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Microplastics in Wastewater and Environmental Aspects

Mohammed Matouq*, Nina Jildeh
Al-Balqa Applied University, Chemical Engineering Department, Amman, P.O. Box 4486, 11131, Jordan.

Abstract

Several research studies focused on understanding the source, distribution, fate, and impact of microplastics in the environment. This article presents the source of microplastics in the environment and the degradation process phenomena under environmental conditions. The changes in physicochemical properties of microplastics can be analysed by several techniques, such as Fourier transfer infrared spectroscopy (FT-IR) analysis, optical microscopy, scanning electron microscopy (SEM), thermogravimetric analysis (TGA), pyrolysis-gas chromatography coupled with mass spectroscopy (PyrGC/MS), thermogravimetric analysis (TGA) coupled with differential scanning calorimetry (DSC). In addition to the impact of plastic concentrations in the environment and the consequence on wildlife population and human health and development and enhancement, the usage of biopolymers under environmental aspects.

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Introduction

The rapid increase of plastic produced since the 1940s and widely risen from 348 million tonnes in 2017 to 359 million tonnes in 2018, with a 3.0 % increase compared to 2017 (PlasticsEurope, 2019). **Figure 1** presents the global plastic distribution in Asia (51%), NAFTA (18%), Europe (17%), Middle East and Africa (7%), Latin America (4%), and CIS (3%). Microplastics refer to polymers including thermoplastics, thermosets, elastomers, and water-soluble that are less than 5mm in diameter. Plastic materials will be transported and distributed between environmental compartments (Lambert and Wagner, 2018). Furthermore, the global increase in demand for consumer-use plastics leads to a high accumulation of plastics in the future marine environment. Usually, microplastics get into the ecosystem through facial cleaners, synthesis clothing, toothpaste, and scrubs (primary microplastics), as well as, large plastics can be broken into smaller fragments, pellets or fibres (secondary microplastics) and are also transported to the environment (Auta *et al*., 2017; da Costa *et al*., 2017).

Over the past decades, several studies have been focusing on the effect of microplastics on the marine environment. The main potential toxicological effects are due to the presence of microplastics in marine environments. These impacts were due to either direct effects of microplastic exposure and/or indirect effects associated with chemicals and light for microplastic degradation. Microplastics are mostly found in the form of primary and secondary microplastics. Microplastics have been widely distributed in Asia (36%; 42.1% China of Asia), Europe (38%; 29.1% UK of Europe), North America (12%), South America (7%), Australia (4%), Africa (2%) and Antarctica (1%) presented in **Figure 2** (Ajith *et al.*, 2020; Bayo *et al.*, 2020; Everaert *et al*., 2018; Figueiredo and Vianna, 2018; Lebreton *et al*., 2017).

Studies have reported that microplastics are mainly composed of various polymeric materials like polyvinyl chloride (PVC), nylon, and polyethene terephthalate (PET), which are likely to sink, whereas polyethene (PE), polypropylene (PP) and polystyrene (PS) which are more likely to float (Auta et *al*., 2017; Avio *et al*., 2016; Carr *et al*., 2016).

* Corresponding author: E-mail: matouq@bau.edu.jo ORCID: https://orcid.org/0000-0002-2497-2117
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In addition to the potential of microplastic surfaces for adsorption heavy metals such as manganese (Mn), copper (Cu), silver (Ag), zinc (Zn), iron (Fe), aluminium (Al), bromine (Br), mercury (Hg), Titanium (Ti) and other metals resulting in increment the contamination concentration. Hence, it affects the potential environmental risks such as decreased habitus, lipids oxidative stress damage to the liver, reduced growth rate, breast cancer, brain damage, gastrointestinal damage, cytotoxicity to epithelial lung and colon cells, a neurodegenerative disorder, and possibly death (Ajith *et al*., 2020; Campanale *et al*., 2020).

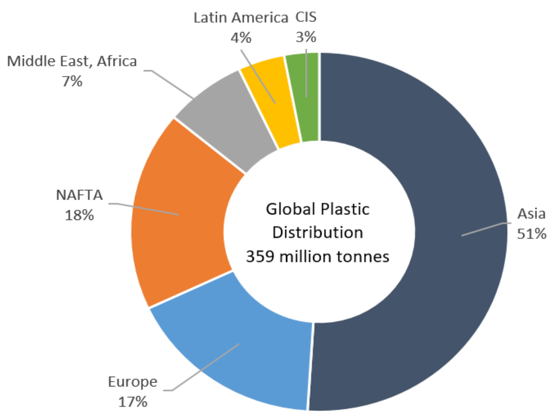

Fig. 1 Distribution of global plastic demands by segment in 2018. It was adapted from PlasticsEurope, 2019

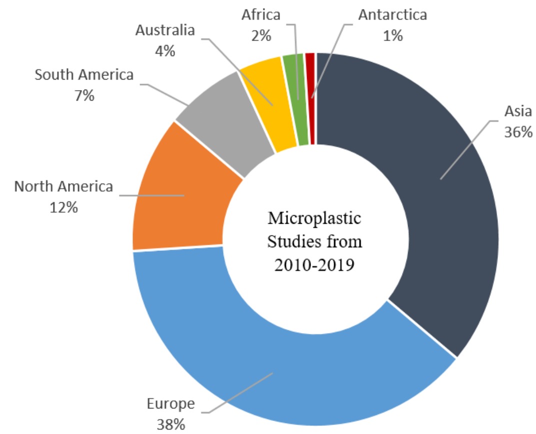

Fig. 2 Microplastic studies across the world from 2010-2019. It is adapted from Ajith *et al*., 2020.

The occurrence of microplastics in soil has an impact on the soil environment. The contamination level of microplastics in the soil causes toxicity in the ecosystem, and their effect has been observed on soil microbes, animals, and plants (Meixner *et al*., 2019; Zhou *et al*., 2019; Zhu *et al*., 2019). Zhu et al. (2017) and Horton et al. (2017) stated that soils are probably receiving more plastic waste than oceans since the plastic tends to degrade due to direct exposure to UV light and temperature, leading to fragmentation which they transfer into deeper soil layers. Another direct effect of microplastics is seeded since commonly polymer seed is non-biodegradable coatings, thus remaining in the soils, since dense polymers are very difficult to remove from soils. Therefore, the Food and Agriculture Organization of the United Nations (FAO), The International Maritime Organization (IMO) and The United Nations Environment Program (UNEP) have worked together with a group of experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) to improve the knowledge base on microplastics in the marine environment and provided policy (Lusher *et al*., 2017).

1 Microplastics Sources:

According to Cole *et al* (2011), microplastics can be classified as primary and secondary microplastics, these microplastics are disposed of and can reach the environment through the wastewater treatment process as presented in **Figure 3** (Li *et al*., 2019, Smith *et al*., 2018, Duis and Coors, 2016):

A. Primary microplastics include (i) pre-production resin pellets, (ii) microbeads incorporated in cosmetics production, and (iii) beads used for abrasive blasting of surfaces.
B. Secondary microplastics include by-products of plastic production such as textiles, paints, and tiers.

Most of the deposal plastic into the environment consists of additives like plasticizers, flame retardants, UV protection, pigments, fillers, and stabilizers. Chemical additives are widely used during the manufacturing process to adjust the suitable properties for indented applications. Various additives are used to improve materials' performance as plasticizers to provide more flexibility; colorants to provide particular color; reinforcement to improve tensile strength and stiffness; light stabilizers to prevent degradation; and flame retardants to prevent ignition or spread of flame. (Lambert and Wagner, 2018; Li and Ko, 2012; Thompson *et al*., 2009). These additives include nanocomposites as reinforced nanofillers to reduce weight as silver which acts as an antimicrobial agent in food packaging materials. However, many additives are hazardous substances and can be released from polymer structures into the environment. Such additives have a negative impact by raising the contamination of the polluted area.

2 Microplastics Affecting Human Health

The actual knowledge of microplastics' source pathway into the environment is quietly unknown. The presence of microplastics in the environment could end up in daily food and drinking water. Transported microplastics to oceans harm human health. Baechler et al. (2020) stated that research is highly required to determine the impact and risk assessment of microplastic ingestion and contamination effects on human health. It is necessary to reduce microplastic pollutants from the environment. Tiny microplastics can be primarily degraded into smaller plastics in the presence of mechanical weathering and sunlight. The algae and bacteria can consume these nanoplastics, subsequently affecting the food chain as presented in **Figure 4** (Lin, 2016).

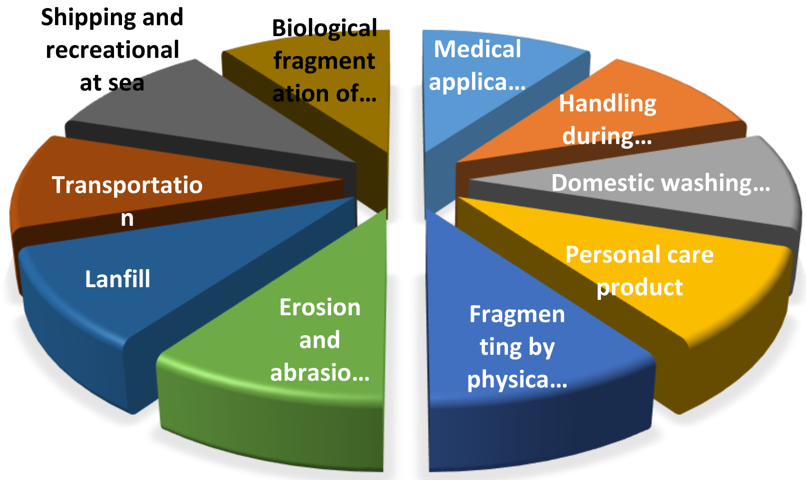

Fig. 3 Microplastic sources dispersed in the environment. Source: Karbalaei *et al*., 2018.

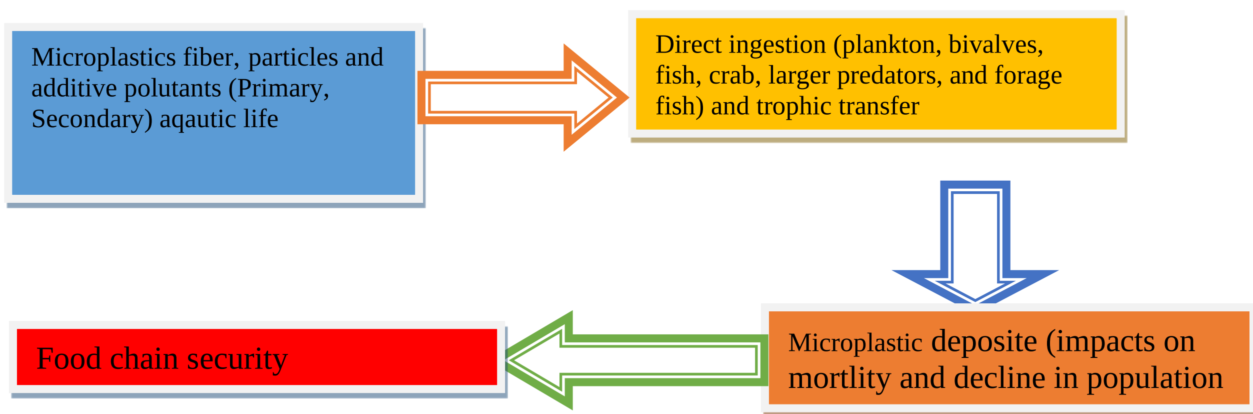

Fig. 4 Primary and secondary microplastic sources and their impact on marine life and human health. Source: Baechler *et al*., 2020.

Environmental conditions such as UV-light exposure caused degradation, hence, biofouling, sinking, and sedimentation. Whereas, chemical exposure caused plastics to degrade and dissolve in water, resulting in pollutants bioaccumulation to marine life, and subsequent high impact on human health (Smith *et al*., 2018; Rist and Hartmann, 2017). Li *et al.* (2019) reported that many organisms could ingest microplastics due to their small sizes after zooplankton, fish, and mammals. The presence of plastic pollution within complex polymer structures in the marine environment kills the marine food chain. Plastic microfiber and small plastic tend to block the gut, killing marine life like fish, whales, and turtles.

Moreover, around 4812.7 million tonnes per year enter oceans within 50-80% of wastes located on beaches and floating on the surface depending on ocean size and wind movement (Bellasi *et al*., 2020). The concentration of microplastics is mainly related to the number of human activities for the usage of polymeric materials. Besides this, the impact of microplastic distributions in water is considered a severe effect on human populations, which presents a severe effect of environmental pollution and human health hazards of microplastics. Several studies and researchers are still working in wastewater treatment plants and waste management for these crucial impacts. **Table 1** presents the most common types of microplastics existing in marine and soil environments. As stated by the American Society for Testing and Materials (ASTM), polymeric materials' specific gravity may vary due to the degree of crystallinity, plasticizers, absorption of solvent, porosity, fillers, or pigment. The value of specific gravity indicates the ability of microplastics to float or sediment in the water.

Table 1 Common types of microplastics present in marine and soil environments.

Microplastics in Marine Environment

Plastic Type	**Application**	**Specific Gravity g/cm³**	**Life (years)**	**References**
Polyethylene - Low-density polyethylene (LDPE) - High-density polyethylene (HDPE)	Packaging, fishing gear, milk containers, detergent bottles, cleaning and cosmetic products	0.91-0.93 0.94	>28	Ajith *et al*., 2020 Picó and Barceló, 2019 Smith *et al*., 2018 DaCosta *et al*., 2017 Rodríguez Seijo and Pereira, 2017
Polypropylene (PP)	Packaging, rope, laboratory equipment, drinking straws Cleaning and cosmetic products	0.83-0.85	>100	Picó and Barceló, 2019 Smith *et al*., 2018 DaCosta *et al*., 2017 RodríguezSeijo and Pereira, 2017
Polystyrene (PS)	Packaging food foam, disposable cups, building materials, cleaning and cosmetic products	1.05	50	Picó and Barceló, 2019 Smith *et al*., 2018 DaCosta *et al*., 2017 RodríguezSeijo and Pereira, 2017
Polyvinyl chloride (PVC)	Pipes, window frames, shower curtains	1.35-1.39	140	Picó and Barceló, 2019 Smith et al., 2018 DaCosta *et al*., 2017 RodríguezSeijo and Pereira, 2017
Polyamides (PA)	Nylon fabric, toothbrush bristles, fishing lines, automotive, sportswear, cleaning and cosmetic products	1.13-1.35	>20	Picó and Barceló, 2019 Smith *et al*., 2018 DaCosta *et al*., 2017 RodríguezSeijo and Pereira, 2017
Polyethylene terephthalate (PET)	Food packaging, soft drink bottles, thermal insulation, lighting products sports goods, photographic applications	1.38-1.41	>20	Picó and Barceló, 2019 Smith et al., 2018 DaCosta *et al*., 2017 RodríguezSeijo and Pereira, 2017 Webb *et al*., 2013

Microplastics in Soil Environment (Industrial Soils, Beach Soils, Agricultural Soils)

Types of Microplastics	**Effect**	**Challenges**	**References**
Nine common types of microplastics spiked in soils, seven types including polypropylene (PP), polyethene (PE), Polyethylene terephthalate (PET), polyamide (PA), polycarbonate (PC), acrylonitrile butadiene styrene (ABS), polymethyl methacrylate (PMMA), polystyrene (PS) and polyvinyl chloride (PVC) particles	Soils are considered the major storage of microplastics, which emphasises the ecological risks on soil animals, and microbiota, and the impact of absorbed by plants on a global potential risk by transferring these microplastics into the food chain.	Analysis of microplastics in soil matrix is challenging due to the presence of complex organic matters and mineral substituents	Möller *et al*., 2020 Zhou et al., 2019 Zhu *et al*., 2019 He *et al*., 2018 Machoda *et al*., 2018

Plastic waste is dangerous for the natural environment due to accumulation in rivers and oceans (Bratovic, 2019). Microplastic intakes have great potential in stress biomarkers, generating reactive oxygen species, lipid peroxidation, DNA damage, and inflammation (Hu and Palić, 2020; Ogonowski et al., 2018), altering chromosomes which leads to obesity and cancer. In addition to aged microplastics' ability to absorb heavy metals higher than virgin microplastics from the marine environment, a subsequent huge impact on tissue accumulation. Microplastics' presence enhances the toxicity of heavy metals causing oxidative damage to the tissues (Lu *et al*., 2018). As concluded, the interaction of heavy metals with microplastics poses threats to the ecosystem.

To address the toxic impact of microplastics in species tissue and their influence on the ecosystem. This could be explained in terms of biological phenomena. Microplastics can tempt the generation of reactive oxygen species at different sizes, doses, and surface characteristics, reducing the immune mechanism. Furthermore, microplastics tend to degrade into smaller particle sizes causing an increase in surface-to-mass ratio, which provides these small particles the ability to penetrate through membrane tissues (Hu and Palić, 2020).

3 Degradation of Plastic Materials

The properties of polymeric materials are correlated with the nature of intermolecular forces between chemical bonds along the chain backbones or side groups and their physical properties. The degradation of plastics under environmental conditions is considered a highly complex process due to its modified physicochemical properties and molecular structures. Several kinds of literature describe the degradation process by chain scission in the backbone of polymer materials into small molecules by oxidative reaction, mechanical degradation, thermal, and photodecomposition. The degree of degradation depends on polymer type morphology, molecular size, stabilizers, and processing conditions or environmental conditions such as light, heat, and exposure to chemicals (Lambert and Wagner, 2018; Jasso-Gastinel *et al*., 2017, Smith *et al*., 2018; Banerjee *et al*., 2014).
Besides, chemical treatment could lead to partial or complete microplastic degradation, leading to changes in tensile strength, colour, shape, and size. Polymers can be crystalline and amorphous phases, glassy or rubbery state depending on the glass transition temperature. The ability of solvents to penetrate through the polymeric matrix depends on the additive substances. The order of the matrix and active site of the functional group will affect the reaction and diffusion rate. The phenomena of adsorption could be explained upon the fundamental knowledge of the glass transition state, in which the diffusion depends on the chemical structure and thermodynamic principle. These factors have an impact on the degradation process. **Table 2** presents a summary of degradation processes (Bratovic, 2019; Ariza-Tarazona *et al*., 2018; Ashter, 2016; Lenz *et al*., 2015; Aboulkas *et al*., 2010).

Table 2 Degradation process of microplastics and changes in characteristics and properties.

Degradation Process	Principle	Description Changes
Physical degradation	Degradation occurs by exposure to abrasive forces, heating/cooling, freezing/melting, wetting/drying	Formation of crack at the surface and reduction of molecular weight
Thermal degradation	Degradation takes place by exposure to high temperatures to give monomers, oils, gases, and water	Provide information on activation energy and kinetic model
Chemical degradation (oxidation or hydrolysis)	Degradation occurs by exposure to chemicals	Lower molecular weight
Mechanical degradation	Degradation occurs by exposure to mechanical stresses	Broken down into nanoparticles leading to a decrease in particle sizes and consequently increase in surface area
Biodegradation: Microbial biodegradation; Aerobic biodegradation; Anaerobic biodegradation	Degradation takes place by microorganisms like bacteria, fungi, algae, and yeast	Lower molecular weight
Photocatalysis	Electromagnetic waves apply high energy of light such as ultraviolet light rays and γ-rays	Lower molecular weight and changes in chemical and morphological structure

As mentioned earlier secondary microplastics contain large plastics that can be broken down under ultraviolet radiation or mechanical abrasion. Primary microplastics are tiny particles that are mainly used for industrial production or domestic applications such as exfoliating facial scrubs, toothpaste, and resin pellets for the plastic industry (Auta *et al*.,2017). **Figure 5** shows the microplastic properties' changes after exposure to degradation (Gong *et al*., 2018; Webb *et al*., 2013). While microplastics are in direct contact with other pollutants present in the environment, microplastics' sorption rate with these particulates depends on surface functional group shape, crystallinity, and ageing (Bellasi *et al*., 2020). The interactions between microplastics and pollutants have an attempted ecotoxicological influence on the organisms.
The chemical reaction rate of microplastics under environmental conditions depends on crosslinking, polymer crystallinity/amorphous phase structure, and physiochemical properties such as hydrophobicity. The presence of water salinity, chemicals, and solvents in the environment might affect the adsorption process upon the polymer matrix's active sites. This reaction often caused concentration gradients due to

diffusion across the polymeric materials. The degradation process results in changing or damaging the polymer's surface structure, thus affecting its characteristics and properties.
Several factors affect the rate of degradation, including temperature, chemical bonds, pH, solvents, copolymers, and catalysis. Since the degradation process breaks the chemical bonds leading to lower molecular weight distribution hence, plastics can be estimated by loss of weight using the following relation (Ariza-Tarazona *et al*., 2018):

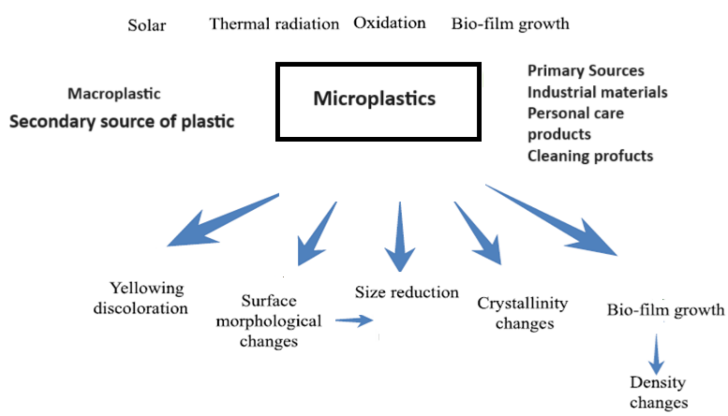

Fig. 5 Changes in microplastic properties after degradation. *Source*: Guo and Wang, 2019.

$$Mass\ Loss\ (\%) = \frac{M_0 - M}{M_0} \times 100\% \quad (1)$$

Where M_0 is the initial mass of microplastics and M final mass of microplastics. The degradation rate can be estimated as first-order degradation kinetics:

$$C = C_0\ exp(-kt) \quad (2)$$

$Where\ C$ is the concentration at time t, C_0 is the initial concentrations of microplastics, k is the first-order rate constant.
Polymer degradation assumes that the conversion rate of reaction is proportional to the concentration of reacted material as expressed in the following correlation (Aboulkas *et al*., 2019):

$$\frac{dx}{dt} = \beta\frac{dx}{dt} = K(T)f(x) \quad (3)$$

The degree of advance (x)

$$x = \frac{w_0 - w}{w - w_f} \quad (4)$$

Where w_0 and w_f refers to the sample's weight at the beginning and end, w is the weight of the sample at time t. $f(x)$ is a function of conversion and $K(T)$ is a function of temperature T. Temperature dependence of the rate of reactions can be determined from the Arrhenius relation:

$$K(T) = A\ exp\left(\frac{-E_a}{RT}\right) \quad (5)$$

Where A is the pre-exponential constant, E_a is the activation energy, and R is the ideal gas constant. By combining both relations, the rate of reaction can be expressed in the term:

$$\beta\frac{dx}{dt} = A\ exp\left(\frac{-E_a}{RT}\right)f(x) \quad (6)$$

It is essential to mention the importance of crystallinity properties in the polymer structure, affecting permeability and swelling behaviour due to more order and tightness in the chain structure. Also, polymers coupled with crystalline formation will exhibit higher thermal stability than amorphous structures. This is due to the high energy needed to break the intermolecular forces between bonds (Lambert and Wagner, 2017; Stivala and Reich, 1980). Overall, the kinetics of adsorption depends on polymer type, characteristics such as density and crystallinity, and the surrounding environment such as pH, temperature, and chemicals.

4 Analysis Techniques for Identifying Microplastics in Wastewater

Microplastics can be identified according to their characteristics properties using appropriate techniques as Fourier transfer infrared spectroscopy (FT-IR) analysis, optical microscopy, scanning electron microscopy (SEM), thermogravimetric analysis (TGA), pyrolysis-gas chromatography coupled with mass spectroscopy (PyrGC/MS), thermogravimetric analysis (TGA) coupled with differential scanning calorimetry (DSC) as summarized in **Table 3**. These methods are applied to identify and characterize the composition of microplastics and the presence of additives, antioxidants, plasticizers, and colours. Polymeric materials are affected by the degree of cross-linkage, branches, and particle size. Furthermore, microplastics tend to adsorb the surfaces and cause partial contamination. Therefore, care should be taken through the analyzing process.

Misidentification by visual inspection ranges from 20 to 70% and is commonly for transparent and fibrous particles (Zhao *et al*., 2018). Therefore, corresponding techniques are applied to attain accurate identifications. The correlation of various analysis techniques provides valuable information as morphological and crystallinity changes or damages, glass transmission temperature and melting temperature, and the possibility of identifying traces of monomers, solvents, and additives after exposure to the degradation process compared to the virgin polymeric samples.

The knowledge of identifying and determining the characteristics and properties of microplastics provides information on the type of polymeric materials and modification, degradation, ability of recycling, and toxicological impact on the environment. This information is considered helpful in environmental risk assessment (Lenz *et al.*, 2015).

Table 3 Analysis techniques for identifying microplastics' molecular structure.

Identification methods	Principle	Microplastics Identifications	Approach	References
Visual Identification	Visual sorting is used to sort, and separate large particles > 1mm and identified by the naked eye	Size, shape, colour	Easy, quick and economical approach, but it is complicated to identify transparent and fibrous particles. Inappropriate for small particles (Limitation in terms of accuracy)	Zhao *et al*., 2018 Wang *et al.* 2020 Harney *et al*., 2017 Lenz *et al*., 2015
Fourier Transform Infrared Spectroscopy (FTIR)	Infrared light from the light source passes through the sample to identify the chemical structure by excited vibrational states of chemical bonds	Chemical characteristics by determining the functional groups	Identification of suspended atmospheric microplastics. For example, PET, PS, PMMA, PVC, PAN, PAA, EVA, EP, and ALK	Huppertsberg and Knepper, 2020 Liu *et al*., 2019 Campo *et al*., 2019 Wang *et al.*, 2019 Zhao *et al*., 2018
Optical Microscopy	The sample is placed on a stage, where visible light passes through to illuminate the sample. The magnified image of small particles can be determined by lenses system and can be directly viewed through eyepieces	Providing molecular structure; the number of particles and surface texture	Enables to identify the morphological classification of particles, fibre types, and size ranges	Wirnkor *et al*., 2019
Scanning Electron Microscopy (SEM)	A beam of electrons interacts in a sample at various depths to generate various signals to produce an image of the surface topography and composition of the sample	Morphology; composition of the sample and mean particle size distribution	Interaction between nano/microplastics and suspended sediment of polystyrene	Bianco *et al*., 2020 Blair *et al*., 2019 Li *et al*., 2019 Wang *et al*., 2019 Zhao *et al*., 2018
Thermogravimetric analysis (TGA)	Temperature is increased at a constant heating rate under a controlled atmosphere to generate data about the mass as a function of temperature and time	Identify mass loss; physical phenomena as decomposition step, adsorption, absorption, and desorption; chemical phenomena as thermal decomposition, oxidation, or reduction reactions	Organic materials can be indicated. Inappropriate to investigate the small number of microplastics	Zainuddin and Syuhada, 2020 Yu *et al*., 2019 Aboulkas *et al*., 2010
Pyrolysis-Gas Chromatography-Mass Spectroscopy (PyrGC/MS)	The sample is decomposed into smaller molecules through thermal fission. The pyrolysis techniques are usually integrated with mass spectroscopy	Characteristics of combustion of polymer and structural properties	A powerful tool for identifying polymer by coupled with mass spectroscopy. However the major disadvantages of identifying the type, morphology, and number of plastics presented in the sample	Wirnkor *et al*., 2019 Zhao *et al*., 2018 Harney *et al*., 2017
Thermogravimetric analysis (TGA) coupled with Differential Scanning Calorimetry (DSC)	Simultaneous measure of both heat flow and mass changes as a function of temperature and time under a controlled atmosphere.	Characteristics of reaction; thermal degradation; thermal stability; kinetic parameter for chemical reactions; mass loss as a function of temperature	Verify the purity of synthesis materials. This method was tested and validated for pure plastic substances such as PE, PP, PVC, PA, PES, PET, and PU; also applied to measure PE and PP in extracts from wastewater effluent samples.	Zhao *et al*., 2018 Majewsky *et al*., 2016

Polyethene terephthalate (PET), polyethene (PE), polystyrene (PS), polyamide (PA), polyurethane (PU), polymethyl methacrylate (PMMA), polyvinyl chloride (PVC), polyacrylonitrile (PAN), poly (N-methyl acrylamide) (PAA), ethylene-vinyl acetate (EVA), epoxy resin (EP) and alkyd resin (ALK)

5 Environmental Risk and Plastic Waste Management

Waste management is considered a serious problem and challenging for managing waste in developing countries; as stated in several types of research, it is impossible to define the origin of microplastics in the environment. Since there is ha uge variety of polymeric materials, the selection of suitable materials to fulfil the requirements and regulations for specific applications is based on several factors (Jasso-Gastinel *et al*.,2017). Inadequate disposal of plastic wastes and mismanagement cause these wastes into oceans and be transported by wind and water flows into other lands. Prata *et al.* (2020) mentioned that inadequate waste management leads to the accumulation of over 250,000 tons of plastic pieces floating in the oceans. Several reports proved the potential effect of microplastics on freshwater organisms, including decreased growth rate, decreased feeding rates, changes in behaviour, and metabolism disorders for lipids and amino acids (Rist and Hartmann, 2018). Microplastics' high surface area may lead to oxidative stress, cytotoxicity, and translocation in tissues resulting in chronic inflammation and diseases (Campanale *et al*., 2020; Li *et al.*, 2020; Yong *et al*., 2020; Ogonowski *et al*., 2018).

Several researchers investigated microplastics in food; the obtained data showed microplastics in fish (Pirsaheb *et al*., 2020; Cole *et al*., 2011), beer, honey, and sea salt (Diaz-Basntes *et al*., 2020; Kosuth *et al*., 2018). Accordingly, microplastics in the environment end up in the consumer emerging world health organizations and waste management on food safety concerns and human health assessment. Despite the importance of using plastic in our daily lives, however, plastics can be found in the environment. Separation of microplastics from other materials can be achieved by sieving, filtration, or density separation; however, these techniques are not suitable for microplastics less than 1nm. Other techniques are required to determine transparent and white particles, such as a fluorescence microscope to confirm the absence of cellular structure (Duis and Coors, 2016). Studies showed that the used plastics could be recycled to minimize the pollution level during manufacturing processes. **Figure 6** presents the management of plastic waste and energy recovery.

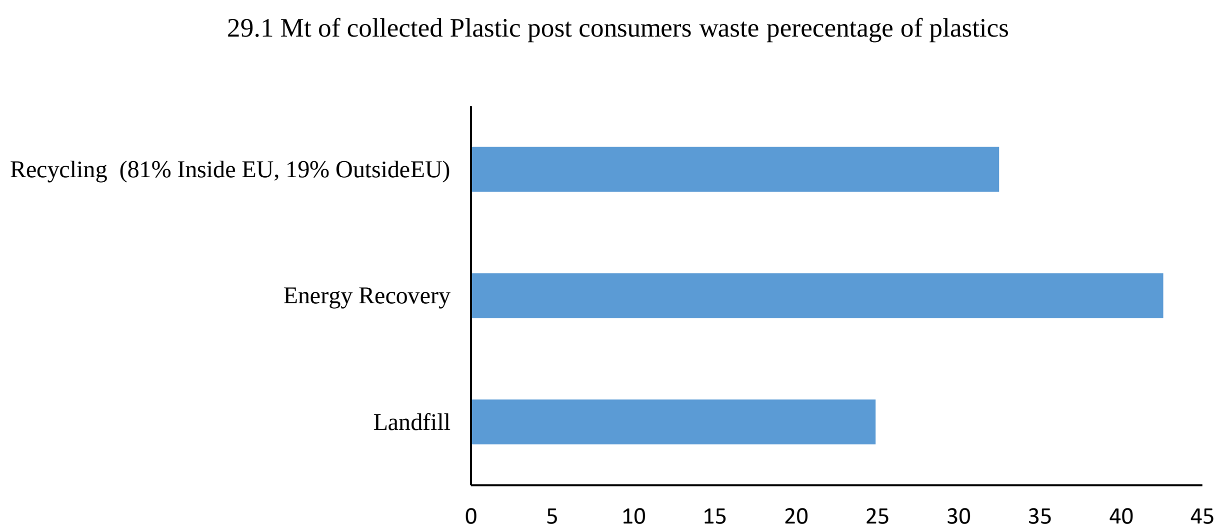

Fig. 6 Management of plastic waste in Europe in 2018. It is adapted from PlasticsEurope, 2019.

Most literature review was concluded with microplastic investigations in marine life. However, exploring the occurrence, distribution, and potential interactions of microplastics in the soil is still being researched (Helmberger *et al*., 2019; Meixner *et al*., 2019; Wang *et al*., 2019; Rillig, 2012). Microplastics and the accumulation of these harmful particles in rivers, soils, and organisms cause severe problems by affecting the food chain, consequently impacting human health and populations.

6 Bioplastics and Biopolymer Effects on the Environment

Over the past years, an increase in plastic demands in the world has ended up in marine and soil environments, affecting human health. As presented in industrial production most used petrochemical plastics are not biodegradable. Because the degradation of polymer materials depends on molecular weight, crystallinity, and hydrophobicity, as discussed in the previous section (Bratovcic, 2019). Therefore, bioplastics including biodegradable, oxo-biodegradable, and bio-based plastics, are currently applied through production processes. These biodegradable polymers exist as natural and synthetic; however, these materials cause an increase in production processes and reduce material properties compared to conventional plastics (Lusher *et al*., 2017; Webb *et al*., 2013):

- Biodegradable plastics can be broken down by microorganisms into water and carbon dioxide under specific conditions.
- Oxo-biodegradable plastics contain a small amount of metal salts that catalyze the degradation process under favourable conditions.
- Bio-based plastics are made from biological and renewable sources and may be more susceptible to biodegradation due to their weak polymeric structure.

The development of biopolymers under environmental aspects and environmental degradations have been increased in the area of research. An example of these biopolymers includes poly(hydroxy alkanoates) (PHAs) which these materials are suitable for packaging, coating, and biomedical applications due to their natural production. A recently published research article by Bratovcic (2019) mentioned that many bottles and packaged products are made from biodegradable plastics like poly (lactic acid) (PLA), poly(ε-caprolactone) (PCL), poly(butylene succinate) (PBS) or poly(butylene succinate-co-butylene adipate) (PBSA) (Narancic *et al*., 2020; Bindu *et al*., 2019: Ragaert *et al*., 2019; Khosravi-Darani and Bucci, 2015).

Biodegradable polymers have been widely applied in medicine and pharmaceutical fields due to their important characteristics, including biocompatibility, absorbability, and mechanical resistance. An example of the main application of biopolymers includes orthopaedic surgery and tissue engineering. It has been widely used as a drug as a protein, gelatin, and chitin due to its biological absorbability (Gopi *et* al., 2018; Zeng *et al*., 2016; Nitta and Numata, 2013).

7 Effect of Media on Microplastics Issues

Environmental issues may be addressed through different media, such as newspapers, radio, television, and the Internet. One of these environmental issues that concern the public domain is microplastic pollution and its negative impact on soil and the marine environment. Throughout history, media has increased, gaining attention from the public. In a represented survey, 87% of Europeans worry about the effects of plastics on the environment, and 74% about their health (Völker *et al*., 2020). Therefore, the media will assess information and support the researcher's/waste management society for awareness and concerns regarding pollutant diffusion. To achieve fundamental knowledge regarding waste and protecting the environment, the media world plays an influential role in warning society based on the information dependence on environmental issues as stated by Thompson-Saud *et al.* (2018) that most news was published in the business and finance section on the production of salmon, fisheries and marine policy (Hnderon and Green, 2020). Furthermore, media roles' efficiency helps in encouraging the citizen to understand, rethink, analyze, and solutions related to environmental issues. In this way, people become more aware and committed to the environmental society, which achieves a better sustainable environment

Conclusions

This review article discussed the negative impact of microplastic exposure on the environment for population and human health. Addressing the source of microplastics in the environment and analyzing these microplastic pollutants for identifying the characterised properties. Several techniques were applied to distinguish between various properties of microplastic types, such as Fourier transfer infrared spectroscopy (FT-IR) analysis, optical microscopy, scanning electron microscopy (SEM), thermogravimetric analysis (TGA), pyrolysis-gas chromatography coupled with mass spectroscopy (PyrGC/MS), thermogravimetric analysis (TGA) coupled with differential scanning calorimetry (DSC). These techniques can be coupled together to have adequate knowledge regarding the materials' characteristics and their additives as size, shape, chemical structure of the functional groups, morphology, thermal stability, and degradation. In addition to the awareness of environmental risk for microplastic pollutants as a severe threat along the food chain and consequently might affect negatively tissues and cause diseases.

Nomenclature

A	=pre-exponential constant in Arrhenius equation	[-]
E_a	=activation energy	[kJ/mol]
C	=concentration at time t,	[weight]
C_0	=initial concentrations of microplastics,	[weight]
k	=first-order rate constant.	[1/time]
M_0	=initial mass of microplastics and M final mass of microplastics	[%]
R	=gas constant	[J/K.mol]
w_0, w_f	=sample's weight at the beginning and end	[weight]
w	=weight of the sample at time t	[weight]

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