Optical Properties Characterization of Drinking Water Using Inductively Coupled Plasma Emission Spectroscopy Techniques in Khartoum State, Sudan

By:

Mohammed Awadh Saeed Salem Al-Ameri

A Thesis Submitted to the College of Graduate Studies in Fulfillment of Requirements for the Degree "Doctorate Philosophy"

in

Physics

Department of Physics

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الآيــــــة

بسم الله الرحمن الرحيم

قال الله تعالى:

أَوَلَمْ يَرَ الَّذِينَ كَفَرُوا أَنَّ السَّمَوَاتِ وَالْأَرْضَ كَانَتَا رَتْقًا فَفَتَقْنَاهُمَا وَجَعَلْنَا مِنَ الْمَاءِ كُلَّ شَيْءٍ حَيٍّ أَفَلَا يُؤْمِنُونَ ﴿٣٠﴾

صدق الله العظيم

سورة الأنبياء الآية (30)

Dedication

I dedicate this research to:

My mother and father, who are the sources of happiness in my life.

My wife and my children, who are the secret of my success and achievement in the study.

My brothers and sisters.

My major Supervisor Prof. Sawsan Ahmed Elhouri Ahmed, who is who helped me and gave me support to complete this work.

My classmates, **all my teachers** from primary school to graduate college, and my best teachers **Dr. AbdEllateef Abbas, Mr. AbdelSakhi, Mr. Mohammed Ahmed Adlan**, and **Mr**. **Hassan Ahmed**, helped me to prepare my thesis of Ph.D.

Mohammed Al-Ameri

   February-2022

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I would also take this opportunity to express my gratitude and my thanks to anyone for his help me and support me. I would also take these thanks to the staff of **Regional Forensic Laboratories** in Khartoum state and the staff of **Laser Institute in Sudan University for Science& Technology** for their help for me, inspiration, and moral support. I take this opportunity to express my profound sense of gratitude and respect to **my colleagues**, and all those who helped me through the duration of this project work.

Mohammed Al-Ameri

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Abstract

In this work, Inductively Coupled Plasma Emission Spectroscopy (ICPE) has been used to detect, and calculate the concentrations, of toxic and radioactive elements at the selected samples for drinking water in Khartoum State, Sudan before and after exposure to sunlight and storage period. Also, the Ultraviolet-Visible Spectroscopy (UV-Visible) technique has been utilized to study the optical properties of samples before expose them to sunlight and storage period. Ten samples for drinking water have been collected from ten various sources that were included rivers and wells in Khartoum state, Sudan at the end of the fall season in 2019.

ICPE results before and after exposure samples to the sunlight and storage period showed that many atoms such as (Cu, Fe, Na, S, Ba, Sb, Al, B, Mn, Zn, Pb, Ca, Mg, K, Rb, Si, Li, Sr, Er, Ho, Sc, Pt, V, Se, Lu, Eu, Ir, Hg, Ni, and Yb) were detected with different concentrations which were at range within background values except for (Tl, Th, Ti, Al, Bi, W, and Ta). After exposing samples to sunlight and storage period, some new atoms appeared, and some of them disappeared, and the concentrations of some atoms also increased and decreased automatically during this experiment. These results may be related to the locations of samples, vital activities, the interaction between water and plastic bottles, and the migration of some atoms during these interactions.

UV-Visible results displayed that all optical properties for the collected samples can be described as functions for wavelength and the optical band energy. The results confirmed that the absorption values were found at (57%, 40%, 25%, 20%, 12%, 12%, 28%, 14%, 4%, and 11%) respectively. Also, this study proved that the optical absorption coefficients were exhibited at (1.3, 0.5, 0.38, 0.27, 0.23, 0.23, 0.19, 0.11, 0.19, and $0.24 cm^{-1}$) sequently. In addition, this technique displayed that the transmittance values were observed at (4.8%, 32%, 46 %, 53 %, 70 %, 71 %, 42 %, 67 %, 85 %, and 66 %) consecutively. Furthermore, this experiment was evidenced that the extinction coefficients were happened at (79, 23, 13, 16, 7, 10, 20, 12, 6, and 15) successively. These results may return to amounts for impurities like silica and mud in

samples and the density for the toxic and radioactive elements in the collected samples on the molecular weights of them in samples.

الخلاصة

في هذا البحث، لقد استخدم تقنية مطيافية انبعاث البلازما المقترنة حثيا للكشف عن العناصر السامة والمشعة، وكذلك حساب تراكيزهم في عينات مياه الشرب بولاية الخرطوم بالسودان قبل وبعد تعريضهم لأشعة الشمس وفترة التخزين. أيضا تقنية الطيف الضوئي للأشعة فوق البنفسجية تم استخدامها لدراسة الخصائص البصرية لهذه العينات قبل التعرض لأشعة الشمس وفترة التخزين. عشر عينات لمياه الشرب تم اختيارها من عشرة مصادر مختلفة تتضمن الأنهار والآبار في ولاية الخرطوم بالسودان أواخر فصل الخريف 2019م.

أظهرت نتائج التحليل بواسطة تقنية مطيافية انبعاث البلازما المقترنة حثيا قبل وبعد تعريض العينات لأشعة الشمس وفترة التخزين الى ظهور عدد من الذرات المختلفة مثل (النحاس، الحديد، الصوديوم، الكبريت، الباريوم، الأنتيمون، الألمنيوم، البورون ، المنجنيز، الزنك، الرصاص ، الكالسيوم، اليود، البوتاسيوم، المغنيسيوم، الريبيديوم ، السيلكون ، الليثيوم ،الاسترنشيوم، الاربييوم، الهومليوم، السكانديوم البلاتينيوم، الفانديوم ، السلينيوم، الاربيبوم، الليثيوم ،الاريديوم ،الزئبق، النيكل ،واليتريوم) بمقادير مختلفة والتي كانت في مدى ضمن القيم المرجعية باستثناء(الثليوم ،التيتانيوم ،الزرنيخ، البزيموث، ، التنجستن، الألمنيوم ،والثوريوم). بعد تعريض العينات لأشعة الشمس وفترة التخزين، بعض الذرات الجديدة ظهرت والبعض الآخر اختفت، وتراكيز بعض الذرات زادت والأخرى نقصت خلال هذه التجربة. هذه النتائج ترجع الى مواقع العينات، الأنشطة الحيوية القريبة من هذه المواضع، التفاعل الذي يحدث بين الماء والقوارير البلاستيكية، وهجرة بعض هذه الذرات خلال هذا التفاعل.

أظهرت نتائج التحليل بواسطة تقنية الطيف الضوئي للأشعة فوق البنفسجية أن جميع الخصائص البصرية لهذه العينات المختارة يمكن وصفها كدوال بالنسبة للطول الموجي وطاقة فجوة النطاق البصرية. اكدت الدراسة أن العينات المختارة كانت لها قيم امتصاصية عند (57%، 40%، 25%، 20%، 12% ،12%، 24%، 14%، 4%، و11%) على التوالي. أيضا، أثبتت النتائج أن معاملات الامتصاص البصرية للعينات ظهرت عند القيم (1.3،0.5، 0.38،0.27 ،0.23 ،0.23 ، 0.19 ، 0.11 ، 0.19،0.24 cm^{-1})على التوالي. بالإضافة الى ذلك، أوضحت نتائج التحليل بواسطة هذه التقنية للعينات أن النفاذية تمت ملاحظتها عند القيم (4.8%، 32%، 46%، 53%، 70%، 71%، 42%، 67%، 85%، و66%) على التوالي. كذلك أيضا، معمل التخمين للعينات حدثت عند القيم (79، 23، 13، 16، 7، 10، 20، 12، 6، و15) على التوالي لكل العينات. يرجع الاختلاف في قيم الخصائص البصرية في هذه العينات الى كميات الشوائب مثل السليكا والطين المتواجدة في مصادر مياه الشرب المختلفة بولاية الخرطوم بالسودان. ويمكن أن تعود هذه النتائج أيضا الى اختلاف كثافة العناصر السامة، العناصر الأرضية، والعناصر المشعة الموجودة في العينات وكذلك لأوزانهم الجزيئية في العينات المختارة.

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List of Abbreviations	
Symbol	**Symbol Item**
SI	International System of Units
$1S^1, 2S^2P^6$	Elliptical Orbitals
ICPE	Inductively Coupled Plasma Emission Spectroscopy
UV-Visible	Ultraviolet-Visible Spectroscopy
H_2O	Water Molecule
O-H	Hydrogen-Oxygen Bond
δ^-	Negative Charge
δ^+	Positive Charge
H-O-H	Molecule of a Water Bond
A°	Angstrom (10^{-10}m)
R	Radius
α	Angel
d, D	Dipole Moment
Xxx, Yyy, Zzz	Coordinates
β	Polarizability
I_w	Ionization Potential
K	Force Constant
N/m	Newton/Meter
KJ	Kilojoule (10^3J)
eV	Electron Volt (1.6x 10^{-10}J)
Mol	Mole (Material Quantity)
KT	Thermal Energy
K	Kelvin ($27315^\circ C$)
μ_p	Magnetic Moment of a Proton
μ_e	Magnetic Moment of an Electron
β_p	Magnetic Induction Created by Proton
β_e	Magnetic Induction Created by Electron
σ	Surface Tension
θ	Angle
ρ, d	Density
G	Gravity
H	Rise the Head of Liquid
γ	Surface Tension Coefficient
$^\circ C$	Celsius
π	Bie (Constance =3.14)

η	Viscosity
V	Volume
T	Time
l	Length Capillary
Pa	Pascal
S	Second
β	Coefficient of Compressibility
P	Pressure
ΔP	Change in Pressure
ΔV	Change in Volume
$\Delta \rho$	Change in Density
T, θ	Temperature
Lim	Limit
F	Force
A	Area
m^2	Square Meters
Hg	Mercury Millimeters
EC	Electric Conductivity
$mS, \mu S$	Milli Seimens, Micro Seimens (units of electrical conductivity)
Cm	Centimeter (10^{-2}m)
DC	Direct Current
AC	Alternating Current
Hz	Hertz
(W.m)	(Ohm. Meter)
σ	Resistivity
p	Conductivity
μ_1, μ_2, μ_3	Vibrations Quantum Numbers
E_e	Electrical Energy
E_v	Vibrational Energy
Er	Rotational Energy
E	Total Energy
λ	Wavelength
nm	Nanometer (10^{-9}m)
IR	Near-Infrared Spectral
C	Specific Heat
E_g	Optical Band Gap Energy
P_{abs}	Absorbed Power Inside Region

$h\nu$	Photon Energy
α, τ, a	Absorption Coefficients
M,m	Mass
x	Thickness
l	Scattering Intensity
$I_\circ$	Incident Intensity
$F_\circ$	Irradiance
$(T_w(\lambda_w))$	Transmittance of Liquid Water
$F_w(\lambda)$	Shape of Liquid Water
$T_w(\lambda)$	Transmittance of Filters in Corresponding Channels
Cm	Heat Capacity of Water
ΔT	Change in Temperature
Q	Quantity of Heat
dQ	Change in Quantity of Heat
f	Surface Area
Cal	Calories
pH	Hydro Genic Number
Log	Logarithm
H	Hydrogen Atom
OH	Hydrogen in Concentration
Km^2	Square Kilometers $(10^3 m)^2$
Kg	Kilogram $(10^3 gm)$
Km	Kilometer $(10^3 m)$
Ca, Ca^{++}, Ca^{+2}	Calcium Atoms and Ions
Mg^{++}, Mg^{2+}	Magnesium Atoms and Ions
Na, Na^+, Na^{++}	Sodium Atoms and Ions
$HCO3^-$	Bicarbonate
SO4, $SO4^-$, $SO4^{-2}$	Sulfate
Cl, Cl^-	Chlorines Atoms and Ions
Mg	Milligram $(10^{-3} kg)$
SiO_2	Silicon Dioxide
K, K^+	Potassium Atoms and Ions
Sr	Strontium Atom
Br	Bromine Atom
NaCl	Sodium Chloride
KCl	Potassium Chloride
$CaCl_2$	Calcium Chloride

$Fe, Fe^{+1}, Fe^{2+}, Fe^{3+}$	Iron Atoms and Ions
Al, Al^{3+}	Aluminum Atoms and Ions
$CO3^{2-}$	Carbon Trioxide
SiO_3^{-2}	Silicon Trioxide
NO^{2-}, NO^{3-}	Nitric Oxide.
HO^{3-}	Hydroxide
NH^{4+}	Nitrate
B	Boron Atom
F, F^-	Fluorine Atoms and Ions
L	Liter ($10^{-3}m^3$)
Hg	Mercury Atom
Be	Beryllium Atom
Te	Tellurium Atom
Cd	Cadmium Atom
Se	Selenium Atom
Pb	Lead Atom
V	Vanadium Atom
As, As^{+1}	Arsenic Atoms and Ions
Cr	Chromium Atoms
CN^-	Cyanides
Cu	Copper Atom
Ni, Ni^+	Nickel Atoms and Ions
La	Lanthanum Atom
Se	Selenium Atom
Pr	Praseodymium Atom
Nd	Neodymium Atom
Pm	Promethium Atom
Eu	Europium Atom
Gd	Gadolinium Atom
Sm	Samarium Atom
Tb	Terbium Atom
Dy	Dysprosium Atom
Ho	Holmium Atom
Er	Erbium Atom
Tm	Thulium Atom
Yb	Ytterbium Atom
Lu	Lutetium Atom
Sc	Scandium Atom

Y	Yttrium Atom
Zn	Zinc Atom
Li, Li$^+$	Lithium Atoms and Ions
Co	Cobalt Atom
Sn	Tin Atom
Ti	Titanium Atom
Ag	Silver Atom
U	Uranium Atom
ppt	Parts-Per-Thousand
ppm	Parts-Per-Million
USEPA	United States Environmental Protection Agency
WHO	World Health Organization
EUC	European Union Commission
PE	Polyethylene
$CH_2 = CH_2$	Ethylene
ICI	Imperial Chemical Industries
PET	Polyethylene Terephthalate
EM	Electromagnetic Radiation
C	Light speed in Space
H	Plank's Constant
J	Joule
NMR	Nuclear Magnetic Resonance
ESR	Electron Spin Resonance
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence
PLXE	Proton/Particle-Induced X-Ray Emission
PIGE	Proton/Particle-Induced Gamma-Ray Emission
EDX	Energy –Dispersive X-Ray Spectroscopy
WD	Wavelength-Dispersive
ED	Energy-Dispersive
FTIR	Fourier-Transform Infrared
LIBS	Laser-Induced Breakdown Spectroscopy
ICP/MS	Inductively Coupled Plasma /Mass Spectroscopy
σ	Bonding Molecular
π	Bonding Molecular Orbital
N	(Non-Bonding) Atomic Orbital
σ^*	(Signal star) Orbital

π^*	(Pi star) Orbital
A	Absorbance
$I_\circ$	Intensity of Incident Light
l	Transmitted Intensity
L	Path Length Through the Sample
C	Concentration of Absorbing Species
ε	Absorbing Molar
He-Ne	Helium-Neon Laser
Ru	Ruthenium Atom
Zr, Zr^{+1}	Zirconium Atoms and Ions
Tb	Terbium Atom
Xe	Xenon Atom
He	Helium Atom
Ne	Neon Atom
Cs, Cs^{+1}, Cs^{+2}	Cesium Atoms and Ions
Cr, Cr^{+1}	Chromium Atoms and Ions
Tl, Tl^{+1}, Tl^{-1}	Thallium Atoms and Ions
Th, Th^{+1}, Th^{+2}	Thorium Atoms and Ions
WN	White Nationalist
AAS	Atomic Absorption Spectroscopy
SSMO	Sudanese Standards and Metrology Organization
NDWQS	National Drinking Water Quality Standard
USA	United States America
$PO4^{2-}$	Phosphate
EPA	Environmental Protection Agency
Mn	Manganese atom
N	Refractive Index
GPa	Giga Pascal (10^9Pa)
IBWA	International Bottled Water Association
ppb	Parts Per Billion (unit of concentration)
ICP-AES	Inductively Coupled Plasma Atomic Emission Spectroscopy
Mg/kg	Milligrams/Kilograms
NIAS	Non-Internationally Added Substance
Ba	Barium Atom
SEM/ EDX	Scanning Electron Microscope/ Energy –Dispersive X-Ray Spectroscopy
HNO_3	Nitric Acid
Rb	Rubidium Atom

S	Sulfur Atom
Si	Silicon Atom
Ho	Holmium Atom
Bi	Bismuth Atom
Pt	Platinum Atom
W	Tungsten Atom
Ta	Tantalum Atom
Yb	Ytterbium Atom
Ir	Iridium Atom
(ICP–OES)	Inductively Coupled Plasma - Optical Emission Spectrometry

CHAPTER ONE

Introduction

1.1. The Importance of Water in Human Life:

Three-quarters of Earth's surface is covered by water. Although most of this water is in liquid form, water is also present on Earth as a solid (ice), and a gas (water vapor). Water is the only common substance to exist in the natural environment in all three physical states of matter [1]. Water plays many important roles in our bodies. It is the major part of most of the body's cells (except for fat cells) because it transports nutrients and carries waste away from the body cells. It also helps to regulate body temperature by redistributing heat from active tissues to the skin and cooling the body through perspiration [2,3]. Water is the main constituent of the human body. It is normally about (60%) of body weight in adult males, and is slightly lower, about (50-55%), in females due to their higher proportion of body fat. The muscles and the brain are about (75%) water, the blood and the kidneys are about (81%), the liver is about 71%, the bones are about (22%) and adipose tissue is about (20%). The body requires sufficient water to survive and function properly. Humans cannot live without drinking water for more than a few days depending on weather, activity levels, and other factors whereas other nutrients may be neglected for weeks or months [4,5].

1.2. Khartoum State, Sudan:

Khartoum state is one of the eighteen states of Sudan. Although it is the smallest state by area (22,142 km^2), it is the most populous (5,274,321 in the 2008 census). It contains the country's second-largest city by population, Um Durman, and the city of Khartoum which is the capital of the state as well as the national capital of Sudan. The capital city contains offices of the state, governmental and non-governmental organizations, cultural institutions, and the main airport [6,7].

The city is located in the heart of Sudan at the confluence of the White Nile and the Blue Nile, where two rivers unite to form the River Nile. The state lies between

longitudes (31.5 to 34 °E) and latitudes (15 to 16 °N). It is surrounded by the River Nile State in the north-east, in the north-west by the Northern State, in the east and south-east by the states of Kassala, Qadarif, Gezira, and White Nile State, and in the west by North Kurdufan. Khartoum state consists of seven localities, Khartoum (Capital), Sharq El Nile, Bahri (Khartoum North), Um Badah, Um Durman, Jebal Aulya, and Karari [4, 5]. Also, it has three rivers (Nile Blue River, Nile White River, and Main Nile River) as shown on the map in figure (1.1) that was designed by geologist Ahmed Adlan on 12/2/20019.
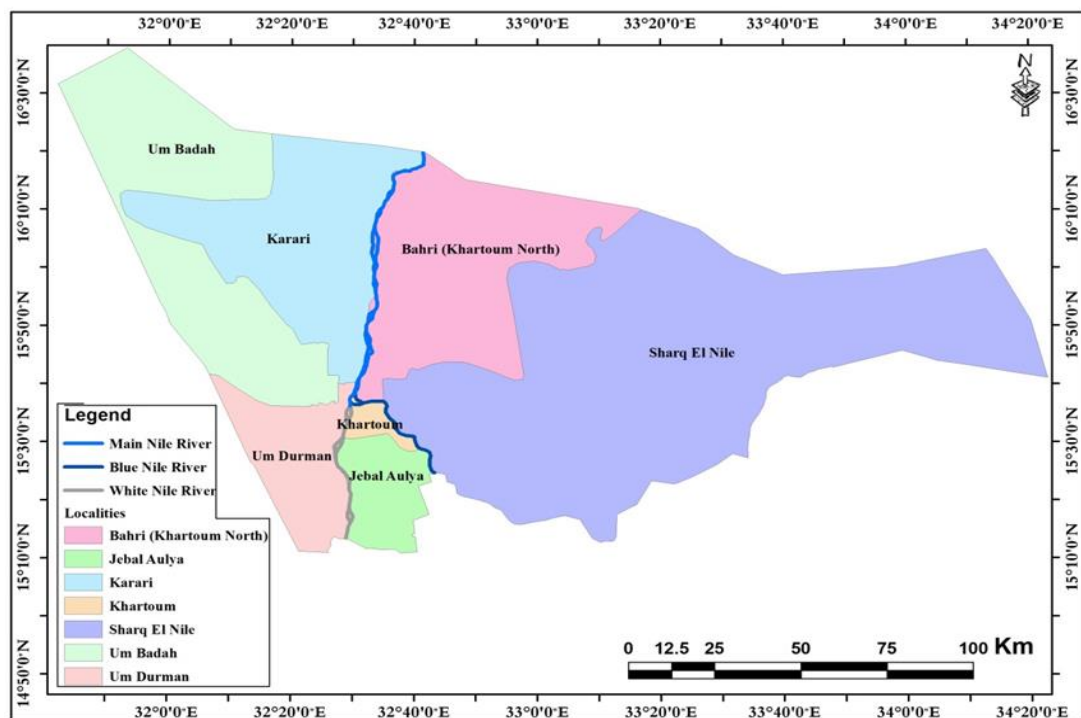
Figure (1.1) Khartoum State Map

2

1.3. Research Problem:

There is an increase of using Sudanese for Nile rivers water and Wells as the main source for drinking in Khartoum state, Sudan. Also, there is a lack of awareness and an absence of clear information about the health effects of toxic, and radioactive metals in drinking water. This study might give us more information about the amount of these elements in the collected samples before and after exposing them to sunlight and the storage period in the plastic bottles. Furthermore, this work will show the relationship between the concentrations of these elements and the optical properties of the collected samples from different locations in Khartoum State, Sudan.

1.4. Aims of the Work:

The aims of the research were summarized as follows:

❖ The first aim of the present work is to detect toxic and radioactive elements in the selected samples and calculate the concentration of these metals via the ICPE technique before and after exposing them to sunlight and the storage period.

❖ The second aim is to compare ICPE results before and after exposure samples to sunlight and the storage period.

❖ The third aim of this project is to study the optical properties of these samples via UV-Visible spectroscopy just before expose them to sunlight and storage period.

1.5. Presentation of the Thesis:

This research contains five chapters. Chapter one presents an introduction, which includes the importance life of drinking water, and information about Khartoum state, Sudan. The second chapter illustrates the theoretical background of the research topic. The third chapter displays a general literature review. The experimental work, the obtained results, and its discussion will be shown in chapter four in detail. Chapter five presents the conclusion, recommendation, references, and appendixes.

CHAPTER TWO

Theoretical Background

2.1. Introduction:

This chapter discussed the theoretical background of a water molecule (H_2O) like the structure of water, the physical and chemical properties of the water molecule, and the various water sources. Also, this chapter explained the most popular spectroscopy techniques that can use to characterize the selected samples for drinking water from different locations in Khartoum state, Sudan as shown below:

2.2. Structure of Water Molecule:

The water molecules have a simple structure consisting of two hydrogen atoms bonded to one oxygen atom at the chemical formula H_2O was established by Lavoisier and Cavendish in the eighteenth century [8]. The ratio of oxygen to hydrogen in water atoms amount to 1:2 shown in figure (2.1) [9].
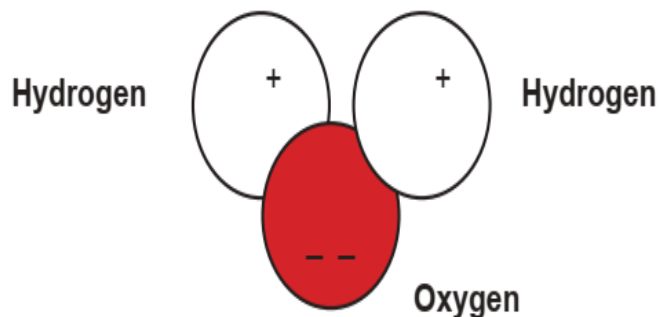
Figure (2.1) Structure of Water Molecule [9]

On the other hand, the bond between each hydrogen atom and the oxygen atom results from a pair of electrons shared between the two atoms. In water, the electrons are not shared equally between the hydrogen and oxygen atoms. The oxygen atom has

a greater affinity for electrons than does the hydrogen atom and the electrons in the hydrogen-oxygen bond (O–H) is more attracted to oxygen. Because electrons have a negative charge, the unequal sharing in the (O–H) bond results in oxygen acquiring a partial negative charge (δ−) and hydrogen a partial positive charge (δ+). The molecule of water bond (H–O–H) angle in water is 104.5°, which means that the molecule has a triangle shape as shown in fig (2.2) [10].
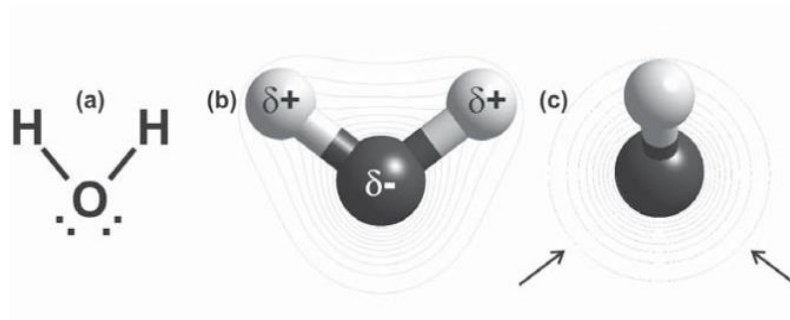
Figure (2.2) O-H-O Bond in Water Molecule [10]

2. 3. Characteristic Parameters of H$_2$O:

The H$_2$O molecule is possible to exist in free cases, and it has a three-nucleus formation. Two electrons $1S^1$ are localized near the oxygen atom, and the other eight electrons $2S^2P^6$ move along the lengthened elliptical orbitals [11]. On the other hand, this molecule has a molecular diameter of about, $2.75A°$, and the water molecule vibrates in several ways. Also, the structure of water molecules is inhomogeneous with a three-dimensional network containing hydrogen-bonded molecules whose average lifetime is nearly a few picoseconds, and it changes neighbors continuously [12]. The water molecule can be characterized by some physical parameters as displayed in table (2.1) below [11]:

Table (2.1) Main Parameters of Water Molecules[11]

Parameters	Values
Length of (O-H) bond	r = 0.96 X10^{-10} m
Angle H-O-H	$\alpha = 104.523 A°$
Dipole moment	d=1.84+0.02D(6.13xl0^{-3}Cm)
Ionization potential	$I_w = 20.11x10^{-19}J(12.56eV)$
Force constant in direction of O-H bond	$K = 8.256x10^2\ N/m$
Energy of water formation, at 0 K	-918.333 kJ/mol (9.511 eV)
Energy of O-H bond, at 0 K	-459.205 kJ/mol (4.40 eV)
The energy of dissociation H-OH bond, at 0 K	-493.205 kJ/mol (5.11 eV)
The lowest energy of vibration	0.198 eV
The lowest energy of rotation	0.005 eV
Thermal energy kT, at T=293 K	2.52xl 0^{-2} eV
The magnetic moment of a proton	$\mu_p = 1.411x10^{-26}Am^2$
The magnetic moment of an electron	$\mu_e = 9.285x10^{-24}Am^2$

A water molecule can exist in three different forms (liquid, solid, and gas), and these forms of water molecules depend on the temperature [13,14].

2.4. Physical Properties of Water:

Water molecules have attractive physical properties such as mechanical, electrical, optical, and thermal properties as were discussed in the next part of this chapter as described below:

2.4.1. Mechanical Properties of H₂O:

The H₂O molecule can characterize by some mechanical properties, which describe the motion of water molecules and the interaction between them as were shown in the following [15]:

2.4.1. a. Surface Tension:

Surface tension is a force that acts on the surface and operates perpendicular and inward from the boundaries of the surface, tending to decrease the area of the interface. Also, there are two features of surface tension the contact angle (θ), and the magnitude of the surface tension (σ) that can be measured by (N/m) as shown in figure (2.3) as cleared below [16].

(a) A "wetted" surface   (b) A nonwetted surface
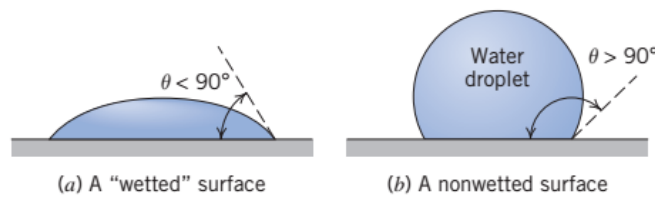
Figure (2.3) Surface Tension Effects on Water [16]

There are two effects of surface tension wetted when $\left(\theta \prec 90^{\circ} \right)$ and nonwetted when $\left(\theta \succ 90^{\circ} \right)$, and all of them depend on the contact angle of the surface[16]. On the other hand, the coefficient surface tension can be calculated by the following equation:

$$\gamma = r\rho gh/2$$ .... (2.1)

Where (r) is the radius, (ρ) is the density of the liquid, (g) is the gravity, (h) is the rise of the liquid, and (γ) is the surface tension coefficient as shown in fig (2.4) at the following [17].
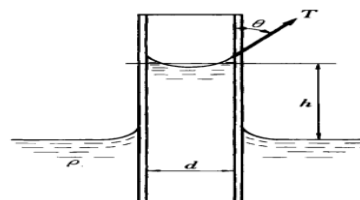
Figure (2.4) Surface Tension of Water[17]

The surface tension of water when it is air surface is (0.0728 N /m) in $20C^{\circ}$, and it depends on the temperature [18].

2.4.1. b. Viscosity:

The viscosity is a property that represents the internal resistance of a fluid to motion. The liquid flows steadily and without eddies or turbulent motion, and that there is no kinetic energy of efflux, the viscosity is given by:

$$\eta = \frac{\pi}{8}\left[\frac{hgr^4}{l \times \upsilon}.d.t\right] \text{.........................} (2.2)$$

Where (η) is the viscosity, (h) is the head of liquid, (g) is the gravity constant, (r) is the radius of the capillary, (d) is the density of the liquid, (t) is the time of flow, (l) is the length of the capillary, and (υ) is the volume of the liquid which has transpired in the time. The viscosity of water is 10^{-3} (Pa .s) at room temperature[19].

2.4.1. c. Compressibility:

A common way to describe the compressibility of fluid is by the following equation:

$$B = \lim_{\Delta V \to 0} = \left[-\frac{\Delta p}{\Delta V/V}\right] = \lim_{\Delta \rho \to 0} \frac{\Delta p}{\Delta \rho/\rho}\Big|_{T} = -V\frac{\partial p}{\partial V}\Big|_{T} = \rho\frac{\partial p}{\partial \rho}\Big|_{T} \text{........................} (2.3)$$

Where (B) is called the coefficient of compressibility that defined as the ratio of the change in pressure (p) to a relative change in density (ρ) while the temperature remains constant. The coefficient of compressibility (B) has the same units as pressure [20].

2.4.1. d. Pressure:

Pressure is defined as the total force applied normally (perpendicular) to a unit surface area. Pressure is given by:

Pressure = Total force /Area ………………………......…………....…….... (2.4)

Or

P = F /A …………………………….……………….……………….. (2.5)

Consider a force (F) applied on area (A) as shown in fig (2.5) where force is a vector. It has a magnitude and a direction of action. The area is a scalar as only a magnitude is needed to define it sufficiently. It should be noted that pressure is a scalar. Pressure has the units N/m that is called a Pascal (P). The other most widely used unit is mercury millimeters (Hg mm) [21].
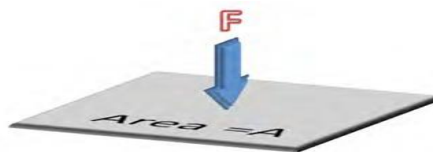
Figure (2.5) Definition of Pressure[21]

Density depends on the mass of an individual molecule and the number of such molecules that occupy a unit of volume. For liquids, density depends primarily on the particular liquid and its temperature. However, the density (ρ) of a fluid is defined as mass per unit volume as shown in the following equation:

$$P = \text{mass /volume} = m/V = M/L^3 \quad\text{... (2.6)}$$

Where (*m*) is the mass of fluid, (V) is the volume of fluid, and the density of water at 20° C is (998 Kg/m³) [22].

2.4.1. e. Capillary Action:

Capillary action is defined in the dictionary of science as the general term for phenomena observed in liquids due to unbalanced inter-molecular attraction at the liquid boundary, for example, the rise or depression of liquid in narrow tubes as displayed in the figure (2.6) [23]**.**
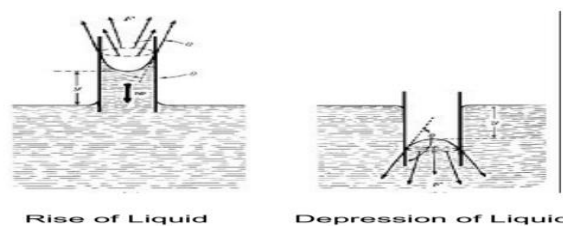
Figure (2.6) Capillary Action [23]

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2.4.2. Electrical Properties of Water:

Water is a terrible conductor of electricity. Pure water is a good insulator. When water contains many dissolved ions, those ions make a good conductor, so these molecules have good electrical properties such as conductivity, resistance, resistivity, and the dielectric constant as were explained as given below:

2.4.2. a. Electrical Conductivity:

Electrical conductivity (EC) is the material to conduct electrical current through it. (EC) is measured in units called Seimens per unit area (mS/cm, or milli Siemens per centimeter [24].

Generally, water molecules are in continuous motion, even at low temperatures and when two water molecules collide, a hydrogen ion is transferred from one molecule to the other. The other molecule that losses the hydrogen ion becomes a negatively charged hydroxide ion. The molecule that gains the hydrogen ion becomes a positively charged hydrogen ion and this process is commonly called self-ionization. The current flow is in the range of conductivity of 0.05 μS/cm at room temperature [25,26].

2.4.2. b. Electrical Resistivity:

The electrical resistivity of water is a number describing how much that water resists the flow of electricity. Resistivity is measured in units of ohm· meters (W. m). If electricity can flow easily through a material, that water has low resistivity. If electricity has great difficulty flowing through water, that water has high resistivity. Electrical resistivity can be represented by the following equation:

$$\sigma = \frac{1}{p}$$ ………...…………………………………………………………… (2.7)

Where (p) is conductivity, (σ) is resistivity [27].

2.4.2. c. Dielectric Constant:

The dielectric behavior of water is found to arise from its local density and molecular Polarisability in response to an external field and can be rationalized in terms of the number and strength of water−surface and water−water H-bonds. The interplay of local density and Polarisability leads to a particularly strong dielectric response, exceeding the external field, of the water layer directly contacting the surfaces, while the second layer exhibits a reduced response [28].

2.4.3. Optical Properties of H_2O:

In general, when a beam of light (the incident beam) hits the interface between two transparent materials, such as air and water, part of the beam is reflected and part of it continues through the interface and on into the other material. The light beam is bent, or refracted, as it passes from one material into the next. So, the water molecule has attractive optical properties like absorption, emission, refraction, Transmittance, and scattering as explained below:

2.4.3. a. Absorption and Emission:

We describe the vibrational energy states of the water molecule by stating the values of all three of its vibrational quantum numbers ($u_1, u_2, and u_3$). In the ground vibrational state, the values of all three quantum numbers are zero, so that we can write this state as (0, 0, 0). The vibrational energy of the water molecule in this state is 0.574 electron volts (eV). In the excited states of the molecule, its vibrational energy is greater, every higher level of excitation being described by the corresponding higher value of the vibrational quantum number. The absorption spectrum of a water molecule is substantially more complex than that of an atom as there can be transitions between energy states of the atoms that make up the molecules, and transitions between energy states associated with the movement of the atoms. In the Born-Oppenheimer approximation the electronic energy (E_e), the vibrational energy (E_v), and the rotational energy (E_r) of an isolated molecule are completely independent so that the total energy (E) can be written as [29]:

$$E = E_e + E_v + E_r \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.8)$$

2.4.3. b. Refractive Index:

The water refractive index depends on temperature and pressure as displayed in the table (2.2) [30]. Wavelength dependence of water in visible and near-infrared spectral ranges has been presented in equations (2.9) and (2.10), where (λ) is the wavelength. In near-Ultraviolet–visible (UV-Visible) and near-infrared spectral (IR) ranges wavelength dependence of water refractive index can be described by [31].

$$n(\lambda) = 1.3199 + \frac{6878}{\lambda^2} - \frac{1.132.10^9}{\lambda^6} + \frac{1.11.10^{14}}{\lambda^6} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.9)$$

$$n(\lambda) = 1.31848 + \frac{6.662}{\lambda[nm] - 129.2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.10)$$

Table (2.2) Refractive Indexes of Water [31]

Temperature	Refractive Index	Temperature	Refractive Index
1.56 ° C	1.33439	28.80° C	1.33293
7.64° C	1.33423	34.50° C	1.33177

2.4.3. c. Optical Band Gap Energy:

The optical band gap energy of liquid water can be estimated through a thermochemical cycle, which, so the optical band gap energy of water can be calculated by the equation below:

$$(\alpha h v)^2 = C(h v - E_g) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.11)$$

Where (C) is constant, (hv) is photon energy, (α) is absorption coefficient, (E_g) is the optical band gap energy [32].

2.4.3. d. Scattering:

When light hits a small molecule and thereby changes its direction, the thing that happens is called light scattering. In this case, the transmitted intensity will decrease exponentially with the thickness (x) of the molecule the light is passing through as shown in fig (2.7). If the attenuation is due to scattering the intensity can be written as:

$$I = I_o . e^{-\tau x} \quad \text{…...…………...….…………….………...……………….…………} \quad (2.12)$$

Where (I_o) is the incident intensity at the scattering case of the light, the (τ) is called the absorption coefficient [33].
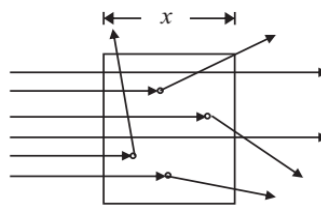
Figure (2.7) Scattering of Molecule [33]

2.4.3. e. Optical Absorption Coefficient:

The optical absorption of pure water is one of the fundamental inherent optical properties of water. However, due to its low value in the visible and UV portions of the spectrum. Typical experiments involve measuring the attenuation of a light source that has been transmitted through a sample volume of water. The problem with these experiments is that the measured quantity is attenuation, not the absorption coefficient. The absorption coefficient is given by:

$$P_{abs} = 4aVF_o \quad \text{…...…………………..………………………………….} \quad (2.13)$$

Where (*V*) is the volume of the sample region, and (*a*) is the absorption coefficient, (F_o) is the irradiance, P_{abs} is the absorbed power inside the region [34].

2.4.3. f. Transmittance and Color:

Water is a substance that has no color, no taste, and no aroma, and water has little transmittance. Some studies show that the transmittance of liquid water depends on a wavelength that can be absorbed by a water sample. Also, the transmittance of liquid water (T_W (λ_W)) is calculated by the following equation:

$$T_w(\lambda_w) = \frac{\int_0^\infty F_w(\lambda) T_w(\lambda) d\lambda}{\int_0^\infty F_w(\lambda) d\lambda} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.14)$$

Where ($F_w(\lambda)$) is the shape of the liquid water, and ($T_w(\lambda)$) is the transmittance of filters in corresponding channels [35].

2.4.4. Thermodynamic Properties of Water:

Water heating is a heat transfer process that uses an energy source to heat water above its initial temperature. Water molecules have fantastic thermodynamic properties such as heat capacity, specific heat, latent heat, and thermal conductivity as displayed below:

2.4.4. a. Heat Capacity:

The heat capacity of water (C_m) can be defined as the ratio of the quantity of heat (Q) absorbed by water to the corresponding rise of temperature (T_2-$T_1 = \Delta T$) that can be expressed by :

$$\frac{Q}{\Delta T} = C_m \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (2.15)$$

2.4.4. b. Specific Heat:

The heat capacity of water per gram (M) is called the specific heat of the water that can be calculated by:

$$C_m = \frac{C_m}{M} = \frac{Q}{M.\Delta T} = \frac{q}{\Delta T} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2.16)$$

Hence the mean of specific heat of water between (C) and (C_l) is equal to the zero calories. If we take infinitely small intervals of temperature, we obtain, for the heat capacity of water, and the specific heat at temperature (T) as shown in the following equation:

$$\frac{Q}{dT} = C, and \frac{q}{\Delta T} = C \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (2.17)$$

The specific heat, in general, varies with the temperature, but, mostly, very slowly. It is usually permissible to put the specific heat at a certain temperature equal to the mean specific heat of an adjoining interval of moderate size [36].

2.4.4. c. Latent Heat:

Latent heat is the heat released or absorbed by water or a thermodynamic system during a constant temperature process. A typical example is a change of state of matter, i.e., the phase transition process during which the temperature of the system remains constant even though heat is absorbed (or released) by the system. The latent heat that is associated with melting a solid or freezing a liquid is called the heat of fusion. The latent heat that is associated with vaporizing a liquid or a solid or condensing vapor is called the latent heat of liquid [37].

2.4.4. d. Thermal Conductivity:

The ability to connect water to the heat is called thermal conductivity, it can be calculated by the following equation:

$$dQ = -\lambda \frac{d\theta}{dx} dfdt$$ …………..………………………………………….... (2.18)

Where (θ) is the temperature, (x) is the thickness, (f) is the surface area in a unit of cm^2,(Q) is the quantity of heat transmitted in Cal/Sec, and λ is the thermal conductivity in $Cal/Cm.Sec.C^\circ$ [38].

2.5. Other Properties of Water:

In general, water can characterize by some unique properties that distinguish water molecules from other compounds like cohesion, adhesion, the universal solvent, the neutral (pH), and three forms of water as were clarified below:

2.5.1. Cohesion and Adhesion:

Cohesion is an attraction process that occurs between similar molecules, primarily as the result of chemical bonds that have formed between the individual components of the adhesive or luting agent. Thus, cohesion may be defined as the internal strength of an adhesive due to various interactions within that adhesive that binds the mass together, whereas adhesion is the bonding of one material to another, namely, an adhesive to a substrate, due to different possible interactions at the adhesive-substrate surface interface [39].

2.5.2. Water as a Universal Solvent:

Water is a universal solvent that is regarded to be the most important substance for the sustenance of life for all the living organisms of the biosphere and also one of the most important biotic factors to the ecosystem [40].

2.5.3. Neutral (pH):

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The (PH), one of the most common analyses in soil and water testing, is the standard measure of how acidic or alkaline in a solution. It is measured on a scale from (0 – 14). PH of 7 is neutral, pH less than 7 is acidic, and pH greater than 7 is basic. The closer pH gets to 1, the more acidic. The closer pH gets to 14, the more basic. Acids and bases are two extremes like hot and cold. Mixing acids and bases can even out the extreme effects much like mixing hot and cold water to even out water temperature [41].

The pH is defined as the negative logarithm of the hydrogen ion concentration. This definition of pH was introduced in 1909 by the Danish and it is expressed mathematically as:

$$PH = -\log [H^+] \quad …..……………………………...…………………………… \quad (2.19)$$

Where $[H^+]$ is hydrogen ion concentration in mole/L [42].

2.5.4. The Three Forms of Water:

For water molecules, there are three common physical states (solid, liquid, and gas). In solids, particles are closely organized in a predictable order, causing them to hold a shape unless force is applied. A gas has no definite shape or volume but occupies the entire container in which it is confined as shown in figure (2.8) below. A phase diagram is a graphical representation of the physical states of a water molecule as they relate to temperature and pressure in figure (2.9) [43].

SOLID   LIQUID   GAS
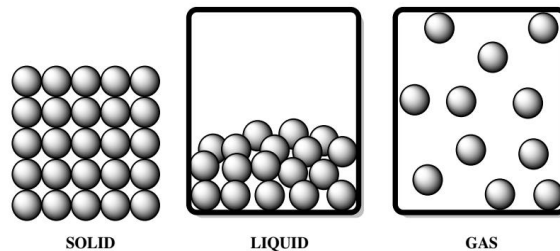
Figure (2.8) Three Forms of Water[43]
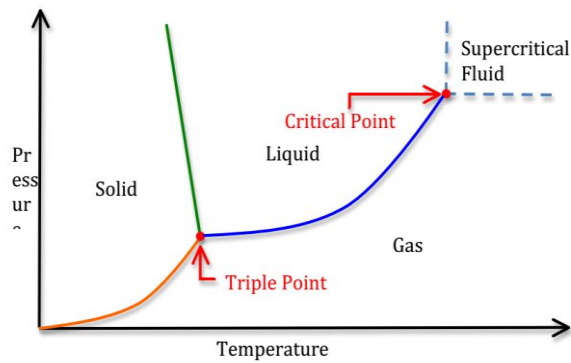
Figure (2.9) Example of a General Phase Diagram [43]

2.6. Water Resources:

The ratio of water that covered the surface of the earth is approximately 75%, and water can exist in different forms in the natural such as oceans, seas, lakes, rivers, ground wells, etc. …[44]. However, water is distributed on the Earth with a special style where oceans have the greater part of this distribution is shown in table (2.3) below [45]:

Table (2.3) Distribution of Water at Earth Surface [45]

The source	The ratio	The source	The ratio
Oceans	97.3%	Atmosphere	0.001%
Ice	2.19%	Inland lakes	0.018%
Groundwater	0.5%	Rivers	0.000096%

2.6.1. Oceans Water:

The ocean covers about 70% of Earth's surface, and so has a total area of about $3.61x10^{14} km^2$. Currently, about two-thirds of Earth's land area is in the Northern Hemisphere, so that about 57% of the ocean is in the Southern Hemisphere, 43% in Northern; Northern Hemisphere itself is 61% ocean, and the Southern Hemisphere is about 80% ocean. The ocean's average depth is about $3.7 Km$, but there are deep trenches where the depth reaches about 10 km. The volume of the ocean is

approximately $1.3x^{18}km^3$ and, given that the average density of seawater is about $1.03x10^3\ Kg/m^3$, the total mass of the ocean is about $1.4x10^{21}Kg$ or (1,400, 000, 000, 000, 000, 000) metric tons. [46].

2.6.2. Seas Water:

Seawater is a complex mixture of water, salts, and many other organic and inorganic substances. Seawater contains more dissolved ions than all other types of water, like river water, rainwater, lake, water, and groundwater. Seawater contains 96.5 percent water, 2.5 percent salts, and smaller amounts of other substances, including dissolved inorganic and organic materials, particulates, and a few atmospheric gases. The chemical constituents of seawater include many major ions and minor trace elements. In addition, seawater also contains the suspended solids, organic substances, and dissolved gases. Seawater chemistry shows 96 percent water and 4 percent other elemental constituents as shown in table (2.4) at the following [47]:

Table (2.4) Sea Water Composition [47]

Element	Percent	Element	Percent
O	85%	S	0.091
H	10.82%	Ca	0.04
Cl	1.94%	K	0.04
Na	1.08%	Br	0.0067
Mg	0.1292	C	0.0028

2.6.3. Lakes water:

The lake can be defined as water surrounded by land and with no direct access to the sea. In many circumstances, these isolated lakes are saline due to evaporation or groundwater inputs. There are many major types of lakes such as Glacial lakes, Tectonic lakes, Fluvial lakes, Shoreline lakes, Dammed lakes, Volcanic lakes, and

Solution lakes[48]. Lake water content different ions such as (Ca^{++}, Mg^{++}, and Na^+) and other anions like (HCO_3^-, SO_4^-, and Cl^-) [49].

2.6.4. Rivers Water:

The composition of river water is significantly different from seawater. The concentrations are compared in the table (2.5) below and shown in the schematic figure (2.10). Some characteristic ratios are also compared. To a first approximation, seawater is mainly a (Na^+ and Cl^-) solution while river water is a (Ca^{2+} and $HCO3^-$) solution as shown in fig (2.10) below [50].
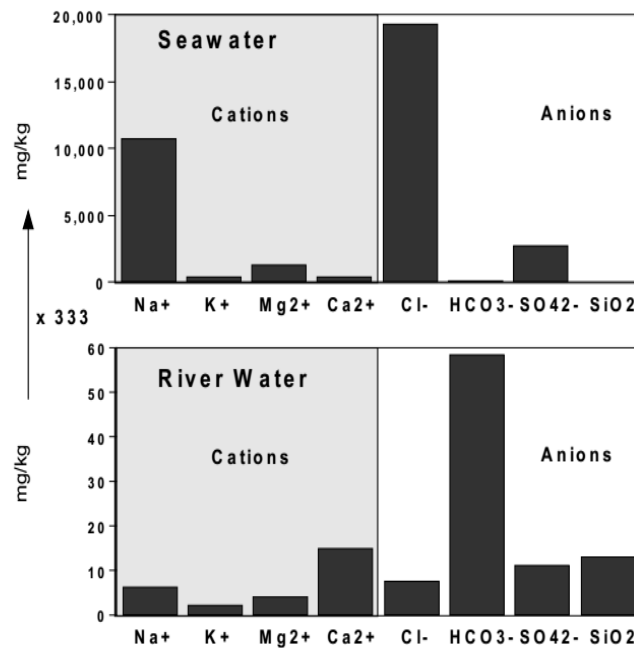
Figure (2.10) Comparing between Cations and Anions in River Water and Sea Water [50]

Table (2.5) Composition of River Water in mol .kg^{-1}[50]

Element	River water (100%)	Element	River water (100%)
Na	0.26	Sr	NO
Mg	0.17	Cl	0.22
Ca	0.38	SO4	0.11
K	0.07	HCO3	0.96

2.6.5. Rains Water:

Rainwater is an important means of scavenging pollutants from the atmosphere, for both gases and the particulate phase. The composition of rainwater reflects the composition of the atmosphere through which it falls. Calcium is considered an essential element for plant and animal life. Chloride is widely spread in nature and comes from different chemical compounds such as (NaCL, KCL, and CaCL$_2$) [51].

2.6.6. Ground Water:

Approximately 30% of global freshwater is groundwater, whereas only 1.2% is found in streams and lakes[52]. Groundwater occurs in most geological formations because nearly all rocks possess openings (pores or voids, or fractured). Groundwater is distributed in different water-bearing formations or layers as explained in figure (2.11). Four regions that can be existed in the structure of groundwater are soil moisture, zone of aeration, capillary fringe, and zone of saturation as shown below [53].
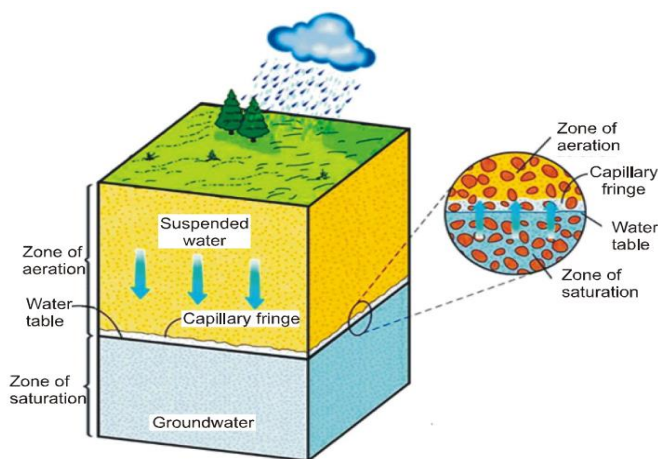
Figure (2.11) Distribution of Groundwater in Different Layers [53]

Groundwater always includes cations like (Na$^+$, Ca^{2+}, and Mg^{2+}), and anions such as (Cl$^-$, SO$_4^{2-}$ and HCO^{3-}) [54].

2.7. Classifications of Chemical Elements in Drinking Water:

Chemical elements in drinking water can be classified into five groups such as major metals (essential metals), trace (nonessential metals), toxic metals (heavy metals), metals that have low toxicity, and radioactive metals as discussed below:

2.7.1. Major Metals (Essential Metals):

Macrominerals are defined as minerals that are required by adults in amounts greater than 100 mg/day. Major (macro) minerals include sodium, potassium, sulfur, calcium, and magnesium. These elements are very beneficial for human health because on many sides like main control on fluid volume inside cells, helps control acid/base balance, very important in membrane functions, water balance, nerve impulses and muscle contractions, calcium is necessary for bones. Magnesium is a cofactor for several enzymes. Also, sulfur is found in many proteins [55][56].

2.7.2. Trace Metals (Nonessential Metals):

Trace elements (or trace minerals) are usually defined as minerals that are required in amounts in the range (1-100) mg/day by adults. Trace mineral group includes some elements like iron, copper, zinc, iodine, rubidium, silicon, boron, lithium, manganese, vanadium, and selenium [56]. These trace elements (or trace metals) are minerals present in living tissues in small amounts. Some of them are known to be nutritionally essential, others may be essential (although the evidence is only suggestive or incomplete), and the remainder is considered to be nonessential. Trace elements function primarily as catalysts in enzyme systems; some metallic ions, such as iron and copper, participate in oxidation-reduction reactions in energy metabolism. Iron, as a constituent of hemoglobin and myoglobin, also plays a vital role in the transport of oxygen. All trace elements are toxic if consumed at sufficiently high levels for long enough periods [57].

2.7.3. Toxic Metals (Heavy Metals):

Heavy metals are naturally occurring elements that have a high atomic weight and a density at least 5 times greater than of water. Their multiple industrial, domestic, agricultural, medical and technological applications have led to their wide distribution in the environment; raising concerns over their potential effects on human health and the environment. Their toxicity depends on several factors including the dose, route of exposure, and chemical species, as well as the age, gender, genetics, and nutritional status of exposed individuals. Because of their high degree of toxicity, arsenic, cadmium, chromium, lead, and mercury rank among the priority metals that are of public health significance. Also, the group of heavy metals includes many chemical elements such as aluminum, barium, thallium, antimony, bismuth, tantalum, and nickel [58,59]. These metallic elements are considered systemic toxicants that are known to induce multiple organ damage, even at lower levels of exposure. They are also classified as human carcinogens (known or probable) according to the U.S. Environmental Protection Agency, and the International Agency for Research on Cancer [60].They are usually included at parts-per-thousand (ppt = μg L^{-1}) or parts-per-million (ppm = mg L^{-1}) levels [58]. These heavy metals cause many diseases like perforation of the nasal Septum, respiratory cancer, dermatomes, skin, cancer, osteomalacia, neuropathies encephalopathy, neuropathy, central nervous, disorders, anemia, visual defects, pneumoconiosis, and proteinuria [61].

2.7.4. Radioactive Metals:

Radioactivity is a part of nature. Everything is made of atoms. Radioactive atoms are unstable; that is, they have too much energy. When radioactive atoms spontaneously release their extra energy, they are said to decay. All radioactive atoms decay eventually, though they do not all decay at the same rate. After releasing all their excess energy, the atoms become stable and are no longer radioactive. The time required for decay depends upon the type of atom. This Fact Sheet explains the process of radioactive decay [62]. Radiation damage to living organisms is divided into two categories: somatic and genetic. Somatic damage by radiation is damage to any part of the body except the reproductive organs. Somatic damage directly affects the

individual exposed to the radiation. Irradiated bone marrow can cause anemia (low red blood cell count) and therefore fatigue and muscle weakness. Poor digestion and absorption of nutrients can stem from an irradiated gastrointestinal tract. Large doses of radiation cause hair loss and dryness of the skin. Over time, large doses of radiation can cause cancer and the formation of cataracts on the lenses of the eyes. The risk of developing these types of somatic damage is usually consistent with the level of exposure to radiation beyond a certain threshold amount [63]. This group of radioactive elements involves (titanium, Strontium, thorium, and iridium) [64].

2.7.5. Elements that have Low Toxicity:

Low toxic elements are elements that are much less dangerous than highly toxic elements for the human body, and they include rare earth elements and some other chemical elements. This classification of these chemical elements contains some metals like (erbium, holmium, scandium, platinum, tungsten, europium, lutetium, and ytterbium) [65]. Based on limited information on REEs' effects, The effects may include detailed outcomes related to growth inhibition, embryotoxicity, cytogenetic effects, and organ-specific toxicity [66].

2.8. Polyethylene Material:

Polyethylene (PE) products are very common in our daily life. A large number of products could be manufactured from plastic which includes plastic bags, plastic film and milk, and plastic bottles of drinking water [67]. Although PE has the simplest structure of the polymer, it is still the most widely used polymer material. The PE is synthesized by polymerization of ethylene (CH2 = CH2) [67].

2.8. 1. Polyethylene Usage:

PE is a promising synthetic material with great physical and chemical properties. It has a high degree of mechanical properties and an excellent combination of good dielectric properties. In addition, the molding process is good and the price is low. They are particularly important in some aspects like electrical insulation, anti-corrosive agents, packaging, after radiation treatment, various medical equipment,

spraying metal, wood, fabric, plastic bottles for drinking water, and other materials [67,68]. On the other hand, the various polyethylene polymer types are manufactured by polymerizing ethylene either on its own, which produces the photopolymer mentioned above [68].

2.8. 2. Polyethylene Properties:

Polyethylene materials have attractive properties such as physical and chemical properties as were displayed below:

2.8. 2.a. Physical Properties of Polyethylene:

PE is a white waxy translucent material that is soft, tough, lighter than water, non-toxic, and has excellent dielectric properties. It is flammable and continued to burn after the fire. Its water permeability is low and the organic vapor transmission rate is larger. The transparency of PE decreases with the increase of crystallinity. Under certain crystallinity, the transparency increases with the increase of molecular weight. Melting point ranges from ($132^{\circ}C$) to $(135^{\circ}C)$ [67].

2.8. 2.b. Chemical Properties of Polyethylene:

PE has excellent chemical stability. It is resistant to acidic and basic solutions such as hydrochloric acid, hydrofluoric acid, phosphoric acid, formic acid, amines, sodium hydroxide, and potassium hydroxide at room temperature [67].

However, water is filled into transparent plastic bottles made from polyethylene terephthalate (PET) and exposed to full sunlight for many hours or many days. During this period there is an interaction between water and plastic, which was very dangerous for human life. Plastic produces some extremely toxic elements, which cause many diseases [69].

2.9. Spectroscopy Techniques:

Spectroscopic techniques employ light to interact with matter and thus probe certain features of a sample to learn about its structure. Light is electromagnetic radiation (EM), and it is a phenomenon exhibiting different energies and is dependent on that energy. The basic principles of the interaction of electromagnetic radiation with matter will discuss in the next part of this chapter [70].

Electromagnetic radiation is described by its wavelength, and frequency, or energy. All electromagnetic energy travels at the speed of light (c), which equal 2.998×10^8 m/s, so the relation between wavelength (λ) and frequency (v) can be represented by:

$c = \lambda v$ …………...………………………………………………………………. (2.20)

Long waves have a low frequency and short waves have a high frequency as displayed in fig (2.12). The wavelength and frequency also indicate the energy of the wave. The relationship between wavelength and energy (E) is described by the following equation:

$E = hc/\lambda$ ………….…………..……………………………………………..…. (2.21)

Where (h) is Planck's constant is (h = 6.625×10^{-34} Joule-seconds or J.s) and c is the speed of light. By replacing the constants (h) and (c) with their respective values, the value of the energy will be (E = 1.986×10^{-25} Joule-meters or J. m/λ). Using equation (2.21), the equation (2.22) can be written as [71,72].

$E = hv$ ……...…………….……………………………………………..………... (2.22)
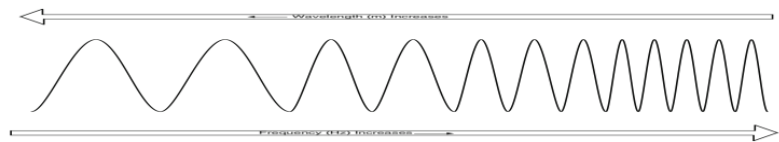
Figure (2.12) Relationship between wavelength and frequency[72]

The electromagnetic spectrum has been divided into many sections; familiar names are assigned to the different ranges as shown in fig (2.12). Gamma rays are types of EM radiation with the shortest wavelength, highest frequencies, and,

consequently, the highest energy. At the other end of the spectrum are the low-energy waves. In order of increasing energy, these include radio waves, television waves, microwaves, and radar waves. The energy we know as light is the middle of the spectrum. The lowest energy light is infrared, followed by visible and ultraviolet. The human eye is capable of discriminating between EM waves of different energy in the visible range between about 400 and 700 nm in wavelength. The spectrum of visible light appears in different colors: red, orange, yellow, green, blue, and violet. Within the visible range, red light has the lowest energy and violet the highest   [72, 73].

Electrons occupying the energy levels closest to the nucleus have the lowest energy; as one moves to the outer energy levels, electrons have progressively higher amounts of energy. Certain types of EM radiation are absorbed by the atoms or molecules in a sample and move them to a higher energy or excited state [74,75].
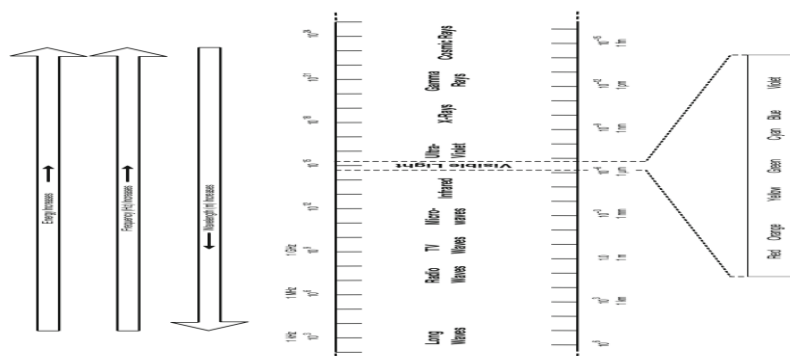
Figure (2.13) Electromagnetic Spectrum with Visible Region Expanded [71]

Several spectroscopy techniques can be used to describe the interaction between the sample and electromagnetic radiation such as nuclear magnetic resonance (NMR), electron spin resonance (ESR), x-ray diffraction (XRD), X-ray fluorescence (XRF), proton/particle-induced X-ray emission (PIXE), proton/particle-induced gamma-ray emission (PIGE), energy-dispersive (ED) or wavelength-dispersive (WD), UV-visible, Fourier-transform infrared (FTIR), and laser-induced breakdown spectroscopy (LIBS) ..etc [75].

2.9.1. Inductively Coupled Plasma Emission Spectroscopy:

ICPE is one of the most powerful and popular analytical tools for the determination of trace elements in a myriad of sample types. The technique is based upon the spontaneous emission of photons from atoms and ions. Liquid and gas samples may be injected directly into the instrument, while solid samples require extraction or acid digestion so that the analyses will be present in a solution. The sample solution is converted to an aerosol and directed into the central channel of the plasma[76]. The primary goal of ICPE is to get elements to emit characteristic wavelength-specific light which can then were measured. The technology for the ICPE method was first employed in the early 1960s to improve upon crystal growing techniques. Since then, ICPE has been refined and used in conjunction with other procedures for quantitative analysis [77].

2.9.2. a. Principle of ICPE Spectroscopy:

The principle used in the inductively coupled plasma optical emission spectroscopy is when plasma energy is given to an analysis sample from outside, the component elements (atoms) are excited. When the excited atoms return to low energy position, emission rays (spectrum rays) are released and the emission rays that correspond to the photon wavelength are measured. The element type is determined based on the position of the photon rays, and the content of each element is determined based on the rays' intensity. To generate plasma, first, argon gas is supplied to the torch coil, and a high-frequency electric current is applied to the work coil at the tip of the torch tube. Using the electromagnetic field created in the torch tube by the high-frequency current, argon gas is ionized and plasma is generated. This plasma has high electron density and temperature (10000K) and this energy is used in the excitation-emission of the sample. Solution samples are introduced into the plasma in an atomized state through the narrow tube in the center of the torch tube [78].

In inductively coupled plasma-optical emission spectrometry, the sample is usually transported into the instrument as a stream of liquid samples. Inside the instrument, the liquid is converted into an aerosol through a process known as nebulization. The sample aerosol is then transported to the plasma where it is

desolated, vaporized, atomized, and excited, and/or ionized by the plasma. The excited atoms and ions emit their characteristic radiation which is collected by a device that sorts the radiation by wavelength. The radiation is detected and turned into electronic signals that are converted into concentration information for the analyst. A representation of the layout of a typical ICPE instrument is shown in figure (2.14) [79].
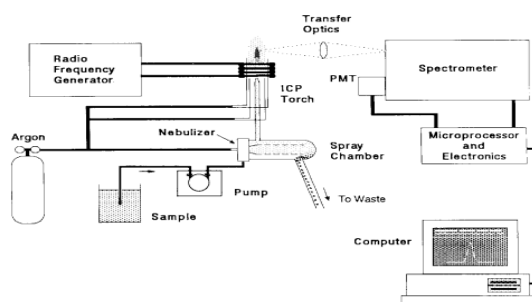
Figure (2.14) Diagram of ICPE Spectroscopy [79]

An ICPE typical includes the following components:

1- Sample introduction system (nebulizer).

2- ICPE torch.

3- High-frequency generator.

4- Transfer optics and spectrometer.

 5- Computer interface.

An ICPE requires that the elements which are to be analyzed be in solution. An aqueous solution is preferred over an organic solution, as organic solutions require special manipulation injection into the ICPE. Solid samples are also discouraged, as clogging of the instrumentation can occur. The nebulizer transforms the aqueous solution into an aerosol. The light emitted by the atoms of an element in the ICPE must be converted to an electrical signal that can be measured quantitatively. This is accomplished by resolving the light into its component radiation (nearly always employing a diffraction grating) and then measuring the light intensity with a

photomultiplier tube at the specific wavelength for each element line. The light emitted by the atoms or ions in the ICPE is converted to electrical signals by the photomultiplier in the spectrometer. The intensity of the electron signal is compared to previously measured intensities of known concentration of the element and a concentration is computed. Each element will have many specific wavelengths in the spectrum which could be used for analysis. Thus, for the selection of the best line, the analytical application in hand requires considerable experience of ICPE wavelengths [80].

2.9.3. UV-Visible spectroscopy:

UV-Visible radiation is a small part of the electromagnetic spectrum, which includes such other forms of radiation as radio, (IR), cosmic, and XRD rays as shown in the figure (2.15) below:

Several processes can occur when interacting with matter such as reflection, scattering, absorbance, fluorescence/phosphorescence (absorption and emission), and photochemical reaction (absorbance and bond breaking). In general, when measuring UV-visible spectra, we want absorbance to occur [81].
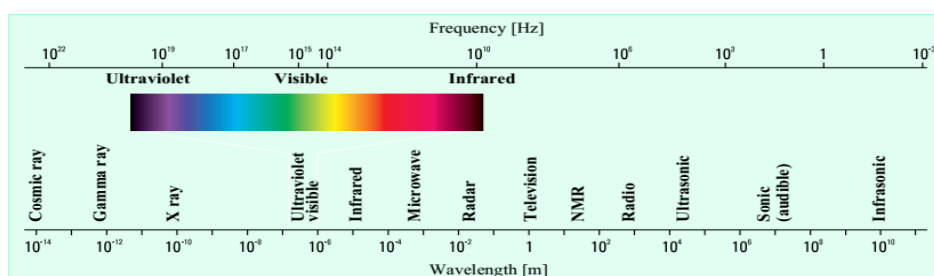
Figure (2.15) Electromagnetic Spectrum [81]

Because light is a style of energy, absorption of light by a matter or sample causes the energy of the molecules (or atoms) to increase. So, the total potential energy of a molecule is the sum of its electronic, vibrational, and rotational energies which can be written as:

$$E_{total} = E_{electronic} + E_{vibrational} + E_{rotational} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (2.23)$$

Also, these energies were mentioned above do not continuum but a series of discrete levels or states, but they can be in the order in the following equation:

$$E_{electronic} > E_{vibrational} > E_{rotational} \quad \text{... (2.24)}$$

UV-Visible spectroscopy is a physical technique of the optical spectra that uses light in the visible, ultraviolet, and near-infrared ranges. Also, a molecule or ion will absorb the light in the visible or ultraviolet region when radiation causes an electronic transition within its structure. Thus, the light can be absorbed by the sample in the ultraviolet or visible region is accompanied by a change in the electronic state of the molecules in the sample. The energy supplied by the light will promote electrons from their ground state orbitals to higher energy, excited state orbitals, or antibonding orbitals. Three types of ground state orbitals may be involved as described below [82].

1) σ (bonding) molecular.
2) π (bonding) molecular orbital.
3) n (non-bonding) atomic orbital.

In addition, two types of antibonding orbitals may be involved in the transition:

i) σ* (sigma star) orbital.

ii) π* (pi star) orbital.

These transitions as displayed in figure (2.16) below[82].
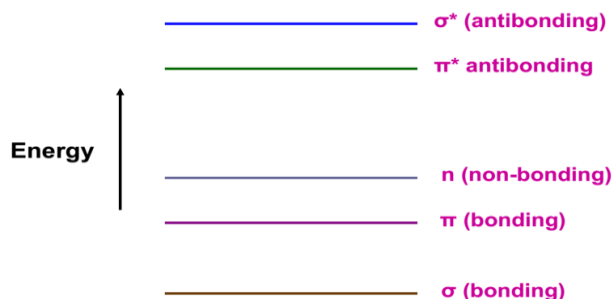
Figure (2.16) Molecular Orbitals, Bonding, Antibonding, and Nonbonding Orbitals [82]

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2.9.3. a. Principle of UV-Visible Spectroscopy:

The main function of a spectrophotometer is to measure the absorbance or transmittance of a sample as a function of the wavelength. In UV–Visible spectroscopy, light from a UV–Visible source is passed through a monochromator to isolate a specific group of wavelengths, and then passed through the analysis where a specific wavelength is absorbed, and finally, the light reaches the detector as shown in the figure (2.17). The main components of the spectrophotometer are the light source, monochromator, sample-holding cell (cuvette), detector, and readout device.

The most common light sources are the deuterium lamp, and the tungsten halogen lamp. The deuterium lamp provides light in the UV region of the electromagnetic spectrum (160–375 nm), while the tungsten lamp provides light in the Vis region of the electromagnetic spectrum (350–2500 nm). They may also be used in near-IR spectroscopy. These light sources work best with quartz cuvettes because glass cuvettes absorb at a wavelength <350 nm. The deuterium lamp has a limited half-life of about 100 h, while the tungsten lamp has a long half-life of more than 1000 h. The detector transforms the light energy into electrical energy. In practice, a good detector should give high linearity over a wider range together with high sensitivity. The detector can be a photomultiplier tube or a photodiode tube.

The monochromator functions as a light that is dispersed. It is important to note that light is dispersed according to its wavelength. The monochromator contains an entrance slit, disperser, and exit slit. The light coming out of the monochromator is of one wavelength, hence the "mono" term. This reduces optical aberration [83].
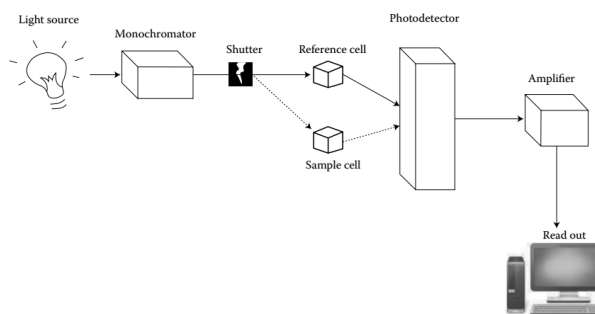
Figure(2.17) Schematic Diagram of a UV–Vis Absorption Spectrometer [83]

2.9.3. b. Beer-Lambert Law:

Beer-Lambert Law (also known as Beer's Law) states that there is a linear relationship between the absorbance and the concentration of a sample. For this reason, Beer's Law can only be applied when there is a linear relationship. The method is most often used in a quantitative way to determine concentrations of an absorbing species in solution, using the Beer-Lambert law as shown in the following equation:

$$A = \log_{10} \frac{I_\circ}{I} = \varepsilon.c.L \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2.25)$$

Where (A) is the measured absorbance, (no units), $(I_\circ)$ is the intensity of the incident light at a given wavelength, (I) is the transmitted intensity, (L) is the path length through the sample, (C) is the concentration of the absorbing species, and (ε) is the molar absorptivity which can be calculated by:

$$\varepsilon = \frac{A}{C.L} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2.26)$$

Molar absorptivity may be very large for strongly absorbing compounds   (ε >10,000) and very small if absorption is weak (ε = 10 to 100). The Beer-Lambert Law is useful for characterizing many compounds but does not hold a universal relationship for the concentration and absorption of all substances. A 2nd order polynomial relationship between absorption and concentration is sometimes encountered for very large, complex molecules such as organic dyes. Beer's Law can be written as:

$$A = \varepsilon.c.L \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2.27)$$

the spectral regions and the color of them as displayed in the tables (2.6) and (2.7) below [84].

Table (2.6) Spectral Regions [84]

Region	A	Absorbing compounds
Far ultraviolet (vacuum UV region)	< 190 nm	saturated and mono-unsaturated
(Near) ultraviolet	190-380 nm	poly-unsaturated and aromatic
Visible light region	380-780 nm	Coloured

Table (2.7) Visible Light Absorption and Colors [84]

λ (nm)	Color of light	Color of absorbing body
400-435	Violet	Yellow-Green
435-480	Blue	Yellow
480-490	Green – Blue	Orange
490-500	Blue-Green	Red – Orange
500-560	Green	Red
560-580	Green-Yellow	Violet
580-595	Yellow –Orange	Blue
595-620	Red –Orange	Green-Blue
620-760	Red	Blue-Green

CHAPTER THREE

Literature Review

3.1. Introduction:

During the last decades, drinking water has been extensively studied as a liquid sample because it has very attractive properties such as physical and chemical properties [85]. Also, many toxic metals can exist in drinking water for instance, (Al,

Cd, Ba, Cr, Ag, Sn, Pb, Hg, and Ni) that may be due to the geogenic structure of water sources locations or may be due to anthropogenic reasons such as uncontrolled discharge of wastewaters of different types of industries [86].

3.2. Literature Review:

Many researchers have been collected a lot of water samples from different sources over all the world, and they have been detected some heavy metals in these samples. On the other hand, they have been studied some physical properties of water like optical, and electrical properties. Also, they have been found fascinating results as shown below:

The optical properties of tap water samples in Bagdad (Iraq) were studied by Al-Azzawi et al., 2014 using He-Ne laser spectroscopy with different power densities. The optical results of the collected samples confirmed that the tap water differs from the pure water because it contains more chemical contents arise in drinking water, and they found that these samples of water mostly contained (NaCl) salts and clay. On the other hand, the optical properties showed that the transmittance, (absorption and extinction coefficients) decreased with increasing concentration and the sample length while the absorbance increased [87].

Other experimental work was to identify heavy metals in some water sources samples in Khartoum state by Almuslet et al., 2017 using LIBS. The researchers were collected four samples from different sources in Khartoum state were irradiated by Q-switched Nd: YAG laser to produce its plasma. The analysis of the spectra showed that considerable amounts of (Ni, As, Ru, Th, Zr, Tb, Eu, Li, I, Cu, Xe, K, He, Ne, Cs, Hg, Cr, Tl, Cl, Na, and Fe). Elements in addition to (Ni^{+1}, As^{+1}, Th^{+1}, Th^{+2}, Zr^{+1}, Cs^{+1}, Cs^{+2}, Cr^{+1}, Cr^+ Tl^{+1}, Tl^{+2}, Fe^{++}, and Fe^{+2}) ions [88].

The concentration of heavy elements such as Cd in drinking water was calculated by Tian et al., 2014 in China via LIBS. The results showed that the spectral intensity of Cd was 214.4nm with concentrations in the range from 0 to 100 µg/L [89].

Also, Frı ́ et al., 2015 have been detected some heavy elements in drinking water using LIBS. This paper was showed two heavy elements (Ni and Cu) at wavelengths values 357.91 nm for (Ni) and 396.41 nm for (Cu). The researchers have been used a multi pulsed Nd: YAG laser [90].

Furthermore, Joda et al., 2019 have been investigated some heavy metals in drinking water in Iraq via LIBS. The level of these elements was found that most trace element levels, As (0.919 ± 0.253), Cd (0.017 ± 0.006), and Pb(0.066±0.040) (µg/ml) were higher than the permissible guidelines for drinking water recommended by World Health Organization (WHO) and Iraqi government [91].

In addition, the heavy metals concentration in the collected samples from the Sewage-Treated water and the White Nile were determined by Mohamed et al., 2014 In Khartoum, Sudan using ICPE. This experimental work displayed that the concentrations of heavy metals (Cd, Cr, Ni, Pb, Cu, Zn, Fe, and Sr) were detected in these samples collected from four stations along with the sewage treatment plant. The range of Fe was (10.6 − 11.6 µg/l) in water from sampling stations, with no significant difference between the four stations. The level of Sr in water was (6.32 − 7.86 µg/l) with increased concentration in station 4, the discharge point of the treated waste-water into the White Nationalist (WN). The concentration of lead was (0.11 − 0.2 µg/l) in water with the highest level in station 3, the discharge point of industrial effluents and (0.2 − 0.3 µg/l) [92].

The heavy metals in drinking water in Khorramabad city, Iran were studied by Ghaderpoori et al., 2017 via ICPE. The results of this study showed that the average concentration of heavy metals such as (Zn, Pb, Cd, Cr, and Cu) was (47.01 µg/l, 3.2 µg/l, 0.42 µg/l, 5.08 µg/l, and 6.79 µg/l), respectively [93].

The levels of some heavy metals like cadmium, copper, lead, and zinc were calculated by Janes et al., 2016 in Kisii town via ICPE. The study showed that the mean concentrations of these metals were 0.074 ppm for Cd, 2.228 ppm for Cu, 1.401 ppm for Pb, and 0.141 for ppm Zn. The study concluded that the concentrations of

cadmium and lead metals in Nyakomisaro stream water were higher than WHO recommended limit in drinking water thus, posing immediate fears of bio-accumulation [94].

Also, some physicochemical properties of groundwater from Bara Basin North Kordofan state, Sudan were studied by Nazik et al., 2016 via AAS. Three samples of groundwater were collected from the area during the season (March-December 2015). Compared with WHO and Sudanese Standards and Metrology Organization (SSMO) standards, results showed that Fluoride and Nitrate concentrations in some samples exceeded the permissible limit. The content of (Cl^-, Na^+, Fe^{2+}, and SO_4^{2-}) was found within the permissible limit [95].

The heavy metal concentrations of drinking water were observed by Ghawi, 2017 in Ad Dīwānīyah City (Iraq) using AAS. The project aimed was to find out the concentration of toxic heavy metals and cancer-causing disease in humans in the case of non-processed. Heavy elements that have been studied in this research are (Ni, Cd, Al, Hg, and Pb). The results of the study showed that the high concentrations of both the Al and Pb were above the permissible limits of the standard Iraqi standard, where concentrations of the Pb were high for all stages of treatment. The results of the study displayed that the concentration of the Al is more than the permissible limits in all stages of drinking water treatment due to adding alum to the rapid mixing tank. Concentrations of the remaining heavy metals (Ni, Cd, and Hg) were few or nil and were within the limits of Iraqi standards [96].

But also, Elhussien et al., 2017 have been found heavy metals in the fish and water of the White Nile from June to July 2017, Atbara Locality in Sudan via AAS. The objective of this study was to determine the concentrations of some heavy metal water samples collected from the White Nile. The obtained results showed the average values (Fe, Pb, Co, and Cd) in water samples were higher than the WHO guideline limit for freshwater [97].

The analysis of physicochemical parameters for evaluating the drinking water quality in the state of Perak, Malaysia was investigated by Rahmanian et al., 2015 via AAS. The results displayed that the drinking water quality was investigated some heavy metals such as (Cu, Zn, Mg, Fe, Cd, Pb, Cr, As, Hg, and Sn) were analyzed for each water sample collected during winter in summer periods. The obtained values of each parameter were compared with the standard values set by the WHO and local standards such as National Drinking Water Quality Standard (NDWQS). The values of each parameter were found to be within the safe limits set by the WHO and NDWQS [98].

On the other hand, the elements such as (Pb, Cu, and Ni) were detected in water in Malaysia by Ho., 2015. The results of this work showed that the heavy metals were metallic elements with relatively high density and mostly toxic at low concentrations. From this research, the effective wavelength within UV range for Pb^{+2} and Cu^{+2} was roughly from 200 nm to 230 nm and both the Cu^{+2} and Ni^{+2} had absorbance from wavelength 600 nm to 800 nm. Also, the Ni^{+2} have high absorbance at wavelength 400 nm too. In this research, the accuracy of this detection method is 0.178 mg/L, 0.243 mg/L, and 1.815 mg/L for Pb^{+2}, Cu^{+2}, and Ni^{+2} in aqueous solution with a detection limit of roughly 0.2 mg/L to 10 mg/L for Pb^{+2} and Cu^{+2} 2 mg/L to 100 mg/L for Ni^{+2} [99].

The absorption spectrum of pure water was obtained by Mason et al., 2016 in the USA. The results of this study confirmed that the spectral light absorption of pure water can happen at the range from 250 to 550 nm. The results showed that the absorption coefficients were in the visible (>400 nm) and (UV) (<200 nm). A minimum absorption coefficient has been observed in the (UV) at 344 nm; the value is 0.000811 0.000227 m $^{-1}$[100].

The organic compounds in water were identified by Kim et al., 2016 using the optical absorbance method. This Experimental work proposed an optical method that

allows the determination of the organic compound concentration in water at a wavelength of (250 nm-300 nm) [101].

Too, Nissen et al., 2017 have been investigated UV absorption spectroscopy in Water-Filled anti-resonant hollow-core fibers for pharmaceutical detection. The results exhibited that strong and characteristic absorption features at wavelengths shorter than 300 nm [102].

Moreover, Szabo et al., 2016 have been used this technique as a method to characterize well water quality. The results of this paper displayed two series absorption spectra area under (250–350) nm, and the area under (250–500) nm [103].

Analysis of physical and chemical parameters in groundwater used for drinking around Konso Area, Southwestern Ethiopia was studied by Tw et al., 2017. The results of this paper showed that the samples were collected from 23 different locations, and they were analyzed for physicochemical parameters to determine the heavy metals in drinking water samples. The common cations were (Li^+, K^+, Na^+, $Ca^{2+,}$ and Mg^{2+}), the common anions were (NO^{3-}, SO_4^{2-}, PO_4^{2-}, F^-, and Cl^-) and heavy metals were (Pb, Ni, Mn, Co, Zn, and Cu). The obtained results were compared with some national and international standards or guidelines for drinking water. Accordingly, the results obtained show that most of the physical and some common ions and heavy metals were within the accepted range of the guideline-recommended by the WHO. In addition to this, some parameters are at an alarming state as compared to the WHO standards for drinking purposes [104].

Also, Cataldo et al.,2016 have been calculated the refractive index of the water in Italy with a pulsed laser diode, and the results indicated that the refractive index of the water equal to n= 1.323 at the wavelength of 665 nm [105].

The electronic gap of water and ice was measured by Pan et al., 2014 in (USA). They have been reported that both refractive index and the electronic gap of water with pressure, at least up to 30 GPa [106].

The effect of sunlight and storage period, determination of toxic elements for samples of drinking water bottled in plastic bottles, which made of polyethylene have been confirmed by many researchers using some spectroscopy techniques as were discussed in the following details:

The effect of sunlight in plastic bottled drinking water was studied by Bach et al., 2014. Bottled waters were exposed to natural sunlight for 2, 6, and 10 days. Migration was dependent on the type of water. Formaldehyde, acetaldehyde, and Sb migration increased with sunlight exposure in ultrapure water [107].

The effect of storage temperature and sunlight exposure on the physicochemical properties of bottled water was investigated by Muhammad et al., 2014 in Kurdistan region-Iraq. The results show each of the sunlight exposure and temperature of storing cause changes in all physicochemical properties of water in the plastic bottle. Compared with manufacturer's labeling reported on the bottles and were compared with the guideline value of WHO and International Bottled Water Association (IBWA) standards. The change of physicochemical properties is investigated when the bottled water is exposed to sunlight or stored at different temperatures for 30 days [108].

The effect of sunlight exposure and storage duration and the temperature on the release of heavy metals from polyethylene terephthalate drinking water bottles was reported by Jafari et al ., 2015 in Iran. The levels of Pb, Ni, Cd, and Sb were determined in bottled waters in different conditions including room-temperature of $27\pm2°C$, sun exposure to $45\pm3°C$, and with/without foil coating. Different temperatures ($45°C$, $60°C$, and $75°C$) were also used in specified time ranges from 5 to 50 days. Measurement was done by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP- AES) and data were analyzed in Minitab. Concentrations of Pb, Ni, and Cd in bottled water did not show any significant changes in direct sunlight exposure and ambient temperature but Sb concentration was found to be higher in all samples when storage duration increased. In some samples, it even exceeded the maximum allowed value   (5 ppb) [109].

The effects of storage temperature and sunlight exposure on the physicochemical properties of bottled water in the Kurdistan region-Iraq were studied by Muhammad et al., 2011. The change of physicochemical properties was investigated when the bottled water was exposed to sunlight or stored at different temperatures for 30 days. FTIR was carried out to deduce the nature of polymer material and its purity. Results indicated that the quality of bottled water samples was within the permissible limit, while it is changed with the time of sunlight exposure or temperature changes. The results indicate the physicochemical properties of all bottled water samples are within the international guidelines of bottled water. The results show each of the sunlight exposure and temperature of storing cause changes in all physicochemical properties of water in the plastic bottle [110].

The heavy and toxic elements were detected in various types of plastic bags by Alam et al., 2019 using the Inductively Coupled Plasma - Optical Emission Spectrometry (ICP–OES) technique. The results demonstrated that the used polymer types at the highest contents of (Pb, Cr, Cd, As, Cu, and Zn) were 66, 75, 16, 28, 96, and 154 in mg/kg unit respectively in PE bags; 71, 74, 34, 39, 430, and 212 in mg/kg unit, respectively in plastic bags which manufactured from polyethylene materials [111].

The contamination of bottled water with antimony leaching from (PET) upon storage was studied by S h o t y k et al., 2007. Antimony concentrations were determined in 132 brands of bottled water from 28 countries. Two of the brands were at or above the maximum allowable Sb concentration for drinking water in Japan (2µg/L). In 14 brands of bottled water from Canada, Sb concentrations increased on average 19% during 6 months of storage at room temperature, but 48 brands of water from 11 European countries increased on average 90% under identical conditions [112].

The Chemical migration in drinking water stored in PET bottles was investigated by Bach et al., 2011. The results showed that all these substances may potentially migrate from the PET bottle wall to bottled water. However, several studies have

shown the presence of other substances not expected a priori in bottled water, sometimes in non-negligible concentrations [113].

The determination of different trace heavy metals in plastic material imported using Inductively Coupled Plasma /Mass Spectroscopy (ICP/MS) was confirmed by Al-Qutob et al., 2014. The content of heavy metals (Pb, Cd, Cr, Hg, As, Se, Ba, and Zn) was analyzed in 50 plastic materials. Results revealed that 40% of the Palestinian toy samples had high concentration (above international limits) of Pb, 30% of Cd, 34% of Cr, 6% of Hg, 42% of As, 32% of Se, 20% of Ba, and 40% of Zn. On the other hand, 95% of the Israeli samples were safe, and their concentrations were less than the maximum internationally allowable limits [114].

The concentrations of Cadmium, Chromium, Iron, and Arsenic were determined in virgins and plastic by Verma et al., 2017 using Scanning Electron Microscope/ Energy –Dispersive X-Ray Spectroscopy (SEM/EDX) technique. The results confirmed that Cd was found in both virgins as well as recycled plastics in the amount of 0.11 -0.43 ppm. The maximum amount of Cr was 0.1 ppm and the minimum was 0.01 ppm. Fe ranges from 0.02 ppm -2.4 ppm and the maximum amount of arsenic was found to be 0.98 ppm and the minimum was 0.03 ppm [115].

The elemental impurities in plastic calibration standards were determined by Ayyalasomayajula et al., 2012 using LIBS. The results confirmed that The seven elements were found in the plastic samples as (Al, Fe, Mg, Na, Ni, Sr, and Ti) were examined in five different samples containing varying amounts of each ion [116].

The trace metals were detected in plastics waste by Siddiqui et al., 2009 via the LIBS technique. The capability of this technique is demonstrated by analyzing various trace metals present inside plastics and also compared with ICPE results. The metal concentration ppm was measured with LIBS and verified by ICPE for Ag (901), Al (522), Fe (231), Co (628), V (275), Ni (558), Pb (325), Mn (167) and Cd (378) are higher than permissible safe limits [117].

The toxic metals in polyethylene plastic were investigated by Nakashima et al., 2010 using an XRF analyzer. In these articles, the concentrations of toxic metals were estimated using a handheld XRF analyzer. Among various toxic metals, Pb and total Cr were detected in PE plastic. The concentration of Pb and total Cr of PE was estimated as 45 ± 14 mg/kg and 14 ± 6 mg/kg respectively. Thereafter, total Pb and total Cr were calculated as 10 ± 5 g and 3 ± 2 g, respectively [118].

The Bismuth atoms were detected in the polyethylene plastics using gamma-ray shielding by Sheela et al., 2020. This study confirmed that the bismuth element can be found in this material with different percentages (0%, 10%, 20%, and 40%) of bismuth in high-density polyethylene [119].

Boron ions were found with different amounts at polyethylene samples with various amounts via gamma-ray spectroscopy technique by Gunsing et al., 2017. This paper showed that the samples of polyethylene were irradiated with thermal neutrons at the reactor Orphee at Saclay in France [120].

Platinum atoms were calculated in polyethylene material samples by Kondo et al., 2017 after high-temperature processes. The results proved that the platinum element ions can be found in the Nano range [121].

Another experiment was to measure the percentage of thorium atoms in polyethylene using a D-T neutron source by Zheng et al., 2016. This study displayed that the amounts of thorium were (5.3% and 6.3%) [122].

CHAPTER FOUR

Material & Methods

4.1. Introduction:

This chapter discussed the experimental work that included the samples collection, methodology, and spectroscopy techniques that can be used to analyze the selected samples, and this chapter involved the results and discussion for each experiment as clarified in the following details:

4.2. Samples preparation:

Ten samples of drinking water were collected randomly from different locations in Khartoum state in plastic bottles. Samples were taken at the end of the fall season during a period time from (22 /10/2019) to (27/10/2019) as explained with more details below in the table (4.1), the map in figure (4.1), the figures from (4.3) to (4.12), and appendixes at the end of this thesis.

Table (4.1) Samples Locations in Khartoum State:

N. Sample	Source	Location
1	Blue Nile River	Al Mogran Station
2	White Nile River	Al Shajara Station
3	The Main Nile River	Al Manara Station
4	Sharq El Nile Locality	Al Byara Well - Block (39)
5	Bahri locality	Al Nahda Well - Block (3)
6	Khartoum Locality	Al Sooq Al Mahly Well – Block (34)
7	Jebal Aulya Locality	Abo Ayob Al Ansary Well - Block (5)
8	Um Badah Locality	Al Bostan Well - Block (47)
9	Um Durman Locality	Al Nakheel Well - Block (18)
10	Karari Locality	Al Thawra Well - Block (9)
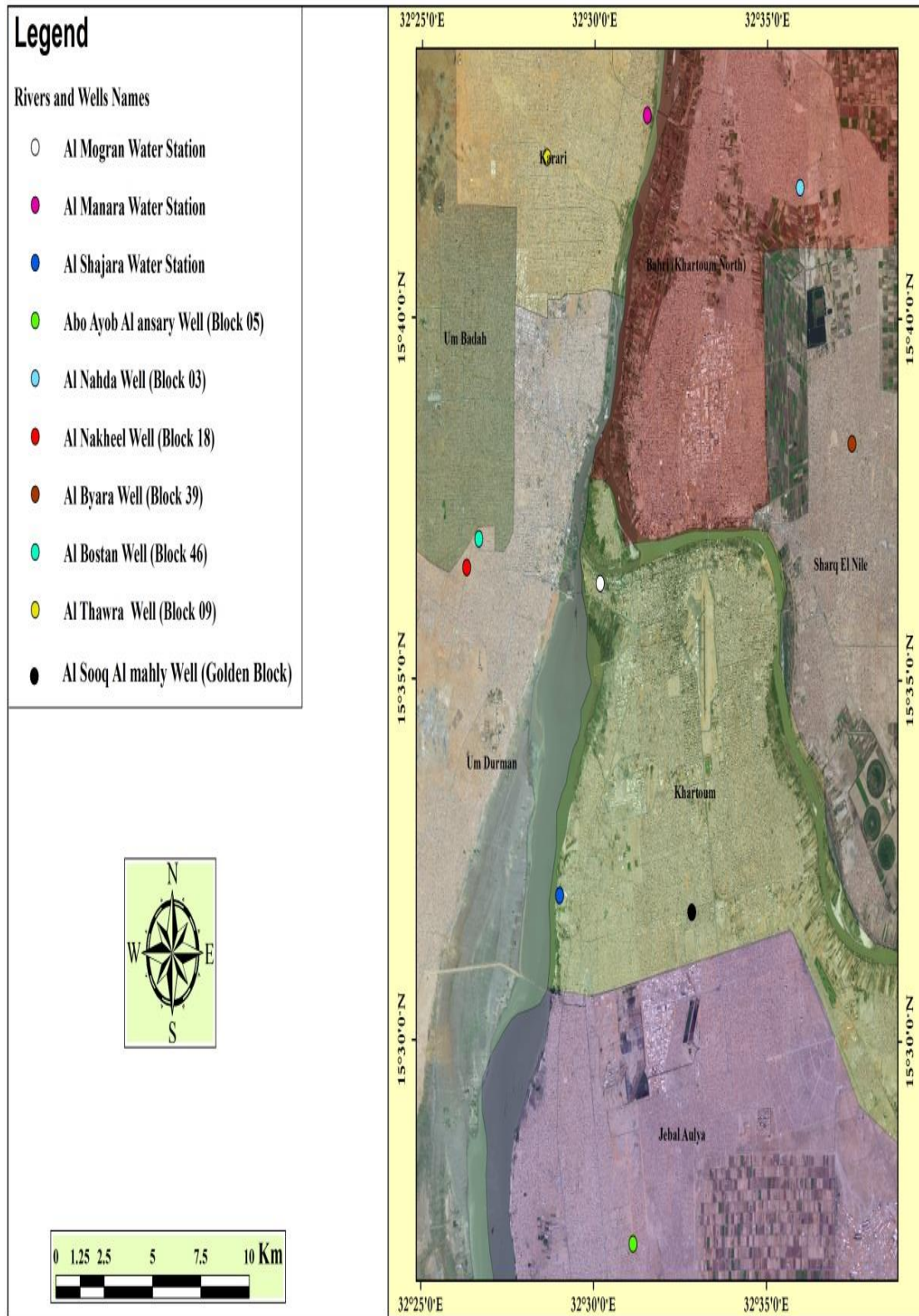
Figure (4.1) Locations of the Collected Samples in Khartoum State

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4.3. Methodology:

This part discussed the main steps of the experimental work that covered samples collection methodology and spectroscopy techniques that were used to analysis for drinking water samples which were taken from ten various locations in Khartoum state, Sudan as shown below:

➤ The plastic bottles of (1.5 L) were cleaned thoroughly with distilled water, and they were washed with the sample water to avoid any type of pollution. The bottles were filled with sample water, and they were closed very well as displayed in figure (4.2) at the following:

Figure (4.2) Model of Plastic Bottles (1.5 L)

➤ The locations of the selected samples were illustrated with more details in figures from (4.3) to (4.12) below:
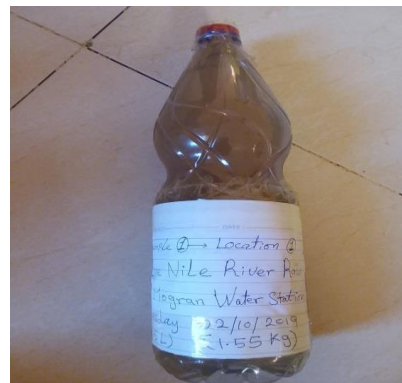
Figure (4.3.a) Location of Sample (1)

Figure (4.3.b) Bottle of Sample (1)
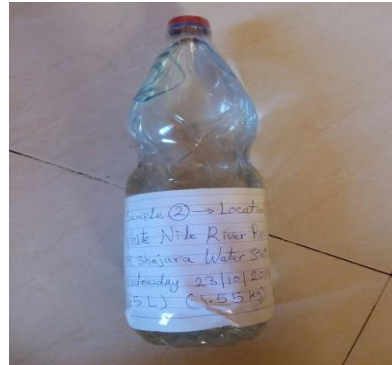
Location of Sample (2)

Figure (4.4.b) Bottle Sample (2)
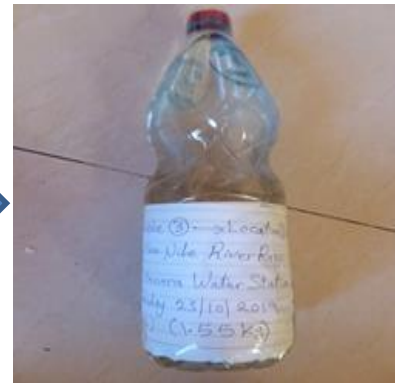
Figure (4.5.a) Location of Sample (3)

Figure (4.5.b) Bottle of Sample (3)
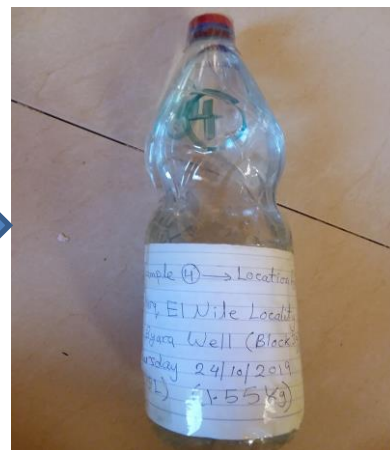
Figure (4.6.a) Location of Sample (4)

Figure (4.6.b) Bottle of Sample (4)

Figure (4.7.a) Location of Sample (5)
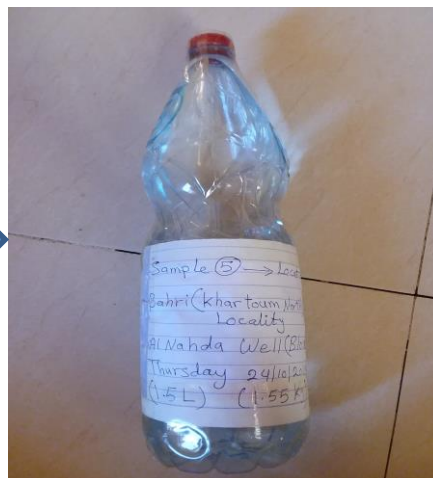
Figure (4.7.b) Bottle of Sample (5)

Figure (4.8.a) Location of Sample (6)
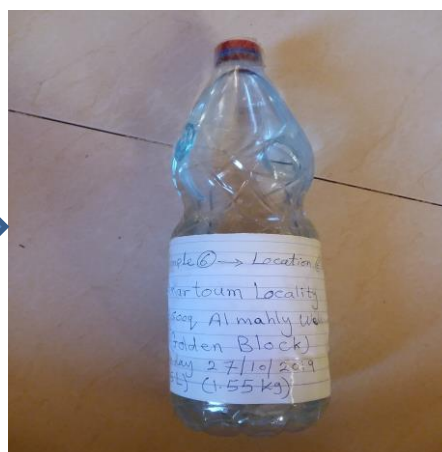
Figure (4.8.b) Bottle of Sample (6)

Figure (4.9.a) Location of Sample (7)
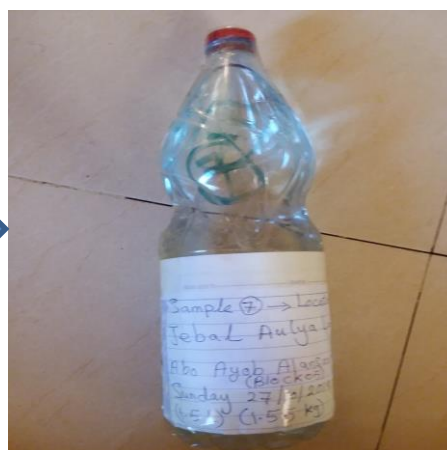
Figure (4.9.b) Bottle of Sample (7)

Figure (4.10.a) Location of Sample (8)

Figure (4.10.b) Bottle of Sample (8)

Figure (4.11.a) Location of Sample (9)
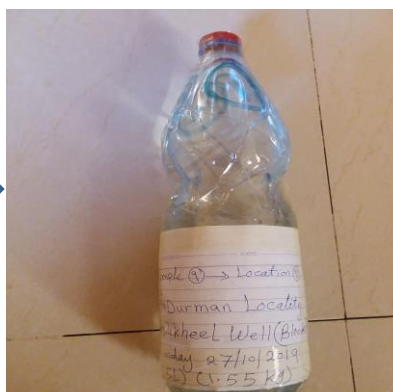
Figure (4.11.b) Bottle of Sample (9)

Figure (4.12.a) Location of Sample (10)
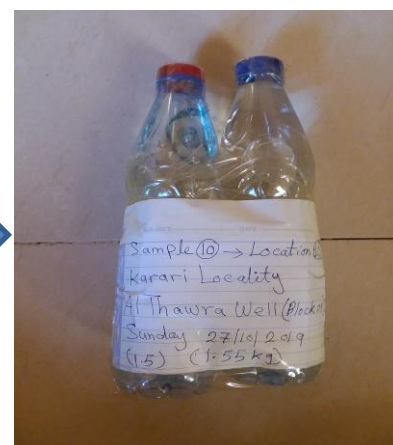
Figure (4.12.b) Bottle of Sample (10)

➢ By repeating the first step, the plastic containers of (5 ml) were filled and closed very well as clarified in figure (4.13) below. The samples were analyzed by two different spectroscopy techniques ICPE to detect and calculate the concentration of the toxic and radioactive elements before exposing samples to sunlight and the storage period, and UV-Visible to study the optical properties before exposing these samples to the normal sunlight and the storage period.

Figure (4.13) Model of Plastic Container (5ml)

➢ The plastic bottles of (350 ml) were filled and closed very well as displayed in the model in figure (4.14) below. These bottles were placed under the normal sunlight for a period time about 50 days. The temperature of the normal sunlight was recorded daily during this period time from 14/11/2019 to 2 / 1 / 2020, and the temperature average was $33^\circ C$. After that, all the ten samples were stored also for 50 days.

Figure (4.14) Samples under Sunlight

➢ The other plastic containers of (5ml) were filled again, and the samples were analyzed via the ICPE technique to detect and calculate the concentration of the toxic and radioactive elements after exposing the selected samples to the normal sunlight and the storage period.

4.4. Characterization Technique:

The toxic and radioactive metals in the several samples and the amount of them were investigated by the ICPE technique in two cases. Also, the optical properties of the prepared samples were evaluated using the UV-Visible technique as clarified in the following details:

4.4.1. ICPE Spectroscopy Technique:

All the selected samples were analyzed by ICPE spectroscopy two times before and after exposing them to the normal sunlight and the period storage as displayed with details below:

4.4.1. a. Preparing Samples for ICPE Spectroscopy:

A water sample of (5 mL) was placed in a beaker, and they were injected in (0.1 ml) of Nitric acid (HNO_3) to restrict the elements and to dissolve the residue of all contents of the samples. The beaker was heated for approximately two hours below boiling. After leaving it to cool to room temperature, it was transferred to a plastic container, made up of (5 mL) with ultrapure water to adjust the sample solution volume separately. Calibration curve samples were prepared so their acid concentration was equivalent to that present in samples used for analysis. After this step, all elements were chemically filtered in the device, and the spectra of elements were recorded on the computer screen, and the spectrum was independent for each element. These results were obtained from the ICPE at the Regional Forensic laboratories in Khartoum state, Sudan on 21/11/2019 as displayed in figure(4.15) below:

Figure (4.15) Shimadzu ICPE-9000 Manufactured in Japan

4.4.1. b. ICPE Results before Exposure to Sunlight and Storage Period:

The ten samples were analyzed using the ICPE spectroscopy techniques before exposing them to sunlight and storage period. The spectra of these samples were created manually as shown in figures from (4.16) to (4.25). The concentrations of toxic and radioactive metals were calculated by the same technique as clarified in tables from (4.2) to (4.11) below:
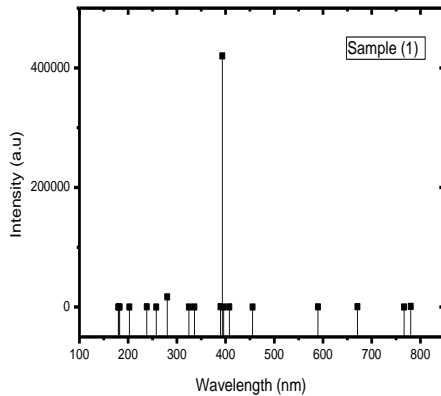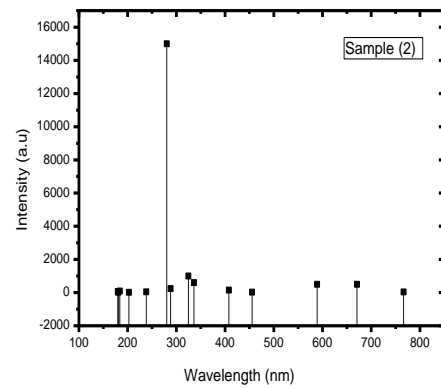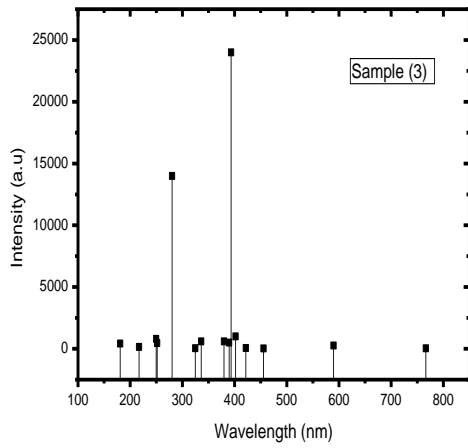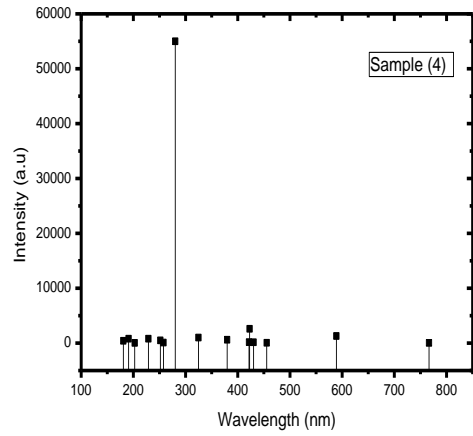
Figure (4.18) ICPE Spectra of Sample (3)
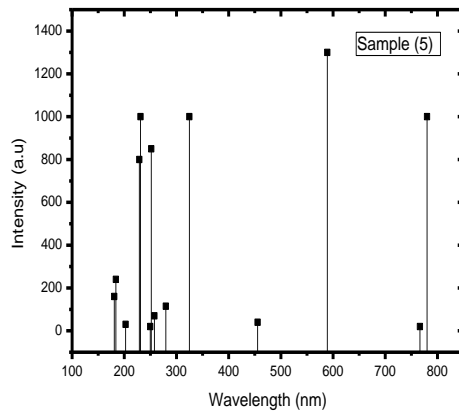
Figure (4.19) ICPE Spectra of Sample (4)
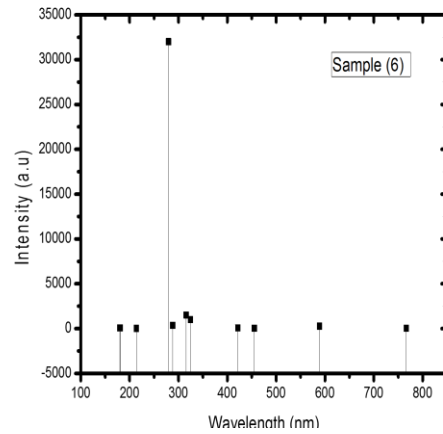
Figure (4.20) ICPE Spectra of Sample (5)

Figure (4.21) ICPE Spectra of Sample (6)
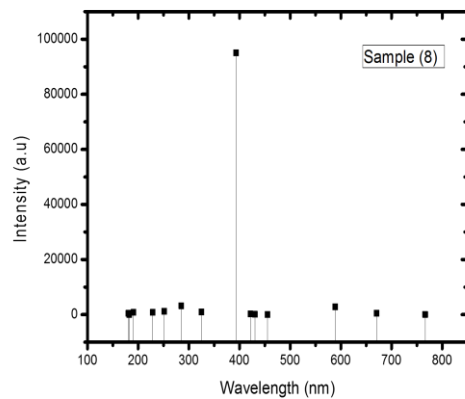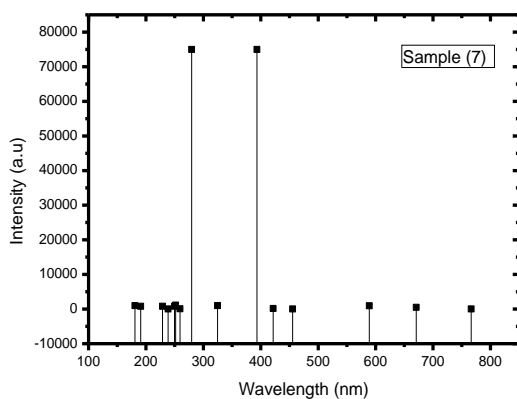
Figure (4.22) ICPE Spectra of Sample (7)   **Figure (4.23)** ICPE Spectra of Sample (8)
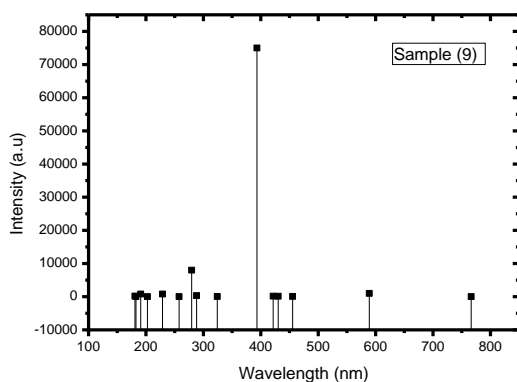
Figure (4.24) ICPE Spectra of Sample (9)   **Figure (4.25)** ICPE Spectra of Sample (10)
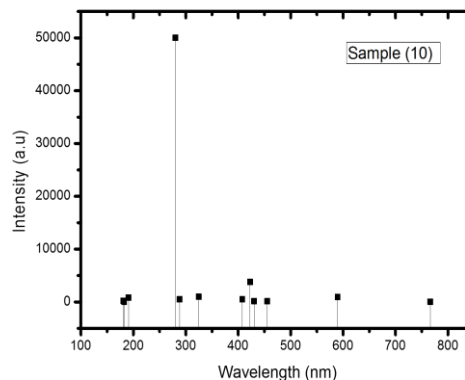
Table (4.2) Existing Elements in Sample (1):

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
Al	63 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+EPA) [123–125]	180.731	70
Ca	97 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	182.64	15
Cu	15 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+EPA) [123–125]	202.548	15
Er	12 $\mu g/L$	Low toxicity[65]	Normal (Ref) [127]	238.204	300
Fe	170 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	257.61	50

I	15 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	280.27	17000
K	3.0 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	288.158	650
Mg	140 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	324.754	45
Na	22 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+EPA) [123]–[125]	336.121	70
Rb	730 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	393.366	420000
S	930 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+EPA) [123]–[125]	396.153	55
Si	220 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	407.771	170
Ti	6.2 $\mu g/L$	Radiant [64]	Not normal (Ref) [126]	455.403	30
B	0.87 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO) [123, 124]	589.592	170
Ba	0.21 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+EPA) [123–125]	766.49	25
Li	0.05 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	389.623	500
Mn	0.75 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO) [123, 124]	780.023	1000
Sr	0.32 $\mu g/L$	Radiant [64]	Normal (Ref) [126]	670.784	500
Zn	0.95 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO) [123, 124]	179.85	70

Table (4.3) Existing Elements in Sample (2):

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
Ca	41 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	180.731	15
Cu	14 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+EPA) [123–125]	183.801	95
Fe	21 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	202.548	15
I	22 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	238.204	45
K	4.6 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	280.27	15000

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
Mg	120 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	288.158	240
Na	36 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+EPA) [123]–[125]	407.771	150
S	130 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+EPA) [123]–[125]	455.403	30
Si	75 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	588.995	500
Ba	0.24 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+EPA) [123–125]	766.49	40
Li	0.05 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	324.754	1000
Sr	0.28 $\mu g/L$	Radiant [64]	Normal (Ref) [126]	179.85	70
Ti	0.67 $\mu g/L$	Radiant [64]	Normal (Ref) [126]	670.784	500
Zn	0.48 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	336.121	600

Table (4.4) Existing Elements in Sample (3):

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
Ca	52 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	202.548	15
Cu	15 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+EPA) [123–125]	238.204	55
Er	1.8 $\mu g/L$	Low toxicity [65]	Normal (Ref) [127]	251.611	460
Fe	28 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	280.27	14000
Ho	1.2 $\mu g/L$	Low toxic[65]	Normal (Ref) [127]	393.366	24000
K	4.1 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	324.754	45
Mg	110 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	421.552	60
Na	35 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	455.403	25
Pb	6.8+ $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO) [123, 124]	589.592	260
S	180 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	766.49	40
Si	83 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	389.623	500

Sr	1.1 $\mu g / L$	Radiant [64]	Normal (Ref) [126]	379.675	600
Th	13 $\mu g / L$	Radiant [64]	Not normal (Ref) [128]	216.999	150
Ti	1.1 $\mu g / L$	Radiant [64]	Not normal (Ref) [126]	180.731	420
B	0.77 $\mu g / L$	Trace [55,56]	Normal (SSMO+WHO) [123, 124]	401.913	1000
Ba	0.18 $\mu g / L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	249.773	800
Zn	0.40 $\mu g / L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	336.121	600

Table (4.5) Existing Elements in Sample (4):

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
S	5.7 mg / L	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	180.731	420
Ca	170 $\mu g / L$	Major [55,56]	Normal (Ref) [126]	202.548	45
Cd	1.3 $\mu g / L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	251.611	500
Cu	16 $\mu g / L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	257.61	90
Ho	1.5 $\mu g / L$	Low toxicity[65]	Normal (Ref) [127]	280.27	55000
K	3.0 $\mu g / L$	Major [55,56]	Normal (Ref) [126]	421.552	170
Mg	390 $\mu g / L$	Major [55,56]	Normal (Ref) [126]	422.673	2600
Mn	1.4 $\mu g / L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	455.403	60
Na	89 $\mu g / L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	588.995	1300
Si	85 $\mu g / L$	Trace [55,56]	Normal (Ref) [126]	766.49	30
Tl	27 $\mu g / L$	Toxic [58, 59]	Not normal (EPA) [125]	228.802	800
Ba	0.62 $\mu g / L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	324.754	1000
Sc	0.31 $\mu g / L$	Low toxicity [65]	Normal (Ref) [127]	379.675	600
Sr	0.77 $\mu g / L$	Radiant [64]	Normal (Ref) [126]	190.86	800

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
Zn	0.57 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	430.358	150

Table (4.6) Existing Elements in Sample (5):

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
S	2.2 mg/L	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	180.731	160
B	1.1 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	183.801	240
Ca	120 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	202.548	30
Cu	18 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	249.773	20
K	1.9 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	251.611	850
Mg	280 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	251.611	70
Mn	2.3 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	257.61	70000
Na	87 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	421.552	115
Rb	840 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	455.403	40
Sb	7.9 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	588.995	1300
Si	150 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	766.49	20
Ba	0.38 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	324.754	1000
Cd	0.90 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	780.023	1000
Sr	0.50 $\mu g/L$	Radiant [64]	Normal (Ref) [126]	231.147	1000
Zn	0.94 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	228.802	800

Table (4.7) Existing Elements in Sample (6):

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
S	1.0 mg/L	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	180.731	80
Ca	93 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	213.856	15

Cu	17 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	279.553	32000
I	18 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	188.158	360
K	2.6 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	315.887	1500
Mg	130 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	421.552	75
Na	19 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	455.403	25
Si	100 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	588.995	280
Ba	0.16 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	766.49	25
Sr	0.30 $\mu g/L$	Radiant [64]	Normal (Ref) [126]	324.754	1000
Zn	0.64 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	179.85	70

Table (4.8) Existing Elements in Sample (7):

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
Ca	140 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	251.611	1150
Cu	18 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	259.373	90
Fe	2.3 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	279.553	75000
K	3.3 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	393.366	75000
Mg	310 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	421.552	170
Mn	3.1 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	455.403	30
Na	64 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	588.995	950
S	200 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	766.49	35
Si	200 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	324.754	1000
Tl	24 $\mu g/L$	Toxic [58, 59]	Not normal (EPA) [125]	238.623	40
B	0.80 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	180.731	1000

Ba	0.21 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	190.86	800
Cd	0.97 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	249.773	800
Li	0.07 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	228.802	800
Sr	0.74 $\mu g/L$	Radiant [64]	Normal (Ref) [126]	670.784	500

Table (4.9) Existing Elements in Sample (8):

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
S	6.7 mg/L	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	180.731	500
B	2.0 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	182.64	65
Ca	180 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	251.611	1200
Cd	1.4 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	285.213	3200
Cu	19 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	393.366	95000
K	5.3 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	421.552	260
Mg	120 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	455.403	45
Na	200 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	588.995	2800
Si	200 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	766.49	65
Sr	1.2 $\mu g/L$	Radiant [64]	Normal (Ref) [126]	228.802	800
Tl	33 $\mu g/L$	Toxic [58, 59]	Not normal (EPA) [125]	324.754	1000
Ba	0.40 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	190.86	800
Li	0.06 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	670.784	500
Sc	0.34 $\mu g/L$	Low toxicity [65]	Normal (Ref) [127]	430.358	150

Table (4.10) Existing Elements in Sample (9):

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)

S	2.6 mg/L	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	180.731	200
Ca	140 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	182.64	30
Cd	1.0 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	202.548	35
Cu	19 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	257.61	35
K	4.1 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	279.553	80000
Mg	310 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	288.158	340
Na	110 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	324.754	55
Si	90 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	393.366	75000
Tl	25 $\mu g/L$	Toxic [58, 59]	Not normal (EPA) [125]	421.552	160
B	0.84 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	455.403	75
Ba	0.78 $\mu g/L$	Toxic [58, 59]	Normal (SSMO +WHO) [123, 124]	766.49	40
Mn	0.37 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	228.802	800
Sc	0.28 $\mu g/L$	Low toxicity [65]	Normal (Ref) [127]	190.86	800
Sr	0.67 $\mu g/L$	Radiant [64]	Normal (Ref) [126]	430.358	150
Zn	0.44 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	588.995	1000

Table (4.11) Existing Elements in Sample (10):

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
S	2.9 mg/L	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	180.731	220
B	1.1 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	182.64	30
Ba	1.5 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	280.27	50000
Ca	200 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	288.158	500

Cd	1.1 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	407.771	500
Cu	18 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	422.673	3800
K	4.2 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	455.403	130
Mg	360 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	589.592	950
Na	100 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	766.49	40
Si	130 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	324.754	1000
Tl	26 $\mu g/L$	Toxic [58, 59]	Not normal (EPA) [125]	228.802	800
Sc	0.44 $\mu g/L$	Low toxicity [65]	Normal (Ref) [127]	190.86	800
Sr	0.85 $\mu g/L$	Radiant [64]	Normal (Ref) [126]	430.358	150

Discussion:

The ten samples of drinking water were injected with Nitric acid (HNO_3), and the spectra of them were obtained via the ICPE technique. The results of samples confirmed that there were 26 chemical elements were detected before exposing them to the normal sunlight and the storage period. Also, the results of the collected samples were illustrated in the figures from (4.16) to (4.25) and tables from (4.2) to (4.11) which were mentioned above.

It is clear from the results in tables from (4.2) to (4.11) that the different amounts of major or macro bio elements like (Ca, Mg, Na, K, and S) were found in all samples in various concentrations, due to the different locations of samples. These results were in good agreement with studies as documented in references in the third chapter of this thesis [87,88], [95], [98], [104]. The sulfur had high concentrations in wells that may be related to the high percentage of the sulfuric rocks in the geologic structure of wells.

The results of this experiment confirmed that the trace or micro bio elements were found in the selected samples as shown at the following details:

Copper atoms were detected in all samples with diverse amounts, due to the several locations of the selected samples, which agreed with results as proved by some researchers in some studies which were mentioned previously in chapter three [88], [90], [93,94], [98,99], [104].

Silicon atoms were discovered in all samples with various levels, due to the different sites of the collected samples.

Iron atoms were appeared just in samples (1, 2, 3, and 7) with different concentrations, and disappeared in other samples. These results may return to the locations of samples, which were agreed with results by some scientists in papers at the third section of this project [88], [92], [95], [98].

Iodine atoms were found in samples (1, 2, and 6) with various quantities, but they weren't found in samples (3, 4, 5, 7, 8, 9, and 10), due to the locations of these samples. The results of this element were confirmed by some authors in a search that was mentioned in chapter three above [88].

Rubidium atoms were observed in samples (1 and 5) with various contents, and they weren't observed in samples (2, 3, 4, 6, 7, 8, 9, and 10), due to the various positions of the collected samples.

Boron atoms were only presented in samples (1, 3, 5, 7, 8, 9, and 10) with very low levels, and they weren't presented in samples (2, 4, and 6), due to the diverse locations of the selected samples.

Lithium atoms were detected in samples (1, 2, 7, and 8) with very low amounts, and they weren't detected in samples (3, 4, 5, 6, 9, and 10), due to the sites of the samples. These results were in good agreement with results in some studies that were mentioned in the third partition of this work [88], [104].

Manganese atoms were appeared in samples (1, 2, 7, and 8) with different concentrations, and disappeared in samples (3, 4, 5, 6, 9, and 10). These results of these atoms may be due to the locations of the selected samples as shown in a lite review of this thesis [104].

Zinc atoms were viewed in samples (1, 2, 3, 4, 5, 6, and 9) with various levels, and they weren't viewed in samples (7, 8, and 10), due to positions of samples. The results of this atom were agreed with results as displayed in the studies at the third part of this thesis [92–94], [98], [104].

The results of ICPE technique proved that the heavy or toxic metals were found in the selected as shown at the following details:

Aluminum atoms were appeared only in a sample (1) with a rather high concentration, and disappeared in the other samples, due to the locations of these samples. Also, these results agreed with results as confirmed in lite reviews of this research [96]. The presence of aluminum specifically in the first sample may be due to the various solid wastes that are placed directly in the Blue Nile River. These results are due to boats and industrial ships have a role in polluting the waters of the Blue Nile River.

Barium atoms were detected in all samples with very low concentrations, due to the positions of the samples. The existence of barium in all samples may be return to rock and soil leaching with different quantities in all sources locations and vital activities that were very close to water sources like factories and farms.

Lead atoms were found only in the sample (3) with moderate concentration, and they weren't found in the other samples, due to locations of the sample as documented in studies in chapter three of this thesis [89], [91], [93,94], [96], [97], [99], [104]. The existence of lead atoms just in sample three may be related to the presence of factories on the shores of the Main Nile River at Al Manara Station and use this river to get rid of industrial waste, wastewater, garbage, wastes, and petroleum waste. The positive sign in the concentration of this element indicates the presence of numbers after the decimal point, but it does not affect the concentration value of the element.

Cadmium atoms were observed in samples (4, 5, 7, 8, 9, and10) with low levels, and they weren't observed in other samples, due to locations of the selected samples which agreed with results as displayed in papers in the third section of this work [89], [91–94], [96–98]. These results might return to related to Industrial Area that located nearly to the Al Byara Well in the Sharq El Nile Locality block (39) and   Al Nahda Well in the Bahri Locality block (3) that may cause water pollution in these wells and the appearance of some toxic elements. Also, these results may due to the waste that is buried and then leaks into the groundwater and mixes with it, causing pollution in Nakheel Well in Um Durman Locality block (18), Al Bostan Well in Um Badah Locality block (46), Al Thawra Well in Karari Badah Locality block (9), and Abu Ayob Al-Ansari Well in Jebal Aulya Locality block (5). Also, the results of these elements are due to the farms that are close to the sites of these samples. Thallium atoms were presented in samples (4, 7, 8, 9, and 10) with various contents, and they weren't presented in samples (1, 2, 3, 5, 6, and), due to locations of samples that agree with results as confirmed at study in chapter three of this research [88]. These results might be due to agricultural lands, and coal and cement factories which were very close to the Al Byara Well in the Sharq El Nile Locality block (39), Abu Ayob Al-Ansari Well in Jebel Aulya Locality block (5), Nakheel Well in Um Durman Locality block (18), Al Bostan well in Um Badah Locality block (46), and Al Thawra Well in Karari Badah Locality block (9).

Antimony atoms were discovered in the sample only in a sample (5) with a little concentration, and they weren't discovered in the other samples, due to positions of samples. The results of these elements may relate to bury industrial waste and waste that were mixed with drinking water in Al Nahda Well in the Bahri Locality block (3). Also, the use of chemical fertilizers and pesticides in agricultural areas near the location of this well can be caused by to appearance of this toxic element at this well.

Also, the rare earth elements that had low toxicity were observed in some samples as shown below:

Erbium atoms were appeared in samples (1 and 3) with different concentrations, and disappeared in samples (2, 4, 5, 6, 7, 8, 9, and 10), due to the locations of samples. The presence of this element in these samples might relate to the ratio of its natural presence in the ground soil, and the dirt were transported by torrents directly to the Blue Nile River in Al Mogran Station and the Main Nile River in Al Manara Station.

Holmium atoms were showed in samples (3, and 4) with low levels in these samples, and they weren't shown in samples (1, 2, 5, 6, 7, 8, 9, and 10), due to sites of samples. The results of these samples may return to the presence of this element in small quantities in the soil surrounding a site of Al Byara Well in the Sharq El Nile Locality, block (39), and to the presence of this element in these samples may be related to the ratio of its natural presence in the ground soil, and to the different quantities of soil and dirt that rain and torrents transport them directly to the Main Nile River in Al Manara Station.

Scandium atoms were showed in samples (4,8,9 and 10) with low levels in these samples, and they weren't shown in samples (1, 2, 3, 5, 6, and 7), due to sites of samples. The results of these samples may return to the presence of this element in small quantities in the soil surrounding a site of Al Byara Well in the Sharq El Nile Locality block (39), Al Bostan Well in Um Badah Locality block (47), Al Nakheel Well in Um Durman Locality block (18), and Al Thawra Well in Karari Locality block (9).

It is very clear from the results of this technique which were explained above that some radioactive elements were discovered in some samples as displayed below:

Titanium ions were noticed in samples (1, 2, and 3) with various amounts, and they weren't noticed in samples (4, 5, 6, 7, 8, 9, and 10), due to the locations of samples. The presence of this element only in the Blue Nile River in Al Mogran Station, the White Nile River in Al Shajara Station, and the Main Nile River in Al Manara Station may relate to the radioactive sources for medical purposes. In addition, the reason may be the pharmaceutical factories, welding workshops, and agricultural fertilizers used in farms that were very close to these sampling sites.

Thorium atoms were existed only in a sample (3), and they weren't existed in the other samples, due to the positions of samples that were in good agreement with the results as shown in a lite review of this project [88]. The existence of this element only in the Main Nile River in Al Manara Station may relate to the radioactive sources for medical purposes. Also, the reason may be the pharmaceutical factories, welding workshops, and agricultural fertilizers used in farms that were very close to these sampling sites.

Strontium atoms were appeared in all samples with different concentrations, due to locations of samples that agreed with results as documented in the third chapter of this thesis [92]. The results of this element only in the Main Nile River in Al Manara Station may relate to the radioactive sources for medical purposes. In addition, the reason may be the presence of some radioactive elements in the soil surrounding the sites of this sample. Also, the reason may be the pharmaceutical factories, welding workshops, and agricultural fertilizers used in farms that were very close to these sampling sites.

The elements like (Cu, Fe, Na, S, Ba, Cd, Sb, and Al) atoms were detected in the permissible guidelines for drinking water recommended by the (SSMO), (WHO), and (EPA) [123−125]. Also, the metals such as (B, Mn, Zn, and Pb) atoms were found with normal standard values set by (SSMO) and (WHO) [123,124]. As well, the atoms like (Ca, I, K, Mg, Rb, Si, Ti, Li, and Sr) atoms were observed in the normal limits for

drinking water that were recommended by some scientists in the main reference which display more information about the background values of the chemical elements in drinking water expect the (Ti) atoms weren't found in the normal limits just in samples (1,3) [126]. On the other hand, the rare earth elements for instance (Er, Ho, and Sc) were obtained in good permissible guidelines were recorded by some authors in the other specific reference about rare earth elements [127]. Also, (Tl) atoms weren't existed at normal limits according to EPA only in samples (4,7,8,9, and10) [125]. Also, the (Th) atoms weren't discovered in the permissible values only in a sample (3) as displayed in the main book which give more details about the normal limits of the concentration for radioactive elements in drinking water [128].

Through the experiments of the practical part of the ICPE technique, it is clear from the results obtained were the best results by this technique because these results had a higher accuracy than other spectroscopy technique used in the detection of the toxic and radioactive elements. Also, this technique is used to calculate the concentrations of these chemical elements directly in the selected samples

4.4.1. c. ICPE Results after Exposure to Sunlight and Storage Period:

The collected samples were placed under normal sunlight for 50 days, and they were stored also for 50 days. After that, all samples were analyzed by ICPE technique at the same lab which was mentioned above as displayed in figures from (4.26) to (4.35) and tables from (4.12) to (4.21) as displayed below:
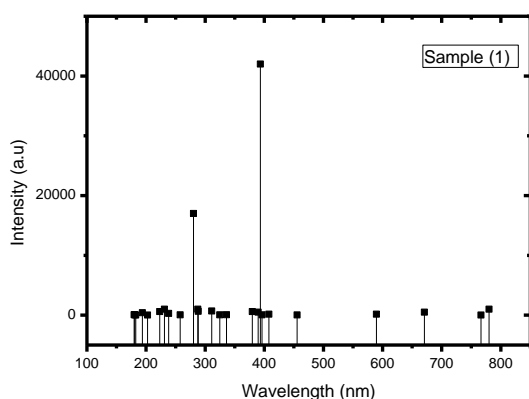
Figure (4.26) ICPE Spectra of Sample (1)
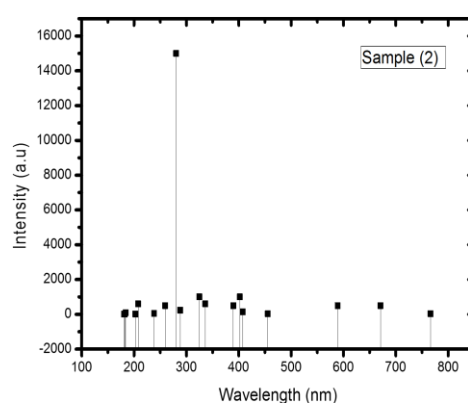
Figure (4.27) ICPE Spectra of Sample (2)
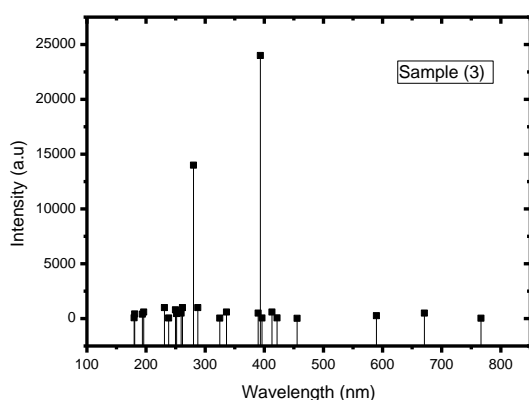
Figure (4.28) ICPE Spectra of Sample (3)
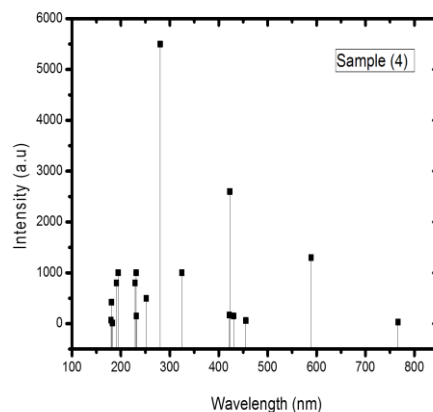
Figure (4.29) ICPE Spectra of Sample (4)
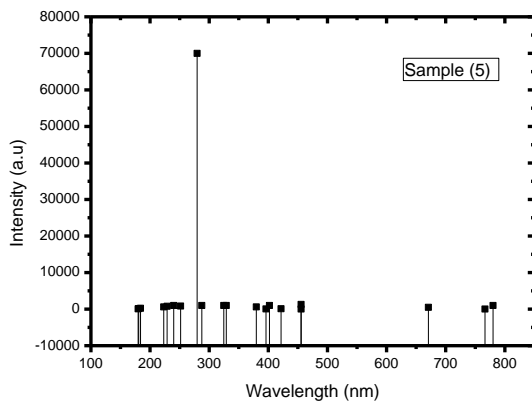
Figure (4.30) ICPE Spectra of Sample (5)
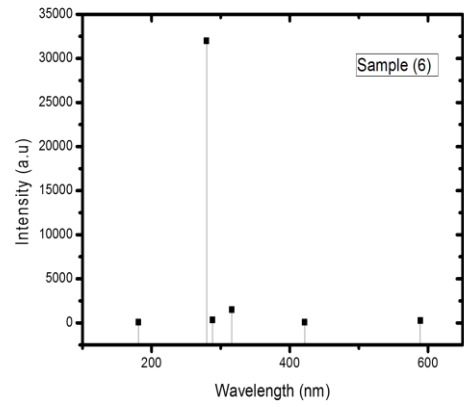
Figure (4.31) ICPE Spectra of Sample (6)
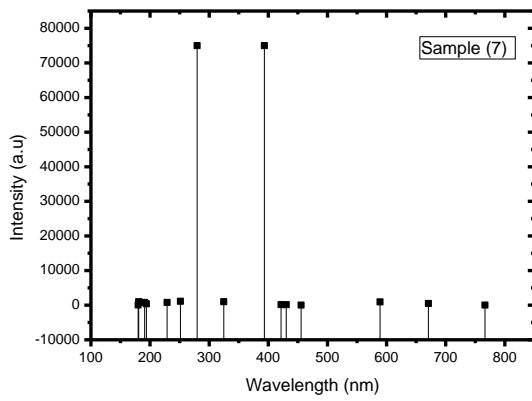
Figure (4.32) ICPE Spectra of Sample (7)
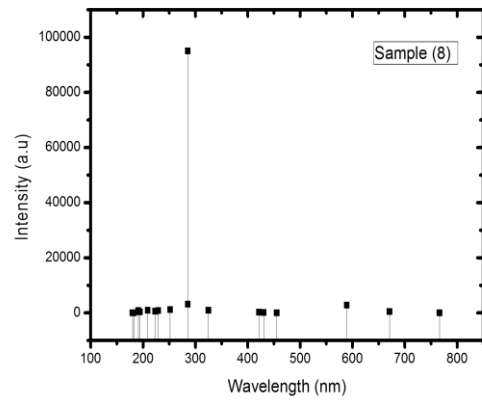
Figure (4.33) ICPE Spectra of Sample (8)
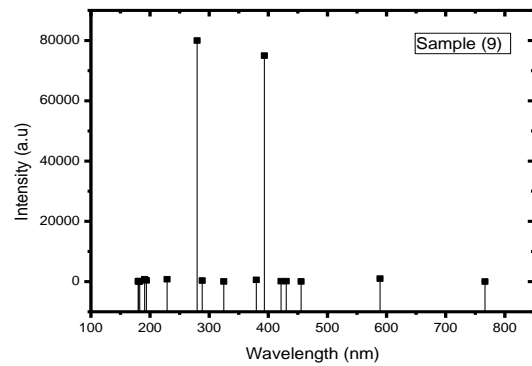
Figure (4.34) ICPE Spectra of Sample (9)
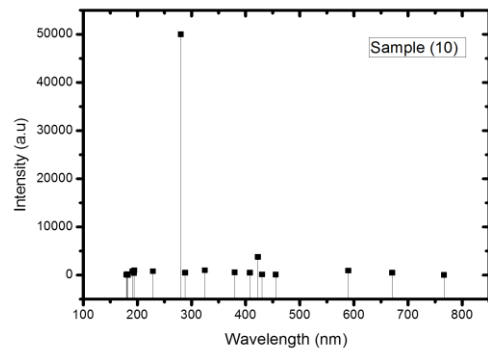
Figure (4.35) ICPE Spectra of Sample (10)

Table (4.12) Existing Elements in Sample (1):

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
Al	29 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	396.153	55
As	12+ $\mu g/L$	Toxic [58, 59]	Not Normal (SSMO+WHO+EPA) [123–125]	193.759	400
Bi	4.8 $\mu g/L$	Toxic [58, 59]	Not Normal (Ref) [129]	223.1	600
Ca	100 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	393.366	42000
Cu	11 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	324.754	45
Er	4.6 $\mu g/L$	Low toxicity [65]	Normal (Ref) [127]	389.623	500
Fe	43 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	238.204	300
Ho	1.5 $\mu g/L$	Low toxicity [65]	Normal (Ref) [127]	379.675	600
I	12 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	179.85	70
K	1.6 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	766.49	25
Mg	100 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	280.27	17000
Na	15 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	589.592	170
Pt	23 $\mu g/L$	Low toxicity [65]	Normal (Ref) [130]	287.563	1000
Rb	700 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	780.023	1000
S	730 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	180.731	70
Sb	5.9 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	231.147	1000
Si	95 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	288.158	650
Ti	2.5 $\mu g/L$	Radiant [64]	Not Normal (Ref) [126]	336.121	70
B	0.49 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	182.548	15
Ba	0.14 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	455.403	30

Li	0.05 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	670.784	500
Mn	0.35 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	257.61	50
Sr	0.35 $\mu g/L$	Radiant [64]	Normal (Ref) [126]	407.771	170
V	0.22 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	311.071	700
Zn	0.26 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	202.548	15

Table (4.13) Existing Elements in Sample (2):

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
Ca	60 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	183.801	95
Cu	13 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	324.754	1000
Er	1.4 $\mu g/L$	Low toxic[65]	Normal (Ref) [127]	389.623	500
Fe	11 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	238.204	45
K	3.8 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	766.49	40
Mg	120 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	280.27	15000
Na	29 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	588.995	500
S	110 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	180.731	15
Si	60 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	288.158	240
Th	8.9 $\mu g/L$	Radiant [64]	Not normal (Ref) [128]	401.913	1000
W	13 $\mu g/L$	Low toxicity [65]	Not normal (EPA) [131]	207.911	600
B	0.55 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	182.548	15
Ba	0.27 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	455.403	30
Li	0.05 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	670.784	500
Mn	0.15 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	259.373	500

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
Sr	0.39 $\mu g/L$	Radiant [64]	Normal (Ref) [126]	407.771	150
Ti	0.74 $\mu g/L$	Radiant [64]	Normal (Ref) [126]	336.121	600
Zn	0.22 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	202.548	15

Table (4.14) Existing Elements in Sample (3):

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
Al	22 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	396.153	55
As	12+ $\mu g/L$	Toxic [58, 59]	Not Normal (SSMO+WHO+EPA) [123–125]	193.759	400
Ca	73 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	393.366	24000
Cu	11 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	324.754	45
Er	2.4 $\mu g/L$	Low toxicity [65]	Normal (Ref) [127]	389.623	500
Fe	24 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	238.204	55
I	11 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	179.85	70
K	3 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	766.49	40
Mg	120 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	280.27	14000
Na	28 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	589.592	260
Pt	19 $\mu g/L$	Low toxicity [65]	Normal (Ref) [130]	287.563	1000
S	170 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	180.731	420
Sb	8 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	231.147	1000
Se	11 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	196.099	600
Si	70 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	251.611	460
Ti	1.4 $\mu g/L$	Radiant [64]	Not normal (Ref) [126]	336.121	600
B	0.60 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	249.773	800

Ba	0.23 $\mu g / L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	455.403	25
Eu	0.18 $\mu g / L$	Low toxicity [65]	Normal (Ref) [127]	412.97	600
Li	0.04 $\mu g / L$	Trace [55,56]	Normal (Ref) [126]	670.784	500
Lu	0.19 $\mu g / L$	Low toxicity [65]	Normal (Ref) [127]	261.542	1000
Mn	0.17 $\mu g / L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	259.373	500
Sr	0.34 $\mu g / L$	Radiant [64]	Normal (Ref) [126]	421.552	60

Table (4.15) Existing Elements in Sample (4):

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
S	4.7mg / L	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	180.731	420
Ca	190 $\mu g / L$	Major [55,56]	Normal (Ref) [126]	422.673	2600
Cd	1.1 $\mu g / L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	228.802	800
Cu	14 $\mu g / L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	324.754	1000
Hg	1.1 $\mu g / L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	194.227	1000
I	9.5 $\mu g / L$	Trace [55,56]	Normal (Ref) [126]	179.85	70
K	2.6 $\mu g / L$	Major [55,56]	Normal (Ref) [126]	766.49	30
Mg	93 $\mu g / L$	Major [55,56]	Normal (Ref) [126]	280.27	5500
Na	72 $\mu g / L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	588.995	1300
Ni	3.7 $\mu g / L$	Toxic [58, 59]	Normal (SSMO +WHO) [123, 124]	231.604	150
Si	67 $\mu g / L$	Trace [55,56]	Normal (Ref) [126]	251.611	500
Sb	6.9 $\mu g / L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	231.604	150
Tl	24 $\mu g / L$	Toxic [58, 59]	Not Normal (EPA) [125]	190.86	800
B	0.60 $\mu g / L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	182.64	15

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
Ba	0.65 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	455.403	60
Sc	0.23 $\mu g/L$	Low toxicity [65]	Normal (Ref) [127]	430.358	150
Sr	0.96 $\mu g/L$	Radiant [64]	Normal (Ref) [126]	421.552	170

Table (4.16) Existing Elements in Sample (5):

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
S	1.7 mg/L	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	180.731	160
Al	230 $\mu g/L$	Toxic [58, 59]	Not normal (SSMO+WHO+EPA) [123–125]	396.153	55
Bi	4.3 $\mu g/L$	Toxic [58, 59]	Not normal (Ref) [129]	223.1	600
Ca	23 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	183.801	240
Cu	7.7 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	324.754	1000
Ho	1.3 $\mu g/L$	Low toxic[65]	Normal (Ref) [127]	379.675	600
I	16 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	179.85	75
K	1.4 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	766.49	20
Mg	39 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	279.553	70000
Na	68 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	455.403	1300
Pt	22 $\mu g/L$	Low toxic[65]	Normal (Ref) [130]	287.563	1000
Rb	650 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	780.023	1000
Si	31 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	251.611	850
Ta	4.5 $\mu g/L$	Toxic [58, 59]	Not normal (Ref) [132]	240.063	1000
Th	6.7 $\mu g/L$	Radiant [64]	Not normal (Ref) [128]	401.913	1000
Ba	0.12 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	455.403	40
Cd	0.40 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	228.802	800

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
Li	0.05 $\mu g / L$	Trace [55,56]	Normal (Ref) [126]	670.784	500
Sr	0.89 $\mu g / L$	Radiant [64]	Normal (Ref) [126]	421.552	115
Yb	0.07 $\mu g / L$	Low toxic[65]	Normal (Ref) [127]	328.937	1000

Table (4.17) Existing Elements in Sample (6):

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
Ca	88 $\mu g / L$	Major [55,56]	Normal (Ref) [126]	315.887	1500
Mg	130 $\mu g / L$	Major [55,56]	Normal (Ref) [126]	279.553	32000
Na	12 $\mu g / L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	588.995	280
S	54 $\mu g / L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	180.731	80
Si	69 $\mu g / L$	Trace [55,56]	Normal (Ref) [126]	288.158	360
Sr	0.10 $\mu g / L$	Radiant [64]	Normal (Ref) [126]	421.552	75

Table (4.18) Existing Elements in Sample (7):

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
As	12 $\mu g / L$	Toxic [55,56]	Not normal (SSMO+WHO+EPA) [123–125]	193.759	400
Ca	120 $\mu g / L$	Major [55,56]	Normal (Ref) [126]	393.366	75000
Cu	13 $\mu g / L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	324.754	1000
I	17 $\mu g / L$	Trace [55,56]	Normal (Ref) [126]	179.85	70
K	3.5 $\mu g / L$	Major [55,56]	Normal (Ref) [126]	766.49	35
Mg	65 $\mu g / L$	Major [55,56]	Normal (Ref) [126]	279.553	75000
Na	55 $\mu g / L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	588.995	950
S	79 $\mu g / L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	180.731	1000
Si	160 $\mu g / L$	Trace [55,56]	Normal (Ref) [126]	251.373	1150

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
Tl	18 $\mu g/L$	Toxic [58, 59]	Not normal (EPA) [125]	190.86	800
Ba	0.18 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	455.403	30
Cd	0.84 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	228.802	800
Li	0.04 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	670.784	500
Sc	0.20 $\mu g/L$	Low toxic[65]	Normal (Ref) [127]	430.358	150
Sr	0.80 $\mu g/L$	Radiant [64]	Normal (Ref) [126]	421.552	170

Table (4.19) Existing Elements in Sample (8):

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
S	5.5mg/L	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	190.731	500
As	10 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	193.759	400
B	1.4 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	182.64	65
Bi	4.9 $\mu g/L$	Toxic [58, 59]	Not normal (Ref) [129]	223.1	600
Ca	210 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	285.213	95000
Cd	1.2 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	228.802	800
Cu	12 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	324.754	1000
I	17 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	179.85	70
Ir	29 $\mu g/L$	Radiant [64]	Normal (Ref) [126]	208.882	1000
K	5.4 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	766.49	65
Mg	110 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	285.213	3200
Na	170 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	588.995	2800
Si	170 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	251.611	1200
Sr	1.5 $\mu g/L$	Radiant [64]	Normal (Ref) [126]	421.552	260

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
Tl	28 $\mu g/L$	Toxic [58, 59]	Not normal (EPA) [125]	190.86	800
Ba	0.45 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	455.403	45
Li	0.06 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	670.784	500
Sc	0.23 $\mu g/L$	Low toxicity[65]	Normal (Ref) [127]	430.358	150

Table (4.20) Existing Elements in Sample (9):

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
S	2.1mg/L	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	180.731	200
As	12 $\mu g/L$	Toxic [58, 59]	Not normal (SSMO+WHO+EPA) [123–125]	193.759	400
Ca	200 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	393.366	75000
Cu	13 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	324.754	55
Ho	1.3 $\mu g/L$	Low toxicity[65]	Normal (Ref) [127]	379.675	600
I	11 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	179.85	70
K	3.8 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	766.49	40
Mg	310 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	279.553	80000
Na	96 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	588.995	1000
Si	70 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	288.158	340
Tl	22 $\mu g/L$	Toxic [58, 59]	Not Normal (EPA) [125]	190.86	800
B	0.68 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	182.64	30
Ba	0.89 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	455.403	75
Cd	0.82 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	228.802	800
Sc	0.19 $\mu g/L$	Low toxicity[65]	Normal (Ref) [127]	430.358	150
Sr	0.84 $\mu g/L$	Radiant [64]	Normal (Ref) [126]	421.552	160

Table (4.21) Existing Elements in Sample (10):

Element	Content	Type	Standards	Wavelength (nm)	Intensity (a.u)
S	2.5 mg/L	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	180.731	220
As	11 $\mu g/L$	Toxic [58, 59]	Not normal (SSMO+WHO+EPA) [123–125]	193.759	400
B	1.1 $\mu g/L$	Trace [55,56]	Normal (SSMO +WHO) [123, 124]	182.64	30
Ba	1.9 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	455.403	130
Ca	250 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	422.673	3800
Cd	1.1 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	228.802	800
Cu	13 $\mu g/L$	Trace [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	324.754	1000
Ho	1.4 $\mu g/L$	Low toxicity [65]	Normal (Ref) [127]	379.675	600
I	8.6 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	179.85	70
K	3.9 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	766.49	40
Mg	88 $\mu g/L$	Major [55,56]	Normal (Ref) [126]	280.27	50000
Na	89 $\mu g/L$	Major [55,56]	Normal (SSMO+WHO+ EPA) [123–125]	589.592	950
Si	100 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	288.158	500
Sr	1.2 $\mu g/L$	Radiant [64]	Normal (Ref) [126]	407.771	500
Tl	23 $\mu g/L$	Toxic [58, 59]	Not Normal (EPA) [125]	190.86	800
Hg	0.99 $\mu g/L$	Toxic [58, 59]	Normal (SSMO+WHO+ EPA) [123–125]	194.227	1000
Li	0.05 $\mu g/L$	Trace [55,56]	Normal (Ref) [126]	670.784	500
Sc	0.29 $\mu g/L$	Low toxicity [65]	Normal (Ref) [127]	430.358	150

Discussion:

The results in figures from (4.26) to (4.35) and tables from (4.12) to (4.21) proved that the new elements were appeared in some samples after exposing them to the normal sunlight and the storage period such as (As, Bi, Pt, V, W, Se, Eu, Lu, Ta, Ir, Hg, Ni, and Yb). Also, some harmful elements were repeated again in some samples only after placed them under sunlight and storage period like (Sb, Er, Th, B, Mn, Al, I, Li, Sc, Ir, and Ho). These elements were included trace, toxic, low toxicity, and radioactive, elements as clarified below:

It is very clear from results in the spectrum from (4.26) to (4.35) and tables from (4.12) to (4.21) that the trace or micro bio elements were detected in many samples as shown below:

Selenium atoms were detected only in a sample (3) with a low level, and they weren't detected in the other samples, due to the interaction between water and the plastic material of bottles. These results were confirmed by some researchers in the third section of this project [114].

Vanadium atoms existed only in a sample (1) with a little amount, and they weren't existed in the other samples, due to the interaction between water and the plastic material bottles during the samples were placed under the normal sunlight. These results agreed with results in the third section of this thesis [117].

Manganese atoms were viewed in the samples (2 and 3) with low concentrations, and they weren't viewed in the other samples, due to the interaction between the plastic bottles and water during exposure to these samples to the sunlight. The results were agreed with results in the third side of this work [117].

Boron atoms were occurred only element in the sample (2) with low content, and they weren't occurred in the other samples, due to the interaction between the plastic material and the water molecules. These results were in good agreement with the results in the third fraction of this research [111].

Lithium atoms were detected in the sample (3, 5, and 10) with different concentrations, and they weren't detected in the other samples, due to the storage period after exposing these samples to sunlight as documented by some researchers in chapter three of this work [107,108],[110],[112,113].

Iodine ions were found in some samples (3, 4, 5, 7, 8, 9, and 10) with different amounts, and they weren't found in the other samples, due to the storage period after exposing these samples to sunlight as confirmed by some authors in third chapter of this research [107,108],[110],[112,113].

The results of ICPE technique after exposing the samples to sunlight and the storage period showed that the toxic elements were discovered in some drinking water samples as displayed below:

Arsine atoms were appeared in samples (1, 3, 7, 8, 9, and 10) with different concentrations, and disappeared in samples (2, 4, 5, and 6), due to the interaction between water and the plastic material during the samples were placed under the normal sunlight. Also, the results of this element were in good agreement with results in papers in the third part of this dissertation [111], [114,115]. The positive sign in the concentration of this element indicates the presence of numbers after the decimal point, but it does not affect the concentration value of the element.

It is clear from the results above that the bismuth atoms were found in samples (1, 5, and 8) with different levels, and they weren't found in samples (2, 3, 4, 6, 7, 9, and 10), due to the interaction between water and the plastic material during the samples were placed under the normal sunlight. These results may be related to the interaction between plastic and water during exposure these samples to the sunlight, and these results of these atoms were in good agreement with results in the second side of this Experimental work [119].

Mercury atoms were found as a toxic element only in samples (4, 10) with several concentrations, and they weren't found in the other samples, due to the

interaction between water and the plastic material bottles. These results were proved by some scientists in chapter three of this project [114].

Nickel atoms were existed just in the sample (4) with specific content and weren't existed in the other samples, due to the interaction between water and the plastic material and the storage period. These results were with good agreement in the third side of this work [109], [116].

Tantalum atoms were existed only in a sample (5) with low level, and they weren't existed in the other samples, due to the storage period after exposure the sample to sunlight as documented by some scientists in lite review of this thesis [107,108], [110], [112,113].

Antimony atoms were seen on the samples (1, 3, and 4), and they weren't seen in the other samples, due to the interaction between plastic bottles and water and the time of the storage period. These results were agreed with results in the third part of this project [109].

Aluminum atoms were discovered in the samples (3 and 5) with a little amount, and they weren't discovered in the other samples, due to the interaction between the polyethylene material and the water. These results were confirmed by some researches in chapter three of this thesis [116,117].

Also, this experimental work confirmed that there were some chemical elements were detected as elements had low toxicity were included rare earth elements and other elements as shown with more details at the following:

Some rare earth elements were appeared as elements that had low toxicity with different amounts in some samples after exposing them to sunlight like Europium and Lutetium atoms were observed just in a sample (3) as rare earth elements with several concentrations, and they weren't observed in other samples. Holmium atoms were existed in samples (1, 5, 9, and 10), and they weren't existed in the other samples. Erbium ions were remarked only in sample (2), and they weren't remarked in the other samples. Ytterbium atoms were found just in a sample (5), and they weren't found in

other samples. Scandium atoms were noted only in a sample (7), and they weren't noted in the other samples. These results may be related to the dirt that sticks to the plastic bottles while exposed to the sun due to the wind and the nature of the weather in the state of Khartoum, which is likely to have a role in the interaction process between water and plastic bottles as proved by some authors in some papers in the third part of this work [107,108], [110], [112,113].

Platinum atoms were discovered in samples (1, 3, and 5) with various contents that have low toxicity, and they weren't discovered in samples (2, 4, 6, 7, 8, 9, and 10), due to the interaction between water and the plastic material. These results were agreed with results in chapter three of this work [121].

Tungsten atoms appeared only in a sample (2) with a little level, and disappeared in the other samples, due to the storage period after exposing this sample to sunlight as confirmed by some researchers in some papers in the third chapter of this project [107,108], [110], [112,113].

The results of this technique proved that the radioactive elements were found in some samples after exposing them to the normal sunlight and the storage period as clarified below:

Iridium atoms were appeared only in a sample (8) as a radioactive element, and disappeared in the other samples with a little amount, due to the storage period after exposure to the sample to sunlight [107,108], [110],[112,113].

Thorium ions were found out just in the samples (2 and 5) with a little quantity, and they weren't found out in the other samples, due to the interaction between the polyethylene materials during exposing the samples to sunlight. These results were agreed with the results only in one study in lite review of this thesis [107].

The atoms like (As, Hg, Ba, Al, Sb, Cd) were appeared in the permissible guidelines for drinking water recommended by the (SSMO), (WHO), and (EPA) except Al in a sample (5), and As in samples (1,3,7, 9, and 10) [123–125].

The Ni atoms were found with normal standard values set by (SSMO) and (WHO) [123,124]. The (Lu, Eu, Ho, Er, Sc, and Yb) atoms have existed in the normal limits as shown in background values that have been documented in an important book about rare earth elements [127]. The elements like (Se, V, Sr, and Ir) were detected in the permissible values that were recorded by some researchers in the other references which show the values about the concentration for these elements in drinking water [126]. The (Bi) atoms were discovered in the not normal levels as displayed in the main source about this element in drinking water [129].

The (Pt) atoms were observed in good standards values as documented in the main book about this element in drinking water [130]. The (W) atoms in a sample (2) were existed in not normal concentrations be based as shown in the other reference about this element in drinking water [131]. The (Ta) atoms were proved in not good guidelines values in a sample (5) as obtained in the other book which was display more details about the standards values for this element in drinking water [132].

The (Tl) atoms were observed in the not normal limits were recommended by EPA in samples (4, 7, 8, 9, and 10) [125]. The (Ti) atoms weren't found in the permissible guidelines for drinking water in samples (1,3) that were recommended by some researchers in the main book about this chemical element in drinking water [126]. Also, (Th) atoms were detected in not permissible guidelines for drinking water in samples (2,5) as displayed in the main sources which was give more information about the amounts of this chemical element in drinking water [128].

Table (4.22) Comparing between the ICPE Results before and after Exposure to the Normal Sunlight and Storage Period:

ICPE Results before Exposure Samples to Sunlight and Storage Period																			
Sample (1)		Sample (2)		Sample (3)		Sample (4)		Sample (5)		Sample (6)		Sample (7)		Sample (8)		Sample (9)		Sample(10)	
Ele	Con	Ele	Con	Ele	Con	Ele	Con	Ele	Con	Ele	Con	Ele	Con	Ele	Con	Ele	Con	Ele	Con
Al	63 µg/L	Ca	41 µg/L	Ca	52 µg/L	S	5700 µg/L	S	2200 µg/L	S	1000 µg/L	Ca	140 µg/L	S	6700 µg/L	S	2600 µg/L	S	2900 µg/L
Ca	97 µg/L	Cu	14 µg/L	Cu	15 µg/L	Ca	170 µg/L	B	1.1 µg/L	Ca	93 µg/L	Cu	18 µg/L	B	2 µg/L	Ca	140 µg/L	B	1.1 µg/L
Cu	15 µg/L	Fe	21 µg/L	Fe	28 µg/L	Cd	1.3 µg/L	Ca	120 µg/L	Cu	17 µg/L	Fe	2.3 µg/L	Ca	180 µg/L	Cd	1 µg/L	Ba	1.5 µg/L
Er	12 µg/L	I	22 µg/L	K	4.1 µg/L	Cu	16 µg/L	Cu	18 µg/L	I	18 µg/L	K	3.3 µg/L	Cd	1.4 µg/L	Cu	19 µg/L	Ca	200 µg/L
Fe	170 µg/L	K	4.6 µg/L	Mg	110	Ho	1.5 µg/L	K	1.9 µg/L	K	2.6 µg/L	Mg	310 µg/L	Cu	19 µg/L	K	4.1 µg/L	Cd	1.1 µg/L
I	15 µg/L	Mg	120 µg/L	Na	35 µg/L	K	3 µg/L	Mg	280 µg/L	Mg	130 µg/L	Mn	3.1 µg/L	K	5.3 µg/L	Mg	310 µg/L	Cu	18 µg/L
K	3 µg/L	Na	36 µg/L	S	180 µg/L	Mg	390 µg/L	Mn	2.3 µg/L	Na	19 µg/L	Na	64 µg/L	Mg	120 µg/L	Na	110 µg/L	K	4.2 µg/L
Mg	140 µg/L	S	130 µg/L	Si	83 µg/L	Mn	1.4 µg/L	Na	87 µg/L	Si	100 µg/L	S	200 µg/L	Na	200 µg/L	Si	90 µg/L	Mg	360 µg/L
Na	22 µg/L	Si	75 µg/L	Ti	1.1 µg/L	Na	89 µg/L	Rb	840 µg/L	Ba	0.16 µg/L	Si	200 µg/L	Si	220 µg/L	Tl	25 µg/L	Na	100 µg/L
Rb	730 µg/L	Ti	0.67 µg/L	Ba	0.18 µg/L	Si	85 µg/L	Sb	7.9 µg/L	Sr	0.3 µg/L	Tl	24 µg/L	Sr	1.2 µg/L	B	0.84 µg/L	Si	130 µg/L

Ele= Element
Con= Concentration

S	930 µg/L	Ba	0.24 µg/L	Sr	1.1 µg/L	Tl	27 µg/L	Si	150 µg/L	Zn	0.64 µg/L	B	0.8 µg/L	Tl	33 µg/L	Ba	0.78 µg/L	Tl	26 µg/L
Si	220 µg/L	Li	0.05 µg/L	Zn	0.4 µg/L	Ba	0.62 µg/L	Ba	0.38 µg/L	-	-	Ba	0.21 µg/L	Ba	0.4 µg/L	Mn	0.37 µg/L	Sc	0.44 µg/L
Ti	6.2 µg/L	Sr	0.28 µg/L	Er	1.8 µg/L	Sc	0.31 µg/L	Cd	0.9 µg/L	-	-	Cd	0.97 µg/L	Li	0.06 µg/L	Sc	0.28 µg/L	Sr	0.85 µg/L
B	0.87 µg/L	Zn	0.48 µg/L	Th	13 µg/L	Sr	0.77 µg/L	Sr	0.5 µg/L	-	-	Li	0.07 µg/L	Sc	0.34 µg/L	Sr	0.67 µg/L	As	0
Ba	0.21 µg/L	Er	0	B	0.77 µg/L	Zn	0.57 µg/L	Zn	0.94 µg/L	-	-	Sr	0.74 µg/L	As	0	Zn	0.44 µg/L	Ho	0
Li	0.05 µg/L	Th	0	Ho	1.2 µg/L	Hg	0	Al	0	-	-	As	0	Bi	0	As	0	I	0
Mn	0.75 µg/L	W	0	Pb	6.8 µg/L	I	0	Bi	0	-	-	I	0	I	0	Ho	0	Hg	0
Sr	0.32 µg/L	B	0	Al	0	Ni	0	Ho	0	-	-	Sc	0	Ir	0	I	0	-	-
Zn	0.95 µg/L	Mn	0	As	0	Sb	0	I	0	-	-	-	-	-	-	-	-	-	-
As	0	-	-	I	0	B	0	Pt	0	-	-	-	-	-	-	-	-	-	-
Bi	0	-	-	Pt	0	-	-	Ta	0	-	-	-	-	-	-	-	-	-	-
Ho	0	-	-	Sb	0	-	-	Th	0	-	-	-	-	-	-	-	-	-	-
Pt	0	-	-	Se	0	-	-	Li	0	-	-	-	-	-	-	-	-	-	-
Sb	0	-	-	Eu	0	-	-	Yb	0	-	-	-	-	-	-	-	-	-	-
V	0	-	-	Li	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	Lu	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	Mn	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

ICPE Results after Exposure Samples to Sunlight and Storage Period

Sample(1)		Sample(2)		Sample (3)		Sample (4)		Sample (5)		Sample (6)		Sample (7)		Sample (8)		Sample (9)		Sample(10)	
Ele	Con	Ele	Con	Ele	Con	Ele	Con	Ele	Con	Ele	Con	Ele	Con	Ele	Con	Ele	Con	Ele	Con
Al	29 µg/L	Ca	60 µg/L	Ca	73 µg/L	S	4700 µg/L	S	1700 µg/L	S	54 µg/L	Ca	120 µg/L	S	5500 µg/L	S	2100 µg/L	S	2500 µg/L
Ca	100 µg/L	Cu	13 µg/L	Cu	11 µg/L	Ca	190 µg/L	B	0	Ca	88 µg/L	Cu	13 µg/L	B	1.4 µg/L	Ca	200 µg/L	B	1.1 µg/L
Cu	11 µg/L	Fe	11 µg/L	Fe	24 µg/L	Cd	1.1 µg/L	Ca	23 µg/L	Cu	0	Fe	0	Ca	210 µg/L	Cd	0.82 µg/L	Ba	1.9 µg/L
Er	4.6 µg/L	I	0	K	3 µg/L	Cu	14 µg/L	Cu	7.7 µg/L	I	0	K	3.5 µg/L	Cd	1.2 µg/L	Cu	13 µg/L	Ca	250 µg/L
Fe	43 µg/L	K	3.8 µg/L	Mg	120 µg/L	Ho	0	K	1.4 µg/L	K	0	Mg	65 µg/L	Cu	12 µg/L	K	3.8 µg/L	Cd	1.1 µg/L
I	12 µg/L	Mg	120 µg/L	Na	28 µg/L	K	2.6 µg/L	Mg	39 µg/L	Mg	130 µg/L	Mn	0	K	5.4 µg/L	Mg	310 µg/L	Cu	13 µg/L
K	1.6 µg/L	Na	29 µg/L	S	170 µg/L	Mg	93 µg/L	Mn	0	Na	12 µg/L	Na	55 µg/L	Mg	110 µg/L	Na	96 µg/L	K	3.9 µg/L
Mg	100 µg/L	S	110 µg/L	Si	70 µg/L	Mn	0 µg/L	Na	68 µg/L	Si	69 µg/L	S	79 µg/L	Na	170 µg/L	Si	70 µg/L	Mg	88 µg/L
Na	15 µg/L	Si	60 µg/L	Ti	1.4 µg/L	Na	72 µg/L	Rb	0	Ba	0	Si	160 µg/L	Si	170 µg/L	Tl	22 µg/L	Na	89 µg/L
Rb	700 µg/L	Ti	0.74 µg/L	Ba	0.23 µg/L	Si	0	Sb	650 µg/L	Sr	0.1 µg/L	Tl	18 µg/L	Sr	1.5 µg/L	B	0.68 µg/L	Si	100 µg/L
S	730 µg/L	Ba	0.27 µg/L	Sr	0.34	Tl	24 µg/L	Si	31 µg/L	Zn	0	B	0	Tl	28 µg/L	Ba	0.89 µg/L	Tl	23 µg/L
Si	95 µg/L	Li	0.05 µg/L	Zn	0	Ba	0.65 µg/L	Ba	0.12 µg/L	-	-	Ba	0.18 µg/L	Ba	0.45 µg/L	Mn	0	Sc	0.23 µg/L

Ti	2.5 µg/L	Sr	0.39 µg/L	Er	2.4	Sc	0.23 µg/L	Cd	0.4 µg/L	-	-	Cd	0.84 µg/L	Li	0.06 µg/L	Sc	0.19 µg/L	Sr	1.2 µg/L
B	0.49 µg/L	Zn	0.22 µg/L	Th	0	Sr	0.96	Sr	0.89 µg/L	-	-	Li	0.04 µg/L	Sc	0.23 µg/L	Sr	0.84 µg/L	As	11 µg/L
Ba	0.14 µg/L	Er	0.22 µg/L	B	0.6 µg/L	Zn	0	Zn	0	-	-	Sr	0.8 µg/L	As	10 µg/L	Zn	0	Ho	1.4 µg/L
Li	0.05 µg/L	Th	8.9 µg/L	Ho	0	Hg	1.1 µg/L	Al	230 µg/L	-	-	As	12 µg/L	Bi	4.9 µg/L	As	12 µg/L	I	8.6 µg/L
Mn	0.35 µg/L	W	13 µg/L	Pb	0	I	9.5 µg/L	Bi	4.3 µg/L	-	-	I	17 µg/L	I	17 µg/L	Ho	1.3 µg/L	Hg	0.99 µg/L
Sr	0.35 µg/L	B	0.55 µg/L	Al	22 µg/L	Ni	3.7 µg/L	Ho	1.3 µg/L	-	-	Sc	0.2 µg/L	Ir	29 µg/L	I	11 µg/L	-	-
Zn	0.26 µg/L	Mn	0.15 µg/L	As	12 µg/L	Sb	6.9 µg/L	I	16 µg/L	-	-	-	-	-	-	-	-
As	12 µg/L	-	-	I	11 µg/L	B	0.6 µg/L	Pt	22 µg/L	-	-	-	-	-	-	-	-
Bi	4.8 µg/L	-	-	Pt	19 µg/L	-	-	Ta	4.5 µg/L	-	-	-	-	-	-	-	-
Ho	1.5 µg/L	-	-	Sb	8 µg/L	-	-	Th	6.7 µg/L	-	-	-	-	-	-	-	-
Pt	23 µg/L	-	-	Se	11 µg/L	-	-	Li	0.05 µg/L	-	-	-	-	-	-	-	-
Sb	5.9 µg/L	-	-	Eu	0.18 µg/L	-	-	Yb	0.07 µg/L	-	-	-	-	-	-	-	-
V	0.22 µg/L	-	-	Li	0.04 µg/L	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	Lu	0.19 µg/L	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	Mn	0.17 µg/L	-	-	-	-	-	-	-	-	-	-	-	-
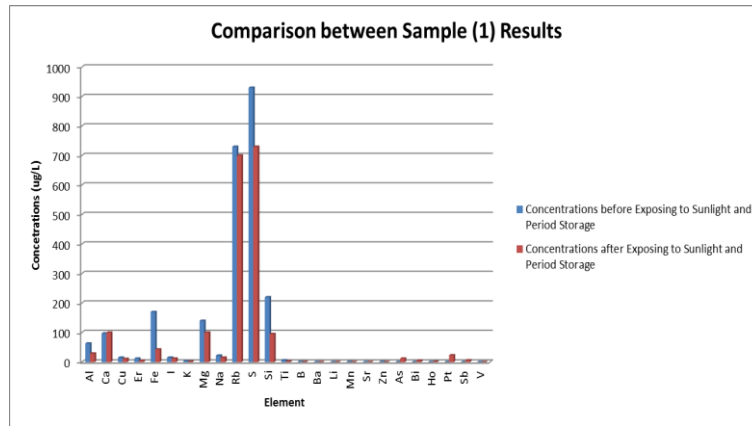
Figure (4.36) Comparison between Sample (1) Results
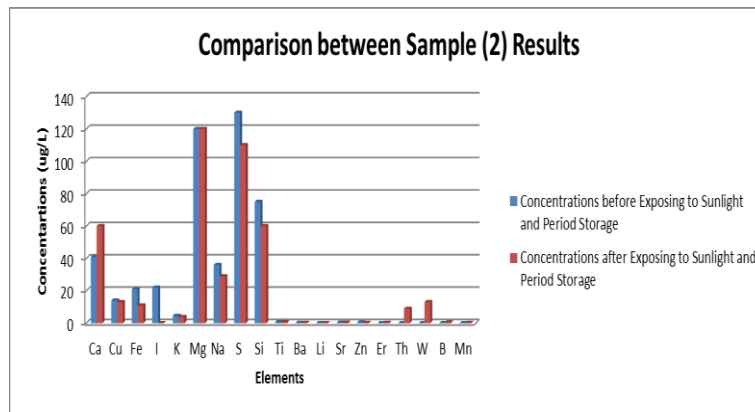
Figure (4.37) Comparison between Sample (2) Results
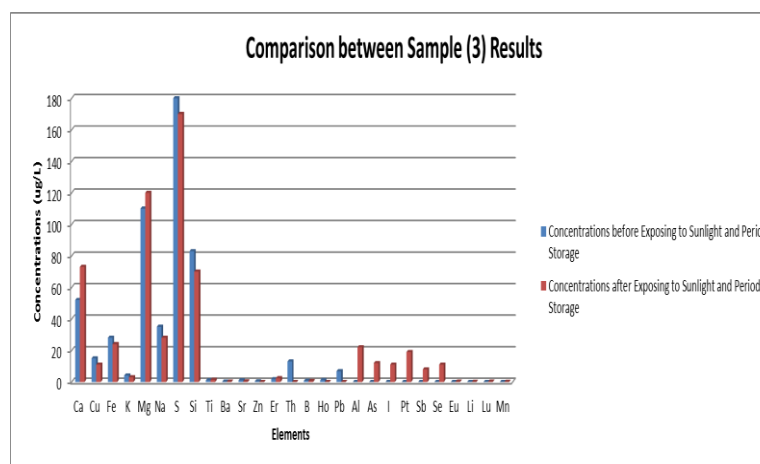
Figure (4.38) Comparison between Sample (3) Results
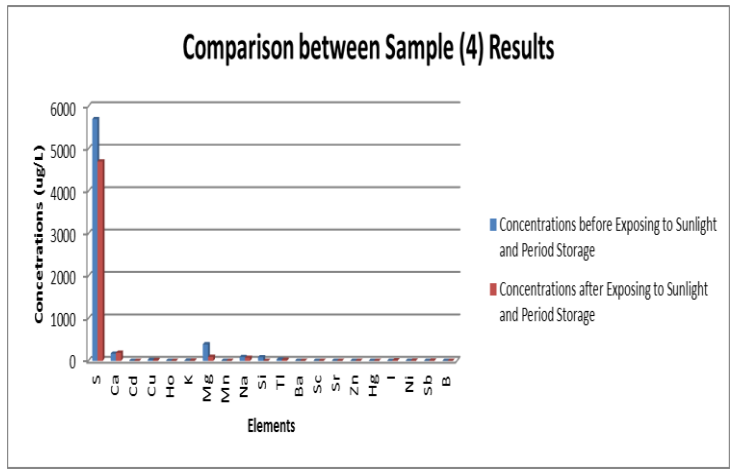
Figure (4.39) Comparison between Sample (4) Results
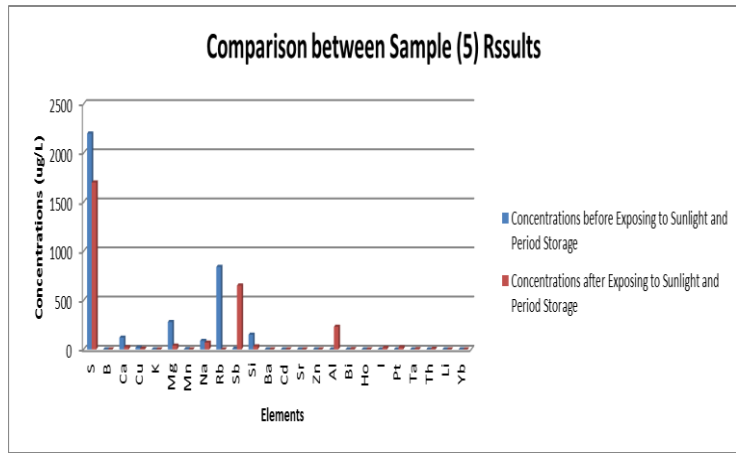
Figure (4.40) Comparison between Sample (5) Results
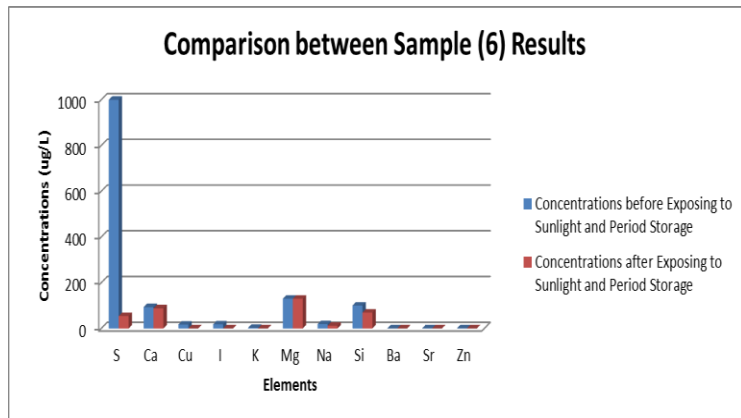
Figure (4.41) Comparison between Sample (6) Results
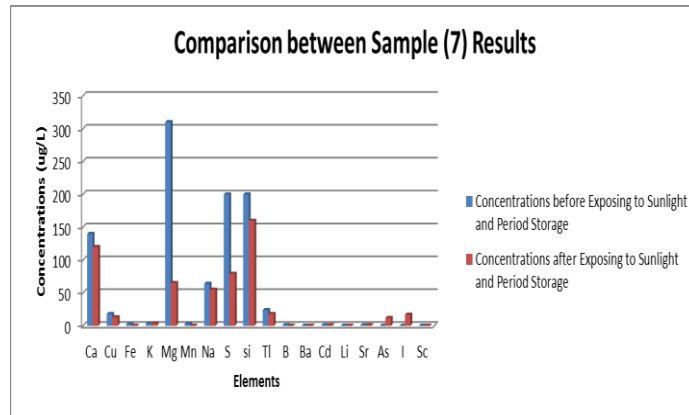
Figure (4.42) Comparison between Sample (7) Results
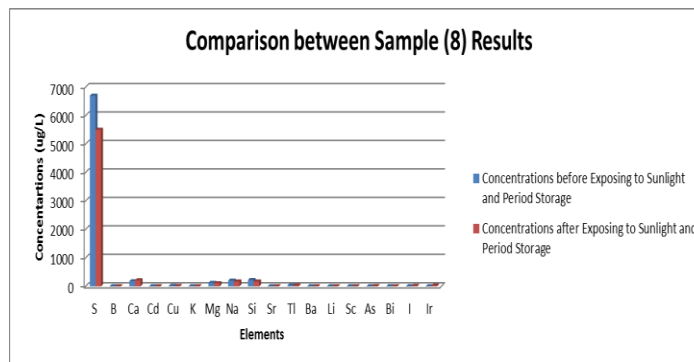
Figure (4.43) Comparison between Sample (8) Results
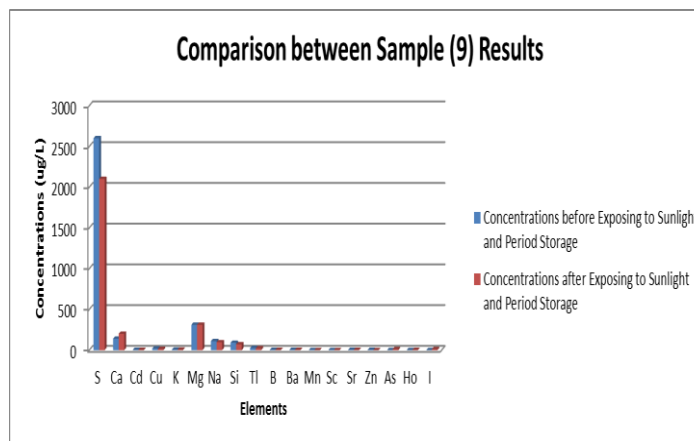
Figure (4.44) Comparison between Sample (9) Results

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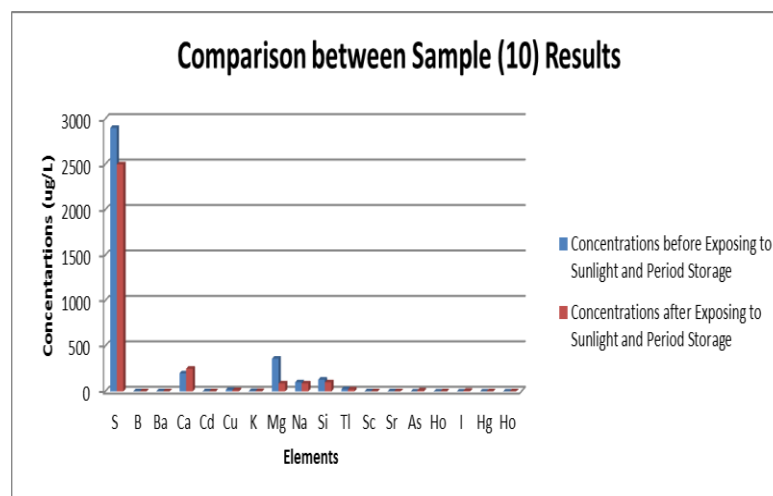
Figure (4.45) Comparison between Sample (10) Results

Discussion:

The results in a table (4.22) and the figures from (4.36) to (4.45) confirmed that various variations can be happened in all samples after exposing them to normal sunlight and storage period. These variations were compared and explained with more details as shown below:

In figure (4.36), the concentrations of many elements at this sample like (Al, Ca, Cu, Er, Fe, I, K, Mg, Na, Rb, S, Si, Ti, B, Ba, Mn, Sr, and Zn) were changed automatically excepting for one atom that was (Li). These results may be related to the migration of atoms from plastic to water. In this sample, there are new six chemical elements were found as modern elements such as (As, Bi, Ho, Pt, Sb, and V), due to the interaction between water samples and the plastic of bottles were manufactured from polyethylene material, and storage period as displayed by some researchers in the third section of this thesis [107,108], [110], [112,113].

In figure (4.37), the levels of some elements at this sample for instance (Ca, Cu, Fe, K, Na, S, Si, Ba, Sr, Ti, and Zn) were converted completely excepting for two atoms that were (Mg, Li). Also, there are two elements were (Mn, and B) were disappeared from this sample, due to some atoms of these elements that may be migrated from plastic to water. In this sample, some elements like (Er, Th, and W)

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were found as new elements at the end of this work, due to the interaction between water samples and the plastic bottles manufactured from polyethylene material, and storage period as displayed by some researchers in the third section of this thesis [107,108], [110], [112,113].

In figure (4.38), the density of many atoms for example (Ca Cu, Er, Fe, K, Mg, Na, S, Si, Sr, Ti, B, and Ba) were changed automatically in this sample. Also, four elements (Ho, Pb, Th, and Zn) were removed completely during this operation, due to some atoms of these elements may be migrated from plastic to water. Through sample (3), some elements for instance (Al, As, I, Pt, Sb, Se, Eu, Lu, Li, and Mn) were discovered too as modern atoms, due to the interaction between water samples and the plastic bottles which manufactured from polyethylene material, and storage period as displayed by some researchers in the third part of this thesis [107,108], [110], [112,113].

In figure (4.39), the concentration of some chemical elements like (S, Ca, Cd, Cu, K, Mg, Na, Si, Tl, Ba, Sc, and Sr) was varied quickly through this experimental work. As well, some atoms for example (Ho, Mn, and B) were vanished also during this experiment, due to some atoms of these elements may be migrated from plastic to water. At this sample, the chemical elements like (Hg, I, Ni, and Sb) were found as new atoms at the end of this work, due to the interaction between water samples and the plastic bottles manufactured from polyethylene material, and storage period as displayed by some researchers in the third section of this thesis [107,108], [110], [112,113].

In figure (4.40), the concentration of number elements such as (S, Ca, Cu, K, Mg, Na, Rb, Si, Ba, Cd, and Sr) was changed automatically during this operation. Also, some elements like (B, Mn, Zn, and Sb) were ejected completely from the structure of this sample, due to some atoms of these elements may be migrated from plastic to water. In this sample, many atoms for example (Al, Bi, Ho, I, Pt, Ta, Th, and Yb) were detected as new elements at the end of this work, due to the interaction between water samples and the plastic of bottles which manufactured from polyethylene material as

displayed by some researchers in the third section of this thesis [107,108], [110], [112,113].

In figure (4.41), the density of some elements like (S, Ca, Na, Si, and Sr) was changed quickly except for one element that was (Mg). On the other hand, there are many elements such as (Cu, I, K, Ba, and Zn) were disappeared suddenly at the end of this experimental work, due to some atoms of these elements may be migrated from plastic to water and the interaction between water samples and the plastic of bottles which manufactured from polyethylene material, and storage period as confirmed by some researchers in the third part of this thesis [107,108], [110], [112,113].

In figure (4.42), the concentration of some elements for example (Ca, Cu, K, Mg, Na, S, Si, Tl, Ba, Cd, Li, and Sr) were changed automatically during this operation. Also, there few atoms such as (Fe, M, and B) were removed completely from the structure of this sample, due to some atoms of these elements may be migrated from plastic to water. There are some elements for example (As, I, and Sc) were detected as modern elements at the end of this experiment, due to the interaction between water samples and the plastic bottles manufactured from polyethylene material as displayed by some researchers in the third section of this thesis, and storage period [107,108], [110], [112,113].

In figure (4.43), the levels of number chemical elements for instance (S, B, Ca, Cd, Cu, K, Mg, Na, Si, Sr, Tl, Ba, and Sc) were modified excepting for one element that was (Li), due to some atoms of these elements may be migrated from plastic to water. Moreover, there are some atoms like (As, Bi, I, and Ir) were discovered as modern atoms during this work, due to the interaction between water samples and the plastic bottles that were manufactured from polyethylene material, and storage period as shown by some researchers in the third side of this thesis [107,108], [110], [112,113].

In figure (4.44), the density of several chemical elements for example   (S, Ca, Cd, Cu, K, Na, Si, Tl, B, Ba, Sc, and Sr) were converted automatically except for

one element that was (Mg). Also, only one element was disappeared from the structure of this sample was (Mn), due to some atoms of these elements may be migrated from plastic to water. In this sample, there are few elements such as (As, Ho, and I) were observed as new elements at the end of this experiment, due to the interaction between water samples and the plastic bottles that were manufactured from polyethylene material, and storage period as documented by some researchers in the third side of this thesis [107,108], [110], [112,113].

In figure (4.45), the concentration of various elements such as (S, Ba, Ca, Cu, K, Mg, Na, Si, Sr, Tl, and Sc) was varied fully expect two elements were (B and Cd), due to some atoms of these elements may be migrated from plastic to water. Furthermore, there are some elements such as (As, Ho, I, and Hg) were discovered as modern chemical elements during this experimental work, due to the interaction between water samples and the plastic bottles that were manufactured from polyethylene material, and storage period as confirmed by some researchers in chapter three [107,108], [110], [112,113].

4.4.2. UV-Visible Spectroscopy technique:

The ten selected samples were prepared and analyzed by UV-Visible spectroscopy technique only one time which was before exposed to normal sunlight and storage period as clarified below:

4.4.2. a. Preparing Samples for UV-Visible Spectroscopy:

The sample holder with a thickness of (1cm) was cleaned and filled with the required sample using air as a source, and the sample holder was placed in the device which contains two lambs that were thallium and tungsten. Then, the absorption spectra were recorded in the UV-Visible technique, and it was displayed on the computer screen that was connected with one system as illustrated in figure (4.46). These results were obtained from the UV-Visible spectroscopy technique at the Laboratory of the Laser Institute at Sudan University for science and technology at room temperature that was $27°C$.

Figure (4.46) UV-Visible –Spuv-26… Serial Number 111311 Manufactured in Germany

4.4.2. b. UV-Visible Results:

The ten collected samples of drinking water which were taken from different locations in Khartoum state, Sudan were investigated by UV-Visible technique to study the optical properties of these samples just before exposing them to sunlight and storage period. In this case, all ten samples were analyzed, and the spectra of these samples were recorded as described in figures from (4.47) to (4.51) below:
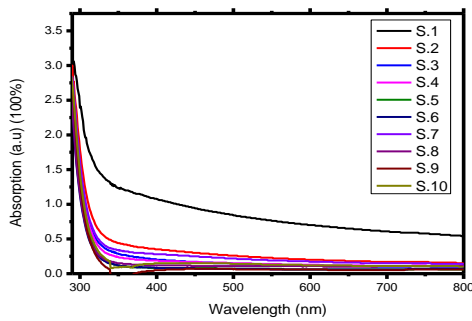
Figure (4.47) Absorption Spectra Combined for all Ten Samples (1)
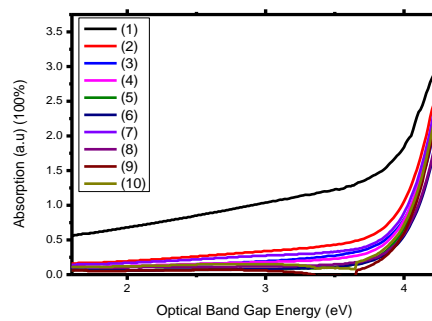
Figure (4.48) Absorption Spectra Combined for all Ten Samples (2)
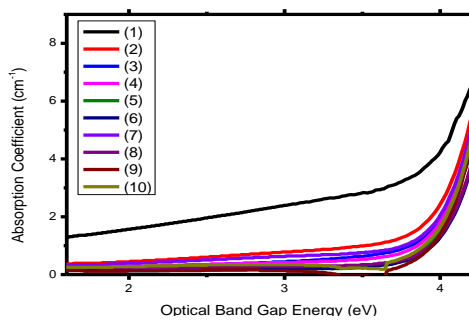
Figure (4.49) Absorption Coefficient Spectra Combined for all Ten Samples
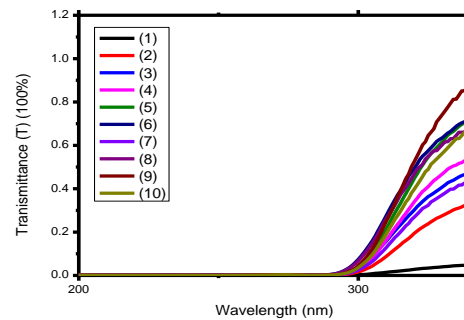
Figure (4.50) Transmittance Spectra Combined for all Ten Samples
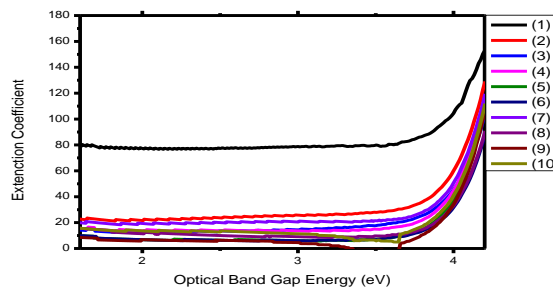
Figure (4.51) Extinction Coefficient Spectra for all Ten Samples

The results in spectrum (4.47) showed that the absorption (A) was displayed as a function of wavelength. Also, the results confirmed that the absorption values were increased slowly at the values more than 300 nm, and they were increased sharply at the values less than 300 nm. The results at these spectrum confirmed that the maximum absorption values were happened in the zone which is called the main edge of absorption for these samples. In addition, the absorption values were at (57%, 40%, 25%, 20%, 12%, 12%, 28%, 14%, 4%, and 11%) for all samples (1, 2, 3, 4, 5, 6, 7, 8, 9, and 10) respectively. In addition, the best values for absorption were happened at the value for wavelength less than 300 nm as confirmed by some researchers in the third chapter for this thesis [100–103].

The results in the spectrum (4.48) proved that the absorption also can be described as a function of photon energy. Also, the results showed that the absorption values were increased slowly at the low values of photon energy less than (4 eV) because the incidents beam energy less than the value of the energy gap. Furthermore, these results due to the incident beam weren't able to excite the electron from the valance band to the conduction band, and thus the absorption was increased suddenly with photon energy at the values more than (4 eV). In addition, the results displayed that all samples had absorption values at (57%, 40%, 25%, 20%, 12%, 12%, 28%, 14%, 4%, and 11%) for all samples (1, 2, 3, 4, 5, 6, 7, 8, 9, and 10) respectively. These results of the absorption values at this spectrum confirmed the results in the spectra (4.48) that were mentioned above as documented by some researchers in the third chapter for this thesis [100–103].

The results in the figure (4.49) discussed the variation at the optical absorption coefficient (α) that can be explained as a function for the photon energy. It is clear from this spectrum the optical absorption coefficient values were increased slowly at the low values for the photon energy at the range less than (4 eV), and they were increased suddenly with photon energy more than (4eV). These results may relate to the suddenly increasing in absorption values which were led to the same increasing in the optical absorption coefficient. The results proved that the values of the optical

absorption coefficients for all samples were at (1.3, 0.5, 0.38, 0.27, 0.23, 0.23, 0.19, 0.11, 0.19, and 0.24cm^{-1}) for all samples (1, 2, 3, 4, 5, 6, 7, 8, 9 and 10) respectively as displayed by some researchers in the third chapter for this thesis [100–103].

The results in the figure (4.50) showed that Transmittance (T) can be explained as a function of the wavelength. The results confirmed that all samples had the same value with wavelengths at the range less than (300 nm) in the Ultraviolet region. After that, the transmittance values for all samples were increased sharply with a range of wavelengths of more than (300 nm) in the same region. The results showed that the samples had transmittance values at (4.8% , 32% , 46 %, 53 % , 70 % , 71 % , 42 % , 67 % , 85 % , and 66 %) for all samples (1, 2, 3, 4, 5, 6, 7, 8, ,9 , and 10) respectively. These results may relate to the suddenly increasing in absorption values and the optical absorption coefficients which were led to the same increasing in the Transmittance values for the selected samples as shown by some researchers in the third chapter of this thesis [100–103].

The results in figure (4.51) explained that the extinction coefficient (K) was described as a function of the photon energy. The extinction values coefficient were increased slowly at the lower photon energy values which were less than (4eV), and they were increased rapidly in high photon energies values more than (4 eV). Furthermore, the extinction coefficient values for all samples at were (79 , 23 , 13 , 16 , 7 , 10 , 20 , 12 , 6 , and 15) for all samples (1, 2, 3, 4, 5, 6, 7, 8, 9, 10) respectively. These results may be related to the suddenly increasing in absorption, the optical absorptions coefficients, and transmittance which were led to the same increasing in the extinction coefficient values as documented by some researchers in the third chapter of this thesis [100–103].

Table (4.23) Comparing between UV-Visible Results:

S. No	(A) (%)	(α)	(T) (%)	(K)
1	57 %	1.3	4.8 %	79
2	40%	0.5	32%	23
3	25%	0.38	46%	13
4	20%	0.27	53%	16
5	12%	0.23	70%	7
6	12%	0.23	71%	10
7	28%	0.19	42%	20
8	14%	0.11	67%	12
9	4%	0.19	85%	6
10	11%	0.24	66%	15

The results of optical properties for all selected samples confirmed that the first sample which was collected from Blue Nile River in Al Mogran station has abnormal behavior, and it has a high value for all-optical properties. These results may be related to a huge amount of the mud and the dirt that can be found in this sample which leads to happen a high scattering of light during this sample. Also, these results may be related to the total of concentrations or densities for the toxic, low toxicity, and radiant elements which were had different values, and they can be led to the variations in the optical properties for this sample and other samples. The difference that can be happened at all the selected samples may be related to the magnitude of the molecular weights for the heavy and radioactive elements in samples. The densities of these chemical elements can affect the beam of light track in the samples as shown by some researchers in the third chapter of this thesis   [100–103].

CHAPTER FIVE

Conclusion and Recommendation

5.1. Conclusion:

From the results obtained in this research, one can conclude that:

1- The ICPE spectroscopy technique is very accurate. ICPE results before and after exposure samples to the sunlight and storage period showed that some atoms like (Cu, Fe, Na, S, Ba, Sb, Al, B, Mn, Zn, Pb, Ca, Mg, K, Rb, Si, Li, Sr, Er, Ho, Sc, Pt, V, Se, Lu, Eu, Ir, Hg, Ni, and Yb) were appeared with amounts in the permissible guidelines for drinking water that were recommended by background values in all samples.

2- The ICPE results before exposure samples to the sunlight and storage period confirmed that some atoms like (Ti) in samples (1 and 3), (Tl) in samples (4, 7, 8, 9, and 10), and Th in sample (3) were detected with concentrations in more than the permissible guidelines for drinking water that were recommended by background values.

3- The ICPE results after exposure samples to the sunlight and storage period proved that some atoms such as (As) in samples (1, 3, 7, 9, and 10), (Ta) in sample (5), Bi in samples (1, 5, and 8), (Ti) in samples (1 and 3), (Th) in samples (2 and 5), (W) in sample (2), (Tl) in samples (4, 7, 8, 9, and 10), (Al) in sample (5) were found with concentrations in the limits more than the permissible guidelines for drinking water by background values.

4- After exposure to sunlight and storage, some new atoms were appeared and others disappeared, the amounts of them were increased and decreased automatically.

5- Some optical properties of samples such as absorption, optical absorption coefficients, transmittance, and extinction coefficient were described as functions of wavelength and optical band energy by UV-Visible spectroscopy technique.

6- The absorption values were found at (57%, 40%, 25%, 20%, 12%, 12%, 28%, 14%, 4%, and 11%) for all samples respectively.

7- The optical absorption coefficients values were appeared at (1.3, 0.5, 0.38, 0.27, 0.23, 0.23, 0.19, 0.11, 0.19, and 0.24cm^{-1}) for all samples respectively.

8- The transmittance values were observed at (4.8%, 32%, 46 %, 53 %, 70 %, 71 %, 42 %, 67 %, 85 %, and 66 %) for all samples respectively.

9- The extinction coefficients values were discovered at (79, 23, 13, 16, 7, 10, 20, 12, 6, and 15) for all samples respectively.

5.2. Recommendation:

The following are suggested as future work based on this study:

1- Detect and calculate concentrations of toxic and radioactive elements in these samples which were collected from different sources in Khartoum state, Sudan before and after exposing them to the sunlight via other spectroscopy techniques such as (LIBS, EDX, and AAS).

2- The researcher recommends that the Khartoum state water authority provide advice and guidance to people when they use polluted water as a basic source for drinking in the selected sources at this research.

3- The researcher recommends that the establishment of stations for purification and treatment of water, which is very necessary to obtain water for human use.

4- The researcher recommends the necessity to drain rainwater in the autumn season and sewage water away from the various drinking water sources in Khartoum State, Sudan.

5- The researcher recommends to shopkeepers and grocery store owners not to expose plastic containers and store them for long time that contain drinking water to sunlight, so as not to be a cause of contamination of water with toxic elements that affect human health.

5.3. References:

[1]   M. F. Chaplin, "Water: Its importance to life," *Biochem. Mol. Biol. Educ.*, vol. 29, no. 2, pp. 54–59, 2001, doi: 10.1016/S1470-8175(01)00017-0.

[2]   M. Khalifa and S. Bidaisee, "The Importance of Clean Water," *Sch. J. Appl. Sci. Res.*, vol. 1, 2018, [Online]. Available: http://innovationinfo.org/articles/SJASR/SJASR-4-142.pdf?fbclid=IwAR26i_xe5Dhz4j391wpO_IqFbk3JsBBrH7rOsNLRIMZtZEaiKM RmOfw_hhk.

[3]   A. French, "Water is life: Climate change, globalization, and adaptive resource governance in Peru's Santa River watershed," 2013.

[4]   Boyd l. O'Dell and R. A. Sunde, *lHANDBOOK OF NUTRITIONALLY ESSENTIAL ELEMENTSe*. Madison Avenue, New York, New York: MARCEL DEKKER, INc, 1997.

[5]   O. Unver, *Water and agriculture for sustainable development*, vol. 3. 2015.

[6]   C. Pezzulo *et al.*, "Data Descriptor : Sub-national mapping of population pyramids and dependency ratios in Africa and Asia," *Sci. DATA*, pp. 1–15, 2017, doi: 10.1038/sdata.2017.89.

[7]   E. Eltayeb, "Khartoum, Sudan," 2002.

[8]   R. Zelsmann, C. Sandorfy, L. Sobczyk, S. Bratos, and H. Ratajczak, *The hydrogen bond and the water molecule: The physics and chemistry of water, aqueous and bio-media*. Elsevier, 2006.

[9]   A. A. Vigasin, "MOLECULAR STRUCTURE AND CHEMICAL PROPERTIES OF ATMOSPHERIC WATER," *Encycl. Life Support Syst.*, vol. I, p. 238, 2009.

[10]   D. Le Bihan and H. Fukuyama, *Water The Forgo?en Biological Molecule*. PAN STANFORD pUBLISHING, 2010.

[11] V. Kochmarsky, "MAGNETIC TREATMENT OF WATER : POSSIBLE MECHANISMS AND CONDITIONS FOR APPLICATIONS," *Magn. and electrical Sep.*, vol. 7, no. C, pp. 77–107, 1996.

[12] F. H. Stillinger, "THEORY AND MOLECULAR MODELS FOR WATER," *Adv. Chem. Phys.*, vol. XXXI, 1975.

[13] S. Soames, "Is H_2O a Liquid , or Water a Gas ?," *Int. Phenomenol. Soc.*, vol. 72, no. 3, pp. 635–639, 2020.

[14] V. S. Kale, "Consequence of Temperature, pH, Turbidity and Dissolved Oxygen Water Quality Parameters," *Int. Adv. Res. J. Sci. Eng. Technol.*, vol. 3, no. 8, pp. 186–190, 2016, doi: 10.17148/IARJSET.2016.3834.

[15] B. M. and J. Ward-Smith, *Mechanics of Fluids*, 8th ed. London and New York: Taylor & Francis, 2005.

[16] P. J. PRITCHARD and J. C. LEYLEGIAN, *INTRODUCTION TO FLUID MECHANICS*, EIGHTH. United States of America: JOHN WILEY & SONS, INC, 2011.

[17] L. Wai, I. S. K. H. Tsang, and S. Tim, "Surface Wave on Water."

[18] U. P. Shinde, S. S. Chougule, C. G. Dighavkar, B. S. Jagadale, and D. K. Halwar, "Surface Tension as a Function of Temperature and Concentration of Liquids," *Int. J. Chem. Phys. Sci.*, vol. 4, no. 3, pp. 1–7, 2015.

[19] A. E. DUNSTAN and FERDINAND BERNARD THOLE, "THE VISCOSITY OF LIQUIDS." New York: EX LIBRIS, 1914.

[20]   and B. R. T. I.-P. Shih, M. C. Potter, D. C. Wiggert, *Mechanics of Fluids*, Copyright,. Stamford: Cengage Learning ALL, 2012.

[21] B. N. Hewakandamby, *A first course in Fluid Mechanics for Engineers*, vol. 53, no. 9. Bookboon, 2012.

[22] J. O. Wilkes, S. G. Birmingham, B. J. Kirby, and C.-Y. Cheng, *Fluid Mechanics for Chemical Engineers Second Edition with Microfluidics and CFD*, 2nd ed. United States of America: Pearson Education, 2006.

[23] J. Legrady and S. Harvey, "Capillary action enhanced surface mount connectors," vol. 16, no. 1, pp. 16–17, 2000.

[24] A. ji and S. uddin, "Analysis of Electrical conductivity of Groundwater at different locations of Phooli of U.P, India," *Int. J. Emerg. Trends Eng. Dev.*, vol. 3, no. 9, 2019, doi: 10.26808/rs.ed.i9v3.01.

[25] M. Hayashi, "WATER FOR ENVIRONMENTAL MONITORING AND GEOPHYSICAL DATA INVERSION," pp. 119–128, 2004.

[26] H. Golnabi, M. R. Matloob, M. Bahar, and M. Sharifian, "Investigation of electrical conductivity of different water liquids and electrolyte solutions," vol. 28, pp. 24–28, 2009.

[27] M. B. Heaney, "Electrical Conductivity and Resistivity Michael," in *Experimental Techniques*, in Electrical Measurment, Signal, and Displays, CRC Press, 2004, pp. 1–14.

[28] S. Parez, M. Předota, and M. Machesky, "Dielectric properties of water at rutile and graphite surfaces: Effect of molecular structure," *J. Phys. Chem. C*, vol. 118, no. 9, pp. 4818–4834, 2014, doi: 10.1021/jp4128012.

[29] G. E. Thomas, K. Stamnes, L. Oreopoulos, and S. Platnick, *Radiative Transfer in the Atmosphere and Ocean*, vol. 53, no. 11. Cambridge University Press, 2006.

[30] R. M. Waxler and C. E. Weir, "Effect of Pressure and Temperature on the Refractive Indices of Benzene, Carbon Tetrachloride, and Water," *Sci. journals*, vol. 67, no. A(2), 1963, doi: 10.6028/jres.067A.016.

[31] A. N. Bashkatov and E. A. Genina, "Water refractive index in dependence on temperature and wavelength : a simple approximation," pp. 1995–1997, 1997.

[32] P. C. Couto, S. G. Estácio, B. J. C. Cabral, and A. M. Carlo, "The Kohn-Sham density of states and band gap of water : From small," no. May 2007, pp. 1–10, 2005, doi: 10.1063/1.1979487.

[33] L. Øgendal, *Light Scattering a brief introduction*, no. May. Copenhagen, 2019.

[34] and E. S. F. M. Cone, E. Figueroa, Z. Lu, "MEASURING THE ABSORPTION COEFFICIENT OF PURE WATER IN THE UV USING AN INTEGRATING CAVITY ABSORPTION METER," no. 1, pp. 1–6.

[35] I. A. Veselovskii, H. K. Cha, D. H. Kim, S. C. Choi, and J. M. Lee, "Raman lidar for the study of liquid water and water vapor in the troposphere," *Appl. Phys. B Lasers Opt*, vol. 71, no. January, pp. 113–117, 2015, doi: 10.1007/s003400000290.

[36] D. M. PLANCK, *TREATISE ON THERMODYNAMICS*. 39 PATERNOSTER ROW, LONDON NEW YORK AND BOMBAY: LONGMANS, GREEN, AND CO, 2016.

[37] A. Mishra, A. Shukla, and A. Sharma, "Latent Heat Storage Through Phase Change Materials," *RESONANCE*, no. June, pp. 532–541, 2015.

[38] R. W. Powell, C. Y. Ho, and P. E. Liley, "Thermal Conductivity of Selected Materials," 1966.

[39] P. Glantz and J. A. von Fraunhofer, "Clinical and Technical Considerations of Luting Agents for Fixed Prosthodontics," *Int. J. Dent*, 2012.

[40] A. Pohorille and L. R. Pratt, "Is Water the Universal Solvent for Life ?," pp. 405–409, 2012, doi: 10.1007/s11084-012-9301-6.

[41] K. Addy, L. Green, and E. Herron, "pH and Alkalinity," University of Rhode

Island, 2004.

[42]	*WHAT IS pH*. HACH, 2018.

[43]	S. Name and C. Period, *Unit 3 : Phases of Matter*. in Regents Chemistry, 2014.

[44]	C. State, *Freshwater Challenges of South Africa and its Upper Vaal River*. Johannesburg, South Africa: Springer International Publishing AG, 2017.

[45]	and C. J. K. Ashton, A. Heckler, *Water For Life Investigating Water as a global issue*. Australia: Global Wducation project, 2012.

[46]	G. K. Vallis, *climate and the oceans*. Princeton: Princeton University Press, 2012.

[47]	A. Balasubramanian, "Properties of Seawater-Documentary," vol. November, 2016, doi: 10.13140/RG.2.2.14014.48969.

[48]	D. Chapman, *Water Quality Assessments - A Guide to Use of Biota, Sediments and Water in Environmental Monitoring - Second Edition Edited by*, 2nd ed. Cambridge: UNESCO/WHO/UNEP Printed, 1996.

[49]	V. Sorocovschi, *THE MINERALISATION DEGREE AND CHEMICAL COMPOSITION OF THE LAKES IN THE TRANSYLVANIAN PLAIN variation depend on the water flow. Thereby the lakes defined by no discharge have a rivers in which case the difference is assessed by the amount of chemical subs*, vol. 3, no. 1. Lakes, Reserv. ponds, 2009.

[50]	B. D. Honeyman, L. S. Balistrieri, and J. W. Murray, "Oceanic trace metal scavenging : the importance of particle concentration," *Deep. Researc*, vol. 35, no. 2, pp. 227–246, 1988.

[51]	G. A. Ganjo and J. J. Toma, "Physical and Chemical properties of rainwater and its suitability for drinking and irrigating in Erbil city which are directly

responsible for the increasing levels of particulate matter suspended atmosphere (Seinfeld ., 2006). A water resource such as," *ZANCO J. Pure Appl. Sci*, vol. 29, pp. 39–50, 2017.

[52] R. A. F. and J. A. Cherry, *GROUNDWATER. United States of America*. Hall. Inc., Englewood Cliffs, N.J., 1979.

[53] O. I. Ojo, F. A. O. Otieno, and G. M. Ochieng, "Groundwater : Characteristics, qualities, pollutions and treatments : An overview," *Int. J. Water Resour. Environ. Eng.*, vol. 4, no. June, pp. 162–170, 2012, doi: 10.5897/IJWREE12.038.

[54] V. V. Tikhomirov, "Groundwater Composition and Chemistry," *Hydrogeochem. Fundam. Adv.*, vol. 1, 2016.

[55] "Basic Elements of the Human Body," *Elements*, no. 1, p. 65.

[56] S. Lehrman, "Trace elements.," *Sci. Am.*, vol. 294, no. 6, pp. 353–357, 2006, doi: 10.1038/scientificamerican0606-16.

[57] R. D. Allowances, "14 Trace Elements Evidence Associating Trace Elements with Chronic Diseases," vol. 1986, no. Dc, pp. 1–67, 2021.

[58] L. M. L. N. and L. S. P. De Gelder, "Radioanalytical Methodology for Water Analysis," *Handb. Water Anal. Leo, S. Alvardo Jorge CRC Press*, 2019, doi: 10.1201/b15314-6.

[59] K.-J. Appenroth, "Soil Heavy Metals," *Crossroads*, vol. 19, no. Im, pp. 1–18, 2010, doi: 10.1007/978-3-642-02436-8.

[60] M. Mehmood, "Rare Earth Elements- A Review," *J. Ecol. Nat. Resour*, vol. 2, no. 2, 2018, doi: 10.23880/JENR-16000128.

[61] M. Mahurpawar, "Effects of Heavy Metals on Human Healtheffects of Heavy Metals on Human Health," *Int. J. Res. -GRANTHAALAYAH*, vol. 3, no. 9SE,

pp. 1–7, 2015, doi: 10.29121/granthaalayah.v3.i9se.2015.3282.

[62] B. G. Muhammad, M. S. Jaafar, A. A. Rahman, and F. A. Ingawa, "Determination of radioactive elements and heavy metals in sediments and soil from domestic water sources in northern peninsular Malaysia," *Environ. Monit. Assess.*, vol. 184, no. 8, pp. 5043–5049, 2012, doi: 10.1007/s10661-011-2320-3.

[63] R. B. Setlow and J. K. Setlow, "Effects of radiation on polynucleotides.," *Annu. Rev. Biophys. Bioeng.*, vol. 1, pp. 293–346, 1972, doi: 10.1146/annurev.bb.01.060172.001453.

[64] "Section One Introduction To Radioactive," pp. 1–19.

[65] "The Rare-Earth Elements— Vital to Modern Technologies and Lifestyles As," *USGS Miner. Resour. Progr.*, vol. 10, no. 3, pp. 154–154, 1966, doi: 10.1177/001698626601000310.

[66] N. Malhotra *et al.*, "An updated review of toxicity effect of the rare earth elements (REEs) on aquatic organisms," *Animals*, vol. 10, no. 9, pp. 1–27, 2020, doi: 10.3390/ani10091663.

[67] X. Zhong, X. Zhao, Y. Qian, and Y. Zou, "Polyethylene plastic production process," vol. 1, no. 1, pp. 1–8, 2018, doi: 10.18282/ims.v1i1.104.

[68] "The manufacture of polyethylene," pp. 1–5.

[69] R. 429670, "Migration of organic components from polyethylene terephthalate (PET) bottles to water," 2003.

[70] A. Hofmann, "Spectroscopic Techniques: I Spectrophotometric Techniques," in *Principles and Techniques of Biochemistry and Molecular Biology Copyright*, Queensland, Austalia: Cambridge University Press, 2010.

[71] M. E.Malainey, *Manuals in Archaeological Method, Theroy and Technique A*

Consumer's Guide to Archaeological Science Analytical Techniques. New York Dordrecht Heidelberg London: Springer, 2010.

[72] "Appendix Electromagnetic Units."

[73] A. P. Potylitsyn, P. Acceleration, B. Physics, and O. Devices, "CD CD," 2011.

[74] M. E. Yousif, "The Electromagnetic Radiation Mechanism," vol. 4, no. 3, pp. 72–79, 2014, doi: 10.14331/ijfps.2014.330068.

[75] L. A. Cabral *et al.*, "Matter Wave Interferometry, the Gouy Phase and Complementarity Principle Matter Wave Interferometry, Matter Wave Interferometry, the Gouy Phase and the Gouy Phase and Complementarity Principle Complementarity Principle," no. November 2012, 2015, doi: 10.5772/53651.

[76] F. Dahmani and F. Dahmani, "Experimental study of laser and wavelength dependences of laser-plasma coupling, transport, and ablation processes in planar gold targets," *Phys. Plasma*, vol. 1943, no. 1992, 2013, doi: 10.1063/1.860047.

[77] b F. C. A. and G. M. H. Andrew M. Leach, a Monika Heisterkamp, "Gas chromatography±inductively coupled plasma time-of-¯ight mass spectrometry for the speciation analysis of organometallic compounds," *J. Anal. At. Spectrom,* vol. 15, pp. 151–155, 2000.

[78] S. Ghosh, V. L. Prasanna, B. Sowjanya, P. Srivani, and M. Alagaraja, "Inductively coupled plasma - Optical emission spectroscopy : A review Inductively Coupled Plasma – Optical Emission Spectroscopy : A Review .," no. January 2013, 2016.

[79] C. B. B. and K. J. Fredeen, *Concepts, Instrumentation and Techniques in Inductively Coupled Plasma Optical Emission Spectrometry*, 3rd ed. USA: PerkinElmer, Inc, 2004.

[80] A. A. Warra and W. L. O. Jimoh, "Overview of an inductively coupled plasma

(icp) system," *Int. J. Chem. Res.*, vol. 3, no. 2, pp. 41–48, 2011.

[81] T. Owen, *Fundamentals of UV-visible spectroscopy, A Primer.* Germany: Hewlett-Packard Company, 1996.

[82] R. Kavitha, V. Premalakshmi, T. Nadu, and T. Nadu, "PHYSICOCHEMICAL AND PHYTOCHEMICAL SCREENING OF ETHANOLIC EXTRACT OF LEAVES OF CLITORIA TERNATEA LINN. (FABACEAE)," *Int. J. INSTITUTIONAL Pharm. LIFE Sci.*, vol. 3, no. October, 2013.

[83] L. M. L. N. and F. Toldrá, *Hand Book of Food Analysis*, 3rd ed., vol. I. Boca Raton London New York CRC: CRC Press.

[84] F. M. Sanda, M. E. Victor, T. A. Monica, and C. Alina, "SPECTROPHOTOMETRIC MEASUREMENTS TECHNIQUES FOR BASE THEORY FOR UV-VIS SPECTROPHOTOMETRIC MEASUREMENTS," 2012.

[85] A. Manuscript, "Accurate calculation of the bandgap of liquid water by means of GW corrections applied to plane-wave density functional theory molecular dynamics simulations," *Phys. Chem. Chem. Phys. Accept. Manuscr*, vol. 00, pp. 1–3, 204AD, doi: 10.1039/x0xx00000x.

[86] B. Sharma and S. Tyagi, "Simplification of Metal Ion Analysis in Fresh Water Samples by Atomic Absorption Spectroscopy for Laboratory Students," *J. Lab. Chem. Educ. 2013,* vol. 1, no. 3, pp. 54–58, 2013, doi: 10.5923/j.jlce.20130103.04.

[87] Z. M. Al-azzawi, N. Z. Abdulzahra, and I. H. Hammood, "Optical Properties of Tap Water Purity using He-Ne Laser with Different Power Density," *J. Al-Nahrain Univ.*, vol. 17, no. 3, 2014.

[88] N. A. Almuslet and E. B. Mirgani, "Identification of Heavy Metals in Some

Water Sources in Khartoum State Using Laser Induced Breakdown Spectroscopy," *Int. J. Multidiscip. Sci. Eng.*, vol. 8, no. 3, pp. 16–20, 2017.

[89] H. Tian, L. Jiao, and D. Dong, "Rapid determination of trace cadmium in drinking water using laser-induced breakdown spectroscopy coupled with chelating resin enrichment," *SCIENNTIFIC REPORTS*, no. January, pp. 1–8, 2019, doi: 10.1038/s41598-019-46924-z.

[90] and R. J. P. A. Mart, C. Furlong, B. Barrientos, *Emerging Challenges for Experimental Mechanics in Energy and Environmental Applications, Proceedings of the 5th International Symposium on Experimental Mechanics and 9th Symposium on Optics in Industry (ISEM-SOI)*. Switzerland: Springer International Publishing, 2015.

[91] B. A. Joda, H. S. Alheloo, H. J. A. Al-mankosh, and A. Sultan, "Determination of heavy metals arsenic, cadmium and lead in water, sediments and fish from Al Delmaj Marshes-Iraq Determination of Heavy Metals Arsenic, Cadmium and Lead in Water, Sediments and Fish from Al Delmaj Marshes-Iraq," *AIP Conf. Proc.*, vol. 020012, no. August, 2019.

[92] E. Haj and A. Mohamed, "Heavy Metals Concentration in Water, Muscles and Gills of Oreochromis niloticus Collected from the Sewage-Treated Water and the White Nile Open Access Heavy Metals Concentration in Water , Muscles and Gills of Oreochromis niloticus Collected from the Sew," no. September, 2016, doi: 10.5376/ija.2014.04.0006.

[93] M. Ghaderpoori, A. Jafari, A. Ghaderpoury, and M. Karami, "Influence of EDTA and NTA on Heavy Metal Extraction from Sandy- Loam contaminated soils : Data in Brief Heavy metals analysis and quality assessment in drinking water – Khorramabad city, Iran," *Data Br.*, vol. 16, no. July, pp. 685–692, 2016, doi: 10.1016/j.dib.2017.11.078.

[94] O. B. Janes, O. John, N. Obed, and K. O. Evans, "Level of Metal Pollutants in

Water from Nyakomisaro Stream through Kisii Town," *Int. J. Sci. Res.*, vol. 5, no. 7, pp. 2015–2016, 2016, doi: 10.21275/v5i7.ART2016141.

[95]   I. Hummada and A. Nassir, "Study on the Physicochemical Properties and Some Heavy Metals in Ground Water of Bara Basin, North Kordofan State, Sudan Study on the Physicochemical Properties and Some Heavy Metals in Ground Water of Bara Basin, North Kordofan State," University of Kordofan, 2017.

[96]   M. Journal and O. F. Engineering, "MUTHANNA JOURNAL OF ENGINEERING AND TECHNOLOGY (MJET)," no. 2, pp. 40–44, 2017, doi: 10.18081/mjet/2017-5/40-44.

[97]   M. E. Elhussien and B. A. Adwok, "Determination of Heavy Metals in Fish and Water of White Nile During Watery Diarrhea Outbreak from June to July ," vol. 6, no. 1, pp. 1–6, 2018, doi: 10.11648/j.sjac.20180601.11.

[98]   N. Rahmanian *et al.*, "Analysis of Physiochemical Parameters to Evaluate the Drinking Water Quality in the State of Perak, Malaysia," vol. 2015, no. Cd, 2015.

[99]   T. C. HO, "DETERMINATION OF Pb(II), Cu(II) AND Ni(II) IN WATER BY DIRECT MEASUREMENT USING UV/VIS SPECTROPHOTOMETER," UNIVERSITI SAINS MALAYSIA, 2015.

[100]   J. D. Mason, M. T. Cone, and E. S. Fry, "Ultraviolet (250-550 nm) absorption spectrum of pure water," *Appl. Opt.*, no. August, 2016, doi: 10.1364/AO.55.007163.

[101]   C. Kim, J. B. Eom, S. Jung, and T. Ji, "Detection of Organic Compounds in Water by an Optical Absorbance Method," no. December 2015, pp. 1–7, 2016, doi: 10.3390/s16010061.

[102]   K. W. Mona Nissen, Brenda Doherty, Jonas Hamperl, Jens Kobelke and T. H.

and M. A. Schmidt, "UV Absorption Spectroscopy in Water-Filled Pharmaceutical Detection," pp. 1–12, 2018, doi: 10.3390/s18020478.

[103] A. Szabo and H. Marta, "UV/VIS SpectroScopy aS a method to characterIze well water qUalIty," vol. 72, no. 3, pp. 169–175, 2017.

[104] B. Tw, B. Ts, and T. Ba, "Analytical & Bioanalytical Techniques Analysis of Physical and Chemical Parameters in Ground Water Used for Drinking around Konso Area, Southwestern Ethiopia," *B i o a l n a a c l i t y t i y l c a a n l A T f e o c l h a n i n r q u u o e s J ISSN 2155-9872 J. Anal. Bioanal. Tech.*, vol. 8, no. 5, 2017, doi: 10.4172/2155-9872.1000379.

[105] E. Cataldo, A. Di Lieto, and F. Maccarrone, "Measuring the refractive index of water with a pulsed laser diode," *Eur. J. Phys.*, vol. 37, no. 6, pp. 1–4, doi: 10.1088/0143-0807/37/6/062002.

[106] D. Pan, Q. Wan, and G. Galli, "The refractive index and electronic gap of water and ice increase with increasing pressure," *Nat. Commun.*, no. May, pp. 1–6, 2014, doi: 10.1038/ncomms4919.

[107] C. Bach, X. Dauchy, I. Severin, J. Munoz, S. Etienne, and M. Chagnon, "Effect of sunlight exposure on the release of intentionally and/or non-intentionally added substances from polyethylene terephthalate (PET) bottles into water : Chemical analysis and in vitro toxicity," *Food Chem.*, vol. 162, pp. 63–71, 2014.

[108] and S. H. H. S. G. Muhamad, L. S. Esmail, "Effect of storage temperature and sunlight exposure on the physicochemical properties of bottled water in Kurdistan region-Iraq," *J. Appl. Sci. Environ. Manag*, vol. 15, no. 1, pp. 147–154, 2011.

[109] A. Jonidi and M. Sciences, "Effect of sunlight exposure and storage duration

and temperature on release of heavy metals from polyethylene terephthalate drinking water bottles Effect of Sunlight Exposure and Storage Duration and Temperature on Release of Heavy Metals from Polyethylen," *J Maz. Univ Med Sci*, no. November, 2016.

[110] S. G. Muhamad, L. S. Esmail, and S. H. Hasan, "Effect of storage temperature and sunlight exposure on the physicochemical properties of bottled water in Kurdistan region-Iraq," *J. Environ. Heal. Sci. Eng.*, vol. 15, no. 1, pp. 147–154, 2019, doi: 10.1007/s40201-019-00337-2.

[111] O. Alam, L. Yang, and X. Yanchun, "Determination of the selected heavy metal and metalloid contents in various types of plastic bags," *J. Environ. Heal. Sci. Eng.*, 2019, doi: 10.1007/s40201-019-00337-2.

[112] W. Shotyk and A. M. KRACHLER, "Contamination of Bottled Waters with Antimony Leaching from Polyethylene Terephthalate (PET) Increases upon Storage," *Environ. Sci. Technol*, vol. 41, no. 5, pp. 1560–1563, 2007.

[113] C. Bach *et al.*, "Chemical migration in drinking water stored in polyethylene terephthalate (PET) bottles : a source of controversy To cite this version : HAL Id : hal-00683918," *HAL Arch.*, 2012, doi: hal-00683918.

[114] M. Al-qutob, A. Asafra, T. Nashashibi, and A. A. Qutob, "Determination of Different Trace Heavy Metals in Children ' s Plastic Toys Imported to the West Bank / Palestine by ICP / MS-Environmental and Health Aspects," *J. Environ. Prot. (Irvine,. Calif).*, vol. 5, no. September, pp. 1104–1110, 2014, doi: 10.4236/jep.2014.512108.

[115] S. Foodstuff, A. Analytical, S. Using, and S. E. M. Edx, "Qualitative Determination of Virgin and Recycled Plastic Used for Drinking International Journal of Health Sciences and Research Qualitative Determination of Virgin and Recycled Plastic Used for Drinking and Storing Foodstuff : An Analytical Study Using S," *Int. J. Heal. Sci. Res.*, vol. 7, no. 3, 2017.

[116] K. K. Ayyalasomayajula, D. L. Mcintyre, and J. Jain, "D e t e r m i n a t i o n of e l e m e n t a l i m p u r i t i e s i n p l a s t i c c a l i b r a t i o n s t a n d a r d s u s i n g l a s e r - i n d u c e d breakdown spectroscopy," *Appl. Opt.*, vol. 51, no. 7, 2012.

[117] M. N. Siddiqui, M. A. Gondal, and M. M. Nasr, "Determination of Trace Metals Using Laser Induced Breakdown Spectroscopy in Insoluble Organic Materials Obtained from Pyrolysis of Plastics Waste Determination of Trace Metals Using Laser Induced Breakdown Spectroscopy in Insoluble Organic Materials Obtai," *Bull Env. Contam Toxicol*, vol. 83, no. June, pp. 141–145, 2009, doi: 10.1007/s00128-009-9749-x.

[118] T. I. and S. T. Etsuko NAKASHIMA, Atsuhiko ISOBE, Shin'ichiro KAKO, Shinya MAGOME, Noriko DEKI, "Toxic Metals in Polyethylene Plastic Litter," *Interdiscip. Stud. Environ. Chem. Environ. Model. Anal.*, no. December, pp. 271–277, 2011.

[119] M. Sheela, V. A. Kamat, K. U. Kiran, and K. M. Eshwarappa, "Preparation and characterization of bismuth-filled high-density polyethylene composites for gamma-ray shielding," pp. 180–186, 2020, doi: 10.4103/rpe.RPE.

[120] F. Gunsing, A. Menelle, and O. Aberle, "Determination of the boron content in polyethylene samples using the reactor Orphée," pp. 1–8, 2017.

[121] T. Kondo, T. Morimura, T. Tsujimoto, T. Aikawa, and M. Yuasa, "Platinum Nanoparticle-embedded Porous Diamond Spherical Particles as an Active and Stable Heterogeneous Catalyst," *Sci. Rep.*, no. July, pp. 1–10, 2017, doi: 10.1038/s41598-017-08949-0.

[122] L. Zheng, Y. Yiwei, L. Zhujun, and R. Liu, "Journals & Books RegisterSign in," *Fusion Eng. Des.*, vol. 13, no. december, pp. 177–182, 2016.

[123] "SSMO," Khartoum, Sudan, 2016.

[124] *Guidelines for Drinking-water Quality*, Fourth. World Health Organization, 2011.

[125] EPA 822-S-12-001 Office, *2012 Edition of the Drinking Water Standards and Health Advisories 2012 Edition of the Drinking Water Standards and Health Advisories*. Washington: Office of Water U.S. Environmental Protection Agency Washington, DC, 2012.

[126] I. Rosborg, F. Kozisek, and S. Precautions, *Drinking Water Minerals and Mineral Balance*, Second. Springer, 2016.

[127] K. K. Ab, "Health and safety issues in REE mining and processing An internal EURARE guidance report Geological Survey of Finland," no. September, 2014.

[128] "CHAPTER 5 . POTENTIAL FOR HUMAN EXPOSURE," in *Thorium*, 2017, pp. 76–104.

[129] S. D. Sheet, "Bismuth AA Standard , 1000ppm (1mL = 1mg Bi) Safety Data Sheet," vol. 77, no. 58, pp. 1–8, 2016.

[130] S. Africa, "Platinum," in *Air Quality Guidelines*, Second Edi., WHO Regional Office for Europe, Copenhagen, Denmark, 2000, pp. 1–13.

[131] "Technical Fact Sheet – Tungsten At a Glance," 2014.

[132] "Ta – Tantalum," 2004.

Appendixes:

Appendix (1) - ICPE Results before Exposure to Sunlight and Storage Period:

File Name:4977-1.ied   Print Date:11/21/2019 09:27:26 Ŏ

Qualitative Results

Sample Name	water 1
Date/Time of Analysis	11/20/2019 12:04:06 ā
Comment	

1000mg/L <=

1mg/L <=

1ug/L <=	Al 63	Ca 97	Cu 15	Er 12	Fe 170	I 15
	K 3.0	Mg 140	Na 22	Rb 730	S 930	Si 220
	Ti 6.2					
< 1ug/L	B 0.87	Ba 0.21	Li 0.05	Mn 0.75	Sr 0.32	Zn 0.95
Not Detected ug/L	Ag < 2.1	As < 17 +	Au < 1.1	Be < 0.04	Bi < 5.9	Cd < 0.72
	Ce < 4.9	Co < 2.4	Cr < 2.1	Cs < 450	Dy < 1.2	Eu < 0.23
	Ga < 2.9	Gd < 2.0	Ge < 2.3	Hf < 5.9	Hg < 1.5	Ho < 1.2
	In < 22	Ir < 42	La < 0.92	Lu < 0.30	Mo < 9.0	Nb < 3.1
	Nd < 3.0	Ni < 5.8	Os < 15	P < 18	Pb < 7.5 +	Pd < 6.6
	Pr < 3.5	Pt < 30	Re < 4.8	Rh < 8.0	Ru < 5.3	Sb < 9.1
	Sc < 0.21	Se < 20	Sm < 4.4	Sn < 10	Ta < 5.6	Tb < 3.3
	Te < 16	Th < 11	Tl < 20	Tm < 1.3	U < 23	V < 0.32
	W < 22	Y < 0.24	Yb < 0.11	Zr < 0.86		

Instrument Name:Forensic

I

Qualitative Results

Sample Name	water 2
Date/Time of Analysis	11/20/2019 12:07:53 ã
Comment	

1000mg/L <=

1mg/L <=

1ug/L <=   Ca 41   Cu 14   Fe 21   I 22   K 4.6   Mg 120
            Na 36   S 130   Si 75

< 1ug/L   Ba 0.24   Li 0.05   Sr 0.28   Ti 0.67   Zn 0.48

Not Detected ug/L   Ag < 2.2   Al < 19   As < 14 +   Au < 1.1   B < 0.72   Be < 0.04
                    Bi < 5.6   Cd < 0.67   Ce < 4.8   Co < 2.3   Cr < 2.1   Cs < 470
                    Dy < 1.3   Er < 1.6   Eu < 0.21   Ga < 2.9   Gd < 2.0   Ge < 2.2
                    Hf < 5.5   Hg < 1.3   Ho < 1.2   In < 23   Ir < 40   La < 0.97
                    Lu < 0.30   Mn < 0.24   Mo < 6.6 + Nb < 3.0   Nd < 2.9   Ni < 5.5
                    Os < 15   P < 17   Pb < 6.6 + Pd < 6.9   Pr < 3.6   Pt < 26 +
                    Rb < 720   Re < 4.4   Rh < 8.2   Ru < 4.9   Sb < 8.2   Sc < 0.20
                    Se < 21   Sm < 4.3   Sn < 9.9   Ta < 5.0   Tb < 3.3   Te < 15
                    Th < 12   Tl < 19   Tm < 1.4   U < 23   V < 0.32   W < 21
                    Y < 0.24   Yb < 0.11   Zr < 0.85

Instrument Name:Forensic

Qualitative Results

Sample Name	water 3
Date/Time of Analysis	11/20/2019 12:11:38 ã
Comment	

1000mg/L <=

1mg/L <=

1ug/L <=

Ca 52	Cu 15	Er 1.8	Fe 28	Ho 1.2	K 4.1
Mg 110	Na 35	Pb 6.8 +	S 180	Si 83	Sr 1.1
Th 13	Ti 1.1				

< 1ug/L

B 0.77	Ba 0.18	Zn 0.40

Not Detected ug/L

Ag < 2.2	Al < 20	As < 15 +	Au < 1.0	Be < 0.04	Bi < 5.2
Cd < 0.65	Ce < 5.0	Co < 2.2	Cr < 2.0	Cs < 470	Dy < 1.3
Eu < 0.21	Ga < 2.9	Gd < 2.0	Ge < 2.3	Hf < 5.6	Hg < 1.4
I < 11	In < 23	Ir < 37	La < 0.95	Li < 0.05	Lu < 0.28
Mn < 0.23	Mo < 7.3 +	Nb < 3.1	Nd < 3.0	Ni < 5.5	Os < 13
P < 17	Pd < 6.9	Pr < 3.9	Pt < 25 +	Rb < 750	Re < 4.1
Rh < 7.8	Ru < 4.8	Sb < 8.1	Sc < 0.21	Se < 18	Sm < 4.5
Sn < 9.9	Ta < 5.1	Tb < 3.3	Te < 15	Tl < 20	Tm < 1.4
U < 23	V < 0.31	W < 20	Y < 0.25	Yb < 0.11	Zr < 0.88

Instrument Name:Forensic

Qualitative Results

Sample Name	water 4
Date/Time of Analysis	11/20/2019 12:15:22 ã
Comment	

1000mg/L <=

1mg/L <=   S 5.7

1ug/L <=

Ca 170	Cd 1.3	Cu 16	Ho 1.5	K 3.0	Mg 390	Mn 1.4
Na 89	Si 85	Tl 27				

< 1ug/L

Ba 0.62	Sc 0.31	Sr 0.77	Zn 0.57			

Not Detected ug/L

Ag < 2.3	Al < 24	As < 15	Au < 1.1	B < 0.75	Be < 0.04	Bi < 6.0
Ce < 5.5	Co < 2.2	Cr < 2.2	Cs < 480	Dy < 1.4	Er < 1.7	Eu < 0.24
Fe < 2.1	Ga < 3.2	Gd < 2.2	Ge < 2.8	Hf < 6.2	Hg < 1.3	I < 12
In < 25	Ir < 40	La < 1.1	Li < 0.05	Lu < 0.31	Mo < 5.3	Nb < 3.3
Nd < 3.3	Ni < 6.0	Os < 15	P < 18	Pb < 6.5	Pd < 7.2	Pr < 3.9
Pt < 26	Rb < 810	Re < 4.5	Rh < 8.8	Ru < 5.2	Sb < 8.5	Se < 18
Sm < 4.8	Sn < 12	Ta < 5.4	Tb < 3.7	Te < 16	Th < 12	Ti < 0.67
Tm < 1.5	U < 26	V < 0.33	W < 21	Y < 0.27	Yb < 0.12	Zr < 0.92

Instrument Name:Forensic

IV

Qualitative Results

Sample Name	water 5
Date/Time of Analysis	11/20/2019 12:19:07 ä
Comment	

1000mg/L <=							
1mg/L <=	S 2.2						
1ug/L <=	B 1.1	Ca 120	Cu 18	K 1.9	Mg 280	Mn 2.3	Na 87
	Rb 840	Sb 7.9	Si 150				
< 1ug/L	Ba 0.38	Cd 0.90	Sr 0.50	Zn 0.94			
Not Detected ug/L	Ag < 2.3	Al < 22	As < 14	Au < 1.0	Be < 0.04	Bi < 5.7	Ce < 5.5
	Co < 2.1	Cr < 2.1	Cs < 480	Dy < 1.4	Er < 1.7	Eu < 0.23	Fe < 2.1
	Ga < 3.1	Gd < 2.2	Ge < 2.5	Hf < 6.0	Hg < 1.4	Ho < 1.2	I < 11
	In < 25	Ir < 39	La < 1.1	Li < 0.05	Lu < 0.31	Mo < 4.9	Nb < 3.3
	Nd < 3.2	Ni < 5.5	Os < 15	P < 17	Pb < 6.2	Pd < 7.5	Pr < 3.9
	Pt < 24	Re < 4.3	Rh < 8.8	Ru < 5.0	Sc < 0.23	Se < 17	Sm < 4.6
	Sn < 11	Ta < 5.2	Tb < 3.7	Te < 16	Th < 12	Ti < 0.67	Tl < 23
	Tm < 1.5	U < 25	V < 0.34	W < 21	Y < 0.27	Yb < 0.12	Zr < 0.90

Instrument Name:Forensic

V

Qualitative Results

Sample Name	water 6					
Date/Time of Analysis	11/20/2019 12:22:50 ā					
Comment						
1000mg/L <=						
1mg/L <=	S 1.0					
1ug/L <=	Ca 93	Cu 17	I 18	K 2.6	Mg 130	Na 19
	Si 100					
< 1ug/L	Ba 0.16	Sr 0.30	Zn 0.64			
Not Detected ug/L	Ag < 2.3	Al < 23	As < 13	Au < 1.0	B < 0.66	Be < 0.04
	Bi < 5.7	Cd < 0.67	Ce < 5.6	Co < 2.1	Cr < 2.2	Cs < 520
	Dy < 1.4	Er < 1.8	Eu < 0.24	Fe < 2.0	Ga < 3.0	Gd < 2.2
	Ge < 2.3	Hf < 5.8	Hg < 1.4	Ho < 1.3	In < 25	Ir < 37
	La < 1.1	Li < 0.05	Lu < 0.29	Mn < 0.24	Mo < 4.4	Nb < 3.3
	Nd < 3.5	Ni < 5.7	Os < 14	P < 17	Pb < 6.4	Pd < 7.4
	Pr < 4.2	Pt < 24	Rb < 830	Re < 4.3	Rh < 8.8	Ru < 4.9
	Sb < 8.9	Sc < 0.23	Se < 20	Sm < 4.7	Sn < 11	Ta < 5.3
	Tb < 3.6	Te < 15	Th < 11	Ti < 0.69	Tl < 20	Tm < 1.6
	U < 26	V < 0.34	W < 21	Y < 0.27	Yb < 0.11	Zr < 0.92

Instrument Name:Forensic

Qualitative Results

Sample Name	water 7
Date/Time of Analysis	11/20/2019 12:26:35 ã
Comment	

1000mg/L <=

1mg/L <=

1ug/L <=

Ca 140	Cu 18	Fe 2.3	K 3.3	Mg 310	Mn 3.1	Na 64
S 200	Si 200	Tl 24				

< 1ug/L

B 0.80	Ba 0.21	Cd 0.97	Li 0.07	Sr 0.74		

Not Detected ug/L

Ag < 2.4	Al < 24	As < 14	Au < 1.1	Be < 0.04	Bi < 5.9	Ce < 5.7
Co < 2.1	Cr < 2.1	Cs < 510	Dy < 1.4	Er < 1.8	Eu < 0.25	Ga < 3.2
Gd < 2.3	Ge < 2.3	Hf < 6.1	Hg < 1.5	Ho < 1.4	I < 9.6	In < 26
Ir < 40	La < 1.1	Lu < 0.30	Mo < 5.1	Nb < 3.4	Nd < 3.5	Ni < 5.7
Os < 14	P < 17	Pb < 6.2	Pd < 7.6	Pr < 4.2	Pt < 25	Rb < 850
Re < 4.3	Rh < 8.8	Ru < 4.8	Sb < 8.9	Sc < 0.24	Se < 19	Sm < 5.0
Sn < 12	Ta < 5.5	Tb < 3.7	Te < 15	Th < 12	Ti < 0.69	Tm < 1.6
U < 27	V < 0.35	W < 20	Y < 0.28	Yb < 0.12	Zn < 0.35	Zr < 0.94

Instrument Name:Forensic

Qualitative Results

Sample Name	water 8
Date/Time of Analysis	11/20/2019 12:30:19 ã
Comment	

1000mg/L <=						
1mg/L <=	S 6.7					
1ug/L <=	B 2.0	Ca 180	Cd 1.4	Cu 19	K 5.3	Mg 120
	Na 200	Si 220	Sr 1.2	Tl 33		
< 1ug/L	Ba 0.40	Li 0.06	Sc 0.34			
Not Detected ug/L	Ag < 2.5	Al < 26	As < 15	Au < 1.1	Be < 0.04	Bi < 6.1
	Ce < 6.0	Co < 2.2	Cr < 2.2	Cs < 520	Dy < 1.5	Er < 1.8
	Eu < 0.27	Fe < 2.2	Ga < 3.4	Gd < 2.3	Ge < 2.7	Hf < 6.3
	Hg < 1.5	Ho < 1.5	I < 12	In < 27	Ir < 41	La < 1.2
	Lu < 0.32	Mn < 0.27	Mo < 5.4	Nb < 3.5	Nd < 3.8	Ni < 5.7
	Os < 15	P < 18	Pb < 6.6	Pd < 7.9	Pr < 4.3	Pt < 25
	Rb < 880	Re < 4.4	Rh < 9.3	Ru < 5.0	Sb < 9.2	Se < 20
	Sm < 5.1	Sn < 13	Ta < 5.7	Tb < 4.0	Te < 16	Th < 13
	Ti < 0.75	Tm < 1.5	U < 28	V < 0.35	W < 22	Y < 0.29
	Yb < 0.13	Zn < 0.35	Zr < 0.99			

Instrument Name:Forensic

Qualitative Results

Sample Name	water 9
Date/Time of Analysis	11/20/2019 12:34:03 ã
Comment	

1000mg/L <=

1mg/L <= S 2.6

1ug/L <= Ca 140 Cd 1.0 Cu 19 K 4.1 Mg 310 Na 110 Si 90
TI 25

< 1ug/L B 0.84 Ba 0.78 Mn 0.37 Sc 0.28 Sr 0.67 Zn 0.44

Not Detected ug/L
Ag < 2.5 Al < 25 As < 15 Au < 1.1 Be < 0.04 Bi < 5.8 Ce < 6.0
Co < 2.2 Cr < 2.3 Cs < 530 Dy < 1.5 Er < 1.9 Eu < 0.26 Fe < 2.1
Ga < 3.2 Gd < 2.3 Ge < 2.4 Hf < 6.1 Hg < 1.4 Ho < 1.4 I < 11
In < 27 Ir < 39 La < 1.2 Li < 0.05 Lu < 0.31 Mo < 5.2 Nb < 3.4
Nd < 3.7 Ni < 5.7 Os < 14 P < 17 Pb < 6.4 Pd < 7.9 Pr < 4.2
Pt < 25 Rb < 880 Re < 4.2 Rh < 9.1 Ru < 5.3 Sb < 8.8 Se < 20
Sm < 5.1 Sn < 12 Ta < 5.4 Tb < 3.9 Te < 16 Th < 12 Ti < 0.73
Tm < 1.6 U < 28 V < 0.36 W < 21 Y < 0.29 Yb < 0.12 Zr < 0.97

Instrument Name:Forensic

Qualitative Results

Sample Name	water 10					
Date/Time of Analysis	11/20/2019 12:37:47 ã					
Comment						

1000mg/L <=						
1mg/L <=	S 2.9					
1ug/L <=	B 1.1	Ba 1.5	Ca 200	Cd 1.1	Cu 18	K 4.2
	Mg 360	Na 100	Si 130	Tl 26 ·		
< 1ug/L	Sc 0.44	Sr 0.85				
Not Detected ug/L	Ag < 2.5	Al < 27	As < 13	Au < 1.1	Be < 0.04	Bi < 6.1
	Ce < 5.8	Co < 2.2	Cr < 2.2	Cs < 510	Dy < 1.5	Er < 1.8
	Eu < 0.25	Fe < 2.1	Ga < 3.3	Gd < 2.3	Ge < 2.5	Hf < 6.1
	Hg < 1.4	Ho < 1.5	I < 11	In < 26	Ir < 39	La < 1.2
	Li < 0.05	Lu < 0.30	Mn < 0.25	Mo < 5.2	Nb < 3.5	Nd < 3.6
	Ni < 5.7	Os < 14	P < 17	Pb < 6.3	Pd < 7.7	Pr < 4.4
	Pt < 23	Rb < 890	Re < 4.3	Rh < 9.1	Ru < 5.0	Sb < 8.6
	Se < 19	Sm < 5.0	Sn < 12	Ta < 5.2	Tb < 4.0	Te < 15
	Th < 13	Ti < 0.78	Tm < 1.5	U < 27	V < 0.35	W < 19
	Y < 0.29	Yb < 0.12	Zn < 0.34	Zr < 0.96		

Instrument Name:Forensic

X

Appendix (2) - ICPE Results after Exposure to Sunlight and Storage Period:

Qualitative Results

Sample Name	1
Date/Time of Analysis	3/25/2020 09:54:41 Õ
Comment	

1000mg/L <=

1mg/L <=

1ug/L <=	Al 29	As 12 +	Bl 4.8	Ca 100	Cu 11	Er 4.6
	Fe 43	Ho 1.5	I 12	K 1.6	Mg 100	Na 15
	Pt 23	Rb 700	S 730	Sb 5.9	Sl 95	Ti 2.5
< 1ug/L	B 0.49	Ba 0.14	Ll 0.05	Mn 0.35	Sr 0.35	V 0.22
	Zn 0.26					
Not Detected ug/L	Ag < 1.7	Au < 0.67	Be < 0.03	Cd < 0.44	Ce < 4.1	Co < 1.4
	Cr < 1.3	Cs < 380	Dy < 0.98	Eu < 0.18	Ga < 1.9	Gd < 1.5
	Ge < 1.6	Hf < 3.6	Hg < 0.88	In < 19	Ir < 26	La < 0.81
	Lu < 0.19	Mo < 6.0	Nb < 2.1	Nd < 2.5	Ni < 3.8	Os < 9.6
	P < 12	Pb < 4.6 +	Pd < 5.3	Pr < 3.3	Re < 3.1	Rh < 6.1
	Ru < 3.2	Sc < 0.17	Se < 13	Sm < 3.5	Sn < 6.7	Ta < 3.7
	Tb < 2.8	Te < 11	Th < 7.2	Tl < 12	Tm < 1.1	U < 17
	W < 15	Y < 0.20	Yb < 0.07	Zr < 0.64		

Instrument Name:Forensic

Qualitative Results

Sample Name	2					
Date/Time of Analysis	3/25/2020 09:58:25 Ö					
Comment						
1000mg/L <=						
1mg/L <=						
1ug/L <=	Ca 60	Cu 13	Er 1.4	Fe 11	K 3.8	Mg 120
	Na 29	S 110	Si 60	Th 8.9	W 13	
< 1ug/L	B 0.55	Ba 0.27	Li 0.05	Mn 0.15	Sr 0.39	Ti 0.74
	Zn 0.22					
Not Detected ug/L	Ag < 1.6	Al < 16	As < 9.3 +	Au < 0.65	Be < 0.02	Bi < 3.9
	Cd < 0.44	Ce < 4.1	Co < 1.3	Cr < 1.3	Cs < 370	Dy < 0.97
	Eu < 0.17	Ga < 1.9	Gd < 1.5	Ge < 1.4	Hf < 3.3	Hg < 0.92
	Ho < 0.98	I < 7.1	In < 18	Ir < 25	La < 0.82	Lu < 0.18
	Mo < 4.3 +	Nb < 2.2	Nd < 2.5	Ni < 3.6	Os < 9.8	P < 11
	Pb < 4.2 +	Pd < 5.3	Pr < 2.8	Pt < 17	Rb < 620	Re < 2.9
	Rh < 5.8	Ru < 3.0	Sb < 5.4	Sc < 0.17	Se < 13	Sm < 3.3
	Sn < 6.4	Ta < 3.3	Tb < 2.7	Te < 10	Tl < 13	Tm < 1.0
	U < 17	V < 0.21	Y < 0.19	Yb < 0.07	Zr < 0.61	

Instrument Name:Forensic

Qualitative Results

Sample Name   3
Date/Time of Analysis   3/25/2020 10:02:09 Ô
Comment

1000mg/L <=

1mg/L <=

1ug/L <=	Al 22	As 12 +	Ca 73	Cu 11	Er 2.4	Fe 24
	I 11	K 3.0	Mg 120	Na 28	Pt 19	S 170
	Sb 8.0	Se 11	Si 70	Tl 1.4		

< 1ug/L	B 0.60	Ba 0.23	Eu 0.18	Li 0.04	Lu 0.19	Mn 0.17
	Sr 0.34					

Not Detected ug/L	Ag < 1.6	Au < 0.62	Be < 0.02	Bi < 3.9	Cd < 0.46	Ce < 4.2
	Co < 1.3	Cr < 1.3	Cs < 380	Dy < 0.97	Ga < 1.9	Gd < 1.5
	Ge < 1.4	Hf < 3.5	Hg < 0.83	Ho < 1.0	In < 19	Ir < 26
	La < 0.83	Mo < 5.7	Nb < 2.1	Nd < 2.5	Ni < 3.5	Os < 8.7
	P < 11	Pb < 4.3 +	Pd < 5.2	Pr < 3.2	Rb < 630	Re < 3.0
	Rh < 5.9	Ru < 3.1	Sc < 0.18	Sm < 3.3	Sn < 6.6	Ta < 3.3
	Tb < 2.8	Te < 11	Th < 6.8	Tl < 13	Tm < 1.1	U < 17
	V < 0.22	W < 13	Y < 0.20	Yb < 0.07	Zn < 0.22	Zr < 0.64

Instrument Name:Forensic

XIII

Qualitative Results

Sample Name	4					
Date/Time of Analysis	3/25/2020 10:05:53 Ö					
Comment						

1000mg/L <=						
1mg/L <=	S 4.7					
1ug/L <=	Ca 190	Cd 1.1	Cu 14	Hg 1.1	I 9.5	K 2.6
	Mg 93	Na 72	Ni 3.7	Sb 6.9	Si 67	TI 24
< 1ug/L	B 0.60	Ba 0.65	Sc 0.23	Sr 0.96		
Not Detected ug/L	Ag < 1.6	Al < 20	As < 9.8 +	Au < 0.70	Be < 0.03	Bi < 4.5
	Ce < 4.4	Co < 1.5	Cr < 1.4	Cs < 400	Dy < 1.0	Er < 1.2
	Eu < 0.20	Fe < 1.4	Ga < 2.2	Gd < 1.6	Ge < 1.8	Hf < 3.8
	Ho < 0.98	In < 20	Ir < 27	La < 0.90	Li < 0.04	Lu < 0.19
	Mn < 0.16	Mo < 4.7 +	Nb < 2.2	Nd < 2.9	Os < 11	P < 12
	Pb < 4.4 +	Pd < 5.6	Pr < 3.3	Pt < 18 +	Rb < 650	Re < 3.0
	Rh < 6.5	Ru < 3.3	Se < 13	Sm < 3.5	Sn < 8.3	Ta < 3.8
	Tb < 2.9	Te < 11	Th < 8.0	Ti < 0.54	Tm < 1.1	U < 19
	V < 0.23	W < 13	Y < 0.21	Yb < 0.08	Zn < 0.24	Zr < 0.65

Instrument Name:Forensic

XIV
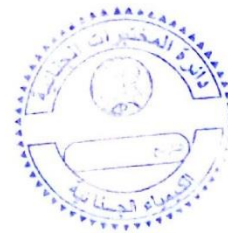
Qualitative Results

Sample Name	5
Date/Time of Analysis	3/25/2020 10:09:37 Ò
Comment	

1000mg/L <=	

1mg/L <=	S 1.7

1ug/L <=						
	Al 230	Bi 4.3	Ca 23	Cu 7.7	Ho 1.3	I 16
	K 1.4	Mg 39	Na 68	Pt 22	Rb 650	Si 31
	Ta 4.5	Th 6.7				

< 1ug/L	Ba 0.12	Cd 0.40	Li 0.05	Sr 0.89	Yb 0.07	
Not Detected ug/L	Ag < 1.7	As < 8.1 +	Au < 0.59	B < 0.42	Be < 0.02	Ce < 4.4
	Co < 1.3	Cr < 1.2	Cs < 390	Dy < 0.99	Er < 1.2	Eu < 0.17
	Fe < 1.2	Ga < 1.8	Gd < 1.5	Ge < 1.4	Hf < 3.3	Hg < 0.88
	In < 18	Ir < 25	La < 0.87	Lu < 0.18	Mn < 0.14	Mo < 3.4 +
	Nb < 2.1	Nd < 2.7	Ni < 2.1	Os < 9.4	P < 11	Pb < 4.0 +
	Pd < 5.3	Pr < 3.4	Re < 2.8	Rh < 6.1	Ru < 2.9	Sb < 5.4
	Sc < 0.18	Se < 12	Sm < 3.5	Sn < 5.9	Tb < 2.9	Te < 9.7
	Ti < 0.53	Tl < 11	Tm < 1.1	U < 16	V < 0.22	W < 13
	Y < 0.19	Zn < 0.22	Zr < 0.64			

Instrument Name:Forensic

XV

Qualitative Results

Sample Name	6
Date/Time of Analysis	3/26/2020 08:22:32 Ö
Comment	

1000mg/L <=

1mg/L <=

1ug/L <=	Ca 88	Mg 130	Na 12	S 54	Si 69
< 1ug/L	Sr 0.10				
Not Detected ug/L	Ag < 0.00	Al < 0.00	As < 0.00	Au < 0.00	B < 0.00	Ba < 0.00
	Be < 0.00	Bi < 0.00	Cd < 0.00	Ce < 0.00	Co < 0.00	Cr < 0.00
	Cs < 0.00	Cu < 0.00	Dy < 0.00	Er < 0.00	Eu < 0.00	Fe < 0.00
	Ga < 0.00	Gd < 0.00	Ge < 0.00	Hf < 0.00	Hg < 0.00	Ho < 0.00
	I < 0.00	In < 0.00	Ir < 0.00	K < 0.00	La < 0.00	Li < 0.00
	Lu < 0.00	Mn < 0.00	Mo < 0.00	Nb < 0.00	Nd < 0.00	Ni < 0.00
	Os < 0.00	P < 0.00	Pb < 0.00	Pd < 0.00	Pr < 0.00	Pt < 0.00
	Rb < 0.00	Re < 0.00	Rh < 0.00	Ru < 0.00	Sb < 0.00	Sc < 0.00
	Se < 0.00	Sm < 0.00	Sn < 0.00	Ta < 0.00	Tb < 0.00	Te < 0.00
	Th < 0.00	Ti < 0.00	Tl < 0.00	Tm < 0.00	U < 0.00	V < 0.00
	W < 0.00	Y < 0.00	Yb < 0.00	Zn < 0.00	Zr < 0.00	

Instrument Name:Forensic

Qualitative Results

Sample Name	7
Date/Time of Analysis	3/26/2020 08:26:16 Ō
Comment	

1000mg/L <=

1mg/L <=

1ug/L <=

As 12	Ca 120	Cu 13	I 17	K 3.5	Mg 65
Na 55	S 79	Si 160	Tl 18		

< 1ug/L

Ba 0.18	Cd 0.84	Li 0.04	Sc 0.20	Sr 0.80	

Not Detected ug/L

Ag < 1.7	Al < 18	Au < 0.72	B < 0.46	Be < 0.03	Bi < 4.5
Ce < 4.3	Co < 1.5	Cr < 1.4	Cs < 370	Dy < 1.0	Er < 1.3
Eu < 0.18	Fe < 1.5	Ga < 2.2	Gd < 1.5	Ge < 1.6	Hf < 3.7
Hg < 0.95	Ho < 0.98	In < 19	Ir < 28	La < 0.89	Lu < 0.20
Mn < 0.16	Mo < 3.6	Nb < 2.2	Nd < 2.7	Ni < 3.9	Os < 10
P < 12	Pb < 4.3	Pd < 5.4	Pr < 3.1	Pt < 18	Rb < 640
Re < 3.1	Rh < 6.3	Ru < 3.3	Sb < 6.5	Se < 12	Sm < 3.5
Sn < 8.1	Ta < 3.8	Tb < 2.9	Te < 12	Th < 8.4	Ti < 0.54
Tm < 1.2	U < 19	V < 0.22	W < 15	Y < 0.21	Yb < 0.08
Zn < 0.24	Zr < 0.64				

Instrument Name:Forensic

Qualitative Results

Sample Name	8
Date/Time of Analysis	3/26/2020 08:30:01 Ỗ
Comment	

1000mg/L <=						
1mg/L <=	S 5.5					
1ug/L <=	As 10	B 1.4	Bi 4.9	Ca 210	Cd 1.2	Cu 12
	I 17	Ir 29	K 5.4	Mg 110	Na 170	Si 170
	Sr 1.5	Tl 28				
< 1ug/L	Ba 0.45	Li 0.06	Sc 0.23			
Not Detected ug/L	Ag < 1.7	Al < 20	Au < 0.73	Be < 0.03	Ce < 4.6	Co < 1.5
	Cr < 1.5	Cs < 390	Dy < 1.1	Er < 1.3	Eu < 0.19	Fe < 1.6
	Ga < 2.3	Gd < 1.6	Ge < 1.8	Hf < 4.0	Hg < 1.0	Ho < 1.2
	In < 19	La < 0.93	Lu < 0.20	Mn < 0.17	Mo < 4.1	Nb < 2.3
	Nd < 2.9	Ni < 4.1	Os < 11	P < 12	Pb < 4.7	Pd < 5.8
	Pr < 3.5	Pt < 18	Rb < 660	Re < 3.3	Rh < 6.4	Ru < 3.4
	Sb < 6.6	Se < 13	Sm < 3.7	Sn < 9.0	Ta < 3.8	Tb < 3.1
	Te < 11	Th < 8.9	Ti < 0.59	Tm < 1.2	U < 20	V < 0.24
	W < 13	Y < 0.21	Yb < 0.09	Zn < 0.26	Zr < 0.68	

Instrument Name:Forensic

Qualitative Results

Sample Name	9
Date/Time of Analysis	3/26/2020 08:33:45 Ö
Comment	

1000mg/L <=

1mg/L <=   S 2.1

1ug/L <=

As 12	Ca 200	Cu 13	Ho 1.3	I 11	K 3.8
Mg 310	Na 96	Si 70	Tl 22		

< 1ug/L

B 0.68	Ba 0.89	Cd 0.82	Sc 0.19	Sr 0.84	

Not Detected ug/L

Ag < 1.6	Al < 20	Au < 0.68	Be < 0.03	Bi < 4.2	Ce < 4.5
Co < 1.4	Cr < 1.4	Cs < 400	Dy < 1.0	Er < 1.2	Eu < 0.18
Fe < 1.5	Ga < 2.2	Gd < 1.6	Ge < 1.6	Hf < 3.8	Hg < 0.95
In < 20	Ir < 28	La < 0.91	Li < 0.04	Lu < 0.20	Mn < 0.16
Mo < 3.5	Nb < 2.2	Nd < 3.0	Ni < 3.9	Os < 10	P < 11
Pb < 4.4	Pd < 5.8	Pr < 3.3	Pt < 17	Rb < 660	Re < 3.1
Rh < 6.4	Ru < 3.4	Sb < 6.1	Se < 12	Sm < 3.7	Sn < 8.0
Ta < 3.7	Tb < 2.9	Te < 11	Th < 7.8	Ti < 0.56	Tm < 1.1
U < 18	V < 0.23	W < 13	Y < 0.20	Yb < 0.08	Zn < 0.22
Zr < 0.68					

Instrument Name:Forensic

Qualitative Results

Sample Name	10
Date/Time of Analysis	3/26/2020 08:37:29 Ŏ
Comment	

1000mg/L <=						
1mg/L <=	S 2.5					
1ug/L <=	As 11	B 1.1	Ba 1.9	Ca 250	Cd 1.1	Cu 13
	Ho 1.4	I 8.6	K 3.9	Mg 88	Na 89	Si 100
	Sr 1.2	Tl 23				
< 1ug/L	Hg 0.99	Li 0.05	Sc 0.29			
Not Detected ug/L	Ag < 1.7	Al < 20	Au < 0.72	Be < 0.03	Bi < 4.7	Ce < 4.8
	Co < 1.5	Cr < 1.5	Cs < 400	Dy < 1.1	Er < 1.3	Eu < 0.21
	Fe < 1.5	Ga < 2.3	Gd < 1.7	Ge < 1.8	Hf < 3.9	In < 20
	Ir < 28	La < 0.95	Lu < 0.20	Mn < 0.17	Mo < 3.9	Nb < 2.3
	Nd < 3.0	Ni < 3.9	Os < 11	P < 12	Pb < 4.5	Pd < 5.9
	Pr < 3.6	Pt < 19	Rb < 690	Re < 3.3	Rh < 6.5	Ru < 3.5
	Sb < 6.3	Se < 14	Sm < 3.8	Sn < 8.6	Ta < 4.0	Tb < 3.1
	Te < 11	Th < 8.6	Ti < 0.55	Tm < 1.1	U < 19	V < 0.24
	W < 15	Y < 0.23	Yb < 0.09	Zn < 0.24	Zr < 0.71	

Instrument Name:Forensic

Appendix (3) – Recommendation Letters:

جمهوريه السودان
وزارة التعليم العالي والبحث العلمي
جامعة بحري
كلية الدراسات العليا
UNIVERSITY OF BAHRI
GRADUATE COLLEGE

Graduate College
كلية الدراسات العليا

Registration's Office

University of Bahri
مكتب المسجل

النمرة ج ب /ك د ع/ 1

التاريخ: 2019/1/14م

السادة / هيئة مياه ولاية الخرطوم

السلام عليكم ورحمة الله وبركاته ١١١١١

الموضوع: الطالب محمد عوض سعيد سالم العامري

تفيد كلية الدراسات العليا بجامعة بحري بأن الطالب / **محمد عوض سعيد سالم العامري** مسجل لدرجة الدكتوراه في الفيزياء بكلية العلوم التطبيقية والصناعية، نرجو التكرم بمساعدته في الحصول علي معلومات كافية عن مصادر مياه الشرب الأساسية لأخذ العينات الخاصة بمياه الشرب.
وهذا منا للأعتماد ؛؛؛

وشكراً ؛؛؛؛؛؛

أ. عبد السلام إسماعيل الفكي
مسجل كلية الدراسات العليا

بسم الله الرحمن الرحيم

هيئة مياه ولاية الخرطوم

رؤيتنا : توفير إمدادات مياه مستقرة كماً وكيفاً ونوعاً للمستهلكين بولاية الخرطوم

إذن دخـــول

الاسم ....محمد عطا سعيد........... تاريخ بداية التدريب ٢٢/١٠/٢٠١٩م

موقع التدريب ....محطة الحمر ع/حمزة/السوبر.... تاريخ نهاية التدريب ....

نوع التدريب ....اخذ عينات من الحقه.............

ملحوظة : (ينتهي هذا الإذن بنهاية الفترة التدريبية).

اعتماد
مسئول الأمن

اعتماد
مدير التدريب

Appendixes (4) – Database of Drinking Water Sources in Khartoum State, Sudan:

ثيئة مياه ولاية الخرطوم للمياه: الإدارة الهندسية لمشاريع مياه الشرب ومعالجتها

الملاحظات	الكفاءة المصممة %	استهلاك الكهرباء kw	استهلاك الشبة kg	استهلاك الكلور kg	سعر الماء بالجنيه	سعر الماء بالجنيه	الإنتاجية الفعلية m3	الطاقة الفعلية m3	الطاقة التصميمية m3	الطاقة التصميمية اليومية m3	المحطة
	90%	2,424,242	1,921	7,080	8	231	270,687	8,120,600	8,563,000	300,000	بحري
	103%	1,879,993	0	13,706	920	375	206,352	6,190,570	6,830,720	200,000	الشمالية
	109%	836,883	1,300	3,000	18	110	108,963	3,268,897	3,378,050	100,000	ميرا
	91%	536,797	1,320	3,600	3	160.00	122,760	3,682,800	4,030,000	135,000	المقرن
	80%	303,030	2,164	1,584	28.00	93.00	54,100	1,623,000	1,777,934	68,000	شمبات
	86%	275,757	2000	1600	25	50	42,783	1,283,500	1,398,500	50,000	جبل أولياء
	75%	303,030	342	1,440	6	38	20,130	603,900	770,000	27,000	فلة البان
المحطات غير عاملة (الصرف)	0%	45,398	800	0	57	0	0	0	0	16,920	جرب
	104%	115,500	0	30	15	15	15,600	467,990	628,320	15,000	الصالحة
	90%	22,300	682	0	4	3.7	3,600	108,000	122,400	4,000	أبو دليق
	46%	9,200	20	27	9	5.50	551	16,532	18,032	1,200	أم دوم
	96%	120,345	1,100	600	27	37	14,340	430,200	466,050	15,000	الكريمت
	92%	6,872,475	11,649	32,667	1,120	1,118	859,866	25,795,989	27,983,006	932,120	الإجمالي

إنتاجية الكثافة الحقلية م³ في إنتاج المياه لسنة 2019م

قائمة الأضرار بالممتلكات في المحافظات في أكتوبر 2019م

التسلسل	المحافظة	الأضرار بذات المدنية	الإصابات	الشهداء	الأضرار بذات المدنية	الأضرار بذات الحكومية	الإجمالي
1	القرشوم	100	-	6	3	14	117
2	حجة الحوطء	171	25	1	119	11	301
3	صنعاء العاصمة	227	23	1	375	10	612
4	صعدة	77	10	2	38	22	137
5	أمانة العاصمة	86	21	1	15	18	119
6	الحديدة	120	58	2	121	28	269
7	كبنة	161	35	-	64	20	245
	الإجمالي	942	-	-	735	123	1800

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إيرادات الأصناف باعتبار ما حصل في الصندوق في الأصناف أول 2019م

الصنف	مبلغ التحصيل في الصندوق في الأصناف أول 2019م	نسبة الإنجاز في الصندوق
الضرائب	250,040,30	138,143,8
طابع الأفراح	30,990,000	171,215,4
حجر	13,819,000	76,348
ضريبة النقل الثقيل	29,789,355	164,582
المواريث	21,991,71	121,498,1
كشف	30,428,675	168,114,2
الملح	15,480,600	85,528,1
الإجمالي	167,502,830	925,430