Effect of UV Light Exposure on Surface Characteristics and Sorption Capacity of Microplastics

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Abstract

Microplastics, particles less than 5 mm in diameter formed from the breakdown of plastic debris, are prevalent environmental pollutants. They have the potential to enter the human body and have relatively unknown effects on health. Little is known about the impact of environmental conditions such as ultraviolet light exposure on sorption capacity of potential pollutants by microplastics. This study tests the effect of ultraviolet light exposure (0, 1, 2, 24, and 96 hours) on the surface texture and sorption capacity of polystyrene microplastic spheres. Scanning electron microscopy and stereo optical microscopy were used to assess surface texture. Sorption capacity was assessed by measuring phenanthrene or hexachlorobenzene concentration over time. No significant difference in surface texture was observed. Phenanthrene concentration showed a steady decrease for 0, 1, 2, and 24 hour light exposed plastics, but this trend was not consistent for 96 hour light exposed plastics or hexachlorobenzene trials.

Introduction

- Approximately 320 million metric tons of plastic are produced per year globally.
- Plastic waste accumulates in marine and terrestrial environments, broken down to micro- and nano- plastics by wind and water.
- UV light causes photooxidation of plastics, causing the texture to turn brittle. 95% of UV light that reaches Earth's surface is UV-A (long wavelength) light.
- Sorption capacity is the ability of microplastics to absorb chemicals from the environment onto the surface.
- Nonpolar, neutral compounds sorb best such as phenanthrene and hexachlorobenzene as shown below

Figure 1: Phenanthrene (left) and hexachlorobenzene (right)

Methods

- 0.99 mm and 1.55 mm polystyrene spheres were visualized using SEM and stereo optical microscopy.
- Microplastics were placed in a petri dish and exposed to 0, 1, 2, 24, and 96 hours of UV light (365 nm). The UV light was placed directly above the petri dish. Irradiance was measured using a pyranometer 15 mm (height of petri dish) from light.
- 0.05 g of spheres were placed in 10 mL of 0.100 g/L solution phenanthrene solution (50% water/50% ethanol) or hexachlorobenzene solution (100% ethanol). Alternatively, 0.02 g plastics in 5 mL solution was used.
- Extraction of phenanthrene/hexachlorobenzene from 1 mL samples with 400 µL cyclohexane
- GC-MS: Single temperature ramp from 180 to 250 ℃. Area under the curve was measured. Phenanthrene displayed a peak at 6 min (m/z = 178). Hexachlorobenzene displayed a peak at 5.4-5.8 min (m/z = 284).
- Limit of detection found through serial dilution
- Concentration ratio = area under curve of initial concentration divided by area under curve of concentration at specific timepoint

Experimental Data

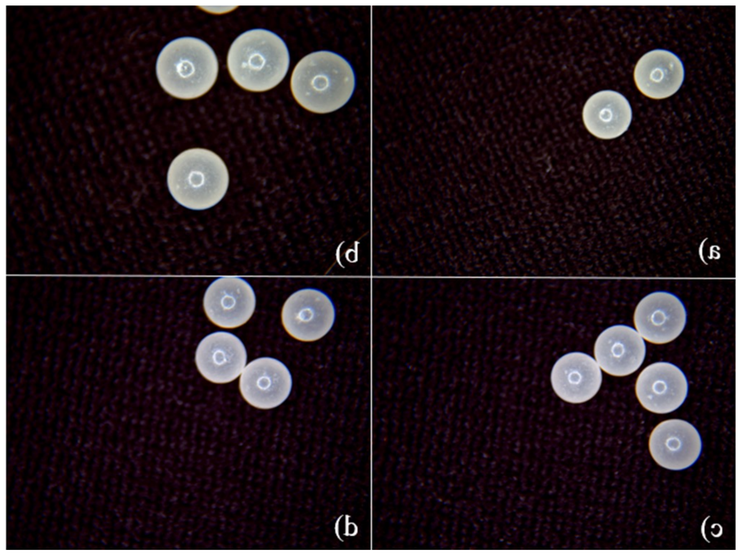

Figure 2: Surface texture showing cracking in a) no UV light b) 24-hour UV light c), d) 96-hour UV light exposed 1.55 mm polystyrene spheres.

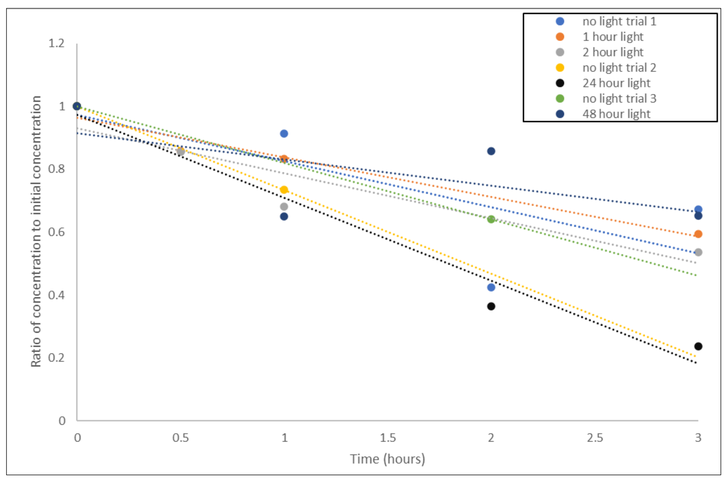

Figure 3: Concentration ratio of phenanthrene in 50% ethanol / 50% water at times 0, 0.5, 1, 2, and 3 hours with 0.99 mm polystyrene spheres exposed to 0-, 1-, 2-, 24-, or 48-hour UV light.

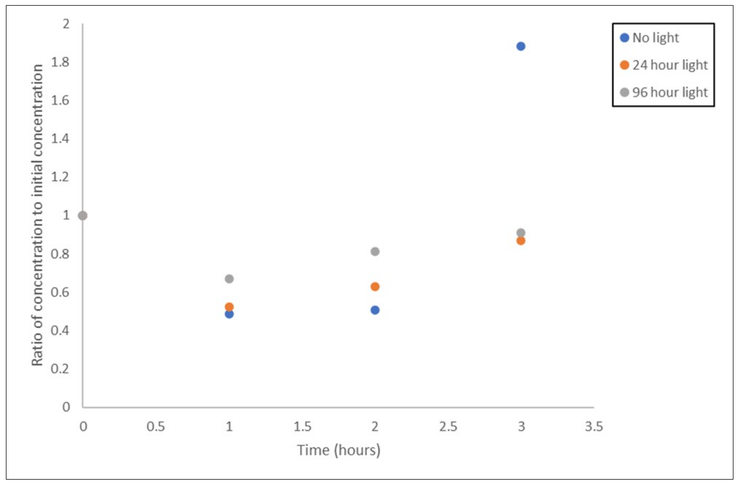

Figure 4: Concentration ratio of phenanthrene in 50% ethanol / 50% water at times 0, 1, 2, and 3 hours with 1.55 mm polystyrene spheres exposed to 0, 24, or 96 hours of UV light.

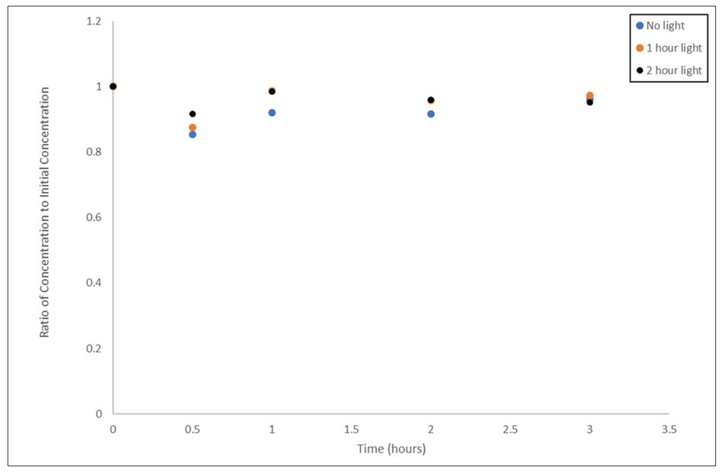

Figure 5: Concentration ratio of hexachlorobenzene in ethanol at time points of 0, 0.5, 1, 2, and 3 hours with 0.99 mm polystyrene spheres exposed to 0, 1, and 2 hours of UV light.

Results & Discussion

Results:

- No difference in surface texture of microplastics spheres
- Most significant decrease in concentration of phenanthrene observed for 24-hour light exposed PS spheres (Figure 3)
- The decrease in concentration over time was not observed for trials comparing 24- and 96-hour light exposed plastics (Figure 4) or hexachlorobenzene trials (Figure 5)

Discussion:

- Stereo optical microscopy produced better images as SEM images presented high charging (accumulation of electrons at the surface of a nonconductive material) and large white areas in images; future experiments should use metal coating on plastic spheres
- Longer light exposure times (on a monthly rather than hourly basis) will produce a visible change in surface texture due to photodegradation
- Lack of difference in surface texture could explain no steady decrease in concentration ratio over time for 24- and 96- hour experiments
- Possibly unreliability of extraction process
- Hexachlorobenzene does not sorb as strongly to the nonpolar surface of PS spheres as phenanthrene does
- Not accurate representation of ocean environment as solutions are 50 or 100% ethanol due to low solubility of phenanthrene and hexachlorobenzene in water

References

- Seidensticker, S. et al. "A combined experimental and modeling study to evaluate pH-dependent sorption of polar and non-polar compounds to polyethylene and polystyrene microplastics", *Environ Sci Eur.*, **2018**, 30(1) pp. 30. DOI: 10.1186/s12302-018-0155-z
- Song, Y.K. et al. "Combined Effects of UV Exposure Duration and Mechanical Abrasion on Microplastic Fragmentation by Polymer Type", *Environ. Sci. Technol.*, **2017**, 51, pp. 4368−4376. DOI: 10.1021/acs.est.6b06155
- Wright, S.L., Kelly, F.J. "Plastic and Human Health: A Micro Issue?", *Environ. Sci. Technol.*, **2017**, 51, pp 6634−6647. DOI: 10.1021/acs.est.7b00423

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