Supplementary Material

The operating procedures for the 7 small high-temperature treatment facilities.

The gasification incinerators, specifically A-1, A-2, and B, operated with intermittent waste feeding. The primary operational process involved waste sorting, automatic feeding into a combustion chamber, and sealing after reaching capacity. Initially, oxygen combustion (with the addition of diesel) was used by a combustion fan to heat the second combustion chamber to over 800℃, followed by igniting the combustion chamber. The combustible gas produced in the first combustion chamber during gasification entered the second combustion chamber for high-temperature combustion. Then, the resulting flue gas was subjected to purification in the air pollutant control devices before emission. A-1 and A-2 were produced by the same manufacturer, differing only in elevation, while B and A had different air distribution designs between the main combustion chamber and second combustion chambers, sharing the same air pollutant control devices. Comparison C with A and B, the processing capacity was larger ,the feeding was continuous, the calorific value of pyrolysis gas produced by gasification was higher, the second combustion chamber did not need to be supplement with fuel, and the flue gas purification facility changed from a fixed activated carbon bed to the spraying of activated carbon powder. Small-scale incinerator D operated with semi-continuous feeding, and the primary process involved the vertical filling of domestic waste into the furnace from top to bottom, with reverse flue gas movement from the bottom to the top. In the furnace chamber, domestic waste sequentially underwent drying, preheating, gasification pyrolysis, and aerobic incineration stages. The final flue gas was then subjected to water spraying, a wet plasma dust collector, and UV photolysis before discharge. Notably, this incinerator lacked a second combustion chamber, and temperature measurement devices were not installed in either the furnace or the second combustion chamber.

The small high-temperature pyrolysis furnace E process was as follows. After passing through a shredder, classified domestic waste entered the inner reaction chamber of the high-temperature pyrolysis furnace. The inner reaction chamber then underwent non-contact heating from the outer liner high-temperature combustion chamber. In the inner reaction chamber, the domestic waste was first heated, dried, and finally subjected to anaerobic pyrolysis at elevated temperatures. The drying stage maintained temperatures below 200℃, while the pyrolysis temperature ranged from 400 to 600℃. During the drying stage, the exhaust gas primarily contained water vapor and was directly discharged through the chimney. The pyrolysis gas generated during the pyrolysis stage was initially condensed, and the resulting oil-water mixture was subsequently separated from the oil and water components. The separated oil and condensed pyrolysis gas were subsequently returned to the outer liner high-temperature combustion chamber to serve as a heat source for the combustion and heating of the inner reaction chamber. The flue gas generated by the high-temperature combustion chamber underwent non-contact heat exchange cooling, weak alkali spraying, and photo-oxidized catalytic treatment before it was discharged. The process for facility F was as follows. After sorting, crushing, and magnetic separation, domestic waste was sent to the pyrolysis kettle. The pyrolysis kettle was heated through non-contact heating provided by the high-temperature combustion chamber. In the reactor, the domestic waste underwent pyrolysis reactions at temperatures ranging from 600 to 800℃, resulting in the production of charcoal and pyrolysis gas. The pyrolysis gas passed through a cyclone dust collector and water spray tower, a

non-contact condenser (condensation separation of oil and water) ,with an electric tar trap ,and all of products returned to the high-temperature combustion chamber as the pyrolysis heat source for combustion. The combustion flue gas was then discharged through the fabric filter and underwent adsorption by an activated carbon bed. Notably, temperature measurement devices were not installed in the furnaces of facilities E and F.

Table S1 Dioxin congeners in flue gas of small-scale high-temperature treatment facilities（ng/Nm³）.

	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF
A-1-1	0.53705	1.31199	1.28114	2.38487	1.9122	10.72578	12.59731	5.69663	2.73174	4.88919	2.5935	2.24647	0.3851	3.42347	6.77569	1.32656	3.53383
A-1-2	0.92567	3.64768	5.66328	9.37185	8.06513	38.21326	31.23712	10.17246	6.7395	18.34843	13.44019	9.35996	1.77738	16.90275	31.92665	6.8852	9.78593
A-1-3	0.59189	2.65426	3.47044	7.99309	6.24577	20.98829	12.09509	4.57214	3.78571	8.4453	8.57009	6.92384	1.18527	11.1703	20.23382	2.49513	3.7012
A-2-1	0.00699	0.01511	0.01242	0.02023	0.01654	0.07709	0.10879	0.09265	0.07229	0.11441	0.07852	0.07643	0.01871	0.09275	0.12992	0.04306	0.04823
A-2-2	0.0422	0.11088	0.07333	0.15708	0.11084	0.35903	0.19834	0.5846	0.36427	0.51141	0.28417	0.26352	0.03732	0.28568	0.47979	0.07029	0.09466
A-2-3	0.02581	0.0625	0.07306	0.10279	0.08944	0.25274	0.17539	0.31634	0.21295	0.43122	0.25672	0.18113	0.03409	0.23155	0.32695	0.09427	0.06397
B-1	0.10524	0.22584	0.11826	0.21059	0.1652	0.43577	0.25163	1.12478	1.29023	1.60097	0.87275	0.90285	0.10502	0.86591	1.16545	0.12442	0.13894
B-2	0.11485	0.13425	0.14152	0.14019	0.13833	0.35813	0.24062	1.34202	0.75223	1.504	0.91879	0.51556	0.06553	0.60519	0.98394	0.28242	0.15677
B-3	0.13895	0.18989	0.10296	0.18865	0.14875	0.47613	0.48292	1.94926	0.98697	1.22488	0.51704	0.49585	0.08054	0.56361	0.72224	0.16295	0.35019
C-1	0.1165	0.1902	0.1128	0.216	0.1503	0.4618	0.3323	1.5637	0.8739	1.1912	0.5579	0.493	0.0679	0.5248	0.697	0.113	0.1572
C-2	0.0209	0.0388	0.0325	0.0687	0.0386	0.1928	0.2389	0.2897	0.2045	0.3242	0.1988	0.1815	0.026	0.1951	0.3355	0.0495	0.1038
C-3	0.0254	0.0364	0.0234	0.0605	0.0332	0.1863	0.2142	0.3128	0.1849	0.2488	0.1492	0.1746	0.0229	0.1765	0.3284	0.0366	0.0964
D-1	0.0019	0.0014	0.0013	0.003	0.0028	0.0133	0.0278	0.0026	0.0024	0.0057	0.0041	0.0043	0.0012	0.0069	0.0129	0.002	0.0102
D-2	0.0017	0.0017	0.002	0.0052	0.0037	0.0276	0.0689	0.0052	0.0046	0.0112	0.0072	0.0065	0.0016	0.0112	0.0242	0.0034	0.0119
D-3	0.0014	0.0011	0.0023	0.005	0.0045	0.0402	0.1068	0.0025	0.0022	0.0058	0.0049	0.0041	0.0012	0.0084	0.0295	0.0033	0.0188
E-1	0.0508	0.1606	0.1294	0.2417	0.1816	0.474	0.2786	0.6451	0.4861	0.8161	0.5107	0.4372	0.0824	0.5089	0.8293	0.1864	0.3405
E-2	0.0487	0.1448	0.11	0.2081	0.1512	0.4073	0.1777	0.6641	0.4823	0.7837	0.4148	0.3842	0.0669	0.4071	0.6165	0.1278	0.1759
E-3	0.0556	0.1583	0.1205	0.2066	0.1609	0.4024	0.1924	0.8178	0.741	0.9985	0.6368	0.5801	0.0992	0.5138	0.825	0.1709	0.247
F-1	0.0384	0.0961	0.0632	0.122	0.0848	0.2565	0.1154	0.447	0.2897	0.4011	0.2179	0.2128	0.0275	0.2139	0.319	0.0408	0.0523
F-2	0.0256	0.0601	0.0361	0.0859	0.0564	0.1768	0.0721	0.2982	0.1968	0.2597	0.1303	0.1374	0.0172	0.1325	0.2109	0.0226	0.0376
F-3	0.0433	0.0997	0.0819	0.1484	0.1126	0.2983	0.1224	0.4807	0.3128	0.5485	0.2881	0.2227	0.03	0.2521	0.3583	0.0534	0.0597
Test 1	0.003	0.005	0.0033	0.0053	0.005	0.017	0.05	0.0024	0.0086	0.00966	0.008	0.0072	0.0067	0.0012	0.013	0.005	0.02

Test 2	0.003	0.003	0.003	0.0033	0.003	0.009	0.03	0.0024	0.005	0.00434	0.003	0.003	0.0037	0.0012	0.004	0.001	0.01

Table S2 Dioxin congeners in fly ash of large-scale municipal solid waste treatment incinerators（ng/g）.

	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF
A-1-1	0.05454	0.17035	0.08552	0.16477	0.08937	0.45432	0.22328	0.56765	0.32601	0.48066	0.22612	0.22296	0.04216	0.28305	0.41071	0.04608	0.07535
A-1-2	0.05338	0.17404	0.08677	0.17349	0.09099	0.454	0.22866	0.56408	0.32397	0.48461	0.22869	0.23412	0.04283	0.28109	0.39665	0.04505	0.07676
A-2-1	0.00195	0.00297	0.00186	0.00367	0.00325	0.01125	0.01124	0.01521	0.01048	0.01332	0.0114	0.01374	0.00225	0.01462	0.03821	0.00475	0.01261
A-2-2	0.00161	0.00211	0.00262	0.00333	0.00321	0.01191	0.01085	0.01496	0.01324	0.01419	0.01179	0.01182	0.00234	0.01406	0.03791	0.0054	0.01383
B-1	0.11273	0.40866	0.27213	0.43304	0.38712	2.14229	1.93842	1.45472	1.82773	2.2681	1.76397	1.96949	0.30431	2.2955	4.93611	0.77685	1.69149
B-2	0.12409	0.40242	0.26913	0.44083	0.37599	2.15263	1.96505	1.41904	1.78142	2.26616	1.78564	1.98455	0.3004	2.2655	4.91248	0.75971	1.7242
C-1	0.25312	1.52117	1.34496	3.72896	2.16869	22.49184	36.76124	1.91005	2.12009	3.77091	2.70642	3.58284	0.66408	5.44055	11.35921	2.38698	6.62611
C-2	0.25132	1.53727	1.4072	3.75969	2.18184	22.11723	36.77524	1.829	2.10764	3.79886	2.74591	3.63497	0.67305	5.36833	11.62961	2.40722	6.73543
D-1	5.40E-04	0.00173	0.00121	0.00284	0.00199	0.01198	0.01102	0.00225	0.0027	0.00461	0.0036	0.00372	7.05E-04	0.00601	0.01321	0.00102	0.00418
D-2	4.73E-04	0.00146	0.00127	0.00286	0.00226	0.01212	0.01174	0.00204	0.00235	0.00427	0.00354	0.00387	6.75E-04	0.00605	0.01329	9.13E-04	0.00394
E-1	0.07987	0.42629	0.23709	0.3007	0.27346	1.1702	1.21077	1.25812	7.01392	3.49346	7.09009	8.91616	1.83728	4.2281	10.26017	3.72473	5.57762
E-2	0.07731	0.40171	0.22732	0.29711	0.2606	1.09441	1.17293	1.22218	6.68384	3.2709	6.73879	8.48232	1.81065	4.24361	9.73607	3.6211	5.4649
F-1	0.33842	1.91146	0.6187	0.93297	0.40637	2.82171	1.65877	6.59332	4.86772	14.44581	5.04949	5.42016	0.6386	7.08617	11.06424	1.05606	1.58367
F-2	0.33964	1.88652	0.65076	0.95165	0.4587	2.79589	1.66371	6.24933	4.74042	12.34241	5.08131	5.55919	0.65546	6.53687	11.27418	1.06288	1.59698
T1	0.1101	0.1524	0.1915	0.4934	0.3729	4.2231	16.9101	1.0101	1.22	3.2201	0.9478	0.2406	1.8302	1.8258	1.0551	1.4406	0.5647
T2	0.0701	0.2451	0.0901	0.1731	0.1521	1.196	2.7111	1.6212	1.2721	1.893	0.369	0.4221	0.2051	0.4192	0.2371	0.1621	0.117
T3	0.0556	0.2002	0.2068	0.6299	0.4749	4.7767	11.444	2.3421	1.3643	2.2359	0.5099	0.586	1.4559	0.6779	0.3601	0.3227	0.1747
T4	0.0153	0.1488	0.0481	0.1121	0.0838	1.0575	3.3711	1.3602	1.1203	2.9693	0.1695	0.1897	1.1473	0.2065	0.2599	0.0893	0.0544
T5	0.0436	0.1843	0.1921	0.5212	0.3721	4.5399	9.3899	2.8173	1.3957	1.9311	0.6949	0.8032	0.741	1.1528	1.9735	0.5277	0.3618

T6	0.0231	0.1642	0.0553	0.1438	0.0978	1.2885	5.7603	5.6801	1.1912	2.8162	0.2245	0.2632	0.2243	0.2999	0.8773	0.1711	0.1028
T7	0.0265	0.0939	0.1149	0.2321	0.1751	2.5586	11.306	2.7329	2.1825	1.2893	0.3579	0.3764	0.2462	0.5048	1.3381	0.2604	0.1187
T8	0.0229	0.1616	0.2236	0.6656	0.4187	4.7097	8.2293	3.0766	1.9322	1.1917	0.5813	0.7046	0.9898	0.9322	0.2224	0.4084	0.3044
T9	0.0741	0.2511	0.2555	0.5015	0.3805	4.3907	16.617	1.5041	1.536	2.2866	0.9151	1.0353	0.9561	1.2305	0.5603	0.7017	0.3357
T10	0.0724	0.2784	0.2585	0.4211	0.3819	3.4855	12.169	2.1811	2.7251	2.3475	1.2921	1.4247	0.9332	1.7568	2.0523	0.9446	0.4311
T11	0.0791	0.2032	0.1315	1.2428	0.2906	2.8541	4.9276	1.4585	0.6827	1.4464	0.715	0.8412	1.6936	0.8098	2.1347	0.4157	0.2356
T12	0.0672	0.1799	0.1431	0.2185	0.2062	1.9151	7.0909	0.7195	0.5613	2.3511	0.7858	0.8692	1.5466	0.8391	1.2707	0.3961	0.2057
T13	0.0051	0.1341	0.0552	0.2353	0.1674	2.0448	4.1466	1.2864	1.0595	0.9397	0.1101	0.1446	1.2107	0.2241	0.5956	0.0989	0.0615
T14	0.0147	0.3395	0.0351	0.0793	0.3552	0.7375	2.8558	1.3682	0.1301	0.5047	0.1554	0.1945	0.6508	0.3075	1.0766	0.1896	0.0763
T15	0.0354	0.3365	0.149	0.5566	0.3541	5.5684	4.5604	1.4183	1.2374	1.1809	0.2843	0.3519	1.3698	0.4506	0.9606	0.1562	0.1147
T16	0.1236	0.6238	0.3831	0.6983	0.5835	6.3189	23.9361	2.6343	1.2076	2.7167	1.7655	1.0446	1.492	0.459	0.4623	1.365	0.6684

Table S3 Dioxin congeners in activated carbon（ng/g） and desulfurization lye（ng/L）.

	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF
AC-A-1-1	0.01512	0.02075	0.00441	0.00784	0.00491	0.00958	0.00912	0.12633	0.05313	0.05582	0.01521	0.0148	0.00129	0.01092	0.01056	9.67E-04	0.00598
AC-A-1-2	0.01454	0.02065	0.00439	0.00733	0.0049	0.00936	0.01008	0.12673	0.05181	0.05477	0.01567	0.0151	0.00152	0.0114	0.01164	0.00109	0.00602
AC-A-2-1	0	0	0	0	0	0.00222	0.00403	0.00317	0.00343	0.00256	0.00216	0.00305	5.67E-04	0.00254	0.00657	0.00109	0.00373
AC-A-2-2	0	0	0	0	0	0.00222	0.00388	0.0028	0.00384	0.00264	0.00197	0.0027	4.66E-04	0.00218	0.0063	9.82E-04	0.00285
AC-B-1	0.00248	0.00156	0	0	0	0.00213	0.00315	0.02418	0.00965	0.00875	0.00285	0.00318	5.50E-04	0.0028	0.00346	0	0.00143
AC-B-2	0.00239	0.00119	0	0	0	0.00192	0.00249	0.02291	0.00989	0.00854	0.00257	0.00311	0	0.00244	0.00315	0	0.0014
DL-A-2-1	4.1456	4.7336	0	4.152	3.548	16.6272	39.4632	26.0072	17.9328	21.8648	13.0424	16.376	2.1392	14.0704	26.756	0	14.8048
DL-A-2-2	3.4544	5.6704	0	3.7456	3.672	17.3808	40.156	22.8704	17.7568	21.2976	12.468	15.428	1.5296	13.6928	24.5272	0	13.1392
DL-B-1	88.1392	173.3664	75.2464	118.864	92.4688	1179.4128	6802.384	965.473	744.2352	916.7648	405.8176	466.0304	88.9328	642.1824	1174.1168	294.1936	3001.32
DL-B-2	81.5808	168.5568	62.056	98.96	91.4688	1118.688	6507.3504	1106.34	748.712	891.3008	401.2608	467.0672	81.9872	647.016	1072.1456	275.4016	2805.88
DL-D-1	32.2771	137.2931	99.79714	242.6706	148.6844	1038.51673	862.48857	228.243	240.9718	435.0885	340.6302	369.0963	51.45469	527.28939	1254.77592	87.51714	242.295
DL-D-2	30.9522	157.1061	99.44082	241.3073	148.0387	1080.62449	881.18571	196.364	248.8040	468.9073	349.2404	363.3987	53.01592	543.59959	1285.25878	93.94204	240.243
DL-E-1	384.298	1352.84	735.0909	851.8509	784.0436	2577.6	3253.3127	10594.2	31857.85	22302.76	23358.19	26330.33	5720.172	13401.872	29239.6581	12247.05	13765.1
DL-E-2	387.494	1394.96	778.0145	822.12	787.9745	2651.65818	3156.1818	10544.2	34189.22	22174.69	23430.38	26154.76	5289.112	13153.181	29859.0218	12026.53	13457.6

Table S4 Dioxin congeners in charcoal（ng/g）and pyrolysis oil（ng/L）.

	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF
Charcoal-E-1	2.33E-04	2.31E-04	2.68E-04	4.85E-04	4.01E-04	0.00173	0.00372	0.01135	0.00714	0.00592	0.00443	0.00494	8.72E-04	0.00325	0.00708	0.002	0.0035
Charcoal-E-2	4.13E-04	3.02E-04	2.90E-04	4.94E-04	4.02E-04	0.00178	0.00346	0.01082	0.00716	0.00599	0.00456	0.0048	8.45E-04	0.00316	0.00704	0.00197	0.0033
pyrolysis oil-E-1	6.52451	65.28389	24.59646	54.0046	76.0865	88.49038	28.7661	21.54884	1568.476	359.2167	3651.1115	6249.47913	1871.907	2961.732	3375.4154	2485.3408	2679.5
pyrolysis oil-E-2	7.28004	63.66304	25.5516	51.51287	75.92807	86.61128	28.7273	18.68466	1625.004	384.6801	3826.612	6374.87761	1740.992	2981.615	3684.2783	2511.7402	2669.7
Charcoal-F-1	0.00435	0.00809	0.00445	0.00697	0.00587	0.0319	0.03394	0.19671	0.1261	0.15615	0.07701	0.08578	0.01697	0.14594	0.231	0.02504	0.0665
Charcoal-F-2	0.00437	0.00813	0.00446	0.00699	0.00589	0.03202	0.03408	0.1975	0.1266	0.15678	0.07732	0.08613	0.01703	0.14652	0.23192	0.02514	0.0668
pyrolysis oil-F-1	19.12256	42.47802	19.03721	24.72865	13.25343	64.7954	34.0469	53.01061	174.8157	268.09	145.7641	143.85419	13.9873	161.6764	233.05482	26.46983	35.023
pyrolysis oil-F-2	17.42915	45.76357	17.14425	25.58652	11.75584	67.11609	34.6037	85.82277	161.5777	222.1703	143.6978	141.98966	12.21001	156.7598	232.84991	24.98343	36.266
Purchased coal-1	0	0	0	0	0	0.0016	0.00335	0.00148	7.22E-04	0.0012	0	0.00163	0	0	0.00345	0	0.0049
Purchased coal-2	4.39E-04	0	0	0	0	0.00147	0.00351	9.16E-04	6.36E-04	8.29E-04	0	0.00136	0	0	0.00277	0	0.0045