

Supplementary Material, containing Tables S1-6

Table S1. Summary of 2023 Event Duration Monitoring (EDM) Combined Sewer Overflow (CSO) records across the nine English water companies. CSOs are categorised according to (i) EDM 2023 monitoring status (monitored / not monitored), (ii) whether the CSO could be linked to a Combined Sewer System (CSS) ("connected" / "not connected"), and (iii) CSO type (Inlet, Network, Pumping station, Storm tank). Values represent the number of CSOs in each category per water company.

EDM 2023 monitoring status	Connected to a CSS	CSO type	Anglian Water	Northumbria n Water	Severn Trent Water	South West Water	Southern Water	Thames Water	United Utilities	Wessex Water	Yorkshire Water
monitored	connected	Inlet	103	103	148	228	64	34	161	79	173
monitored	connected	Other	7	0	0	0	3	0	0	4	0
monitored	connected	Network	449	1039	1854	567	318	280	1462	635	1468
monitored	connected	Pumping station	501	263	43	382	390	95	320	388	302
monitored	connected	Storm tank	358	118	364	156	180	199	186	189	178
monitored	not connected	Inlet	0	1	1	0	1	0	9	0	2
monitored	not connected	Network	0	11	9	1	1	1	3	0	37
monitored	not connected	Pumping station	4	10	0	7	5	0	5	0	5
monitored	not connected	Storm tank	1	1	2	1	0	1	1	0	0
not monitored	connected	Inlet	8	4	12	1	1	6	2	0	5
not monitored	connected	Network	90	5	25	20	13	39	98	0	21
not monitored	connected	Pumping station	41	4	3	6	1	39	16	0	3
not monitored	connected	Storm tank	0	5	11	5	0	1	0	0	0
not monitored	not connected	Inlet	0	1	0	0	0	0	0	0	0
not monitored	not connected	Network	1	0	0	0	0	0	1	0	1
not monitored	not connected	Pumping station	0	0	0	0	0	3	0	0	0

Table S2. Summary statistics of the DETE consents of WWTWs per determinand (DETE)

DETE	CSSs (n)	min	q25	median	mean	q75	max	sd
BOD	2,583	5.000	15.000	25.000	31.301	30.000	400.000	36.741
Cadmium	23	0.001	0.002	0.005	0.008	0.010	0.046	0.010
Chromium	13	0.006	0.012	0.025	0.067	0.100	0.218	0.070
Copper	60	0.010	0.050	0.070	0.092	0.100	0.385	0.074
Lead	14	0.000	0.011	0.041	0.043	0.050	0.117	0.038
Mercury	6	0.000	0.000	0.001	0.001	0.002	0.003	0.001
Nickel	20	0.006	0.012	0.044	0.069	0.094	0.400	0.091
Nitrogen	1,936	1.000	5.000	10.000	10.499	15.000	70.000	8.110
Solids	2,598	10.000	30.000	45.000	48.320	60.000	250.000	35.495
Total Phosphorus	517	0.003	0.700	1.000	1.309	1.500	9.000	1.166
Zinc	54	0.021	0.050	0.065	0.126	0.166	0.500	0.123

Table S3. Summary statistics of annual CSO pollutant loads (kg) per determinand (DETE), stratified by WWTW size category, and hydraulic capacity classification. Hydraulic capacity categories distinguish WWTWs classified as having sufficient or insufficient capacity.

DETE	WWTW Size	WWTW Hydr Capacity Category	mean_load	median_load	n
BOD	Large	Insufficient	302,809.76	15,651.23	978
BOD	Large	Sufficient	108,523.70	5,375.95	281
BOD	Small	Insufficient	1,601.41	524.31	525
BOD	Small	Sufficient	689.87	138.46	102
Cadmium	Large	Insufficient	18.52	2.09	12
Cadmium	Large	Sufficient	22.59	3.48	7
Chromium	Large	Insufficient	10.20	1.91	8
Chromium	Large	Sufficient	19.94	19.94	1
Copper	Large	Insufficient	179.91	16.52	42
Copper	Large	Sufficient	8.58	6.35	8
Lead	Large	Insufficient	9.96	2.19	9
Lead	Large	Sufficient	4.99	4.99	2
Mercury	Large	Insufficient	2.25	2.20	4
Mercury	Large	Sufficient	0.01	0.01	1
Mercury	Small	Insufficient	0.01	0.01	1
Nickel	Large	Insufficient	5.18	2.44	12
Nickel	Large	Sufficient	90.88	15.23	4
Nitrogen	Large	Insufficient	3,474.91	335.09	823
Nitrogen	Large	Sufficient	885.21	126.55	235
Nitrogen	Small	Insufficient	54.35	22.21	332
Nitrogen	Small	Sufficient	24.71	5.93	69
Solids	Large	Insufficient	269,876.82	12,640.99	982
Solids	Large	Sufficient	62,998.66	4,221.90	279
Solids	Small	Insufficient	1,554.81	684.79	525
Solids	Small	Sufficient	722.57	173.72	102
Total Phosphorus	Large	Insufficient	433.46	79.25	257
Total Phosphorus	Large	Sufficient	244.88	24.46	89
Total Phosphorus	Small	Insufficient	25.71	6.50	66
Total Phosphorus	Small	Sufficient	19.29	6.73	15
Zinc	Large	Insufficient	385.71	10.99	36
Zinc	Large	Sufficient	188.35	1.94	10
Zinc	Small	Insufficient	0.24	0.24	2

Table S4. Wilcoxon rank-sum test results for Table S5

DETE	WWTW Size	p_value	n
BOD	Large	2.67E-12	1,259
BOD	Small	2.17E-05	627
Cadmium	Large	4.32E-01	19
Chromium	Large	4.44E-01	9
Copper	Large	1.09E-01	50
Lead	Large	5.82E-01	11
Mercury	Large	8.00E-01	5
Mercury	Small	NA	1
Nickel	Large	8.62E-01	16
Nitrogen	Large	1.23E-12	1,058
Nitrogen	Small	7.52E-07	401
Solids	Large	3.65E-13	1,261
Solids	Small	6.62E-07	627
Total Phosphorus	Large	1.46E-03	346
Total Phosphorus	Small	5.55E-01	81
Zinc	Large	1.41E-01	46
Zinc	Small	NA	2

Table S5. Summary statistics of the relative annual inputs (in kg) from Combined Sewer Overflows (CSOs), Wastewater Treatment Works (WWTWs), their combined contributions, the ratio of CSO inputs to total CSO and WWTW inputs (%) and the CSO inputs in WBs without WWTWs inputs for different determinand categories (DETEs) in 2023 per waterbody.

DETE	CSO inputs (kg)				WWTWs inputs (kg)				CSOs and WWTWs inputs (kg)				Ratio CSO to combined inputs (%)			CSO inputs (kg) in WBs without WWTWs inputs			
	Median	Mean	Sum	WB (n)	Median	Mean	Sum	WB (n)	Median	Mean	Sum	WB (n)	Median	Mean	WB (n)	Median	Mean	Sum	WB (n)
BOD	7,550.50	172,181.80	419,951,399.39	2,439	7,259.55	124,823.75	210,203,188.67	1,684	15,569.59	258,365.96	630,154,588.06	2,439	69%	62%	2,383	7,855.52	156,003.22	117,782,433.20	755
Cadmium	0.89	5.19	389.29	75	41.03	204.76	3,890.51	19	2.05	57.06	4,279.80	75	100%	75%	72	0.48	5.26	294.32	56
Chromium	2.19	9.25	259.08	28	151.93	644.53	7,734.31	12	6.33	285.48	7,993.39	28	100%	57%	27	1.70	3.01	48.17	16
Copper	5.55	85.09	11,656.80	137	231.14	637.85	35,081.57	55	29.96	341.16	46,738.37	137	100%	62%	131	3.10	69.25	5,678.40	82
Lead	2.33	6.28	182.00	29	58.38	311.60	4,050.77	13	8.06	145.96	4,232.76	29	100%	56%	28	1.80	3.26	52.22	16
Mercury	0.01	0.39	9.01	23	7.29	7.35	36.76	5	0.02	1.99	45.77	23	100%	78%	21	0.01	0.31	5.64	18
Nickel	1.96	11.40	626.98	55	253.65	556.77	10,021.86	18	7.93	193.62	10,648.84	55	100%	70%	54	1.46	6.89	254.87	37
Nitrogen	176.75	1,879.32	3,931,539.71	2,092	2,770.99	22,883.51	31,830,956.47	1,391	1,695.45	17,094.88	35,762,496.18	2,092	12%	39%	2,044	164.08	1,758.31	1,232,576.53	701
Solids	7,065.27	146,740.21	360,100,474.65	2,454	12,936.72	168,825.53	285,146,323.80	1,689	19,326.83	262,936.76	645,246,798.45	2,454	52%	55%	2,397	7,233.14	134,920.14	103,213,907.51	765
Phosphorus	28.62	264.33	169,697.85	642	414.62	1,318.42	551,098.73	418	232.03	1,122.74	720,796.58	642	24%	44%	628	13.76	218.63	48,972.74	224
Zinc	7.44	125.48	16,186.79	129	134.98	1,591.08	79,554.19	50	22.17	742.18	95,740.98	129	100%	64%	126	5.29	110.79	8,752.66	79

Table S6. Pearson correlation coefficients between annual CSO pollutant load (kg) and annual spill duration (hours).

DETE	r	n
BOD	0.18	12847
Cadmium	0.58	535
Chromium	0.36	86
Copper	0.64	598
Lead	0.47	88
Mercury	0.91	97
Nickel	0.36	403
Nitrogen	0.24	9960
Solids	0.19	13054
Total Phosphorus	0.27	1938
Zinc	0.52	725

Table S7. Pearson correlation coefficients (r) calculated using raw values of annual CSO pollutant load and explanatory variables.

DETE	r_duration	r_dwf	r_conc	r_removal	n
BOD	0.11	0.35	0.30	0.03	2,583
Cadmium	0.37	0.78	0.05	0.14	23
Chromium	- 0.03	0.37	0.82	0.14	13
Copper	0.53	0.84	0.20	0.08	60
Lead	0.16	0.65	0.54	0.20	14
Mercury	0.81	0.84	- 0.60	NA	6
Nickel	0.19	0.90	0.19	0.07	20
Nitrogen	0.13	0.56	0.06	0.13	1,936
Solids	0.12	0.45	0.24	0.03	2,598
Total Phosphorus	0.14	0.43	0.07	0.17	517
Zinc	0.39	0.76	0.46	0.02	54