An-Najah National University

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PREVALENCE OF MICROPLASTICS IN DRINKING WATER IN PALESTINE

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Dedication

First and foremost, all praise is due to Allah, always and forever, for His guidance and blessings.

To my beloved homeland, Palestine, and especially to steadfast Gaza, the symbol of dignity and resilience.

To the souls of the martyrs,
To the wounded who sacrificed in the path of freedom,
To the prisoners who remain steadfast behind bars,
To every grieving heart that endures with patience.

To my dear parents, the light of my life and the source of my strength,

I dedicate this research.

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Finally, I extend my profound thanks and appreciation to my beloved family, whose constant encouragement and unwavering support have been the true foundation of my journey, enabling me to complete this research and obtain my master's degree.

Declaration

I, the undersigned, declare that I submitted the thesis entitled:

PREVALENCE OF MICROPLASTICS IN DRINKING WATER IN PALESTINE

I declare that the work provided in this thesis, unless otherwise referenced, is the researcher’s own work, and has not been submitted elsewhere for any other degree or qualification.

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List of Abbreviations

Abbreviation	**Meaning**
MPs	Microplastics
PE	Polyethylene
PET	Polyethylene Terephthalate
WHO	World Health Organization
PP	Polypropylene
PS	Polystyrene
FTIR	Fourier Transform Infrared Spectroscopy

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Abstract

Microplastics (MPs) have become a significant pollution problem in recent years, attracting increased attention because they are detected across diverse environments and may affect human health. They are microscopic particles, the size less than 5 millimeters, which can enter drinking water—whether tap water or bottled water—through different sources and ways.

This research tests the existence of MPs in drinking water, knowing potential sources, and creates baseline data to increase awareness about water pollution. We tested water samples from Nablus city using filtration, microscopy, and FTIR spectroscopy. The results show that tap water contained MP concentrations and range from 44 to 268 µg/L, while bottled water have concentrations ranging from 27 to 253 µg/L. Also, we found the most common polymers in the samples, like polyethylene (PE) and polyethylene terephthalate (PET). The existence of microplastics in both bottled and tap water in Palestine shows a public health and environmental concern. These results show the importance of developing national monitoring programs and considering microplastics in water safety management plans. The results also show that improving water infrastructure, reducing plastic waste, and supporting relevant research are important steps in reduce microplastic pollution, in line with SDG 6. Additional studies may help clarify how microplastic levels vary across different Palestinian cities, seasons, and storage conditions, also how they may affect human health.

Keywords: Microplastics, Bottled water, Tap water, Polyethylene, Polyethylene Terephthalate.

Chapter One
Introduction and Theoretical Background

1.1 General background

Access to safe and sufficient water consider a key public health issue and is linked to food security, living conditions, and climate change. In some regions, limited water resources have also linked to social and political challenges.

The United Nations defined the basic principle, declare that everyone has the right, without any form of difference, to have reach to sufficient, safe, usable, and affordable water (Kanjin et al., 2024).

In the Palestinian case, the practical application of this principle shows important challenges affecting the water sector. These challenges are largely linked to existing political and administrative constraints, which limit Palestinians ability to obtain their water rights. Current water governance arrangements have resulted in unequal access to water resources, with a large proportion of available water remaining under external control. This situation has linked to a persistent water deficit, which continues to increase due to population growth and increasing water demands linked to economic development across different sectors.

Limited access to water resources in line with increasing demand, has showed the importance of water for humanitarian needs, development, and environmental protection. Water is essential for daily life and plays a key role in economic and social development.

Recent global health events have showed the strong link between water security and public health, confirmation the importance of protecting water sources from pollution and maintaining their quality.

In addition to these traditional challenges related to water, a new type of pollutant has appeared in recent years, known as MPs.

MPs, defined as plastic particles smaller than 5 millimeters, have become common environmental pollutants, enter many ecosystems, including freshwater sources and drinking water supplies (Isenaj, 2023).

Recent studies show the spread of MPs in oceans and soil, as well as their presence in tap and bottled water, raising serious concerns about human exposure and the potential health risks linked to them (Contie, 2024).

The World Health Organization has stressed the urgent need for further studies on the effects of MPs in drinking water, confirming the importance of knowing their sources, distribution, and impact on human health (WHO, 2019).

MP particles enter drinking water systems primarily through runoff, wastewater, and the breakdown of larger plastic debris. These particles are released from various sources, including industrial processes, household waste, and the breakdown of synthetic fibers during laundry washing (WHO, 2019).

When this amount reaches the water supply, humans may be exposed to MPs through water consumption and food, potentially leading to health effects that remain undefined (Singh et al., 2022).

Recent studies show that MPs may have low toxicity risks, but they can also act as carriers for harmful chemicals and pathogens (Zea Cobos et al., 2024). This dual threat increases concerns about endocrine disruption, inflammatory responses, and differences other adverse health effects linked to consuming contaminated water. Despite these alarming discoveries, there is still a large knowledge gap regarding the specific health effects of exposure to these particles (Li et al., 2023).

Published peer-reviewed studies on microplastic pollution in drinking water in Palestine are limited, this study focuses on drinking water samples collected from the Nablus Governorate to help address and reduce this knowledge gap.

This research aims to (1) quantify MPs in drinking water sources in Nablus; (2) find potential sources of pollution; (3) check potential health-related implications; and (4) review available technologies for microplastic removal.

By examining these aspects, the present work helps explain the occurrence of microplastics in drinking water and provides suitable information that can support public health decision-making linked to human exposure.

1.2 Problem statement

The increasing existence of MPs in drinking water sources forms a huge challenge to public health and the environment. These MPs, defined as plastic particles smaller than 5 millimeters detected in bottled and tap water around the world, raising widespread concerns about their potential health effects on humans. (Gambino et al., 2022), Despite growing evidence of the spread of pollution of drinking water with MPs, there remains a huge gap in understanding the specific health risks linked to their ingestion.(Hung Wong, 2025). Existing literature shows that microplastics are capable of carrying chemical pollutants and microorganisms, potentially linked to adverse health effects.

The World Health Organization (WHO) has shown the uncertainty regarding the health effects of exposure to these particles, and announced that current levels may present low toxicity risks. Still, the long-term impact of their consumption remains unclear. This uncertainty is increased by MPs' ability to accumulate in human tissues, which potentially affects endocrine disorder functions or triggering inflammatory responses (Nguyen et al., 2023).

Several studies show that existing wastewater treatment processes are not effective in removing microplastic particles. As a result, these particles can reach drinking water sources through different pathways, including surface runoff and atmospheric deposition. In addition, the absence of standardized methods for measuring microplastic concentrations in drinking water makes regulatory assessment and public health planning more challenging (Carnevale et al., 2024).

In summary, this research addresses the need to quantify microplastics in drinking water, check their potential health-related implications, and review available technologies for their removal. Addressing these aspects is important for developing drinking water safety and supporting public health, particularly in light of the increasing existence of plastic pollution in the environment.

In Palestine, research addressing microplastic pollution in water is still limited. The region faces water scarcity, which places greater importance on the quality and safety of available water resources. At present, comprehensive data on the occurrence and concentrations of microplastics in drinking water across Palestine are scarce. This lack of information limits the ability to properly estimate potential risks to public health, the environment, and overall drinking water safety.

This study aims to help address the existing research gap by applying a systematic approach to detecting microplastics in drinking water in Palestine. By checking the existence of microplastics and exploring possible sources of pollution, the study provides evidence that can support discussions related to public health, environmental protection, and water management in Palestine.

Creating baseline information on microplastic pollution in Palestinian drinking water, particularly in urban areas such as Nablus, is important for improving understanding of potential exposure and supporting mitigation planning.

1.3 Objectives of the study

- To detect and calculate the amount of MPs in bottled water from Palestine and tap water in Nablus.
- To compare contamination levels with international benchmarks.
- To assess sources and polymer types contributing to contamination.
- To support decision makers with scientific evidence for reducing plastic pollution risk.

1.4 Importance of the study

a. Policy and Public Health

- Understanding the spread and concentration of these particles in drinking water helps support the estimation of potential health risks and provides information suitable to public health planning.
- This information is suitable for informing discussions on regulatory thresholds for microplastic concentrations in water and potential approaches to reduce pollution.
- The results can help inform environmental policy discussions linked to reducing plastic exposure and improving public health.

b. Environmental Impact Assessment

- Microplastics pose concerns not only for human health but also for aquatic ecosystems. Investigating their existence in drinking water linked to a better understanding of how these pollutants are transported to water sources and their potential effects on aquatic organisms. Such knowledge can also help in developing approaches to reduce environmental pollution and support biodiversity conservation.

c. Water Resource Management

- Palestine faces continuous challenges related to water scarcity and water quality, which place greater importance on ensuring the safety of available water resources. This study provides data that can support improvements in water management and treatment practices, including wastewater management, and so contributing to safer water supplies for the population.

d. Awareness and Education

- The results can increase awareness among key stakeholders, including government institutions, water authorities, industrial sectors, and the public, regarding the risks linked with microplastic pollution. Greater awareness may encourage improvements in industrial practices, consumer behavior, and environmental protection efforts.

e. Foundation for Future Research

- This study shows an early contribution to research on microplastics in the Palestinian case and provides baseline information that can support future research and monitoring activities. Also, the results help identify existing knowledge gaps and offer a basis for further investigations into the sources, distribution, and potential long-term impacts of microplastics in the region.
- The approach and results of this study may be used as a reference for similar research in other regions facing similar challenges, and so supporting broader understanding of microplastic pollution.

f. International Collaboration and Support

- By checking microplastic pollution within a global environmental context, this study shows opportunities for collaboration between Palestinian institutions and international environmental organizations and researchers. Such collaboration could contribute to providing technical support, opening funding, and sharing knowledge and best practices in addressing MPs challenges.

1.5 Research hypotheses

- H1: MPs are present in both bottled water from Palestine and tap water in Nablus.

- H2: Bottled water contains higher MP concentrations due to polymer leaching from packaging materials.
- H3: Temperature and sunlight increase MPs shed

1.6 Literature review

1.6.1 Introduction

According to the U.S. Environmental Protection Agency, Plastics are high molecular weight organic polymers composed of various elements such as carbon, hydrogen, oxygen, nitrogen, sulphur and chlorine. According to the International Union of Pure and Applied Chemistry, plastics are polymeric materials containing additives to improve performance or reduce cost (Adhikari et al., 2022).

The word "plastic" refers to a diverse class of synthetic or semi-synthetic materials made from organic compounds, such as cellulose, carbon, natural gas, and petroleum. Since the invention of the first synthetic plastic in 1855, which later became known as celluloid, the plastics industry has undergone tremendous development, resulting in the production of a wide variety of different types used today in countless applications (Domenech & Marcos, 2021).

Plastics can be formed into countless shapes and have varying physical features, making them attractive for a wide range of products. The common and different uses of plastics lead to large quantities of them that will turn into waste. This waste includes large plastic particles that are easily visible and commonly handle with in everyday plastic products. However, MP particles may small (<10 µm) so we couldn't detect with normal techniques and that represent challenging to detect it (Fisher Scientific, 2019).

Plastic products are used in everyday in our life and are present apart a large range of human activities. With their increasing relay on different sectors, global plastic production is so rapid and huge growth (Verla et al., 2019).

The large-scale production of plastics has led to important advantages, like low cost, flexibility, and durability. (Geyer et al., 2017). While plastic has been used for approximately a century in the world, plastic production grown speedily last few decades, increasing from about two million tons in 1950 to nearly 370 million tons by 2019. (Andrade et al., 2021), this upward trend is expected to continue in the future. The scientific estimated that plastic production will be double in the next two decades, and could quadruple current amounts by 2020. (Barra & Leonard, 2018), with this huge production and increasing use of plastic, the volume of plastic waste produced annually is possible to more than 400 million tons after 2020 (Ali et al., 2021).

Plastic products, which are widely consumed, are ubiquitous in our daily lives, and annual plastic production is increasing dramatically. (Verla et al., 2019). It is now expected to reach 33 billion tons by 2050. (Rochman & Browne, 2013), Plastic waste in the environment is expected to reach 67.8 million metric tons by the same year (Ebere et al., 2019).

According to Garcia and Robertson (2017), nearly 76% of all plastic production is treated as waste, with 12% being incinerated, 79% being buried or released into the environment, and only 9% being recycled (Garcia & Robertson, 2017).

Depending on Verla, plastics can be categorized into two main types:

- Thermoplastics: These are a family of plastics that can be easily changed in shape by changing temperatures. Examples include Polyethylene (PE), polycarbonate (PC), expanded polystyrene (EPS), polyarylsulfone (PSU), polystyrene (PS), thermoplastic elastomers (TPE), polyethylene terephthalate (PET), polymethyl methacrylate (PMMA), polyvinyl chloride (PVC), polypropylene (PP), polyamides (PA), fluoropolymers, etc. These are the most prevalent in the environment (Verla et al., 2019).
- Thermosetting plastics: These are a family of plastics that are irreversible when heated. They undergo a chemical change that creates a three-dimensional network, making them rigid. Some examples are: epoxy resins, vinyl ester, polyurethane (PUR), urea (formaldehyde), acrylic resin, silicone, melamine resin, phenolic (formaldehyde) resins, phenol (formaldehyde), unsaturated polyester, and others (Verla et al., 2019).

MPs are synthetic plastics with a high molecular weight, broken down into particles smaller than 5 mm. These particles are highly resistant to biodegradation, leading to their long-term accumulation in the environment. Because they can enter the food chain, they may eventually reach humans, where they can potentially cause adverse health effects (Lee et al., 2023).

Also MPs are a heterogeneous mixture of particles of different sizes, colors, shapes, and polymers, emanating from a variety of other sources (Eerkes-Medrano & Thompson, 2018).

MPs have a variety of uses and compositions; for example, they are used as raw materials for the plastics industry, abrasives in cleaning products, cosmetics, personal care products, and toiletries, and as air-blowing media (Eerkes-Medrano & Thompson, 2018).

A wide range of polymers are classified as primary MPs. Plastic powders, granules, or small beads used as raw materials for the plastics industry may consist of polyethylene, commonly used in plastic packaging, or polyvinyl chloride and polypropylene, used in the manufacture of building materials and automotive parts. MPs beads used as abrasives in personal care and cosmetic products, such as shower gels, face washes, and liquid soaps, are usually made of polyethylene (Eerkes-Medrano & Thompson, 2018).

MPs are also classified by origin into:

1. Primary MPs: Plastic particles with particle sizes less than 5 mm, found in most industries, used for specific purposes, and forming the basis of consumer and commercial products. They are primarily used in personal hygiene products, cosmetics, skincare, fibers and textiles, industrial laundry, and tire wear during driving (Muniv & Supanekar, 2024).

2. Secondary MPs: Produced from medium-sized (5 mm-25 mm) and large-sized (>25 mm) plastic waste after being exposed to physical, chemical, and biological processes. These particles are formed as a result of disintegration, photodegradation, and biological processes, along with strong ultraviolet radiation, oxygen availability, and physical erosion by waves and turbulent air currents (Mariano et al., 2021). Look at Figure 1.

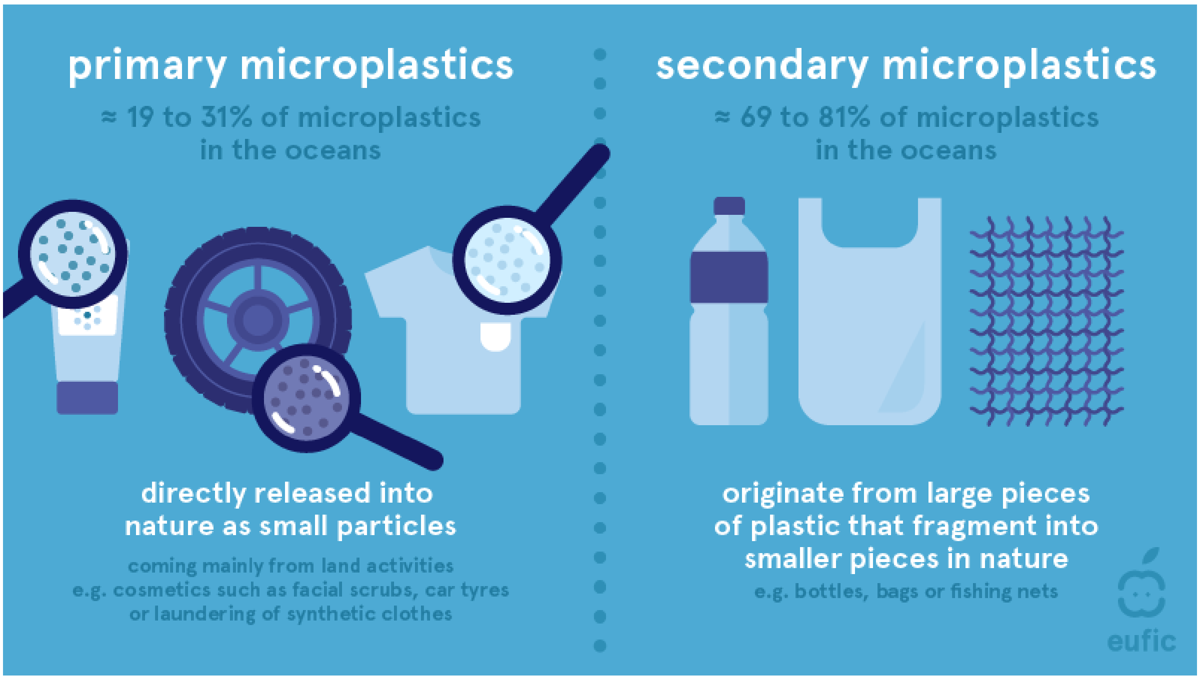

***Figure 1*: Classification of MPs by origin (eufic, 2021)

As (Muniv & Supanekar, 2024) mentioned, sources of primary MPs vary from dust, paints, personal care and hygiene products, to roads, streets, tires, and synthetic textiles.

- Dust (weathering, abrasion, and casting) includes dust particles resulting from the abrasion of objects, infrastructure, and casting processes. This type of loss is mostly unintentional.
- Marine Coatings (maintenance, disposal, and weathering). From marine coatings, primary MPs are released from boats during construction, maintenance, repair, or use, surface pretreatment, paint application, and equipment cleaning. This type of loss is entirely unintentional.
- Personal Care Products: The use of personal care products releases plastic particles directly into wastewater from homes, hotels, hospitals, and sports facilities. This type of loss is considered intentional.
- Plastic Particles (during manufacturing, transportation, and recycling) As a result of processing, transportation, and recycling, plastic particles are released into the environment through small or significant accidents, resulting in unintentional loss.
- Roads: The erosion of road surfaces made of paint, thermoplastics, molded polymers, and epoxy produces MP particles. Rain and runoff carry these particles into oceans or sewage systems.
- Synthetic textiles: Home and other laundry processes erode polymer-based clothing, producing tiny, non-biodegradable plastic fibers. This loss is unintentional.

- Tires: Due to constant use and friction, car tires wear down, producing plastic particles. Wind and rain carry these particles to various water sources. This loss is unexpected.

Several studies estimates that secondary plastic polymers represent between 70% and 80% of the plastic polymers released into the environment, while primary plastic polymers represent only between 15% and 31%. Also, some physical properties are used to classify plastic polymers, such as density (light/heavy), elasticity (hard/soft), and shape (shards, granules, filaments, and pellets). The components and structure of plastic polymers are closely related to the source material. The most abundant plastic polymers they are composed of are polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), nylon (PA), cellulose acetate (CA), and thermoplastic polyester (PET) (Mariano et al., 2021).

There are three types of MPs:

- Microfibers, the most common type of MPs, are formed in synthetic textiles and shed during daily use and washing. These microfibers range in size from 0.1 to 0.8 mm in clothing (such as sweaters) (Hernandez et al., 2017).
- Fragments: Fragments are formed through the physical breakage of larger plastics.
- Microbeads: These are commonly found in personal care products.

Look at figure 2 below:

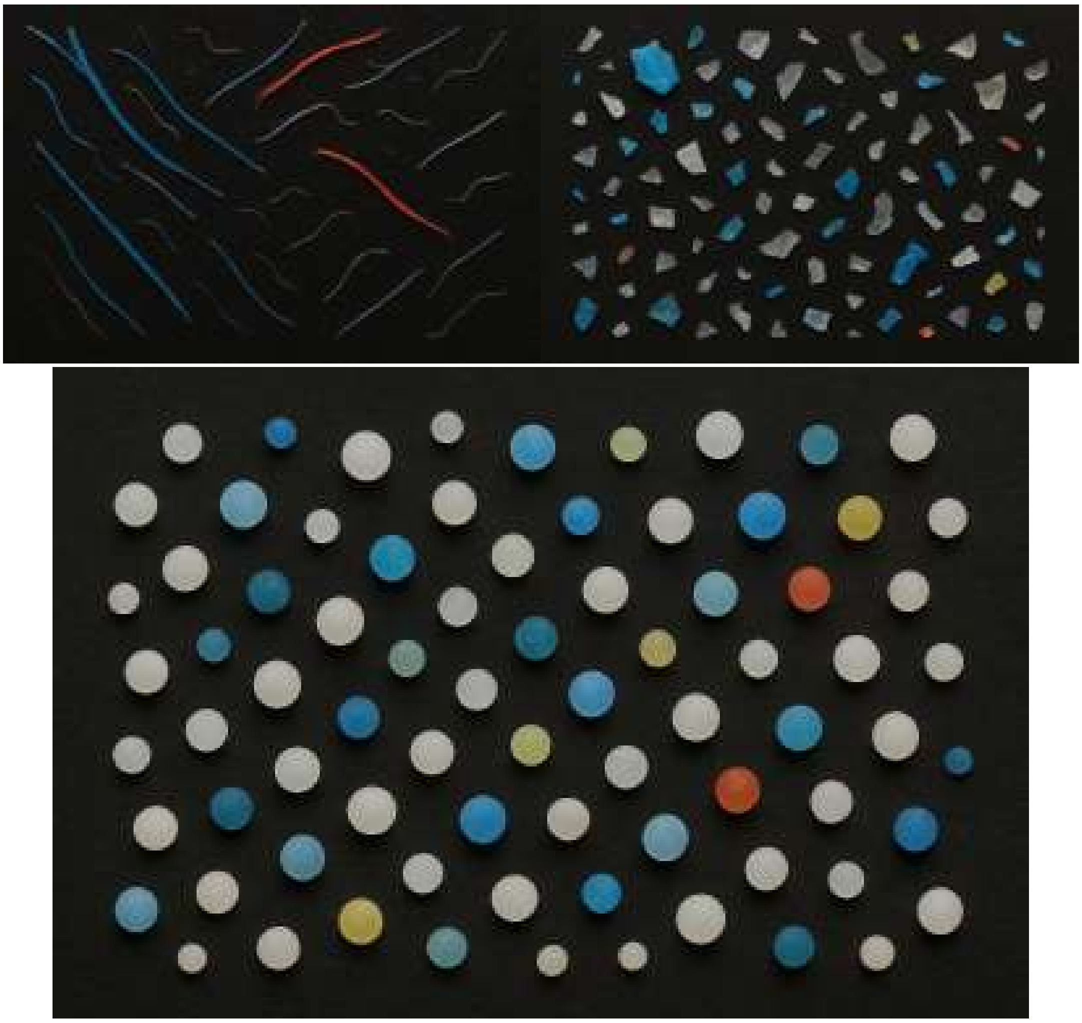

Figure 2: *Microfibers, Fragments and Microbeads.*

MPs are also classified into different types based on their polymer types. For example, some are biodegradable, such as polylactic acid, while others are non-biodegradable, such as polyurethane, polyvinyl chloride, polyamide, polypropylene, polymethyl methacrylate, and polystyrene (Rafa et al., 2024).

MPs have several sources and uses according to Muniv & Supanekar:

- Land-based sources of MPs: The primary source of MPs includes plastic fragments from cosmetics, household plastic containers, detergents, synthetic fibers, and single-use products (Muniv & Supanekar, 2024).
- Marine sources of MPs: These include fishing components and supplies, ships and marine vehicles, and marine debris resulting from various recreational and marine tourism activities (Muniv & Supanekar, 2024).

It is important to note that while bulk plastic waste can be easily removed and recycled, disposing of small plastic particles are pose a greater challenge, and sometimes impossible. Consequently, there is growing concern about the environmental impacts, particularly those caused by small plastic pieces (less than 5 mm), as their high surface-to-volume ratio enhances their ability to absorb pollutants and increase their bioavailability to living organisms. For fine and small nanoparticles, the effects may be even more serious, given their ability to cross biological barriers, pass through tissues, and bioaccumulate within organs. Therefore, nanoparticles may cause significant adverse effects in various environments, as well as their negative affect on human health (Bolea-Fernandez et al., 2020).

MPs are now ubiquitous in the global ecosystem, so all living organisms are at risk of exposure and potential toxicity (Enyoh et al., 2020).

Previous studies estimate that humans are exposed to between tens of thousands and millions of MP particles annually, or many milligrams per day, with the main sources of exposure likely being bottled drinking water and indoor air (Lee et al., 2023).

It is now clear that drinking water contains wastewater particles (MP), but there are mixed opinions about the concentrations used. There is a wide variation in the numbers used. Determining this difference is challenging, but it may be due to variations in water quality, differences in quantitative measurement methods, or inconsistencies in following to accurate analysis standards. There is a lack of reliable leadership despite the urgent need to understand human perception of drinking water (Kirstein et al., 2021).

In a Chinese study, 38 tap water samples were taken from different cities. After analysis, the amount of MP particles in tap water ranged from 440 ± 275 particles per liter. Particles smaller than 50 mm were significantly more prevalent in most samples. In addition, fibers, spheres, and fragments were found in tap water samples, with fragments being the most common form in most samples (Tong et al., 2020).

A German study on some brands of single-use bottled drinking water made from polyethylene terephthalate (PET) revealed that they contained an average concentration of polymer particles of 2,649 ± 2,857 particles/liter, with size less than 1 micrometer. The presence of polyethylene, polypropylene, polyethylene terephthalate, polyvinyl chloride, and polystyrene (PVC) was observed after a study was conducted on them (Koelmans et al., 2019) (Kankanige & Babel, 2020).

The differences in sampling, quantification and identification methods have led to big differences in reported tap water concentrations, with differences of up to six times. The EU created Directive 2020/2184 to standardize the quality of drinking water and monitor organic matter (Gambino et al., 2022).

The first main report reporting the existence of microplastic particles in drinking water represented a large shift in understanding the extent of this form of pollution. Researchers analyzed 159 tap water samples from 15 different countries and found that the average concentration of MPs was 5.45 particles per liter which represent a noticeable level. This report made the problem of MPs in drinking water to the attention of the scientific community and the public, encouraging more global studies to explore the existence, removal and distribution of these particles from water, in the search for ways to decrease the health and environmental impacts (Hossain et al., 2023).

Many studies show that microplastic pollution in bottled water is largely linked with packaging materials. In particular, some investigations have reported higher average particle counts in drinking water stored in reusable plastic bottles compared to other container types. Researchers checked water from several types of containers, including glass bottles, single-use plastic bottles, reusable plastic bottles, and beverage cans, as well as other types of packaging. Additional factors related to the packaging material itself were also found. MP load may also be affected by carbonation and bottle age. In reusable bottles, the addition of trisphosphate may indicate potential leakage from the packaging. According to other studies, cleaning reusable bottles may be an important entry point for MP particles. In addition to other equipment used in water treatment processes, such as bottle filling machines, water conveying systems, often made of polyethylene (PE) and equipped with polyamide (PA) connectors, are a potential source of water contamination with MP particles. The discovery of polymers such as polyethylene terephthalate (PET) and polyvinyl chloride (PVC) in drinking water bottles has shown that these particles may result from the corrosion of plastic components used in the purification, transportation, and packaging stages. This suggests that some of the MPs contamination comes not only from the bottle or packaging, but also from the infrastructure of the production lines themselves (Hossain et al., 2023) (Eerkes-Medrano & Thompson, 2018).

Only four of the 50 studies met the advanced quality criteria, indicating a pressing need to improve the quality of plastics in drinking water samples. These studies ranked the most commonly detected polymers globally as follows: PE > PP > PS > PVC > PET, with fragments, fibers, films, foams, and granules being the most common forms (Koelmans et al., 2019).

Small waste is intentionally produced, or when products from large industrial mills, such as plastic packaging, are not properly removed. Once they become inert, MP particles often become trapped, where they can decompose (Lee et al., 2023).

A variety of chemical compositions of MPs have been identified in drinking water, including polyethylene (PE), polypropylene (PP), acrylic, polyamide (PA), polyester (PEST), ethylene-vinyl acetate (EVA), polyethylene terephthalate (PET), polyurethane (PU), polyamide chloride (PVC), polyacrylamide (PAA), polyethersulfone (PES), and polystyrene (PS) (Hossain et al., 2023).

Looking at polymer composition, polyethylene terephthalate (PET) and polyethylene (PE) were the most common polymers in bottled water. PE is assumed to be resulting from the cap, of which it is the main component, while PET results from the container itself and the neck of the bottle. Regarding to groundwater, polypropylene (PP) and polyethylene (PP) were represent the most common polymers. More different studies showed the existence of other polymers, Like epoxy resins and polyvinyl chloride (PVC), that showing water leakage from pipes in supply systems or storage tanks (Gambino et al., 2022).

MPs can play as pollutant carriers in different ways, like through surface cracks or ionic interactions or adsorption or hydrogen bonds. The existence of surface cracks in old MP particles creates suitable environments for the physical accumulation of pollutants (Rafa et al., 2024).

Also, the physical and chemical properties of MPs develop their ability to interact with environmental pollutants. Ionic interactions between plastic particles and oppositely charged pollutants make it is easy to link of these pollutants to the particle surfaces. The hydrophobic properties of plastic particles make easy the adsorption of hydrophobic organic pollutants, promoting their accumulation on particle surfaces, also microplastics often include polar functional groups that can interact with polar pollutants through hydrogen bonding, which may improve the retention of these substances on the particles. The interaction of these different mechanisms allows MPs to play an effective carriers of pollutants, thus contributing to their common transport and spread in ecosystems, both in aquatic and terrestrial environments (Rafa et al., 2024).

The adsorption of pollutants onto MPs is affected by many factors, which are represented by pH, particle size, aging, temperature, salinity, crystallinity, functional groups, ionic strength, and existence of surfactants, solubility, concentration, dosage, and tendency to adsorb certain compounds.(Rafa et al., 2024).

The separation of larger plastic items into secondary microplastics is strongly affected by environmental conditions, including sunlight exposure, temperature, and oxygen availability. These conditions vary between locations, resulting in a different rate and extent of plastic degradation accordingly. For example, polyethylene materials have been found to break down faster in air than in seawater, with higher temperature, oxygen content, and direct exposure to sunlight accelerate the process. However, degradation in submerged environments (such as oceans or lakes) is so slower because of the less exposure to environmental factors like sunlight and limited ventilation (Singh et al., 2022).

1.6.2 Occurrence of MPs in Drinking Water

Microplastics, primary or secondary, can enter drinking water sources mainly through wastewater discharge and surface runoff. Primary microplastics used in different industrial applications, including pharmaceuticals and cosmetics, and then released into domestic wastewater after use. The conventional water treatment processes are not effective in removing all these small particles so microplastics may continue in treated water. so when this water is discharged into freshwater sources, the pollution move with it and become part of the drinking water supply system (Singh et al., 2022).

For example, polyethylene, polypropylene, and polystyrene particles used in cleaning products and cosmetics reach aquatic environments via domestic wastewater discharge (Eerkes-Medrano & Thompson, 2018).

Based in the World Health Organization (WHO), microplastic particles can enter drinking water sources through many ways. These include surface runoff, especially after rainfall events, treated and untreated wastewater, combined sewer overflows, industrial effluents, the environmental breakdown of plastic waste, and atmospheric deposition. Although surface runoff and wastewater are currently known as the two major contributors, more accurate measurements are required to better characterize these sources and create clear correlations with particular plastic waste streams. Add to this, the packaging process may also produce microplastics. For example, plastic bottles and caps used in water bottling have been known as potential direct sources of pollution in drinking water (WHO, 2019).

Reports indicate that bottled water, these bottled tested in nine different countries, despite being treated, also contains MPs. Each liter of bottled drinking water contains approximately 10.4 MP particles larger than 100 micrometers. The World Health Organization (2019) reported that the smallest MPs particle detected in drinking water were only 1 micrometer in size. Evidence suggests that the primary cause of MPs contamination of bottled water is bottling processes and plastic caps. Water bottled in plastic bottles has been shown to contain higher levels of MPs than water bottled in glass, despite the same water source. Polypropylene is the most common type of MPs in this water, while another study showed that a polyester/polyethylene terephthalate blend predominates in single-use plastic bottles. Overall, the presence of MPs in drinking water is primarily attributed to plastic packaging and improper disposal of plastic waste (Singh et al., 2022).

There are currently no accurate statistics that precisely determine the sources of MPs or the total quantities deposited in terrestrial and marine environments. However, reports show that a wide range of human activities and products contribute to the release of these particles, such as washing operations, tire wear, urban dust, road and ship paint, and cleaning products, making it difficult to find a single primary source of this type of pollution (IUCN, 2021).

The potential risks related with MPs show in three main forms: physical particles, chemicals, and microbial pathogens that may stick to to plastic within biofilms. Although limited, available evidence suggests that the health effects of MPs-associated chemicals and pathogens in drinking water are considered to be of low risk to human health. To date, there is insufficient information to draw main conclusions regarding the toxicity resulting from the physical action of MPs, particularly nanoparticles, nor is there reliable evidence of a direct risk from these particles. Available data show that the most important sources of MPs contamination of freshwater are runoff and wastewater. Although improved wastewater and drinking water treatment systems are able to removing the majority of these particles. For individuals without adequate access to wastewater treatment services, the greatest public health risk is not MPs but microbial contaminants and other chemicals (WHO, 2019).

However, the existence of these particles is not the only concern; their potential health implications raise even greater challenges.

1.6.3 Health Implications

The potential risks associated with MPs fall into three main categories: physical particles, chemicals, and pathogenic microorganisms that form part of biofilms. MPs affect the body based on their physical and chemical characteristics, such as size, surface area, and shape. However, the effects of MPs on human health after ingestion are still poorly understood, as direct human studies in this area are currently lacking. Although plastic polymers are widely classified as low-toxicity, MPs may contain unbound monomers and additives. They can also absorb hydrophobic environmental chemicals, such as persistent organic pollutants (WHO, 2019).

Bio-oxygen is synthesized during the water absorption process when microorganisms grow extensively throughout water distribution systems. Although most of these organisms are harmless, some may cause contamination of the water system, such as Pseudomonas aeruginosa, Elephant species, non-tuberculous Mycobacterium, and Naegleria fowleri. The health risks of MPs in water are related to two main factors: the level of hazard (the potential to cause serious health damage) and the level of exposure (the amount that enters the body). The impact also depends on the particle and the route of entry into the body, whether through ingestion, exposure, or contact with fabric (WHO, 2019).

Human exposure to MPs occurs mainly through the use of a variety of plastic products, including packaging, degraded plastics, fishing nets, textiles, and personal care products. These particles can also result from paint shards released into the environment through air, water, and soil, including seawater. Consequently, exposure to MPs can occur through ingestion, inhalation, or direct contact with these particles (Enyoh et al., 2020).

The potential health impacts of microplastics relay on the characteristics of exposure and the individual's susceptibility to infection. While the toxicity of MPs has been primarily studied with respect to inhaled particles, the transport and effects of these particles after ingestion have not yet been extensively studied. Preliminary research has demonstrated several mechanisms by which MPs affect human health, such as an exaggerated inflammatory response, genotoxicity, and oxidative stress, leading to cell and tissue damage, fibrosis, and potentially carcinogenesis. Organ-specific toxicity has been reported in the gastrointestinal tract, liver, reproductive system, and nervous system. The effects of MPs on distant human organ systems range from an increased incidence of immune or neurodegenerative diseases to an increased risk of lung disease, impaired kidney function, and bone loss resulting from increased activity of osteoclasts responsible for bone resorption. Polyvinyl chloride (PVC) is also a proven carcinogen, causing hemangiosarcoma of the liver. Moreover, studies show that MP particles can enter and penetrate the placental barrier, which may lead to adverse effects on fetal development (Singh et al., 2022).

The long-term exposure to low concentration of MPs maybe lead to many concerns health aspects, like diseases in respiratory system and heart and cardiovascular system, and that relay on the sensitive of person and particles characteristic like size and chemical composition. So that emphasize the importance of assess the long term exposure for MPs and that effects on human health (Prata, 2018).

There are many compounds used in plastic manufacturing categorized as chemical materials that effect on endocrine system function. This compounds form an important raising challenging for to the chemical and consumer goods industries because the potential health affects and the difficulty in organize use it (Vandenberg et al., 2017).

The digestive, respiratory, endocrine, reproductive, and immune systems may be affected by microplastic particles from cellular and animal evidence from studies. When these particles are ingested, the digestive system is the first one affected because they can irritate intestinal tissue, and that may potential leading to chronic inflammation and different digestive symptoms (Bouwmeester et al., 2015).

MP particles may lead to a change in the gut microbiome, disrupting the balance of beneficial and harmful bacteria. And this disruption can impact digestive health, causing a range of symptoms like abdominal pain, bloating, and bowel movements (Jin et al., 2019).

Also physical effects on the digestive system we have another problem represented by the ability of microplastics to carry and move environmental toxins like heavy metals and polycyclic aromatic hydrocarbons, which may increase chemical toxicity. When these particles are ingested, the toxins can enter the body via the digestive tract and causing different gastrointestinal symptoms like nausea, vomiting, and abdominal pain (Abbasi et al., 2021).

Also, when inhaled, microplastics may be a reason for oxidative stress in the lungs and airways, that leading to inflammation and tissue damage. Linked respiratory symptoms include coughing, sneezing, and shortness of breath, and may also be accompanied by fatigue and dizziness due to decreased blood oxygen levels (Wright & Kelly, 2017).

Microplastics have the potential to carry and move environmental pollutants like as heavy metals and hydrophobic organic compounds. Also exposure to high concentrations of PS may cause damage to human lung cells and increasing the risk of chronic obstructive pulmonary disease as the studies shown that (Dong et al., 2020).

Recent research show that nanoplastics may cause damage to mitochondria in human respiratory cells. This damage can huge impact cell function, improve oxidative stress, and lead to increased damage to respiratory tissue (Lin et al., 2022).

Furthermore, interfering with hormone production, secretion, transport, metabolism, and excretion disrupt endocrine function by microplastics. This disruption can cause a range of hormonal disorders, including metabolic disturbances, developmental disorders, and even reproductive problems such as infertility, miscarriage, and birth defects (Vandenberg et al., 2017).

Also the MPs may be play as a carrier and mover for the environmental toxics and pollutants, like bisphenol A (BPA). These toxics material caused harms on the endocrine and reproductive systems (Campanale et al., 2020).

The MPs have been found in different human tissues and biological matrices, like blood, respiratory tissue, breast milk and the placenta. Also the recent research and studies show to the potential health effects may be linked by with oxidative stress, genotoxic effects, apoptosis, inflammatory responses and necrosis. And these effects may lead to damage of tissue, fibrosis or malignancy. Although the interaction between the human tissues not clear, the detection in human body indicates a warning sgin, and show the important to control with the total amount which human eats from this particles (Liu et al., 2024).

In a recent study, Raman spectroscopy find MP particles in the placentas of six pregnant women, showing that these particles may be transferred and move to fetuses during pregnancy (Ragusa et al., 2021).

We need to more research to better understand to how microplastics may affect the human immune system. Cumulative exposure to MPs has been shown in animal experiments to lead to chronic inflammation and alterations in homeostasis (Detri and Gallardo-Escarate, 2018). Also we find a study on human lung cells show that MPs can stimulate innate immunity by regulating the expression of genes and proteins involved in the immune response (Chiu et al., 2015).

Beyond the microplastic particles themselves, chemical additives and environmental pollutants adsorbed onto these particles may add additional health risks. Studies on marine organisms have shown that pollutants linked to microplastics can be transferred and move to other tissues as the particles pass through the gastrointestinal tract. Similar carry mechanisms may also occur in the human body after microplastic ingestion. Some chemicals added to plastics and microplastics may affect human health when it ingested. Material like phthalates and BPA, commonly used in plastics, have been detected and showed in the human body.Also Epidemiological studies have shown a correlation between phthalate levels and adverse human health effects. Moreover, MPs adsorb different metals and metalloids like cadmium, manganese, lead, arsenic, copper, zinc, and chromium, onto their surfaces (Singh et al., 2022).

Evidence shows that PET microplastics can play as sorbents for heavy metals like lead, cadmium, and zinc. In addition, HDPE has been showed to interact with metals including arsenic and chromium. The negative effects of these metals on human health are common reported, including disruption of the hormonal and endocrine systems, and abnormal hormonal responses observed in organisms exposed to these materials. (Oßmann, 2021), additionally, MPs play a dangerous role as carriers and mover for harmful microorganisms. Also, they can absorb pathogenic bacteria like Vibrio spp on their surfaces. Upon entering the body, these particles release their microbial payload into the digestive tract, potentially disrupting the balance of the gut microbiome, leading to inflammation and a host of potential health problems.

The biofilms which linked to MPs that consider a little relative effects on the human health. Regarding to limited and a little abundance compared with other particles in freshwater environments that may be pose a fertile environment for sticking with pathogens. For to MPs that still not removed in water treatment process, that’s likely the biofilms effects linked with is low. If drinking water distribution systems provide extensive surfaces that support biofilm formation to a much greater extent than microplastics. Also disinfection processes including these happened in distribution systems, can inactivate pathogens and limit their growth (WHO, 2019).

However, when microplastics interact with toxic chemicals, they may create additional environmental risks, as the harmful effects of these chemicals have been linked to mutagenic, teratogenic, and carcinogenic effects. Examples of these toxic chemicals include heavy metals such as iron (Fe), manganese (Mn), aluminum (Al), lead (Pb), copper (Cu), silver (Ag), and zinc (Zn), as well as hydrophobic organic pollutants (HOCs), also known as persistent organic pollutants (POPs), such as polyaromatic hydrocarbons (PAHs), organochlorine pesticides (OCPs), and polychlorinated biphenyls (PCBs). At this study, we review and check the concentrations of these toxic chemicals (halogens, heavy metals, and organic pollutants) on MPs in the environment and animals. And we present their potential absorption and release mechanisms and techniques, and the effects of their interactions on humans and their environment (Verla et al., 2019).

After understanding these risks, it must to be known the suitable and best analytical techniques that can identifying and quantifying microplastics in water.

1.6.4 MPs Detection Methods

The number and types of microplastics detected depend on the analytical method used, which is why more than one technique is often needed. This is mainly because of their small size, complex composition, and similarity to other environmental particles. To detect different types of MPs, we require high-precision analytical equipment, which is often expensive and not easily available in normal laboratories (TWRF, 2018).

A range of analytical techniques will be applied to identify and quantify microplastics, like microscopic, spectroscopic, and chromatographic methods. One of them, optical microscopy is the most commonly used approach because it’s approximately simplicity, with particles typically identified through manual counting. Despite its common application, optical microscopy has notable limitations, including the risk of particle misidentification and limited resolution, which may result in either overestimation or underestimation of microplastic abundance. To overcome these limitations, electron microscopy techniques, like the scanning electron microscope (SEM), can be used which offers higher resolution for imaging and identifying particles (Singh et al., 2022).

However, spectroscopic techniques like FTIR and Raman spectroscopy are highly effective for identifying the specific polymer composition of fine-grained particles, which helps distinguish between different types of polymers. When combined with microscopy, spectroscopy yields more comprehensive and distinct results. (Singh et al., 2022). Additionally, more advanced techniques such as pyrolysis gas chromatography coupled with mass spectrometry (Py-GC-MS) have been introduced to identify polymers through thermal analysis. Although it provides accurate chemical information, it is a destructive technique for the sample and does not provide information about the shape, number, or size of molecules. Moreover, the technology can indicate the indirect release of small amounts of plastics, where the semi-volatile organic matter from solid plastics is released under high temperature and pressure conditions without reaching a critical state.

Every technique from these techniques has advantages and limitation. Which related to accuracy and sensitive and the ability to distinguish between other polymers types. Still research related to categorized the nanoparticles in fresh water and marine system limited. And the absent of the standardized methodologies prevent to conduct the comparison between studies and their results (TWRF, 2018).

Spectroscopic techniques, like Fourier transform infrared (FTIR) and Raman spectroscopy, along with microscopy-based approaches, are common applied to analyze samples and characterize the basic chemical structure of microplastic particles. However, these methods suffer from limitations in the number of samples that can be processed, especially when they rely on microscopy, which makes them less effective in environments that require large-scale analysis. (Rajski et al., 2023), By comparison, pyrolysis–gas chromatography–mass spectrometry (Py-GC-MS) offers a strong alternative for the detection and identification of microplastics, especially when the analysis of large sample volumes is required. This technique is capable of rapid and accurate detecting large quantities of plastic particles, including nanoparticles that are smaller than the detection limits of conventional microscopic techniques, making it a powerful tool for large-scale environmental monitoring.

Nile Red dye, which offer a strong affinity for lipophilic materials, is commonly used to stain microplastic particles, enabling their detection by flow cytometry. This technique allows rapid and sensitive analysis based on fluorescence signals. (Bianco et al., 2023), This method is much more efficient compared to traditional spectroscopic techniques like micro-Raman, because the sample can be analyzed in just 90 seconds, hundreds of times faster than analyzing filter fragments manually. The results showed that this method is especially effective with polyethylene, where the staining efficiency reached over 70%, and a clear relationship was found between signal intensity and particle concentration. We observed high staining efficiencies of up to 96% also we observed with other types of polymers like polyvinyl chloride (PVC) and polystyrene (PS), confirming the reliability of this technique in efficient and quick detecting multiple types of MPs.

In the absence of standardized protocols for labeling microplastics, many fluorescent dyes have been evaluated for labeling laboratory-prepared polymer particles. These approaches aim to improve the different of polymer types and expand the scope of morphological and chemical characterization, among the dyes commonly applied, Nile Red and its derivatives are the most frequently used, together with other dyes such as Oil Red (EGN), Rose Bengal, Neutral Red, Trypan Blue, and commercial textile dyes like iDye and Rit. These dyes have all been shown to stain different polymer types effectively. However, the strength of dye attachment differs from one polymer to another, mainly because differences in polymer structure and surface characteristics. Although Nile Red is the most widely applied dye, it has several limitations. Its low solubility in water and high sensitivity to polarity cause the fluorescence color to vary depending on the hydrophobic nature of the polymer surface. In addition, surface pollutants on particles, including biofilms or lipid layers, can modify surface properties and reduce staining efficiency (Gao et al., 2022).

Textile dyes with aromatic amine groups were tested and were found to perform better than Nile Red under certain conditions as an alternative approach, For example, when used with particles made of PS, PET, PVC, HDPE, PET, and PAN, they recorded much stronger fluorescence signals, making them a promising option for distinguishing MP particles in complex media.

FTIR and Raman spectroscopy are commonly applied methods for microplastic characterization. While FTIR typically detects particles ≥10 µm, Raman spectroscopy provides more accurate resolution and can identify particles at the micrometer scale. However, the existence of pollutants or unremoved organic matter in samples can slow down the analysis process or hinder accurate identification of polymer types. (Gomiero et al., 2021), Therefore, the use of these methods requires careful sample preparation to eliminate and remove impurities that may affect the accuracy of the results, with the need to choose the most appropriate and suitable technique based on the particle size and type of environmental matrix.

Although FTIR and Raman spectroscopy are effective for identifying polymer types, they are limited in their ability to quantify the mass of microplastic particles. Microplastic concentrations are common reported as particle counts (MPs/L), which do not provide direct information on particle mass. In this case, thermal analysis combined with gas chromatography–mass spectrometry (Py-GC-MS) provides an alternative method for characterizing microplastics based on mass. This approach enables accurate measurement of plastic mass and offers more detailed insight into microplastic composition. Through thermal decomposition, plastic particles are broken down into smaller compounds that can be separated and checked using chromatography, which allows for a more reliable determination of both their chemical makeup and mass (Gambino et al., 2022).

Among the common GC-MS instruments, Py-GC-MS is the most advanced and effective analytical tool for identifying and quantifying MP particles (MPs). Py-GC-MS offers a wide range of advantages, which makes it suitable for many environmental studies. A key advantage of pyrolysis–gas chromatography–mass spectrometry (Py-GC-MS) lies in its ability to detect very small microplastic particles, including micro- and nanoplastics (<100 nm), which are often challenging to identify using other analytical techniques. In addition, Py-GC-MS is less affected by background pollutants that are common found in environmental samples, which leads to improved analytical sensitivity. The method is suitable with a wide range of extraction and purification procedures, helping to minimize interference from organic matter present in the sample. Another practical advantage is that the analysis can be carried out direct on liquid or solid samples, without the need for extensive pre-treatment steps, that will save both time and effort. The high sensitivity achieved through the combination of pyrolysis, gas chromatography, and mass spectrometry is one of the main strengths of this technique. As a result, Py-GC-MS is so suitable for analyzing complex mixtures of micro- and nanoplastics in diverse environmental samples, which is especially valuable when working with heterogeneous environmental materials (Ainali et al., 2021).

As microplastics became common and have been found in many environments, increasing attention for this is being aimed at the development of effective removal technologies to reduce their potential impacts.

1.6.5 Removal Technologies

Wastewater and drinking water treatment systems have high efficiency in removing particles with physical properties and size ranges comparable to microplastics. Available evidence shows that wastewater treatment plants can remove more than 90% of microplastics, and we achieved the highest removal efficiencies during tertiary treatment stages like advanced filtration processes. Conventional processes in drinking water treatment effectively remove particles at high concentrations. When optimized for low turbidity, these systems can also eliminate particles smaller than a micrometer. However, completely removing sub-micrometer microplastics remains a challenge. Advanced treatments also enable the removal of even smaller particles; for example, nanofiltration can remove particles larger than 0.001 micrometers (1 nm), while ultrafiltration can remove particles larger than 0.01 micrometers (WHO, 2019).

In addition to these essential accessories and improving the quality of water, they are as small as plastic to delay, in addition to the safety of water used for drinking and drainage. (WHO, 2019) Currently, some specific feedstocks have been developed to catalyze the degradation of MPs or to manufacture non-degradable, environmentally friendly polymers. For example, Chomlah used tal phosphide and non-noble metal nickel as a bifunctional electrocatalyst to convert polyethylene terephthalate waste into high-value-added products, such as terephthalic acid, diformate, and oxygen gas. Additionally, Shi and colleagues used a palladium-modified nickel foam catalyst to improve PET waste and convert it into high-value-added chemicals such as terephthalate and carbonate. These types of chemical transformations represent significant progress toward reducing the environmental impact of plastics and converting them into useful products that can be reused in the chemical and energy industries (Huang et al., 2023).

Chapter Two
Methods

2.1 Study design

This descriptive cross-sectional study aims to assess the prevalence of MPs in the drinking water available in Nablus City, whether bottled or tap water. Several water samples, including both tap and bottled water, were collected from different areas of the city between May and June 2025. We analyze the samples using established analytical techniques, such as microfiltration and Fourier-transform infrared (FTIR) spectroscopy, to identify the existence of microplastic particles and, where possible, to determine their size, abundance, and polymer type. The analysis focused on description the quantity and spatial distribution of microplastics, without checking direct linked with specific health outcomes. We used the descriptive statistical methods, including percentages, mean values, and graphical representations, to summarize and show the results. The study aims to provide baseline data that will contribute to increasing awareness of the problem of drinking water contamination and to provide preliminary recommendations to relevant authorities to improve water quality and reduce exposure to MPs.

Eight samples were randomly collected and distributed equally: 4 bottled water samples and 4 tap water samples, one of which was Milli-Q water, as illustrated in table 1 below.

Table 1*: Description of Water Samples*

Sample ID	Sample type	Size(L)	Storage condition
1	Bottled water	3	Stored in dark at room temperature
2	Bottled water	3	Stored in dark at room temperature
3	Bottled water	3	Stored in dark at room temperature
4	Tap water	5	Stored in dark at room temperature
5	Milli-Q water	5	Stored in dark at room temperature
6	Tap water	5	Stored in dark at room temperature
7	Bottled water	3	Exposed to sunlight and heat (30°C-35° C) for 1 month before analysis
8	Tap water	5	Stored in dark at room temperature

Samples 3 & 7 are from the same brand, collected from the same supermarket.

Inclusion criteria:

- Samples must be household or drinking water (bottled and tap water).
- Sample size must be according to specifications (5 liters for tap water and 3 liters for bottled water).
- Use a filter with a pore size of 0.45 micrometers, along with standard filtration procedures.

2.2 Study population

The study population of this thesis includes of all drinking water sources used within the administrative boundaries of the city of Nablus. This includes water distributed through the public network supplied by the Nablus Municipality or official authorities, also to bottled water of different brands available in the city's markets, and domestic or private wells water, if available.

Nablus was chosen due to its different drinking water sources and dense population, making it a suitable model for studying the existence of MP particles in water designed for human consumption. The study population does not include water designed for agricultural or industrial purposes, and areas outside the city limits, like surrounding villages, camps, and towns, were also excluded.

About 77% of the water supplied to Nablus Governorate is from springs and wells (about 15.5 million cubic meters).

2.3 Study sample

The study sample consisted of a group of drinking water samples collected from various sources within the city of Nablus. A number of sites were selected to represent the diversity of water sources used by residents. The sample included: samples from the city's public water network, samples of bottled water of various brands, collected from various supermarkets, and samples of domestic well water in areas that rely on these sources. The sample was selected randomly city of Nablus. The total number of samples was (8), and they were collected over a specific period of time (May and June 2025), taking into account the conditions for collecting and storing samples to ensure they are not contaminated, in accordance with the scientific standards adopted for MPs analysis.

2.4 Instruments of study and validation indicators

Sampling Tools: sampling tools used in this study.

- Sieve: Separates MPs by size, retaining particles larger than its pore size.
- Sieve base: Collects and stores MPs smaller than the sieve’s pore size.
- Laboratory spatula: Used to collect solid particles in powder or granule form.
- Beaker: Prepares solid and liquid samples in required quantities.
- Volumetric flask: Accurately measures and prepares solutions of precise volumes.
- 0.45 µm cellulose nitrate filter: Retains solid particles larger than 0.45 µm from liquids.
- Metallic tweezers: Handle materials to avoid contamination and allow precise gripping.
- Kitasato flask: Facilitates vacuum filtration by accelerating solid-liquid separation.
- Watch glass: Used to weigh solid particles on an analytical balance.

- Buchner funnel: Equipment for vacuum filtration.

- Glass containers: Store solid particles safely.

- Microscope slide: Holds the filter with the sample for microscopic observation.

- Glass Petri dishes: Store filtered samples or filtrates.

- Test tube: Measures and holds reagents for experiments.

Laboratory Equipment: laboratory tools used in this study**.**

- Analytical balance: Measures and weighs small quantities of materials with high precision.

- FTIR spectrometer: Identifies polymer types present in the sample by analyzing their infrared spectra.

- Vacuum pump: Creates pressure differences to facilitate the extraction of solids and liquids during filtration.

- Fluorescence microscope: Observes MPs by using specific lenses to detect their fluorescence properties.

- Oven: Provides controlled heat necessary for drying or processing MPs samples.

Laboratory Reagents

Analytical Reagents for readability

- Hydrogen peroxide (H□O□): Used in the digestion process to oxidize organic matter and to avoid false results.

- Methanol: Acts as a solvent for preparing the Nile Red staining solution for microplastics (MPs).

Filter Mass Analysis

Filter Mass Analysis (FMA) is a gravimetric approach based on weight measurements that is used to estimate the total amount of particulate matter retained on a filter after sample processing, including microplastics.

Filter Mass Analysis plays an important role in microplastic detection by providing an initial estimate of the total particulate load in a sample before the application of more advanced identification techniques.

Nile Red Dye Staining

The Nile Red staining was used to identify and visualize microplastic particles on filter membranes. After staining, the plastic particles exhibited a reddish hue that was visible to the naked eye, without the need for fluorescence microscopy. After show the visualization, we showed patterns similar to those observed before staining using fluorescence microscopy, and this supporting the correlation of the results.

2.5 Analysis plan

The analysis plan for this study will based on quantitative and qualitative analysis of collected water samples, to detect the presence of MPs particles and identifying their types and concentrations in different drinking water sources within the city of Nablus. The analysis was carried out in several stages. At first, we prepared water samples using microfiltration to separate solid particles. Then followed by chemical treatment with oxidizing solutions, hydrogen peroxide, to remove organic matter. The resulting sediment will then be examined using an optical microscope to determine the size and shape of the particles. Further analysis will be performed using a Fourier Transform Infrared (FTIR) spectrometer to determine the chemical composition of the plastic.

2.6 Study procedures

According to (Zea Cobos et al., 2024) the following Procedures were adopted:

Procedures Phases

2.6.1 Phase 1: MPs sampling

Water samples used to analyze MPs intended for human consumption are collected from a variety of sources, and collection methodologies vary depending on the source. The following are the most prominent sampling methods, which were identified after a systematic analysis of several studies to select the most appropriate techniques for the target environment:

- Sampling from Drinking Water Systems

Five liters of water should be filtered through a kitasato flask fitted with a 0.45 µm cellulose nitrate filter, and the process repeated at each sampling point. To prevent contamination, all containers and filters were pre-cleaned, and blank control samples were analyzed alongside the actual samples to verify the absence of background microplastics. The analysis of the blank control (distilled water) showed little to no detectable microplastic particles, confirming that the laboratory procedures and filtration system were properly controlled and that the particles found in the environmental samples genuinely reflected the water samples.

- Sampling from Bottled Water

When processing water samples in the laboratory, it is preferable to filter the entire contents of the bottle directly without transferring it to another container. Use bottles of approximately 3 L of the same brand to ensure uniformity. To speed up the filtration process, it is recommended to use vacuum filtration equipment, along with a Buchner funnel and a 0.45 µm membrane nitrate filter.

- Tap water samples were collected from the university and home, and collected in clean glass containers to avoid contamination and mixing with other MP particles.
- Samples were stored away from sunlight and high temperatures.

2.6.2 Phase 2: Sample Processing

- After filtration, carefully rinse the filter with 250 mL of distilled water in a beaker to remove any remaining impurities.
- To prevent false-positive results, carry out oxidative digestion by adding 20 mL of 30% concentrated hydrogen peroxide (H_2O_2) to the reconstituted sample, and allow the reaction to proceed for at least 5 minutes.
- The sample should then be filtered under vacuum using a Buchner funnel equipped with a 0.45 µm cellulose nitrate membrane filter.
- Carefully lift the filter from the funnel using metal tweezers and place it in covered, sterilized Petri dishes for storage.
- Place the filter in an oven set at 30 °C for 24 hours to ensure it is completely dry.

- Prepare the Nile Red reagent at a concentration of 1 µg/mL by dissolving the dye in 50 mL of methanol using a volumetric flask.

- Using a glass atomizer covered with aluminum foil to prevent fluorescence loss, equally spray the Nile Red solution across the filter surface.

- Dry the filter after staining in an oven at 30 °C for 30 minutes

2.6.3 Phase 3: Fluorescence Microscopy Analysis

We followed a standard operating procedures during fluorescence microscopy analysis, at first, setup the instrument to image acquisition using NIS-Elements BR 5.11 FLUO software. Then dried sections of the filters were placed in dedicated storage chambers to allow accurate observation, identification, and quantification of microplastic particles.

For accurate observation, the filter was placed with its surface facing the microscope objective.

2.6.4 Phase 4: FTIR Microscopy Analysis

After labeling of the filters and preliminary identification of suspected polymeric particles, the selected particles were transferred to a Fourier transform infrared (FTIR) spectrometer for spectral analysis to estimate their chemical composition.

The methodological workflow is summarized in a flowchart, as explained in Figure 3.

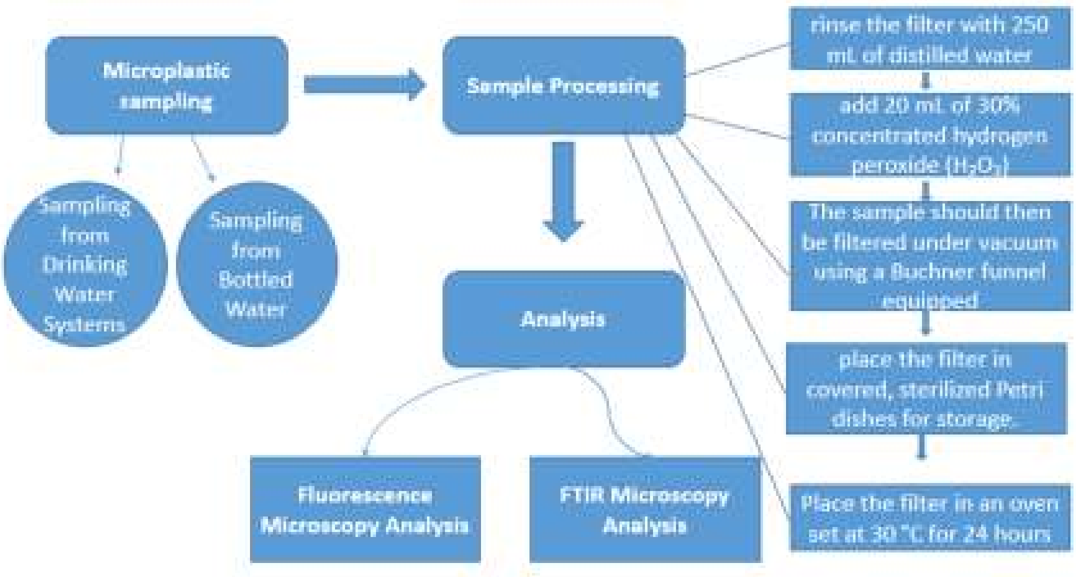

Figure 3: *Flowcharts for methodology*

Statistically, the data will be entered into a program (Excel) to collect and arrange the data, then analyze it statistically from mean to median to standard deviation and draw appropriate charts. It is also used to analyze the data resulting from the FTIR device and compare it with a library reference specific to a specific type of plastic to determine the type of MPs in the sample. And descriptive analysis will be used to calculate frequencies, percentages, and averages of MPs concentrations in each type of water source.

Chapter Three
Results

3.1 Filter Mass Analysis

Measurement of the particle mass retained on a filter after filtration and drying provides an estimate of the total concentration of solid material present, including microplastics. These measurements support the creation of baseline data and facilitate normalization of results, enabling meaningful comparisons across different samples, locations, and experimental conditions. Also, this process acts as a quality control step by verifying that sample treatment, filtration, and drying procedures were performed consistently and without pollution. When combined with spectroscopic or chemical analyses, it supports a more integrated assessment of microplastic pollution and provides suitable information for environmental monitoring, pollution management, and research on plastic-related impacts.

Table 2*: Presents the filter mass before and after the filtration process*

Sample ID	Sample type	Filter Mass Before(g)	Filter Mass after(g)	Δ Mass (g)	concentration(g/L)
1	**Bottled water**	**0.07682**	**0.07691**	**9×10^{-5}**	**3×10^{-5}**
2	**Bottled water**	**0.07682**	**0.07693**	**1.1×10^{-4}**	**3.67×10^{-5}**
3	**Bottled water**	**0.07682**	**0.07690**	**8×10^{-5}**	**2.67×10^{-5}**
4	**Tap water**	**0.07682**	**0.07816**	**1.34×10^{-3}**	**4.47×10^{-4}**
5	**Milli-Q water**	**0.07682**	**0.07691**	**9×10^{-5}**	**3×10^{-5}**
6	**Tap water**	**0.07682**	**0.07787**	**1.05×10^{-3}**	**3.5×10^{-4}**
7	**Bottled water**	**0.07682**	**0.07758**	**7.6×10^{-4}**	**2.53×10^{-4}**
8	**Tap water**	**0.07682**	**0.07704**	**2.2×10^{-4}**	**7.33×10^{-5}**

The increase in mass indicates the retention of particulate matter, which represents MPs.

Performing this type of analysis provides evidence of the presence of MPs if the sample is prepared according to scientific principles as described in our method. Rinse the filter with 250 mL of distilled water in a beaker to remove any remaining impurities and carry out oxidative digestion by adding 20 mL of 30% concentrated hydrogen peroxide (H_2O_2) to the reconstituted sample, to prevent false-positive results.

From Table (2) Sample 3 and Sample 7 are bottled water samples from the same brand. However, Sample 7 was exposed to heat and sunlight for a period of time. Therefore, we noticed that the filter mass after filtration was significantly different from Sample 3. This explains the presence of additional MPs in it as a result of the plastic decomposing due to heat and sunlight. This explains our third hypothesis.

Figures 4 & 5 show some statistics of concentration in µg/L.

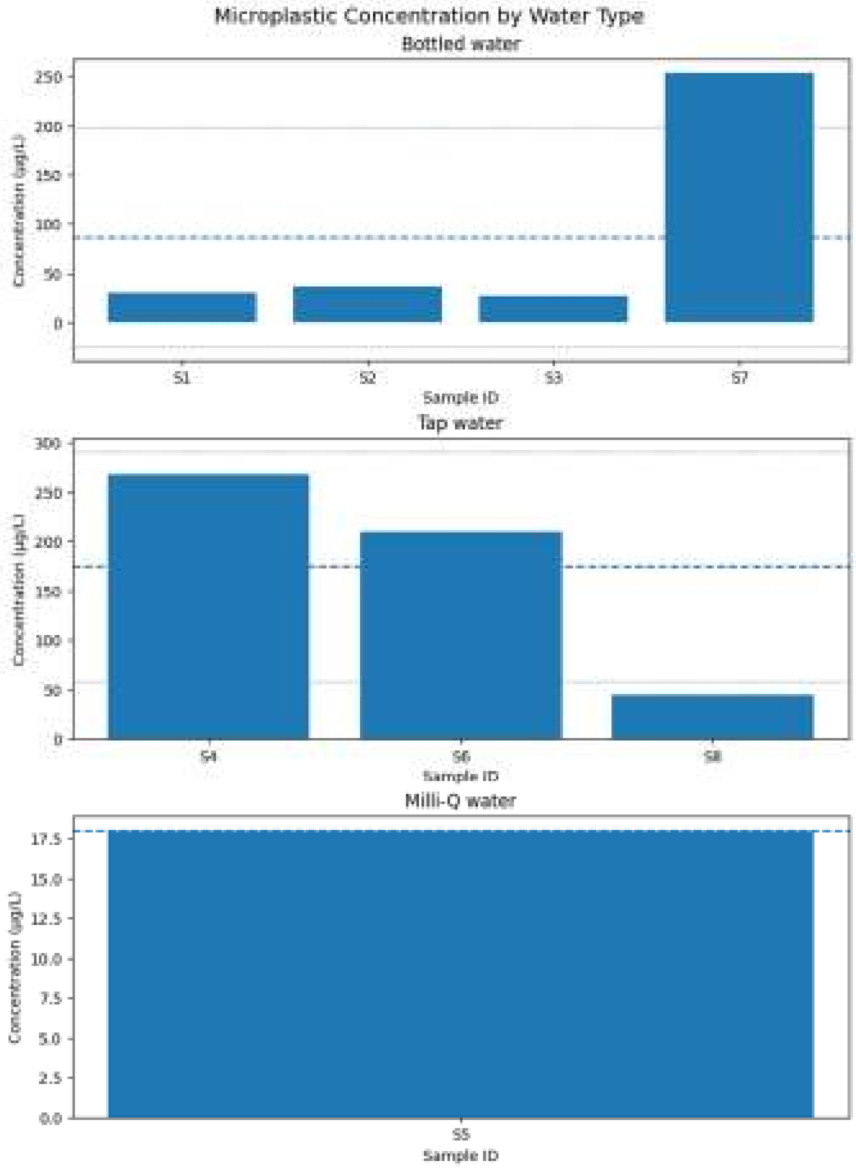

Figure 4: *Histogram of Concentration of microplastics in micrograms per liter*

This figure 4 presents microplastic concentrations separately for each water type. Tap water samples showed the highest concentrations overall, while bottled water samples were generally lower except for one outlier sample, S7, which was exposed to heat and sunlight. The Milli-Q sample showed minimal concentration, indicating low background contamination.

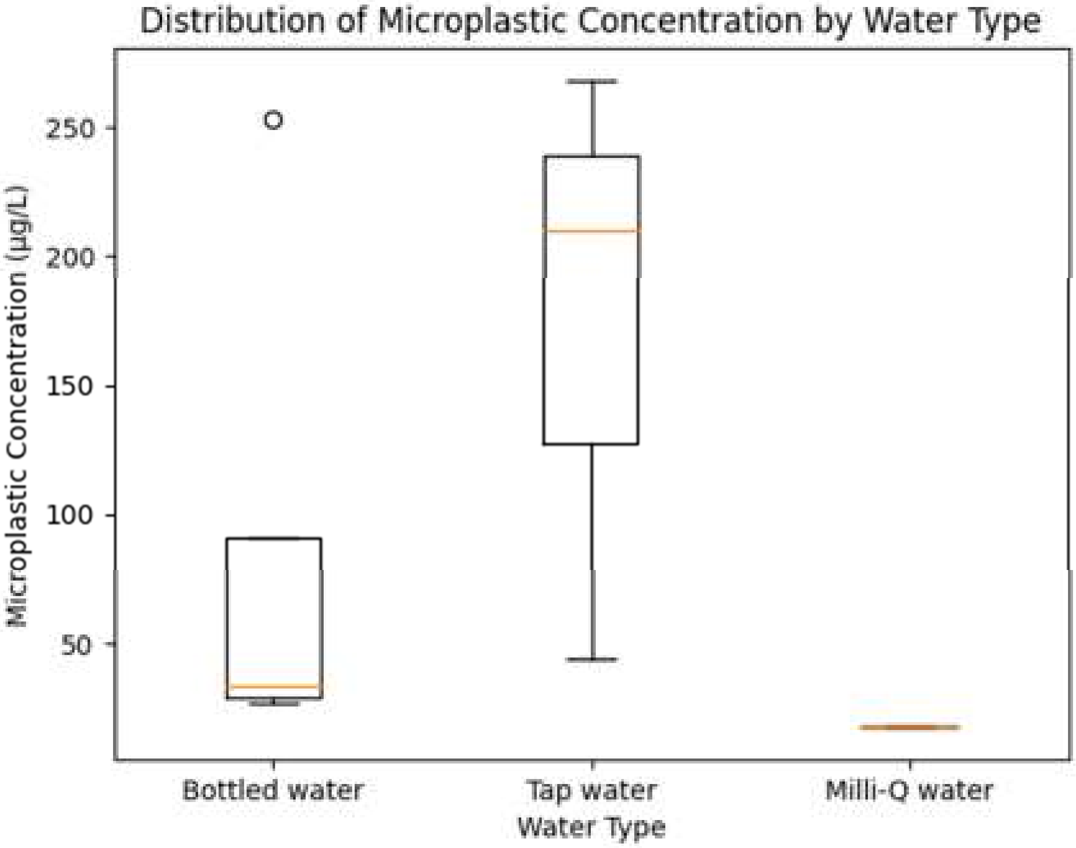

Figure 5*: Boxplot of Concentration of microplastics in micrograms per liter*

The box plot shows that tap water samples have higher concentrations and a wider distribution compared to bottled water samples. Bottled water samples generally show lower concentrations, except for one outlier sample (sample 7), which was exposed to heat and sunlight. The Milli-Q sample shows very low concentration, indicating minimal background contamination.

In the case of tap water, the second hypothesis was not supported. This results may be attributed to many practical limitations facing during the study, including the inability to collect tap water samples using glass containers, which may have affect on the analytical results. Also, restricted access to water wells during the study period and the limited of available of suitable equipment further constrained the sampling and analysis process.

3.2 FTIR Analysis

By applying the FTIR spectra to the retained particles, we verified their polymeric composition. The resulting spectra were compared with reference spectra of common polymers, like PET, PE, PP, PS, PA, PVC, and PES.

We analyze each filter sample at different locations using FTIR spectroscopy to verify polymer identity. We compared the observed absorbance peaks with reference spectra of known polymers to support accurate identification. We obtained the reference spectra of known polymers from the Hummel Polymer Spectral Library (Hummel, 2002). Then these readings were taken and analyzed manually due to the lack of a library of plastic and polymer types in the device's library.

For sample No. 1, for example:

This FTIR analysis was performed on the provided sample 1. The spectrum shows a strong carbonyl band (~1707 cm^{-1}), aromatic ring vibrations (~1529–1445 cm^{-1}), ester C–O–C bands (~1240–1100 cm^{-1}), and out-of-plane aromatic peaks (~870–730 cm^{-1}). These features are characteristic of Polyethylene Terephthalate (PET) as shown in Figure 6 and Table 3:

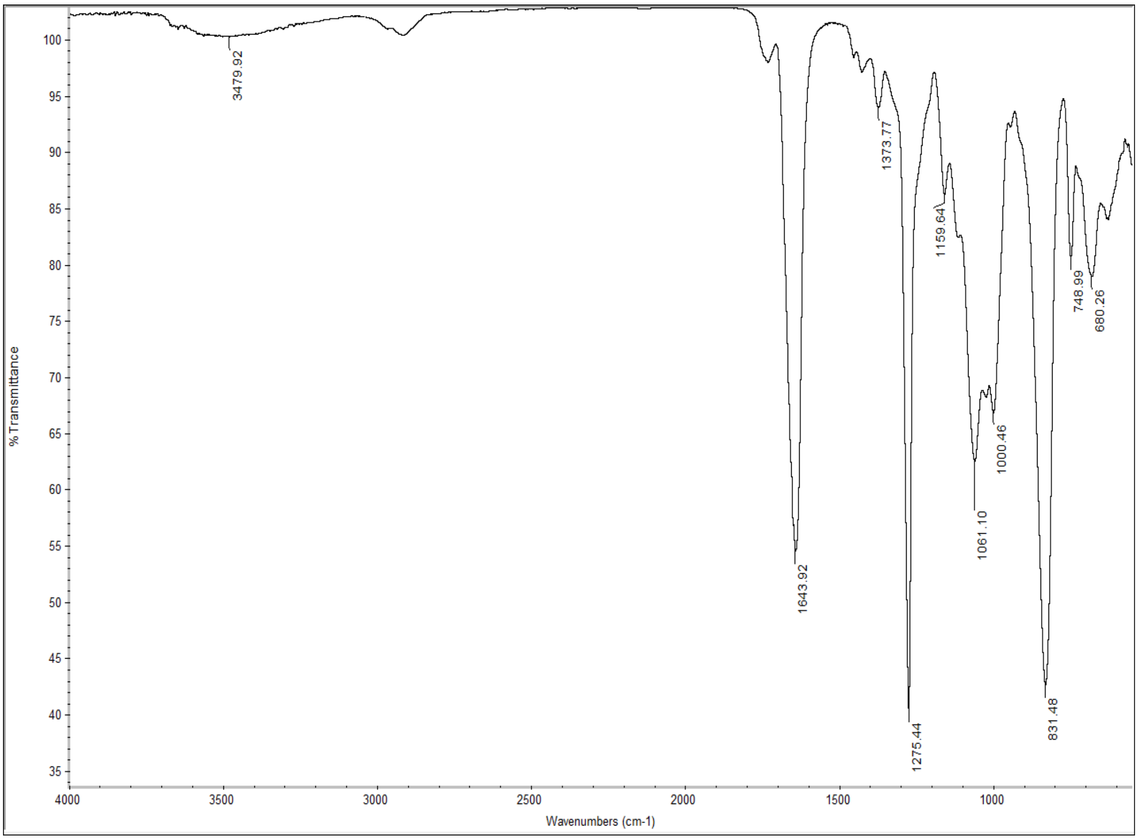

Figure 6: *FTIR spectrum of Sample 1 showing observed peaks.*

The peak readings from the device analysis were compared with the PET reference readings.

Table 3: *Reference vs Observed PET Peaks for sample 1*

Reference PET Peak (cm^{-1})	Observed Nearest (cm^{-1})	Δ (Observed - Ref)
1715	1714.9	-0.11
1600	1600.1	0.14
1505	1505.2	0.17
1409	1409.2	0.23
1341	1340.8	-0.23
1240	1240.0	0.0
1100	1100.2	0.19
1017	1016.8	-0.22
872	872.1	0.15
725	725.1	0.1

The FTIR spectrum of Sample 1 matches closely with literature spectra of PET (Polyethylene Terephthalate). Minor Δ shifts are expected due to ATR, crystallinity, and particle orientation.

For Sample No.4:

This FTIR analysis was performed on the provided sample. The spectrum shows strong aliphatic C–H stretches (~2918 and 2849 cm^{-1}), CH_2 bending (~1470 cm^{-1}), CH_3 bending (~1377 cm^{-1}), and CH_2 rocking (~730–720 cm^{-1}). These features are characteristic of Polyethylene (PE). As shown in Figure B 4 in Appendix B and Table 4:

Table 4: *Presents the peak readings from the device analysis for sample 4*

Reference PE Peak (cm^{-1})	Observed Nearest (cm^{-1})	Δ (Observed - Ref)
2918	2917.8	-0.23
2849	2848.8	-0.17
1472	1471.9	-0.1
1463	1463.2	0.22
730	729.9	-0.08
720	719.8	-0.2

The FTIR spectrum of Sample 4 matches closely with literature spectra of Polyethylene (PE). The characteristic aliphatic C–H stretches (~2918 and 2849 cm^{-1}), CH_2 bending (~1470 cm^{-1}), and CH_2 rocking (~730–720 cm^{-1}) confirm this identification. Minor Δ shifts are expected due to ATR, crystallinity, and particle orientation.

For the FTIR spectrum of other samples showing observed peaks, show it in Appendix B.

Table 5: *Summary of Identified MPs Types.*

Sample	Identified Polymer
Sample 1	PET
Sample 2	PET
Sample 3	PET
Sample 4	PE
Sample 5	PE
Sample 6	PE, PET
Sample 7	PET
Sample 8	PE

Through this analysis, it was observed that all bottled water samples contained PET, while tap water samples contained PE. Confirming the validity of the analysis is that PET is the primary material used in the manufacture of plastic water bottles. PE is also a key material in the manufacture of water pipes and household connections, which explains its presence in the tap water samples. For Sample 6, the presence of PE and PET was observed. This is a tap water sample collected by plastic bottles, unlike the other tap water samples. This indicates the presence of PET in the analysis.

3.3 Microscopic Analysis

Microscopic analysis was performed on the filtered samples. Figure 8 and Figure A1 in Appendix A illustrate representative MP particles observed under the microscope. The detected particles varied in size, shape, and color (e.g., transparent, orange, blue).

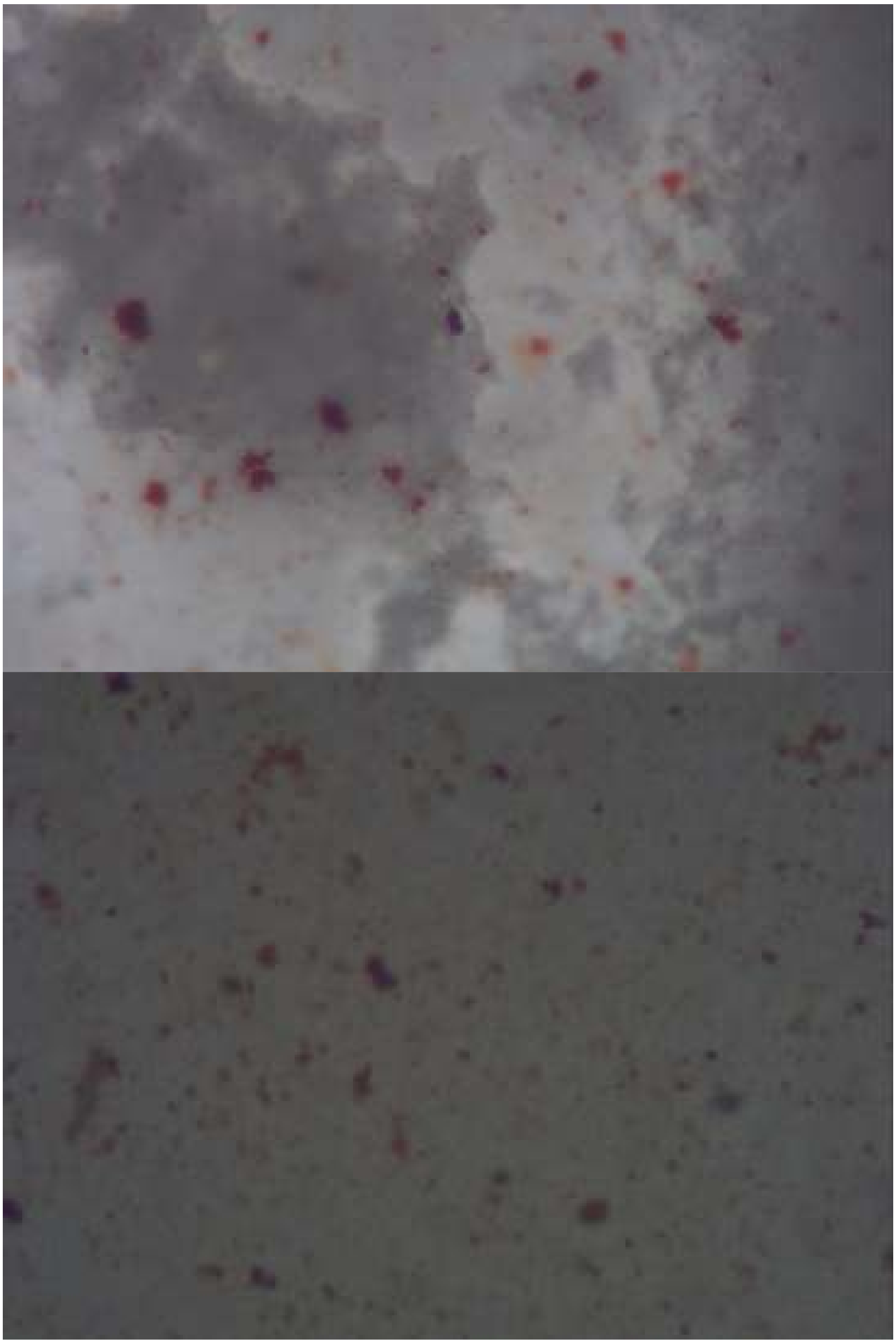

Figure 7*: Microscopic image of MPs particle for sample 4*

Figure 7 shows the resulting microscope image at 400x magnification. This image was taken from an analysis of a sample of water from an old, partially worn plastic tap. Large quantities of MPs appeared in various shapes and colors. Several shapes appeared, including spherical and irregular shapes, threads, fibers, and other forms. They also appeared in various colors, including orange, blue, and green. This is due to the dyes on the plastic. It is difficult to count the MPs here, as they are on a very small portion of the filter, and this method does not provide an accurate count.

Figure A1 shows a microscope image of a sample of bottled water of a particular brand that is popular in the country. The image also shows the presence of a number of MPs of different shapes and sizes.

The diameters of the majority of particles (about 75% of particles) range between 1 and 10 micrometers, and there are very few particles that reach 200 micrometers.

For the other resulting microscopic image, show it in Appendix A.

3.4 Nile Red Dye Staining Analysis

The Nile Red staining was used to identify and visualize microplastic particles on filter membranes. After staining, the plastic particles exhibited a reddish hue that was visible to the naked eye, without the need for fluorescence microscopy. After show the visualization, we showed patterns similar to those observed before staining using fluorescence microscopy, and this supporting the correlation of the results.

The results shows strong binding of Nile Red dye to hydrophobic polymers, showing its suitability as a simple and cost-effective approach for detecting microplastics in environmental samples without depend on advanced microscopic techniques. See the figures 8&9 below.

By integrating filter mass measurements, microscopic images, Nile Red dye staining and Fourier transform infrared (FTIR) spectroscopy, the results indicate the presence of MP particles of various sizes and shapes in drinking water samples, both bottled and tap water. The identified polymers include polyethylene terephthalate (PET) and polyethylene terephthalate (PE).

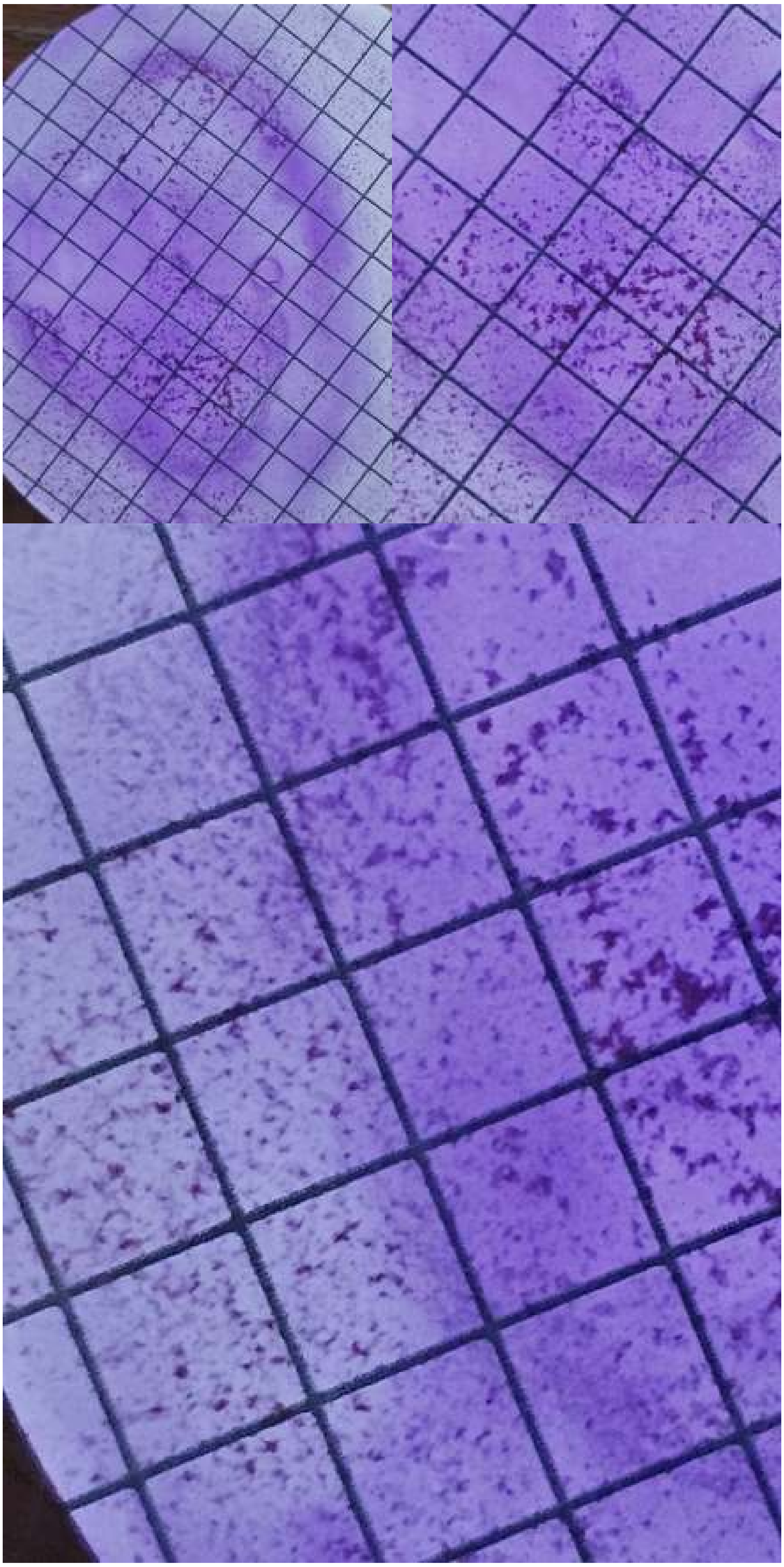

Figure 8: *Filter membrane after Nile Red dye staining for sample 6*

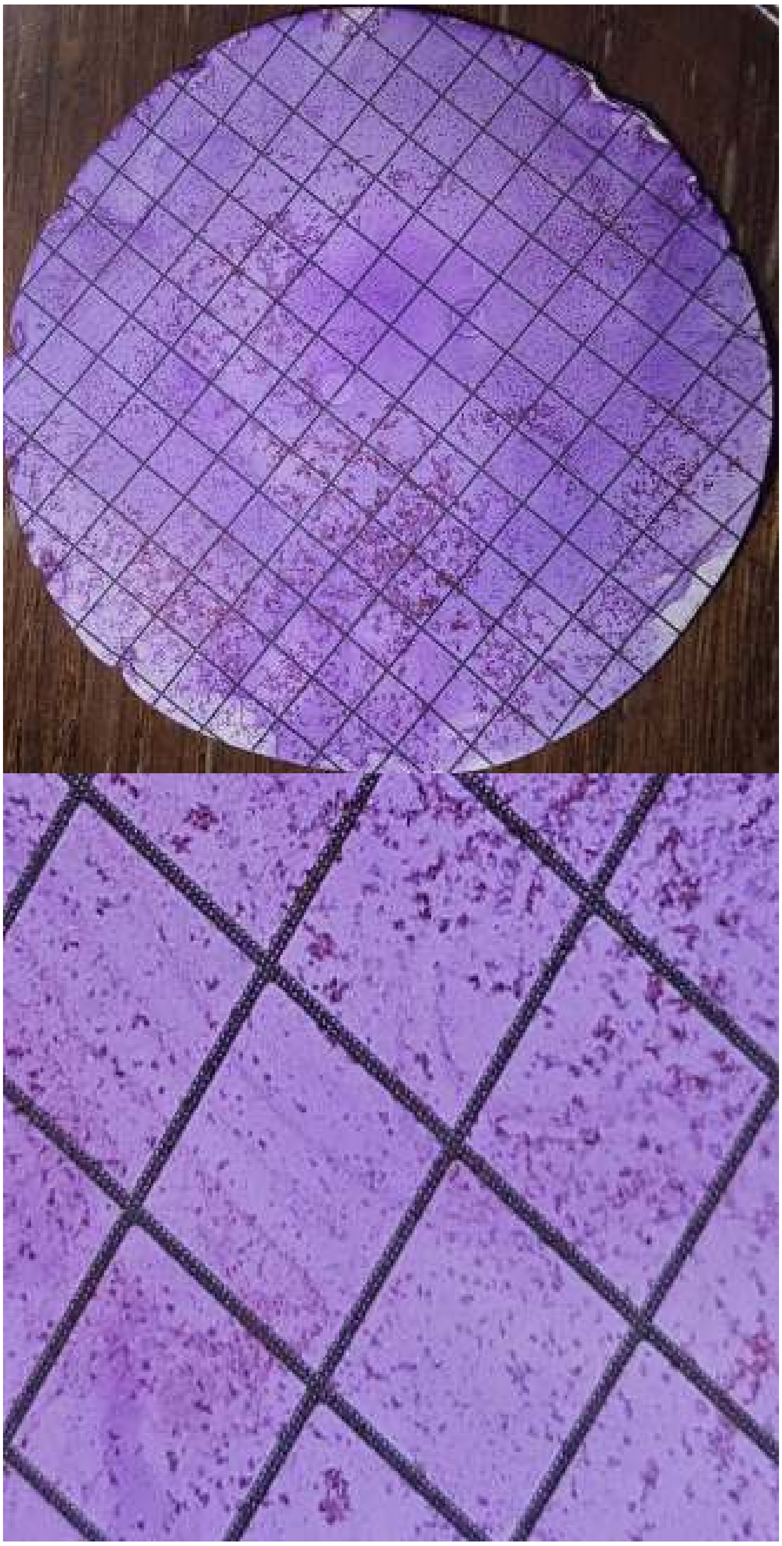

Figure 9: *Filter membrane after Nile Red dye staining for sample 7*

Chapter Four
Discussions and Conclusions

4.1 Overview of Findings

After conducting filter mass analysis before and after, microscope image analysis, Nile red dye staining, and FTIR analysis of the eight samples, and integrating the results from the four analyses, it was found that MP particles were present in all samples, but in varying proportions and quantities. The increased filter mass after filtration and the use of techniques to minimize the presence of particles other than MPs were found to be MPs after monitoring them via microscope images and FTIR analysis.

All bottled water samples contained relatively small amounts of MP particles, except Sample 7, due to its exposure to heat and sunlight for a period of time. PET was also found in the bottled water samples, unlike the tap water samples, which contained PE. The tap water samples contained large amounts of MP particles. This is because sample (4) was taken from an old, nearly worn plastic tap. This observation corresponds to the relatively high number of microplastic particles detected both in the microscopic images and on the filter surface. Similarly, in Sample 6, we observed a large amount of microplastics relative to the other samples, which may be attributable to its collection in a plastic bottle. This is consistent with the detection of PET beside PE during FTIR analysis. Also, sample (5) which analysis of purified Milli-Q water, also contained a small number of microplastic particles, likely emerge from contact with plastic components during storage or release from the plastic-based device used.

At now days, until now no regulatory standards or guideline limits have been created for microplastic particles in drinking water.

4.2 Potential Sources of MPs

The detection and existence of PET and PE give an evidence possible pollution sources, including bottled water containers, plastic pipes, and common household products. Also, environmental pollution during processing, transportation, and storage may have contributed to the existence of these polymers.

This pattern was showed in bottled water samples, where PET was detected, consistent with its common use as the primary material in plastic water bottles. Also, PE is commonly used in plastic pipes and household products, that was identified in tap water samples.

4.3 Implications for Human Health and Environment

The ingestion of MPs through drinking water increases concerns about human health. Although the toxicological effects are still under investigation, studies show possible risks including inflammation, oxidative stress, and accumulation of toxic additives or adsorbed pollutants (Singh et al., 2022). From an environmental aspect, MPs may also show wide pollution in water sources.

4.4 Strengths and Limitations of the Study

One of the main strengths of this study is the use of a combined methodological approach, including gravimetric analysis, microscopy, and FTIR spectroscopy, which increase the reliability of microplastic detection. However, the study has many limitations. One of them, Particles smaller than the detection limit of the microscope could not be identified, also, partial overlap of spectral features between different polymers may affect FTIR-based identification. In addition, accurate counting of MPs particles using microscopic images still challenging because of the small particle size relative to the filter surface limits precise quantification.

4.5 Conclusions

- MPs were detected in all drinking water samples analyzed.

- Tap water showed higher variability and concentrations compared to bottled water.

- PET and PE were the dominant polymers identified using FTIR.

- Heat and sunlight may increase MPs release from plastic bottles.

- The applied methodology proved effective for MPs detection in drinking water.

4.6 Recommendations

To improve polymer identification in future research we must incorporate Raman spectroscopy beside FTIR, apply advanced imaging techniques to better characterize smaller particles, and expand sampling to include different drinking water sources such as tap, bottled, and well water. Also, we recommend standardization of methodologies for better comparability across studies.

From the results we showed I suggest the need for comprehensive strategies to reduce sources of microplastic pollution, particularly during packaging, storage, and distribution processes. They also show the importance of depending more advanced and efficient filtration and treatment technologies in water purification facilities. In addition, further research is needed to improve understanding of the potential long-term health effects linked with microplastic exposure. Finally, increasing public awareness of proper plastic use and waste management may contribute to reducing environmental pollution and linked public health risks.

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Appendices

Appendix A

Microscopic Images

Figure A 1*: Microscopic image for sample 1*

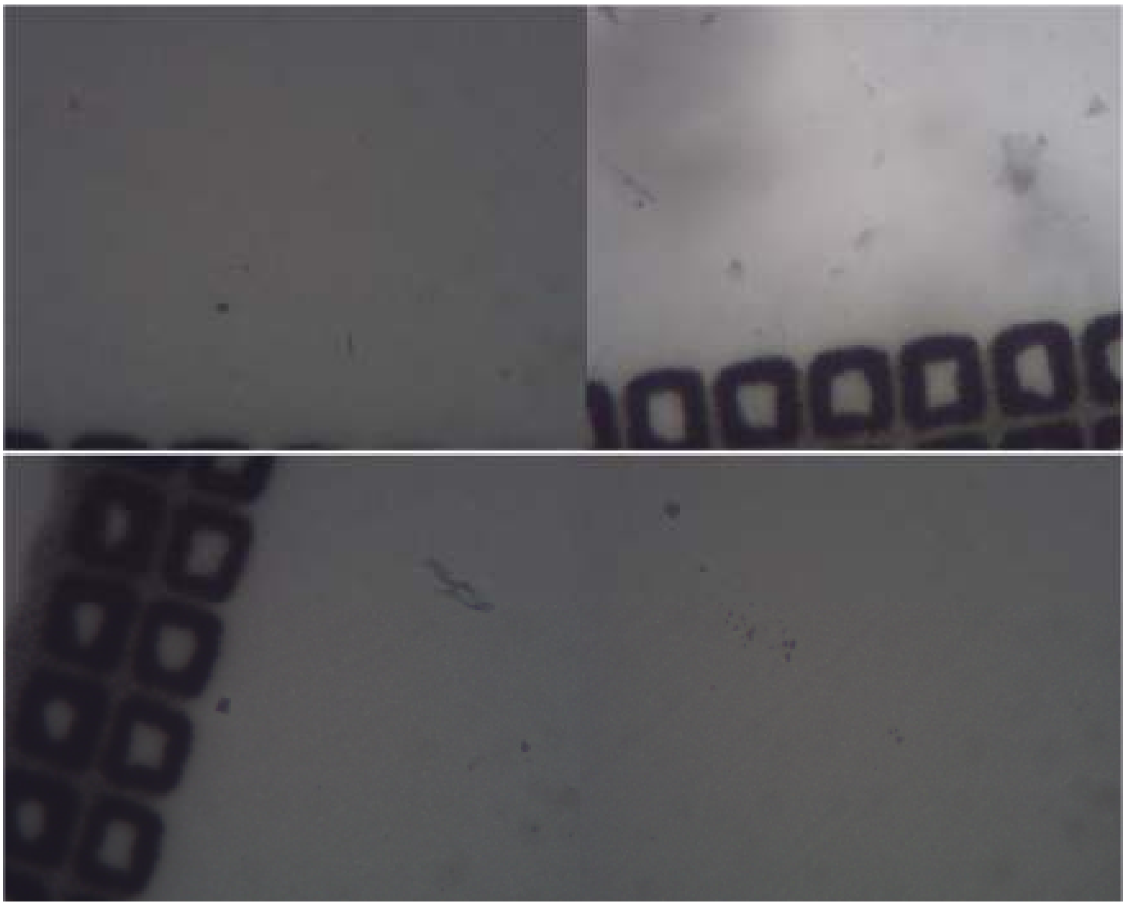

Figure A 2: *Microscopic image for sample 2*

Figure A 3: *Microscopic image for sample 3*

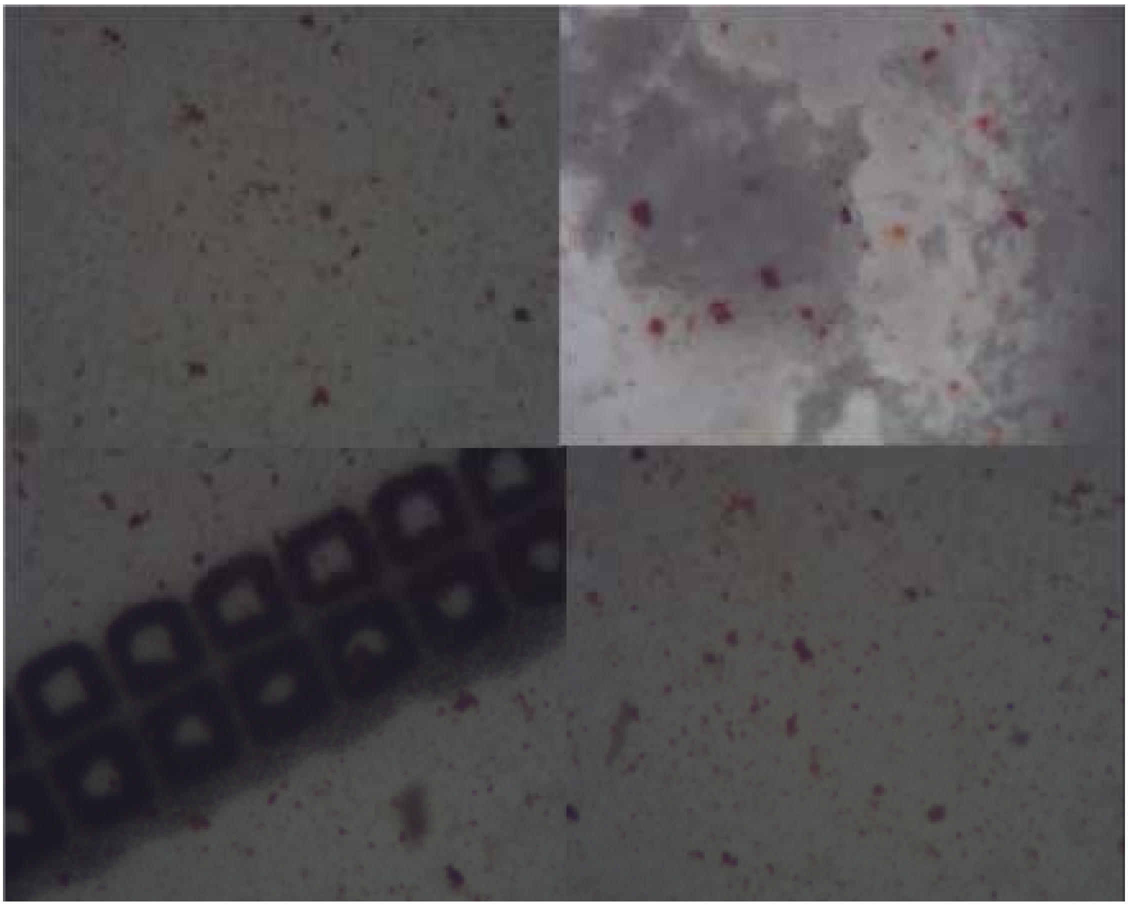

Figure A 4: *Microscopic image for sample 4*

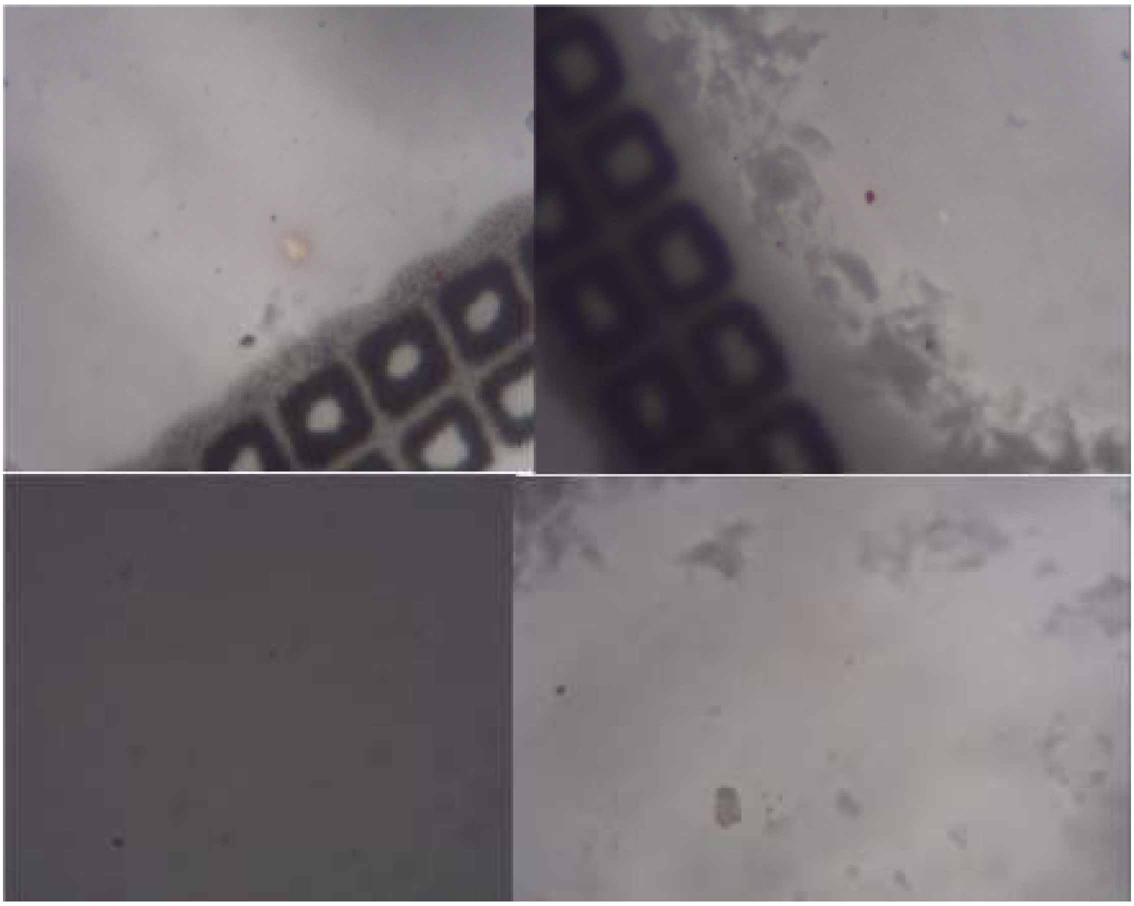

Figure A 5: *Microscopic image for sample 5*

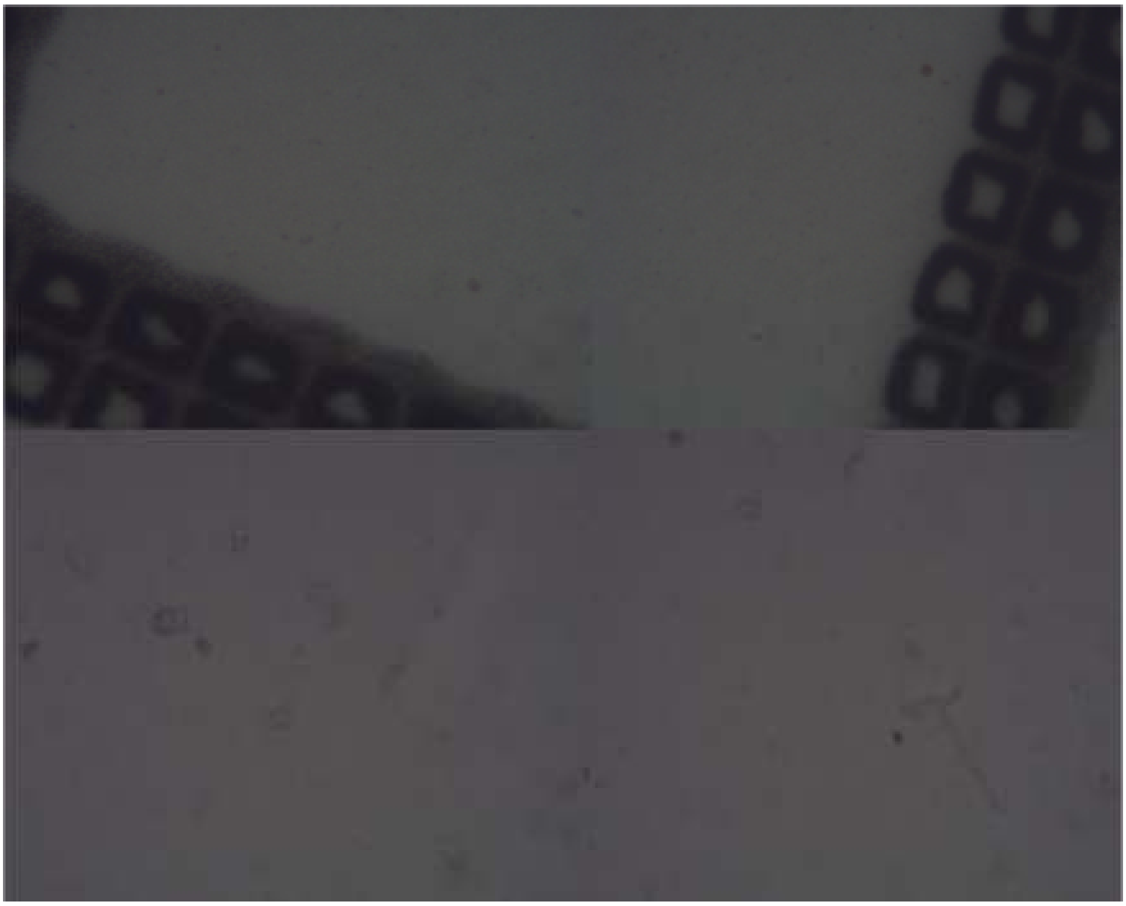

Figure A 6 : *Microscopic image for sample 6*

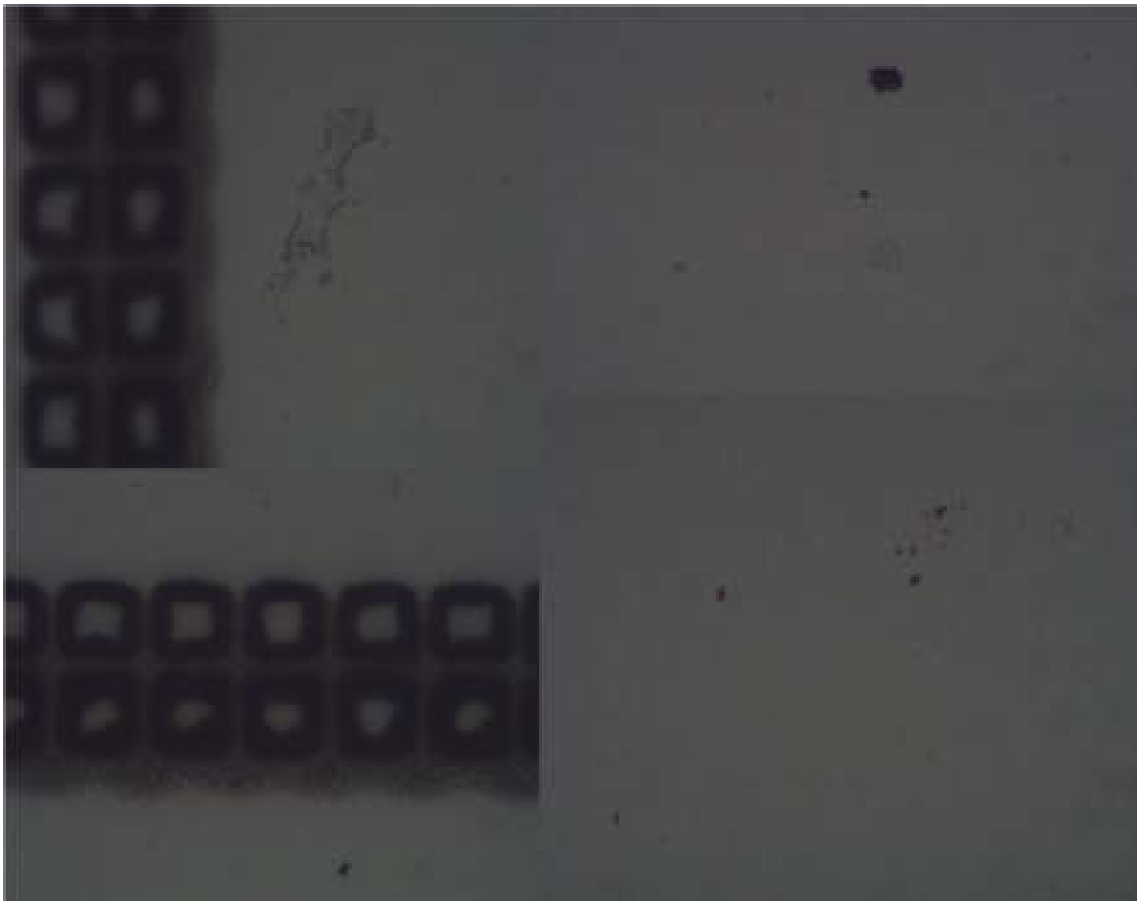

Figure A 7 : *Microscopic image for sample 7*

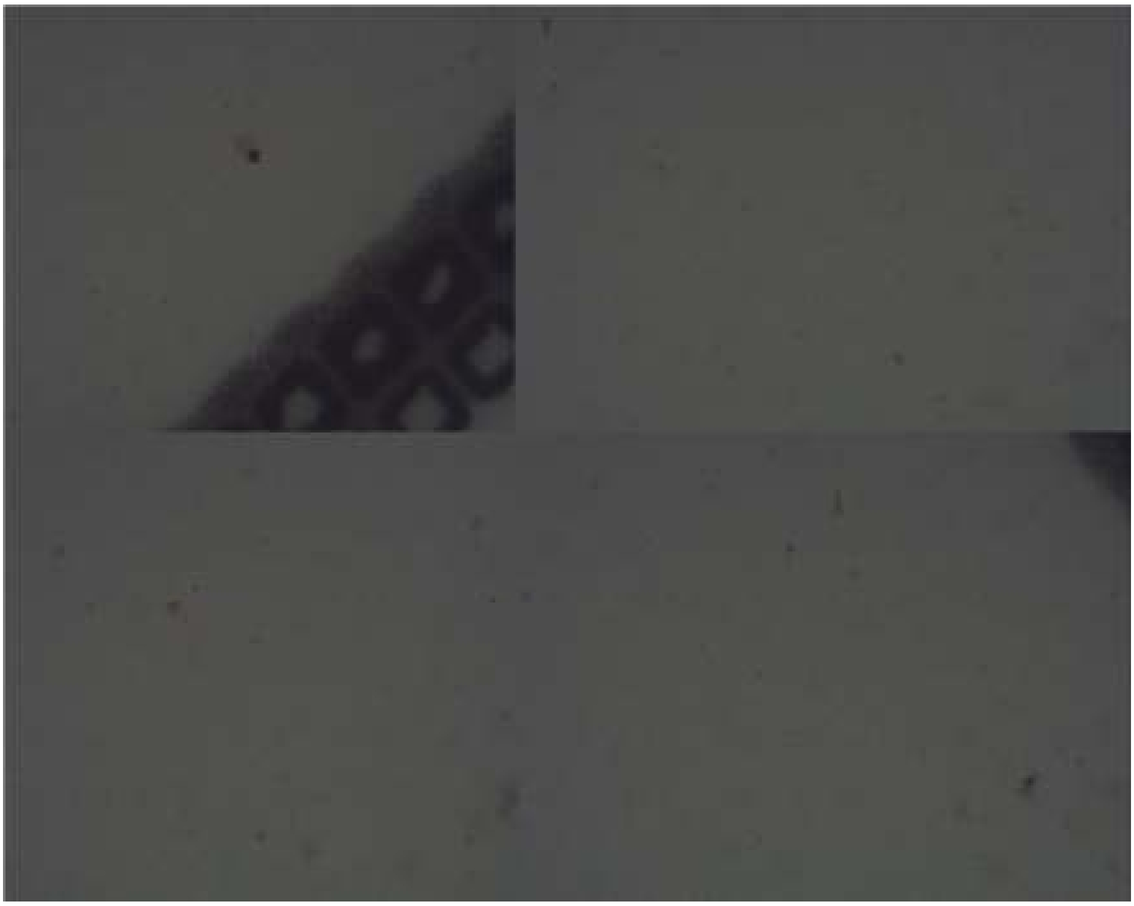

Figure A 8 : *Microscopic image for sample 8*

Appendix B

FTIR Analyses

Table B 1: *Reference PET Peak vs observed*

Reference PET Peak (cm^{-1})	Observed Nearest (cm^{-1})	Δ (Observed - Ref)
1715	1714.9	-0.11
1600	1600.1	0.14
1505	1505.2	0.17
1409	1409.2	0.23
1341	1340.8	-0.23
1240	1240.0	0.0
1100	1100.2	0.19
1017	1016.8	-0.22
872	872.1	0.15
725	725.1	0.1

Table B 2: *Reference PE Peak vs observed*

Reference PE Peak (cm^{-1})	Observed Nearest (cm^{-1})	Δ (Observed - Ref)
2918	2917.8	-0.23
2849	2848.8	-0.17
1472	1471.9	-0.1
1463	1463.2	0.22
730	729.9	-0.08
720	719.8	-0.2

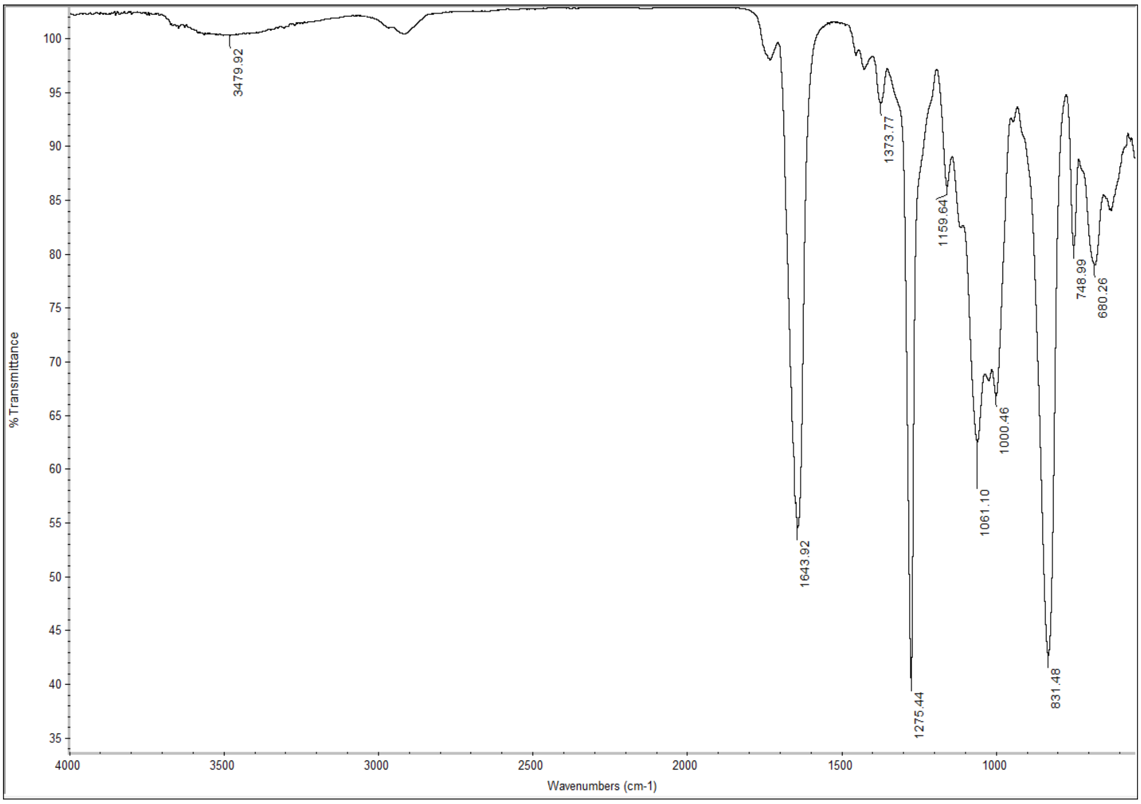

Figure B 1 : *FTIR spectrum of Sample 1 with observed peaks.*

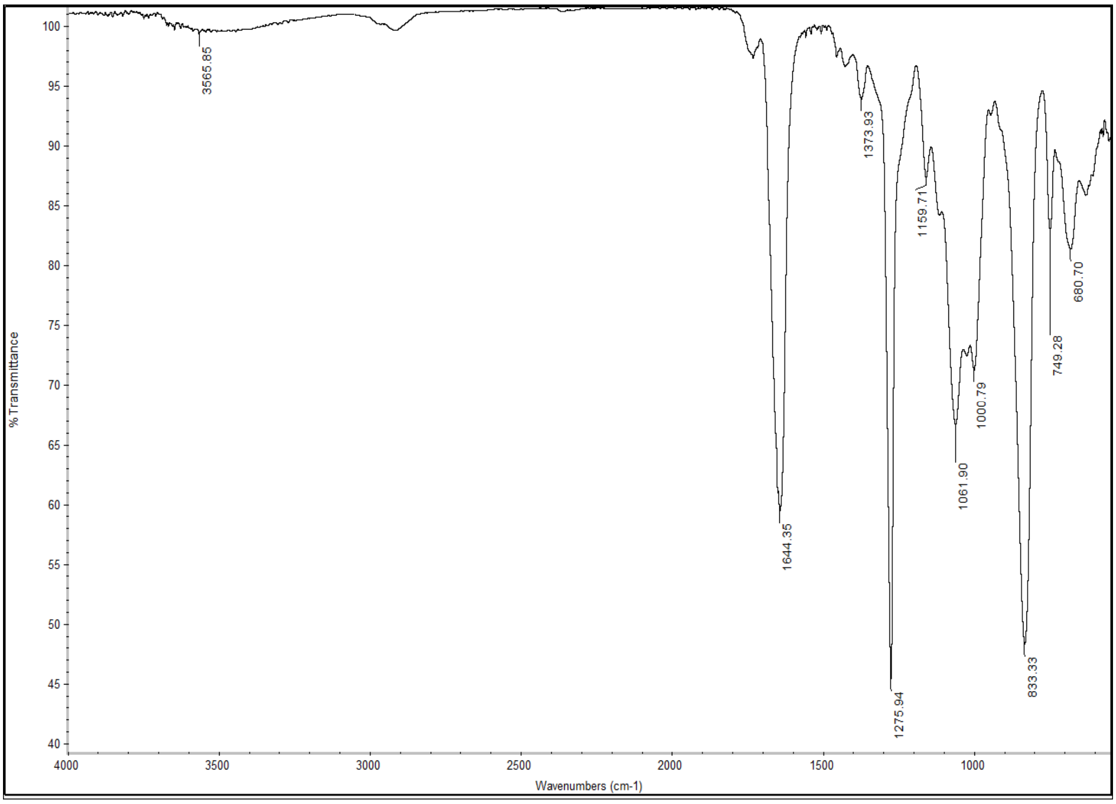

Figure B 2 : *FTIR spectrum of Sample 2 with observed peaks.*

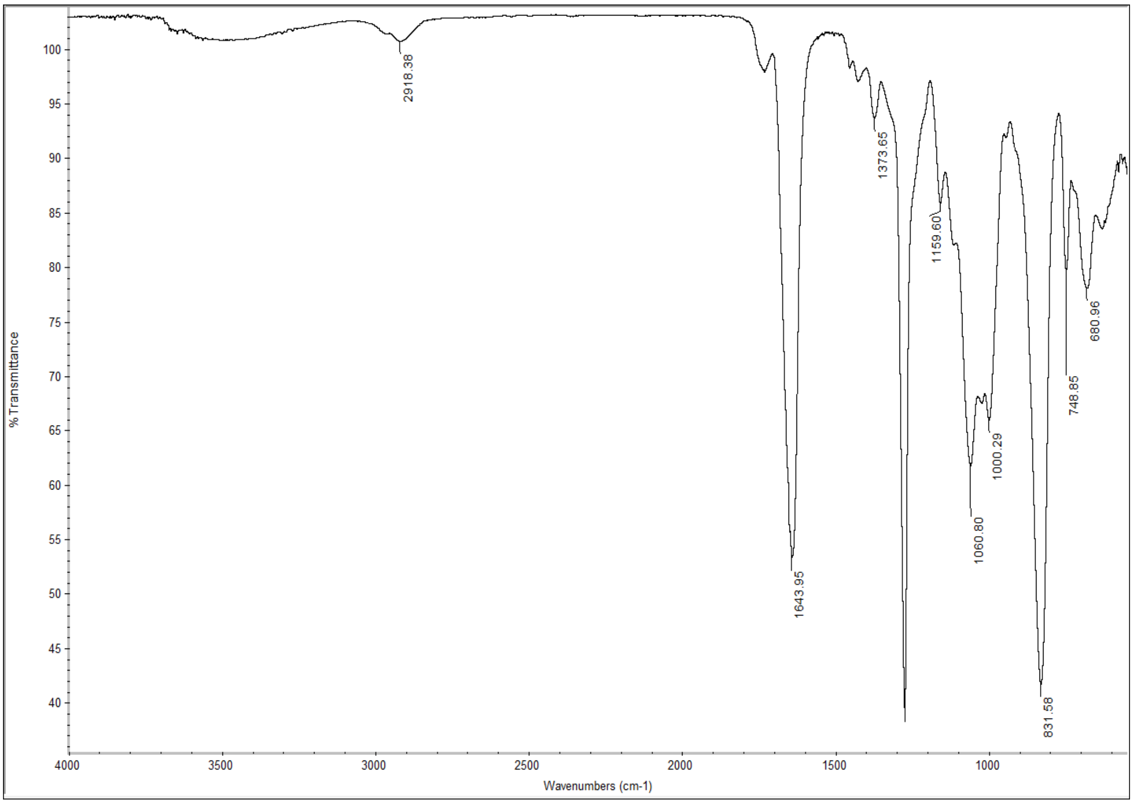

Figure B 3 : *FTIR spectrum of Sample 3 with observed peaks.*

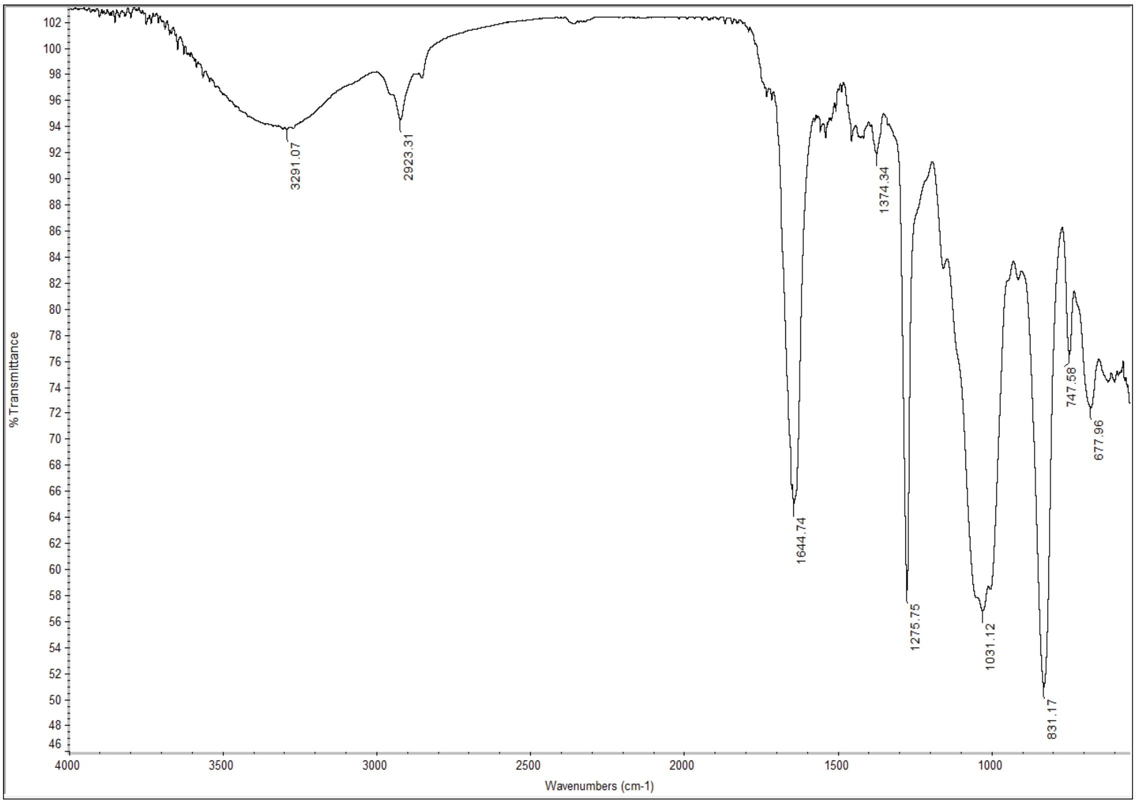

Figure B 4 : *FTIR spectrum of Sample 4 with observed peaks.*

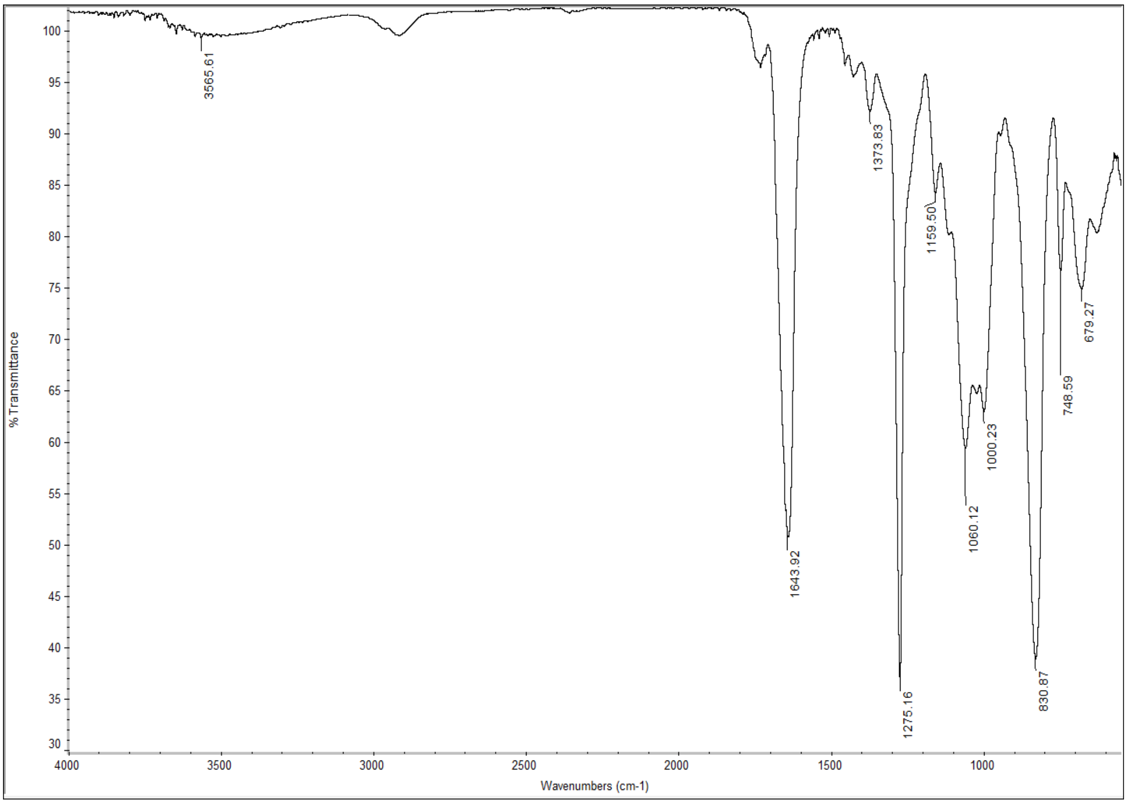

Figure B 5 : *FTIR spectrum of Sample 5 with observed peaks.*

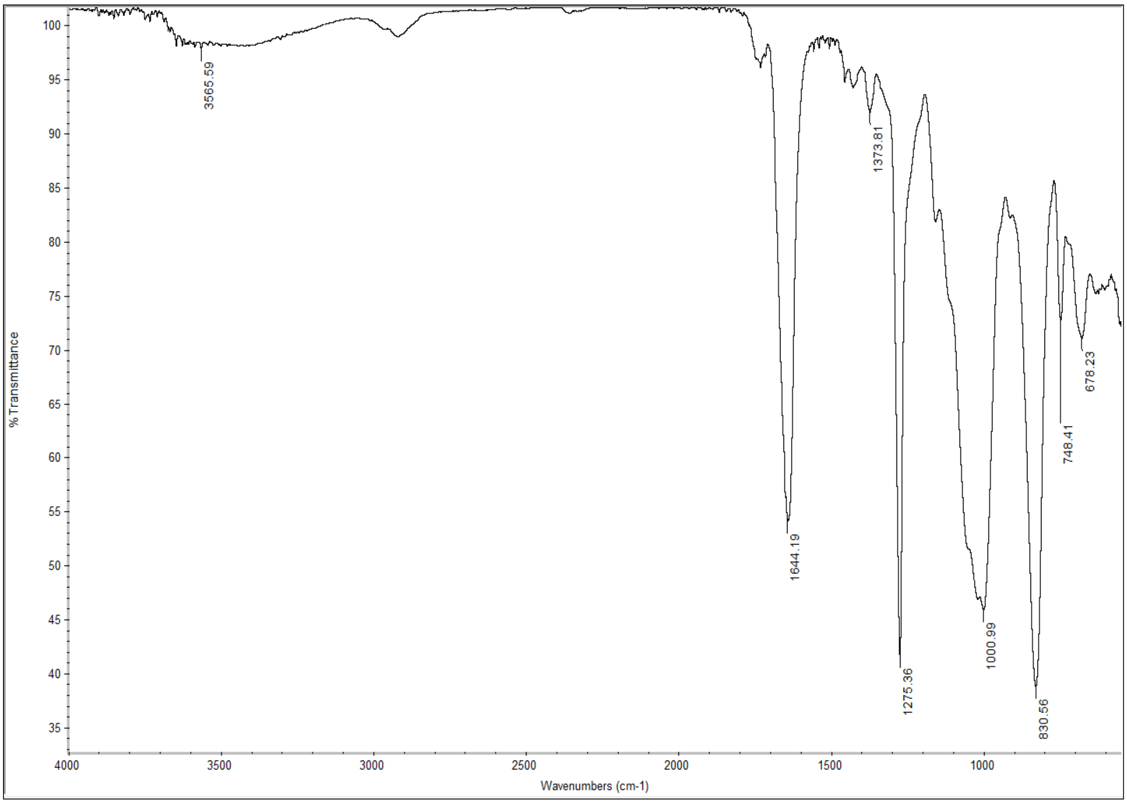

Figure B 6 : *FTIR spectrum of Sample 6 with observed peaks.*

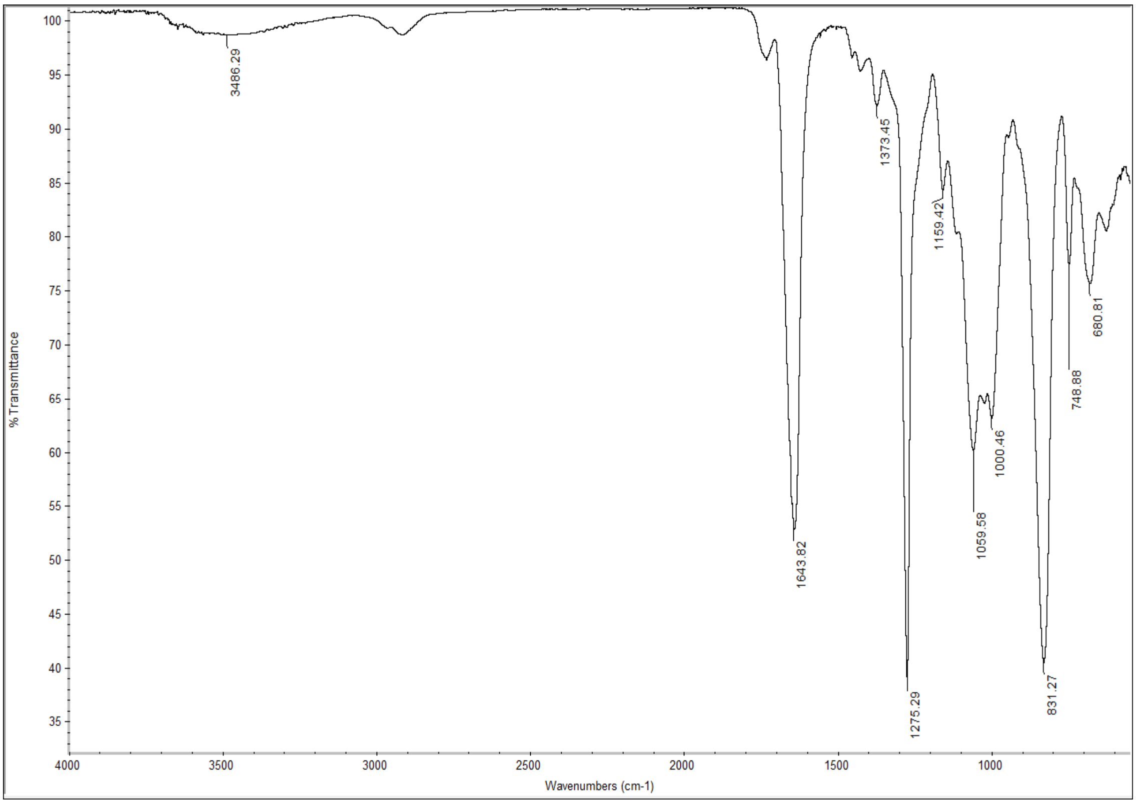

Figure B 7 : *FTIR spectrum of Sample 7 with observed peaks.*

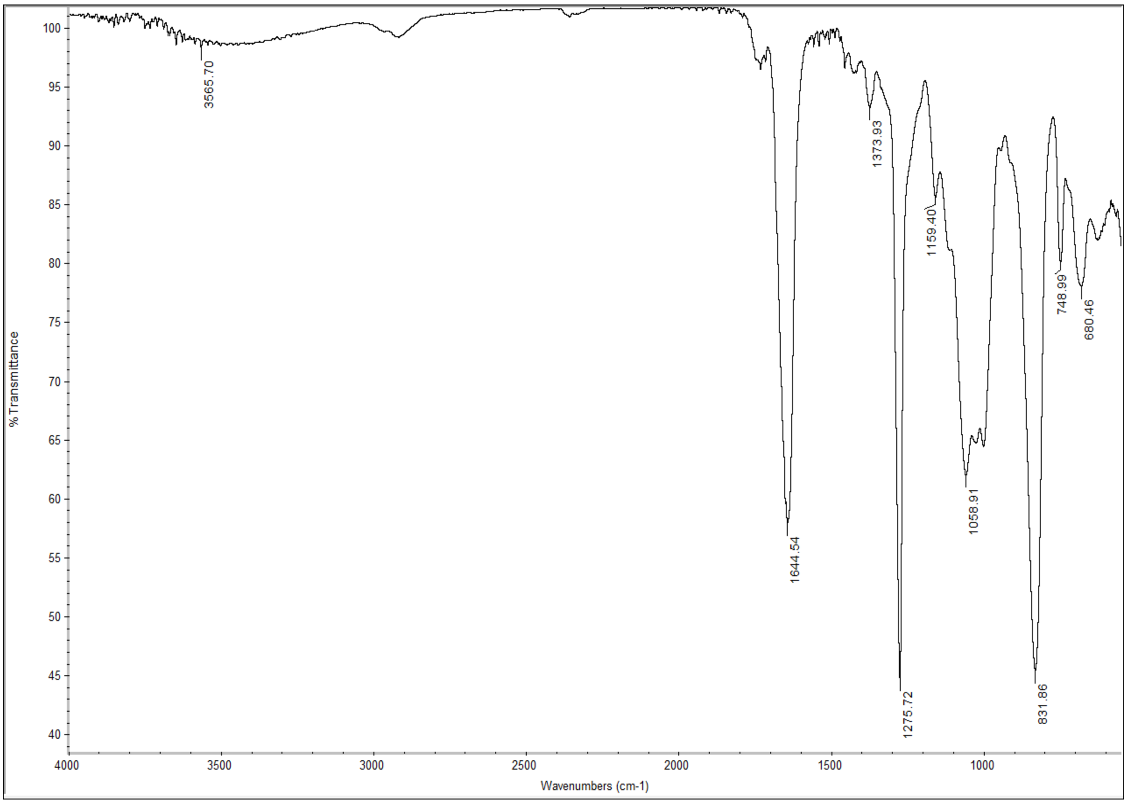

Figure B 8 : *FTIR spectrum of Sample 8 with observed peaks.*

Appendix C

Nile Red Analysis

Figure C 1: *Filter membrane after Nile Red dye staining for sample 1*

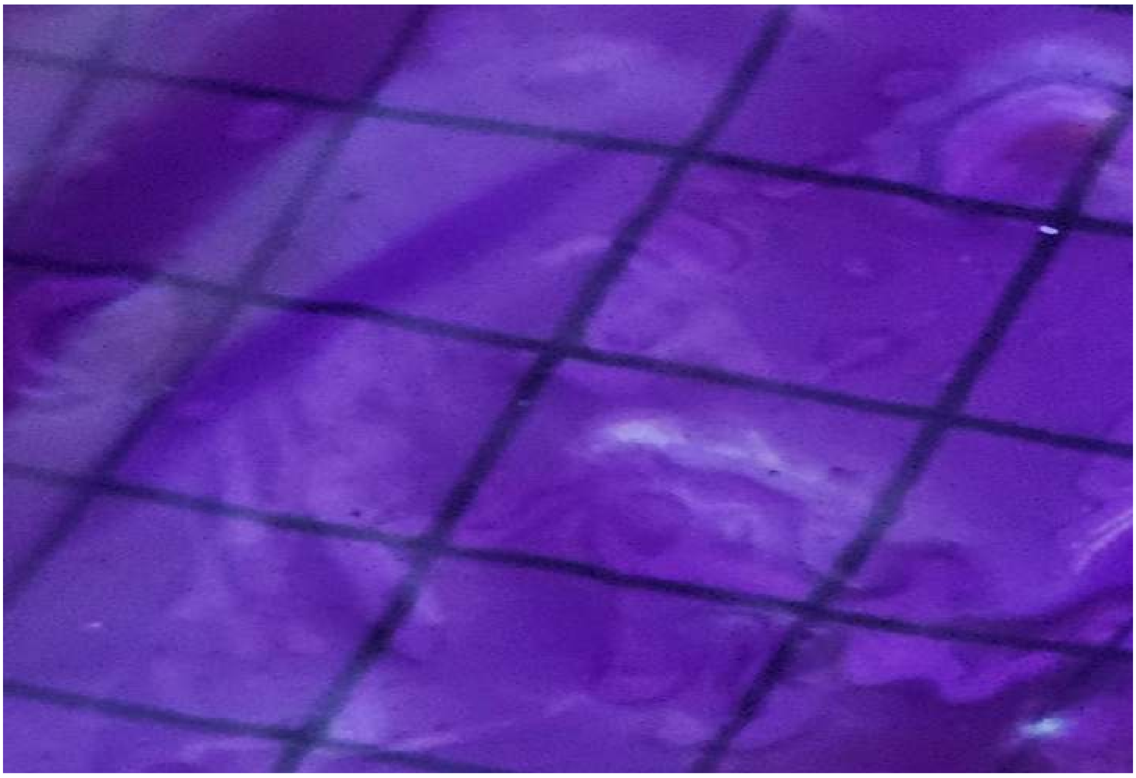

Figure C 2: *Filter membrane after Nile Red dye staining for sample 2*

Figure C 3*: Filter membrane after Nile Red dye staining for sample 3*

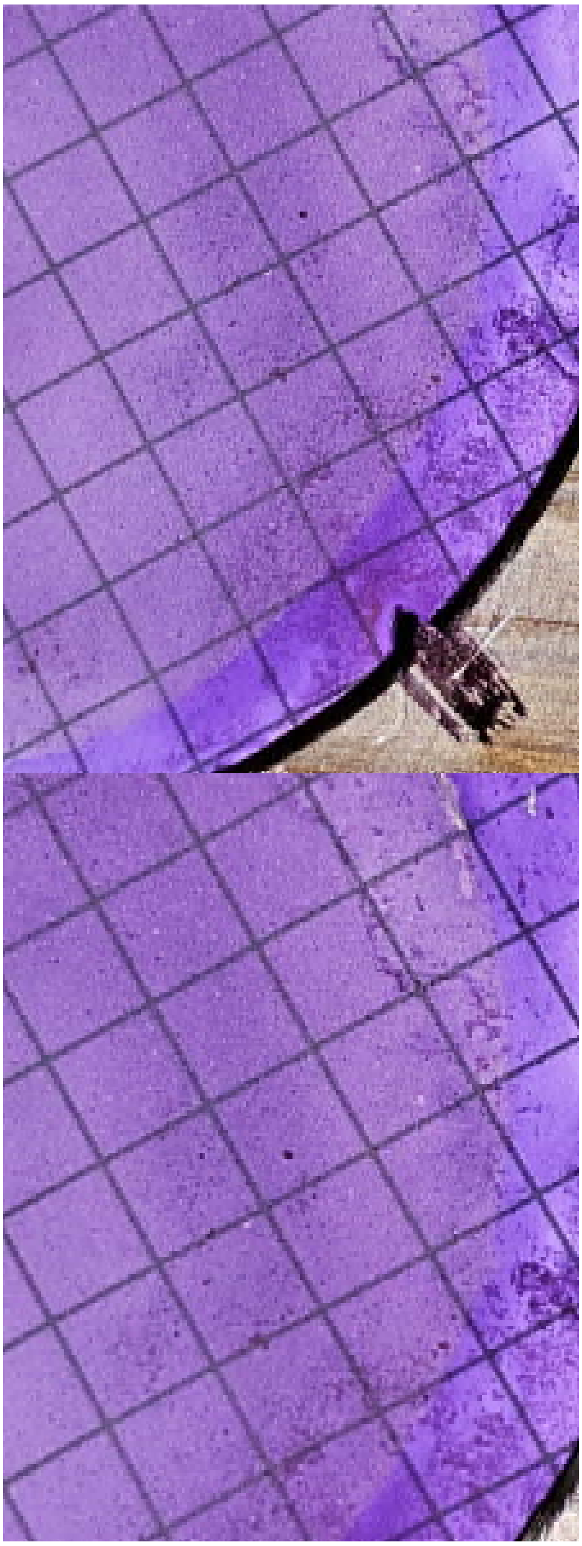

Figure C 4*: Filter membrane after Nile Red dye staining for sample 4*

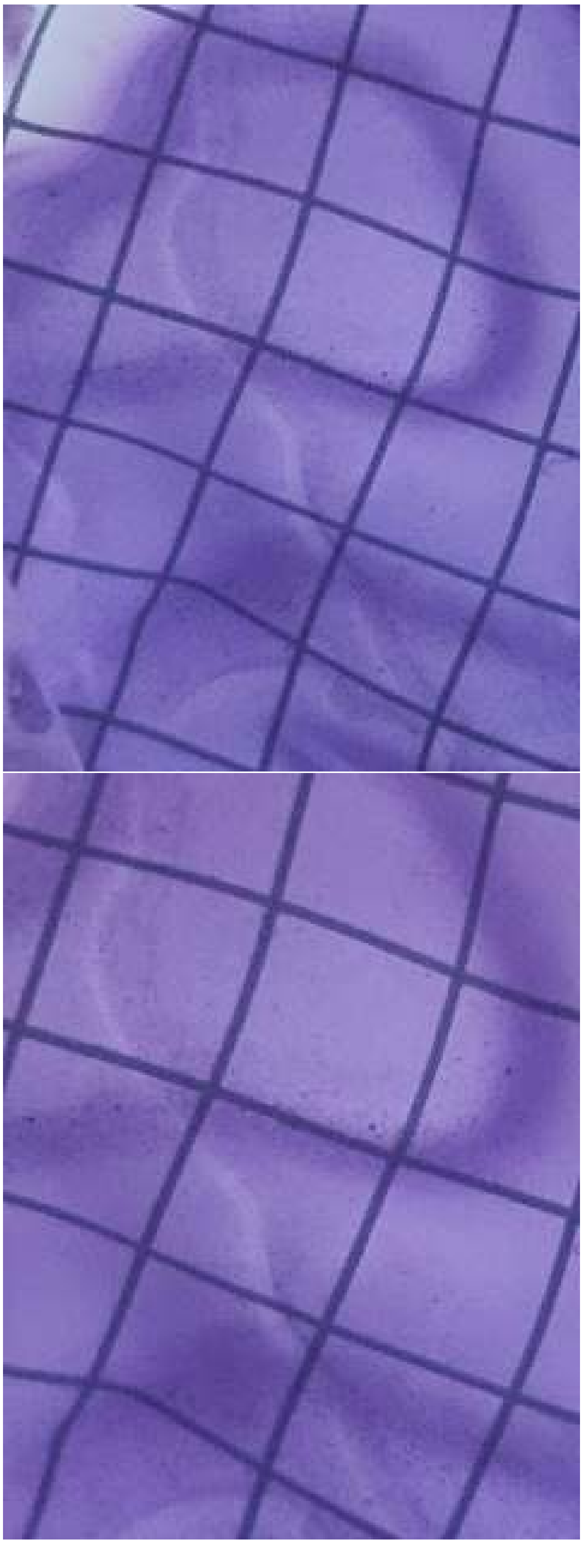

Figure C 5*:* *Filter membrane after Nile Red dye staining for sample 5*

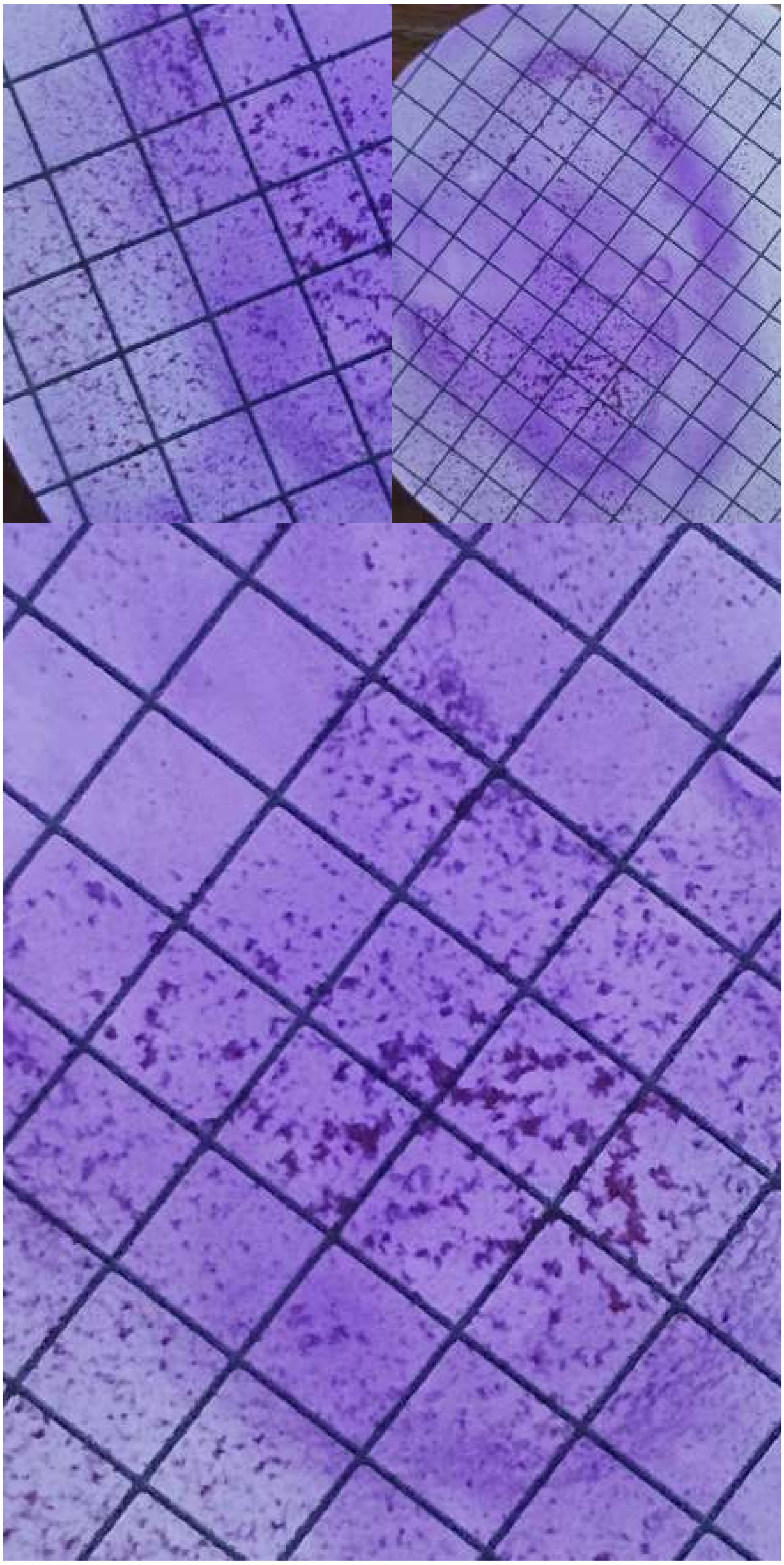

Figure C 6*: Filter membrane after Nile Red dye staining for sample 6*

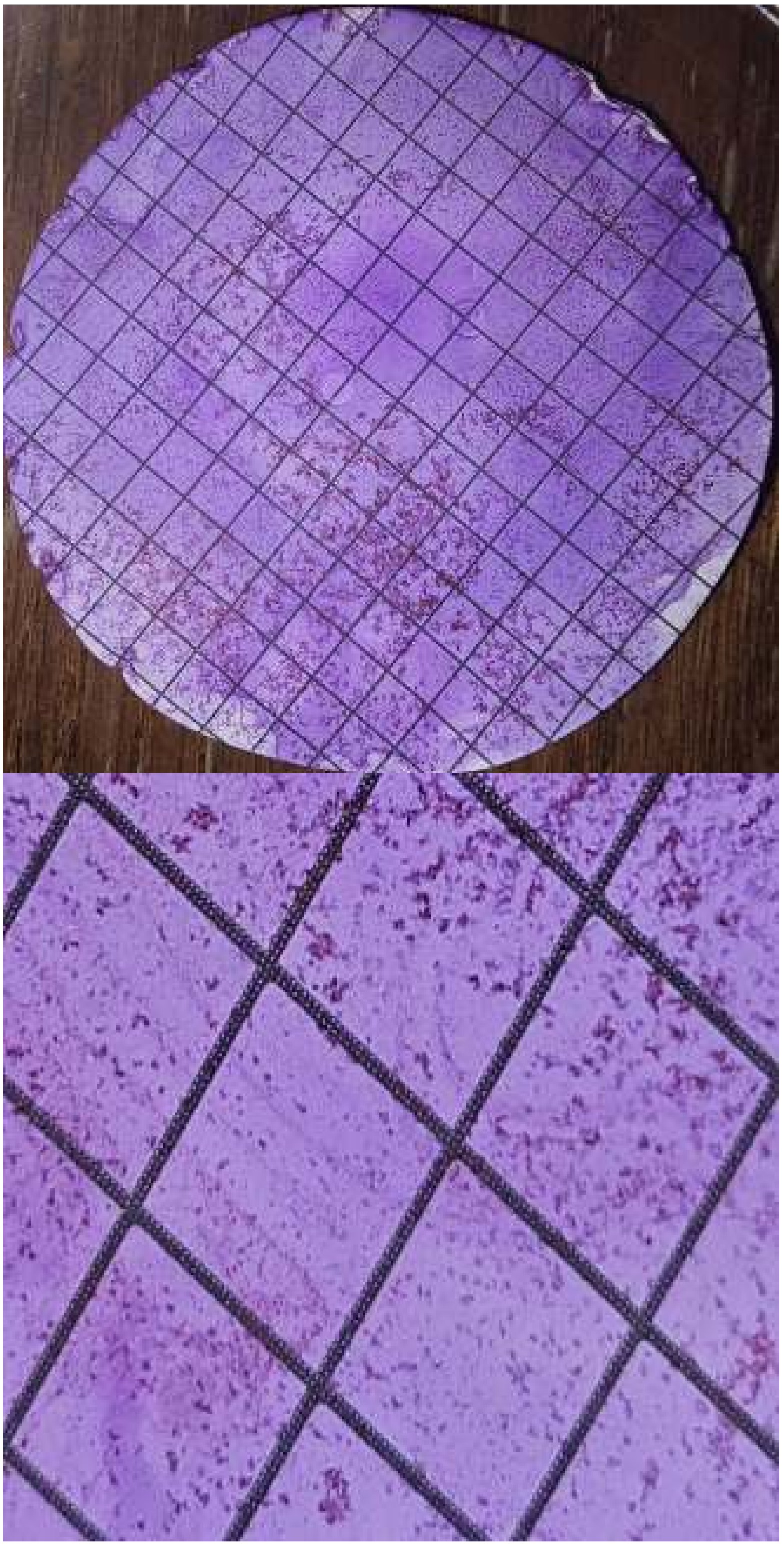

Figure C 7: *Filter membrane after Nile Red dye staining for sample 7*

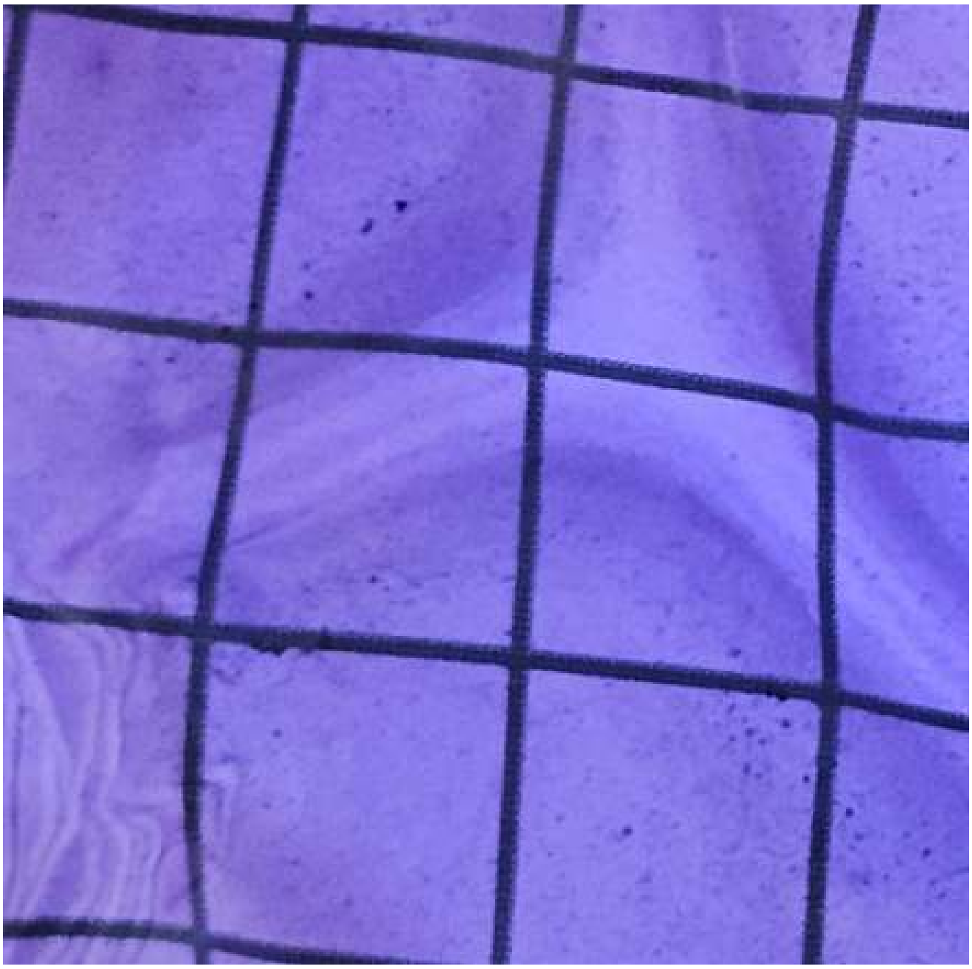

Figure C 8: *Filter membrane after Nile Red dye staining for sample 8*

جامعة النجاح الوطنية

كلية الدراسات العليا

انتشار البلاستيك الدقيق في مياه الشرب في فلسطين

إعداد

عمرو حسني سعدي برقاوي

إشراف

د. عبد الحليم خضر

د. شادي صوالحة

قدمت هذه الرسالة استكمالا لمتطلبات الحصول على درجة الماجستير في هندسة المياه والبيئة، من كلية الدارسات العليا، في جامعة النجاح الوطنية، نابلس- فلسطين.

2026

انتشار البلاستيك الدقيق في مياه الشرب في فلسطين

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الملخص

تُعَدُّ جزيئات الميكروبلاستيك واحدة من أبرز الملوثات الناشئة التي حظيت مؤخرًا باهتمام عالمي واسع نظرًا لانتشارها الواسع وتأثيراتها الصحية المحتملة. وهي عبارة عن جزيئات صغيرة للغاية يقل حجمها عن 5 مليمترات، تدخل إلى مياه الشرب — سواء كانت مياه الصنبور أو المياه المعبأة — من خلال مصادر ومسارات متعددة.

تهدف هذه الدراسة إلى تقييم وجود الميكروبلاستيك في مياه الشرب، وتحديد مصادره المحتملة، وتوفير بيانات أساسية قد تسهم في رفع مستوى الوعي بمشكلة تلوث مياه الشرب، فضلًا عن تقديم توصيات أولية للجهات المعنية لتحسين جودة المياه والحد من التعرض للجزيئات البلاستيكية الدقيقة. وقد اعتمد البحث على المنهج الوصفي التحليلي، حيث جُمعت عينات من مياه الشرب من مناطق مختلفة وخضعت لعمليات ترشيح وتحليل باستخدام المجهر الضوئي والتقنيات الطيفية.

أظهرت النتائج وجود جزيئات الميكروبلاستيك في جميع عينات مياه الشرب ولكن بتراكيز متفاوتة. ومن المثير للانتباه أن مياه الصنبور كانت أكثر تلوثًا من المياه المعبأة، نتيجة ظروف مختلفة عن تلك المعتادة في الواقع. كما تم التعرف على البولي إيثيلين والبولي إيثيلين تيرفثالات باعتبارهما البوليمرين الأكثر شيوعًا في مياه الشرب. وأشارت الدراسة أيضًا إلى أن مصادر التلوث تشمل أنظمة الأنابيب البلاستيكية،

وعمليات التعبئة والتخزين، إضافة إلى تأثير الحرارة وأشعة الشمس في زيادة وجود وتركيز الميكروبلاستيك في مياه الشرب.

خلصت الدراسة إلى أن وجود الميكروبلاستيك في مياه الشرب يمثل تحديًا حقيقيًا للصحة العامة، إذ يرتبط بتأثيرات سلبية محتملة على صحة الإنسان. وتوصي الدراسة بضرورة تطوير استراتيجيات للحد من مصادر الميكروبلاستيك، وتشجيع اعتماد تقنيات ترشيح ومعالجة أكثر كفاءة في محطات تنقية المياه، إلى جانب تعزيز الدراسات المستقبلية لفهم التأثيرات الصحية طويلة الأمد.

الكلمات المفتاحية: الميكروبلاستيك، المياه المعبأة، مياه الصنبور، بولي إيثيلين، بولي إيثيلين تيريفثاليت.