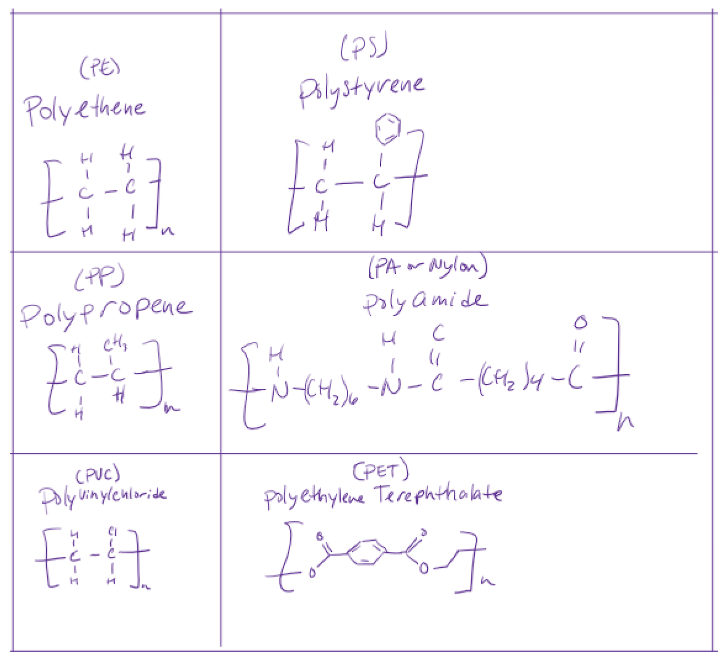
Microplastics:
Presence in Human Tissues and Analytical Detection Methods

Shannel Lampkey and Hannah Baughman and Peter Selkin

Introduction

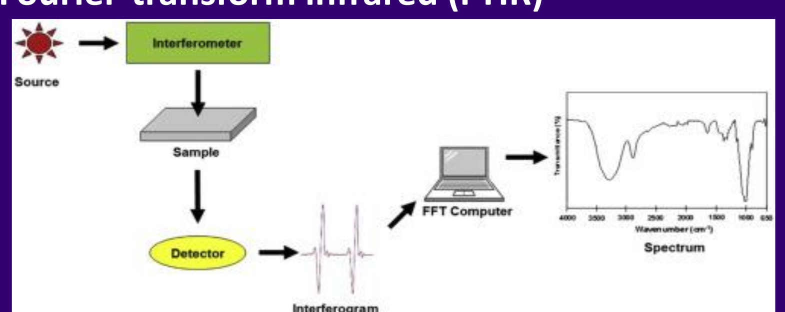
- Global production of plastics has surpassed 450 million tons in the year 2019, rising from zero at the beginning of the 20th century (Ritchie et al. 2023).
- In terrestrial environments, produce grown on soils contaminated with MP's have been shown to accumulate microplastics (Gao et al., 2013;Ghaffar et al. 2013; Enyoh et al., 2019). It's been estimated that humans consume up to 80 g per day of microplastics via crops(fruits and vegetables) grown in MP contaminated soil (Enyoh et al., 2019).
- A byproduct of plastics are microplastics, particles smaller than 5 mm through degradation of plastics (Velaquez et al., 2021). Nanoplastics are also a byproduct of plastics, particles ranging from 25 to 500 nm (Ragusa et al., 2022).
- Actions such as physical abrasion, ultraviolet radiation, and certain bacteria can degrade plastic into micro and nanosized particles. MP's and NP's have been detected in many aspects of the environment.
- This literature review discusses studies on MP present in human tissues and suggests a future direction of this research topic.



Molecular Structures of Common Plastic Types
(image credit: Shannel Lampkey)

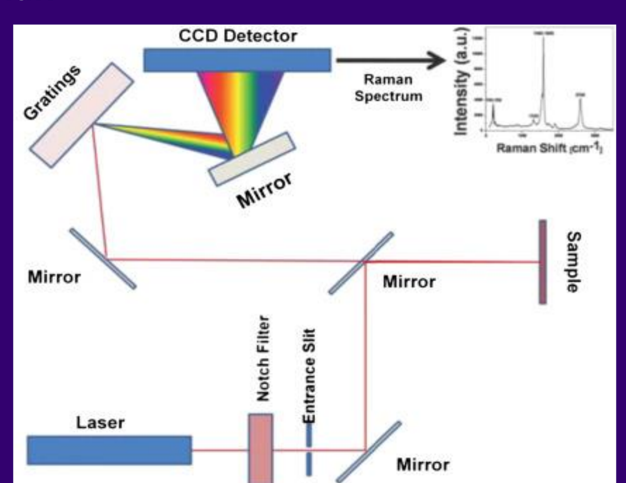
How FTIR and Raman Spectrometers Work:

- Fourier-transform infrared (FTIR)



(Undavalli & Khandelwal, 2021)

- Raman



(John & George, 2017)

Microplastics in Various Tissues

Figure 2

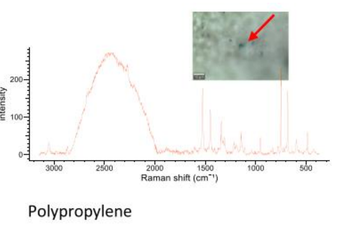


Figure 3

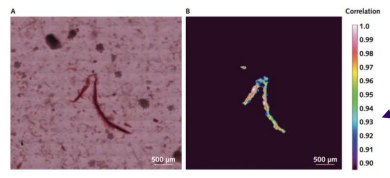


Figure 1

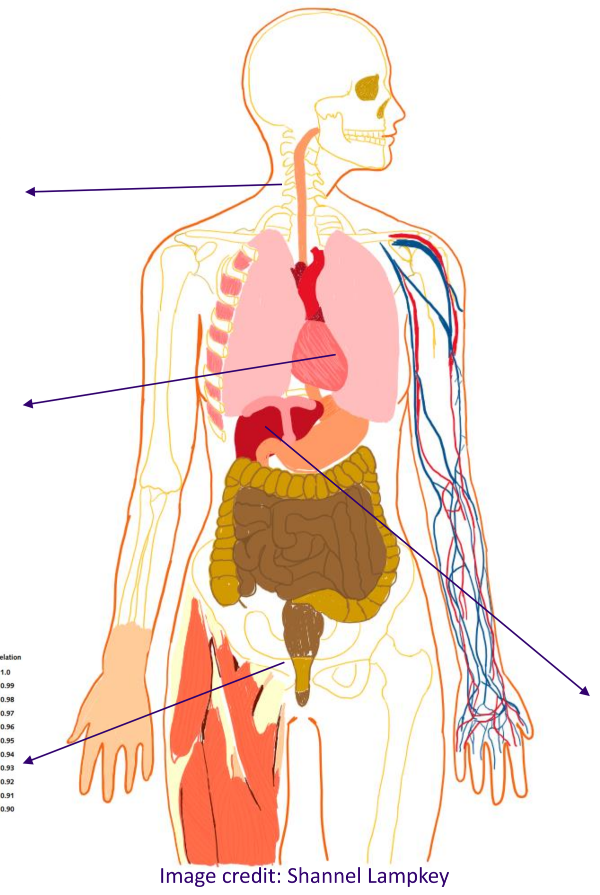


Image credit: Shannel Lampkey

In recent years, there have been numerous studies reporting the presence of MP's in various human tissues, fluids and secretions

> (Figure1) MPs were detected in human stool samples by Scwabl et. al. (2019) using FTIR. An estimated median concentration of 20 MPs per 10 g of stool was reported.

>(Figure 2) Sputum samples from 22 patients suffering from various respiratory diseases were positive for MPs (Huang et al., 2022). Polyester (PET) had the second highest exposure level of MPs in the sputum samples (99.25% of total), while polycarbonate (PC) had the lowest exposure level (0.07%) (Huang et al.,2022).

>(Figure 3) Parenchymal tissue from the distal and proximal regions of the left lung was collected from 20 adult individuals (Amato-Lourenco et al., 2021). 31 MPs were observed in 13 of the 20 samples, 87.5% were particle fragments and 12.5% were fibers (Amato-Lourenco et al., 2021). The most frequent polymer detected was polypropylene (35.1%), followed by polyethylene (24.3%) and cotton (16.2%).

>(Figure 4) MP concentrations were compared in cirrhotic livers and healthy livers (Horvatits et al., 2022). MPs identified from human tissues were: PS, PVC, PET, PMMA, POM, and PP (Horvatits et al., 2022). The quality of spectra matching was reported for the MPs identified, the mean signal to noise ratio was 24± 13 while the mean match quality was 76%±12% (Horvatits et al., 2022).

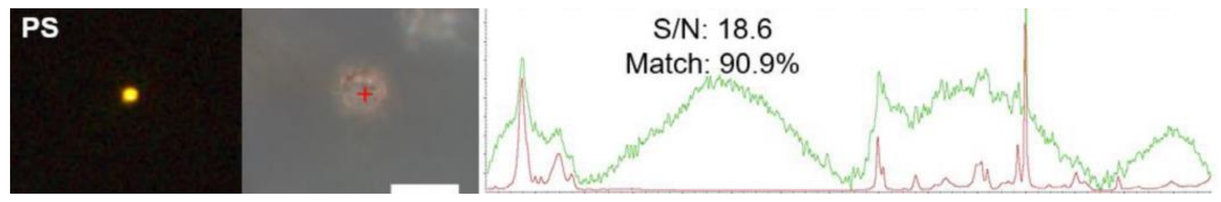


Figure 4

Microplastics as a Co-vector of Pollutants

MP exposure to the digestive system is of concern, especially when considering how much MPs are consumed through inhalation and ingestion

> Figure 5

- MPs as a vector of Chromium in a stimulated human digestive model, comparing PE, PP, PVC, PS and PLA MP's was studied (Liao and Yang, 2020).
- All MPs were put into a 'Whole Digestive System Method' (WDSM), a method that was established in a previous study Yu and Yang (2019). This method included a series of solutions that are meant to stimulate the environment of the various human digestive phases.
- The average Chromium(VI)/ Chromium(III) bioaccessibilites of the treated MPs simulating inhalation in the gastric, small intestinal and large intestinal phases were determined to be 13.2%/4.0%, 6.3%/5.3% and 2.8%/2.0%, respectively (Liao and Yang, 2020). The oral bioaccessibility in the gastric phases, oral bioaccessibility of Chromium (VI) was highest in the gastric phase (p<0.05) (Liao and Yang, 2020). While oral bioaccessibility of Chromium (III) was highest in the small intestinal phase (Liao and Yang, 2020).

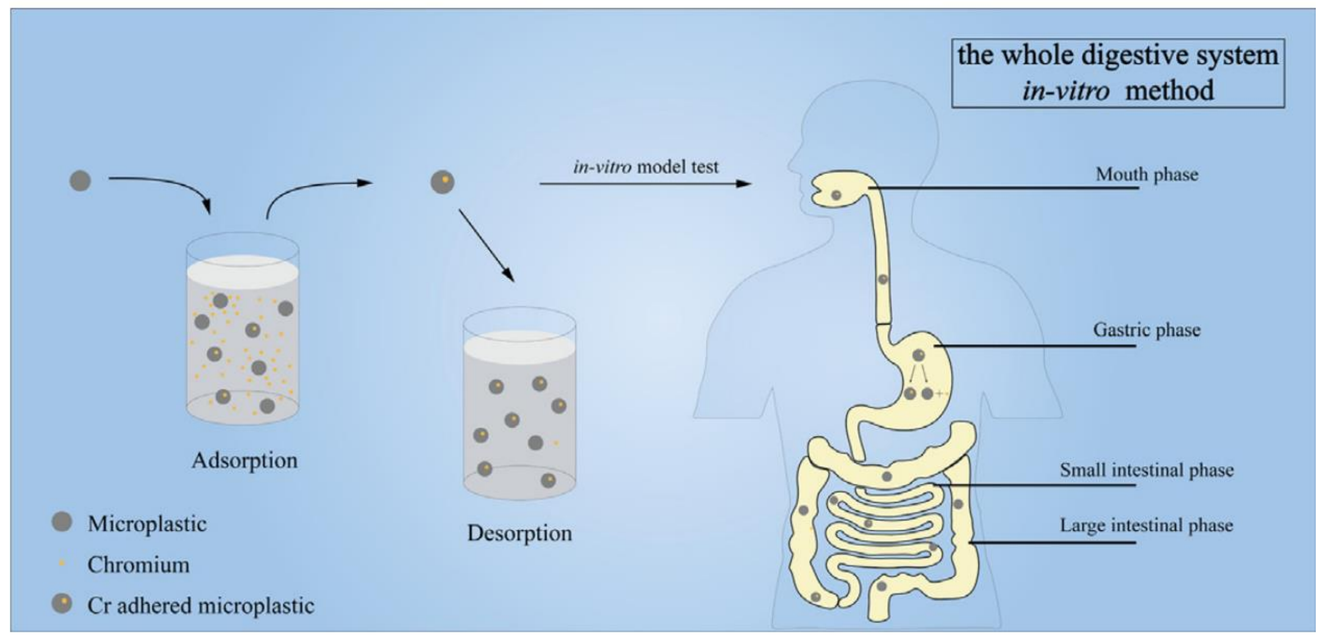


Figure 5

Microplastics in Placenta Tissue

>(Figure 6)

Researchers in Italy sought to better understand the impact of MPs in different placental cell compartments, using SEM and TEM analytical methods (Ragusa et al., 2023). MPs were found on the surface of various villous typologies, in intra/extracellular compartments of human placenta tissues sampled (Ragusa et al., 2023). Researchers reported morphological changes in rough ER and mitochondria are characteristic of ER stress and mitochondrial dysfunction, alongside presence of MPs (Ragusa et al., 2023).

>(Figure 7)

Using Raman spectroscopy, MPs were detected in different layers of placenta tissue (Ragusa et al., 2021). 12 MPs were detected and studied in detail, 5 of the 12 particles detected were found in the fetal side portion of the placenta, identified as Particles #1, #3, #10, #11, and #12 (Ragusa et al., 2021).

>(Figure 8, 9A/B)

MPs were detected in 6 out of 10 samples collected in 2006, 9 out of 10 samples collected from 2013 and 10 out of 10 in samples collected from 2021 (Weingrill et al. 2023). The average MP size detected from samples collected in 2006 were 2.82 ± 0.31 nanometers (Weingrill et al. 2023). The average MP size detected from samples collected in 2013 were 6.24 ± 0.57 nanometers (Weingrill et al. 2023). The average MP size detected from samples collected in 2021 was 5.14± 0.75 nanometers (Weingrill et al. 2023).

>(Figure 10)

Abundance of MP types varied between sample collection years. All MPs isolated and analyzed from 2006 samples were able to be classified and the percent abundance calculated: 22.73% polypropylene (PP), 22.73% polyester (PES), 13.64% polyurethane, 9.09% polyethylene vinyl acetate (PVA), 4.54% polyethylene terephthalate (PET), 4.54% polyethylene (PE) and 4.54% polyamide (Weingrill et al. 2023). The abundance of identified MP types from 2013 samples were calculated to be the following: 15.79% PP, 10.53% for PET, PVA and PES, 7.89% acrylonitrile butadiene styrene (ABS), 5.26% PE, 5.26% PU, 5.26% polycarbonate, 5.26% PA, 2.63% PVC, 2.63& polyvinyl alcohol and 2.63% polyacrylonitrile (Weingrill et al. 2023). The abundance of identified MP types were calculated to be the following: 15.79% PP, 10.53% for PET, PVA and PES, 7.89% acrylonitrile butadiene styrene (ABS), 5.26% PE, 5.26% PU, 5.26% polycarbonate, 5.26% PA, 2.63% PVC, 2.63& polyvinyl alcohol and 2.63% polyacrylonitrile (Weingrill et al. 2023).

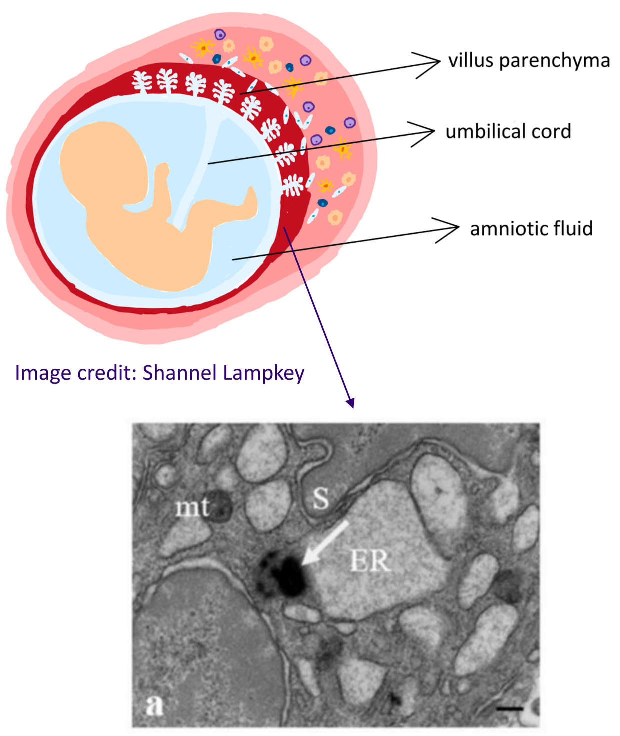


Figure 6

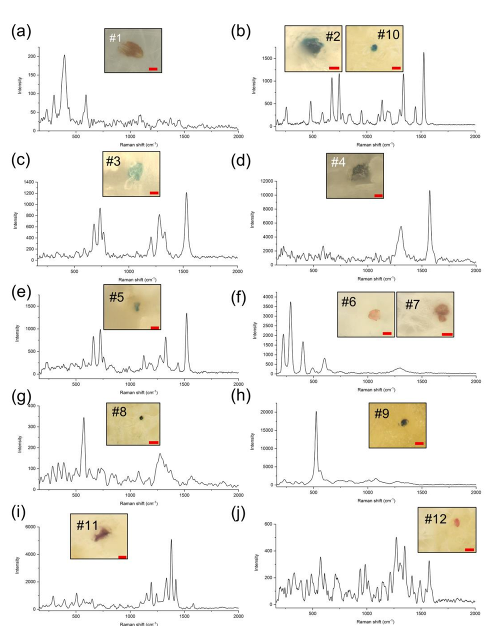


Figure 7

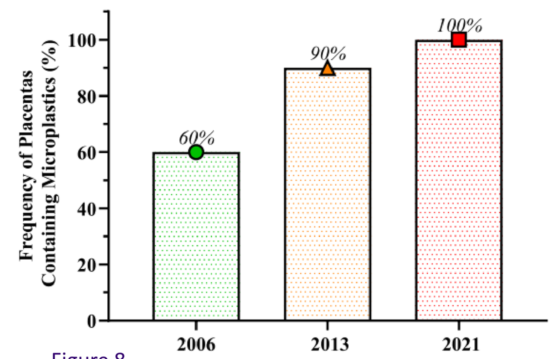


Figure 8

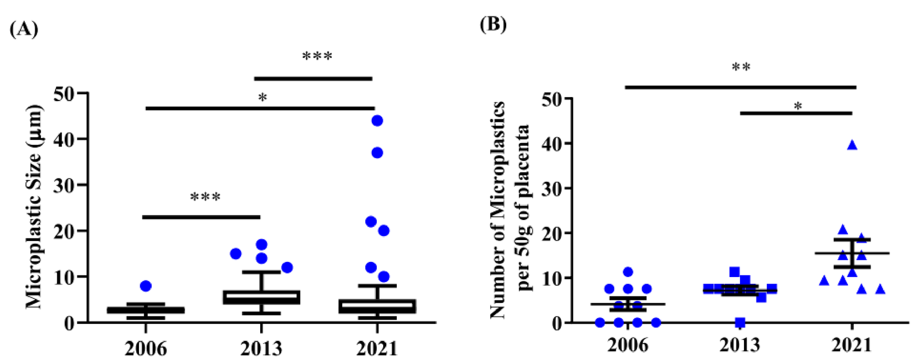


Figure 9: *p<0.05, **P<0.001, ***p<0.0001, One-way ANOVA

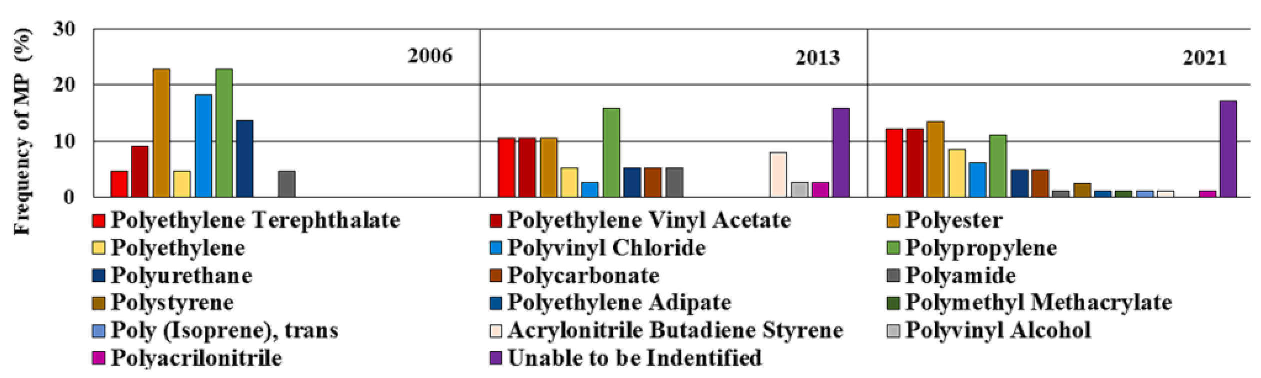


Figure 10

Discussion of Analytical Methods for Microplastics

- **(FTIR) spectroscopy and Raman spectroscopy are commonly used analytical methods for detecting MPs in environmental samples (Käppler et al., 2016)**
- **Precision of detecting total amount of MPs varies between FTIR and Raman spectroscopy methods. In environmental samples, the total number of Identified MPs was significantly higher using Raman imaging than FTIR imaging, 49 particles identified, and 32 particles identified respectively (Käppler et al., 2016)**
- **FTIR imaging was more appropriate for identifying polyesters because of an increase sensitivity of detecting C=O groups (Käppler et al., 2016)**
- **Raman imaging might lead to an underestimation of polyesters (except for PET) because of lack of sensitivity to C=O groups (Käppler et al., 2016)**
- **FTIR imaging is ideal for analyzing small MPs (500 µm – 50 µm) while Raman imaging is ideal for analyzing very small MPs (50 µm -1 µm) (Käppler et al., 2016)**
- **Cited studies note the limitations of various reference spectra libraries because reference spectra don't account for environmental degradation of MP samples**

Future directions

FTIR and Raman imaging can provide details on the characteristics of MP's present humans. These methods cannot provide insight on how MPs are interacting with specific parts of the body or influencing chronic conditions, if any.

- Scanning electron microscopy (SEM) and transmission electron microscopy (TEM) are methods that can provide insight as to how MPs are interacting with various tissues on a cellular level.
- Flow cytometry is a technology that is already available commercially. In combination with spectroscopy methods, it has the potential for providing additional insight on MPs present in patients and its impact on health conditions
- An expansion of reference spectra libraries like KnowItAll library (BD product), would allow for more accurate identification of degraded MP samples
- Incorporating AI image reading software to speed up MP analytical detection methods

Original Literature Review and Citations Requires OneDrive

Acknowledgements:

Many thanks to the Faculty and Staff at UWT for their guidance and support. Additional thanks to my fellow peers