and lung cancer, aluminum can cause lung and bladder cancer (IARC, 2012).

2.4 Occurrence of heavy metals in water: Case studies

Many local and international studies around the world were made to test the occurrence of heavy metals in harvested rainwater and drinking water.

Table 1 summarizes the occurrence of a number of heavy metals in samples of harvested and drinking water for five countries: Turkey (Tuza and Soylak, 2006), Palestine (Malassa *et al.*, 2014; Almur, 2016), Pakistan (Muhammad *et al.*, 2011), Saudi Arabia (Assubaie, 2011) and Iran (Kamani *et al.*, 2014).

Table 1: Occurrence of heavy metals in samples of harvested and drinking water in the five countries

Country	City/Region	Cr	Mn	Co	Ni	Cu	Zn	Cd	Pb	Fe
Palestine	Hebron	✓	✓	✓	✓	✓	✓	✓	✓	
Turkey	Tokat-Black Sea Region	✓	✓	✓	✓	✓	✓			✓
Pakistan	Kohistan	✓	✓	✓	✓	✓	✓	✓	✓	
Iran	Tehran	✓			✓	✓	✓	✓	✓	✓
Palestine	Tulkarm	✓	✓	✓	✓	✓	✓	✓	✓	✓
Saudi Arabia	Alahsa Oasis Farms		✓			✓	✓	✓	✓	✓
New Zealand	Auckland					✓	✓		✓	

In Hebron, the results of the study revealed that eleven heavy metals (Cr, Mn, Co, Ni, Cu, Zn, Mo, Ag, Cd, Pb and Bi) were detected in the harvested water samples analyzed (44 samples). Eight heavy metals (Cr, Mn, Co, Ni, Cu, Zn, Bi and Pb) were detected in all samples, while Mo, Ag and Cd were detected in 37, 18 and 38 samples, respectively. For the metal Cr, 59% of the samples exceeded the WHO limit. For the metal Mn, 4.5 % of the samples exceeded the limit. For the metal Ni, 34% of the samples exceeded the limit. For the metal Ag, 4.5 % exceeded the limit. For the metal Pb, all samples exceeded the limit. For the metals Cu, Zn and Mo, neither of the samples exceeded the limit. According to the study, results and literature, possible sources of these heavy metals in harvested rainwater might be attributed to uncontrolled burning of solid wastes in illegal waste dumping sites, where it is expected that the ashes and dust of these incinerated wastes contain heavy metals that are transported through wind to the house roofs, and, consequently, to the harvested rainwater in the study area. Another sources of these heavy metals are the exhausts of vehicles, engines' leakage, pesticides, sand, soil and silt ((Malassa *et al.*, 2014).

In Tokat, the metals Cr, Ni, Cu, Mn, Zn, Fe, Co and Al were tested in drinking water samples. For all metals, all samples were below the WHO limits (Tuza and Soylak, 2006).

In Kohistan, a study was conducted to investigate heavy metal (Cu, Co, Cr, Mn, Ni, Pb, Zn and Cd) concentrations in drinking water (surface water and groundwater). Also, the study aimed to assess the potential health risk of the heavy metal concentration to local population. The heavy metal concentrations were compared with acceptable limits set by Pakistan Environmental Protection Agency (Pak EPA) and the WHO limits. The results showed that all samples were safe indicating no health risks (Muhammad *et al.*, 2011).

In Tehran, measurements of the metals Zn, Cd, Cr, Ni, Pb, Cu, Fe and Al were performed on 53 wet atmospheric precipitation samples. The concentrations of Al and Fe were the highest. A possible source of Zn, Pb, Cu, Ni, and Cd is anthropogenic activities mostly related to industrial combustion and local traffic emissions (Kamani *et al.*, 2014).

In Tulkarm, a study was conducted at An-najah university in Palestine to assess the quality of rainwater harvesting cisterns for drinking purposes in Sha'rawiya rural areas. Fifty water samples were collected from different cisterns for 12 rural areas. The water samples were analyzed for different physiochemical parameters and heavy metals. The tested heavy metals were: Ag, Al, Ba, Be, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn. The results were compared with the WHO and Palestinian standards for drinking water quality. All the heavy metals in the water samples were within the WHO and Palestinian standards except the metal Fe, in which 33% of the results exceeded the allowed limits. Cistern characteristics and sources of contamination were studied by distributing 100 questionnaires on the households, the results showed that in 78% of the cases, the sources of contamination were the presence of trees around the cisterns and storage of the first storm in the cisterns (Almur, 2016).

In Alahsa farms, three types of water were analyzed including groundwater, mixed water and wastewater. The metals Mn, Fe, Cu, Zn, Cd and Pb were determined. The results showed that the concentrations of Mn, Fe, Cu, Zn, Cd and Pb in groundwater were lower than those in mixed water and wastewater (Assubaie, 2011).

In New Zealand, roof collected rainwater in Auckland was tested for the occurrence of a number of heavy metals namely, lead, copper and zinc. The results showed that eighteen samples of water exceeded the New Zealand drinking water maximum acceptable values for lead which is 0.01 mg/L. The sample results were in the range 0.011-0.14 mg/L. Considering the metal Cu, three out of 125 samples had copper levels above the New Zealand maximum acceptable values, which is 2 mg/L. The results were 2.8, 4.4 and 4.5 mg/L. For the metal Zn, only one sample exceed the acceptable limit, which is 3 mg/L. The value was 3.2 mg/L (Simmons *et al*., 2000).

From Table 1, it can be concluded that contamination of harvested and drinking water by heavy metals is a worldwide problem, as in the five countries mentioned above, most of the heavy metals were detected in each country. Therefore, care must be taken concerning the practices of water harvesting and distribution.

Chapter Three

Study Area

3.1 General

The focus of this research is on Yatta region. Yatta is approximately 8 km south of the city of Hebron. According to the PCBS, it had a population of 64,277 in 2016 (PCBS, 2016).

3.1.1 Location and topography

Hebron is a Palestinian city located in the southern West Bank, 30 km south of Jerusalem. It lies 930 meters above sea level. It is the largest city in the West Bank, and the second largest in the Palestinian Territories after Gaza. Hebron is attached to cities of Adh Dhahiriya, Dura, Yatta, the surrounding villages with no borders. In 2016, its population has reached 215,452 capita (PCBS, 2016). Figure 1 shows the Hebron District Map.

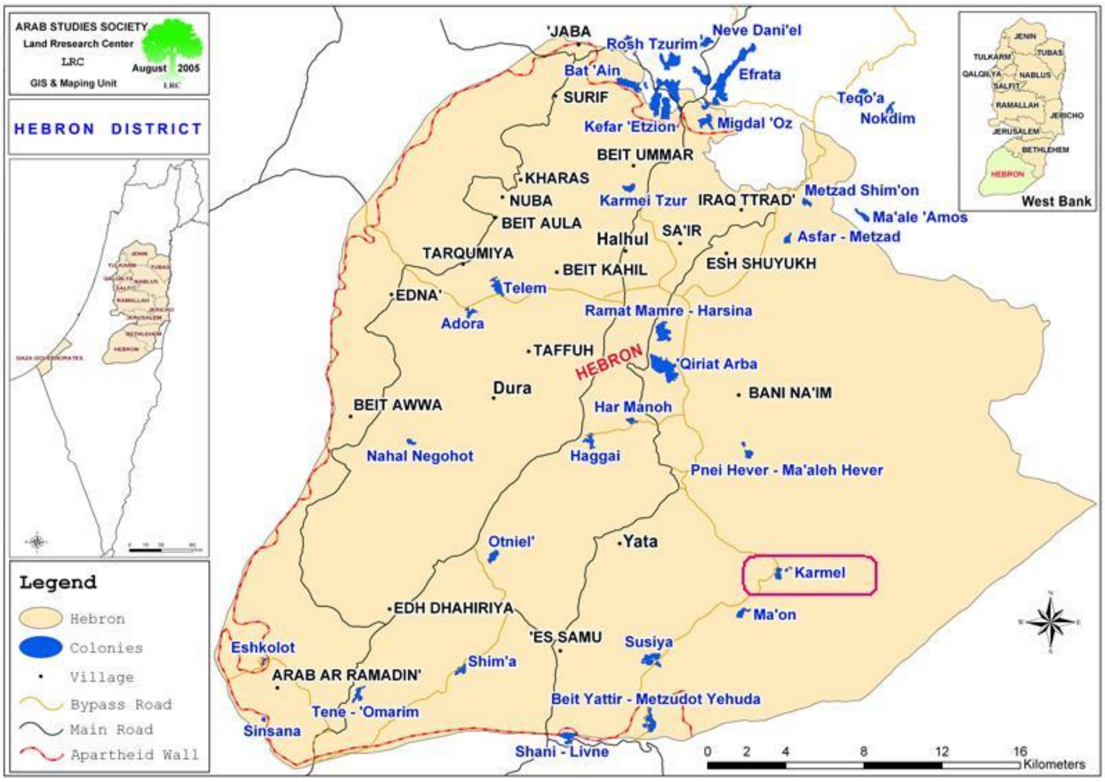

Figure 2: Study area, Hebron District, (PCBS, 2016).

3.1.2 Climate

Hebron District climate ranges from arid to semiarid with an increase in aridity towards the Negev Desert in the south and the Jordan Valley in the east. The monthly average temperature ranges from 7.5 to 10 °C in winter to 22 °C in summer. The minimum temperature is -3 °C in January and the maximum is 40 °C in August. Most of the rainfalls are during December through February, although there may be rain from mid-October to the end of April. The amounts of rainfalls per month ranges between 400 mm during the rainfall season and 0 mm during the dry season. Hebron District is facing due to the arid and semiarid climatic conditions (ARIJ, 2009).

3.1.3 Trade

Hebron is the centre of West Bank trade, responsible for roughly a third of the area's gross domestic product, due to the sale of marble from quarries (Zacharia, 2010). It is locally well known for its grapes, figs, limestone, pottery workshops and glassblowing factories, and it is the location of the major dairy product manufacturer, *al-Junaidi*.

3.2 Sampling location

75 water samples were collected from different neighborhoods in Yatta town including: Al Heila, Yatta Center, Khallet Salih, Khallet al Maiyya and Al-Hadedeyah, and were tested for the occurrence of a number of heavy metals namely, Pb, Cr, Mn, Co, Ni, Cu, Zn and Cd.

Chapter Four

Methodology

4.1 Overview

The study aims to determine the heavy metals concentrations in harvested rainwater, possible sources of contamination, and their potential health risks. The study area chosen for this research was Yatta and its neighborhoods in Hebron district.

4.2 Sampling and survey

Water samples from 75 houses were collected in February 2016. The sampling process was accomplished in 5 days, each day, water samples were collected from a number of households in one neighborhood. Yatta center and four of its neighborhoods were the main focus areas of this research. In day 1, 12 samples were collected in Al-hila neighborhood from 12 different rainfed cisterns in 12 different households. In day 2, 21 water samples were collected from Yatta center. In day 3, 13 samples were collected from Khelet Saleh. In day 4, 13 samples were collected from Khelet el mayya and in day 5, 15 samples were collected from Al-hadidya. In each household, a questionnaire of 19 questions was distributed on the housewives. A copy of the questionnaire is shown in Appendix 1. The questionnaire included questions about the source of water in the cistern, the frequency of cleaning the roof and the cistern, age of the cistern, shape of the cistern, existence of impurities or algae on the surface and sides of cistern and many others.

4.3 Analysis

The 75 water samples were taken to the lab of Al-Quds University and analyzed for the existence of a number of heavy metals (Pb, Cr, Mn, Co, Ni, Cu, Zn and Cd). Analysis was made using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Sample results are shown in Appendix 2.

4.3.1 The instrument

ICP-MS (Agilent 7500) with an onboard peristaltic pump, a nebulizer (MicroMist nebulizer), an ICP argon plasma torch, two pumps for evacuation, a quadrupole mass analyzer, an octapole reaction system (ORS), and an electron multiplier detector was used for the analysis of the heavy metals in this study.

ICP-MS is a type of mass spectrometry that is capable of detecting several trace metals and non-metals at concentrations as low as one part in 10^{15} (part per quadrillion, ppq) on non-interfered low-background isotopes. The detection is achieved by ionizing the sample with inductively coupled plasma first and then using a mass spectrometer to separate and quantify the ions.

The operating conditions for ICP-MS are as follows:

- ✓ Nebulizer gas (argon); flow-rate: 0.9 L/min.
- ✓ Auxiliary gas (argon); flow-rate: 0.3 L/min.
- ✓ Plasma gas (argon); flow-rate: 15 L/min.
- ✓ Reaction gas (helium); flow-rate: 4 L/min.
- ✓ Lens voltage; 7.25 V.
- ✓ ICP RF power; 1100 W.

Figure 3 shows a photo for the ICP-MS instrument. Figure 4 shows a labeling for the parts of the ICP-MS instrument.

Figure 3: ICP-MS instrument, (Corman Center for Mass Spectrometry,2017).

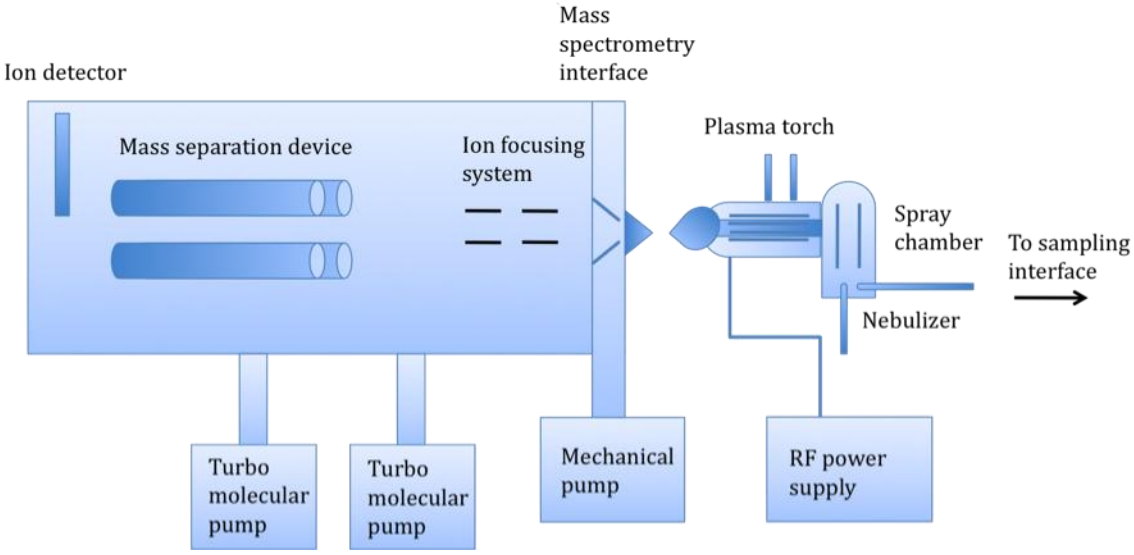

Figure 4: Parts of the ICP-MS instrument, (openstax, 2009).

4.3.2 Sampling and analysis procedures

First, the water samples were collected in a 1-L high density polyethylene bottles; pre-cleaned with 10% nitric acid followed by repeated rinsing with bi-distilled water, stabilized with ultrapure nitric acid (0.5 % HNO_3), preserved in a cool place (about 4 °C) and transported to the lab of Al-Quds University for further analysis. The samples were then analyzed for heavy metal content (Pb, Cr, Mn, Co, Ni, Cu, Zn and Cd) by inductively coupled plasma mass spectrometry (ICP-MS). Preparation of samples was made by diluting 1.0 mL of the water samples to 10.0 mL with 0.3% ultrapure nitric acid. After that, the samples were analyzed by ICP-MS.

4.4 Statistical Analysis

The main aim of the questionnaire was to connect the results of the sampling analysis by the sources of pollution of the samples by heavy metals. In order to connect them together, statistical analysis was made using the SPSS program. All the sample results exceeding the WHO and Palestinian limits were considered polluted by heavy metals. Cross tabulation method was used in the statistical analysis in order to see whether there is a statistical significance between the questions; which are considered as possible sources of pollution by heavy metals, and the sample results.

4.5 Calculations

4.5.1 Health risk assessment

As the harvested rainwater in the study area is to be used for drinking and other domestic purposes, it is important to make sure that this water is safe to be used by consumers.

Two approaches were used to test the safety of the harvested rainwater (US EPA, 2011):

1. Chronic daily intakes of metals (CDIs) and,
2. Health risk indexes of metals (HRIs).

In this research, the health risk assessment was made for all the samples that exceeded either the WHO or the Palestinian standards for drinking water quality or both.

4.5.2 Chronic daily intakes of metals (CDIs)

Heavy metals enter the human body through several pathways including: food intake, dermal contact and inhalation. In comparison to oral intake, however, all other pathways are considered negligible (Muhammad *et al.*, 2011). The CDI (µg/(kg.day)) of heavy metal through water ingestion was calculated by Eq. (1) (Muhammad *et al.*, 2011; Shah *et al.*, 2012).

$$\boldsymbol{CDI = \frac{C_m}{W_b} * I_w} \qquad \textbf{(1)}$$

where, C_m (µg/L) means the heavy metal concentration in water, I_w (L/day) is the average daily intake of water (assumed to be 2 L/day for adult and 1 L/day for child) (US EPA, 2011), and W_b (kg) is the average body weights (assumed to be 72 kg for adult and 32.7 kg for child), respectively (Jan *et al.*, 2010; Khan *et al.*, 2010 and Muhammad *et al.*, 2011).

4.5.3 Health risk indexes of metals (HRIs)

To estimate the chronic health risks, HRIs were calculated by Eq. (2) ((Muhammad *et al.*, 2011; Shah *et al.*, 2012).

$$\boldsymbol{HRI = \frac{CDI}{RfD}} \qquad \textbf{(2)}$$

Where, the oral toxicity reference dose (Rfd, µg/(kg.day)) values for Cd, Cr, Cu, Mn, Ni, Pb, Zn and Co are $5*10^{-1}$, $1.5*10^{1}$, $3.7*10^{1}$, $1.4*10^{2}$, $2*10^{1}$, $3.6*10^{1}$, $3*10^{2}$ and $3*10^{1}$, respectively (Muhammad *et al.*, 2011; Shal *et al.*, 2012). The HRI value less than 1 is considered to be safe for the consumers (Khan *et al.*, 2008).

Chapter Five

Results and Discussion

This chapter introduces the results of this study with a detailed discussion on them. First of all, it summarizes the occurrence of the heavy metals in the samples analyzed, and then it compares the results with local and international studies.

5.1 Occurrence of the heavy metals

The occurrence of eight heavy metals were tested in the study. The heavy metals are: Pb, Cr, Mn, Co, Ni, Cu, Zn and Cd. Cr, Ni and Cu existed in all samples. Pb, Mn, Co, Zn and Cd were detected in 71, 60, 40, 68 and 46 out of 75 samples, respectively. The concentration of Pb, Cr, Mn, Co, Ni, Cu, Zn, and Cd in water samples ranged as follows: 0-24, 0.11-101.44, 0-57.94, 0-2.51, 0.60-518.10, 0.54-123.21, 0-3452.52 and 0-1.86 μg/L, respectively.

Table 2 summarizes the concentrations of heavy metals which are detected in the harvested rainwater samples analyzed in this study (average concentration (standard deviation), range, WHO limit, Palestinian limit, number of samples exceeding WHO limit, % of samples exceeding WHO limit, number of samples exceeding Palestinian limit and % of samples exceeding Palestinian Limit).

Table 2: Concentrations of the heavy metals for all of the samples analyzed in harvested rainwater, Yatta, Hebron.

Element	Average Conc. (μg/L) (SD)	Range (μg/L)	WHO Limit (μg/L)	Pal. Limit (μg/L)	No. of samples exceeding WHO Limit	(%) of samples exceeding WHO Limit	No. of samples exceeding Pal. Limit.	(%) of samples exceeding Pal. Limit.
Pb	1.80 (1.49)	0.00-24.00	10	10	2	2.70	2	2.70
Cr	4.31 (3.69)	0.11-101.00	50	50	2	2.70	2	2.70
Mn	4.32 (2.99)	0.00-58.00	500	100	0	0	0	0
Co	0.24 (0.66)	0.00-3.00	10	-	0	0	0	0
Ni	19.06 (8.01)	0.60-518.00	70	50	2	2.70	2	2.70
Cu	8.18 (3.99)	0.54-123.00	2000	1000	0	0	0	0
Zn	201.34 (21.04)	0.00-3453.00	3000	5000	1	1.35	0	0
Cd	0.10 (0.56)	0.00-2.00	3	3	0	0	0	0

As mentioned earlier in this research, there are a lot of international and local studies on the occurrence of heavy metals in harvested rainwater, a number of studies were illustrated in Chapter 2. Table 3 gives a summary for the results of these studies and the study area of this research in terms of the occurrence of these heavy metals and a comparison of these results with the WHO and local standards.

Table 3: Occurrence of the heavy metals in rain water in several countries.

Element	**Hebron**, Palestine (µg/L)	**Tokat-Black Sea Region**, Turkey (µg/L)	**Kohistan**, Pakistan (µg/L)	**Tehran**, Iran (µg/L)	**Tulkarm**, Palestine (µg/L)	**Yatta***, Hebron (µg/L)	WHO Limit** (µg/L)	Palestinian Limit*** (µg/L)
Cr	56.1	4.40	3.61	1.74	0.008	4.31	50	50
Mn	112.6	3.98	14.01	-	0.003	4.32	500	100
Co	3.16	<<	0.52	-	<<	0.24	10	-
Ni	26.7	3.82	4.25	7.14	0.003	19.06	70	50
Cu	143.6	6.01	65.8	21.4	0.003	8.18	2000	1000
Zn	111.8	6.12	34.2	80.93	0.05	201.34	3000	5000
Cd	1.17	-	0.53	0.67	<<	0.10	3	3
Pb	45.8	-	5.03	69.7	<<	1.80	10	10

***** The study area of this research. ** WHO (2011). *** PSI (2010).

From table 3, it is obvious that the water samples are considered safe in terms of the occurrence of the heavy metal Cr except for the study in Hebron, as the mean values are above the WHO and local limits. In this research, two samples exceeded the WHO and Palestinian limits. Based on the study in Hebron, the study area of this research and literature, possible sources of Cr are road dust, asbestos brakes or anthropogenic activities occurring around the house (Mendez *et al.*, 2010; ATSDR, 2013). Also, Cr is emitted from solid waste, fossil fuel combustion and steel industry (Wise Sr *et al.*, 2009; Cong *et al.*, 2010). However, no industrial or nuclear activities are occurring in the study area, and this explains the low value of this metal in the harvested rainwater samples of this research.

The harvested rainwater samples in the all the studies are considered safe in terms of the occurrence of Mn. In the study area of this research, nor of the samples exceed the WHO and Palestinian limits for this metal. Based on the literature, a possible source of Mn is dust transported through wind to the roofs of the houses (Malassa *et al.*, 2014)

The heavy metal Co occurred in very low amounts in the study areas, especially, in Tulkarm and the Tokat-Black Sea Region in turkey. In this research, Co amounts were acceptable according to the WHO and Palestinian limits. Possible sources of Co in harvested rainwater are uncontrolled incineration of solid wastes in illegal dumping sites, vehicles' exhausts and leakage from engines, pesticides, and sand, soil, silt and others (Malassa *et al*., 2014).

It can be concluded from table 3 that in all the studies, the occurrence of the metal Ni is below the WHO and local limits. Possible source of Ni is leaching from metals in contact with harvested rainwater such as pipes and fittings which are used to collect the harvested rainwater (WHO, 2005; Mendez *et al.*, 2010). For this research, the statistical analysis showed that there is a relationship between the source of the water in the cistern and the high level of Ni in two samples. The chemical reactions occurring between the roofing material or pipe with the harvested rainwater may leach out many chemicals including nickel (Che *et al*., 2001; Spinks *et al.*, 2003).

Nor of the harvested rainwater samples in this study contained the heavy metal Cu above the WHO and Palestinian limits. Possible sources of Cu in harvested rainwater are vehicles' exhausts, pesticides and industrial activities (Hu and Balasubramanian, 2003; Cong *et al*., 2010 and Malassa *et al.*, 2014).

Also, for the metal Zn, its value in all the tested samples of the studies was below the WHO and Palestinian limits. In this research, one sample exceeded the WHO limit only for Zn. Based on the questionnaire results and literature; possible sources of Zn are the roof and storage tanks. Rainwater can dissolve the heavy metal Zn and other impurities from materials of the catchment and storage tank. Other sources of Zn are distribution system (pipes) and plumbing, as the pipes are used to collect harvested rainwater from the roofs (Mendez *et al.*, 2010).

All of the tested harvested rainwater samples in the studies were considered safe in terms of the occurrence of the heavy metal Cd. Possible sources of this metal in harvested rainwater are vehicles' exhausts, leakage from engines, ashes and dust containing Cd transported through wind to roof houses, pesticides and others (Malassa *et al*., 2014).

Also, for the metal Pb, its value in all the samples of the studies was below the WHO and local limits. In this research, two samples in two different cisterns exceeded the WHO limit only for the metal Pb. Based on the questionnaire results and literature, possible sources of Pb are the roof and storage tanks. Elevated levels of Pb could be from leaching from metallic roofs and storage tanks or from atmospheric precipitation. Also, municipal solid waste incinerators are a major source of Pb (Özsoy and Örnektekin, 2009), because of the use of their metal oxides as pigments, stabilizers and catalysts in plastic processing (Hu and Balasubramanian, 2003).

5.2 Factors affecting heavy metals contamination

In this study, 19 factors which were considered may lead to contamination by heavy metals were taken into consideration. Section 5.2.1 shows the households distribution according to different factors presented in tables 4 through 26. Section 5.2.2 shows a summary of the existence of the heavy metals in the rainfed cisterns.

5.2.1 Households distribution according to different factors

Tables 4 through 26 present the factors which are considered possible causes of heavy metals occurrence in drinking water above local and international limits.

Source of water in cistern

Considering the source of water in cistern factor, Table 4 shows that 77.3 % of the households depend on water collected from the roof of the house as a major source of domestic water. During winter, they harvest the water in the cisterns laid in the backyard of the house. 1.3 % collects water from the garden or the backyard of the house. 2.7 % collect the water from the street.

Table 4: Households distribution according to "Source of water in cistern".

What is the source of water in cistern?	Frequency	Percent
Roof of the house	58	77.3
Garden or the backyard of the house	1	1.3
Street	2	2.7
Otherwise	5	6.7
Roof of house and garden or backyard	6	8.0
Roof, garden and street	1	1.3
Roof and street	2	2.7
Total	75	100.0

Do you take any actions before collecting rainwater

As shown in Table 5, 98.6 % of the households take actions before collecting rainwater. According to this percent, it can be concluded that taking actions justifies the concentrations of the heavy metals being low in the samples analyzed. Table 6 shows in details these actions, and their percentage distribution on the households.

Table 5: Households distribution according to "Do you take any actions before collecting rainwater".

Do you take any actions before collecting the rainwater?	Frequency	Percent
Yes	73	98.6
No	1	1.4
Total	74	100.0

If Q 2 is Yes, what are these actions?

Table 6 shows in details the distribution of the actions on the households, 81.3 % clean the roofs and get rid of the first rain before starting with the harvesting techniques. Cleaning the roofs guarantees that no or little amounts of heavy metals can present in the harvested rainwater and that is the case in this study.

Table 6: Households distribution according to "If Q 2 is Yes, what are these actions?".

If the answer of Q 2 is Yes, what are these actions?	Frequency	Percent
Cleaning the roof of the house	11	14.7
Getting rid of first rain water	2	2.7
Cleaning roof and getting rid of first rain	61	81.3
Otherwise	1	1.3
Total	75	100.0

When the cistern was last cleaned (in years)

As shown in Table 7, 70 % of the households clean the cisterns periodically before harvesting the rainwater. Cleaning the cisterns from while to while guarantees that no or very little amounts of heavy metals will be stuck in their walls and this justifies the low concentrations of the heavy metals in the samples analyzed.

Table 7: Households distribution according to "When the cistern was last cleaned (in years)".

When the cistern was cleaned last time ? (In years)	Frequency	Percent
.000	49	70.0
.083	2	2.9
.750	1	1.4
1.000	6	8.6
2.000	5	7.1
3.000	4	5.7
4.000	1	1.4
5.000	2	2.9
Total	70	100.0

For what purposes is the water in the cistern used

Table 8 shows that 21.3 % of the households use the harvested rainwater for many purposes including drinking, cooking and cleaning the house. 1.3 % use it for drinking only. Using harvested rainwater for many purposes means that it is important that the water be clean and safe for the consumers, i.e. in case of the presence of heavy metals, they should be in minimal amounts or amounts below local and international limits, also, the CDI and HRI (Section 5.3) must be within the international limits to consider the water safe for daily intake.

Table 8: Households distribution according to "For what purposes is the water in the cistern used".

For what purposes is the water in the cistern used? (The answer may be more than one choice)	Frequency	Percent
Drinking	1	1.3
Drinking and animals	7	9.3
Drinking, animals and Irrigation	1	1.3
Animals and cooking	1	1.3
Drinking and irrigation	1	1.3
Drinking and cooking	2	2.7
Drinking and cleaning house	9	12.0
Drinking, animals and cooking	2	2.7
Drinking, animals and cleaning house	1	1.3
Drinking, irrigation and cooking	8	10.7
Drinking, irrigation and cleaning house	2	2.7
Drinking, cooking and cleaning house	16	21.3
Irrigation, cooking and cleaning house	1	1.3
Drinking, animals, irrigation and cooking	2	2.7
Drinking, animals, irrigation and cleaning house	1	1.3
Drinking, animals, cooking and cleaning house	4	5.3
Drinking, irrigation, cooking and cleaning house	12	16.0
Drinking, animals, irrigation, cooking and cleaning house	4	5.3
Total	75	100.0

Age of cistern (in years)

The age of cistern varies between the households as shown in Table 9, 25.6 % of the households indicated that their cistern's age is about 15 years. 12.8 % had older cisterns with an age of about 30 years. The age of the cistern can be linked to the quality of the water collected inside it, the older the cistern, the more the probability that it contains impurities and accumulated heavy metals and therefore the harvested rainwater will get contaminated inside the cistern.

Table 9: Households distribution according to "Age of cistern (in years)".

Indicate approximately the age of cistern in years	Frequency	Valid Percent
0	2	5.1
4	1	2.6
7	1	2.6
10	3	7.7
12	3	7.7
15	10	25.6
20	2	5.1
25	4	10.3
30	5	12.8
35	2	5.1
40	3	7.7
50	2	5.1
70	1	2.6
Total	39	100.0

Volume of cistern in cubic meters

As shown in Table 10, the volume of the cisterns of the households varies between few to 200 cubic meters. 15.4 % of the households have a cistern of about 40 cubic meters (adequate volume).

Table 10: Households distribution according to "Volume of cistern in cubic meters".

What is the volume of the cistern:	Frequency	Percent
0	3	11.5
15	1	3.8
18	2	7.7
30	1	3.8
40	4	15.4
45	1	3.8
50	1	3.8
55	1	3.8
60	3	11.5
70	3	11.5
75	1	3.8
80	2	7.7
100	1	3.8
120	1	3.8
200	1	3.8
Total	26	100.0

Walls of cistern

Table 11 summarizes the household distribution according to “walls of cistern” factor. 81.3 % of the cisterns are made from concrete, while only 14.7 % are made from rock. The acidic components of rainwater react with the alkaline components of concrete cisterns or cement mortar, dissolving mineral salts (mainly calcium carbonate), therefore using harvested rainwater in concrete cisterns may affect its quality.

Table 11: Households distribution according to "Walls of cistern".

The walls of the cistern are from	Frequency	Valid Percent
Concerte	61	83.6
Rock	11	15.1
Concrete and Rock	1	1.4
Total	73	100.0

Situation of the cistern cover

According to Table 12, 97.3 % of the households indicated that the cover of the cistern is closed while 1.3 % indicated that the cover is perforated. Closing the cisterns totally guarantee that no or little impurities and heavy metals may enter into them.

Table 12: Households distribution according to "Situation of the cistern cover".

Is the cover of the cistern	Frequency	Percent
Closed	73	98.6
Perforated	1	1.4
Total	74	100.0

Shape of the cistern

It is shown in Table 13 that 61.3 % of the households have a cuboid cistern shape, while 38.7 % have a peer-shaped cistern.

Table 13: Households distribution according to "Shape of the cistern".

The shape of cistern	Frequency	Percent
Cuboid	46	61.3
Peer-shaped	29	38.7
Total	75	100.0

Distance between cesspit and cistern (in meters)

The distribution of the "distance between cesspit and cistern" factor on the households is shown in Table 14. 71.9 % have a distance less than 5 m between the cesspit and the cistern. The larger the distance between the cesspit and the cistern, the lower is the probability of the wastewater intrusion from cesspit to the cistern.

Table 14: Households distribution according to "Distance between cesspit and cistern (in meters)".

The distance between cistern and cesspit (in meters)	Frequency	Percent
0	46	71.9
5	1	1.6
7	1	1.6
10	5	7.8
15	2	3.1
20	3	4.7
30	2	3.1
50	1	1.6
70	1	1.6
80	2	3.1
Total	64	100.0

Level of cesspit

As shown in table 15, 48.5 % of the households have the level of cesspit below the cistern level, while 32.4 % have the level of cesspit the same level as cistern. It is better that the level of cesspit be lower than the cistern level to prevent wastewater intrusion from the cesspit to the cistern.

Table 15: Households distribution according to "Level of cesspit".

The level of cesspit	Frequency	Percent
0	1	1.5
Above cistern level	12	17.6
Below cistern level	33	48.5
Same level as cistern	22	32.4
Total	68	100.0

Last time cesspit was discharged (in years)

As shown in table 16, 93.8 % of the households discharge the cesspits periodically. 1.6 % of the households discharge it within a year, 1.6 % within 2 years, 1.6 % within 3 years and 1.6 % within 15 years. Discharging the cesspits periodically guarantees that the wastewater intrusion from these cesspits into the cisterns is kept as minimum, therefore making sure that the quality of the harvested rainwater is kept at its maximum level.

Table 16: Households distribution according to "Last time cesspit was discharged (in years)".

When the cistern was discharged last time? (In years)	Frequency	Percent
0	60	93.8
1	1	1.6
2	1	1.6
3	1	1.6
15	1	1.6
Total	64	100.0

Is there any animals or birds raised in the house

According to Table 17, 38.4 % of the households raise animals and birds around the house. 37 % sometimes raise and 24.7 % do not raise at all. Raising animals or birds in the backyard of the house increases the opportunity that these animals pick the heavy metals from streets and therefore these heavy metals may enter the harvested rainwater affecting its quality.

Table 17: Households distribution according to "Is there any animals or birds raised in the house".

Do you raise animals or birds around the house?	Frequency	Percent
Yes, always	28	38.4
Sometimes	27	37.0
No	18	24.7
Total	73	100.0

Is there any trees close to the cistern

According to Table 18, most of the households (74.7 %) do not have trees close to the cistern. 25.3 % have trees around the house and close to the cistern. Heavy metals can stuck into these trees coming from streets through the air and then can enter into the cisterns affecting the quality of the harvested rainwater.

Table 18: Households distribution according to "Is there any trees close to the cistern".

Is there any trees close to the house?	Frequency	Percent
Yes	19	25.3
No	56	74.7
Total	75	100.0

Do you notice impurities floating on the surface of the cistern

As shown in Table 19, 67.6 % of the households do not notice any impurities floating on the surface of the water in the cistern, while 32.4 % do notice. Impurities may include heavy metals which are considered an important pollutant affecting harvested rainwater quality.

Table 19: Households distribution according to "Do you notice impurities floating on the surface of the cistern".

Do you notice any impurities on the surface of the water in the cistern?	Frequency	Percent
Yes	24	32.4
No	50	67.6
Total	74	100.0

Do you notice a green layer on the sides of the cistern

According to Table 20, most of the households (80 %) do not notice a green layer (algae) on the sides of the cistern. The presence of algae in the cistern ends up fermenting in anaerobiosis (absence of air) giving the water an odour of rotten eggs, although perfectly harmless.

Table 20: Households distribution according to "Do you notice a green layer on the sides of the cistern".

Do you notice algae on the sides of the cistern?	Frequency	Percent
Yes	14	18.9
No	60	81.1
Total	74	100.0

Do you use the roof of the house for hanging the laundry

According to Table 21, 61.3 % use the roof of the house for hanging the laundry, while 38.7 % do not. Heavy metals coming from laundry detergents may accumulate on the surface of the roofs entering the harvested rainwater collection system and ending up in the cisterns.

Table 21: Households distribution according to "Do you use the roof of the house for hanging the laundry".

Do you use the roof of the house in winter for hanging the laundary?	Frequency	Percent
Yes	46	61.3
No	29	38.7
Total	75	100.0

Do you collect solid waste in the yard of the house

As shown in Table 22, 22.7 % of the households collect solid waste in the yard of the house. 77.3 % do not. Solid waste contains many components that may contain heavy metals, collecting the waste in the backyard of the house increases the opportunity of contamination of the harvested rainwater with a number of heavy metals such as Pb and Cr coming from batteries for example.

Table 22: Households distribution according to "Do you collect solid waste in the yard of the house".

Do you collect solid waste in the backyard of the house?	Frequency	Percent
Yes	17	22.7
No	58	77.3
Total	75	100.0

5.2.2 Presence of heavy metals in rainfed cisterns

A summary of the existence of the heavy metals in the harvested rainwater cisterns is shown in Tables 23 through 26.

Table 23: Presence of the metal Pb in rainfed cisterns

Metal Pb	Frequency	Percent
Contaminated	2	2.7
Uncontaminated	73	97.3
Total	75	100.0

Table 24: Presence of the metal Cr in rainfed cisterns

Metal Cr	Frequency	Percent
Contaminated	2	2.7
Uncontaminated	73	97.3
Total	75	100.0

Table 25: Presence of the metal Ni in rainfed cisterns

Metal Ni	Frequency	Percent
Contaminated	2	2.7
Uncontaminated	73	97.3
Total	75	100.0

Table 26: Presence of the metal Zn in rainfed cisterns

Metal Zn	Frequency	Percent
Contaminated	1	1.3
Uncontaminated	74	98.7
Total	75	100.0

Note: Contaminated means exceeding WHO and Palestinian Limits.

As the survey contained 19 questions, they were considered as a factor which may lead to contamination by heavy metals, exceeding WHO and Palestinian limits and therefore, a source of pollution. Each factor was analyzed with all sample results. As can be seen from section 5.1, only for the metals Pb, Cr, Ni and Zn, there is an exceedance of the samples, either the WHO or the Palestinian or both, therefore, the statistical analysis was made for these four metals only.

Table 27 shows a summary of the results of the statistical analysis. Four metals that exceeded the limits were considered: Pb, Cr, Ni and Zn. 19 factors which were considered may lead to contamination of the harvested rainwater by heavy metals were tested against the results of the laboratory for the four metals. Also, appendix 3 will show in details the analysis results and tables. Each factor was considered alone, with all the results of the four metals.

Table 27: Cross tabulation between the factors that may lead to contamination with heavy metals and the sample results.

Factor	**Significance P-value**			
	Metal Zn	**Metal Ni**	**Metal Cr**	**Metal Pb**
Sources of water in cistern	1.000	**.000**	.996	.996
Do you take any actions before collecting rainwater	0.906	0.867	0.867	0.867
If the answer of “Do you take any actions before collecting rainwater” is Yes, what are these actions?	0.972	0.925	**0.000**	**0.000**
For what purposes is the water in the cistern used	0.977	0.996	0.983	0.983
When the cistern was cleaned last time?	1.000	0.997	0.997	0.997
Walls of cistern	0.905	0.817	0.817	0.817
Situation of the cistern cover	0.906	0.867	0.867	0.867
Shape of the cistern	0.424	0.739	0.255	0.255
Distance between cistern and cesspit	1.000	1.000	1.000	1.000
Level of cesspit	0.192	0.230	0.230	0.230
When the cistern was discharged last time	0.999	0.996	0.996	0.996
Is there any animals or birds raised in the house	0.443	0.714	0.714	0.714
Is there any trees close to the cistern	0.558	0.404	0.404	0.404
Do you notice impurities floating on the surface of the cistern	0.485	0.321	0.321	0.321
Do you notice a algae on the sides of the cistern	0.627	0.489	0.489	0.489
Do you use the roof of the house for hanging the laundry	0.424	0.255	0.255	0.255
Do you collect solid waste in the yard of the house	0.586	0.438	0.349	0.349

According to the results presented in Table 27, there is no statistical significance between the probability of danger of contamination by the four heavy metals Zn, Ni, Cr and Pb and these factors, i.e. statistically insignificant (Sig > 0.05), except for the factor "Source of water in cistern" with the metal Ni and the factor "Actions taken before collecting rainwater" with the metals Pb and Cr (Statistically Significant; Sig <0.05).

5.3 Health risk assessment

According to the results shown in sections 5.1 and 5.2, it is obvious that about 98 % of the samples are considered safe according to the WHO and Palestinian standards for drinking water quality in terms of heavy metals content. However, the 3 % of the samples exceeded the limits by only a small amount. As a result, an assessment for the potential health risks due to contamination of these samples by heavy metals was made to make sure that the harvested rainwater used is safe for consumers.

A detailed calculation for CDI and HRI was made for all the samples that exceeded the WHO and Palestinian standards (Appendix 4). Two samples exceeded the WHO and the Palestinian limits for Pb, two samples for Cr and two samples for Ni. One sample exceeded the WHO limit only for Zn. Table 6 summarizes the results of the calculations of the CDI and HRI for adults. Table 7 summarizes the results of the calculations of the CDI and HRI for children.

Table 28: Summary of the health risk assessment calculations (for adults)

Heavy Metal	Sample No.	CDI Value (µg/kg.day)	HRI Value	Result
Pb	1	0.668	0.019	Safe
	2	0.382	0.011	Safe
Cr	3	2.82	0.188	Safe
	4	1.70	0.113	Safe
Ni	5	5.97	0.30	Safe
	6	14.39	0.72	Safe
Zn	7	95.90	0.32	Safe

Table 29: Summary of the health risk assessment calculations (for children)

Heavy Metal	Sample No.	CDI Value (µg/kg.day)	HRI Value	Result
Pb	1	0.735	0.020	Safe
	2	0.421	0.012	Safe
Cr	3	3.10	0.207	Safe
	4	1.87	0.125	Safe
Ni	5	6.57	0.33	Safe
	6	15.84	0.79	Safe
Zn	7	105.60	0.35	Safe

The results for adults and children are considered all safe, and this makes sense, as the samples exceeded the WHO and Palestinian standards by small amounts only.

It is obvious from the results of the studies mentioned in the content, including the results of this study that heavy metals are not considered a big issue, as their occurrence is usually below the local and international limits. Most of the studies around the world focus on testing many parameters in drinking water including physiochemical parameters (pH, electrical conductivity, turbidity, alkalinity, hardness, calcium, magnesium and many others) and Microbiological parameters (Fecal coliform and Total coliform). For example, the study in Tulkarm mentioned in this research, which considered 12 rural areas focused on these parameters, and the testing of the occurrence of the heavy metals was a secondary mission, and this is reasonable, as in general, rural areas do not have industrial or anthropogenic activities that may result in a number of heavy metals like Pb, Cr and Zn, and this is the case of this research, 28% of the tested samples exceeded the WHO and Palestinian standards for the metal Mg^{+2}, and this percentage is considered somehow high. Also, the percentage of contamination of drinking water with Total coliform and Fecal coliform were 86% and 80%, respectively (Almur, 2016) and these are considered very high values, therefore, it can be concluded that more concern must be given to the microbial quality of harvested and drinking waters, especially in rural areas in Palestine.

Chapter Six

Conclusions and Recommendations

6.1 Conclusions

From this research, it can be concluded that most of the water samples analyzed were safe concerning heavy metals contamination. For the metals Pb, Cr and Ni; 97.3% of the samples were below the WHO and Palestinian limits, for the metals Mn, Co, Cu and Cd; neither of the samples exceeded the WHO and Palestinian limits. For the metal Zn, 98.7% of the samples were below the WHO limits and neither of them exceeded the Palestinian limits.

Statistical analysis was made in order to connect the laboratory results with the questionnaire, and therefore identifying possible source of contamination by heavy metals. The results showed that there is no relationship between the factors that may lead to contamination with heavy metals and the laboratory results except for the metal Ni and the "Source of water in cistern" factor and for the metals Pb and Cr and "Actions taken before collecting rainwater" factor. This means that these factors have no influence on the existence of these heavy metals in values beyond the local and international limits.

Health risk assessment was made for all samples that exceeded the WHO and Palestinian limits. However, and as the samples which exceeded the limits exceeded them by small amounts, the samples results were considered all safe, which means that the harvested rainwater imposes no health risks on consumers, whether they were adults or children.

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Appendices

Appendix 1:

Survey (Arabic and English versions):

هذا الاستبيان وضع لاغراض البحث العلمي من قبل الباحث فتحي عنبتاوي لدراسة مصادر تلوث آبار تجميع المياه في مدينة الخليل.

الاسم (اختياري):

Q 1	**ما هي مصادر المياه في البئر 1- سطح المنزل 2- ساحة المنزل أو الحديقة 3- الشارع 4- غير ذلك حدد ....**
Q 2	**هل تتخذ إجراءات محددة قبل تجميع مياه الأمطار؟ 1- نعم 2- لا**
Q 3	**إذا كان جواب Q 2 نعم، فما هي هذه الإجراءات؟ 1- تنظيف سطح المنزل 2- التخلص من مياه الشتوة الأولى 3- الاثنين معا 4- غير ذلك حدد ....**
Q 4	**متى تم تنظيف البئر آخر مرة؟ قبل ....**
Q 5	**ما هي استخداماتك لماء البئر؟ (يمكن أن يكون الجواب أكثر من خيار) 1- للشرب 2- لسقي الحيوانات 3- لري المزروعات 4- للطهي 5- لتنظيف البيت 6- غير ذلك حدد ---------------**
Q 6	**اذكر عمر البئر بالتقريب ....**
Q 7	**ما هو حجم بئر التجميع لديك ....م3......**
Q 8	**جدران البئر من 1- الباطون 2- الصخر 3 غير ذلك حدد ....**
Q 9	**هل باب بئر التجميع 1- مفتوح 2- مغلق 3- شبك 4- غير ذلك حدد ....**
Q 10	**شكل البئر 1- متوازي المستطيلات 2- آجاصي 3- غير ذلك حدد ....**
Q 11	**بعد الحفرة الامتصاصية عن البئر بالمتر.........................**
Q 12	**مستوى الحفرة الامتصاصية 1- أعلى من مستوى البئر 2- أهبط من مستوى البئر 3- نفس المستوى**
Q 13	**متى تم نضح الحفرة الامتصاصية آخر مرة؟ قبل..........................**
Q 14	**هل تقوم بتربية حيوانات او طيور اليفة في المنزل 1- نعم دائما 2- أحيانا 3- لا**
Q 15	**هل يوجد أشجار قريبة من بئر التجميع 1- نعم 2- لا**
Q 16	**هل تلاحظ شوائب عائمة على سطح مياه البئر 1- نعم 2- لا**
Q 17	**هل تلاحظ اخضرار على جوانب البئر 1- نعم 2- لا**
Q 18	**هل يتم استعمال سطح المنزل في الشتاء لغرض نشر الغسيل 1- نعم 2- لا**
Q 19	**هل يتم تجميع النفايات في ساحة المنزل 1- نعم 2- لا**

Q 1	• What is the source of water in cistern? 1- Roof of the house 2- Garden or the backyard of the house 3- Street 4- Otherwise (indicate):…………………………….
Q 2	• Do you take any actions before collecting the rainwater? 1- Yes 2- No
Q 3	• If the answer of Q 2 is Yes, what are these actions ? 1- Cleaning the roof of the house 2- Getting rid of first rain water 3- Both 1 and 2 4- Otherwise (indicate):……………………………..
Q 4	• When the cistern was cleaned last time ? Before:……………………..
Q 5	• For what purposes is the water in the cistern used? (The answer may be more than one choice) 1- Drinking 2- Animals 3- Irrigation 4- Cooking 5- Cleaning the house 6- Otherwise (indicate):……………………………
Q 6	• Indicate approximately the age of cistern in years:……………………………
Q 7	• What is the volume of the cistern:……………………….
Q 8	• The walls of the cistern are from: 1- Concrete 2- Rock 3- Otherwise (indicate):……………………………..
Q 9	• Is the cover of the cistern: 1- Open 2- Closed 3- Perforated
Q 10	• The shape of cistern: 1- Cuboid 2- Peer-shaped 3- Otherwise (indicate):………………………………..
Q 11	• The distance between cistern and cesspit (in meters):…………………………..
Q 12	• The level of cesspit: 1- Above cistern level 2- Below cistern level 3- Same level as cistern
Q 13	• When the cistern was discharged last time? Before:………………………….
Q 14	• Do you raise animals or birds around the house? 1- Yes, always 2- Sometimes

	3- No
Q 15	• Is there any trees close to the house? 1- Yes 2- No
Q 16	• Do you notice any impurities on the surface of the water in the cistern? 1- Yes 2- No
Q 17	• Do you notice algae on the sides of the cistern? 1- Yes 2- No
Q 18	• Do you use the roof of the house in winter for hanging the laundary? 1- Yes 2- No
Q 19	• Do you collect solid waste in the backyard of the house? 1- Yes 2- No

Appendix 2:

Laboratory results for the heavy metals' concentrations in water samples:

Locality name	Pb (ppb)	Cr (ppb)	Mn (ppb)	Co (ppb)	Ni (ppb)	Cu (ppb)	Zn (ppb)	Cd (ppb)
Al Heila	3.44	8.82	1.25	0.06	5.66	1.66	68.96	0.08
Al Heila	1.45	0.59	1.80	<0.000	3.60	3.77	364.16	0.02
Al Heila	1.08	5.00	0.18	<0.000	1.49	1.01	20.73	0.05
Al Heila	0.51	3.58	0.71	0.06	16.96	2.07	15.79	0.01
Al Heila	4.44	0.70	3.47	<0.000	11.08	26.74	565.66	0.01
Al Heila	0.29	1.46	2.30	<0.000	1.70	2.80	96.55	0.01
Al Heila	0.43	0.31	0.05	<0.000	1.03	0.94	28.36	<0.000
Al Heila	0.46	0.32	8.14	<0.000	8.25	4.26	511.64	<0.000
Al Heila	1.55	5.18	2.28	0.19	4.30	28.89	300.20	0.04
Al Heila	2.52	6.02	13.65	0.26	5.04	14.39	118.82	0.12
Al Heila	1.37	6.49	2.22	<0.000	1.83	2.45	46.00	0.01
Al Heila	2.66	0.95	1.34	<0.000	3.50	23.12	331.81	0.03
Yatta Center	0.87	0.33	1.44	<0.000	2.67	1.62	91.66	0.01
Yatta Center	<0.000	0.65	3.84	<0.000	0.94	0.74	<0.000	<0.000
Yatta Center	0.19	1.83	5.40	0.00	2.10	1.91	20.88	0.01
Yatta Center	0.71	1.99	18.75	0.13	3.61	3.30	5.78	0.01
Yatta Center	1.96	1.24	3.60	<0.000	5.05	15.13	549.88	0.01
Yatta Center	0.54	0.97	57.94	0.48	2.85	4.66	13.71	0.01
Yatta Center	0.57	1.59	1.59	<0.000	1.76	3.73	326.68	0.01
Yatta Center	0.73	0.53	<0.000	<0.000	20.04	8.09	13.57	<0.000
Yatta Center	4.28	2.43	4.21	0.17	12.94	15.53	872.38	0.04
Yatta Center	3.12	0.62	2.41	<0.000	1.97	123.21	464.13	0.03
Yatta Center	0.67	1.25	0.97	<0.000	1.47	5.29	359.25	0.01
Yatta Center	0.65	2.76	6.45	0.36	3.30	10.67	209.40	0.01
Yatta Center	<0.000	0.35	<0.000	<0.000	4.44	1.64	<0.000	<0.000
Yatta Center	0.05	0.67	<0.000	<0.000	0.60	0.68	22.87	0.01
Yatta Center	0.56	0.28	0.28	<0.000	0.74	1.76	315.01	0.03
Yatta Center	0.48	1.48	<0.000	<0.000	1.82	3.30	118.61	0.01
Yatta Center	0.68	1.25	0.06	<0.000	2.19	8.23	130.03	0.03
Yatta Center	0.69	0.84	1.13	<0.000	5.21	3.63	74.73	0.00
Yatta Center	0.86	1.14	0.29	0.16	1.71	6.39	187.87	0.02
Yatta Center	4.36	0.77	0.53	0.14	4.64	40.67	244.02	0.10
Yatta Center	<0.000	0.33	<0.000	<0.000	0.63	0.54	<0.000	<0.000
Khallet Salih	0.00	0.11	<0.000	<0.000	1.17	1.22	0.61	<0.000
Khallet Salih	0.12	0.55	0.03	<0.000	3.40	1.75	<0.000	<0.000
Khallet Salih	0.86	7.82	16.10	0.04	1.64	1.84	448.76	0.01
Khallet Salih	0.12	0.61	<0.000	<0.000	0.90	1.26	4.46	<0.000
Khallet Salih	0.53	0.69	0.56	<0.000	12.51	1.61	12.50	<0.000

Khallet Salih	1.68	3.95	27.19	0.18	3.64	8.64	130.73	0.02
Khallet Salih	0.49	1.19	<0.000	0.08	1.21	0.99	10.68	<0.000
Khallet Salih	0.84	0.70	1.62	0.03	2.41	2.51	33.81	0.00
Khallet Salih	3.23	9.05	1.66	0.31	11.55	2.10	52.92	0.18
Khallet Salih	2.24	1.17	3.21	<0.000	2.37	4.04	68.05	0.02
Khallet Salih	**24.05**	**101.44**	21.26	2.51	45.53	5.99	26.20	1.86
Khallet Salih	**13.76**	**61.13**	4.83	1.28	26.31	3.78	10.04	1.10
Khallet Salih	0.98	14.45	1.92	0.11	0.94	1.73	<0.000	0.01
Khallet al Maiyya	0.61	4.39	0.46	0.15	14.81	1.49	26.82	<0.000
Khallet al Maiyya	0.70	2.04	0.34	<0.000	1.40	1.99	10.62	<0.000
Khallet al Maiyya	2.16	6.97	0.59	0.10	3.71	4.48	140.95	0.08
Khallet al Maiyya	2.33	3.14	9.04	0.11	2.68	18.46	556.14	0.06
Khallet al Maiyya	0.23	0.33	<0.000	0.11	19.63	1.38	133.52	<0.000
Khallet al Maiyya	1.02	0.44	0.18	0.16	1.44	6.26	48.09	<0.000
Khallet al Maiyya	0.67	0.62	0.52	0.02	4.46	4.80	41.23	0.00
Khallet al Maiyya	3.09	0.36	<0.000	0.09	11.48	21.81	40.25	<0.000
Khallet al Maiyya	2.78	1.02	0.45	0.10	**214.99**	3.14	103.21	<0.000
Khallet al Maiyya	0.07	1.79	<0.000	0.62	**518.10**	0.52	<0.000	<0.000
Khallet al Maiyya	1.58	0.81	1.45	<0.000	13.95	2.83	31.48	0.00
Khallet al Maiyya	1.94	0.70	0.41	0.15	37.32	13.97	**3452.52**	0.44
Khallet al Maiyya	1.24	0.61	0.34	0.32	13.97	6.77	109.23	<0.000
Al-Hadedeyah	8.34	4.63	7.07	0.19	19.90	39.05	482.75	0.10
Al-Hadedeyah	1.37	1.74	0.58	0.29	23.70	6.18	98.22	0.04
Al-Hadedeyah	0.45	2.51	0.73	0.11	17.12	1.65	23.62	0.01
Al-Hadedeyah	0.80	0.52	0.59	0.18	22.56	2.19	44.76	<0.000
Al-Hadedeyah	0.01	0.25	<0.000	0.24	26.86	0.82	10.40	<0.000
Al-Hadedeyah	0.39	1.30	<0.000	<0.000	14.59	0.78	8.54	0.01
Al-Hadedeyah	1.21	6.14	1.96	0.02	14.87	1.50	10.07	0.04
Al-Hadedeyah	0.02	0.29	<0.000	<0.000	25.38	2.06	<0.000	<0.000
Al-Hadedeyah	0.31	0.59	<0.000	<0.000	16.41	9.05	199.44	<0.000
Al-Hadedeyah	0.53	0.57	0.49	<0.000	15.39	8.23	60.72	<0.000
Al-Hadedeyah	0.72	2.65	1.18	0.04	19.11	4.45	134.48	0.01
Al-Hadedeyah	1.18	3.23	1.10	0.02	25.48	7.96	90.64	0.06
Al-Hadedeyah	0.84	3.05	0.44	0.01	15.85	3.00	16.53	0.01
Al-Hadedeyah	0.62	0.45	0.39	<0.000	15.75	7.25	125.27	<0.000
Al-Hadedeyah	1.20	1.87	1.87	0.08	21.20	13.01	202.54	0.06

Appendix 3:

Cross Tabulation and Chi-square tests tables:

What is the volume of the cistern: * V20_Pb

Crosstab

			V20_Pb	Total
			uncontaminated	
What is the volume of the cistern:	0	Count	3	3
		% of Total	11.5%	11.5%
	15	Count	1	1
		% of Total	3.8%	3.8%
	18	Count	2	2
		% of Total	7.7%	7.7%
	30	Count	1	1
		% of Total	3.8%	3.8%
	40	Count	4	4
		% of Total	15.4%	15.4%
	45	Count	1	1
		% of Total	3.8%	3.8%
	50	Count	1	1
		% of Total	3.8%	3.8%
	55	Count	1	1
		% of Total	3.8%	3.8%
	60	Count	3	3
		% of Total	11.5%	11.5%
	70	Count	3	3
		% of Total	11.5%	11.5%
	75	Count	1	1
		% of Total	3.8%	3.8%
	80	Count	2	2
		% of Total	7.7%	7.7%
	100	Count	1	1
		% of Total	3.8%	3.8%
	120	Count	1	1
		% of Total	3.8%	3.8%
	200	Count	1	1
		% of Total	3.8%	3.8%
Total		Count	26	26
		% of Total	100.0%	100.0%

Chi-Square Tests

	Value
Pearson Chi-Square	.[a]
N of Valid Cases	26

a. No statistics are computed because V20_Pb is a constant.

What is the volume of the cistern: * V21_Cr

Crosstab

			V21_Cr	Total
			uncontaminated	
What is the volume of the cistern:	0	Count	3	3
		% of Total	11.5%	11.5%
	15	Count	1	1
		% of Total	3.8%	3.8%
	18	Count	2	2
		% of Total	7.7%	7.7%
	30	Count	1	1
		% of Total	3.8%	3.8%
	40	Count	4	4
		% of Total	15.4%	15.4%
	45	Count	1	1
		% of Total	3.8%	3.8%
	50	Count	1	1
		% of Total	3.8%	3.8%
	55	Count	1	1
		% of Total	3.8%	3.8%
	60	Count	3	3
		% of Total	11.5%	11.5%
	70	Count	3	3
		% of Total	11.5%	11.5%
	75	Count	1	1
		% of Total	3.8%	3.8%
	80	Count	2	2
		% of Total	7.7%	7.7%
	100	Count	1	1
		% of Total	3.8%	3.8%
	120	Count	1	1
		% of Total	3.8%	3.8%
	200	Count	1	1
		% of Total	3.8%	3.8%
Total		Count	26	26
		% of Total	100.0%	100.0%

Chi-Square Tests

	Value
Pearson Chi-Square	.[a]
N of Valid Cases	26

a. No statistics are computed because V21_Cr is a constant.

What is the volume of the cistern: * V24_Ni

Crosstab

			V24_Ni	Total
			uncontaminated	
What is the volume of the cistern:	0	Count	3	3
		% of Total	11.5%	11.5%
	15	Count	1	1
		% of Total	3.8%	3.8%
	18	Count	2	2
		% of Total	7.7%	7.7%
	30	Count	1	1
		% of Total	3.8%	3.8%
	40	Count	4	4
		% of Total	15.4%	15.4%
	45	Count	1	1
		% of Total	3.8%	3.8%
	50	Count	1	1
		% of Total	3.8%	3.8%
	55	Count	1	1
		% of Total	3.8%	3.8%
	60	Count	3	3
		% of Total	11.5%	11.5%
	70	Count	3	3
		% of Total	11.5%	11.5%
	75	Count	1	1
		% of Total	3.8%	3.8%
	80	Count	2	2
		% of Total	7.7%	7.7%
	100	Count	1	1
		% of Total	3.8%	3.8%
	120	Count	1	1
		% of Total	3.8%	3.8%
	200	Count	1	1
		% of Total	3.8%	3.8%
Total		Count	26	26
		% of Total	100.0%	100.0%

Chi-Square Tests

	Value
Pearson Chi-Square	.[a]
N of Valid Cases	26

a. No statistics are computed because V24_Ni is a constant.

What is the volume of the cistern: * V26_Zn

Crosstab

			V26_Zn	Total
			uncontaminated	
What is the volume of the cistern:	0	Count	3	3
		% of Total	11.5%	11.5%
	15	Count	1	1
		% of Total	3.8%	3.8%
	18	Count	2	2
		% of Total	7.7%	7.7%
	30	Count	1	1
		% of Total	3.8%	3.8%
	40	Count	4	4
		% of Total	15.4%	15.4%
	45	Count	1	1
		% of Total	3.8%	3.8%
	50	Count	1	1
		% of Total	3.8%	3.8%
	55	Count	1	1
		% of Total	3.8%	3.8%
	60	Count	3	3
		% of Total	11.5%	11.5%
	70	Count	3	3
		% of Total	11.5%	11.5%
	75	Count	1	1
		% of Total	3.8%	3.8%
	80	Count	2	2
		% of Total	7.7%	7.7%
	100	Count	1	1
		% of Total	3.8%	3.8%
	120	Count	1	1
		% of Total	3.8%	3.8%
	200	Count	1	1
		% of Total	3.8%	3.8%
Total		Count	26	26
		% of Total	100.0%	100.0%

Chi-Square Tests

	Value
Pearson Chi-Square	.[a]
N of Valid Cases	26

a. No statistics are computed because V26_Zn is a constant.

The walls of the cistern are from * V20_Pb

Crosstab

			V20_Pb		Total
			contaminated	uncontaminated	
The walls of the cistern are from	concrete	Count	2	59	61
		% of Total	2.7%	80.8%	83.6%
	Rock	Count	0	11	11
		% of Total	0.0%	15.1%	15.1%
	1+2	Count	0	1	1
		% of Total	0.0%	1.4%	1.4%
Total		Count	2	71	73
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.405[a]	2	.817	1.000
Likelihood Ratio	.729	2	.694	1.000
Fisher's Exact Test	2.080			1.000
N of Valid Cases	73			

a. 4 cells (66.7%) have expected count less than 5. The minimum expected count is .03.

The walls of the cistern are from * V21_Cr

Crosstab

			V21_Cr		Total
			contaminated	uncontaminated	
The walls of the cistern are from	concrete	Count	2	59	61
		% of Total	2.7%	80.8%	83.6%
	Rock	Count	0	11	11
		% of Total	0.0%	15.1%	15.1%
	1+2	Count	0	1	1
		% of Total	0.0%	1.4%	1.4%
Total		Count	2	71	73
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.405[a]	2	.817	1.000
Likelihood Ratio	.729	2	.694	1.000
Fisher's Exact Test	2.080			1.000
N of Valid Cases	73			

a. 4 cells (66.7%) have expected count less than 5. The minimum expected count is .03.

The walls of the cistern are from * V24_Ni

Crosstab

			V24_Ni		Total
			contaminated	uncontaminated	
The walls of the cistern are from	concerte	Count	2	59	61
		% of Total	2.7%	80.8%	83.6%
	Rock	Count	0	11	11
		% of Total	0.0%	15.1%	15.1%
	1+2	Count	0	1	1
		% of Total	0.0%	1.4%	1.4%
Total		Count	2	71	73
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.405[a]	2	.817	1.000
Likelihood Ratio	.729	2	.694	1.000
Fisher's Exact Test	2.080			1.000
N of Valid Cases	73			

a. 4 cells (66.7%) have expected count less than 5. The minimum expected count is .03.

The walls of the cistern are from * V26_Zn

Crosstab

			V26_Zn		Total
			contaminated	uncontaminated	
The walls of the cistern are from	Concerte	Count	1	60	61
		% of Total	1.4%	82.2%	83.6%
	Rock	Count	0	11	11
		% of Total	0.0%	15.1%	15.1%
	1+2	Count	0	1	1
		% of Total	0.0%	1.4%	1.4%
Total		Count	1	72	73
		% of Total	1.4%	98.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.199[a]	2	.905	1.000
Likelihood Ratio	.362	2	.834	1.000
Fisher's Exact Test	3.074			1.000
N of Valid Cases	73			

a. 4 cells (66.7%) have expected count less than 5. The minimum expected count is .01.

Is the cover of the cistern * V20_Pb

Crosstab

			V20_Pb		Total
			contaminated	uncontaminated	
Is the cover of the cistern	Closed	Count	2	71	73
		% of Total	2.7%	95.9%	98.6%
	Perforated	Count	0	1	1
		% of Total	0.0%	1.4%	1.4%
Total		Count	2	72	74
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.028[a]	1	.867	1.000	.973
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.055	1	.814	1.000	.973
Fisher's Exact Test				1.000	.973
N of Valid Cases	74				

a. 3 cells (75.0%) have expected count less than 5. The minimum expected count is .03.

b. Computed only for a 2x2 table

Is the cover of the cistern * V21_Cr

Crosstab

			V21_Cr		Total
			contaminated	uncontaminated	
Is the cover of the cistern	Closed	Count	2	71	73
		% of Total	2.7%	95.9%	98.6%
	perforated	Count	0	1	1
		% of Total	0.0%	1.4%	1.4%
Total		Count	2	72	74
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.028[a]	1	.867	1.000	.973
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.055	1	.814	1.000	.973
Fisher's Exact Test				1.000	.973
N of Valid Cases	74				

a. 3 cells (75.0%) have expected count less than 5. The minimum expected count is .03.

b. Computed only for a 2x2 table

Is the cover of the cistern * V24_Ni

Crosstab

			V24_Ni		Total
			contaminated	uncontaminated	
Is the cover of the cistern	Closed	Count	2	71	73
		% of Total	2.7%	95.9%	98.6%
	perforated	Count	0	1	1
		% of Total	0.0%	1.4%	1.4%
Total		Count	2	72	74
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.028[a]	1	.867	1.000	.973
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.055	1	.814	1.000	.973
Fisher's Exact Test				1.000	.973
N of Valid Cases	74				

a. 3 cells (75.0%) have expected count less than 5. The minimum expected count is .03.

b. Computed only for a 2x2 table

Is the cover of the cistern * V26_Zn

Crosstab

			V26_Zn		Total
			contaminated	uncontaminated	
Is the cover of the cistern	Closed	Count	1	72	73
		% of Total	1.4%	97.3%	98.6%
	perforated	Count	0	1	1
		% of Total	0.0%	1.4%	1.4%
Total		Count	1	73	74
		% of Total	1.4%	98.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.014[a]	1	.906	1.000	.986
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.027	1	.869	1.000	.986
Fisher's Exact Test				1.000	.986
N of Valid Cases	74				

a. 3 cells (75.0%) have expected count less than 5. The minimum expected count is .01.

b. Computed only for a 2x2 table

The shape of cistern * V20_Pb

Crosstab

			V20_Pb		Total
			contaminated	uncontaminated	
The shape of cistern	Cuboid	Count	2	44	46
		% of Total	2.7%	58.7%	61.3%
	peer-shaped	Count	0	29	29
		% of Total	0.0%	38.7%	38.7%
Total		Count	2	73	75
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.295[a]	1	.255	.519	.373
Continuity Correction[b]	.162	1	.687		
Likelihood Ratio	1.990	1	.158	.519	.373
Fisher's Exact Test				.519	.373
N of Valid Cases	75				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .77.

b. Computed only for a 2x2 table

The shape of cistern * V21_Cr

Crosstab

			V21_Cr		Total
			contaminated	uncontaminated	
The shape of cistern	cuboid	Count	2	44	46
		% of Total	2.7%	58.7%	61.3%
	peer-shaped	Count	0	29	29
		% of Total	0.0%	38.7%	38.7%
Total		Count	2	73	75
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.295[a]	1	.255	.519	.373
Continuity Correction[b]	.162	1	.687		
Likelihood Ratio	1.990	1	.158	.519	.373
Fisher's Exact Test				.519	.373
N of Valid Cases	75				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .77.

b. Computed only for a 2x2 table

The shape of cistern * V24_Ni

Crosstab

			V24_Ni		Total
			contaminated	uncontaminated	
The shape of cistern	cuboid	Count	1	45	46
		% of Total	1.3%	60.0%	61.3%
	peer-shaped	Count	1	28	29
		% of Total	1.3%	37.3%	38.7%
Total		Count	2	73	75
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.111[a]	1	.739	1.000	.627
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.108	1	.742	1.000	.627
Fisher's Exact Test				1.000	.627
N of Valid Cases	75				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .77.

b. Computed only for a 2x2 table

The shape of cistern * V26_Zn

Crosstab

			V26_Zn		Total
			contaminated	uncontaminated	
The shape of cistern	Cuboid	Count	1	45	46
		% of Total	1.3%	60.0%	61.3%
	peer-shaped	Count	0	29	29
		% of Total	0.0%	38.7%	38.7%
Total		Count	1	74	75
		% of Total	1.3%	98.7%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.639[a]	1	.424	1.000	.613
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.986	1	.321	1.000	.613
Fisher's Exact Test				1.000	.613
N of Valid Cases	75				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .39.

b. Computed only for a 2x2 table

The distance between cistern and cesspit (in meters) * V20_Pb

Crosstab

			V20_Pb		Total
			contaminated	uncontaminated	
The distance between cistern and cesspit (in meters)	0	Count	2	44	46
		% of Total	3.1%	68.8%	71.9%
	5	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	7	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	10	Count	0	5	5
		% of Total	0.0%	7.8%	7.8%
	15	Count	0	2	2
		% of Total	0.0%	3.1%	3.1%
	20	Count	0	3	3
		% of Total	0.0%	4.7%	4.7%
	30	Count	0	2	2
		% of Total	0.0%	3.1%	3.1%
	50	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	70	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	80	Count	0	2	2
		% of Total	0.0%	3.1%	3.1%
Total		Count	2	62	64
		% of Total	3.1%	96.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.808[a]	9	1.000	1.000
Likelihood Ratio	1.346	9	.998	1.000
Fisher's Exact Test	11.813			1.000
N of Valid Cases	64			

a. 19 cells (95.0%) have expected count less than 5. The minimum expected count is .03.

The distance between cistern and cesspit (in meters) * V21_Cr

Crosstab

			V21_Cr		Total
			contaminated	uncontaminated	
The distance between cistern and cesspit (in meters)	0	Count	2	44	46
		% of Total	3.1%	68.8%	71.9%
	5	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	7	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	10	Count	0	5	5
		% of Total	0.0%	7.8%	7.8%
	15	Count	0	2	2
		% of Total	0.0%	3.1%	3.1%
	20	Count	0	3	3
		% of Total	0.0%	4.7%	4.7%
	30	Count	0	2	2
		% of Total	0.0%	3.1%	3.1%
	50	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	70	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	80	Count	0	2	2
		% of Total	0.0%	3.1%	3.1%
Total		Count	2	62	64
		% of Total	3.1%	96.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.808[a]	9	1.000	1.000
Likelihood Ratio	1.346	9	.998	1.000
Fisher's Exact Test	11.813			1.000
N of Valid Cases	64			

a. 19 cells (95.0%) have expected count less than 5. The minimum expected count is .03.

The distance between cistern and cesspit (in meters) * V24_Ni

Crosstab

			V24_Ni		Total
			contaminated	uncontaminated	
The distance between cistern and cesspit (in meters)	0	Count	1	45	46
		% of Total	1.6%	70.3%	71.9%
	5	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	7	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	10	Count	0	5	5
		% of Total	0.0%	7.8%	7.8%
	15	Count	0	2	2
		% of Total	0.0%	3.1%	3.1%
	20	Count	0	3	3
		% of Total	0.0%	4.7%	4.7%
	30	Count	0	2	2
		% of Total	0.0%	3.1%	3.1%
	50	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	70	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	80	Count	0	2	2
		% of Total	0.0%	3.1%	3.1%
Total		Count	1	63	64
		% of Total	1.6%	98.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.398[a]	9	1.000	1.000
Likelihood Ratio	.667	9	1.000	1.000
Fisher's Exact Test	17.234			1.000
N of Valid Cases	64			

a. 19 cells (95.0%) have expected count less than 5. The minimum expected count is .02.

The distance between cistern and cesspit (in meters) * V26_Zn

Crosstab

			V26_Zn		Total
			contaminated	uncontaminated	
The distance between cistern and cesspit (in meters)	0	Count	1	45	46
		% of Total	1.6%	70.3%	71.9%
	5	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	7	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	10	Count	0	5	5
		% of Total	0.0%	7.8%	7.8%
	15	Count	0	2	2
		% of Total	0.0%	3.1%	3.1%
	20	Count	0	3	3
		% of Total	0.0%	4.7%	4.7%
	30	Count	0	2	2
		% of Total	0.0%	3.1%	3.1%
	50	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	70	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	80	Count	0	2	2
		% of Total	0.0%	3.1%	3.1%
Total		Count	1	63	64
		% of Total	1.6%	98.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.398[a]	9	1.000	1.000
Likelihood Ratio	.667	9	1.000	1.000
Fisher's Exact Test	17.234			1.000
N of Valid Cases	64			

a. 19 cells (95.0%) have expected count less than 5. The minimum expected count is .02.

The level of cesspit * V20_Pb

Crosstab

			V20_Pb		Total
			contaminated	uncontaminated	
The level of cesspit	0	Count	0	1	1
		% of Total	0.0%	1.5%	1.5%
	above cistern level	Count	0	12	12
		% of Total	0.0%	17.6%	17.6%
	below cistern level	Count	0	33	33
		% of Total	0.0%	48.5%	48.5%
	same level as cistern	Count	2	20	22
		% of Total	2.9%	29.4%	32.4%
Total		Count	2	66	68
		% of Total	2.9%	97.1%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	4.309[a]	3	.230	.160
Likelihood Ratio	4.642	3	.200	.160
Fisher's Exact Test	4.879			.160
N of Valid Cases	68			

a. 5 cells (62.5%) have expected count less than 5. The minimum expected count is .03.

The level of cesspit * V21_Cr

Crosstab

			V21_Cr		Total
			contaminated	uncontaminated	
The level of cesspit	0	Count	0	1	1
		% of Total	0.0%	1.5%	1.5%
	above cistern level	Count	0	12	12
		% of Total	0.0%	17.6%	17.6%
	below cistern level	Count	0	33	33
		% of Total	0.0%	48.5%	48.5%
	same level as cistern	Count	2	20	22
		% of Total	2.9%	29.4%	32.4%
Total		Count	2	66	68
		% of Total	2.9%	97.1%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	4.309[a]	3	.230	.160
Likelihood Ratio	4.642	3	.200	.160
Fisher's Exact Test	4.879			.160
N of Valid Cases	68			

a. 5 cells (62.5%) have expected count less than 5. The minimum expected count is .03.

The level of cesspit * V24_Ni

Crosstab

			V24_Ni		Total
			contaminated	uncontaminated	
The level of cesspit	0	Count	0	1	1
		% of Total	0.0%	1.5%	1.5%
	above cistern level	Count	0	12	12
		% of Total	0.0%	17.6%	17.6%
	below cistern level	Count	0	33	33
		% of Total	0.0%	48.5%	48.5%
	same level as cistern	Count	2	20	22
		% of Total	2.9%	29.4%	32.4%
Total		Count	2	66	68
		% of Total	2.9%	97.1%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	4.309[a]	3	.230	.160
Likelihood Ratio	4.642	3	.200	.160
Fisher's Exact Test	4.879			.160
N of Valid Cases	68			

a. 5 cells (62.5%) have expected count less than 5. The minimum expected count is .03.

The level of cesspit * V26_Zn

Crosstab

			V26_Zn		Total
			contaminated	uncontaminated	
The level of cesspit	0	Count	0	1	1
		% of Total	0.0%	1.5%	1.5%
	above cistern level	Count	1	11	12
		% of Total	1.5%	16.2%	17.6%
	below cistern level	Count	0	33	33
		% of Total	0.0%	48.5%	48.5%
	same level as cistern	Count	0	22	22
		% of Total	0.0%	32.4%	32.4%
Total		Count	1	67	68
		% of Total	1.5%	98.5%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	4.736[a]	3	.192	.191
Likelihood Ratio	3.540	3	.316	.191
Fisher's Exact Test	5.806			.191
N of Valid Cases	68			

a. 5 cells (62.5%) have expected count less than 5. The minimum expected count is .01.

When the cistern was discharged last time? Before * V20_Pb

Crosstab

			V20_Pb		Total
			contaminated	uncontaminated	
When the cistern was discharged last time? Before	0	Count	2	58	60
		% of Total	3.1%	90.6%	93.8%
	1	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	2	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	3	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	15	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
Total		Count	2	62	64
		% of Total	3.1%	96.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.138[a]	4	.998	1.000
Likelihood Ratio	.262	4	.992	1.000
Fisher's Exact Test	6.963			1.000
N of Valid Cases	64			

a. 9 cells (90.0%) have expected count less than 5. The minimum expected count is .03.

When the cistern was discharged last time? Before * V21_Cr

Crosstab

			V21_Cr		Total
			contaminated	uncontaminated	
When the cistern was discharged last time? Before	0	Count	2	58	60
		% of Total	3.1%	90.6%	93.8%
	1	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	2	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	3	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	15	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
Total		Count	2	62	64
		% of Total	3.1%	96.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.138[a]	4	.998	1.000
Likelihood Ratio	.262	4	.992	1.000
Fisher's Exact Test	6.963			1.000
N of Valid Cases	64			

a. 9 cells (90.0%) have expected count less than 5. The minimum expected count is .03.

When the cistern was discharged last time? Before * V24_Ni

Crosstab

			V24_Ni		Total
			contaminated	uncontaminated	
When the cistern was discharged last time? Before	0	Count	2	58	60
		% of Total	3.1%	90.6%	93.8%
	1	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	2	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	3	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	15	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
Total		Count	2	62	64
		% of Total	3.1%	96.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.138[a]	4	.998	1.000
Likelihood Ratio	.262	4	.992	1.000
Fisher's Exact Test	6.963			1.000
N of Valid Cases	64			

a. 9 cells (90.0%) have expected count less than 5. The minimum expected count is .03.

When the cistern was discharged last time? Before * V26_Zn

Crosstab

			V26_Zn		Total
			contaminated	uncontaminated	
When the cistern was discharged last time? Before	0	Count	1	59	60
		% of Total	1.6%	92.2%	93.8%
	1	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	2	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	3	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
	15	Count	0	1	1
		% of Total	0.0%	1.6%	1.6%
Total		Count	1	63	64
		% of Total	1.6%	98.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.068[a]	4	.999	1.000
Likelihood Ratio	.130	4	.998	.[b]
Fisher's Exact Test	.[b]			.[b]
N of Valid Cases	64			

a. 9 cells (90.0%) have expected count less than 5. The minimum expected count is .02.

b. Cannot be computed because there is insufficient memory.

Do you raise animals or birds around the house? * V20_Pb

Crosstab

			V20_Pb		Total
			contaminated	uncontaminated	
Do you raise animals or birds around the house?	yes.always	Count	1	27	28
		% of Total	1.4%	37.0%	38.4%
	sometimes	Count	1	26	27
		% of Total	1.4%	35.6%	37.0%
	no	Count	0	18	18
		% of Total	0.0%	24.7%	24.7%
Total		Count	2	71	73
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.674[a]	2	.714	1.000
Likelihood Ratio	1.152	2	.562	1.000
Fisher's Exact Test	.838			1.000
N of Valid Cases	73			

a. 3 cells (50.0%) have expected count less than 5. The minimum expected count is .49.

Do you raise animals or birds around the house? * V21_Cr

Crosstab

			V21_Cr		Total
			contaminated	uncontaminated	
Do you raise animals or birds around the house?	yes.always	Count	1	27	28
		% of Total	1.4%	37.0%	38.4%
	Sometimes	Count	1	26	27
		% of Total	1.4%	35.6%	37.0%
	No	Count	0	18	18
		% of Total	0.0%	24.7%	24.7%
Total		Count	2	71	73
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.674[a]	2	.714	1.000
Likelihood Ratio	1.152	2	.562	1.000
Fisher's Exact Test	.838			1.000
N of Valid Cases	73			

a. 3 cells (50.0%) have expected count less than 5. The minimum expected count is .49.

Do you raise animals or birds around the house? * V24_Ni

Crosstab

			V24_Ni		Total
			contaminated	uncontaminated	
Do you raise animals or birds around the house?	yes.always	Count	1	27	28
		% of Total	1.4%	37.0%	38.4%
	Sometimes	Count	1	26	27
		% of Total	1.4%	35.6%	37.0%
	No	Count	0	18	18
		% of Total	0.0%	24.7%	24.7%
Total		Count	2	71	73
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.674[a]	2	.714	1.000
Likelihood Ratio	1.152	2	.562	1.000
Fisher's Exact Test	.838			1.000
N of Valid Cases	73			

a. 3 cells (50.0%) have expected count less than 5. The minimum expected count is .49.

Do you raise animals or birds around the house? * V26_Zn

Crosstab

			V26_Zn		Total
			contaminated	uncontaminated	
Do you raise animals or birds around the house?	yes.always	Count	1	27	28
		% of Total	1.4%	37.0%	38.4%
	sometimes	Count	0	27	27
		% of Total	0.0%	37.0%	37.0%
	no	Count	0	18	18
		% of Total	0.0%	24.7%	24.7%
Total		Count	1	72	73
		% of Total	1.4%	98.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	1.629[a]	2	.443	1.000
Likelihood Ratio	1.939	2	.379	1.000
Fisher's Exact Test	1.621			1.000
N of Valid Cases	73			

a. 3 cells (50.0%) have expected count less than 5. The minimum expected count is .25.

Is there any trees close to the house? * V20_Pb

Crosstab

			V20_Pb		Total
			contaminated	uncontaminated	
Is there any trees close to the house?	yes	Count	0	19	19
		% of Total	0.0%	25.3%	25.3%
	no	Count	2	54	56
		% of Total	2.7%	72.0%	74.7%
Total		Count	2	73	75
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.697[a]	1	.404	.617	.555
Continuity Correction[b]	.000	1	.991		
Likelihood Ratio	1.187	1	.276	.617	.555
Fisher's Exact Test				1.000	.555
N of Valid Cases	75				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .51.

b. Computed only for a 2x2 table

Is there any trees close to the house? * V21_Cr

Crosstab

			V21_Cr		Total
			contaminated	uncontaminated	
Is there any trees close to the house?	yes	Count	0	19	19
		% of Total	0.0%	25.3%	25.3%
	no	Count	2	54	56
		% of Total	2.7%	72.0%	74.7%
Total		Count	2	73	75
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.697[a]	1	.404	.617	.555
Continuity Correction[b]	.000	1	.991		
Likelihood Ratio	1.187	1	.276	.617	.555
Fisher's Exact Test				1.000	.555
N of Valid Cases	75				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .51.

b. Computed only for a 2x2 table

Is there any trees close to the house? * V24_Ni

Crosstab

			V24_Ni		Total
			contaminated	uncontaminated	
Is there any trees close to the house?	yes	Count	0	19	19
		% of Total	0.0%	25.3%	25.3%
	no	Count	2	54	56
		% of Total	2.7%	72.0%	74.7%
Total		Count	2	73	75
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.697[a]	1	.404	.617	.555
Continuity Correction[b]	.000	1	.991		
Likelihood Ratio	1.187	1	.276	.617	.555
Fisher's Exact Test				1.000	.555
N of Valid Cases	75				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .51.

b. Computed only for a 2x2 table

Is there any trees close to the house? * V26_Zn

Crosstab

			V26_Zn		Total
			contaminated	uncontaminated	
Is there any trees close to the house?	yes	Count	0	19	19
		% of Total	0.0%	25.3%	25.3%
	no	Count	1	55	56
		% of Total	1.3%	73.3%	74.7%
Total		Count	1	74	75
		% of Total	1.3%	98.7%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.344[a]	1	.558	1.000	.747
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.589	1	.443	1.000	.747
Fisher's Exact Test				1.000	.747
N of Valid Cases	75				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .25.

b. Computed only for a 2x2 table

Do you notice any impurities on the surface of the water in the cistern? * V20_Pb

Crosstab

			V20_Pb		Total
			contaminated	uncontaminated	
Do you notice any impurities on the surface of the water in the cistern?	yes	Count	0	24	24
		% of Total	0.0%	32.4%	32.4%
	no	Count	2	48	50
		% of Total	2.7%	64.9%	67.6%
Total		Count	2	72	74
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.987[a]	1	.321	.556	.454
Continuity Correction[b]	.052	1	.820		
Likelihood Ratio	1.595	1	.207	.556	.454
Fisher's Exact Test				1.000	.454
N of Valid Cases	74				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .65.

b. Computed only for a 2x2 table

Do you notice any impurities on the surface of the water in the cistern? * V21_Cr

Crosstab

			V21_Cr		Total
			contaminated	uncontaminated	
Do you notice any impurities on the surface of the water in the cistern?	yes	Count	0	24	24
		% of Total	0.0%	32.4%	32.4%
	no	Count	2	48	50
		% of Total	2.7%	64.9%	67.6%
Total		Count	2	72	74
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.987[a]	1	.321	.556	.454
Continuity Correction[b]	.052	1	.820		
Likelihood Ratio	1.595	1	.207	.556	.454
Fisher's Exact Test				1.000	.454
N of Valid Cases	74				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .65.

b. Computed only for a 2x2 table

Do you notice any impurities on the surface of the water in the cistern? * V24_Ni

Crosstab

			V24_Ni		Total
			contaminated	uncontaminated	
Do you notice any impurities on the surface of the water in the cistern?	yes	Count	0	24	24
		% of Total	0.0%	32.4%	32.4%
	no	Count	2	48	50
		% of Total	2.7%	64.9%	67.6%
Total		Count	2	72	74
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.987[a]	1	.321	.556	.454
Continuity Correction[b]	.052	1	.820		
Likelihood Ratio	1.595	1	.207	.556	.454
Fisher's Exact Test				1.000	.454
N of Valid Cases	74				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .65.

b. Computed only for a 2x2 table

Do you notice any impurities on the surface of the water in the cistern? * V26_Zn

Crosstab

			V26_Zn		Total
			contaminated	uncontaminated	
Do you notice any impurities on the surface of the water in the cistern?	yes	Count	0	24	24
		% of Total	0.0%	32.4%	32.4%
	no	Count	1	49	50
		% of Total	1.4%	66.2%	67.6%
Total		Count	1	73	74
		% of Total	1.4%	98.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.487[a]	1	.485	1.000	.676
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.791	1	.374	1.000	.676
Fisher's Exact Test				1.000	.676
N of Valid Cases	74				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .32.

b. Computed only for a 2x2 table

Do you notice algae on the sides of the cistern? * V20_Pb

Crosstab

			V20_Pb		Total
			contaminated	uncontaminated	
Do you notice algae on the sides of the cistern?	yes	Count	0	14	14
		% of Total	0.0%	18.9%	18.9%
	no	Count	2	58	60
		% of Total	2.7%	78.4%	81.1%
Total		Count	2	72	74
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.480[a]	1	.489	1.000	.655
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.852	1	.356	1.000	.655
Fisher's Exact Test				1.000	.655
N of Valid Cases	74				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .38.

b. Computed only for a 2x2 table

Do you notice algae on the sides of the cistern? * V21_Cr

Crosstab

			V21_Cr		Total
			contaminated	uncontaminated	
Do you notice algae on the sides of the cistern?	yes	Count	0	14	14
		% of Total	0.0%	18.9%	18.9%
	no	Count	2	58	60
		% of Total	2.7%	78.4%	81.1%
Total		Count	2	72	74
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.480[a]	1	.489	1.000	.655
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.852	1	.356	1.000	.655
Fisher's Exact Test				1.000	.655
N of Valid Cases	74				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .38.

b. Computed only for a 2x2 table

Do you notice algae on the sides of the cistern? * V24_Ni

Crosstab

			V24_Ni		Total
			contaminated	uncontaminated	
Do you notice algae on the sides of the cistern?	yes	Count	0	14	14
		% of Total	0.0%	18.9%	18.9%
	no	Count	2	58	60
		% of Total	2.7%	78.4%	81.1%
Total		Count	2	72	74
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.480[a]	1	.489	1.000	.655
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.852	1	.356	1.000	.655
Fisher's Exact Test				1.000	.655
N of Valid Cases	74				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .38.

b. Computed only for a 2x2 table

Do you notice algae on the sides of the cistern? * V26_Zn

Crosstab

			V26_Zn		Total
			contaminated	uncontaminated	
Do you notice algae on the sides of the cistern?	yes	Count	0	14	14
		% of Total	0.0%	18.9%	18.9%
	no	Count	1	59	60
		% of Total	1.4%	79.7%	81.1%
Total		Count	1	73	74
		% of Total	1.4%	98.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.237[a]	1	.627	1.000	.811
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.423	1	.516	1.000	.811
Fisher's Exact Test				1.000	.811
N of Valid Cases	74				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .19.

b. Computed only for a 2x2 table

Do you use the roof of the house in winter for hanging the laundary? * V20_Pb

Crosstab

			V20_Pb		Total
			contaminated	Uncontaminated	
Do you use the roof of the house in winter for hanging the laundary?	yes	Count	2	44	46
		% of Total	2.7%	58.7%	61.3%
	no	Count	0	29	29
		% of Total	0.0%	38.7%	38.7%
Total		Count	2	73	75
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.295[a]	1	.255	.519	.373
Continuity Correction[b]	.162	1	.687		
Likelihood Ratio	1.990	1	.158	.519	.373
Fisher's Exact Test				.519	.373
N of Valid Cases	75				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .77.

b. Computed only for a 2x2 table

Do you use the roof of the house in winter for hanging the laundary? * V21_Cr

Crosstab

			V21_Cr		Total
			contaminated	uncontaminated	
Do you use the roof of the house in winter for hanging the laundary?	yes	Count	2	44	46
		% of Total	2.7%	58.7%	61.3%
	no	Count	0	29	29
		% of Total	0.0%	38.7%	38.7%
Total		Count	2	73	75
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.295[a]	1	.255	.519	.373
Continuity Correction[b]	.162	1	.687		
Likelihood Ratio	1.990	1	.158	.519	.373
Fisher's Exact Test				.519	.373
N of Valid Cases	75				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .77.

b. Computed only for a 2x2 table

Do you use the roof of the house in winter for hanging the laundary? * V24_Ni

Crosstab

			V24_Ni		Total
			contaminated	uncontaminated	
Do you use the roof of the house in winter for hanging the laundary?	yes	Count	2	44	46
		% of Total	2.7%	58.7%	61.3%
	no	Count	0	29	29
		% of Total	0.0%	38.7%	38.7%
Total		Count	2	73	75
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.295[a]	1	.255	.519	.373
Continuity Correction[b]	.162	1	.687		
Likelihood Ratio	1.990	1	.158	.519	.373
Fisher's Exact Test				.519	.373
N of Valid Cases	75				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .77.

b. Computed only for a 2x2 table

Do you use the roof of the house in winter for hanging the laundary? * V26_Zn

Crosstab

			V26_Zn		Total
			contaminated	uncontaminated	
Do you use the roof of the house in winter for hanging the laundary?	yes	Count	1	45	46
		% of Total	1.3%	60.0%	61.3%
	no	Count	0	29	29
		% of Total	0.0%	38.7%	38.7%
Total		Count	1	74	75
		% of Total	1.3%	98.7%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.639[a]	1	.424	1.000	.613
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.986	1	.321	1.000	.613
Fisher's Exact Test				1.000	.613
N of Valid Cases	75				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .39.

b. Computed only for a 2x2 table

Do you collect solid waste in the backyard of the house? * V20_Pb

Crosstab

			V20_Pb		Total
			contaminated	uncontaminated	
Do you collect solid waste in the backyard of the house?	yes	Count	1	16	17
		% of Total	1.3%	21.3%	22.7%
	no	Count	1	57	58
		% of Total	1.3%	76.0%	77.3%
Total		Count	2	73	75
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.876[a]	1	.349	.404	.404
Continuity Correction[b]	.006	1	.936		
Likelihood Ratio	.734	1	.392	1.000	.404
Fisher's Exact Test				.404	.404
N of Valid Cases	75				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .45.

b. Computed only for a 2x2 table

Do you collect solid waste in the backyard of the house? * V21_Cr

Crosstab

			V21_Cr		Total
			contaminated	uncontaminated	
Do you collect solid waste in the backyard of the house?	yes	Count	1	16	17
		% of Total	1.3%	21.3%	22.7%
	no	Count	1	57	58
		% of Total	1.3%	76.0%	77.3%
Total		Count	2	73	75
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.876[a]	1	.349	.404	.404
Continuity Correction[b]	.006	1	.936		
Likelihood Ratio	.734	1	.392	1.000	.404
Fisher's Exact Test				.404	.404
N of Valid Cases	75				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .45.

b. Computed only for a 2x2 table

Do you collect solid waste in the backyard of the house? * V24_Ni

Crosstab

			V24_Ni		Total
			contaminated	uncontaminated	
Do you collect solid waste in the backyard of the house?	yes	Count	0	17	17
		% of Total	0.0%	22.7%	22.7%
	no	Count	2	56	58
		% of Total	2.7%	74.7%	77.3%
Total		Count	2	73	75
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.602[a]	1	.438	1.000	.596
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	1.044	1	.307	.645	.596
Fisher's Exact Test				1.000	.596
N of Valid Cases	75				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .45.

b. Computed only for a 2x2 table

Do you collect solid waste in the backyard of the house? * V26_Zn

Crosstab

			V26_Zn		Total
			contaminated	uncontaminated	
Do you collect solid waste in the backyard of the house?	yes	Count	0	17	17
		% of Total	0.0%	22.7%	22.7%
	no	Count	1	57	58
		% of Total	1.3%	76.0%	77.3%
Total		Count	1	74	75
		% of Total	1.3%	98.7%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.297[a]	1	.586	1.000	.773
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.518	1	.472	1.000	.773
Fisher's Exact Test				1.000	.773
N of Valid Cases	75				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .23.

b. Computed only for a 2x2 table

What is the source of water in cistern? * V20_Pb

Crosstab

			V20_Pb		Total
			contaminated	uncontaminated	
What is the source of water in cistern?	Roof of the house	Count	2	56	58
		% of Total	2.7%	74.7%	77.3%
	Garden or the backyard of the house	Count	0	1	1
		% of Total	0.0%	1.3%	1.3%
	Street	Count	0	2	2
		% of Total	0.0%	2.7%	2.7%
	Otherwise (indicate)	Count	0	5	5
		% of Total	0.0%	6.7%	6.7%
	1+2	Count	0	6	6
		% of Total	0.0%	8.0%	8.0%
	1 +2+3	Count	0	1	1
		% of Total	0.0%	1.3%	1.3%
	1+3	Count	0	2	2
		% of Total	0.0%	2.7%	2.7%
Total		Count	2	73	75
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.602[a]	6	.996	1.000
Likelihood Ratio	1.044	6	.984	1.000
Fisher's Exact Test	7.387			1.000
N of Valid Cases	75			

a. 12 cells (85.7%) have expected count less than 5. The minimum expected count is .03.

What is the source of water in cistern? * V21_Cr

Crosstab

			V21_Cr		Total
			contaminated	uncontaminated	
What is the source of water in cistern?	Roof of the house	Count	2	56	58
		% of Total	2.7%	74.7%	77.3%
	Garden or the backyard of the house	Count	0	1	1
		% of Total	0.0%	1.3%	1.3%
	Street	Count	0	2	2
		% of Total	0.0%	2.7%	2.7%
	Otherwise (indicate)	Count	0	5	5
		% of Total	0.0%	6.7%	6.7%
	1+2	Count	0	6	6
		% of Total	0.0%	8.0%	8.0%
	1 +2+3	Count	0	1	1
		% of Total	0.0%	1.3%	1.3%
	1+3	Count	0	2	2
		% of Total	0.0%	2.7%	2.7%
Total		Count	2	73	75
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.602[a]	6	.996	1.000
Likelihood Ratio	1.044	6	.984	1.000
Fisher's Exact Test	7.387			1.000
N of Valid Cases	75			

a. 12 cells (85.7%) have expected count less than 5. The minimum expected count is .03.

What is the source of water in cistern? * V24_Ni

Crosstab

			V24_Ni		Total
			contaminated	uncontaminated	
What is the source of water in cistern?	Roof of the house	Count	1	57	58
		% of Total	1.3%	76.0%	77.3%
	Garden or the backyard of the house	Count	1	0	1
		% of Total	1.3%	0.0%	1.3%
	Street	Count	0	2	2
		% of Total	0.0%	2.7%	2.7%
	Otherwise (indicate)	Count	0	5	5
		% of Total	0.0%	6.7%	6.7%
	1+2	Count	0	6	6
		% of Total	0.0%	8.0%	8.0%
	1 +2+3	Count	0	1	1
		% of Total	0.0%	1.3%	1.3%
	1+3	Count	0	2	2
		% of Total	0.0%	2.7%	2.7%
Total		Count	2	73	75
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	37.137[a]	6	.000	.054
Likelihood Ratio	8.340	6	.214	.080
Fisher's Exact Test	14.086			.091
N of Valid Cases	75			

a. 12 cells (85.7%) have expected count less than 5. The minimum expected count is .03.

What is the source of water in cistern? * V26_Zn

Crosstab

			V26_Zn		Total
			contaminated	uncontaminated	
What is the source of water in cistern?	Roof of the house	Count	1	57	58
		% of Total	1.3%	76.0%	77.3%
	Garden or the backyard of the house	Count	0	1	1
		% of Total	0.0%	1.3%	1.3%
	Street	Count	0	2	2
		% of Total	0.0%	2.7%	2.7%
	Otherwise (indicate)	Count	0	5	5
		% of Total	0.0%	6.7%	6.7%
	1+2	Count	0	6	6
		% of Total	0.0%	8.0%	8.0%
	1 +2+3	Count	0	1	1
		% of Total	0.0%	1.3%	1.3%
	1+3	Count	0	2	2
		% of Total	0.0%	2.7%	2.7%
Total		Count	1	74	75
		% of Total	1.3%	98.7%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.297[a]	6	1.000	1.000
Likelihood Ratio	.518	6	.998	1.000
Fisher's Exact Test	10.942			1.000
N of Valid Cases	75			

a. 12 cells (85.7%) have expected count less than 5. The minimum expected count is .01.

Do you take any actions before collecting the rainwater? * V20_Pb

Crosstab

			V20_Pb		Total
			contaminated	uncontaminated	
Do you take any actions before collecting the rainwater?	yes	Count	2	71	73
		% of Total	2.7%	95.9%	98.6%
	no	Count	0	1	1
		% of Total	0.0%	1.4%	1.4%
Total		Count	2	72	74
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.028[a]	1	.867	1.000	.973
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.055	1	.814	1.000	.973
Fisher's Exact Test				1.000	.973
N of Valid Cases	74				

a. 3 cells (75.0%) have expected count less than 5. The minimum expected count is .03.

b. Computed only for a 2x2 table

Do you take any actions before collecting the rainwater? * V21_Cr

Crosstab

			V21_Cr		Total
			contaminated	uncontaminated	
Do you take any actions before collecting the rainwater?	yes	Count	2	71	73
		% of Total	2.7%	95.9%	98.6%
	no	Count	0	1	1
		% of Total	0.0%	1.4%	1.4%
Total		Count	2	72	74
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.028[a]	1	.867	1.000	.973
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.055	1	.814	1.000	.973
Fisher's Exact Test				1.000	.973
N of Valid Cases	74				

a. 3 cells (75.0%) have expected count less than 5. The minimum expected count is .03.

b. Computed only for a 2x2 table

Do you take any actions before collecting the rainwater? * V24_Ni

Crosstab

			V24_Ni		Total
			contaminated	uncontaminated	
Do you take any actions before collecting the rainwater?	yes	Count	2	71	73
		% of Total	2.7%	95.9%	98.6%
	no	Count	0	1	1
		% of Total	0.0%	1.4%	1.4%
Total		Count	2	72	74
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.028[a]	1	.867	1.000	.973
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.055	1	.814	1.000	.973
Fisher's Exact Test				1.000	.973
N of Valid Cases	74				

a. 3 cells (75.0%) have expected count less than 5. The minimum expected count is .03.

b. Computed only for a 2x2 table

Do you take any actions before collecting the rainwater? * V26_Zn

Crosstab

			V26_Zn		Total
			contaminated	uncontaminated	
Do you take any actions before collecting the rainwater?	yes	Count	1	72	73
		% of Total	1.4%	97.3%	98.6%
	no	Count	0	1	1
		% of Total	0.0%	1.4%	1.4%
Total		Count	1	73	74
		% of Total	1.4%	98.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.014[a]	1	.906	1.000	.986
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.027	1	.869	1.000	.986
Fisher's Exact Test				1.000	.986
N of Valid Cases	74				

a. 3 cells (75.0%) have expected count less than 5. The minimum expected count is .01.

b. Computed only for a 2x2 table

If the answer of Q 2 is Yes, what are these actions ? * V20_Pb

Crosstab

			V20_Pb		Total
			contaminated	uncontaminated	
If the answer of Q 2 is Yes, what are these actions ?	Cleaning the roof of the house	Count	0	11	11
		% of Total	0.0%	14.7%	14.7%
	Getting rid of first rain water	Count	1	1	2
		% of Total	1.3%	1.3%	2.7%
	Both 1 and 2	Count	1	60	61
		% of Total	1.3%	80.0%	81.3%
	Otherwise (indicate)	Count	0	1	1
		% of Total	0.0%	1.3%	1.3%
Total		Count	2	73	75
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	17.841[a]	3	.000	.079
Likelihood Ratio	5.466	3	.141	.099
Fisher's Exact Test	8.805			.099
N of Valid Cases	75			

a. 6 cells (75.0%) have expected count less than 5. The minimum expected count is .03.

If the answer of Q 2 is Yes, what are these actions ? * V21_Cr

Crosstab

			V21_Cr		Total
			contaminated	uncontaminated	
If the answer of Q 2 is Yes, what are these actions ?	Cleaning the roof of the house	Count	0	11	11
		% of Total	0.0%	14.7%	14.7%
	Getting rid of first rain water	Count	1	1	2
		% of Total	1.3%	1.3%	2.7%
	Both 1 and 2	Count	1	60	61
		% of Total	1.3%	80.0%	81.3%
	Otherwise (indicate)	Count	0	1	1
		% of Total	0.0%	1.3%	1.3%
Total		Count	2	73	75
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	17.841[a]	3	.000	.079
Likelihood Ratio	5.466	3	.141	.099
Fisher's Exact Test	8.805			.099
N of Valid Cases	75			

a. 6 cells (75.0%) have expected count less than 5. The minimum expected count is .03.

If the answer of Q 2 is Yes, what are these actions ? * V24_Ni

Crosstab

			V24_Ni		Total
			contaminated	uncontaminated	
If the answer of Q 2 is Yes, what are these actions ?	Cleaning the roof of the house	Count	0	11	11
		% of Total	0.0%	14.7%	14.7%
	Getting rid of first rain water	Count	0	2	2
		% of Total	0.0%	2.7%	2.7%
	Both 1 and 2	Count	2	59	61
		% of Total	2.7%	78.7%	81.3%
	Otherwise (indicate)	Count	0	1	1
		% of Total	0.0%	1.3%	1.3%
Total		Count	2	73	75
		% of Total	2.7%	97.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.472[a]	3	.925	1.000
Likelihood Ratio	.839	3	.840	1.000
Fisher's Exact Test	3.389			1.000
N of Valid Cases	75			

a. 6 cells (75.0%) have expected count less than 5. The minimum expected count is .03.

If the answer of Q 2 is Yes, what are these actions ? * V26_Zn

Crosstab

			V26_Zn		Total
			contaminated	uncontaminated	
If the answer of Q 2 is Yes, what are these actions ?	Cleaning the roof of the house	Count	0	11	11
		% of Total	0.0%	14.7%	14.7%
	Getting rid of first rain water	Count	0	2	2
		% of Total	0.0%	2.7%	2.7%
	Both 1 and 2	Count	1	60	61
		% of Total	1.3%	80.0%	81.3%
	Otherwise (indicate)	Count	0	1	1
		% of Total	0.0%	1.3%	1.3%
Total		Count	1	74	75
		% of Total	1.3%	98.7%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.233[a]	3	.972	1.000
Likelihood Ratio	.416	3	.937	1.000
Fisher's Exact Test	5.008			1.000
N of Valid Cases	75			

a. 6 cells (75.0%) have expected count less than 5. The minimum expected count is .01.

When the cistern was cleaned last time ? Before * V20_Pb

Crosstab

			V20_Pb		Total
			contaminated	uncontaminated	
When the cistern was cleaned last time ? Before	.000	Count	2	47	49
		% of Total	2.9%	67.1%	70.0%
	.083	Count	0	2	2
		% of Total	0.0%	2.9%	2.9%
	.750	Count	0	1	1
		% of Total	0.0%	1.4%	1.4%
	1.000	Count	0	6	6
		% of Total	0.0%	8.6%	8.6%
	2.000	Count	0	5	5
		% of Total	0.0%	7.1%	7.1%
	3.000	Count	0	4	4
		% of Total	0.0%	5.7%	5.7%
	4.000	Count	0	1	1
		% of Total	0.0%	1.4%	1.4%
	5.000	Count	0	2	2
		% of Total	0.0%	2.9%	2.9%
Total		Count	2	68	70
		% of Total	2.9%	97.1%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.882[a]	7	.997	1.000
Likelihood Ratio	1.452	7	.984	1.000
Fisher's Exact Test	7.847			1.000
N of Valid Cases	70			

a. 14 cells (87.5%) have expected count less than 5. The minimum expected count is .03.

When the cistern was cleaned last time ? Before * V21_Cr

Crosstab

			V21_Cr		Total
			contaminated	uncontaminated	
When the cistern was cleaned last time ? Before	.000	Count	2	47	49
		% of Total	2.9%	67.1%	70.0%
	.083	Count	0	2	2
		% of Total	0.0%	2.9%	2.9%
	.750	Count	0	1	1
		% of Total	0.0%	1.4%	1.4%
	1.000	Count	0	6	6
		% of Total	0.0%	8.6%	8.6%
	2.000	Count	0	5	5
		% of Total	0.0%	7.1%	7.1%
	3.000	Count	0	4	4
		% of Total	0.0%	5.7%	5.7%
	4.000	Count	0	1	1
		% of Total	0.0%	1.4%	1.4%
	5.000	Count	0	2	2
		% of Total	0.0%	2.9%	2.9%
Total		Count	2	68	70
		% of Total	2.9%	97.1%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.882[a]	7	.997	1.000
Likelihood Ratio	1.452	7	.984	1.000
Fisher's Exact Test	7.847			1.000
N of Valid Cases	70			

a. 14 cells (87.5%) have expected count less than 5. The minimum expected count is .03.

When the cistern was cleaned last time ? Before * V24_Ni

Crosstab

			V24_Ni		Total
			contaminated	uncontaminated	
When the cistern was cleaned last time ? Before	.000	Count	2	47	49
		% of Total	2.9%	67.1%	70.0%
	.083	Count	0	2	2
		% of Total	0.0%	2.9%	2.9%
	.750	Count	0	1	1
		% of Total	0.0%	1.4%	1.4%
	1.000	Count	0	6	6
		% of Total	0.0%	8.6%	8.6%
	2.000	Count	0	5	5
		% of Total	0.0%	7.1%	7.1%
	3.000	Count	0	4	4
		% of Total	0.0%	5.7%	5.7%
	4.000	Count	0	1	1
		% of Total	0.0%	1.4%	1.4%
	5.000	Count	0	2	2
		% of Total	0.0%	2.9%	2.9%
Total		Count	2	68	70
		% of Total	2.9%	97.1%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.882[a]	7	.997	1.000
Likelihood Ratio	1.452	7	.984	1.000
Fisher's Exact Test	7.847			1.000
N of Valid Cases	70			

a. 14 cells (87.5%) have expected count less than 5. The minimum expected count is .03.

When the cistern was cleaned last time ? Before * V26_Zn

Crosstab

			V26_Zn		Total
			contaminated	uncontaminated	
When the cistern was cleaned last time ? Before	.000	Count	1	48	49
		% of Total	1.4%	68.6%	70.0%
	.083	Count	0	2	2
		% of Total	0.0%	2.9%	2.9%
	.750	Count	0	1	1
		% of Total	0.0%	1.4%	1.4%
	1.000	Count	0	6	6
		% of Total	0.0%	8.6%	8.6%
	2.000	Count	0	5	5
		% of Total	0.0%	7.1%	7.1%
	3.000	Count	0	4	4
		% of Total	0.0%	5.7%	5.7%
	4.000	Count	0	1	1
		% of Total	0.0%	1.4%	1.4%
	5.000	Count	0	2	2
		% of Total	0.0%	2.9%	2.9%
Total		Count	1	69	70
		% of Total	1.4%	98.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	.435[a]	7	1.000	1.000
Likelihood Ratio	.720	7	.998	1.000
Fisher's Exact Test	11.871			1.000
N of Valid Cases	70			

a. 14 cells (87.5%) have expected count less than 5. The minimum expected count is .01.

Indicate approximately the age of cistern in years * V26_Zn

Crosstab

			V26_Zn	Total
			uncontaminated	
Indicate approximately the age of cistern in years	0	Count	2	2
		% of Total	5.1%	5.1%
	4	Count	1	1
		% of Total	2.6%	2.6%
	7	Count	1	1
		% of Total	2.6%	2.6%
	10	Count	3	3
		% of Total	7.7%	7.7%
	12	Count	3	3
		% of Total	7.7%	7.7%
	15	Count	10	10
		% of Total	25.6%	25.6%
	20	Count	2	2
		% of Total	5.1%	5.1%
	25	Count	4	4
		% of Total	10.3%	10.3%
	30	Count	5	5
		% of Total	12.8%	12.8%
	35	Count	2	2
		% of Total	5.1%	5.1%
	40	Count	3	3
		% of Total	7.7%	7.7%
	50	Count	2	2
		% of Total	5.1%	5.1%
	70	Count	1	1
		% of Total	2.6%	2.6%
Total		Count	39	39
		% of Total	100.0%	100.0%

Chi-Square Tests

	Value
Pearson Chi-Square	.[a]
N of Valid Cases	39

a. No statistics are computed because V26_Zn is a constant.

Appendix 4:

CDI and HRI calculations for samples exceeding WHO and Palestinian standards.

Samples exceeding WHO and Palestinian Limits:

Sample 1 (Pb, 24.05 µg/L):

CDI (for adults):

$$CDI = \frac{C_m}{W_b} * I_w$$

$$CDI = \frac{24.05}{72} * 2 \;\; = \mathbf{0.668}\ \mu g/kg.day$$

HRI (for adults):

$$HRI = \frac{CDI}{RfD} \;\; = \frac{0.668}{3.6*10^1} \;\; = \mathbf{0.019 < 1\ (O.K....Safe\ !)}$$

CDI (for children):

$$CDI = \frac{C_m}{W_b} * I_w$$

$$CDI = \frac{24.05}{32.7} * 1 \;\; = \mathbf{0.735}\ \mu g/kg.day$$

HRI (for adults):

$$HRI = \frac{CDI}{RfD} \;\; = \frac{0.735}{3.6*10^1} \;\; = \mathbf{0.020 < 1\ (O.K....Safe\ !)}$$

Sample 2 (Pb, 13.76 µg/L):

CDI (for adults):

$$\boldsymbol{CDI = \frac{C_m}{W_b} * I_w}$$

$$\boldsymbol{CDI = \frac{13.76}{72} * 2 = 0.382}\ \mu g/kg.day$$

HRI (for adults):

$$\boldsymbol{HRI = \frac{CDI}{RfD} = \frac{0.382}{3.6 * 10^1} = 0.011 < 1\ (O.K....Safe\ !)}$$

CDI (for children):

$$\boldsymbol{CDI = \frac{C_m}{W_b} * I_w}$$

$$\boldsymbol{CDI = \frac{13.76}{32.7} * 1 = 0.421}\ \mu g/kg.day$$

HRI (for adults):

$$\boldsymbol{HRI = \frac{CDI}{RfD} = \frac{0.421}{3.6 * 10^1} = 0.012 < 1\ (O.K....Safe\ !)}$$

Sample 3 (Cr, 101.44 μg/L):

CDI (for adults):

$$\boldsymbol{CDI = \frac{C_m}{W_b} * I_w}$$

$$\boldsymbol{CDI = \frac{101.44}{72} * 2 = 2.82}\ \mu g/kg.day$$

HRI (for adults):

$$\boldsymbol{HRI = \frac{CDI}{RfD} = \frac{2.82}{1.5 * 10^1} = 0.188 < 1\ (O.K....Safe\ !)}$$

CDI (for children):

$$\boldsymbol{CDI = \frac{C_m}{W_b} * I_w}$$

$$\boldsymbol{CDI = \frac{101.44}{32.7} * 1 = 3.10}\ \mu g/kg.day$$

HRI (for adults):

$$\boldsymbol{HRI = \frac{CDI}{RfD} = \frac{3.10}{1.5 * 10^1} = 0.207 < 1\ (O.K....Safe\ !)}$$

Sample 4 (Cr, 61.13 μg/L):

CDI (for adults):

$$\boldsymbol{CDI = \frac{C_m}{W_b} * I_w}$$

$$\boldsymbol{CDI = \frac{61.13}{72} * 2} \ \ \mathbf{= 1.70}\ \mu\text{g/kg.day}$$

HRI (for adults):

$$\boldsymbol{HRI = \frac{CDI}{RfD}} \ \ \mathbf{=} \frac{\mathbf{1.70}}{\mathbf{1.5*10^1}} \ \mathbf{= \ 0.113 < 1\ (O.K….Safe\ !)}$$

CDI (for children):

$$\boldsymbol{CDI = \frac{C_m}{W_b} * I_w}$$

$$\boldsymbol{CDI = \frac{61.13}{32.7} * 1} \ \ \mathbf{= 1.87}\ \mu\text{g/kg.day}$$

HRI (for adults):

$$\boldsymbol{HRI = \frac{CDI}{RfD}} \ \ \mathbf{=} \frac{\mathbf{1.87}}{\mathbf{1.5*10^1}} \ \mathbf{= \ 0.125 < 1\ (O.K….Safe\ !)}$$

Sample 5 (Ni, 214.99 µg/L):

CDI (for adults):

$$\boldsymbol{CDI = \frac{C_m}{W_b} * I_w}$$

$$\boldsymbol{CDI = \frac{214.99}{72} * 2} \ \ \mathbf{= 5.97}\ \mu g/kg.day$$

HRI (for adults):

$$\boldsymbol{HRI = \frac{CDI}{RfD}} \ \ \mathbf{= \frac{5.97}{2*10^1} \ = \ 0.30 < 1\ (O.K….Safe\ !)}$$

CDI (for children):

$$\boldsymbol{CDI = \frac{C_m}{W_b} * I_w}$$

$$\boldsymbol{CDI = \frac{214.99}{32.7} * 1} \ \ \mathbf{= 6.57}\ \mu g/kg.day$$

HRI (for adults):

$$\boldsymbol{HRI = \frac{CDI}{RfD}} \ \ \mathbf{= \frac{6.57}{2*10^1} \ = \ 0.33 < 1\ (O.K….Safe\ !)}$$

Sample 6 (Ni, 518.10 µg/L):

CDI (for adults):

$$\boldsymbol{CDI = \frac{C_m}{W_b} * I_w}$$

$$\boldsymbol{CDI = \frac{518.10}{72} * 2 \ = 14.39}\ \mu\text{g/kg.day}$$

HRI (for adults):

$$\boldsymbol{HRI = \frac{CDI}{RfD} \ = \frac{14.39}{2*10^1} \ = 0.72 < 1\ (\text{O.K….Safe !})}$$

CDI (for children):

$$\boldsymbol{CDI = \frac{C_m}{W_b} * I_w}$$

$$\boldsymbol{CDI = \frac{518.10}{32.7} * 1 \ = 15.84}\ \mu\text{g/kg.day}$$

HRI (for adults):

$$\boldsymbol{HRI = \frac{CDI}{RfD} \ = \frac{15.84}{2*10^1} \ = \ 0.79 < 1\ (\text{O.K….Safe !})}$$

Samples exceeding WHO Limits ONLY:

Sample 7 (Zn, 3452.52 μg/L):

CDI (for adults):

$$\boldsymbol{CDI = \frac{C_m}{W_b} * I_w}$$

$$\boldsymbol{CDI = \frac{3452.52}{72} * 2} \ \ \mathbf{=95.90}\ \mu\text{g/kg.day}$$

HRI (for adults):

$$\boldsymbol{HRI = \frac{CDI}{RfD}} \ \ \mathbf{=} \frac{\mathbf{95.90}}{\mathbf{3*10^2}} \ \ \mathbf{= \ 0.32 < 1\ (O.K....Safe\ !)}$$

CDI (for children):

$$\boldsymbol{CDI = \frac{C_m}{W_b} * I_w}$$

$$\boldsymbol{CDI = \frac{3452.52}{32.7} * 1} \ \ \mathbf{= 105.60}\ \mu\text{g/kg.day}$$

HRI (for adults):

$$\boldsymbol{HRI = \frac{CDI}{RfD}} \ \ \mathbf{=} \frac{\mathbf{105.60}}{\mathbf{3*10^2}} \ \ \mathbf{= \ 0.35 < 1\ (O.K....Safe\ !)}$$