Triclosan Photolysis Facilitated by Polyethylene Microplastics; A Look into Surface Area

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OVERVIEW

Purpose

The objective of this study is to investigate how the surface area of polyethylene (PE) may affect the rate of photolysis of Triclosan absorbed to the surface of the plastic.

Methods

Aqueous solutions of triclosan with and without plastic were irradiated by UV light (300 nm wavelength) for different periods of time.

Results

There was no apparent increase in the rate of the photolysis when the surface area of the PE plastic was increased relative to amount of triclosan in solution.

METHODS

Photolysis Experiments

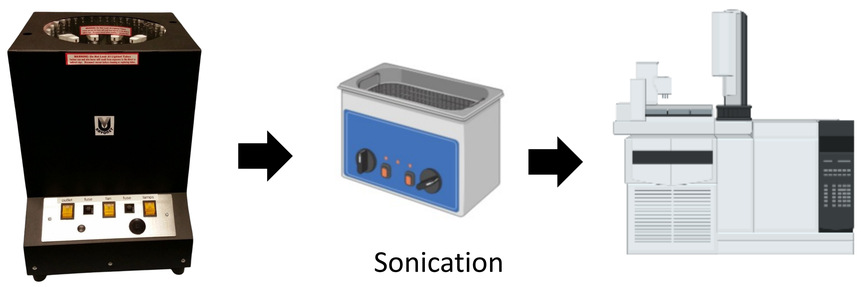
Aqueous solutions of TCS (10 mL, 11 ppm) were irradiated by 300nm wavelength light with and without PE particles (50.0 mg) from 0-20 minutes in a RPR-100 Rayonet reactor. The power density of the lamps was 240 W/cm^2. PE spheres having average diameters of 36, 69, 226, and 780 um were used in these experiments. PE spheres were purchased from Cospheric, Inc (Santa Barbara, CA). Triclosan and 2,8-DCDD standards were purchased from Millipore-Sigma (Milwaukee, WI) and used without further purification. Four replicates at each diameter and irradiation time were analyzed. Solutions with no PE present were irradiated, extracted by liquid-liquid extractions, and analyzed as controls.

Extraction

PE particles were separated by filtration and collected in a separate 4-dram vial and stored in a refrigerator until extraction. The particles were extracted by sonication for 10 minutes with 3.0 mL of MTBE and transferred to an autosampler vial with dry sodium sulfate prior to analysis.

GC-MS Analysis

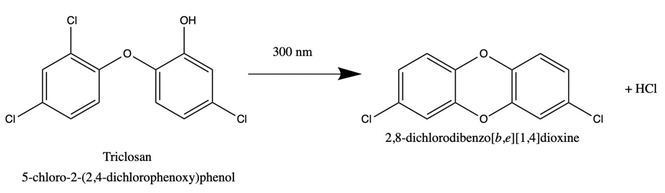
Samples were analyzed by an Agilent 6890 GC-MS. A linear gradient from 100 °C to 260 °C was used for separation. Total runtime was 13.7 minutes. One microliter was injected, and the mass analyzer was operated in selective ion monitoring mode. Two ions were monitored for triclosan (m/z 288 and m/z 290) and 2,8-DCDD (m/z 252 and m/z 254). The retention times for the 2,8-DCDD and Triclosan were 9.1 and 10.1 minutes, respectively.



INTRODUCTION

The production and widespread, versatile use of plastic in the last century has shown to have detrimental effects on the aquatic environment and thus poses consequential threats to human health [1]. As plastic debris accumulates in aqueous environments, it degrades into smaller fragments that are often ingested by aquatic organisms and their subsequent consumers.

Sunlight is known to convert triclosan to 2,8-dichlorodibenzodioxin (**Equation 1**) in the surface water of rivers and streams [3]. In natural water, microplastics can absorb persistent organic pollutants (POPs) and catalyze their transformation to other potentially more harmful molecules at a higher rate than in water alone [2]. This study aims to determine how the surface area of plastic affects the rate of POP photolysis. Photolysis reactions of triclosan (TCS), an antimicrobial agent, to 2,8-dichlorodibenzodioxin (2,8-DCDD) are being carried out in the presence of polyethylene particles ranging from 36 to 780 um in average diameter. The results will provide insight into plastic surface interactions and energy sharing with adsorbed molecules.



Triclosan
5-chloro-2-(2,4-dichlorophenoxy)phenol

2,8-dichlorodibenzo[*b*,*e*][1,4]dioxine

Equation 1. Photolytic conversion of triclosan to 2,8-DCDD

RESULTS AND DISCUSSION

We plotted the chromatographic peak ratios (2,8 DCDD/Triclosan) versus time for each particle size and irradiation time. These results are summarized in the Figure 1 bar graph.

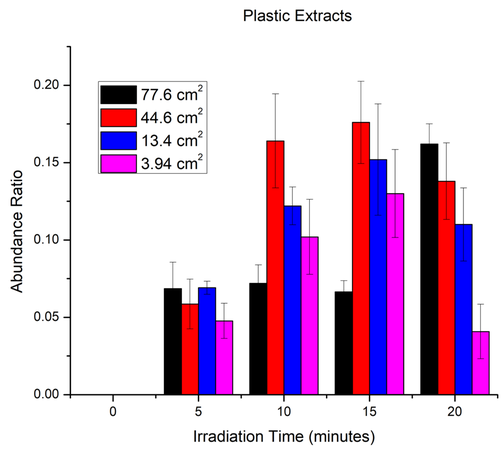


Figure 1. Plot of 2,8-DCDD/Triclosan abundance ratio versus time for different total surface areas of PE plastic and for reactions were no PE particles were present. The total surface area of each of the different diameter beads is shown in the inset.

It was hypothesized that the rate of photolysis would increase with the surface area of the plastic, since a greater surface area would create a larger area for pollutant attachment. The 2,8-DCDD/Triclosan ratio is observed to increase relative to the water alone (green bars) as time increases up to 15 minutes. At 20 minutes irradiation time, we found the absolute abundances of both the triclosan and 2,8-DCDD, suggesting that these products were being degraded to smaller molecules at extended irradiation times.

The Figure 1 plot does not show any clear correlation between the total surface area of the beads and the extent of photolysis when the amount of triclosan in solution is kept constant. The extent of photolysis is observed to be the greatest for the smallest total surface area beads (3.94 cm^2) at 10 minutes irradiation time. At 15 minutes irradiation time, the 13.4 cm^2 total Surface area beads show the greatest extent of photolysis. The smallest diameter beads (77.6 cm^2 total surface) never show the greatest amount of photolysis at any irradiation time.

CONCLUSIONS

The total surface area of the plastic particles in solution does not appear to influence the rate of photolysis of triclosan. These results suggest that the triclosan may exist on the surface of these particles in segregated clusters of triclosan (islands) that are hydrogen-bonded or held together by Van der waals forces. The absorbed energy might be randomized throughout these clusters prior to the formation of 2,8-DCDD.

REFERENCES

[1] Tong, H., Hu, X., Zhong, X., & Jiang, Q. (2021). Adsorption and Desorption of Triclosan on Biodegradable Polyhydroxybutyrate Microplastics. *Environmental toxicology and chemistry*, *40*(1), 72–78. https://doi.org/10.1002/etc.4902

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