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SUPPLEMENTARY INFORMATION

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Microplastic contamination of river beds significantly reduced by catchment-wide flooding

Rachel Hurley*, Jamie Woodward* and James J. Rothwell

Department of Geography, The University of Manchester, Manchester, UK. *e-mail: rachel.hurley@manchester.ac.uk; jamie.woodward@manchester.ac.uk

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Rachel Hurley, Jamie Woodward, James J. Rothwell

Department of Geography, The University of Manchester, Manchester, M13 9PL, UK

Supplementary Information

Supplementary Figure 1

Supplementary Figure 2

Supplementary Table 1

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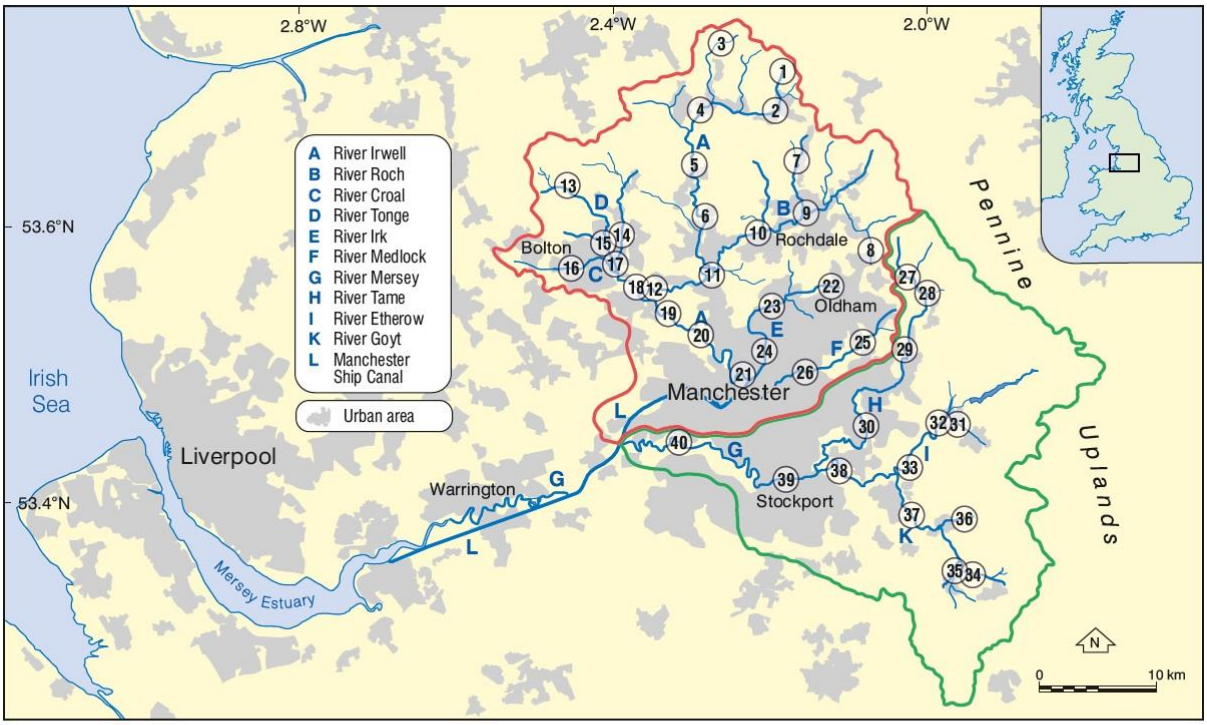
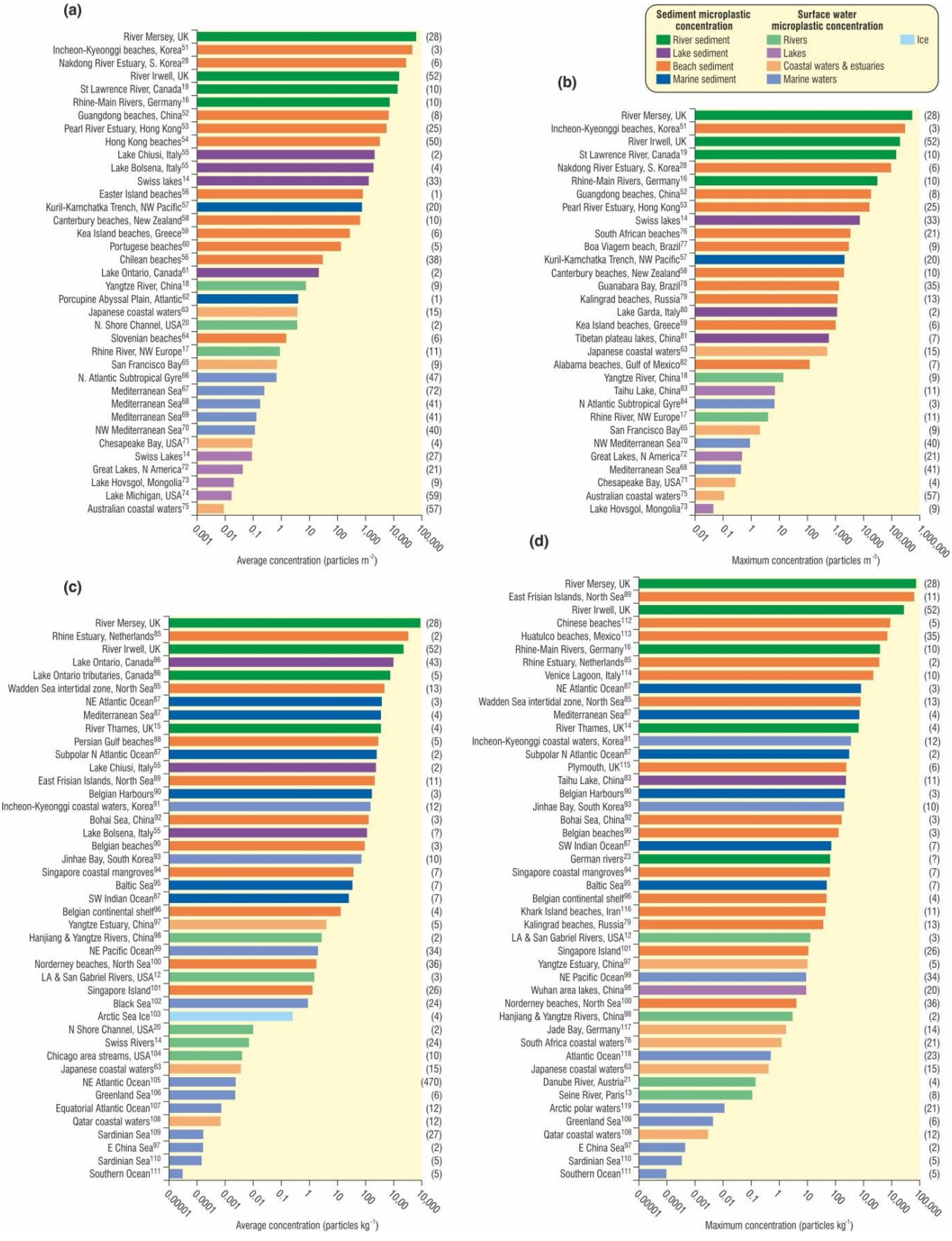
Supplementary Table 5

Supplementary Data (.xls)



1. Irwell Springs	9. Rochdale	17. Darcy Lever	25. Bardsley	33. Compstall
2. Bacup	10. Heywood	18. Nob End SSSI	26. Piccadilly	34. Buxworth
3. Love Clough	11. Roch-Irwell Confluence	19. Clifton	27. Delph	35. Whaley Bridge
4. Rawtenstall	12. Irwell-Croal Confluence	20. Pendlebury	28. Greenfield	36. Hayfield
5. Ramsbottom	13. Egerton	21. Manchester	29. Mossley	37. Strines
6. Bury	14. Bradshaw	22. Chadderton	30. Denton	38. Vernon Park
7. Whitworth	15. Waters Meeting	23. Middleton	31. Brookfield	39. Heaton Mersey
8. Shaw	16. Heaton	24. Harpurhey	32. Gamesley	40. Urmston

Supplementary Figure 1: **The 40 channel bed sediment sampling sites in the Irwell and upper Mersey catchments.** Catchment boundaries are shown for the upper Mersey (green) and Irwell (red). Physical and hydrological information for all sampling sites is provided in the Supplementary Data (.xls file).



Supplementary Figure 2: Global ranking of microplastic concentrations. This global dataset incorporates published studies of microplastic contamination in both aquatic and sedimentary environments where concentrations of plastic debris (<5 mm) have been reported. The references are given as superscripts at the end of each study location and listed in full in the Methods. The number of samples in each case is given in brackets. Concentrations are shown as average (a,c) and maximum (b,d) concentrations for particles m^{-2} (a,b) and particles kg^{-1} (c,d).

Supplementary Table 1: Total microplastic bed sediment concentrations pre- and post-flooding. Data are presented as multiple expressions to permit inter-study comparison. Concentrations associated with the 1.025 g cm^{-3} and 1.2 g cm^{-3} extracts are collated in (c) and (d) to allow comparison between those studies that do not utilise an additional 1.8 g cm^{-3} density extraction.

a. Pre-flooding: all densities

	Average	Minimum	Maximum
particles m^{-2}	45,357	0	444,286
particles kg^{-1}	6,350	0	62,200
mg kg^{-1}	129	0	551

b. Post-flooding: all densities

	Average	Minimum	Maximum
particles m^{-2}	20,089	1,428	517,142
particles kg^{-1}	2,812	200	72,400
mg kg^{-1}	85.3	11.3	868

c. Pre-flooding: <1.2 g cm^{-3}

	Average	Minimum	Maximum
particles m^{-2}	28,919	0	288,571
particles kg^{-1}	4,048	0	40,400
mg kg^{-1}	79.8	0	312

d. Post-flooding: <1.2 g cm^{-3}

	Average	Minimum	Maximum
particles m^{-2}	2,375	0	64,200
particles kg^{-1}	16,964	0	458,571
mg kg^{-1}	61.9	0	789

Supplementary Table 2: Microplastic concentrations pre- and post-flooding for all 40 sites with change (% loss or gain) post-flooding. Blue shading (light and dark) indicates a significant (i.e. % change > uncertainty) *decrease* in microplastic concentration; red represents a significant *increase*; and yellow represents results that show no significant change. Results are shown for total microplastics, microbeads, and fragments. The dark blue shading indicates those sites where *complete removal* of microbeads or microplastic fragments took place post-flooding. Our analyses show that the uncertainty in this environment associated with the quantification of microplastic fibres and those classified as "other" is much higher than that of microbeads and fragments. The uncertainty analysis is described in the Methods and the results are given in full in Supplementary Table 5. *Site with an increase from zero.

	Total microplastics (particles kg^{-1})			
	Site	*Pre-flooding*	*Post-flooding*	*Change*
River Irwell	Waters Meeting	26800	1500	-94%
	Chadderton	2700	200	-93%
	Piccadilly	3400	400	-88%
	Rochdale	15100	1800	-88%
	Manchester	2100	300	-86%
	Heaton	4100	600	-85%
	Nob End SSSI	2500	400	-84%
	Shaw	6600	1400	-79%
	Irwell-Croal confluence	1400	300	-79%
	Bury	2300	700	-70%
	Bardsley	1700	600	-65%
	Pendlebury	5200	2200	-58%
	Harpurhey	5400	2500	-54%
	Whitworth	1000	600	-40%
	Bradshaw	1200	800	-33%
	Irwell Springs	900	600	-33%
	Love Clough	300	200	-33%
	Darcy Lever	600	400	-33%
	Heywood	700	500	-29%
	Egerton	500	600	20%
	Middleton	600	1000	67%
	Roch-Irwell confluence	2000	3400	70%
	Clifton	900	1700	89%
	Bacup	800	1600	100%
	Rawtenstall	400	1200	200%
	Ramsbottom	100	1000	900%
River Mersey	Brookfield	62200	1700	-97%
	Buxworth	4800	200	-96%
	Strines	9100	600	-93%
	Urmston	21800	2200	-90%
	Mossley	3900	500	-87%
	Hayfield	1600	400	-75%
	Heaton Mersey	4800	1300	-73%
	Compstall	500	200	-60%
	Greenfield	4300	1800	-58%
	Vernon Park	1800	1900	6%
	Delph	1300	1400	8%
	Denton	48300	72400	50%
	Gamesley	300	1200	300%
	Whaley Bridge*	0	200	–

	Microbeads (particles kg^{-1})		
Site	*Pre-flooding*	*Post-flooding*	*Change*
Chadderton	900	0	-100%
Egerton	100	0	-100%
Whitworth	400	0	-100%
Waters Meeting	25500	1100	-96%
Shaw	4100	300	-93%
Manchester	1100	200	-82%
Heaton	500	100	-80%
Rochdale	4200	1000	-76%
Piccadilly	1600	400	-75%
Rawtenstall	300	100	-67%
Bardsley	900	400	-56%
Irwell-Croal confluence	200	100	-50%
Bury	300	200	-33%
Nob End SSSI	300	200	-33%
Heywood	300	200	-33%
Bradshaw	700	500	-29%
Harpurhey	2000	1900	-5%
Love Clough	100	100	0%
Ramsbottom	0	0	0%
Clifton	400	600	50%
Pendlebury	500	800	60%
Middleton	100	200	100%
Darcy Lever	100	200	100%
Roch-Irwell confluence	500	1100	120%
Bacup	300	600	100%
Irwell Springs*	0	100	–
Buxworth	100	0	-100%
Compstall	300	0	-100%
Brookfield	100	0	-100%
Strines	800	0	-100%
Delph	800	100	-88%
Urmston	5900	1000	-83%
Vernon Park	500	100	-80%
Heaton Mersey	1600	700	-56%
Greenfield	500	300	-40%
Gamesley	200	200	0%
Mossley	200	200	0%
Hayfield	0	0	0%
Whaley Bridge	0	0	0%
Denton	14000	70600	404%

	Fragments (particles kg^{-1})		
Site	*Pre-flooding*	*Post-flooding*	*Change*
Chadderton	1400	0	-100%
Piccadilly	1300	0	-100%
Rochdale	9300	700	-92%
Manchester	900	100	-89%
Heaton	3000	400	-87%
Pendlebury	3500	600	-83%
Irwell-Croal confluence	1100	200	-82%
Nob End SSSI	1000	200	-80%
Harpurhey	2100	600	-71%
Bury	1600	500	-69%
Waters Meeting	1200	400	-67%
Irwell Springs	500	200	-60%
Shaw	1900	800	-58%
Bacup	400	200	-50%
Bradshaw	400	200	-50%
Bardsley	400	200	-50%
Darcy Lever	400	200	-50%
Heywood	500	300	-40%
Love Clough	100	100	0%
Roch-Irwell confluence	1000	1000	0%
Egerton	400	500	25%
Middleton	300	400	33%
Whitworth	200	400	100%
Rawtenstall	100	600	500%
Clifton*	0	700	–
Ramsbottom*	0	1000	–
Brookfield	39800	1500	-96%
Buxworth	4700	200	-96%
Strines	8000	600	-93%
Mossley	3300	300	-91%
Urmston	10700	1000	-91%
Denton	14400	1600	-89%
Heaton Mersey	2700	600	-78%
Greenfield	3000	800	-73%
Hayfield	1300	400	-69%
Compstall	200	200	0%
Vernon Park	1200	1800	50%
Delph	300	1200	300%
Gamesley	100	600	500%
Whaley Bridge*	0	100	–

Supplementary Table 3: Pre- and post-flooding bed sediment microplastic loads. Data for the Irwell (a) and Mersey (b) and both catchments (c). The results for each of the three reach-scale estimation methods are also given. Method 3 values are used in the main paper and in all figures (see Methods). Tonnes of microplastics have been rounded to 2 decimal places and numbers of particles to the nearest 1,000. The uncertainty associated with post-flooding change has been derived using the uncertainty estimates given in Supplementary Table 5.

(a) **Irwell**

		Pre-Flooding	Post-Flooding	Change ± uncertainty	Change (%)
Method 1	Microplastics (*tonnes*)	0.37	0.14	0.23 ± 0.07	-63%
	Microplastics (*particles*)	12,809,175,000	2,487,208,000	10,321,967,000 ± 3,402,121,000	-81%
	Microbeads (*particles*)	5,051,621,000	1,173,724,000	3,877,898,000 ± 1,976,784,000	-77%
	Seawater buoyant (*tonnes*)	0.20	0.05	0.15 ± 0.05	-75%
Method 2	Microplastics (*tonnes*)	0.38	0.13	0.25 ± 0.08	-65%
	Microplastics (*particles*)	14,815,277,000	2,290,432,000	12,524,845,000 ± 4,128,190,000	-85%
	Microbeads (*particles*)	4,658,581,000	1,118,571,000	3,540,009,000 ± 1,804,543,000	-76%
	Seawater buoyant (*tonnes*)	0.18	0.05	0.13 ± 0.04	-73%
Method 3	Microplastics (*tonnes*)	0.82	0.13	0.69 ±0.22	-84%
	Microplastics (*particles*)	35,322,981,000	3,075,358,000	32,247,622,000 ± 10,628,820,000	-91%
	Microbeads (*particles*)	10,854,441,000	1,571,532,000	9,282,908,000 ± 4,735,863,000	-86%
	Seawater buoyant (*tonnes*)	0.34	0.05	0.30 ± 0.10	-86%

(b) **Mersey**

		Pre-Flooding	Post-Flooding	Change ± uncertainty	Change (%)
Method 1	Microplastics (*tonnes*)	0.38	0.23	0.15 ± 0.05	-39%
	Microplastics (*particles*)	22,265,236,000	14,029,825,000	8,235,411,000 ± 2,714,392,000	-37%
	Microbeads (*particles*)	5,886,668,000	8,254,823,000	2,368,155,000 ± 1,207,183,000	40%
	Seawater buoyant (*tonnes*)	0.09	0.01	0.08 ± 0.03	-87%
Method 2	Microplastics (*tonnes*)	0.35	0.13	0.22 ± 0.07	-63%
	Microplastics (*particles*)	17,891,186,000	8,447,849,000	9,443,338,000 ± 3,112,525,000	-53%
	Microbeads (*particles*)	5,618,007,000	6,754,452,000	1,136,445,000 ± 579,310,000	20%
	Seawater buoyant (*tonnes*)	0.08	0.01	0.07 ± 0.02	-89%
Method 3	Microplastics (*tonnes*)	0.38	0.22	0.16 ± 0.05	-42%
	Microplastics (*particles*)	23,639,102,000	12,515,530,000	11,123,571,000 ± 3,666,330,000	-47%
	Microbeads (*particles*)	8,851,755,000	11,135,925,000	2,284,170,000 ± 1,165,315,000	26%
	Seawater buoyant (*tonnes*)	0.07	0.02	0.06 ± 0.02	-74%

(c) **Irwell and Mersey combined**

		Pre-Flooding	Post-Flooding	Change ± uncertainty	Change (%)
Method 1	Microplastics (*tonnes*)	0.75	0.36	0.39 ± 0.12	-52%
	Microplastics (*particles*)	35,074,411,000	16,517,033,000	18,557,378,000 ± 6,116,514,000	-53%
	Microbeads (*particles*)	10,938,290,000	9,428,547,000	1,509,743,000 ± 769,602,000	-14%
	Seawater buoyant (*tonnes*)	0.28	0.06	0.22 ± 0.07	-77%
Method 2	Microplastics (*tonnes*)	0.73	0.25	0.48 ± 0.16	-66%
	Microplastics (*particles*)	32,706,463,000	10,738,281,000	21,968,183,000 ± 7,240,715,000	-67%
	Microbeads (*particles*)	10,276,588,000	7,873,024,000	2,403,564,000 ± 1,225,234,000	-23%
	Seawater buoyant (*tonnes*)	0.26	0.06	0.20 ± 0.07	-78%
Method 3	Microplastics (*tonnes*)	1.20	0.35	0.85 ± 0.27	-71%
	Microplastics (*particles*)	58,962,082,000	15,590,889,000	43,371,194,000 ± 14,295,150,000	-74%
	Microbeads (*particles*)	19,706,196,000	12,707,457,000	6,998,738,000 ± 3,570,547,000	-36%
	Seawater buoyant (*tonnes*)	0.42	0.06	0.36 ± 0.12	-85%

Supplementary Table 4: Microplastic bed sediment loads by particle type and density pre- and post-flooding. Results are presented by Irwell (a), and Mersey (b), and both catchments (c). Tonnes of microplastics have been rounded to 2 decimal places and numbers of particles to the nearest 1,000. The final column shows percentage change pre- and post-flooding. The uncertainty associated with the post-flooding changes has been derived using the uncertainty estimates given in Supplementary Table 5.

(a) **Irwell**

		Pre-Flooding	Post-Flooding	Change ± uncertainty	Change (%)
Type (*particles*)	Fragments	20,459,501,000	1,320,101,000	19,139,399,000 ± 9,571,257,000	-94%
	Fibres	2,725,232,000	153,883,000	2,571,349,000 ± 3,091,322,000	-94%
	Microbeads	10,854,441,000	1,571,532,000	9,282,908,000 ± 4,735,863,000	-86%
	Other	1,283,807,000	29,842,000	1,253,964,000 ± 4,351,191,000	-98%
Density (*tonnes*)	1.025 g cm^{-3}	0.34	0.05	0.30 ± 0.10	-86%
	1.2 g cm^{-3}	0.20	0.04	0.16 ± 0.07	-79%
	1.8 g cm^{-3}	0.27	0.03	0.24 ± 0.11	-88%

(b) **Mersey**

		Pre-Flooding	Post-Flooding	Change ± uncertainty	Change (%)
Type (*particles*)	Fragments	13,518,034,000	1,289,722,000	12,228,309,000 ± 6,115,151,000	-89%
	Fibres	994,823,000	89,883,000	904,940,000 ± 1,087,935,000	-91%
	Microbeads	8,851,755,000	11,135,925,000	2,284,170,000 ± 1,165,315,000	26%
	Other	274,490,000	0	274,490,000 ± 952,466,000	-100%
Density (*tonnes*)	1.025 g cm^{-3}	0.07	0.02	0.06 ± 0.02	-78%
	1.2 g cm^{-3}	0.10	0.16	0.06 ± 0.02	55%
	1.8 g cm^{-3}	0.21	0.05	0.15 ± 0.07	-73%

(c) **Irwell and Mersey combined**

		Pre-Flooding	Post-Flooding	Change ± uncertainty	Change (%)
Type (*particles*)	Fragments	33,977,535,000	2,609,823,000	31,367,712,000 ± 15,686,408,000	-92%
	Fibres	3,720,055,000	243,767,000	3,476,288,000 ± 4,179,256,000	-93%
	Microbeads	19,706,196,000	12,707,457,000	6,998,738,000 ± 3,570,547,000	-36%
	Other	1,558,297,000	29,842,000	1,528,454,000 ± 5,303,657,000	-98%
Density (*tonnes*)	1.025 g cm^{-3}	0.42	0.06	0.36 ± 0.12	-85%
	1.2 g cm^{-3}	0.30	0.20	0.10 ± 0.04	-34%
	1.8 g cm^{-3}	0.47	0.09	0.39 ± 0.19	-82%

Supplementary Table 5: Uncertainty analysis. Data for both microplastic concentrations and sediment storage estimates from a grid of 12 bed sediment samples in the Urmston reach on the River Mersey. A full description of this uncertainty analysis is given in the Methods. Microplastics are shown by type and density (1.025, 1.2 and 1.8 g cm^{-3}). RSD = Relative Standard Deviation.

Sample	Microplastics (particles kg^{-1})								Microplastics (mg kg^{-1})				Sediment storage ($g\ cm^{-2}$)
	Total particles	1.025	1.2	1.8	Fragments	Fibres	Microbeads	Other	Total particles	1.025	1.2	1.8	
1	1558	692	692	173	866	173	519	0	112	40.7	46.2	25.1	8.87
2	2271	757	1262	252	1262	252	757	0	169	60.3	75.7	33.3	8.65
3	2318	1324	993	0	1987	0	331	0	155	71.8	83.1	0	6.6
4	1547	580	774	193	774	0	580	193	123	51.6	42.4	29.4	8.42
5	1552	582	776	194	776	582	194	0	108	47	38.2	23.3	9.79
6	1557	778	311	467	778	156	623	0	118	49.2	43	26	11.8
7	1169	212	637	319	956	0	212	0	61.7	24.8	11.6	25.4	12.6
8	2632	921	1053	658	1448	263	921	0	159	58	59.9	41.1	11.6
9	2817	1084	1517	217	2600	0	217	0	181	75.2	73.9	31.6	13.5
10	1808	657	822	329	822	164	822	0	133	50.8	49.6	32.7	12.7
11	2313	723	723	867	1445	145	723	0	151	38.3	59.3	53.8	12.5
12	1967	787	983	197	1180	0	787	0	129	51.5	52.3	25	11
Mean	1959	758	879	322	1241	145	557	16	133	51.6	52.9	28.9	10.7
Standard deviation	509	275	312	238	567	171	261	56	32.4	13.9	19.4	12.5	2.17
RSD (%)	26	36	36	74	46	118	47	346	24	27	37	43	20