The Role of Mechanical Aging and Photoweathering in the Fragmentation of Glitter Microplastics

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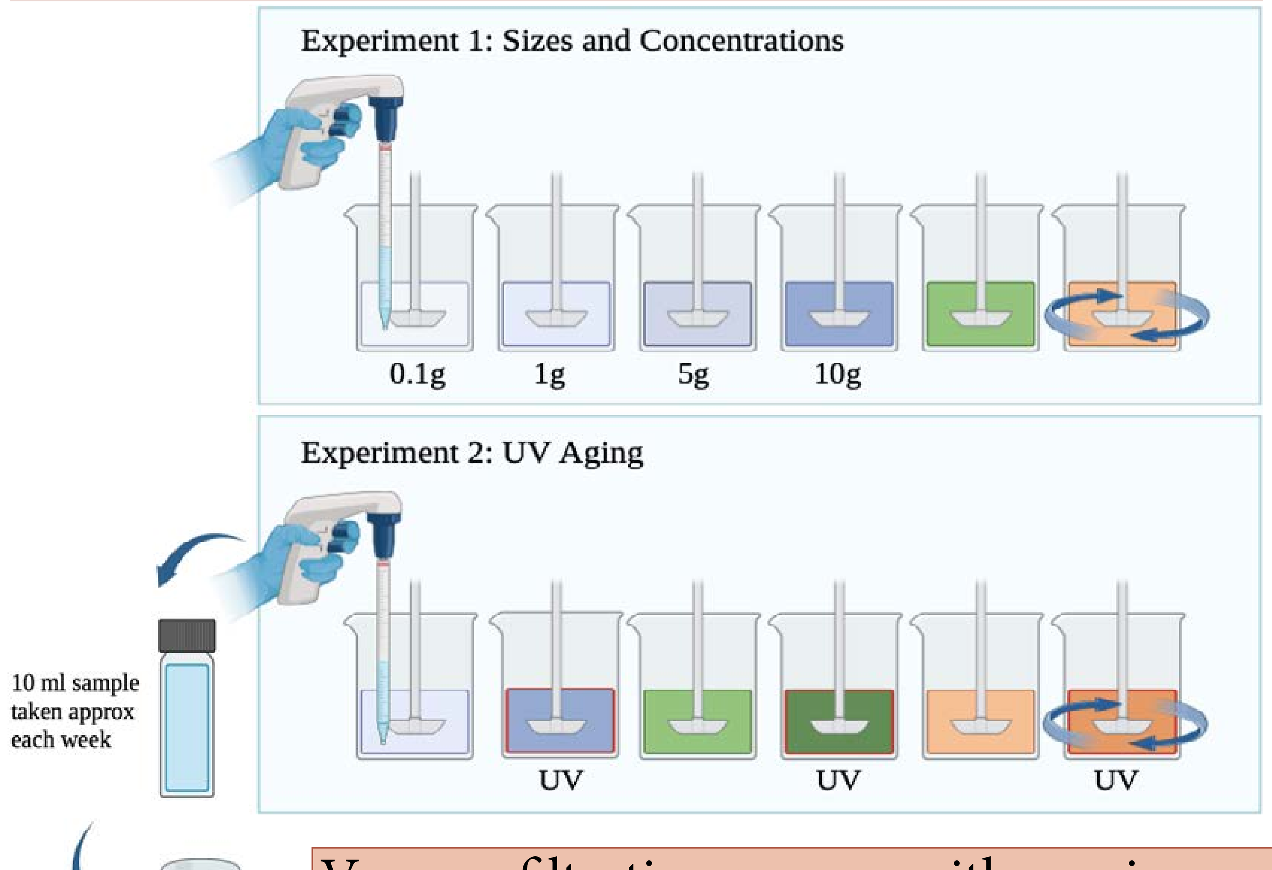
Introduction

Microplastic pollution in freshwater poses ecological and health risks, but key processes like fragmentation remain poorly understood. This study investigates how weathering processes such as particle-particle collisions and ultraviolet (UV) aging contribute to the formation of secondary micro- and nanoplastics. Glitter was used as a model microplastic due to it's uniformity and real world relevance as a primary microplastic.

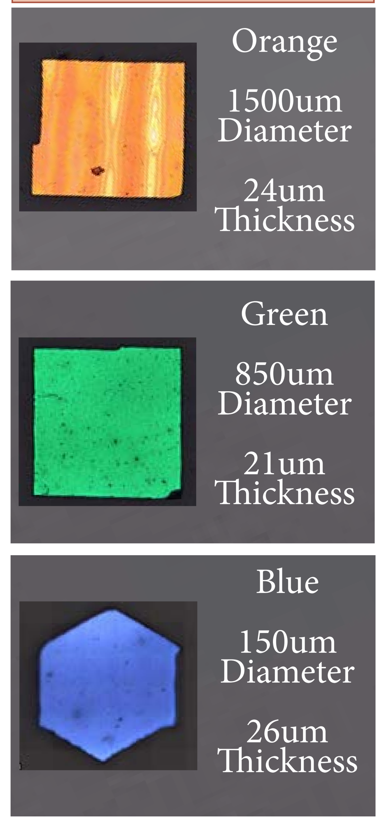
The main goals of this study are to:
1) characterize the physical and chemical properties of different size classes and colors of commercial microplastic glitters; and
2) test the weathering effects on microplastic glitters by simulating their degradability in wastewater treatment plants and the environment

Methodology

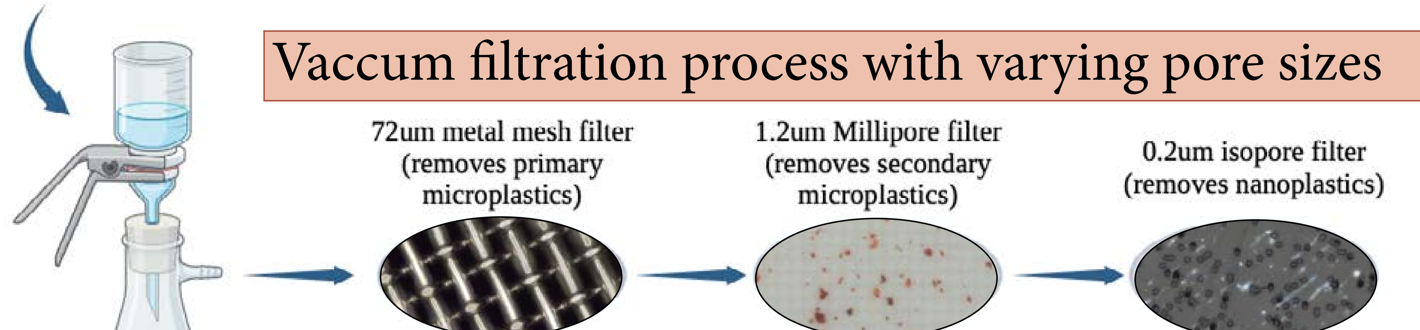
Experimental setup of jar tester with paddles to simulate particle-particle collisions and water shear forces:



Model Glitters Used



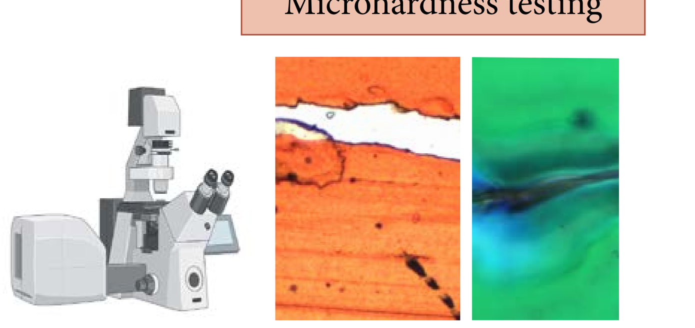
Vaccum filtration process with varying pore sizes

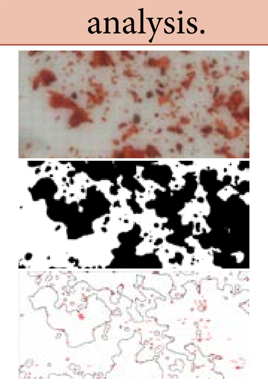


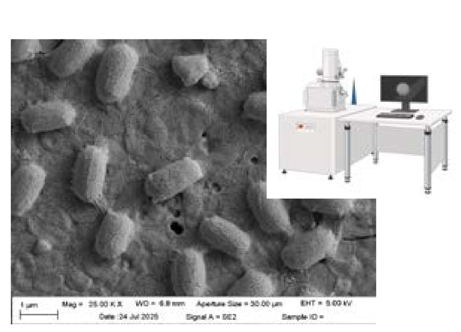
Isolated primary microplastics for further analysis by optical microscopy, Raman spectroscopy and Microhardness testing

Imaged 20x20 center of filter using at 100x objective. Used ImageJ for quantitative image analysis.

Used scanning electron microscopy to detect secondary nanoplastics and bacteria







Raman Spectroscopy

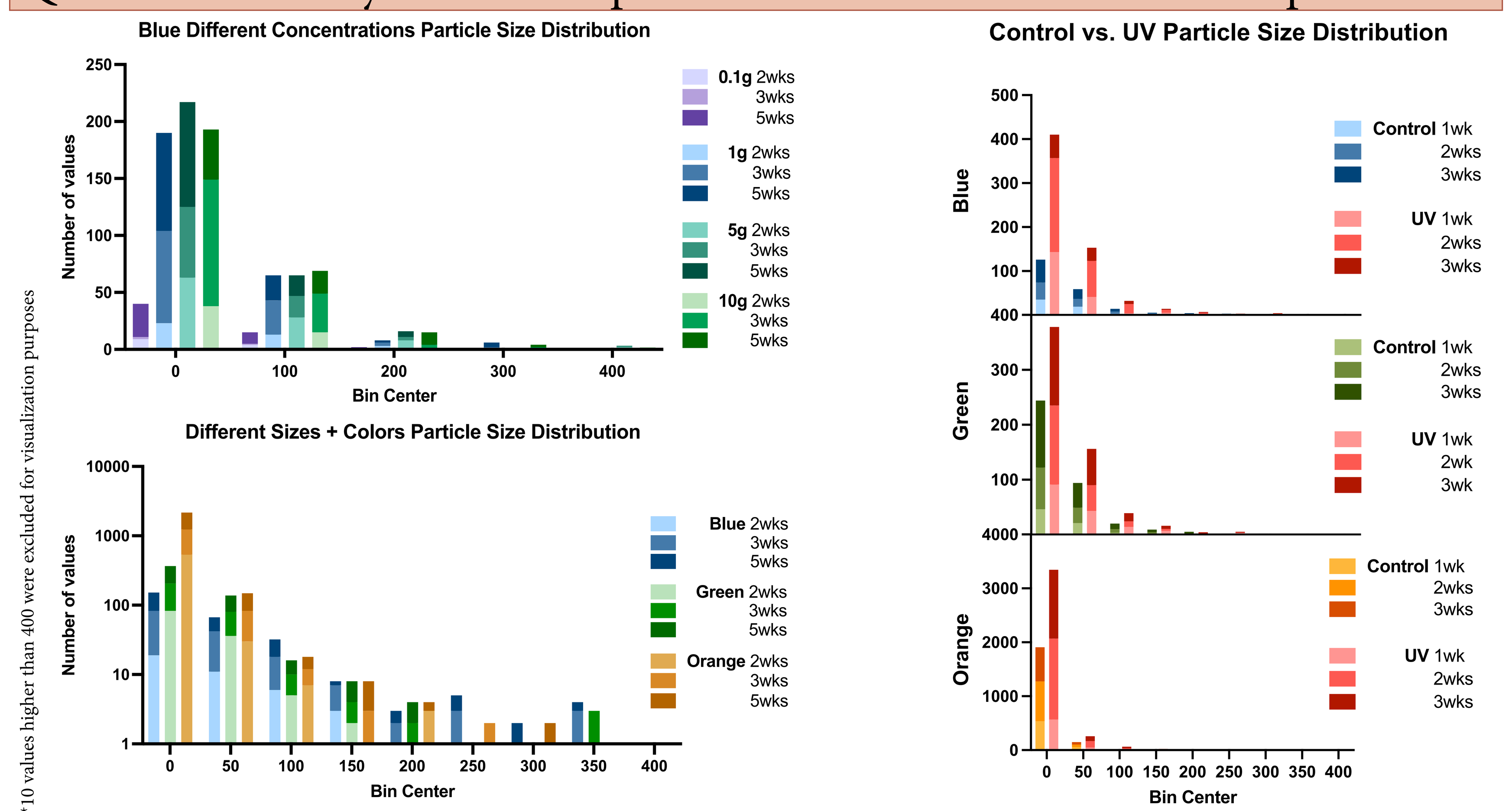
reflects chemical bonds to identify material composition an chemical changes. Raman spectra were taken from pristine glitters and after UV weathering.

Microhardness Testing

Evaluates material properties by indentation such as hardness (HT115) and elastic modulus (Eit). Testing was done on pristine glitters and after UV and mechanical weathering.

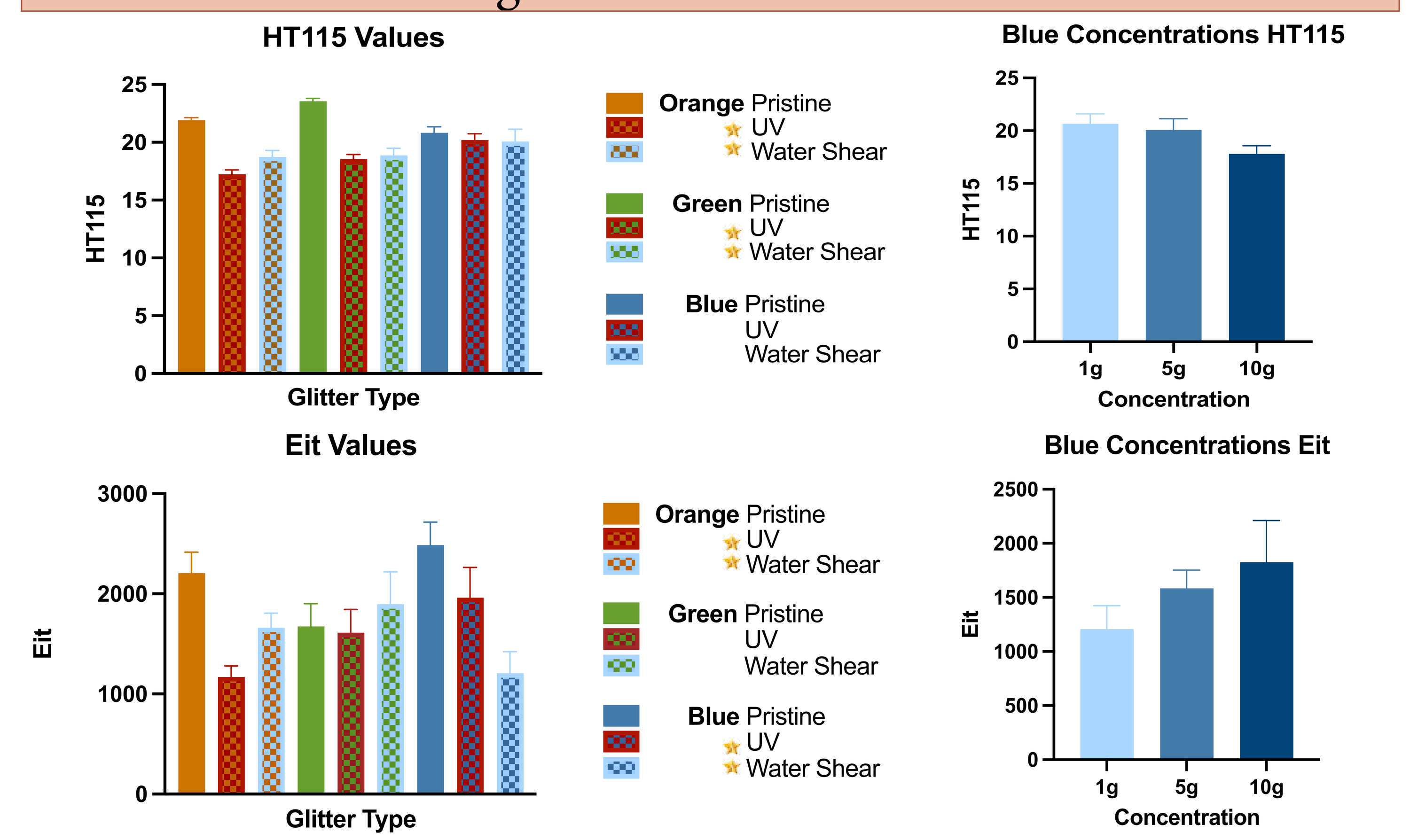
Results

Quantitative analysis of microplastics distributed on 1.2um Millipore filter



The histograms show a trend of exponential decay in the size distribution of the microplastics, with most particles in the 0–100 μm range and few above 400 μm. Particle concentration of the blue glitter had no significant effect on size distribution, while glitter size did: the largest glitter (orange, 1500 μm) produced ~10 times more small particles (0–100 μm) than the smallest glitter (blue, 150 μm).

Microhardness Testing



Orange: Significant* changes in both Eit and HIT115 after UV and mechanical weathering.

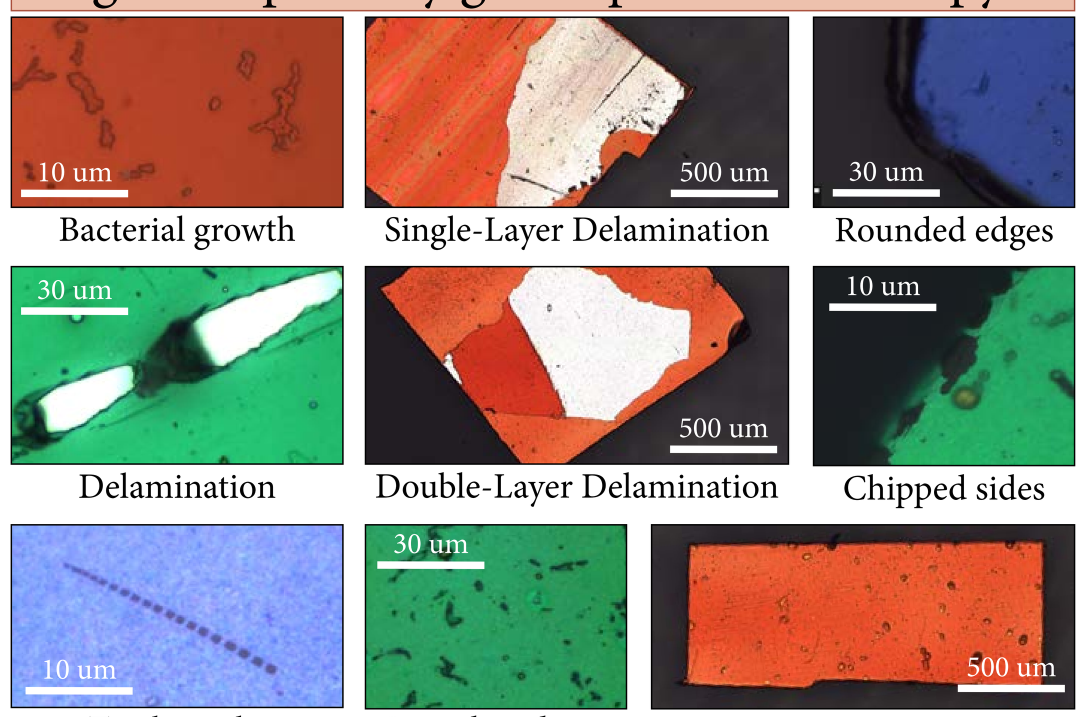
Green: Significant* change in HIT115 only; Eit unchanged.

Blue: Significant* change in Eit only; HIT115 unchanged.

Differencing concentrations show significant* differences in Eit (positive correlation) and HT115 (negative correlation)

*significant = p-value <0.0001

Degraded primary glitter photomicroscopy



Bacterial growth | Single-Layer Delamination | Rounded edges | Delamination | Double-Layer Delamination | Chipped sides | Track marks | Scratches/dents | Fragmentation

SEM Photomicroscopy

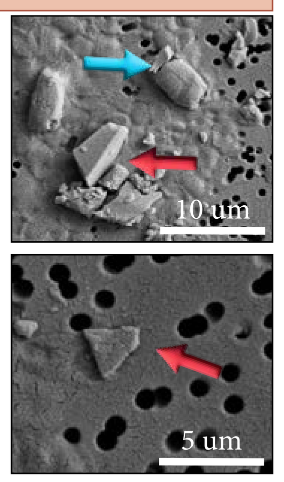
SEM revealed bacterial growth in the wastewater simulation and nanoplastics generated from particle collisions.

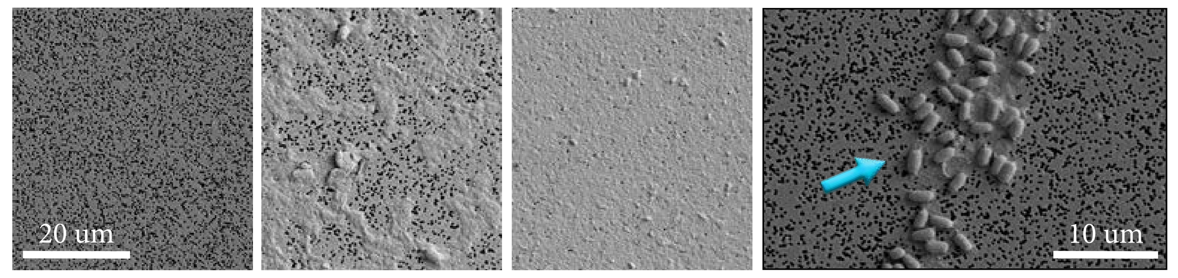
Bacteria were uniformly rod-shaped (~1 μm × ~2 μm).

Nanoplastics were not uniformly shaped, but generally had sharp edges and triangular shapes (~0.1 μm × ~2 μm).

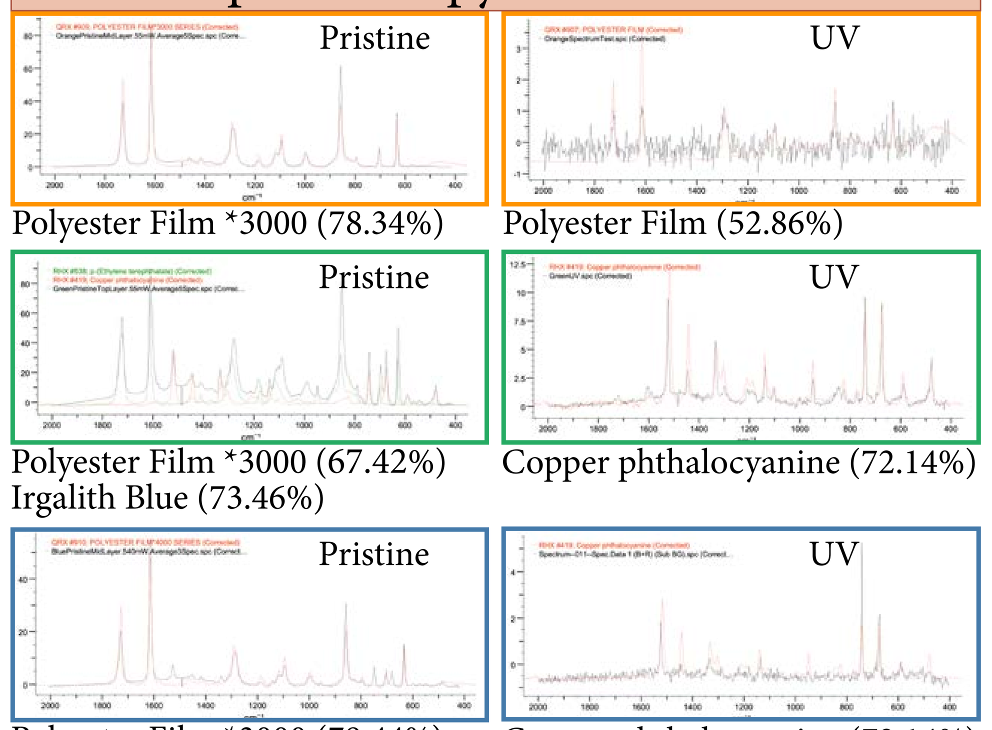
A biofilm-like layer, likely dead cells and extracellular matrix, covered much of the filter, hindering nanoplastic detection.

More cell material was observed in filters from higher-concentration samples and larger glitter sizes.





Raman Spectroscopy



Polyester Film *3000 (78.34%) | Polyester Film (52.86%)

Polyester Film *3000 (67.42%) Irgalith Blue (73.46%) | Copper phthalocyanine (72.14%)

Polyester Film *3000 (79.44%) | Copper phthalocyanine (72.14%)

Conclusions

Developed a reproducible methodology for filtering and imaging microplastics across size classes.

Secondary microplastics (1–2000 μm) formed via mechanical aging collisions showed an exponential decay in size distribution.

Photomicroscopy identified key damage types from glitter-on-glitter collisions.

SEM and optical microscopy confirmed biofilm growth on glitter; higher glitter concentrations and sizes likely increased bacterial presence due to greater surface area.

UV-aged glitter produced ~2× more secondary microplastics compared to pristine samples.

UV and mechanical weathering altered glitter properties, affecting hardness and elastic modulus, with color-dependent responses.

In blue glitter, increasing concentration raised elastic modulus but reduced hardness.

Raman spectroscopy revealed material differences between glitter colors — explaining variation in responses to aging and fragmentation — and chemical differences in the glitters after UV aging.

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