BIRZEIT UNIVERSITY

Faculty of Graduate Studies
Water and Environmental Engineering Masters Program

MSc. Thesis

The Opportunity Cost of Drinking Water Quality Degradation in Ramallah and Al-Bireh Governorate

تكاليف الفرصة البديلة لتدني نوعية مياه الشرب
في محافظة رام الله و البيرة

Master's Thesis Submitted By
Najwan Imseih

Student number
1075349

Supervised By
Dr. Maher Abu-Madi

June 2010

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This thesis was submitted in partial fulfillment of the requirements for the Master's Degree in Water and Environmental Engineering from the Faculty of Graduate Studies, Water Institute Studies, at Birzeit University, Palestine.

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Submitted by
Najwan Imseih

This thesis was prepared under the main supervision of Dr. Maher Abu-Madi and has been approved by all members of the examination committee**.**

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Dr. Maher Abu-Madi ……………………………………….
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Dr. Ziad Mimi ……………………………………….
Member

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Member

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ABSTRACT

In the recent years, it has been observed that there is an increase of consumption of bottled drinking water in Palestine, mostly due to the perception that public drinking water is of low quality, while some consumption is due to taste and lifestyle preferences. In addition, many households have installed water purification equipment to protect against inferior (real or perceived) public water quality. In the past 10 years mainly, the consumption of bottled water and the installation of home water purification apparatuses have noticeably increased in the Ramallah and Al-Bireh governorate. This research attempts to assess the quality of public drinking water in the Ramallah and Al-Bireh Governorate, and to estimate the averted expenditure on different drinking water to monetize the opportunity cost in 2009.

Generally, it was found that the supplied public water in the Ramallah and Al-Bireh governorate conforms to the Palestinian standards for safe and healthy drinking water. Bottled water consumption in 2009 is estimated at 58.3 liters per capita per year in the Ramallah and Al-Bireh governorate. The total expenditure on bottled water in the Ramallah and Al-Bireh governorate was found to be 23.25 million NIS in 2009, the total averted expenditure on bottled water was estimated to be 22.0 million NIS and the total expenditure on water purification apparatuses was found to be about 1.43 million NIS. Thus, the total expenditure on drinking water totaled to 23.43 million NIS in 2009. When these expenditures are represented as the opportunity costs, the average person purchasing bottled water is forgoing the opportunity to save 400.94 NIS/yr, and the average person who has installed a water filter is forgoing the opportunity to save 74.74 NIS/yr, which are both costs associated with drinking water expenditures. This research has shown that water pollution and possible contamination, or the perception thereof, of public drinking water has a cost to society.

الخلاصة

خلال السنوات الأخيرة الماضية, لوحظ ارتفاع في استهلاك المياه المعبأة في المناطق الفلسطينية. تعز زيادة الاستهلاك للمياه المعبأة غالبا لاعتقاد المواطنين بأن مياه الشرب العامة ذات جودة منخفضة, بالإضافة إلى أسباب أخرى منها طعم المياه, ونمط الحياة العصرية. كما أن هناك عدد من المنازل يستخدم أجهزة تنقية المياه البيتية لحمايتهم من تدني مستوى المياه العامة. خلال العشرة سنوات الماضية لوحظ ارتفاع في استهلاك المياه المعبأة وتركيب أجهزة تنقية المياه في منطقة محافظة رام الله و البيره, كما تضاعف عدد الشركات المزودة للمياه المعبئة وعملاء شركات أجهزة تنقية المياه. تهدف هذه الدراسة إلى فحص جودة المياه في منطقة رام الله و البيره خلال العشر سنوات الماضية , وتقدير مجموع ما تم انفاقه على المياه المعبأة خلال عام 2009.

بشكل عام وجد أن جودة المياه في رام الله والبيرة تطابق المواصفات الفلسطينية لجودة مياه الشرب. قدرت كمية استهلاك المياه المعبئة خلال العام 2009 بحوالي 85.3 لتر ماء لكل شخص سنويا في منطقة رام الله والبيرة. وتم إنفاق مبلغ 22.0 مليون شيكل في عام 2009 على المياه المعبأة و 1.43 مليون شيكل على أجهزة تنقية المياه البيتية. وهذا يعني انه تم انفاق ما مجموعه 23.43 مليون شيكل في عام 2009. عندما يتم تمثيل هذه النفقات بسعر الفرصة البديلة , فان المواطن عند شراءه للمياه المعبأة فقد تخلى عن فرصة لإنقاذ 400.94 شيكل في السنة ، كما أن المواطن الذي قام بتركيب أجهزة تنقية المياه البيتية قد تخلى عن فرصة لإنقاذ 74.74 شيكل في السنة ، و جميع هذه التكاليف مرتبطة بنفقات مياه الشرب. أظهرت هذه الدراسة أن تلوث المياه, أو احتمالات تلوثها, أو الاعتقاد العام بين المواطنين بتدني مستوى المياه العامة, تشكل عبء اقتصادي على المجتمع.

DEDICATION

To my loving husband,

To my amazing parents,

To my wonderful family and friends.

ACKNOWLEDGEMENTS

My greatest gratitude and appreciation goes to all those who contributed to this study, whose active support, encouragement and guidance made this research possible.

My personal thanks go to my husband, my parents, my family and friends for their assistance, much appreciated words of encouragement, and constant moral support.

Particular thanks are due to the Birzeit University, Institute of Environmental and Water Studies, and especially Dr. Maher Abu Madi for providing the inspiration for the topic of this research, for his continuous guidance and for his intellectual leadership. Thank you to Dr. Ziad Mimi and Dr. Yousef Naser, members of the examination committee, for your thoughtful comments and suggestions.

Special thanks to the Palestinian Water Authority, Jerusalem Water Undertaking, Ministry of Health, Central Public Health Lab, Ministry of National Economy, the Palestinian Central Bureau of Statistics, and to all those who took the time to meet with me, for all the valuable information they provided.

LIST OF ABBREVIATIONS

CPHL	Central Public Health Lab
JWU	Jerusalem Water Undertaking
L.	Liters
l/c/d	Liters per capita per day
Mcm	Million cubic meters
MoH	Ministry of Health
MoNE	Ministry of National Economy
NIS	New Israeli Shekel
PCBS	Palestinian Central Bureau of Statistics
PSI	Palestinian Standards Institute
PWA	Palestinian Water Authority
WBWD	West Bank Water Department
WHO	World Health Organization

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CHAPTER ONE INTRODUCTION

1.1 Overview

Issues associated with drinking water have been stirring some attention in the environmental and economic fields as well as among regular consumers worldwide. Bottled water industries especially have seen increasing demands for their products in recent years. The world bottled-water market represents an annual volume of 89,000 million liters, and is estimated to be worth USD 22,000 million (Ferrier, 2001). Palestinian consumers are drinking more bottled water every year, partly due to the fact that it is perceived as safer or of better quality than the public drinking water. There seems to be many perceptions and some speculation regarding the public drinking water quality of the Ramallah and Al-Bireh governorate. Collectively, hundreds or thousands of New Israeli Shekels (NIS) are being spent on drinking water, which includes public drinking water, purchased bottled water, and the costs incurred for the installation and maintenance of water purification apparatuses in the homes. If in fact the public drinking water is safe and healthy to drink, then this means that a significant amount of expenditure is being spent on bottled water and water purification apparatuses and thus represents a significant opportunity cost. In today's economy, the opportunity cost, or the value of what is foregone to have the next best alternative, is an important cost for the average consumer.

1.2 Statement of the Problem

In the past ten years, the consumption of bottled water and the installation of home water purification apparatuses have noticeably increased in the Ramallah and Al-Bireh governorate. In fact, the number of bottled water companies and water filter dealers has multiplied. The observable and sometimes intrusive marketing efforts of these industries are causing a stir among the local residents. People are troubled with the various allegations that their tap water is contaminated or unhealthy and are generally confused as to which drinking water is the healthier choice, causing them to expend more of their income on drinking water supplies. By shedding some light on the quality and cost of public water, in comparison to the quality and cost of bottled and filtered water, consumers will be able to make an educated decision about the type of water which is most suitable for them and their families. Additionally, the per capita water consumption in the Ramallah and Al-Bireh governorate has generally been calculated by dividing the total quantity of supplied water by the population. This estimate, though, does not take into consideration the amounts of bottled drinking water consumption into the equation, leaving a gap in this regard.

1.3 Research Questions

Some of the questions which this research aims to answer are:

- What is the quality of public drinking water in the Ramallah and Al-Bireh governorate?
- What is the expenditure on drinking water supplies (which includes tap water, bottled water and/or filtered water) and how does this translate as the opportunity cost?
- What is the average bottled water consumption in the Ramallah and Al-Bireh governorate?
- What are the proportions of the population drinking different types of water in the governorate?
- What are some perceptions of residents regarding the public drinking water?

1.4 Research Objectives

The main objectives of this research are to assess the quality of public drinking water in the Ramallah and Al-Bireh governorate, to estimate the expenditure on different drinking water supplies, which include bottled drinking water and home water purification apparatuses, and to monetize the opportunity cost of these expenditures. The specific objectives of this research are to:

1) Compile a grouping of chemical and microbial water quality data for public drinking water supplies in the Ramallah and Al-Bireh governorate and carry out a water quality assessment.
2) Gather information on the bottled water industries in Ramallah and Al-Bireh governorate and provide an estimate of the quantity of bottled water sold in the governorate.
3) Estimate the yearly bottled water consumption in the Ramallah and Al-Bireh governorate.
4) Provide an estimate of the cost of water degradation, if any, in the Ramallah and Al-Bireh governorate based on averted expenditures, using the most recent data available, and monetize the opportunity cost of these expenditures.
5) Estimate indicator values of the proportions of residents in the Ramallah and Al-Bireh governorate consuming different types of water.
6) Better understand the perceptions of consumers regarding their choice of drinking water type.

1.5 Significance of the Study

This study will be a significant endeavor in assessing the quality of drinking water and the expenditure on its various sources in the Ramallah and Al-Bireh governorate. This study will contribute to enhancing the knowledge of average consumers on drinking water quality based on scientific facts and economic calculations. The results of this study will provide some insight and information for further research for water scientists and water economists. The study provides a scientific discussion of concerning water quality issues and intends to provide useful information on common issues and concerns related to drinking water in the Ramallah-Al Bireh governorate.

1.6 Approach and Methodology

The research approach adopted in this study is made up of a combination of methods. The study is both desk-based and field-based. Scholarly articles and books were reviewed on water quality assessments and standards, the international bottled water industry, and home water purification processes and systems. In addition, primary and secondary data on water quality was collected. Interviews were carried out with actors in the bottled water industry and filter dealers as an aid to reveal essential primary data. Research data was sourced, collected and collated accordingly. A questionnaire was distributed to 155 households in order to obtain indicator values of the proportions of residents in the Ramallah and Al-Bireh governorate consuming different types of water, to estimate the household expenditures on drinking water, to better understand perceptions regarding public drinking water, and to provide an estimate of the average bottled water consumption in the Ramallah and Al-Bireh governorate. The aggregated data from the company surveys and questionnaires is used to find the total expenditure on drinking water supplies for the year 2009 in the Ramallah and Al-Bireh governorate and to provide an estimation of the opportunity costs.

1.7 Assumptions and Limitations

Several assumptions and limitations influenced this study and it should be noted that a study is only as good as the data on which it is based. Based on water supply data and population estimates, it is assumed that in the study area there is no shortage of water, i.e. that sufficient water reaches the residents at all times of the year. Thus, it is assumed that the purchase of bottled water in the Ramallah and Al-Bireh governorate is not attributed to a shortage in public drinking water. One scenario in this case plays out when tap water becomes fouled following water cuts and people avert to purchasing bottled water. It is also assumed that bottled water is consumed all year long, and not only during the summer months when intermittent water shortages in some areas do in fact occur. Environmental information was difficult to collect and in the real world data gaps can be a significant limitation, such as missing data on water quality in certain years, and lack of data on bottled water consumption and water filter industries in Palestine.

1.8 Scope

In discussing the issue of purchased water, it is essential to note that Palestine is a special case. Many Palestinian communities rely a great deal on purchased tankered water, private wells, springs, etc. to meet their daily water demands. Considering that many rural areas are not even served by a water distribution network, a study of the quality and costs associated with public drinking water and bottled water for Palestine as a whole would be inaccurate. Yet the situation in Ramallah and Al-Bireh governorate is quite different. Significant parts of Ramallah and Al Bireh governorate, including the Ramallah and Al-Bireh twin cities, ten other cities/towns, more than 43 villages and 5 refugee camps, are served by a water distribution network. There are a few remaining localities not served by a water network, which is about 3% of the households in the governorate, but these will be disregarded in this study.

This study does not attempt to be considered as a purely economic study rather it collaborates between the scientific, technical and economic aspects of the general topic of drinking water. Additionally, it is important to note that this study does not intend to undermine the importance of the bottled water and filter industries which are an important sector in the Palestinian economy and livelihood, yet this study does provide a discussion of concerning issues and intends to a provide useful information and a comprehensible understanding of selected issues regarding drinking water in the Ramallah-Al Bireh governorate.

1.9 Thesis Outline

This thesis is composed of six chapters. Chapter 1 offers an introduction to the content and structure of the research, including the statement of the problem, research questions and objectives and research assumptions and limitations. Chapter 2 describes the study area of Ramallah and Al-Bireh governorate, providing a briefing of the general characteristics and water resources of the area. Chapter 3, the literature review, discusses environmental economics, water quality standards, parameters and assessments, bottled water guidelines and trends and briefly discusses filtered water. Chapter 4 explains the approach and methodology adopted in this research from purpose of the study to the data collection and analysis phase. Chapter 5 provides the results and offers a discussion of the results. Chapter 6 draws conclusions and offers recommendations formulated as an outcome of this research.

CHAPTER TWO THE STUDY AREA: RAMALLAH AND AL-BIREH GOVERNORATE

2.1 Location

In the central area of the West Bank, lies the governorate of Ramallah and Al-Bireh. It is bordered by the Jerusalem governorate in the south, the Nablus and Salfit governorates in the north, Jericho governorate in the east, and the 1948 borderline between Israel and West Bank from the west, as shown in Figure 1. The twin cities of Ramallah and Al-Bireh are located within this governorate. The two cities are about 860 meters above sea level, and have a moderate and pleasant climate, allowing them to be a center for commercial and tourist attraction.

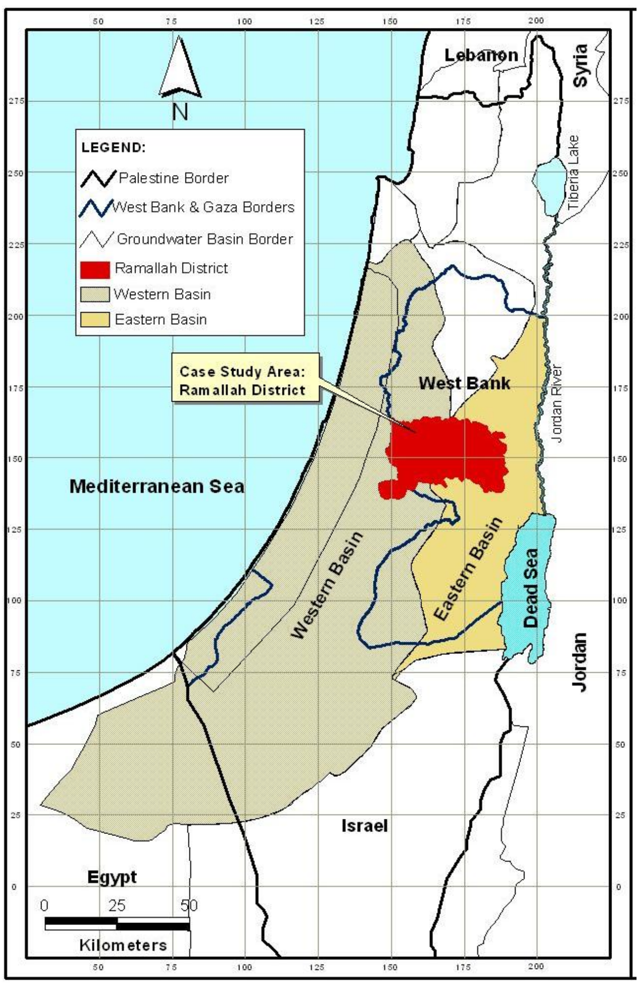


Figure 2-1 Location map for Ramallah and Al-Bireh governorate (HWE, 2009)

2.2 Climate

The climate of the area is mainly that of the Mediterranean type, characterized by long, warm, dry summers and short, cool, rainy winters.

2.2.1 Rainfall

Rainfall is limited to about six rainy months per year, usually between November and April. In general, the distribution of rainfall is strongly influenced by the topography, with higher rainfall in the hills and mountains. The average rainfall was recorded by the Palestinian Meteorological Department, with over 80 rainfall stations distributed geographically from the northern to the southern parts of the West Bank, and was found to be 40-70 days for the rainy season of the year 2008. The annual quantity of rainfall in Ramallah and Al-Bireh governorate in 2007 was 543.9 mm (PCBS, 2008*a*). The average annual rainfall is higher in the western part of the governorate than the eastern part. The average annual rainfall in the eastern part of the governorate varies from 200 to 450 mm, whereas in the western part of the governorate, the average annual rainfall varies from 350 to 550 mm. In the mountains the average annual rainfall heights vary from 550 to 700 mm (HWE, 2009).

2.2.2 Temperature

Since the Ramallah and Al-Bireh governorate is part of the hilly region of the West Bank, it has lower temperatures compared to other governorates. The mean annual temperature is 17.1 °C, as stated by the PCBS in 2008, and the maximum annual average temperature is 21.4°C whereas the minimum annual average temperature is 13.1°C. January is the coldest month with temperatures between 6-12 °C, while August is the hottest month with temperatures between 22-27 °C (PCBS, 2008*a*).

2.2.3 Humidity

The average annual relative humidity in the Ramallah and Al-Bireh governorate was 57% in 2007 and reaches its highest rates during the months of January and February. For the extreme maximum relative humidity, the highest value was 100% registered for (January – April) in Ramallah Station (PCBS, 2008*a*).

2.2.4 Wind

In winter season, the wind moves in a general west-east direction with an average daily wind speed of 16.0 km/hour in December, but during summer winds are northwestern and northeastern, hot and dry with an average wind speed of 18.6 km/hour in August (PCBS, 2008*a*).

2.3 Topography and Drainage

Surface elevations in the Ramallah and Al Bireh governorate vary widely. The highest point in the governorate is 1,022 m above sea level at Tal A'sur, whereas the lowest elevation is 100 m below sea level at the southeast corner of the governorate. The topography of Ramallah and Al-Bireh is divided into three main parts: the eastern slopes, mountain crests and western slopes. The eastern slopes are located between the Jordan Valley and the mountains and are characterized by steep slope forming wadis. The mountain crests form a steep surface water divide that separates the eastern and western slopes, with an elevation ranging between 750 and 800 meters above sea level. The western slopes are characterized by gentle slopes with an elevation ranging between 250-500 meters above sea level (HWE, 2009).

There are two major drainage systems in the Ramallah and Al-Bireh governorate: one runs to the west towards the Mediterranean while the second runs to the east towards the Jordan River (as shown in Figure 2-2). Figure 2-2 also shows that the groundwater divide and the surface water divide do not coincide on the same line. As it can be seen for the surface water divide, Ramallah drains to the west while Al-Bireh drains to the east. As for the groundwater flow movement, both cities drain to the east.

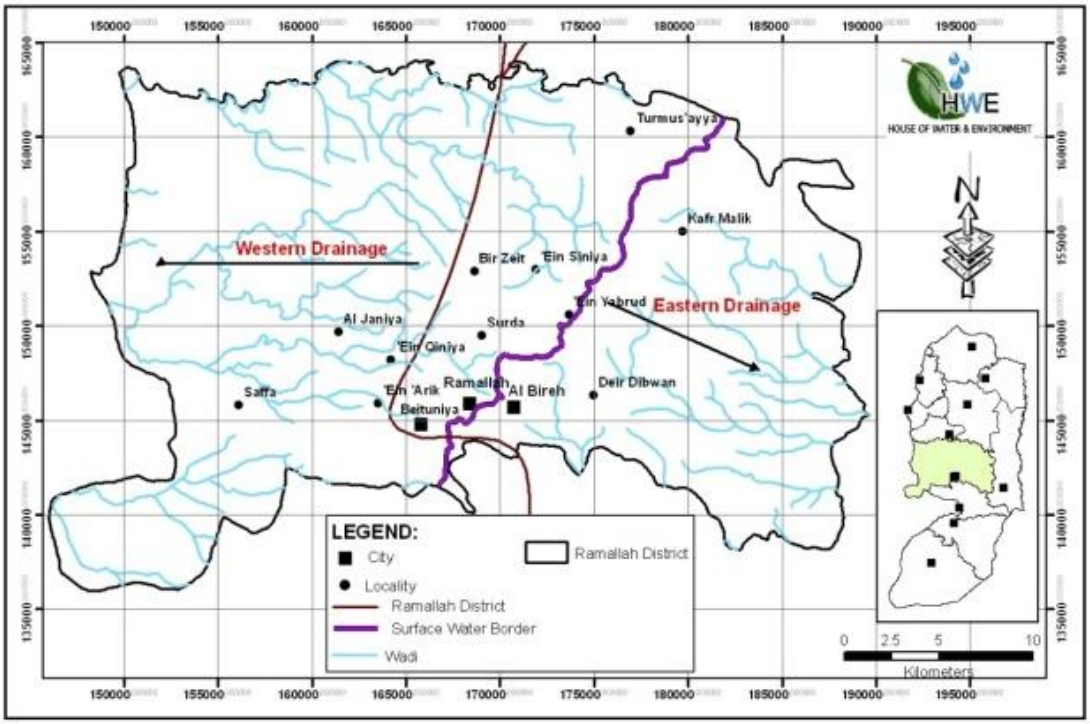


Figure 2-2 Drainage systems in Ramallah and Al-Bireh Governorate (HWE, 2009)

2.4 Land Use

The Ramallah and Al- Bireh Governorate covers an area of approximately 855 km². This makes up about 15.1% of the West Bank and 14.2% of the Palestinian territories (Gaza Strip and West Bank) (PCBS, 2008*b*).

There are a number of different land use classes within the Governorate boundaries, and these include Palestinian built up areas, Israeli settlements, cultivated areas, forests, nature reserves and industrial areas.

There are about 80 Palestinian built up areas in the governorate. Ramallah, Al-Bireh, Silwad, Bani Zeid, Birzeit, Deir Dibwan and Bitunia are the only communities designated as municipalities. Village councils govern other built up areas. In addition, there are five refugee camps, Al-Amari, Qaddura, Al-Jalazone, Silwad and Deir A'mmar. Figure 2-3 shows the built up areas in Ramallah and Al-Bireh governorate.

There are 24 Israeli settlements in the Ramallah and Al-Bireh governorate, occupying approximately 30.27 km^2 of the governorate's land (3.54 % of the total governorate's land). The current population of the Israeli settlements is estimated to be 81,851 settlers (PCBS, 2008*b*).

The total cultivated area in Governorate covers approximately 184.9 km^2 (PCBS, 2008*b*). Rain-fed agriculture is the most dominant farming pattern in the governorate, occupying approximately 184.4 km^2 while the remaining lands are irrigated (see Figure 2-4). The total forested area is about 2.1 km^2 and the areas designated as 'Natural Reserves' in the governorate make up a total area of almost 34.9 km^2 (PCBS, 2008*b*).

There are two industrial areas in Ramallah and Al-Bireh governorate; one is located to the south of Ramallah City and the other to the east of Al-Bireh City. Together they cover an area of approximately 1.34 km^2.

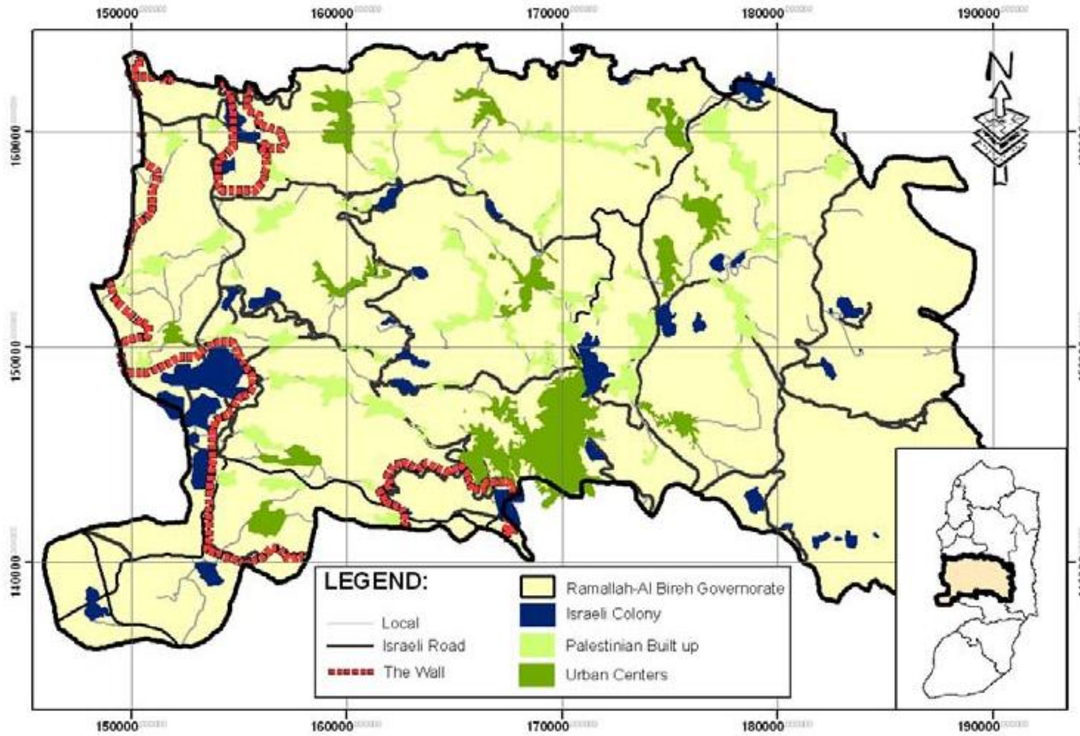


Figure 2-3 Built up areas (HWE, 2009)

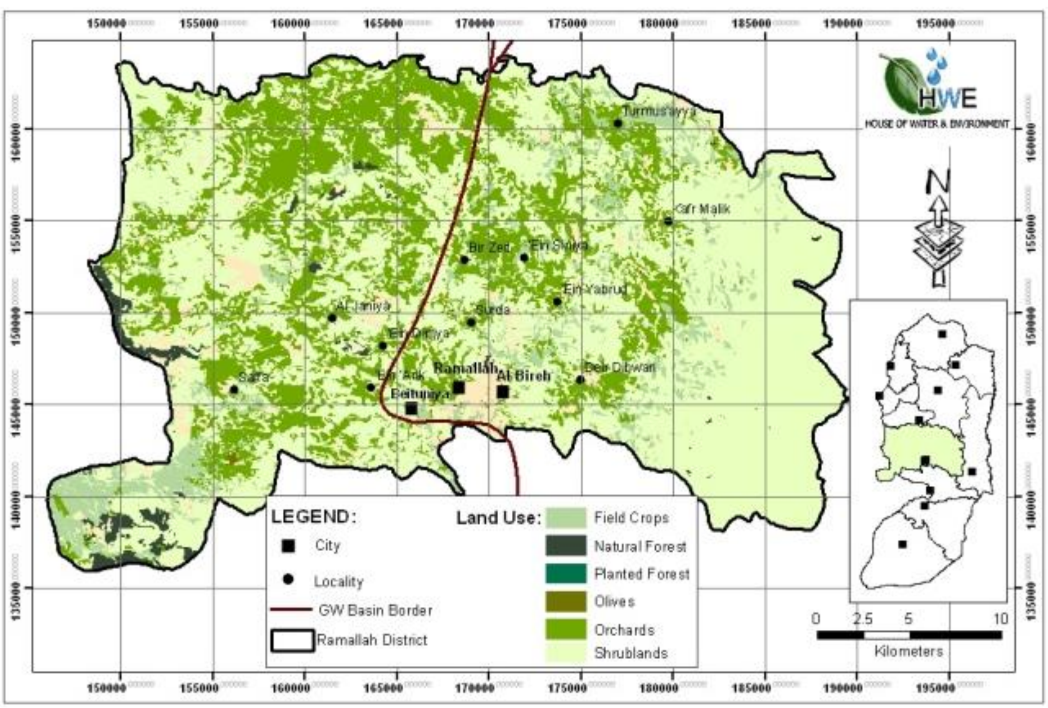


Figure 2-4 Land use map (HWE, 2009)

2.5 Demography

The Ramallah and Al-Bireh governorate covers an area of about 855 km^2 and holds a population of approximately 279,730 persons, as of December 1, 2007. This includes 140,827 males and 138,903 females. The population density is about 327 capita/km^2. The population of Ramallah and Al-Bireh governorate can be classified by type of locality, where 136,406 or 51.9% of the total governorate population live in urban areas, 111,259 or 42.3% of the total governorate population live in rural areas, 15,276 or 5.8% of the total governorate population live in camps. The total number of households in the governorate is 49,676, where 27,182 are located in the urban areas, 19,750 are in the rural areas, and 2,744 are in camps. The average size of the governorate households is 5.3 and the population natural increase rate is 3%. According to estimates in 2009, the percentage of people aged 0-14 years in the governorate is about 38.1% of the total governorate population. About 55.5% of the total population is aged between 15-64 and 3.9% of the population is aged 65 years and over (2.6% of Governorate population ages are unstated) (PCBS, 2009). This data is summarized in Table 2-1.

Table 2-1 Summary of demography characteristics

Total Population of Ramallah and Al-Bireh governorate			279,730
Number of households in Ramallah and Al-Bireh governorate			49,676
Population Density			327 capita/km^2
Average size of household			5.3 persons
Natural population increase rate			3%
		Males	**Females**
Population classification by sex		140,827	138,903
	0-14 years	**between 15-64**	**65 years +**
Population classification by age	38.1%	55.5%	3.9%
	Urban	**Rural**	**Camps**
Population classification by locality	136,406 (51.9%)	111,259 (42.3%)	15,276 (5.8%)
Number of households	27,182	19,750	2,744

Source: PCBS, 2009

2.6 Groundwater Aquifer Basins

The West Bank lies over three main aquifer basins: Eastern, Northeastern and Western Basins. Ramallah and Al-Bireh governorate lies over the Eastern and Western Basins. The Eastern Aquifer Basin underlies the Eastern part of governorate. Its water flows towards the east and southeast. The Western Aquifer Basin underlies about 45% of the Ramallah and Al-Bireh governorate to the west and its water flows towards the west (HWE, 2009).

2.7 Water Demand

In calculating the water demand for Ramallah and Al-Bireh governorate, the World Health Organization standard for the amount of required water for drinking and other domestic uses per capita of 150 l/c/d is adopted (WHO, 2008). Considering the most recent population consensus for 2007 was 279,730 inhabitants, the needed amount of water is about 15.3 Mcm/yr. The Palestinian Central Bureau of Statistics calculated the per capita daily allocation of water for Ramallah- Al Bireh governorate from the quantity of water supplied, which is about 13.70 Mcm, with a population of about 279,730, leading to a daily allocation per capita of 134.2 l/c/d. The Palestinians can supply only about 3.4 Mcm/yr from their own resources (PCBS, 2008*c*); the rest are purchased from the Israeli water company ‘Mekorot’. This is discussed further in the next section.

2.8 Water Supply

The main water resources in the West Bank, and region as a whole, are groundwater aquifers. Wells and springs constitute the main sources of water in the West Bank. Surface water and seasonal small rivers running in the wadis can also be considered as additional water sources which are used mainly for agricultural purposes.

In general, the supply of drinking water in the West Bank can be classified into 2 main sources: i) wells and springs managed by municipalities, village councils, or water distribution organizations; and ii) purchased water from the Israeli water company 'Mekorot', which is distributed by the West Bank Water Department (PWA, 2007).

2.8.1 Domestic Water Resources

In the Ramallah and Al-Bireh governorate, the sources of domestic water supply are Palestinian owned wells, purchased water resources, and springs. About 25% of water in the Ramallah- Al Bireh governorate is obtained from Palestinian owned wells, mainly the Ein Samia groundwater wells, which are operated by the Jerusalem Water Undertaking and about 75% of water is purchased from Mekorot (PWA, 2007). The water produced from the Ein Samia wells is mixed with the water purchased from Mekorot to supply about 50 communities in the Ramallah and Al-Bireh governorate, and some communities within the jurisdiction of the Jerusalem governorate.

1. **Palestinian owned wells** - Ein Samia Well Field: This well field is made up of 5 Palestinian wells owned by the Jerusalem Water Undertaking (JWU) for the Ramallah and Al-Bireh governorate. The JWU is responsible for the management, operation, and monitoring of these wells. The Ein Samia wells are located in the eastern aquifer of the West Bank at a depth of 60 to 600 meters below ground level. The annual extraction from the Ein Samia wells in 2007 was about 3.356 Mcm (PCBS, 2008*d*). The maximum annual extraction capacity of the wells in Ein Samiya is 3.5 Mcm which is possible only with adequate rainfall during the winter season, and it has been shown that there is a decrease in the productivity of the Ein Samia wells (HWE, 2009).
2. **Purchased water resources**: These include water purchased for the West Bank Water Department and from the Israeli water company 'Mekorot'.

- West Bank Water Department (WBWD) Wells: These wells are originally Palestinian wells which were drilled during the Jordanian Mandate period, but were confiscated by the Israeli occupation authorities and were handed over to Mekorot. The WBWD holds the responsibility for distribution of waters to the Palestinian cities, villages and the Israeli settlements inside the West Bank. Four wells are located in the Shibtin area, west of Ramallah city, but only one of them is currently in operation, producing about 0.552 Mcm/yr, (PWA, 2007).
- Israeli Water Company (Mekorot): The sources of water for Mekorot are either from wells inside the green line or inside the West Bank, and recently also from desalination plants constructed inside Israel. The total amount of the purchased water from Mekorot in 2007 was about 10.875 Mcm (PCBS, 2008*e*) to supply the major parts of Ramallah and Al-Bireh governorate. This includes the pumped water from the wells which are located in the Palestinian Territory and controlled by Mekorot.

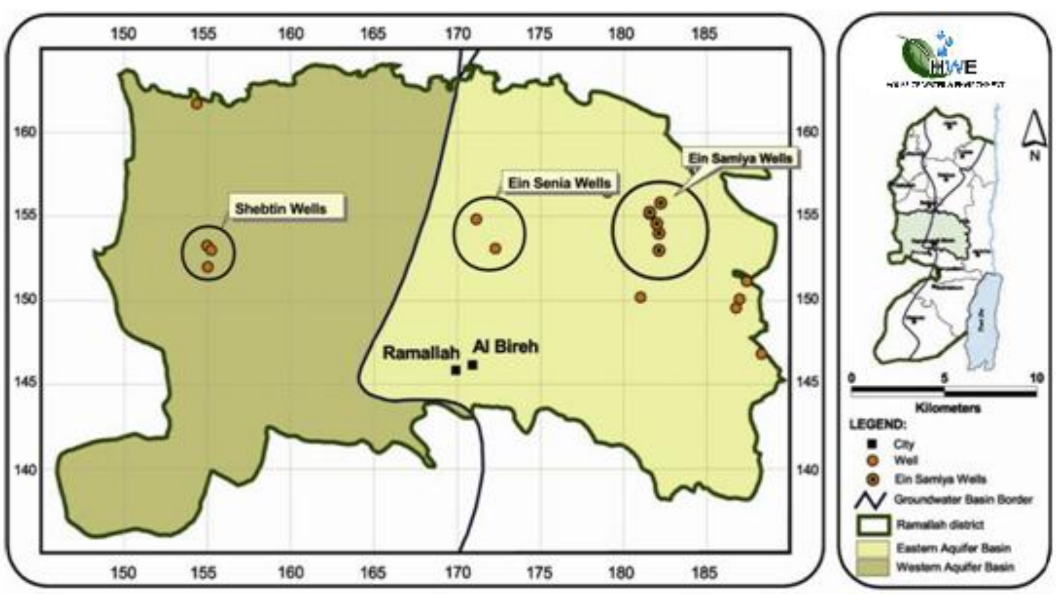


Figure 2-5 Palestinian wells in Ramallah and Al-Bireh governorate (HWE, 2006)

3. **Springs:** There are a total of 31 springs in the governorate, with an annual discharge of 1.714 Mcm (PCBS, 2008*f*). Only 6 of these springs are used for drinking water. The springs are located in villages within the governorate. A number of these springs, such as Ein Arik spring and Al'Ajool spring are no longer used for drinking water purposes because water distribution networks have been installed and the JWU has supplied these areas with piped water (PWA, 2007).

2.8.2 Quantity of Water Supply

The quantity of water supplied for the domestic sector in Ramallah and Al-Bireh governorate was 2.82 Mcm in 2007 (PCBS, 2008*g*). This represents the water quantities pumped from wells with domestic permits. No water quantities used for domestic use and pumped from agricultural wells with agricultural permits were recorded, and likewise no water quantity discharged from springs and used to supply localities through public networks were recorded. About 10.88 Mcm of water was purchased from Mekorot (which includes the pumped water from the wells which are located in the Palestinian Territory and controlled by Mekorot). Thus, the total quantity of water supplied for the domestic sector in Ramallah and Al-Bireh governorate was about 13.70 Mcm in 2007, the second highest governorate in the West Bank following Hebron, which was supplied with 16.87 Mcm in 2007 (PCBS, 2008*g*). It is important to note that in some areas there is a big difference between supply and actual household use. By taking into consideration the commercial and public consumption and after deducting the loss rate, this difference can be high.

2.9 Economy

Ramallah and Al-Bireh governorate has become the economic center in the West Bank. In recent years, the governorate has developed at an incredibly high rate, where many new commercial centers and housing projects have been constructed and many investors have established new businesses (HWE, 2009). Economic activities in Ramallah and Al-Bireh governorate range from agricultural to commercial and industrial activities, but generally speaking, agricultural activity has declined and cultivated lands are being replaced by residential and commercial ventures.

The number of economically active Palestinian population in Ramallah and Al-Bireh governorate is 67,254 or 35.6% of the total Palestinian population (in the age group of 10 and over), including 54,356 males or 57.5% of the total male population in the governorate (in the age group of 10 and over) and 12,898 females or 13.7% of the total female population in the governorate (in the age group of 10 and over). The number of unemployed people of the Palestinian population of the Ramallah and Al-Bireh governorate is about 7,516 or 11.2% of the total population (in the age group of 10 and over). The rate of unemployment by locality type is 16.1% in refugee camps, 13.4% in rural areas, and 11.8% in urban areas (PCBS, 2009). The average household's monthly expenditure in the West Bank (household consisting of 6.1 persons) was JD 707.7 in 2008 and the food share of total expenditure is 35.4% (PCBS, 2008*h*).

The most commonly used indicator of the national output of goods and services has been the gross domestic product (GDP), which is the value of final goods and services produced within the nation during a specified period of time. GDP per capita is calculated by dividing GDP by the population of the country, while GDP at constant prices may be measured over a series of years by discounting changes in the value of money (Gilpin, 2000). Table 2-2 shows the GDP in constant prices, GDP per capita, and household expenditure in Palestine from 1994 to 2008.

Table 2-2 Economic indicators in Palestine from 1994 to 2008

Indicator	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Population by mid 2009															
Palestinian Territories	-	-	-	2,871.60	2,962.20	-	3,053.30	3,138.50	3,225.20	3,314.50	3,407.40	3,508.10	3,612.00	3,719.20	3,825.50
West Bank	-	-	-	1,838.80	1,891.20	-	1,943.70	1,992.60	2,042.30	2,093.40	2,146.40	2,203.70	2,262.70	2,323.50	2,385.20
Gaza Strip	-	-	-	1,032.80	1,071.10	-	1,109.70	1,145.90	1,182.90	1,221.10	1,261.00	1,304.40	1,349.30	1,395.70	1,440.30
National Accounts															
GDP	3,012	3,193	3,286	3,702	4,148	4,512	4,119	3,765	3,264	3,750	4,198	4,560	4,322	4,536	4,640
GDP per capita (USD)**	1,406	1,388	1,348	1,438	1,558	1,640	1,450	1,288	1,085	1,211	1,317	1,387	1,275	1,298	1,290
Household Expenditure**	3,062	3,093	3,106	3,493	3,807	4,180	3,982	3,901	3,628	4,103	4,400	4,468	4,198	4,374	-

Source: Central Bureau of Statistics. the Palestinian Monetary Authority.

* West Bank: means the West Bank except that part of the Jerusalem governorate which was annexed forcefully by Israel following its occupation of the West Bank in 1967.

** Data in constant prices. Base year for the 1994-2003 is 1997; base year for 2004-2008 is 2004. Data for 2008 is preliminary and subject to revision and amendment and is based on quarterly estimates.

Source: MAS, 2010.

2.10 Water and Sanitation Infrastructure

In Ramallah and Al-Bireh governorate, there are two main institutions working in the water sector as suppliers: the Jerusalem Water Undertaking and the West Bank Water Department. The served area of JWU extends over 600 km^2 and covers for the time being, significant parts of Ramallah and Al-Bireh governorate, which includes Ramallah and Al-Bireh twin cities, 10 other cities/towns, more than 43 villages and 5 refugee camps, and the northern part of Jerusalem. The number of subscriptions is about 51,567 serving a total estimated population of 280,000 people. The remaining localities in the Ramallah and Al-Bireh governorate are either supplied with water by the West Bank Water Department or not yet served (JWU, 2007). About 92% of the governorate is served by a public network, 5% is served by a private system, and about 3% has no piped water supply (PCBS, 2007).

2.11 Water Tariffs

The Palestine Water Authority (PWA) is officially mandated to establish an appropriate unified tariff system and monitor its implementation for the water supply and wastewater utilities. The PWA, with the Ministry of Local Government and various municipalities and institutions, produced the ‘Tariff Policy Guidelines’ which interprets the Water Law No. 3 / 2002, with the aim to promote water conservation and ideal consumption. The main goals of the guidelines are to: allow water departments to recover costs for producing and distributing water; ensure social equality, such that households with limited income are able to pay for the tariffs on water consumed for basic human needs; and to promote water conservation, such that the tariff increases with increase water usage (PWA personal communication, 2010).

To differentiate between different water consumers, the tariff system classifies consumers according to water usage, and applies the water tariff accordingly, as shown in Table 2-3. The price of one cubic meter in level 1 is the same as that in level 2, thus they can be considered one main group. The value of 10 m^3 was selected as the end range for level 2 because it was found to be the highest amount of consumption essential for basic human needs in the average Palestinian household, where the average Palestinian household was considered to have 6 persons, thus:

$$10\ m^3 = 10{,}000\ \text{liters}/6\ \text{months} = 1666.7\ \text{liters/capita/month} = 1666.7/30 = 55.6\ \text{l/c/d}$$

This amount (55.6 l/c/d) was considered sufficient for basic human needs, including drinking and cooking, etc. Based on mathematical calculations and classifications of different sectors, the factors for water tariff structure, shown in Table 2-3, were developed to be adopted by the PWA, municipalities, and water providers.

Table 2-3 Factors for water tariff structure

Type of Use	**Levels of Consumption (m^3)**				
	Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
	<5	**5.1 – 10**	**10.1 – 20**	**20.1 – 30**	**>30**
Domestic	1.0	1.0	1.2 – 2.0	2.0 – 2.5	2.5 – 3.0
Public Institution	1.0	1.0	1.5 – 2.0	2.0 – 2.5	2.5 – 3.0
Commercial	2.0 – 3.0	2.0 – 3.0	2.5 – 4.0	2.5 – 4.0	2.5 – 4.0
Industrial	2.0 – 3.0	2.0 – 3.0	2.5 – 4.0	2.5 – 5.0	2.5 – 6.0

Source: PWA, personal communication.

Depending on the type of water use and on the levels of consumption, the price of water is multiplied by the respective factor to determine the water tariff. Presently, each municipality or water provider in the West Bank charges a different price for the quantities of water sold, and each applies their own water tariffs. In the Ramallah and Al-Bireh governorate, the Jerusalem Water Undertaking has adopted a tariff structure which is fundamentally similar to the structure developed by the PWA (Table 2-3), yet the West Bank Water Department and many municipalities have not (PWA, personal communication). It is envisioned by the PWA that all water providers in Palestine will adopt this unified water tariff structure.

CHAPTER THREE LITERATURE REVIEW

This chapter reviews the literature on environmental economics, valuation of water quality degradation and opportunity costs, drinking water quality, and bottled water and filtered water production both locally and internationally. Given the importance of drinking water, there is a wealth of literature on the topic.

3.1 Environmental Economics

'Environmental economics' is a specialized branch of economics which embraces the issues of pollution control, climate change, protection of the natural environment, and conservation, and issues in the resolution of which markets play little or no part, but in which vast natural assets need to be allocated sensibly to the common good (Gilpin, 2000). The subject is therefore concerned with costs and benefits on a social and global scale. Likewise, 'Ecological Economics' is a multidisciplinary field which integrates elements of economics, ecology and other sciences. According to Costanza et. al (1997), ecological economics, encompasses a concern for: (1) sustainability, or the maintenance of human well-being and the services rendered by natural systems over intergenerational time scales; (2) economic efficiency, or the satisfaction of human preferences as operationalized through cost-benefit analysis; and (3) distributional equity, or the just sharing of burdens and benefits between social groups. Economists analyze the problem of environmental disruption as a form of external effects (Ng, 2005) and thus pollution can be considered a negative externality.

3.2 Economic Valuation of Water Degradation

Economic valuation refers to the assignment of monetary values to non-market goods and services, where the monetary values have a particular and precise meaning (Bateman, et.al., 2002). Here, the non-marketed good has no market but contributes positively to human wellbeing, such as cleaner water or air. One way of measuring the economic values attached to non-marketed goods and services is by seeing if they influence actual markets for some other good.

The concept of ‘economic value’ is discussed by Bolt et. al (2005), where it is defined as the maximum willingness to pay for an environmental or natural resource. For example, individuals spend money on bottled water or water filters to avoid exposure to water pollution. This information allows economists to measure the economic values. Some guidance to the value that people place on their environment can be estimated by observing how much is spent on preventing damage to it and on its enhancement, such as the costs of water filters (Gilpen, 2000). Bolt et. al (2005) outline the effects of water pollution, the impacts associated with them and possible techniques to value these impacts, as shown in Figure 3-1.

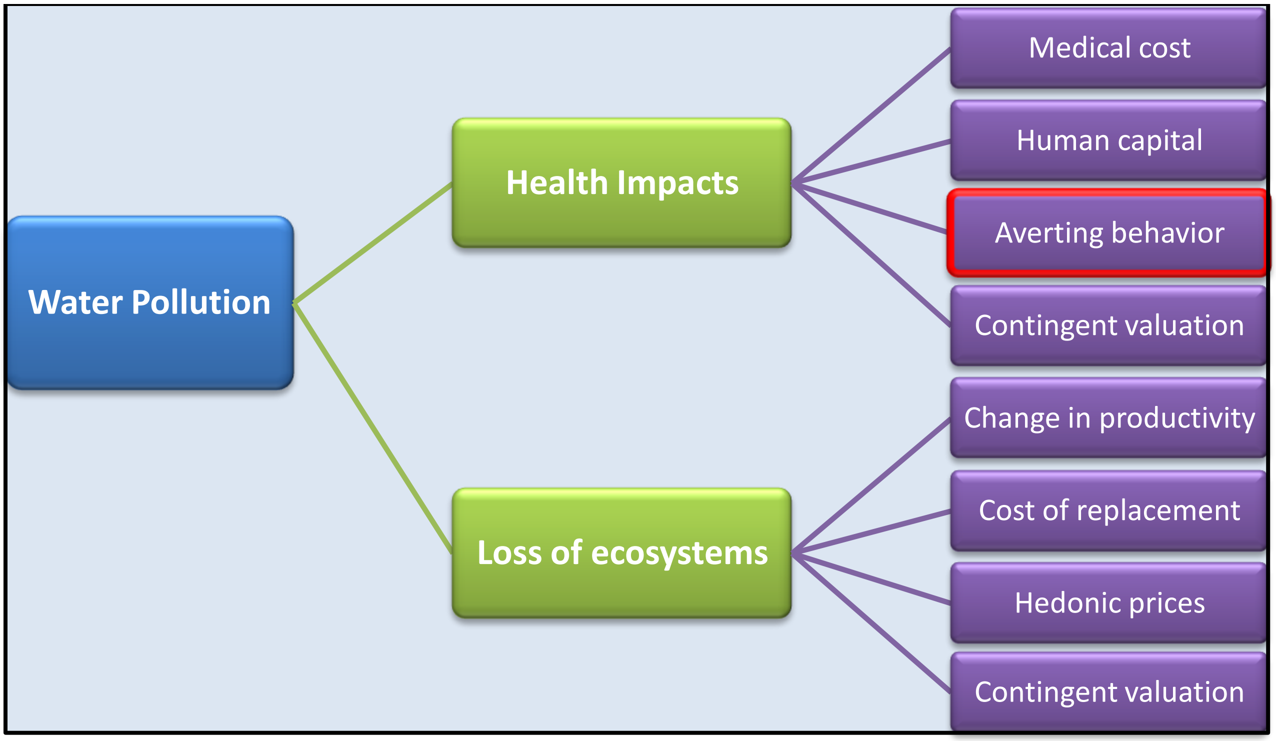


Figure 3-1 Water pollution impacts (Bolt et. al., 2005)

Bolt et. al. (2005) state that often the valuation of health impacts from pollution considers only the actual number of cases of sickness, however, when defensive actions are possible, a researcher must consider how individuals respond to avoid (increase) exposure to an environmental hazard. This is known as averting or defensive behavior. Therefore, the effect of pollution is not only sickness, but also the amount of resources spent to avoid it.

The averting behavior method begins with the notion that people try to protect themselves when faced with environmental risk thus requiring expenditures that would not be made if not faced with the environmental health risk. For example, the purchase of bottled water or water filters may only be made when faced with the risk of contaminated drinking water. In the context of water resources, households may respond to increased degradation in various ways that are generally referred to as averting or defensive behaviors so as to avoid the adverse impacts of water contaminants (Birol, 2006). These include buying non-durables (e.g., bottled water), making expenditures to reduce water contamination (e.g. purchasing filters), and changing behavior to avoid exposure to the contaminant. Um et. al. (2001) studied the willingness to pay for improved drinking water quality using averting behavior method with perception and found that the perception measure provided a valid explanation for citizens' aversion to using tap water in Korea.

The averted expenditures on bottled water in Lebanon were studied by Sarraf et al. (2004), where it was found that the lack of safe potable water, or perception thereof, has an additional cost in terms of averted expenditure on bottled water, estimated at US$82-89 million per year, or around 0.5 percent of GDP per year.

3.3 Economics of Opportunity Cost

'Opportunity Cost' is defined as the value of the thing that is sacrificed by making a particular choice, where the value of resources allocation to the options chosen is conventionally measured in money terms (Bateman et. al., 2002). In other words, opportunity cost is the value of what is foregone in order to have something else. This value is personal to each individual and determined by wants and resources (such as income). Today economists recognize that water resources, and the natural systems they support, provide many economic goods and services (Jarvis, 2008). A consideration of opportunity cost assists in ensuring that resource are put to the best use and that all costs are taken into account, thus in cost-benefit analysis (CBA), the opportunity costs should be taken into account in the assessment, yet CBA is often used in situations where the signals that market prices often provide are either absent of fail to reflect adequately the opportunity cost of the resources involved (Gilpin, 2000).

3.4 International Drinking Water Quality

The United Nations General Assembly, at its Millennium meeting in 2000, established eight Millennium Development Goals (MDGs) with targets to be achieved by 2015, with the aim of speeding up poverty alleviation and socio-economic development. The MDGs, which respond to the world's main development challenges, were drawn from the actions and targets contained in the Millennium Declaration that was adopted by 189 nations-and signed by 147 heads of state and governments during the UN Millennium Summit in September 2000 (UN, 2009). Water quality management contributes both directly and indirectly to achieving the targets set out in all eight MDGs, and it is most significant to ensure environmental sustainability and indicators of water quality can be used to demonstrate progress toward the targets, by plotting trends in water quality over time and over space (UN, 2006). Overall, the total economic benefits of meeting the MDG target, to halving the proportion of people without access to safe water and sanitation by 2015, have been estimated at US$ 84 billion (SIWI, 2005). Water contributes to poverty alleviation in many ways – through sanitation services, water supply, affordable food and enhanced resilience of poor communities to disease, climate shocks and environmental degradation (UN, 2009).

The problem of drinking water quality, however, is not confined to the developing world where water treatment may not exist or is inadequate. Studies have also shown that drinking water quality in developed countries may also not be assured. Many first world waters suffer from serious and long lasting contamination, mainly due to: high amounts of salt, a particular problem for many irrigated areas and coastal areas with over-exploited aquifers; and fertilizer and pesticide residues from agriculture which in some areas have percolated down to deep aquifers (Dickie, 2006). For example, in the US, there is increasing anxiety over the level of contamination with chemicals and pathogens in water sources and water supplies (Richardson, 2003; Berry et al, 2006). In France, drinking water testing uncovered that 3 million people were drinking water whose quality did not meet WHO standards, and 97% of groundwater samples did not meet standards for nitrate in the same study (UN, 2009).

3.5 Local Water Quality

Water quality in the Eastern, North Eastern and Western aquifers of the West Bank area are characterized as good, with some limitations concerning the major parameters such as chloride, sodium, potassium, sulphate, nitrate, and other biological indicators such as fecal coliform, and total coliform (Samhan et al., 2009). Generally, water in the Ramallah area is considered of good quality (interview with staff of Palestinian Water Authority, Jerusalem Water Undertaking and Ministry of Health). Anayah, and Almasri (2009), carried out an assessment of nitrate concentrations in the aquifers of the West Bank, Palestine, and found that in general, all the districts except Ramallah and Al-Bireh, have nitrate concentrations that severely exceed the maximum contaminant level of 10 mg/l NO_3-N (50 mg/l NO_3, based on the USEPA for the year 2000.

3.6 Water Quality Testing and Monitoring in the West Bank

The protection of valuable water resources and regular monitoring of the water quality in the West Bank are the main environmental priorities of the Palestinian National Authority. Water quality monitoring in the West Bank is not only one of the main responsibilities of the

Palestinian Water Authority (PWA) but is also a fundamental concern for many other national organizations. Thus, the joint efforts and cooperation of all concerned parties ensure that safe and clean water reaches the population.

3.6.1 The Palestinian Water Authority

The Palestinian Water Authority (PWA) is the regulating body for the water sector in the West Bank and Gaza. By its own definition, its roles and responsibilities include the enforcement of water pollution controls and protection of water resources. One of the highest priorities of the PWA is to ensure the safety and health of Palestinian residents, the protection of water resources, and the prevention of their contamination and overexploitation. The PWA regularly monitors water quality through a monitoring program, carried out by the Water Quality Department. Water samples are regularly gathered from wells and springs, and are analyzed chemically and physically (PWA, 2007). Bacteriological tests are carried out by the Ministry of Health, since that ministry is responsible for the water purification/chlorination.

3.6.2 The Palestinian Ministry of Health

The Palestinian Ministry of Health (MoH) is the regulator of the health subsector in Palestine. The MoH is responsible for establishing and regulating health standards and guidelines in the West Bank. These include drinking water standards and guidelines for other uses of water in the West Bank (MAS, 2009). MoH is responsible for monitoring the quality of water reaching the users. The tests performed are mainly physical, chemical, and microbiological tests, which are carried out by the Central Public Health Laboratory. The Central Public Health Laboratory (CPHL) is the technical and scientific body of the Ministry of Health, accredited by the Palestinian Standards Institute (PSI) according to the ISO/IEC 17025, 1999 (updated in 2005). It provides suggestions and opinions to the Ministry of Health concerning health issues. The mission of the CPHL is to identify and control the agents that might affect human health, which is achieved by performing suitable laboratory analysis, surveys and scientific researches on special issues.

The CPHL cooperates with other public health divisions to prevent and control diseases and to identify health hazards in the environment, food, water, etc. and to help in corrective action decision. These divisions include the: Sample Receiving Division, which is responsible for receiving and handling water samples, among others; Microbiology Division, where microbiological test are carried out for water, wastewater, etc.; Chemistry Division, where chemical tests are carried out; Quality Assurance Division, which monitors and maintains the quality assurance program and reports the results of its observations to the Directorate (personal communication with CPHL).

3.6.3 Jerusalem Water Undertaking and West Bank Water Department

These institutions are responsible for monitoring their water systems, which includes the sources, water tanks, and main distribution networks which fall under their jurisdiction (PWA, 2007). Regular monitoring includes physical and bacteriological testing, which have the most significance in regards to public health based on WHO guidelines (WHO, 2008).

3.6.4 UNRWA

The United Nations Relief and Works Agency for Palestine Refugees in the Near East (UNRWA) provides assistance, protection and advocacy for Palestinian refugees. UNRWA is the main provider of basic services, including water, to registered Palestine refugees, and is responsible for monitoring their water services inside Palestinian refugee camps. Their water resources, which include springs, wells, water distribution pipelines carrying purchased water from Mekorot, main water tanks, are regularly monitored according to WHO standards (PWA, 2007).

3.7 Laboratory Water Testing

To ensure that water quality in Palestine is in accordance with standards, the Jerusalem Water Undertaking and Central Public Health Lab of the Palestinian Ministry of Health undergo regular sampling of the water at different sources and carry out a variety of quality tests. This process includes: i) Sampling ii) Transport of samples iii) Testing of samples. These are considered equally important for ensuring accurate test results (JWU, 2006). In reality, every water sample in contact with the atmosphere contains dissolved gases, including oxygen and carbon dioxide and every water sample in contact with sediment and rock contains other dissolved constituents such silicon and calcium. Therefore, in the natural environment there is no such thing as ‘pure water’ in the chemically rigorous definition (Vanloon and Duffy, 2005).

Water samples in Ramallah and Al-Bireh governorate are collected regularly by the proper authorities and are tested for major chemical and microbial parameters. Main chemical analysis includes major cations such as calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K), and major anions like bicarbonates (HCO_3), chloride (Cl), sulphate (SO_4) and nitrate (NO_3). Major physical parameters include pH, temperature and conductivity and major microbial parameters are fecal coliform and total coliform.

The following sections provide the usual chemical, physical, and microbiological characteristics of water and describe their significance. Reference is made to the following standards:

a) The Palestinian Standards Institute Guidelines for Drinking Water- updated in 2005;

b) The World Health Organization Guidelines for Drinking Water-Water Quality, updated in 2008.

3.7.1 Major Chemical and Physical parameters in water

Chemical substances are naturally found in some drinking water supplies but these are generally only a concern if they are present above guideline levels and if a person is exposed to them over a period of years. Advances in science are showing that exposure to some chemical contaminants above guideline levels may be a concern in the short-term as well. Physical and aesthetic quality guidelines address parameters which may affect consumer acceptance of drinking water, such as taste, odor and color. A description of each of these parameters, based on scientific references (Twort, et al, 2000; WHO, 2008; EPA, 2009) is presented below:

- ***Calcium***

Calcium is found in most water in the form of calcium carbonate or bicarbonate, especially in water that are associated with chalk or limestone, and as calcium sulphate. The level of calcium depends on the type of rock through which the water has passed. Since calcium is an essential part of the human diet and since the nutritional value from water is usually minimal compared to the amounts of calcium obtained from an average diet, there are no health objections to high calcium content in drinking water. Thus, no maximum allowable limits are specified in the WHO guidelines. The PSI guidelines suggest a maximum desirable limit of 100 mg/l. Main limitations may be expressed to prevent excessive scale formation.

- ***Chloride***

Chlorides are found in almost all water, usually in combination with sodium. Chlorides occur from several sources including mineral deposits, agricultural or irrigation discharges, urban runoff, or from sewage and industrial effluents. The main problems caused by high chloride content in water are: i) increase corrosion rate of iron, steel and plumbing metals; ii) taste, where some people may detect chlorides in drinking water at concentration levels as low as 150 mg/l, and at levels above 250 mg/l a salty taste can be obvious to most people. The WHO guide level for chloride is 250 mg/l. This is the same level required by the PSI guidelines.

- ***Magnesium***

Magnesium forms highly soluble salts which contribute to the hardness of water. Thus, high amounts of magnesium in domestic water cause problems of scale formation. The WHO guidelines do not specify maximum concentrations of magnesium. The PSI guidelines suggest a maximum desirable limit of 100 mg/l.

- ***Sodium***

Sodium compounds are very abundant in the environment and are soluble in water. Sodium may impart a taste on water, depending on the water temperature and anions present. The WHO guideline value and the PSI guideline value for sodium is 200 mg/l, based on taste.

- ***Potassium***

Potassium is an abundant element, but rarely found in high concentrations in natural waters. The WHO guideline does not specify a maximum value for potassium. The PSI guideline suggests a maximum acceptable limit of 10 mg/l.

- ***Fluoride***

Fluoride in drinking water has been associated with dental issues. Fluoride levels have to be closely controlled since an excessive amount can lead to fluorosis, resulting in mottling of the teeth, and low levels of fluoride may result in increased dental problems. The greatest reduction of dental decay occurs if the fluoridated water is drunk in childhood during the period of tooth formation. The WHO and PSI guideline value is 1.5 mg/l.

- ***Sulphates***

Sulphates come from several sources such as the dissolution of gypsum and other mineral deposits containing sulphates; from seawater intrusion; from the oxidation of sulphides, sulphites, and thiosulphates in well aerated surface waters; and from industrial effluents where sulphates or sulpuric acid have been used in processes such as tanning and pulp paper manufacturing. The WHO maximum allowable value is 250 mg/l SO_4 based on taste and corrosion potential, where the PSI maximum allowable value is 200 mg/l SO_4.

- ***Nitrite and Nitrate***

Nitrite is an intermediate oxidation state of nitrogen. The presence of nitrites may be a sign of sewage pollution, but that may not always be the case. Nitrate is the final stage of oxidation of ammonia and the mineralization of nitrogen from organic matter. High Nitrate concentrations in both surface water and groundwater may be attributed to the use of nitrogenous fertilizers on the land. Water with high nitrates may be potentially harmful to infants, causing methaemoglobinamia, also known as ‘Blue Baby Syndrome’. The WHO guideline value for nitrate as NO_3 is 50 mg/l and for nitrite as NO_2 is 3 mg/l. The PSI guideline value for nitrate as NO_3 is 50 mg/l, but may be acceptable to a maximum limit of 80 mg/l if no alternative water source is available. The PSI guideline does not specify a value for nitrite.

- ***Total Dissolved Solids and Electrical Conductivity***

The total dissolved solids (TSD) refer to the amount of salts in water. Since salts are in the form of ions in solution, then this allows electrical conductivity. Thus, electrical conductivity, which is a measure of the ability of a solution to carry electrical current, is dependent on the amount of

TDS. Water with high levels of TDS can result in a salty taste and may cause scaling to water systems. On the other hand, water with low levels, which is desirable for many industrial processes, may also have an unacceptable taste to consumers and may be corrosive to domestic plumbing. There is no WHO or PSI guideline value for conductivity, instead the WHO and PSI have set a guideline level of 1,000 mg/l for total dissolved solids.

- ***pH value***

The pH value is a measurement of the acidity of water. It is an important parameter in water chemistry since many of the processes involved in water treatment are pH dependent. A solution is said to be neutral when the numbers of hydrogen ions and hydroxyl ions are equal, each corresponding to an approximate concentration of 10^{-7} moles/l. This neutral point occurs at pH 7.0 at 25°C. At pH values less than 7.0, the water has acid characteristics; at pH values greater than 7.0, the water has basic characteristics. Waters which have percolated through chalk or limestone, as is the case in most of the West Bank, generally have higher pH values. The WHO guidelines give a range of 6.5-8.5 for the pH value of drinking water and a treatment pH value of <8.0 for effective disinfection with chlorine. Likewise the PSI sets a pH range of 6.5-8.5 for drinking water.

- ***Hardness***

Hardness refers to the characteristic of typical hard water, which when it reacts with ordinary soap forms a curd or scum. Hardness is expressed as $CaCO_3$. The problems caused by excessive hardness are mainly the formation of scale in kettles, boilers and hot water systems. Based on aesthetic characteristics, the WHO and PSI guidelines suggest maximum desirable limit for total hardness as $CaCO_3$ to 500 mg/l.

- ***Alkalinity***

Alkalinity is generally considered as the opposite of acidity, where as the pH value increases, the alkalinity increases. The alkalinity of water actually comes from the sum of bicarbonates, carbonates, and hydroxides of calcium, sodium, and potassium. Alkalinity is a key factor in determining the corrosive properties of water. Both the WHO and PSI guidelines do not specify a maximum value for alkalinity.

- ***Turbidity***

Turbidity is an optical property which causes light to be scattered and absorbed rather than transmitted in straight lines through a sample. The WHO guidelines set the maximum value to be 5 NTU, which is acceptable to consumers, and also set a treatment standard of less than or equal to 1 NTU for successful disinfection. The PSI set a maximum value of 1 NTU.

- ***Color***

The color of water is a physical characteristic which determines the acceptability of water upon consumer perception. The WHO and PSI guidelines give a guide level of 15 TCU (true color units), above which the color would be noticeable in a glass of water by most people.

3.7.2 Microbiological parameters in water

The most significant risks to people's health from drinking water come from microscopic organisms such as disease-causing bacteria, protozoa and viruses. The guidelines that relate to these microorganisms are stringent because the associated health effects can be quite severe and can also affect health over the long-term.

- ***Total Coliform and Fecal Coliform***

Coliform bacteria are found all over the environment and have been used as indicator organisms by water microbiologists. This group may contain a species that are referred to as 'thermotolerant (fecal) coliforms', which is natural to the intestine and is present in the feces of man and other warm blooded animals. E.coli is one of these, which if found in drinking water provides clear evidence of fecal pollution. The WHO and PSI standards have a common standard for drinking water:

- no fecal coliforms detected in 100 ml of sample;
- the Total Coliform in the water tested must not exceed 3/100 ml;
- 95% of 100 ml samples must not show the presence of coliform organisms.

3.8 Water Quality Standards and Guidelines

3.8.1 General Definitions

In water quality, the terms 'standards' and 'guidelines' are used interchangeably. These terms can be generally defined to prevent confusion. According to the Merriam-Webster Dictionary (2010), a 'standard' is something set up and established by authority as a rule for the measure of quantity, weight, extent, value, or quality and a 'guideline' is a guide or an indication or outline of policy or conduct. In other words, a standard is usually a collection of specific requirements for a system or procedure, which must be met by everyone. A guideline is typically a collection of 'suggestions', developed for best practice and they are not requirements to be met, but are strongly recommended based on facts and evidence.

The words 'pollutant' and 'contaminant' are also generally used interchangeably, but a distinction can be made by adopting the definitions made by the *Dictionary of Environmental Science and Technology*, where a contaminant is defined as "any substance present in the environment above a 'natural' level whether or not it causes a detrimental effect" and a pollutant is defined as "a contaminant that causes adverse effects". Here, it is possible to define water pollution as any concentration of chemical (or microorganism) in water above the 'natural' (also called background or baseline) level (Vanloon and Duffy, 2005). This definition implies that there must be a set of standards or guidelines which provide an indication of the properties which if exceeded would constitute an adverse effect. Scientific research over the past years have helped identify many toxic products in drinking water and have helped develop regulations and guidelines for the protection of the public health from waterborne diseases. The World Health Organization (WHO) set such guidelines for drinking water quality which act as advisory values for world-wide application. The Palestinian Standards Institute also set such standards which are mandatory for water undertakers in Palestine. These are discussed below.

3.8.2 WHO Drinking Water Standards

An established goal of WHO and its Member States is that *'all people, whatever their stage of development and their social and economic conditions have the right to have access to an adequate supply of safe drinking-water'* (WHO, 2008). 'Safe drinking water' here refers to a water supply which is of a quality which does not represent a significant health risk, is of sufficient quantity to meet all domestic needs, is available continuously, is available to all the population and is affordable. These conditions can be summarized as five key words: quality; quantity; continuity; coverage; and, cost (WHO, 2008). The first WHO publication dealing specifically with drinking water quality was published in 1958 as '*International Standards for Drinking-Water'*.

Thousands of organisms and substances have been identified in drinking water supplies around the world, but the WHO Guidelines do not specifically discuss each and every one because it is neither necessary nor feasible to develop recommendations for all these. Microorganisms selected for evaluation were selected through an international consultation process, on the basis of the presence in water and likely risk to human health. A special emphasis was given to developing guidance on selection of indicator organisms that can give early warning of faecal contamination and likely potential risks of disease.

The WHO Guidelines adopted a clear policy that microbiological quality must be the key water quality priority, and thus the chemicals for evaluation were selected through an international consultative process, guided by three main criteria: i) The substance presents a potential hazard for human health; ii) The substance was detected relatively frequently and at relatively high concentrations in drinking-water indicating that there may be significant exposure to humans; iii) The substance was of major international concern (i.e. of interest to several countries). On this basis, 128 priority chemicals were selected for evaluation in the WHO *Guidelines* and health-based acceptable levels of exposure from drinking-water (Guideline Values) recommended for 95 of these, taking into account all sources of exposure. *Guideline* values were not recommended for certain substances because they were found to be not hazardous to health, because of inadequate health effects information, or because the concentration of the chemical normally found in drinking-water does not represent a hazard to human health.

The guideline values set forth by the WHO represent the concentration of a chemical constituent that does not result in any significant risk to the health of the consumer over a lifetime of consumption. *Guidelines* are set for indicator bacteria - *E.coli* or thermotolerant (faecal) coliforms and total coliforms, which give a good indication of the likelihood of faecal contamination in a water supply.

It is important to note that short-term deviations above the guideline values do not necessarily mean that the water is unsuitable for consumption. The amount by which, and the period for which, any guideline value can be exceeded without affecting public health depends upon the specific substance involved. Also, no attempt was made in the guidelines neither to define minimum desirable concentrations of essential elements in drinking-water nor to determine aesthetic parameters.

3.8.3 Palestinian Drinking Water Standards

The Palestinian Standards Institute (PSI) is Palestine's standards organization, founded in 1994. PSI provides access to national and global standards, mainly in the fields of food, electrical engineering, mechanical engineering, civil engineering, and chemistry.

In 2005, PSI released an updated version of the 'Drinking Water' specifications, PSI 41-2005 (PSI, 2005). This publication presents conditions for the physical, biological, and chemical characteristics of drinking water. In the same year, the PSI also released 'Bottled Drinking Water' specifications. These are discussed in section 3.12. The 'Drinking Water' specifications specifically refer to that water 'which is suitable for drinking, domestic purposes, that which is used in the food industry, and that which complies with specifications PSI 41-2005.

3.9 International Bottled Water Consumption

The world bottled-water market represents an annual volume of 89,000 million liters, and is estimated to be worth USD 22,000 million; western Europeans are the world's major bottled water consumers, consuming about 85 l/c/year (Ferrier, 2001). According to the Food and Water Watch, a nonprofit consumer rights organization based in Washington-DC, consumers are wasting hundreds and thousands of dollars on bottled water because they think it is healthier or safer than its counterpart from the tap. Their report shows that Americans alone are drinking a lot of bottled water: 31.4 billion gallons or 98.4 liters per person in 2006 (FWW, 2007). Lebanon's population consumes a large quantity of bottled water, where the bottled water consumption is about 115 liters per capita per year (Sarraf et. al., 2004). Table 3-1 shows the global bottled water statistics for production volume, production value, and per capita consumption for bottled water between 2000 and 2003. The numbers show that the per capita consumption is generally increasing over the years for most countries and in terms of per capita consumption, West Europe and the USA top the list. Appendix 1 offers the per capita bottled water consumption by country from 1999 to 2004. It is shown that Italy, Mexico, and the United Arab Emirates lead the table with over 160 liters per person per year. European countries dominate the top of the list and poorer countries are found at the bottom of the list, as shown in table 3-1, providing some indication of perhaps the limited availability and/or the high cost of bottled water in developing countries. Appendix 1 also offers the global bottled water, which shows that bottled water consumption is greatest in Europe, though the rate of increase in North America and Asia is higher.

Table 3-1 Global Bottled Water Statistics

Region	Production volume (in million litres)				Production value (in million USD)				Per Capita Consumption (litres)			
	2003	2002	2001	2000	2003	2002	2001	2000	2003	2002	2001	2000
Africa & Middle East	12,400	11,220	9,200	8,720	2,110	1,825	1,450	1,250	11	10	9	9
Asia	33,465	30,100	24,030	19,990	7,395	6,490	4,500	3,650	10	9	7	6
Australia	695	650	850	740	440	340	400	350	35	33	37	33
Canada	1,490	1,310	920	820	650	525	350	310	47	41	29	26
East Europe	9,500	8,330	6,770	6,010	2,630	2,250	1,500	1,400	24	21	17	15
Latin America	27,050	26,060	26,950	25,150	3,970	3,800	5,050	5,809	51	50	53	50
USA*	24,463	23,803	24,414	22,020	8,277	7,724	14,500	13,600	90	85	74	67
West Europe	44,020	39,970	38,210	36,350	20,300	15,200	14,500	14,600	112	102	97	93
TOTAL	153,083	141,443	131,344	119,800	45,772	38,154	34,227	30,819				

Source: International Council of Bottled Water Associations, 2004

According to Gleick, 2004, the global consumption of bottled water is growing faster than 10% per year with substantial growth in sales volumes on every continent. The highest growth rates are occurring in Asia and South America, with annual sales increases of 15% or more in places as diverse as Egypt, Kuwait, the United States, and Vietnam, and the slowest growth is occurring in European countries, where bottled water has long had a commercial foothold. Even there, growth rates of five to ten percent per year are common.

3.10 Bottled Water Consumption in Palestine

In 2007, the average monthly household quantity of mineral water consumed in the Palestinian territory was 0.765 L, where 0.049 L. were consumed in the Gaza Strip, 1.105 L in the West Bank, and 0.615 L in the West Bank not including Jerusalem. In the Palestinian territory, the average household monthly consumption is subdivided by localities as follows: 0.113 L in camps, 0.5 L in rural areas and 1.098 in urban areas. This is also subdivided by 'household level of living' as 0.06 L for households classified as 'worse-off', 0.911 for households classified as 'middle', and 1.159 for households classified as 'better-off' (PCBS, 2008). The Level of Living is identified by the proportion of consumption on food out of the total consumption and is distributed to three categories: Better-off (food consumption to total consumption less than 30%); Middle category (food consumption to total consumption between 30-44%); Worse-off (food consumption to total consumption between 45-100%).

3.11 Bottled Water Quality Assessments

The main selling point of bottled water companies has generally been the superior water quality over any other sources. Yet, the quality of bottled water has been questioned in several reports and scientific studies. The Natural Resources Defense Council carried out a four-year scientific study of bottled water which included the testing of more than 1,000 bottles of 103 brands of bottled water, and found that while most of the tested waters were found to be of high quality, some brands were contaminated -about one-third of the waters tested contained levels of contamination (NRDC, 1999). Zamberlan da Silva et al, (2006) showed that the bacteriological quality of municipal tap water is superior when compared with the 20-L bottles of mineral water collected from water dispensers and samples collected from new 20-L bottles of mineral water before installation in the dispensers. Other studies have investigated chemicals and trace metals found in bottled water (Snyder, et al, 2009; Keresztes, et al, 2009; Krachler, et al, 2008).

3.12 Bottled Water Standards and Guidelines

Bottled water standards and guidelines have been set by the Palestinian Standards Institute. The WHO Guidelines apply to bottled water and ice intended for human consumption but do not apply to natural mineral waters, which should be regarded as beverages rather than drinking-water. The Codex Alimentarius Commission has developed Codex standards for such mineral and bottled waters.

In 2005, the Palestinian Standards Institute (PSI) released an updated version of the PSI ‘Bottled Drinking Water’ specification, PSI 69-2005, updated in 2008 (PSI, 2008). This publication outlines the types of bottled water and their classification, guidelines for methods of water production, treatment, bottling, storage, and transport. These guidelines describe procedures for labeling and marketing bottled water, and provide requirements for the chemical and microbiological characteristics of the water, as well as methods for testing. The PSI standard refers to complementary references from:

- Codex Alimentarius Commission, second edition (revised 1999)

- FDA, Food Code U.S. Public Health Service -1999
- Food Chemcial Codex FCC

These are discussed in further below.

- **Codex Alimentarius Commission, second edition (revised 1999)**

The Codex Alimentarius Commission was created in 1963 by FAO and WHO to develop food standards, guidelines and related texts such as codes of practice under the Joint FAO/WHO Food Standards Program. The main purposes of this Program are protecting health of the consumers and ensuring fair trade practices in the food trade, and promoting coordination of all food standards work undertaken by international governmental and non-governmental organizations. The Codex Alimentarius provides a collection of internationally recognized standards, codes of practice, guidelines and other recommendations relating to foods, food production and food safety. It has been published in many languages including Arabic. Codex Alimentarius standards and guidelines have been published for bottled water and drinking water.

- **FDA Food Code U.S. Public Health Service, 1999**

The US Food and Drug Administration (FDA) publishes the *Food Code* to assist food control governmental authorities in regulating the retail and food service industry, which includes restaurants, grocery stores and institutions. The Food Code provides a scientifically sound technical and legal basis for regulators and allows them to develop or update their own food safety rules and to be consistent with national food regulatory policy. The Food Code is updated every four years but during this period the Food Code Supplement provides updates, modifications, or clarification on certain provisions. In 2009, the latest edition of the FDA Food Code was published.

- **Food Chemical Codex FCC**

The FCC, first published in 1966, provides a collection of internationally recognized standards for the purity and identity of food ingredients. The FCC aims to protect commerce and public health by providing criteria and analytical methods to determine the quality of food ingredients. FCC standards are used as agreed standards between suppliers and manufacturers in ongoing purchasing and supply decisions and transactions and they can aid manufacturers in distinguishing genuine products from inferior ingredients and substances. This helps to make the food supply chain safer and assuring consumers of the quality of the food products they eat.

3.13 Adopted Definitions for Bottled Water

According to the Palestinian Standards Institute Guidelines for Bottled Drinking Water (PSI 69-2005), the following definitions have been adopted to classify the different types of bottled water:

1) Bottled water: Water filled into sealed containers which is safe and suitable for direct consumption, and complies with these set forth standards.
2) Sparkling Bottled Water: bottled water to which CO_2 has been added during treatment.
3) Groundwater: water which originates from the subsurface and aquifers.
4) Natural water: water which has not been subjected to any type of treatment, except for disinfection, such that there have been no changes made to the natural physical and chemical properties.
5) Mineral water: water which originates from a natural source and has a value of TDS which is equal to or less than 250 mg/l.

6) Treated drinking water (purified): water which has been subjected to a type of treatment method or technology, such as ion exchange or reverse osmosis or any other suitable treatment which allows the water to comply with drinking water standards.
7) Spring water: water which naturally emerges from underground to the surface at a natural location.
8) Well water: water which is pumped from a groundwater well.

3.14 Production and Treatment of Bottled Water in Palestine

The Palestinian Standards Institute guideline for 'Bottled Drinking Water' describes standards and procedures for the production and treatment of bottled drinking water, and its filling, storage, transport, and marketing.

The standards for bottled drinking water production and treatment include:

- The water source must be licensed by the Palestinian Water Authority (PWA) and monitored by the Palestinian Ministry of Health (MoH), through which a microbial test must be performed daily and chemical tests must be performed routinely every six months.
- Water must be transferred from the source to the bottling factory by a transmission line or water tanks, which must be licensed by the MoH and PWA.
- The water bottling production line must only be used for water and not any other product.
- Only the following processes may be used for the treatment of water:
    - Sedimentation and filtration;
    - Activated Carbon Filter;
    - Disinfection, using methods approved by the MoH;
    - Distillation;

  - Reverse Osmosis;
  - Ion exchange.

The standards (PSI, 2005) for bottled drinking water filling, storage, transport and marketing include:

- Water may be filled in glass containers or plastic ‘PET’ only for 2 L. volumes; other types of plastic such as ‘PC’ may be used for volumes greater than 2L., only with MoH approval.
- Re-filling plastic bottles of the 2 L. volume or smaller is prohibited.
- Refillable plastic bottles and caps must be cleaned and disinfected, based on MoH procedures, before each use.
- Bottles must be sealed properly after filling to ensure that the water is not contaminated throughout the transporting and storage process; sealing caps must be new and must be produced from materials such as PP, PE.
- Water bottles must adhere to PSI standards, if available, or to Codex standards.
- Water must be transported and stored under sanitary conditions and away from direct sunlight.
- The bottled water label must describe:
  - The type/classification of water;
  - Type of treatment (for treated water);
  - Source of water name and location, production country, production factory and location.
  - Constituents: Mineral constituents (calcium, magnesium, sodium, potassium, bicarbonate, chloride, sulphate, nitrate, nitrite, fluoride, iron) and pH, TDS.
  - Additions of CO_2;
  - Size of container;

- Production and expiration date;
- Etc.

3.15 Footprints of Bottled water

The bottling processes adopted by companies in Palestine generally consume 1.5-2 L. of water for every 1 L. of water (interviews with bottled water companies' personnel). This volume is mainly needed by bottling operation and process, packaging and the transportation phases. This signifies a considerable water footprint for the bottled water industry. In an Italian study, a Footprint Integrated approach was used to assess and compare the impact on the environment and on the resources of tap water and PET-bottled natural mineral water. The results showed that in comparison based on Ecological Footprint and Carbon Footprint, tap water showed about 300 times lower values than bottled water, however, the water footprint values, where only water consumption was accounted, were almost the same for tap water and bottled water (Botto, 2009).

3.16 Local Bottled Water Industries

The bottled water industry in Palestine is a relatively new industry. Before 1999 there were very few bottled water brands being sold in the Palestinian market, and very few of the companies were local. The number of local bottled water companies in Palestine has significantly increased since the year 2000 and the bottled water industry has greatly expanded.

Recently in the Ramallah and Al-Bireh governorate, there has been a noticeable increase in bottled water brands being found in the market. Based on records from the Ministry of National Economy and on field visits, there are over 14 companies producing bottled water for the

Palestinian market. According to the Ministry of National Economy, about 90% the bottled water industry in Ramallah is dominated by four major companies, 2 of which are locally bottled and 2 are imported either from Jordan or Israel.

3.17 Filtered Water

Residents of Ramallah and Al-Bireh are increasingly purchasing water purification apparatuses to treat their drinking water. It should be noted that different units remove different contaminants or classes of contaminants from the water. A water treatment device can either be free-standing, attached to a tap, plumbed in with a dedicated faucet (also called a point-of-use device) connected to a refrigerator's water and ice dispensing system; or centrally attached to treat all water entering a house (a point-of-entry device) (EPA, 2005). Generally, homes are equipped with point-of-use devices. The following provides a description of the types of point-of-use-devices used in the homes in Palestine and their processes (EPA, 2005):

- Filter pitchers: Most water pitchers use granular- activated carbon and resins to bond with and trap contaminants. These filters are effective at improving the taste of water, and many will also reduce lead and other contaminants.
- Activated carbon filters: These filters are effective at improving the taste of tap water and some will also reduce lead, protozoan cysts, and many other contaminants
- Reverse Osmosis Units: Reverse osmosis units force water through a semi-permeable membrane under pressure, leaving contaminants behind. Reverse osmosis units use approximately three times as much water as they treat, but they are effective in eliminating all disease-causing organisms and most chemical contaminants.

CHAPTER FOUR APPROACH AND METHODOLOGY

This chapter presents the study's selected research methodology. The methodology is influenced by the purpose of this study and is based on an assessment of the optimal strategy for responding to the research questions. Based on the purpose of the study and the research questions stated in chapter one, this chapter discusses the research approach adopted for the data collection phase and data analysis procedures.

4.1 Research Approach

The basic research method used in this study is a combination of approaches. The study was both desk-based and field-based. Scholarly articles and books were reviewed on environmental economic assessments, water quality assessments and standards, the international bottled water industry, and home water purification processes and systems. In addition, secondary data on water quality was collected. Interviews were carried out with actors in the bottled water industry and filter dealers as an aid to reveal essential primary data. Research data was sourced, collected and collated accordingly. A survey was conducted to reaffirm selected results and to provide the additional aspect of consumer perception to the discussion of drinking water. Figure 4-1 shows the key steps in the research approach process.

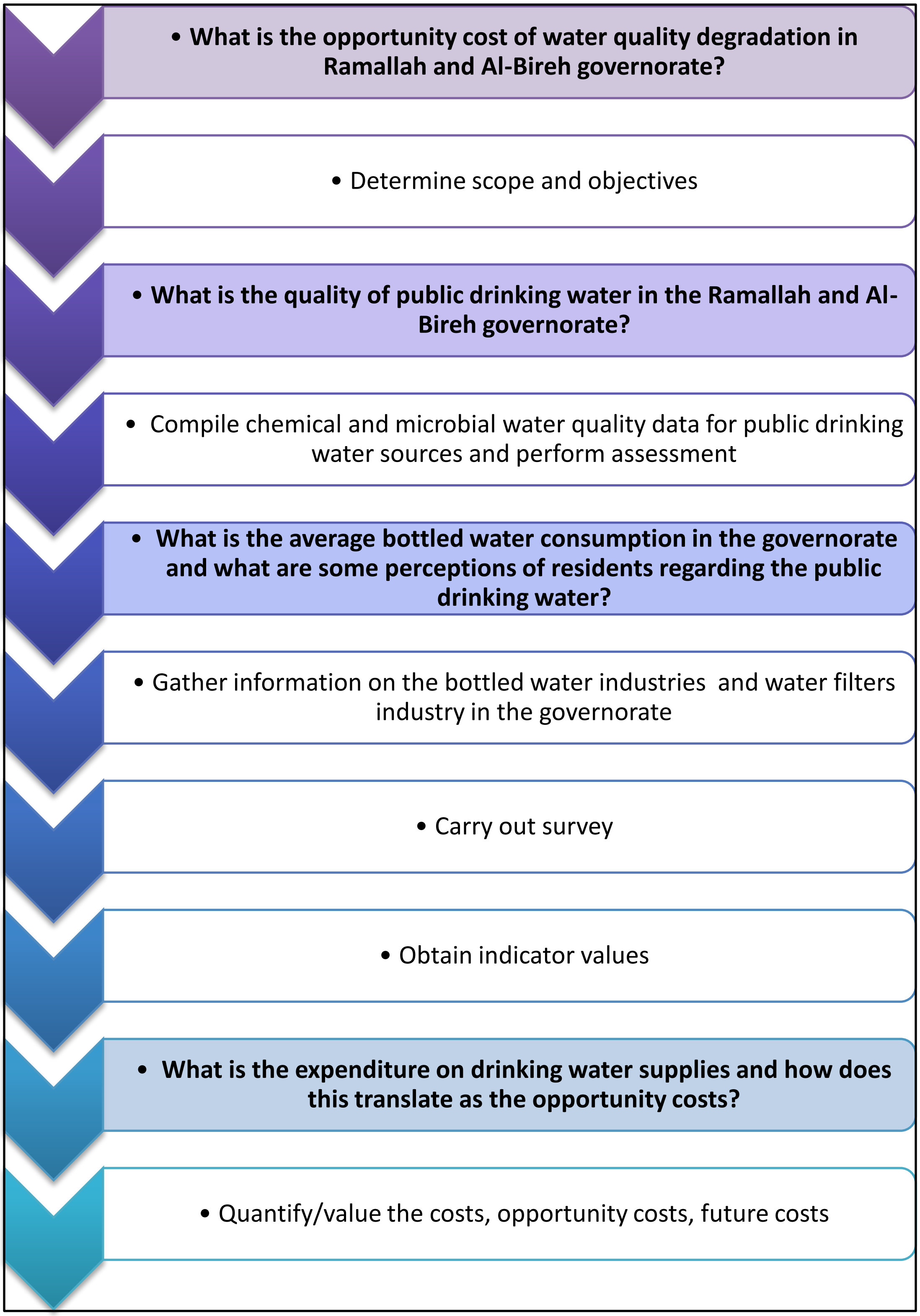


Figure 4-1 Key Steps in the Research Approach Process

4.2 Data Collection

Secondary data was primarily collected through desk-based research, where data was obtained from electronic databases, libraries, and scholarly articles and books. The so-called ‘ancestry approach’, in which references from key papers are systematically traced, was also used. The data used for the public water quality assessment was gathered and assembled from several sources, mainly the databases of the Palestinian Water Authority, Jerusalem Water Undertaking, and the Central Public Health Lab of the Palestinian Ministry of Health. Interviews were held with officials from these institutions to pursue in-depth information about the topics and to identify gaps and questions which can be tackled through this research.

The field-study consisted of a survey of fourteen bottled water companies and/or suppliers, which offer bottled water in the Ramallah and Al-Bireh governorate market. A list of these companies, with contact information, was obtained from the Ministry of National Economy. Interviews were arranged with the directors, mangers and/or technicians of each company. The ‘general interview guide approach’ was adopted, which is an interview approach that intends to ensure that the same general areas of information are collected from each interviewee. This method was selected because it is more structured than the informal conversational interview (Turner, 2010), and provides more focus than the conversational approach but still allows some adaptability in getting the information from the interviewee.

The same approach was adopted to gather information from the water filter dealers. In this case it was more difficult to obtain a list of all the dealers. According to the Ministry of National Economy, no such list exists because water filter suppliers are not registered under a specialized company name, rather many are registered under a ‘general trading’ company name, which deals with many products, including the filters. Therefore, interviews were arranged with the managers of one of the main water filter dealers in the governorate, which supplies units to many smaller companies, and with the managers of a number of water filter companies, identified through local listings.

To gather supplementary data on consumers' intentions, behavior, attitudes and opinions regarding their drinking water supplies, an unstructured questionnaire was prepared and distributed to 155 households, which were selected randomly. The sample size was selected based on adopted scientific procedures for selection of the appropriate sample size in survey research as follows:

$$n = \frac{N}{1 + Ne^2}$$

Where *n* is the sample size, *N* is the number of households in the Ramallah and Al-Bireh governorate and *e* is the level of precision. The level of precision, or sampling error, is assumed to be ±8 percent, the confidence or risk level is selected at 2, which indicates the maximum variability in a population. This gives the sample size as follows:

$$n = \frac{49{,}676}{1 + (49{,}676)(0.08)^2}$$

$$n = 155$$

The questionnaires were distributed evenly over the urban and rural areas of the governorate to justly reflect the behaviors and opinions of the different regions of the governorate. The questions asked aimed to gather information on:

- Type of water consumed in the household (tap, bottled or filtered water).

- Reasons for consuming that water type.
- Amount of water consumed for drinking purposes only.
- Satisfaction of the water consumed.

The main purpose of the questionnaire is to obtain indicator values of the proportions of residents in the Ramallah and Al-Bireh governorate consuming different types of water, in order to estimate the household expenditures on drinking water, to better understand perceptions regarding public drinking water, and to provide an estimate of the average bottled water consumption in the Ramallah and Al-Bireh governorate. The questionnaires were distributed to university students, government officials, employed persons, housewives, and random members of society, etc., through direct, face-to-face interviews and through phone interviews. Open format questions, which are those questions that give an opportunity for people to express their opinions, were asked to solicit true, insightful and even unexpected suggestions.

4.3 Analytical Procedures

The analysis adopted in this research was generally inspired by the ‘averting behavior method’. The averting behavior method begins with the notion that people try to protect themselves when faced with environmental risk thus requiring expenditures that would not be made if not faced with the environmental health risk. The averting behavior method in practice is outlined by Sarraf et.al, (2004) where the application of this approach to valuation is based on the assumption that individuals recognize the existence of a hazard and take actions to avoid it. The steps to be followed in the analysis are:

1. Identification of the environmental hazard and the affected population
2. Observation of the responses of individuals
3. Measurement of the cost of taking actions

There are however important limitations to this method. Individuals may undertake more than one form of averting behavior in response to an environmental change and the averting behavior may have other beneficial effects that are not considered explicitly (Birol, et. al., 2006). For example, the purchase of bottled water to avoid the risk of consuming polluted supplies may also provide added taste benefits. This limitation is mitigated in this study, as described below.

This study thus begins with an analysis of the public water quality in the Ramallah and Al Bireh governorate. Data was gathered for the past 10 years, between 2000 and 2010, from the Palestinian Water Authority, Jerusalem Water Undertaking, and the Central Public Health Lab of the Palestinian Ministry of Health. The chemical and microbial water quality data which was collected is analyzed and compared against Palestinian Standards Institute guidelines and standards for drinking water. The water quality data which was analyzed consists of chemical parameters (including Ca, Mg, Na, K, Cl, HCO_3, SO_4, NO_3), physical parameters (including total hardness, TDS, EC, pH) and microbiological parameters (mainly total coliform, fecal coliform).

The assessment was carried out for water quality ‘at the source’, which includes the Ein Samia well field, Shibtin Well, and Mekorot connections, and water quality ‘in the network’, which includes sampling points within the municipal water distribution network. The data for water quality taken at monitoring points within the distribution network of the (CPHL) Ramallah and Al-Bireh governorate was obtained mainly from the Central Public Health Lab of the Palestinian Ministry of Health. It is important to note the following in regards to this data from the CPHL:

- The laboratory was established in 2002, but the water quality database was organized and digitized in 2004. Thus, it is difficult to obtain any water quality data before 2004.

- In 2004, 2005, and 2006, the terminology for types of water being tested was ambiguous and inexplicit. The exact location of the water samples collected during these years was not recorded. For example, water type classified as 'Groundwater well' does not specify which well the sample was taken from and water types classified as 'Municipal water' did not specify whether the sample was taken from the distribution network, home connection, water tanks, etc. making is impossible to differentiate. In this case, more explicit data was adopted for the groundwater wells from the JWU, and the municipal water was assumed to mean samples from the water distribution networks.
- In 2007, the CPHL created a comprehensive and explicit 'water quality sampling data sheet', to allow proper classification of water sample types.

It has been noted in literature that the costs associated with monitoring the many parameters that influence water quality, when compared to those associated with monitoring only a few water quantity variables, usually means that water quality monitoring is not undertaken as frequently as water quantity monitoring (Rogers et al, 1998). This was observed in the data collection phase since much of the data gathered was not comprehensive enough to include measurements for all the major parameters, at all the monitoring points, throughout the years. For example, the majority of water quality data for the sources was obtained from the Jerusalem Water Undertaking, and the some of the missing data was found in the Palestinian Water Authority, though altogether there still remains to be some major gaps, as will be noticed in the graphs.

The water quality assessment answers the first research question regarding the quality of public drinking water in the Ramallah and Al-Bireh governorate and identifies whether or not there actually is an environmental hazard of water quality degradation.

The data collected from the bottled water companies is compiled, explored and evaluated to find the amount of bottled water sold and to estimate the volume of the bottled water market in the governorate. The data collected from water filter companies is gathered and analyzed to determine the types of water purification apparatuses available in the Palestinian market, and to calculate the average cost for installation, operation and maintenance of these apparatuses.

The method for calculating the averted expenditure on bottled water is adopted from the research report 'Cost of Environmental Degradation- The Case of Lebanon and Tunisia' carried out by Sarraf et. al. (2004). In this report, a method for determining this type of expenditure is developed and applied. This report also applies the concepts and methods outlined in the manual 'Estimating the Cost of Environmental Degradation- A training manual', which is a result of several studies undertaken by the Middle East and North Africa Department on estimating the monetary value of environmental degradation in eight countries in the region. The method for calculating the averted expenditure on bottled water assumes that since bottled water consumption is most likely to be avertive behavior to avoid risk of illness from inferior quality tap water and in part is also a preference (taste, accessibility, etc), the quantity associated with choice of preference is estimated by adjusting for GDP per capita differentials and price differentials between several European countries (in the 1970s) and Ramallah and Al-Bireh governorate (using income elasticities of demand of 0.25 to 0.40 and price elasticities of demand of -1.5 to -2.0). The difference between the actual quantity of consumption and the estimated quantity associated with preferences is the estimated quantity associated with avertive behavior to reduce the risk of waterborne illnesses.

The estimate of "expected" bottled water consumption if consumers perceived no health risk of potable municipal water is estimated by adjusting consumption levels of bottled water in several European countries in the 1970s before the doubling and tripling in consumption that resulted in large part because of perceptions of increased health risk of potable municipal water. The European consumption level in the 1970s is adjusted to Ramallah and Al-Bireh governorate's by applying the income elasticities of demand and the price elasticities of demand according to the formula:

$$Q = Q_{eu} * \left(\frac{Y}{Y_{eu}}\right)^{e} * \left(\frac{P}{P_{eu}}\right)^{e'}$$

Where Q is expected consumption level in Ramallah and Al-Bireh governorate, Q_{eu} is consumption level in the European countries in the 1970s, Y is GDP per capita in Palestine, Y_{eu} is GDP per capita in 1975 in the European countries, e is income elasticity of demand, P is bottled water prices in Ramallah and Al-Bireh governorate, P_{eu} is bottled water prices in the European countries, and e' is price elasticity of demand. The bottled water expenditure to protect against risk (avertive behavior) is then the actual expenditure minus the expected expenditure on bottled water due to non-risk reasons (such as preference, taste, accessibility, etc.).

The aggregated data from the company surveys and questionnaires is used to find the total expenditure on drinking water supplies (other than public water) for the year 2009. The total expenditure is calculated as follows:

Total Expenditure on Drinking Water Supplies =

Total expenditure on bottled water + Total expenditure on water purification apparatuses

Where the total expenditure on bottled water and water purification apparatuses is calculated from the data gathered from the companies and based on proportions found in the questionnaire.

The notion of opportunity cost is fundamental to decision-making, and it involves the comparison of the ‘worth’ of a given choice and the value of the scarified choice, where the latter is expressed in terms of the cost of making the given choice (Bateman et. al., 2002). Thus, based on the calculated expenditure on the different drinking water supplies, the opportunity cost of each type is calculated.

The total present expenditure is projected into the future to see what this present value will be worth in the future 10 or 20 years. The future value is calculated based on the compounding interest equation:

$$\textit{Future Value} = \textit{Present Value}\ (1 + i)^{n}$$

Where *i* represents the growth rate per year and *n* represents the number of years. The growth rate *i* is calculated by taking into account the population growth and market growth rates.

Summary

The methods outlined in this chapter will provide guidance for the research carried out within this study. The next chapter will apply these methods and will offer additional details for the adopted methods within this research.

CHAPTER FIVE RESULTS AND DISCUSSION

This chapter discusses the results of the public water quality analysis carried out for the Ramallah and Al-Bireh governorate. The results of the field visit to the bottled water companies and filter dealers are discussed in the next sections, followed by a discussion of the questionnaire.

5.1 Public Water Quality Assessment

One of the keys for successfully understanding the phenomenon of the booming bottled water industry in Ramallah is to undergo an assessment of the public water quality in the area, to be able to understand why bottled water is increasingly being consumed. Water quality measurements are essential for demonstrating the comparability of data obtained and water quality assessments worldwide. Quality tests for various types of physical, chemical and biological contaminants in drinking water also provide the data for necessary quality control tools. Water which is potable for human use can be described as that water which does not pose any threat to the health of a human being over its prolonged use over a human lifetime, water which does not contain any color, taste, smell or suspended material, and does not contain any chemical, organic or biological matter which may cause harm to humans (WHO, 2008). Water may contain a number of elements and salts in limited amounts which may be beneficial to the human body. For these reasons, water is treated and tested to ensure that it is safe and healthy for consumption. Water pumped at the sources from Ein Samia wells is treated by chlorination, while water from the Mekorot connections is already treated and ready for consumption.

To reach a reasonable and comprehensive assessment of water quality in Ramallah- Al Bireh governorate, it is important to assess the water quality ‘at the source’, which includes the Ein Samia well field, Shibtin Well, and Mekorot connections, and to assess the water quality ‘in the network’, which includes sampling points within the municipal water distribution network. This should provide a view of the quality of water at all points, i.e. the source and the network before reaching the end user.

5.1.1 Chemical and Physical Water Quality Parameters Measured at the Sources

Based on the data collected from the PWA, CPHL and JWU, the main chemical and physical parameters were plotted against the PSI standard values to analyze the compliance of municipal water with the PSI drinking water standards. This is depicted in the graphs below, Figure 5-1, for the major drinking water parameters.

The sources of drinking water for Ramallah and Al-Bireh governorate, as of 2009, which were analyzed are:

1. Ein Samia well no. 1
2. Ein Samia well no. 2
3. Ein Samia well no. 3
4. Ein Samia well no. 4
5. Ein Samia well no. 6
6. Shu’fat connection (Mekorot water supply point)
7. Ramallah connection (Mekorot water supply point)
8. Doleb connection (Mekorot water supply point)
9. Umm Saffa connection (Mekorot water supply point)

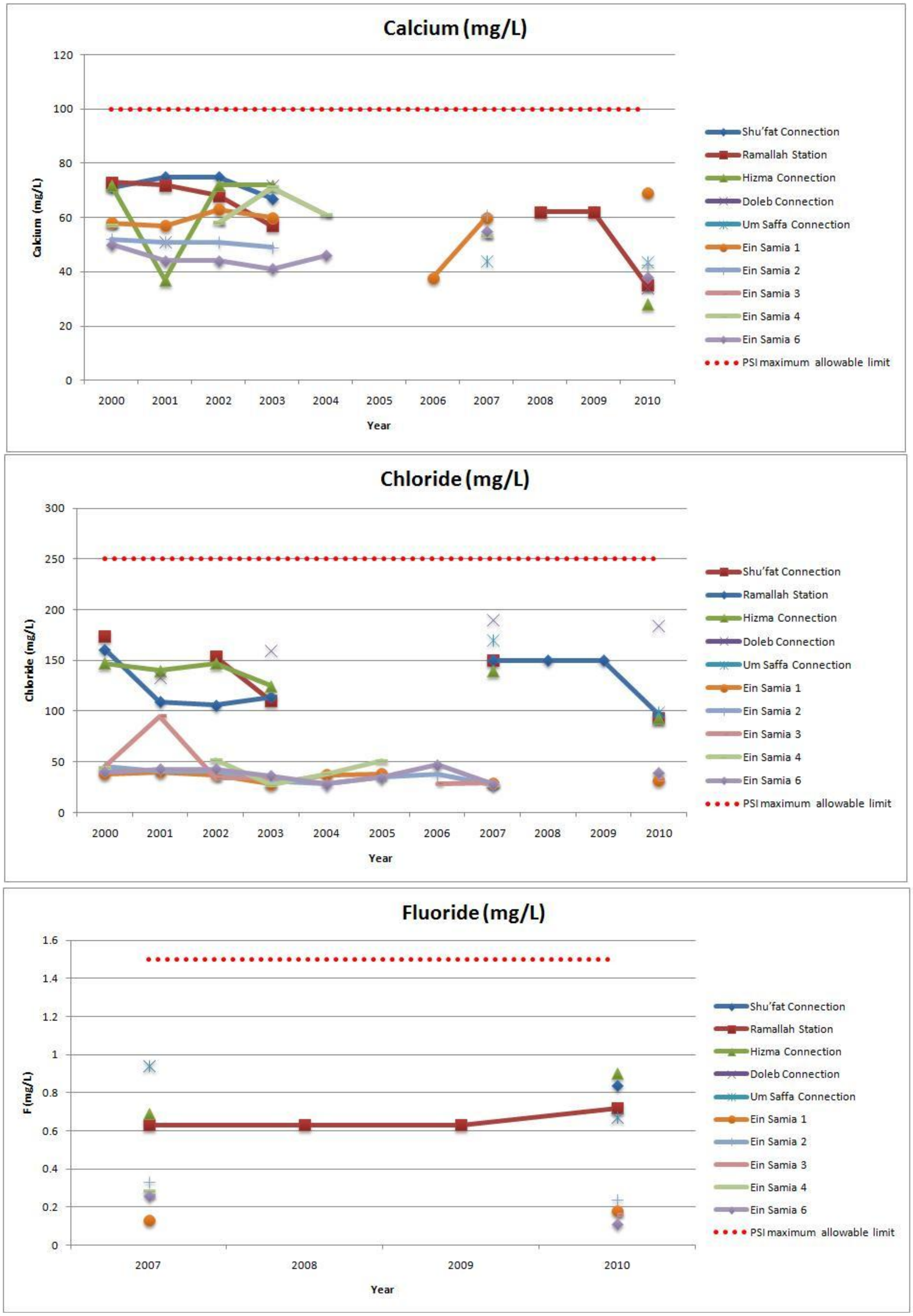


Figure 5-1 Major chemical and physical parameters measured at the sources
Source: Compiled data from PWA, CPHL, and JWU.

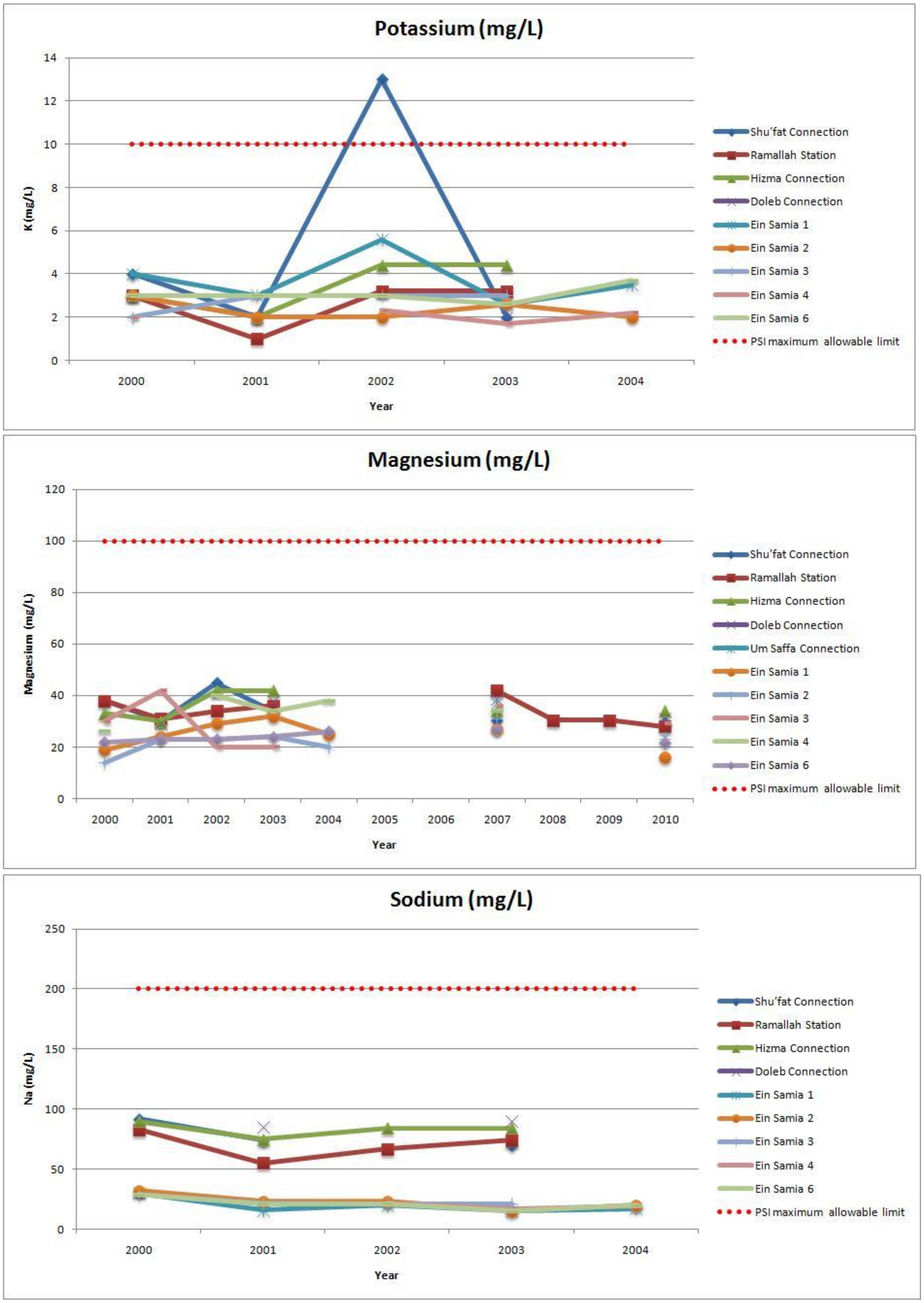


Figure 5-1 Major chemical and physical parameters measured at the sources (cont.)
Source: Compiled data from PWA, CPHL, and JWU.

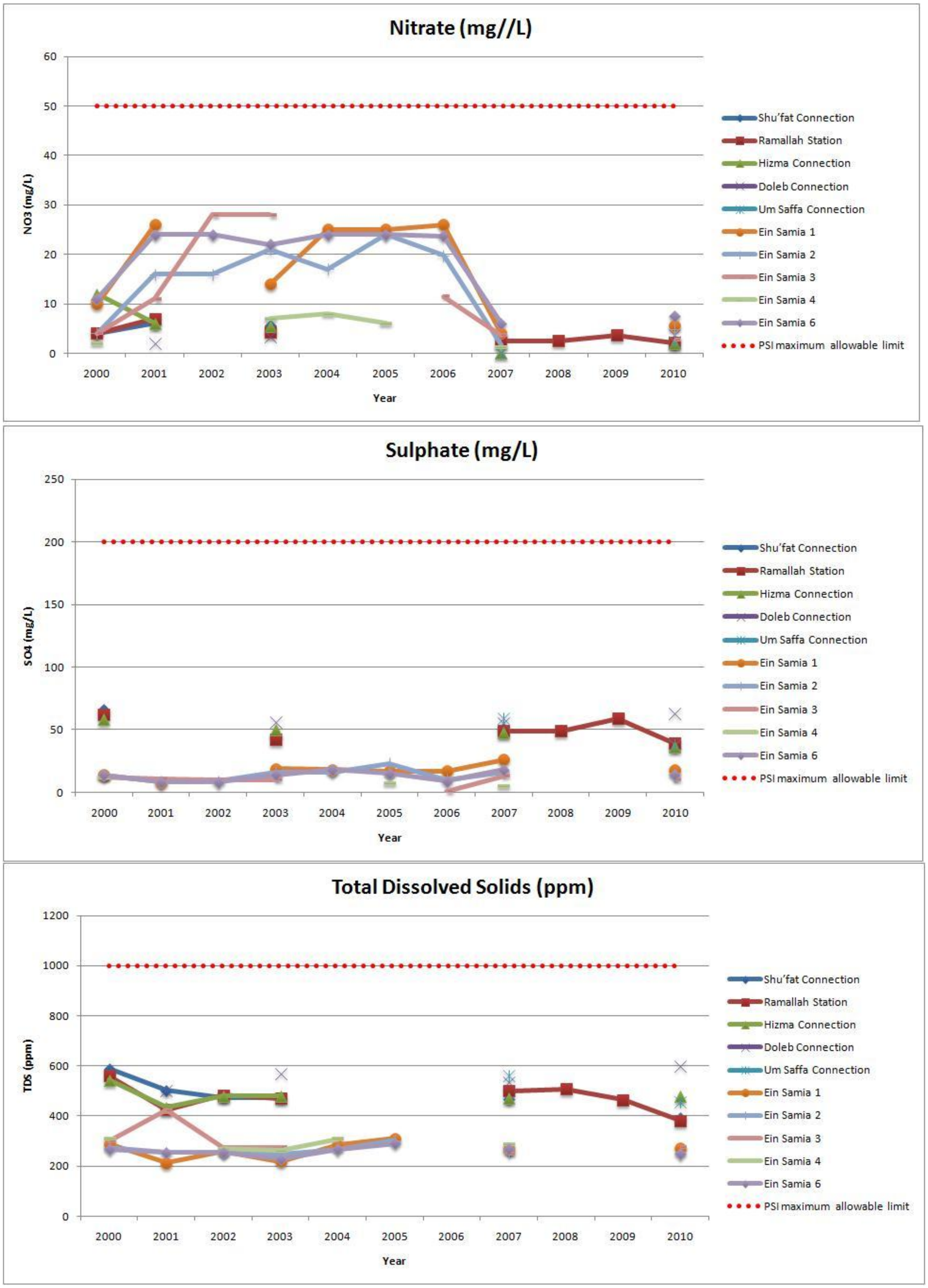
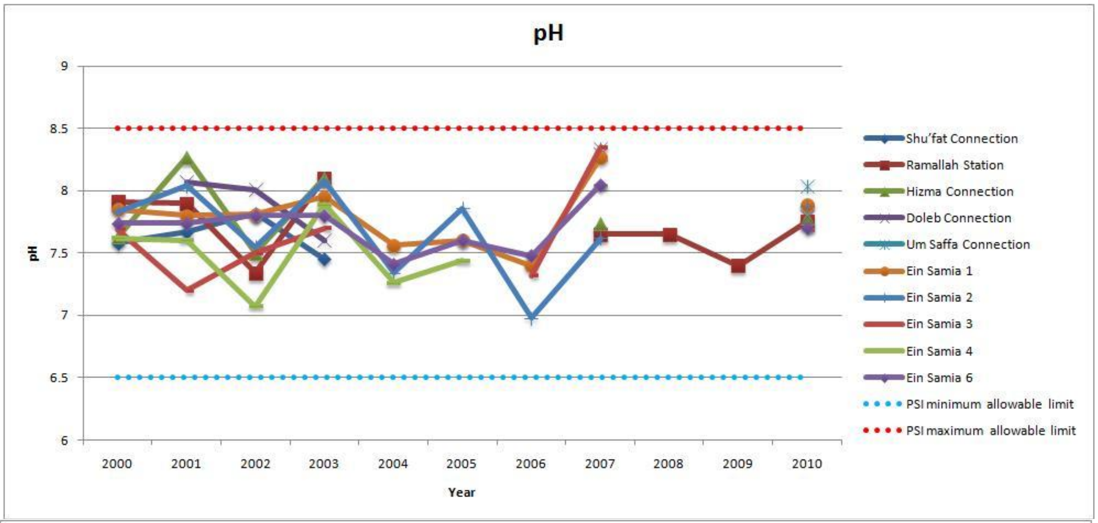
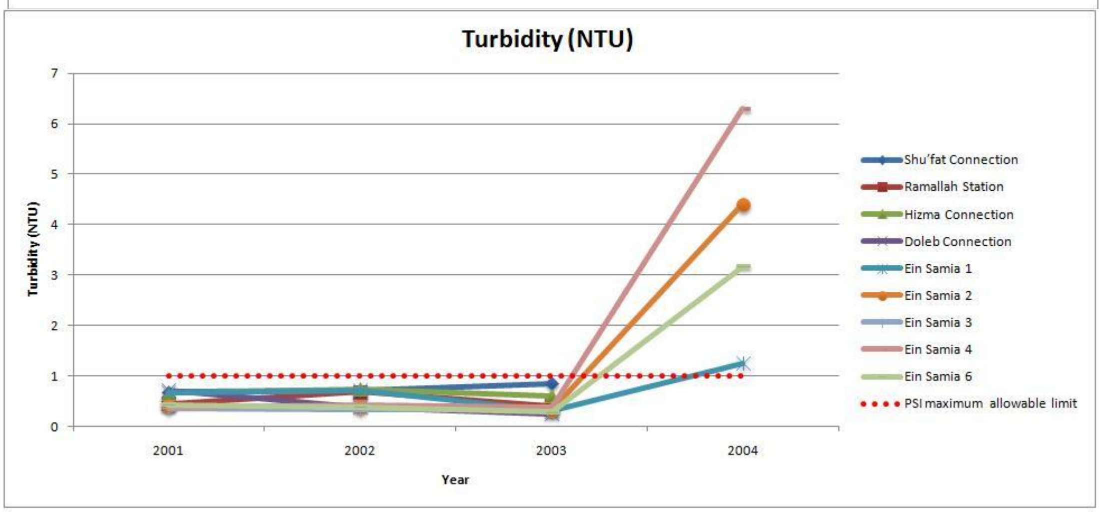


Figure 5-1 Major chemical and physical parameters measured at the sources (cont.)
Source: Compiled data from PWA, CPHL, and JWU.





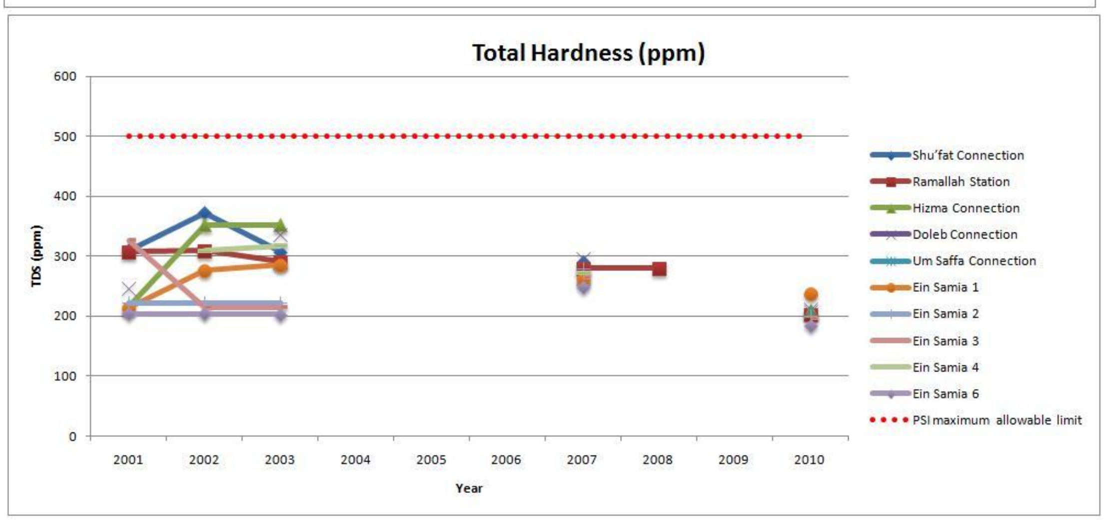


Figure 5-1 Major chemical and physical parameters measured at the sources (cont.)
Source: Compiled data from PWA, CPHL, and JWU.

It is shown that all the major parameters which have occurred in the water samples taken at the sources, range within or below the maximum allowable limits, according to the PSI standards. Two exceptions can be noticed:

1) Potassium levels from the Shu'fat connection exceed the maximum allowable limit in 2002. No specific reason was found for this increase. According to the WHO, potassium is an essential element in humans and is seldom, if ever, found in drinking water at levels that could be a concern for healthy humans, but it can occur in drinking-water as a consequence of the use of potassium permanganate as an oxidant in water treatment. Thus, adverse health effects due to potassium consumption from drinking-water are unlikely to occur in healthy individuals (WHO, 2009).
2) Turbidity levels in 2004 at all the Ein Samia wells exceed the maximum allowable limit in 2004. According to hydro-geologists from the PWA, some possible explanations for the increase in turbidity in that year can be attributed to:

- Over abstraction from the wells, which promotes the release of sediments and fine particles into the water as it is being pumped;
- Reduced rainfall causing reduced recharge, in that lower rainfall leads to an increase in solubility of some minerals and ions into the surrounding formation to dissolve in water;
- Earthquake, or slight shifting of tectonic plates, causing a 'stir' in the groundwater.

5.1.2 Chemical and Physical Water Quality Parameters in the Network

If water testing is performed only at sources in such settings, then results of monitoring may not reflect the quality of water actually consumed in the home (Wright et al, 2004), so it was important to consider this in the water quality assessment. The results are shown in Figure 5-2.

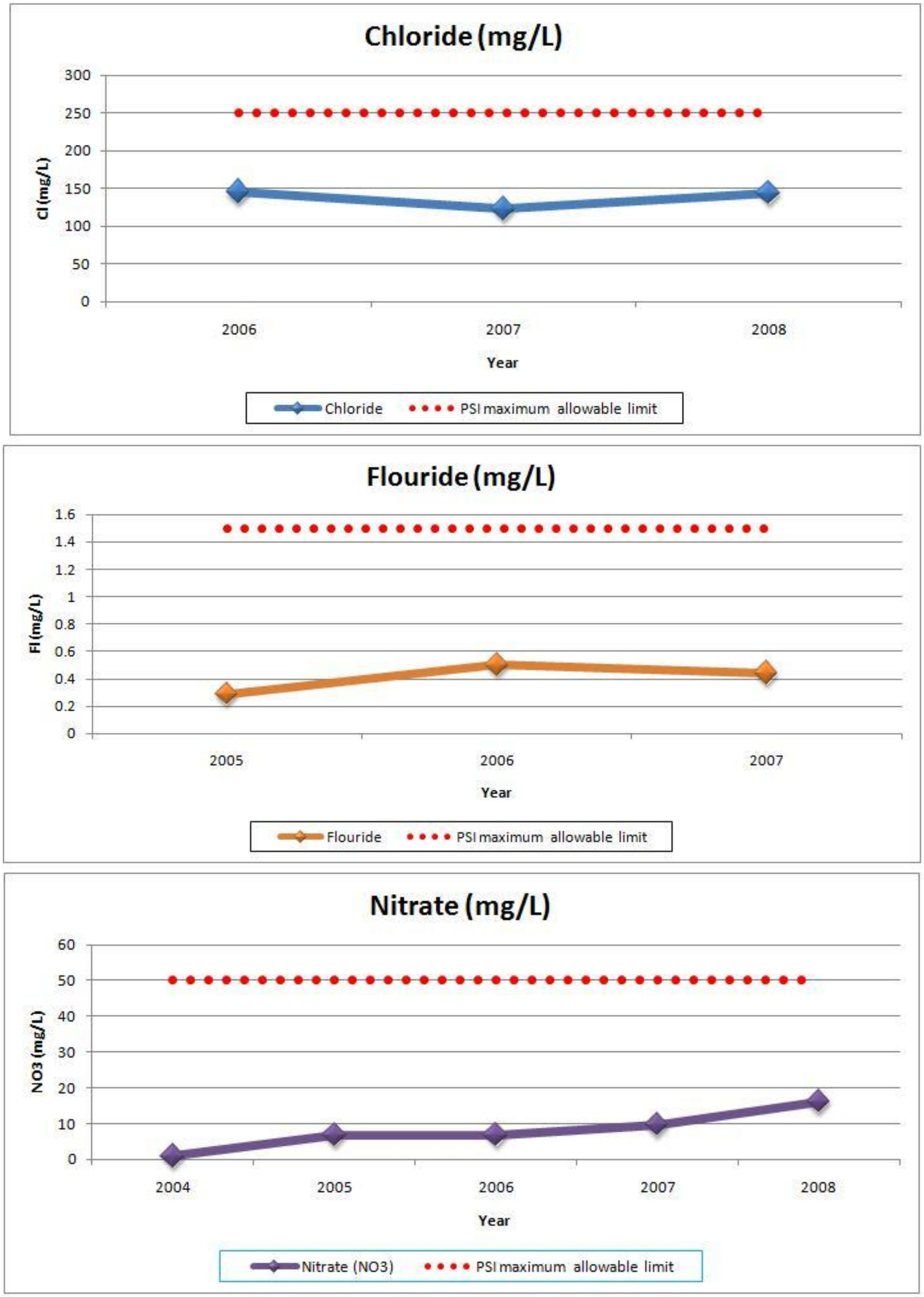


Figure 5-2 Major chemical and physical parameters measured in the network
Source: Compiled data from PWA, CPHL, and JWU.

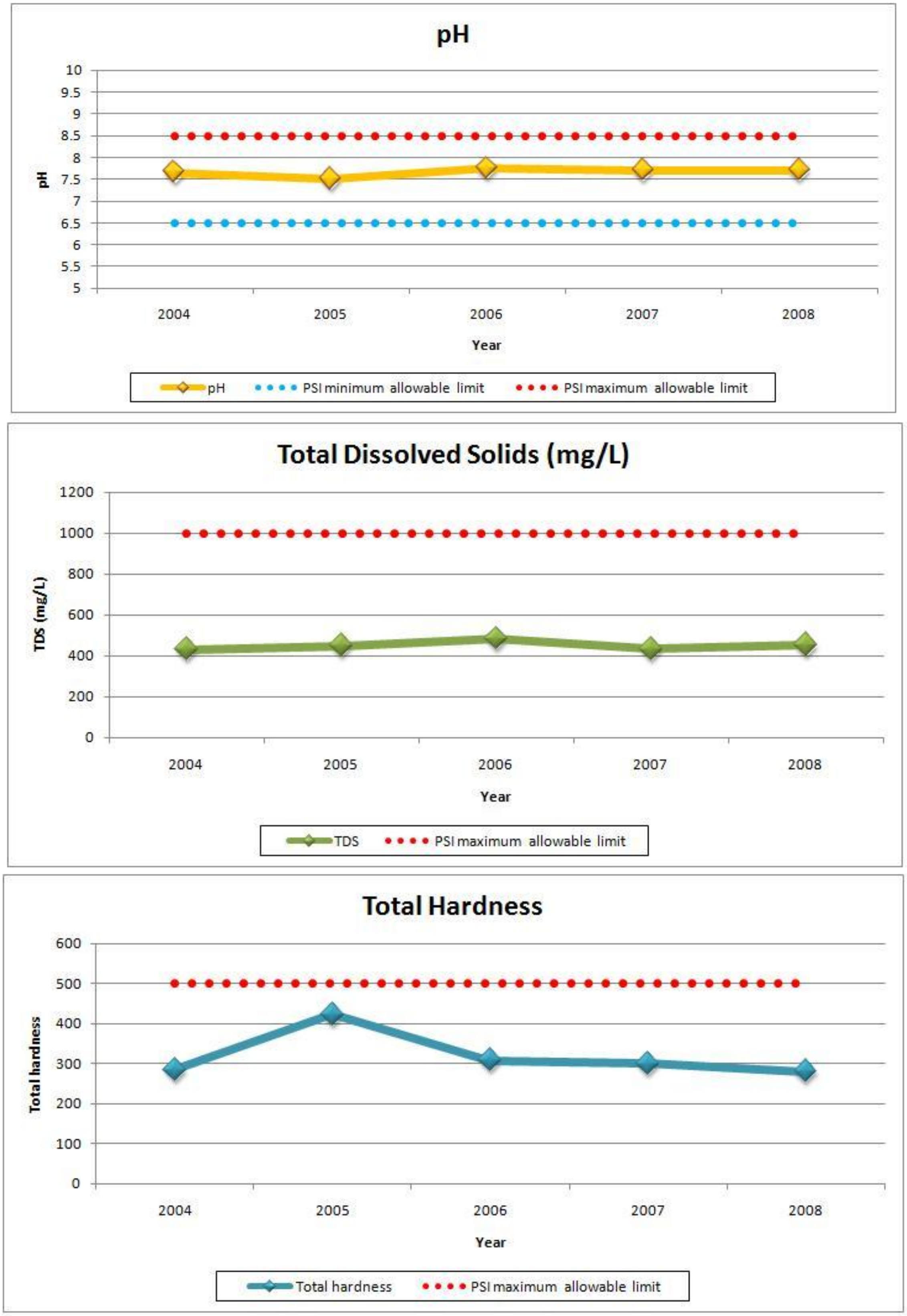


Figure 5-2 Major chemical and physical parameters measured in the network
Source: Compiled data from PWA, CPHL, and JWU.

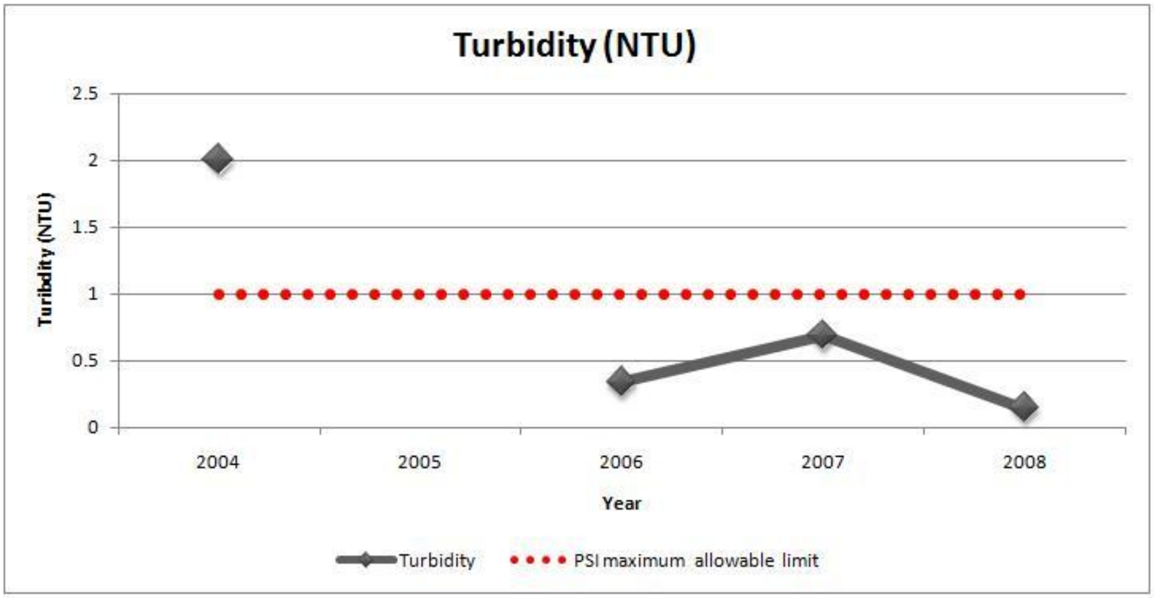


Figure 5-2 Major chemical and physical parameters measured in the network
Source: Compiled data from PWA, CPHL, and JWU.

From the above assessment of chemical and physical parameters in water samples taken at the sources and from within the distribution network, it can be seen that all major parameter values fall within the PSI standard values for drinking water. One exception is noticed regarding the turbidity, where it ranged between 0-0.8mg/L between the years 2000-2010 (the PSI limit is 1mg/l), but was measured at 2 mg/L in 2004. High turbidity in drinking water means that it may not be acceptable for consumers due to high amounts of sediments, possibly sand and other unappealing matter. The turbidity returned to acceptable limits in the following years.

Calcium values were found to range between 20-79 mg/L, where the PSI limit is 100 mg/L. Calcium is an essential part of the human diet and according to the WHO there are no health objections to high calcium content, if it should occur, in drinking water, however the PSI did specify a maximum limit of 100 mg/L to prevent excessive scale formation. Chloride was found to range between 25-190 mg/L at the sources and 125-159 mg/L in the network (PSI limit is

250mg/L). Increased chloride values, over 250 mg/L may inflict a salty taste to water, but most people will not be able to detect the salty taste if chloride values are below 150mg/L. Too high or too low values of fluoride in drinking water may be harmful for human consumption. Values of fluoride were found to range from 0.1-0.85 mg/L which is within the allowable PSI limits. Potassium values ranged from 1-6 mg/L, which are within PSI limits of 10 mg/L, with an exception in 2002 where it averaged 13mg/L, but this does not pose any direct harmful effects on human health (WHO, 2009). Magnesium values ranged from 18-42 mg/L (PSI limit 100 mg/L) and sodium values ranged from 10-80 mg/L (PSI limit 200 mg/L). Both magnesium and sodium may impart a salty taste to water if they occur above the allowable limits. Nitrates averaged between 0-28 mg/L (PSI limit 50 mg/L) and sulphates ranged from 0-70 mg/L (PSI limit 200 mg/L). TDS, another indicator of the taste of water, ranged between 200-600 mg/L (PSI limit 1000 mg/L). pH values were found to be within acceptable limits, measured between 7.0-8.3 mg/L (PSI limit 6.5-8.5 mg/L). The total hardness, which relates to aesthetic characteristics and scaling affects in water, was found to range between 180-380 mg/L in the sources and was found to measure up to 420 mg/L in the network, where the PSI limit is 500 mg/L, so it is also within the allowable limits.

5.1.3 Microbial Analysis of Public Drinking Water

Table 5-1 below provides a summary of microbial tests performed by the Jerusalem Water Undertaking at the sources and within the network, through the years 2000 to 2009. The number of tests performed is classified as number of tests passed and number of test failed. The calculation of ‘percent passing’ is described by the PSI Drinking Water Standard, sections 4-1-1, 4-1-2 and 4-1-5, which state that “95% of the water samples, which must be taken from the same source within a period of 12 months, must comply by the stated biological specifications”. This includes "the Total Coliform in the water sample must not exceed 3/100 ml" and "the Total Fecal Coliform in the water sample must not exceed 0/100 ml". Figure 5-3 shows that from 2000 to 2009, all the microbial tests performed passed the PSI value of at least 95% of test must be passing. This shows that based on the data, the water sources serving the governorate are microbially safe for drinking purposes.

Table 5-1 Summary of microbial tests performed from 2000-2009

Year	Total number of tests (Coliform bacteria)	Number of tests passed	Number of tests failed	% passing
2000	660	656	4	99.4
2001	519	517	2	99.6
2002	414	411	3	99.3
2003	416	414	2	99.5
2004	556	554	2	99.6
2005	795	786	9	98.9
2006	905	893	12	98.7
2007	845	844	1	99.9
2008	828	826	2	99.8
2009	805	804	1	99.9

Note: Membrane Filtration method used.
Note: WHO standards limits % passing not less than 95% within a 12 month sampling period.
Source: Department of Testing and Analysis, Jerusalem Water Undertaking- Ramallah District, 2010

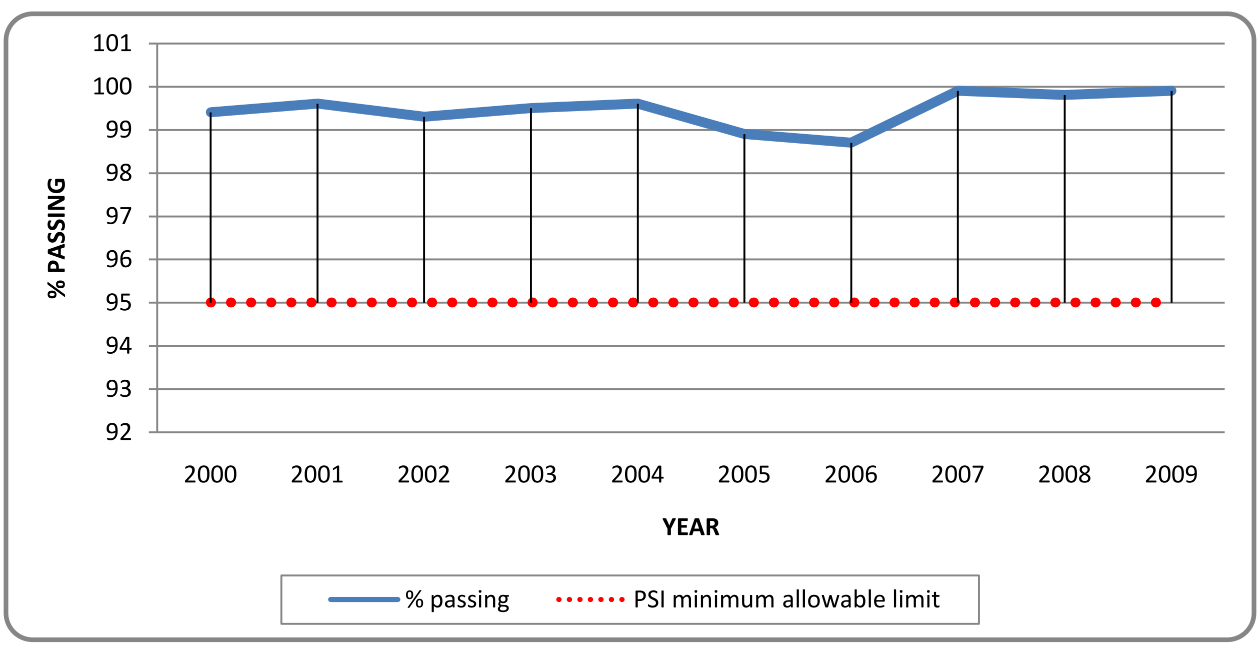


Figure 5-3 Summary of coliform tests from 2000 to 2009

5.2 Bottled Water Industry Analysis

The bottled water industry in Palestine is a new and rapidly growing industry. A summary of the data gathered through the field visits which were carried out to the fourteen bottled water companies and or suppliers is provided in Appendix 2. The number of bottled water providers in Ramallah and Al-Bireh governorate has increased over the years, from 1996 (when there was only one company) to 2010 (when there is about 13 companies), as it is shown in Figure 5-4.

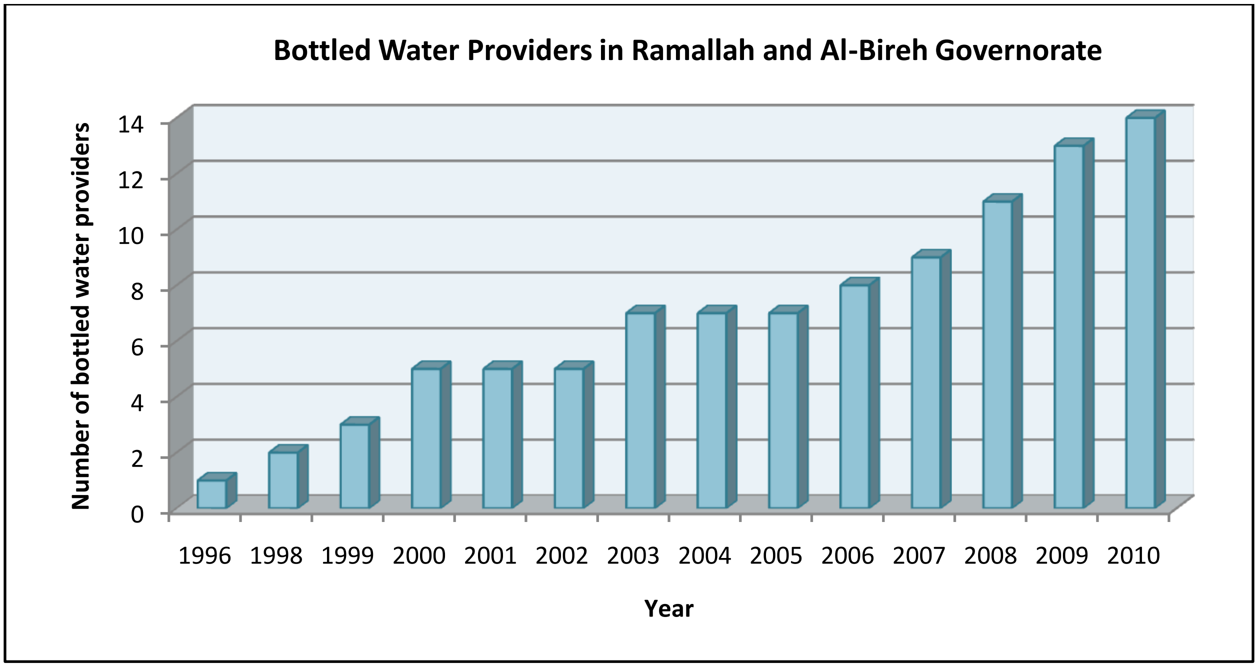


Figure 5-4 Bottled water providers in the Ramallah and Al-Bireh governorate

Of the current bottled water providers, 4 companies offer the bulk (19 L) containers and about 10 other companies offer the 0.5 L and 1.5 L and 2 L bottles. Information gathered from the companies shows that the Ramallah and Al-Bireh governorate is one of the highest consumers of bottled water compared to other governorates in the West Bank. Generally, all companies stated that the highest demand for bottled water is in the urban areas of the governorate, mainly in

Ramallah city, Al-Bireh, and Birzeit. All companies noted an increase in the demand for bottled water since their year of establishment, but this has been difficult to monitor due to the increasing competition. Statistics from one company show that sales nearly tripled since its establishment in 1999, when it was the only bulk bottled water provider serving the Ramallah region.

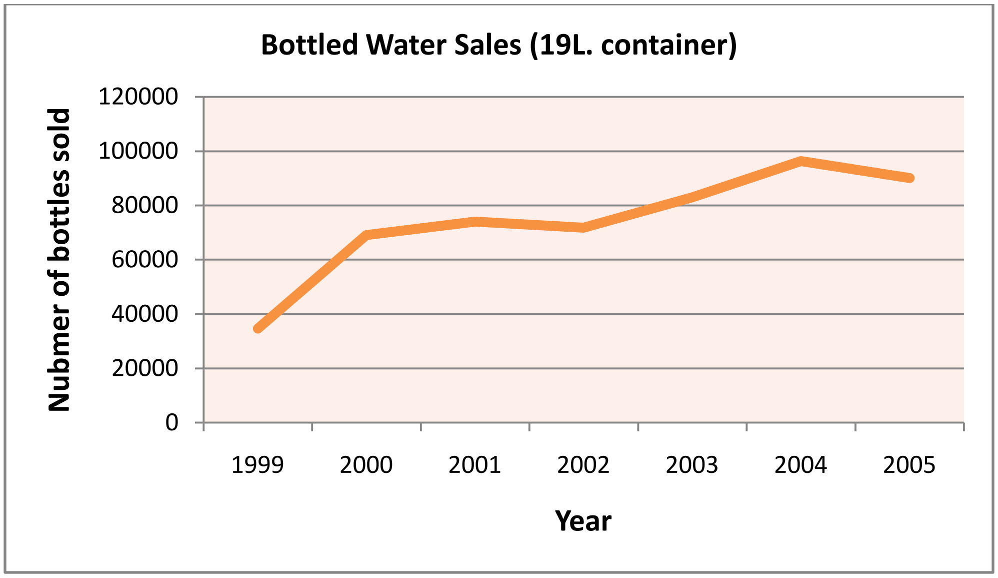


Figure 5-5 Sales from the first bulk bottled water provider in the Ramallah region

In general, sales data from bottled water companies showed that bottled water sales in the winter are about one third of the sales in the summer. Therefore, it can be inferred that the purchasing of bottled water is not solely a reaction to the public water shortages in the summer months.

5.2.1 Comparison of Quality versus Cost

To provide a comparison of the drinking water providers in the governorate, Table 5-2 was prepared. This table shows some of the main water quality parameters, as provided by each source, and the related cost of one cubic meter of water. From the first glance, it is obvious that there is a huge difference in the cost of public water, which costs about 4.1 NIS per cubic meter for the first 10 m^3 and the cost of bottled water, which ranges from about 700 NIS to 1,600 NIS per cubic meter. So what exactly is the consumer paying for with this huge price difference?

A comparison between, for example, the public water source and bottled company number 1 shows that for an extra cost of 1,838 NIS/m^3, one receives water with 52.4 mg/l less sodium (which gives the water a slightly less salty taste), 21.52 mg/l more Ca (which may be considered healthy for humans but may increase the hardness), 4.99 mg/l less Mg, 28.11 mg/l less SO_4, 9.54 mg/l more NO_3, 0.45 mg/l more F, 77.58 mg/l more Cl, 188.3 mg/l less TDS (also giving the water a less salty taste), and the same pH value.

It is also worth noting the differences in cost and quality between the different bottled water companies. In comparing company 6 and 8, which are both 1.5 L bottled water producers, company 6 will cost 611.1 NIS more for every cubic meter purchased, but will offer 13.3 mg/l more sodium, 11.85 mg/l more calcium, 14.04 mg/l more magnesium, 9.5 mg/l less sulphate, 18.77 mg/l more nitrate, 0.12 mg/l less fluoride, 14.99 mg/l more chloride, 115 mg/l more TDS and just about 1 pH higher.

A discussion of the health benefits or detriments associated with the higher or lower values of these measured parameters is beyond the scope of this study, but table 5-2 does point out that all types of water conform to Palestinian drinking water standards for acceptable and healthy drinking water. Thus, there is a significant difference in cost for essentially the same healthy, acceptable drinking water.

Table 5-2 Comparison of bottled water providers in the Ramallah and Al-Bireh governorate

Parameter (mg/l)	**Public Water Source**	**19 L containers**				**1 ½ L bottles**										
		1*	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**PSI standard**
Na	71.7	19.3	44.62	26.6	30	9.9	25.3	3	12	46	23	27	14	12	12	200
Ca	41.18	62.7	29.92	74.5	35	20	75.85	20	64	62	38	50	66	64	64	100
Mg	30.49	25.5	14.42	28.6	22	9.5	28.7	18	14.66	31	16	25	27	14.66	14.66	100
SO_4	39.71	11.6	10	28.2	12	9.9	24.5	<0.1	34	28	10	23	12	34	34	200
NO_3	3.36	12.9	2.39	12.3	10	-	26.3	0.4	7.53	33	16.4	-	17	7.53	7.53	50
F	0.68	0.23	0.198	0.33	0.2	0.08	0.2	0.05	0.32	-	0	-	-	0.32	0.32	1.5
Cl	105.08	27.5	68.52	37.2	50	-	50	72	35.01	80	50	-	25	35.01	35.01	250
TDS	458.3	270	220	320	250	-	390	163	275	-	-	300	-	275	275	1,000
pH	7.8	7.75	7.5	7.6	7.5	-	8.36	7.2	7.4	7.9	-	-	7.5	7.4	7.4	6.5-8.5
Cost (NIS/m^3)	***4.1***	***1842.1***	***1052.6***	***1578.9***	***1052.6***	***1333.3***	***1333.3***	***1333.3***	***722.2***	***1333.3***	***833.3***	***1333.3***	***2000***	***1000***	***1000***	

**Note: Names of the bottled water companies (providers) have been replaced with numbers.*

5.3 Water Filter Industry Analysis

The domestic water purification apparatuses being marketed in the Palestinian market have caused a stir with many people. Vigorous marketing efforts have been adopted by some companies, in which company representatives test water samples from a potential client's home then purposely scare them into buying the units. It is very difficult to obtain list of all the water filter dealers in the governorate due to the fact that most of these dealers are not registered under a company name indicating that they sell these filters. In the Ministry of National Economy, companies selling water purification systems are mostly registered under 'general trading' classification, so it would be extremely difficult to pinpoint the ones selling these systems.

Through a field study, it was found that the types of water filtration systems available in the Palestinian market are:

- 1st-stage filter: Polypropylene filter cartridge, 5 micron opening, which removes sand, silt, dirt, and rust particles.
- 2nd-stage filters: Carbon block cartridge, 5µm nominal sediment filter, which removes chlorine, bad taste and odor, and organic chemicals from water, while providing filtration capabilities and dirt-holding capacity.
- 3rd-stage filter system: This system is made up of one polypropylene filter cartridge and two carbon block cartridges, set up consecutively.
- 4th-stage filter system: This system is made up of one polypropylene filter cartridge, two carbon block cartridges, and a membrane set up consecutively. The membrane may be one of:

- Microfiltration membranes, which have a nominal pore size of 0.2 microns, are capable of removing suspended solids, bacteria or other impurities.
- Ultrafiltration membranes, which have a nominal pore size of 0.0025 to 0.1 microns, capable of removing salts, proteins and other very fine particles or other suspended matters.
- Nanofiltration membranes, which can separate very fine particles or other suspended matters, with a particle size in the range of approximately 0.0001 to 0.005 microns, and is capable of removing viruses, pesticides and herbicides.
    - o 5^{th}-stage filter system: Reverse Osmosis Filter, made up of a sediment filter, 2 carbon filters, RO membrane, post carbon filter. RO is the finest available membrane separation technique and separates very fine particles or other suspended matters, with a particle size up to 0.001 microns, so it is capable of removing metal ions and fully removing aqueous salts.
    - o 6^{th}- stage filter system: This system adds to the 5^{th}-stage system a UV-radiation unit to kill germs and bacteria and fungi.

On average, the costs of these systems are:

- 1^{st} –stage: Initial cost = 150 NIS; Routine cost = 40-60 NIS/year
- 2^{nd}-stage: Initial cost = 250 NIS; Routine cost = 70-100 NIS/year
- 3^{rd}-stage: Initial cost = 400 NIS; Routine cost = 70-100 NIS/year
- 4^{th}-stage: Initial cost = 500 NIS; Routine cost = 70-100 NIS/year
- 5^{th}-stage: Initial cost = 1800 NIS; Routine cost = 200-250 NIS/year
- 6^{th}-stage: Initial cost = 3000 NIS; Routine cost = 200-250 NIS/year

Filter companies have stated that sales are also on the rise. One of the main water filters dealers in the year 2000 sold 200 filters units, in 2005 sold 2000 units, and in 2009 sold about 3000 units in the Ramallah and Al-Bireh governorate alone.

5.4 Questionnaire Analysis

As outlined in Chapter 4, 155 questionnaires were distributed among residents of the governorate of Ramallah and Al-Bireh to obtain indicator values of the proportions of residents consuming different types of water, to estimate the household expenditures on drinking water, to better understand perceptions regarding public drinking water, and to provide an estimate of the average bottled water consumption in the Ramallah and Al-Bireh governorate. Results of the survey showed that 32.0% of the sample drink bottled water, 37.4% drink tap water, 11.3% have installed a water filter and drink from the filtered water, 14.0% drink both tap and bottled water, 2.0% drink both bottled and filtered water, 0.6% drink both tap and filtered water, and 2.7% drink from other sources which include private rainwater cisterns, private springs, etc..

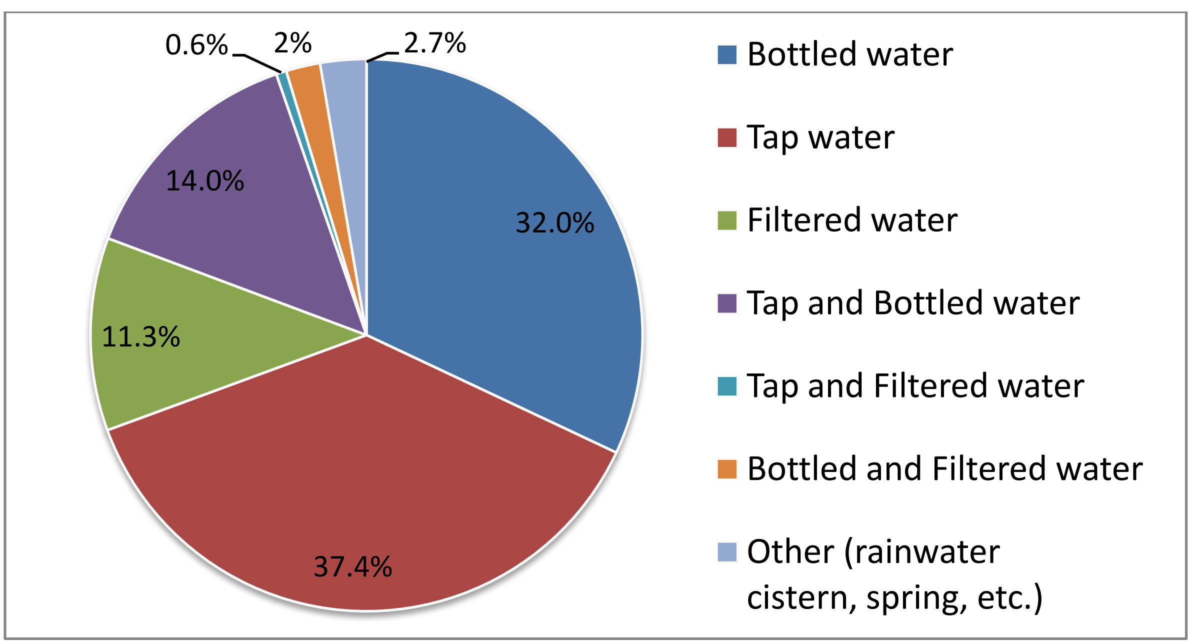


Figure 5-6 Distribution of types of drinking water Source: Questionnaire

It was found that 11.3% of the sample has installed a point-of-use water filter at their taps. The average capital cost for the installed water filters was about 1,400 NIS. About 58% of the respondents had installed multi-stage filters, with an average cost of about 2,000 NIS, 32% installed a standard 1-2 stage filter, with an average cost of 315 NIS, and 11% did not know what type of filter they had installed.

The results of the questionnaire showed that of the bottled water consumers, their average bottled water consumption is about 259.7 liters per capita per year, or about 0.71 liters/capita/day. Of these bottled water consumers, the highest consumption was 864 l/c/yr (2.37 l/c/d) and the lowest consumption was 67.5 l/c/yr (0.18 l/c/d).

It is important to note that the questionnaire results showed about 32% of the sample drink only bottled water and this result seems somewhat high and may be attributed to the following reasons: the sample size taken was not large enough to be representative of the actual population; the answers of some respondents may not have been entirely accurate; the precision may not have been high enough.

Another aim of the questionnaire was to better understand the perceptions of consumers of different water types. The reasons stated by respondents for their selection of drinking water type in their homes are displayed in the Figure 5-7.

When asked ‘Why do you choose to drink (tap/bottled/filtered water), the responses showed that the greatest reason for not drinking tap water among bottled water consumers is there is a lack of trust of the supplied tap water. The majority of filtered water drinkers felt that their tap water is unclean. Over half of tap water drinkers felt that their water was clean and felt no reason to resort to any other type.

About 33% of consumers of both tap and bottled water regularly drink tap water and only purchase bottled water when they feel their tap water tastes bad, during and/or after water cuts. This is due to the fact that during or after a prolonged water cut, sediments from the roof tanks reach the tap causing a change in taste and color. About 24% stated that there is a difference of opinions inside the household, where some members had no problem drinking tap water while others preferred to drink bottled water, and 14% of the households stated that drinking bottled water alone is too expensive so these household consumed both. Consumers of both bottled water and filtered water felt that either bottled water alone was too expensive or that bottled water is more accessible than the tap/filtered water.

Generally speaking, about 48% of the respondents do not drink tap water while about 52% will drink tap water, regardless of their preference. In summary, it can be said that there are conflicting perceptions of the public drinking water in the Ramallah and Al Bireh governorate.

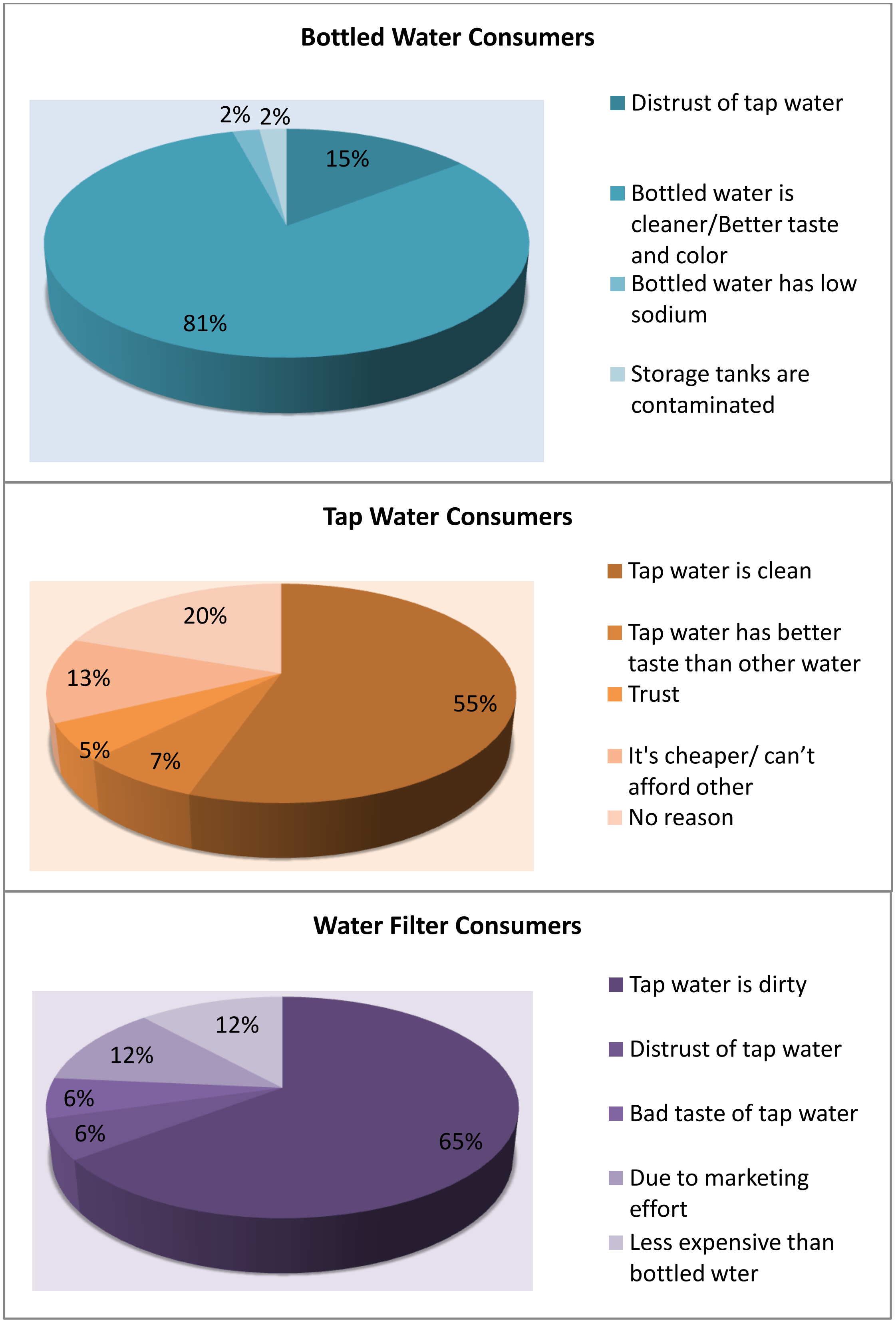


Figure 5-7 Respondents’ reasons for water type selection

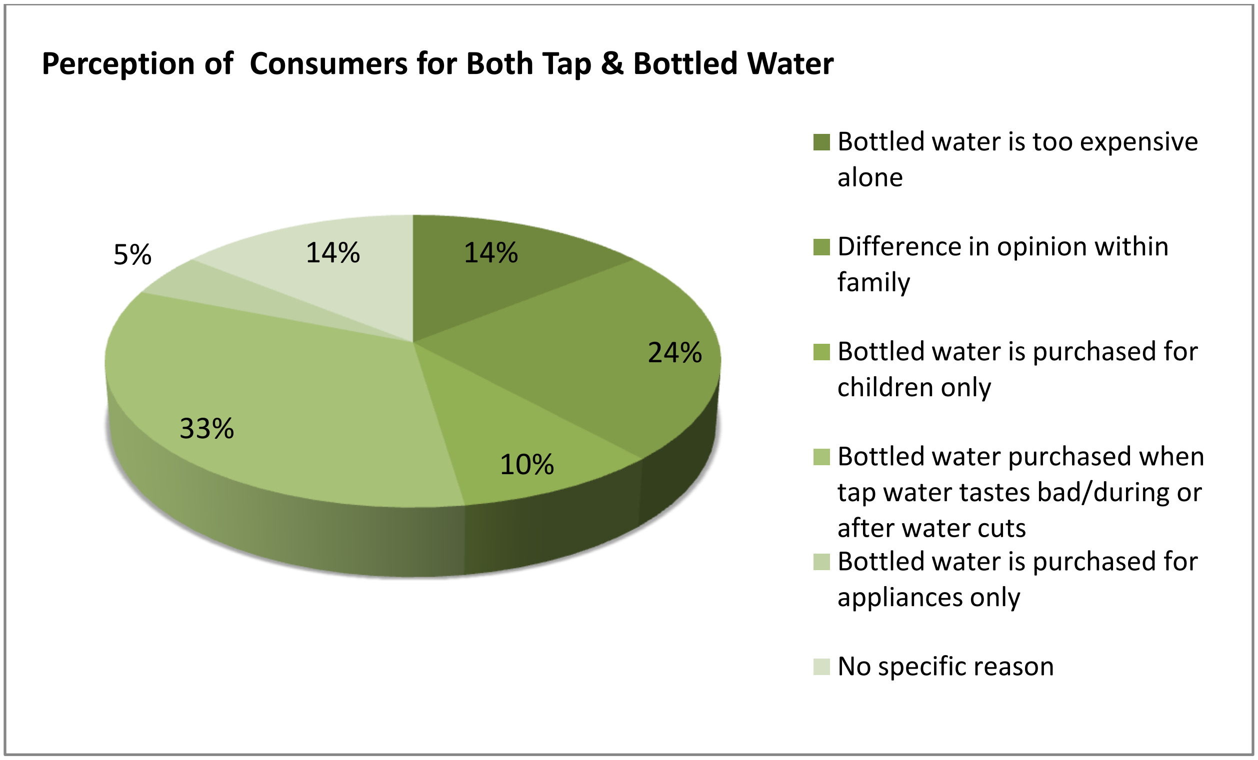


Figure 5-7 Respondents' reasons for water type selection (cont.)

5.5 Economic Analysis

The data collected throughout this research with the aggregated results of both the survey of bottled water companies and water filter providers and the questionnaire are employed to carry out an economic analysis of the situation. The aim of this analysis is to estimate the total expenditures on drinking water, using the most recent data available, and to monetize the opportunity cost.

5.5.1 Expenditure on Bottled Water

The total number of bottles sold in 2009 from the bottled water companies and providers available in the governorate's market was found to be as follows:

18.9 L ⟶ 258,456 bottles

2 L ⟶ 860,400 bottles

1.5 L ⟶ 5.22 million bottles

0.5 L ⟶ 3.84 million bottles

The total volume of bottled water sold in 2009 in the Ramallah and Al Bireh governorate was:

[258,456 * 18.9] + [860,400 * 2] + [5,220,000 * 1.5] + [3,840,000 * 0.5] = **16.35 million liters**, where 4.88 million liters were sold as 18.9 L bottles, 1.72 million liters were sold as 2 L bottles, 7.83 million liters were sold as 1.5 L bottles and 1.92 million liters were sold as 0.5 L bottles.

Considering a population of 279,730 persons (PCBS, 2008), then the bottled water consumption in the Ramallah and Al-Bireh governorate in 2009 was 58.3 liters per capita.

The average cost of bottled water was calculated by taking the average price of bottles sold in bulk and as single. The average costs are shown in Table 5-3.

Table 5-3 Average costs of bottled water

Size of bottle (L)	Average Price (NIS)	Cost per liter (NIS)
18.9	25.0	1.3
2	3.0	1.5
1.5	1.95	1.3
0.5	1.05	2.1
Average cost (NIS/L)		1.55
Average cost ($US/L)		≈ 0.4

The total expenditure on bottled water in 2009 can thus be calculated as follows:

[258,456 * 25] + [860,400 * 3] + [5,220,000 * 1.95] + [3,840,000 * 1.05] = **23.25 million NIS,** or just about $6.25 million US (where US$ 1 = 3.72 NIS). This is equivalent to about $22.3 US/yr.

The bottled water expenditure to protect against risk (avertive behavior) is the actual expenditure minus the “expected” expenditure (on bottled water for reasons such as preference, taste, accessibility, etc.). The estimate of "expected" bottled water consumption if consumers perceived no health risk of potable municipal water is estimated according to Table 5-4. This table provides the information used to arrive at an estimate for the avertive expenditure on bottled water, and offers a range of values for the income and price elasticities of bottled water demand, since these values may exist over a range and are difficult to fix due to lack of concrete data in the region.

Table 5-4 Bottled Water Consumption (Avertive Behavior)

		Value		Units
1.	Per capita expenditures in Palestine[1]	1967		US$/capita/yr
2.	Bottled water expenditures in Ramallah and Al-Bireh governorate (2009)[2]	22.3		US$/capita/yr
3.	Average price of bottled water in Ramallah and Al-Bireh governorate [3]	0.4		US$/liter
4.	**Bottled water consumption in Ramallah and Al-Bireh governorate (actual)** [4]	58.3		Liters/capita/yr
5.	GDP per capita 1975 (Western Europe and US) [5]	17253		US$/capita
6.	GDP per capita 2008 (Palestine) [6]	1290		US$/capita
		"LOW"	**"HIGH"**	
7.	Bottled water consumption in several European countries in the 1970s [5]	30	30	Liters/c/yr
8.	Income elasticity of bottled water demand ("Low" and "High") [5]	0.25	0.4	
9.	Price elasticity of bottled water demand ("Low") [5]	-1.5	-1.5	
10.	Price elasticity of bottled water demand ("High") [5]	-2	-2	
11.	Average price of bottled water in several European countries [5]	0.3	0.3	US $/liter
12.	Average price of bottled water in Ramallah and Al-Bireh governorate [3]	0.23	0.23	US $/liter
13.	**"Expected" bottled water consumption in Ramallah and Al-Bireh governorate: non-risk related ("Low")**	**10**	**7**	Liters/c/yr
14.	**"Expected" bottled water consumption in Ramallah and Al-Bireh governorate: non-risk related ("High")**	**9**	**6**	Liters/c/yr
	Protection against risk of waterborne illnesses:			
15.	Bottled water consumption to protect against risk [7]	49.8	51.8	Liters/c/yr
16.	Average bottled water consumption to protect against risk [8]	50.8		Liters/c/yr
17.	Total cost of bottled water consumption to protect against risk [9]	$20.3		US$/capita/yr

[1] *See section 2.9*
[2] *See section 5.5.1*
[3] *See table 5-3*
[4] *See section 5.5.1*
[5] *Source: Various sources, as cited by Sarraf et al, 2004*
[6] *Source: MAS, 2010 (see table 2-2)*
[7] *Calculated by: item 4 minus the average of items13 and 14*
[8] *Calculated by: average of high and low values from item 15*
[9] *Calculated by: item 16 multiplied by item 3*

As it is shown in Table 5-4, the per capita expenditures in Palestine, the bottled water expenditures in Ramallah and Al-Bireh governorate, the average price of bottled water, and the bottled water consumption in Ramallah and Al-Bireh governorate are factors which are taken into consideration within the calculations and are obtained from various sections throughout this report. The GDP per capita in Western Europe and US in 1975, before the doubling and tripling in consumption that resulted in large part because of perceptions of increased health risk of potable municipal water, is compared to the GDP per capita in Palestine for 2008, where it is assumed that a significant amount of consumption results from perceptions of adverse health risks. To illustrate the calculations made in Table 5-4, a sample calculation of the "expected" quantity of bottled water consumption in Ramallah and Al-Bireh governorate, which is non-risk related, as a result of the 'low' income elasticity of bottled water demand and 'low' price elasticity of bottled water demand is shown as follows:

$$Q = Q_{eu} * \left(\frac{Y}{Y_{eu}}\right)^{e} * \left(\frac{P}{P_{eu}}\right)^{e'} = 30 * \left(\frac{1290}{17253}\right)^{0.25} * \left(\frac{0.4}{0.3}\right)^{-1.5} \approx 10 \text{ L.}$$

Where Q is expected consumption level in Ramallah and Al-Bireh governorate, Q_{eu} is consumption level in the European countries in the 1970s, Y is GDP per capita in Palestine, Y_{eu} is GDP per capita in 1975 in the European countries, e is income elasticity of demand, P is bottled water prices in Ramallah and Al-Bireh governorate, P_{eu} is bottled water prices in the European countries, and e' is price elasticity of demand.

This equation is part of a method adopted by Sarraf et. al. 2004 for estimating the avertive expenditure on bottled water. The price elasticity of demand is a measure of the rate of response of quantity demanded due to a price change. It is used to see how sensitive the demand for a good is to a price change. The higher the price elasticity, the more sensitive consumers are to price changes, and a very low price elasticity implies that changes in price have little influence on demand.

The average of the values of “expected” bottled water consumption in Ramallah and Al-Bireh governorate which are non-risk related and are related to low price elasticity of bottled water demand is 9.5 L/c/yr and the average of the values which are related to high price elasticity of bottled water demand is 6.5 L/c/yr. The actual bottled water consumption in Ramallah and Al-Bireh governorate (58.3 L/c/yr) minus the averages of “expected” consumption is 49.8 L/c/yr and 51.8 L/c/yr respectively. Thus, the ‘low’ value of bottled water consumption to protect against risk is 49.8 L/c/yr and the high value is 51.8 L/c/yr, the average of which is 50.8 L/c.yr.

Based on the amount of average bottled water consumption to protect against risk (50.8 L/c/year), the total expenditure on bottled water to protect against risk is:

(50.8 L/c/year) * (1.55 nis/L) * (279730 capita) = **22.0 million NIS/yr**, or 78.7 NIS/c/yr.

5.5.2 Expenditure on Water Purification Apparatuses

The results of the questionnaire showed that a total of 13.9% of households in the governorate have installed water filters. This includes the households which drink filtered water exclusively, households which drink both bottled and filtered water, and households which drink both tap and filtered water, which are 11.3%, 2.0% and 0.6% of the total sample respectively. Of these households, 80% are living in urban areas and 20% are living in rural areas. Therefore, 11.12% of households with filters are located in urban areas and 2.78% of households with filters are located in rural areas. In the Ramallah and Al-Bireh governorate, there is a total of 27,182 households in urban areas and 19,750 households in rural areas (PCBS, 2008). The estimated number of households with filters can then be estimated as:

[27,182 * 0.1112] + [19,750 * 0.0278] = **3,572 households with filters in the governorate,** where 3023 households are located in urban areas and 549 households are located in rural areas.

Responses from the questionnaire showed that the average capital cost of the water filters installed is 1,400 NIS and the average operation and maintenance cost is about 261.5 NIS/year.

As the technical life of the filtration apparatus is limited, the routine cost for operation and maintenance, needed for the upkeep of the apparatus over its service life, is added to the capital cost, needed for the provision of the apparatus. The annual cost for investment, operation, and maintenance is calculated to account for the depreciation rate, where:

Depreciation rate (d) = 1/*n* *100% (*n*=service life)

Assuming that the service life of the average water filter is 10 years, the depreciation (based on a fixed annual rate) is 10% (1/10*100%) per year.

The annual costs to be paid by user are:

- Operation and maintenance: 261.5 NIS/year
- Depreciation: 0.1 * 1400NIS = 140 NIS/year

The total annual cost is thus 401.5 NIS/household (261.5 NIS + 140NIS).

The total expenditure on water purification apparatuses in the Ramallah and Al-Bireh governorate can be calculated as follows:

[3,572 households] * [401.5 NIS per household per year] = **1.43 million NIS**.

Another illustration of future costs associated with the capital investment and routine costs of water filtration apparatuses, by taking into consideration the time value of money, is by adding the present value (PV) of the routine cost, over the service life, to the initial investment. The present value is equivalent to a present sum, which invested with a compound interest, is equal to a future cost:

$$PV = C * \frac{\{1-(1+i)^{-n}\}}{i}$$

Where *C* is the routine cost (assuming equal annual cost for operation and maintenance over the entire service life), *i* is the interest rate, and *n* is the service life. The routine cost C is 261.5 NIS/year, the interest *i* is assumed to be 7% (based on general knowledge of Palestinian banks), and the service life is 10 years. The present value of the investment is 1400 NIS. The present value of the routine cost is calculated as follows:

$$PV = 261.5 * \frac{\{1-(1+0.07)^{-10}\}}{0.07} = 1837 \text{ NIS}$$

The present value of the total cost = 1400 + 1837 = 3237 NIS per unit household.

5.5.3 Total Expenditure on Drinking Water

Based on the results found in sections 5.5.1 and 5.5.2, the total averted expenditure on drinking water supplies in 2009 can be calculated as follows:

Total Expenditure on Drinking Water Supplies =
Total averted expenditure on bottled water + Total expenditure on water purification apparatuses

Total Expenditure on Drinking Water = 22.0 million NIS + 1.43 million NIS

= 23.43 million NIS.

Therefore, about 23.43 million NIS were expended in 2009 on drinking water supplies other than the supplied tap water.

5.5.4 Opportunity Cost of Drinking Water Expenditures

The opportunity cost can be considered as the value of what is foregone in order to have something else, or the cost of foregoing the opportunity to purchase something else. This concept can be visualized as follows:

The results of the questionnaire showed that the bottled water drinkers consume 0.71 l/c/d of bottled water. Let's assume that the average person drinks 0.71 l/d of water, then the cost for that amount of tap water is:

0.71 l/c/d * (1m^3/1000L) * (4.1 NIS/1m^3) * (365 days/yr) = **1.06 NIS/c/yr**

Assuming that the average cost of bottled water per liter is 1.55 NIS/L. (Table 5-3), for that same consumption, the cost of bottled water would be:

0.71 l/c/d * (1.55 NIS/L) * (365 days/yr) = **402 NIS/c/yr**

Assuming that the average cost of a filter over its service life is 401.5 NIS/household/year and the average household size is 5.3 (PCBS, 2008), then the cost for that same consumption of water from a filter would be:

[401.5 NIS /5.3] = **75.8 NIS/c/yr**

So, for a 1-year period, the average person purchasing bottled drinking water is forgoing the opportunity to save (402 - 1.06) = 400.94 NIS /yr. The average person who has installed a water filter is forgoing the opportunity to save (75.8 - 1.06) = 74.74 NIS/yr. These amounts represent the opportunity costs associated with drinking water expenditures.

5.5.5 Future Value of Total Expenditure on Drinking Water Supplies

To illustrate the concept of the time value of money, and to evaluate the worth of the expenditure after a given period of time, the value of total expenditure on drinking water can be forecasted into the future for 10 years or 20 years, using the future value equation:

$$\textbf{Future Value} = \textbf{Present Value} \ (1 + i)^{n}$$

Where *i* represents the growth rate per year and *n* represents the number of years.

To compound the amount of money at a given rate, as a scenario, it is assumed that the proportion of bottled water and filter consumers remains constant throughout the next 20 years. The growth rate will be set to include both the yearly natural population growth rate, which is 3%, and the yearly increasing demand for bottled water, which is estimated to be about 10% per year worldwide (Gleick, 2004). Thus the total growth rate is considered to be 13%. The future value of the drinking water expenditure in the next 10 years is:

$$\text{Future Value}_{2020} = (23.43 * 10^{6}) * (1 + 0.13)^{11}$$

$$= 89.87 \text{ million NIS}$$

The future value of the drinking water expenditure in the next 20 years is:

$$\text{Future Value}_{2030} = (23.43 * 10^6) * (1 + 0.13)^{21}$$

$$= 305.08 \text{ million NIS}$$

These forecasted values show the value that a sum of money will have in the future, taking into account the effects of population growth rate and bottled water demand. These future costs will accrue to future generations if trends continue at the same rates. This brings up the question of what is the responsibility of policy makers to future generations and whether utility can be derived from providing benefits to others. These forecasted values also question whether these expenditures, present and future, can be invested to improve the quality, taste, color, etc. of public drinking water reaching consumers through rehabilitating main water lines and household connections and by raising awareness and improving trust among the residents regarding their drinking water supplies.

CHAPTER SIX CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Palestine's population consumes bottled water mostly due to the perception that public drinking water is of a low quality, while some consumption is due to taste and lifestyle preferences. In addition to bottled water consumption to protect against inferior (real or perceived) public water quality, many households have installed water purification equipment. Water pollution and possible contamination, or the perception thereof, of public drinking water has a cost to society.

The main objective of this research was to assess the quality of public drinking water in the Ramallah and Al-Bireh Governorate, and to estimate the expenditure on different drinking water to monetize the opportunity cost. The compilation and assessment of chemical and microbial water quality data for public drinking water supplies in the Ramallah and Al-Bireh governorate showed that generally speaking, the supplied public water in the governorate conforms to the Palestinian standards for safe and healthy drinking water.

Bottled water consumption in 2009 is estimated at 58.3 liters per capita per year in the Ramallah and Al-Bireh governorate where about 16.35 million liters of bottled water were sold in total. Bottled water consumption is in large part likely due to be avertive behavior to avoid perceived risk of illness from inferior quality tap water and in part is also a preference (taste, accessibility, etc.). The total expenditure on bottled water in the Ramallah and Al-Bireh governorate was found to be 23.25 million NIS in 2009, the total averted expenditure on bottled water was estimated to be 22.0 million NIS and the total expenditure on water purification apparatuses was found to be about 1.43 million NIS. Thus, the total expenditure on drinking water totaled to

23.43 million NIS. When these expenditures are represented as the opportunity costs, the average person purchasing bottled water is forgoing the opportunity to save 400.94 NIS/yr, and the average person who has installed a water filter is forgoing the opportunity to save 74.74 NIS/yr, which are both costs associated with drinking water expenditures.

This information shows that despite the fact that water quality data, obtained from water providers, shows that there is no adverse health risks associated with the consumption of public drinking water, there remains to be perceived health risks among consumers and a significant amount of money is being spent on avertive actions such as the purchase of bottled water and installation of tap water filters.

6.2 Recommendations

It is apparent from this research that the general perception of public drinking water being of low quality is leading many consumers into expending a significant amount of money into purchasing what is thought to be ‘better’ drinking water. It is recommended that public water providers exert greater effort firstly into maintaining high drinking water quality in the distribution system of the governorate and secondly marketing this water to the general public to gain their trust and approval. This can be achieved by providing the public with accurate and concise annual water quality reports which can be easily accessed and comprehended by the average population and by providing a transparent monitoring system. It is also essential to raise awareness among the public on the importance of regular maintaining and cleaning of private roof and water tanks, checking household connections and fixing leaking or deteriorated pipes to ensure that the water being supplied to them is not being contaminated as it enters the home.

For residents who perceive a problem with their tap water, it is recommended that home tap water quality be tested by the proper authorities, such as the Palestinian Water Authority and Ministry of Health who will carry out a professional testing and will provide an un-biased assessment, based on which the consumer may make educated decisions regarding their choices on their choice of drinking water. These actions can undoubtedly raise the level of trust among residents of the governorate and would eventually reduce their reliance on alternative, more costly, drinking water supplies. In today's economy, the opportunity cost for drinking water expenditures should be an important consideration and valuable concept to the average consumer.

For water monitoring institutions and regulators, the following recommendations are derived:

- The labels of locally bottled and internationally imported bottled water must be monitored more closely to ensure that they conform to PSI bottled water standards (PSI 69-2005).
- The constituents of imported bottled water must be checked to make sure that this water is safe for human consumption.
- Bottled water must be monitored and analyzed regularly to ensure this it adheres to the claims made on the bottle labels.
- More information is needed at the regulatory level regarding the industries and products dealing with drinking water, for both bottled water and filter industries, due to the high importance and apparent misconceptions regarding this issue.
- Increased information exchange and coordination between the Palestinian Water Authority, water providers, Ministry of Health, Ministry of National Economy, among others, regarding the issues of public drinking water and the industries dealing with drinking water.

6.3 Further Research

This study has provided a discussion of water quality issues and bottled drinking water in the Ramallah-Al Bireh governorate. As with any study, further research is required to reveal additional information and to take this study to the next level. Some possible further research, which would elaborate on certain issues mentioned throughout this study, may be as follows:

- Study on the socio-economic aspects of bottled water consumption, taking into consideration factors such as household income, price of bottled water, price of alternatives, preferences, etc.
- Study on household water quality, comparison of quality at the network, in the roof tank, at the tap.
- Study on the quality of filtered water: threats and benefits.
- Study on the quality of bottled water compared to drinking water standards and to the bottle labels; the quality of bottled water after time and storage effects, etc.

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APPENDIX 1

Per Capita Bottled Water Consumption by Country, 1999 to 2004

(Source: The Pacific Institute, 2009)

Liters per person

Countries	1999	2000	2001	2002	2003	2004 (P)
Italy	155	160	164	167	179	184
Mexico	117	124	130	143	157	169
United Arab Emirates	110	114	119	133	145	164
Belgium-Luxembourg	122	118	118	124	133	148
France	118	126	131	141	148	142
Spain	102	105	109	112	127	137
Germany	101	102	103	105	121	125
Lebanon	68	77	85	94	96	102
Switzerland	90	90	90	92	96	100
Cyprus	67	72	76	81	86	92
United States	64	67	74	82	85	91
Saudi Arabia	76	80	85	90	88	88
Czech Republic	62	68	74	80	84	87
Austria	75	75	78	79	86	82
Portugal	70	72	73	76	78	80
Slovenia	48.4	56.3	64.4	71.4	77.7	80.3
Qatar	59.5	63.3	67.1	70.8	74.3	78
Thailand	67	70	73.4	76	76.8	76.5
Kuwait	50.2	57	62.9	68.2	72.6	76.1
Pacific Islands*	48.3	50.8	54.1	57.3	66.6	72.1
Croatia	41.6	46.7	51.6	56.3	62.3	68.6
Bahrain	50.5	53.7	56.9	60.2	63.3	66.6
Hungary	29.5	39.2	46.2	51.1	61.5	66
Brazil	33.1	39.4	46.8	53.5	59.1	63
Israel	23.1	29.1	37.9	47	55.6	60.9
Hong Kong SAR	35.1	38.1	41.4	45.3	49.2	58.4
Brunei Darussalam	36.9	40.3	43.5	46.6	49.7	53.2
Bulgaria	17.9	23.1	29.6	37.5	43	51.1
Greece	41.2	42.5	43.6	45.4	47	49
Poland	28.6	33.1	37.8	44.6	47.9	48.5
Serbia	29.6	31.4	33.5	39.1	43.7	46.6
Romania	26	28.6	35.8	37.6	40	44.4
Korea, Republic of	23.6	25.1	26.6	28.3	33.8	40.3
United Kingdom	20.2	23.8	26.6	29.7	34.4	36.6
Turkey	21.1	25.4	28.1	29.8	34.2	35.7
Slovakia	31.2	31.5	32	32.9	33.8	35
Canada	24.4	27.1	29.7	32.2	33	34.3
Ireland	17.6	22.6	25.6	27.6	30.3	32.4
Latvia	12.7	16.1	19.7	23.7	30.7	31.9
Indonesia	15.5	19.1	22.4	26.6	29.6	30.9
Australia	20.5	23.1	25.2	29	29.6	29.9
Estonia	14.5	16.7	18.8	21.4	24	27.2
Singapore	17.4	18.2	19	19.8	20.7	23.6
Norway	17.7	17.6	19.5	20.1	19.4	22.1
Netherlands	17.3	18	18.5	19.7	20.6	21.1
Sweden	16.2	17	18.1	19.7	20.6	21
Denmark	15.4	15.4	15.4	15.7	17.7	17.9

Liters per person

Countries	1999	2000	2001	2002	2003	2004 (P)
Argentina	16.3	16.2	16.1	15.7	16.7	17.1
Philippines	12.6	13.8	14.6	15.6	16.1	16.4
Finland	11.3	12	12.7	13.2	13.9	14.1
Venezuela, Boliv Rep of	9.9	10.5	11	11.9	12.9	13.8
Colombia	14.4	13.8	13.6	13.6	13.6	13.6
Russian Federation	5.4	6.6	8	9.7	11.7	13.5
Ukraine	6.4	7.4	8.6	9.9	11.4	12.8
Lithuania	5.6	6.6	7.9	9.6	11.2	12.8
Oman	8.3	9.2	10	10.9	11.8	12.6
Japan	7.3	9.1	9.7	11.5	12.1	12.3
Malaysia	8.4	9.1	9.8	10.4	11.1	12.2
Paraguay	9.8	10.2	10.6	11	11.4	11.8
Jordan	7.4	8.1	8.6	9.1	9.6	10.1
China**	3.6	4.7	5.9	7.6	8.1	9
Chile	6.8	7.6	7.6	7.6	7.8	8.2
Uruguay	6.2	6.6	6.9	7.2	7.5	7.9
Peru	3.4	3.8	4.3	4.7	5.2	5.9
India	1.7	2.1	2.6	3.3	4	4.8
Nicaragua	3.3	3.6	3.9	4.1	4.3	4.4
Pakistan	1.1	1.7	2.5	3.7	3.8	4
Egypt	2.5	2.8	3	3.2	3.5	3.8
Viet Nam	2.1	2.3	2.5	2.7	2.9	3
Cuba	1.2	1.3	1.5	1.6	2.6	2.8
South Africa	1.3	1.6	1.9	2.2	2.2	2.4
Subtotal	**20**	**21.8**	**23.7**	**26.1**	**28.3**	**29.8**
All Others	0.7	0.8	0.9	1	1.1	1.3
TOTAL	**16.4**	**17.8**	**19.3**	**21.3**	**23**	**24.2**

P, Preliminary

* Includes the Caroline Islands (Micronesia excluding Palau), the Marshall Islands, and the Northern Marianas (excluding Guam).

** Includes Taiwan.

Total bottled Water Consumption by Region, 1997 to 2004

(Source: The Pacific Institute, 2009)

Thousand Cubic Meters

Regions	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004 (P)**
Europe	34,328	36,074	39,965	42,276	44,520	47,037	51,768	53,661
North America	25,398	25,822	29,695	31,850	34,734	38,349	41,778	44,715
Asia	12,472	14,820	17,647	21,170	24,824	29,783	32,795	35,977
South America	5,484	6,362	7,323	8,528	9,915	11,437	12,677	13,607
Africa/Middle East/ Oceania	2,459	2,808	3,092	3,456	3,837	4,302	4,499	4,823
All Others	508	1,953	737	891	1,033	1,592	1,407	1,597
TOTAL	80,649	87,838	98,459	108,171	118,864	132,499	144,925	154,381

P, Preliminary

APPENDIX 2
Summary of Bottled Water Industry Data

No	Year of Establishment	Source of Water	Size of Containers Produced	Water Treatment Process	Areas of Distribution	# of bottles sold in Ramallah and Al-Bireh governorate (2009)	Approx Price (NIS)
1	1996	Spring	½ L., 2L.	Reverse Osmosis	West Bank	2L. : 828,000 ½ L. : 168,000	½ L.= 2 2L.= 3
2	1998	Spring	½ L., 1½ L.	Sedimentation, sand filtration, activated carbon filtration, ozonation, ultra filtration, UV	West Bank, Gaza, Israel	Approx total: 5.6 million ½ L.: 1.68 million 1 ½ L.:3.92 million	½ L.= 2 1 ½ L.= 1.4
3	1999	Spring	18.9 L.	Sedementation, chlorination, sand filtration, carbon filtration, RO, softner, UV	West Bank, Jerusalem	Approx. 115,000	35
4	2000	Imported from Jordan	½ L., 1½ L	Reverse Osmosis	West Bank	½ L. : 741,600 1 ½ L. : 225,000	½ L.=2 1 ½ L.= 2
5	2000	Imported from Jordan	½ L., 1½ L, 2L.	Filtration	West Bank	½ L.: 43,200 1½ L.:55,800 2L.: 32,400	½ L.= 2 1 ½ L.= 2.5 2L.= 3
6	2003	Municipality	18.9L.	Sand filtration, carbon filtration, nitrate filtration, softner, UV, RO, Ozone filter	Ramallah and Jericho governorates	Approx. 35,000	20
7	2003	Spring	1 ½ L.		West Bank	Approx. 108,456	1 ½ L. = 3
8	2006	Well	½ L., 1½ L	Chlorination, sand filtration, RO, UV, ozonation	West Bank	Approx total: 175,000 ½ L.: 105,000 1 ½ L.: 70,000	½ L.= 2 1 ½ L.= 2
9	2007	Municipality	½ L., 1½ L	Sedimentation, sand filtration, carbon filtration, RO, softner	West Bank	½ L.: 10,800 1 ½ L.: 10,080	½ L.= 1 1½L.=1.25
10	2008	Spring	½ L., 1½ L	Chlorination, sand filtration, carbon filtration, UV, ozonation	West Bank, Israel, Gaza	Approx total: 2.028 million ½ L.: 1.092 million	½ L. =1 1½ L.=1.5

						1½ L. 0.936 million	
11	2008	Municipality	18.9L.	Sand filtration, carbon filtration, nitrate filtration, softner, UV, RO, ozone filtration,	West Bank	-	20
12	2009	Municipality	18.9L.	Sand filtration, carbon filtration, softner, RO, cellulose filter, UV, ozonation	West Bank	-	30
13	2009	Spring	1½ L	Chlorination, sand filtration, carbon filtration, UV, ozonation	West Bank	-	1 ½ L.=1.5
14	2010	Spring	1½ L	Chlorination, sand filtration, carbon filtration, UV, ozonation	West Bank	-	1 ½ L.= 1.5