Supplementary Information

Microplastic release from fiber and coated commercial tea bags: a fluorescence microscopy screening of eight products

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Supplementary Figures.

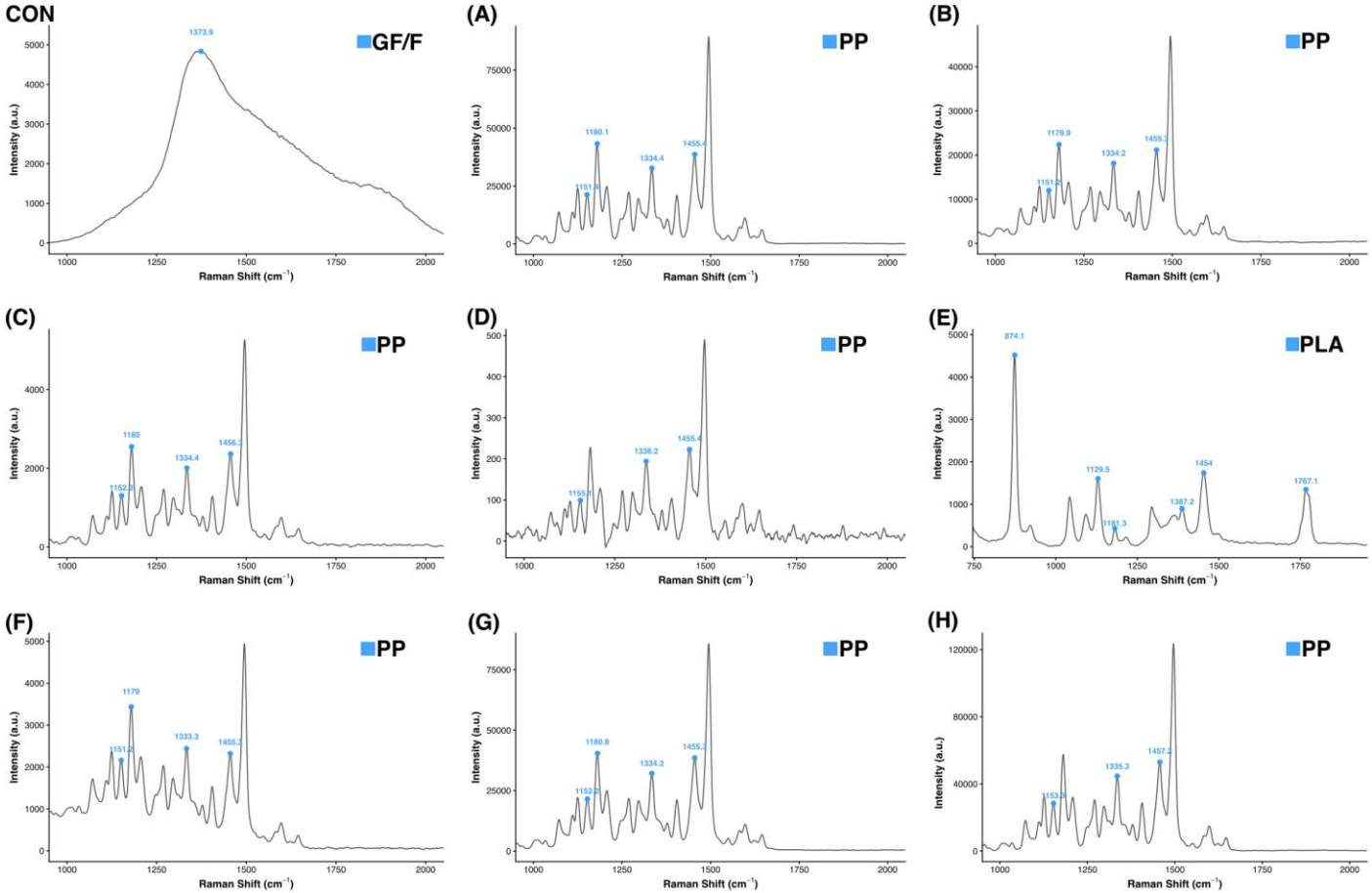

Figure S1. Raman spectroscopic identification of particles from tea bag samples. Representative Raman spectra from selected fluorescent features in tea bag samples (A–H) and a blank glass fiber filter (GF/F; CON) were used for qualitative polymer identification by comparison with reference spectra. Samples A–D and F–H showed Raman features consistent with polypropylene (PP), whereas sample E exhibited features consistent with polylactic acid (PLA). No polymer-specific Raman bands were observed in the GF/F control. The observed bands and literature-supported vibrational assignments are summarized in Table S2.

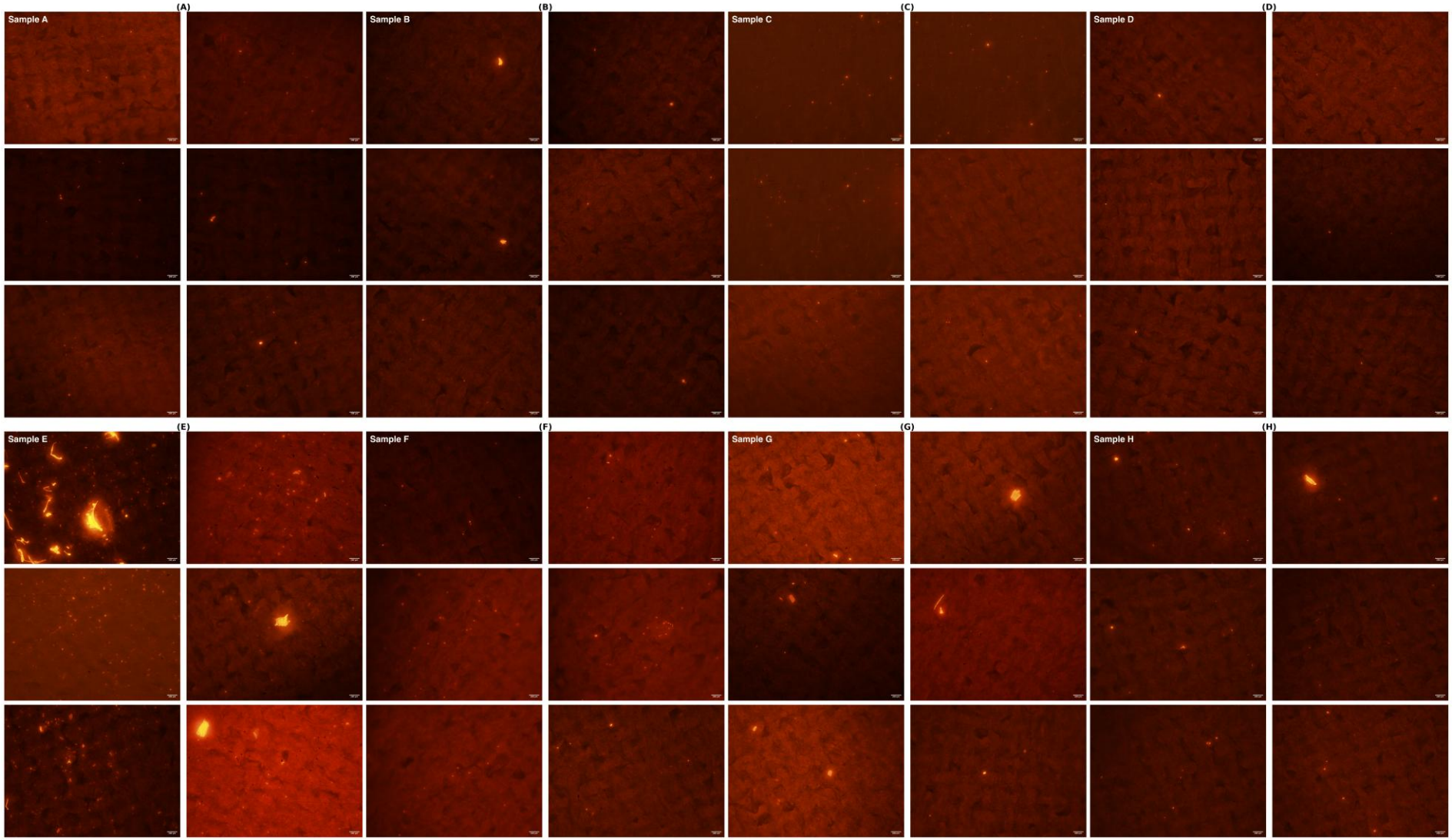

Figure S2. Representative fluorescence microscopy images from tea-bag products. Six illustrative images are shown for each product (A–H); these panels are not the complete set of fields of view used for quantification. Images were acquired after Nile Red staining under identical imaging conditions. The panels show examples of smaller fibrous features in A and G and larger irregular features in E, but morphology classes were not assigned. The scale bar represents 200 µm.

Supplementary Table.

Table S1. Area-equivalent size summary of segmented retained features from tea-bag products.

Sample	Segmented retained features (n)	Median projected area (µm²)	Median ECD (µm)	Between-filter ECD range (µm)
A	833	106.25	11.63	3.99–17.39
B	416	100.00	11.28	6.91–20.73
C	2,036	50.00	7.98	5.64–13.23
D	332	68.75	9.36	4.89–16.69
E	3,807	131.25	12.93	9.36–20.73
F	839	181.25	15.19	7.98–20.54
G	491	118.75	12.30	6.91–21.02
H	649	156.25	14.10	7.98–22.57

ECD, equivalent circular diameter. ECD was calculated for each segmented feature as 2 × sqrt(projected area/π). Projected area and ECD were first summarized by their median within each independent filter. Product values in the median columns are the medians of nine filter medians (n = 9); the ECD range is the minimum–maximum across those nine medians. ECD is an area-equivalent size descriptor and does not classify fibres, flakes, or fragments.

Table S2. Observed Raman bands and literature-supported vibrational assignments for PP and PLA.

Polymer assignment	Sample(s)	Observed band(s) (cm^{-1})	Literature-supported vibrational assignment
PP	A–D, F–H	1151–1155	C–C skeletal stretching (ref. S1)
PP	A–D, F–H	1333–1336	CH_2 twisting (refs. S1, S2)
PP	A–D, F–H	1454–1457	CH_2 scissoring (ref. S1)
PLA	E	874	C–COO stretching (refs. S3, S4)
PLA	E	1129	O–C–O stretching / CH_3 rocking (refs. S3, S4)
PLA	E	1181	C–C stretching / CH wagging (refs. S3, S4)
PLA	E	1387	Symmetric CH_3 deformation (refs. S3, S4)
PLA	E	1454	Asymmetric CH_3 deformation (refs. S3, S4)
PLA	E	1767	C=O stretching (refs. S3, S4)

Band assignments were based on primary Raman studies (refs. S1–S4).

Text S1. Estimation of Per-Capita Tea Bag Consumption

A screening estimate of per-capita tea-bag consumption in South Korea was calculated from publicly available government statistics. The Korea Rural Economic Institute (KREI), citing Ministry of Food and Drug Safety data, reported domestic sales of approximately 12,519 metric tons of infused tea products in 2024, valued at approximately KRW 235 billion.

The calculation assumed that (1) tea bags accounted for 75% of the infused-tea market by volume, based on general market observations; (2) an average tea bag weighed 2 g; and (3) the 2023 population of South Korea was 51.3 million, according to the Ministry of the Interior and Safety.

Based on these assumptions, the total annual consumption of tea bags was estimated as follows:

1. Tea bag market volume = 12,519,000 kg × 0.75 = 9,389,250 kg
2. Number of tea bags = 9,389,250 kg ÷ 0.002 kg/bag ≈ 4.69×10^9 bags
3. Per-capita annual consumption = $4.69 \times 10^9 \div 5.13 \times 10^7 \approx 91$ tea bags per person per year

This corresponds to approximately 0.25 tea bags per day on a per-capita basis. Because sales volume serves as an upper-bound proxy for actual consumption, the following consumption scenarios were adopted for screening-level exposure assessment: a "National Average" scenario of 0.25 tea bags per day, and a "Daily Consumer" scenario of 1.0 tea bag per day (representative of individuals who regularly consume tea).

These estimates are approximate because tea-bag market share, product weight, and consumption patterns vary among products and consumers. They are used only to define the screening scenarios and are not precise consumption statistics.

Supplementary References

S1. Zhu, S., Song, Z., Shi, S., Wang, M. & Jin, G. Fusion of near-infrared and Raman spectroscopy for in-line measurement of component content of molten polymer blends. Sensors 19, 3463 (2019). https://doi.org/10.3390/s19163463

S2. Hiejima, Y., Takeda, K. & Nitta, K.-H. Investigation of the molecular mechanisms of melting and crystallization of isotactic polypropylene by in situ Raman spectroscopy. Macromolecules 50, 5867–5876 (2017). https://doi.org/10.1021/acs.macromol.7b00229

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