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Microplastic fragmentation by rotifers in aquatic ecosystems contributes to global nanoplastic pollution

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Supplementary Video 1. Uptake and grinding of PS microplastics by the rotifer. (video)

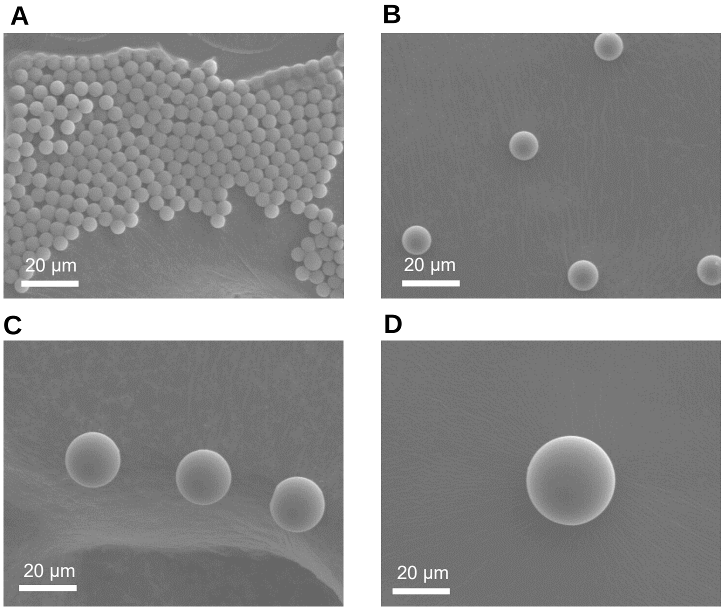
Supplementary Video 2. Grinding of 10-μm PS microplastics by the rotifer for 60 times before internalization. (video).

Supplementary Video 3. Excretion of photo-aged PS microplastics and the fragments by the rotifer. (video)

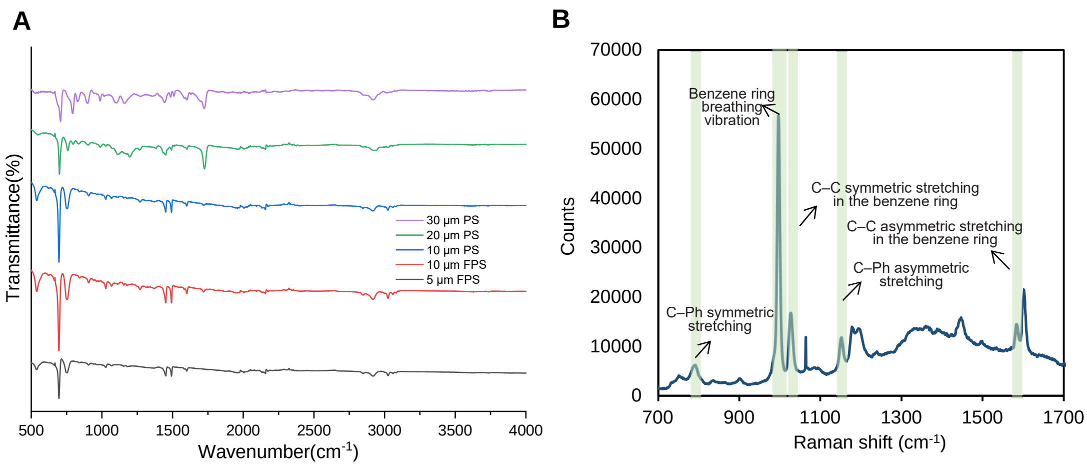
Supplementary Table 1 Different species of rotifers in aquatic environments (Segers and Yule, 2004; Oh et al., 2017).

Supplementary Table 2 Distribution of freshwater and marine rotifers in water (individuals/L)

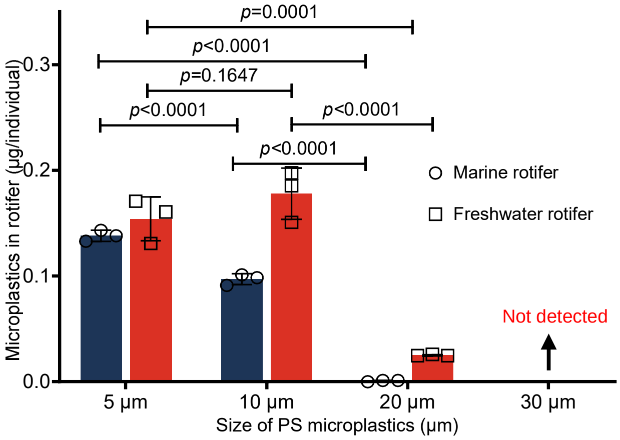
Supplementary Table 3 Distribution of microplastics in water (particle size less than 500 μm, particles/m^3)



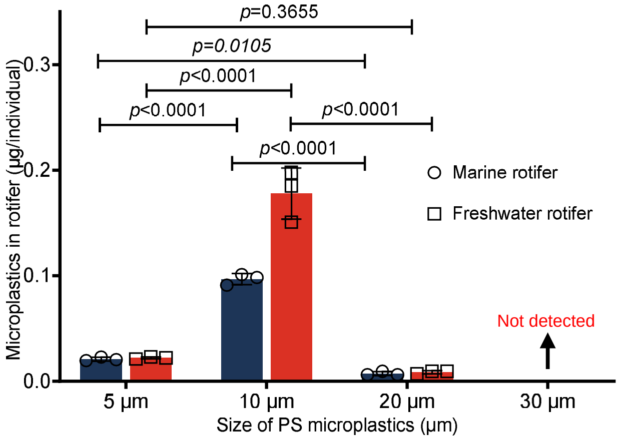
Supplementary Fig. 1. SEM images of PS microplastics with different sizes. (A): 5 μm, (B): 10 μm, (C): 20 μm, (D): 30 μm. It is noted that the actual size of 20-μm microplastics is around 18 μm.



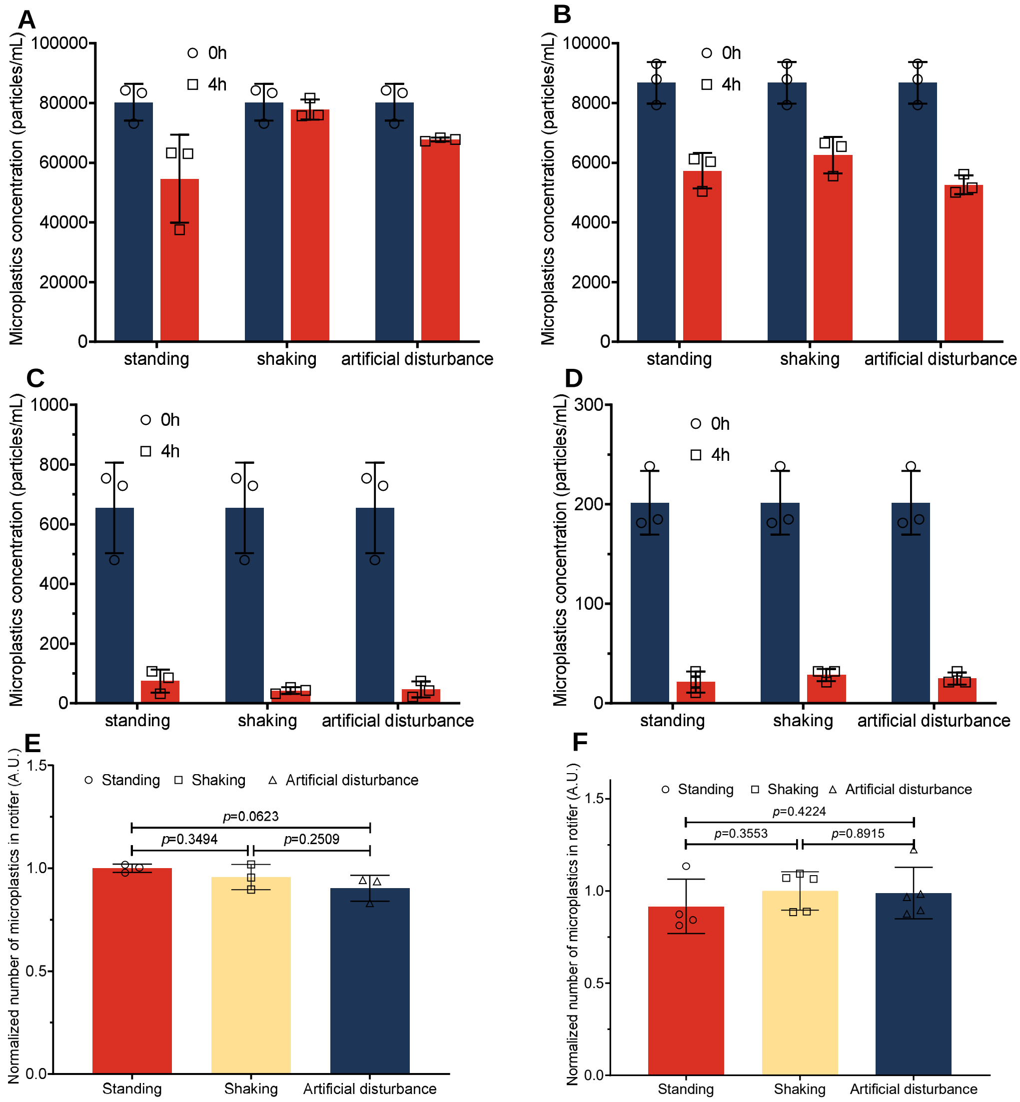
Supplementary Fig. 2. ATR-FTIR and Raman spectra of PS microplastics. (A): ATR-FTIR spectra of PS microplastics with different sizes. (B): Raman spectrum of 10-μm PS microplastics.



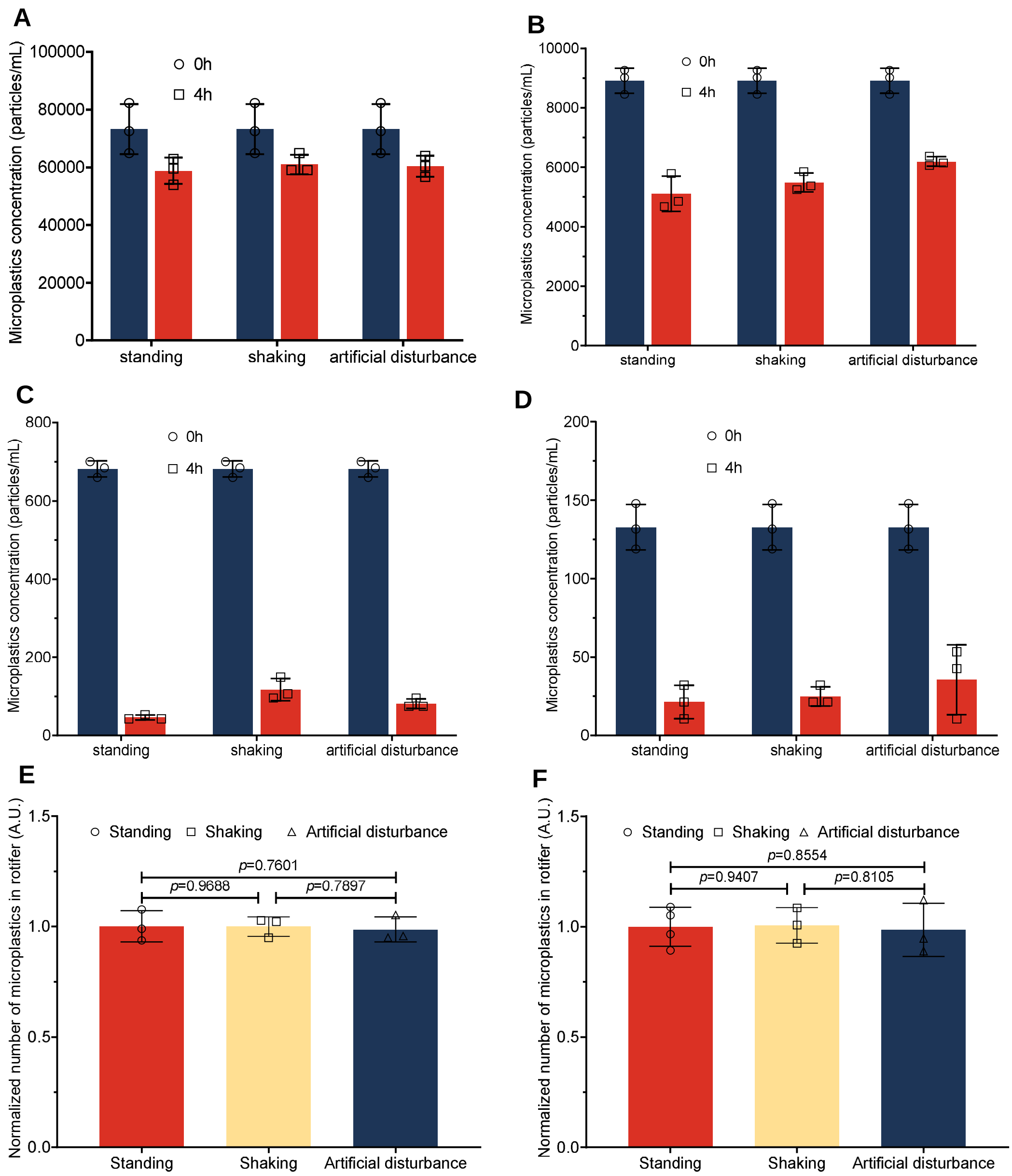
Supplementary Fig. 3. Quantitative results (as expressed with μg/individual) of ingested PS microplastics at the same mass concentration (5 mg/L). Marine and freshwater rotifers were exposure to 5-, 10-, 20-, and 30-μm microplastics, respectively. Data are presented as mean ± s.d. (n = 3). Statistical analyses among differently sized microplastics were performed using a one-sided ANOVA followed by LSD post-hoc test.



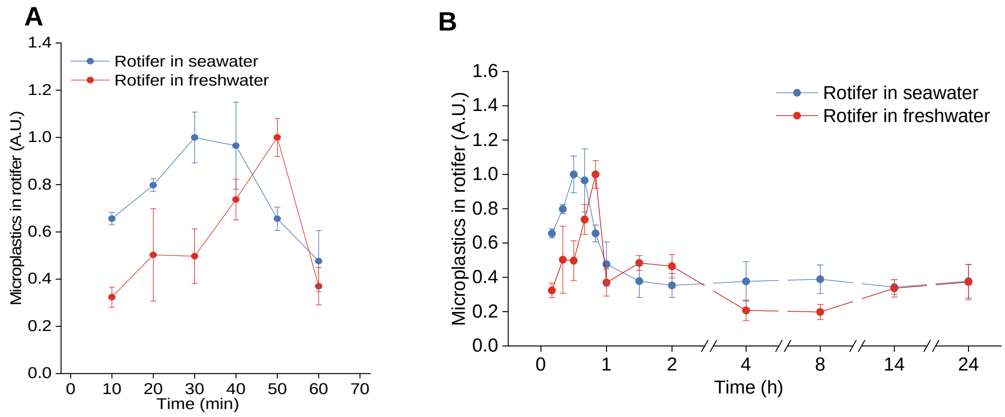
Supplementary Fig. 4. Quantitative results (as expressed with μg/individual) of ingested PS microplastics at the same number concentration (9.3×10^6 particles/L). Marine and freshwater rotifers were exposure to 5, 10, 20, and 30 μm microplastics, respectively. Data are presented as mean ± s.d. (n = 3). Statistical analyses among differently sized microplastics were performed using a one-sided ANOVA followed by LSD post-hoc test.



Supplementary Fig. 5. Sedimentation of PS microplastics (5 mg/L) in seawater (salinity: 28.6‰, locally sampled) and its influence on the ingestion/retention of PS microplastics by marine rotifers (*Brachionus plicatilis*) after 4-h incubation. (A-D): Sedimentation of microplastics with the sizes at 5, 10, 20, and 30 μm, respectively. (E, F): Ingestion/retention of microplastics (E: 5 μm; F: 10 μm) by marine rotifers after 4-h incubation. In Panels E and F, the Y-axis shows the normalized number of microplastics in individual rotifers under different treatments relative to the number of microplastics in rotifers under the "Standing" treatment. Data are presented as mean ± s.d. (n = 3 for panels A-E; n = 4 for standing group and n = 5 for shaking and artificial disturbance group in panel F). Statistical analyses among differently sized microplastics were performed using a one-sided ANOVA followed by LSD post-hoc test.



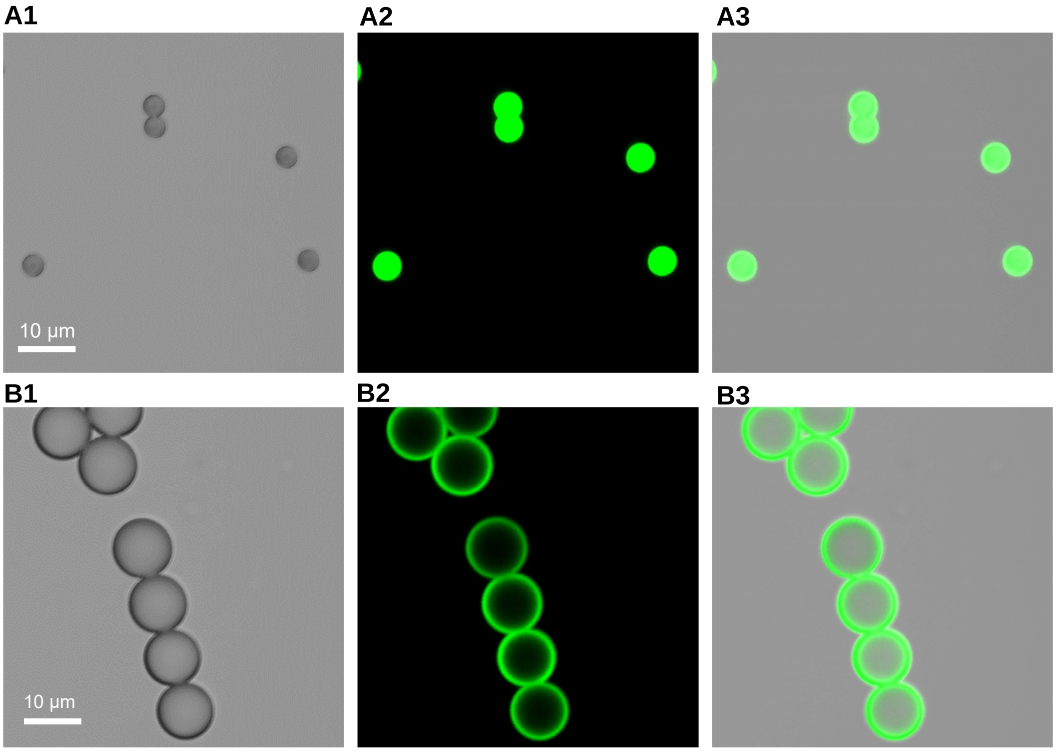
Supplementary Fig. 6. Sedimentation of PS microplastics (5 mg/L) in freshwater and its influence on the ingestion/retention of PS microplastics by freshwater rotifers (*Brachionus calyciflorus*) after 4-h incubation. (A-D): Sedimentation of microplastics with the sizes at 5, 10, 20, and 30 μm, respectively. (E, F): Ingestion/retention of microplastics (E: 5 μm; F: 10 μm) by freshwater rotifers after 4-h incubation. In Panels E and F, the Y-axis shows the normalized number of microplastics in individual rotifers under different treatments relative to the number of microplastics in rotifers under the "Standing" treatment. Data are presented as mean ± s.d. (n = 3). Statistical analyses were performed using a one-sided ANOVA followed by LSD post-hoc test.



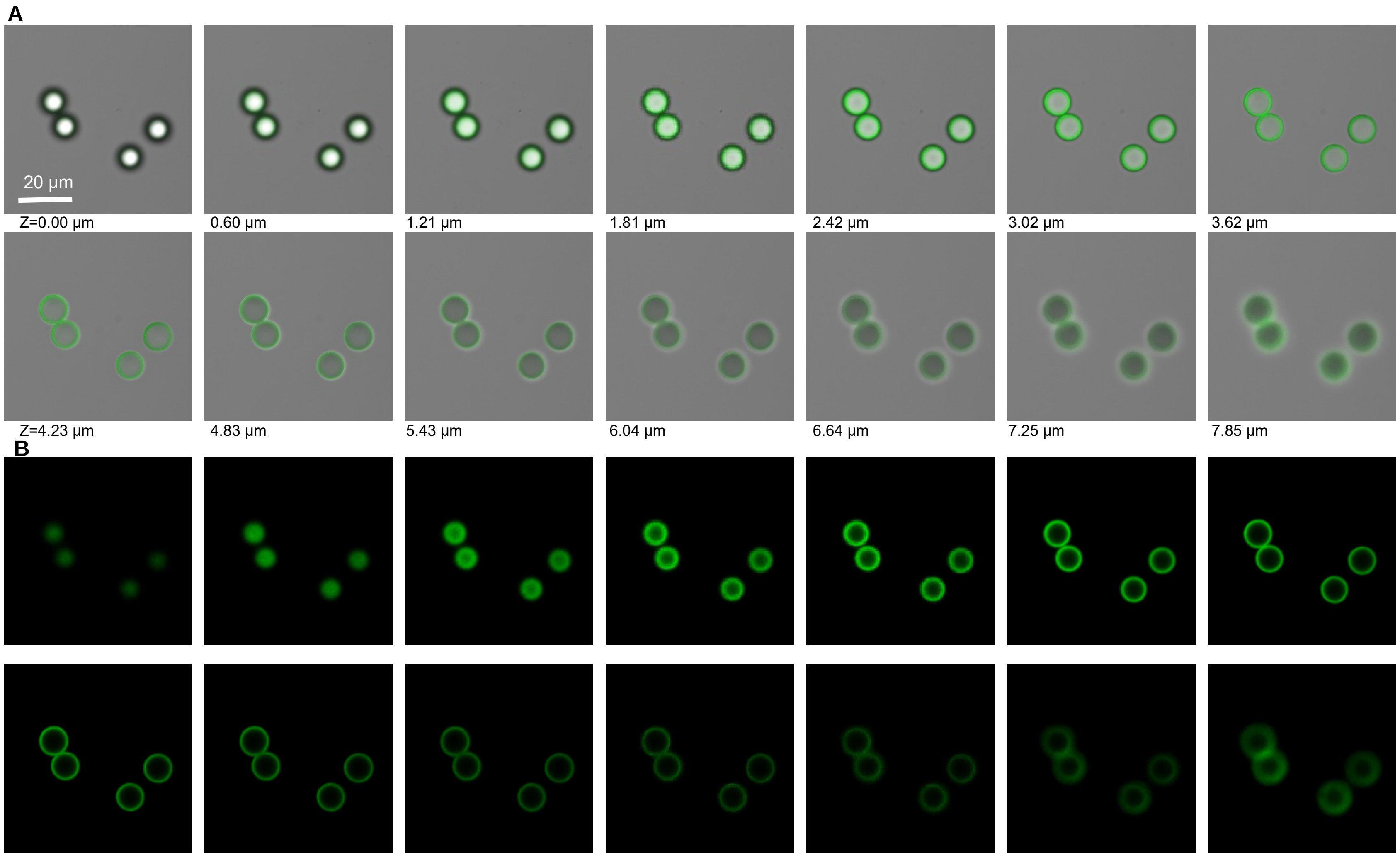
Supplementary Fig. 7. Retention rates of PS microplastics (10 μm, 5 mg/L) by marine and freshwater rotifers. (A): short-term (60 min). (B): long-term (24 h). In these panels, the Y-axis shows the normalized number of microplastics in individual rotifers at different exposure times relative to the highest number of microplastics in rotifers. For the short-term exposure, the maximal retention of microplastics occurred at around 30 min and 50 min for marine and freshwater rotifers, respectively. The retention rates (from the beginning to the time at maximal retention amounts) were calculated as around 1.8 microplastics/individual/min. Data are presented as mean ± s.d. (n = 3). In this figure (Supplementary Fig. 7), the numbers of retained microplastics decreased due to higher egestion, and finally achieved an equilibrium for both rotifer species after long-term exposure. Based on short-term incubation, the retention rates (from 0 min to the time at maximal retention amounts) of 10-μm microplastics by *B. plicatilis* were calculated at around 1.8 microplastics/individual/min, lower than the retention rate (10 microplastics/individual/min) of 4.5-μm microplastics as observed by the previous study (Baer et al., 2008). When switching to volumetric retention rates, the retention of microplastics with two different sizes (10 vs. 4.5 μm) was much closer (942 vs. 510 μm^3/individual/min).

Reference:

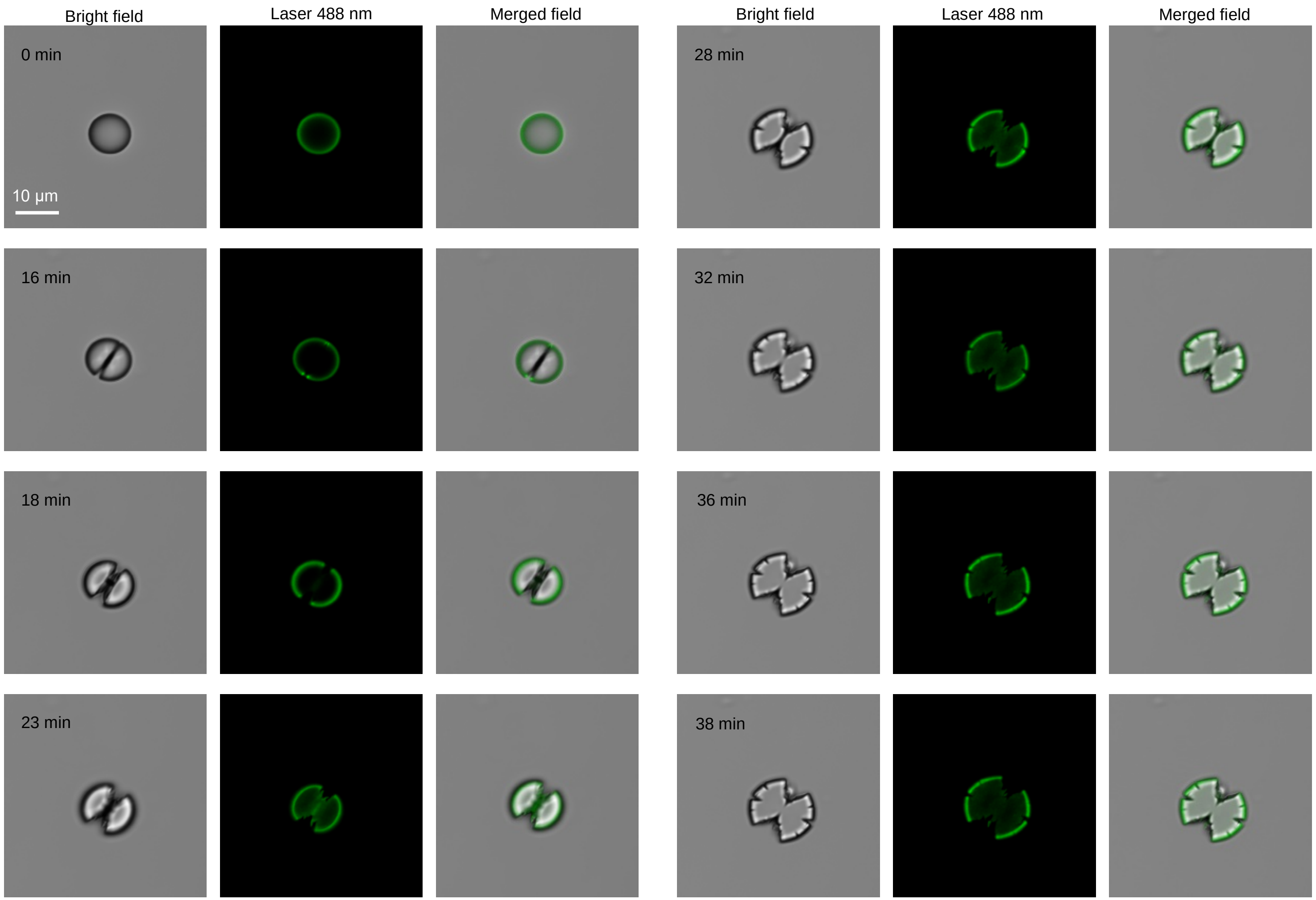
Baer, A., Langdon, C., Mills, S., Schulz, C., & Hamre, K. Particle size preference, gut filling and evacuation rates of the rotifer Brachionus "Cayman" using polystyrene latex beads. Aquaculture 282, 75-82 (2008).



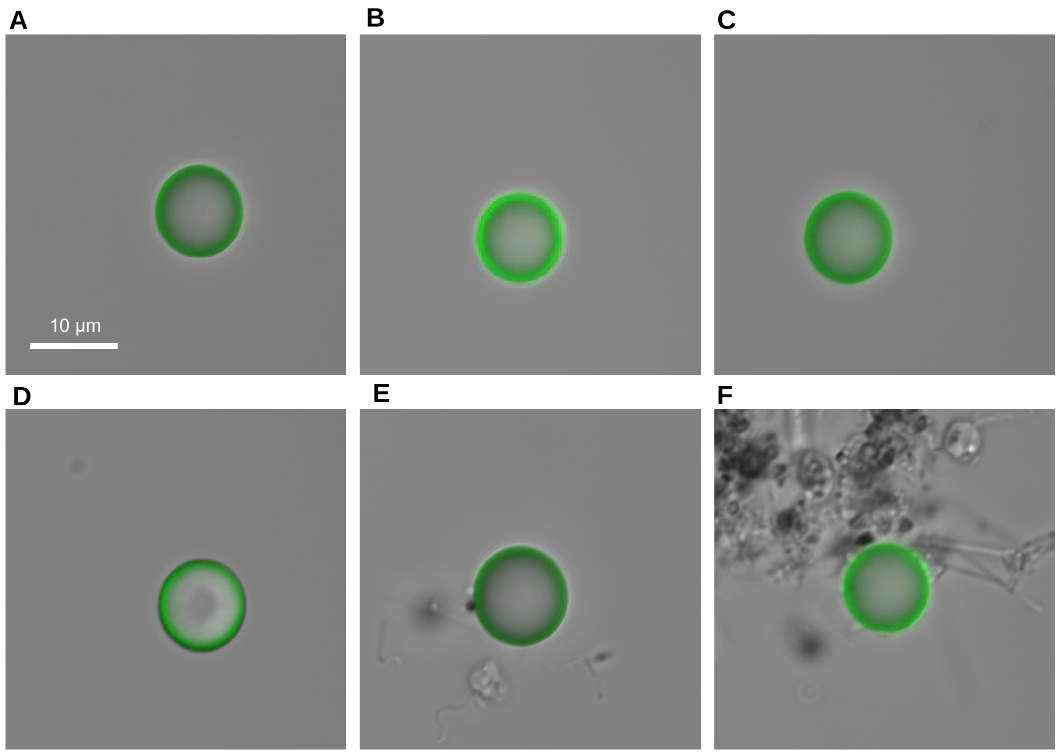
Supplementary Fig. 8. LSCM images of fluorescent PS microplastics. (A1-A3): 5-μm fluorescent PS microplastics. (B1-B3): 10-μm fluorescent PS microplastics. A1 and B1, A2 and B2, A3 and B3 show the bright field image, image excited from 488 nm and merged field of PS microplastics, respectively.



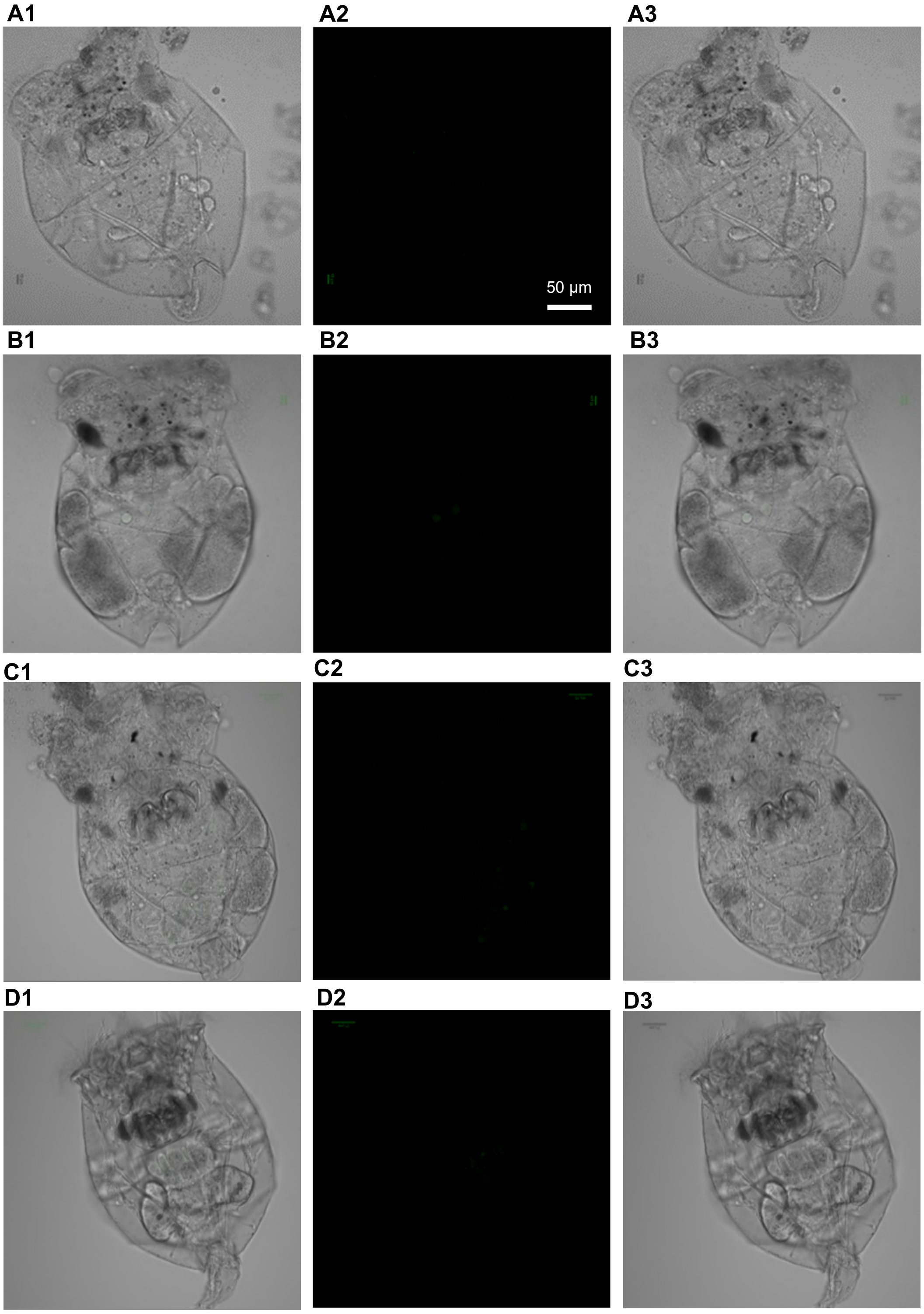
Supplementary Fig. 9. Multi-layer Z-stack confocal images of 10-μm fluorescent PS with a z-step of 0.6 μm. (A): merged field. (B): image excited from 488 nm.



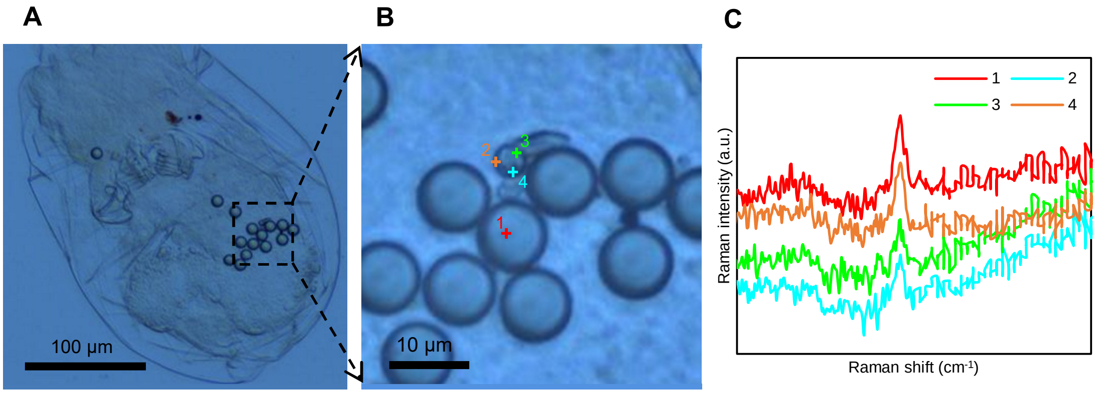
Supplementary Fig. 10. LSCM images of 10-μm fluorescent PS microplastics during artificial destruction over time. During the evaporation of water between the two films, the fluorescent PS microplastics were manually fragmented, but the release of fluorescence dyes was not observed.



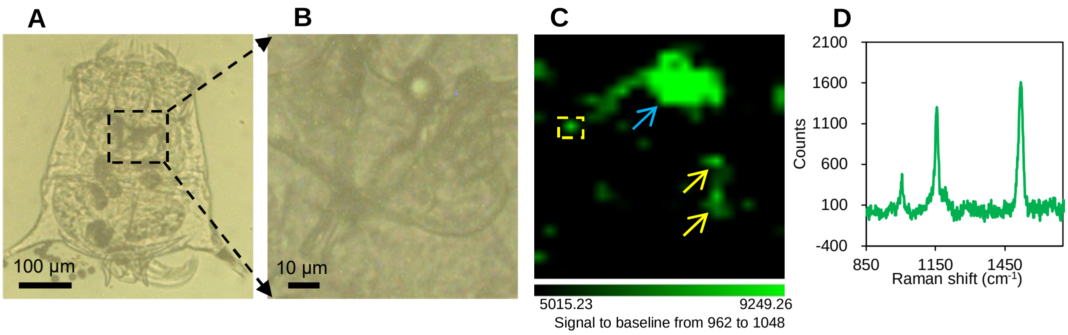
Supplementary Fig. 11. LSCM images of 10-μm fluorescent PS after incubation with digestive juice of marine rotifers. For all the images, PS microplastics were incubated with digestive juice, showing no fluorescence leakage.



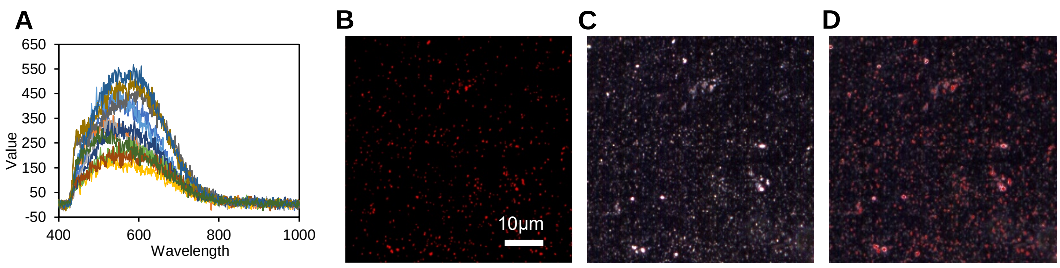
Supplementary Fig. 12. LSCM images of marine rotifers without exposure to microplastics. A1, B1, C1, and D1 show the bright field images; A2, B2, C2, and D2 show the images excited from 488 nm; A3, B3, C3, and D3 show the merged fields. This figure suggested that the green fluorescence generated from algal cells was very weak, which had no interference to the detection of microplastics (also nanoplastics) with green fluorescence.



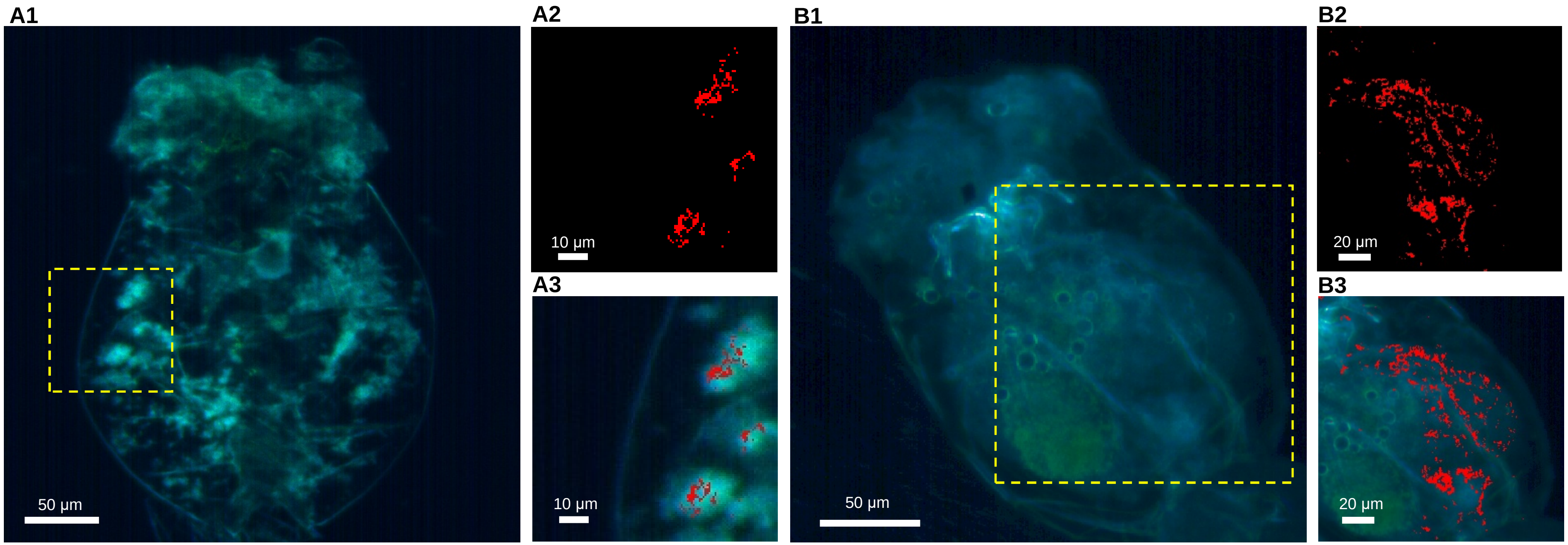
Supplementary Fig. 13. Images and analysis of PS microplastics after exposure to marine rotifers. (A, B): Optical microscopic images. (C): Raman spectra of the four points in (B), and the characteristic peaks (1000 cm^{-1}) of PS were observed for all the four points, confirming that in addition to the ingested 10-μm PS microplastics (Point 1), the observed fragment was indeed PS. This fragment would be a piece which was peeled off from the surface of microplastics by the trophi, this is the reason for the observed circular shape from top view of the fragment (or overview from the top).



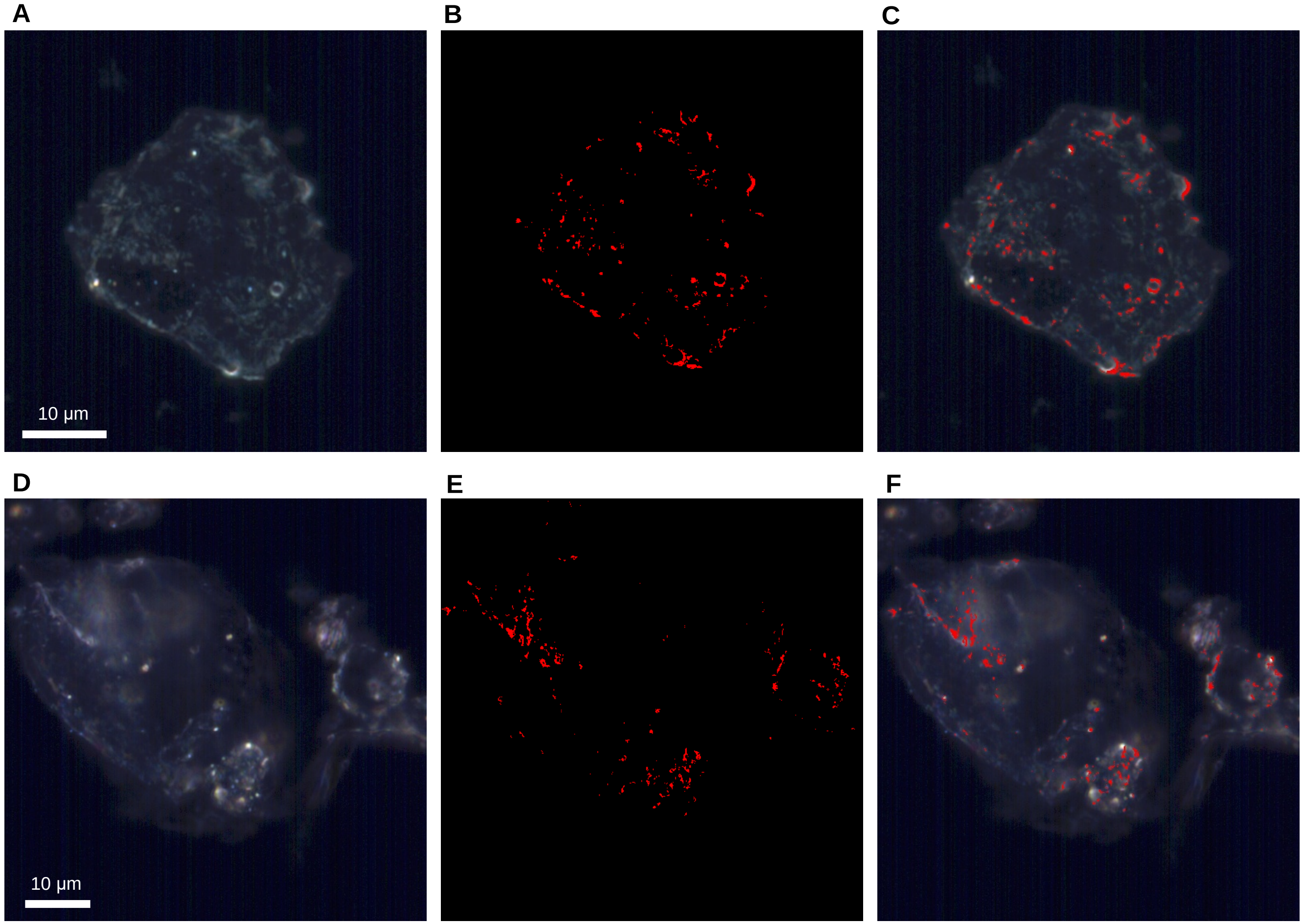
Supplementary Fig. 14. LCM-Raman images of PS microplastics in freshwater rotifers after exposure to 10 μm PS. (A, B): Optical microscopic images. (C): Raman mapping image of the area in the black dotted box in Image B with the wavelength of 1000 cm^{-1}. (D): Raman spectrum of the yellow point marked in Image C. The blue and yellow arrows represent the intact PS microplastics and PS microplastics fragments, respectively.



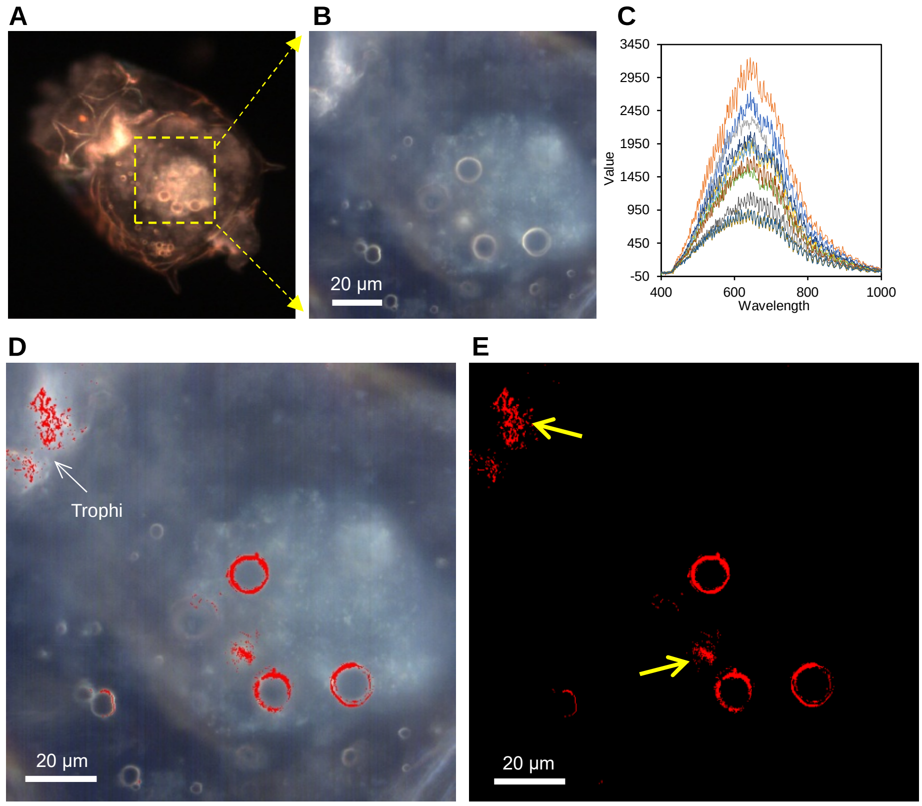
Supplementary Fig. 15. Hyperspectral images of PS nanoplastics (25 nm) in the pure media. (A): Spectral library of PS nanoplastics. (B): The mapping image of nanoplastics after matching with spectral library. (C): Optical microscopic image of nanoplastics under dark field. (D): Merged one from Images (B) and (C).



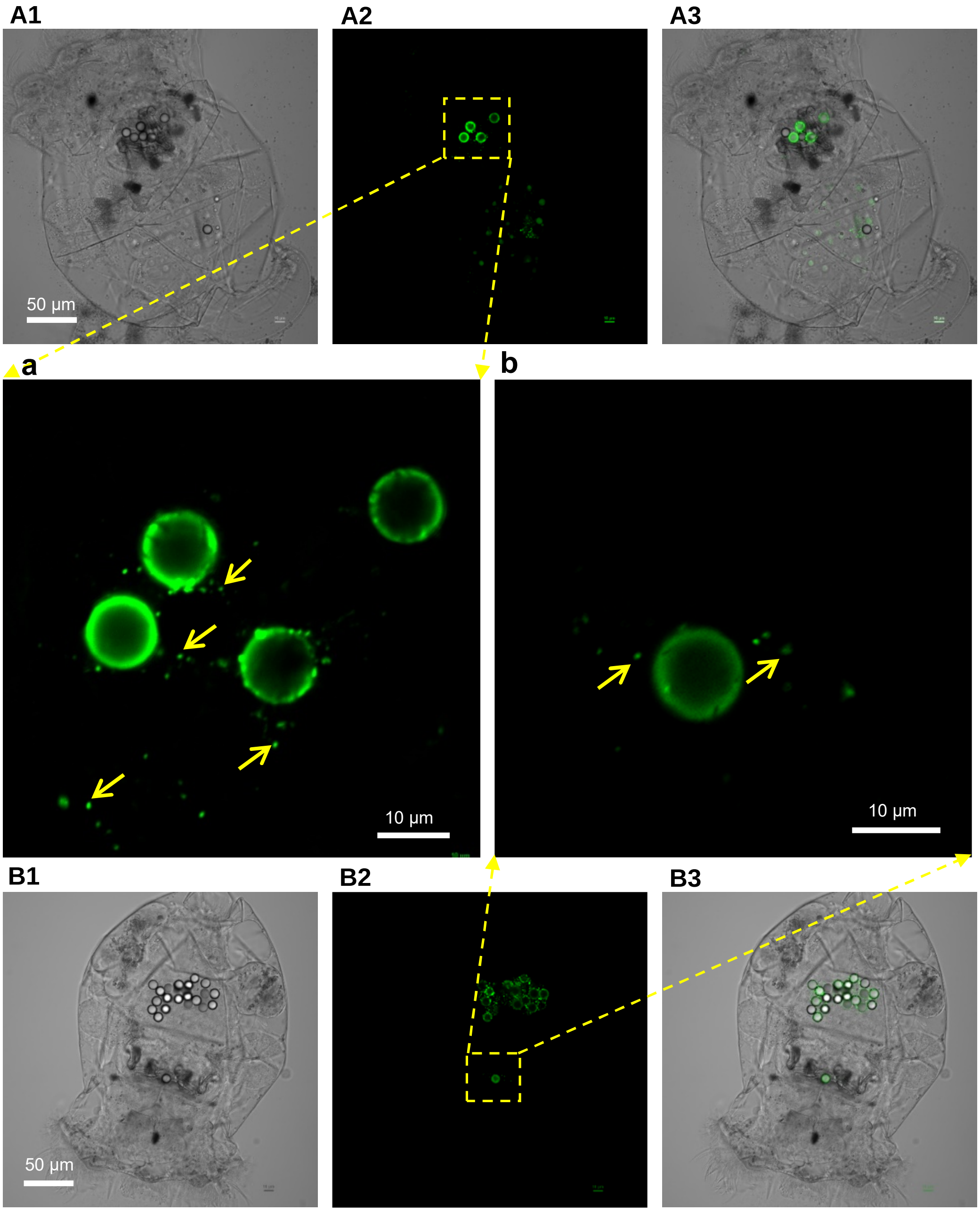
Supplementary Fig. 16. Hyperspectral images of PS (25 nm) in the bodies of rotifers after 4-h exposure. (A1-A3): marine rotifers. (B1-B3): freshwater rotifers. (A1, B1): Optical microscopic images (dark field); The HSI mapping images (A2, A3) and (B2, B3) were enlarged from (A1), (B1), respectively. The red pixels in (A2, A3) and (B2, B3) were matched to the spectral library of reference PS nanoplastics (25 nm).



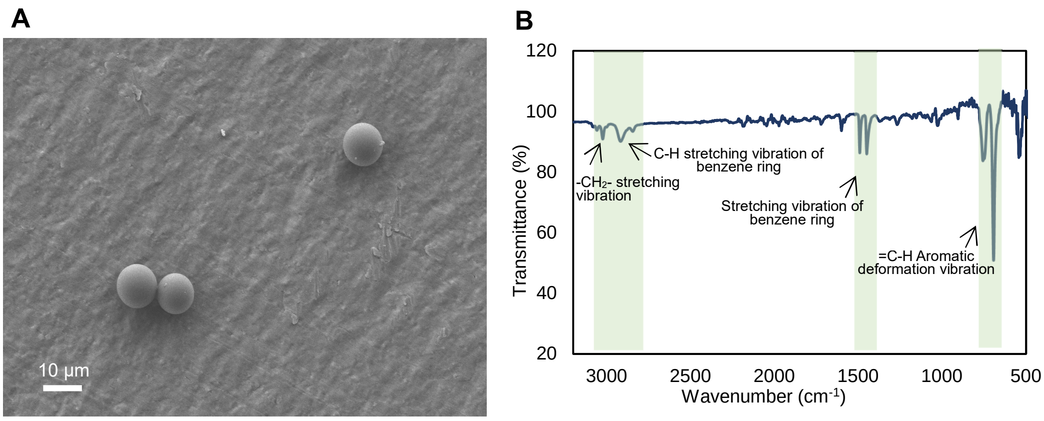
Supplementary Fig. 17. Hyperspectral images of PS nanoplastics (25 nm) after mixing with the homogenates of rotifers. (A-C): Marine rotifers. (D-F): Freshwater rotifers. (A, D): Optical microscopic images of the organic matters (rotifer homogenates) under dark field. The red pixels in (B, E) and (C, F) were matched to the spectral library of reference PS nanoplastics (25 nm).



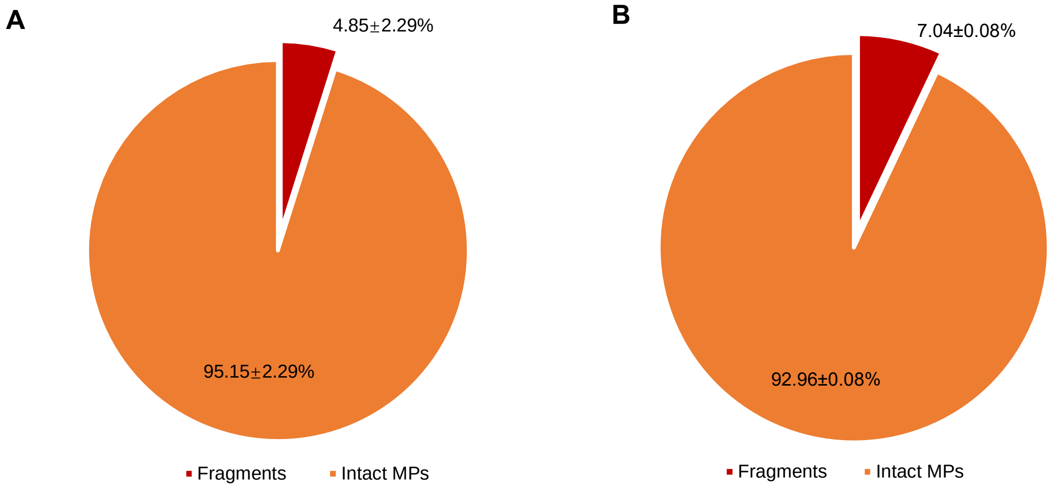
Supplementary Fig. 18. Hyperspectral images of PS after exposure to freshwater rotifer. (A), (B): Optical microscopic images (dark field) of rotifers under 10X, and 60X, respectively. (C): Spectral library of PS; (D, E): Images of PS microplastics and their fragments after matching spectral library.



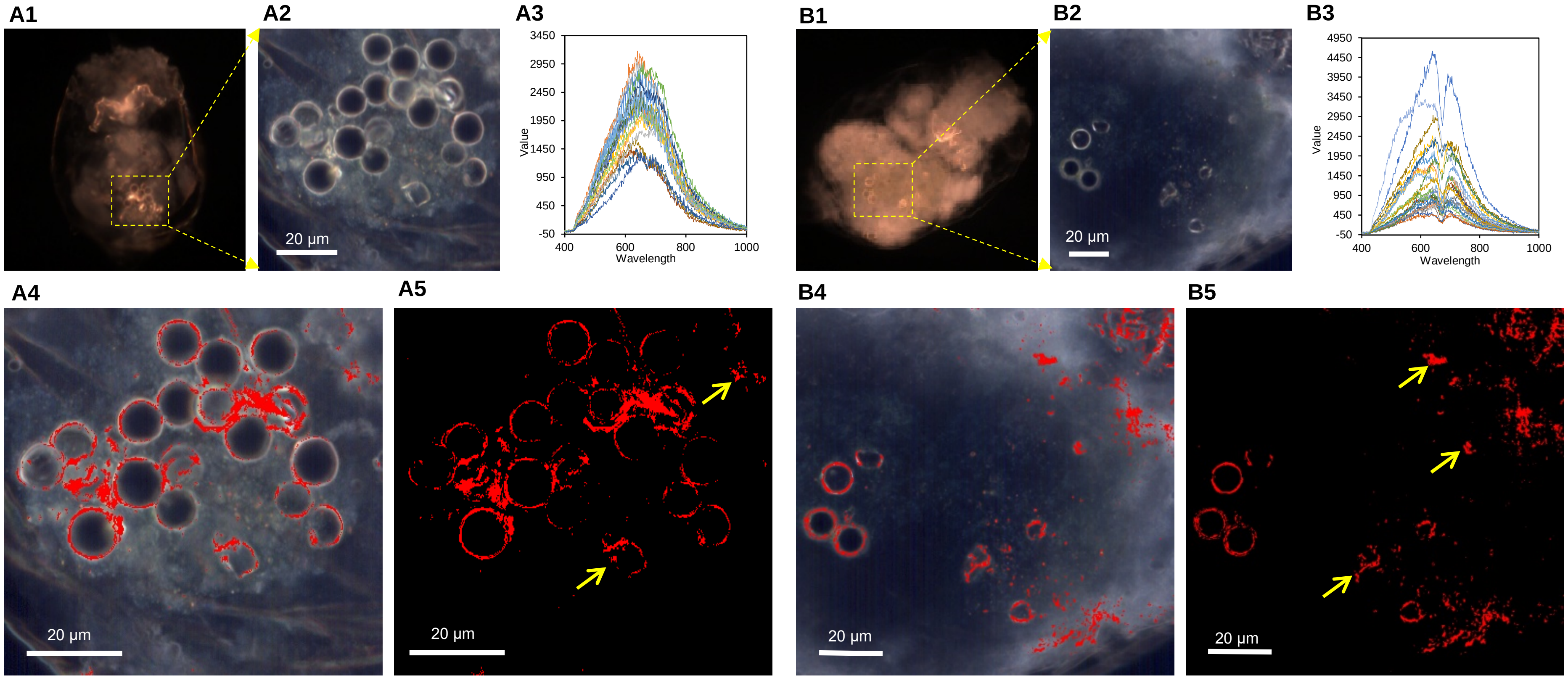
Supplementary Fig. 19. LSCM images of marine rotifers after ingestion of fluorescent PS microplastics (10 μm). A1 and B1, A2 and B2, A3 and B3 are the bright-field images, dark-field images, and merged-field images, respectively. Images a and b were enlarged from the yellow dotted boxes in images A2 and B2, respectively. The yellow arrows indicate fluorescent fragments in the trophi of a marine rotifer.



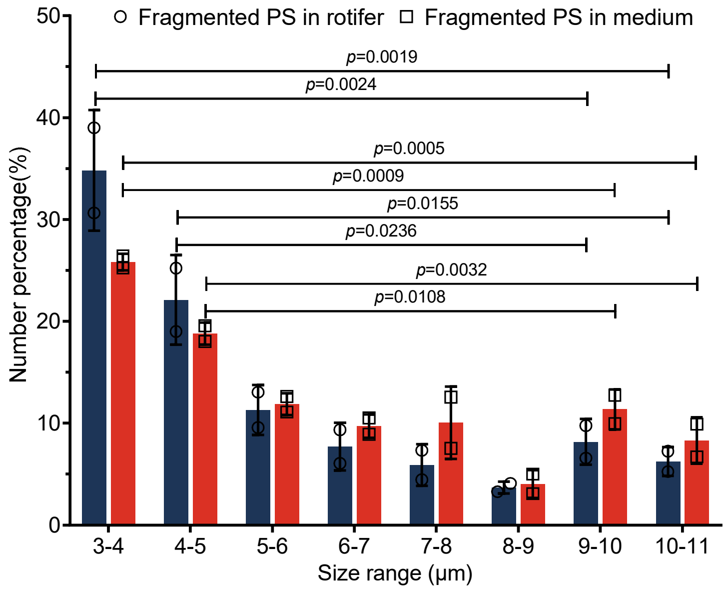
Supplementary Fig. 20. SEM image (A) and ATR-FTIR spectrum (B) of photo-aged PS microplastics.



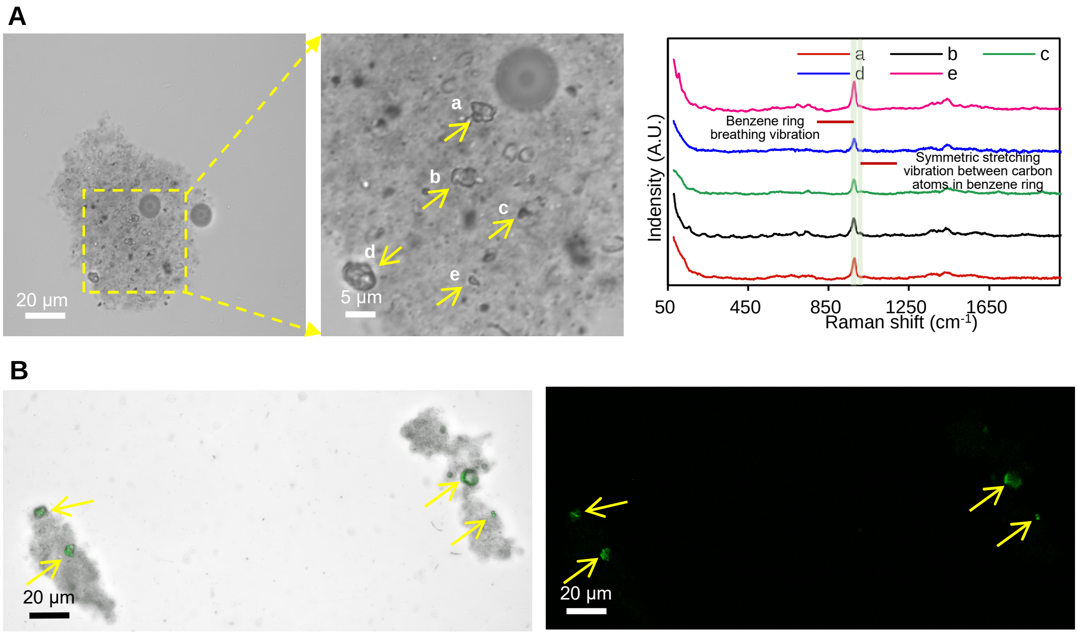
Supplementary Fig. 21. Particle size distribution (number percentage) of PS microplastics before and after photo-ageing. (A): Original 10 μm PS microplastics. (B) 10-μm microplastics after 12-h photo-aging. All the data were obtained by a cell/particle size analyzer.



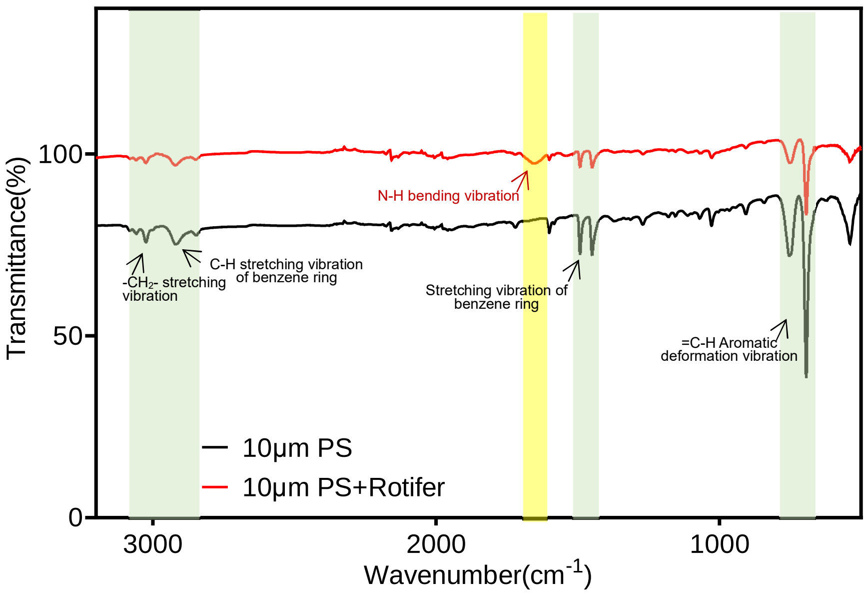
Supplementary Fig. 22. Hyperspectral images of microplastics and nanoplastics in rotifers after exposure to photo-aged PS microplastics. (A1-A5) and (B1-B5): The images of marine rotifer and freshwater rotifer, respectively. Optical microscopic images (dark field) of rotifers under 10X (A1, B1), and 60X (A2, B2), respectively; (A3) and (B3): The standard spectral libraries of PS; (A4, B4): Overlay of the collected PS signals with the optical microscopic image (dark field); (A5) and (B5): The mapping images of PS in rotifers.



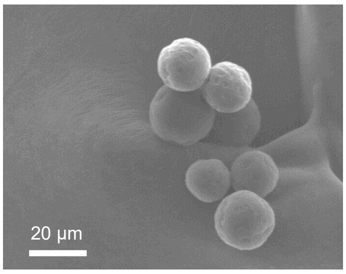
Supplementary Fig. 23. Particle size distribution (3-11 μm) of PS fragments by marine rotifers after exposure to photo-aged PS microplastics. Data are presented as mean ± s.d. ($n = 2$). Statistical analyses were performed using a one-sided ANOVA followed by LSD post-hoc test.



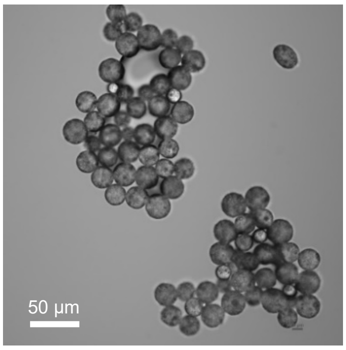
Supplementary Fig. 24. Characterization of PS fragments in the faeces of marine rotifers. (A): Optical microscopic images of the fragments of PS microplastics in the faeces of marine rotifers after exposure to photo-aged PS microplastics. Points "a", "b", "c", "d" and "e" in the image were detected with Raman microscopy, and they were confirmed to be PS. (B): LSCM images of the fragments of PS microplastics in the feces of marine rotifers after exposure to photo-aged fluorescent microplastics. The yellow arrows indicate microplastics fragments.



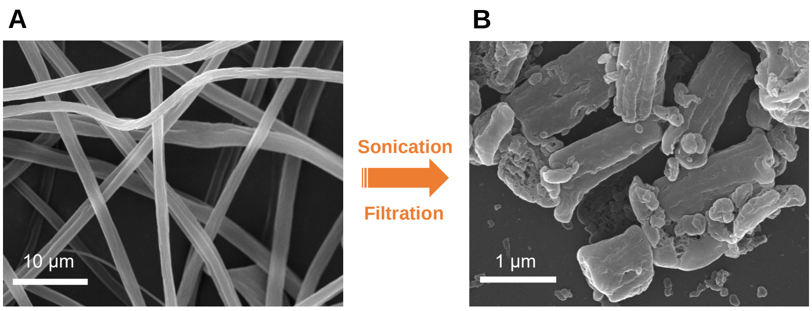
Supplementary Fig. 25. ATR-FTIR spectra of PS microplastics before and after ingestion-excretion by rotifers.



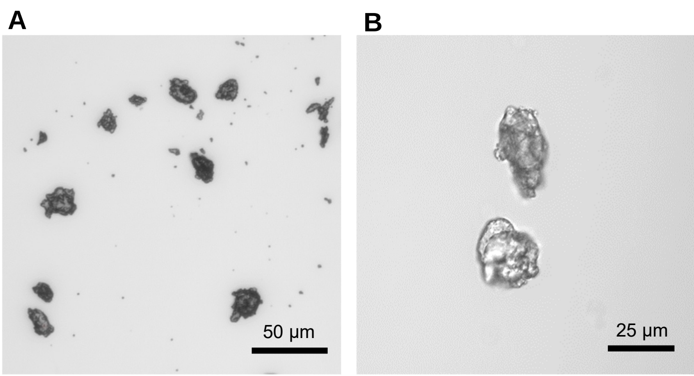
Supplementary Fig. 26. SEM images of PE microplastics.



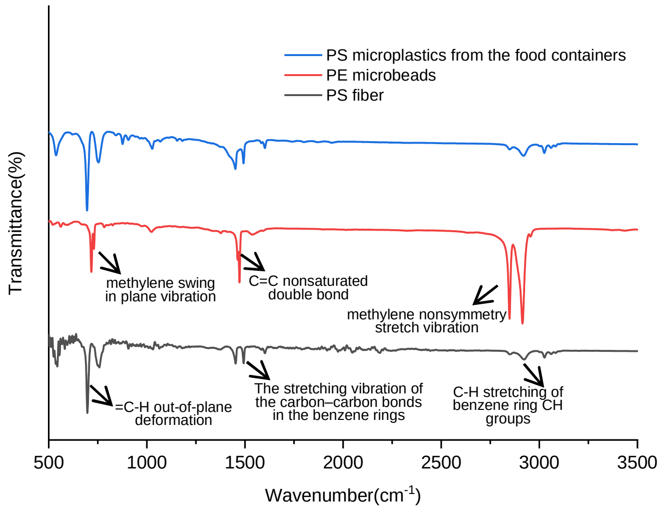
Supplementary Fig. 27. Optical image of PE microplastics.



Supplementary Fig. 28. SEM images of PS fibers before (A) and after sonication-filtration (B).

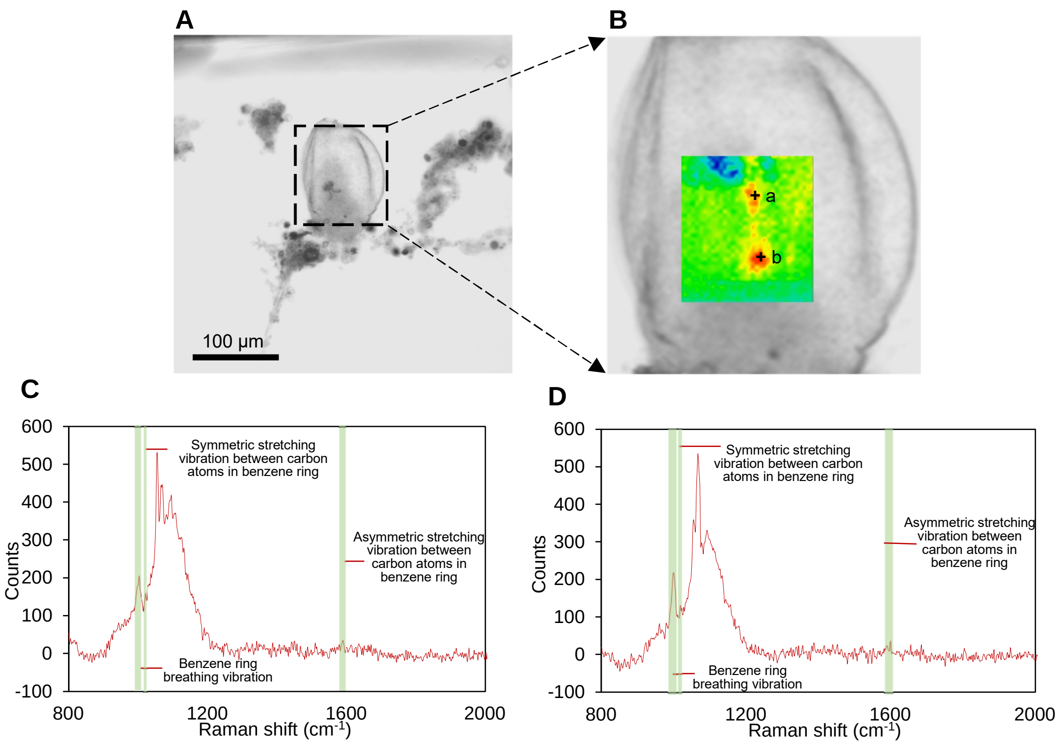


Supplementary Fig. 29. Optical microscopic images of PS microplastics obtained from the food containers.

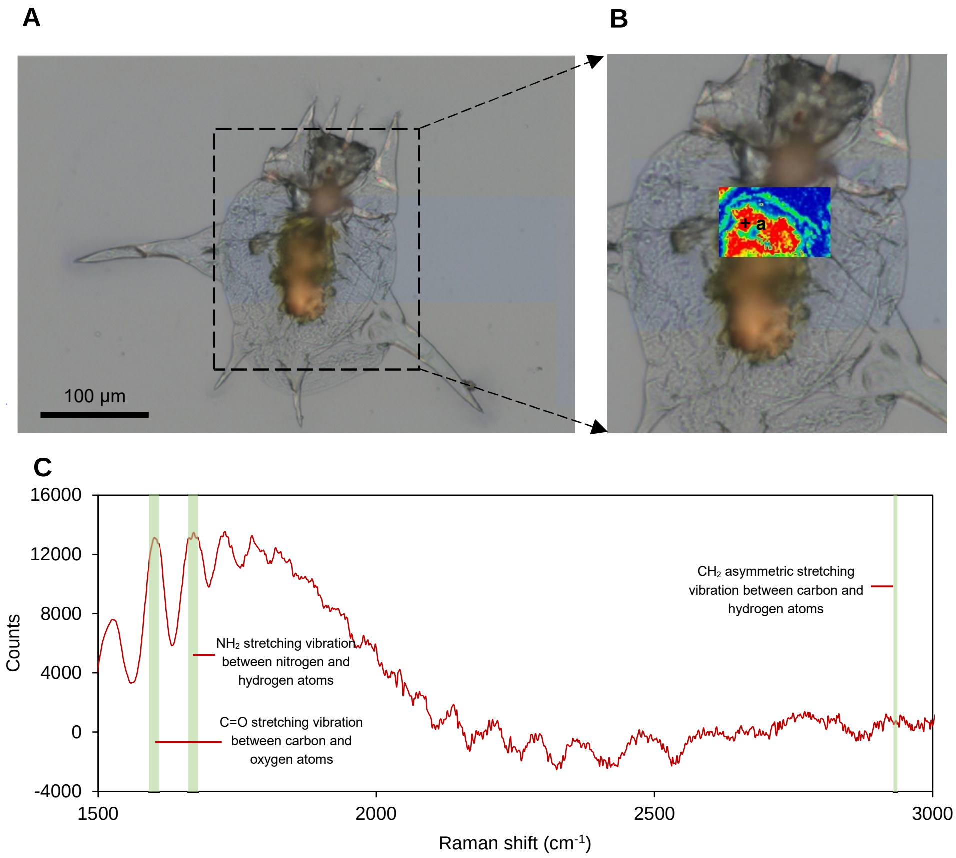


Supplementary Fig. 30. ATR-FTIR spectra of commercial PE microplastics, PS microplastics from the food containers and PS fibers. The characteristic peaks of all these microplastics were identified in the spectra.

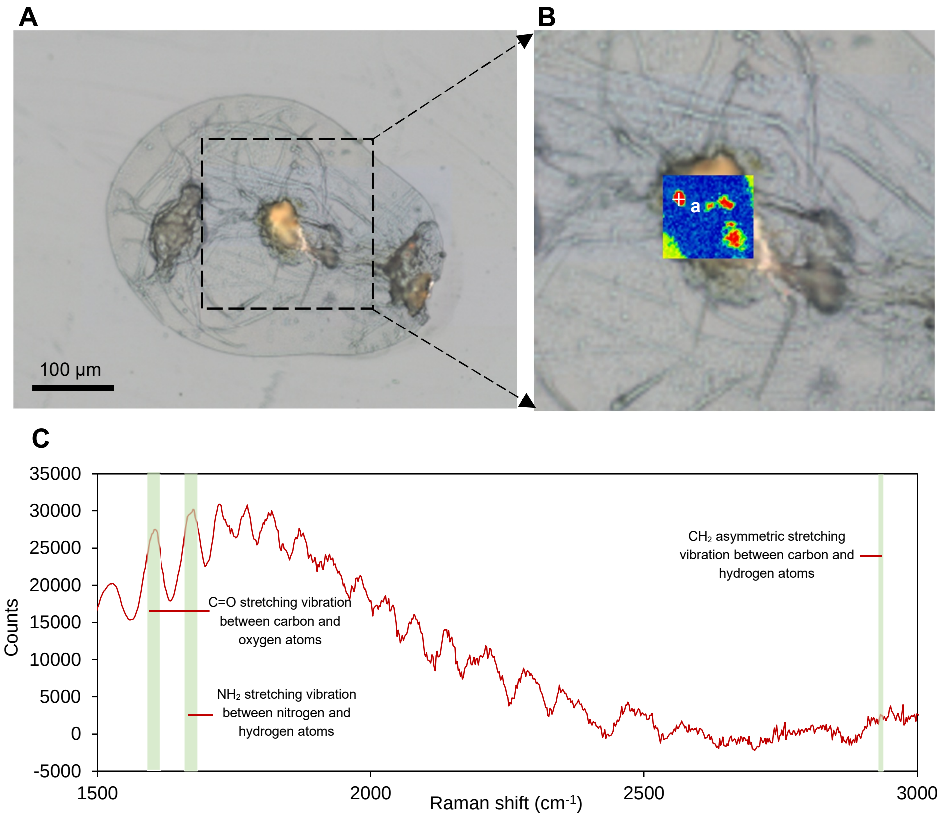
Supplementary Fig. 31. The locations (Qingdao, China) of the surface waters where different rotifers were sampled. The rotifers were sampled and isolated from all the five sampling sites. The map was drawn by ourselves based on the data of Tianditu (copyright free, https://www.tianditu.gov.cn/).



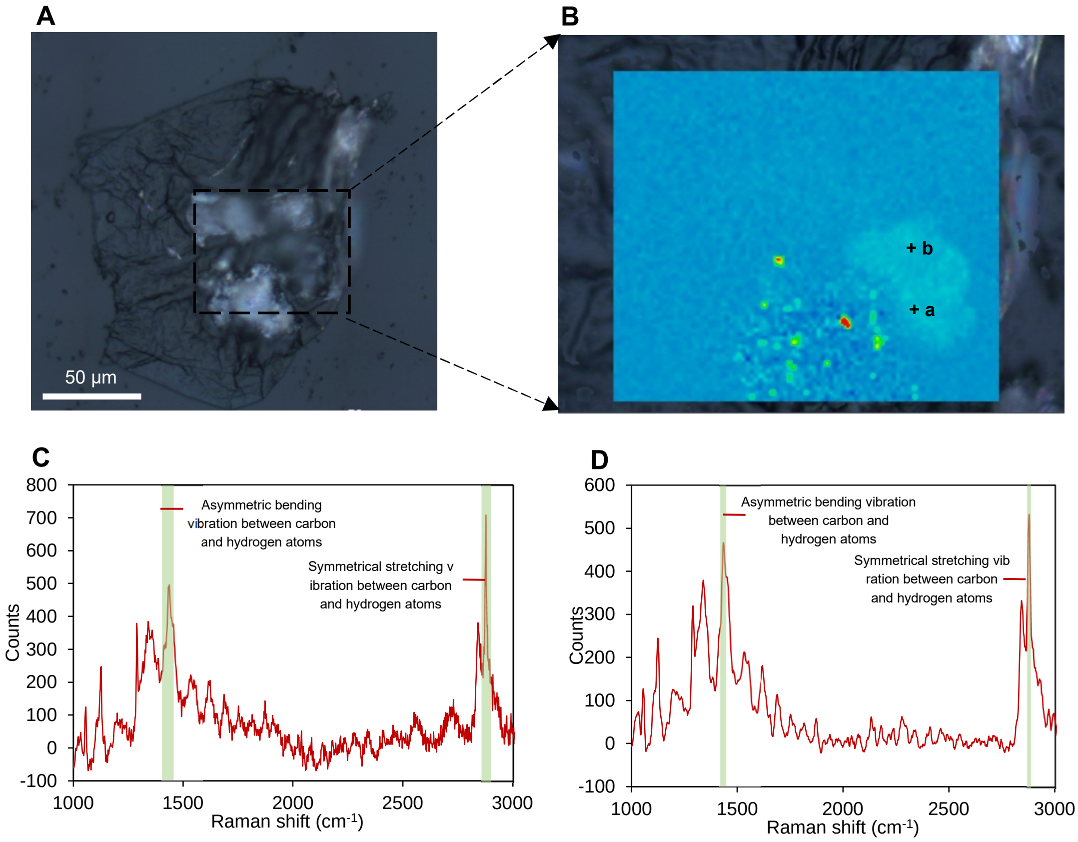
Supplementary Fig. 32. LCM-Raman images of environmental microplastics in the rotifers (*Brachionus angularis*) as isolated from Shuyuan reservoir. (A): Optical microscopic image of rotifer; (B): Overlay of color-coded Raman mapping image and optical microscopic image; (C), (D): Raman spectra of “Point a” and “Point b” in Image B. Raman characteristic peaks show that Points “a” and “b” are PS microplastics.



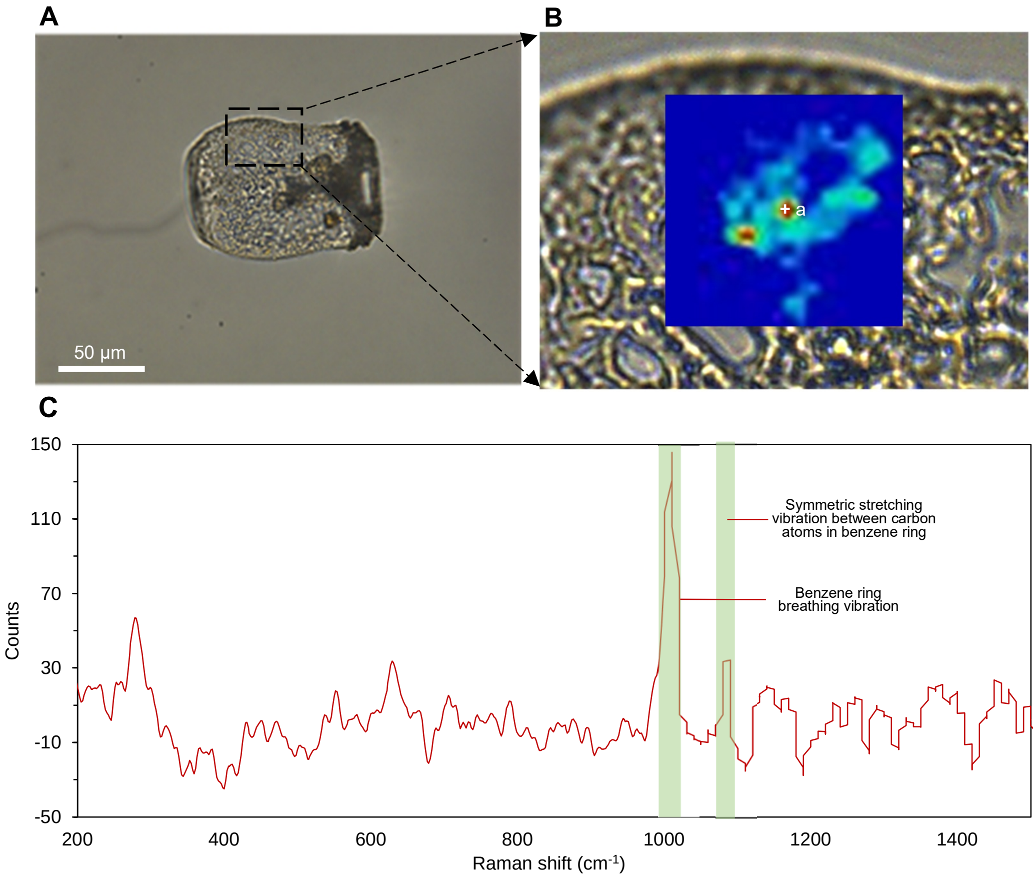
Supplementary Fig. 33. LCM-Raman images of microplastics in the rotifers (*Brachionus calyciflorus*) as isolated from Baisha River. (A): Optical microscopic image of rotifer; (B): Overlay of color-coded Raman mapping image and optical microscopic image; (C): Raman spectrum of “Point a” in Image B. Raman characteristic peaks indicate that Point “a” is polyacrylamide (PAM).



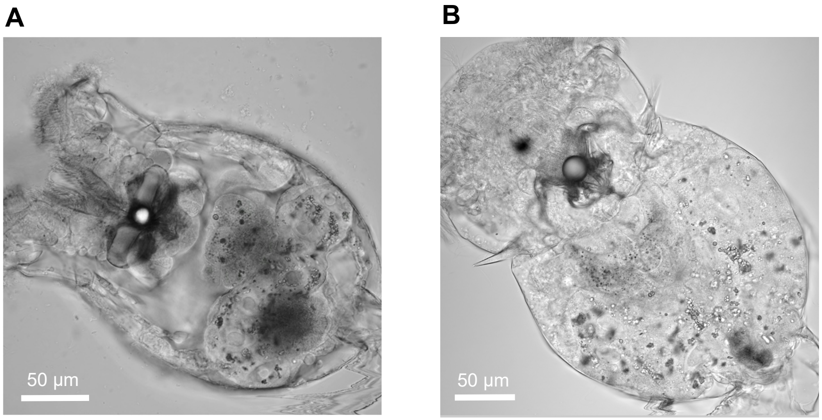
Supplementary Fig. 34. LCM-Raman images of microplastics in the rotifers (*Asplanchna*) as isolated from Dagu River. (A): Optical microscopic image of rotifer; (B): Overlay of color-coded Raman mapping image and optical microscopic image; (C): Raman spectrum of "Point a" in Image B. Raman characteristic peaks indicate that Point "a" is PAM.



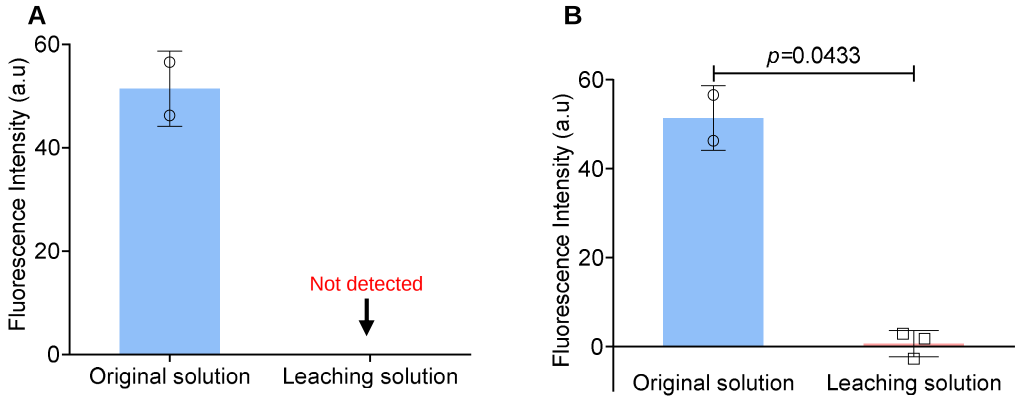
Supplementary Fig. 35. LCM-Raman images of microplastics in the rotifers (*Brachionus angularis*) as isolated from the mouth of Jiaozhou Bay. (A): Optical microscopic image of rotifer; (B): Overlay of color-coded Raman mapping image and optical microscopic image; (C), (D): Raman spectra of "Point a" and "Point b" in Image B. Raman characteristic peaks indicate that Points "a" and "b" are PE microplastics.



Supplementary Fig. 36. LCM-Raman images of microplastics in the marine rotifer as isolated from Jiaozhou Bay (Qingdao, China). (A): Optical microscopic images of the isolated marine rotifers; (B): Overlay of color-coded Raman mapping image and optical microscopic image; (C): Raman spectrum of "Point a" in Image B. Raman characteristic peaks indicate that Point a is PS. It is noted that the isolated rotifer was first detected with LCM-Raman and then imaged with an optical microscope. The rotifer body was partly damaged due to the high energy of laser during LCM-Raman detection, and the specific species could not be identified.



Supplementary Fig. 37. Optical microscopic images of rotifers after exposure to microplastics (20 μm). (A): marine rotifer (*Brachionus plicatilis*); (B): freshwater rotifer (*Brachionus calyciflorus*). During ingestion, 20-μm PS microplastics were blocked by the trophi (inner size, around 20 μm) of both marine and freshwater rotifers, thus preventing the ingestion or uptake of microplastics by rotifers.



Supplementary Fig. 38. Possible leaching of free fluorescent dyes from 10-μm PS microplastics in seawater (A) and freshwater (B). Original solutions of PS microplastics were dialyzed (pore size, 10 nm) in both seawater and freshwater for 4 h, and the obtained leaching solutions were detected with a fluorescence spectrophotometer (Hatachi F-4600, excitation wavelength: 475 nm, emission wavelength: 560 nm). The percentages of leached fluorescent dyes were negligible (lower or around the detection limit) in both seawater and freshwater. Data are presented as mean ± s.d. (n = 3 for leaching solution group, n = 2 for original solution group). Statistical analyses were performed using a two-tailed unpaired Student's *t*-test.

Supplementary Video 1. Uptake and grinding of PS microplastics by the rotifer. (video)
Supplementary Video 2. Grinding of 10-μm PS microplastics by the rotifer for 60 times before internalization. (video)
Supplementary Video 3. Excretion of photo-aged PS microplastics and the fragments by the rotifer. (video)

Supplementary Table 1 Different species of rotifers in aquatic environments (Segers and Yule, 2004; Oh et al., 2017).

Common rotifers	Trophi type	Trophi size (Length× width)
Asplanchna	Incudate type	~100 μm × 75 μm
Synchaeta, *Polyarthra*, *Trichocerca*	Virgate type	~30 μm × 50 μm
Brachionus, *Lecane*	Malleate type	~50 μm × 40 μm
Keratella, *Filinia*	Malleoramate type	~50 μm × 35 μm

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Supplementary Table 2 Distribution of freshwater and marine rotifers in water (individuals/L)

Region	Latitude	Longitude	Density	Main species	References
Freshwater rotifers					
Dianchi Lake, China	24.863039	102.725276	3567	*Brachionus* sp.	Sun et al., 2010
Fuchun River, China	30.113774	120.154568	280	*Brachionus* sp.	Guo et al., 2019
Shijiu Lake and Gucheng Lake, China	31.479094	118.886921	3023.19	*Trichocerca* sp., *Brachionus* sp.	Zheng et al., 2014
GeHu Lake, China	31.620976	119.831934	3555	*Keratella quadrata, Keratella cochlearis, Polyarthra vulgaris*	Yang et al., 2017
West Lake, China	30.251565	120.156043	2247	*Brachionus angularis, Keratella cochlearis*	Rao et al., 2013
Hongze Lake, China	33.31598	118.704746	620	*Keratella cochlearis, Asplanchna priodonta, Polyarthra dolichoptera*	Du et al., 2014
lakes of Huaibei, China	33.980678	116.845325	2722	*Polyarthra dolichoptera, trichocerca pusilla*	Yang et al., 2020
Five medium reservoirs in Nanjing, China	32.091086	118.72912	390	*Trichocerca* spp., *Polyarthra* spp.	Wang et al., 2017
Keluke Lake, China	37.283611	96.916825	1916	*Keratella cochlearis, Polyarthra trigla*	Liu et al., 2018
Lake Buluntuohai, China	47.221558	87.237132	247.6	*Polyarthra trigla, Filina longiseta, Hexarthra mira, Brachionus quadridentatus*	Yang et al., 2011
Pearl River Delta, China	22.785517	113.749937	26425	*Filinia longiseta, Polyarthra vulgaris, Brachionus angularia*	Li et al., 2017
Pearl River Delta, China	22.528309	113.413036	476	*B. Angularis, B. calyciflorus, K. cochlearis*	Gao et al., 2014
Reservoir in the southern mountainous area of Jinan, China	36.661186	117.126686	19.5	*Brachionus* sp.	Wang et al., 2017
Huangpu River, China	31.249259	121.502605	21128	*Polyarthra vulgaris*	Wu et al., 2018

Xiangjiang river, China	28.378194	112.853199	670	*Asplanchna priodonta*	Lu et al., 2019
Moguhu Reservoir, China	28.378194	112.853199	2500	*Brachionus calyciflorus, B. Forficula, Monostyla bulla*	Gao et al., 2018
Mingzhu Lake, China	31.746872	121.264741	5329.17	*Polyarthra trigla*, *Brachionus* sp., *Philodina* sp.	Zhou et al., 2014
Changdang Lake, China	31.630634	119.562997	2760	*Keratella cochlearis, Brachionus calyciflorus*	Liu et al., 2019
Songhua River, China	45.968338	126.857216	4000	*Brachionus calyciflorus, Polyarthra trigla, Keratella cochlearis*	Ju et al., 2017
Shengjin Lake, China	30.40824	117.073344	826.15	*Brachionus angularis, Asplanchna priodonta*	Wang et al., 2016
Yuehai Lake, China	38.56842	106.2138	801.72	*B.calyciflorus, B. angularis, A.priodonta*	Li et al., 2016
Jinan Watershed, China	36.664892	117.128986	453	*Brachionus* sp., *Keratella* sp.	Wang et al., 2015
Shahu Lake, China	38.818697	106.367861	547	*Brachionus angularis, Keratella valga, Brachionus calyciflorus*	Zhao et al., 2011
Yangtze River estuary, China	31.455511	121.717693	28	*Trichocerca pusilla, Brachionus calyciflorus*	Guo et al., 2014
The water sources rivers, China	30.716666	119.916666	936.5	*Polyarthra trigla*	Li et al., 2020
Changyang Lake, China	30.967521	120.518821	362	*Polyarthra trigla, Keratella ticinensis, Asplanchna priodonta*	Zhu et al., 2015
Dishui Lake River System of Shanghai, China	30.903569	121.947301	1194.58	*Polyarthra trigla, Trichocerca pusilla, Anuraeopsis fissa*	Jiang et al., 2011
Tongzi Lake Reservoir, China	37.483402	105.008511	824.5	/	Hu et al., 2018
Poyang Lake, China	29.457774	116.107596	815.8	*Asplanchna girodi*	Lv et al., 2019
Yangcheng Lake, China	31.443976	120.799775	14000	*Polyarthra trigla, Keratella cochlearis*	Chen et al., 2011

Urban River of TaiYuan, China	37.873344	112.548635	1834	*Keratella cochlearis, Polyarthra vulgaris, Brachionus calyciflorus*	Gao et al., 2016
Three Gorges Reservoir, China	30.823275	111.023927	4481.67	*Polyarthra trigla, Keratella cochlearis*	Xue et al., 2013
Qingshan Reservoir, China	30.25433	119.773975	450	*Polyarthra dolichoptera, Polyarthra trigla*	Liu et al., 2015
Qianhehu Lake, China	32.963895	117.121072	1104	*Keratella quadrata, Keratella ticinensis*	Liu et al., 2020
Oglethorpe County, America	33.88	-83.14	7980	*Trichocerca rousseleti, Polyarthra sp.,Keratella cochlearis and Kellicottia bostoniensis*	Orcutt et al., 1984
Vasikkalampi pond, Finland	65.215653	27.121337	17000	*Keratella cochlear*	Eloranta et al., 1982
Priest Pot, UK	54.3667	2.9667	40000	*Keratella cochlearis*	Hewitt et al., 1987
Leczna-Wlodawa Lakeland, Poland	51.95	19.09	2667	*Keratella cochlearis*	Radwanet al., 1989
Adyar estuary, India	13.08	80.27	10133	*Brachionus plicatilis*	Janakiramanet al., 2012
Caura river, Venezuela	7.693722	-65.893992	35	*Keratell*	Saunderset al., 1988
Königssee Lake, German	47.55	12.98	/	*Polyarthra vulgaris/dolichoptera, Kellicottia longispina* and *Keratella cochlearis*	Laxhuber et al., 1987
Loch Lomond, Scotland, UK	56.06	-4.63	849	*K. cochlearis* and *T. stylata*	May et al., 2005
Parana´ River, Brazil	-22.75	-53.4166	/	*Brachionidae, Lecanidae* and *Trichocercidae*	Costa et al., 2015
Corumba´ reservoir, Brazil	-19.010121	-57.650876	120	*Brachionus calyciflorus, Polyarthra vulgaris, Keratella tropica, K. cochlearis, K. americana* and *Pompholyx complanata*	Bonecker et al., 2005

Szczecinek County, Poland	53.633	16.6	16000	*Cephalodella catellina* and *Lecane closterocerca*	Bielańska-Grajneret al., 2005
Meuse river, Belgium	49.103388	5.286424	4515	*Brachionus calyciflorus Pallas, Brachionus angularis Gosse, Keratella cochlearis (Gosse) and Synchaeta* spp.	Marneffe et al., 1996
Lake Kinneret, Israel	32.81134	35.59281	/	*Asplanchna brightwelli*, *Asplanchna priodonta*, *Synchaeta pectinata*, *Brachionus calyciflorus*	Gophen et al., 2005
Lough Neagh, Northern Ireland	54.78772	-6.492314	/	*Keratella cochlearis*,*Polyarthra dolichoptera* and *Notholca acuminata*	Andrew et al., 1992
Middle Loire, France	47.47116	-0.551826	4600	*Anuraeopsis fissa*,*Ascomorpha ovalis*, *Asplanchna priodonta* and *B. calyciflorus*	Lair et al., 2005
Meso-eutrophic Rimov Reservoir, Czech	48.97554	14.48038	/	*Keratella cochlearis*, *Synchaeta lakowitziana*, *Polyarthra dolichoptera*, *Polyarthra vulgaris*, *Kellicottia longispina*, and *Conochilus hippocrepis*	Devetter et al., 2005
Budzynskie Lake, Poland	52.26728	16.79425	2316	*Conochilus unicornis*, *Keratella cochlearis*, *Lecane luna*	Kuczyńska et al., 2001
Brahmaputra river basin, India	27.25	94.9333	/	Lecanidae, Brachionidae, Colurellidae, Trichocercidae, Testudinellidae	Sharma et al., 2001

Vortsjarv Lake, Estonia	58.20307	26.05995	0.648	*Synchaeta verrucosa, Polyarthra dolichoptera,Keratella cochlearis,Keratella quadrata frenzeli*	Haberman et al., 1995
Murray River, Australia	-35.86161	145.5884	/	*Lecanidae,Trichocercidae, Brachionidae, Notommatidae*	Shiel et al., 1998
Kalahari Gemsbok National Park, South Africa	-25.31895	20.87427	/	*Brachionus calyciflorus, B. plicatilis* and *Hexarthra jenkinae*	Brain et al., 1995
Pripyat River, Ukraine	51.31346	30.21434	17970	*Trichocerca pusilla, Synchaeta oblonga, Keratella cochlearis, Filinia longiseta, Brachionus angularis, Polyarthra vulgaris*	Galkovskaya et al., 2001
Nyahiry Lake, Uganda	0.509965	30.32254	437	*Brachionus falcatus, Asplanchna sieboldi and Conochiloides natans)*	Kizito et al., 1995
Chaohu, China	117.7237	31.60859	662.3	*Cephalodellacatellina, Polyarthra vulgarisConochilus unicornis, B. calyciflorus, Keratella quadrate, K. cochlearis, Trichoercabrachyura,* and *Lecan hornemanni.*	Geng et al., 2005
Kud-Thing Lake, Thailand	17.86076	102.738	/	*Lecane* and *Trichocerca*	Sanoamuang et al., 2001
Poznan agglomeration area, western Poland	52.41059	16.92661	1503	*Brachionus angularis Keratella cochlearis, Colurella uncinata, Lecane closterocerca Lepadella patella L.closterocerca K. cochlearis.*	Ejsmont et al., 2001
Vasikkalampi pond, Finland	62.2333	25.71666	15000	*Keratella cochlearis*	Eloranta rt al., 1982

in the Sapucaí River, Brazil	-20.67066	-46.31523	166.9	*Ascomorpha ecaudis,Brachionus dolabratus,Collotheca sp.,Conochilus coenobasis, C. unicornis, Filinia longiseta,F. opoliensis, Hexarthra intermedia, Kellicottia bostoniensis, Keratella americana, K. cochlearis, Lecane proiecta, Polyarthraaff. vulgaris* and *Sinantherina semibullata*	Negreiros et al., 2010
Lakes Mira, Vela and Linhos, Portugal	40.64204	-8.653179	2000	*Keratella cochlearis*	Castro et al., 2005
Raccoon Creek, U .S.A.	40.40388	-82.97726	4000	*Lecane spp.*, *Cephalodella* spp. and *Trichocerca* spp.	Evans et al., 1984
Elbe Estuary, Germany	53.54049	9.901937	2048	*Keratella cochlearis*	Holst et al., 1998
Konin County, Poland	58.26873	11.33047	1600	*Keratella cochlearis*, *Pompholyx sulcata*	Ejsmont et al., 2020
Bosisitenghu Lake, China	41.995	87.03704	174	*Collotheca sp., Polyarthra trigla, Keratella cochlearis*	Qi et al., 2017
Baiyangdian Lake, Chine	38.96036	116.0174	34520	*Brachionus angularis, Polyarthra trigla*	Yang et al., 2010
Guanting Reservoir, China	40.40506	115.8052	3015	*Keratella cochlearis, Polyarthra trigla*	Guo et al., 2010
River in BeiJing, China	39.90305	116.3756	374.6	*Brachionus calyciflorus, Brachionus diversicornis, Brachionus urceus*	Wang et al., 2019
Danjiangkou Reservoir, China	32.75188	111.5975	5373	*Polyarthra vulgaris, Keratella cochlearis, Synchaeta oblonga, Trichocerca similes, Trichocerca lophoessa, Anuraeopsis fissa*	Kong et al., 2010

Daotianhe Reservoir and Biyang Lake, China	27.31956	105.267	28000	*Brachionus* spp. and *Tortoise* spp.	Gong et al., 2019
Fuhai Reservoir, China	46.74592	88.00006	515.19	*Philodina* sp., *Brachionus angularis, Brachionus calyciflorus, Keratella cochlearis, Keratella ticinensis, Asplanchna* sp.	Xue et al., 2011
Reservoirs in Shenzhen, China	22.54712	114.0663	1048	*Brachionus angularis, Brachionus falcatus, Brachionus diversicornis, Brachionus forficula, Ploesoma truncatum, Synchaetidae stylata, Polyarthra euryptera, Asplanchna brightwelli*	Huang et al., 2019
Dongting Lake, China	29.26975	112.9168	1750	*Polyarthra* spp.	Wang et al., 2018
Marine rotifers					
Northern Adriatic Sea	45.72305	13.56	/	*Lecane insulaconae*	Fontaneto et al., 2008
Gullmar Fjord, Sweden	58.343	11.567	/	*Synchaeta vorax*	Hernroth et al., 1983
Baltic Sea	56.751714	18.719158	289	*Synchaeta* spp, *Keratella quadrata*, *K. cochlearis* and *K. cruciformis*	Johansson et al., 1983
Neva Bay, Russia	59.941686	29.992136	2832	*Kellicottia longispina,Synchaeta* spp., *Polyarthra* spp.	Telesh et al., 1995
Canadian high arctic	75.5	-86	/	Cephalodella, Trichocerca, Lepadella	De Smet et al., 1995
North Sea island of Sylt	54.90828	8.317985	/	Colurellidae,Proalidae,Dicranophoridae	Tzschaschel et al., 1983
Floridian saltwater beach	28.924349	-79.75533	/	*Lecane inermis*, *Colurella salina*	Turner et al., 1993
Kaw River estuary (French Guiana)	4.889836	-52.212241	750	*Synchaeta cecilia*, *Trichocerca marina*	Rougier et al., 2005
coastal waters of the northeast Pacific Ocean	43.593273	-124.94885	64	*Synchaeta* sp.	Fradkin et al., 2001
Gullmar Fjord, Sweden	58.268731	11.330472	850	*Synchaeta* sp.	Hernroth et al., 1983

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Supplementary Table 3 Distribution of microplastics in water (particle size less than 500 μm, particles/m^3)

Region	latitude	longitude	Concentration	Main polymer type	Size range (μm)	Reference
Freshwater environments						
Yulin River, China	29.6182	106.5995	525	PE, PP, PS	64-500	Mao et al., 2020
Tuojiang River, China	28.9596	105.2926	679	PE, PP, PS, PVC	<500	Zhou et al., 2020
Laoshan Reservoir, China	36.1016	120.39	900	PET, Rayon, PE, PVC, PES	<500	Zhang et al., 2020
Pearl River, China	23.1141	113.3917	18867	PA, PE, PP, VAC, PVC	<500	Yan et al., 2019
Poyang Lake, China	29.1530	116.2841	23800	Nylon, PVC, PP, PE	<500	Yuan et al., 2019
Kallavesi Lake, Finland	62.9869	27.8453	300	PET, PAN, PP, PE, PMMA	20-300	Uurasjärvi et al., 2020
Seine and Marne River, France	48.8587	2.4063	22.26	—	100-500	Dris et al., 2015
Ciwalengke River, Indonesia	6.1338	106.8184	224000	—	50-500	Alam et al., 2019
Chiusi Lake, Italy	43.0581	12.4383	1.5	—	<500	Fischer et al., 2016
Amsterdam canal, Netherlands	52.3715	4.8948	106590	—	100-300	Leslie et al.,2017
Ofanto River, Italy	41.1679	15.7809	2	PE, PS, PP, PVC, TPU	<500	Campanale et al.
Qin River, China	21.8519	108.5424	54	PP, PE, PET, PS	<300	Zhang et al.,2020
Lijiang River, China	25.2491	110.3106	87.5	PP, PB, PE, PS	75-300	Zhang et al., 2021
Dongting Lake, China	29.2698	112.9088	67	PET, PP, PS, PE	<500	Jiang et al., 2018
Wei River, China	34.5580	109.4423	5500	—	<500	Ding et al., 2019
Taihu Lake, China	31.0441	120.1679	12900	—	5-333	Su et al., 2016
Wuliangsuhai Lake	41.5356	110.993	6750	PS, PP, PE, PVC	<500	Mao et al., 2020

Fengshan River, China	22.7006	120.4109	800	PE, PET, PA, PES	50-297	Tien et al., 2020
Luoyang Lake,China	30.5641	114.3081	2700	PET, PP, PE, Nylon,	PS <500	Wang et al., 2017
Han River, South Korea	37.5232	126.9679	66.3	PS, PP, PES, PU	100-300	Park et al., 2020
Nakdong River, South Korea	35.2669	128.9691	3522.4	PES, PE, PA, PS	<300	Eo et al., 2019
Wando River, USA	32.7901	-79.9431	31752	PE, PP, PVA	63-499	Leads et al., 2019
Ebro River, Spain	40.6950	0.79683	2.6	PA, PMMA, PES, PP	<500	Sánchez et al., 2019
Zhangjiang River, China	23.9334	117.3842	355	PP, PE, PS, PES, PET	300-500	Pan et al., 2020
Tsurumi River, Japan	19.5422	110.84	775	PE, PET, PMMA, PP	<335	Kameda et al., 2021
Chishui River, China	27.7910	106.3881	10490	PE, PP, PS, PVC	<500	Li et al., 2021
Danjiangkou Reservoir, China	32.8333	111.5	22318	PA, PE, PP, PVF	75-500	Lin et al., 2021
Taihu Lake, China	33.9167	120.2333	17356	PVC, PE, PS, PP	<500	Zhang et al., 2021
Klang River, Malaysia	2.9943	101.3594	3150	PA, PE	<300	Zaki et al., 2021
West River, China	23	112.4583	2700	PP, PE, PS	<500	Huang et al., 2021
Dafeng River, China	21.7794	108.55	0.2	PET, Rayon, PBT, POM, PS, PE	<500	Liu et al., 2021
Guanyingyan Reservoir, China	26.5242	101.4467	5557	PS, PP, PE, PA	<500	Liu et al., 2022
Scheldt River, Belgium	51.2296	4.3973	164	----	<500	Liu et al., 2022
Seawater						
South China Sea	9.6734	114.0432	0.000606	PP, PE, PPC, PAN	<333	Tan et al., 2020
Chukchi Sea	64.2617	-170.064	0.0117	PET, PP, PE, PA	<500	Mu et al., 2019

western equatorial Atlantic, Brazil	-0.0205	-48.0772	0.12	—	120-300	Garcia et al., 2020
Yellow Sea	32.8053	121.3341	0.253	PET, PE	50-500	Wang et al., 2018
Caspian Sea, Iran	37.4778	49.4444	1.41	PE, PP, PEST, PAN, PS	<500	Rasta et al., 2020
Winyah Bay, USA	33.1663	-79.2436	110000	PS, PP, PET, PE	63-499	Gray et al., 2018
Bohai Sea, China	38.9312	120.5968	0.0845	PE, PP, PS, PET	200-500	Panti et al., 2015
Arctic Ocean	82.46812	-2.4673	2720	PES, PA, PVC	250-500	La Daana et al., 2020
Jiaozhou Bay, China	36.1413	120.2402	10.8	PET, PP, PE, PVC, PVAC	<500	Zheng et al., 2020
Southern North Sea	56.1434	3.3962	230.63	PP, PE, PEST	<500	Lorenz et al., 2019
Maowei Sea, China	21.3781	108.5667	2.03	Rayon, PES, PP, PE, PS	<500	Zhu et al, 2019
South China Sea	16.3928	112.1347	7056	Rayon, PET	<500	Ding et al., 2019
South Yellow Sea	34.0578	123.6333	5135	PE, PP, PS, PA, PET	50-500	Jiang et al., 2020
South China Sea	21.9078	114.8117	2363	alkyd resin, PCL, PEA, PS	20-300	Cai et al., 2018
Incheon/Kyeonggi Coastal, Korea	37.3255	126.4896	1100	Alkyd, poly(acryl ate/styrene)	50-500	Chae et al., 2015
Chabahar Bay, Iran	25.1701	58.8762	49331	PE, PET, nylon	330-500	Hosseini et al., 2020
Ulsan Bay, South Korea	35.4	129.4	1.25	PE, PP	<500	Kwon et al., 2020
Seto Inland Sea, Japan	33.9519	131.3159	18600	PET., PE	50-500	Kabir et al., 2020
Bathing beaches, China	36.0603	120.3197	370.88	Rayon, PET, PE, PS, PVC	<500	Gao et a., 2021
Benoa Bay, Indonesia	8.75	115.2	0.498	PE, PP, PS, Nylon	<500	Suteja et al., 2021
South China sea	9.76237	111.9383	729	PP, PE, PVC	100-500	Cui et al., 2022
Gulf of Thailand	12.62652	101.4416	2019.89	PE, PP, PS	<500	Prarat et al., 2022
coastal waters, China	19.5541	110.8661	18780	PE, PET, PP	30-415	Gao et al., 2022

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