زانکۆی سەلاحەددین-هەولێر

Salahaddin University-Erbil

Water Quality Assessment of some Bottled, Filtered, and Tap waters in Erbil City

Research Project

This research project has been written under my supervision and has been submitted for the award of the degree of B.Sc. in **(PHYSICS)**.

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بِسْمِ اللهِ الرَّحْمنِ الرَّحِيمِ

قَالُواْ سُبْحَانَكَ لاَ عِلْمَ لَنَا إِلاَّ مَا عَلَّمْتَنَا إِنَّكَ أَنتَ الْعَلِيمُ الْحَكِيمُ

صدق الله العظيم

سورة البقرة الاية32

SUPERVISOR CERTIFICATE

This research project has been written under my supervision and has been submitted for the award of the degree of B.Sc. in (Physics)

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Date: / /2024

I confirm that all requirements have been completed.

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Date: / / 2024

Dedication

This project is dedicated:

- ✓ *To My Parents*
- ✓ *To My Brother and Sisters*

Acknowledgments

First and foremost, I must acknowledge my limitless thanks to **Allah**, the Ever-Magnificent; the Ever-Thankful, for His help and bless. I owe a deep debt of gratitude to the physics department and Salahaddin university for giving us an opportunity to complete this work. I am very appreciative to my colleagues in the physics department. I am grateful to some people, who worked hard with me from the beginning till the completion of the present research particularly my supervisor **Assistant Prof. Dr. Sardar P. Yaba** who has been always generous during all phases of the research. I like to thank **Dr Abdula H. Aziz** in the Biology Department for supporting this project. Also, I would like to take this opportunity to say warm thanks to all my beloved friends, who have been so supportive along the way of doing my thesis. Last but not least, deepest thanks go to all people who took part in making this thesis real.

Summary

In the present study a total of five brands of drinking bottled waters, five Groundwater and Surface water, and five filtered waters were selected in Erbil city during October 2023 and January 2024. The samples were analyzed for Physical properties of water including pH, EC and TDS.

The results showed that pH value ranges (7.01- 7.80), accordingly, all studied bottled water brands in Erbil city do not exceed the allowable limits. The laboratory results of Groundwater, Surface water and outlets of filtered water indicated that inlet water and the water after passing water filters is the same with value of percent of reduction with less than 10%, which means that home water filters not affect the change of water pH.

Electrical conductivity of inlet water ranged from 384 to 481.5 μS cm^{-1} and for outlet of filters ranged between 51 and 1157 μS cm^{-1}. The highest performance for EC reduction of 86.74% was detected at site 2 in New Zanko Village. The results revealed that all types of home water filters showed high performance in Electrical Conductivity-EC percent reduction.

Total dissolved solids TDS results revealed that The peak levels of TDS 232.50 $mg.l^{-1}$ was recorded in surface water at Naznaz quarter during October 2023, while the minimum value of 22 mg l^{-1} was measured in groundwater at New Zanko Village home filtration system during January 2024. The TDS removal efficiency ranged between 64.32% to 88.20% in the same manner as showed in EC. The maximum acceptable concentration of TDS in drinking water according to the mentioned guidelines is 500 mgl^{-1}, thus, all sites were considered as potable water.

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CHAPTER ONE

INTRODUCTION AND THEORETICAL BACKGROUND

1.1. Introduction

Water is an essential element to life on planet Earth and everyone needs water to survive, especially when up to 60% of the human body is composed of it (Ellie and Rolfes, 2008). It is one of the most critical, scarce, precious, and replenishable natural resources that cannot be created (Prasad, 2008). It is well known that clean water is essential for healthy living. In addition, water is an important asset for domestic, industrial, and agricultural purposes. It is mainly used for drinking purposes which come from the surface and underground water sources (Daud et al., 2017). 97% of water exists in the oceans which are not suitable for drinking purposes 3% is freshwater, and 3% fresh water 2.97% is comprised of glaciers and ice caps and the remaining little portion of 0.3% is available as a surface and groundwater for human use (Mohsin et al., 2013). Drinking water of a high quality is essential for good health. Therefore, water quality parameters are the physical, chemical, and biological characteristics of water in association with the set of standards (Daud et al., 2017, Weldemariam, 2013). In addition, the quality of water is the degree of its portability and is determined by the level of physicochemical, microbial and heavy metals (which include suspended and dissolved substances in the water, the degree of alkalinity (pH), and the presence of non-desirable microorganisms). Water for drinking purposes should therefore be free from these substances to prevent waterborne diseases (Akoteyon et al., 2011).

However national statistics don't tell customers specifically about the quality and safety of the water coming out of their tap, that's because drinking water quality varies from place to place, depending on the condition of the source of the water

from which it drowned and the treatment it receives. Bottled water is the only reliable healthy drinking water in any part of the globe. It is widely accepted as potable and thereby free from physical, chemical, and microbial contaminants that could initiate adverse health effects in humans when consumed. Bottled waters are becoming increasingly popular worldwide (Versari et al., 2002).

Bottled water comes from a variety of sources, like spring and mineral water drawn from underground; they differ in their composition and mineral content (Warburton, 2000). Environmental pollution is one of the most horrible crises that we are facing today. Due to the increased urbanization and industrialization. Surface water pollution has become a crucial problem. It is necessary to have precise and appropriate information to observe the quality of any water resources and to develop some useful tools for monitoring the quality of such free resources to retain their excellent quality for various beneficial uses (Alam and Pathak, 2010). The water quality index is one of the most effective tools to monitor surface as well as groundwater pollution and can be used efficiently in the implementation of a water quality upgrading program. The objective of an index is to turn multifaceted water quality data into simple information that is comprehensible and useable by the public (Alam and Pathak, 2010). The water quality index provides information on a rating scale from zero to hundred. The higher value of WQI indicates better quality of water and the lower value shows poor water quality. The need for research on the quality of bottled water is crucial. And, there is very limited information on bottled drinking water quality that comes from the ground and surface water. Thus, there is an urgent need to evaluate and classify the commercially available bottled waters concerning the Standards to safeguard the health and safety of the consumers. Furthermore, the mineral content of bottled water is one of the most important indicators of water quality. Thus, some minerals are required by our bodies for numerous biological and physiological processes that are necessary for the maintenance of health and growth.

In addition, some minerals are extremely essential in our daily lives and play a significant role in the nutrition of our bodies (Ellie and Rolfes, 2008). The aim of the study is to evaluate the quality of water after each type of treatment (treatment of bottled waters, treatment of tap waters, and treatment of water filtration) in Erbil City.

1.2 Theoretical background

1.2.1 water

Water is a transparent, tasteless, odourless, and nearly colourless chemical substance with the chemical formula H_2O. It is a vital component for all known forms of life and is essential for various physical and chemical processes on Earth. Safe drinking water is a fundamental requirement for human health. Water quality standards are established to ensure that water is free from contaminants harmful to human health. Water is an essential resource for sustaining life on Earth, and its availability, quality, and distribution play critical roles in ecosystems, climate patterns, and human societies. "Bottled water," "filtered water," and "tap water" are terms that refer to different sources and treatment methods for obtaining drinking water. Here's an overview of each:

A. Bottled Water:

Bottled water is water that is packaged in plastic or glass bottles and is intended for human consumption. It is available for purchase in various sizes and types, such as spring water, purified water, mineral water, and artesian water. The characteristics of bottled water can vary based on its source and treatment. Bottled water is regulated by health authorities to ensure safety and quality. However, it can be more expensive and has environmental considerations due to the production and disposal of plastic bottles.

B. Filtered Water:

Filtered water is tap water that has undergone a filtration process to remove impurities. Filtration can occur through various methods, including:

Activated Carbon Filtration: Removes chlorine, odors, and some contaminants.

Reverse Osmosis: A membrane-based filtration process that removes a wide range of contaminants.

UV Filtration: Uses ultraviolet light to kill bacteria and other microorganisms.

Filtered water is often considered a more sustainable and cost-effective alternative to bottled water. Home filtration systems, pitcher filters, and faucet-mounted filters are common methods of obtaining filtered water.

C. Tap Water:

Tap water, also known as municipal or public water, is supplied by local water utilities through a network of pipes to homes and businesses. It undergoes a treatment process to meet regulatory standards before reaching consumers. The treatment typically includes:

Coagulation and Flocculation: Chemicals are added to clump together particles.

Sedimentation: The clumps settle, and clear water is separated.

Filtration: Additional removal of particles and impurities.

Disinfection: Usually with chlorine or chloramine to kill bacteria and pathogens.

Tap water quality varies globally and is subject to regulations set by local health authorities. Regular testing and monitoring are conducted to ensure safety. In many developed countries, tap water undergoes stringent quality control measures and is safe for consumption (Tomar, 1999, MWH, 2005).

1-2-2 water quality assessment

Water quality is water that is safe for humans to drink and to use for other domestic purposes, such as cooking, washing up, bathing, and showering. Water quality assessment involves evaluating various physical, chemical, and biological parameters to ensure that water is safe for consumption and use. Here's a breakdown of key aspects of water quality assessment:

1. Physical Characteristics:

pH is defined as the negative log of the hydrogen ion concentration. pH Indicates the acidity or alkalinity of water. The range of pH extends from zero to 14. A pH value of 7 is neutral because pure water has a pH value of exactly 7. Values lower than 7 are acidic; values greater than 7 are basic or alkaline.

Total Dissolved Solids (TDS): The concentration of dissolved minerals in water. Dissolved solids refer to any minerals, salts, metals, cations, or anions dissolved in water. Total dissolved solids (TDS) comprise inorganic salts, principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates, and some small amounts of organic matter that are dissolved in water.

EC: or Electrical Conductivity of water is its ability to conduct an electric current. Salts or other chemicals that dissolve in water can break down into positively and negatively charged ions. These free ions in the water conduct electricity, so the water's electrical conductivity depends on the concentration of ions (Tomar, 1999).

1.3. Literature Review

Water is an essential element for all living organisms. Water is the most vital liquid for maintaining the life on the earth. Safe drinking water is a basic need for good health and it is also a basic right of human. Many water resources were affected by this pollution. New technologies made it possible to treat all kinds of pollutants. Clean water should not contain radioactive elements and should be free of any disease-causing organisms. Drinking water should be clean and safe. Fresh water is already a limiting resource in many parts of the world. In the next century, it will become even more limiting due to increased population, urbanization and climate change. Unfortunately, in developing countries the drinking quality of water is continuously being contaminated and hazardous for human use due to the high growth of population, expansion in industries, and throwing away of wastewater and chemical effluents into canals and other water sources. Many studies have been done in past related to water analysis, some of them are heightened here as below:

(Kafia et al., 2009) Collected water samples from three water treatment plants (WTP) of the Greater Zab River in Erbil, Kurdistan, Iraq, to ascertain the drinking water quality for human consumption. The following water quality parameters were determined which were chosen as the major indicators namely PH, Total Dissolved Solid(TDS), Electrical conductivity(EC), Total Hardness(TH), Ca, Mg, Na, K, Cl, and the concentration of eight heavy metals (Fe, Pb, Hg, Zn, Cd, Ni, Cu, and Ag). Concentrations of the metals in the water samples were determined by flame atomic absorption spectrometry. The research results showed that the efficiency of the filtration unit of the three WTPs was: Efraz 1> Efraz 2> Efraz 3. Most of the parameters analyzed in this study were within the guidelines given by WHO or US EPA for drinking water.

(Ismail et al., 2013) Fifteen local bottled water brands (Best-selling brands) purchased randomly covering nine Iraqi governorates were analyzed for various physicochemical as well as bacterial water quality parameters. The obtained results were compared to national and international water standards for drinking water as well as to the reported label values of the bottled water. Results showed that the majority of bottled water met the different drinking water quality standards for physicochemical parameters except for calcium (one brand at Baghdad), magnesium (Ten brands at all studied governorates except Basrah) and total alkalinity (Two brands at Baghdad and Duhok). All bottled water brands showed negative growth for faecal coliforms, total coliforms and heterotrophic plate count at 37◦C. Analysis was used to classify bottled water brands with similar properties and results distinguished five groups of brands. Comparison of the study results with reported label values indicated considerable variation for pH, Ca, Mg, Na, K, Cl, TH, TA, TDS, EC and SO4.

(Toma, 2013) study Quality assessment of some bottled water that available in Erbil City, Iraq by using Water Quality Index for drinking purposes. This was done by subjecting 84 bottled samples collected from different markets within 6 months from January to June 2012. Comprehensive physicochemical analysis using standard methods of analysis. For calculating the WQI, ten parameters have been considered: Turbidity, Electrical conductivity, Total Dissolved Solids, pH, Alkalinity, Hardness, Calcium, Magnesium, Nitrate and Sulfate. The WQI for these samples ranges from 11.953 to 137.532. Using the water quality index all the bottled samples were classified as excellent to good water they were suitable for drinking purposes except Vauban bottled water which was bad and unsuitable for drinking.

(Toma et al., 2013) Apply the water quality index to assess the water quality of six different types of bottled water that are available in Erbil city (Life, Shireen, Kani, Al-Hayat, Rawan, and Masafi) for drinking purposes, depending on the

physicochemical parameters of water (Turbidity, EC, TDS, pH, Alkalinity, Hardness, Ca+2 , Mg). The water quality index showed that the Life, Rawan, and Masafi is excellent; also, Shireen, Kani, and Al-Hayat are good for drinking purposes depending on the World Health Organization (WHO) standards.

(EmanHussein and Sabah, 2014) demonstrated the suitability of bottled water used in Kirkuk City - Iraq and Tap water processed by the Directorate of Kirkuk's water for human consumption collected 20 types of bottled water (locally made and imported) and nine Tap water samples from different city regions, samples analysis bothchemical& physical properties included (PH, Turbidity, E.C., T.D.S, T. Hardness, Alkalinity, T.S.S) with measuring elements (Ca +, Mg+, Cl-, So4 =, Na+&K+), all data compared with (IBWA, 2008) & (IS 470 /2001), bottled water results compare with brand labels. Results showed the existence of discrepancies between the data obtained in vitro with what is listed on brand labels, note that many of the brands did not cover all properties that should be known by the consumer for the safety of use, also the results showed that three regions in Kirkuk city and processed its water by the Water Directorate of Kirkuk is not suitable to drink.

(Bapper and Younis, 2016) Demonstrate the suitability of bottled water used in Erbil City - Iraq and Tap water processed by the Directorate of Erbil's water for human drinking and domestic consumption, about 37 brands of bottled water were collected including local and imported from different places in the Erbil market from February 2015 to May 2015, samples were examined by correlation analysis and (water quality index)WQI. The water quality index is used to evaluate the suitability of bottled water states for drinking purposes, samples were analyzed for chemical, physical and bacteriological properties such as PH, Turbidity, E.C., T.D.S, T. Hardness and Alkalinity with measuring some elements (Ca+, Mg+, Cl^-, $SO4^=$, $NO3^-$, Na^+&K^+) and coliform bacteria, all data compared with the International Bottled Water Association (IBWA, 2008) and World Health Organization for drinking

water (WHO). Results showed that the WQI for these samples range from 24.233 to 101.122. Using the WQI all the bottled water and tap water samples were classified as excellent to poor water they are suitable for drinking and other domestic purpose. (Shekha, 2016) Determining the variable effects on water quality of Greater Zab River in Erbil province, Iraq, using multivariate statistical analysis. Seventeen variables were monitored in four sampling sites during one year (from May 2012 to April 2013). Their pH and TDS values were found in agreement for drinking and irrigation purposes with drinking water quality standard for Iraq, WHO, and Richards standards. Generally, results of most water quality parameters revealed that Greater Zab River were within permissible level for drinking water consumption, while it regarded as safe water type for all kinds of crops.

(AL-Dulaimi and Younes, 2017) evaluated the quality of potable water in Baghdad city. Furthermore, this study compares the quality of tap and bottled water. Baghdad City was divided into 4 districts based on the water source, and 40 water samples were collected from each district. Moreover, the most popular bottled water brands were sampled and compared with the tap water samples. The quality of the analyzed potable water samples varied based on the water source. The total dissolved solid (TDS) levels exceed the palatable (>600ppm) water levels in some districts. In addition, the concentration of sulfate was relatively high in both tap and bottled water and ranged from 200 to 330 ppm. The bottled water quality was within the acceptable limits set by the World Health Organization, but the TDS levels were relatively high. The hardness, Cl^{-}, Pb^{+2}, and bacteria contents in both tap and bottled water were within the standard limits. Finally, it is important to conduct radiological analyses in the future to investigate the effect of wars on Iraqi water resources.

(AMEEN, 2019) collected 136 samples of bottled water randomly from different markets and supermarkets in Duhok city, Kurdistan region, Iraq, and were analyzed for their major physicochemical characteristics including calcium (Ca^{+2}),

magnesium (Mg^{+2}), sodium (Na^{+}), potassium (K^{+}), chloride (Cl^{-}), pH, total dissolved solids (TDS), turbidity and total hardness (TH). The data were analyzed statistically and compared to the labels and Iraqi standards (IQS: 417, 2001) and other international standards. The obtained results indicated that, except Ca^{+2} at brands (Evain, Kara and Kani) and K^{+} at brand (Kani), almost all the values obtained in the laboratory were lower than the maximum permissible limits set by Iraqi standards and other international standards for drinking water. Regarding the comparison between the laboratory and reported label values, there was a huge variation in most of the studied parameter values. It was observed that the majority of parameter values (about 86.7% on average) tested in the laboratory were higher than the label values and some (about 12.2%) were lower than label values, while only 1.1% had the same values as labels.

(Hamaamin and Abdullah, 2020) made up a monitoring of the quality of drinking water in Sulaimani City for 1 year. A total number of 78 water samples were collected and analyzed for 17 physical and chemical properties of the water supply system to the city. Samples of water are collected from the three main sources of drinking water for Sulaimani City (Sarchnar, Dukan line-1, and Dukan line-2) from February to August 2019. The results of the physical and chemical parameters of collected water samples were compared with the World Health Organization and Iraqi standards for drinking water quality. The results of this study showed that mostly all parameters were within the standards except the turbidity parameter which exceeded the allowable standards in some cases. This research concluded that, in general, the quality of drinking water at the three main sources of Sulaimani City is suitable and acceptable for drinking.

(Tahir, 2022) used the Water Quality Index (WQI) to evaluate the overall drinking water quality status in Erbil (at Ifraz two), Kurdistan Region of Iraq, by estimating the quality of the Greater Zab River (raw water) and the water treatment plant WTP

at Ifraz-2 on the Greater Zab River, a tributary of the Tigris River. Thirteen hysicochemical parameters, including turbidity, pH, electrical conductivity, total dissolved solids, total hardness, calcium, magnesium, alkalinity, chloride, sodium, potassium, nitrate, and sulfate, were evaluated between 2010 and 2021 using the WQI. The calculated WQI for the Greater Zab River's raw water quality ranged from (140.532) to (422.455) and the calculated WQI for WTP (Ifraz-2) ranged from (44.197) to (69.118). Accordingly, the results of Greater Zab River water were categorized as "very poor," "poor," and "unsuitable" for drinking purposes during the studied period (2010–2021). Furthermore, the results of the computed WQI for WTP of (Ifraz-2) are classified as "Excellent" and "Good". According to WQI, the WTP of Ifraz-2 from the current study was of good quality and suitable for consumption by humans. As a result, the efficiency (E%) of the Ifraz-2 WTP was found to be more efficient in 2016 (89.49%) than in other years and suitable for drinking.

(Al-Mayah, 2021) The study objectives were to show the suitability of drinking water produced from basic filtration projects and compare it with the Iraqi and international standard for drinking water in order to investigate potential contamination. Therefore, physical, chemical and biological tests of drinking water were conducted at the drinking water treatment in the city of Al- Aziziyah City, Wasit Governorate from October 2020 to September 2021.for year. The samples were measuring the values and concentrations of water indicators. Water temperature was between 1133°C, and the turbidity values ranged 3-75 NTU, while the electrical conductivity values were between 939-1316 µS/cm. The values of the dissolved solids were 600.96 - 842.24 mg/L. The pH values recorded 7.1 - 8.1 with varying values of residual free chlorine (0.3- 3.5) mg/L. The results showed that the concentrations of turbidity, free chlorine, total hardness, sulfates, and total numbers

of bacteria and E. Coli bacteria in this study did not match the standard specifications of Iraqi (ICS. 2001) and international standards (WHO, 2017).

(Sarkhell Araz Fadhl, 2023) The study aims to assess the physicochemical safety of the water supply in the main sources (water tank and tab water) of Sulaymaniyah city hospitals, as it directly impacts the health of patients. This study involved collecting and analyzing water samples from twelve major hospitals in the city of Sulaymaniyah, Iraq. The samples were collected from the main sources of water and analyzed twice to ensure accuracy of data. The physical and chemical parameters assessed included pH, TDS, EC, hardness, as well as the concentrations of calcium, magnesium, chloride, sodium, nitrate, and sulfate. The physicochemical parameters of water samples in hospitals were found to be within international standards, indicating that the chemical and physical quality of the produced water did not pose any health risks.

CHAPTER TWO

MATERIALS AND METHODS

2.1. Materials

The following are the equipment's and materials used during the laboratory work:

A pH meter is an instrument used to measure hydrogen ion activity in solutions - in other words, this instrument measures the acidity/alkalinity of a solution.

A TDS meter is a small hand-held device used to indicate the Total Dissolved Solids in a solution, usually water. Since dissolved ionized solids, such as salts and minerals, increase the conductivity of a solution, a TDS meter measures the conductivity of the solution and estimates the TDS from that reading.

Electrical conductivity (EC) is a measurement of water's ability to conduct electricity. EC is related to water temperature and the total concentration, mobility, valence, and relative concentration of ions.

Chemicals materials some of the chemicals materials were used during the lab, such as- buffer solutions of (pH=4, 7and9), and potassium chloride solution.

2.2. Methods

Some water sampling tests are for measuring the real physical properties of water quality including hydrogen ion concentration in solutions (pH), Total Dissolved Solids in a solution (TDS), and water's ability to conduct electricity (EC). All of these physical parameters that were examined using the standard methods described in Standard Methods for the Examination of Water.

2.2.1. Hydrogen ion concentration (pH):

It was measured directly in the field by Electrometric method using a portable pH-meter model (HANNA instrument, Portugal). The instrument was calibrated

before each sampling using buffer solutions of(pH=4, 7and9)as described by (Rice et al., 2012).

2.2.2. Electrical Conductivity (EC):

It was measured in the field using a portable conductivity meter model(HI 9811,HANNA instruments, 2000) calibrated with (0.01M) potassium chloride solution before each sampling, the results were expressed in $\mu S.cm^{-1}$ as described by (Rice et al., 2012).

2.2.3. Total Dissolved Solids (TDS):

Measured in the field using a portable T.D.S-meter model (HI9811, HANNA instruments, 2000), the results were expressed in mg l^{-1} (Rice et al., 2012).

CHAPTER THREE

RESULTS AND DISCUSSION

The data has been collected from various locations in Erbil City and the source of water supply is taken as Bottled, Filtered and Tap waters. The table mentioned below shows the location, source of the water sample and the values of each parameter which are considered for safe drinking purposes. The collected samples were analyzed for major physical water quality parameters like pH, electrical conductivity and total dissolved solid TDS.

3.1. Hydrogen ion concentrations-pH

Water pH is the negative logarithm of the activity of hydrogen ions (WHO, 2011), and its meaning reflects the strength of water's acid or alkaline state (Sawyer and McCarty, 1978). Generally speaking, the pH of water in Kurdistan region was distinguished by alkaline neutrality due to the geological formation of the region, which mainly consisted of $CaCO_3$ as stated by (Al-Naqishbandi, 2002, Ganjo, 1997) in Arbil province, (Maulood et al., 1978) in Sulaimani province, and (Al-Naqishbandi, 2002) in Duhok province.

From the (Table 3-1 and 3-2, and Figure 3-1), the hydrogen ion concentrations for all water samples were more than 7. The minimum pH value 7.01 was recorded in Lava bottled water during October 2023, and the maximum pH value 7.80 was measured at New Zanko Village groundwater. Whereas, during the second sampling in January 2024, the minimum pH value 7.07 was recorded at Naznaz filtered water and the maximum pH value 7.80 was measured at New Zanko Village groundwater. On the other hand, the percent % of reduction in filtered water samples never exceed 9% at all studied home water filteration equiepments. The maximum value of % of reduction corresponding the pH values was calculated at New Zanko Village of 8.50%, while the minimum value of 1.66% was calculated at kwestan quarter during

October 2023. In general, all studied types of home drinking water filteration systems in Erbil city showed low efficiency to reduce the pH values of studid water samples in both grounwater and surface water, i.e. we can conclude that home water filters not affect the change of water pH. In relation to the water potability and according to guideline of WHO (1996), and USEPA ground water and drinking water standards (2004), the water pH value should be between 6.5 and 8.5 for drinking purpose, thus, the pH levels of the studied water samples (Bottled water, Surface water, Groundwater and Filtered water) is in the acceptable condition as potable water.

Table 3-1: Physical properties of different water samples collected in Erbil city during Oct. 2023.

Sites	pH	% Reduction	EC µS cm^{-1}	% Reduction	TDS, mg/l	% Reduction
Manra,G.W	7.70	2.60	466.00	76.82	231.50	77.32
Manara,Filter	7.50		108.00		52.50	
Zanko,G.W	**7.80**	**8.59**	384.50	**86.74**	186.50	**86.86**
Zanko,Filter	7.13		**51.00**		**24.50**	
Andaza,G.W	7.65	1.96	404.00	83.42	195.00	83.08
Andaza, Filter	7.50		67.00		33.00	
Kwestan,S.W	7.22	**1.66**	439.50	**64.28**	213.00	**64.32**
Kwestan,Filter	7.10		157.00		76.00	
Naznaz,S.W	7.72	8.42	**481.50**	79.13	**232.50**	79.14
Naznaz,Filter	7.07		100.50		48.50	
Lava	**7.01**		165.50		80.50	
Hawler	7.32		178.50		86.50	
Sulav	7.44		186.00		90.00	
Sulaimani	7.29		199.50		96.50	
Tiyan	7.05		218.50		106.00	
Minimum	**7.01**	**1.66**	**51.00**	**64.28**	**24.50**	**64.32**
Maximum	**7.80**	**8.59**	**481.50**	**86.74**	**232.50**	**86.86**
WHO Guideline	**6.5-8.5**		**>500**		**>250**	

G.W= Groundwater**. S.W=** Surface Water**. Filter=** Filtered water from outlets of filteration equipments.

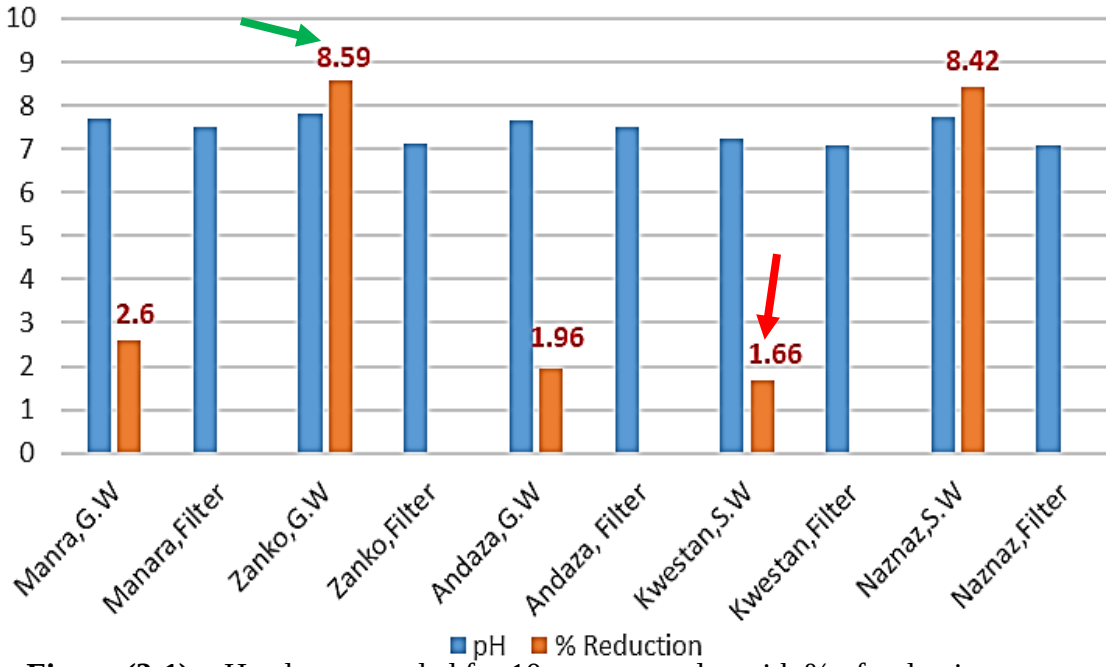

Figure (3-1): pH values recorded for 10 water samples with % of reduction.

Table 3-2: Physical properties of different water samples collected in Erbil city during Jan. 2024.

Sites	pH	% Reduction	EC µS cm^{-1}	% Reduction	TDS, mg/l	% Reduction
Manra,G.W	7.28	1.37	344.50	82.87	**202.50**	73.58
Manara,Filter	7.18		59.00		53.50	
Zanko,G.W	**7.80**	**8.33**	**384.50**	**88.43**	186.50	**88.20**
Zanko,Filter	7.15		**44.50**		**22.00**	
Andaza,G.W	7.20	**0.83**	341.00	**66.86**	166.00	**66.87**
Andaza, Filter	7.14		113.00		55.00	
Kwestan,S.W	7.22	1.11	358.50	82.57	174.00	82.76
Kwestan,Filter	7.14		62.50		30.00	
Naznaz,S.W	7.18	1.53	371.00	86.93	179.50	86.91
Naznaz,Filter	**7.07**		48.50		23.50	
Lava	7.50		181.00		90.00	
Hawler	7.60		186.00		93.00	
Sulav	7.60		182.00		91.00	
Sulaimani	7.30		160.00		80.00	
Tiyan	7.10		223.00		11.00	
Minimum	**7.07**	**0.83**	**44.50**	**66.86**	**22.00**	**66.87**
Maximum	**7.80**	**8.33**	**384.50**	**88.43**	**202.50**	**88.20**
WHO Guideline	**6.5-8.5**		**>500**		**>250**	

G.W= Groundwater**. S.W=** Surface Water**. Filter=** Filtered water from outlets of filteration equipments.

3.2. Electrical conductivity-EC:

Conductivity is a mathematical representation of an aqueous solution's ability to carry an electrical current. Such capacity relies on the existence of ions, their overall amounts, their flexibility and the measuring temperature (Rice et al., 2012). A wide range of differences between inlet and outlet water samples were observed during the first and second periods of sampling. From the (Table 3-1 and 3-2, and Figure 3-2), the minimum value of 51.00 $\mu S.cm^{-1}$ was recorded in outlet of filteration system at New Zanko Village during October 2023, while the maximum value of 481.50 $\mu S.cm^{-1}$ was observed in surface water at Naznaz quarter. On the other hand, it is worth to mention that during the second sampling period, the maximum and minimum EC values were observed at the same site in New Zanko Village which means that the home filteration system is the best between the studied systems. Generally the EC values in studied bottled waters were ranged between 160 to 223 $\mu S.cm^{-1}$ recorded for brands Sulaimani and Tiyan respectively. While I the EC values were ranged from 44 to 113 $\mu S.cm^{-1}$ in filtered waters recorded in Zanko and Andaza home filteration systems respectively. Finally, all types of home water filters showed high performance in EC percent reduction and renged from 64.28% to 88.43%. The maximum acceptable level of conductivity as indicated by USEPA (2018) is 1000 $\mu S.cm^{-1}$. Because all studied samples containing low levels of conductivity and never exceeded 1000 $\mu S.cm^{-1}$, therefore they were suitable for drinking.

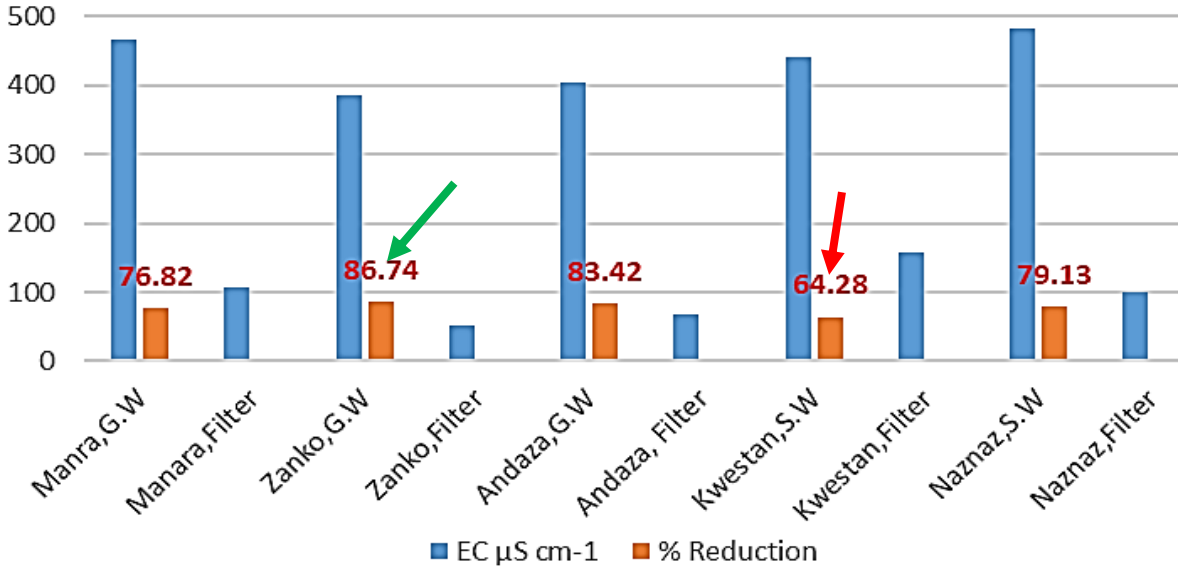

Figure (3-2): EC values recorded for 10 water samples with % of reduction.

3.3. Total dissolved solids-TDS

Total dissolved solids are a measurement of all chemical components dissolved in water, often affected by main ion concentrations; calcium, bicarbonate, magnesium, sulfate and chloride, it is also an important indicator for the assessment of groundwater residence time in the aquifer (Starks and Champion, 2001). The TDS of water is intimately linked to conductivity, where high levels of TDS are commonly associated with high levels of conductivity (Gómez and Licursi, 2001), as revealed in this study, maximum TDS levels recorded when the conductivity is in the peak concentrations. From the (Table 3-1 and 3-2, and Figure 3-3), the peak levels of TDS 232.50 $mg.l^{-1}$ was recorded in surface water at Naznaz quarter October 2023, while the minimum value of 22 mg l^{-1} was measured in groundwater at New Zako Village home filteration system during January 2024. The TDS removal efficiency ranged between 64.32% to 88.20% in the same manner as showed in EC. The maximum acceptable concentration of TDS in drinking water according to the mentioned guidelines is 500 mgl^{-1}, thus, all sites were considered as potable water.

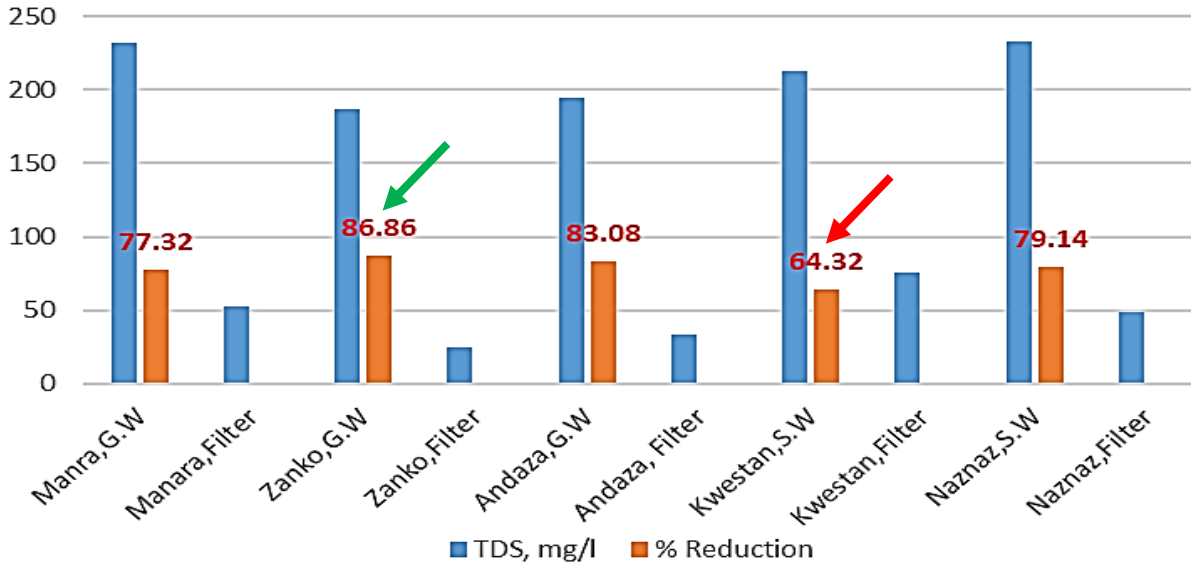

Figure (3-3): TDS values recorded for 10 water samples with % of reduction.

Figure (3-4) Shows the comparison of percent % reduction between pH, EC and TDS. It is obvious that the filtration of water not affected the pH values between inlet and outlet of home filtration system in all studied sites. On the other hand, the filtration systems showed high percent of reduction in relation to EC and TDS values and exceeded 80% in some cases.

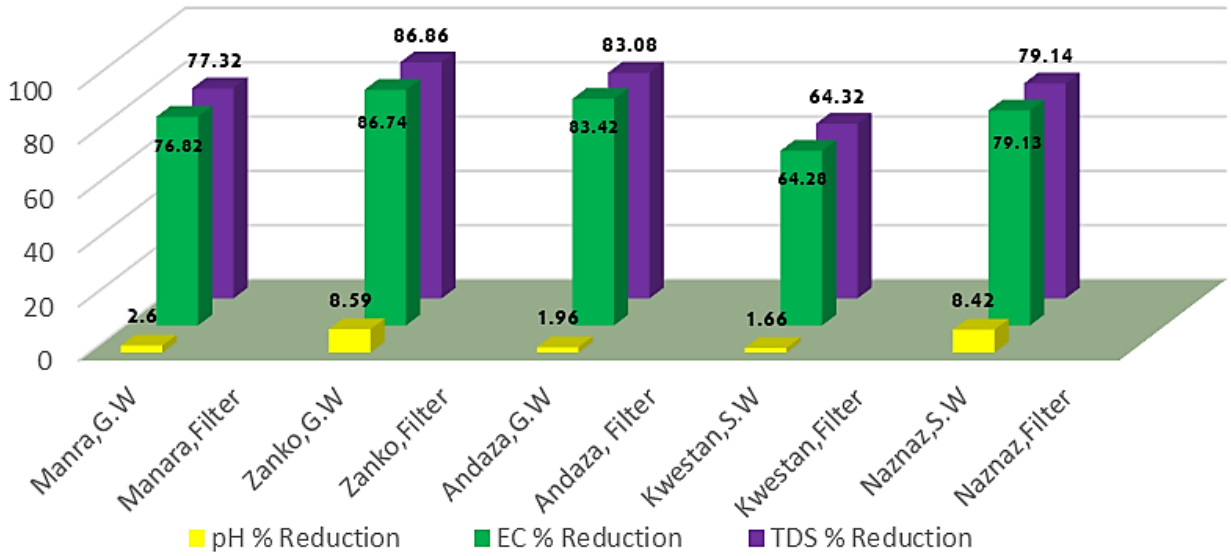

Figure (3-4): Comparison values of pH, EC and TDS calculated with % of reduction.

CHAPTER FOUR

CONCLUSION AND FUTURE WORK

4.1. Conclusions

During the studied period the following conclusions were noted:

1. Home water filters available in Erbil city are performing high percent of Reduction in improvement of EC and TDS.

2. The filters are poorly performing the percent of Reduction in improvement of pH.

3. Some water filters were performing zero or even negative percent of Reduction for Turbidity, Chloride, Nitrite, Nitrate and phosphate.

4. All physical tests for drinking water were in accordance with the Iraqi and international standards.

4.2. Future work

For future research, the following directions have been suggested:

Further analyses are required for heavy metal levels and turbidity studies.

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