Leaching and Fluorescence Characteristics of Dissolved Organic Matter Released from Common Consumer Plastics

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ABSTRACT

Plastic pollution poses increasing risks to wildlife, human health, and aquatic ecosystems, acting as a source and vector of dissolved compounds. This study investigated the leaching and fluorescence characteristics of dissolved organic matter (DOM) from three common consumer plastics: polypropylene (PP), low-density polyethylene (LDPE), and polyethylene terephthalate (PET). Plastics were incubated under simulated light or dark conditions for 21 days, and dissolved organic carbon (DOC) and fluorescent DOM (FDOM) were measured to quantify leaching amounts and characterize DOM quality. Our results showed that PP released the highest DOC concentrations, while LDPE and PET showed much lower levels. By day 21, average DOC leaching from PP, LDPE, and PET was 10.50, 1.62 and 0.53 mg $C \cdot m^{-2}$ of plastic surface, respectively. Corresponding leaching rates were 4.02, 0.56 and <0.10 mg $C \cdot m^{-2} \cdot d^{-1}$. In contrast to differences in DOC quantity, the FDOM of all plastics exhibited similar spectral features, with a major tryptophan-like peak at 295–305 nm excitation and 335–340 nm emission, and a minor peak at 235–254 nm excitation and 335–340 nm emission. These fluorescence signals suggest that plastic-derived DOM is bio-labile and potentially influenced by additives. Overall, the results confirm that common consumer plastics are a reactive source of DOM that may alter carbon cycling and microbial processes in aquatic environments. We suggest that both plastic type and additives likely affect DOM leaching behavior, with implications for understanding the broader ecological impacts of plastic pollution.

Keywords: Carbon cycling, Dissolved organic matter, Fluorescent DOM, Leaching, Plastic pollution

INTRODUCTION

Plastics are synthetic organic polymers composed of long, high molecular-weight molecules consisting of repeating units called monomers (Thevenon *et al*., 2014). They are widely used to produce a wide range of products such as bags, cups, straws, bottles, and boxes, and play an important role in modern daily life. However, these products are discarded after a short period of use. In Thailand, 26.8 million tonnes of solid waste are generated annually, with plastic waste largely disposed of in landfills, although a portion inevitably enters rivers and coastal waters (Leknoi *et al*., 2024).

Many researchers have studied the impact of plastic waste on wildlife, human health, and ecosystems. Plastics can cause malnutrition, injury, or death in marine mammals, fish, and seabirds, and also absorb harmful chemicals from the environment (Sigler, 2014 and references therein). Another concern is the leaching of dissolved organic matter (DOM) from plastics and its impact on carbon cycling and microbial ecology in the ocean. Ward *et al*. (2019) and Zhu *et al*. (2020) reported DOC leaching from several plastic types, including virgin plastics, commercial polystyrene (PS), post-consumer plastics, and debris collected from the North Pacific Gyre. Lee *et al*. (2020a) revealed that DOM derived from microplastics can act as a precursor of trihalomethanes. Romera-Castillo *et al*. (2018) found that six types of commercial

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plastics release DOC into seawater and stimulate heterotrophic microbes, while Romera-Castillo *et al*. (2022) reported increased bacterial activity in DOM derived from plastic.

DOM is a complex mixture of organic compounds that plays a key role in aquatic processes. DOM plays a crucial role in the microbial loop, a fundamental component of aquatic ecosystems. It serves as a primary carbon source for microbial metabolism and growth (Chen *et al*., 2021), contributes to nutrient cycling (Ogawa and Tanoue, 2003), and affects the concentration and fate of atmospheric CO_2 (Moran *et al*., 2016). However, DOM may also deteriorate water quality. For example, Parveen *et al*. (2024) reported that DOC leached from microplastics can form trihalomethanes (THMs) and haloacetic acids (HAAs), which are toxic disinfection byproducts (DBPs) in chlorinated water. Importantly, the effectiveness of DOM depends on its reactivity, which is governed by its characteristics (Fellman *et al*., 2010).

Despite increasing concerns, there is limited information about the production and characteristics of plastic-derived DOM in Thailand, particularly from commercial plastics. This study investigated DOC leaching from three commonly used plastics, and characterized the leachates using fluorescence excitation–emission matrix (EEM) spectroscopy. A better understanding of the amount, rate, and characteristics of DOM leached from commercial plastics can help inform pollution mitigation strategies.

MATERIALS AND METHODS

Plastic samples and preparation

Three common and widely used commercial plastics in Thailand were selected: polypropylene (PP) and low-density polyethylene (LDPE) plastic bags, and polyethylene terephthalate (PET) food boxes. Each type of plastic was purchased from a local supermarket. The plastics were cut into pieces of 0.7×0.7 cm, giving a total surface area of approximately 1 cm^2 (both sides).

To minimize contamination of DOM, strict handling procedures were followed: plastic gloves and use stainless-steel forceps were used whenever possible, a rotary paper cutter was used instead of scissors, and each type of plastic was wrapped separately in aluminum foil until use.

Leaching experiments

For the leaching experiments, 1,135 cm^2 of each plastic type was placed in pre-cleaned 1,000 mL glass bottles filled with 900 mL of sterilized DI water (autoclaved at 121 °C for 20 min). For dark controls, bottles were fully wrapped in aluminum foil. Additional controls containing only sterilized DI water were included. All treatments were performed in triplicate (n = 3).

Incubations were conducted in a temperature-controlled incubator (JSR JSCC-150CP) under simulated sunlight from a 200W full-spectrum LED lamp (400–800 nm). Light intensity was 72,750.5 lx (approximately 80 Klux), with PAR of 259 $W \cdot m^{-2}$ and PPFD 1,246 $\mu mol \cdot m^{-2} \cdot s^{-1}$, under a 12 h light:12 h dark cycle. These light intensities are within the ranges commonly found in Thailand. The incubator temperature was maintained at ~ 29 °C, and bottles were continuously mixed on a shaker at 45 rpm throughout the incubation period (21 days).

Sampling and filtration

Water samples were collected at 0, 1, 2, 3, 7, 14, and 21 days from each replicate of light, dark, and control treatments. Samples were filtered through pre-ashed (2 h, 550 °C) Whatman GF/F filters using a stainless-steel filter holder. To prevent contamination from extraneous plastic materials, only non-plastic equipment was used (e.g., glass syringes, stainless-steel tubes, and aluminum foil-wrapped stoppers). Filtered water samples were stored in a pre-cleaned amber glass bottles and keep in the dark at -20 °C until further analysis. Samples were not stored for longer than one week.

DOC analysis

DOC concentrations were measured using a TOC analyzer (Analytik Jena Multi N/C 3100, Germany). Standard solutions [potassium hydrogen phthalate (KHP), Na_2CO_3, and $NaHCO_3$] were prepared fresh daily to ensure accuracy. DOC concentrations from control treatments were subtracted from those in plastic treatments. Values were normalized to the plastic surface area (mg $C \cdot m^{-2}$).

Leaching rates were calculated as:

$$\text{Leaching rate} = (C_f - C_o) / (t_f - t_o)$$

where C_f and C_o are the final and initial DOC (mg $C \cdot m^{-2}$), and t_f and t_o are the corresponding sampling time (days).

FOM analysis

Fluorescent dissolved organic matter (FDOM) was analyzed using spectrofluorometer (JASCO FP-8350, Japan). Excitation and emission wavelengths were scanned between 220–500 nm at 5 nm increments, with a measurement speed to 500 $nm \cdot min^{-1}$. Analyses were conducted at 25 °C in 1 cm quartz fluorescence cuvettes, using Milli-Q water as a blank.

Three-dimensional excitation–emission matrices (EEMs) were processed with JASCO software. Fluorescence peaks were identified using peak-picking and compared to published references DOM classification (Coble, 1996; Coble *et al*., 1998; Yamashita and Tanoue, 2003).

Statistical analysis

Differences among plastic types were assessed using one-way analysis of variance (ANOVA) followed by Tukey's post-hoc test (IBM SPSS statistic version 28.0). The t-test was used to analyze the significant differences between dark and light conditions within each plastic type.

RESULTS

Leached DOC and light influence

All tested commercial plastics released DOC into the water under both light and dark conditions. Leaching began immediately upon contact with water, but the amounts of DOC varied greatly among plastic types. PP released the highest amount of DOC, whereas LDPE and PET showed negligible and nearly constant values throughout the incubation.

After 24 h, DOC concentration in the PP treatment were 0.71 mg $C \cdot L^{-1}$ under light and 0.83 mg $C \cdot L^{-1}$ under dark conditions. DOC concentrations in PP continued to increase gradually over the 21-day incubation, reaching 1.45 (light) and 1.62 mg $C \cdot L^{-1}$ (dark) by day 21 (Figure 1). In contrast, DOC concentrations from LDPE and PET remained low: 0.35 (light), 0.26 mg $C \cdot L^{-1}$ (dark) and 0.19 (light) and 0.08 mg $C \cdot L^{-1}$ (dark) for PET at 24 h. By day 21, concentrations of leached DOC from LDPE and PET were ~0.2 and <0.1 mg $C \cdot L^{-1}$, respectively.

Normalized to plastic surface area, PP consistently exhibited the highest leaching and significantly difference ($p<0.05$) from LDPE and PET (Table 1, Figure 2). After 24 h, the average amounts of leached DOC were 6.10, 2.42, and 1.00 mg $C \cdot m^{-2}$ for PP, LDPE, and PET, respectively under both conditions. By day 21, PP released 10.50 mg $C \cdot m^{-2}$, while LDPE and PET released 1.62 and 0.53 mg $C \cdot m^{-2}$, respectively. No significant difference ($p \geq 0.05$) were detected between light and dark treatments.

Leaching rates of DOC

Leaching rates (LR) of DOC from PP were highest (4.02 mg $C \cdot m^{-2} \cdot d^{-1}$) during the first two days of incubation under both light and dark conditions. The average LR for PP was 3.45±1.19 (range: 2.67–4.82) mg $C \cdot m^{-2} \cdot d^{-1}$ under light and 4.59±0.29 (range: 4.32–4.90) mg $C \cdot m^{-2} \cdot d^{-1}$ under dark conditions. After day 2, LR declined steadily until day 14, ranging from 0.21–0.33 (light) and 0.05–0.12 (dark) mg $C \cdot m^{-2} \cdot d^{-1}$. No further DOC release was detected after day 14, indicating stabilization of leaching.

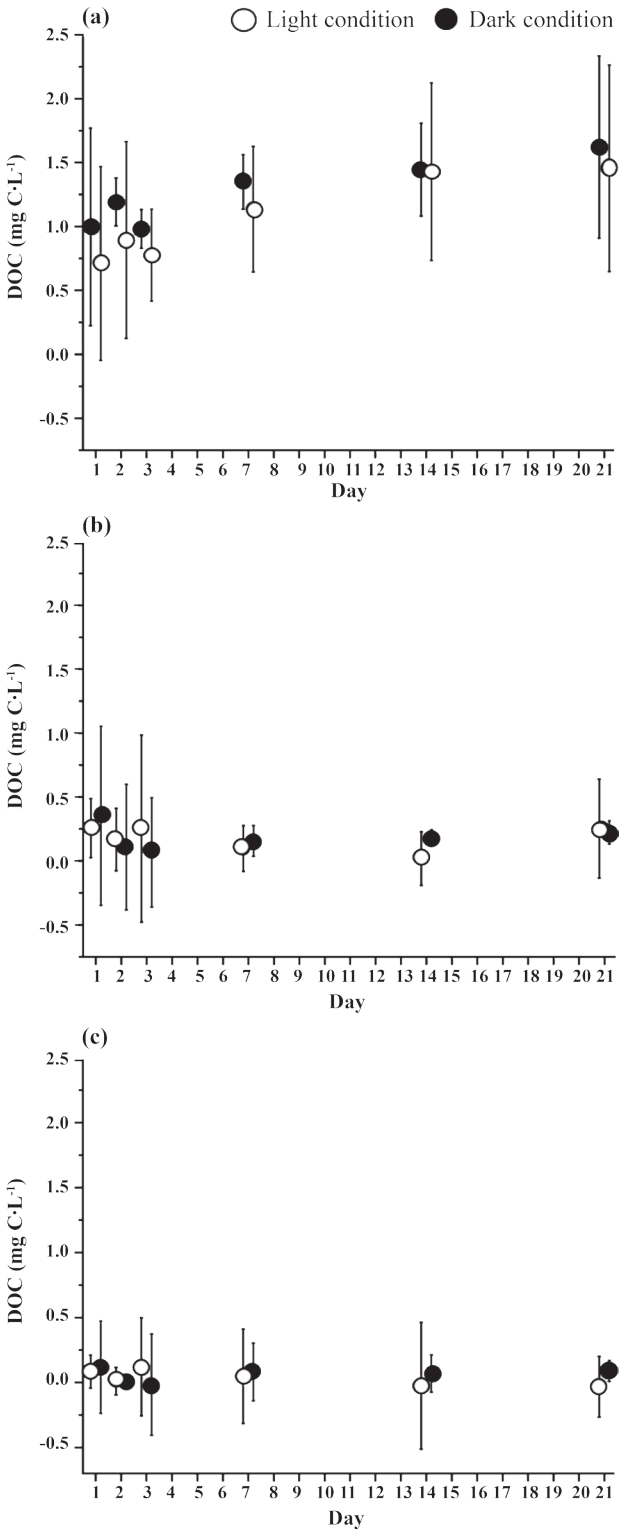

Figure 1. Dissolved organic carbon (DOC) released from (a) polypropylene (PP), (b) low-density polyethylene (LDPE) bags, and (c) polyethylene terephthalate (PET) under light (open circles) and dark (closed circles) conditions during a 21-day incubation. Data represent mean values±standard deviation (SD) of replicate measurements.

Table 1. Dissolved organic carbon (DOC) released from polypropylene (PP), low-density polyethylene (LDPE), and polyethylene terephthalate (PET) under light and dark conditions at day 1 and 21.

Type	Time (day)	DOC		Average	p-value
		Artificial light	Dark		
PP	1	5.63±2.42	6.57±0.48	6.10±1.64[a]	2.4×10^{-5}
LDPE		2.80±2.24	2.03±0.74	2.42±1.55[b]	
PET		1.00±1.03	0.66±0.40	0.83±0.72[c]	
PP	21	9.93±2.22	11.07±1.96	10.50±1.97[a]	2.7×10^{-9}
LDPE		1.52±0.25	1.72±1.07	1.62±0.70[b]	
PET		0.60±0.31	0.12±0.21	0.32±0.34[c]	

Mean±SD with different lowercase superscript letters are significantly different ($p<0.05$).

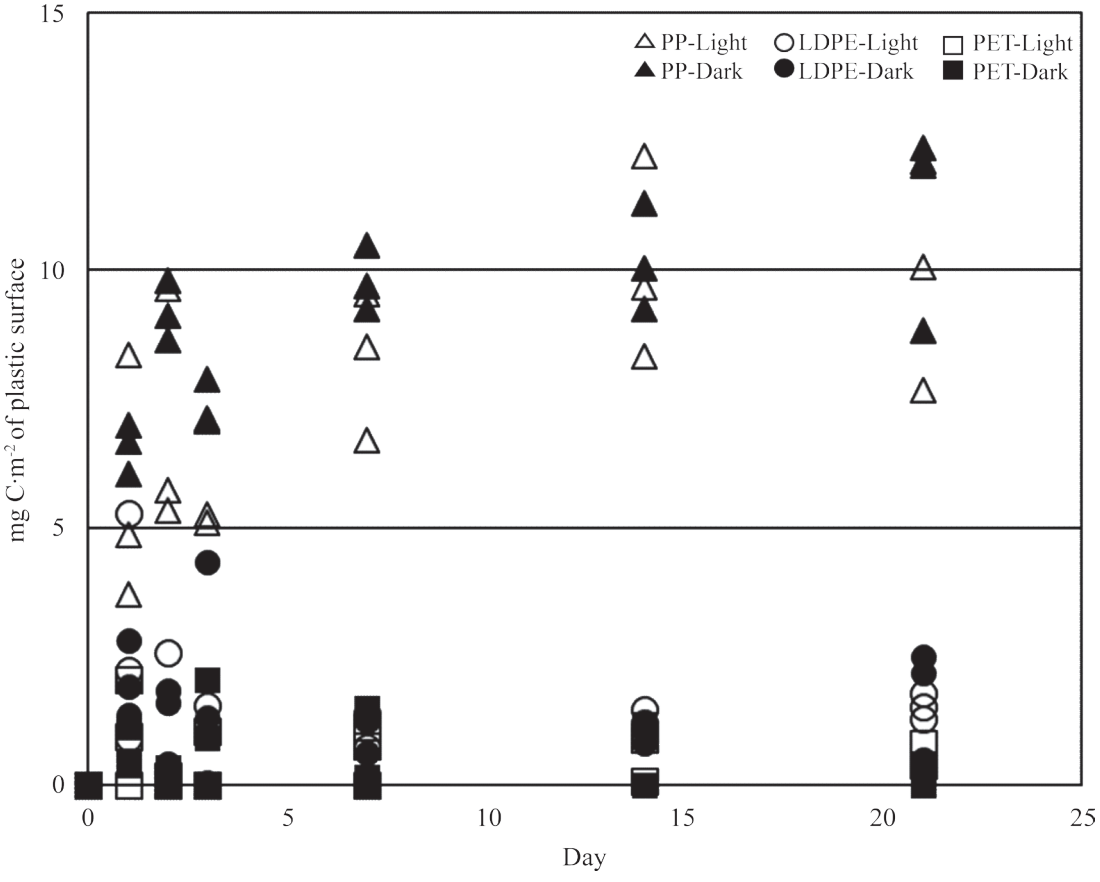

Figure 2. Dissolved organic carbon (DOC) leaching (mg C·m^{-2} of plastic surface) from different plastic types (polypropylene, PP; low-density polyethylene, LDPE; polyethylene terephthalate, PET) under light and dark conditions over a 21-day incubation. Data points represent replicate measurements for each treatment across sampling days.

In contrast, LDPE and PET exhibited consistently low leaching rates throughout the experiment. During the first two days, the average LR values of LDPE and PET were 0.56 and <0.10 mg $C \cdot m^{-2} \cdot d^{-1}$, respectively.

Fluorescence characteristic of leached DOM

No fluorescence peaks were detected in the control samples (data not shown), confirming that all observed peaks originated from plastics. Distinct peaks were detected in the excitation-emission spectra of all three commercial plastics over the incubation period.

For PP, the major fluorescence peak appeared at 300–305 nm excitation and 335–340 nm emission. Similar peaks were observed for LDPE (295–305 nm excitation, 335–340 nm emission) and PET (300 nm excitation, and 335–340 nm emission). Additionally, a minor peak was consistently detected for all three plastics at 235–254 nm excitation and 335–340 nm emission.

Fluorescence excitation–emission matrix (EEM) plots of leached DOM under dark conditions showed peak patterns similar to those under light. Representative EEMs of leached DOM from day 1 and 21 are presented in Figure 3.

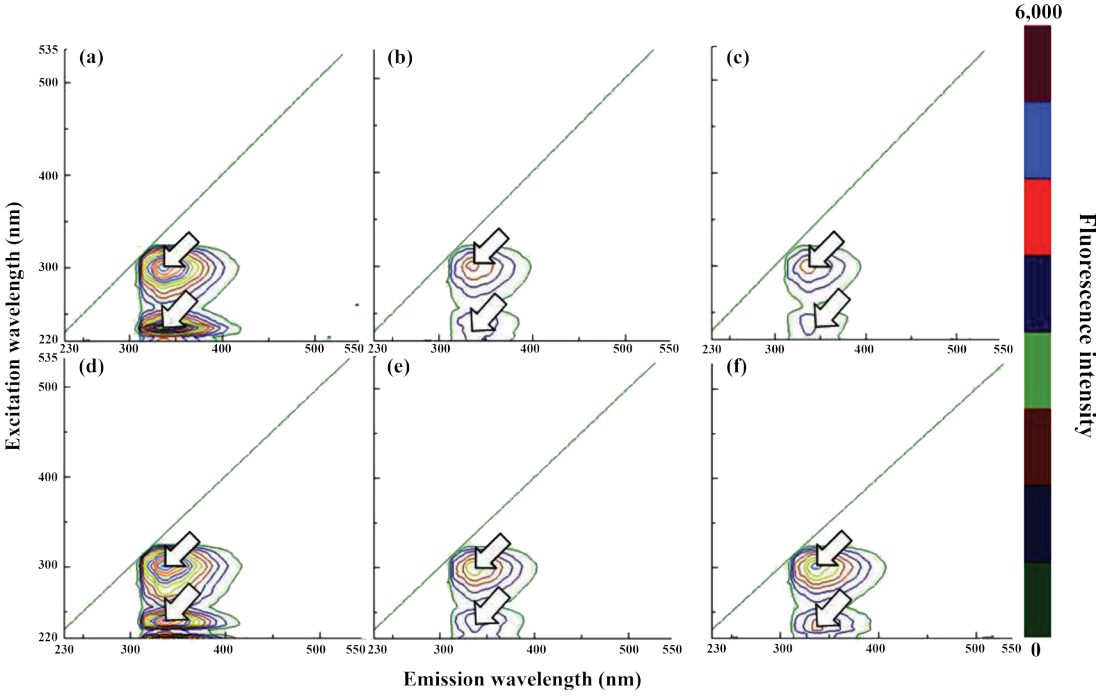

Figure 3. Excitation-emission matrix (EEM) fluorescence spectra of dissolved organic matter (DOM) leached from polypropylene (PP), low-density polyethylene (LDPE), polyethylene terephthalate (PET) under light and dark conditions at day 1 and day 21: (a) Day 1 PP-light, (b) Day 21 PP-light, (c) Day 1 LDPE-light, (d) Day 21 LDPE-light, (e) Day 1 PET-light, (f) Day 21 PET-light, (g) Day 1 PP-dark, (h) Day 21 PP-dark, (i) Day 1 LDPE-dark, (j) Day 21 LDPE-dark, (k) Day 1 PET-dark, and (l) Day 21 PET-dark. Contour plots show fluorescence intensity (arbitrary units, color scale) with arrows indicating fluorescence peaks.

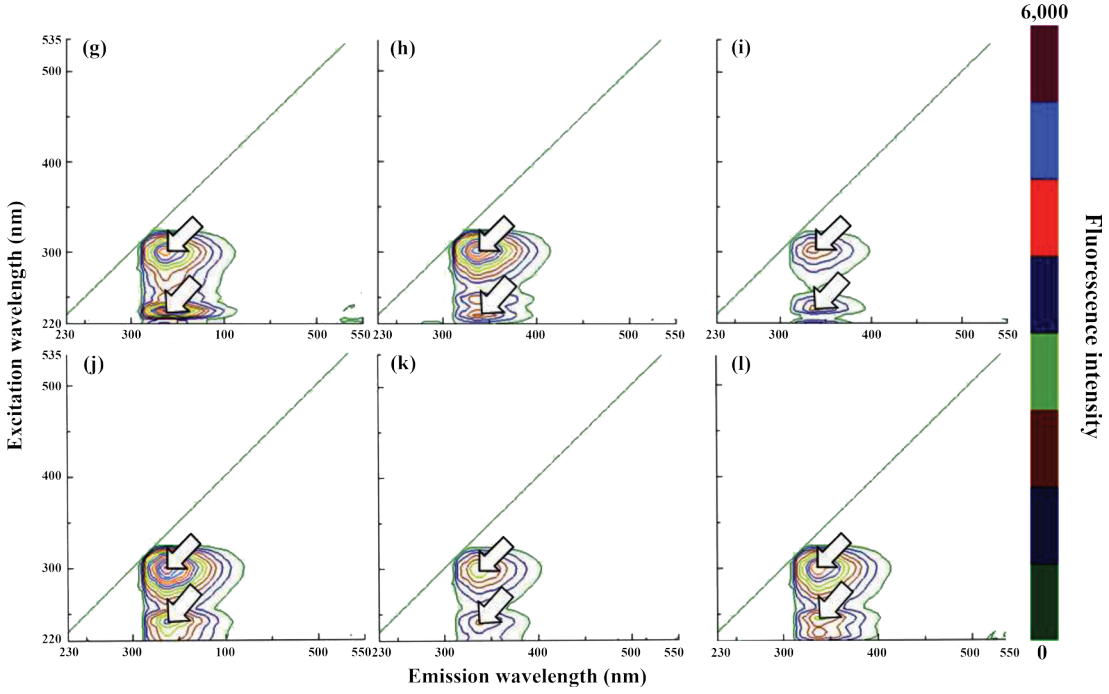

Figure 3. Cont.

DISCUSSION

DOC release among plastics

This study demonstrated that PP released the highest amounts of DOC, while low concentrations were observed from LDPE and PET. These results confirm that commercial plastics can act as a source of DOM in aquatic environments. Our findings align with previous studies. Romera-Castillo *et al*. (2018) reported higher DOC leaching from PP than PE, with values of 21.7 and 16.1 mg C·m^{-2} under light and dark conditions, respectively. Similarly, Chen *et al*. (2024) found that PP leached more DOC than PS, polyamide, and PET, while Egea *et al*. (2024) also observed greater leaching from PP (28.5 mg C·m^{-2}) than from PE (24.8 mg C·m^{-2}).

Differences among plastics likely arise from both polymer structure and additive composition. Masry *et al*. (2021) showed that PP exhibited greater mass reduction and DOC release than PE, which was more resistant to dissolution. Additives may also play an important role. For instance, Lee *et al*. (2021a) reported that PVC and expandable polystyrene (EPS) released more DOC than PP due to higher additive content. Additives such as plasticizers and antioxidants, which are not covalently bound to the polymer backbone, can leach during degradation (Gewert *et al*., 2015; Suhrhoff and Scholz-Böttcher, 2016). Fauvelle *et al*. (2021) demonstrated that several additives were released from PE into seawater within the first week of a 30-day incubation. Together, these studies suggest that DOC release from plastics depends not only on polymer type but also on the quantity and nature of additives incorporated.

Effect of light versus dark conditions

DOC concentrations in our study did not differ significantly ($p \geq 0.05$) between simulated light and dark treatments. This contrasts with previous findings of enhanced DOC release under UV irradiation. For example, Lee *et al*. (2020b) observed higher DOC leaching under UV light, while Yuan *et al*. (2023) reported nearly twofold increases in DOC from microplastics under UV compared to dark conditions after 7 days.

The discrepancy is likely due to differences in light sources. Our experiment used a 200 W full-spectrum LED lamp (460–627 nm) that lacked UV emission, whereas previous studies included UV irradiation. UV exposure is known to alter polymer structures, enhancing their susceptibility to dissolution (Cheng *et al.*, 2022). Natural sunlight, which includes UV, visible, and infrared (IR) radiation, can therefore stimulate plastic degradation and DOC release (Ward *et al*., 2019; Yuan *et al*., 2023). Our results indicate that DOC leaching occurs even without UV exposure, though higher rates may be expected under natural solar spectra.

Leaching rates and environmental implications

Leaching rates provide a useful measure of the potential contribution of plastics to DOM pools in aquatic ecosystems. However, published data on DOC leaching rates remain scarce. Zhu *et al*. (2020) reported DOC release at 0.235±0.003 mg DOC $g^{-1}{\cdot}d^{-1}$ from plastic debris collected in the North Pacific Gyre. In comparison, we estimated leaching rates of 3.45 mg $C{\cdot}m^{-2}{\cdot}d^{-1}$ for PP and 0.47 mg $C{\cdot}m^{-2}{\cdot}d^{-1}$ for LDPE.

Although extrapolation to environmental conditions is uncertain, these values suggest that plastics represent a non-negligible source of DOC in aquatic systems. Refining global estimates of plastic-derived DOC will require studies under natural sunlight, variable environmental conditions, and across different polymer and additive types.

FDOM characterization and additive influence

All three commercial plastics released fluorescent dissolved organic matter (FDOM) with similar excitation–emission matrix (EEM) spectra. Dominant peaks were observed at ~300 nm excitation and ~350 nm emission, corresponding to tryptophan-like substances (peak T), which are typically bio-labile (Coble, 1996; Coble *et al*., 1998; Yamashita and Tanoue, 2003; Sheridan *et al*., 2022). Comparable protein-like peaks have been reported in plastic leachates by Romera-Castillo *et al*. (2018), Lee *et al*. (2020b), Chen *et al*. (2024), and Yuan *et al*. (2023).

Several studies have also linked fluorescence signals to plastic additives. Lee *et al*. (2020b) identified distinct peaks associated with DEHP, while Lee *et al*. (2021b) reported bisphenol A–related fluorescence. These findings suggest that part of the observed FDOM originates from additives rather than the base polymer. Although our study did not include chemical composition analyses, the similarity of fluorescence peaks across plastics and conditions indicates that additive leaching likely contributed to the observed signals. Further work combining fluorescence spectroscopy with targeted chemical analyses (e.g., GC–MS, LC–MS) will be essential to clarify the role of additives in shaping DOM quality.

CONCLUSIONS

Overall, this study demonstrates that PP releases the highest amounts of DOC compared to LDPE and PET, with leaching influenced by both polymer type and additives. Light conditions lacking UV did not significantly affect DOC release, though natural solar spectra may enhance leaching. Estimated leaching rates highlight plastics as a potential contributor to aquatic DOM pools. Finally, fluorescence analyses indicate that plastic-derived DOM includes bio-labile components and may reflect additive inputs. These findings emphasize the importance of considering both polymer chemistry and environmental conditions when evaluating the role of plastics as a source of DOM in aquatic ecosystems.

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LITERATURE CITED

Chen, Q., F. Chen, M. Gonsior, *et al*. 2021. Correspondence between DOM molecules and microbial community in a subtropical coastal estuary on a spatiotemporal scale. **Environment International** 154: 106558. DOI: 10.1016/j.envint.2021.106558.

Chen, C., R. Du, J. Tang, B. Wang, F. Li, Z. Zhang and G. Yu. 2024. Characterization of microplastic-derived dissolved organic matter in freshwater: Effects of light irradiation and polymer types. **Environment International** 185: 108536. DOI: 10.1016/j.envint.2024.108536.

Cheng, F., T. Zhang, Y. Liu, Y. Zhang and J. Qu. 2022. Non-negligible effects of UV irradiation on transformation and environmental risks of microplastics in the water environment. **Journal of Xenobiotics** 12: 1–12. DOI: 10.3390/jox12010001.

Coble, P.G. 1996. Characterization of marine and terrestrial DOM in seawater using excitation-emission matrix spectroscopy. **Marine Chemistry** 51: 325–346.

Coble, P.G., C.E.D. Castillo and B. Avril. 1998. Distribution and optical properties of CDOM in the Arabian Sea during the 1995 Southwest Monsoon. **Deep-Sea Research II** 45: 2195–2223.

Egea, L.G., F.G. Brun and R. Jiménez-RamosEgea. 2024. Dissolved organic carbon leaching from microplastics and bioavailability in coastal ecosystems. **Science of the Total Environment** 909: 168673. DOI: 10.1016/j.scitotenv.2023.168673.

Fauvelle, V., M. Garel, C. Tamburini, *et al*. 2021. Organic additive release from plastic to seawater is lower under deep-sea conditions. **Nature Communications** 12: 4426. DOI: 10.1038/s41467-021-24738-w.

Fellman, J.B., E. Hood and R.G.M. Spencer. 2010. Fluorescence spectroscopy opens new windows into dissolved organic matter dynamics in freshwater ecosystems: A review. **Limnology and Oceanography** 55(6): 2452–2462. DOI: 10.4319/lo.2010.55.6.2452.

Gewert, B., M.M. Plassmann and M. MacLeod. 2015. Pathways for degradation of plastic polymers floating in the marine environment. **Environmental Science Progresses and Impacts** 17: 1513. DOI: 10.1039/C5EM00207A.

Lee, Y.K., C. Romera-Castillo, S. Hong and J. Hur. 2020a. Characteristics of microplastic polymer-derived dissolved organic matter and its potential as a disinfection byproduct precursor. **Water Research** 175: 115678. DOI: 10.1016/j.watres.2020.115678.

Lee, Y.K., K.R. Murphy and J. Hur. 2020b. Fluorescence signature of dissolved organic matter leached from microplastic: polymers and additives. **Environmental Science and Technology** 54: 11905–11914. DOI: 10.1021/acs.est.0c00942.

Lee, Y.K., S. Hong and J. Hur. 2021a. Copper-binding properties of microplastic-derived dissolved organic matter revealed by fluorescence spectroscopy and two-dimensional correlation spectroscopy. **Water Research** 190: 116775. DOI: 10.1016/j.watres.2020.116775.

Lee, Y.K., S. Hong and J. Hur. 2021b. A fluorescence indicators for source discrimination between microplastic-derived dissolved organic matter and aquatic natural organic matter. **Water Research** 207: 117833. DOI: 10.1016/j.watres.2021.117833.

Leknoi, U., A. Yiengthaisong and S. Likitlersuang. 2024. Social factors influencing waste separation behaviour among the multi-class residents in a megacity: A Survey analysis from a community in Bangkok, Thailand. **Sustainable Futures** 7: 100202. DOI: 10.1016/j.sftr.2024.100202.

Masry, M., S. Rossignol, J.L. Gardette, S. Therias, P.O. Bussière and P. Wong-Wah-Chung. 2021. Characteristics, fate, and impact of marine plastic debris exposed to sunlight: A review. **Marine Pollution Bulletin** 171: 112701. DOI: 10.1016/j.marpolbul.2021.112701.

Moran, M.A., E.B. Kujawinski, A. Stubbins, *et al*. 2016. Deciphering ocean carbon in a changing world. **Proceedings of the National Academy of Sciences (PNAS)** 113(12): 3143–3151. DOI: 10.1073/pnas.1514645113.

Ogawa, H. and E. Tanoue. 2003. Dissolved organic matter in oceanic waters. **Journal of Oceanography** 59: 129–147.

Parveen, N., A. Joseph and S. Goel. 2024. Leaching of organic matter from microplastics and its role in disinfection by-product formation. **Science of The Total Environment** 906: 167640. DOI: 10.1016/j.scitotenv.2023.167640.

Romera-Castillo, C., M. Pinto, T.M. Langer, X.A. Álvarez-Salgado and G.J. Herndl. 2018. Dissolved organic carbon leaching from plastics stimulates microbial activity in the ocean. **Nature Communication** 9: 1430. DOI: 10.1038/s41467-018-03798-5.

Romera-Castillo, C., S. Birnstiel, X.A. Álvarez-Salgado and M. Sebastián. 2022. Aged plastic leaching of dissolved organic matter is two orders of magnitude higher than virgin plastic leading to a strong uplift in marine microbial activity. **Frontiers in Marine Science** 9: 861557. DOI: 10.3389/fmars.2022.861557.

Sheridan, E.A., J.A. Fonvielle, S. Cottingham, Y. Zhang, T. Dittmar, D.C. Aldridge and A.J. Tanentzap. 2022. Plastic pollution fosters more microbial growth in lakes than natural organic matter. **Nature Communication** 13: 4175. DOI: 10.1038/s41467-022-31691-9.

Sigler, M. 2014. The effects of plastic pollution on aquatic wildlife: Current situations and future solutions. **Water, Air, and Soil Pollution** 225: 2184. DOI: 10.1007/s11270-014-2184-6.

Suhrhoff, T.J. and B.M. Scholz-Böttcher. 2016. Qualitative impact of salinity, UV radiation and turbulence on leaching of organic plastic additives from four common plastics -A lab experiment. **Marine Pollution Bulletin** 102(1): 84–94. DOI: 10.1016/j.marpolbul.2015.11.054.

Thevenon, F., C. Carroll and J. Sousa. 2014. **Plastic Debris in the Ocean: The Characterization of Marine Plastics and their Environmental Impacts, Situation Analysis Report.** IUCN, Gland, Switzerland. 52 pp.

Ward, C.P., C.J. Armstrong, A.N. Walsh, J.H. Jackson and C.M. Reddy. 2019. Sunlight converts polystyrene to carbon dioxide and dissolved organic carbon. **Environmental Science and Technology Letters** 6(11): 669–674. DOI: 10.1021/acs.estlett.9b00532.

Yamashita, Y. and E. Tanoue. 2003. Chemical characterization of protein-like fluorescences in DOM in relation to aromatic amino acids. **Marine Chemistry** 82: 255–271.

Yuan, M., H. Xiang, Y. Tong, K. Zhou, C. Peng and W. Chen. 2023. Spectroscopic tracking of the characteristics of microplastic-derived dissolved organic matter. **Separations** 10(2): 101. DOI: 10.3390/separations10020101.

Zhu, L., S. Zhao, T.B. Bittar, A. Stubbins and D. Li. 2020. Photochemical dissolution of buoyant microplastics to dissolved organic carbon: rates and microbial impacts. **Journal of Hazardous Materials** 383: 121065. DOI: 10.1016/j.jhazmat.2019.121065.