ASSESSMENT OF THE PHYSICOCHEMICAL PROPERTIES OF DRINKING WATER OF SELECTED SCHOOLS IN KUWAIT

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FACULTY OF ENGINEERING
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ASSESSMENT OF THE PHYSICOCHEMICAL PROPERTIES OF DRINKING WATER OF SELECTED SCHOOLS IN KUWAIT

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ABSTRACT

The drinking water is the most important natural element in eco system which cannot be ideally utilized and managed unless its quality is appropriately evaluated. Despite the efforts made in the best use of technology to ensure delivery of high-quality water to consumers, governments in the most countries still need to intensify efforts to promote and follow-up field studies with continuous improvement of guidelines standards.

The predominant hyper-dry climate of Kuwait is not positive to the presence of any waterway frameworks in the nation, inward renewable groundwater sources are negligible so that Kuwait's main source is from Bay of Kuwait supplied by desalination plants. The main objectives of this study are, first, to characterize tap drinking water quality of 51 selected schools in Kuwait, and second, to assess the physicochemical properties of drinking water in Kuwait with national, regional and international standards, Data for drinking water is extracted selected schools in different residential areas in 5 Governorates of Kuwait. A total of analyzed data reading is 3015 monthly average collected during a period of 12 months of 2014. A third, objective is to suggest improved national standards of physicochemical properties of tap water comparing with international standards. Data from secondary data were provided by the Environmental Public Authority-State of Kuwait, The physicochemical parameters were analyzed using Microsoft Excel Version 2010, Descriptive statistics methods was used for quantitative variables analysis and multivariate Statistical Methods with the objective of evaluating significant differences among the sites for all water quality variables.

The results show that the concentrations of most physical parameters were within the recommended limits concentrations except the temperature reaching a mean value of 32.31±5.35 °C. This value is 3 times higher than the desirable water temperature of 4 °C to 10 °C and is directly related to the natural hot weather condition. Most of the

chemical parameters such as TOC, TA and major cations and anions as Ca^{2+}, Mg^{2+}, Na^{+}, F^{-}, Cl^{-}, NO_3^{-} , SO_4^{2-}, and trace metals such as Al, As, Ba, Cd, Cr, Cu, Pb, Mn, Hg, Ni, Zn were the concentrations in tap drinking water below threshold values stipulated by most national, regional and international agencies. However the analysis results revealed the maximum average concentration of Cl were at 0.55 mg/l of the samples investigated thus exceeding the allowable set standards. However the means of all the samples were at 0.25±0.06 mg/l. while the mean values lower between all five governorates. Trace metal such as Se mean concentration varied between 5 µg/l and 29.9 µg/l. while the means of all the samples was at 6.95±6.37 mg/l. The maximum concentration was higher than the national standard value of KUW-EPA of 10 µg/l, whereas it is lower than the standards of GSO and WHO set at 40 µg/l.

Keywords: Kuwait; Desalinated water; Tap water; Drinking water; Water quality; Trace Metals; physicochemical properties;

ABSTRAK

Air minuman adalah unsur semulajadi terpenting ekosistem. Ia tidak akan dapat diguna dan diurus dengan sempurna sekiranya kualiti air ini tidak nilai dengan betul. Walaupun terdapat usaha untuk menggunakan teknologi yang terbaik bagi memastikan air minuman yang disalurkan kepada pengguna adalah air yang berkualiti tinggi, namun pihak pemerintah di kebanyakkan negara masih perlu memperhebatkan usaha bagi menggalak dan membuat susulan terhadap kajian lapangan dengan penambahbaikan piawaian garis panduan secara berterusan, sementara dunia pada. Iklim predominan hiper-kering di Kuwait tidak memungkinkan sebarang rangka kerja laluan air di negara tersebut. Kadar hujan yang memasuki bekalan air bawah tanah adalah sedikit dan sumber air bawah tanah yang boleh diperbaharui ini adalah diabaikan. Sumber utama Kuwait adalah dari teluk Laut Kuwait yang dibekalkan oleh loji penyahgaraman. Objektif utama kajian ini adalah, pertama, untuk mencirikan kualiti air minuman dari paip di 51 buah sekolah terpilih di Kuwait, dan kedua, untuk menilai ciri-ciri fizikokimia air minumam di Kuwait berdasarkan kepada piawaian kebangsaan, serantau dan antarabangsa. Bacaan air minuman telah diekstrak dari sekolah-sekolah terpilih di kawasan perumahan yang berbeza di 5 negeri di Kuwait. Jumlah keseluruhan data bacaan yang telah dikumpul dan dianalisa adalah purata sebanyak 3,015 sepanjang tempoh 12 bulan bagi tahun 2014, ketiga adalah untuk mencadangkan penambahbaikan piawaian kebangsaan bagi ciri-ciri fizikokimia air paip berpandukan kepada piawaian antarabangsa. Data sekunder adalah diperolehi daripada KUW-EPA. Parameter fizikokimia dianalisa menggunakan Microsoft Excel Versi 2010. Kaedah statistik diskriptif telah digunakan bagi analisa pembolehubah yang kuantitatif dan kaedah statistik multivariate dengan objektif untuk menilai perbezaan yang signifikan antara lokasi bagi kesemua pembolehubah kualiti air. Keputusan menunjukkan bahawa kepekatan kebanyakan parameter fizikal adalah dalam had kepekatan yang disyorkan

kecuali bagi suhu iaitu mencecah nilai min 32.31±5.35 °C. Nilai ini adalah lebih tinggi berbanding suhu air yang wajar (4 °C to 10 °C) dan ianya berkait dengan cuaca panas semulajadi, sementara kebanyakan parameter kimia seperti TOC, TA dan cation dan anion utama seperti Ca^{2+}, Mg^{2+}, Na^{+}, F^{-}, Cl^{-}, NO_3^{-} , SO_4^{2-}, dan logam surih seperti Al, As, Ba, Cd, Cr, Cu, Pb, Mn, Hg, Ni, Zn di dalam air minuman dari paip adalah berkepekatan dibawah nilai ambang yang telah ditetapkan oleh kebanyakan agensi kebangsaan, serantau dan antarabangsa. Namun begitu, keputusan analisa mendedahkan bahawa purata kepekatan maksimum Cl yang berkepekatan 0.55mg/l bagi sampel kajian adalah melebihi tahap yang dibenarkan oleh ketetapan piawaian. Walau bagaimanapun, bacaan min bagi kesemua sampel adalah pada 0.25±0.06 mg/l, sementara nilai min adalah rendah bagi kesemua lima negeri. Bacaan min kepekatan bagi logam surih seperti Se adalah berbeza-beza diantara 5 µg/l dan 29.9 µg/l. Manakala nilai min bagi kesemua sampel adalah 6.95±6.37 mg/l. Kepekatan maksimum adalah lebih tinggi berbanding nilai piawaian kebangsaan yang ditetapkan oleh KUW-EPA iaitu pada 10 µg/l, namun bacaan ini adalah lebih rendah berbanding bacaan piawaian yang ditetapkan oleh GSO dan WHO iaitu pada 40 µg/l.

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DEDICATION

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Whose affection, love, encouragement, and prays of day and night make me able to get such success and honor.

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TABLE OF CONTENTS

Abstract iii

Abstrak v

Acknowledgements vii

DEDICATION viii

Table of Contents ix

List of Figures xiii

List of Tables xvi

List of Symbols and Abbreviations xvii

List of Appendices xx

CHAPTER 1: INTRODUCTION 1

1.1 Background of the Study 1

1.2 Problem Statement 5

1.3 Objectives 6

1.3.1 Main Objective 6

1.3.2 Specific Objectives 6

1.4 Scope of the Study 7

1.5 Significance of the Study 7

1.6 Outline of the Study 7

CHAPTER 2: LITERATURE REVIEW 9

2.1 Overview of the State of Kuwait 9

2.2 Resources of Water in Kuwait 9

2.3 Kuwait Bay 11

2.4 The Plumbing System of Drinking Water in Kuwait. 12

2.5 Drinking Water Characterization............14
2.5.1 Physical Properties of Water............14
2.5.1.1 Temperature............15
2.5.1.2 Electrical Conductivity (EC)............16
2.5.1.3 Total Dissolved Solids (TDS)............17
2.5.2 Chemical Characteristics of Water............17
2.5.2.1 Total Organic Carbon (TOC)............17
2.5.2.2 Total Alkalinity (TA)............18
2.5.2.3 Free Residual Chlorine............19
2.5.3 Inorganic Minerals Major Cations............20
2.5.4 Inorganic Minerals Major Anions............21
2.5.5 Trace Metals............24
2.6 Drinking Water Quality Parameters............25
2.7 Risk Assessment in Drinking Water............26
2.8 International Drinking Water Contaminants Categories............27
2.9 National & International Standards for Drinking Water Quality............27
2.10 Kuwait's Drinking Water Quality Standards............28
2.11 Gulf Cooperation Council (GCC) Gulf Standardization Organization (GSO)............29
2.12 World Health Organization Guidelines for Drinking Water............30
2.13 Water Resource Management............31
2.14 Water Quality Index (WQI)............31
2.15 Water Quality Monitoring............32
2.16 Difference between Trace Metals and Heavy Metals............32
2.17 Challenges in Desalinated Drinking Water Quality Sector............32
2.18 Water Quality of Security Nexus for Water, Food, Energy............32
2.19 Tap Drinking Water Quality Criteria/Standards Statistical Analysis Indicator............33

2.20 Water Drinking Quality Watch Program 34
2.21 Enforcement Environmental Management System Tools to Reduce Pollution from Source of Pollutants 34

CHAPTER 3: METHODOLOGY 35
3.1 Study Design 35
3.2 Study Area 38
3.3 Sampling Size and Data Collection 42
3.4 Data Analysis 50
3.5 Analysis Tools used in study 52

CHAPTER 4: RESULTS AND DISCUSSION 54
4.1 Introduction 54
4.2 Standards evaluation 56
4.2.1 Physical Parameters 56
4.2.1.1 Temperature 56
4.2.1.2 Electrical Conductivity (EC) 58
4.2.1.3 Total Dissolved Solids (TDS) 59
4.3 Chemical parameters 62
4.3.1 Total Organic Carbon (TOC) 62
4.3.2 Total Alkalinity (TA) 63
4.3.3 Free Residual Chlorine 64
4.4 Major Ions 66
4.4.1 Major Cations 66
4.4.2 Major Anions 70
4.5 Trace Metals 74

CHAPTER 5: CONCLUSION AND RECOMMENDATION 87

5.1 Conclusion 87

5.2 Limitations 89

5.3 Recommendations.. 89

References 91

APPENDICES 101

LIST OF FIGURES

Figure 1.1: State of Kuwait Map (source: Food and Agriculture Organization of the United Nations-UN (FAO - Database of Global Water Statistics, AQUASTAT)............3

Figure 1.2: Outline of the Study...8

Figure 2.1: Ground water Fields in Kuwait 10

Figure 2.2: Desalination and Power Plants in State of Kuwait. 13

Figure 3.1: Method of Study is analyzed in Flowchart Explains the Research Steps toward Achieving the Objectives of the Current Study. 37

Figure 3.2: GIS Map for Urban Area at State of Kuwait. 39

Figure 3.3: Locations of the Collected Samples from 51selected Schools in 25 Areas in Five Governorates of Kuwait using GIS Tool in Scribble Map 2016.............................40

Figure 3.4: Map of Locations of Selected Schools in (KU) the Capital of Kuwait City Using GIS Scribble Maps Tools under Map Data 2016 Google....................................45

Figure 3.5: Map of Locations of Selected Schools in Hawalli (HA) Governorate Using GIS Scribble Maps Tools under Map Data 2016 Google. 46

Figure 3.6: Map of Locations of Selected Schools in (MU) Mubarak Al-Kabeer Governorate Using GIS Scribble Maps Tools under Map Data 2016 Google................47

Figure 3.7: Map of Locations of Selected Schools in (FA) Farwaniyah Governorate Using GIS Scribble Maps Tools under Map Data 2016 Google....................................48

Figure 3.8: Map of Locations of Selected Schools in (AH) Ahmadi Governorate Using GIS Scribble Maps Tools under Map Data 2016 Google. 49

Figure 4.1: The temperature values of the tap water samples examined in the selected schools...57

Figure 4.2: The EC values of the tap water samples examined in the selected schools. 59

Figure 4.3: The TDS values of the tap water samples examined in the selected schools. 60

Figure 4.4: Comparison Summary of Physical Parameters between All Five Governorates 62

Figure 4.5: The TOC values of the tap water samples examined in the selected schools. 63

Figure 4.6: The TA values of the tap water samples examined in the selected schools. 64

Figure 4.7: The Cl values of the tap water samples examined in the selected schools. .. 65

Figure 4.8: Comparison Summary of Chemical Parameters between All Five Governorates 66

Figure 4.9: The Ca^{2+} values of the tap water samples examined in the selected schools. 67

Figure 4.10: The Mg^{2+} values of the tap water samples examined in the selected schools. 67

Figure 4.11: The Na^{+} values of the tap water samples examined in the selected schools. 68

Figure 4.12: Comparison Summary of Major Cations between All Five Governorates . 69

Figure 4.13: The F^{-} values of the tap water samples examined in the selected schools.. 70

Figure 4.14: The Cl^{-} values of the tap water samples examined in the selected schools. 71

Figure 4.15: The NO_3^{2-} values of the tap water samples examined in the selected schools. 72

Figure 4.16: The SO_4^{2-} values of the tap water samples examined in the selected schools. 73

Figure 4.17: Comparison Summary of Major Anions between All Five Governorates . 74

Figure 4.18: The Al values of the tap water samples examined in the selected schools. 75

Figure 4.19: The As values of the tap water samples examined in the selected schools. 76

Figure 4.20: The Ba values of the tap water samples examined in the selected schools. 77

Figure 4.21: The Cd values of the tap water samples examined in the selected schools. 78

Figure 4.22: The Cr values of the tap water samples examined in the selected schools. 78

Figure 4.23: The Cr values of the tap water samples examined in the selected schools. 79

Figure 4.24: The pb values of the tap water samples examined in the selected schools. 80

Figure 4.25: The Mn values of the tap water samples examined in the selected schools. 81

Figure 4.26: The Hg values of the tap water samples examined in the selected schools. 82

Figure 4.27: The Ni values of the tap water samples examined in the selected schools. 83

Figure 4.28: The Se values of the tap water samples examined in the selected schools. 84

Figure 4.29: The Zn values of the tap water samples examined in the selected schools. 85

Figure 4.30: Comparison Summary of Trace Metals between All Five Governorates ... 86

LIST OF TABLES

Table 2.1: Standards for Major Ions and Physical Parameters Level of Consumer Complaint (Alsulaili et al., 2015)......24

Table 2.2: Kuwait's Drinking Water Quality Standards (KDWQS). 28

Table 2.3: GCC Standardization Organization (GSO) Drinking Water Quality Standards......29

Table 2.4: World Health Organization (WHO) Guidelines for Drinking Water. 30

Table 3.1: List of Governorates Code......41

Table 3.2: List of the Selected Schools where Tap Drinking Water Samples were collected in the Five Governorates of Kuwait......41

Table 3.3: List of Symbol Parameters and Units. 44

Table 4.1: Analytical Results of Measured Physicochemical Parameters For Tap Drinking Water From 51 Selected Schools In Five Governorates in Kuwait For 12 Months (Year of 2014)......57

Table 4.2: Mean values of the concentrations of physicochemical parameters in tap drinking water at locations of selected schools in five Governorates of Kuwait......60

LIST OF SYMBOLS AND ABBREVIATIONS

°C	Temperature
°F	Fahrenheit
µg/l	micrograms per liter
A	Alpha
AH	Ahmadi governorate.
Al	Aluminium
ANOVA	Analysis of Variance for Measures
As	Arsenic
Ba	Barium
BOD	Biochemical Oxygen Demand
Ca^{2+}	Calcium
Cd	Cadmium
Cl^{-}	Chloride
Cl	Free Residual Chlorine
CO_3^{2-}	Carbonate alkalinity
Cr	Chromium
Cu	Copper
CWQM	Continuous water quality monitoring system
DBPs	formation of disinfection byproducts
E	East
e MISK	Environmental Monitoring Information System of Kuwait
EC	Electrical Conductivity
F^{-}	Flouride
FA	Farwaniyah governorate.
FAO	Food and Agriculture Organization
FDA	Food and Drug Administration
Ft	Feet
GCC	Gulf Cooperation Council
GIS	geographic information system
GSO	Gulf Standardization Organization
H_2CO_3	carbonic acid
HA	Hawalli governorate.
HCO_3^{-}	Bicarbonate alkalinity
Hg	Mercury
IC	inorganic carbon

In	Inches
KDWQS	Kuwait Drinking Water Quality Standards
KEMC	Kuwait Environment Monitoring Centre
KU	The Capital of Kuwait City governorate.
KUW-EPA	Environmental Public Authority - state of Kuwait
m2/day	square meters
m^3	Cubic meter
Max	Maximum
mg/l	milligrams per liter
Mg^{2+}	Magnesium
MIGD	Million Imperial Gallons per Day
Min	Minimum
Mm	Millimeter
Mn	Manganese
MSF	Multi-Stage-Flash strategy
MU	Mubarak Al-Kabeer governorate.
N	North
N/A	not applicable, not available
Na^+	Sodium
NEWP	National Environmental Monitoring program
NGOs	Non-Governmental Organisations
Ni	Nickel
NO_3^-	Nitrate
OH^-	Hydroxide alkalinity
Pb	Lead
PCA	principal component analysis
Ph	Potential of Hydrogen/ Hydrogen Ion Concentration
Ppb	parts per billion
Ppm	parts per million
PW	Product water
SD	Standard Deviation
Se	Selenium
SO_4^{2-}	Sulphate
SW	Seawater
TA	Total Alkalinity
TC	total carbon

TDS	Total Dissolved Solids
THMs	Total trihalomethanes
TOC	Total Organic Carbon
UN	United Nation
US-EPA	United States Environmental Protection Agency
WHO	World Health Organisation
WQI	Water Quality Index
WQPs	water quality parameters
Zn	Zinc
µS/cm	micro-Siemens per centimeter

LIST OF APPENDICES

APPENDIX A : Permission and approval from EPA of Kuwait to provide the data for research project. 101

APPENDIX B : Sources Health and Effects of Major Cations and Anions in Water 102

APPENDIX C: Mean value of the concentrations of physicochemical parameters in tap drinking water at locations of selected schools in (KU) The Capital of Kuwait City governorate. 103

APPENDIX D : Mean value of the concentrations of physicochemical parameters in tap drinking water at locations of selected schools in (HA) Hawalli governorate........ 104

APPENDIX E: Mean value of the concentrations of physicochemical parameters in tap drinking water at locations of selected schools in (AH) Ahmadi governorate. 105

APPENDIX F: Mean value of the concentrations of physicochemical parameters in tap drinking water at locations of selected schools in (FA) Farwaniyah governorate. 106

APPENDIX G: Mean value of the concentrations of physicochemical parameters in tap drinking water at locations of selected schools in (MU) Mubarak Al-Kabeer governorate. 107

APPENDIX H: Mean values of the concentrations of physicochemical parameters in tap drinking water at locations of selected schools in five Governorates of Kuwait. .....**Error! Bookmark not defined.**

APPENDIX I: Map of Marine Sediment Texture in Kuwait Bay 108

APPENDIX J: Map of Marine Monitoring Locations in Kuwait 109

APPENDIX K: Old & New water Wells Locations in Kuwait 110

CHAPTER 1: INTRODUCTION

1.1 Background of the Study

Water pollution can be referred as any physical or chemical change in regards to the quality of water. This change can either be direct or indirect. Pollution has adverse effects on living organisms and makes water unfit for consumption or use. Water pollution has many repercussions on the life of a human society and economy as well and this is because water is a vital requirement for human health (Abdullahi et,al 2007). Water is essential for life; it is consumed and used daily by billions of people. Water plays a significant role as its contamination can threaten the human life.

Contamination of water is divided into two major types: natural pollution and chemical pollution. In natural pollution, contamination occurs through the changing of water temperature, salinity levels, or dramatic changes in the physical properties of materials in the water body. In form of chemical pollution, contamination occurs due to chemicals such as the spillage of oil in water, agricultural residues such as pesticides, fungicides and other fertilizers.

Karikari, et al., (2013) determined water quality from 2 treatment plants in Ghana. They tested fifteen areas and were checked month to month for a year at 15 distinct areas. Chlorine residuals between from 0.13 - 1.35 mg/l were observed at these plants. There have been several chemicals spills or leaks into potable water consumed by people and this very hazard risks for people. As such, there have been efforts of governments and other internal organizations to sensitize people on water pollution and as for the former, to guarantee the supply of high quality drinking water to its citizens. This is often done by the relevant authorities to increase public awareness towards water pollution consequences on health and environment through media, schools, non-governmental organizations (NGOs) activities.

However, the ongoing monitoring and testing of water samples taken from different sources is not sufficient enough to ensure water quality (WHO, 2010). There needs to be an analysis of the measurements and study of statistics to identify the hazard and risk to human health, food and other needs to ensure that the quality of drinking water is safe, meets the set health standards, and is protected from any pollution and all risks mitigated. Risk assessment of water quality has consequently become a global trend due to the sensitive impact of water quality on communities (Refer to appendix J).

Water pollution can only be dealt with the commitment to enhance the national and international guidelines and policies when it comes to quality of water and following directions in the treatment and control of various sources of pollution to prevent any outbreaks. Water pollution is a serious phenomenon due to the increasing population growth, urbanization and increasing anthropogenic and industrial activities (Garizi, et al., 2011).

Governments are often tasked with ensuring that citizens have access to safe drinking water and it is imperative for them to build the necessary infrastructure that is needed and required to provide safe drinking water for everyone.

Kuwait lies in the northwest part of the Persian Gulf, between latitudes of 28.30 and 30.06 north, and longitudes of 46.30 and 49.00 east,The total area of Kuwait is 17 820 km2 and the total population is 3,971,031 (Bureau, 2015). The state of Kuwait has six administrative governorates. These are Kuwait City, Hawalli, Farwaniyah, Jahra, Ahmadi and Mubarak Al-Kabeer. Its North West borders are with Iraq, and its south and south west borders are with Saudi Arabia. Its shores of the Persian Gulf lie on the west are as shown in Fig. 1.1.

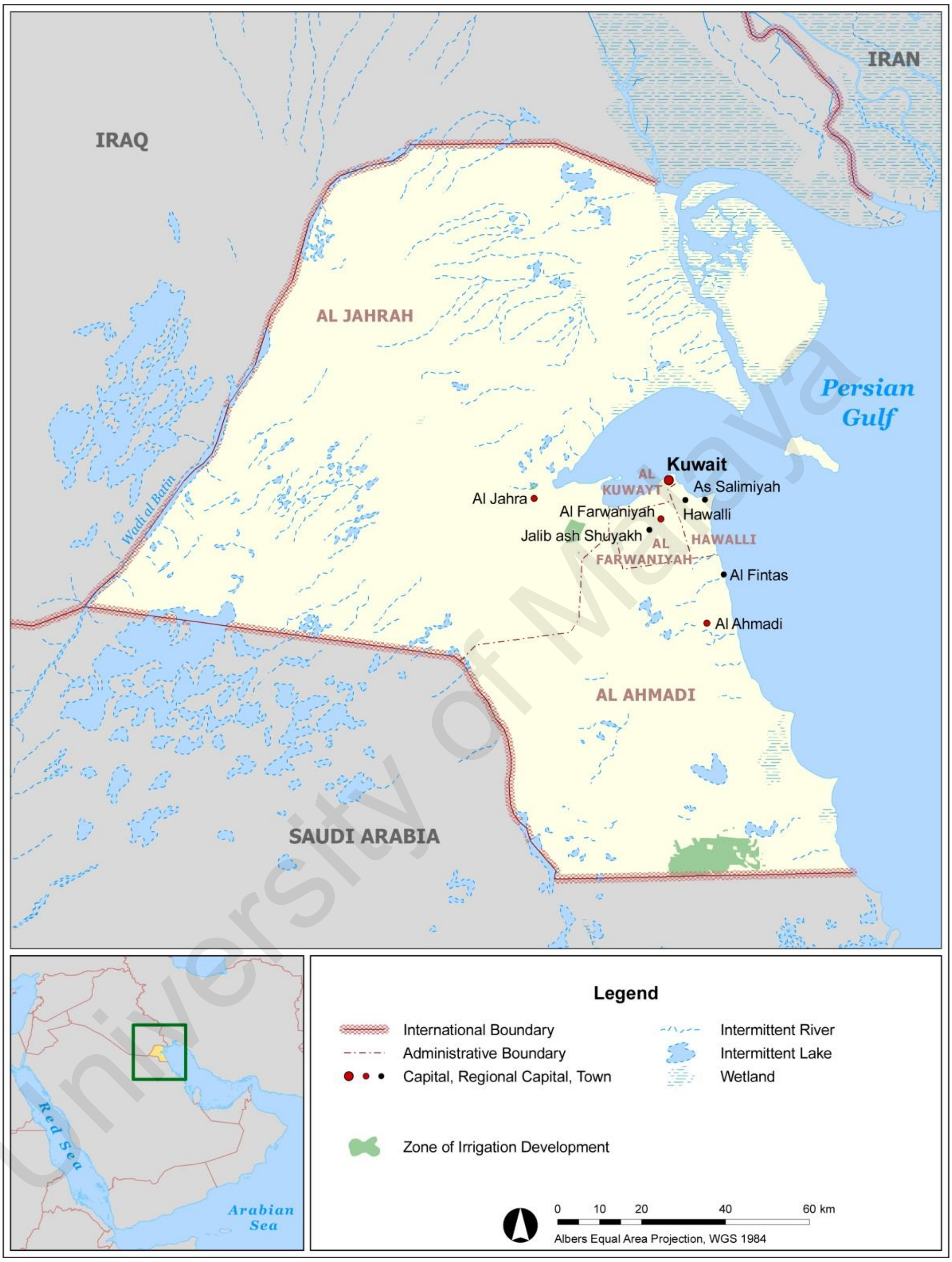


Figure 1.1: State of Kuwait Map (source: Food and Agriculture Organization of the United Nations-UN (FAO - Database of Global Water Statistics, AQUASTAT)

Kuwait City is the capital, political, cultural and economic center of Kuwait: 200 km^2 . The Kuwait city is largest and located on the southern shore of Kuwait Bay off the Persian Gulf. The total number of districts in the six Kuwait governorates is 137 districts as of August 2016. The smallest district area does not exceed 5 km^2 and its generally low lying, with the highest point being 306 m above sea level.

Kuwait has a variable continental atmosphere, with to high degree of hot and dry summers (April to October), with temperatures surpassing 51°C. Winters (November through February), with temperatures exceeding (-7°C), are cool with some precipitation and average temperatures around 56°F (13°C).

Kuwait has limited natural fresh water resources. Therefore, some of world's largest and most sophisticated desalination facilities provide the water for all State of Kuwait, Kuwait experiences very cold winters in comparison to other Gulf Cooperation Countries (GCC) and the main reason for this is because it is located on the northern position and secondly, because of the cold winds which blow from the northern side of Iraq and Iran.

The State of Kuwait is a country in Western Asia. Kuwait has an arid climate with temperatures between winter and summer. Kuwait experiences an average of 107.3 mm of rainfall per year, the maximum average precipitation occurs in January. Furthermore, average daily temperatures range between 7.2 to 44.6 °C. This is the highest recorded temperature in Asia and also the third highest in the world (retrieved from www.kuwait.climatemps.com).

Kuwait has very serious water problems and if these problems remain unaddressed, then it will have the potential of turning into a major crisis in the near future. Kuwait's natural water source is 60 m^3 yearly and this water is from renewable water wells, extraction from well extraction is at 307m^3 yearly per capita (H. Bakr, et al, 2003). The absolute water poverty levels are at 200m^3 yearly while the normal water poverty levels stand at 1000 m^3 yearly per capita as studied by (Darwish & Al-Najem 2005).

Desalinated seawater happens to be the major source of potable water, the secondary source being low salinity brackish well water (Al-Mudhaf, et al. 2012). In the year

2002, the average daily water production and consumption were at 248 MIGD of distilled water, 268MIGD fresh water and 70 million imperial gallons of brackish water. As such, it can be seen that desalinated water accounts for 74% of total water resources plus 3% of fresh water.

The Government, State of Kuwait, has made extensive efforts to try and ensure that the quality of drinking water in Kuwait is high, but the public still lacks confidence in tap water and this is mostly because of pollution, contaminants and the water's undesirable physical and chemical properties.

Quality of water has to be measured and analyzed and the physical characteristics evaluated include; temperature of the water, electrical Conductivity (EC) and Total Dissolved Solids (TDS).

Chemical properties of water need to be analyzed as well, and these properties include Total Organic Carbon (TOC), Total Alkalinity (TA), Free Residual Chlorine (Cl), and Major Cations and Anions such as Ca^{2+}, Mg^{2+}, Na^{+}, F^{-}, Cl^{-}, NO_3^{-} , SO_4^{2-} , and trace metals such as Al, As, Ba, Cd, Cr, Cu, Pb, Mn, Hg, Ni, Se, Zn.

1.2 Problem Statement

Due to the high temperature in Kuwait and low rainfall precipitation, water sources are very limited. Precipitation in the country shifts from 75 to 150 mm in a year. Genuine precipitation ranges from 120 mm in a year to as much as 600 mm. In summer, normal day by day temperatures go between 42 to 48 °C ; the most astounding ever temperature recorded in Kuwait was 54 °C at a remote weather station in Mitribah on 21, July 2016. This is the most elevated recorded temperature in Asia furthermore the third highest in the world (retrieved from www.kuwait.climatemps.com).

The main source for drinking water in Kuwait is seawater desalination stations. As water quality in Kuwait has been monitored but not compared with international guidelines standards, a study is needed to analyze the quality of the produced tap water to ensure to meet the guidelines for drinking water quality for World Health Organization. This will help to suggest the regulations and policy makers and governors in Kuwait to take mitigation action against water scarcity and poor water quality.

If found any physical and chemical concentration level exceed threshold, health concern and significance in drinking water, some of concentrations of the substance at or below the health based guideline value may affect water quality.

At same time must calibrate disinfection value in the water being exceeded, improve guideline value because of uncertainties in the health database, monitor any value is below the level that can be achieved through practical treatment method, source protection.

Calculate any substances that are considered to be carcinogenic concentrations associated with upper bound estimated excess lifetime cancer risk, etc.

1.3 Objectives

1.3.1 Main Objective

The main objective of this research is to assess the quality of drinking water in Kuwait. In order to meet this end, the following sub-objectives need to be achieved:

1.3.2 Specific Objectives

The study was conducted by the following objectives:

1) To characterize tap drinking water quality of selected schools in Kuwait.
2) To assess the physicochemical properties of drinking water in Kuwait with national, regional and international standards.
3) To suggest improve national standards of physicochemical properties of tap water comparing with international standards.

1.4 Scope of the Study

This project aims to assess the physical and chemical properties of drinking water in Kuwait. The present study relied on secondary data provided by the environment public health authority of Kuwait. These secondary data includes 25 physicochemical parameters recorded in tap drinking water of the 51 selected schools in five governorate; Kuwait City, Hawalli, Ahmedi, Farwaniyah, and Mubarak Al-Kabeer; with a number of schools being 12, 12, 9, 8, and 9, respectively. The sixth governorate in Kuwait, *Jahra*, is not included in the current study due to the unavailability of the data. Please refer to (Appendix A) for the detailed regarding permission and approval from EPA of Kuwait to provide the data for research project.

1.5 Significance of the Study

As the water in Kuwait is tap potable, during the day time provided by tap water for drinking.This group of community are students children’s and young generation in the schools.

Therefor the study has been conducted in selected schools in Kuwait. This research studies drinking water quality in Kuwait schools which directly affects the health of school students. Analyzing the quality of drinking water in Kuwait and comparing it to the regional and international standards will help to assess the quality level of the offered tap water for human consumption purposes.

1.6 Outline of the Study

This research report contains five main chapters. A brief introduction of each chapter that will be discussed is shown in Fig.1.2:

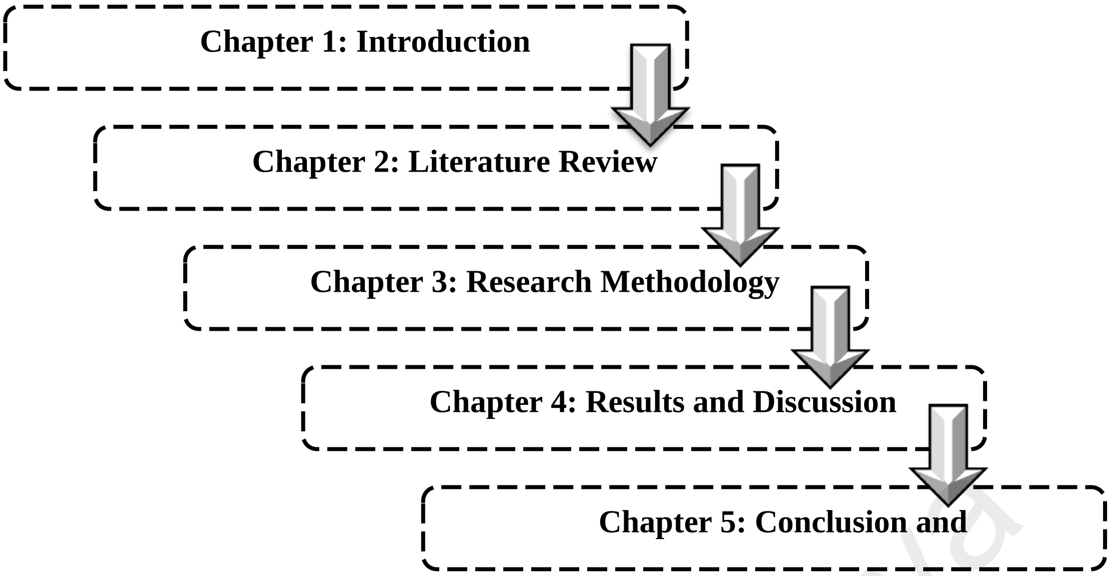


Figure 1.2: Outline of the Study

CHAPTER 2: LITERATURE REVIEW

2.1 Overview of the State of Kuwait

The state of Kuwait has six administrative governorates. These are Kuwait City, Hawalli, Farwaniyah, Jahra, Ahmadi and Mubarak Al-Kabeer. Its North West fringes are with Iraq, and its south and south west outskirts are with Saudi Arabia. Its shores of the Persian Gulf lie on the west. This special location provided Kuwait with a business significance. It is a characteristic outlet for the northwest part of the Arab Peninsula. Kuwait's territorial waters are characterized by shallow seas. These waters have temperatures of >30 ^{o}C and salinities of about 40 ppt Kuwait Bay is one of the most prominent features in Kuwait's marine environment. It covers an area of about 750 km2 and is home to many aquatic animals. The average yearly rainfall is 107 mm and the greatest average rainfall for the most part happens in January. Kuwait is the Gulf nation with slightest new water assets and the minimum renewable fresh water level (Lyons, et al., 2015). This nation's drinking water comes just from one source, the drinking water of Kuwait is desalinated from only source which is Kuwait Bay, the treated water from this process need high requirements.

In order to provide high quality of treated water following the international guidelines standards (Al-Mudhaf, 2012).Consequently, a portion of the world's biggest and most advanced desalination plants give the water to Kuwait City.

2.2 Resources of Water in Kuwait

In the past, the major resource of water in Kuwait was the brackish groundwater. These are mainly located in the Kuwait Group and the Dammam aquifers. Salinity in

Kuwait Group ranges between 4200 to 10200 mg/l while that of the Dammam aquifers ranges between 2500 and 10000mg/l.

There are also some limited fresh groundwater resources which are present in Rawdhatain and Umm Al-Aish fields, these contain a salinity of about 360-1738 mg/l. Kuwait's underground water is mostly used for irrigation purposes, domestic use, in industries and blending with distilled water (Refer to Fig. 2.1) . Because of the increase in population, there has been a drastic decline in the level of groundwater together with the deterioration of the quality of water. There have been desalination plants which have been established and they all have a combined distillation capacity of 315.6 Million Imperial Gallons per Day (MIGD).

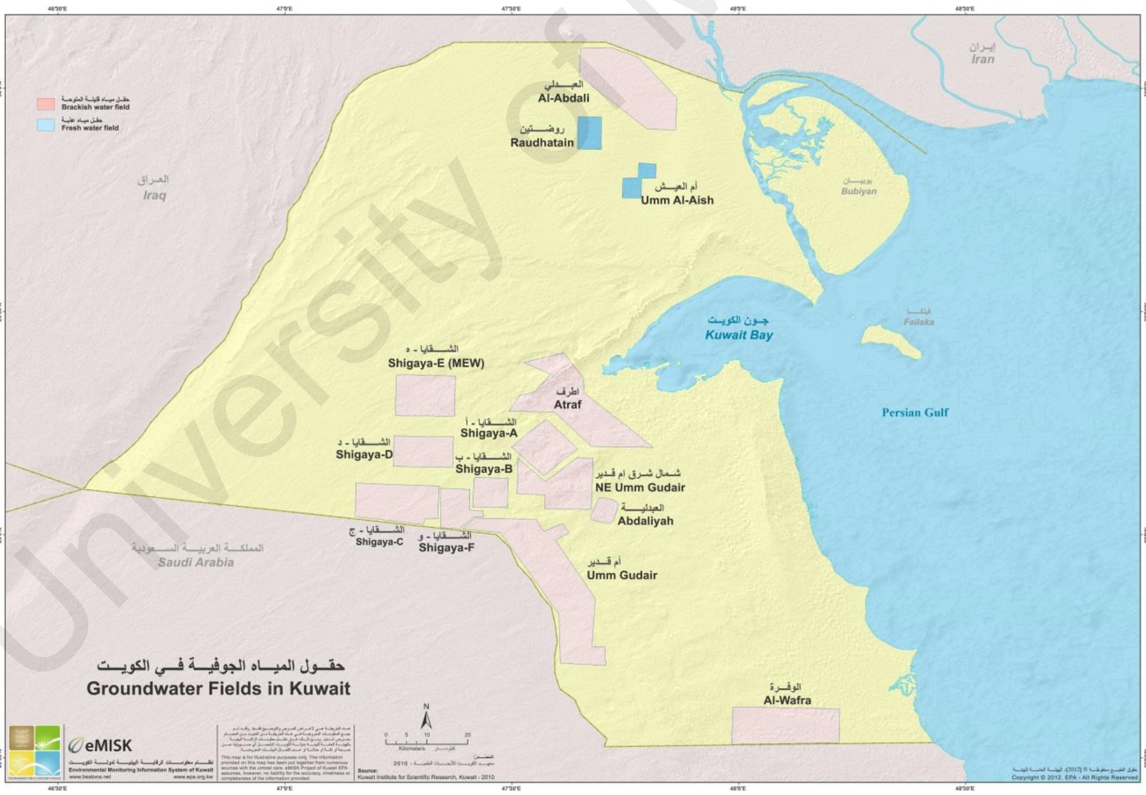


Figure 2.1: Ground water Fields in Kuwait

Desalination is now the primary source of fresh water in Kuwait. In fact, Kuwait became the first nation in the world to use desalination to supply water for use domestically and in large quantities. Other resources of water in Kuwait include treated wastewater effluents and desalinated sea water (Al-Mudhaf, et al, 2012). Kuwait has three major wastewater treatment plants which also supply water; however, much of the water demand is served through seawater desalination plants. Some of the wastewater treatment plants include Ardiya Plant (Production capacity is 280,000 m^2/day), Rigga Station (Production capacity is 185,000 m^2/day), East Jahra Station (Production capacity is 70,000 m^2/day), Umm Al-Hayman Station (Production capacity is 27,000 m^2/day) and the Giant Sulaibiya Station (Production capacity is 375,000 m^2/day).

2.3 Kuwait Bay

The most prominent geographic feature in Kuwait is referred to as the Kuwait Bay *(Jun al Kuwait).* This Bay indents the shoreline a distance of up to 40 km. The Kuwait Bay offers natural protection for Kuwait's port (Al-Mudhaf, et al, 2012). It is also very important as it accounts for almost half of the total shoreline in Kuwait.

Since 1985, there has been a drastic increase in the temperature of seawater in Kuwait Bay, with the rate of growth being around 0.62 degrees Celsius after every decade. This rate is three times more than the world's average rate as shown by the Inter-governmental Panel on Climate Change (Al-Rashidi, 2009). This change in temperature is mainly due to the effects of the desalination plants.

Increased seawater temperatures have several effects. one being that they reduce the amount of dissolved oxygen in the water and this kills fish. Another effect is that it leads to coral bleaching and if the trend continues, then very serious environment degradation of the marine ecosystems of the Persian Gulf is going to take place (Sawade, et al., 2016). In addition from previous study observed a lot of marine sedimentation in Kuwait Bay (Refer to appendix I).

2.4 The Plumbing System of Drinking Water in Kuwait

Historically, the state of Kuwait relied on wells and rain for drinking purposes (Refer to Appendix K). Because this water was at times salty and impure hence sustainable methods are required. As a result, the water towers and the sewage water treatment plants were built. The main source of water is from desalination tanks (Lyons et al., 2015). The famous “Mushroom Water Towers" are the most modern water tanks in the world and there are thirty-one of these water towers in Kuwait City which are the main sources of water within the country. Each of these water towers has the capacity of holding three thousand cubic meters of treated water currently from more than six power and desalination plants as shown (Fig 2.2) (retrieved from http://www.fao.org/docrep/w4356e/w4356e0g.htm, 2016). The treated water is then piped to consumers in their various districts.

Impact of residential storage and plumbing systems on the level of trace elements and quality in desalinated drinking water in Kuwait, however there are many issues need to be exploring due to water production authorities and consumer in Kuwait.

Need to promote survey to find effective factors as corrosion, leaching, piping, network, and all desalination treatment processes etc.

Figure 2.2: Desalination and Power Plants in State of Kuwait.

Source: e MISK, Kuwait-EPA

2.5 Drinking Water Characterization

The quality of water is determined by three main properties of water. These properties are physical, microbiological and chemical characteristics. Globally, these properties that determine the quality of water are characterized by wide variability (WHO, 2010). It is therefore imperative to establish the quality of natural water sources, whose use varies from one source to another, particularly with regard to the specific parameters of water quality which impact heavily on the most probable use of water (Jasmin, I., & Mallikarjuna, P., 2014).

The water quality in Kuwait is measured from time to time, However there are many issues to be explored due to limited water resources and difficulty of water treatment as most of the resources are sea water with high salinity.

2.5.1 Physical Properties of Water

Most physical properties of water, such as color, taste, smell and temperature, can easily be identified through the senses of the body, or through touching, seeing, smelling and testing. The temperature of water can be known through feeling or touching, its color, turbidity, sediments, muddiness and floating particles can be noted, through seeing, the taste can be identified through tasting while the odour can be noted through smelling (Gavrilova et al., 2016).

These two physical properties of water are human perceptions of the quality of water. The tongue has four main perceptions of taste and these include: bitter (caffeine), salt (sodium chloride), sour (hydrochloric acid) and sweet (sucrose). Generally, sour and salty taste is mostly generated by simple compounds, whereas complex organic compounds usually produce sweet and bitter tastes. The tongue is able to discern several other types of odour and not just taste alone (Scott et al., 2016). Some organic materials, for example, leaves that fall in water sources, might slightly change the taste and odour of water. This is because most of these compounds, when undergoing the biodegradation process while in water, usually produce compounds which might alter the taste and odour of water.

In Kuwait drinking water is obtained from seawater mixed with brackish water through the treatment process which contained Na^+ and Cl^- and other minerals salt that when tasted the presence of the elements is felt and odour of Chlorine can be smelt.

The physical properties effect of drinking water quality in Kuwait is monitored by The Environmental Public Authority, however this need to be standardize based on both national and international standards.

2.5.1.1 Temperature

Temperature is an important aspect as it affects chemical and properties of surface water. It influences and impacts the amount of dissolved water that is present in water. The amount of dissolved oxygen decreases with an increase in water temperatures.

Water temperature affects a number of vital physical characteristics of water. Some of these properties which are dependent on the temperature of water include the density of the water, the rate of solubility of dissolved gases in it, the surface tension, the specific weight of water, the viscosity of the water, its conductivity, its thermal capacity and salinity. When temperature increases by a margin of 10 °C, then the rate of reaction increases twice as much, The temperature of water in various water sources, such as rivers, lakes and seas, range from 0 to 35 °C (Retrieved from http://www.seatemperature.org).

Kuwait has a high temperature, which varies between, as low as -6^{o}C to as high as 47^{o}C. This has a direct effect on the physical and chemical nature of the seawater as such it affects the physicochemical parameters content in the water.

2.5.1.2 Electrical Conductivity (EC)

It is realized that EC is a measure of the capacity of fluid answer to convey an electric current that relies on upon the nearness and aggregate grouping of particles, their portability and valance and on the temperature. The EC is a significant measure of metal particles separate in wastewater and water.

Electrical conductivity is characteristic of total dissolved solids content in water tests, in a study by (Abdullah et al., 2007) investigated that water tests with high EC values frequently contain abnormal amounts of TDS. In study by (Trivedi and Goel, 1984).is shown there was a solid relationship amongst EC and TDS, which is predictable with perceptions reported already.

In Kuwait it should be noted that there are no health guidelines for the minimum allowable electrical conductivity of water. We take note of that there are no known well-being rules for the base reasonable electrical conductivity in drinking water. (Alsulaili *et al.*, 2015).

There is no standard for the degree of electrical conductivity in drinking water in bottled in accordance with Decision no. 210/2001pertaining to the executive by law of the Law of Environment Public Authority, an Appendix No. (16) Un-bottled Potable water, in Kuwait, need to find the limits of the threshold for EC compared with international guidelines standards.

2.5.1.3 Total Dissolved Solids (TDS)

Generally, TDS value is usually taken as an index of contamination potential of drinking water. This may introduce different diseases which affect all living things especial Human beings.

In Kuwait, TDS has impact on other physical and chemical properties in drinking water and hence alters the water quality, Because of several factors, these effect need to be compared with international standard.

2.5.2 Chemical Characteristics of Water

Chemical features or properties of water as a reflection of the type of soils & rocks that the water has had contact with. Other things that affect the quality of water are pesticides, urban runoff, insecticides, industrial treated waste water and other fertilizers used for agricultural purposes. Chemical properties of water are also impacted by other microbial and chemical transformations (Bates, 2008).

2.5.2.1 Total Organic Carbon (TOC)

Dissolved organic carbon has several impacts on the water quality as it affects the pH of water and its alkalinity as well. Depending on its concentration, dissolved organic carbon has the potential to either harm or protect aquatic life as well as the human body.

Organic materials also influence the quality of water. These materials are present in natural water because of a number of reasons. Some of these reasons include; the interaction between soils and precipitation. The source of organic materials in soils is mostly from plant and animal products that have decomposed over time (Richardson, 2013), When these products condense and polymer forming fulmic and humic acids, then these turns to rustiness and eventually to coal.

Organic materials in water can be expressed mostly in terms of total organic carbon (TOC). TOC can be defined as the difference between the total carbon (TC) and inorganic carbon (IC).

In Kuwait, organic materials affect other physical and chemical properties in drinking water and eventually influencing the water quality, the effect of such need to be standardized.

2.5.2.2 Total Alkalinity (TA)

Alkalinity of water is defined as the ionic concentration, which can neutralize the hydrogen ions. Drinking water should contain moderate amounts of carbonate alkalinity so that they can counter the corrosive impacts of acidity.

Alkalinity can be defined also as the ability of natural water to neutralize any acids that are added to the water. Total alkalinity is the amount of acid which is needed so that a certain level of pH can be attained. The total alkalinity can be expressed as shown below:

$$\text{Total alkalinity} = [HCO_3^-] + 2[CO_3^{2-}] + [OH^-] - [H^+]$$

The main alkalinity ions which are in total alkalinity are Hydroxide alkalinity $[OH^-]$, Bicarbonate alkalinity $[HCO_3^-]$ and Carbonate alkalinity $[CO_3^{2-}]$. It is possible to evaluate the concentration of the proponents of the alkalinity through the use of values of α_1 and α_2 evaluated for the pH of water. However, the measurement of pH and alkalinity of the ions to be conducted first, the calculation of values of alkalinity can be done as follows:

$$\text{Hydroxide alkalinity} = \frac{K_w}{[H^+]}$$

Bicarbonate alkalinity = $\alpha_1 C_t$

Carbonate alkalinity = 2 $\alpha_2 C_t$

C_t represents overall carbonate and $C_t = [H_2CO_3] + [HCO_3^-] + [CO_3^{2-}]$.

The total amount of acid that is needed to change the color of water from pink to colorless which a little amount of phenolphthalein reagent is added into a sample of water is referred to as phenolphthalein alkalinity. The change of color happens when the pH is approximately 8.4.

In Kuwait, alkalinity indicator was normal but if increase may effect on other physical and chemical properties in drinking water and eventually influencing the water quality, the effect of such need to be standardized.

2.5.2.3 Free Residual Chlorine

Cl is normally the most dominant anion in water and it imparts a salty taste to the water. The permissible limit of chloride in drinking water is 250 mg/L as given by WHO and SON. According to the USEPA guideline high level of Cl results in eye/nose irritation; stomach discomfort and increase corrosive character of water.

In Kuwait high temperature tap water always indicates the presence of chlorine. This is evident as it can be smelled; also it can felt by irritation on the skin and eyes. The high level of chlorine can eventually lead to skin and health issues. Free residual chlorine (Cl) is the amount of chlorine that remains in the water after a certain period or contact time. Kuwait standards concentration of Cl in water when reaches the consumer should be between 0.2 – 0.5 parts per million, However there are many remarks by WHO guidelines should be considered and maintained throughout before release Cl in the distribution system and network at the point of delivery.

2.5.3 Inorganic Minerals Major Cations

Runoff has several effects, among these effects; it leads to soil erosion and the weathering of rocks. The runoff water carries all these substances into surface water bodies (S. Uddin et al., 2013). The contact between the runoff water and rocks leads to the detachment of inorganic minerals into natural waters. These inorganic minerals may contain different cations or anions.

Some of the major cations which are present in natural water are Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Potassium (K^{+}) and Sodium (Na^{+}). Of the four, Calcium is the cations that are mostly present in water and in surface waters as an inorganic ion. Bicarbonate ions are the most present ions in surface water. Calcium is the major reason for water hardness. In addition to that, calcium also forms calcium carbonate in steel and iron pipes (Uddin et al, 2013). Calcium carbonate can help in reducing corrosion in metals, but this only happens when that layer is small. If the layer of calcium carbonate becomes big, especially in heat exchanges, heaters and boilers, then the transfer of heat is highly affected and this results in plugging inside the pipes. The concentration of calcium should not be allowed to accumulate to very high levels; there are acceptable levels of concentrations and range between 40 to 120 mg/L.

Unlike Calcium, Magnesium is only found in smaller contacts in rocks. In as much as magnesium salt's rate of dissolving is higher when compared to calcium salt, surface water contains more of calcium salts that magnesium salts (Uddin et al., 2013). Some of the other free cations found in water are sodium ions and potassium ions, however, their concentration is not that high. Other than the aforementioned ions, there are others which are found in very little quantities and these include: phosphorous ions, iron, aluminium ions and manganese ions.

During treatment process mix fresh and brackish water which contains minerals cations can taste the presence of the elements is felt, the highest level of such element can eventually lead to undesirable taste. The water quality in Kuwait is measured from time to time, this made it empirical to be looked into due to limited water resources and difficulty of water treatment as most of the resources are sea water with high salinity containing Calcium(Ca^{2+}), Magnesium(Mg^{2+}), Potassium (K^+) and Sodium(Na^+). There is need to have an acceptable range standard for such cations to be desirable. However especially Na+ that constituents levels of health significance in potable water should considered WHO guidelines standards.

2.5.4 Inorganic Minerals Major Anions

Some of the major anions which are present in water include nitrate ions, carbonate ions, bicarbonate ions, sulphate ions, chloride ions and fluoride ions among others. The major anion that is present in natural water is Bicarbonate (HCO_3^-)(S. Uddin et al., 2013). All these ions are vital in regards to the carbonate system, and this is because they offer a buffer capacity to most natural waters. These ions are cause alkalinity in natural waters.

There are several sources from which bicarbonate ions present in water come from. The most common is when carbonic acid (H_2CO_3) breaks down and dissociates forming carbon (IV) oxide. This gas dissolves in water, reacting to it and forms the acid.

There are also other ions which are present in natural waters. These include: Chlorides (Cl^-), Nitrates (NO_3^-) and Sulfates (SO_4^{2-}). The main source of these ions is when common salts present in rocks dissolve and dissociate in water (S. Uddin et al., 2013).

One of the major determinants of the quality of water is the concentration levels of chloride anions. This is due to the fact that an increase in the concentration of these ions will reduce the quality of water and render it unusable, especially when it comes to consumption by both humans and animals and also use for agricultural purposes such as irrigation. The main source of these chloride ions in natural water is magnetic rock formations. The second source of these anions is Ocean from where a considerable amount of chlorides anions Cl^- enter in the atmosphere, from atmosphere chlorides anions Cl^- enter in the natural water in result of interaction between precipitation and soil.; this is partly responsible for the presence of these ions in the water (S. Uddin et al., 2013). Once the anions are in the atmosphere, they will dissolve in natural water because of the interaction that is present be textured soils and the respective precipitates (Jasmin, I., et al 2014).

Sulphate anions are also present in the natural water. The main reason why they are present is because of chemical dissolution. The equations given below show the source of sulphate anions in water:

$$CaCO_3 + H_2SO_4 = CaSO_4 + H_2O+CO_2;$$

$$2FeS_2 + 7O_2 + 2H_2O = 2FeSO_4 + 2H_2SO_4;$$

$$2S + 3O_2+ 2\ H_2O = 2\ H_2SO_4.$$

Because of the oxidation process that takes place from substances of plant and animals, sulphate anions are released into water bodies (WHO, 2010). When the concentration of these anions increases, most of the physical properties of water, for example taste and odour, are adversely affected. Higher consumption makes that water hazardous to the human body. Most surface waters contain concentrations of sulphate anions within margins of 5 mg/l to 60 mg/l (Refer to appendix B).

Nitrate ions (NO_3) are also present in the natural water, with the main source of the ions being bacteriological oxidation of nitrogenous materials in soils. It is important to note that the concentration of these ions is very high in the summer and this is because nitrification process is usually at its peak (WHO, 2010). Precipitations are another source for the presence of these ions in surface water. These precipitates absorb nitric acid, and then they convert the precipitates forming nitrate salts. Agricultural water wastes, industrial water wastes and domestic water wastes are other sources of nitrate anions (NO_3). The level of concentration of these anions in water bodies is an indication of the extent and degree of how polluted and contaminated that water is with organic nitrate compound carbonates (CO_3^{2-}), Fluorides (F^-) and Phosphates (PO_4^{3-}) are anions which are also present in water.

Hydroxyl ions can be defined as the quantitative ability of aqueous media to react with acidity. Acidity is important because it shows the corrosiveness of acidic water on steel and concrete among other materials.

Table 2.1 indicates the average concentration of major ions in water bodies around the world. The standards used in research were obtained from the Food and Drug Administration (FDA), the World Health Organization (WHO), the United States Environmental Protection Agency (US-EPA), the GCC Standardization Organization (GSO), and the Kuwait Environment Public Authority (KUW-EPA) (Alsulaili *et al.*, 2015).

The major ions water quality in Kuwait is monitored by The Environmental Public Authority, the ions such as F^-, Cl^-, NO_3^-, SO_4^{2-} are important as natural nutrition source in desalinated water, for F^-, NO_3^- the national and international standards is same levels of health significance in potable water.

But Cl^-, SO_4^{2-} no criterion for protection of human health from consumption of potable water, but available with national standards only for constituents levels of consumer complaint and WHO international standards reason for not establishing a guideline value is not of health concern at levels found in drinking water, but may affect acceptability of water quality .

Table 2.1: Standards for Major Ions and Physical Parameters Level of Consumer Complaint (Alsulaili et al., 2015).

Parameter	Ca^{2+} mg/l	Na^+ mg/l	K^+ mg/l	Mg^{2+} mg/l	F^- mg/l	Cl^- mg/l	NO_2^- mg/l	SO_4^{2-} mg/l	NO_3^- mg/l	pH mg/l	TDS mg/l
FDA	N/A	N/A	N/A	N/A	N/A	250	1	250	10	N/A	500
WHO	N/A	50	12	50	1.5	N/A	3	N/A	50	N/A	N/A
WHO aesthetic	200	200	200	N/A	N/A	200	N/A	250	N/A	6.5-8.5	600
KUW-EPA	200	200	10	150	1.5	250	3	250	50	6.5-8.5	1000
GSO	N/A	N/A	N/A	150	N/A	N/A	N/A	N/A	N/A	6.5-8.5	600

2.5.5 Trace Metals

Trace metals are elements which occur at very low concentrations in the drinking water. Some of these elements include; copper, magnesium, zinc, cobalt and iron among others. Ions, there are others which are found in very little quantities and these include: phosphorous ions, iron, aluminium ions and manganese ions.

The color of water is a major indicator of water quality, especially for aesthetic reasons Mostly, when we see colored water, which gives the impression that the water is contaminated and therefore unfit for consumption. The water might be safe for use, but due to the color, the interpretation is that it is unsafe (Lytle, 2007). However, the presence of color in the water can also indicate that there’re trace metals and organic substances there, for example, algae and humic compounds. Of late, color has been a major determinant in the qualitative assessment of finding out the existence of hazardous and harmful organic materials present in the water.

The chemical water quality in Kuwait is monitored by (Kuw-EPA) laboratories, however this need to be standardize based on both national and international standards.

The water sometimes contains trace elements higher than the maximum permissible limit lead to change the Color, turbidity, taste. The sources of Iron, Copper, and Manganese from natural deposition caused corrosion, leaching, piping, network, plumping and storage.

2.6 Drinking Water Quality Parameters

As mentioned previously, some of the physical parameters used to measure the quality of water include color, odor, dissolved solids, taste, smell and suspended solids among others.

The presence of color in drinking water indicates the probable presence of minerals such as iron or the presence of substances of vegetable nature, for example, algae. Tests on water color show the efficacy of the water treatment system.

Turbidity in water is mostly caused due to the presence of suspended solids together with colloidal matter. Turbidity can also be caused by eroding soil, as a result of dredging or the growth of micro-organisms. When the levels of turbidity are high, then the costs incurred in the filtration of the water are going to be pretty expensive. In addition to that, when sewage solids are present in water, then the likelihood of pathogens being encased in particles will be higher and thus they will remain unaffected by the chlorination process.

Odour and taste indicate the presence of living microscopic organisms in the water. They may also indicate decaying organic matter such as weeds and algae, industrial refuse having ammonia, hydrocarbons and other compounds. In as much as the chlorination process is able to remove odour and taste in water, chlorine itself produces a bad odour.

Some of the chemical tests conducted to check the quality of water include pH, hardness, the presence of biocides and other chemical parameters. pH measures the concentration of hydrogen ions in water. It shows the acidity or alkalinity of the water. A value between 8 -10 indicates that the water is highly alkaline while values between 0-3 show that the water is acidic. Low values of pH are good when it comes to chlorination; however, they are problematic as they lead to corrosion. Mostly values between 0-4 are not habitable for any living organisms in water bodies. Good high quality drinking water should have a pH that a range between the values of 6.5 to 8.5 BOD is also a chemical parameter in the measurement of water quality. It shows the amount of oxygen that is required for stabilization of decomposing organic matter in aerobic conditions for micro-organisms. If there are high levels of the BOD, then this indicates that the levels of oxygen are very low; consequently, this shows the presence of organic pollutants.

2.7 Risk Assessment in Drinking Water

There have been many studies conducted to assess the physicochemical properties of Drinking Water in both developing and developed countries. Access to safe and quality drinking water together basic sanitation is very important for sustainable development and human health of any nation. The good news is that there have been progress on water connectivity in the past 25 years, there have been tremendous efforts in ensuring more people are accessing piped water, however; most developing countries are still struggling, and those with piped water have to deal with contamination and pollution issues. The situation is critical as almost half of the sub-Saharan Africa does not have access to clean water.

2.8 International Drinking Water Contaminants Categories

The World Health Organization (WHO) is the main body that is responsible for identification of contaminants in the regulation of drinking water. The body sets regulatory limits for the amounts of various contaminants present in water meant for consumption. Contaminant standards are required by the Safe Drinking Water Act.

It categorizes contaminants in drinking water into six main categories; these are microorganisms, disinfectants, disinfection byproducts, inorganic chemicals, organic chemicals and radionuclides.

2.9 National & International Standards for Drinking Water Quality

There are a number of water quality standards which describe the parameters that have been established for drinking water, however, there are no universally recognized and accepted international standards for drinking water. Different countries have their own different standards. In U.S.A, they have the United States Environmental Protection Agency (EPA), in Europe, they have the European Drinking Water Directive, in China, they use Water Standard GB3838-2002 (Type II), in Kuwait, they use the Kuwait Drinking Water Quality Standards (KDWQS) and for countries which do not have an administrative framework tasked with the responsibility of formulating these water quality standards, then they use the World Health Organization guidelines and policies (Al-Mudhaf, et al, 2014).

In as much as drinking water quality standards are in existence, many are viewed as guidelines, but not as legal requirements, this implies that they are not subject to enforcement. The only exceptions are Europeans Drinking Water Directive together with the Safe Drinking Water Act in the USA.

2.10 Kuwait's Drinking Water Quality Standards

Kuwait is an arid nation with little natural water. For this reason, Kuwait obtained its drinking water utilizing the Multi-Stage-Flash strategy (MSF) in desalination plants to deliver refined water from sea water. The refined water is mixed with the brackish ground water in various mixing proportions, to deliver drinking water, as prescribed by the World Health Organization (Al-Ruwaih, 2010). Please refer to Table 2.2 for the detailed water quality standards in Kuwait related.

Table 2.2: Kuwait's Drinking Water Quality Standards (KDWQS).

Physical Parameters	**KUW-EPA**
Temperature (◦C)	---
Electrical Conductivity (µS/cm)	---
Total Dissolved Solids (mg/l)	---
Chemical Parameters	**KUW-EPA**
Total Organic Carbon (mg/l)	---
Total Alkalinity (mg/l)	---
Free Residual Chlorine (mg/l)	0.20 - 0.50
Major ions	**KUW-EPA**
Calcium (mg/l)	---
Magnesium (mg/l)	---
Sodium (mg/l)	---
Flouride (mg/l)	1.5
Chloride (mg/l)	---
Nitrate (mg/l)	50
Sulphate (mg/l)	---
Trace Metal	**KUW-EPA**
Aluminium (mg/l)	---
Arsenic (µg/l)	10.00
Barium (µg/l)	700.00
Cadmium (µg/l)	3.00
Chromium (µg/l)	50.00
Copper(µg/l)	2000.00
Lead (µg/l)	10.00
Manganese (µg/l)	500.00
Mercury (µg/l)	1.00
Nickel (µg/l)	20.00
Selenium (µg/l)	10.00
Sliver (µg/l)	---
Zinc (µg/l)	---

2.11 Gulf Cooperation Council (GCC) Gulf Standardization Organization (GSO)

The Gulf Cooperation Council is a regional intergovernmental political and economic union and it consists of all countries of the Persian Gulf other than Iraq. Kuwait is one of the member countries of this union. GSO is the standardization organization of the GCC. It has its headquarters in Riyadh. In the case that there are no GSO standards which have been established, then member countries adopt global standards. By 2010, GSO had mandated close to three thousand standards, however, the implementation of all these guidelines and policies is the sole responsibility of the member counties. Some of the domains which are covered by GSO include water, fire protection, halal foods, and food safety among others. Please refer to Table 2.3 for the detailed water quality standards by GCC.

Table 2.3: GCC Standardization Organization (GSO) Drinking Water Quality Standards.

Physical Parameters	**GSO**
Temperature (◦C)	---
Electrical Conductivity (µS/cm)	---
Total Dissolved Solids (mg/l)	---
Chemical Parameters	**GSO**
Total Organic Carbon (mg/l)	---
Total Alkalinity (mg/l)	---
Free Residual Chlorine (mg/l)	≤ 0.50
Major ions	**GSO**
Calcium (mg/l)	---
Magnesium (mg/l)	---
Sodium (mg/l)	---
Flouride (mg/l)	1.50
Chloride (mg/l)	---
Nitrate (mg/l)	50.00
Sulphate (mg/l)	---
Trace Metal	**GSO**
Aluminium (mg/l)	---
Arsenic (µg/l)	10.00
Barium (µg/l)	700.00
Cadmium (µg/l)	3.00

Chromium (µg/l)	50.00
Copper(µg/l)	2000.00
Lead (µg/l)	10.00
Manganese (µg/l)	400.00
Mercury (µg/l)	6.00
Nickel (µg/l)	70.00
Selenium (µg/l)	40.00
Zinc (µg/l)	---

2.12 World Health Organization Guidelines for Drinking Water

World Health Organization water quality standards and guidelines were set up in Geneva, 1993. Most countries which do not have their own standards use WHO guidelines as their reference points when it comes to establishing drinking-water safety standards. If focuses on organic compounds, pesticides, disinfectants and disinfectant by-products and other elements. Please refer to Table 2.4 for the detailed water quality standards by (WHO).

Table 2.4: World Health Organization (WHO) Guidelines for Drinking Water.

Physical Parameters	**WHO**
Temperature (◦C)	---
Electrical Conductivity (µS/cm)	---
Total Dissolved Solids (mg/l)	1000.00
Chemical Parameters	**WHO**
Total Organic Carbon (mg/l)	---
Total Alkalinity (mg/l)	---
Free Residual Chlorine (mg/l)	$\leq$ 0.50
Major ions	**WHO**
Calcium (mg/l)	---
Magnesium (mg/l)	---
Sodium (mg/l)	50.00
Flouride (mg/l)	1.50
Chloride (mg/l)	---
Nitrate (mg/l)	50.00
Sulphate (mg/l)	---
Trace Metal	**WHO**
Aluminium (mg/l)	---
Arsenic (µg/l)	10.00
Barium (µg/l)	700.00
Cadmium (µg/l)	3.00

Chromium (µg/l)	50.00
Copper(µg/l)	2000.00
Lead (µg/l)	10.00
Manganese (µg/l)	400.00
Mercury (µg/l)	6.00
Nickel (µg/l)	70.00
Selenium (µg/l)	40.00
Zinc (µg/l)	---

2.13 Water Resource Management

Water resource management can be referred to as the planning, development, distribution and management of water resources and their use optimally. The main aim of water resource management is allocation of water on an equitable basis to the all the users. Currently, almost all the challenges that are facing the world, food charges, growth and expansion of urban centers, energy security, protection of the environment- they all require water urgently. This creates the need to use the water that is present optimized, reducing any wastage.

2.14 Water Quality Index (WQI)

Water Quality Index is a means through which data on the quality of water can be summarized so that it can be reported to the public in a way that it can be understood clearly. The Water Quality Index ranges from 1 to 100 and when the reading is high, this shows that the quality of water is higher. Some of the major determinants of scores in the water quality index include nitrogen levels. Phosphorus levels, turbidity, pH value, temperature, fecal coliform bacteria, suspended and dissolved sediments among other parameters.

2.15 Water Quality Monitoring

Water quality monitoring is a very important tool that is used in the management of water resources. It can also be defined as a protocol and guidance for the analysis of data in regards to the quality of water (Deutsch at al, 2016). Water quality monitoring protects sources of water from pollution. Information on water quality monitoring assists those in the agricultural sector to manage their crops and land in a much better way. It assists the government in coming up with guidelines which control the levels of pollution and the information helps us know how individuals impact water supply and what each person can do to promote water conservation.

2.16 Difference between Trace Metals and Heavy Metals

Heavy metals can be defined as members of an ill-defined subset of elements. These elements show some metallic properties (Calderon, 2000). They mostly comprise transition metals, metalloids and actinides. Trace elements, on the other hand, are elements present in samples that have a mean concentration of > than 100 parts/million or atoms are > than 100 micrograms/gram.

2.17 Challenges in Desalinated Drinking Water Quality Sector

Desalination has been growing steadily over the years. However, it has several demerits and some of these include: It incurs very high costs in setting up the plants and maintaining them, its energy intensity is very high and it has adverse environmental effects. It is not advisable to indulge in large scale desalination of water not unless there are serious water shortages in that particular country.

2.18 Water Quality of Security Nexus for Water, Food, Energy

Water, energy and food security nexus implies that all these three components are linked together and that anything that happens in any one of the sectors is going to affect the other factors as well. Because of the massive population growth that the world is experiencing, it has become even more important to ensure that there is a conscious stewardship of these important resources and components (Edzwald, 2011). A nexus perspective enhances an in depth understanding of the interdependence that exists among water, energy and food sectors and impacts on policies and other areas of concern such as climate and biodiversity.

2.19 Tap Drinking Water Quality Criteria/Standards Statistical Analysis Indicator

Drinking water quality standards stipulate and the exponents in the parameters used in the measurement of the quality of drinking water. For microbial water quality, confirmation is probably going to incorporate microbiological testing. Much of the time, it will include the investigation of fecal marker microorganisms, yet in a few conditions, it might likewise incorporate appraisal of particular pathogen densities. Check of the microbial nature of drinking-water might be attempted by the provider, surveillance agencies or a combination of the two (EPA, 1993). Evaluation of the the adequacy of the chemical quality of drinking-water relies on comparison of drinking-water depends on examination of the consequences of water quality investigation with rule values. For added substances (i.e. Chemicals getting principally from materials and chemicals utilized as a part of the generation and dissemination of drinking-water), accentuation is set on the immediate control of the nature of these items (EPA, 1993). In controlling drinking-water added substances, testing systems regularly evaluate the commitment of the added substance to drinking water and assess varieties over time in deriving a value that can be compared with the guideline value.

2.20 Water Drinking Quality Watch Program

This program provides information regarding the quality of water that is used and produced by several water sources and bodies around the world. Information entails surface water and groundwater as well. There is a drinking water watch web portal that enables people to have access to data on monitoring data, the compliance guidelines and required water quality standards etc. (Hudak, 2012).

2.21 Enforcement Environmental Management System Tools to Reduce Pollution from Source of Pollutants

An Environmental Management System is a set of tools, processes and techniques which help an organization in mitigating and lowering its pollution levels while increasing its operating efficiency. This framework helps organizations to achieve the objectives that they have set in regards to environmental performance. Some of the elements of this system include: it assesses and reviews the organization’s environmental goals; it assesses the environmental effects and the respective legal guidelines and policies; it comes up with environmental objectives and goals so as to reduce adverse effects on the environment and increase compliance on the legal requirements; it formulates programs to assist in achieving the set environmental goals and targets; monitoring and evaluation of the progress made in the achievement of those goals; make sure that employees and workers are aware of environmental issues and concerns and finally, the system reviews the progress and growth of the environmental management system and proposes any improvements (Wilby, 2006).

CHAPTER 3: METHODOLOGY

3.1 Study Design

This chapter explains the methodology followed to conduct the current project. First, was used to collected secondary raw data is described briefly, Please refer to (Appendix A) for the detailed regarding permission and approval from EPA of Kuwait to provide the data for these study of research project. Then, the filters and screening process to extract for the data are explained.

Then, Coding governorates and areas name to list and data mapping is briefly explained along with detailed maps of the five governorates. Next step is comparison Standards from KUW-EPA National, GSO Regional and WHO International were obtained.

To analyses whole the data's the Min. and Max, mean, SD of data’s were collected for the physicochemical parameters in selected schools from different areas of Kuwait.

Then compare the results with the guidelines standards, and other analyses comparison between different 5 governorates separately for different selected schools in State of Kuwait, finally combined the results to compare with guidelines standards to find and conclude which physical and chemicals parameters concentration above guideline values that are of health significance in drinking water and what correlation between different average parameters (Refer to Fig. 3.1).

A cross-sectional research design was used to collect and extract secondary data for a physical and chemicals parameters obtained from Environmental Monitoring Information System of Kuwait (e MISK) data base was collected by Kuwait Environment Monitoring Centre (KEMC), Environmental Public Authority (EPA), state of Kuwait. To analyze the drinking water quality in different residential areas and governorates in State of Kuwait. This enabled the study to be focused on specific selected schools related to the objective. There are various types of approaches that can be used for the health risk assessment namely qualitative method and quantitative method. The assessment of this project involves quantitative method.

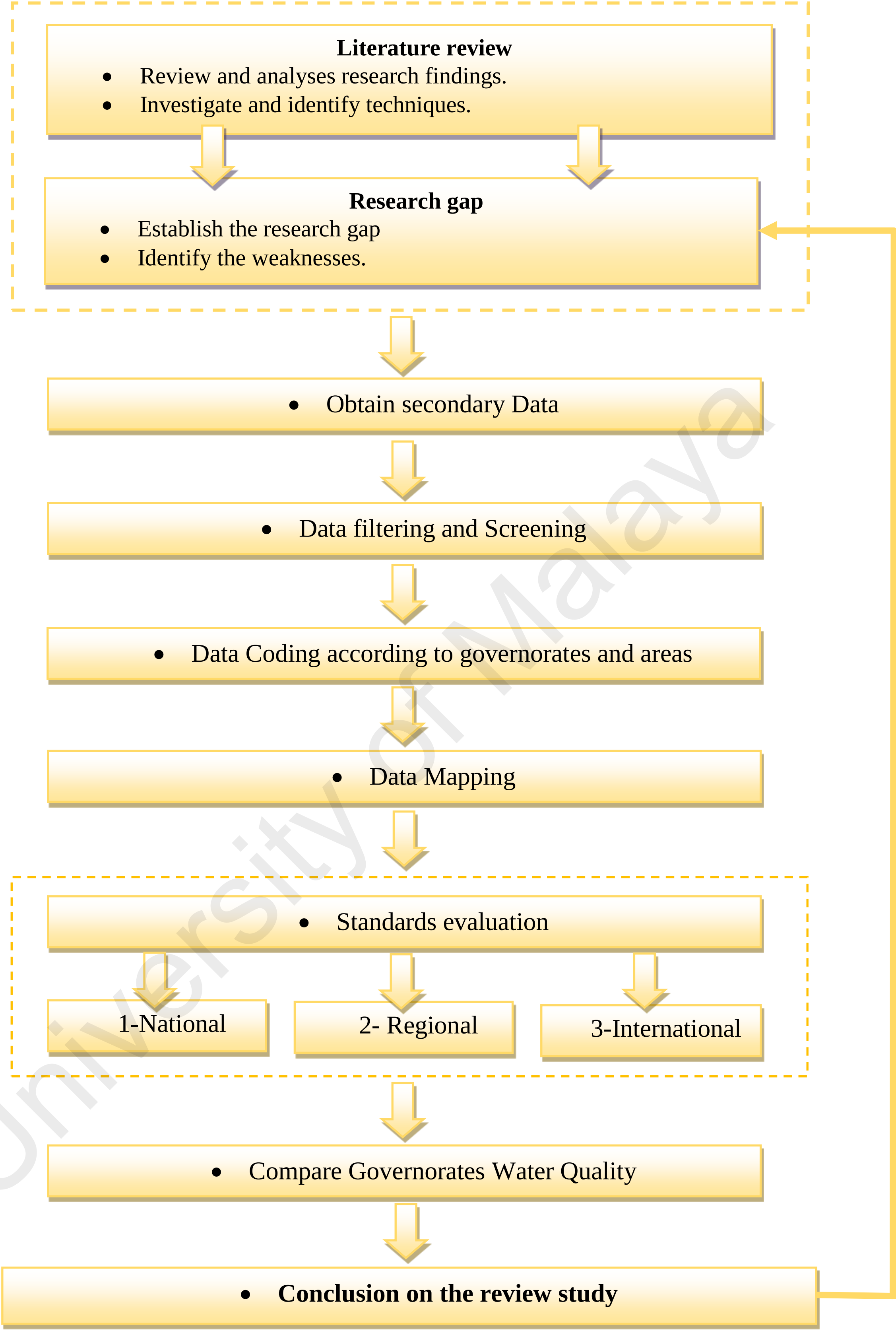


Figure 3.1: Method of Study is analyzed in Flowchart Explains the Research Steps toward Achieving the Objectives of the Current Study.

3.2 Study Area

This study was undertaken specifically at the characterizations and guidelines standards for tap drinking water quality in State of Kuwait. Kuwait lies between latitudes 28° and 31° N, and longitudes 46° and 49° E. The state of Kuwait has six administrative governorates. These are *Kuwait City (Capital) (KU), Hawalli (HA), Mubarak Al-Kabeer (MU), Farwaniyah (FA), and Ahmadi (AH), exclude Jahra (JA)* because was no samples taken. *Kuwait City* is largest city and total area 200 km^2, is located on the southern shore of Kuwait Bay off the Persian Gulf. The total number of districts in the six Kuwait governorates is 137 districts as of August 2016. The smallest district area does not exceed 5 km^2 and its generally low lying, with the highest point being 306 m above sea level.

The total area of Kuwait is 17.82 km^2 and total population 3,971,031 as of 2015 national statistics, Kuwait has a variable continental atmosphere, with greatly hot and dry summers (April through October), with temperatures surpassing 51°C. Winters (November to February), with temperatures surpassing - 7°C, are cool with some precipitation and normal temperatures around 13°C. Average yearly precipitation is 107mm. The greatest normal precipitation happens in January.

Kuwait its North West borders are with Iraq, and its south and south west outskirts are with Saudi Arabia. Its shores of the Persian Gulf lie on the west. Kuwait Bay is the main water resource for desalinated water and one of the most prominent features in Kuwait's marine environment. The normal yearly rainfall is (107 mm) and the greatest normal rainfall for the most part happens in January. Kuwait is the Gulf nation with slightest new water assets and the minimum renewable fresh water level (Lyons, B. P., et al., 2015). This nation drinking water comes just from one source – the desalination sea water all things considered there is high requirement for the water desalination as the populace increment and the interest for compact drinking water is turning out to be high (Al-Mudhaf, 2012).Consequently, a portion of the world's biggest and most advanced desalination plants give the water to Kuwait City.

Government are often tasked with ensuring that citizens have access to safe drinking water and it is imperative for them to build the necessary infrastructure that is needed and required to provide safe drinking water for everyone.

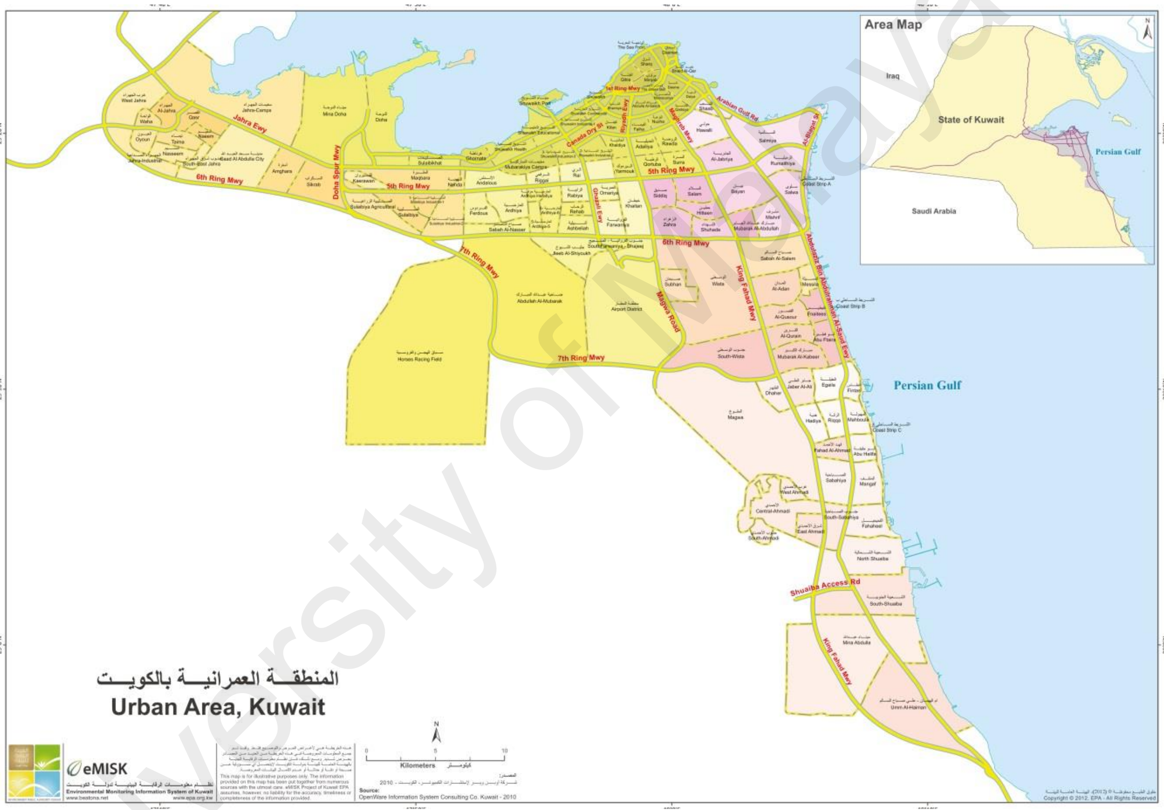


Figure 3.2: GIS Map for Urban Area at State of Kuwait.

(Source: e MISK, Kuwait-EPA 2016)

Figure 3.3: Locations of the Collected Samples from 51selected Schools in 25 Areas in Five Governorates of Kuwait using GIS Tool in Scribble Map 2016.

Table 3.1: List of Governorates Code

Governorates Code	Governorates Name
KU	The Capital of Kuwait City
HA	Hawalli
AH	Ahmadi
JA	Jahra
FA	Farwaniyah
MU	Mubarak Al-Kabeer

Table 3.2: List of the Selected Schools where Tap Drinking Water Samples were collected in the Five Governorates of Kuwait.

Gov.	School Code	Name of Area and School
The Capital of Kuwait City (KU)	KU15-GHS	Qurtuba - Girls High School
	KU4-ISE	Daiya - Ibn Sina Elementary School (Boys)
	KU3-ARS	Al-Dasma - Al-Rashid School
	KU21-RKS	Al-Shuwaikh- Residential - Khawlah School
	KU21-RAM	Al-Shuwaikh Residential - Al-Mansour Kindergarten
	KU19-JAM	Al-Surra - Jaber Al-Mubarak High School
	KU19-BAS	Al-Surra - Bargash Alsadon School
	KU19-AES	Al-Surra - Al-Esraa School
	KU15-AGS	Al-Adailiya - Girls School
	KU12-IRE	Faiha - Ibn Rushd Elementary School
	KU10-UAG	Abdulla Al-Salem Area - Umm Ateia Girls School
	KU10-SQK	Abdulla Al-Salem Area - Saqer Quraysh Kindergarten
	KU10-JGH	Abdulla Al-Salem Area - Jumana Girls High School
Hawalli (HA)	HA7-GHS	Bayan- Girls High School
	HA7-ANK	Bayan - Al-Nuwair Kindergarten
	HA7-AAK	Bayan - Al-Amana Kindergarten
	HA6-OBZ	Shaab - Osamah Bn Zaid Kindergarten
	HA6-AIA	Shaab - Ali Ibn Abi Talib School
	HA5-MKS	Mishref - Mishref Kindergarten School
	HA5-ALA	Mishref - Abdul Latif Al-Omar School
	HA5-AAA	Mishref - Abdu Al-Aziz Al-Shaheen Kindergarten
	HA3-MAW	Jabriya - Mohamad Al-Weheab School
	HA2-USI	Al-Rumaithiya - Umm Salama Intermediate School
	HA1-AJA	Hawalli - Al-Jeel Al-Jadeed School

Mubarak Al-Kabeer (MU)	MU9-MNA	Al-Fintas - Mullah Naser Al-Mazaiel Elementary School (Boys)
	MU9-FAA	Al-Fintas - Fatima Abdullah Al-Haqan Elementary School (Girls)
	MU9-OBN	Al-Fintas - Ouqba Bin Nafee Kindergarten
	MU9-AGS	Al-Fintas - Anisa Girls School
	MU5-ZZK	Sabah Al-Salem - Zam Zam Kindergarten
	MU5-ANS	Sabah Al-Salem - Al-Nojabaa Kindergarten
	MU5-ANK	Sabah Al-Salem - Al-Nada Kindergarten
	MU5-AKK	Sabah Al-Salem - Al-Khamael Kindergarten
	MU3-BAO	Al-Qurain - Badria Al-Otaiqy Elementary School (Girls)
	MU2-SIG	Al-Adan - Salhiya Intermediate School (Girls)
Farwaniyah (FA)	FA8-SRS	Al-Ardhiya - Saleh Rowaieh School
	FA8-AKK	Al-Ardhiya - Al-Kefah Kindergarten
	FA5-PEM	Khaitan - Pakistani English Modern School
	FA5-MBJ	Khaitan - Muath Bin Jabal School
	FA5-ANS	Khaitan - Al-Nahdah School
	FA5-AKS	Khaitan - Abraq Khaitan School
	FA15-ZAH	Al-Rabiya - Zaid Al-Harb School
	FA15-GHS	Al-Rabiya - Girls High School
Ahmadi (AH)	AH7-GSH	Hadiya- Girls High School
	AH7-ARB	Hadiya - Abdul Rahman Ben Baker School
	AH6-RGS	Al-Riqqa - Raihanah Girls School
	AH6-RBE	Al-Riqqa - Riqqa Boys Elementary School
	AH3-OBQ	Al-Dhaher - Omayia Bint Qais School
	AH11-UHI	Al-Fahaheel - Umm Hakeem Intermediate Girls School
	AH11-UAE	Al-Fahaheel - Umm Ayman Elementary School
	AH11-BAN	Al-Fahaheel - Barakah Al-Nuoman Intermediate School
	AH11-ASK	Al-Fahaheel - Al-Salamah Kindergarten School

3.3 Sampling Size and Data Collection

The present study relied on secondary data provided by the Environment Public Authority of Kuwait (KUW-EPA). The analyses were performed in the laboratories for organic materials, water specifications, and trace metals of the (KUW-EPA). These procedures followed the determination of physicochemical parameters in the tap drinking water based on Standard Methods for the Examination of the Water and Waste water (Rice, et al, 2012).The data was collected in accordance with the international standard methods for the examination of water and wastewater. The data's drinking water were collected during a period of 12 months (January to December 2014). The obtained data included data from various locations (i.e. Hospitals, reservoirs, water towers, tanker filling stations, mosques, blending plants, pump stations, sports clubs, police stations, etc.). These random samples were collected from different areas.

To achieve the objectives of study, the study employed simple random sampling of respondents who study and working at the schools in 25 residential areas in 5 governorates around State of Kuwait with high population density within the about 152 samples of schools, accordingly, 2 – 3 samples periodically for 25 physicochemical parameters were collected randomly from 51 selected schools also are chosen randomly as there are spread within the of administrative divisions of only five from six Kuwait governorates were listed in (tables 3.1): *Kuwait City (Capital) (KU), Hawalli (HA), Mubarak Al-Kabeer (MU), Farwaniyah (FA), and Ahmadi (AH)*, with a number of schools of 11, 13, 8, 9, and 10, respectively were listed in Tables 3.2 and presented in figures 3.4 - 3.8 shown below. In addition a detailed analysis of each individual governorate for a more detailed refer to the appendices C, D, E, F and G, respectively.

Table 3.3: List of Symbol Parameters and Units.

Symbol	Parameter Name	Unit
Physical Parameters		
T	Temperature	°C
EC	Electrical Conductivity	(µS/cm)
TDS	Total Dissolved Solids	mg/l
Chemical Parameters		
TOC	Total Organic Carbon	mg/l
TA	Total Alkalinity	mg/l
Cl	Free Residual Chlorine	mg/l
Major ions		
Ca^{2+}	Calcium	mg/l
Mg^{2+}	Magnesium	mg/l
Na^{+}	Sodium	mg/l
F^{-}	Flouride	mg/l
Cl^{-}	Chloride	mg/l
NO_3^{-}	Nitrate	mg/l
SO_4^{2-}	Sulphate	mg/l
Trace Metal		
Al	Aluminium	mg/l
As	Arsenic	µg/l
Ba	Barium	µg/l
Cd	Cadmium	µg/l
Cr	Chromium	µg/l
Cu	Copper	µg/l
Pb	Lead	µg/l
Mn	Manganese	µg/l
Hg	Mercury	µg/l
Ni	Nickel	µg/l
Se	Selenium	µg/l
Zn	Zinc	µg/l

The total of analyzed data reading is 3015 monthly average; the results of the present investigation, including 25 physical and chemical parameters were listed in Tables 3.3 shown above.

Figure 3.4: Map of Locations of Selected Schools in (KU) the Capital of Kuwait City Using GIS Scribble Maps Tools under Map Data 2016 Google.

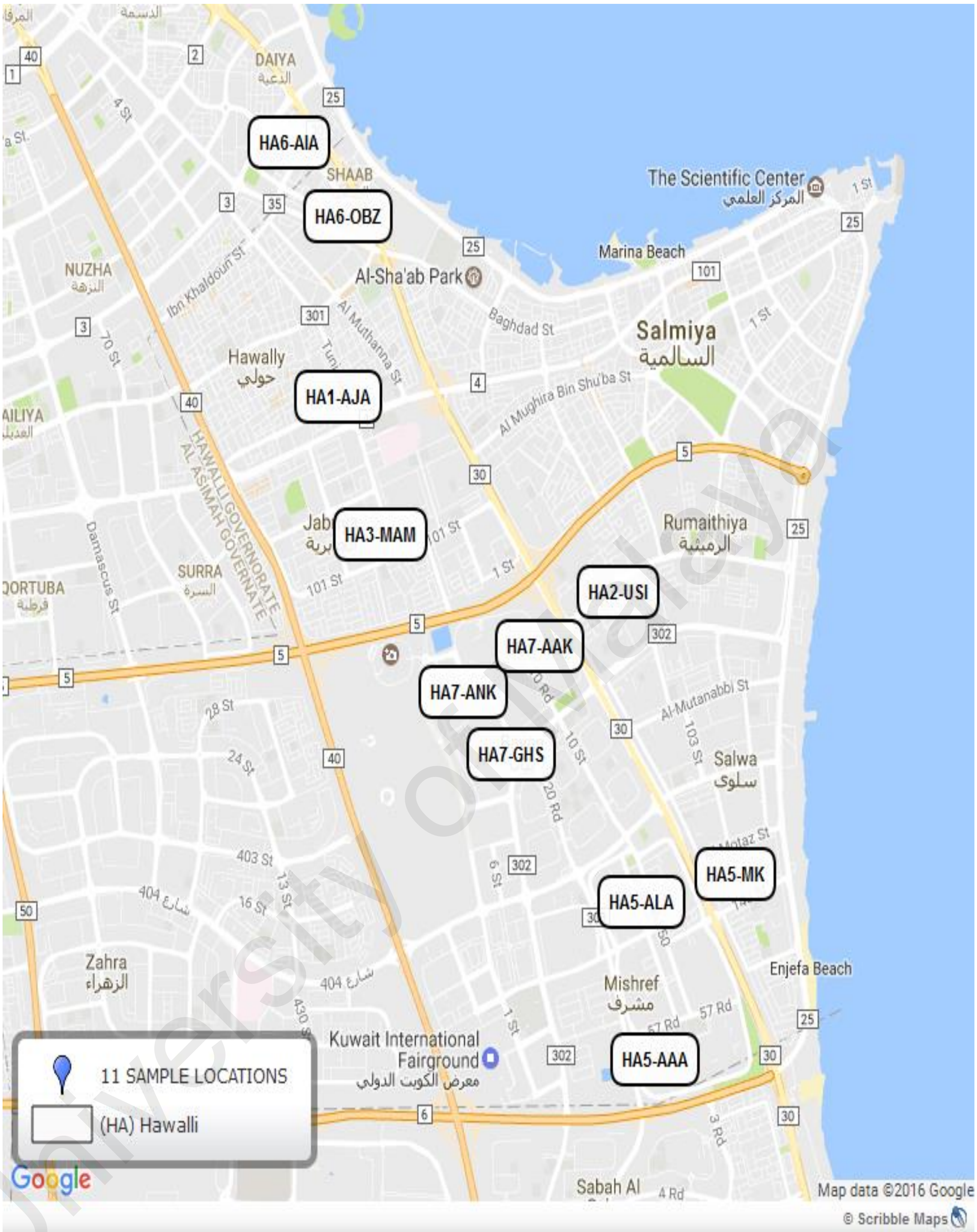


Figure 3.5: Map of Locations of Selected Schools in Hawalli (HA) Governorate Using GIS Scribble Maps Tools under Map Data 2016 Google.

Figure 3.6: Map of Locations of Selected Schools in (MU) Mubarak Al-Kabeer Governorate Using GIS Scribble Maps Tools under Map Data 2016 Google.

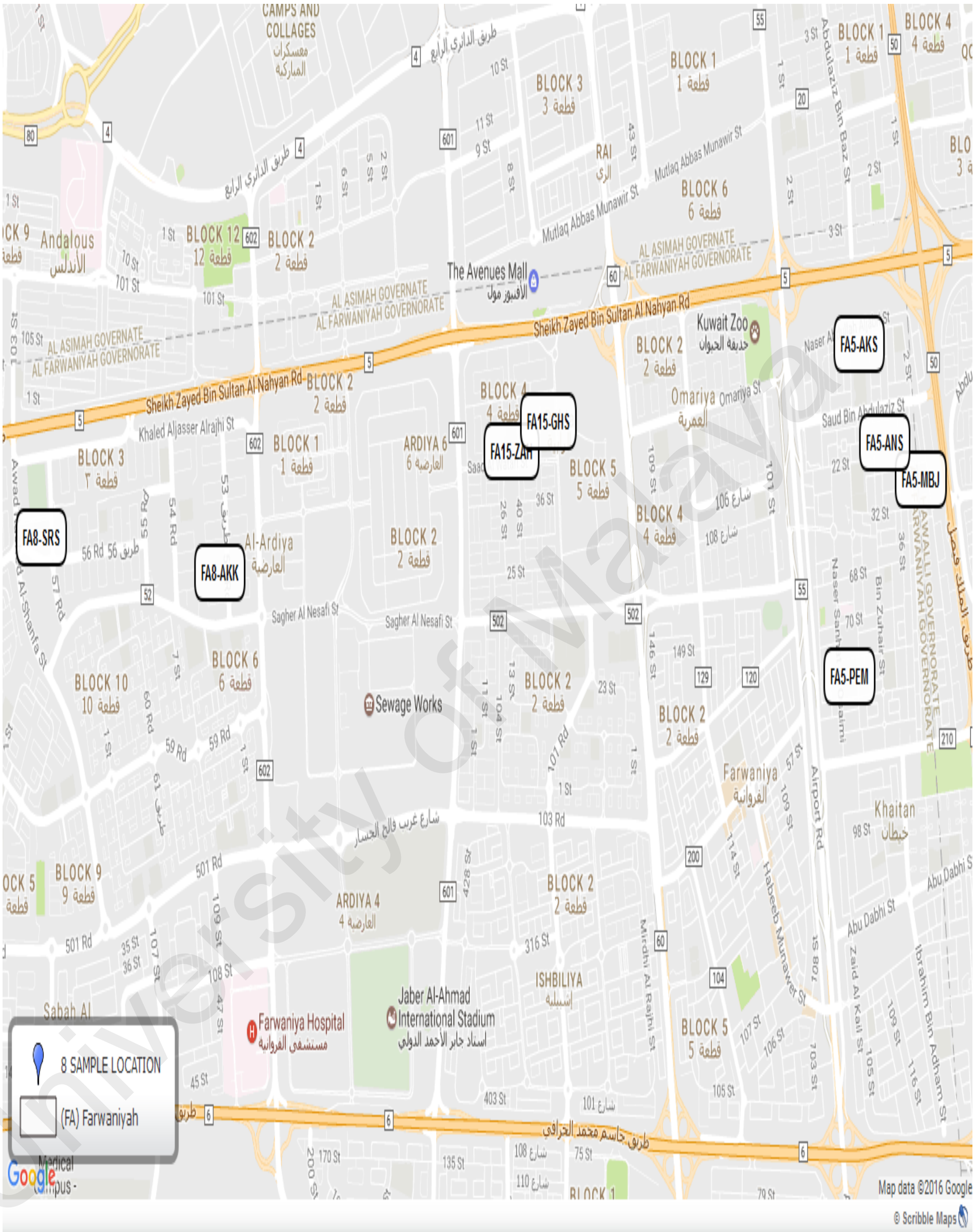


Figure 3.7: Map of Locations of Selected Schools in (FA) Farwaniyah Governorate Using GIS Scribble Maps Tools under Map Data 2016 Google.

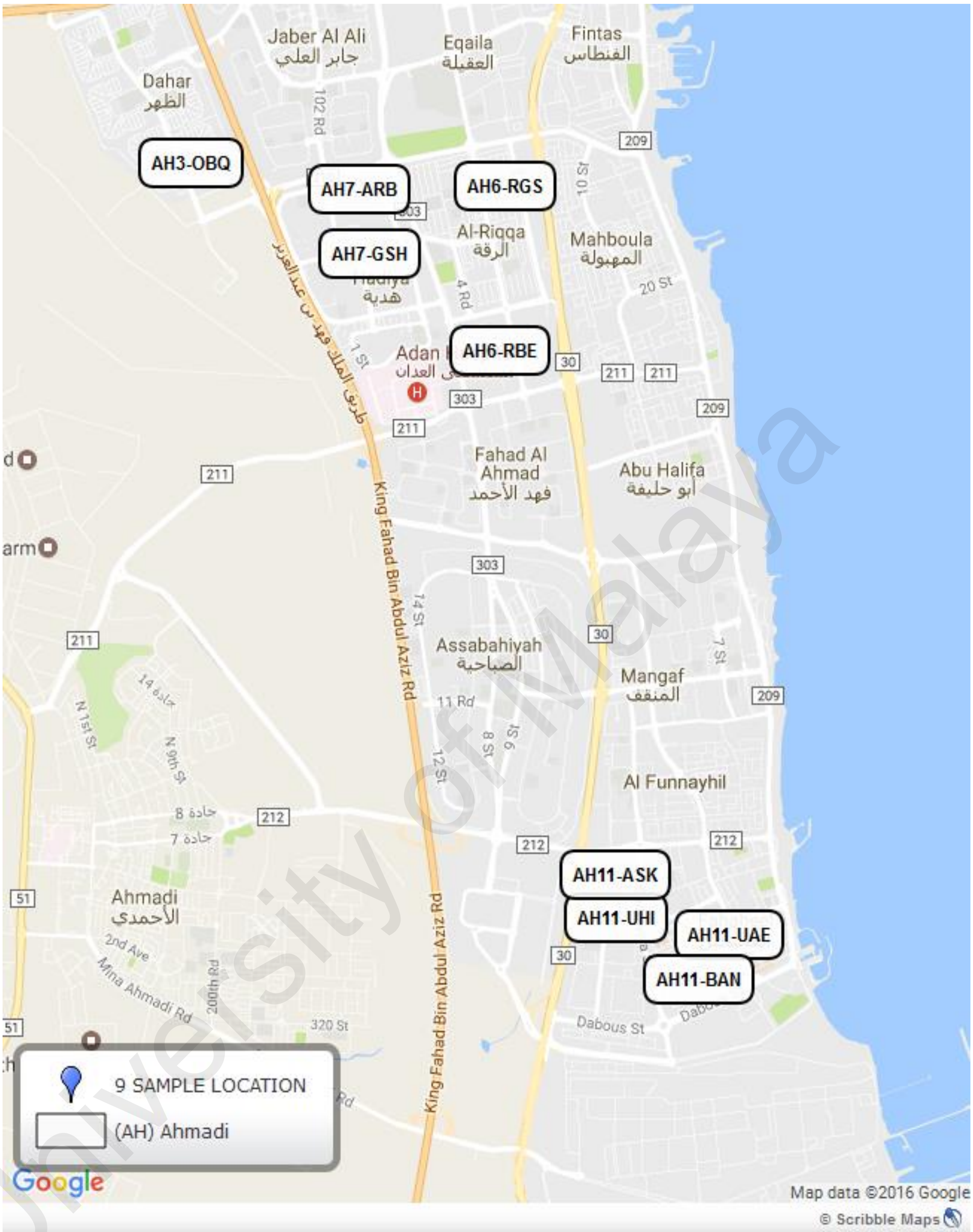


Figure 3.8: Map of Locations of Selected Schools in (AH) Ahmadi Governorate Using GIS Scribble Maps Tools under Map Data 2016 Google.

3.4 Data Analysis

The raw data contained chemical, physical and excluded biological properties of the water. Therefore, a second filter was designed to select the chemical and physical parameters only.

In addition, a screening step was conducted to omit the *zero* parameters and those parameters that are not included in the national, regional and international standards.

The filters and screen steps resulted in reducing the number of parameters to 25 physical and chemical properties of the drinking water.

Data coding and mapping was done in the current project to show the locations of the different selected schools in each governorate. This is to ensure that the used data in this research was taken randomly and therefore to ensure non-biased findings.

Figures: 3.3 - 3.8 show the maps illustrating locations of the selected schools in the 5 governorates of Kuwait.

The sampling collection of KUW-EPA data base is the data collection tool that provides related measurements to physicochemical parameters. A structured compute statistical analysis method was developed based on the objectives of this study.

The statistical analysis comprises 7 steps and the statements were counted to compute variables between physicochemical parameters, what the characterizations tap drinking water and to evaluate the quality of drinking water with national standards, comparing with regional and international guidelines standards.

Finally assess physicochemical parameters between governorates and comparing with guidelines standards.

1) The first step of the sampling collection of KUW-EPA data base is Section A which required a list of general information of the parameters. The required information included physical and chemical characteristic and the type of constituents, sampling locations, duration of sampling.

2) Next step the data base was related to the quantitative and qualitative count of parameters properties at the tap drinking water that has been classified into two parts which are physical and chemical divided for three which are chemical factors, major ions, trace metals. This step identified the of type and analysis values by providing statements regarding exposure to contaminants in tap drinking water of schools to be sure is within the permissible limits of health concern and significance .

3) This step was coding and mapping sampling location, this step identified the ID address for each selected school and areas and governorates in State of Kuwait.

4) Inventory all national, regional, international guidelines standards related with physicochemical parameters to compare.

5) The first compute, count and analysis for whole physicochemical parameters data base obtained in all selected schools and compared with national, regional, international guidelines.

6) The second compute, count and analysis for whole physicochemical parameters data base obtained in different governorates separately and compared with national, regional, international guidelines.

7) The final analysis compared mean values between all governorates and compared with national, regional, international guidelines. In addition a detailed analysis of each individual governorate for a more detailed refer to the appendices C, D, E, F and G, respectively.

3.5 Analysis Tools used in study

To accomplish the objectives of this study the following were used:

All data were analyzed using Microsoft Excel (Microsoft Office, 2010) its statistical functions were utilized during the analysis. The data from the 51 schools from the 5 governorate were fed into the computer and each governorate data was analyzed using effective filtering method and sorting functions. The results were then segmented and statistical measures were taken for comparing the physicochemical parameters data with international standard. The analysis was done statistically based on the research design outlined by the researcher, which are as illustrated in section 3.1 study designs and presented in (Fig. 3.1).

Descriptive statistics methods was used for quantitative variables analysis and multivariate Statistical Methods with the objective of evaluating significant differences among the sites for all water quality variables, data was analyzed using one-way or whether two or more means are significantly different from each other is a hypothesis testing procedure that tests analysis of variance (ANOVA).

The ANOVA procedure was utilized in order to identify the parameters which have significant effects on the predictions made and arrive at a combination of system parameters that yields minimum, at level of significance water quality was subjected to multivariate techniques, is principal component analysis (PCA).

PCA explore groups and sets of variables with similar properties, thus potentially allowing us to simplify our description of observations by allowing us to find the structure or patterns in the presence of chaotic or confusing data, analysis as to obtain the number of occurrences such as minimum and maximum average, mean value, standard deviation (SD), of each physical and chemical parameter measured of the sample locations. The analysis result's correlation is used to find the correlation between variables and compared with national , regional, international, guidelines standards and between also different areas and governorates in State of Kuwait is outlined in research chapter 4.

The strength of association between physicochemical parameters variables between them are measured and using correlation to conclude the deference between variables in selected schools at governorates and also compared with national , regional, international, guidelines standards.

To determine sample locations which were used national Kuwait finder GIS from the public authority for civil information to search the locations unique ID address. These locations from the five governorates are then mapped and saved on the scribble map tool.

To locate sample locations which were used Scribble Map GIS tool powered by Google data 2016, a real time mapping tool was deployed to map out the discrete location of the samples in governorates at Kuwait.

In order to obtain exact and discrete other maps related with research study, Environmental Monitoring Information System of Kuwait (e Misk) GIS tool - An environment explorer tool from EPA, Kuwait to obtain a comprehensive government owned map of the selected locations.

Adobe Photo Shop CS5 Extended application was used to convert KUW-EPA e MISK Map and Scribble Map GIS tool from PDF to JPEG format with high resolution quality.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

This chapter explains tap drinking water were collected from fifty-one selected Schools in different residential areas in Five Governorates. Together, these areas cover more than 95% of the neighborhoods in Kuwait. At every examining accumulation, from 2 to 3 samples were gathered by (KUW-EPA) from tap drinking water points in each selected schools, The samples were gathered from an inside fixture (tap) after the drinking water had gone through the capacity and pipes systems as the school-hold piping system of the building, At schools or residential, the storage tanks are mainly roof-top tanks (12 – 18 m^3) that are constructed from various materials of water tank: plastics (polyethylene, polypropylene), fiberglass, and the type of internal distribution network made of high Density Polypropylene Random Copolymer (PPRC) pipe fittings. Samples were collected simultaneously between January and December 2014 with different sampling locations.

To achieve the objectives of study, Twenty-five residential areas in Five governorates with high population density within the about 152 samples of schools, Accordingly, 2 – 3 samples periodically were collected from 51 selected schools of five from six Kuwait governorates: *Kuwait City (Capital) (KU), Hawalli (HA), Mubarak Al-Kabeer (MU), Farwaniyah (FA), and Ahmadi (AH),* with a number of schools of 11, 13, 8, 9, and 10, respectively, In addition a detailed analysis of each individual governorate for a more detailed refer to the appendices C, D, E, F, and G, respectively . The comparison between all Five governorates shown in Table 4.2, the total of analyzed data reading is 3015 monthly average; the results of the present investigation, including 25 physical and chemical parameters were listed in Tables 4.1 and 4.2 and presented in figures 4.1 - 4.30 shown below, However, Any factors increase or decrease the concentration of physicochemical parameters there are Causative factors may be of plumbing systems or storage, piping network, corrosion, sedimentation, transportation via the general distribution networks and through private household utilities or from desalination treatment processes because of the leaching of the contaminations of drinking-water is a significant concern for public health throughout the schools (Al-Mudhaf, Humood F., et al. 2012).

Physiochemical concentrations exceed in water supplies can cause serious health problems which pose serious health threat to the students and staffs of drinking water, the 25 parameters analyzed in 152 samples of selected schools collected in this study were Temperature, EC, TDS, chemical properties analyzed as TOC, TA, Free Residual (Cl) as well as the concentration of the major cations and anions as Ca^{2+}, Mg^{2+}, Na^{+}, F^{-}, Cl^{-}, NO_3^{-} , SO_4^{2-}, and trace metals as Al, As, Ba, Cd, Cr, Cu, Pb, Mn, Hg, Ni, Se, Zn. In addition, analyzed water quality parameters (WQPs) were compared with national, regional, International standards, and analyzed physicochemical parameters separately to find different average correlation analysis between 5 different governorates.

Regularly, identification and evaluation of dangers to health from drinking-water depends too much on analysis of water samples. The limitations of this approach are well recognized, and added to the deferral in perceiving arsenic in drinking-water as a significant health concern in Bangladesh and somewhere else. To overcome such limitations, the latest edition of the World Health Organization (WHO) Guidelines for Drinking-water Quality (WHO, 2004; WHO, 2006) was referred.

4.2 Standards evaluation

This section describes the results of the drinking water quality standards evaluations national, regional, International. Please refer comparison to Table 4.1.

4.2.1 Physical Parameters

4.2.1.1 Temperature

The temperature values of the tap water samples examined in the selected schools were as follows: The minimum average was at 20 °C while the maximum average was at 40 °C and the mean was 32.31±5.35 °C (Refer. to Table 4.1).

There were wide variations in the increases for each of these temperature among the sampling locations and between all five governorates mean values were the KU (33.40 °C), HA (34.13 °C), AH (30.20 °C), MU (31.59 °C) are less an EC increase (compared with FA 34.67 °C) the higher mean value of FA governorate as shown in Table 4.2 and illustrated in figures 4.1 and 4.4, There are no set standard limits by either KUW-EPA (2001), GSO (2008), or WHO (2011) pertaining the standards of temperature for drinking water. This can be explained by the hot climate in Kuwait as studied by (Darwish & Al-Najem 2005). However, desirable water temperatures in consumption range between 4 °C to 10 °C. Corrosions increase the concentration of trace metals, especially the concentrations of iron and manganese. The rate of pipe corrosion is directly proportional to drinking water temperatures, the higher the temperature of the water, the quicker the rate of oxidation and consequently the higher rate of corrosion (Darwish & Al-Najem 2005).

Corrosion of pipes in relation to temperature, if not addressed, leads to health problems, especially when trace elements such as lead and copper are leached into the water system.

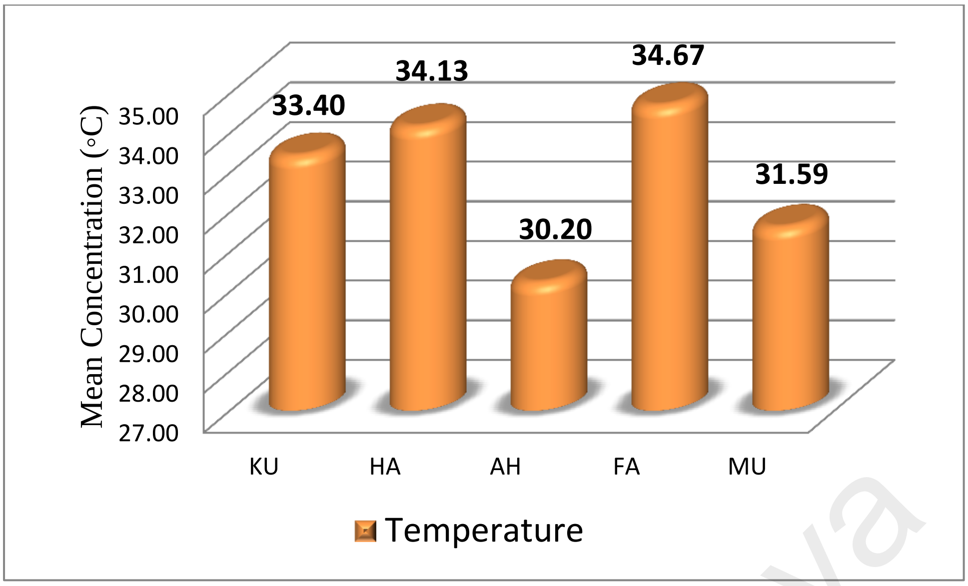


Figure 4.1: The temperature values of the tap water samples examined in the selected schools.

Table 4.1: Analytical Results of Measured Physicochemical Parameters For Tap Drinking Water From 51 Selected Schools In Five Governorates in Kuwait For 12 Months (Year of 2014).

Physical Parameters	**Min**	**Max**	**Mean**	**SD**	**KUW-EPA**	**GSO**	**WHO**
Temperature (◦C)	20.00	40.00	32.31	5.35	---	---	---
Electrical Conductivity (µS/cm)	9.52	440.63	252.14	97.91	---	---	---
Total Dissolved Solids (mg/l)	4.00	213.00	120.89	47.20	---	---	1000.00
Chemical Parameters	**Min**	**Max**	**Mean**	**SD**	**KUW-EPA**	**GSO**	**WHO**
Total Organic Carbon (mg/l)	0.07	1.12	0.44	0.25	---	---	---
Total Alkalinity (mg/l)	1.15	152.99	47.32	19.25	---	---	---
Free Residual Chlorine (mg/l)	0.05	0.55	0.25	0.06	0.50	≤ 0.50	≤ 0.50
Major ions	**Min**	**Max**	**Mean**	**SD**	**KUW-EPA**	**GSO**	**WHO**
Calcium (mg/l)	0.50	29.10	19.46	3.95	---	---	---
Magnesium (mg/l)	0.50	4.01	1.68	1.00	---	---	---
Sodium (mg/l)	2.57	75.69	35.73	16.80	---	---	---
Flouride (mg/l)	0.01	0.05	0.01	0.01	1.50	1.50	1.50
Chloride (mg/l)	1.26	110.26	47.37	23.77	---	---	---
Nitrate (mg/l)	0.29	6.33	3.61	1.06	50.00	50.00	50.00
Sulphate (mg/l)	0.12	37.55	6.57	7.39	---	---	---

Trace Metal	Min	Max	Mean	SD	KUW-EPA	GSO	WHO
Aluminium (mg/l)	2.00	34.74	11.79	9.62	---	---	---
Arsenic (μg/l)	2.00	7.08	3.90	3.11	10.00	10.00	10.00
Barium (μg/l)	2.00	9.01	2.57	1.74	700.00	700.00	700.00
Cadmium (μg/l)	2.00	2.00	2.00	0.00	3.00	3.00	3.00
Chromium (μg/l)	2.00	5.80	2.24	0.95	50.00	50.00	50.00
Copper(μg/l)	2.57	116.79	29.55	32.35	2000.0	2000.0	2000.0
Lead (μg/l)	2.00	2.20	2.02	0.06	10.00	10.00	10.00
Manganese (μg/l)	2.00	3.53	2.13	0.37	500.00	400.00	400.00
Mercury (μg/l)	0.50	0.50	0.50	0.00	1.00	6.00	6.00
Nickel (μg/l)	2.00	13.53	3.98	3.04	20.00	70.00	70.00
Selenium (μg/l)	5.00	29.90	6.95	6.37	10.00	40.00	40.00
Zinc (μg/l)	2.00	85.86	14.52	19.87	---	---	---

4.2.1.2 Electrical Conductivity (EC)

Electrical conductivity (EC) could be defined as a measure of the ability of water to conduct an electric current. Concentration of the ions, temperature of the solution, and specific nature of the ions are the major factors affecting on the EC (Ab Razak, Nurul Hafiza, et al., 2015).

The electrical conductivity (EC) of the tap water samples from the selected schools had a minimum average of 9.52 µS/cm and a maximum average of 440.63 µS/cm, with an average value of 252.14±97.91 µS/cm. There are however, no stipulated health guidelines or set standards for the minimum or maximum allowable electrical conductivity that should be present in water as shown in Table 4.1.

The (EC) varied between all five governorates mean values were the KU (265.90 µS/cm), HA (240.04 µS/cm), AH (243.20 µS/cm), MU (238.04 µS/cm) are less an EC increase (compared with FA 284.19 µS/cm) the higher mean value of FA governorate may be attributed to the different source water of desalination plant and the piping network in the area, as shown in Table 4.2 and presented in figures 4.2 and 4.4, It should be noted that there are no health guidelines standards. There are no set standard limits by either KUW-EPA (2001), GSO (2008), or WHO (2011) pertaining the standards of EC for drinking water.

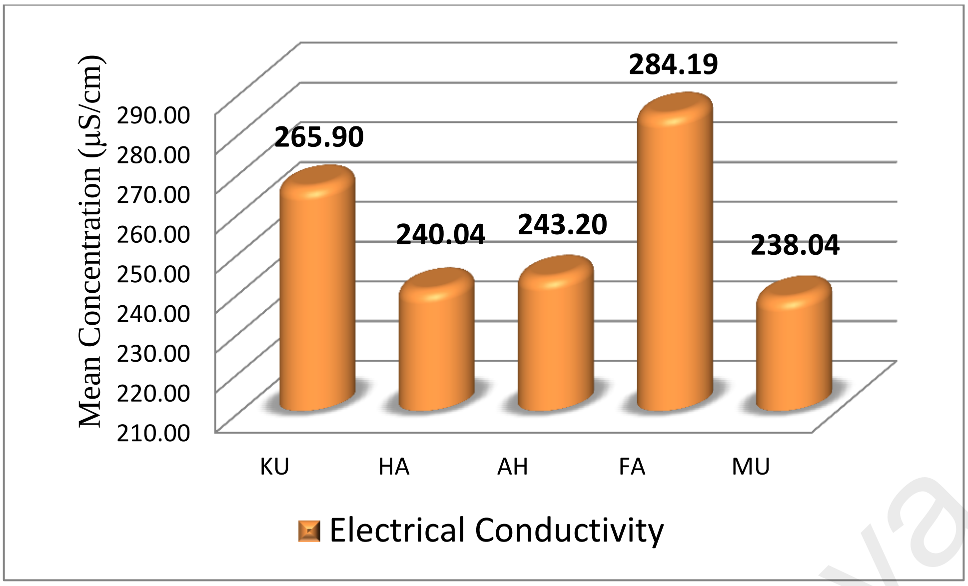


Figure 4.2: The EC values of the tap water samples examined in the selected schools.

4.2.1.3 Total Dissolved Solids (TDS)

The values for total dissolved values (TDS) for the selected schools were as follows: The minimum average was at 4 mg/l while the maximum average was at 213 mg/l. The average value of the samples was at 120.89±47.2 mg/l. The maximum average of the tap drinking water samples collected for the selected schools was at 213 mg/l. This was within the set limit level which is greater than 1000 mg/l and 1500 mg/l is the maximum allowable by WHO and no allowable limits for TDS that have been set by KUW-EPA, GSO, all of. The palatability of the tap drinking water in the selected schools in Kuwait is considered to be excellent due to the TDS desirable limit levels is less than 500 mg/l by (WHO, 2011) as shown in Table 4.1.

The TDS varied between all five governorates mean values were the KU (127.66 mg/l), HA (116.44 mg/l), AH (115.45 mg/l), MU (113.70 mg/l) are less an TDS increase (compared with FA 284.19 mg/l) the lower mean value of MU and the higher mean value of FA governorate may be attributed to the different source water of desalination plant and the piping network in the area, as shown in Table 4.2 and presented in figures 4.3 and 4.4, It should to be noticed that there are no health rules guidelines for the base suitable EC of water (Alsulaili *et al.*, 2015), reported that EC is demonstrative of TDS substance in water tests. In reality, it has been found that water tests with high EC values frequently contain elevated amounts of TDS (Abdullah et al., 2007). In this study, there was a strong correlation (r = 1.0) which is reliable with perceptions reported beforehand (Trivedi & Goel, 1984). There are no set standard limits by either KUW-EPA (2001), GSO (2008), or WHO (2011) pertaining the standards of TDS for drinking water.

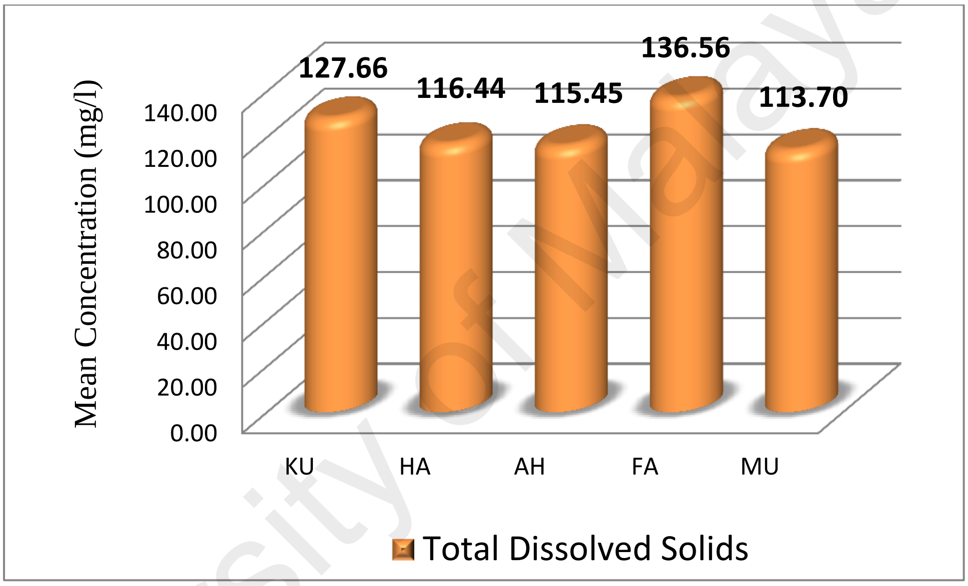
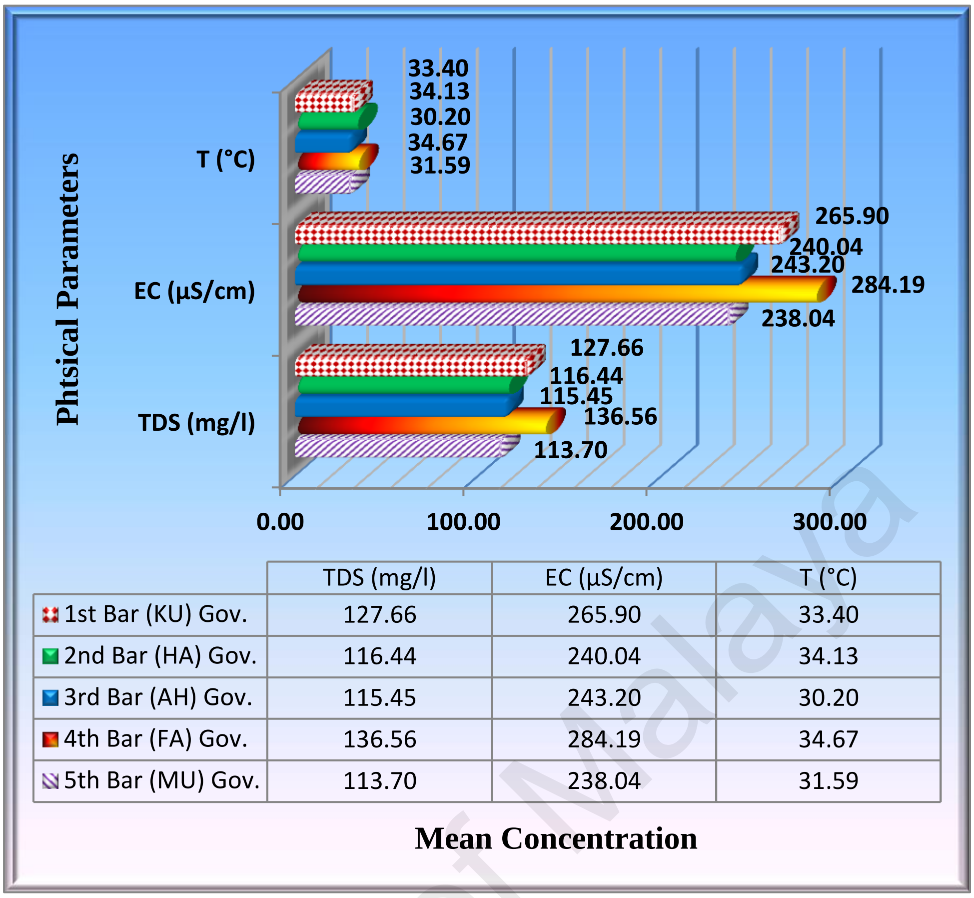


Figure 4.3: The TDS values of the tap water samples examined in the selected schools.

Table 4.2: Mean values of the concentrations of physicochemical parameters in tap drinking water at locations of selected schools in five Governorates of Kuwait**.**

Physical Parameters	(KU) Gov.	(HA) Gov.	(AH) Gov.	(FA) Gov.	(MU) Gov.	KUW-EPA	GSO	WHO
Temperature (°C)	33.40	34.13	30.20	34.67	31.59	---	---	---
Electrical Conductivity (µS/cm)	265.90	240.04	243.20	284.19	238.04	---	---	---
Total Dissolved Solids (mg/l)	127.66	116.44	115.45	136.56	113.70	---	---	1000

Chemical Parameters	(KU) Gov.	(HA) Gov.	(AH) Gov.	(FA) Gov.	(MU) Gov.	KUW-EPA	GSO	WHO
Total Organic Carbon (mg/l)	0.48	0.29	0.46	0.51	0.48	---	---	---
Total Alkalinity (mg/l)	44.02	44.75	51.28	52.93	45.60	---	---	---
Free Residual Chlorine (mg/l)	0.26	0.25	0.24	0.25	0.22	0.50	$\leq$ 0.50	$\leq$ 0.50
Major ions	**(KU) Gov.**	**(HA) Gov.**	**(AH) Gov.**	**(FA) Gov.**	**(MU) Gov.**	**KUW-EPA**	**GSO**	**WHO**
Calcium (mg/l)	0.50	19.03	19.17	19.10	20.15	---	---	---
Magnesium (mg/l)	0.50	1.73	1.96	1.36	1.63	---	---	---
Sodium (mg/l)	4.76	36.18	33.3	42.9	33.55	---	---	---
Flouride (mg/l)	0.01	0.01	0.01	0.02	0.01	1.50	1.50	1.50
Chloride (mg/l)	2.09	42.20	48.24	55.83	41.87	---	---	---
Nitrate (mg/l)	0.30	3.81	3.53	3.76	3.85	50.00	50.00	50.00
Sulphate (mg/l)	6.13	5.47	8.68	8.68	5.17	---	---	---
Trace Metal	**(KU) Gov.**	**(HA) Gov.**	**(AH) Gov.**	**(FA) Gov.**	**(MU) Gov.**	**KUW-EPA**	**GSO**	**WHO**
Aluminium (mg/l)	2.00	6.69	10.93	3.45	20.18	---	---	---
Arsenic (µg/l)	2.00	5.55	2.37	8.94	2.54	10.00	10.00	10.00
Barium (µg/l)	2.00	4.34	3.10	2.00	2.01	700	700	700
Cadmium (µg/l)	2.00	2.00	2.00	2.00	2.00	3.00	3.00	3.00
Chromium (µg/l)	2.00	2.00	2.00	2.00	2.00	50.00	50.00	50.00
Copper(µg/l)	2.57	36.33	21.14	29.73	33.43	2000	2000	2000
Lead (µg/l)	2.00	2.00	2.00	2.00	2.05	10.00	10.00	10.00
Manganese (µg/l)	2.00	2.10	2.11	2.00	2.26	500	400	400
Mercury (µg/l)	0.50	0.50	0.50	0.50	0.50	1.00	6.00	6.00
Nickel (µg/l)	2.00	5.85	2.72	4.36	3.12	20.00	70.00	70.00
Selenium (µg/l)	5.00	13.30	5.00	6.68	5.32	10.00	40.00	40.00
Zinc (µg/l)	2.00	35.81	10.42	4.97	11.41	---	---	---



	TDS (mg/l)	EC (µS/cm)	T (°C)
1st Bar (KU) Gov.	127.66	265.90	33.40
2nd Bar (HA) Gov.	116.44	240.04	34.13
3rd Bar (AH) Gov.	115.45	243.20	30.20
4th Bar (FA) Gov.	136.56	284.19	34.67
5th Bar (MU) Gov.	113.70	238.04	31.59

Figure 4.4: Comparison Summary of Physical Parameters between All Five Governorates

4.3 Chemical parameters

This section present the results obtained 25 chemicals parameters covering 52 selected schools in 25 random areas at 5 different governorates in State of Kuwait.

4.3.1 Total Organic Carbon (TOC)

Total dissolved organic carbon present in the tap drinking water for the samples collected in the selected schools were as follows: The minimum average concentrations were at 0.07 mg/l; the maximum average concentrations were at 1.12 mg/l while the mean concentration for all the samples was at 0.44±0.25 mg/l as shown in Table 4.1.

The TOC between five governorates mean values were ranged (0.29 mg/l to 0.51 mg/l) whereas the lowest mean value of HA and the highest mean value were found at the FA governorate, Indeed observed previously in these study there is indicators correlation in the highest mean value for temperature, EC and TDS was also samples of FA governorates, the results illustrate the role of source water production treatment processes and distribution network. There are no cause health concerns for the consumers and no allowable limits for TOC that have been set by KUW-EPA, GSO, or WHO. As shown in Tables 4.1& 4.2 and presented in Fig. 4.5 and 4.8.

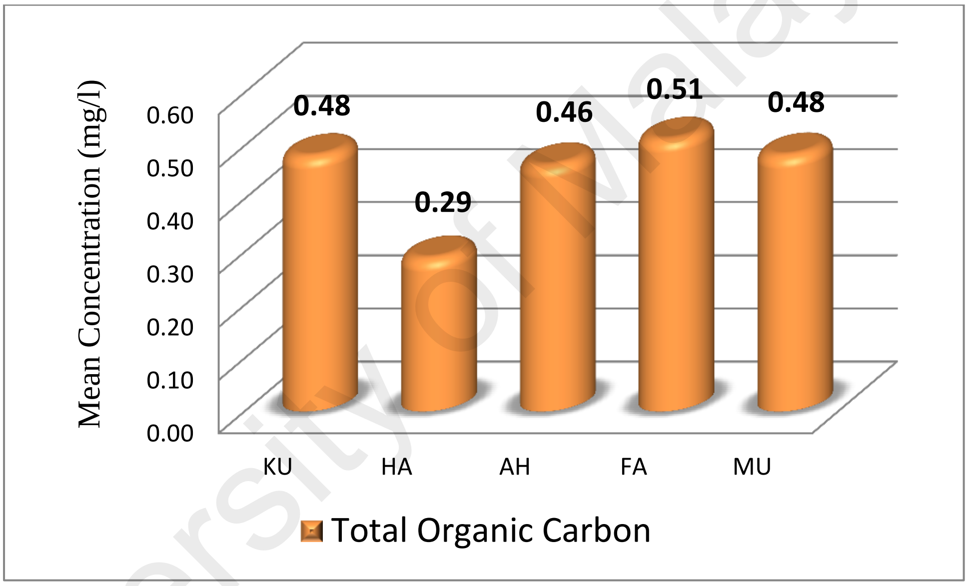


Figure 4.5: The TOC values of the tap water samples examined in the selected schools.

4.3.2 Total Alkalinity (TA)

The total Alkalinity values of the samples of water examined for the selected schools had a minimum average of 1.15 mg/l and a maximum average of 152.99 mg/l. The mean value was at 47.32±19.25 mg/l as shown in Table 4.1.

Relatively no difference between the TA mean values between in five governorates mean values which ranged (44.02 mg/l to 52.93 mg/l) whereas the highest mean value were found at the FA governorate, Indeed observed previously in these study observed correlation in the highest mean value for temperature, EC, TDS, and TOC was also samples of FA governorates, As shown in Table 4.2 and presented in Fig. 4.6 and Fig. 4.8.

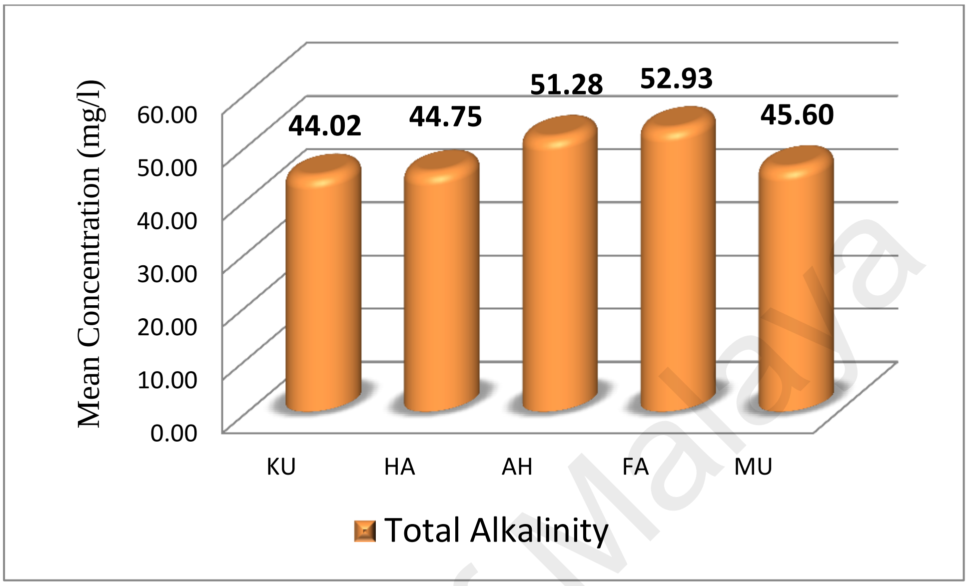


Figure 4.6: The TA values of the tap water samples examined in the selected schools.

The results illustrate the role of source water production treatment processes, There are however, no stipulated guidelines or set standards for the allowable minimum or maximum levels of total alkalinity by KUW-EPA (2001), GSO (2008), or WHO (2011).

4.3.3 Free Residual Chlorine

The concentration of free residual chlorine (Cl) from the tap drinking water samples collected from the selected schools were as follows: The minimum average was at 0.05 mg/l; the maximum average concentration was at 0.55 mg/l while the mean of all the samples was at 0.25±0.06 mg/l. The allowable set standards by KUW-EPA (2001), GSO (2008) and WHO (2011) are at ≤ 0.50 mg/l. The maximum average samples exceeded the allowable set limits as shown in Table 4.1.

The Cl between all five governorates mean values were the HA, AH , FA, MU, (0.25 mg/l, 0.24 mg/l, 0.25 mg/l, 0.22 mg/l respectively). Whereas the highest mean value were found at the KU governorate 0.26 mg/l. The spatial variation Is shown in Table 4.2 and presented in Fig. 4.7 and 4.8.

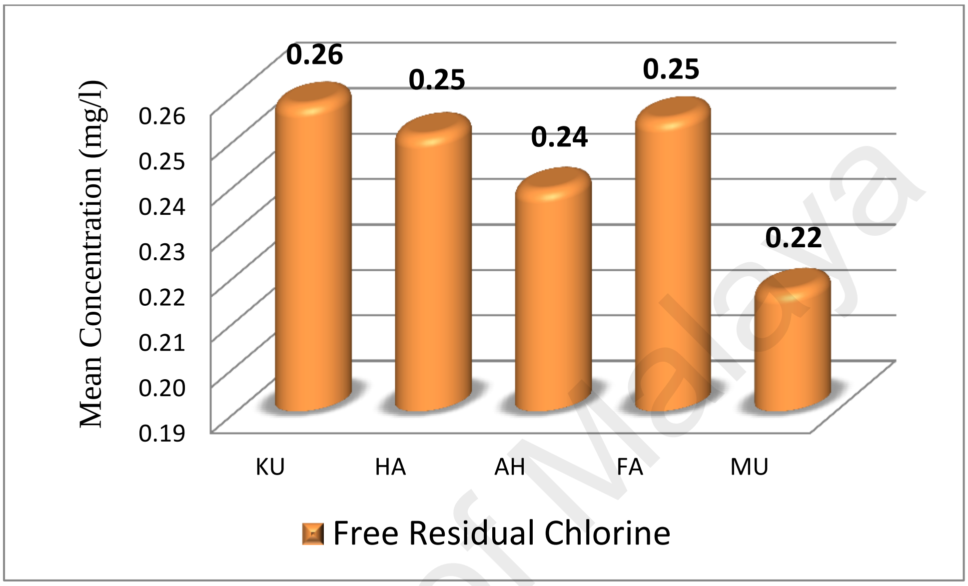


Figure 4.7: The Cl values of the tap water samples examined in the selected schools.

The increased concentration of Cl in some tap drinking water samples could be the result of the disinfection process utilizing chlorination. This has to be looked into as there are several side effects associated with chlorination and free residual chlorine. Some of these effects include; the formation of disinfection byproducts (DBPs), for example, Total trihalomethanes (THMs), which have been shown to cause cancers in the human bladder and rectal (Baris *et al.*, 2016). On the other hand, (Al-Mudhaf *et al.* 2012) stated that the increases in Cu, Fe, and Zn concentrations, through household storage and plumbing systems, are directly proportional to the increase in Cl concentrations. Additionally, according to the US-EPA guideline (2004) high level of Cl results eye/nose irritation; stomach discomfort and increase corrosive character of water.

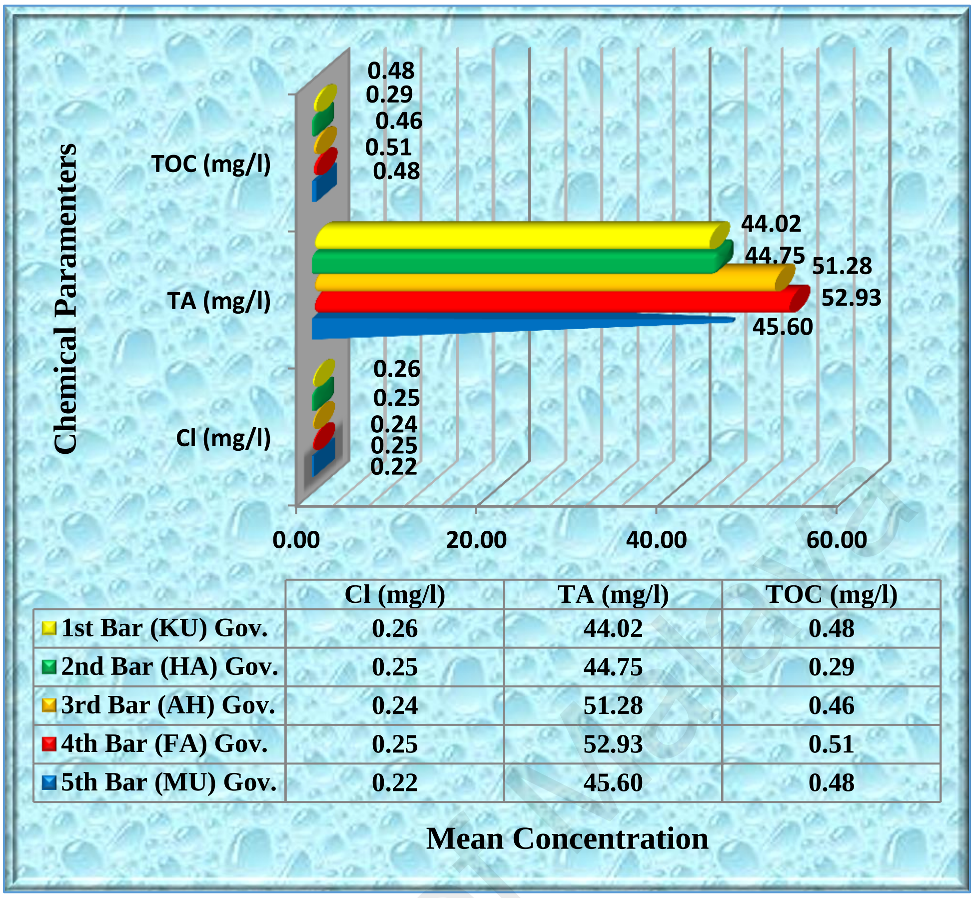


Figure 4.8: Comparison Summary of Chemical Parameters between All Five Governorates

4.4 Major Ions

4.4.1 Major Cations

The values of the major cations Ca^{2+} and Mg^{2+} were in the range of 0.50 mg/l to 29.10 mg/l (minimum average and maximum average), 0.50 mg/l to 4.01 mg/l, respectively. The averages for these Cations are 19.46±3.95 mg/l and 1.68±1 mg/l, for Ca^{2+} and Mg^{2+} respectively as shown in Table 4.1.

The (Ca^{2+}, Mg^{2+}) between five governorates mean values were the HA, AH, FA, MU, (19.03 mg/l, 19.17 mg/l, 19.10 mg/l, 20.15 mg/l respectively) and, (1.73 mg/l, 1.96 mg/l, 1.36 mg/l, 1.63 mg/l respectively). Whereas the (Ca^{2+}, Mg^{2+}) lowest mean value were found at the KU governorate (0.50 mg/l, 0.50 mg/l respectively). While Na^{+} the highest and lowest mean values were found at the (FA (4.76 mg/l), KU (42.9 mg/l) governorate respectively). There are no set standard limits by either KUW-EPA (2001), GSO (2008), or WHO (2011) pertaining the standards of Ca^{2+}, Mg^{2+} for drinking water. The spatial variation is shown in Table 4.2 and presented in Fig. 4.9, 4.10, 4.11 and Fig. 4.12 respectively.

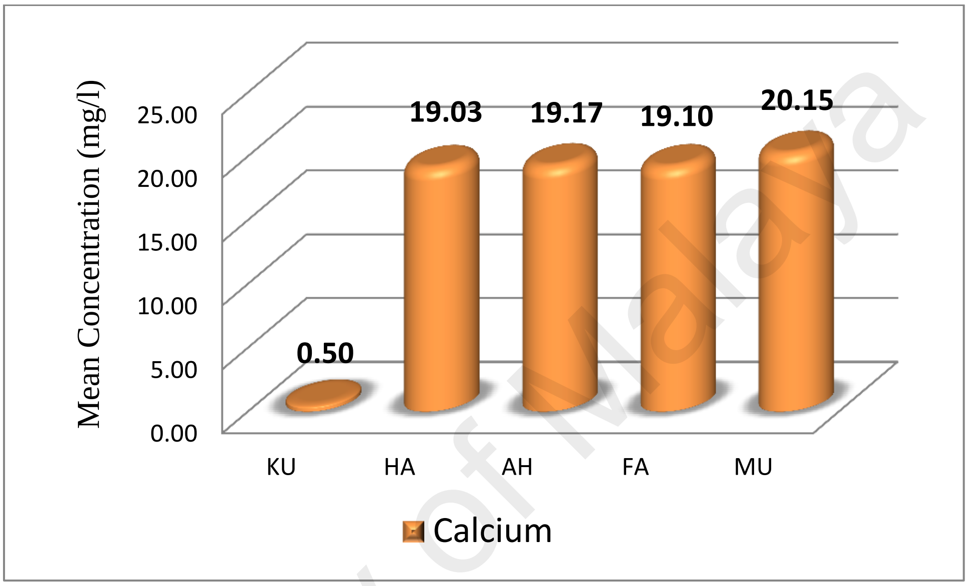


Figure 4.9: The Ca^{2+} values of the tap water samples examined in the selected schools.

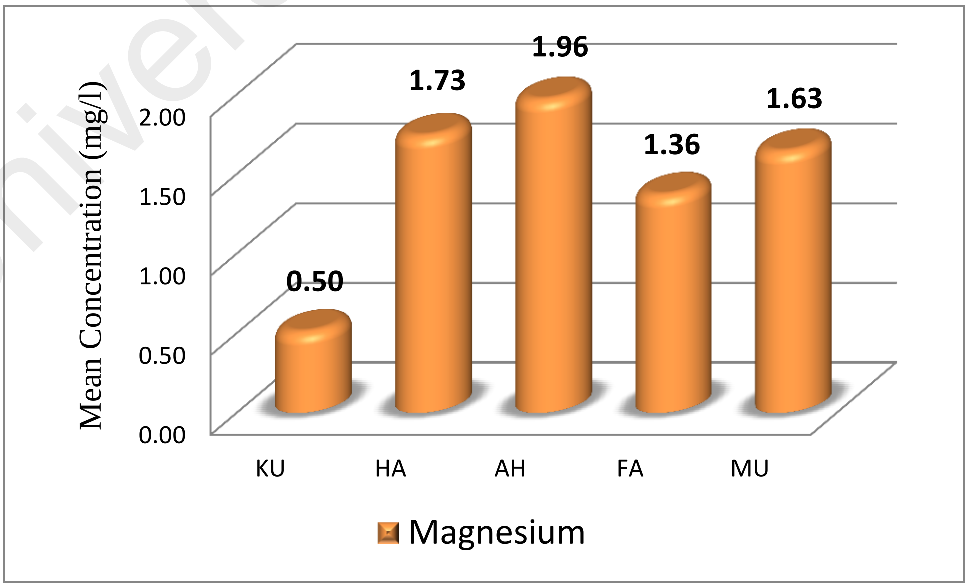


Figure 4.10: The Mg^{2+} values of the tap water samples examined in the selected schools.

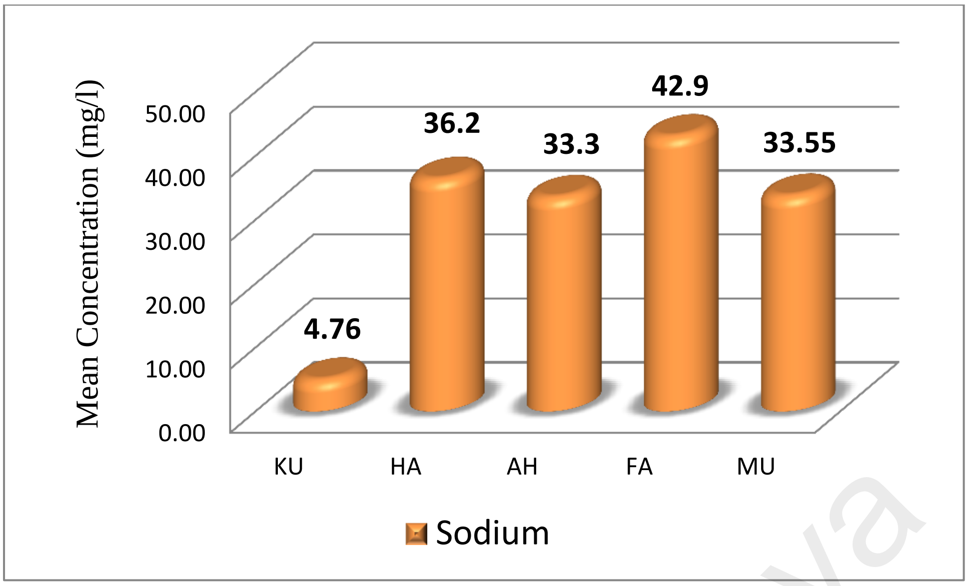
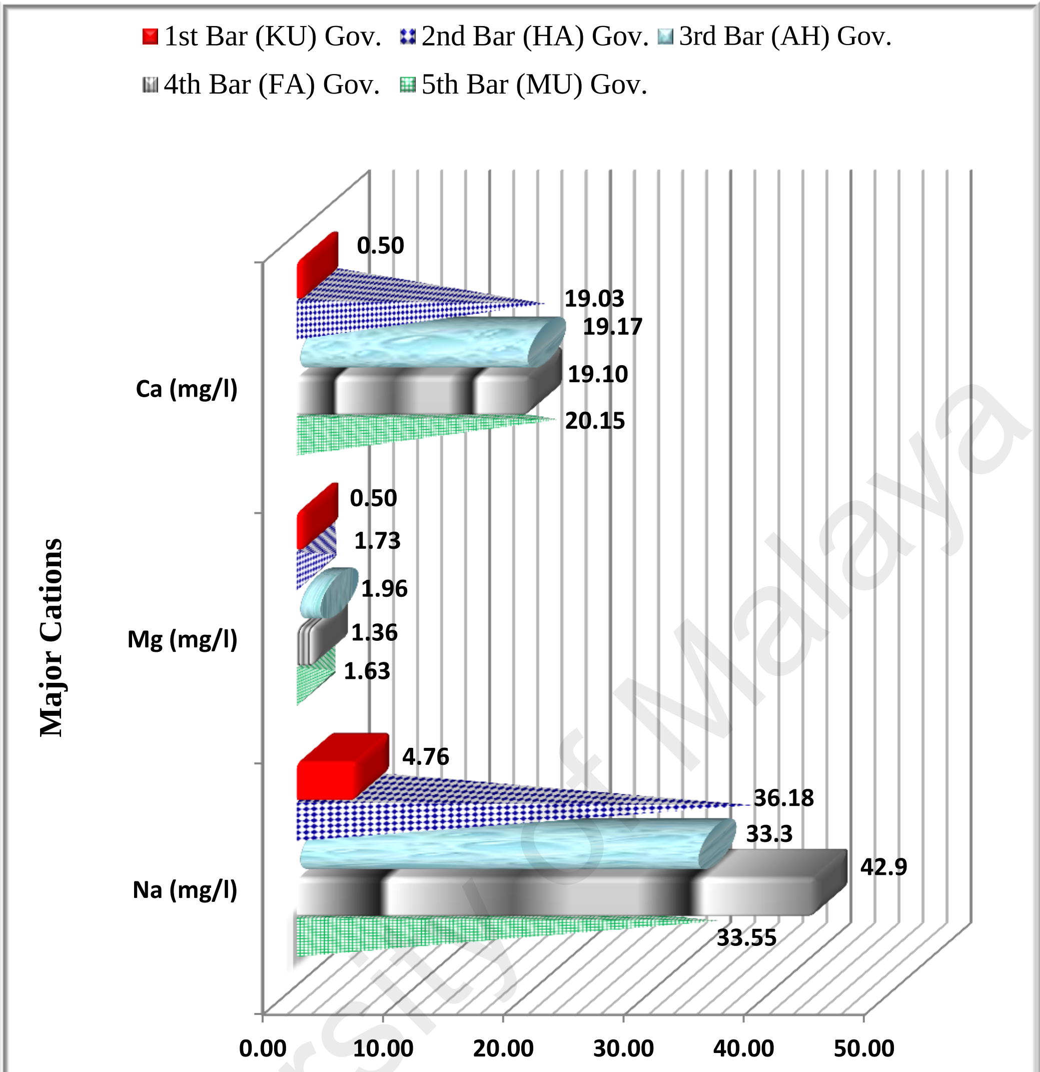


Figure 4.11: The Na^+ values of the tap water samples examined in the selected schools.

The sodium mean concentration is varied between 2.57 mg/l and 75.69 mg/l. while the mean of all the samples was at 35.73±16.80 mg/l. whereas it is no standards have not been established by KUW-EPA (2001), GSO (2008) and WHO (2011). There were wide variations in the increases for each of these sodium among the sampling locations and between all five governorates mean values were the KU, HA, AH, MU, (4.76 mg/l, 36.18 mg/l, 33.3 mg/l, 33.55 mg/l respectively) and, Whereas relatively the highest mean value were found at the FA governorate (42.9 mg/l). The spatial variation is shown in Table 4.2 and presented in Fig. 4.11 and 4.12.

Indeed observed previously in these study, correlation in the highest mean value for temperature, EC, TDS, TOC, and Ions were also samples of FA governorates, All Ca^{2+}, Mg^{2+}, and Na^+ values were below the 200 mg/l acceptability under the maximum permissible limit allowable standard of WHO (2011). For Na^+ was of the samples had concentrations above the health guideline of 50 mg/l suggested by the WHO (2011).



	Na (mg/l)	Mg (mg/l)	Ca (mg/l)
1st Bar (KU) Gov.	4.76	0.50	0.50
2nd Bar (HA) Gov.	36.18	1.73	19.03
3rd Bar (AH) Gov.	33.3	1.96	19.17
4th Bar (FA) Gov.	42.9	1.36	19.10
5th Bar (MU) Gov.	33.55	1.63	20.15

Mean Concentration

Figure 4.12: Comparison Summary of Major Cations between All Five Governorates

4.4.2 Major Anions

The fluoride (F^-) contents of the tap water samples collected from the selected schools had minimum and maximum averages of 0.01 mg/l to 0.05 mg/l with the mean value for F^- is 0.01±0.01 mg/l, In other mean values between five governorates were mean values were ranged (0.01 mg/l to 0.02 mg/l) whereas the highest mean value were found at the FA governorate, which are below the 1.5 mg/l health guideline suggested by either KUW-EPA (2001), GSO (2008), and WHO (2011), As shown in Table 4.1 and presented in Fig. 4.13.

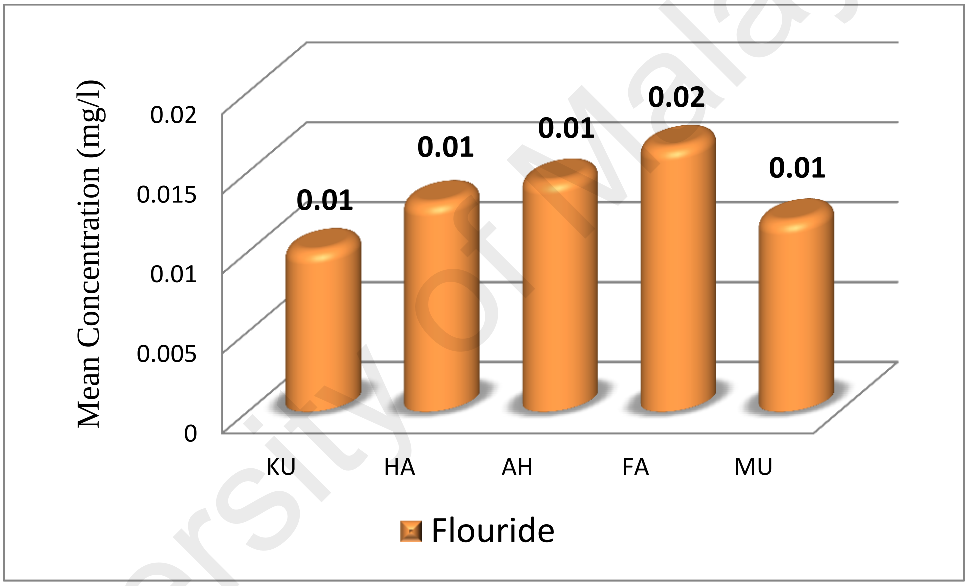


Figure 4.13: The F^- values of the tap water samples examined in the selected schools.

The Chloride Cl^- concentrations were found to vary from 1.26 mg/l to 110.26 mg/l with the mean value for Cl^- is 47.37±23.77 mg/l. Chloride has no health-based proposed guideline value. The Cl^- between five governorates mean values were the KU, HA, AH, MU, (2.09 mg/l, 42.20 mg/l, 48.24 mg/l, and 42.87 mg/l respectively). Whereas the highest mean value were found at FA the governorate 55.83 mg/l. The spatial variation is shown in Table 4.2 and presented in Fig. 4.14 and 4.17, Indeed observed previously in these study there is indicators correlation in the highest mean value for temperature, EC, TDS, TOC and Na^+ was also samples of FA governorates In spite of that, the chloride concentrations higher than 250 mg/l leads to detectable water taste. This implies that the tap drinking water of the selected schools in Kuwait is palatable for human use. There are no set standard limits by either KUW-EPA (2001), GSO (2008), or WHO (2011) pertaining the standards of Cl^- for drinking water.

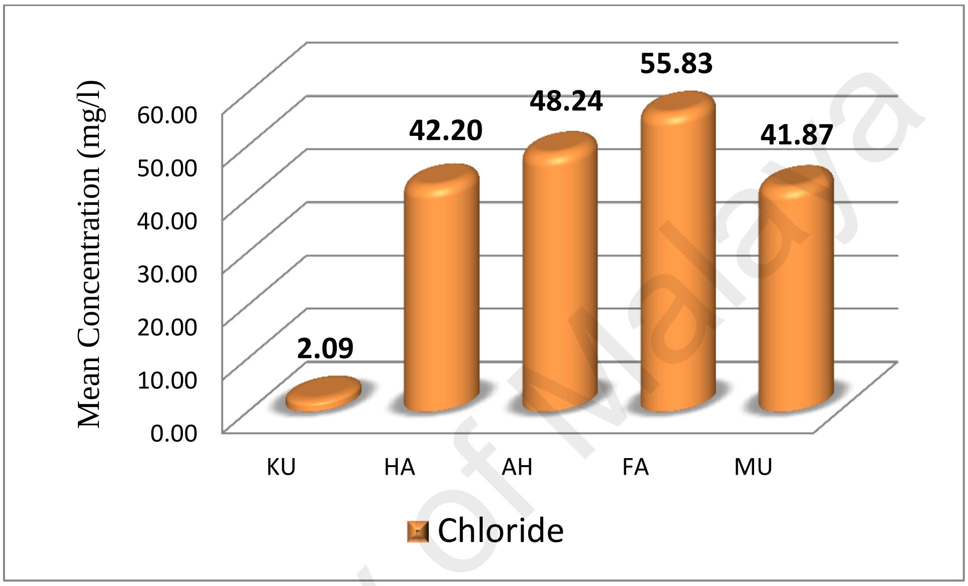


Figure 4.14: The Cl^- values of the tap water samples examined in the selected schools.

The measured concentrations of NO_3^{2-} had a minimum average concentration of 0.29 mg/l and a maximum average concentration of 6.33 mg/l, with an average concentration of 3.61±1.06 mg/l As shown in Table 4.1 and presented in Fig. 4.15, In other mean values between five governorates were very high variation mean values were ranged (0.30 mg/l to 3.85 mg/l) whereas the lowest mean value of KU and highest mean value were found at the MU governorate, In all of the tap water samples examined for the selected schools. These results for NO_3^{2-} are per the standard guidelines set by KUW-EPA (2001), GSO (2008), and WHO (2011) of 50 mg/l. is shown in Table 4.2 and presented in Fig. 4.15 and 4.17.

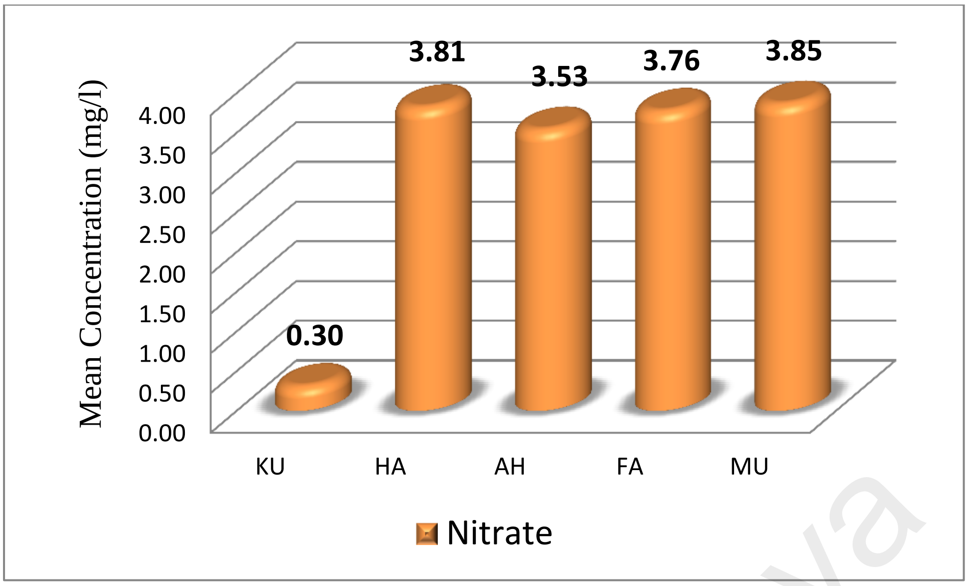


Figure 4.15: The NO_3^{2-} values of the tap water samples examined in the selected schools.

The concentrations of sulfate (SO_4^{2-}) were between a minimum average of 0.12 mg/l and a maximum average of 37.55 mg/l, with an average concentration of 6.57±7.39 mg/l in all of the tap water samples examined for the selected schools As shown in Table 4.1 and presented in Fig. 4.16.

The mean values between five governorates were very high variations mean values were ranged (5.17 mg/l to 8.68 mg/l) whereas the highest mean values were found at the AH governorate and the lowest mean values were found at the FA , The SO_4^{2-} in all of the tap water samples examined for the selected schools.

These results for SO_4^{2-} are per the standard guidelines, There are no set standard limits by either KUW-EPA (2001), GSO (2008), or WHO (2011). Is shown in Table 4.2 and presented in Fig. 4.16 and 4.17.

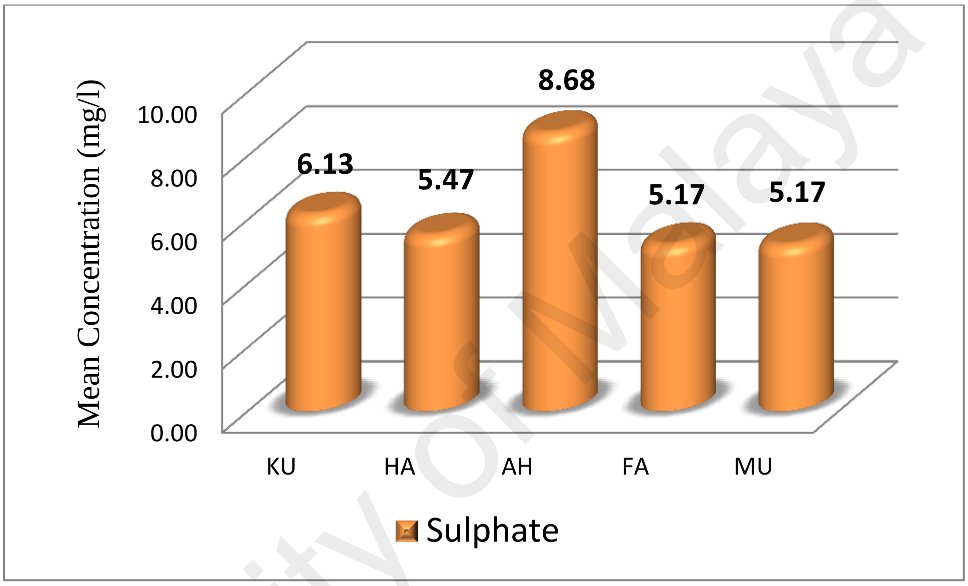
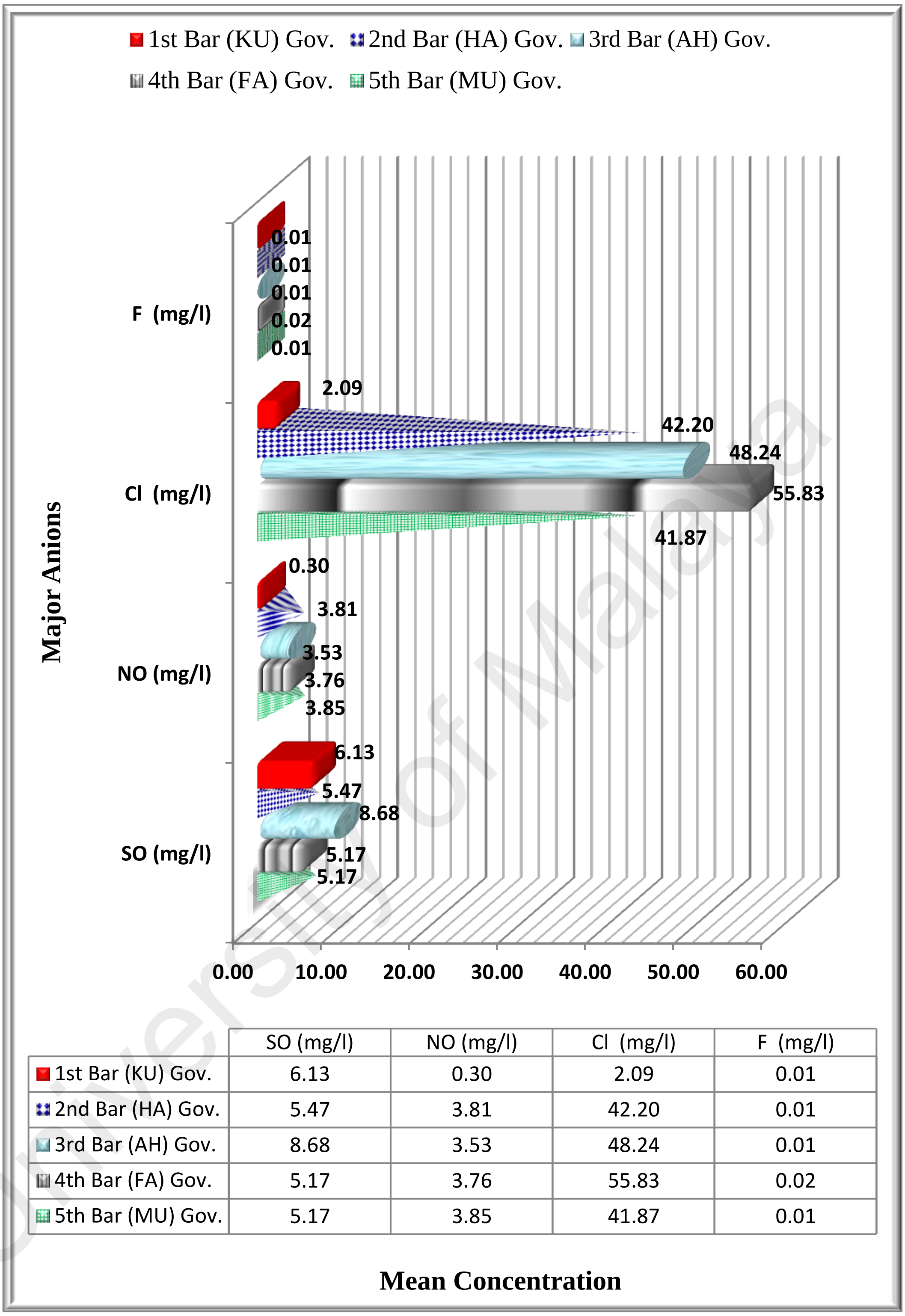


Figure 4.16: The SO_4^{2-} values of the tap water samples examined in the selected schools.



	SO (mg/l)	NO (mg/l)	Cl (mg/l)	F (mg/l)
1st Bar (KU) Gov.	6.13	0.30	2.09	0.01
2nd Bar (HA) Gov.	5.47	3.81	42.20	0.01
3rd Bar (AH) Gov.	8.68	3.53	48.24	0.01
4th Bar (FA) Gov.	5.17	3.76	55.83	0.02
5th Bar (MU) Gov.	5.17	3.85	41.87	0.01

Figure 4.17: Comparison Summary of Major Anions between All Five Governorates

4.5 Trace Metals

The mean concentrations of trace elements in the samples of drinking water from the 51 schools were as follows.

Aluminium concentration was ranged from 2 mg/l to 34.74 mg/l with an average concentration of 11.79±9.62 mg/l.

There were wide variations in the increases for each of these Aluminium among the sampling locations and between all five governorates mean values were the KU (2 mg/l), HA (6.69 mg/l), AH (10.93 mg/l), FA (3.45 mg/l) are less an Al increase (compared with MU 20.18 mg/l) the higher mean value of MU governorate as shown in Table 4.2 and illustrated in figure 4.18, There are no set standard limits by either KUW-EPA (2001), GSO (2008), or WHO (2011) pertaining the standards of temperature for drinking water.

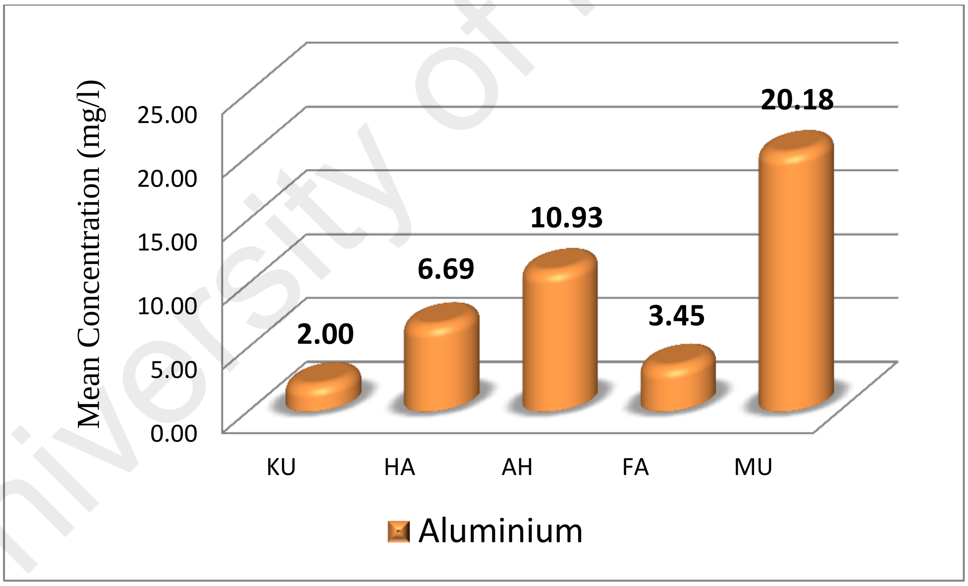


Figure 4.18: The Al values of the tap water samples examined in the selected schools.

The concentration of Arsenic for the tap water samples for the selected schools in Kuwait had a minimum average of 2 µg/l and a maximum average of 7.08 µg/l. The average was at 3.9±3.11 µg/l as shown in Table 4.1 and presented in Fig. 4.19.

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The (As) between five governorates mean values were the KU, HA, AH, MU, (2 µg/l, 5.55 µg/l, 2.37 µg/l, and 2.54 µg/l respectively). Whereas relatively the highest mean value were found at FA the governorate 8.94 mg/l. The spatial variation is shown in Table 4.2 and presented in Fig. 4.19 and 4.30, the allowable guideline limit standards set by KUW-EPA (2001), GSO (2008), and WHO (2011) all stand at 10 µg/l.

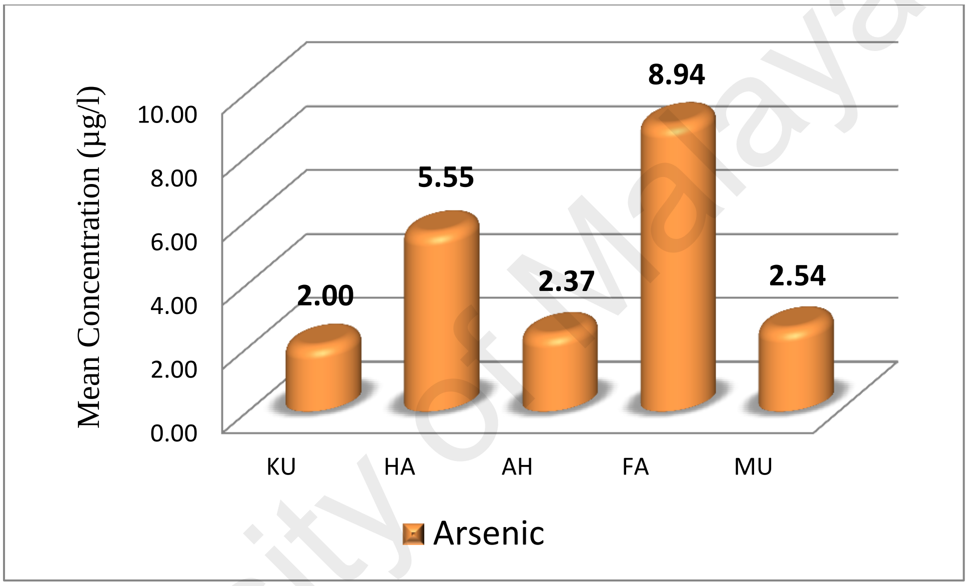

Figure 4.19: The As values of the tap water samples examined in the selected schools.

The minimum average concentration for Barium was at 2 µg/l while the maximum average concentration was at 9.01 µg/l. The mean average was at 2.57±1.74 µg/l As shown in Table 4.1 and presented in Fig. 4.20.

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The Ba relatively between five governorates mean values were ranged (2 µg/l to 4.34 µg/l) whereas the highest mean value were found at the HA governorate as shown in Table 4.2 and presented in Fig. 4.20 and 4.30.

There are concentrations standard guidelines established 700 µg/l by KUW-EPA (2001), GSO (2008), and WHO (2011). Therefore, this implies that all of the tap drinking water did not exceed the allowable health guidelines.

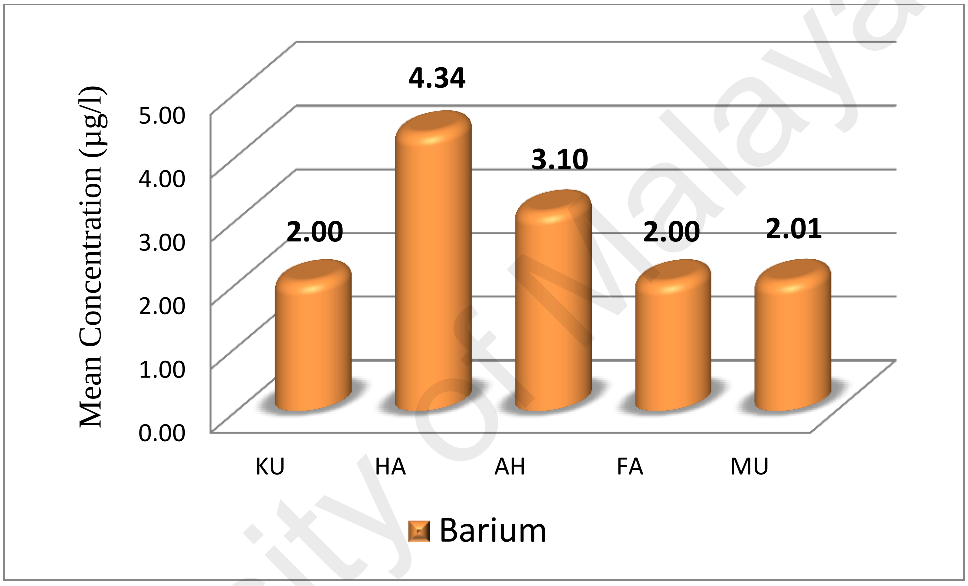


Figure 4.20: The Ba values of the tap water samples examined in the selected schools.

The concentration of Cadmium was at 2 µg/l for the minimum, average and 2 µg/l for the maximum average as shown in Table 4.1 and presented in Fig. 4.21.

The mean averages between all governorates were at 2µg/l as well. The set allowable standards set by the KUW-EPA (2001), GSO (2008), and WHO (2011) are at 3 µg/l, As shown in Table 4.2 and presented in Fig. 4.21 and 4.30.

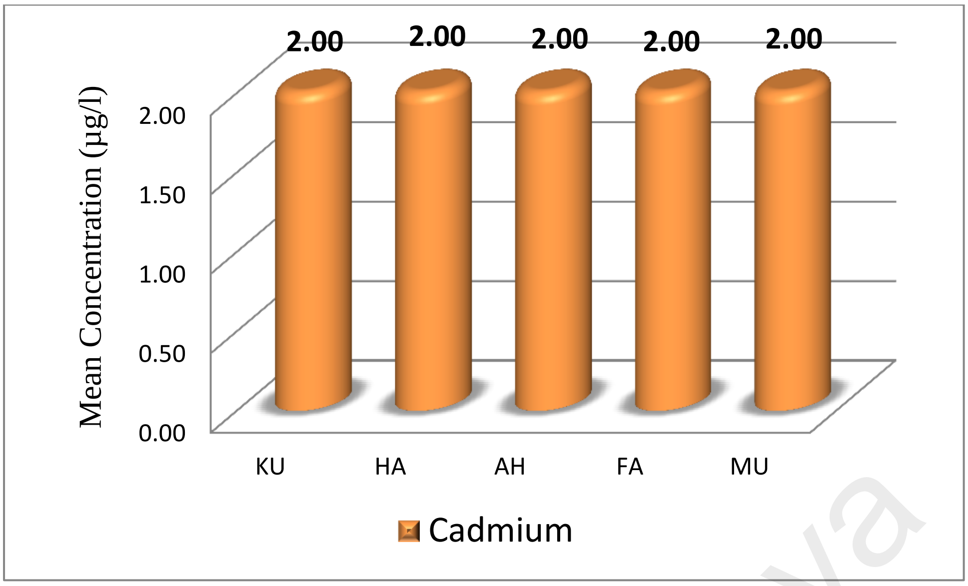


Figure 4.21: The Cd values of the tap water samples examined in the selected schools.

The Chromium concentration is ranged from 2 µg/l to 5.8 µg/l with an average of 2.24±0.95µg/l as shown in Table 4.1 and presented in Fig. 4.22. The mean averages between all governorates were at 2µg/l as well. The guideline standard value of KUW-EPA (2001), GSO (2008), and WHO (2011) is 50 µg/l, which much higher the concentration level of Chromium determined in the present study. As shown in Table 4.2 and presented in Fig. 4.22 and 4.30.

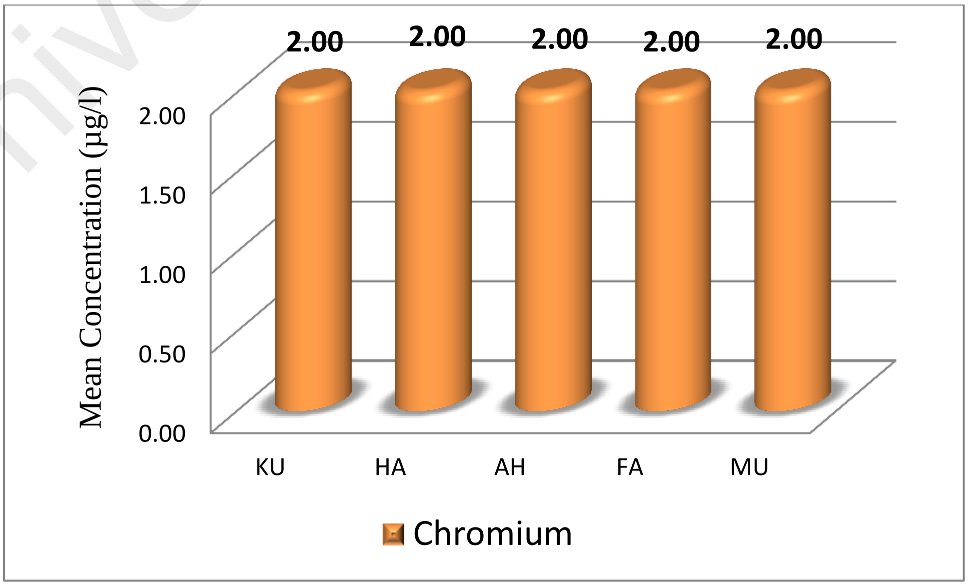


Figure 4.22: The Cr values of the tap water samples examined in the selected schools.

The concentration of copper had a maximum average of 116.79 µg/l. The allowable set standard set by KUW-EPA (2001) and WHO (2011) is at 1000 µg/l. Therefore, the tap water met these standards, As shown in Table 4.1 and presented in Fig. 4.23.

The Cu between all five governorates mean values were the KU, AH, FA, MU, (2.57 µg/l, 21.14 µg/l, 29.73 µg/l, 33.34 µg/l respectively) whereas relatively the highest mean value were found at the HA governorate (36.33 µg/l). The spatial variation is shown in Table 4.2 and presented in Fig. 4.23 and 4.30.

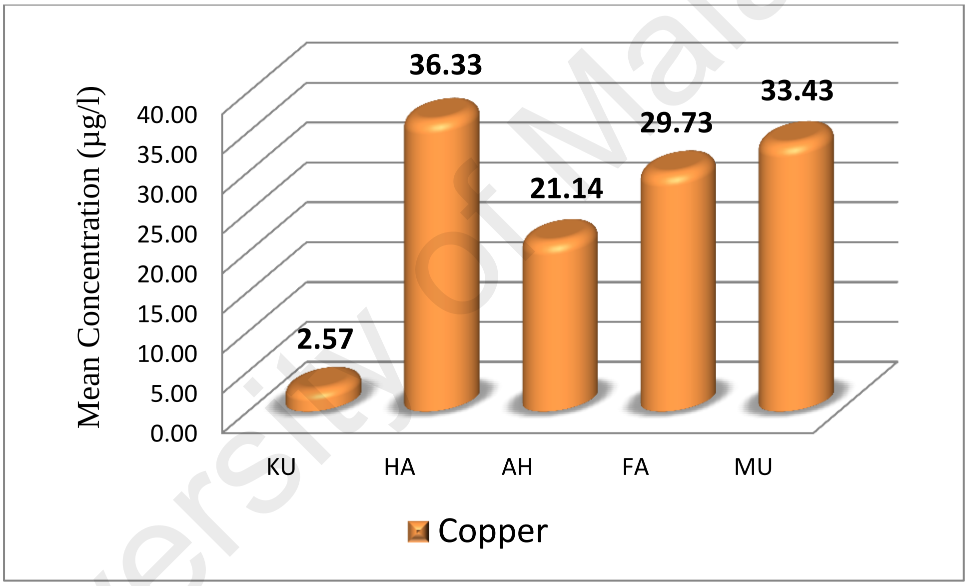


Figure 4.23: The Cr values of the tap water samples examined in the selected schools.

The concentration of lead had a maximum average of 2.2 µg/l. The limit set by KUW-EPA (2001), GSO (2008), and WHO (2011) is 10 as shown in Table 4.1 and presented in Fig. 4.24.

Also the mean averages between all governorates were at 2µg/l as well. As such, we can safely conclude that in regards to the allowable limits for lead concentrations in tap drinking water, and then the standards were sufficiently met. As shown in Table 4.2 and presented in Fig. 4.24 and 4.30.

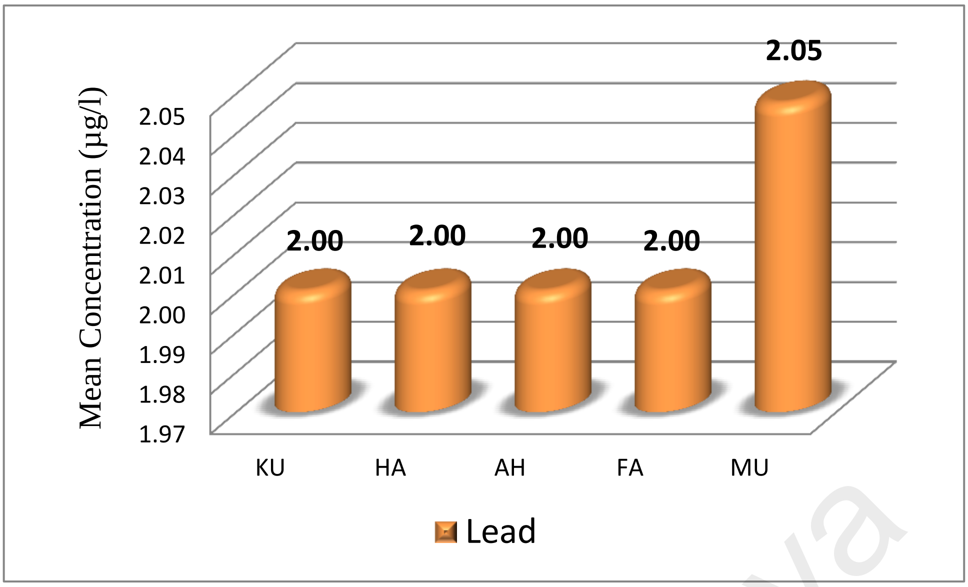


Figure 4.24: The pb values of the tap water samples examined in the selected schools.

The manganese concentration fluctuated between 2 µg/l to 3.53 µg/l and an average of 2.13±0.37 µg/l as shown in Table 4.1 and presented in Fig. 4.24.

The maximum concentration of manganese is much lower than the allowable set standards set by KUW-EPA (2001), GSO (2008), and WHO (2011), whilst the mean averages between all governorates were at ranged 2-2.26µg/l as well. The results illustrated in Table 4.2 and Fig. 4.25 and 4.30.

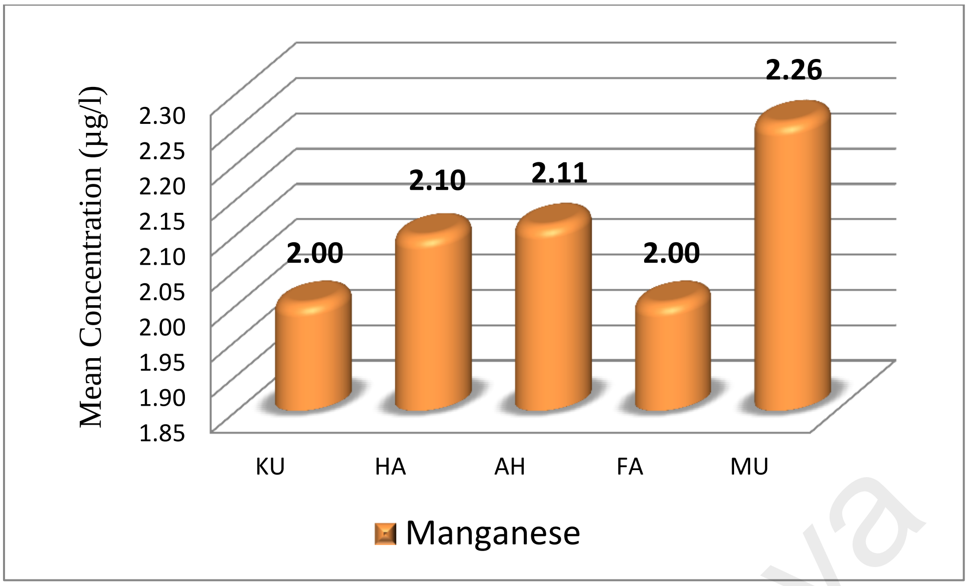


Figure 4.25: The Mn values of the tap water samples examined in the selected schools.

When it comes to the analysis of Mercury, the mean value for tap drinking water samples from the selected schools stood at 0.5 µg/l as shown in Table 4.1 and presented in Fig. 4.26.

The mean values between all governorates were at 0.50µg/l as well. As such, we can safely conclude that in regards to the allowable limits for Hg concentrations in tap drinking water The national limit set by the KUW-EPA (2001) is at 1 µg/l is more safer with sufficient quality, whereas the limit set by the GSO (2008) and WHO (2011) is at 6 µg/l meaning that levels of mercury have to be highly monitored, As illustrated in Table 4.2 and shown in Fig. 4.26.

In any case, Seawater (SW) samples were collected from one of the feeder lines to the desalination the dumping of plants and product water (PW) may not be viewed as fitting since other national regulatory agencies for example, USEPA and USSR had set much higher limits for Hg in drinking water, namely, 2.0 and 5.0mg/l, (Kutty., et al., 1995).

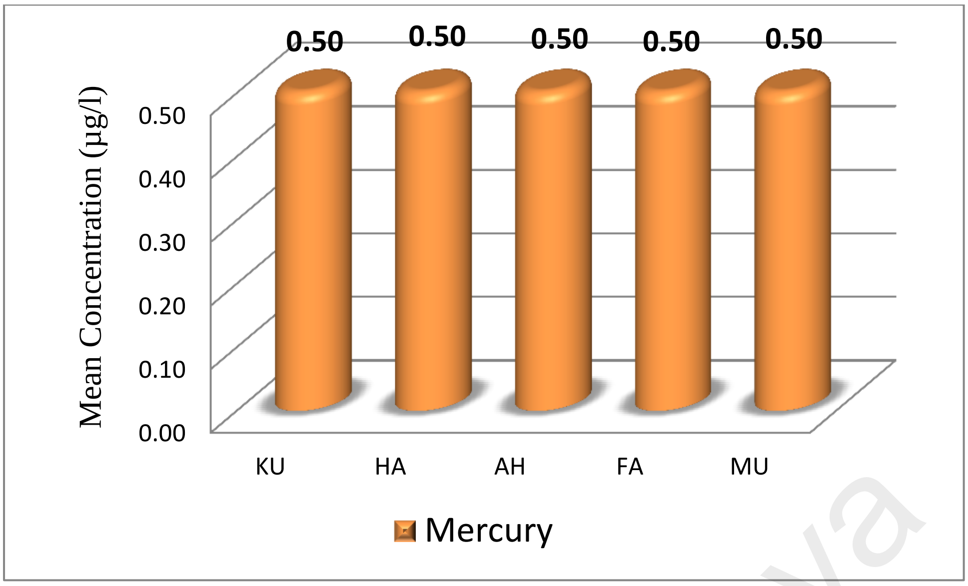


Figure 4.26: The Hg values of the tap water samples examined in the selected schools.

The maximum average concentration for Nickel was at 3.98 µg/l, The Nickel concentration fluctuated between 2 µg/l to 13.53 µg/l and an average of 3.98±3.04 µg/l as shown in Table 4.1 and presented in Fig. 4.27.

. The Ni between all five governorates mean values were the KU, AH, FA, MU, (2 µg/l, 2.72 µg/l, 4.36 µg/l, 3.12 µg/l respectively) whereas relatively the highest mean value were found at the HA governorate (5.85 µg/l). The spatial variation is shown in Table 4.2 and presented in Fig. 4.27 and 4.30.

The allowable standard set by KUW-EPA (2001) is at 20µg/l and this set by GSO (2008) and WHO (2011) is at 70µg/l. The tap drinking water from the samples collected met the standard values by all organizations.

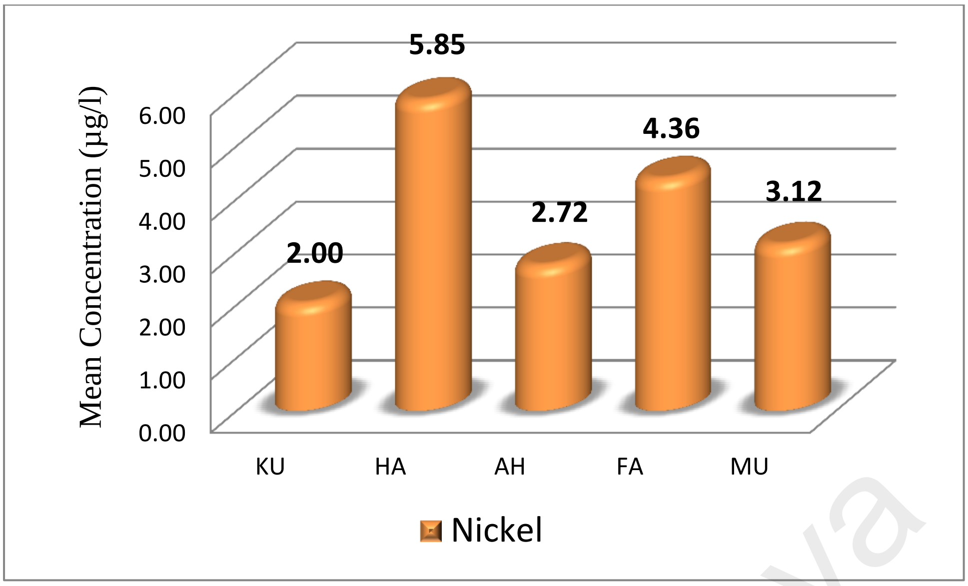


Figure 4.27: The Ni values of the tap water samples examined in the selected schools.

The selenium mean concentration is varied between 5 µg/l and 29.9 µg/l. while the mean of all the samples was at 6.95±6.37 µg/l. The maximum concentration is slightly higher than the standard value of KUW-EPA (2001) which set at 10 µg/l, whereas it is lower than the standards of GSO (2008) and WHO (2011) set at 40 µg/l as shown in Table 4.1 and presented in Fig. 4.28.

There were wide variations in the increases for each of these selenium among the sampling locations and between all five governorates mean values were the KU, AH, FA, MU, (5 µg/l, 5 µg/l, 6.68 µg/l, 5.32 µg/l respectively) and, Whereas relatively the highest mean value were found at the HA governorate (13.30 µg/l). The spatial variation is shown in Table 4.2 and presented in Fig. 4.28 and 4.30.

Selenium is dangerous in huge sums, however follow sums of it are essential for cell work in most, for people, selenium is a fundamental supplement. For instance, selenium assumes a part in the component working of the thyroid gland. The Tolerable upper Intake level is 400 micrograms of selenium for each day. Utilization over that level can prompt to selenosis, Short-term oral exposure to high concentrations can cause nausea, vomiting, and diarrhea (M artin, & Griswold 2009).

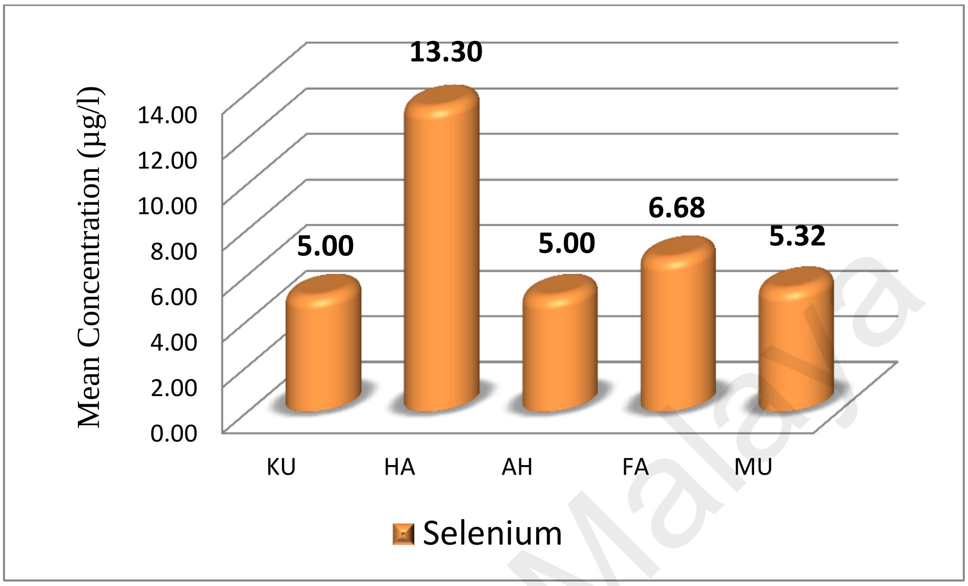


Figure 4.28: The Se values of the tap water samples examined in the selected schools.

The zinc concentration in the tap water had a minimum value of 2 µg/l and a maximum value of 85.86µg/l. The mean for the selected schools was at 14.52±19.87 µg/l. zinc not of health concern at levels found in drinking water and their guideline values have not been established. In as much as Zinc is important for human health (this is because it functions as a catalyst for enzymatic activity) when the concentrations of zinc metal are high, then they can cause harmful side effects such as an acceleration of the conditions associated with anemia As shown in Table 4.1 and presented in Fig. 4.29.

There were wide variations in the increases for each of these zinc among the sampling locations and between all five governorates mean values were the KU, AH, FA, MU, (2 µg/l, 10.42 µg/l, 4.97 µg/l, 11.41 µg/l respectively) and, Whereas relatively the highest mean value were found at the HA governorate (35.81 µg/l). The spatial variation is shown in Table 4.2 and presented in Fig. 4.29 and 4.30.

There are no set standard limits by either KUW-EPA (2001), GSO (2008), or WHO (2011) pertaining the standards of temperature for drinking water.

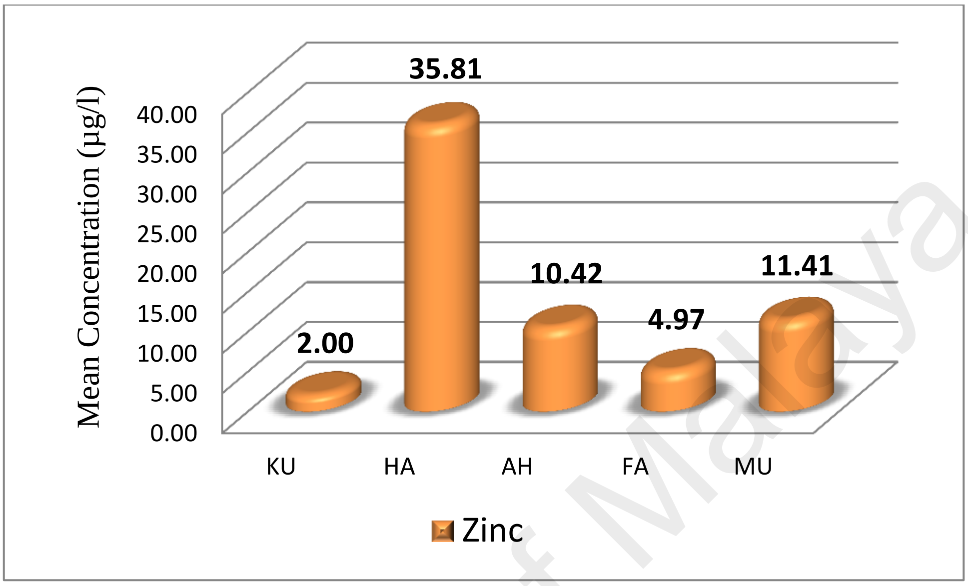
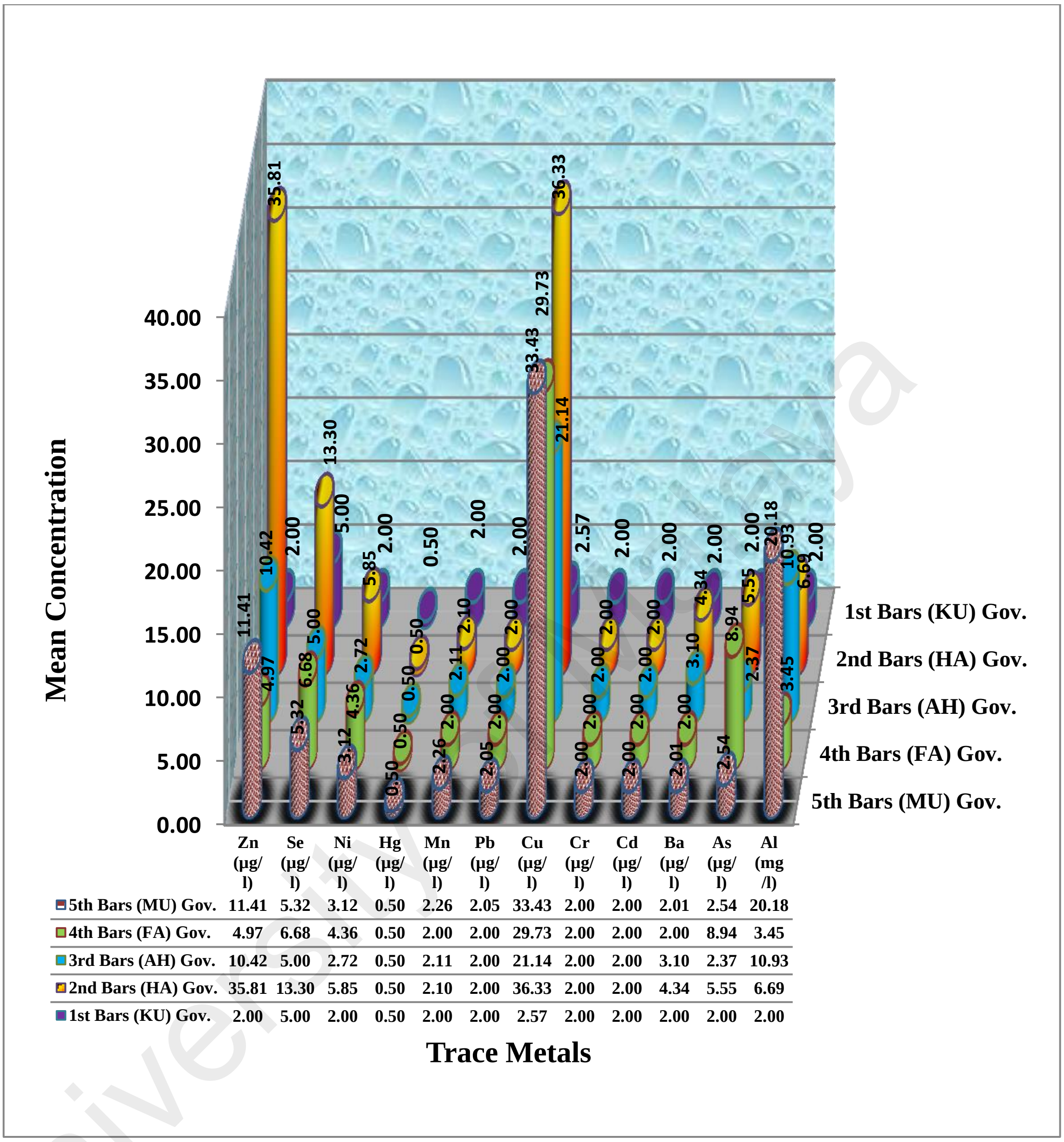


Figure 4.29: The Zn values of the tap water samples examined in the selected schools.



	Zn (µg/l)	Se (µg/l)	Ni (µg/l)	Hg (µg/l)	Mn (µg/l)	Pb (µg/l)	Cu (µg/l)	Cr (µg/l)	Cd (µg/l)	Ba (µg/l)	As (µg/l)	Al (mg/l)
5th Bars (MU) Gov.	11.41	5.32	3.12	0.50	2.26	2.05	33.43	2.00	2.00	2.01	2.54	20.18
4th Bars (FA) Gov.	4.97	6.68	4.36	0.50	2.00	2.00	29.73	2.00	2.00	2.00	8.94	3.45
3rd Bars (AH) Gov.	10.42	5.00	2.72	0.50	2.11	2.00	21.14	2.00	2.00	3.10	2.37	10.93
2nd Bars (HA) Gov.	35.81	13.30	5.85	0.50	2.10	2.00	36.33	2.00	2.00	4.34	5.55	6.69
1st Bars (KU) Gov.	2.00	5.00	2.00	0.50	2.00	2.00	2.57	2.00	2.00	2.00	2.00	2.00

Figure 4.30: Comparison Summary of Trace Metals between All Five Governorates

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In the current investigation, the tap drinking water quality in Kuwait was thoroughly analyzed and investigated. Tap drinking water from total of 51 selected schools from 5 of the main 6 Kuwait's governorates were analyzed. The main purpose being establish their physical and chemical characteristics and detecting if this were as per the standards set by Kuwait's Environment, Public Authority as well as those set by regional and international organizations in regards to the quality of tap drinking water.

- The physical properties of tap drinking water are characterized by high temperature reaching a mean value of 32.31±5.35 °C. This value is much higher the desirable water temperature (4 °C to 10 °C) and related to the natural hot weather condition in the state of Kuwait.

  The chemical properties results, as shown previously, indicate that the concentrations of most chemical parameters were within the recommended limits except for free residual Chlorine and Selenium the concentrations from 51 selected schools were the amount of free residual chlorine the maximum average concentration was at 0.55 mg/l while the mean of all the samples was at 0.25±0.06 mg/l. while the mean value lower between all five governorates. The allowable set standards by KUW-EPA (2001), GSO (2008) and WHO (2011) are at ≤ 0.50 mg/l. The maximum average samples exceeded the allowable set limits. The increased concentration of Cl in some tap drinking water samples could be the result of the disinfection process utilizing chlorination.

  The trace metal such as selenium mean concentration varied between 5 µg/l and 29.9 µg/l. while the mean of all the samples was at 6.95±6.37 mg/l. The maximum concentration were higher than the standard value of KUW-EPA (2001) which is set at 10 µg/l, whereas it is lower than the standards of GSO (2008) and WHO (2011) set at 40 µg/l there were wide variations in the increases for selenium among the sampling locations and between all of five governorates mean values were the KU, AH, FA, MU, (5 µg/l, 5 µg/l, 6.68 µg/l, 5.32 µg/l respectively) and, Whereas relatively the highest mean value were found at the HA governorate (13.30 µg/l).

- Major ions (cations and anions) in the tap water are either within or below the threshold levels that have been set by most international organization dealing with the quality of drinking tap water such as WHO.

  With regards to the concentration of residuum of trace metals, the samples of tap water that were analyzed indicated that the concentrations were below those set by the regulatory of permissible limits of drinking water standards (KUW-EPA, GSO and WHO).

  Tap drinking water quality should not pose any serious threat to the public as most of the standards have been met, some of the standards are even higher compared to those that have been set by different world organizations. The concentrations of Cl have to be reduced.

- This study shows that GCC countries, who's depend fundamentally on seawater desalination to meet their drinking water prerequisites build up and develop their own guideline of drinking water contaminants at which unfavorable for health and wellbeing impacts would not be foreseen to happen over short and long exposure terms with Regular monitoring to ensure quality assurance and evaluation the drinking water.

  The water supply and the public health authorities have to look into the levels of chemicals that are present from the chlorination and the concentration of trace metals plants as this may result to public health risks in the long-term by improve national standards comparing with international guidelines criteria's.

5.2 Limitations

In this research one governorate - *Jahra* is excluded because that sampling was randomly chosen in the governorate for that reason the *Jahra* was excluded due to high missing data. The study limits its physiochemical parameters to 25 due to unavailability of readings in the samples. Some governorate has not covered all schools in the areas also sample taking is very irregularly throughout the year (i.e. some parameters were taken in January while some can be taken in December). Nevertheless, 5 governorates have uneven parameters throughout the sampling processes.

5.3 Recommendations

For the protection of human health, it is imperative to ensure that proper and effective drinking water monitoring systems are put in place. This will ensure that all the physiochemical parameters in regards to tap drinking water quality are at per with the acceptable and allowable international and national standards.

In accordance to the large quantity of missing data, there is important recommendation for well designing the sampling procedures to fulfill the objective of such studies. Sampling procedures should be carried out systemically, regularly, temporally and spatially to attain such precise and accurate results.

In order to ensure a healthy drinking water, samples from the sources, network and delivery points must be taken to check the standards of the physicochemical parameters along the course of transportation stages to determine the functionality of the network before reaching the consumer.

In spite of the previous valuable work, Kuwaiti national guideline standard values for many other physicochemical properties such as electrical conductivity, TDS, sodium, have not been established yet. It is highly recommended that a brief revision and precious updating of physiochemical parameters that already have derived guideline standard and derivation of such values for those physiochemical parameters have not been established.

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