MICROPLASTICS IN LANDFILL LEACHATE - CHARACTERISTICS AND COMMON METHODS OF IDENTIFICATION

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Abstract: *Climate change implies a statistically significant change in the long-term mean state or characteristics of the* ***Abstract:*** *According to estimates, around 40 % of the world's plastic waste production is buried in landfills, which are still a widely used approach for waste disposal. Waste undergoes a number of physical, chemical, and biological changes after being landfilled, producing landfill leachate, a highly contaminated effluent. These complex physical, chemical, and biological processes that occur in landfills also cause plastics to break into smaller fragments called microplastics (MPs) which are accumulated in landfill leachate due to their small size. Depending on waste type, the degree of degradation, the climate, the characteristics of the landfill sites, socioeconomic factors, and the applied landfilling technology, leachate composition differs between landfills. Microplastics are now emerging particle anthropogenic contaminants, and their study is generating more and more attention from the scientific community and the general public. Even though landfills have taken steps to decrease the severity of this problem, MPs continue to be produced by plastics in both current and former landfills. In this way, humans and biota may be adversely affected by landfill leachate that has been released into the environment. In order to comprehend the patterns of microplastics degradation and the most typical forms of polymers that they contain, identification and characterization of MPs from landfills is highly required. These efforts will contribute to a better understanding of how MPs from landfills affect the environment.*
Keywords: *microplastics, landfill, leachate*

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1. INTRODUCTION

Plastic is a polymeric substance with molding or shaping potential that is typically produced by applying pressure and heat. Plastics may be produced into a wide range of products thanks to their plasticity, which is frequently combined with other unique features including low density, low electrical conductivity, transparency and durability. Although some are more commonly known by their abbreviations or commercial names, consumers are already familiar with many of the chemical names of the polymers used to make plastics. Plastics are usually classified according to their technical behavior rather than their chemical makeup. More specifically, they are classified as either thermoplastics or thermosets. Most commonly used plastic materials by type are listed in **Table 1**. The polymer structure that comprises thermoplastics is formed up of distinct molecules that flow past one another and are not connected to one another. The essential property is that of separability and subsequent mobility, regardless of the molecules' molecular weight, branching, or linear shape. On the other hand, after being heated again, thermosets cannot be processed repeatedly. The chemical reaction that thermosetting resins go through during the initial stages of production creates an insoluble, infusible network. In essence, the entire heated completed product merges into a single large molecule. The material is not softened by additional heat application to the point where it may be manipulated again.

Since its discovery in the beginning of the 20th century, global plastic production has been growing and will continue to grow into the future. Plastic is a major part of our modern lifestyle with global annual production of more than 335 million metric tons (Mt) (He et al. 2021). According to the analysis provided by Geyer et al. (2017) a total mass of 8300 million Mt of plastics has been produced globally to date. It is estimated that around 6300 Mt of plastic waste has been generated in the year 2015 alone. Of that quantity, approximately 79 % of plastic waste has been disposed to landfills or to the environment, 12 % has been incinerated, and only 9% of plastic waste has been recycled (**Figure 1**). In the global context, 21 - 45 % of plastic waste is being disposed to landfills (Hou et al. 2021). In the period from 1950 to 2020, China has generated around 14 million Mt of plastic waste with approximately 40 % of plastic waste being landfilled (Luan et al. 2021). According to the available data, 7.2 million Mt of plastic waste was received by the European Union landfills in 2018 (Association of Plastics Mnufacturers 2020). Prevailing plastic materials in landfills are the ones commonly used in packaging plastics: HDPE, LDPE, PP, PET, PS, and PVC. If current trends continue, around 12000 million Mt of plastic waste will be deposited in landfills or in the environment by the year 2050 (Ozbay et al. 2021). As it can be concluded from the data presented above, landfills act as a significant repository of HDPE, LDPE, PP, PET and PS plastic waste, according to Kawecki et al. (2021), from 48 to 60 %.

Table 1. Commonly used plastic materials

THERMOPLASTICS NAME (ABBREVIATION)	THERMOSETS NAME (ABBREVIATION)
High density Polyethylene (HDPE)	Phenol-formaldehyde
Low density Polyethylene (LDPE)	Epoxy resins
Polyamides (PA)	Vinyl esters
Polypropylene (PP)	Melamine resins
Polyvinyl-chloride (PVC)	Unsaturated polyesters
Expanded polystyrene (EPS)	Phenol-formaldehyde resins
Polystyrene (PS)	Polyurethane (PUR)
Thermoplastic elastomers (TPE)	Urea-formaldehyde resins
Polyethylene terephthalate (PET)	Silicone
Poly methyl methacrylate (PMMA)	Phenolic resins
Polycarbonate (PC)	Acrylic resins

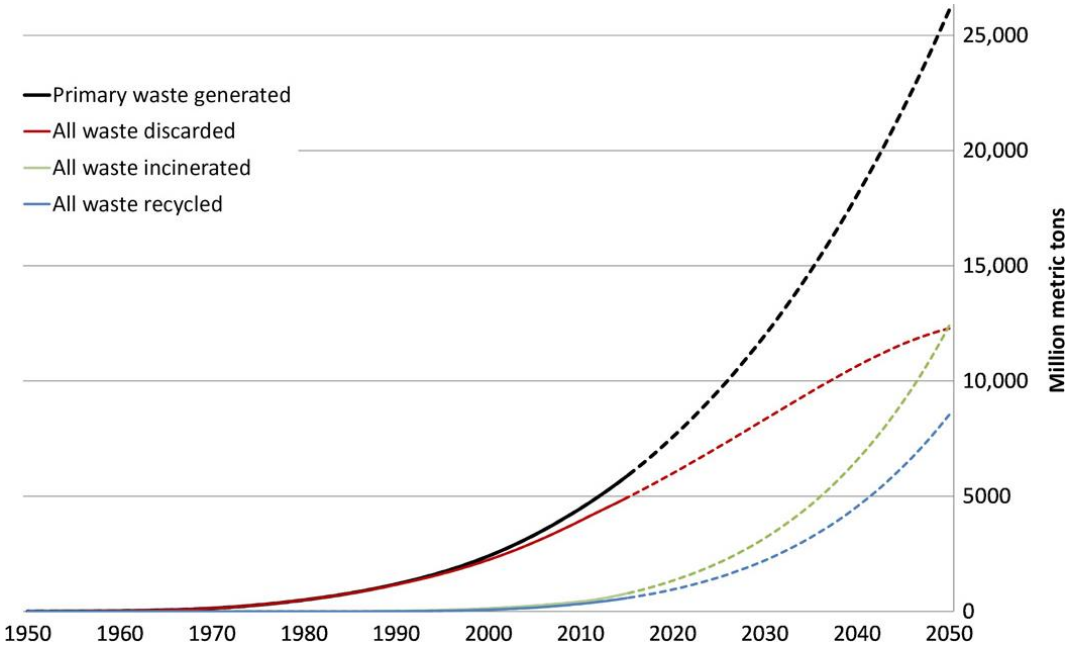

Figure 1. Cumulative plastic waste generation and disposal (Geyer et al. 2017)

In relation to their size, plastics can be categorized as macro (> 25 mm), meso (< 25 and > 5 mm), micro (from 5 mm to 0.1 μm) and nano (< 0.1 μm) plastics (Crawford and Quinn 2017). First detection of microplastics in the environment was in the oceans and the term 'microplastics' was first introduced by Thompson in 2004 and defined as plastic particles less or equal to 5 mm in size. Since then, microplastics has been discovered practically everywhere in the environment, including: surface water, soil, potable water, waste water and landfill (Nizzetto et al. 2016; Eriksen et al. 2014; He et al. 2021; Cheng et al. 2021). Of the above-mentioned sources of microplastics, landfills are the least explored, although there are studies which identify landfills as microplastics hotspots and as an input of microplastics to the environment. In a study conducted by Kilponen in 2016 concentrations of MPs in the range from 0.005 to 0.017 particles/L were detected in a river which acted as a landfill leachate receiver. Likewise, Kazour et. al. (2019) measured a concentration of 6 particles/L in a water body located in close proximity to a landfill site. He et al. (2019) analyzed the concentrations of MPs in leachate samples from 6 landfills in China. Concentrations of MPs ranged from 0.42 to 24.58 particles/L. According to a study conducted on untreated leachate samples collected from landfills from 11 Nordic countries, concentrations of up to 4.5 particles/L were detected (Praagh et al. 2018), confirming landfill sites as an important source of MPs to the environment.

2. ORIGIN OF MPS IN LANDFILL LEACHATE

Solid waste and wastewater treatment plant residual (solid sludge, fat, oil, and grease (FOG)) are the two main sources of MPs in landfill leachate. Solid waste may contain large amounts of primary MPs. Large plastic objects that are disposed of in landfills can also undergo a number of abrasive processes that result in the production of secondary MPs. Another large MP point of collection is domestic wastewater. During treatment, MPs become trapped in solid sludge and FOG. Sludge and FOG from sewage disposal in landfills can increase the total amount of MPs in landfill leachate (Iyare et al. 2020).

In landfills, all waste passes through multiple stages of treatment, including initial aerobic biodegradation, a change from anaerobic to aerobic conditions, acid production and hydrolysis, methanogenesis, and finally maturation and stabilization. The rate of plastic breakdown increases with each stage. Physical stress resulting from aerobic biodegradation can cause plastic waste to start to decompose. Additionally, fragmentation of plastic can occur throughout the entire landfill treatment process due to mechanical stresses such as pressure, abrasion and friction. Plastics can be ruptured by hydrolysis and turned into MPs as they break down in landfill body. In addition, the acid generation phase in landfills can speed up internal hydrolysis reactions and facilitate the synthesis of MP.

One of the most significant locations for MP collection is the wastewater treatment facility. Wastewater contains MPs from a variety of sources, including household activities like clothes washing, agriculture, industry, and other sources. According to Gatidou et al. (2019), there can be up to 3160 particles per liter, and $170.9 \cdot 10^3$ particles per kilogram of total solid dry weight of MPs in wastewater that has not been treated. According to Talvitie et al. (2017); Gies et al. (2018); and Jia et al. (2019), the majority of MPs are detained in the FOG flocs and sludge. Due to the lack of effective technology, it is practically impossible to separate entrapped MPs from FOG and sludge, therefore their end destination is landfills (He et al. 2021; Hou et al. 2021). Municipal solid waste (MSW) landfills in the US are used to dispose of 22 % of wastewater sludge.

3. CHARACTERISTICS OF MPs

According to type, MPs can be characterized as primary or secondary MPs. Primary MPs are represented as small beads and granules that are purposefully manufactured. They are used as resin pellets for production of larger plastic products or directly as abrasives in various cosmetic personal care products such as exfoliating hand cleansers, facial scrubs and toothpaste. Also, plastic microbeads are heavily applied in air blasting technologies as paint and rust scrubbers.

Secondary MPs are formed in the environment as a result of degradation and fragmentation of different plastic debris. Fragmentation is the result of exposure of plastic materials to various environmental influences. According to the predominant environmental factors that cause degradation of plastics we can distinguish five different processes of degradation. These are: biodegradation - caused by biological activity, photodegradation - caused by the influence of UV radiation, thermal degradation - exposure of plastics to high temperatures, thermal-oxidative degradation - induced by heat and oxygen, and hydrolysis - through contact of plastics with water. Constantly present environmental degradation of primary and also secondary MPs changes the original properties of MPs including their size, color, surface morphology, density and crystallinity.

3.1. Size

One of the most important factors affecting microplastic's potential impact to the environment is its size. The greatest length of a plastic particle is referred to as the size of microplastic. MPs in leachate showed a broad size range, from 20 μm to 5000 μm (**Figure 2**). The detecting technique may have a significant impact on the large range in size. For instance, most of the minute particles will be lost if a bigger filter is used during sampling. Generally, different studies need to look into extracting MPs for a wider size range (1 μm - 5000 μm) in order to provide a complete picture of particle distribution. Clear criteria for identifying the size of MPs should be followed in order to appropriately compare data across different studies, and the implementation of consistent sample and extraction techniques is essential. As the particle size gets smaller, there are more MPs in the landfill leachate. For instance, He et al. (2019) found that 75 % of the sample's microplastics were between 100 and 1000 μm, 20 % were between 1000 and 5000 μm, and just about 5 % were larger than 5000 μm. When examining the prevalence of microplastic in groundwater near municipal solid waste dumpsites in South India, Natesan et al. (2021) discovered a similar finding. When MP gets generated during the landfilling process, it flows to leachate with rainwater. Larger MPs would retain more in the solid phase of landfills, whereas smaller particles were more easily gathered in the leachate. By comparing the MP incidence in landfill refuse and leachate, Su et al. (2019) established this fact and found that the size of microplastic in the leachate is significantly less than that in the refuse, 0.83 and 4.97 mm, respectively.

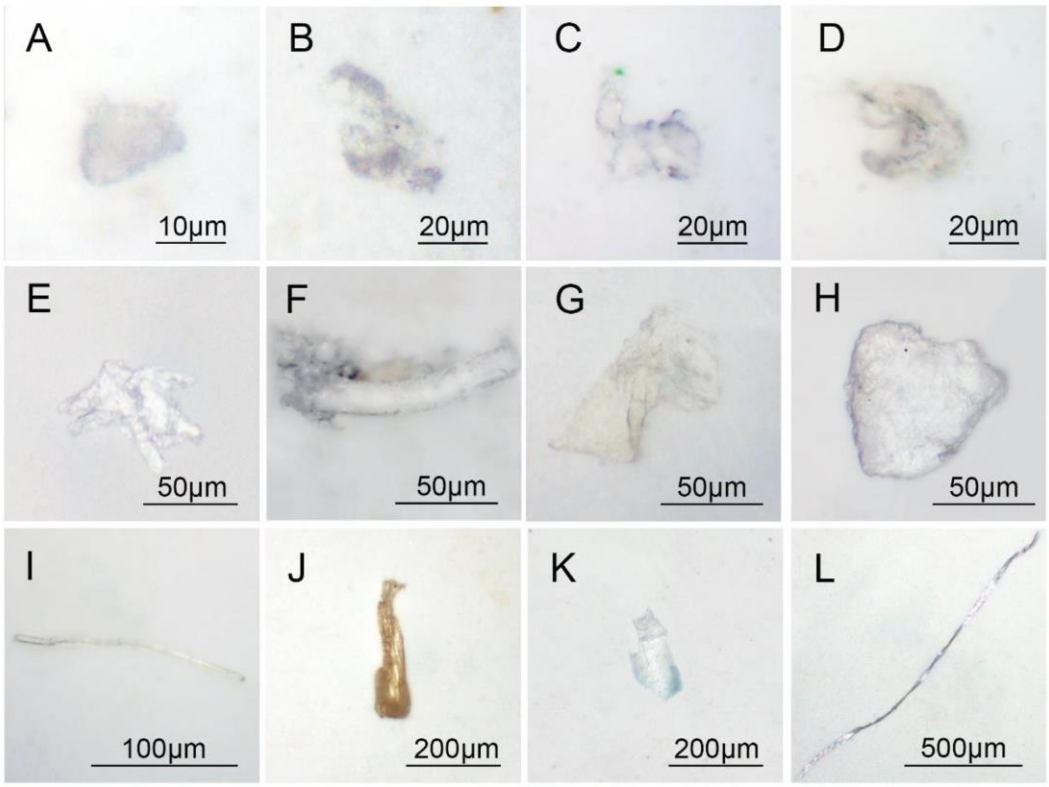

Figure 2. Stereomicrographs of microplastics detected in the leachate and sludge samples (Sun et al. 2020)

3.2. Shape

Another important aspect of MPs in landfill leachate is their form. Lines, flakes, films, pellets, beads, foam fiber, fragments and granules are some of the MPs morphologies found in leachate (**Figure 3**). The most prevalent MP forms found in landfill leachate around the world are fiber and fragments. Fiber and fragments may be more likely to permeate the leachate from landfills with rainwater due to the shape. Wastewater also demonstrated the similar pattern. One of the major sources of fiber in wastewater is the wear and tear on synthetic textile fibers during machine washing (Cheng et al. 2021).

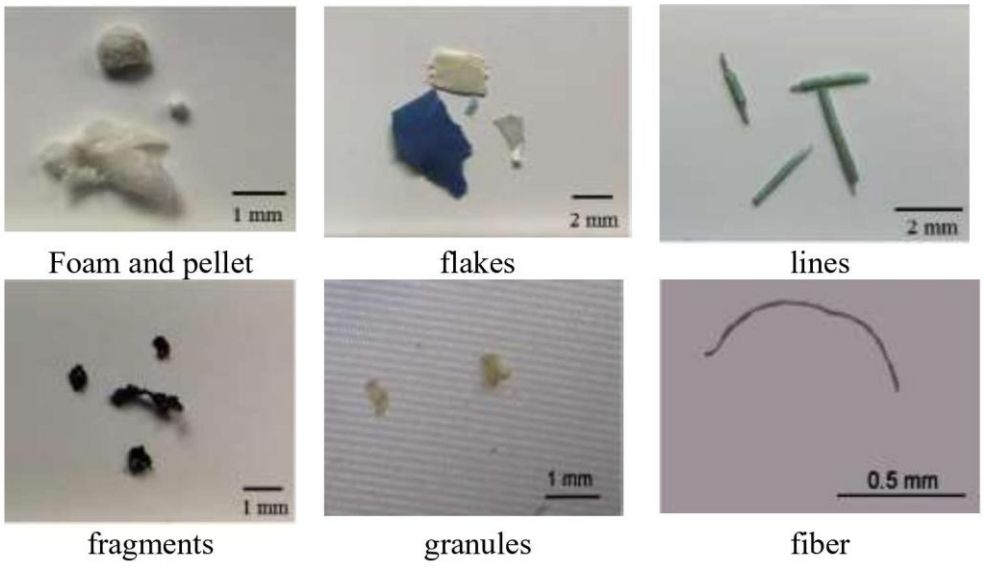

Figure 3. Different shapes of microplastic particles detected in landfill leachate (He et al. 2019; Su et al. 2019)

The shape of MP can be used to identify the parent plastic items. For instance, plastic bags and other plastic packaging are typically sources of plastic films. Plastic bags are translucent and thin, making them vulnerable to breaking in the sun. According to Puthcharoen and Leungprasert (2019), the majority of granules and spheres come from plastic containers, water bottles, food storage containers or microbeads. The source of plastic, primary or secondary, can also be determined by the shape. For instance, the majority of MPs discovered in the leachate have irregular shapes, a hackly structure, and rough edges (Su et al. 2019; He et al. 2019), which suggests that secondary MPs were produced from plastic debris during the fragmentation process. Shapes can also reveal the origin of the MPs, which is another useful information. According to Antunes et al. (2018), resin pellets might be the most common type of MP close to industrial locations, whereas fragment and foam might be found in greater quantities nearby fishing ports.

Most studies from various regions had concluded that MPs detected in landfill leachate had a rough surface texture and irregular forms as a result of fragmentation of plastic items in the landfill (Sun et al. 2020; Narevski et al. 2021). The MP's surface roughness is a crucial factor in determining the environmental impact of MP. A husky surface was also identified after Su et al. (2019) examined the surface structure of MPs isolated from landfill leachate. The husky surface may facilitate the adsorption of contaminants, including organic and heavy metal pollutants, increasing the environmental risk associated with leachate discharge. Also, the various treatment methods' clearance rates are influenced by the surface roughness. For example, fibers and pellets with a smooth texture were substantially less likely to be trapped by mechanical means (Long et al. 2019) while fragments and grains which are characterized by angular, twisted morphologies and curved surface textures are captured more easily.

Leachate's shape composition may alter as a result of the treatment process. For instance, a sample might not have a specific shape when it is in its raw form, but it might show that shape after undergoing a treatment stage (Lv et al. 2019). Leachates may go through many processes at a leachate treatment facility to remove solids. Each treatment unit's water flow turbulence may help macro and microplastics break down mechanically (Cheng et al. 2021). Therefore, MP shape modification during leachate treatment processes is possible.

3.3. Color

The colors of MPs are influenced by the parent plastic's colors and durability. The breakdown of regularly used plastic goods, such as textile and packing materials, is more likely to produce colorful particles than transparent fibers, which could come from the fragmentation of fishing lines or nets (Wang et al. 2020). However, the weathering impact has the capability to alter them. The significant concentration of translucent and yellowish particles indicated that the majority of the particles had been existing in the landfill for a considerable amount of time (Sun et al. 2020). The samples' yellowish color may also point to a greater concentration of organic material therein (Kilponen 2016). Over 90 % of the MPs that the researchers Sun et al. (2020) found are translucent or yellowish, with the remaining 10 % being various colors. From the Finnish leachate sample, Kilponen (2016) also found a lot of translucent and yellowish-colored particles. When compared to landfill leachate, colored MPs (white, yellow, blue, red, green, orange, black, and grey) make up between 50 and 87 % of all MPs in flowing water (Chen et al. 2020). This discrepancy may be caused by the different plastic retention times in landfill leachate and flowing water. Due to the weathering impact, the initial color of the polymer changes when MPs remain and break down in the landfill for an extended period of time. Various colors of MP particles identified in leachate are presented in **Figure 4**.

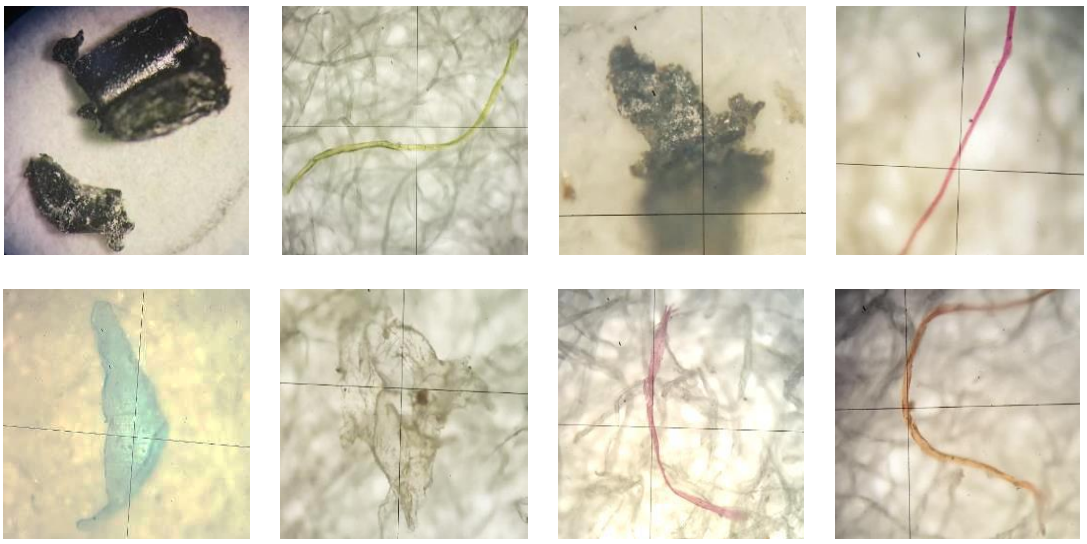

Figure 4. MP particles of various colors recovered from landfill leachate (Waddell et al. 2020)

4. METHODS OF IDENTIFICATION

4.1. SEM

In the majority of studies, MPs are initially identified visually before a polymer type identification is made. Larger particles can be observed with the naked eye, but microscopic MPs can only be identified via binocular microscope or scanning electron microscope (SEM). SEM generates images with a depth of field and high resolution that are not otherwise possible with conventional optical microscopy. SEM is a technology that is typically used to identify the surface properties of particles and verify the presence of MPs in leachate samples.

When primary electrons enter a solid material, various scattering processes, both elastic and inelastic, are created. These linked signals are then gathered by various detection systems to create an image (Bogner et al. 2007). The back-scattered electrons passing through the specimen produce an increasing intensity that provides information about the topography and contrast of the material based on the atomic number, whereas the secondary electrons produce a detailed image that aids in understanding the morphology of objects.

SEM can be combined with energy-dispersive X-ray spectroscopy (SEM-EDS), which generates high-resolution images of the particles being examined and offers an insight into the microplastic element composition. High vacuum (< 10-4 Pa) measurements are possible, but to obtain higher quality images, insolating materials are frequently coated with metals (Al, Au, or Pt). As an alternative, uncoated materials can be examined using the technique known as environmental or variable pressure mode, which uses nitrogen, ambient gas, or water vapor (to analyze wet samples) with a chamber pressure ranging from 1 to 2000 Pa. SEM-EDS aids in quick differentiation between non-plastic and plastic pellets and has the ability to find particles that are missed by optical inspection. In a study by Waddell et. al (2019) conducted on leachate samples from a landfill in the UK, backscattered electron images were utilized in combination with elemental spectra to search for different elements. MP particles were identified by a pronounced carbon peak, without a large diversity of other elements in the spectra, a characteristic of plastics (**Figure 5**).

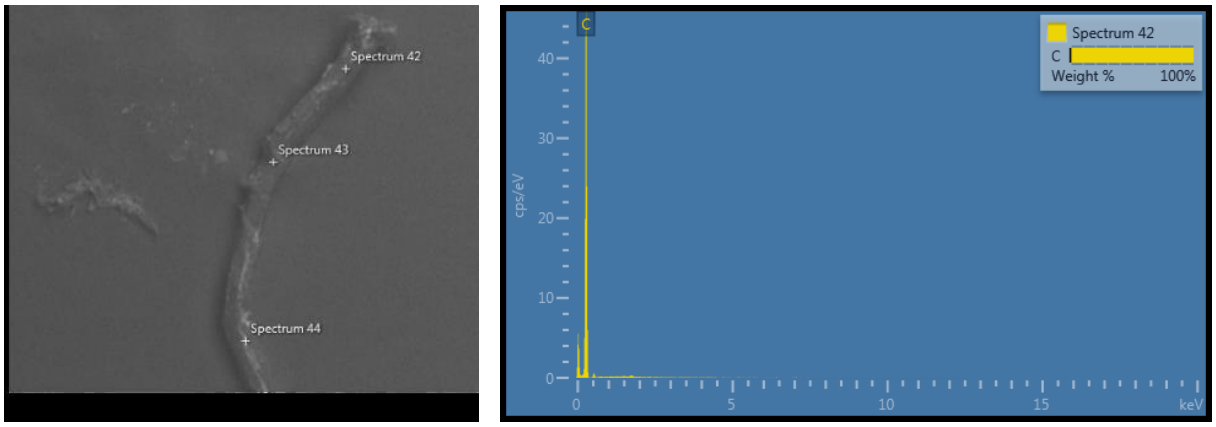

Figure 5. SEM-EDS results of MP fiber recovered from landfill leachate (Waddell et al. 2019)

Generally speaking, SEM-EDS is an expensive technique of detection and involves a greater amount of time and effort to prepare the sample, therefore handling a large number of samples would be challenging. Visual identification is not regarded state-of-the-art and as such is frequently not sufficient, leading to false-positive results, depending on the effectiveness of the sample treatment and particle size. Additional spectroscopic or spectrometric approaches are therefore required for ensuring the unmistakable identification of MP particles. Furthermore, colored microplastics cannot be distinguished by SEM-EDS. However, according to Shim et al. (2017), this central laboratory method can be successfully utilized as a confirmatory method for identifying MPs within a sample.

4.2. FTIR

The most used non-destructive method for the detection of MPs is Fourier transform infrared (FTIR). This technique creates an adequate spectrum for the oscillation of an atomic chemical bond by exposing plastic particles to infrared radiation. Depending on the chemical make-up of the sample, infrared radiation is absorbed and recorded in either reflection or transmission mode (Kappler et al. 2016). The chemical bonds in the sample change their dipole moment upon IR absorption, allowing polar functional groups to be detected. By examining the oxidation intensity of microplastics, FTIR can not only reliably identify the polymer kinds of microplastics but also provide further details about the physiochemical weathering of microplastics (Cooper and Corcoran 2010). Three FTIR optimizing technologies include: micro-FTIR, attenuated total reflection (ATR), and focal-plane array (FPA).

By combining FTIR with an optical microscope, micro-FTIR is used for MPs with microscopic particle sizes, up to 20 µm. According to Löder and Gerdts (2015), micro-FTIR has the capacity to characterize samples smaller than 10 µm. The elimination of inorganic and organic matrices is vital particularly for this kind of analysis, which takes into account very small particles. The matrix removal will raise the proportion of plastic to nonplastic particles, which will favorably enhance the analysis's statistical certainty and representativeness for the studied sample. As a result, it will be easier to avoid or at least decrease the agglomeration and overlap of microplastics with natural fragments, which can cause an under/overestimation of particle size and number during analysis. For examination, only a small portion of the sample is frequently deposited on the filter or slide in order to further reduce the amount of particles. Harrison et al. (2012) successfully demonstrated the potential of these techniques through molecular mapping based on the spectral characteristics of the micro-FTIR and reflectance micro-FTIR techniques for the detection of microplastics in marine sediments. A unique band approach has been established for the detection of combinations of natural and semi-synthetic fibers. The bands in micro-FTIR are examined in transmittance mode. It is confirmed that there are semi-synthetic fibers present if the band value is in the 1105 cm^{-1} range, which is the band that represents this type of fiber. It is necessary to improve the polymer spectra library because environmental samples are frequently different in composition, weathered, and biofouled, which makes it challenging for the matching algorithm to match with the commercially available spectral library (Cai et al. 2019). To ensure the appropriate comparison of plastic particles, it is crucial to build a library with a non-typical spectrum of plastics as a reference from various plastic sources. **Figure 6** displays the FTIR spectra of MPs identified in landfill leachate (Su et al. 2019) as well the standard spectra of the corresponding polymers.

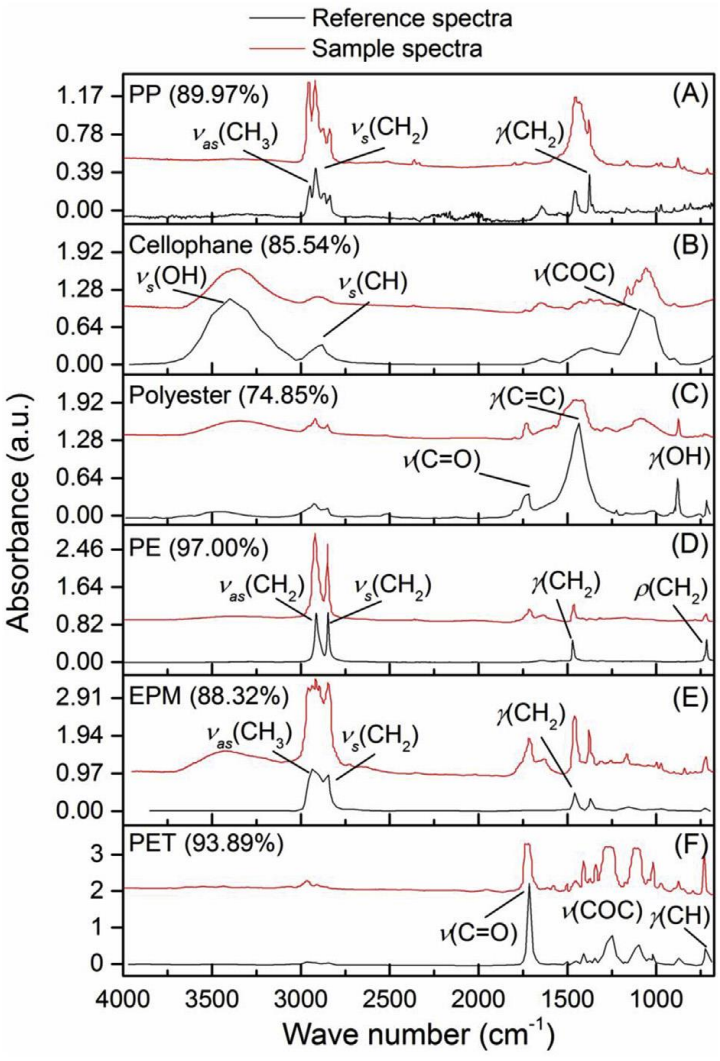

Figure 6. Identification of MPs polymer types by micro-FTIR spectra. A-F represent the polymer spectra of PP, cellophane, polyester, PE, EPM and PET. The polymer spectra of detected MPs samples and standards are shown as black and red lines, respectively, and the numbers in brackets represent matching degrees (Su et al. 2019)

Another accurate and quick detection method for characterizing polymers that have been separated is ATR-FTIR (Kappler et al., 2018). Sample preparation is not necessary for opaque or thick samples when using ATR-FTIR to analyze larger microplastic particles. An ATR crystal with a high refractive index, such as one made of diamond, germanium or zinc selenide is pushed against the sample surface in order to perform the measurement. The plastic sample must come into touch with the crystal for ATR-FTIR to work (Crawford and Quinn 2017; Shim et al. 2017). The ATR mode also generates steady spectra from irregular microplastic surfaces. Because it is so simple to obtain information on altered particle surfaces caused by the aging process, ATR-FTIR is frequently used for the identification of visually presorted particles with sizes greater than 200-500 μm (Primpke et al. 2020) and also for the characterization of weathered MP particles (Ter Halle et al. 2017). However, ATR has several drawbacks. For example, the high pressure produced by the probe can destroy delicate or highly worn microplastics, and electrostatic forces could cause microscopic MP particles to adhere to the probe tip (Shim et al. 2017).

By scanning the isolated MPs on a filter paper with a high degree of lateral resolution without presorting the filter area, FPA-FTIR provides identification and analysis of MP particles smaller than 20 μm (Löder and Gerdts 2015). For the examination of MPs, FPA uses a grid of detectors to record several spectra in one measurement or thousands of spectra in a minute. The entire membrane filter area including microplastic residues is imaged using FPA-based reflectance micro FTIR, where each pixel corresponding to the MPs generates a distinct infrared spectrum. In order to obtain robust results with little analytical bias, FPA-FTIR filter images offer superior information on small size microplastics with high resolution and a faster rate (Tagg et al. 2015). Large data sets are produced by imaging-based analyses, particularly when the automatic FPA-FTIR option is used. These data sets must be processed in order to obtain the identity of the particles as well as additional information, particle number, size, and shape, needed for the extensive quantitative analysis. As a result, automated data analysis techniques are required, including spectrum preparation (baseline correction, smoothing) and evaluation. Library search, a form of instance-based supervised machine learning that is frequently used for the assignment of spectra, uses search algorithms to produce a hit quality index (HQI). A comparison of the query spectrum and each reference spectrum is represented by the HQI. Primpke et al. (2017) have created siMPle, an innovative and free software application that enables the systematic identification of MPs in the environment. The siMPle software algorithm compares the sample's infrared spectrum to each reference spectrum in the database, assigns a material to each, and calculates a probability score for each. In particular, the amount of time needed for spectral correlation data analysis can be greatly decreased. Automated analytic techniques can then be used to further evaluate the obtained data for particle and fiber counts.

4.3. Raman spectroscopy

Another effective chemical analytical method for locating MPs in various environmental matrices is Raman spectroscopy. This technique is based on the impact of inelastic or Raman light scattering on molecules and produces vibrational fingerprint spectra. Therefore, utilizing a commercial spectral databases, it is possible to correctly identify plastic particles, some additives such as pigments and oxides, as well as other organic/inorganic and biological compounds. In addition to the examination of MP particles, Raman spectroscopy is also appropriate for the separation of synthetic and natural fibers. While conventional Raman spectroscopy often detects only microplastics greater than 10 μm (**Figure 7**), finer particles can be detected by the means of a micro-Raman spectroscopy. The Raman spectroscope and optical microscope interact to enable the visual selection of the precise region of the sample for analysis. This allows MPs as small as 1 μm to be examined together with its chemical and structural characteristics, which can not be performed with any other spectroscopic technique (Crawford and Quinn 2017).

In comparison to FTIR spectroscopy, Raman spectroscopy offers a number of benefits. With the use of lasers of varying powers capable of affecting the material, it enables non-destructive study of materials in any state of aggregation with typically less sample preparation. The result is a Raman spectrum distinctive to the investigated material. Additionally, sample thickness is not a factor in the measurement. Samples in solutions, gases, films, surfaces, solids, and single crystals can all be analyzed. Various temperatures can be used for analysis. The low-temperature spectra (10 K) enable the reduction of any sample damage resulting from local heating induced by the laser and comparison with studies obtained with other low-temperature approaches.

When paired with Raman spectroscopy, fluorescence can be a very serious issue, which is one of the drawbacks of the method. Since the photons emitted in both phenomena are produced by stimulation in the absorption band and the quantum yield of the fluorescence is frequently a factor of magnitude higher than the intensity of the Raman diffusion, the Raman and the fluorescence are actually closely related phenomena. This interference by fluorescence can be caused by additives as well as inorganic and organic contaminants in the matrix. Therefore, prior to the Raman analysis, the removal of inorganic and organic nonplastic particles is frequently necessary (Primpke et al. 2020). The matrix removal will also sharply raise the proportion of plastic to nonplastic particles, which will enhance the statistical confidence and representativity of the microplastic analysis. Additionally, it is

possible to reduce microplastic agglomeration and overlap with natural particles, which can result in an over/underestimate of particle size and quantity. However, by using an algorithm or more effective detectors, some fluorescence interference can be reduced (Araujo et al. 2018).

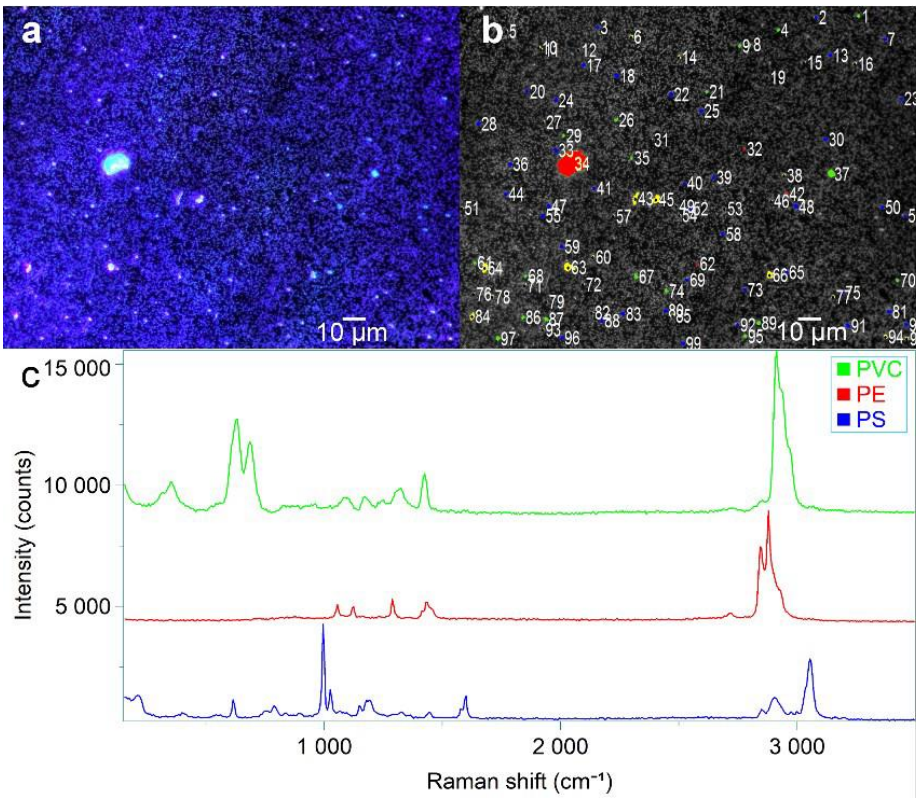

Figure 7. Microscopic image of MPs on the filter surface in dark field (a) and as a grey scale image analyzed with Particle Finder module (b) with the corresponding Raman spectra (c) (Oßmann et al. 2017)

5. CONCLUSION

Plastics continue to exist and cause pollution long after they have served their intended purpose, therefore their effects cannot be completely mitigated within a typical human lifespan. Depending on how it is manipulated, plastic may, when it reaches the waste stage of its life cycle, constitute a serious threat to the environment. Because of the way landfills are administered, the effects of environmental processes like wind, leaching, flooding, and runoff, as well as the dispersal of trash by animals, landfills have a direct impact on the creation of microplastics in the ecosystem. Although landfills have made efforts to lessen the severity of this issue, plastics in current and former landfills continues to be a source of MPs. Due to the MPs containing nature of plastic waste and various processes of defragmentation present during landfilling, landfills have an indirect effect on the creation and spread of MPs. Leachate and air may transmit fine particles and fibers from landfills to the environment. When plastic waste ages, oxidative photodegradation processes trigger the production of dangerous volatile organic compounds. Additionally, MPs serve as transporters for a variety of contaminants, including heavy metals. Due to their hydrophobicity, these contaminants readily bond to the microplastic surface.

It will be important to conduct comprehensive multidisciplinary studies that address the migration and fate of MPs in order to better understand the indirect impacts of MPs pollution. It is also important to identify the plastic waste components that are most likely to fragment so that the effect may be lessened by better product design techniques, as well as ways to decrease consumption or increase recycling. Consumer behavior can also be changed by promoting the avoidance of single-use plastics and other disposable products. Plastic waste should be diverted from landfills by putting waste reduction, recycling, and energy recovery measures first.

Reduction of MP release from landfills to the environment can only be accomplished by an enhanced understanding of current landfill management and landfill leacheate treatment practices. Future efforts should concentrate on standardizing the methods for collecting landfill leachates, particularly for smaller MP particles, and to identify additional contaminants that have been adsorbed to their surface, as well as characterizing MPs from landfills to find the most prevalent polymers and their weathering characteristics.

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