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Effects of Sunlight Exposure on the some Parameters of glass and plastic water bottles

By

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DEDICATION

- I dedicate this achievement to my Father and my wonderful mother. They have been by my side since the very beginning with endless love and support. So much so that my dream became their dream.
- To my dear brothers and sisters.
- To my supportive close friends and colleagues.

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Lastly, I would like to give the greatest thanks to **My Family.**

Sima Jumaa Ahmed
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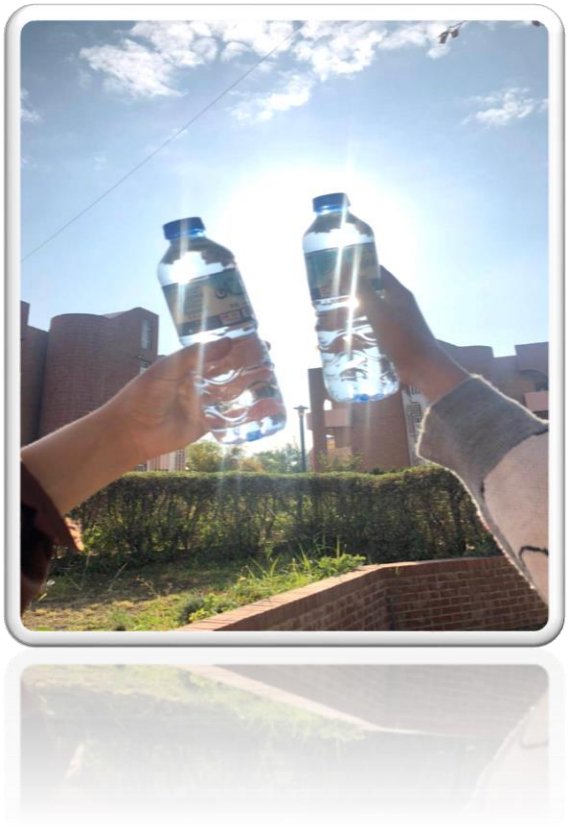

Abstract

This study investigated the effects of sunlight exposure on glass and plastic water bottles by analyzing changes in various parameters. Both glass and plastic bottles were exposed to sunlight for varying durations, and the following parameters were measured: pH level, Total Dissolved Solids(TDS), and Electrical conductivity. The results showed that prolonged exposure to sunlight led to an changed in the pH level Total Dissolved Solids(TDS), and Electrical conductivity of the water in plastic bottles, indicating potential degradation of the plastic, suggesting the release of organic compounds from the plastic. Also the molecular vibration of PET has been observed in FTIR spectra

In contrast, there were no significant changes observed in glass bottles for either pH level or TDS content. Overall, this study highlights the importance of protecting plastic water bottles from prolonged sunlight exposure to prevent potential degradation and release of organic compounds

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Chapter One
Introduction

1.1 Introduction

Sunlight exposure is known to have various effects on materials, including plastic and glass water bottles. In recent years, concerns have been raised regarding the potential health risks associated with the use of plastic water bottles due to the potential release of chemicals from the plastic under certain conditions. One such condition is exposure to sunlight, which can cause the plastic to degrade and release organic compounds into the water.

Polyethylene terephthalate (PET) is a semi-crystalline polymer belonging to the family of polyesters. It is the most favorable packaging material for drinking water. PET bottles have been marketed for the last four decades and they have gradually replaced polyvinylchloride (PVC) and glass bottles on the markets(Salinas *et al.*, 2010) Glass water bottles, on the other hand, are often considered a safer alternative to plastic due to their inert nature and resistance to chemical leaching. However, it is still unclear how glass water bottles may be affected by prolonged sunlight exposure. The health and growth of plant and animal life depend heavily on water. Water makes up more than half of a person's bodily weigh. An adult should drink 2-3 liters of water per day while sedentary or 4.5 liters per day if physically active to be hydrated.(Wegelin *et al.*, 2001; Petraccia *et al.*, 2006; Organization, 2017; Schymanski *et al.*, 2018; Praveena, Shamsul Ariffin and Nafisyah, 2022)

The component of water that is present at the ideal level for healthy plant and animal growth is often referred to as the water's quality. Only when the physical and chemical factors are present at their optimum level can the greatest production be achieved. Water that is intended for human consumption must be free of chemicals and organisms because their high quantities can be harmful to health.Health issues

have arisen as a result of the lack of access to high-quality drinking water because water is recognized to be a key cause of many communicable diseases. Over 30% of fatalities and 80% of illnesses in underdeveloped nations are connected to drinking water .

Drinking water that has been bottled and marketed in containers like bottles and sachets or plastic bags is extensively used. The documented sales of bottled water (1500 ml) worldwide in 2011 were more than 225 billion litres.

Bottled water is categorized as a consumer food product and is made up of spring, purified, mineral, sparkling, artesian, and well water that has undergone thorough processing to adhere to legal requirements .

In comparison to other beverages, particularly those with a high sugar content, bottled water is an excellent choice.

Drinking bottled water has grown increasingly popular, and it seems to have satisfied the demand for clean drinking water, which has greatly increased demand for it (Ankon *et al.*, 2022)

Sales of bottled water are very significant, particularly in areas with heavy traffic where vendors hawk different brands of water on the side of the road. The majority of fast food establishments and restaurants also sell bottled water. However, the way that it is stored before it is traded has come into more focus. It is normal practice for local retailers to keep bottled water exposed to sunlight before being sold, despite studies showing that plastic bottles (polyethylene terephthalate) are prone to breakdown under high temperature(Ankon *et al.*, 2022). The clear plastic bottles in which bottled water is sold and the polyethylene water sachets (PWS), also known as "Pure Water" Nylon, are most frequently made of polyethylene terephthalate (PET). The rate and amount of organic and inorganic compounds that leach from PET bottles appear to be influenced by both the contents of the PET bottle and the storage temperature (Westerhoff *et al.*, 2008).

There are substances in bottled water, at concentrations that are not negligible, according to several studies. During the polymerization reaction and the hot step procedure in the creation of bottle water, acetaldehyde was found to develop by Cristina Bach and et al (Bach, Dauchy and Etienne, 2009).

After being exposed to extremely hot temperatures and ultraviolet (UV) radiation, water bottles were tested by(Bach *et al.*, 2013) to see how quickly chemicals would migrate.

The practice of keeping bottled water in a car or on the open market during the summer when temperatures in some areas exceed 45°C is highly widespread. Therefore, it is important to investigate how temperature affects the physicochemical characteristics of bottled water. On the other hand, individuals frequently use plastic water bottles outside, and some markets leave them out in the sun. Therefore, it is crucial to comprehend how sunshine affects the quality of bottled water.

In this study, we aimed to investigate the effects of sunlight exposure on some parameters of glass and plastic water bottles. Specifically, we measured the pH level, total organic carbon (TDS) content, and presence of leached chemicals in water stored in both types of bottles after varying durations of sunlight exposure. The results of this study can provide important insights into the potential risks associated with using glass and plastic water bottles and may help inform guidelines for safe use and storage.

1.2 Research Objectives

1. To evaluate the physicochemical water quality of locally produced bottled water in Kurdistan region Comparisons of the results to standards as well as to the reported label values are presented .
2. To determine the effect of sunlight exposure on the physicochemical properties of water quality in Erbil City and to underscore the possible health effect of drinking bottled water exposed to sunlight over a period of time.
3. To study the vibration and vibration properties of water bottles before and after sunlight exposure for a period time

1.3 Thesis Organization

The thesis is organized as follows:

Chapters 1: Introduction and some general information about water in bottle, along with a statement of the problem and research objectives.

Chapter 2: Describing the Theoretical background of the study

Chapter 3: Describing the Experimental Techniques .

Chapter 4: Show the result of the study: The Effect of sun exposure on physicochemical of bottled water

Chapter 5: The conclusion of the reported research, alongside suggestions for possible future works, are presented in this chapter.

Chapter Two
Theoretical background

2.1 Drinking water:

Defines drinking water as Water suited for human consumption and domestic use must be hygienic, typically devoid of minerals, organic compounds, and harmful agents in excess of what is reasonable for domestic use, and must be sufficient in quantity and quality to meet the basic health requirements of the people served.

Nobody wants to consume dirty water. It can be challenging to prevent water pollution, though. Any material in the water that is biological, chemical, physical, or radioactive is referred to as a contamination. In other words, everything in the water that isn't water itself is considered a contaminant by the Safe Drinking Water Act.
There are four categories of contaminants that are recognized by law, as was already mentioned:

1. Physical - These compounds have an impact on the physical characteristics of water, such as how it looks. The two most prevalent categories of physical pollutants are soil and organic material. When we've noticed brown water in a pond or river, the water is tainted with dirt. Another illustration is algae. It is frequently simpler to remove this kind of contamination than others.
2. Chemical - Chemical substances range from pesticides and agricultural nitrogen to bleach, metals, poisons, and other other chemicals that are usually natural but frequently man-made in origin. The Flint water crisis was caused by lead pollution, which is an excellent example of chemical contamination. This contamination rendered the water unfit for human consumption.
3 .Biological –These elements are living things. Here, fish isn't truly the topic at hand. It is possible to get sick and get waterborne diseases by drinking water that

has been polluted with these compounds (which are a really big deal in underdeveloped countries, but also happen in the U.S.) If we've ever been to a foreign place and were advised not to drink the local water, it was probably due to some form of biological pollution.

4. Radiological — These compounds have the potential to be harmful. They produce some form of radiation. Radium, cesium, and uranium are a few examples. Just example, one research estimates that 170 million Americans consume water that includes radioactive substances(Sharma and Bhattacharya, 2017).

2.1.1. Common types of drinking water and the differences between them:

1.Tap water:

Tap water is frequently one of the first possibilities that spring to mind when considering a beverage. This water is the liquid that flows out of our faucet. It can originate from surface water like a river or stream as well as groundwater like a well. Before flowing from the main supply to your thirsty lips, this water needs be purified for the sake of public safety. According to the Safe Drinking Water Act, public water systems (those that offer water to at least 25 people) are required to adhere to certain standards for their tap water (SDWA). The United States Environmental Protection Agency (EPA) is authorized under this federal statute to establish and uphold limits for contaminants in drinking water. The standards established by state and local agencies must also be met by tap water from a public water system. However, 25% of tap water does not exceed EPA requirements even with current laws in place. This indicates that the amount of natural and artificial pollutants in the water is unacceptable.(Van der Aa, 2003)

2. Water

Mineral water contains a lot of minerals, as its name indicates. This water naturally

includes minerals like calcium and magnesium since it comes from subsurface sources. Mineral water has earned a reputation as healthful drinking water because to these vital minerals. They also contribute to the distinctively saline flavor of this kind of water. One significant characteristic of mineral water is that extra minerals cannot be added by water providers. Additionally, it can only be treated with carbonation or iron removal before to bottling. This sort of water's mineral makeup might differ between brands. Some people will have greater mineral content than others.(Petraccia *et al.*, 2006) Natural fluctuations in the mineral water sources are to blame for this.

4. Spring Water

Spring water is the most often used form of drinking water among all the sources. When rainfall collects underground, it might occasionally appear as a puddle, also known as a spring. Although the water from these subterranean natural springs does not pass through a communal water system, it is nonetheless safe to drink. Many supporters of spring water like its pleasant and natural flavor. They also like that the water is largely pure and devoid of toxins without the need of contemporary treatment methods. They see spring water as a pure substitute for other types of water.

4 . Purified Water

Tap water that has been treated to become purified. To make the water drinkable, the purification procedure eliminates any impurities like bacteria, fungus, parasites, and other dissolved substances. However, purification also entails the removal from the water of potentially beneficial elements like minerals and probiotic microbes. Without identifying any names, many of the top bottled water producers merely filter tap water from municipalities, rename it, and then sell it in unsustainable (and hazardous) plastic bottles. A home filtration system may significantly lessen the

impact of many of these dangerous chemicals, even though filtered tap water isn't always the greatest option for drinking water.

5. Distilled Water

Demineralized water is often referred to as distilled water. Such water has been distilled to get rid of all minerals and salt. The water is heated during this procedure to separate the pure H2O from impurities and minerals. Water has substantially lower melting and boiling points than pollutants in water. Pure water will convert to steam when it is heated to a boil. The vapor can then be captured and cooled by the person distilling the water, resulting in distilled water.(Adams *et al.*, 2002)

6. Sparkling water

Carbon dioxide is added to sparkling water, sometimes referred to as carbonated water. Natural sparkling waters typically include a lot of minerals since they come from mineral springs. For certain brands, like Perrier, the source spring's carbonation is replicated throughout the bottling process. Perhaps may we have observed how well-liked flavored sparkling water has grown to be. A portion of the rise in demand can be attributed to customers who are more health aware and are switching from soft drinks to sparkling beverages. In general, sparkling water is healthier than soft drinks (which is a pretty low bar), but researchers are still looking into how sparkling water compares to other types of water and how it affects the body.

7 .Alkaline water:

The pH level of alkaline water is greater than that of regular drinking water. The pH value determines how acidic or alkaline a substance is. The range of this value is 0 to 14, with 0 being extremely acidic and 14 being extremely alkaline. Alkaline water typically has a pH of 8 or 9, while neutral drinking water has a neutral pH of 7. Alkaline water must have alkaline minerals and a negative oxidation-reduction

potential in addition to having a high ph. (ORP). The water's capacity to serve as an antioxidant increases with increasing ORP value. Water naturally turns alkaline by traveling through rocks and absorbing minerals. However, electrolysis, a deliberate chemical process, is how most alkaline water is produced. Ionizers are used in this procedure. This procedure raises the pH of ordinary water using an ionizer.

8. Well water:

Well water, which is obtained directly from the earth, is most frequently found in rural locations. When it is not cost-effective to construct direct pipes from a local municipal system, wells are frequently employed for properties that are spread out across large distances. When streams and rivers flow onto nearby grounds, or when rain and snowmelt soak into the soil, a well gathers the water. Similar to spring or glacier water, this water is untreated and raw, but it is less clean since it might draw surface contaminants. Contaminants like e-coli, heavy metals, and other poisons may seep into the water depending on where the well is situated. Well water is not covered by the EPA's water safety laws, thus households who use well water should test it annually for pollutants including bacteria, nitrates, and pH levels. Commercially, some well water is packaged and marketed as "artesian water." In addition to the possibility of pollutants, this procedure could not be sustainable. Well water and subterranean aquifers are being used up in many areas faster than they can naturally be restored. As a result of the water being drained from the earth and the soil starting to contract, this causes ground subsidence, also known as sinking.(Salinas *et al.*, 2010)

9. Ground Water:

Subsurface areas of the earth are where ground water is found. Sand, dirt, and porous rock all function as natural filters to catch water that seeps through the earth. However, since the water does not have as much time to "seep and filter," there is a

higher risk of contamination when we quickly pull water from shallow wells.(Taylor *et al.*, 2013)

10 .Spring and Mineral water

Unique minerals and chemical compounds found in spring water have a number of positive health effects. 10% to 15% of our recommended calcium intake and 33% of our recommended magnesium intake are both met by drinking two liters of spring water every day. The high calcium, bicarbonate, and magnesium content helps support the maintenance of strong bones, making it especially crucial in the diets of elderly people . Also, there is the WHO water standards and Iraqi water standards [3] for drinking water (Table 1). Information on the classes of chemical compounds found in various types of bottled water is shown in Figure 1. (4-9).

TABLE 2-1: Drinking water standards (Organization, 2017)**.**

Parameter	WHO standards	Iraqi standards
PH	6.5–8.5	6.5–8.5
Conductivity (µs/cm)	600	1500
TDS (mg/l)	1000	1000
Alkalinity (mg/l $CaCO_3$)	600	--
Turbidity (NTU)	5	5
Free Chlorine (mg/l)	5	5
Hardness (mg/l $CaCO_3$)	500	500
Calcium (mg/l Ca)	75	50
Ammonia (mg/l NH_3)	1.5	--
Fluoride (mg/l F)	0.7–1.5	--
Chloride (mg/l Cl)	250	250
Nitrate Nitrogen (mg/l N)	10	--
Nitrate (mg/l NO_3)	50	50

2.3. Describe bottled water

Water that has been sealed-off and packaged for human consumption is known as bottled water. Water for human consumption may be treated once it is obtained from a number of sources, such as springs, aquifers, or municipal supplies.

There are four main Types of Water Bottles:

- Plastic
- Aluminum

- Stainless Steel
- Glass

1. Environmental impact of the bottled water

Most water bottles are constructed of polyethylene terephthalate, often known as PET, a form of plastic that is generated from petroleum. According to a National Geographic article, the United States, the largest user of bottled mineral water in the world, buys the equivalent of 29 billion bottles of the beverage each year, with the production of PET using around 17 million barrels of oil. Especially when we consider that it is essentially a throwaway product, a fair sum. That's accurate, using the product only once used a significant quantity of energy. The material's potential to be recycled is important, but we also need to keep in mind the energy and logistics required for recycling, as well as the fact that only a small portion of the product is ultimately reprocessed. In addition to being headed for landfills, a significant quantity of waste frequently finds its way into rivers and oceans. In addition to all of this, new researches have shown a variety of risks associated with PET, including: If the bottles are kept at room temperature, the release of the hazardous metalloid antimony from PET is limited by legal requirements. On the other hand, the amount of the metalloid can dangerously rise if the bottles are exposed to higher temperatures and/or are kept for an extended period of time. As suggested by its name, PET includes phthalates, which are safe plasticizers that make plastic more flexible. It's unfortunate that a German research from Frankfurt's Johann Wolfgang Goethe University, published online in 2009, not only listed a number of earlier studies that found hormone-mimicking phthalates in mineral water stored in PET bottles, but also found them in mineral water. Furthermore, the cost of bottled water is high. Bottle, lid, and label components account for almost 90% of the price of a water bottle.(Horowitz, Frago and Mu, 2018; Oßmann *et al.*, 2018; Makhdoumi *et*

al., 2021)

2. Health impact of the bottled water

The bottles take around 400 years to degrade once they are in the environment, mostly in the oceans. They also become microplastic, which are tiny polluting and deadly plastic particles that have killed countless of animals. As its name indicates, polyethylene terephthalate contains phthalates. According to studies, this chemical molecule increases the risk of diabetes and obesity in males. This substance is also thought to be a source of xenoestrogen, which can cause a variety of health issues in women, including hormonal imbalances and ovarian illnesses (among them: endometriosis and polycystic ovary syndrome (1). Recalls of bottled water because to contamination happen quite infrequently. The usage of plastic in bottled water is one reason for worry. According to research, the majority of bottled water includes microplastics, which may be harmful to your health. (2) For instance, a 2018 Trusted Source research (3) examined 11 internationally sourced brands of bottled water from nine various nations. Microplastics are minute pieces of plastic. They are officially classified as polymers with a diameter smaller than five millimeters (0.2 inches). Microplastics may be divided into two groups: primary and secondary. Microfibers shed from clothes and other fabrics, such as fishing nets, as well as microscopic particles made for commercial purpose, such as those found in cosmetics, are the two main types of microplastics. Particles known as secondary microplastics are produced when bigger plastic objects, such as water bottles, break down. The sun's rays and ocean waves are the key environmental variables that contribute to this disintegration. (Fig. 2.1) displays the several types of MPs that were found, together with information on their size, shapes, polymer types and color (5).

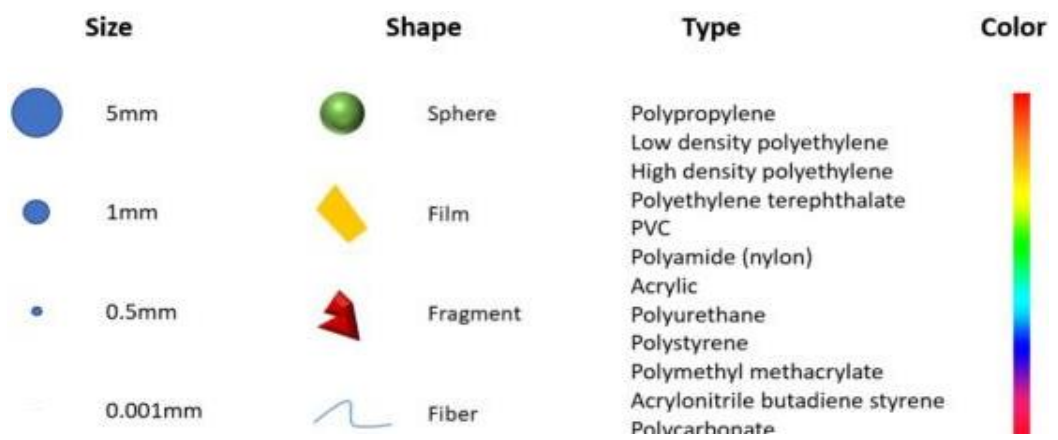


Figure 2.1: Microplastics come in a variety of sizes, shapes, polymer types, and colors.(Praveena, Shamsul Ariffin and Nafisyah, 2022)

The amount of microplastic in the bottles was double that in tap water, according to the researchers, who discovered that 93% of them had some evidence of microplastic contamination. These results imply that the packaging procedure itself is at least somewhat to blame for the contamination. The release of MPs into the bottled water has been explained by a number of models that have been devised and put forth. Additionally, they investigated how crushing or compressing bottles affected the MPs' release into the bottled water. Mechanical characteristics of the manufacturing process have an impact on the dispersion and fragmentation of PP, according to Pouran Makhdoumi et al. (Praveena, Shamsul Ariffin and Nafisyah, 2022).

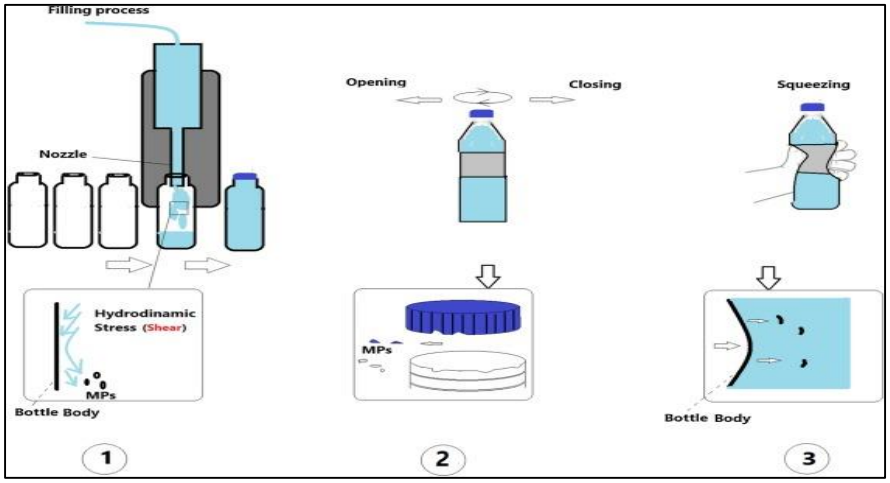


Figure 2.2: Mechanisms via which microplastics from bottle bodies enter mineral water.,(Praveena, Shamsul Ariffin and Nafisyah, 2022).

The shear stress during the filling process, when the bottle bodies were subjected to scraping forces from hydrodynamic pressure and under high pressure, is shown in Part 1. MP particles may be discharged into water under certain circumstances. Part 2 illustrates how opening and shutting the bottle has an impact. Due to the mechanical stress associated with opening and shutting, caps and bottlenecks are susceptible to damage. The impact of squeezing travel plastic from the bottle body into the aquatic environment is demonstrated in the final paragraph (part 3).

MPs can fall out of the atmosphere in addition to being released from the packing and the caps by physical or external force placed on the container during storage, shipping, bottle shaking, opening, and/or during an injection .The movement of MPs and their additions can be accelerated by thermal effects. Leaching of MP during production operations is another possibility. According to Kankanige and Babel's research, PE concentrations can come from bottle caps while PET concentrations can come from packaging (Kankanige and Babel, 2020)

They found that all bottled mineral waters examined were contaminated with microplastics. This paper is the first study to report detection of microplastics,

pigments, and additive particles in bottled mineral water samples with a minimum analytical particle size of 1 µm. (Figure 3) provides further explanation of the study.

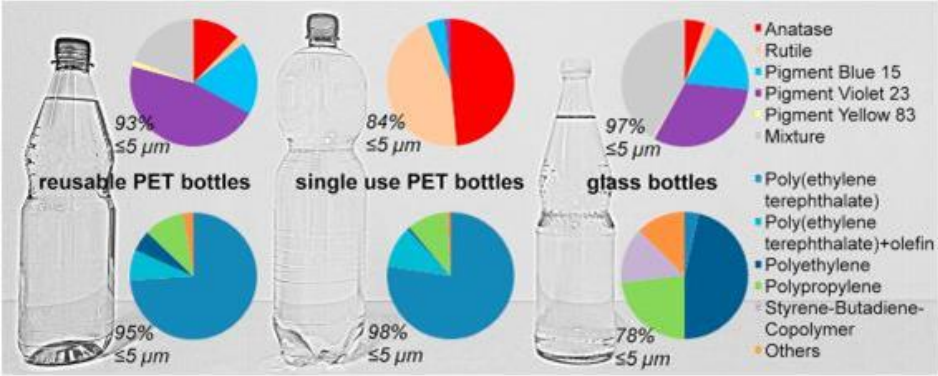


Figure 2.3 Breakdown of pigment particles (upper) and microplastics (lower) detected in each bottle(Kankanige and Babel, 2020)

Microplastics appear to belong to the same class of endocrine-disrupting compounds as obesogens Trusted Source , influencing oxidative stress, reproduction, metabolism, and other aspects in humans, animals, and marine life.

2.4. Reasons to avoid bottled water

1. Personal health risks

Before recent studies revealed that estrogenic substances leak from the polyethylene terephthalate (PET) plastic used in the typical drinking water bottle into the water, it was believed that PET polymers were innocuous.

2. Cost and environmental effect

Seven liters of water and 1.5 megajoules of energy are needed to make one one-liter plastic bottle of water. An estimated 50 million liters of oil are needed annually

in Australia to make the plastic bottles we use. Plastic bottles are created from oil. Over 400 million plastic bottles end up in landfills each year, with only about 36% of plastic bottles being recycled.

3. Financial Cost

Compared to bottled water, which costs more than $2.50 a litre, a litre of tap water costs less than 1% of that amount.

2.5. The Different Kinds of Plastics

The thermoplastic and thermoset polymer families, which include a variety of plastic kinds, are the two largest polymer families. The class of polymers known as thermoplastics is capable of melting at high temperatures and cooling to a rigid state. They are reversible properties that give the substance its name. It can therefore be repeatedly warmed, molded, and hardened. They are mechanically recyclable as a result of this property. Thermosets: When handled, synthetic materials known as thermosetting or thermoset plastics go through a chemical transition that results in the formation of a three-dimensional network. These molecules cannot be heated again to a molten state and reformed after they have been produced.

1. Thermal plastics

The degree of the qualities and performances of thermoplastics may be categorized based on their chemical structural organization (Figure 4). They account for roughly 80% of the demand for plastics.

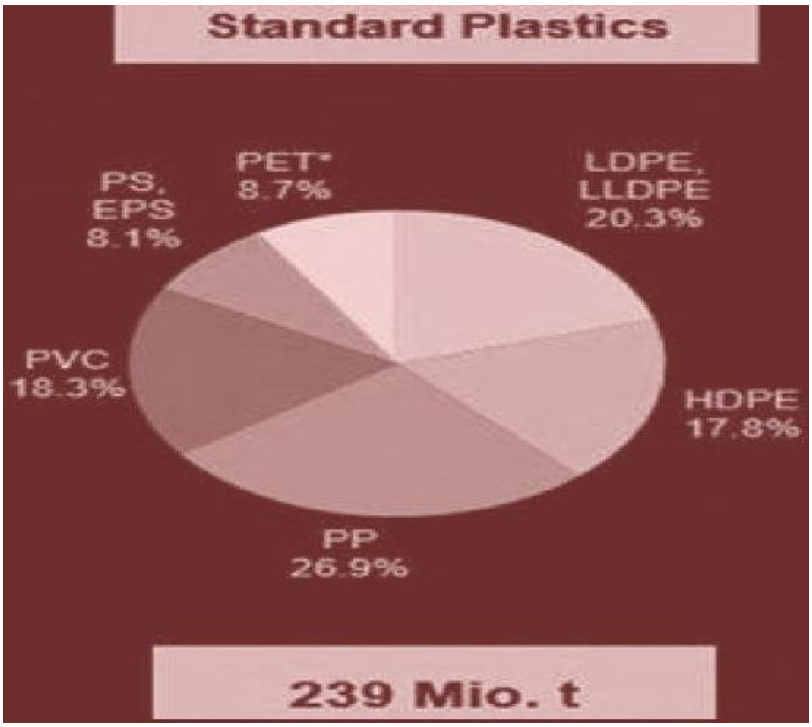


Figure 2.5: Triangle of thermoplastics by structure capability and price.(Gleick and Cooley, 2009)

1-Polyolefins

Which comprise all varieties of polyethylene (LDPE, LLDPE, HDPE) and poly propylene, are the biggest family of thermoplastics (55%) by volume. They are mostly made from oil and natural gas using ethylene (PE) and propylene (PP) polymerization processes. Polyolefins are employed in a highly diverse variety of applications because of their adaptability, including packaging, automotive, building and construction, medical sports, and consumer products.

- LDPE: Cling film, carrier bags, agricultural films, milk carton coatings, electrical wire coatings, and heavy-duty industrial bags are all examples of products that employ LDPE.

- LLDPE: Stretch film, industrial packaging film, thin-walled containers, and heavy-duty, medium-, and tiny bags are all made of LLDPE.

- HDPE: Crates and cartons, bottles (for food, detergents, and cosmetics), food

containers, toys, gas tanks, industrial wrapping and film, pipelines, and household items are all made of HDPE.

- PP: Used for pipes, carpet fibers, garden furniture, medical packaging and equipment, yoghurt and margarine pots, sweet and snack wrappers, and microwave-proof containers.

2. Polyvinyl chloride (PVC)

Is one of the oldest polymers and the third-largest thermoplastic. It is made from oil or gas (43%) and salt (57%) respectively. It comes in two different forms: stiff, typically used to make pipes and fittings or window frames, or soft, often utilized in flooring or cable applications.

3.Polystyrene

Is a thermoplastic polymer that comes in both solid and foamed forms. Styrene is the monomer used to make it. It is extensively utilized in packaging, cosmetic packaging, toys, and refrigerator trays, among many other uses.

4. Expanded polystyrene (EPS)

Is a solid foam with a special blend of properties, including light weight, insulating qualities, durability, and great processability. Building thermal insulation boards, packaging, protecting priceless items, and food packaging all make use of EPS.

5. Ethylene terephthalate

Monomers are converted into polymerized units to form polyethylene terephthalate (PET). It is utilized in both food and beverage containers as well as textile fibers.

6. Engineering Plastics

A subset of plastic materials, engineering plastics are utilized in applications that often need better performance in the areas of heat resistance, chemical resistance, impact, fire retardancy, or mechanical strength (Figure 3). They supply 10% of the world's demand for thermoplastics. One-third of all engineering plastic demand is filled by Acrylonitrile Butadiene Styrene (ABS), which is then followed by

Polyamide (PA), Polycarbonate (PC), PET injection (PET), Polybutylene terephthalate (PBT), Polyoxymethylene (POM), and Polymethylmethacrylate (PMMA). The two main market sectors, consumer products and electrical and electronic applications, account for a quarter of worldwide consumption, with the transportation sector being the third-largest individual market.

Chapter Three
Experimental Techniques

3.1 Introduction

The experimental methods employed in this work are discussed in this chapter. In the previous 5 years, especially during the summer, the use of bottled water has significantly increased in the Kurdish area (north of Iraq). According to the ministry of industry in 2010, 27 bottled water firms in Kurdistan region produced roughly 1.692 x 109 L of bottled water. Bottled water is also imported from Turkey nation. The Life Corporation, which produces $27 * 10^6$ liters of bottled water annually, is the largest producer of bottled water in the Kurdistan area. Springs, wells, and surface water supply are the major sources of bottled water used for sale in the Kurdistan area. Summertime temperatures in the Kurdistan area approach 45°C, making the storage of bottled water necessary.

3.2 Material and methods

There are several experimental techniques that can be used to study the effects of sunlight exposure on glass and plastic water bottles. Here are our possible methods:

1- Bottled water sample: twelves samples life brands of plastic bottled water and glass were collected from same supermarkets with in city (Erbil) in Kurdistan region. As showing Fig 3.1.

Figure 3-1 life brand name, Erbil city of production of bottled water samples according to date and exposure sun light

2. **Fourier Transform Infrared (FTIR) spectroscopy**:

FTIR can be used to detect changes in the chemical composition of the materials due to sunlight exposure. By measuring the absorption of infrared radiation by the materials, it is possible to identify specific functional groups that may have been altered by exposure to sunlight.

Figure 3-2 FTIR spectroscopy

3. pH measurement:

The pH of the water in the bottles can be measured before and after exposure to sunlight using a pH meter. This will give an indication of any changes in the acidity or alkalinity of the water due to exposure to sunlight. pH is a measurement of electrically charged particles in a substance. It indicates how acidic or alkaline (basic) that substance is. The pH scale ranges from 0 to 14**:**

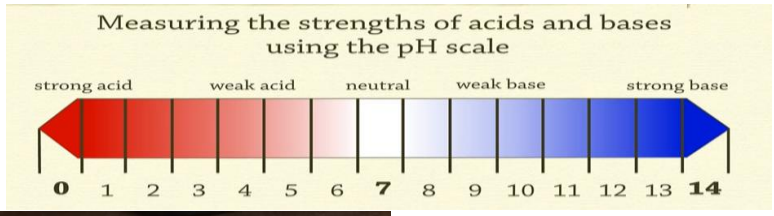


Figure 3-3 PH meter

4- Conductivity measurement:

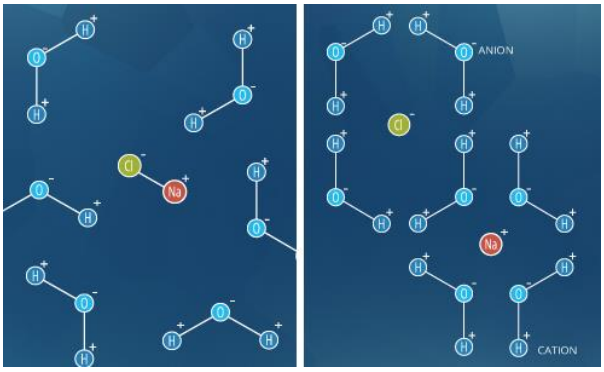
The electrical conductivity of the water in the bottles can also be measured before and after exposure to sunlight using a conductivity meter. This can give an indication of any changes in the concentration of dissolved ions in the water due to exposure to sunlight.

Factors affecting the conductivity of water

1. Type of substance that is dissolving into water.
2. The temperature
3. The concentration of ions in the solution present. (Higher the number of ions, higher will be the conductivity) If the inflow is a freshwater source then the salinity and conductivity value decreases.

What is the standard conductivity of water?

Conductivity can refer to electrical conductivity (EC), it is the measurement of solutions potential to conduct an electric current.



Overall, a combination of these techniques could be used to comprehensively study the effects of sunlight exposure on the pH and conductivity of glass and plastic water bottles, as well as any changes in the chemical composition of the water

the following steps could be taken:

4 Total dissolved solids (TDS)

Total dissolved solids (TDS) are the amount of organic and inorganic materials, such as metals, minerals, salts, and ions, dissolved in a particular volume of water; TDS are essentially a measure of anything dissolved in water that is not an H2O molecule.

TDS Water Chart

<50-250 ppm	**Low:** Lacking minerals, such as calcium, magnesium, and zinc.
300-500 ppm	**Ideal:** This level is the sweet spot for TDS in drinking water. The water most likely contains minerals and does not taste flat.
600-900 ppm	**Not great:** Consider a reverse osmosis system to filter TDS.
1000-2000 ppm	**Bad:** It is not recommended to drink water at this TDS level.
>2000	**Unacceptable:** A TDS level above 2000 ppm is unsafe and household filters can not properly filter this level of contamination.

How is TDS measured?

Total dissolved solids (TDS) is measured as a volume of water with the unit milligrams per liter (mg/L), otherwise known as parts per million (ppm). According to the EPA secondary drinking water regulations500 ppm is the recommended maximum amount of TDS for your drinking water. Any measurement higher than 1000 ppm is an unsafe level of TDS. If the level exceeds 2000 ppm, then a filtration system may be unable to properly filter TDS.

Bottled waters were exposed to sunlight for 20,40,60, 80,100,120 and 160 days during July and Desember 2022 in erbil city . During the experiments, the solar irradiation received by the packaging material for each exposure duration was measured and the temperature of the bottled water was monitored using (Climate & **Weather** Averages **in Erbil**, Kurdistan,)

Chapter Four

Result and Discussion

4-1 Average monthly peak daytime temperatures at Erbil

Figure 4-1 The bar chart below shows the average monthly peak daytime temperatures at Erbil in 2022 these are the average peak daytime temperatures (usually around mid-afternoon). The mean and maximum temperature from the 1st of July to the 15th of December/2022 ranged between (17 - 34 °C) and (19 – 46 °C), as it recorded with the highest mean degree of 34 °C during the first half of December/2022, while the lowest mean was recorded temperature of 17 during the first half of July. The mean and maximum sunlight temperature recorded from 1st July to 15th December/2022 are shown in Figure 4.1

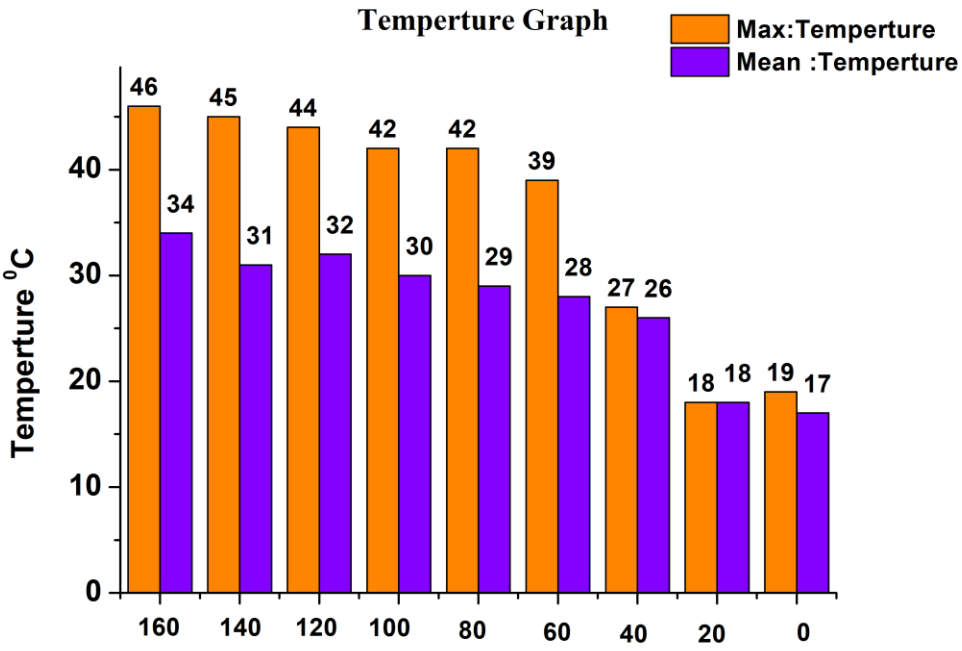


Figure 4-1 average monthly peak daytime temperatures at Erbil

4-2 Fourier-transform infrared spectroscopy (FTIR)

Polyethylene terephthalate (PET) is the material most commonly used to make the clear plastic bottles in which bottled water is sold. The contents of the PET bottle, and the temperature at which it is stored, both appear to influence the rate and magnitude of leaching of organic and inorganic compounds from pet bottle according to the research (Wegelin *et al.*, 2001) sunlight changed the material and content of polyethylene terephthalate (PET) bottles Figure 4.2 show That at 1641 cm−1 was assigned to C=C stretching vibrations That at 3416 cm−1 was assigned to O- H stretching vibration after an exposure time 160 days the band 1641 cm-1is broadening represent PET vibration mode

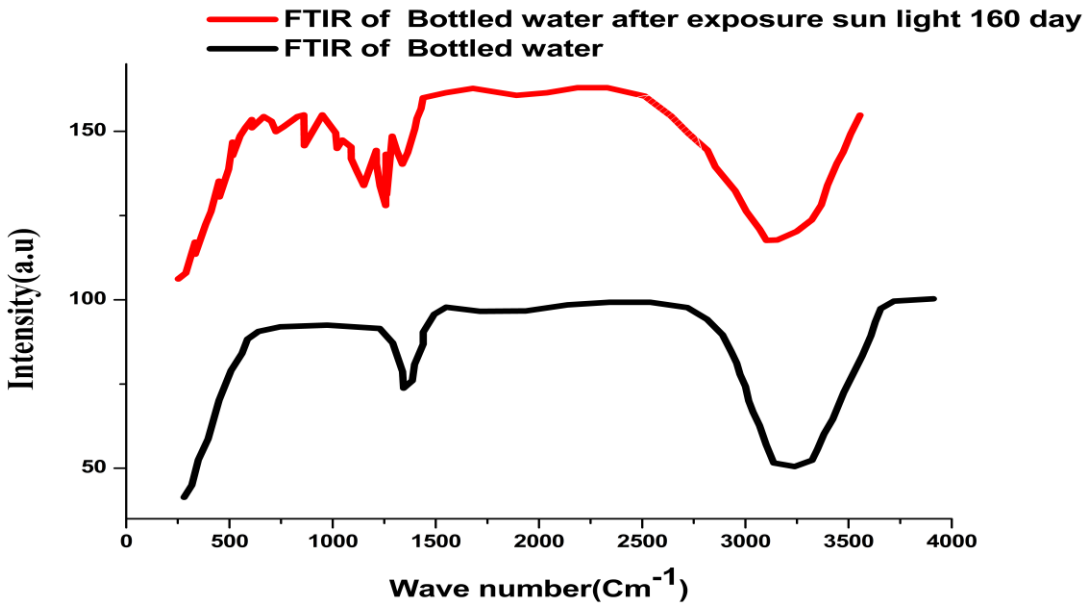


Figure 4-2 FTIR spectrum of Bottled water and FTIR of Bottled water after exposure sun light 160 day

4-3 Physio-chemical Analysis

After exposing bottled water to natural sunshine to produce radiation, the physicochemical parameters of the samples were measured at intervals of two, four, ten, twelve, fourteen, sixteen, eighteen, twenty, and twenty-two weeks. The findings clearly show that each physicochemical parameter changes as solar exposure duration increases, which includes (pH value, Electrical Conductivity (EC), and Total Dissolved Salts (TDS). Usually, their values are written on the bottle's label. The physicochemical properties of plastic bottled water after sunlight exposure are presented in Table 4-1

Exposed to sunlight	PH	TDS/ (mg. L^{-1})	EC/ (µs/cm)
1/7/2022	**7.2**	**320**	**330**
1st July - 15th Dec	**6.9**	**389**	**331**
15th July - 15thDec	**7.61**	**369**	**330**
1st Aug - 15thDec	**7.12**	**359**	**336**
15th Aug - 15thDec	**7.15**	**343**	**340**
1stSep - 15thDec	**7.25**	**340**	**343**
15th Sep - 15thDec	**7.29**	**336**	**359**
1st Oct - 15thDec	**7.39**	**330**	**369**
15thOct - 15th Dec	**7.38**	**331**	**379**
1st Dec - 15th Dec	**7.34**	**330**	**383**

1- Acidity Degree (pH):

One of the most important aspects of water quality is a ph. The acidity or alkalinity of the water is determined using the pH scale. If a sample's pH is lower than 7.0, it is regarded as acidic. If the pH is more than 7.0, it is alkaline. Acidic water may cause metal plumbing and pipes to corrode. Alkaline water, meantime, makes water disinfected. According to WHO recommendations, the pH range for appropriate drinking water is between 6.5 and 8.5, also Iraqi standards shown in (Table 4.1). pH is influenced by organic and inorganic solutions as well as the reactivity of carbon dioxide.

Table (4.1): International standard-related bottled water quality.

Parameter	WHO standards	Iraqi standards
PH	6.5–8.5	6.5–8.5
Conductivity (µs/cm)	600	1500
TDS (mg/l)	1000	1000

The pH levels of the 9 sampled water exposed to sunlight ranged between (6.9-7.61), as it is shown in Table 2 and Figure 2. where the highest reading was recorded at pH 7.61 during the second half of July, while the lowest pH reading was recorded at pH 6.9 during the first half of July. The PH of water show a slightly alkaline trend. The results were within the Iraqi standard for drinking water, which determined the pH (6.5-8.5) and did not exceed the permissible limit.

Also, the pH values of the 6 samples of water stored at the temperature room ranged from 7.12 to 7.44, as shown in Table 3 and Figure 3, with pH 7.44 recording the highest reading for S5 and pH 7.1 recording the lowest reading for S6. The findings did not exceed the allowable limit and fell within the range of the Iraqi drinking water standard (pH, 6.5–8.5).

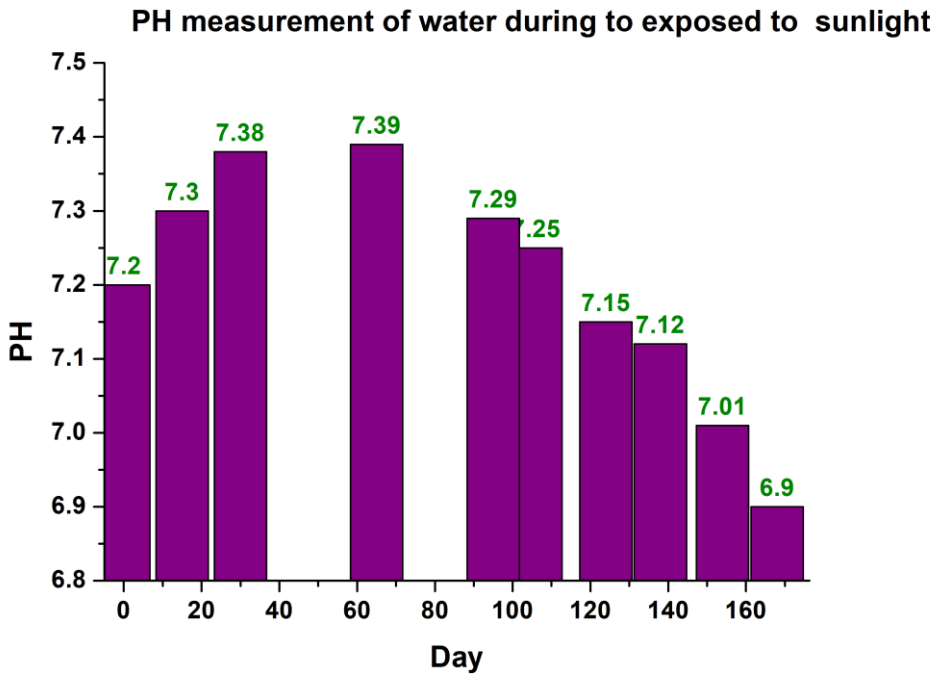


Figure 4-3 Effect of sunlight on physicochemical properties (PH) of water samples in Erbil city

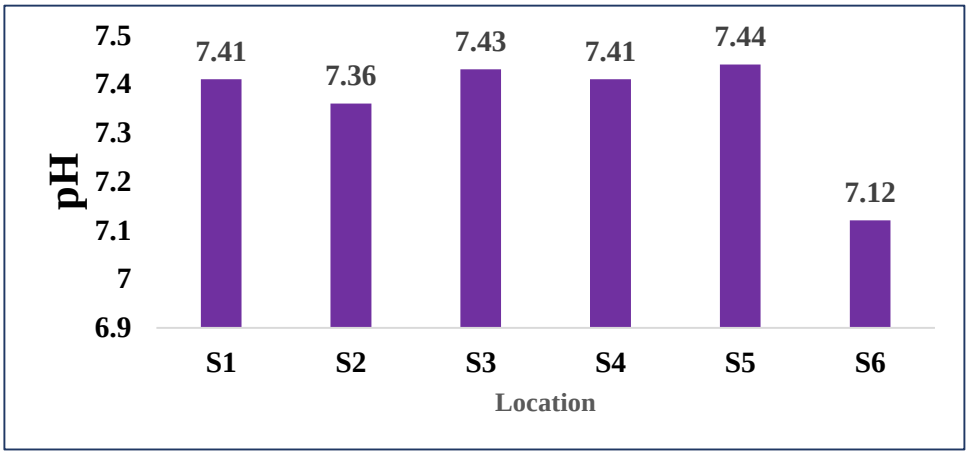


Figure 4-4 : Physicochemical properties (PH) of water samples stored at room temperature in Erbil city.

Several physical and chemical factors alter along with a change in water pH. (1). As all biological reactions in an aquatic system depend on the pH of the water, pH value is one of the most crucial characteristics. The pH of the water was found to be slightly alkaline (7.5–8.0) and within the HACCP-set upper range for home consumption (2). Both low and high pH levels are problematic since low pH water can be acidic and harm metal pipes, while high pH water indicates a high amount of alkalinity (3). Increased pH levels shield pipelines from corrosion and pollution (4). Due to waste discharge and microbial degradation of organic materials in the water body, high pH values in liquids might occur (5,6). The presence of both organic and inorganic solutes in the water in this situation may be the cause of the elevated pH.

2-Electrical Conductivity (EC) Analysis:

An aqueous solution's ability to transmit an electric current is expressed numerically as electrical conductance, which depends on the presence of ions.

The electrical conductivity values of the sampled bottled water exposed to sunlight ranged between (330-383 μS/cm). Where the highest electrical conductivity reading was recorded at 383 μS/cm during the second half of July/2022, and the lowest electrical conductivity reading was 330 μS/cm during the first half of December/2022, it is shown in Table 2 and Figure (4). The results were within the Iraqi standard for drinking water and did not exceed the limits allowed.

And sampled bottled water that has been stored at room temperature had electrical conductivity readings between (205 and 504) μS/cm. The electrical conductivity readings are displayed in Table 3 and Figure 5, with the greatest electrical conductivity measurement occurring for S6 at 205 S/cm and the lowest occurring for S1 at 504 μS/cm, it is shown in Table 3 and Figure (5). The outcomes did not exceed the permitted limits and were within the Iraqi drinking water standard.

The source of the soil is responsible for this EC variation. Conductivity is a crucial indicator of water quality because it provides a clear picture of the quantity of

dissolved material present in the water [1]. The lithology and geological origin of the source are used to make each bottle of water [2]. The composition of the water from various source areas may be the cause of the variability in EC values between samples of bottled water. There is a tight association between EC and soil composition variety, various mineral rocks, and increases in water conductivity and total dissolved solids (3).

The health of humans is not directly impacted by conductivity. By imparting a mineral flavor to the water, high conductivity might reduce its aesthetic appeal. The conductivity of water is crucial to assess for industrial and agricultural operations. High-conductivity water can corrode the metal surfaces of equipment like boilers. It also applies to household items like faucets and water heaters. Excessive conductivity also kills plant species that provide food and provide habitat(4,5,6,7).

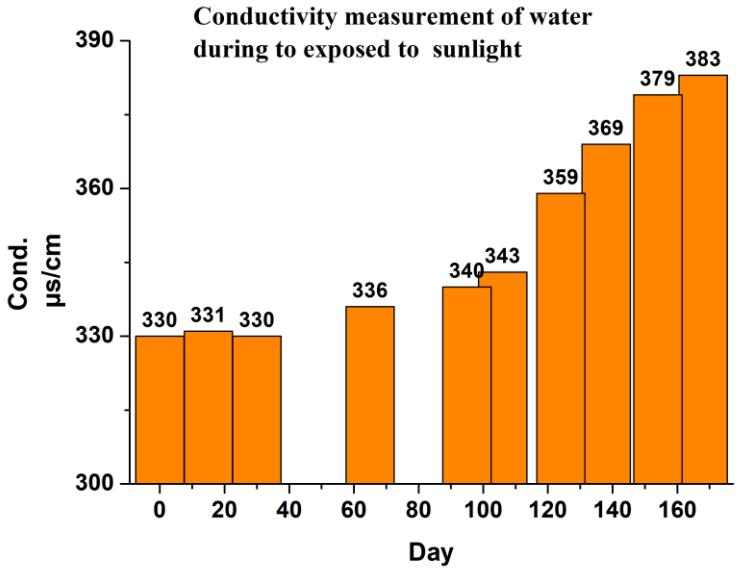


Figure 4.5: Effect of sunlight on physicochemical properties (EC) of water samples in Erbil city.

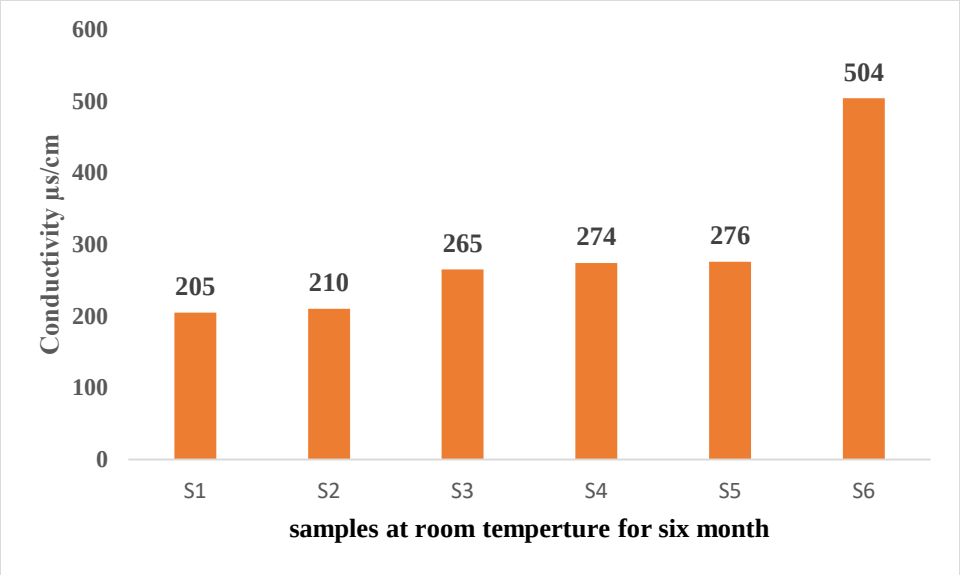


Figure 4.6 : Physicochemical properties (EC) of water samples stored at room temperature in Erbil city.

The results of this study can provide important insights into the potential risks associated with using glass and plastic water bottles and may help inform guidelines for safe use and storage.

3- TDS stands for total dissolved solids

TDS stands for total dissolved solids and represents the total concentration of dissolved substances in water. TDS is made up of inorganic salts, as well as a smallamount of organic matter. Common inorganic salts that can be found in water include calcium, magnesium, potassium, and sodium, which are all cations, and carbonates, nitrates, bicarbonates, chlorides, and sulfates, which are all anions. Cations are positively charged ions and anions are negatively charged ions.

The values of the total dissolved solid salts of the sampled bottled water that was exposed to sunlight ranged between (330-389 mg /liter), where the highest TDS reading was recorded at 389 mg/liter during the first half of the month of October and December, while the lowest reading was recorded TDS 330 mg/liter during the first half of July as in Table 2 and Figure 6. The results were within the Iraqi standard for drinking water and did not exceed the permissible limit of 1000 mg/liter.

And Total dissolved solids (TDS) levels in the sampled bottled water that was stored at room temperature ranged from 102 to 253 mg per liter, with the highest readings occurring for S6 at 253 mg/liter and the lowest readings occurring for S1 at 102 mg/liter, as shown in Table 3 and Figure 7. The findings were under the permitted level of 1000 mg per liter and within the Iraqi standard for drinking water.

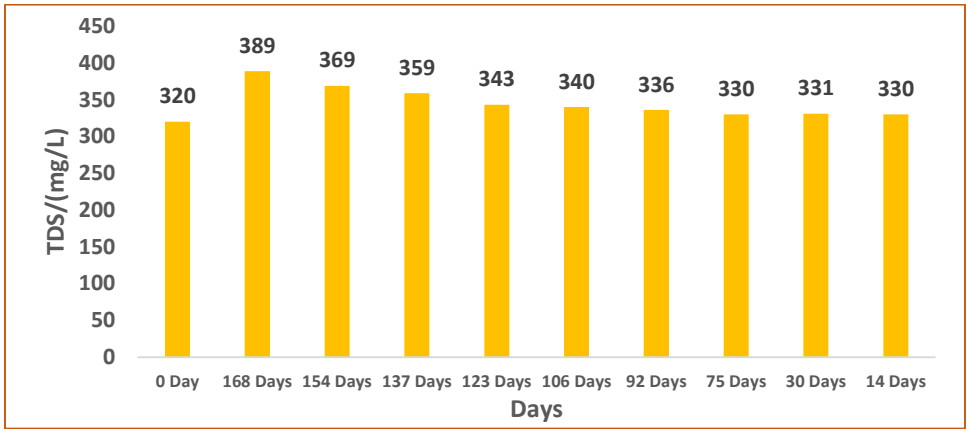


Figure 4.7: Effect of sunlight on physicochemical properties (TDS) of water samples in Erbil city.

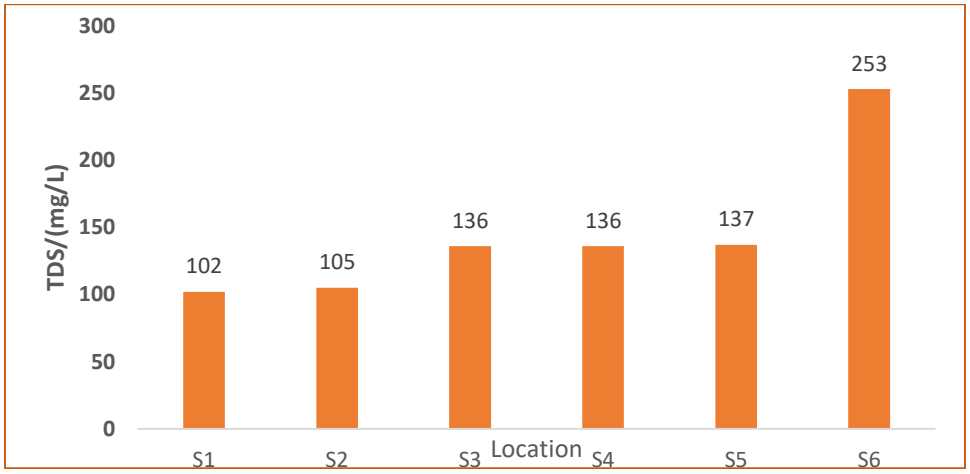


Figure 4.8: Physicochemical properties (TDS) of water samples stored at room temperature in Erbil city.

The research of the reasons for the clear variety in TDS levels noticed throughout all bottled water brands may be attributed to the natural resource from which the water was bottled and TDS came, or from urban run-off and the geology of the location.

Drinking water with a high TDS might taste different, whereas water with a very low TDS can taste flat and unappealing. The low values of dissolved solids make it suitable for non-container distilled water on the salts, as the use of this water does

not benefit the human body except by hydration and apparent refreshment. Distilled water does not contain mineral salts, and therefore, over time, it can harm humans. It has been scientifically proven that this type of water causes heart disease, heart attack, and high blood pressure. premature aging, premature death, and osteoporosis, in addition to many other diseases.

Chapter Four
Conclusion

4-1 Conclusion

On the foundations of our data we can infer the following::

1- The present study investigated 12 bottled water(life) samples under exposure to sunlight for PET contamination and six samples stored at room temperature in Erbil city.

We study physicochemical properties to find PET in bottled water

1- The concentration levels of various physiochemical parameters in the analyzed bottled water kinds did not surpassed the worldwide criteria for drinking water.

2- The concentration levels of various physiochemical parameters in the analyzed bottled water kinds did not surpass the worldwide criteria for drinking water only, physiochemical parameters changed under exposure light without opening the bottled water

a. The storage of bottled water in condition exposure to sunlight leads to decreasing the values (pH) changed during the ph value 7.2 to 6.9 for 0 day to 160 days respectively due to inorganic compounds leaching from bottled to the content water

b. The conductivity of bottled water in condition exposure to sunlight leads to increasing

c. **TDS/ (mg. L^{-1})** of bottled water in condition exposure to sunlight leads to increasing

d. The Ph, conductivity and TDs is not changed under exposure time from 0 day to 160 day is equal to 7.2 ,200 TDS/ (mg. L-1) and 320 (µs/cm)

2- That at 1641 cm−1 was assigned to C=C stretching vibrations That at 3416 cm−1 was assigned to O- H stretching vibration after an exposure time 160 days the band 1641 cm-1is broadening represent PET vibration mode

It has been suggested that we need to solve the problem avoid drinking water from a plastic bottle when sun exposure on water from a plastic bottle especially , water from a plastic bottle is in front of shops or Transportation by a large vehicle for period time

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