國 立 臺 灣 海 洋 大 學
海洋環境與生態研究所 專題討論

中文題目：紅外線光譜分析微塑膠老化過程

英文題目：Characterizing photochemical ageing processes of microplastic materials using multivariate analysis of infrared spectra

作者: Misha Zvekic, Larissa C. Richards, Christine C. Tong a and Erik T. Krogh

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報告人：郭芷妤 環態所預研生

指導教授：許瑞峯助理教授

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Abstract

Microplastics in the environment are an emerging concern due to impacts on human and environmental health. In addition to direct effects on biota, microplastics influence the fate and distribution of trace organic contaminants through sorption and transport. Environmental weathering may influence the rate and extent of chemical sorption. Changes in the surface characteristics of four common plastics including low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), and polystyrene (PS) were followed under the influence of both artificial light (UV-B) and natural sunlight for up to six months. Attenuated total reflectance Fourier transform infrared (ATR-FTIR) spectra were collected at regular intervals. Principal component analysis (PCA) of the full dataset of UV-B weathered samples (n >500 spectra) simultaneously discriminated plastic type and extent of photochemical weathering. The magnitude of PCA scores correlated with exposure time and the loadings were consistent with surface chemistry changes including photooxidation. Projecting sunlight and UV-C exposed samples onto this PCA model demonstrated that similar chemical changes occurred, albeit at different rates. The results were compared to the carbonyl index (CI) with similar weathering trends indicating PP weathered at a faster initial rate than LDPE and HDPE. We propose that a multivariate approach is more widely applicable than CI as illustrated by PS, which lacked a stable reference peak. Kinetic analysis of the time series indicated that outdoor weathering occurred 5–12 times slower than the artificial exposure used here, depending on the plastic and the light source employed. The results provide unique insights into weathering processes and the photochemical age of naturally weathered plastics.

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中文摘要

由於微塑膠對人體和環境的負面影響，環境中存在的微塑膠儼然已成為新興的議題。微塑膠除了可直接對生物產生影響外，亦可通過吸附和傳輸調節痕量有機污染物的宿命和分佈。而環境風化則會影響化學吸附的速度和程度。於是該研究進行長達六個月的風化實驗以追蹤四種常見塑膠低密度聚乙烯（LDPE）、高密度聚乙烯（HDPE）、聚丙烯（PP）和聚苯乙烯（PS）在人造光（UV-B）和自然陽光下影響微塑膠的表面特性變化，並定期收集受風化之微塑膠衰減全反射傅立葉變換紅外線光譜(ATR-FTIR)。藉由經 UV-B 人造光風化樣品的 FTIR 圖譜數據(n > 500 spectra)進行主成分分析 (PCA)分析塑膠類型和光化學風化程度。結果指出 PCA 成份分數與曝曬時間及化學風化程度相關，而自然陽光和 UV-C 人造光下暴露樣品的 PCA 結果發現儘管速率不同，但化學風化亦有相似的變化。進一步使用 PCA 分群方式與傳統表達風化的羰基指數（CI）進行比較，兩者結果有相似的風化趨勢，並觀察到 PP 的初始風化速率比 LDPE 和 HDPE 更快。該研究建議多變量方法較 CI 適用於多種塑膠的老化判斷，如 PS 因缺乏穩定的參考峰，因而不適用於 CI 方法。此外，時間序列的老化動力學分析亦指出室外(自然)風化的速度較此處使用的人工風化慢 5-12 倍，其差異在於所使用的塑膠材質與光源。綜上所述，該研究為微塑膠風化過程與光化學速率提供獨特的見解。