SUPPLEMENTARY INFORMATION

Geochemical speciation, pollution assessment, and source identification of heavy metals in sediment cores of Cau River basin, Hai Duong province, Vietnam

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Number of pages: 8

Number of tables: 5

Number of figures: 2

Upon request, we provide the data used to support the findings of this research project as follows. The fractionation analyses and ecological risk evaluations are based on the contents of heavy metals in each geochemical phase in the sediment depth of 10 cm, 20 cm, 30 cm, and 40 cm, presented explicitly in Tables S1, S2, S3, and S4, respectively. The values of heavy metals concentration in pore water samples in order to investigate the sediment-water transfer rates are indicated in Table S5. All figures less than 10 are presented with 3 decimal places. Otherwise, they are given with 4 significant digits.

Table S1. Contents of heavy metals in the sediment depth of 10 cm ($\mu g \cdot g^{-1}$)

Sampling site	Fraction	Cu	Pb	Cd	Zn	Fe	Co	Ni	Mn	Cr
S5	Exchangeable	0.186	0.014	0.053	0.254	9.437	0.038	0.088	79.16	0.005
	Carbonate	2.043	3.532	0.114	5.877	754.1	0.952	0.778	158.7	0.434
	Fe-Mn oxide	1.115	6.649	0.026	5.082	2694	1.054	0.799	120.2	0.817
	Organic	5.211	11.52	0.031	3.215	1855	0.542	0.624	46.15	1.047
	Residual	0.800	1.673	0.014	2.987	1138	0.368	1.284	7.396	3.533
	Non-residual	8.555	21.72	0.224	14.43	5312	2.587	2.289	404.2	2.303
	Total	9.356	23.39	0.238	17.41	6450	2.955	3.572	411.6	5.836
	ICF	10.69	12.98	16.05	4.830	4.667	7.023	1.783	54.65	0.652
S11	Exchangeable	0.035	0.084	0.027	0.973	8.958	0.285	0.383	101.1	0.030
	Carbonate	0.266	0.611	0.022	2.052	80.72	0.624	0.588	31.58	0.243
	Fe-Mn oxide	0.221	1.716	0.009	3.105	1638	0.593	0.733	36.07	0.896
	Organic	4.233	4.780	0.018	2.038	1609	0.371	0.655	14.17	1.033
	Residual	0.682	1.861	0.021	2.181	1039	0.294	0.975	5.165	3.167
	Non-residual	4.755	7.190	0.076	8.168	3337	1.873	2.359	182.9	2.202
	Total	5.437	9.051	0.096	10.35	4376	2.167	3.334	188.1	5.370
	ICF	6.970	3.864	3.646	3.746	3.211	6.377	2.420	35.42	0.695
S15	Exchangeable	0.026	0.145	0.039	1.027	3.442	1.216	0.439	143.8	0.006
	Carbonate	0.209	0.782	0.026	1.886	152.3	1.686	1.145	58.44	0.333
	Fe-Mn oxide	0.102	1.064	0.008	2.590	1299	0.805	0.823	80.19	0.639
	Organic	2.590	3.151	0.013	2.209	1311	0.521	0.732	33.34	0.756
	Residual	0.693	2.518	0.048	34.95	831.8	0.243	0.651	5.008	2.115
	Non-residual	2.927	5.143	0.086	7.711	2765	4.228	3.139	315.7	1.735
	Total	3.619	7.661	0.133	42.66	3597	4.471	3.790	320.8	3.849
	ICF	4.225	2.042	1.795	0.221	3.325	17.40	4.819	63.04	0.820
S22	Exchangeable	3.592	0.317	0.101	0.889	27.92	0.035	0.169	61.51	0.029
	Carbonate	16.48	25.02	0.172	10.65	922.9	1.144	0.985	250.2	0.440
	Fe-Mn oxide	2.753	5.181	0.009	4.660	657.3	0.458	0.432	25.72	0.316
	Organic	3.161	3.691	0.015	2.843	1525	0.465	0.641	32.80	0.993
	Residual	0.933	1.678	0.006	4.206	1363	0.431	1.569	7.398	3.891

	Non-residual	25.99	34.21	0.297	19.04	3133	2.103	2.229	370.3	1.778
	Total	26.92	35.89	0.303	23.25	4496	2.534	3.798	377.7	5.669
	ICF	27.85	20.38	53.68	4.527	2.299	4.878	1.420	50.05	0.457
S25L2	Exchangeable	0.395	0.029	0.037	1.002	7.831	0.064	0.168	49.53	0.014
	Carbonate	2.889	4.466	0.063	8.726	340.7	0.852	1.143	97.34	0.307
	Fe-Mn oxide	1.780	4.852	0.015	8.145	1493	0.936	1.301	52.44	0.796
	Organic	5.560	10.26	0.024	2.963	1623	0.384	0.723	25.88	0.977
	Residual	1.242	1.531	0.007	5.156	1216	0.389	1.513	7.224	3.736
	Non-residual	10.63	19.61	0.139	20.83	3465	2.236	3.335	225.2	2.093
	Total	11.87	21.14	0.146	25.99	4681	2.625	4.848	232.4	5.829
	ICF	8.551	12.80	19.74	4.041	2.849	5.753	2.204	31.17	0.560
S31	Exchangeable	0.106	0.032	0.042	0.761	8.546	0.189	0.242	148.8	0.006
	Carbonate	1.348	1.926	0.053	4.324	230.3	1.077	1.555	84.75	0.539
	Fe-Mn oxide	0.683	3.469	0.016	4.967	2016	1.071	1.458	75.31	0.968
	Organic	5.018	6.317	0.018	2.831	1706	0.555	0.978	28.19	1.136
	Residual	1.441	2.364	0.014	4.254	1266	0.476	1.779	6.909	4.614
	Non-residual	7.156	11.74	0.129	12.88	3960	2.893	4.233	337.0	2.649
	Total	8.598	14.11	0.144	17.14	5226	3.369	6.011	343.9	7.263
	ICF	4.964	4.967	9.044	3.028	3.129	6.083	2.379	48.78	0.574

Table S2. Contents of heavy metals in the sediment depth of 20 cm ($\mu g \cdot g^{-1}$)

Sampling site	**Fraction**	**Cu**	**Pb**	**Cd**	**Zn**	**Fe**	**Co**	**Ni**	**Mn**	**Cr**
S5	Exchangeable	0.141	0.067	0.052	0.436	7.861	0.063	0.091	129.1	0.003
	Carbonate	1.596	3.004	0.087	4.571	478.4	0.768	0.583	125.8	0.387
	Fe-Mn oxide	0.976	6.341	0.026	4.569	2633	1.071	0.777	102.1	0.882
	Organic	4.292	9.080	0.030	2.558	1610	0.514	0.589	31.39	1.056
	Residual	3.106	1.427	0.005	3.874	1471	0.438	1.599	10.07	4.573
	Non-residual	7.005	18.49	0.195	12.13	4729	2.416	2.040	388.4	2.329
	Total	10.11	19.92	0.201	16.00	6200	2.854	3.640	398.4	6.902
	ICF	2.256	12.95	35.71	3.132	3.216	5.518	1.276	38.57	0.509
S11	Exchangeable	0.026	0.055	0.017	0.500	7.979	0.185	0.119	128.1	0.001
	Carbonate	0.431	0.881	0.025	2.491	170.9	0.977	1.005	90.82	0.395
	Fe-Mn oxide	0.214	1.903	0.007	4.142	2135	0.521	0.644	56.39	0.631
	Organic	0.023	0.070	0.001	0.257	0.831	0.001	0.020	0.020	0.103
	Residual	1.315	0.053					0.105		0.039
	Non-residual	0.694	2.909	0.049	7.390	2315	1.684	1.788	275.3	1.130
	Total	2.009	2.962	0.049	7.390	2315	1.684	1.893	275.3	1.168

S15	Exchangeable	0.018	0.021	0.020	0.466	3.627	0.472	0.247	123.1	0.003
	Carbonate	0.162	0.413	0.013	1.008	81.11	0.668	0.641	49.70	0.188
	Fe-Mn oxide	0.122	0.428	0.003	2.136	754.3	0.348	0.378	83.69	0.327
	Organic	1.545	1.878	0.013	1.401	829.7	0.276	0.334	32.45	0.536
	Residual	0.361	0.711	0.002	1.514	551.3	0.147	0.458	3.421	1.455
	Non-residual	1.847	2.739	0.049	5.012	1669	1.764	1.601	288.9	1.053
	Total	2.208	3.450	0.051	6.526	2220	1.911	2.059	292.3	2.508
	ICF	5.117	3.854	24.24	3.309	3.027	11.97	3.491	84.45	0.724
S22	Exchangeable	2.367	0.131	0.079	0.832	13.29	0.027	0.192	36.90	0.042
	Carbonate	7.865	13.35	0.096	7.132	592.4	0.695	0.598	121.6	0.281
	Fe-Mn oxide	5.789	17.94	0.036	12.16	2033	1.578	1.367	107.6	0.763
	Residual	1.885	2.157	0.007	3.483	1383	0.341	1.334	11.04	3.191
	Non-residual	16.02	31.42	0.210	20.12	2639	2.300	2.157	266.2	1.085
	Total	17.90	33.58	0.217	23.60	4022	2.642	3.491	277.2	4.276
	ICF	8.499	14.57	31.16	5.777	1.909	6.742	1.617	24.11	0.340
S25 L2	Exchangeable	0.265	0.092	0.036	0.764	13.27	0.050	0.151	38.37	0.029
	Carbonate	1.419	2.545	0.042	5.491	292.7	0.913	1.148	97.72	0.329
	Residual	0.847	1.231	0.009	66.35	957.8	0.301	1.037	6.315	2.650
	Non-residual	1.684	2.637	0.077	6.255	306.0	0.963	1.300	136.1	0.358
	Total	2.531	3.868	0.086	72.61	1264	1.264	2.337	142.4	3.007
	ICF	1.990	2.141	8.652	0.094	0.319	3.199	1.253	21.55	0.135
S31	Exchangeable	0.053	0.048	0.031	0.548	4.296	0.202	0.177	98.58	0.013
	Carbonate	0.857	1.533	0.046	3.572	154.3	1.057	1.335	64.44	0.581
	Fe-Mn oxide	4.878	4.729	0.015	3.063	1702	0.566	0.891	40.02	1.454
	Residual	1.063	1.184	0.007	3.086	1268	0.465	1.775	7.679	4.618
	Non-residual	5.788	6.310	0.091	7.183	1861	1.825	2.403	203.0	2.048
	Total	6.851	7.495	0.098	10.27	3129	2.290	4.178	210.7	6.666
	ICF	5.446	5.328	12.97	2.328	1.467	3.927	1.354	26.44	0.444

Table S3. Contents of heavy metals in the sediment depth of 30 cm ($\mu g \cdot g^{-1}$)

Sampling site	Fraction	Cu	Pb	Cd	Zn	Fe	Co	Ni	Mn	Cr
S5	Exchangeable	0.125	0.085	0.062	0.351	5.956	0.066	0.087	121.1	0.012
	Carbonate	1.354	3.604	0.094	4.690	463.5	0.815	0.797	112.1	0.528
	Fe-Mn oxide	0.956	6.617	0.030	4.850	2484	1.145	0.883	75.69	0.965
	Residual	1.489	1.723	0.003	4.690	1430	0.492	1.869	9.636	4.569

	Non-residual	2.435	10.31	0.186	9.891	2953	2.027	1.767	308.9	1.505
	Total	3.924	12.03	0.189	14.58	4384	2.519	3.635	318.5	6.074
	ICF	1.635	5.981	59.20	2.109	2.065	4.121	0.945	32.06	0.329
S11	Exchangeable	0.034	0.083	0.023	0.622	5.111	0.219	0.131	176.3	0.035
	Carbonate	0.363	1.009	0.028	2.411	164.6	0.996	0.940	110.5	0.479
	Fe-Mn oxide	0.299	2.232	0.010	2.785	2388	0.635	0.760	68.94	0.947
	Organic	4.029	5.528	0.018	2.821	2234	0.456	0.697	26.41	1.172
	Residual	0.669	2.841	0.027	2.794	875.4	0.302	1.201	4.58	3.330
	Non-residual	4.726	8.853	0.079	8.640	4792	2.307	2.528	382.2	2.634
	Total	5.395	11.69	0.106	11.43	5667	2.608	3.729	386.7	5.964
	ICF	7.060	3.116	2.917	3.092	5.474	7.645	2.104	83.44	0.791
S15	Exchangeable	0.029	0.069	0.018	0.663	5.59	0.304	0.160	56.01	0.018
	Carbonate	0.314	0.832	0.037	2.375	91.96	0.760	0.684	23.32	0.343
	Organic	2.221	2.384	0.017	2.218	1039	0.391	0.437	12.18	0.763
	Residual	0.379	0.956		1.204	679.7	0.192	0.566	4.117	1.762
	Non-residual	2.563	3.286	0.071	5.256	1136	1.454	1.281	91.50	1.124
	Total	2.942	4.241	0.071	6.461	1816	1.647	1.846	95.62	2.886
	ICF	6.768	3.438		4.365	1.672	7.559	2.263	22.22	0.638
S22	Exchangeable	1.594	0.107	0.060	0.623	12.87	0.026	0.763	41.74	0.023
	Carbonate	5.247	10.51	0.071	5.142	643.2	0.636	0.633	112.9	0.239
	Fe-Mn oxide	2.951	6.060	0.013	6.804	1139	0.992	0.857	41.55	0.469
	Organic	3.916	4.391	0.018	2.412	567.8	0.313	0.464	11.50	0.469
	Residual	0.871	1.887	0.003	2.101	910.4	0.266	0.897	7.912	2.409
	Non-residual	13.71	21.07	0.161	14.98	2363	1.966	2.718	207.7	1.199
	Total	14.58	22.96	0.164	17.08	3273	2.232	3.615	215.6	3.608
	ICF	15.73	11.16	54.35	7.131	2.595	7.391	3.030	26.25	0.498
S25 L2	Exchangeable	0.210	0.045	0.029	0.417	8.654	0.070	0.115	56.40	0.014
	Carbonate	2.219	3.925	0.057	6.126	383.4	0.973	0.944	103.2	0.286
	Fe-Mn oxide	1.251	5.779	0.019	14.91	1613	0.880	1.078	63.12	0.670
	Organic	5.497	11.55	0.024	4.145	1698	0.404	0.657	31.98	0.780
	Residual	0.812	1.084	0.004	2.386	959.9	0.302	1.094	5.289	2.847
	Non-residual	9.177	21.30	0.130	25.59	3703	2.328	2.795	254.7	1.749
	Total	9.989	22.39	0.133	27.98	4663	2.630	3.889	259.9	4.597
	ICF	11.31	19.65	34.57	10.73	3.858	7.703	2.553	48.15	0.614
S31	Exchangeable	0.038	0.016	0.024	0.620	9.198	0.221	0.175	104.7	0.013
	Carbonate	0.623	0.940	0.038	3.168	125.6	0.994	1.196	66.42	0.466
	Fe-Mn oxide	0.342	1.855	0.012	3.074	2022	0.723	0.838	106.5	0.714
	Organic	4.039	4.885	0.013	2.178	1705	0.447	0.675	45.32	0.929
	Residual	0.750	1.092	0.008	2.061	878.4	0.307	1.088	5.666	3.247

	Non-residual	5.042	7.696	0.086	9.040	3862	2.385	2.884	322.9	2.121
	Total	5.792	8.788	0.093	11.10	4741	2.692	3.972	328.5	5.367
	ICF	6.719	7.049	11.44	4.387	4.397	7.760	2.651	56.98	0.653

Table S4. Contents of heavy metals in the sediment depth of 40 cm ($\mu g \cdot g^{-1}$)

Sampling site	Fraction	Cu	Pb	Cd	Zn	Fe	Co	Ni	Mn	Cr
S11	Exchangeable	0.026	0.270	0.039	0.692	7.774	0.231	0.305	118.1	0.024
	Carbonate	0.403	1.669	0.034	3.125	149.8	1.183	1.096	80.76	0.524
	Fe-Mn oxide	0.229	2.624	0.011	12.14	2101	0.768	0.958	55.48	1.053
	Organic	4.131	5.706	0.018	3.892	1748	0.455	0.776	19.38	1.205
	Residual	1.007	2.099	0.025	7.319	1053	0.341	1.320	4.614	3.744
	Non-residual	4.788	10.27	0.102	19.85	4007	2.637	3.134	273.8	2.806
	Total	5.796	12.37	0.126	27.17	5060	2.978	4.454	278.4	6.550
	ICF	4.753	4.893	4.129	2.712	3.806	7.733	2.375	59.33	0.749
S15	Exchangeable	0.012	0.032	0.024	0.784	3.983	0.315	0.241	61.01	0.009
	Carbonate	0.248	0.406	0.023	2.437	80.68	0.822	1.027	25.71	0.288
	Fe-Mn oxide	0.130	0.512	0.007	3.880	1124	0.743	0.805	28.20	0.688
	Organic	2.023	1.694	0.013	2.200	1044	0.453	0.634	12.12	0.702
	Residual	0.530	2.403	0.086	1.654	863.7	0.248	0.711	4.520	2.159
	Non-residual	2.413	2.644	0.068	9.301	2253	2.333	2.708	127.1	1.687
	Total	2.943	5.046	0.154	10.96	3117	2.582	3.419	131.6	3.846
	ICF	4.556	1.100	0.792	5.624	2.608	9.402	3.808	28.12	0.781
S22	Exchangeable	0.060	0.004	0.011	0.599	3.667	0.160	0.136	153.1	0.027
	Fe-Mn oxide	0.412	1.784	0.005	3.743	2183	0.720	0.821	91.45	0.718
	Organic	3.716	7.650	0.023	2.115	1353	0.454	0.550	20.35	0.972
	Residual	0.630	0.871	0.007	2.439	957.8	0.351	1.080	6.351	3.086
	Non-residual	4.189	9.439	0.039	6.457	3539	1.333	1.507	264.9	1.718
	Total	4.819	10.31	0.046	8.897	4497	1.685	2.587	271.2	4.804
	ICF	6.649	10.83	5.832	2.647	3.695	3.795	1.395	41.71	0.557
S25 L2	Exchangeable	0.052	0.002	0.038	0.960	11.59	0.169	0.223	48.24	0.021
	Carbonate	0.337	1.050	0.100	10.35	218.2	1.878	1.526	48.86	0.450
	Fe-Mn oxide	0.187	1.625	0.030	8.955	1855	1.341	1.413	83.12	0.775
	Organic	4.186	5.663	0.030	5.266	2095	0.779	1.292	86.63	1.366
	Residual	1.108	1.244	0.005	3.716	1497	0.526	1.706	8.057	5.169
	Non-residual	4.762	8.339	0.198	25.54	4179	4.166	4.454	266.8	2.612
	Total	5.870	9.583	0.203	29.25	5676	4.692	6.160	274.9	7.781

	ICF	4.298	6.702	36.29	6.873	2.791	7.920	2.611	33.12	0.505
S31	Exchangeable	0.052	0.043	0.029	1.341	7.487	0.195	0.196	64.45	0.024
	Carbonate	0.844	1.185	0.037	3.330	137.4	1.000	1.317	42.99	0.490
	Fe-Mn oxide	0.416	1.952	0.010	3.508	2000	0.826	0.949	84.27	0.813
	Organic	3.834	4.010	0.018	2.282	1438	0.428	0.656	28.23	0.933
	Residual	0.834	0.846	0.005	2.548	1161	0.374	1.328	6.995	3.995
	Non-residual	5.146	7.191	0.093	10.46	3583	2.448	3.118	219.9	2.260
	Total	5.980	8.037	0.099	13.01	4744	2.821	4.447	226.9	6.255
	ICF	6.174	8.496	17.96	4.106	3.086	6.553	2.348	31.44	0.566

Table S5. Concentrations of heavy metals in pore water in different depths ($\mu g \cdot L^{-1}$)

Depth	Sampling site	Cu	Pb	Cd	Zn	Fe	Co	Ni	Mn	Cr
10 cm	S5	56.14	8.879	0.425	107.4	5827	2.558	9.390	237.9	3.470
	S11	57.44	14.26	0.414	208.0	1647	0.820	9.516	114.4	4.413
	S15	20.10	15.58	0.786	44.05	419.6	0.724	22.70	315.5	2.863
	S22	13.04	9.238	0.050	49.20	2719	0.311	2.524	367.6	0.130
	S25L2	12.31	6.920	0.099	19.34	2862	1.382	2.721	620.8	0.110
	S31	26.15	23.75	1.059	72.94	1286	2.320	10.11	606.7	1.548
20 cm	S5	59.20	13.05	0.372	157.0	8170	2.986	7.854	387.7	2.814
	S11	53.98	7.238	0.106	111.6	2823	1.125	7.071	341.86	2.135
	S15	18.99	4.046	0.083	39.54	665.3	0.915	14.01	292.3	2.062
	S22	12.42	5.941	0.132	36.24	1515	0.631	3.615	598.6	0.801
	S25L2	18.54	5.026	0.029	32.10	1267	1.006	4.587	445.5	0.264
	S31	42.60	20.64	0.902	90.11	501.3	0.656	9.106	56.65	1.657
30 cm	S5	72.52	11.91	0.553	203.4	13621	2.971	12.22	640.3	4.797
	S11	62.19	8.382	0.213	84.39	5222	1.913	8.137	426.9	2.263
	S15	21.21	29.74	1.762	58.08	469.1	0.629	23.29	151.6	3.318
	S22	5.417	0.975	0.025	21.08	106.8	0.471	2.874	376.5	0.411
	S25L2	29.27	6.076	0.161	85.28	639.7	0.597	6.004	121.1	1.949
	S31	22.09	7.229	0.265	39.66	687.7	0.675	4.154	150.8	1.260

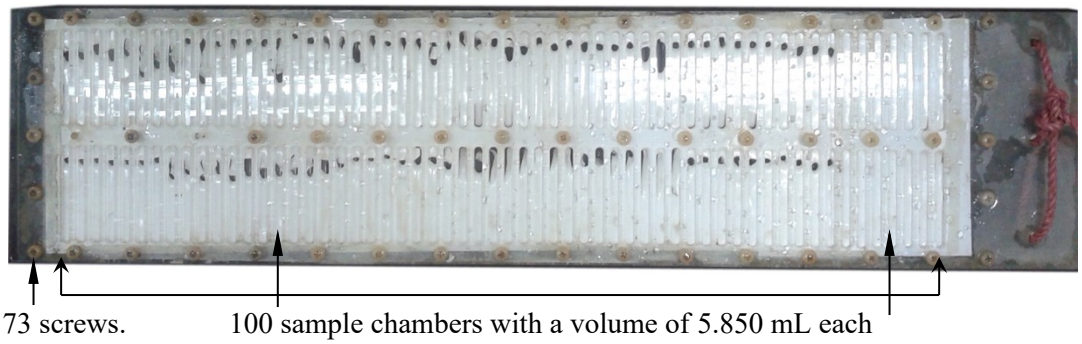

Figure S1. Sampling device for collecting pore water samples (peeper)

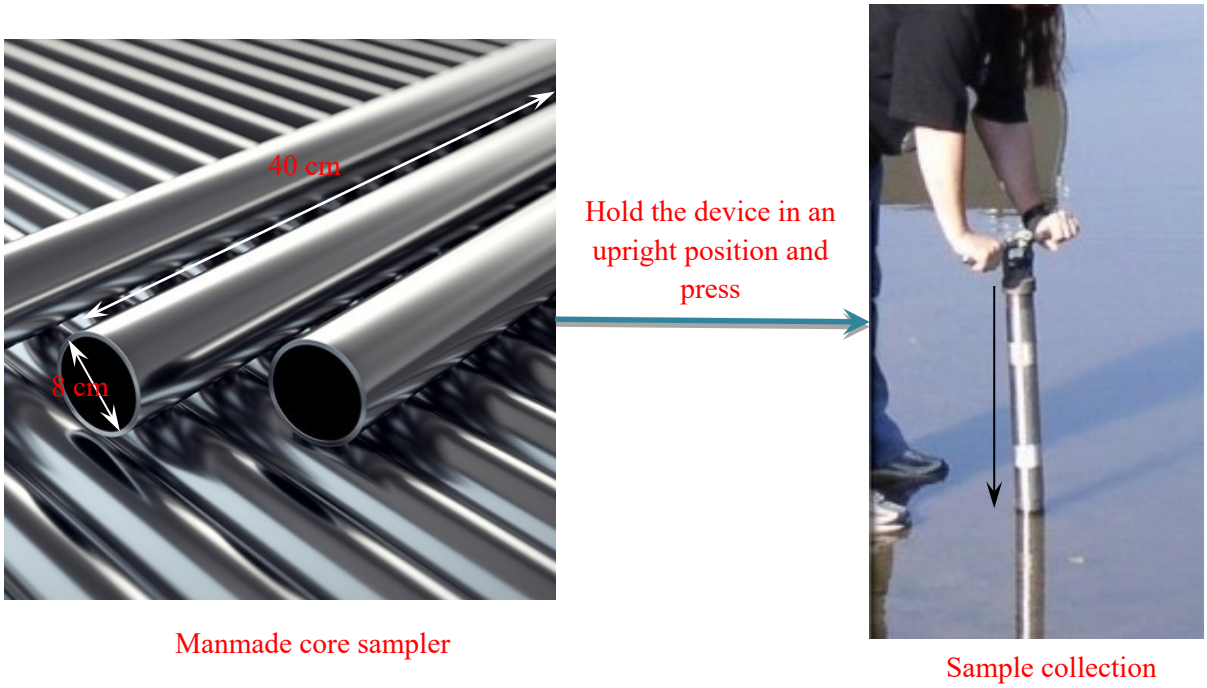

Figure S2. Sampling device for collecting sediment core samples