Faculty of Graduate Studies

Master Program in Water and Environmental Sciences

A Quality Assessment of Drinking Water in Ramallah and Al-Bireh District: Measurements versus Residents' Viewpoints and Practices

تقييم جودة مياه الشرب في محافظة رام الله والبيرة: القياسات مقابل وجهات نظر السكان وممارساتهم

A Master Thesis

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

بسم الله الذي لا نبدأ شيئاً إلا باسمه

إهداء

"وَمَا تَوْفِيقِي إِلَّا بِاللَّهِ عَلَيْهِ تَوَكَّلْتُ وَإِلَيْهِ أُنِيبُ (٨٨)" [سورة هود]

الحمدُ لله حتى تعجز كلماتُ العربِ كلها عن حمدِه، والصلاة والسلام على هادِ العالمين،
شفيعنا ومنقذنا من الظلمات الى النور، الحبيب المصطفى محمد،

فإني أهدي عملي هذا:

الى منافسي الأوحد والوحيد، شقيق روحي، أخي الغالي الدكتور نضال،

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الى قبلتي الثالثة، جامعة بيرزيت،

الى كل من أحب و شجع ودعم بكلماته،

شكر وتقدير

قال الله جل في عُلاه: "وَإِذْ تَأَذَّنَ رَبُّكُمْ لَئِنْ شَكَرْتُمْ لَأَزِيدَنَّكُمْ ۖ وَلَئِنْ كَفَرْتُمْ إِنَّ عَذَابِي لَشَدِيدٌ (٧)" [سورة إبراهيم]

فإني أشكر الله عز وجل الذي منَّ علي بإتمام أطروحتي، مع خالص دعائي أن يتقبله مني ويجعله خالصاً لوجهه الكريم، ويجعله حجةً لي لا حجةً علي.

كما أتقدم بشكرٍ خاصٍ من أعماق قلبي لمشرف رسالتي الأستاذ الدكتور عصام الخطيب على إرشاده وتوصياته الحكيمة والرشيدة، الذي وجهني وساندني طوال فترة عملي على هذه الأطروحة، لقد كان لشرف لي أن أكون واحدة من طلبته.

كما أتقدم بالشكر العميق والإمتنان إلى الدكتور نضال محمود، الذي دعمني وآمن بي وبقدراتي وشجعني على إكمال المسير.

كما أتوجه بخالص الشكر إلى أعضاء لجنة نقاش الأطروحة؛ الدكتور ماهر أبو ماضي، والدكتورفتحي عناية لدعمهم وتحفيزهم و تعليقاتهم القيمة.

أود أن أشكر كل من ساندني ودعمني لإكمال أطروحة الماجستير، عائلتي و زملائي وأصدقائي.

الباحثة آلاء بزار

آب، 2021

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List of Acronyms

°C	Celsius
µS/cm	Microsiemens Per Centimeter
ANOVA	Analysis Of Variance
CFU	Colony Forming Unit
CPHL	Central Public Health Laboratories
EC	Electrical Conductivity.
EPA	Environmental Protection Agency
MCL	Maximum Contaminant Level
MCM	Million Cubic Meter
Mg/L	Milligram/Liter.
NA	Not Applicable
NTU	Nephelometric Turbidity Units
Ppm	Part Per Million
PSI	Palestinian Standards Institution
PWA	Palestinian Water Authority
SPSS	Statistical Package for the Social Sciences
TDS	Total Dissolved Substances.
WHO	World Health Organization

Abstract

The demand for drinking water is increasing in the Palestinian society, where a study on the quality of household drinking water at the home level in Ramallah and Al-Bireh district or the residents' practices in maintaining water quality and their viewpoint on the quality of drinking water was not observed. As so, one of the main objectives of this study was to evaluate the quality of drinking water in the Ramallah and Al-Bireh district. The data of the various quality parameters (physicochemical and microbiological) of drinking water samples were obtained from the records of the Central Public Health Laboratories (CPHL) of the Palestinian Ministry of Health in the West Bank, Palestine, during the period March 2018 to December 2019.

The results showed that most of the physical and chemical parameters include electrical conductivity (3 – 711 ppm), fluoride (0.02 – 0.33 ppm), chloride (32.25 – 116 ppm), hardness (0 – 263.4 ppm), salinity (0 – 0.3%), turbidity (0.11 – 0.56 ppm), ammonia (0 – 2.34 ppm), sodium (19.35 – 39.8 ppm), magnesium (2.135 – 23.75 ppm), calcium (17.04 – 56.87 ppm), potassium (0.803 – 2.93 ppm), sulfate (9.98 – 24.45 ppm), total alkalinity (57 – 240 ppm), chlorine (0 – 0.2 ppm), and TDS (1 – 367 ppm) were within the permissible limit of WHO and PSI. But 24% of tested nitrate samples and 4% of tested ammonia samples were above WHO and PSI water quality standards. Moreover, 15.4% of tested pH samples were below WHO and PSI water quality standards. The microbiological analysis for samples showed that only a small fraction 5.38% and 2.69% of the tested samples were contaminated with total coliforms and fecal coliforms, respectively.

The second objective of the study was to determine the residents' viewpoint and practices in maintaining water quality. As so, a questionnaire was specially designed to collect data from a statistically representative sample of households in the district. The results indicate the majority of the respondents (>77%) were either very satisfied or satisfied with the quality of drinking water. The study showed a correlation between the level of public satisfaction and the actual quality of drinking water in the district.

The results revealed that the quality of drinking water in Ramallah and Al-Bireh district is good and safe enough to be utilized as a drinking water. As so, there is no need to buy filters, in which 19.9% of the residents expense their money on buying filters. It was

recommended to keep a continuous monitoring to provide a high drinking water quality. Moreover, more other tests are recommended to identify the existence of other Enterobacteriaceae species, and more specific kinds of pathogenic bacteria in the district, like *Salmonella* and *Shigella*. Further studies are recommended to address other parameters for drinking water quality such as trace organic components and heavy metals.

ملخص

يتزايد الطلب على مياه الشرب في المجتمع الفلسطيني، وحيث أنه لم يتم إجراء أي دراسة حول جودة مياه الشرب المنزلية في محافظة رام الله والبيرة أو ممارسات السكان في الحفاظ على جودة المياه ووجهة نظرهم حولها. على هذا النحو، كان أحد الأهداف الرئيسية لهذه الدراسة هو تقييم جودة مياه الشرب في محافظة رام الله والبيرة. تم الحصول على بيانات معايير الجودة المختلفة (الفيزيائية والكيميائية والميكروبيولوجية) لعينات مياه الشرب من سجلات مختبرات الصحة العامة المركزية التابعة لوزارة الصحة الفلسطينية في الضفة الغربية، فلسطين، خلال الفترة الواقعة بين آذار 2018 إلى كانون الأول 2019.

أظهرت النتائج أن معظم المتغيرات الفيزيائية والكيميائية كانت ضمن الحد المسموح به لمنظمة الصحة العالمية و لمؤسسة المواصفات والمقاييس الفلسطينية والتي تشمل الموصلية الكهربائية (3 - 711 جزء في المليون)، الفلورايد (0.02 - 0.33 جزء في المليون)، الكلوريد (32.25 - 116 جزء في المليون)، الصلابة (0 - 263.4 جزء في المليون)، الملوحة (0 - 0.3٪)، العكورة (0.11 - 0.56 جزء في المليون)، الأمونيا (0 - 2.34 جزء في المليون)، الصوديوم (19.35 - 39.8 جزء في المليون)، المغنيسيوم (2.135 - 23.75 جزء في المليون)، الكالسيوم (17.04 - 56.87 جزء في المليون)، البوتاسيوم (0.803 - 2.93 جزء في المليون)، الكبريتات (9.98 - 24.45 جزء في المليون)، القلوية الكلية (57 - 240 جزء في المليون)، الكلور (0 - 0.2 جزء في المليون)، والمواد الصلبة الذائبة (1 - 367 جزء في المليون). لكن 24٪ من عينات النترات المختبرة و 4٪ من عينات الأمونيا المختبرة كانت أعلى من معايير جودة المياه لمنظمة الصحة العالمية و لمؤسسة المواصفات والمقاييس الفلسطينية. علاوة على ذلك ، فإن 15.4٪ من عينات الرقم الهيدروجيني المختبرة كانت أقل من معايير جودة المياه لمنظمة الصحة العالمية و لمؤسسة المواصفات والمقاييس الفلسطينية. أظهر التحليل الميكروبيولوجي للعينات أن نسبة صغيرة فقط 5.38٪ و 2.69٪ من العينات المختبرة كانت ملوثة بالبكتيريا القولونية الكلية والبكتيريا القولونية البرازية على التوالي.

الهدف الثاني من الدراسة كان تحديد ممارسات السكان في الحفاظ على جودة المياه ووجهة نظرهم حولها. وعلى هذا النحو، تم تصميم استبيان خصيصًا لجمع البيانات من عينة ممثلة إحصائيًا للأسر في المحافظة. تشير النتائج إلى أن غالبية المستجيبين (> 77٪) كانوا إما راضين جدًا أو راضين عن جودة مياه الشرب. أظهرت الدراسة وجود ارتباط بين مستوى الرضا العام ونوعية مياه الشرب الفعلية في المحافظة.

أظهرت النتائج أن جودة مياه الشرب في محافظة رام الله والبيرة جيدة وآمنة بما يكفي لاستخدامها كمياه للشرب. لذلك لا داعي لشراء الفلاتر، حيث ينفق 19.9٪ من السكان أموالهم على شراء الفلاتر. يوصى بالحفاظ على مراقبة مستمرة لتوفير جودة عالية لمياه الشرب. علاوة على ذلك، يوصى بإجراء المزيد من الاختبارات الأخرى لتحديد وجود أنواع أخرى من بكتيريا Enterobacteriaceae، وأنواع أكثر تحديدًا من البكتيريا المسببة للأمراض في المنطقة، مثل *Salmonella* و *Shigella*. يوصى بإجراء مزيد من الدراسات لمعالجة المعايير الأخرى لجودة مياه الشرب مثل تتبع المكونات العضوية والمعادن الثقيلة.

Chapter One: Introduction

1.1 Overview

There is a daily need for water, as it is an essential resource for life, and it affects the well-being of individuals. Therefore, governmental institutions make great efforts to provide safe drinking water to respondents, especially through water networks, and developed countries in this area are distinguished from developing countries (Ashton, 2014). In recent decades, an increase in global household water consumption has been observed. In developing countries, the management and distribution of high-quality drinking water helps to reduce water-related illnesses and infections (Foka et al., 2018).

Although water is abundant and covers more than 67% of the earth's surface, but this water is undrinkable since it is salty water. Humans can only use about 0.3 % of drinkable water (Bibi et al. 2016). Onda et al. (2012) reported that 28% of the world's population uses unsafe water. Rijsberman (2006) expected that by the year of 2025, 60% of the world's population may suffer from water shortage.

Water is essential for every form of life since all living organisms need water for survival. As for humans, water is important for various issues including drinking. Water must be clean and free from any toxic elements, or harmful and pathogenic organisms, including viruses, bacteria, protozoans, etc. As a result, water must be tested before it is considered potable and a good source for drinking.

Access to safe and potable drinking water is an essential need for a good and healthy life, moreover, it is considered a human right. As a result, this right was confirmed in 2010 by United Nations (UNGA, 2010). UNICEF and World Health Organization (WHO) (2004) tracked worldwide access to clean and drinkable water, estimating that 1.1 billion people lack access to safe drinking water and 2.6 billion people need sufficient sanitation.

Every year, over a million people (the majority of whom are children under the age of 5) die as a consequence of illnesses caused by a lack of clean drinking water, inadequate sanitation, and poor hygiene (Prüss-Ustün et al., 2014). Furthermore, it is estimated that in developing countries, 80% of illnesses caused by waterborne pathogens are caused by consuming unsafe and polluted water (Khan et al., 2013). Another study reported that about

3.1% of deaths in various countries occur because of poor quality of water (Pawari and Gawande, 2018). According to WHO (2018), waterborne illnesses are still the leading cause of death worldwide, accounting for more than 2.2 million fatalities per year, most of which occur in poor countries.

There is a strong relationship between the use of safe and clean drinking water and excellent health results, and vice versa. To the right, millions of people across the world have a significant problem in obtaining long term sustainable access to clean water supplies. This problem is worsened in rural regions of most poor nations across the world, caused by a lack of infrastructure for water source or an inadequate supply of drinking water (Edokpayi et al., 2018a, 2018b).

Due to growing demand for drinking water, recreational use, and agricultural productivity, there is a significant need to balance water quality and quantity to fulfill such needs. Many people are careless in protecting water sources. Because of lack of preventative legislation and their assumption that water is available (Shahady and Boniface, 2018). As a result, community involvement, as well as a water quality indicator that the general public can use, are crucial to any water management program's success (Shahady and Boniface, 2018).

Because having clean and safe drinking water is a fundamental human right, the government must ensure that all residents have access to it. Therefor water quality must be assessed for each water source that can be used for drinking water. The growth of population and the different anthropogenic activities such as urbanization, industrialization, and advancement in agriculture, have made surface water pollution a global issue. These activities decrease the availability of safe drinking water that polluted with various substances and organic chemicals of human origin, these substances are affecting the water quality (Aremu et al., 2011).

1.2 Research Objectives

The following are the primary Objectives of this study:

1. Assessment of drinking water’s quality in Ramallah and the Al-Bireh district.
2. Evaluation of the residents’ practices and their viewpoint to maintain drinking water quality in Ramallah and the Al-Bireh district.

1.3 Problem Statement

The demand for drinking water is increasing in the Palestinian society, where a study on the quality of drinking water in Ramallah and Al-Bireh district and residents' viewpoints and practices was not observed. Especially since some people are doubtful about the drinking water's quality supplied to households in the West Bank. The importance of this study comes in bridging this research gap. In addition, the importance of this study in comparing the results of the quality of drinking water, and the residents' practices in maintaining water quality and their viewpoint on the quality of drinking water, and thus know the compatibility of water quality and trends on the use.

1.4 Research Questions

The objectives of this research were to answer the following research questions:

1. Is the quality of drinking water in Ramallah and the Al-Bireh district within the Palestinian Standards Institution (PSI) and WHO drinking water standards?
2. Are the viewpoints of local people on the quality of drinking water positive?
3. What are the current residents’ practices in Ramallah and Al-Bireh district to maintain the quality of drinking water?

1.5 Water Quality Parameters

Assessment of water resource quality is an important aspect for every water source that is supplied for domestic, industrial and agricultural purposes. Water quality is dependent on a wide range of physical, chemical and microbiological parameters. Monitoring these parameters is critical for determining water quality. Many outbreaks, epidemics, and severe illnesses such as diarrhea, typhoid, cholera, and tuberculosis are spread primarily through contaminated water (WHO, 2011).

For monitoring and achieving a better quality for drinking water, three main parameters must be analyzed to assess drinking water quality: physical, chemical, and microbiological. UNICEF and WHO (2004) had reported that safe drinking water must have these physical, chemical, and microbiological characteristics that include: tasteless and colorless, no pathogens, free from impurities, and toxic chemical concentrations should be in accordance with EPA or WHO recommendations.

Moreover, WHO (2004) recommends important parameters that must be tested to assess drinking water quality to ensure its viability for the human to use which reduce the probability of diseases that include: pH, turbidity, thermotolerant coliforms and *Escherichia coli*, and residual chlorine when chlorination is used for water disinfection.

1.5.1 Microbiological Parameters

Since a microbial contamination poses a serious threat to human health in water, microbiological assessment, which is the assessment of microorganisms present in the water sample to examine the drinking water's quality, must be performed. This assessment for drinking water aimed to prevent human from getting sick as a result of consuming drinking water contaminated with pathogens that cause water-borne illness, such as bacteria, viruses, and protozoa (Wen et al., 2020).

Pathogenic Organisms

Pathogenic organisms are organisms that can cause illness when they enter the body of a host and grow inside (Balloux, & van Dorp, 2017).Three groups of pathogenic microorganisms can be transmitted by water to human which includes: bacteria, viruses, and protozoa (Leclerc et al., 2002). In laboratory cultures, many pathogens are impossible or difficult to cultivate. However, molecular tests can identify them, but they are expensive, time-consuming, complex, and unable to detect low-pathogen quantities (Payment, 2003). Water testing for the presence of pathogens is considered a challenge for all of these reasons (Payment, 2003).

From all microorganisms, bacteria are considered as the ideal indicators for pollution, because of their metabolic diversity and their quick response to environmental changes (Meays et al, 2004). Furthermore, comparing to pathogen testing, bacterial detection procedures are simple, inexpensive, and quick (Payment, 2003).

Indicator Bacteria

A microbiological water quality indicator is a microorganism that can enter into drinking water through feces, but is easier to be measured than the other microorganisms that are harmful human health (Bosch, 2007).

A good indicator has the following characteristics: it must be particularly abundant in the fecal matter of warm-blooded mammals, it must not grow in natural water or water supply systems, and it must be easily identified by simple techniques (WHO, 1997).

Members of the Enterobacteriaceae family are recognized as primary indicators for assessing water quality which include: total coliform bacteria, fecal coliform bacteria, enteric bacteria, and *Escherichia coli* (Meays et al, 2004). Facal streptococci and Enterococci are another family that also used as microbiological water quality indicator. Both of which, in comparison to other pathogens, are employed to assess pollution in water quality management due to their easy and cost-effective detection (Meays et al, 2004).

1. Total Coliforms

Facultative anaerobic and aerobic and bacteria that convert lactose to acid and gas in 24–48 hours at 36±2 °C, owing to the availability of the -galactosidase enzyme (Ashbolt et al., 2001). These bacteria are rod-shaped, gram-negative, oxidase-negative, and non-spore forming bacteria (Ashbolt et al., 2001).These bacteria are not specific indicators for fecal contamination because many members can originate from different soil and plant sources (Edzwald, 2010).

2. Thermotolerant Coliforms

Thermotolerant bacteria that generate gas and acid when exposed to lactose at a temperature of 44.5±0.2 °C, for a time around 24±2 hours are termed as fecal coliforms because of their role as fecal biomarkers (Ashbolt et al., 2001). Fecal coliforms are frequently used to assess disease risk and the microbiological quality of water, and they have long been recognized as a sign of fecal contamination (Ashbolt et al., 2001). As so, if fecal coliform is found in water, it confirms that water is contaminated with fecal material (Ashbolt et al., 2001).

3. *Escherichia coli* (*E. coli*)

Is a type of thermophilic coliforms utilize tryptophan which leads to producing indole but is also defined as coliforms because it is able to produce the β-glucuronidase enzyme that ferments lactose, although 10% of *E. coli* that present in the environment may not possess that enzyme (Ashbolt et al., 2001). *E. coli* is the most suitable bacterial group of coliforms to signify fecal contamination produced by warm-blooded mammals (Ashbolt et al., 2001).

Therefore, *E. coli* can be used for monitoring drinking water quality (Percival & Williams, 2014).

4. Enteric Bacteria

Enteric bacteria such as *Pseudomonas*, *Salmonella,* and *Cholera* belong to the Enterobacteriaceae family (Cabral, 2010). These bacteria are foodborne and waterborne pathogens that infect humans via the fecal-oral route are members of this family (Cabral, 2010). Waterborne outbreaks occur when drinking water is polluted with these pathogens generated from animal or human excrement (Edzwald, 2010).

Enteric bacteria were responsible for many waterborne disease epidemics around the world until the early 1900s. Typhoid fever, caused by *Salmonella Typhi, dysentery*, caused by *Shigella dysenteriae*, and cholera, produced by *Vibrio cholera*, and all resulted in significant fatality rates (Percival & Williams, 2014).

5. Fecal Streptococci

Streptococci bacteria are Gram-positive cocci that had no catalase enzyme. It grows at a temperature of 45 °C on bile aesculin agar and has the Lancefield group D-antigen. They belong to the genera enterococcus and etreptococcus (Edzwald, 2010).

If the concentration of indicator bacteria is high in water, it means high water pollution which will lead to high health risks (Cabral, 2010). Treated water from a certain operating water treatment system should be free of bacteria. All disinfectants used during water treatment inactivate bacteria in this case (Cabral, 2010). Waterborne illnesses caused by these bacteria have only occurred after drinking water that polluted after treatment, left untreated, or treated insufficiently (Percival & Williams, 2014). Because water may be a substantial source of disease-causing organisms, a water safety framework and water safety strategies should receive a lot of attention in order to maintain excellent water quality and safeguard public health.

1.5.2 Physical Parameters

Monitoring the physical parameters of water quality is critical for determining whether or not the water is contaminated. These parameters include: electrical conductivity, turbidity, color, total dissolved solids (TDS), etc.

Electrical Conductivity

Electrical conductivity (EC**)** is the ability of an aqueous solution to conduct current flow, and it is determined by the existence of ions, the overall concentration of ions, valence, motility, relative concentrations, as well as the solution's temperature (Rhoades, 1996). Solutions that contain salts, and most inorganic acids and bases are good conductors. The EC of distilled water is less than 1 mhos/cm (the unit of EC measurement). EC is the inverse of resistance, and the mho, or micromho in weak conductivity water sources, is the unit of EC (Rhoades, 1996). It is important to study the EC of water because it affects the taste and so it has an important impact on the acceptance of the user to the water.

Color

Color is one of the important aesthetic aspects of water quality. Ideally, there should be no apparent color in drinking water. According to WHO (2011), the main reasons for color in drinking water are the presence of: organic matter that had colors such as fulvic acids and humi, iron and other metals that either found as corrosion products or as natural impurities, or contamination of the water supply by industrial pollutants.

Color in drinking water might be the first sign of a risky situation, as result of; the origin and the cause of color in a drinking water supply should be investigated. Color can be removed by one of these processes including: filtration, flocculation, coagulation, and clarification (dissolved air flotation or sedimentation) (WHO, 2011). In a glass of water, most people can detect color above 15 true color units (TCU). Consumers frequently tolerate color levels of less than 15 TCU (WHO, 2011).

Turbidity

Turbidity is one of the important aesthetic aspects of water quality, and it's produced by suspended solids or colloidal particles that block light from passing through the water, which can be caused by both organic and inorganic particles, and microorganisms linked to particulate matter (WHO, 2017). Turbidity in surface waters can be caused by a variety of particle debris, including attached microbes that pose a health risk (WHO, 2011). Turbidity can arise in distribution systems as a result of disturbed biofilms and sediments, as well as the entry of unclean water from outside the system (WHO, 2011).

By raising the disinfectant demand, high levels of turbidity might impair the disinfection process' effectiveness (WHO, 2011). By adsorbing or coating pathogens and indicator organisms, the particles may shield them from disinfection, offer absorption sites for hazardous substances in the water, and interfere with total coliform measurement (Edzwald, 2010). As a result, filtration, sedimentation, and coagulation are key treatments for removing particle debris to reduce microbial contamination in water and achieve safe and drinkable water (WHO, 2017).

Turbidity is measured in nephelometric turbidity units (NTU), and beyond 4.0 NTU, it may be seen with the human eye (WHO, 2017). To ensure that the disinfection method is effective, the turbidity should be less than 1 NTU (WHO, 2017). Because of the apparent cloudiness, turbidity can have a detrimental influence on consumer acceptance of water (WHO, 2017).

Total Dissolved Solids

Total dissolved solids are the summation of inorganic ions in water including phosphate, calcium, sodium, nitrate, carbonate, bicarbonate, chloride, magnesium, sulfate, organic ions, and other ions (Rhoades, 1996). TDS in drinking water comes from a variety of places, including natural origin, waste, agriculture and urban runoff, and industrial effluent (Rhoades, 1996). De-icing roadways with salt have the potential to increase TDS levels in water sources (Rhoades, 1996). According to WHO (2011) TDS poses no health risk at any levels found in drinking water, but it is recommended to be less than 600 milgram per liter (mg/l). TDS levels in drinking water more than 1000 mg/l may have an impact on its acceptability, in which water becomes unpleasant in taste WHO (2011).

1.5.3 Chemical Parameters

The health consequences of chemical contaminants for drinking water differ from health consequences that are associated with microbial contaminants. The chemical contaminants cause unhealthy effects after an extended period of exposure (WHO, 2011).

There are just some few chemical components in water that might cause health problems after a single exposure (WHO, 2011). This can occur when the drinking water supply is exposed to accidental pollution, and if that happened, the water becomes unsafe and undrinkable because of the unacceptable taste, appearance, and odor (WHO, 2011).Over time, if some chemical characteristics in drinking water above specified international guideline limits, severe health consequences may occur, perhaps leading to irreparable damage (WHO, 2011).

pH

The concentration of hydrogen ions in a water solution is measured by pH (Covington et al., 1985). The pH scale is a logarithmic, not a linear, scale that ranges from 0 to 14 (Covington et al., 1985). Neutral water has a pH of 7, but water with a pH of higher than 7.0 is alkaline, whereas water with a pH of less than 7.0 is acidic (WHO, 2011). Water with a pH less than 6.5 has acidic and corrosive characteristics (WHO, 2011). The availability of hazardous metallic ions including zinc, iron, copper, and lead is increased when water is acidic (WHO, 2011).

Water acidity affects water quality in which the taste of water becomes sour and metallic (WHO, 2011). Moreover, acidic water causes adverse health effects for humans (WHO, 2011). It is important to study the pH of water because it affects the biological activities and chemical reactions that only exist at a specific pH range (Kolawole et al. 2013).

Nitrate and Nitrite

Nitrate and nitrite ions are produced naturally as part of the nitrogen cycle (WHO, 2003). In natural waters, nitrate is one of the major anions, whereas nitrite does not occur in water at a significant level, however, it can appear in reducing conditions or as a result of ammonia oxidation (WHO, 2003b). The nitrate ion (NO^{3-}) is a stable nitrogen ion that has been linked to oxygen. Although bacteria can reduce nitrate, it is chemically inactive. The nitrite ion is nitrogen in an unstable oxidation state (NO^{2-}). Through biological and chemical processes, nitrite can be reduced to various compounds or oxidized to nitrate (WHO, 2003b).

Nitrate concentrations in water can be substantially raised as a result of wastewater discharges and oxidation of nitrogenous chemicals found in human and animal waste. It also rose as a result of agricultural actions which include excessive use of manures and inorganic nitrogenous fertilizers (WHO, 2003b). Nitrate concentrations in surface water can fluctuate rapidly due to inorganic nitrogenous fertilizer runoff, phytoplankton absorption, and bacterial denitrification (WHO, 2003b).

Nitrite concentration in water may increase because of using sodium nitrite which is commonly used for beer, cured meats, and pickling, however, similar usage has been restricted (WHO, 2003b). Occasionally, improper techniques during boiler cleaning with nitrous acid might cause a nitrite to pollute building water supplies (WHO, 2003b).

Nitrite, or nitrate transformed to nitrite in the body, can cause two harmful chemical reactions and affecting human health: the potential formation of carcinogenic nitrosamines and nitrosamides, and the initiation of methemoglobinemia, specifically in babies with the age under six months (blue-baby syndrome) (Shuval & Gruener, 2013). In humans, Methemoglobinemia occurs when nitrite reacts with hemoglobin in red blood cells to create methemoglobin. Nitrite ions oxidize hemoglobin to methemoglobin, which binds oxygen firmly and prevents it from releasing, and preventing oxygen delivery to tissues (Shuval & Gruener, 2013).

Carcinogenic agents such as nitrosamides and nitrosamines are produced once the nitrite ion interacts with secondary amines in the stomach, like amino acids from meals (IARC, 1978).This process can be inhibited by antioxidants in the diet, such as vitamin C. As a result of these adverse health effects on humans, WHO (2003b).sets a nitrate guideline of 50 mg/l and a nitrite guideline of 3 mg/l.

Sulfate

Sulfate is an anion that is naturally occurring in water (WHO, 2011). If it presents in high concentrations in drinking water it may cause temporary diarrhea (WHO, 2011). A laxative effect happens for most adults when sulfate concentrations are more than 1000 mg/l, while at a concentration than 600 mg/l bottle-fed infants develop diarrhea (WHO, 2011). If a microbiological diarrheal infection affects babies and young children, acute diarrhea may happen to them which may lead to dehydration (Backer, 2000). People who live in areas that have high sulfate concentrations in drinking water easily will not be affected and have no illness (Backer, 2000).

Although high sulfate levels in drinking water may not be harmful to human health, health authorities should be alerted if drinking water sources contain sulfate concentrations of more than 500 mg/l (WHO, 2011), because of the gastrointestinal effects resulting from the ingestion of drinking water containing high sulfate concentration (WHO, 2011). The taste of high sulfate concentrations in drinking water varies depending on the nature of the paired cation (WHO, 2011). Tasting limits have been reported to occur between 250 mg/l for sodium sulfate to 1000 mg/l for calcium sulfate (WHO, 2011).

Potassium

Potassium can be found in drinking water as a result of use of potassium permanganate as an oxidant in treatment of water (WHO, 2009b). It is also found because exchanging between ions, in which potassium ions exchange with magnesium and calcium ions when potassium chloride is employed in ion exchange for home water softening (WHO, 2009b). Moreover, potassium can be found as a result of the partial substitution of potassium salts for sodium salts in desalinated water conditioning (WHO, 2009b).

Potassium is a vital mineral for humans, as it is necessary for creatinine phosphorylation, secretion of insulin, and carbohydrate metabolism, and protein production (WHO, 2009). In addition, potassium and Sodium play a key role in the normal osmotic pressure in cells (WHO, 2009b). As a result, the recommended daily need may exceed 3000 mg (WHO, 2009b). WHO (2009b) reported that high concentrations of potassium in drinking water have no adverse health effects, since potassium consumption from drinking water is considerably below the recommended amount. Moreover, an overdose of potassium leads to induce vomiting or is rapidly excreted kidney if there is no kidney disease (Gosselin et al, 1984).

Adverse health effects may be associated with the intake of drinking water that was treated with potassium salts principally potassium chloride, as so potassium may have serious health consequences for those who are vulnerable, including (WHO, 2009b):

1. People with heart disease, kidney disease, coronary artery disease, diabetes, adrenal insufficiency, pressure, or hyperkalemia.
2. Seniors with decreased physiological capacity in their kidney function
3. Individuals who've been using drugs that interfere with the body's regular potassium handling
4. Babies with an immature kidney function

Magnesium and Calcium

Magnesium and calcium are generally occurring in water. They may dissolve from many types of rocks like apatite, limestone, gypsum, dolomite, and magnetite. Calcium is an essential element for humans, and the human body has around 1.2 kg of it. Together with vitamin D, calcium phosphate is a supporting material that promotes bone and tooth growth. Calcium is also found in muscular tissues and blood, and it is necessary for a variety of processes such as cell division, membrane formation, blood coagulation, and muscular contraction.

Magnesium is an important element to living creatures, and it presents in the human body in amounts of about 25 g with a percentage of 40% in muscles and tissues and 60% in bones (WHO, 2009a). It functions as a cofactor for over 300 cellular enzymes that control a variety of metabolic processes in the body (WHO, 2009a). It is also involved in the production of nucleic acids and proteins. Endothelial dysfunction, higher circulation levels of C-reactive protein, enhanced vascular responses, and reduced insulin sensitivity are all linked to low magnesium levels (WHO, 2009a).

That high concentration of calcium and magnesium in drinking water has no adverse health effects, which it reported that calcium intake from drinking water has a significant protective effect on the risk of dying from acute myocardial infarction (Yang et al., 2006). Furthermore, other studies have linked a lack of cations, like magnesium and calcium, in drinkable water to heart disease (Nerbrand et al., 2003; Kousa et al., 2006; Yang et al., 2006).

Hardness is linked to the negative effects of calcium and magnesium in drinking water (WHO, 2011). Hard water includes high quantities of dissolved calcium and magnesium, and calcium and magnesium are the determinants of water hardness (WHO, 2011). Hard water has no negative health consequences, but it can create scale accumulation in the distribution system, treatment plants, pipes, tanks inside buildings, and poor soap and detergent performance (WHO, 2009a). Moreover, it forms deposits of calcium carbonate on heating, if the hardness is greater than 200 mg/l (WHO, 2011).

Fluoride

Fluoride is found in a variety of water sources (WHO, 2004). For most people, drinking water is the primary source of exposure; however, additional sources of exposure include food, dental products, and pesticides (WHO, 2004). Fluoride is added to public water supplies on occasion to assist prevent dental caries (WHO, 2004). Fluoride has both positive and negative health impacts on people, depending on the overall amount consumed (WHO, 2004)

Fluoride concentrations of 1.5 mg/l are thought to be ideal for preventing dental cavities (Warren et al., 2009). A total daily fluoride intake of 0.05–0.07 mg/kg of body weight is best for oral health (Warren et al., 2009). Fluoride consumption should not exceed 0.10 mg/kg of body weight to prevent the danger of dental fluorosis (Warren et al., 2009).

High concentrations of Fluoride in drinking water have adverse health effects which include: gastritis, ulcers, kidney failure, dental and bone fluorosis (Warren et al., 2009). Moreover, it can increase the risk of fractures, and if fluoride builds up in the bone over time, it can cause joint stiffness and discomfort, as well as alterations in bone structure and ligament calcification (Warren et al., 2009).

Ammonia

Because of its alkalinity, ammonia is a water-soluble molecule with poisonous and corrosive properties (WHO, 2004). Ammonia is a nitrogenous chemical that is found in most water sources as a result of biological breakdown of organic matter that contains it (WHO, 2004). It may be found in surface water and groundwater because of the disposal of industrial wastes that contain ammonia and fertilizers (WHO, 2004). Because of the chloramine disinfecting, ammonia may be present in drinking water, in which ammonia is added to enhance the formation of chloramines which may cause unfavorable taste and odor (WHO, 2004). Ammonia might also be due to the usage of cement mortar to cover the insides of water pipes, which could lead to the discharge of ammonia into the drinkable water (WHO, 2004).

The concentrations of ammonia in surface water and groundwater are normally less than 0.2 mg/l (WHO, 2004). WHO (2004) recommended a threshold odor of 1.5 mg/l and a threshold taste of 35 mg/l for ammonium. The presence of ammonia at higher than natural levels indicates fecal pollution, in which the water may be contaminated with a fecal matter or with fertilizer (WHO, 2003a). At these levels, ammonia in drinking water has no negative health consequences, thus no health-based guideline value has been provided, but toxic effects are caused when ammonia's concentration is above 200 mg/kg of body weight which may lead to kidney damage nervous system dysfunction, lung edema, and acidosis (WHO, 1986, 2004).

Sodium

Sodium occurs naturally in drinking water. Most water sources contain below 20 mg/l, but in other water sources, sodium concentration may reach 250 mg/l (WHO, 2004). There are several causes for this elevation including mineral sediments, saline intrusion, wastewater effluents, as well as salt for roads de-icing (WHO, 2004). Furthermore, water treatment agents including sodium hypochlorite, sodium bicarbonate, and sodium fluoride can raise sodium concentrations to as high as 30 mg/l (WHO, 2004). In household water, softeners can produce amounts of above 300 mg/l (WHO, 1979).

Sodium is an essential element to humans. The total daily intake is estimated to be 500 mg for adults (National Research Council, 1989). Sodium salts have no toxic effects since mature and healthy kidneys excrete high concentrations, so no value for a health-based recommendation has been provided (WHO, 2004). But overdoses of sodium chloride may cause death and acute effects including vomiting, muscular rigidity, nausea convulsions, and cerebral and pulmonary edema (Health and Welfare Canada, 1993).

In addition, some people are at risk from taking high concentrations of sodium in their diet, such as those who have high blood pressure (hypertension) (Dahl, 1960). Hypertension can develop into additional illnesses, like coronary artery disease and stroke (Dahl, 1960). At a concentration of more than 200 mg/l, sodium can alter the flavor of drinking water (WHO, 2004).

Chloride

Chloride occurs naturally in drinking water in which originates from natural sources such as deposition from various rocks into water and soil by weathering (WHO, 2004). Chloride also occurs from anthropogenic sources such as saline intrusion, sewage, and industrial effluents, salt used in de-icing roads, using of inorganic fertilizers and septic tank effluents (WHO, 2004). Moreover, chloride concentration in water might be elevated by treatment processes (WHO, 2004).

Chloride is an essential element to humans in which it helps to keep bodily fluids osmotically active (Health and Welfare Canada, 1978). Excretion via the kidneys keeps the electrolyte balance in the body in balance and by adjusting total dietary intake. The total daily intake is estimated to be 9 mg/kg of body (Health and Welfare Canada, 1978). Chloride has no toxic effects on humans, in which healthy people can tolerate the high concentrations of chloride, as their healthy kidneys excrete the excess amount (Health and Welfare Canada, 1978). So, no value for a health-based recommendation has been suggested (WHO, 2004). People with heart or kidney diseases, on the other hand, should avoid excessive chloride concentrations since they may have negative health consequences (WHO, 2004).

Chloride may affect the taste of drinking water at a concentration above 250 mg/l; moreover, high concentrations of chloride may increase metals' corrosion in the distribution network (WHO, 2004). Because it increases the electrical conductivity as a result the concentrations of metals in the water will increase (WHO, 2004). Chloride from soluble salts reacts with metal ions in metal pipes, causing metal levels in drinking water to rise. It can also cause metal pipes to corrode more quickly (WHO, 1979).

1.6 Literature Review

Drinking water quality is addressed by several studies that try to find ways to guarantee safe drinkable water for humans since water can threaten human public health.

Ibrahim (2019) conducted a study to assess the acceptability of groundwater for drinking in Jordan's major groundwater basins. The groundwater quality data from 16 sampling stations were monitored for one year from March 2015 to February 2016. The study examined at 16 microbiological, physical, and chemical characteristics. According to Jordanian drinking water standards, all physical and chemical indicators were virtually at or below the maximum permitted level, but the microbiological parameters (such as E. coli count) were above the maximum allowed level in all of the examined locations. Three places were categorized as excellent water classes, nine as good water classes, one as a Bad water class, two as a very poor water class, and one as water unfit for human consumption, according to the researcher (Ibrahim, 2019).

Mkwate et al. (2017) conducted a study to investigate quality of drinking water and small town domestic water treatment in Malawi's Balaka district, in which water samples have been collected from 11 different locations and examined for Physical and chemical and microbial parameters such as TDS, electrical conductivity, turbidity, pH, F-, Cl-, Na, K, NO3-, Fe, fecal streptococcus, and fecal coliform. Standard techniques were used to test these parameters.

pH, F-, Cl, NO^{3-}, Na, K, and Fe were all within the standard values for most sites. The electrical conductivity, turbidity, fecal coliform, and fecal streptococcus all exceeded WHO water quality standards. Because of the presence of fecal coliform, the most of the samples collected (73%) were categorized as moderate risk, meaning they were not suitable for human consumption (Mkwate et al., 2017).

Sarker et al. (2019) performed a research to determine the physicochemical and microbiological characteristics of different ponds, jars, and tube-well water samples to verify that they were safe to drink. A total of 30 samples were chosen at random from Nakla Paurosova in the Sherpur district (Bangladesh). The results of the different physicochemical analyses were below the standard limit in most water bodies, but the microbiological analysis showed that the total counts for pathogenic bacteria including *Salmonella* spp., *Shigella* spp., *Vibrio* spp., *E. coli*, and total coliform bacteria exceeding the permissible limit for drinking the water, and they were resistant to a wide variety of medicines.

The researchers had performed a survey, according to the findings, people in the research region who used or drank these waters were sick from a variety of water-borne illnesses. They came to the conclusion that these types of water supplies are a serious health risk. As a result, public awareness, adequate treatment, and exact management are all required prior to the use and consumption of this water (Sarker et al., 2019).

In Babol, Northern Iran, a research was done to evaluate the drinking water quality in terms of chemical characteristics then compare results to WHO (2011) allowable limits. A total of 375 samples from 71 drinking water wells were examined. The results of chemical tests of samples from 2011 to 2014 were tracked. The concentration levels of iron, nitrate, manganese, and nitrite over all locations during the years 2011-2014 were 0.239±0.15 mg/L, 2.201±0.73 mg/L, 0.132±0.95 mg/L, and 0.008±0.012 mg/L respectively.

The average amounts of nitrite and nitrate were below the permissible level, which is acceptable, according to statistical studies. During this time, the mean amounts of iron and manganese (Mn^{2+}) in several regions of Iran's drinking water were higher than the permissible level (Yousefi et al., 2017).

A study was conducted by Roopavathi et al., (2016) to assess the microbiological, the physical, and the chemical drinking water parameters of different water resources in Kote town, in Mysore district, India. Water samples were collected from various water sources like public taps, stored household domestic water, and hand pumps. The water samples' physicochemical and microbiological characteristics were evaluated using standard techniques for determining the quality of drinking water. All physicochemical parameters were found to be within the WHO's permitted limits. The biological investigation revealed that coliform bacteria were present in roughly 53% of the samples. In terms of total plate count, there was a substantial variation across water sources, with stored home water having a higher total plate count than tap and borewell water, both of which above the guideline value.

E. coli infection was not found in either the hand pump or tap water, however *E. coli* contamination was found in 80% of the household stored water samples. The presence of large coliform levels in stored home water implies existence human activity and poor inadequate sanitation. To preserve and prevent heavy microbial growth, special attention should be paid to collection and storage by further treatment.

Abuzerr et al. (2019) performed a descriptive cross-sectional study using a questionnaire method to examine the Gaza community's knowledge, attitude, practice (KAP), and satisfaction on problems linked to domestic drinking water safety. The research was carried out across the Gaza Strip districts, between 2017 and 2018. The findings revealed that 47.7% of those surveyed lived in refugee camps. Households with 5–7 people made up 40.1 % of those questioned, while 87.3 % of household heads were men, with the majority (52.1 %) having a university degree.

Some sociodemographic factors have statistically significant relationships with the average percentage of KAP scores. The only factor that was statistically related (p less than 0.05) with all mean KAP scores was level of education. As a result, the local government authority should organize community awareness programs on the necessity of drinkable water storage safety and cleanliness procedures (Abuzerr et al., 2019).

Another study in the Middle district of the Gaza Strip, Palestine, was carried out in order to assess the quality of drinking water and to try to identify possible contamination sources during the water production, transportation, and delivery process (Aish, 2013).. In 74% of drinking water distribution points, 27% of storage tanks, 76% of drinking water home storage tanks, and 20% of private desalination plant tanks, microbiological contamination was discovered. The pH was frequently below the permissible range, varying from 4.4 to 6.3 (Aish, 2013).

A study was performed in Nigeria to evaluate the quality of water from 12 different sources and assess their suitability for domestic and drinking use. The samples were tested for fecal coliforms and *E. coli*, and all samples excluding one sample of tap drinking water were positive. Based on chemical and physical characteristics, the most of the water samples (86%) were classified good (Olasoji et al., 2019).

A group of Ethiopian researchers conducted a study to assess the biological, chemical, and physical properties of water from household sources in Nekemte town, Ethiopia (Duressa et al., 2019). The results showed that only 37% of tap water samples were polluted with fecal coliforms, but 100% of samples were polluted with total coliforms bacteria, and the results ranged between 12 to 120 cfu per 100 ml in general (Duressa et al., 2019).

The concentrations of nitrates and phosphate ranged between 2.2-6.5 mg/l and 0.65 and 1 mg/l, respectively in the water samples. Most of water samples had a free residual of chlorine of less than 0.5 mg/l. The majority of the results of the parameters were within acceptable Ethiopian and WHO drinking water limits, except temperature, total coliforms, fecal coliforms, manganese, and iron (Duressa et al., 2019).

From a chemical standpoint, Napacho and Manyele (2010) studied the drinking water quality in Tanzania's Temeke district. The assessment of chemical parameters in water sources to WHO/TBS permitted limits revealed that the majority of chemical parameters were over the allowed range. This indicates that the chemical characteristics of the water sources examined from Temeke district are more contaminated. Tap water was determined to be higher quality than other sources of drinking water (well water and river water) depending on water quality criteria evaluated in this study.

Several studies focused on residents’ practices and their viewpoint on drinking water quality, in which a study of the public's views of drinking water quality is generally done for the purposes of tracking drinking water quality, developing water quality standards, and managing water resources as a whole (Jayyousi, 2001). It has been admitted by WHO the need for public engagement in drinking water quality monitoring since the public is the primary recipient of safe and clean water sources, as well as the first to experience the repercussions of deteriorating water quality (WHO, 2011).

A study conducted by Aini et al. (2007) designed to measure respondents' degree of water knowledge, identify activities taken by households to improve quality of drinking water, and assess sustainable water behaviors, and analyze their perceptions of drinking water quality. The majority of respondents (70%) thought the quality of the drinking water provided to their home was bad, while some said it was extremely poor (16%). Only 16% said that water was with good quality.

The major issues with their tap water, according to the respondents, were color, odor, and taste. These issues arose from respondents' perceptions of low tap water quality. As a result, the majority of them took further steps to enhance water quality. About 85% purchased home water filters, 41% boiled water, and the remaining 17% purchased bottled water. Health concerns, perceptions of inadequate tap water quality, and the country's rising water pollution and contamination were all causes for purchasing water. Some areas of conservation were enhanced by the responders, such as the speed with which leaky pipes were repaired, the planning of water-saving activities, and the method of washing cars (Aini et al., 2007).

A study was conducted in four informal neighborhoods of Kisumu, Kenya to examine the link among community participation and proper water handling cleanliness. Those four informal communities have a similar thread running through them: potable water delivery systems funded by Sustainable Aid in Africa International, a Kisumu-based non-governmental organization (NGO). Sustainable Aid in Africa International’s purpose is to increase access to safe drinking water and improved sanitation in Kisumu. It accomplishes this through encouraging participatory approaches and developing long-term technology (Ananga et al., 2017).

As so, a structural survey tool was employed to answer this question: "what are the contributions of community participation in the production of clean potable water in Kisumu's informal neighborhoods?" There were 58 items in the tool, and the items examined for this study were chosen to provide insight into families' water handling hygiene routines. The informed consent part, household demographics, the home's major source of water, and the sanitary status inside a household were all examined. To validate the data, Data on some of the most often used factors in community involvement research was also requested in the questions., including cleanliness, covering of water storage, and meeting attendance. (Ananga et al., 2017).

Beneficiaries of community participation water systems practice better hygiene (for example, cleaning water storage containers and protecting sources of water) than beneficiaries that did not conduct community participation, according to the findings. Those in the earlier sample showed fewer cases of waterborne illnesses and odor in their water than those in the latter group sample. The results support a lesser-known motivation for community participation, namely the promotion and protection of drinkable water hygiene quality. The researchers recommend that Authorities in Africa and other disadvantaged areas would be well to consider community participation as a feasible method for enhancing the results of potable water delivery projects. (Ananga et al., 2017).

Ormerod et al. (2019) used a case study of the Reno-Sparks area of northern Nevada in United States to investigate the role of local identity in determining public views of potable reuse. As a result, in the spring of 2018, the proponents utilized a community survey of Reno-Sparks inhabitants to determine the water concerns that were most important to them and their readiness to consume reclaimed water.

The survey asked about individual opinions for water source and collected water, household structure and demographic data. In order to gain a better understanding of the inhabitants' larger issues, the opening page of the questionnaire includes questions regarding attitudes and preferences, and an open-ended prompt: “What water issue in northern Nevada matters most to you?”. Moreover, a brief explanation of reclaimed water was provided in the questionnaire, which stated: Normally, treated wastewater (sewage effluent) is released into rivers, although it can be recycled. Then questionnaire asked: “Would you be willing to drink reclaimed water if it matched or exceeded current tap water Quality?” respondents could answer “yes”, “no”, or “unsure” (Ormerod et al., 2019).

Residents across the region are concerned about future water resources, especially the influence of population expansion on future availability of water, according to the findings. When compared to their urban or rural peers, individuals who identify as suburban inhabitants were much more receptive of drinking water reuse. Different views of local identity, according to the researchers, influence public acceptability of potable reuse in the Reno-Sparks area, and these location identities may have consequences for water management in other towns across the western United States and abroad (Ormerod et al., 2019).

Another research was carried out in Newfoundland district in Canada to investigate into the people's views of water quality and the related health concerns, as well as the actual quality of public water sources in the same areas characteristics (Ochoo et al., 2017). The research was carried out in 45 localities, with a telephone poll of 100 families being performed to assess public views of the quality of their drinking water. The researchers then used the province government's water resources site to pull public water quality records for the same communities from 1988 to 2011. The examination of 2091 water samples was included in these reports, which included levels of disinfection by-products, nutrients, ions, metals, and physical characteristics (Ochoo et al., 2017).

Color, total dissolved solids, turbidity, manganese, iron, and disinfection by-products, were the most commonly identified characteristics in public water, according to the studies. The majority of respondents (> 56%), on the other hand, were either totally or very satisfied with the quality of their drinking water characteristics (Ochoo et al., 2017). Water quality was rated higher by the older, more educated, and higher-income groups than by the younger, less educated, and low-income groups. There was no link between public satisfaction and actual water quality in the communities, according to the study. Even within villages served by the same water supply, there were variations of opinion among the respondents. The research revealed that there is a disconnect between public perceptions of drinking water quality and actual water quality (Ochoo et al., 2017).

A study by Ab Razak et al. (2016) was conducted in Pasir Mas, Malaysia amid to determine the level of knowledge, attitude, and practice regarding heavy metal contaminated drinking water; determining the level of heavy metals (aluminum, chromium, copper, iron, nickle, lead, zinc, and cadmium) in drinking water, and to estimate the health consequences (carcinogenic and non-carcinogenic) caused by massive heavy metals via drinking water by using hazard quotient and lifetime risk of cancer.

According to the findings, the people of Pasir Mas have good knowledge (80%), a less favorable attitude (93%), and good practice (81%) when it comes to heavy metal pollution of drinking water. The heavy metal concentrations discovered in this investigation were determined to be less than the Malaysian ministry of health's and the WHOs permissible drinking water standards. Heavy metal consumption through drinking water had no possible non-carcinogenic or carcinogenic hazards, according to the Health risk assessment (Ab Razak et al., 2016).

Another study conducted by Prokopy et al. (2008) focused on the adoption of agricultural best management practices since fertilizer and pesticides are a substantial source of nonpoint source pollution in urban and suburban areas, they have been linked to a range of water quality issues, including algal blooms, eutrophication, and polluted groundwater that might be utilized as a drinking water source (Law et al., 2004). The researchers explored several variables that affect best management practices within an agricultural environment. Education levels, farm size, income, access to information, good environmental attitudes, environmental awareness, and use of social networks were all found to be positively linked with the adoption of optimal management techniques (Prokopy et al., 2008).

1.7 Thesis Outline

The thesis consists of four chapters. The first chapter provides an overview of the study, thesis questions, objectives, and literature reviews on drinking water quality and the residents' practices and viewpoint for maintaining it. The methodology is presented in chapter two. The results and discussions are presented in chapter three. Chapter four summarizes the conclusions and provides recommendations.

Chapter Two: Research Methodology

2.1 Study Area

2.1.1 Location

Ramallah and Al-Bireh district is in the central part of the West Bank, which extends from Nablus district in the north to Jerusalem district in the south and from Jericho district in the east to the 1948 Israel and West Bank border in the west (Figure 1). It occupies approximately 14.5% of the West Bank. Ramallah and Al-Bireh district has a population of 355,202 (PCBS, 2021).

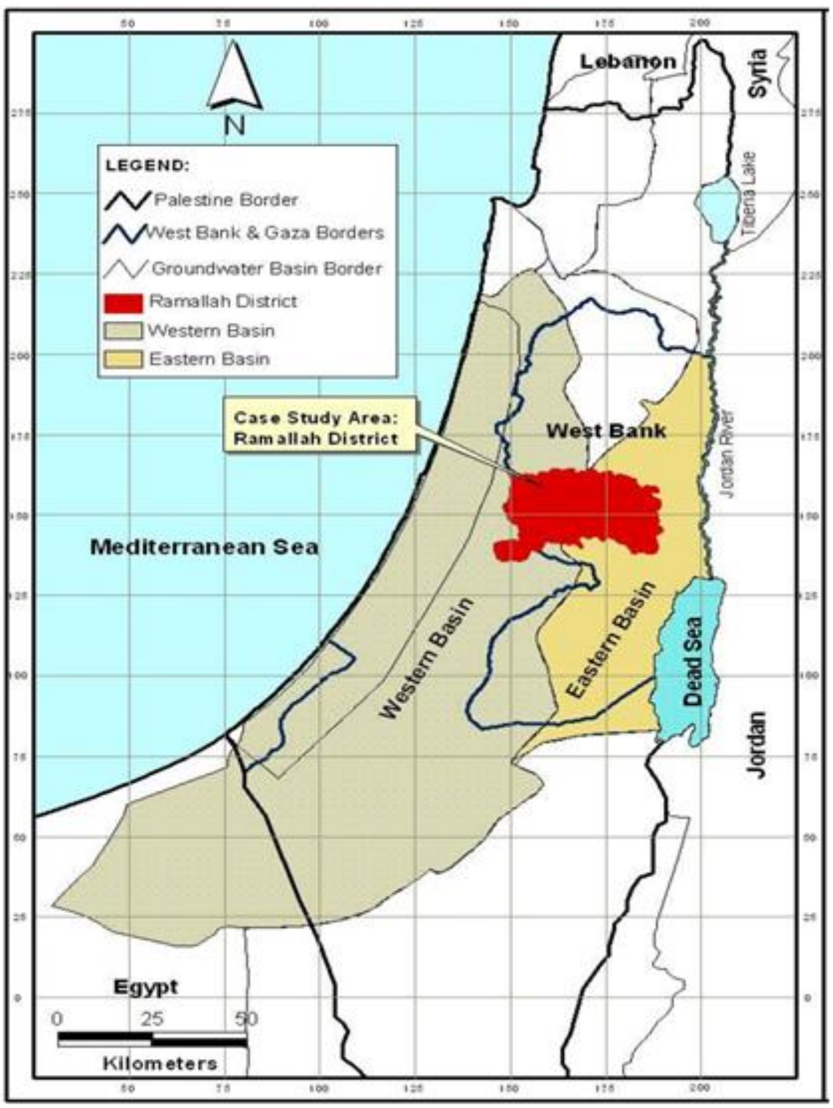


Figure 1: Ramallah and Al-Bireh districts' location map (HWE, 2009).

2.1.2 Climate

Ramallah and Al-Bireh district is affected by the Mediterranean climate, which has rainy, cold winters and dry, sunny summers. As for temperature, Ramallah and Al-Bireh district like other districts in the West Bank, August is the warmest month and January is the coldest. However, Ramallah and Al-Bireh district had the coldest winter temperatures than the rest of the West Bank, since it is a part of the Hill Regions. The mean annual temperature in the district ranges between 15-20 °C, with a temperature of 6-12 °C, at the coldest month (January), and with a temperature of 22-27 °C, at the hottest month (August) (PCBS, 2008).

In terms of rainfall, about 85% of the overall rainfall falling throughout November and February and being spread out across 59 days on average (PCBS, 2008). Rainfall distribution in the district is influenced by its topography, with more rainfall in the hills and mountains. The district's western part receives higher annual rainfall than the eastern part. In 2007, the annual rainfall in Ramallah and Al-Bireh district was 543.9 mm (PCBS, 2008a). As for Humidity, the mean humidity level in Ramallah and Al-Bireh district is around 57%, and during the months of January and February, it reaches its highest levels (PCBS, 2008).

2.1.3 Water Sources

In Ramallah and Al-Bireh district, the mainly renewable water resources is groundwater resources, which are all part of the Eastern aquifer system. Palestinian springs and wells that located in the Eastern Basin generated about 3.6 MCM in 2010 (PWA, 2013).

As for the resources of drinking water in Ramallah and Al-Bireh district, there are two main resources: local resources, mostly springs and Palestinian owned wells, mainly the Ein Samia groundwater wells, and water bought resources from Israel's National Water Company, Mekorot (PWA, 2007). In 2010, Mekorot in Ramallah & Al- Bireh Governorate acquired 16.4 MCM of water (PWA, 2013).

In West Bank, 72 liters per capita per day is the average per capita water consumption rate for domestic uses, which it is below the amount recommended by WHO (2008) standard minimum of 100 liters per capita per day and the Palestinian Water Authority (PWA)'s target of 120−150 liters per capita per day (PWA, 2013)

Piped Water Supply

Around 91.5% of houses in Ramallah and Al- Bireh district were linked to public networks, while 5% used private networks. Only 3% did not have piped water, and only 0.1% did not specify their water source (PCBS, 2017).

According to PWA (2007), Palestinian-owned wells provide around 25% of the water in the Ramallah and Al-Bireh district, primarily the Ein Samia groundwater wells. These wells operated by the Jerusalem Water Undertaking, while Mekorot provides the remaining 75%. The water from the Ein Samia wells is combined with Mekorot water to feed around 50 villages in the Ramallah and Al-Bireh district (PWA, 2007).

Jerusalem Water Undertaking for Ramallah and Al Bireh district is responsible for the majority of water supply services and management for almost all of the 73 villages in the district, with the exception of the 27 villages whose water services are controlled by the West Bank Water Department (PWA, 2013)

Groundwater Basins

There are two groundwater basins in Ramallah and Al-Bireh district, the eastern and western groundwater basins (Sabbah et al., 1996). Around 65% of Ramallah and Al-Bireh district is covered by the western groundwater basin (Auja Tamaseeh sub-basin). The water from this basin is directed westward, and the basin is tapped by Shebtin wells. Approximately 35% of Ramallah and Al-Bireh district is covered by the eastern groundwater basin. The water in this basin flows eastward and southeastward (Sabbah et al., 1996).

Aquifer Systems

In Ramallah and Al-Bireh district, the Upper Cenomanian Aquifer System and the Lower Cenomanian Aquifer System are the main aquifer present (Sabbah et al., 1996). The Upper Cenomanian Aquifer System is made up of the Hebron formation, whereas the Lower and Upper Beit Kahil formations make up the Lower Cenomanian Aquifer System (Sabbah et al., 1996).

2.2 Sampling

Data of various quality parameters (microbiological, chemical, and physical) of drinking water samples at the household level in Ramallah and Al-Bireh district were acquired from the CPHL of the Palestinian ministry of health in the West Bank of Palestine. The water samples were collected during the period March 2018 to December 2019 by the staff of the CPHL. Samples were collected into sterilized glass bottles and transferred to the laboratories in a cold box containing ice-freezer packets within 24 hours.

2.3 Physical and Chemical Measurement

Water samples were tested for different physical (EC, TDS, turbidity) and chemical (pH, hardness, chlorine, fluoride, chloride, sodium, salinity, ammonia, nitrate, magnesium, calcium, potassium, sulfate, total alkalinity) parameters. Physical and chemical parameters were assessed in the laboratory using gravimetric, spectrophotometric, and titrimetric standard techniques recommended by Baird et al. (2017).

2.4 Microbiological Analysis

The microbiological parameters (total coliforms and fecal coliforms) were analyzed using the membrane filtration method as specified in the standard techniques for the analysis of water (Baird et al., 2017). The results for total coliforms and fecal coliforms were represented in colony forming unit (cfu) per 100 ml.

2.5 Sample Analysis

The results of the physical, chemical, and microbial parameters of the collected water samples were organized and analyzed using Microsoft Excel Sheet, then compared with PSI (2004) and WHO (2004) guidelines for drinking water quality.

2.6 Study Design

The second objective of the study was to determine the residents' viewpoint and practices in maintaining water quality. The current study was conducted in Ramallah and Al-Bireh district. The study population was all households in Ramallah and Al-Bireh district. Using a specifically constructed questionnaire, data was collected from a statistically representative sample of households during October 2020 to March 2021. The survey was carried out entirely in Arabic (Palestinian native language).

2.7 Study Tool

A 33-item designed questionnaire was used to gather information about socio-demographic characteristics that established the respondent's gender, age, education levels, and number of family members, family income, and community type. The questionnaire also contained main topics for drinking water choices including hygiene, availability, convenience, taste, trust in the Jerusalem Water Undertaking (water supplier), environmental concerns, personal and family habits, barriers to drinking water from water network reuse, and actions to maintain a good quality of drinking water and self-impact. The sub-topics of each of these main topics were subsequently identified.

Before the actual study was conducted, questionnaire was pre-tested to verify that respondents could comprehend the questionnaire. Ten respondents from Ramallah and the Al-Bireh area participated in the pre-test, these respondents were not included in the sample from the study area. Minor alterations were done after the testing to guarantee acceptance and consistency.

2.8 Sample Size Determination

The sample size was determined according to the following equation (Spero, 1983):

$$n = \frac{p(1-p)}{(SE \div t) + [p(1-p) \div N]}$$

where:

- N: The population size = 70,049
- n: The sample size = 382
- t: standard normal variate (The value= 1.96 for 95% confidence level)
- SE: Percentage of Errors = 0.05
- p: response distribution = 0.50

2.9 Sampling Process

The questionnaire was distributed to targeted people by Google forms in which they fill it online and filled personally using a papered questionnaire. The sample of the study was distributed among seven urban areas, 67 villages, and five refugee camps, based on the distribution of the number of households in Ramallah and Al-Bireh district, in which the total number of households was 70,049 in the district according to PCBS (2019). 382 questionnaires were distributed among 382 respondents according to Table 1.

Table 1: The distribution of the sample study depends on the distribution of the number of households in Ramallah and Al-Bireh district.

	Urban	Villages	Refugee camps	Total
Number of households	30,418	36,236	3,395	70,049
Number of the distributed questionnaire	191	176	16	383
Percentage of the distributed questionnaire	50%	46%	4%	100%

2.10 Data Analysis

To ensure data quality, each filled questionnaire was reviewed before being coded in Microsoft Excel. The Statistical Package for the Social Sciences (SPSS) program version 23.0 was used to examine the data. The results were presented as frequency and percentage tables, and a Chi-square test with $p < 0.05$ was used to find correlations between categorical variables.

Chapter Three: Results and Discussion

3.1 Physical Parameters

The results of the physical parameters of samples collected from drinking water sources in Ramallah and Al-Bireh district are summarized in Table 2. The values were compared with PSI (2004) and WHO (2004) standards.

Table 2: The physical parameters of drinking water in Ramallah and Al-Bireh district compared to the PSI and WHO's recommended allowable limits.

Parameter (Unit)	Range	MCL of WHO (2004)	MCL of PSI (2004)	Percentage of samples above MCL of PSI (%)
Electrical conductivity (µS/cm)	3 – 711	Up to 2000	Up to 2000	0%
Turbidity (NTU)	0.11 – 0.56	Up to 5.0	Up to 5.0	0%
TDS (ppm)	1 – 367	Up to 500	Up to 500	0%

Electric Conductivity

The amount of ions present in water is measured by EC, and these ions have a major influence on the taste of water, therefore EC has a substantial impact on the user's acceptability of the drinking water.

In this study, 24 samples were tested for EC, the values ranging from 3 to 711 µS/cm and with a mean value of 291 µS/cm (Table 2), and all results were less than the allowable drinking water threshold set by WHO, and PSI which is 2000 µS/cm. Similar results were reported by Shit et al., (2019) on drinking water sources of Sikkim in India.

Table 3 shows the classification of water quality according to the range of EC. The result show that the water in the research region is excellent or good, meaning it is not highly ionized and has a low degree of ionic concentration activity due to little dissolved solids.

Table 3: Water quality classification at 25 °C for varied EC values in µS/cm.

Range of water electrical conductivity	Water quality classification (Rajankar et al., 2011)	Percentage of samples (%)
>3,000	Unsuitable	0
2,000–3,000	Doubtful	0
750–2,000	Permissible	0
250–750	Good	62.5
<250	Excellent	37.5

Total Dissolved Solids

The presence of a high TDS value in water implies that it is heavily mineralized. Water with a TDS content of more than 500 ppm is not deemed fit for human consumption, so according to WHO (2004) and PSI guidelines TDS concentrations should not exceed 500 ppm. In this study, 79 samples were tested for TDS. The results show that all of the testes samples were within the acceptable limit, in which the values range from 1 ppm to 367 ppm, and with a mean value of 207.7 ppm (Table 2). A similar result was reported by Meride and Ayenew (2016) in the drinking water in Wondo genet campus, in Ethiopia.

High concentrations of TDS in water had no health concerns to humans, However, those with heart or renal problems may be affected by excessive amounts (Kumar and Puri, 2012), and may cause constipation or laxative effects as reported by Sasikaran et al. (2012). Furthermore, high TDS levels alter the flavor of drinking water, making it taste metallic, salty, or bitter, and emitting unpleasant odors if present at levels above the WHO recommended threshold (WHO, 2004).

Turbidity

The clarity and transparency of a water sample are influenced by its turbidity. It is determined by the amount of solid matter present in the suspended form. The turbidity test for water is a measurement of the water's light-emitting characteristics, and it is used to determine the quality of waste discharge in terms of colloidal particles. (Kurup et al., 2010). In this study, 15 samples were tested for turbidity. The average turbidity obtained in the study area (0.273 NTU) was below than the WHO's recommended limit of 5.00 NTU. Turbidity ranged from 0.11 NTU to 0.56 NTU in this study (Table 2). Similar results were reported by Sunday and Chidi (2019) in Nigeria.

Due of the apparent cloudiness, high turbidity levels may have a negative influence on consumer acceptance of water (WHO, 2011). Moreover, turbid water leads to staining of clothes exposed during washing, and it affects negatively the disinfection processes including ultraviolet light and chlorination (WHO, 2017).

3.2 Chemical Parameters

The results of the chemical parameters of samples collected from drinking water sources in Ramallah and Al-Bireh district are summarized in Table 4. The values were compared with PSI (2004) and WHO (2004) standards.

Table 4: The chemical parameters of drinking water in Ramallah and Al-Bireh district compared to the PSI and WHO's recommended allowable limits.

Parameter (Unit)	Range	MCL of WHO (2004)	MCL of PSI (2004)	Percentage of samples above MCL of PSI (%)
pH	3.4 – 8.39	6.5–8.5	6.5 – 8.5	15.4%
Fluoride (ppm)	0.02 – 0.33	1.5	1.5	0%
Chloride (ppm)	32.25 – 116	Up to 250	Up to 250	0%
Hardness (ppm)	0 – 263.4	NA	500	0%
Salinity (%)	0 – 0.3	Up to 1.0	Up to 1.0	0%
Ammonia (ppm)	0 – 2.34	1.5	NA	4%
Sodium (ppm)	19.35 – 39.8	NA	200	0%
Magnesium (ppm)	2.135 – 23.75	Up to 100	Up to 100	0%
Calcium (ppm	17.04 – 56.87	Up to 100	Up to 100	0%
Potassium (ppm)	0.803 – 2.93	30	10	0%
Sulfate (ppm)	9.98 – 24.45	250	250	0%
Total alkalinity (ppm)	57 – 240	NA	400	0%
Chlorine (ppm)	0 – 0.2	NA	NA	0%
Nitrate (ppm)	0 – 33.5	Up to 10 as NO3– N	Up to 10 as NO3-N	24%

Nitrate

Nitrate is the most predominant form of inorganic nitrogen entering freshwater, groundwater, and precipitation due to its high water solubility, and it represents the highest oxidized form of nitrogen, and nitrogen is a highly critical nutritional need of the body, in which it is a basic building block for various compounds including proteins, enzymes, amino acid, and nucleic acid. However, Nitrate is of the most significant disease-causing factors of water quality. As so, 10 ppm is set as the maximum allowable limit of nitrate in drinking water according to WHO (2004).

High concentration of nitrate can cause and adverse health effect on humans, It was found that nitrate concentrations more than the permissible limit of 10 ppm are harmful to pregnant women, and that it also has a significant health impact on babies aged three to six months due to its tendency to induce methemoglobinemia or blue baby syndrome (Shuval & Gruener, 2013).

In this study, 25 samples were tested for Nitrate. The mean value of nitrate concentration was recorded to be 6.81 ppm, and the minimum value was recorded to be 0 ppm, and with a maximum concentration of 33.5 ppm (Table 4) which is higher than the allowable limit that premised by WHO and PSI standards. There were 24% of the samples that were above the accepted limit. The source of drinking water in these samples was groundwater (spring or underground well). These high concentrations of Nitrate that presented in the samples may due to industrial waste, wastewater, nitrogenous fertilizers, or leakage from nearby cesspits that are built without lining, and that allow wastewater to enter groundwater in which PCBS (2019) reported that 43.3% of households use porous cesspits, or from wastewater that collected from cesspits and discharged by wastewater tankers without any treatment (ARIJ – WERU, 2012). Runoff and infiltration can transfer nitrate from such sources into groundwater systems (Liu et al., 2005).

Similar results were reported by Shomar et al. (2008) Gaza strip in which they reported a high level of nitrate in 90% of the sampled wells. Manure, septic effluents, sludge, and synthetic fertilizers are the basic sources of nitrate in Gaza’s groundwater.

Chloride

Chlorides are an inorganic substance formed by combining chlorine gas with metal, and it is the most dominant anion in water. In this study, 23 samples were tested for chloride, and the chloride concentration for all samples was found to be in the permissible range which is 250 ppm according to PSI and WHO (2004). The chloride values range from 32.25 ppm to 116 ppm, with an average value of 53.1 ppm (Table 4). The highest chloride concentration value (116 ppm) was recorded in a house that uses municipality water as a drinking water source. Similar results were reported by Sunday and Chidi (2019) in Nigeria.

Pitting and corrosion of iron pipes are caused by high chloride levels in the water. Small quantities of chlorides are required for proper cell functioning, and it plays a key role in the human body's metabolism and other key physiological processes.

Inorganic fertilizers, run-off including leachates from landfills, livestock feed, septic tank effluents, de-icing of roads by salts, and industrial effluents are all examples of anthropogenic and natural sources of chloride in surface and groundwater (Department of National Health and Welfare, 1978). The weathering of the rocks might cause high amounts of chlorine in groundwater.

Sulfate

Sulfate is the measure of sulfur content in water. High concentrations of sulfate in water may make it unpleasant to drink (Chapman, 1996), but no significant detrimental effects of sulfate on public health have been observed. Sulfate levels in drinking water should not exceed 250 ppm, according to the WHO (2004). Sulfate concentrations exceeding 600 ppm function as a purgative in humans, however high levels of sulfate in water are typically not hazardous to people (WHO, 2004).

In this study, 7 samples were tested for Sulfate, in which the values range from 9.98 to 24.45 ppm, and with an average value of 18.4 ppm (Table 4). The results show that the concentrations of sulfate for all samples were within the WHO and PSI standards. Similar results were reported by Sunday and Chidi (2019) in Nigeria.

The taste of high sulfate concentrations in drinking water varies depending on the nature of the accompanying cation; taste thresholds have been estimated to vary from 250 mg/l for sodium sulfate to 1000 mg/l for calcium sulfate (WHO, 2011).

Magnesium

Magnesium is an essential element for the human health in which it acts as a co-factor for an enzyme activity that includes: ATP metabolism, element's transportation through membranes such as potassium, calcium, and sodium, and glycolysis process (Soetan et al., 2010).

The allowable range of magnesium in water, according to WHO (2004) and PSI guidelines, should not exceed 100 ppm. In this study, 8 samples were tested for Magnesium and the values range from 2.135 to 23.75 ppm and with a mean value of 9.30 ppm (Table 4). The results show that the concentrations of magnesium in Ramallah and Al-Bireh district were less than the guideline limit of WHO (2004). Similar findings have been reported by (Shit et al., 2019) in Sikkim, North Eastern Himalaya, India.

Calcium

Calcium is one of the major cations that almost exist in all-natural water, and it is very essential for the physiology of human cells, body development, teeth, and bones. In this study, 8 samples were tested for Calcium, and the results indicate that the concentration of calcium ranging from 17.04 to 56.87 ppm and with a mean value of 37.82 ppm (Table 4), and according to WHO (2004) and PSI standards all samples were within the permissible limit, in which it should not exceed 100 ppm. Similar values were reported by Duressa et al. (2019) in which he reported that the concentrations of calcium in Nekemte, Oromia, Ethiopia were within the WHO's permitted range for drinking water.

A high level of calcium in drinking water are not harmful to humans, in which it was shown that calcium intake from drinkable water had a substantial protective impact against mortality from Acute Myocardial Infarction (Yang et al., 2006).

Hardness is linked to the negative effects of both calcium and magnesium in drinking water. Hard water includes high quantities of dissolved calcium and magnesium, and calcium and magnesium are the factors of water hardness. Hard water has no negative health consequences, but it can create scale accumulation in the distribution system, treatment plants, pipes, and tanks inside buildings, poor soap and detergent performance, Moreover, it forms deposits of calcium carbonate on heating, if the hardness is greater than 200 mg/l (WHO, 2004).

Potassium

Potassium is a crucial element for human body functioning such as stimulation of the nerves, contraction of muscle, regulation of blood pressure, and dissolution of protein. The deficiency of potassium might cause muscle weakness, disorders in heart rhythm, and depression, but its deficiency is rare (Lanham-New et al., 2012).

In this study; 8 samples were tested for Potassium, and the Potassium concentration for all samples was found to be in the permissible range which is 30 ppm according to WHO (2004). The Potassium value ranges from 0.803 ppm to 2.9 ppm, with an average value of 1.84 ppm (Table 4). Similar results were reported by Sunday and Chidi (2019) in Nigeria.

Potassium in high levels in drinking water has no negative health impacts, but high milligram levels have serious consequences for those with renal disease or other disorders like heart disease, coronary artery disease, diabetes, adrenal insufficiency, pressure, or hyperkalemia (WHO, 2009b).

Sodium

Sodium is an essential element to the human body as it is required for maintaining blood pressure and body fluid volume. In Humans, sodium deficiency is very rare since sodium is a common ingredient in food and water. In this study, 8 samples were tested for Sodium and the values range from 19.35 to 39.8 ppm and with a mean value of 31.1 ppm (Table 4). According to WHO (2004) and PSI standards the allowable range of Sodium in water should not exceed 200 ppm. Levels that exceed 200 ppm, will affect the taste of drinking water (WHO, 2004). Similar results were reported by Sunday and Chidi (2019) in Nigeria. High concentrations of sodium in water are not harmful to humans, since mature and healthy kidney excretes the excess amount. As so high concentration may affect persons who had kidney diseases (WHO, 1996).

Ammonia

Because of its alkalinity, ammonia is a water-soluble molecule with poisonous and corrosive properties. In drinking water, ammonia might be found due to disinfection processes (WHO, 2004). In this study, 27 samples were tested. The average of ammonia was 0.14 ppm and with a minimum concentration of 0 ppm and with a maximum concentration of 2.34 ppm (Table 4) which is higher than the allowable limit (1.5 ppm) that premised by WHO (2004).

There were 4% of the samples that were above the accepted limit. The source of drinking water in these samples was groundwater (spring or underground well) the high concentrations of ammonia that presented in these samples may due to leakage from nearby cesspits that are built without lining, and that allow wastewater to enter groundwater or from wastewater that collected from cesspits and discharged by wastewater tankers (ARIJ – WERU, 2012). Ammonia in drinking water has no adverse health effects at these levels, but WHO (2004) recommended that the value of ammonia should not be more than 1.5.

Fluoride

Fluoride has both positive and negative impacts on human health, according to the total intake (WHO, 2004). High concentrations may cause gastritis, ulcers, kidney failure, dental and bone fluorosis whereas low concentrations can cause dental caries (Warren et al., 2009).

In this study, 24 samples were tested for fluoride, and the results show that Fluoride concentration ranges between 0.02 and 0.33 pm, with a mean value of 0.09 (Table 4) which are below the accepted limit according to the PSI and WHO (1.5 ppm), as so Fluoride addition to drinking water may be implemented as precautionary options to prevent dental cavities and other associated health problems. Similar findings were observed by Radfarda et al. (2019).

Hardness

Water hardness is indicated by the existence of dissolved magnesium and calcium salts in the water. According to WHO, hardness poses no health risk at levels found in drinking water, but it is recommended to be less than 500 ppm (WHO, 2004).

In this study, 24 samples were tested for Hardness, and according to results, values range from 0 to 263.4 ppm, with a mean value of 91.8 ppm (Table 4). As so all samples were found to be in the permissible range. Similar results were reported by Al-Salaymeh (2008) in Hebron city, Palestine.

Table 5 shows the total hardness classification for water quality, and according to the table, drinking water in Ramallah and Al-Bireh district were ranged from soft water to hard water. Hard water has no health risk but has an adverse effect in the household in which hardness above 200 mg/l might cause scale accumulation in the distribution system, treatment plants, pipes, and tanks inside buildings, poor soap and detergent performance, Moreover, it forms deposits of calcium carbonate on heating (WHO, 2004).

Table 5: Classification of water quality based on different levels of hardness (Prakash & Somashekar, 2006).

Total Hardness (mg/L as $CaCO_3$)	The degree of hardness	Percentage of samples (%)
>300	Very hard	0
150–300	Hard	33
75–150	Moderately hard	25
0–75	Soft	41.7

Salinity

In this study, 25 samples were tested for Salinity, and according to results values ranged from 0 to 0.3%, with an average value of 0.0224% (Table 4), and according to WHO (2011) and PSI standards all samples were within the permissible range which should be up to 1.0. High salinity in Drinking water may increase blood pressure because of high sodium concentration (Naser et al., 2019).

Chlorine

In an aqueous solution, free chlorine is unstable and can rapidly deplete, especially at high temperatures and when exposed to intense light or agitation. For health reasons, a level of free chlorine of around 1 mg/l is required, which is added to water to minimize the presence of bacteria, viruses, and protozoa, and this level should indeed be maintained at sites of consumption (Momba et al., 2006).

In this study; the free residual chlorine concentration in all water samples was below 0.5 ppm. In which 7 samples were tested for chlorine. The results show that chlorine concentration ranges between 0 and 0.2 ppm, with an average value of 0.067 ppm (Table 4). Similar results were reported by Duressa et al. (2019).

pH

The pH of water is an important measure in identifying its acid-base balance, and determining whether it is acidic or alkaline. The quantity of dissolved carbon dioxide in water that produces carbonic acid determines the pH. WHO has recommended the maximum permissible limit of pH from 6.5 to 8.5. In this study, 79 samples were tested for pH, and the results ranged from 3.4 to 8.39, with an average of 7.54 (Table 4). In this study, 15.4% of samples recorded to be below than 6.5 which are excessively acidic for human ingestion and can trigger health problems; moreover, the acidic pH has a corrosive effect on water pipes in household water distribution systems, and it has a synergistic effect on the toxicity of the heavy metal in water (WHO, 2011).

Alkalinity

Total alkalinity is the buffering capacity of water to neutralize a strong acid (hydrogen ions) to adjust water pH, and it is usually because water contains bicarbonate, carbonate, and potassium, calcium, and sodium hydroxide compounds (Murhekar et al, 2011).

It's crucial to understand pH since it has a direct impact on organisms and an indirect impact on the toxicity of other pollutants in the water. As a result, water quality relies heavily on buffering capacity.

Total alkalinity test is performed using a titration technique to achieve a pH of 4.5 and is stated in milligrams per liter as calcium carbonate (Rounds, 2001). All of the samples in this research had alkalinity values that were under the permitted limit of 400 ppm, in which 7 samples were tested for alkalinity, and the values range from 57 to 240 ppm and with an average value of 118.3 ppm (Table 4). The abnormal value of alkalinity has no adverse health effect on the human.

3.3 Microbiological Parameters

The results of the microbiological parameters of samples collected from drinking water sources in Ramallah and Al-Bireh district are summarized in Table 6. The values were compared with PSI (2004) and WHO (2004) standards.

Table 6: The microbiological parameters of drinking water in Ramallah and Al-Bireh district compared to the PSI and WHO's recommended allowable limits.

Parameter (Unit)	Range	MCL of WHO (2004)	MCL of PSI (2004)	Percentage of samples above MCL of PSI (%)
Total coliforms (cfu/100ml)	0 – Too many to count	0	0 – 3	5.38%
Fecal coliforms (cfu/100ml)	0 – Too many to count	0	0	2.69%

Total Coliforms and Fecal Coliforms

Coliforms bacteria are not independently associated with illness in which they are not harmful (Barrell et al., 2000). However, the occurrence of these bacterial species in drinking water suggests fecal pollution as well as the existence of other disease-causing organisms according to Aziz (2005). Such as diarrhea, typhoid, and dysentery (WHO, 2011). As so these bacteria are the primary key determinants of the appropriateness of water for drinking and consumption use.

In this study, 2,868 samples were tested for total coliforms bacteria, and the count ranged from (Nil to too many to count) cfu/100 ml. 2,872 samples were tested for fecal coliform bacteria, and the count ranged from Nil to too many to count cfu/100 ml. Total coliforms were found to be greater than the permitted limit in a small percentage of the examined samples (5.38 %). Only 2.69 % of samples were contaminated with fecal coliforms, which is a small fraction of all samples, and these results are not agreed with the WHO's (2004) and the PSI's (2004) acceptable limits. These results contradict results reported by Roopavathi et al., (2016) in which he reported that 53 % drinking water samples were contaminated with coliform bacteria.

About 33.3 % of the highly contaminated drinking water samples of total coliforms their source were from drinking water storage tank, these results indicate the improper cleaning of the drinking water storage tank. About 55.6 % of samples were from public water network and 7.4% of samples were from a close local spring.

The treatment methods proposed by the WHO (2004) for each classified degree of contamination, based on the total coliforms range are shown in Table 7. In which 94.6% of the samples, total coliforms were not detected, so no treatment process is required. Only 5.38 % of samples need further treatment processes. In which 1.3% of the samples are categorized as very high contamination, and so need special treatment.

Table 7: Total coliforms in drinking water are distributed based on their contamination level and the treatment procedure required (WHO, 2004).

Procedure for treatment that is recommended	Total coliforms (cfu/100 ml) range	Number of tested samples	Percentage of examined samples (%)
Contamination levels are quite high, require specific treatment.	>50,000	37	1.3%
Flocculation, sedimentation, and then chlorination	51–50,000	45	1.57%
Chlorination only	4–50	72	2.51%
No treatment required	0–3	2714	94.6%

Table 8 shows the results of the risk analysis of drinking water samples. It also indicates the level of risk and the proportion of tested drinking water samples for fecal coliforms (cfu/100 ml) based on the WHO's (2004) risk classification, in which 97.4% of the tested samples have no risks, 1.2% have low risk, while 0.31% have a very high risk level.

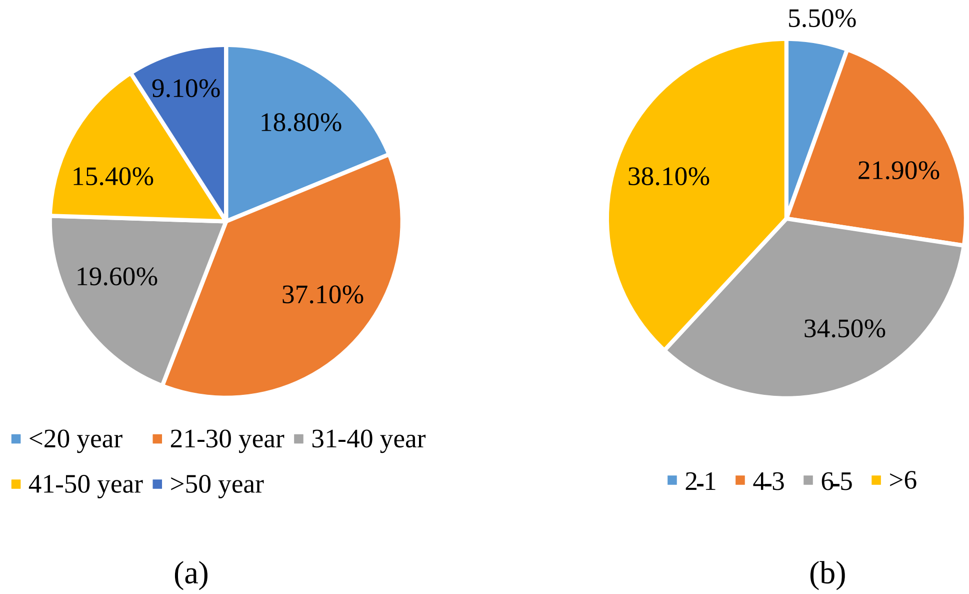
Table 8: Distribution of fecal coliforms-tested drinking water samples according on their level of risk.

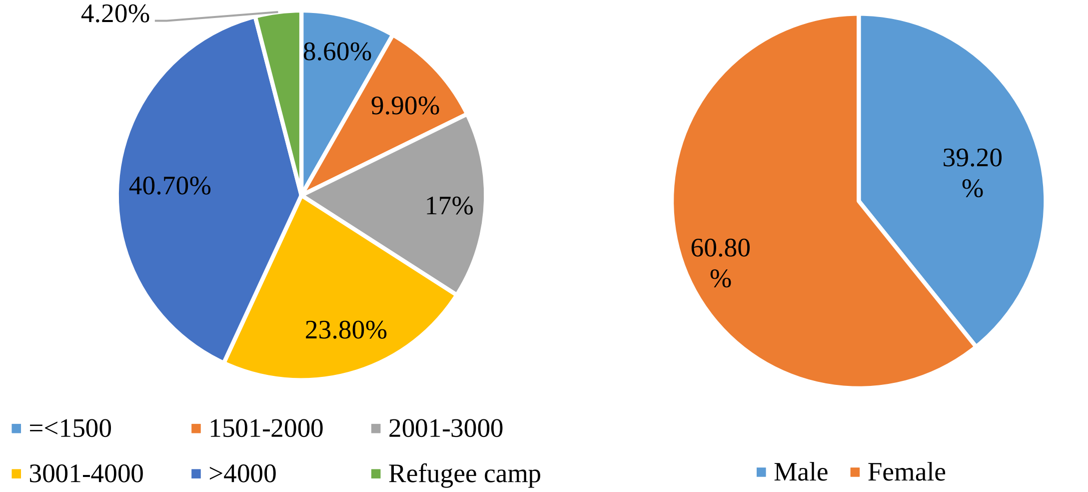
Range of fecal coliforms (cfu /100 l)	Level of risk (WHO, 2004)	Number of examined samples	Percentage of examined samples (%)
>1000	Very high risk	9	0.31%
101–1000	High risk	9	0.31%
11–100	Moderate risk	25	0.87%
1–10	Low risk	34	1.2%
0	No risk	2795	97.4%

Our findings showed that most of the physical and chemical parameters were within the allowable limits to PSI and WHO, except pH, nitrate, and ammonia. The microbiological analysis for samples showed that only a small fraction of the tested samples were contaminated with fecal coliforms and total coliforms, with a percentage of 2.69% and 5.38%, respectively. These results exceeded the WHO's (2004) and PSI's (2004) maximum permitted limits. According to the results, the quality of drinking water in Ramallah and Al-Bireh district is good and safe enough to be utilized for drinking water.

3.4 Residents' Viewpoints and Practices in Maintaining the Quality of Drinking Water.

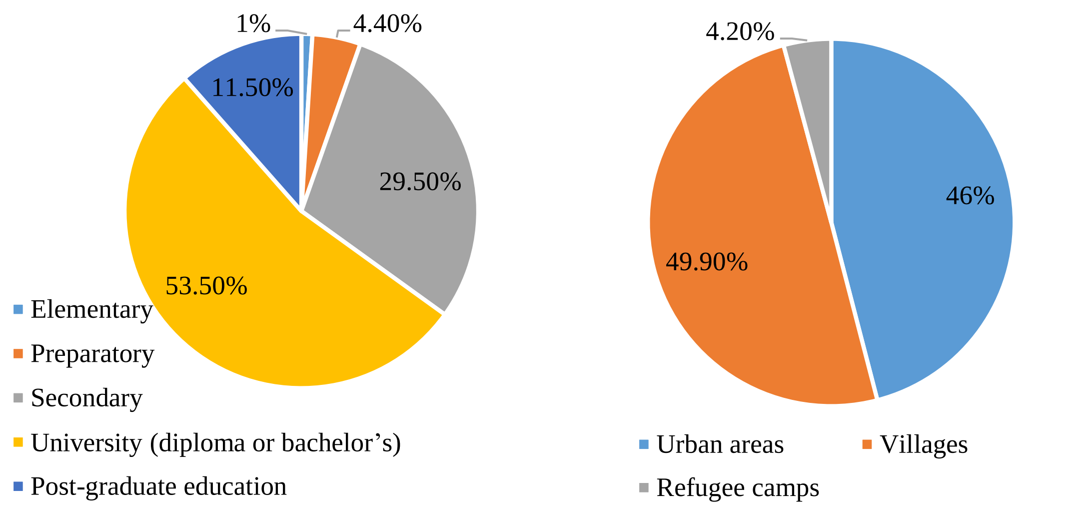
The study has been conducted on 383 residents in Ramallah and Al-Bireh district (see Chapter 3). The questionnaire was distributed to them (see Appendix 1). Figure 2 represents the distribution of the independent factors of the residents of the surveyed sample by numbers and percentages based on respondents' age, gender, level of education, number of family members, average household income is (NIS), and type of residence.





(c) (d)

Figure 2: Continued.



(e) (f)

Figure 2: Demographic comparison of survey respondents of Ramallah and Al-Bireh district (independent factors) (a) Age (b) Number of family members (c) Average household income (NIS/month) (d) Gender (e) Level of education (f) Type of residence.

The highest percentage of respondents (53.5%) in terms of the level of education was those who have a diploma or bachelor's degree. As for age, the highest percentage (37.1%) of respondents were in the age between 21 and 30 years old, while the lowest percentage (9.1%) was of respondents with an age of more than 50 years old.

As for gender, 60.8% of respondents were females and 39.2% were males. The highest percentage (37.1%) of respondents in terms of the number of family members were those who have more than six members in their family and the lowest percentage (9.1%) was of those who have between 1-2 members in their family.

In terms of average household income (NIS), those with an average household income of more than 4000 NIS had the highest percentage (40.7%), while those with an average household income equal to or less than 1500 NIS had the lowest percentage (8.6%). In terms of the type of residence, the percentages were according to the number of households in Ramallah and Al-Bireh district and according to sample size (see Chapter 3). 49.9% of respondents live in villages, which accounted the highest percentage, while respondents live refugee camps, which accounted the lowest percentage (4.2%).

Figure 3 shows the overall respondents' response to the basic source of water, the basic source of drinking water in their homes, and the amount of water that they consumed per month. As can be seen from this table, 89.6% of the respondents answered that the major source of water in their homes is from a public water network which is the highest percentage. 3.4 % of the respondents are depending on buying water from a water tank vehicle, and only 2.3% are depending on rainwater collection well.

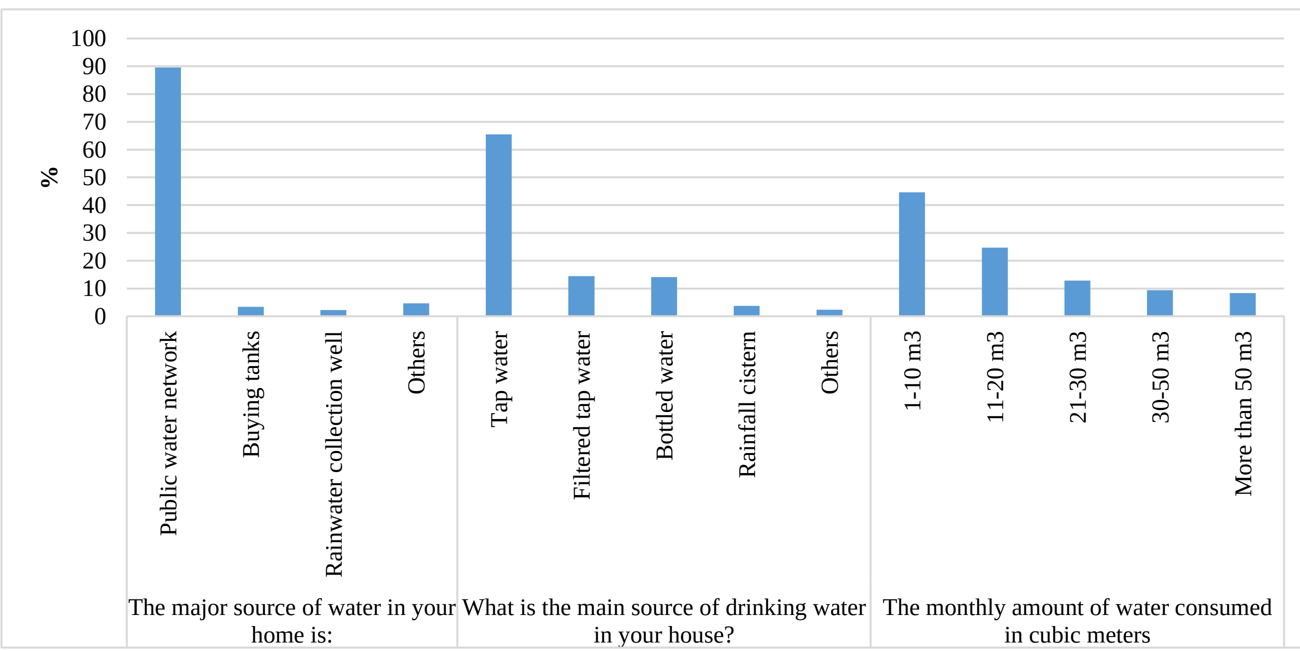


Figure 3: Respondents' responses to the basic water source, the basic source of drinking water in their houses, and the amount of water that they consumed per month (dependent factors).

The survey data showed that 65.5% of respondents drink tap water. This result shows a higher percentage compared to the result (41%) observed by Proulx et al. (2010). But Similar findings were obtained by Abdah et al. (2020), in which they conducted a study in West Bank, reported that 66.4% of the responses use in their homes Tap water as the major source of drinking water (Abdah et al., 2020). Additionally, 14.4% of the respondents are using a treatment device (mainly filters) to improve the quality of their tap water compared to 85% observed by Aini et al. (2007). According to his results, 85% of the Malaysian respondents were using household water filters because they believe the water delivered to their houses is of low quality.
The survey data also showed 14.1% of respondents drink bottled water. Our results contradict the results reported by Contu et al. (2005) in which he reported that despite the good quality of drinking water in Italy, 44.7% of the respondents distrust tap water and use bottled water instead.

Figure 3 indicates the amount of water that the respondents consumed per month, and according to respondents, the highest percentage of responses consumed 1-10 m^3 with a percentage of 44.6%, 24.7% of responses consumed 11-20 m^3, 12.9% of responses consumed 21-30 m^3, 9.4% of responses consumed 30-50 m^3, and only 8.4% of responses consumed more than 50 m^3 per month.

According to the findings of our study, the majority of respondents (44.6 %) consume 1-10 m^3 of water per month, which is the minimum consumption block for a family of six members, as reported by Arlene et al. (1999), who reported that the minimum consumption block for a family of six members is about 10 m^3per month (Arlene et al., 1999).

Figure 4 shows the overall respondents response to questions about risk perception and the degree of satisfaction, color, and taste. When respondents were questioned about if they were satisfied with their drinking water quality, 77.5% of responses were very satisfied and satisfied, and only 22.5% of responses were not satisfied with the quality of drinking water. Our results contradict the results reported by Aini et al., (2007) in which he reported almost all respondents rated water as low quality, at 1.81 of his scale “a scale of 1 (very poor) to 4 (very good)”, and most respondents are not satisfied with the quality of drinking water in which 70 % of them ranked the quality of the water provided to their home as poor and other ranked it as extremely poor (16 %).

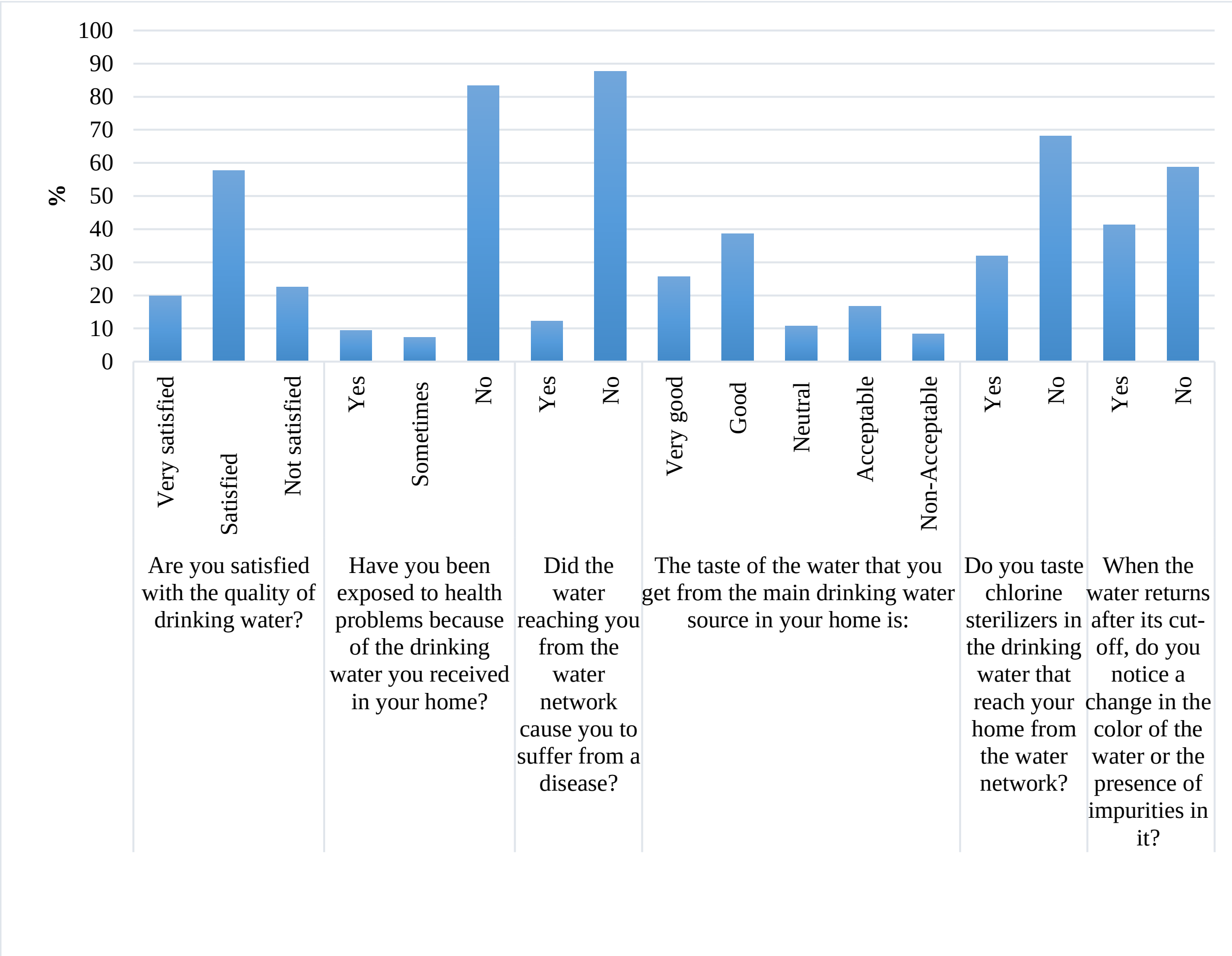


Figure 4: Respondents' response to the degree of satisfaction of water quality (dependent factors).

Respondents also were asked if they had been exposed to health problems because of the drinking water they received in their homes, the highest percentage of responses were "No" with a percentage of 83.3%, 9.4% of responses were "Yes", and only 7.3% of responses were "Sometimes" as shown in Figure 4. They were also questioned if they suffered from any disease caused by the water reached their homes from the water network, the majority of responses answered that they did not suffer from any disease with a percentage of 87.7%, while only 12.3% answered that they suffer from diseases caused by the water reached theirs from water network.

When respondents were questioned about the taste of water that they get from the main drinking water source in their homes, the highest percentage of responses were "Very good" and "Good" with a percentage of 64.2%, 10.7% were "Neutral", 16.7% were "Acceptable", and only 8.4% of responses were "Not-Acceptable". They were also asked if they taste chlorine sterilizers in the drinking water that reach their homes from the water network, the highest percentage of responses were "No" with a percentage of 68.1% in which they did not taste chlorine sterilizers in water, while only 31.9% of responses were "Yes".

Another question for them was about if they notice a change in the water color or the presence of impurities in water after it was cut off, the highest percentage of responses answer that they did not notice any change in the color or the presence of impurities in with a percentage of 58.7%, while 41.3% of questioned people answered that they notice a change in the color or the presence of impurities in it.

Respondents were questioned about if there is a tank for drinking water at their homes, 88.3% of respondents answered that they do have a tank for drinking water, whereas only 11.7% do not have a tank for drinking water (Table 9a). They were asked if they clean the drinking water tank, 20.5% of respondent’s answered that they do not clean their tanks, whereas 79.5% answered they clean their tanks. The latter group when asked about the periodicity for cleaning their drinking water tanks, the highest percentage of responses were that they clean it once yearly with a percentage of 47.3%, 18.5% clean it once every six months, 9.9% clean it once every two months, 21.2% do not clean it, and the rest clean it once every two years or more.

They were also asked if they think that the cleaning of drinking water storage tank is important for improving water quality, the majority of responses (77.2 %) were “Agree” and ‘Strongly agree” with a percentage of 49.9% and 37.3% respectively (Table 8).

Respondents were questioned about if they use a rainfed cistern as drinking water source, the majority of answers were “No” with a percentage of 79.9%, and only 20.1% drink from a rainfed cistern. Those respondents who use rainfed cistern were asked if they clean the rainfed cistern, the majority of answers were "No" with a percentage of 61.2%, and only 38.8% clean their rainfed cistern.

Table 9a: Respondents practices to improve the water quality for water that reaches their homes.

Question no.	Question (dependent groups)	Answer	Percentage of respondents (%)
7	Is there a tank for drinking water at your home?	Yes	338 (88.3%)
		No, if no, go to Question V17	45 (11.7%)
8	Do you clean the drinking water tank?	Yes	267 (79.5%)
		No	69 (20.5%)
9	What is the periodicity for cleaning the drinking water tank?	Once every two months	33 (9.9%)
		Once every 6 months	62 (18.5%)
		Once yearly	158 (47.3%)
		Not cleaned	71 (21.2%)
		Others	10 (3%)
10	Do you think that the cleaning of drinking water storage tank is important for improving water quality?	Strongly agree	143 (37.3%)
		Agree	191 (49.9%)
		Neutral	40 (10.4%)
		Not agree	8 (2.1%)
		Strongly do not agree	1 (0.3%)
12	Do you use a rainfed cistern as drinking water?	Yes	77 (20.1%)
		No	306 (79.9%)
13	Do you clean the rainfed cistern?	Yes	99 (38.8%)
		No	156(61.2%)

Table 9b shows other respondents' practices to improve the water quality for water that reaches their homes. In which respondents were asked if they use filters for tap water. The highest percentage of responses were "No" with a percentage of 80.1%, and only 19.9% of responses were "Yes" they do use filters for tap water in their homes. Those who answer "Yes" were asked about the interval of changing the internal tap water filter, more than half (58.1%) of questioned people answered that they changed the filter every 6 months, which is the highest percentage. 25.7% of questioned people change the filter every year, 10.8% change it every two years and only 5.4% do not change it.

Table 9b: Respondents practices to improve the water quality for water that reaches their homes.

Question no.	Question (dependent groups)	Answer	Percentage of respondents (%)
14	Do you use filters for tap water?	Yes	75 (19.9 %)
		No, If the answer is no; (Go to question No. V26	302 (80.1 %)
15	If Yes: You change the internal filter water every:	6 months	43 (58.1 %)
		Year	19 (25.7%)
		2 years	8 (10.8%)
		It is not changed	4 (5.4%)
16	The main reason for using the filter is:	To improve your health	50 (69.2%)
		You are not satisfied with the water quality that you were getting from the previous source	22 (30.5%)
		Because of the presence of children	1 (0.3%)
17	Did you use water from other sources before using the filter?	Yes	25 (33.8%)
		Sometimes	18 (24.3%)
		No	31 (41.9%)
18	If yes, you changed the previous sources because of:	Health problems	10 (26.3%)
		Aesthetic aspects	15 (39.5%)
		Poor quality	9 (23.7%)
		Because of the presence of children	2(5.3%)
		For purification of water as much as possible	1 (2.6%)
		It easier than buying bottled water	1(2.6%)
19	Did you feel better in your health and the health of your family after using the filter?	Yes	30 (44.8%)
		Sometimes	21 (31.3%)
		No	16 (23.9%)
20	If a filter is not used, then why?	Not needed as water quality is monitored by the water authority	55 (18.9%)
		Not needed as water is safe and good	78(26.8%)
		Not needed as I drink bottled water	49 (16.8%)
		Use spring water	9 (3.1%)
		Expensive	39 (13.4%)
		Inconvenient	22 (7.6%)
		A mix of the above	39 (13.4%)

For identifying the main reason for using the filter, respondents were asked about that, and 69.2% of questioned people answered that they use it to improve their health, 30.5% answered that they use it because they are not satisfied with the water quality that they get from the other previous source, and only 0.3% use it because of the presence of children. Our result contradicts the result reported by Aini et al. (2007) in which they reported that 60% of respondents were using filters because of water's poor quality.

Those respondents were questioned about if they use water from other sources before using the filter, the highest percentage of responses were "No" with a percentage of 41.9%, 24.3% answered "Sometimes", and the remaining 33.8% answered "Yes". Those respondents who answered "Yes" were asked about the main reason for changing the previous source, 39.5% answered because of aesthetic aspects, 26.3% answered because of health problems, 23.7% answered because of poor quality. They were also asked if they feel better in their health and the health of their families after using the filter, 44.8% of questioned people answered that their health was getting better, 23.9% answered that their health was not getting better when using it.

The remaining respondents were then questioned about the reason for not using filters. 220 respondents answered for a number of reasons. The main reasons given for not utilizing a water filter were "Not needed as water is safe and good" (26.8%) and it was "Not needed as water quality is monitored by the water authority" (16.8%). A minority of respondents answered that it was because it was "expensive" (13.4%), because they "Not needed as I drink bottled water" (6.3%), or because it was "Inconvenient" (7.6%). These reasons were also reported by Ochoo et al. (2017).

Respondents were questioned about if they have the water authority phone number to call when there is a water cutoff, breakage, pollution, or any other malfunction in the water pipeline network, the highest percentage of responses were "Yes" with a percentage of 62.4%, while only 37.6% of responses were "No". They were also asked about the interval in which water reaches their homes from the water network, the highest percentage of responses were "Daily" with a percentage of 34.0%, 33.5% of questioned people answered 'Once a week" with a percentage of 33.5%, and 27.2% of them answered to two days as shown in Table 10.

Table 10: The extent of respondents' commitment to the public interest in the field of water.

Question no.	Question (dependent groups)	Answer	Percentage of respondents (%)
21	Do you have the water authority phone number to call when there is a water cutoff, breakage, pollution, or any other malfunction in the water pipeline network?	Yes	239 (62.4%)
		No	144 (37.6%)
22	The water that reaches your home from the water network reaches every:	Daily	130 (34.0%)
		2 days	104 (27.2%)
		Once a week	128 (33.5%)
		Every 10 days	3 (0.8%)
		Every 3 days	5 (1.3%)
		I don't use water from the municipal water network	3 (0.8%)
		I don't know	4 (1.0%)
		Once every two weeks	2 (0.5%)
		Every 4 days	3 (0.8%)
24	Do you pay your water bill monthly for the water authority?	Yes	332 (86.7%)
		No	51 (13.3%)
25	If not, is it due to:	Your inability to pay the bill	38 (79.2%)
		Your dissatisfaction with the services provided by the water authority	8 (16.7%)
		The water quality is poor	1 (2.1%)
		My house is far away from the payment place	1 (2.1%)

About 86.7% of respondents pay their water bills monthly for their service water provider, while only 13.3% of the respondents do not pay their bills. Those respondents who do not pay their water bills were asked about the main reason for not paying water bills, the majority answered (79.2%) because of the inability to pay the bills, 16.7% answered because of dissatisfaction with the services provided by the service water provider, 2.1% answered because of water quality is poor, and 2.1% answered because their homes are far

away from the payment place. These results indicate that respondents have a commitment to the public interest in the field of water.

3.4.1 Effect of Independent Factors on the Respondents' Response

SPSS was used to apply a cross-tabulation. The aim of cross-tabulation is to figure out which of the dependent factors are associated with the independent factors within a 95 % confidence interval. The dependent factors listed below were determined to be significant to a certain independent factor with a p-value <0.05. Because the variables are not independent of one another, there is a statistical correlation between them. Each dependent factor was explained according to the independent factors in the following paragraphs.

Effect of Type of Locality

The ANOVA test (the analysis of variance) -a statistical method for determining if the means of two or more groups vary significantly- revealed that only 4 of the 23 dependent factors in Figure 2 were determined to be significant to the independent factor "Type of locality" with a p-value less than 0.05, as shown in Figure 5. A cross-tabulation testing was used to examine the effect of the type of locality on the dependent components of the inhabitants' response to cleaning the rainfed cistern., the periodicity of changing the internal filter water, paying the water bill monthly for the water authority, and their water consumption, and the p-values for them were equals to 0.004, 0.018 and 0.007, respectively (see Figure 5).

Figure 5 illustrates how residents' responses vary according to the independent factor "Type of locality." The following were determined to be relevant dependent variables: "cleaning the rainfed cistern" and "the periodicity of change the internal filter water", "paying the water bill monthly for the water authority" and "Water consumption".

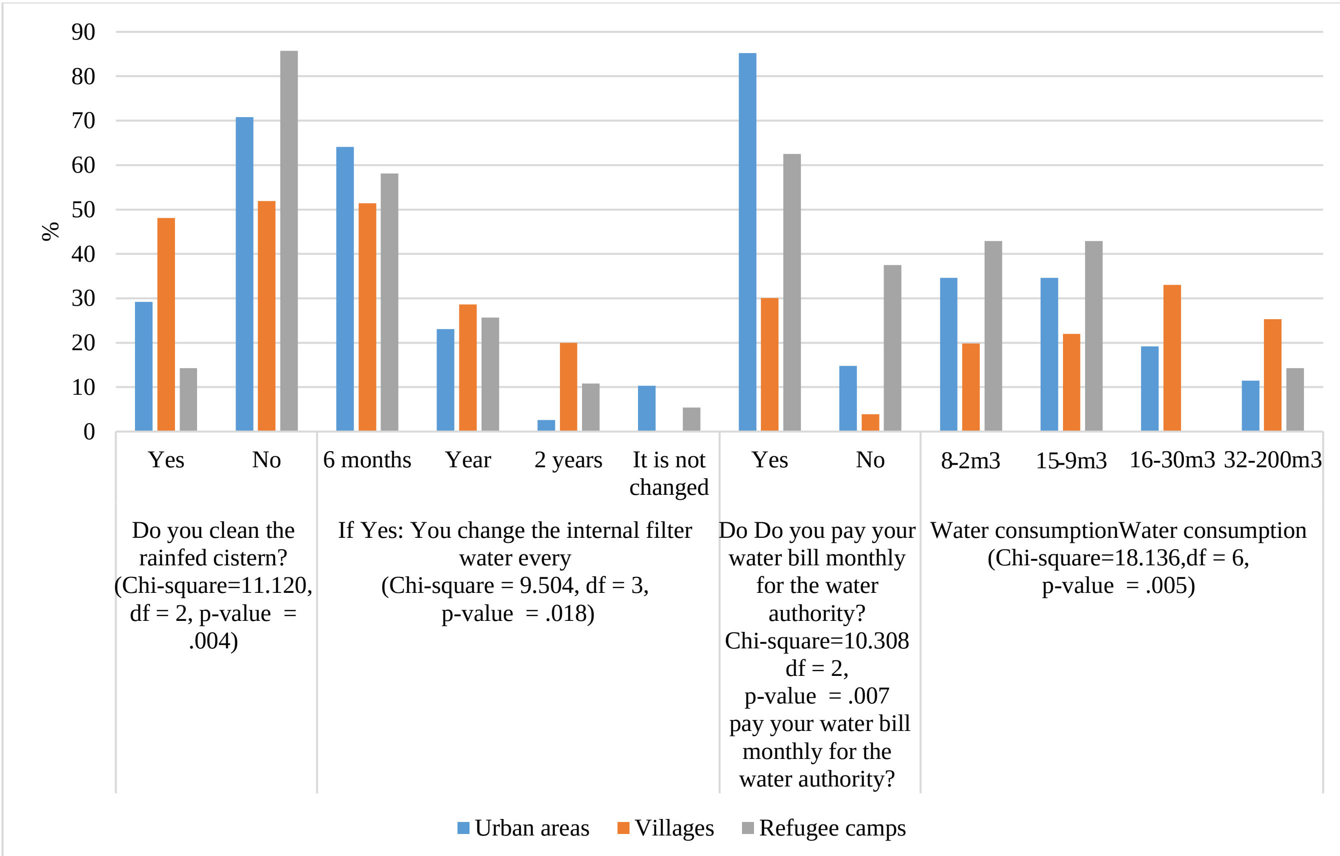


Figure 5: Respondents' responses depending on the type of location.

The respondents who clean the rainfed cistern were mostly from villages and the least were from the refugee camps. When respondents were asked about the periodicity of change the internal filter for tap water, 64.1% of respondents in the urban areas were changed the filter every 6 months and this is the highest percentage among the other types of localities, both villages and refugee camps were had almost a close results, 51.4%, and 58.1%, respectively. As for the second answer "changing the filter every year", the responses for the three localities had almost close results, in which the percentages were 23.1%, 28.6%, and 25.7%, in the urban areas, the village, and the refugee camp, respectively.

There were obvious and huge differences in the citizen's responses about the two remaining answers "every 2 years" and "not changing the filters", according to the type of their locality. In which the lowest percentage for respondents who change their filters every two years was in the urban areas with a percentage of 2.6%, but the highest percentage was in the village, in which the respondents were changing their filters every two years with a percentage of 20.0%. While in the refugee camp almost half of the previous percentage of the respondents changes their filters every two years (10.8%).

The last answer "not changing the filters" was the highest percentage for respondents who live in the urban areas with a percentage of 10.3% while in refugee camp almost half of the previous percentage of the respondents that do not change their filters (5.4%). In the village all the respondents were changing their filters and the percentage of respondents who do not change the filters was 0%.

As for the amount of water consumption, there were obvious differences in respondent's answers according to the type of their locality. When looking at respondents who live in the urban areas, the highest percentage consumes 2-8m^3 and 9-15 m^3 per month with an equal percentage (34.6%) for each amount of water consumption. The same amount of water consumption was for respondents who live in refugee camps, in which they also consume 2-8 m^3 and 9-15 m^3 per month with the highest percentage of 42.9% for each of which.

As for respondents who live in villages, the amount of water consumption increased; with monthly consumption ranging from 16 to 30 m^3 as the highest percentage of 33.0%, results also show that they also consume 32-200 m^3 with a second-highest percentage of 25.3%.

Effect of Gender

As indicated in Figure 6, the ANOVA test revealed that only 2 of the 23 dependent factors in Figure 2 were significant to the independent factor "gender," with a p-value of less than 0.05. The correlation between the independent factor "gender" and the dependent factors "the degree of satisfaction with the quality of drinking water" and "the periodicity for cleaning the drinking water tank" were evaluated using cross-tabulation, yielding p-values of 0.039 and 0.010, respectively (see Figure 6).

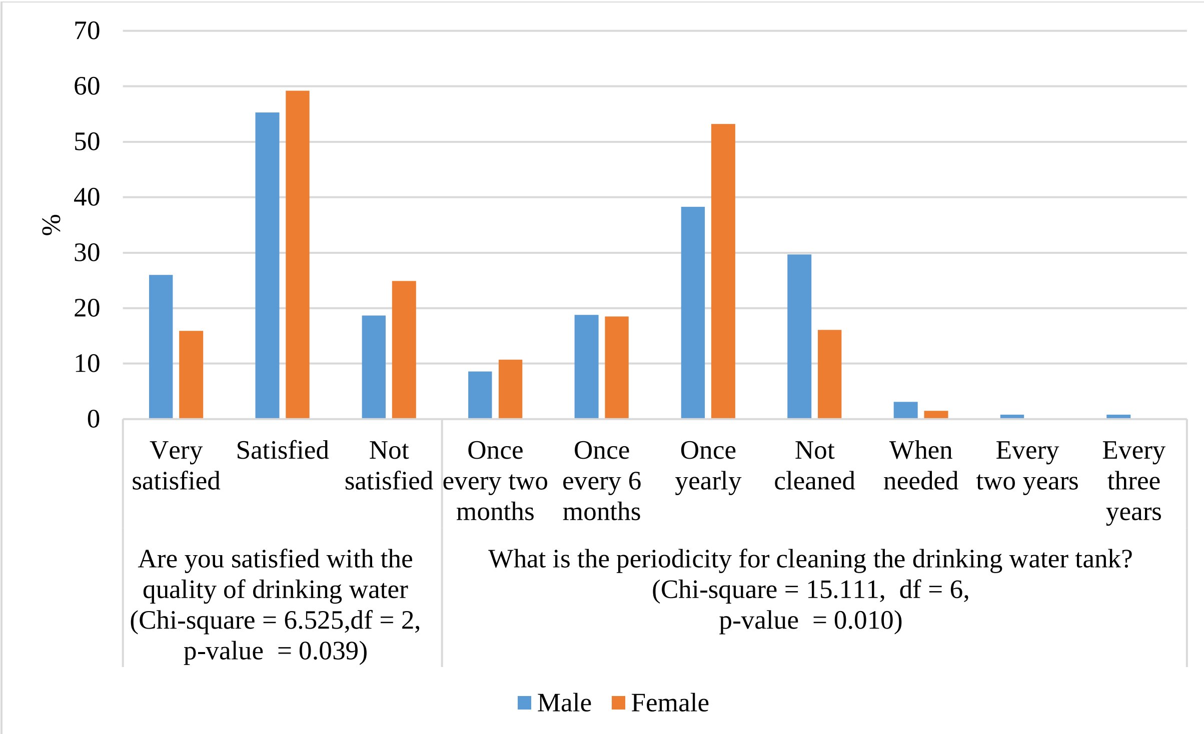


Figure 6: Respondents' responses depending on gender.

As for variation in respondents responses based on gender, there were obvious differences in the citizen's responses about the satisfaction of drinking water quality according to the gender, in which 26.0% of males were very satisfied, while responses of females were almost the half of the previous percentage (15.9%). As for the second answer “Satisfied”, both males and females had almost the same percentage (59.2% and 55.3%). The third answer shows that more females than males were "Not satisfied" with their water quality, 24.9% vs 18.7%. Ochoo et al. (2017) reported similar findings.

As for the periodicity for cleaning the drinking water tank, there was a difference in males and females answers, in which 53.2% of females answered that they clean water tanks one time per year, whereas 38.3% of males clean them yearly. There was another difference in the answer “Not cleaned”, in which 16.1% of females answer that they do not clean water tanks, whereas 29.7% of males do not clean them. These results might indicate that women are more aware of risks and are more concerned than men. de França Doria (2010) reported the same result for tap water quality.

Effect of Level of Education

Only one of the 23 dependent factors in Figure 2 was found to be significant to the independent factor "level of education" with a p-value of less than 0.05. The independent factor of "level of education" and the dependent factor of "the presence of a tank for drinking water at residents' homes" were found to be related, with a p-value of 0.026 (See Table 11).

Table 11: Respondents' responses depending on level of education.

Question	Answer	Percentage of respondents (%)				
		Elementary	Preparatory	Secondary	University (diploma or bachelors)	Postgraduate studies
Is there a tank for drinking water at your home? Chi-square =11.320 df =4, p-value=0.026	<u>Yes</u>	100%	100%	94.7%	84.9%	81.8%
	No	0%	0%	5.3%	15.1%	18.2%

As for the level of education, respondents who had an elementary and preparatory level of education were all had a tank for drinking water in their homes. 18.2% of people who had Postgraduate studies and 15.1% of people who had a university degree (diploma or bachelor) were had no tank for drinking water at their homes.

This result may be because those educated people care more about drinking water quality in their homes, as a result, they turned to use bottled water as a source of drinking water while the less educated people care less about water quality in their homes or they know a little information about water quality, or they believe that water reaches them is with good quality.

Effect of Number of Family

Figure 7 indicated that the ANOVA test revealed that only 4 out of 23 dependent factors in Figure 2 were significant to the independent factor "number of family members" where p-value < 0.05. The independent factor “number of family members” and the dependent factors “Using as rainfed cistern a drinking water source”, “cleaning the rainfed cistern”, "Noticing a change in the color of the water or presence of impurities in it when the water returns", "Paying the water bill monthly for the water authority" and Water consumption" were found to be related, with a p-values equals to 0.004, 0.037, 0.033, and 0.000, respectively, (see Figure 7).

Figure 7 indicates that there were obvious differences in the respondent's responses, between families that have more than six members, and families that have less than six members, when they asked if they use a rainfed cistern as drinking water. It is clear from Figure 7 that as the number of family members increases, the percentage of using a rainfed cistern as a drinking water source increases. This may indicate that as the family member's number increases, they need more water, so they need another source of drinking water.

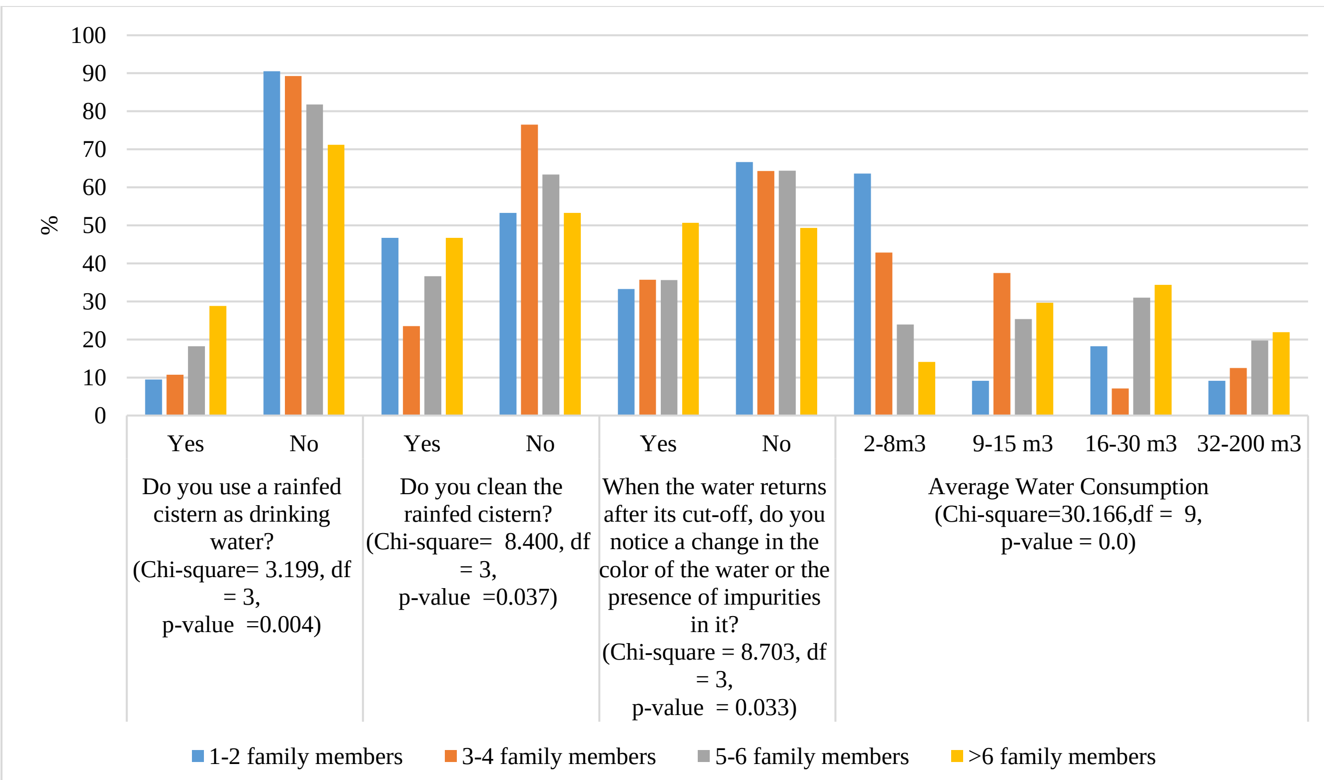


Figure 7: Respondents' responses depending on the number of family members.

More than half of families' responses from the different four categories were answered that they do not clean their rainfed cistern, and the high percentage was for families that have 3-4 members with a percentage of 76.5%, which is almost close to the percentage of families that have 5-6 members (63.4%). Both families that have 1-2 members and have >6 members had the same percentage (53.3%).

As for Noticing a change in the color of the water or the presence of impurities in it when the water returns, the answer from the different categories of families were "No" and were almost with the same percentage except the family that has more than 6 members, in which they answered that they do notice changing in the color of the water or presence of impurities in it when the water returns with a percentage of 50.7%.

As for the amount of water consumption, there were obvious differences in the respondent's responses, between families that have more than 6 members, and families that have less than six members. It is clear from Figure 7 that as the number of family members increases, the amount of water consumption increases, in which they consume 16-30 m3 per month. Families that have 5-6 members also consume the same amount with a percentage of 31.0%.

When looking at families that have 1-2 members, the highest percentage (63.6%) consume 2-8 m^3 per month, as well as families that have 3-4 members with a percentage of 42.9% they consume 2-8 m^3 per month with a percentage of 63.6%. These findings suggest that as the family members number increases, their consumption of water increases.

Effect of Average Household Income

Only 4 out of 23 dependent factors in Figure 2 were determined to be significant to the independent factor "average household income" where p-value < 0.05 as indicated in Figure 8. A cross-tabulation testing was used to examine the effect of “average household income” on the dependent components of the respondents' responses “the presence of a tank for drinking Water at respondents’ homes”, “cleaning of drinking water storage tank is important for improving water”, “using filters for tap water” and “having the water authority phone number to call when there is a water cutoff, breakage, pollution, or any other malfunction in the water pipeline network” and the p-values for them were equals to 0.025, 0.029, 0.031, and 0.000, respectively (see Figure 8).

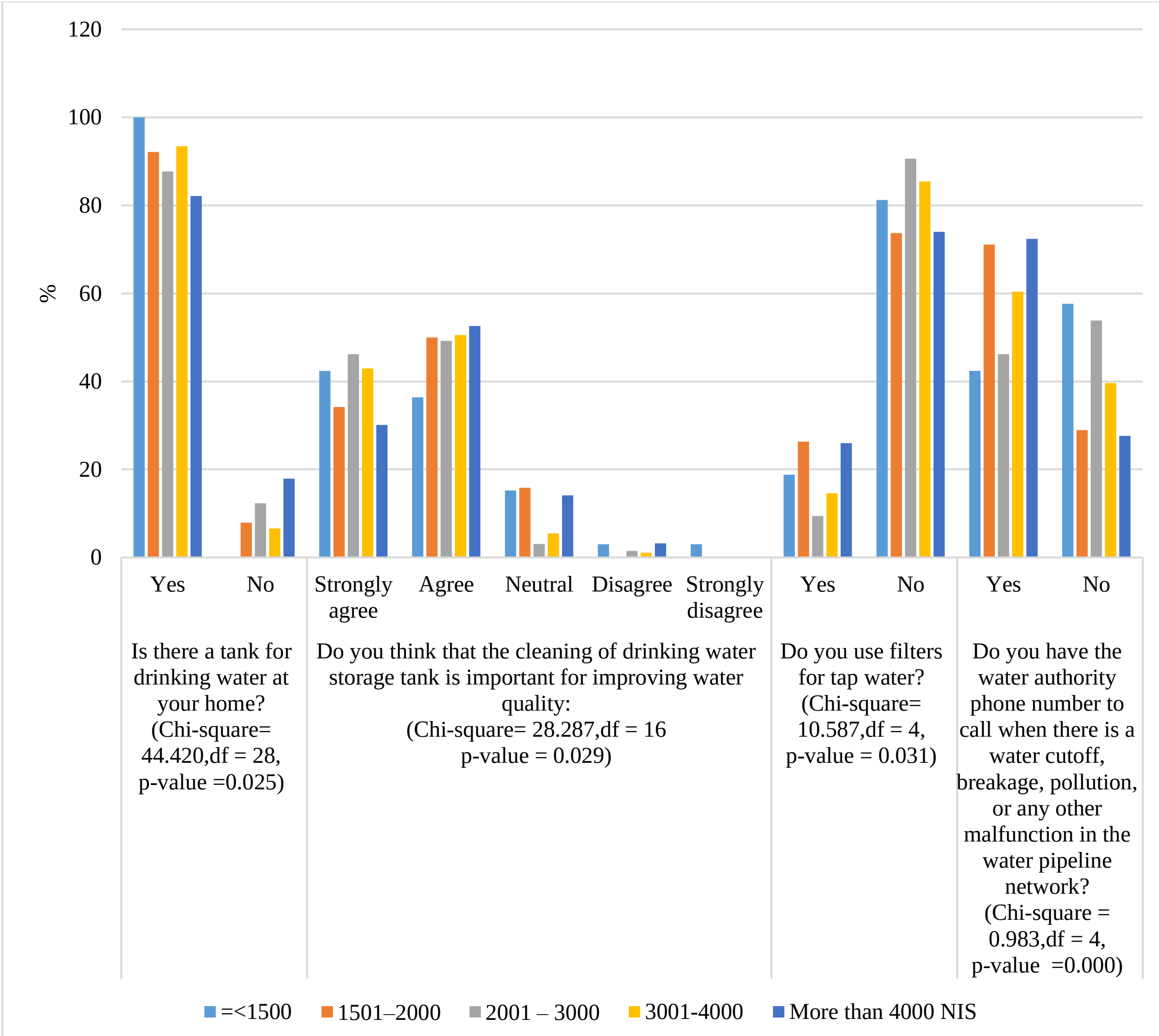


Figure 8: Respondents' responses depending on average household income (NIS).

As for variation in respondents responses based on average household income, there were obvious differences in the citizen's responses when asking if they had a tank for drinking Water at respondents' homes, in which 100.0% of families that had the lowest average household income (=<1500) answered that they do have a tank in their homes, and it is the highest percentage. The lowest percentage was for families that had the highest average household income (more than 4000) with a percentage of 82.1%. These respondents that these results may indicate that the families that had the highest average household income may rely on other water resources.

When asking about if cleaning of drinking water storage tank is important for improving water, there were no obvious huge differences in the citizen's responses, between families that had different household income, in which the highest percentage in each category was for the answer "Agree" except the families with the lowest average household income; their answer was "Strongly agree".

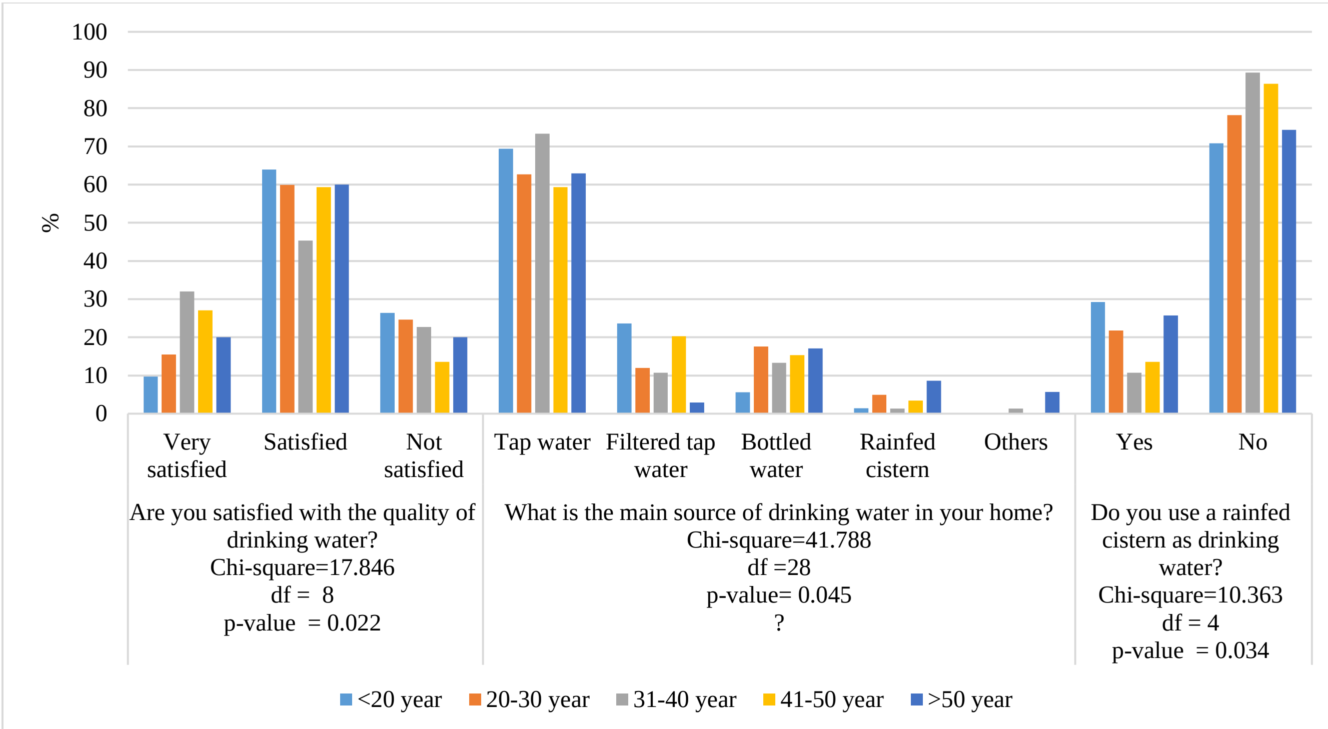
As for using filters for tap water, there was a difference among the different categories, and the highest percentage (26.3%) was for those who had a household income (1501 – 2000), which was approximately the same for those who had a household income of more than 4000 NIS. respondents who had a household income range from 2001 to 3000 had the lowest percentage (9.4%). These results indicate that there is no relation between household income and using a filter for tap water in homes.

When asking if they have the water authority phone number to call when there is a water cutoff, breakage, pollution, or any other malfunction in the water pipeline network, there was a difference among the different categories, and the highest percentage (72.4%) was for those who had a household income More than 4000 NIS, which was approximately the same for those who had a household income (1501 – 2000 NIS). The lowest percentage (42.4%) was for those who had a household income (=<1500).

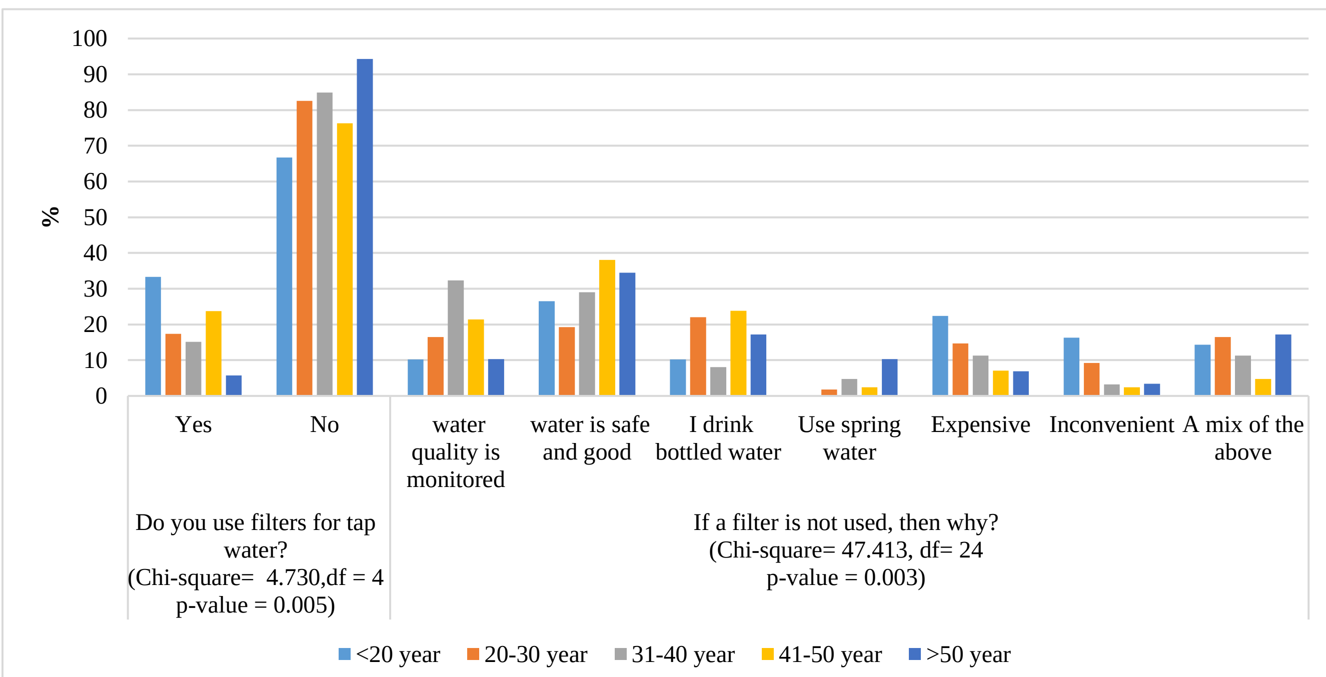
Effect of Age

Only 5 of the 23 dependent factors in Figure 2 were found to be significant to the independent factor “Age" with a p-value of less than 0.05, as demonstrated in Figure 10 (a, b). The independent factor of "Age" and the dependent factors of the response of the respondents’ satisfaction with the quality of their drinking water, the basic source of drinking water in respondents’ homes, using a rainfed cistern as drinking water, using filters for tap water and the reason for using filters. The p-values for them were equals to 0.022, 0.045, 0.034, 0.005 and 0.003, respectively (see Figure 9 (a and b)).

Respondents’ response based on the independent factor “Age” are shown in Figure 9 (a and b). The relevant dependent factors were determined to be the following: “the degree of satisfaction with the quality of drinking water” and “the main source of drinking water in respondents’ homes”, ‘using a rainfed cistern as drinking water”, “using filters for tap water” and “the reason for not using filters”.



(a)



(b)

Figure 9 (a & b): Respondents' responses depending on Age. (a) the dependent factors “the degree of satisfaction with the quality of drinking water” and “the main source of drinking water in respondents’ homes”, ‘using a rainfed cistern as drinking water”, (b) the dependent factors “using filters for tap water” and “the reason for not using filters”.

As for variation in respondent's answers based on age, respondents with age 41-50 years tend to be "Very satisfied and satisfied" with their drinking water quality with the highest percentage among others (86.4%) for both answers" Very satisfied and satisfied", the second highest percentage was for respondents older than 50 years with a percentage of 80 %. Similar results were reported by Ochoo et al. (2017). This percentage becomes lower for respondents under the age of 41, which indicates that younger respondents tend to be dissatisfied with their drinking water quality, as reported by MORI (2002).

The respondents were questioned about their main source of drinking water; "tap water" received the highest percentage in each category, with approximately close percentages ranging from 59.3 % to 73.3 %.

Across all categories, more than 70% of respondents answered that they do not clean their rainfed cistern. The high percentage (89.3%) was for respondents between the ages of 31 and 40 while the lowest percentage was for respondents with age less than 20 with a percentage of 70.8%.

As for using filters for tap water, more than 66% of citizen's responses across all categories answered that they do not use filters for tap water in their homes. The highest percentage (94.3%) was for respondents with age more than 50, and the lowest percentage (66.7%) was for respondents with age less than 20. These results suggest that as respondents get older, they become less likely to use filters in their homes.

Those respondents were also asked about the reason for not using filters in their homes, the answer "Not needed as water is safe and good" received the highest percentage in each category with approximately close percentages ranging from 26.5% to 38.1%, except respondents between the ages of 20 and 30 in which they answered, "Not needed as I drink bottled water" with a percentage of 22.0%. These results indicate that respondents of different ages think that the water that they received is safe and good, except for respondents between the ages of 20 and 30.

Chapter Four: Conclusions and Recommendations

4.1 Conclusions

Our study was performed to evaluate drinking water quality in Ramallah and Al-Bireh district, in which several physical and chemical and microbiological parameters for the water samples were examined following the standard analytical methods then compared to PSI (2004) and WHO (2004) standards. The results showed that most of the physical and chemical parameters were within the allowable limits to PSI and WHO, except pH, nitrate, and ammonia. The microbiological analysis for samples showed that only a small fraction of the tested samples were contaminated with fecal coliforms and total coliforms, with a percentage of 2.69% and 5.38%, respectively. These results exceeded the WHO's (2004) and PSI's (2004) maximum permitted limits.

Our study also aimed to examine the residents' practices in Ramallah and Al-Bireh district to maintain water quality, and their viewpoint on drinking water quality supplied to them from water networks. The results indicate the majority of the respondents (>77%) were very satisfied and satisfied with drinking water quality. Moreover, 83.3% of them had not been exposed to health problems because of drinking water. The respondents (87.7%) did not suffer from any water-borne disease caused by the water that reached their homes from the water network. These results are consistent with results about drinking water quality in the district, in which the results indicate that there was a correlation between public contentment and the district's real water quality.

The results also indicate that tap water, filtered tap water, bottled water, and a rainfall cistern and a close-local spring were the sources of drinking water in respondents’ houses in the district, with a percentage of 65.5%, 14.4%, 14.1%, and 3.7% respectively.

Approximately 28.5% of respondents utilized in-home treatment equipment (filters) and bottled water within their homes, mostly to improve their health, and because they were not satisfied with the water quality obtained from the previous source.

The residents' practices to maintain water quality were represented as cleaning the drinking water tank, in which 79.5% of respondents do clean their tanks, and 75.7% of them clean their drinking water tanks once each year or even more.

4.2 Recommendations

According to our results, the quality of drinking water in Ramallah and Al-Bireh district is good and safe enough to be utilized for drinking water. Even though, our recommendation to keep a continuous monitoring manner to provide a high drinking water quality that ensures the safety and healthy living for all residents. Moreover, more other tests are recommended to identify the existence of other Enterobacteriaceae species, and more specific kinds of pathogenic bacteria in the district, like *Salmonella*, *Shigella*, and others. Further studies are recommended to be addressed other parameters for drinking water quality such as trace organic components and heavy metals.

The results of the study showed that 22.5% of residents were not satisfied with the quality of drinking water reaching them. Our recommendation to this group to review the water quality reports in the Ramallah and Al-Bireh district to see that the drinking water is safe, valid, and of high quality.

The results also revealed that 20.5% of the residents do not clean their drinking water tanks, which leads to a decrease in drinking water quality. Our recommendation to this group to clean their drinking water tanks regularly, which positively affects the quality of the drinking water, they drink.

The results showed that 19.9% of residents use filters to improve their health. But, 41.9% of them change their filters every year or more and this leads to a decrease in the drinking water quality. As so, the incorrect use and not periodically changing the filter reduce the quality of drinking water. Our recommendation to this group that the drinking water delivered to them at their homes is safe and healthy without using the filter, and if they want to use filters, they should regularly change the filter to avoid health problems caused by it.

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Appendix I: The Questionnaire (final version in Arabic)

بســــــــم اللــــــــه الرحمــــــــن الرحيــــــــــم

أخي الكريم/ أختي الكريمة:
تقوم الباحثة بإعداد دراسة تحت إشراف الأستاذ الدكتور عصام الخطيب بعنوان

"تقييم جودة مياه الشرب في محافظة رام الله والبيرة: القياسات مقابل وجهات نظر السكان وممارساتهم"

حيث تقوم الباحثة بتعبئة الاستمارة التالية من قبل سكان محافظة رام الله وذلك استكمالاً لمتطلبات الحصول على درجه الماجستير في علوم المياه والبيئة /جامعة بيرزيت، يرجى الإجابة على فقرات هذه الاستمارة من أجل تحقيق أهداف هذه الدراسة، مع العلم أن البيانات تجمع لأغراض البحث العلمي فقط وتعامل بسرية تامة.

شاكرين مساعدتكم وحسن تعاونكم

الباحثة : آلاء بزار
جامعة بيرزيت

V1	نوع التجمع السكاني: 1. مدينة 2. قرية 3. مخيم
V2	اسم التجمع السكاني:
V3	النوع الاجتماعي: 1. ذكر 2. أُنثى
V4	العمر: 1. أقل من 20 2. 20 إلى 30 3. من 31 إلى 40 4. 41 إلى 50 5. أكثر من 50 سنة
V5	مستوى التعليم: 1. ابتدائي 2. إعدادي 3. ثانوي 4. دبلوم أو جامعة 5. دراسات عليا
V6	عدد أفراد الاسرة: 1. 1−2 2. 3−4 3. 5−6 4. أكثر من 6
V7	معدل دخل لإاسرة (شيكل): 1. أقل أو يساوي 1500 شيكل 2. 1501 − 2000 شيكل 3. 2001 − 3000 شيكل 4. 3001 − 4000 شيكل 5. أكثر من 4000 شيكل

V8	المصدر الرئيسي للحصول على المياه: 1. شبكة مياه عامة 2. شراء تنكات 3. بئر جمع مياه الأمطار 4. غير ذلك حدد........................
V9	المعدل الشهري لكمية المياه المستهلكة بالمتر المكعب ....
V10	هل أنت راضٍ عن جودة مياه الشرب لديكم؟ 1. راضٍ جدًا 2. راضٍ 3. غير راضٍ
V11	هل تعرضت لمشاكل صحية بسبب المياه الواصل إليك من مصدر مياه الشرب الرئيسي في منزلك؟ 1. نعم 2. أحياناً 3. لا
V12	طعم المياه الواصل إليك من مصدر مياه الشرب الرئيسي في منزلك: 1. جيد جداً 2. جيد 3. لا أدري 4. مقبول 5. غير مقبول
V13	ما هو مصدر مياه الشرب الرئيسي في منزلك: 1. ماء الصنبور 2. مياه الصنبور المفلترة 3. المياه المعبأة 4. صهريج بعلي: ينبوع محلي مغلق 5. غير ذلك، حدد ذلك المصدر..
V14	هل يوجد خزان مياه خاص بالمنزل؟ 1. نعم 2. لا، إذا كانت الإجابة لا ؛ (انتقل إلى سؤال رقم V20)
V15	هل تقوم بتنظيف خزان مياه الشرب؟ 1. نعم

2. لا	
ما هي معدل تنظيف خزّان مياه الشرب ؟ 1. مرة كل شهرين 2. مرة كل ستة أشهر 3. مرة كل سنة 4. غير ذلك حدد،	V16
هل تعتقد أن تنظيف خزّان مياه الشرب مهم لتحسين جودة المياه؟ 1. موافق بشدة 2. موافق 3. لا ادري 4. لا أوافق 5. لا أوافق بشدة	V17
هل تستخدم بئر تجميع مياه الأمطار كمياه للشرب؟ 1. نعم 2. لا	V18
هل تقوم بتنظيف بئر تجميع مياه الأمطار؟ 1. نعم 2. لا	V19
هل تستخدم مرشحات (فلاتر) لمياه الصنبور؟ 1. نعم 2. لا	V20
إذا كانت الإجابة بنعم، تقوم بتغيير فلتر مياه الصنبور كل: 1. ستة أشهر 2. سنة 3. سنتين 4. غير ذلك،	V21
السبب الرئيسي لاستخدام الفلتر هو: 1. لتحسين صحتك 2. لم تكن راضيًا عن جودة المياه التي كنت تحصل عليها من المصدر السابق 3. لأسباب أخرى غير ذلك، حدد	V22

هل استخدمت مياه من مصادر أخرى قبل استخدام الفلتر؟ 1. نعم 2. أحياناً 3. لا	V23
إذا كانت الإجابة بنعم، فلماذا قمت بتغيير مصدر المياه السابق؟ 1. تعرضك لمشاكل صحية 2. عدم رضاك عن الجوانب الجمالية مثل: لون وطعم ورائحة المياه 3. جودة المياه رديئة	V24
هل شعرت بتحسن في صحتك وصحة عائلتك بعد استخدام الفلتر؟ 1. نعم 2. أحياناً 3. لا	V25
إذا لم تستخدم الفلتر، فلماذا؟ 1. ليست هناك حاجة لأنه يتم مراقبة جودة المياه من قبل سلطة المياه 2. لا حاجة لأن المياه آمنة وجيدة 3. لا حاجة لأنني أشرب المياه المعبأة في قوارير 4. استخدم مياه الينابيع 5. باهظة الثمن 6. غير مريح	V26
هل لديك رقم هاتف مصلحة المياه للاتصال به عند حدوث انقطاع، كسر، تلوث، أو أي عطل آخر في شبكة أنابيب المياه؟ 1. نعم 2. لا	V27
المياه الواصلة لبيتك من قبل شبكة المياه تصل كل: 1. يومياً 2. يومين 3. مرة في الأسبوع 4. غير ذلك حدد،....................	V28
بعد رجوع المياه بعد انقطاعها، هل تلاحظ تغير في لون المياه أو ووجود شوائب فيها؟ 1. نعم	V29

	2. لا
V30	هل تقوم شهرياً بتسديد فاتورة المياه الخاصة بك لمصلحة المياه؟ 1. نعم 2. لا
V31	إذا كان لا، هل سبب ذلك يعود إلى: 1. عدم مقدرتك على دفع الفاتورة 2. عدم رضاك عن الخدمات التي تقدمها مصلحة المياه 3. جودة المياه رديئة
V32	هل تتذوق طعم معقمات الكلور عند شرب المياه الواصلة إليك من شبكة المياه؟ 1. نعم 2. لا
V33	هل تسببت المياه الواصلة إليك من شبكة المياه بإصابتك بأحد الأمراض؟ 1. نعم 2. لا

Appendix II: The Questionnaire (final version in English)

Type of locality: 1. urban areas 2. Village 3. Camp	V1
The name of the locality is: …………………	V2
Gender: 1. Male 2. Female	V3
Age: 1. Less than 20 2. From 20 to 30 3. From 30 to 40 4. From 40 to 50 5. From 50 years or more	V4
Education level: 1. Elementary 2. Preparatory 3. Secondary 4. University (diploma or bachelor's) 5. Postgraduate studies	V5
Number of family members: 1. 1-2 2. 3-4 3. 5-6 4. More than 6	V6
The average household income is (NIS): 1. Less or equal to 1500 NIS 2. 1501 – 2000 NIS 3. 2001 – 3000 NIS 4. 3001 – 4000 NIS 5. More than 4000 NIS	V7
The main source of water in your home is: 1. A public water network 2. Buying tanks (buying water from a water tank car) 3. A rainwater collection well 4. Others	V8
The average monthly amount of water consumed in cubic meters is: …..	V9
Are you satisfied with the quality of drinking water? 1. Very satisfied	V10

2. Satisfied 3. Not satisfied	
Have you been exposed to health problems because of the drinking water you received in your home? 1. Yes 2. Sometimes 3. No	V11
The taste of the water that you get from the main drinking water source in your home is: 1. Very good 2. Good 3. Neutral 4. Acceptable 5. Non Acceptable	V12
What is the main source of drinking water in your home? 1. Tap water 2. Filtered tap water 3. Bottled water (mineral water) 4. Rainfall cistern: a closed local spring 5. Others	V13
Is there a tank for drinking Water at your home? 1. Yes 2. No, if no, go to Question V17	V14
Do you clean the drinking water tank? 1. Yes 2. No	V15
What is the periodicity for cleaning the drinking water tank? 1. Once every two months 2. Once every 6 months 3. Once yearly 4. Not cleaned 5. When needed 6. Others	V16
Do you think that the cleaning of drinking water storage tank is important for improving water quality: 1. Agree 2. Strongly agree 3. Neutral 4. Not agree 5. Strongly do not agree	V17
Do you use a rainfed cistern as drinking water? 1. Yes 2. No	V18

Do you clean the rainfed cistern? 1. Yes 2. No	V19
Do you use filters for tap water? 1. Yes 2. No, If the answer is no; (Go to question No. V26)	V20
If Yes: You change the internal filter water every: 1- 6 months 2- Year 3- 2 years 4- It is not changed	
The main reason for using the filter is: 1. To improve your health 2. You are not satisfied with the water quality that you were getting from the previous source 3. Because of the presence of children	V22
Did you use water from other sources before using the filter: 1. Yes 2. Sometimes 3. No	V23
If yes, you changed the previous sources because of: 1. Health problems 2. Aesthetic aspects 3. Poor quality 4. Because of the presence of children 5. For purification of water as much as possible 6. It easier than buying bottled in water	V24
Did you feel better in your health and the health of your family after using the filter? 1. Yes 2. Sometimes 3. No	V25
If a filter is not used, then why? 1. Not needed as water quality is monitored by the water authority 2. Not needed as water is safe and good 3. Not needed as I drink bottled water 4. Use spring water 5. Expensive 6. Inconvenient 7. Mix of the above	V26
Do you have the water authority phone number to call when there is a water cutoff, breakage, pollution, or any other malfunction in the water pipeline network? 1. Yes 2. No	V27

The water that reaches your home from the water network reaches every: daily 1. 2 days 2. Once a week 3. Every 10 days 4. Every 3 days 5. I don't use water from the municipal water network 6. I don't know 7. Once every two weeks 8. Every 4 days	V28
When the water returns after its cut off, do you notice a change in the color of the water or the presence of impurities in it? 1. Yes 2. No	V29
Do you pay your water bill monthly for the water authority? 1. Yes 2. No	V30
If not, is it due to: 1. Your inability to pay the bill 2. Your dissatisfaction with the services provided by the water authority 3. The water quality is poor 4. My house is far away from the payment place	V31
Do you taste chlorine sterilizers in the drinking water that reach your home from the water network? 1. Yes 2. No	V32
Did the water reaching you from the water network cause you to suffer from a disease? 1. Yes 2. No	V33

Appendix III: The physical and chemical data of drinking water samples that were obtained from the records of CPHL

Sample Number	Source	Date	Water Source	Year	Conductivity µS/cm	Fluoride ppm	Nitrate ppm	PH	Salinity %
1	جمعيه ضخ مصلحه المياه	8/8/2018	مياه شبكة	2018	606	0.14	6.79	7.58	0.02
2	مركز الاحصاء المركزي	8/8/2018	مياه معبأه	2018	515	0.09	5.38	7.85	0.02
3	سلطه جوده البيئه	8/8/2018	مياه معبأه	2018	441	0.04	3.44	7.88	0.01
4	مستشفى رام الله	18/09/2018	غسيل كيلى	2018	3	NANA	NA	4	NA
5	مصنع سنقرط	30/09/2018	مياه معبأه	2018	NA	NA	NA	NA	NA
6	منزل محمد الكركراوي	3/10/2018	مياه شبكة	2018	711	0.2	0.3	7.907	0.3
7	مستشفى رام الله	9/10/2018	غسيل كيلى	2018	20	NA	NA	8.31	0
8	شركة كوليجان	19/9/2018	مياه معبأه	2018	NA	0.24	NA	7.786	NA
9	منزل علي غازي	3/10/2018	مياه شبكة	2018	430	0.09	7.68	7.945	0.1
10	النيل الازرق	27/8/2018	مياه معبأه	2018	NA	NA	NA	7.73	NA
11	مرجان	17/10/2018	مياه معبأه	2018	NA	NA	NA	8.015	NA
12	شركة المشروبات الوطنية	28/10/2018	مياه معبأه	2018	NA	NA	NA	6.22	NA
13	النيل الازرق	17/10/2018	مياه معبأه	2018	NA	NA	NA	7.972	NA
14	شركة تسنيم لتنقية المياه والتجارة	17/12/2018	مياه معبأه	2018	NA	NA	NA	7.968	NA
15	شركة أبو لبن	17/10/2018	مياه معبأه	2018	NA	NA	NA	7.54	NA
16	شكة سلسبيل/ غنام	17/10/2018	مياه معبأه	2018	NA	NA	NA	NA	NA
17	مرجان	5/11/2018	مياه معبأه	2018	NA	NA	NA	7.67	NA
18	كوليجان	5/12/2018	مياه معبأه	2018	NA	NA	NA	NA	NA
19	مرجان	19/12/2018	مياه معبأه	2018	NA	0.02	0.17	7.96	NA
20	النيل الازرق	23/12/2018	مياه معبأه	2018	NA	0.034	0.3	7.8	NA
21	شركة أبو لبن	23/12/2018	مياه معبأه	2018	NA	0.02	0.28	7.804	NA
22	مرجان	19/12/2018	مياه معبأه	2018	NA	0.02	0.17	7.96	NA
23	شركة كوليجان	19/12/2018	مياه معبأه	2018	NA	0.182	18.3	8.01	NA
24	شركة سلسبيل / الغنام	19/12/2018	مياه معبأه	2018	NA	0.02	0.43	7.89	NA
25	مستشفى رام الله	5/12/2018	غسل كلى	2018	NA	NA	NA	3.4	0
26	شركة دير دبوان للاستيراد والتصدير	26/11/2028	مياه شبكة	2018	374	0.03	0.4	7.82	0.01
27	ميني ماركت الأرض المقدسة	14/04/2019	مياه شبكة	2019	324	0.04	0.4	8.06	0.01
28	شركة تسنيم لتنقية المياه والتجارة	20/03/2019	مياه معبأه	2019	NA	NA	NA	NA	NA
29	مستشفى رام الله	15/04/2019	غسيل كلى	2019	9	NA	NA	6.1	0
30	مستشفى رام الله	2/7/2019	غسل كلى	2019	5	NA	NA	5.85	0
31	كاليجان	3/7/2019	مياه معبأه	2019	NA	NA	NA	NA	NA
32	شركة المشروبات الوطنية	26/06/2019	مياه معبأه	2019	NA	NA	NA	6.1	NA
33	مرجان	26/06/2019	مياه معبأه	2019	NA	NA	NA	8.2	NA
34	مرجان	21/04/2019	مياه معبأه	2019	NA	NA	NA	7.946	NA
35	بجانب العيادة الصحية	1/7/2019	مياه شبكة	2019	470	0.11	7.22	7.94	0.01

36	شركة سلسبيل / الغنام	10/7/2019	مياه معبأه	2019	NA	NA	NA	NA	NA
37	مرجان	17/7/2016	مياه معبأه	2019	NA	NA	NA	8.05	NA
38	شركة كوليجان	17/7/2016	مياه معبأه	2019	NA	NA	NA	8	NA
39	النيل الازرق	17/7/2019	مياه معبأه	2019	NA	NA	NA	8.02	NA
40	شركة تسنيم لتنقية المياه والتجارة	17/7/2019	مياه معبأه	2019	NA	NA	NA	7.67	NA
41	مرجان	17/7/2019	مياه معبأه	2019	NA	NA	NA	8.05	NA
42	شكة سلسبيل/ غنام	17/7/2019	مياه معبأه	2019	NA	NA	NA	7.96	NA
43	شركة الاتقان	17/7/2019	مياه معبأه	2019	NA	NA	NA	7.61	NA
44	مرجان	26/6/2019	مياه معبأه	2019	NA	0.11	7.93	8.38	NA
45	شركة كوليجان	17/7/2019	مياه معبأه	2019	NA	NA	NA	8	NA
46	مرجان	14/7/2019	مياه معبأه	2018	NA	NA	NA	NA	NA
47	مرجان	14/7/2019	مياه معبأه	2019	NA	NA	NA	7.95	NA
48	بجانب عياده عين يبرود	15/7/2019	مياه شبكة	2019	476	0.1	13.74	7.94	0.01
49	المجلس الاعلى للشباب والرياضه	14/7/2019	مياه معبأه	2019	NA	NA	NA	7.82	NA
50	مستشفى رام الله	5/8/2019	مياه معبأه	2019	4	NA		5.99	0
51	شركة سلسبيل / الغنام	10/7/2019	مياه معبأه	2018	NA	NA	NA	8.39	NA
52	شركة أبو لبن	28/8/2018	مياه معبأه	2019	NA	NA	NA	7.51	NA
53	كاليجان	28/8/2019	مياه معبأه	2019	NA	NA	NA	7.86	NA
54	مرجان	5/8/2019	مياه معبأه	2015	NA	NA	NA	7.8	NA
55	مرجان	5/8/2016	مياه معبأه	2019	NA	NA	NA	7.74	NA
56	شركه فاميلي ون التجاريه الصناعيه	28/8/2019	مياه معبأه	2019	NA	NA	NA	NA	NA
57	شركة سلسبيل / الغنام	28/8/2019	مياه معبأه	2019	NA	NA	NA	7.88	NA
58	الشرطة	3/9/2019	مياه معبأه	2019	444	0.08	8.2	7.83	0.01
59	مطعم توستي	2/1/2019	نبع، بئر جوفي	2019	NA	NA	20.35	NA	NA
60	مستشفى رام الله	16/1/2019	غسيل كيلى	2019	7	NA	NA	5.82	0
61	شركة المشروبات الوطنية	20/1/2019	مياه معبأه	2019	NA	NA	NA	6.1	NA
62	نبع ماء عين قينيا الرئيسيه	27/1/2019	نبع، بئر جوفي	2019	NA	NA	33.5	NA	NA
63	مرجان	24/1/2019	مياه معبأه	2019	NA	NA	NA	7.92	NA
64	منزل احمد صلاح الدين	18/2/2019	مياه شبكة	2019	339	0.022	0	8.13	0.01
65	محطه ضخ عين ساميه الفرعيه	25/2/2019	نبع، بئر جوفي	2019	533	0.14	23.95	7.79	0.02
66	شركة تسنيم لتنقية المياه والتجارة	26/06/2019	مياه معبأه	2019	NA	NA	NA	7.43	NA
67	شركة سلسبيل / الغنام	26/06/2019	مياه معبأه	2019	NA	NA	NA	8.03	NA
68	شركه فاميلي	20/30/2019	مياه معبأه	2019	NA	NA	NA	7.86	NA
69	شركة سلسبيل / الغنام	20/3/2019	مياه معبأه	2019	NA	NA	NA	7.92	NA
70	بجانب بقاله نشأت العطاري	6/3/2019	مياه شبكة	2019	437	0.04	0.2	8.31	0.01
71	بجانب بقاله نشأت العطاري	6/3/2019	مياه شبكة	2019	437	0.04	0.2	8.31	0.01
72	مستشفى رام الله	20/3/2019	غسل كلى	2019	6	NA	NA	4.9	0

73	قاعه افراح خليل عيسى	18/3/2019	مياه شبكة	2019	379	0.034	0.34	8.1	0.01
74	مرجان	8/5/2019	مياه معبأه	2019	NA	NA	NA	NA	NA
75	مرجان	8/5/2019	مياه معبأه	2019	NA	NA	NA	7.96	NA
76	مرجان	8/5/2019	مياه معبأه	2019	NA	NA	NA	8.01	NA
77	مستشفى رام الله	15/5/2018	غسل كلى	2019	3	NA	NA	3.71	0
78	النيل الازرق	12/6/2019	مياه معبأه	2019	NA	NA	NA	8.01	NA
79	مرجان	22/5/2019	مياه معبأه	2019	NA	NA	NA	8.11	NA
80	النيل الازرق	19/6/2019	مياه معبأه	2019	NA	NA	NA	7.88	NA
81	مستشفى رام الله	19/06/2019	غسل كلى	2019	3	NA	NA	6	0
82	شركه النعمان للصناعات	11/6/2019	مياه معبأه	2019	NA	0.33	10.63	7.739	NA
83	مرجان	12/6/2019	مياه معبأه	2019	NA	NA	NA	8.09	NA
84	شركة الاتقان	24/4/2019	مياه معبأه	2019	NA	NA	NA	8.1	0
85	النيل الازرق	21/4/2019	مياه معبأه	2019	NA	NA	NA	8.01	NA
86	شركة كوليجان	24/4/2019	مياه معبأه	2019	NA	NA	NA	7.98	NA
87	شركه سلسبيل/ الغنام	24/04/2019	مياه معبأه	2019	NA	NA	NA	7.97	NA
88	شركة تسنيم لتنقية المياه والتجارة	24/04/2019	مياه معبأه	2019	NA	NA	NA	8.06	NA
89	مرجان	24/04/2019	مياه معبأه	2019	NA	NA	NA	7.95	NA
90	شركة الاتقان/مياه معبأة	26/06/2019	مياه معبأه	2019	NA	NA	NA	7.74	NA

Appendix III: The physical and chemical data of drinking water samples that were obtained from the records of CPHL (continued).

Sample Number	TDS ppm	Turbidity NTU	Hardness ppm	Ammonia ppm	Chloride ppm	Chlorine ppm
1	351	0.24	197	0	71.2	NA
2	300	0.11	191	0	60.05	0
3	134.11	0.13	NA	0	52.33	0
4	2	NA	0	NA	NA	NA
5	258	NA	NA	NA	NA	NA
6	199.14	0.35	199.14	0	116	NA
7	12	NA	0	NA	NA	NA
8	318	NA	NA	NA	NA	NA
9	249	0.36	178.82	0.06	37.32	NA
10	367	NA	NA	NA	NA	NA
11	265	NA	NA	NA	NA	NA
12	142	NA	NA	NA	NA	NA
13	282	NA	NA	NA	NA	NA
14	220	NA	NA	NA	NA	NA
15	293	NA	NA	NA	NA	NA
16	119	NA	NA	NA	NA	NA
17	242	NA	NA	NA	NA	NA
18	NA	NA	NA	NA	NA	NA
19	216	NA	NA	NA	57.19	NA
20	216	NA	NA	NA	58.48	NA
21	201	NA	NA	NA	54.18	NA
22	216	NA	NA	NA	57.19	NA
23	304	NA	NA	NA	33.97	NA
24	124	NA	NA	NA	32.25	NA
25	18	NA	0	NA	NA	NA
26	217	0.2	103.33	0	58.05	NA
27	188	0.21	93.2	0	42.57	NA
28	NA	NA	NA	NA	NA	NA
29	4	NA	0	NA	NA	NA
30	3	NA	0	NA	NA	NA
31	NA	NA	NA	NA	NA	NA
32	147	NA	NA	NA	NA	NA
33	274	NA	NA	NA	NA	NA
34	202	NA	NA	NA	NA	NA
35	273	0.56	200.9	0	46.88	NA
36	NA	NA	NA	NA	NA	NA
37	275	NA	NA	NA	NA	NA
38	322	NA	NA	NA	NA	NA
39	281	NA	NA	NA	NA	NA
40	184	NA	NA	NA	NA	NA
41	277	NA	NA	NA	NA	NA
42	NA	NA	NA	NA	NA	NA
43	224	NA	NA	NA	NA	NA
44	274	NA	NA	NA	43.56	NA

45	322	NA	NA	NA	NA	NA
46	NA	NA	NA	NA	NA	NA
47	279	NA	NA	NA	NA	NA
48	276	0.3	194	0	47.8	NA
49	275	NA	NA	NA	NA	NA
50	2	NA	0	NA	NA	NA
51	291	NA	NA	NA	NA	NA
52	135	NA	NA	NA	NA	NA
53	322	NA	NA	NA	NA	NA
54	289	NA	NA	NA	NA	NA
55	287	NA	NA	NA	NA	NA
56	251	NA	NA	NA	NA	NA
57	164	NA	NA	NA	NA	NA
58	259	0.41	184	0	40.2	NA
59	NA	NA	NA	2.34	NA	NA
60	4	NA	0	NA	NA	NA
61	131	NA	NA	NA	NA	NA
62	NA	NA	NA	0	NA	NA
63	229	NA	NA	NA	NA	NA
64	199	0.19	85.1	0	50.74	NA
65	322	0.19	263.38	0	35.26	NA
66	183	NA	NA	NA	NA	NA
67	223	NA	NA	NA	NA	NA
68	218	NA	NA	NA	NA	NA
69	148	NA	NA	NA	NA	NA
70	253	0.31	113.8	0	61.92	NA
71	253	0.31	113.8	0	61.92	NA
72	4	NA	0	NA	NA	NA
73	220	0.23	85.34	0	59.34	0.2
74	NA	NA	NA	NA	NA	NA
75	273	NA	NA	NA	NA	NA
76	280	NA	NA	NA	NA	NA
77	1	NA	0	NA	NA	NA
78	254	NA	NA	NA	NA	NA
79	286	NA	NA	NA	NA	NA
80	300	NA	NA	NA	NA	NA
81	2	NA	0	NA	NA	NA
82	33	NA	NA	NA	41.97	NA
83	25	NA	NA	NA	NA	NA
84	227	NA	NA	NA	NA	NA
85	240	NA	NA	NA	NA	NA
86	327	NA	NA	NA	NA	NA
87	NA	NA	NA	NA	NA	NA
88	228	NA	NA	NA	NA	NA
89	202	NA	NA	NA	NA	NA
90	NA	NA	NA	NA	NA	NA

Appendix III: The physical and chemical data of drinking water samples that were obtained from the records of CPHL (continued).

Sample Number	Sulfate ppm	Calcium ppm	Magnesium ppm	Sodium ppm	Potassium ppm
1	NA	NA	NA	NA	NA
2	NA	NA	NA	NA	NA
3	NA	NA	NA	NA	NA
4	NA	NA	NA	NA	NA
5	NA	NA	NA	NA	NA
6	NA	NA	NA	NA	NA
7	NA	NA	NA	NA	NA
8	NA	NA	NA	NA	NA
9	NA	NA	NA	NA	NA
10	NA	NA	NA	NA	NA
11	NA	NA	NA	NA	NA
12	NA	NA	NA	NA	NA
13	NA	NA	NA	NA	NA
14	NA	NA	NA	NA	NA
15	NA	NA	NA	NA	NA
16	NA	NA	NA	NA	NA
17	NA	NA	NA	NA	NA
18	NA	NA	NA	NA	NA
19	20.94	32.74	3.268	39.04	1.697
20	NA	31.95	2.803	39.8	1.667
21	18.69	30.3	2.208	36.68	1.598
22	20.94	32.74	3.268	39.04	1.697
23	14.52	56.36	23.74	19.35	2.295
24	9.98	17.04	2.135	23.67	0.803
25	NA	NA	NA	NA	NA
26	NA	NA	NA	NA	NA
27	NA	NA	NA	NA	NA
28	NA	NA	NA	NA	NA
29	NA	NA	NA	NA	NA
30	NA	NA	NA	NA	NA
31	NA	NA	NA	NA	NA
32	NA	NA	NA	NA	NA
33	NA	NA	NA	NA	NA
34	NA	NA	NA	NA	NA
35	NA	NA	NA	NA	NA
36	NA	NA	NA	NA	NA
37	NA	NA	NA	NA	NA
38	NA	NA	NA	NA	NA

39	NA	NA	NA	NA	NA
40	NA	NA	NA	NA	NA
41	NA	NA	NA	NA	NA
42	NA	NA	NA	NA	NA
43	NA	NA	NA	NA	NA
44	24.45	44.56	13.22	25.55	2.037
45	NA	NA	NA	NA	NA
46	NA	NA	NA	NA	NA
47	NA	NA	NA	NA	NA
48	NA	NA	NA	NA	NA
49	NA	NA	NA	NA	NA
50	NA	NA	NA	NA	NA
51	NA	NA	NA	NA	NA
52	NA	NA	NA	NA	NA
53	NA	NA	NA	NA	NA
54	NA	NA	NA	NA	NA
55	NA	NA	NA	NA	NA
56	NA	NA	NA	NA	NA
57	NA	NA	NA	NA	NA
58	NA	NA	NA	NA	NA
59	NA	NA	NA	NA	NA
60	NA	NA	NA	NA	NA
61	NA	NA	NA	NA	NA
62	NA	NA	NA	NA	NA
63	NA	NA	NA	NA	NA
64	NA	NA	NA	NA	NA
65	NA	NA	NA	NA	NA
66	NA	NA	NA	NA	NA
67	NA	NA	NA	NA	NA
68	NA	NA	NA	NA	NA
69	NA	NA	NA	NA	NA
70	NA	NA	NA	NA	NA
71	NA	NA	NA	NA	NA
72	NA	NA	NA	NA	NA
73	NA	NA	NA	NA	NA
74	NA	NA	NA	NA	NA
75	NA	NA	NA	NA	NA
76	NA	NA	NA	NA	NA
77	NA	NA	NA	NA	NA
78	NA	NA	NA	NA	NA
79	NA	NA	NA	NA	NA
80	NA	NA	NA	NA	NA
81	NA	NA	NA	NA	NA

82	19.36	56.87	23.75	25.56	2.93
83	NA	NA	NA	NA	NA
84	NA	NA	NA	NA	NA
85	NA	NA	NA	NA	NA
86	NA	NA	NA	NA	NA
87	NA	NA	NA	NA	NA
88	NA	NA	NA	NA	NA
89	NA	NA	NA	NA	NA
90	NA	NA	NA	NA	NA

NA: Not applicable