Supplementary Materials

Network analyses reveal geographically continuous elemental patterns in municipal solid waste incineration fly ash

Khin Thant Sin[1], Siyuan Yu (✉)[1], Ke Chang[1], Pinjing He[1,2], Fan Lü[1,2], Hua Zhang (✉)[1,2]

1 Institute of Waste Treatment & Reclamation, College of Environmental Science and Engineering, Tongji University, Shanghai 200092, China

2 Shanghai Institute of Pollution Control and Ecological Security, Shanghai 200092, China

✉ Corresponding authors
E-mail: siyuan_yu@tongji.edu.cn (S. Yu); zhanghua_tj@tongji.edu.cn (H. Zhang)

Text S1. Engineering parameters processing

Sampling time: The sampling time was recorded for laboratory collected samples, and some papers also reported their sampling time. For the sampling period, the initial date was recorded as sampling time. Samples reported with seasonal descriptors were converted to numerical months using mid-season months. The sampling month and year were retained for time-series analyses, while those without reported sampling time may use the paper publication year as surrogate.

Geographic information: The geographic information of waste incinerators was normalized into countries. Due to the large incineration capacity and broad land size, the provinces were retained for incinerator located in China. Various samples with missing geographic information were retained as null.

Capacity: The capacity of the reported incinerators was recorded, with the unit of metric tons per day. The ranges of capacity were simplified to the midpoint values.

Waste composition: Although the dataset was established to analyze the MSWI fly ash, the waste composition can be complex for many incinerators. The waste composition combusted in the incinerator was standardized using MSW, RDF (refuse-derived fuel), IW (industrial waste), MW (medical waste), HW (hazardous waste), SS (sewage sludge or channel cleaning sludge), BM (biomass, garden waste, agriculture waste, and compost), CW (sorted construction debris), DW (sorted demolition debris), FUEL (fossil fuel except coal), CAW (combustible waste), FWR (residues from food waste treatment), RW (trash collected on the surface of rivers), RCW (road cleaning waste), OW (organic waste and food waste), and OTHER (other waste and special waste). The waste composition with exact percentages or ratios was maintained, while "small amount", "mainly/major", and undefined mixtures were assigned as 10%, 80%, and equal proportion distribution among identified components. A proportion matrix was established using standardized waste categories and proportions, ensuring sum of 100% except 0 for missing or unspecified components.

APC system: The terminology of individual unit of APC systems were standardized using abbreviations including AC (activated carbon), BF (bag filter or fabric filter), SD (semi-dry scrubber), DRY (dry scrubber), WET (wet scrubber), ESP (electrostatic precipitator), SCR (selective catalytic reduction), SNCR (selective non-catalytic reduction), LIME (lime injection without identification of exact scrubbers), CY (cyclone), NONE (no APC unit or boiler ash), and OTHERS (units with low frequency). Given that modern APC systems often employ multiple treatment technologies in series, binary vector indicating presence (1) or absence (0) of each standardized unit was assigned to each sample, enabling quantitative analysis of individual technology effects and combination on elemental compositions.

*Table S1 Available data amount and completeness rate of collected data**

Elements	Effect data amount	Complete rate (%)	Elements	Effect data amount	Complete rate (%)
Ag	119	8.3	Mg	991	68.9
Al	1064	73.9	Mn	471	32.7
As	464	32.2	Mo	109	7.6
Au	4	0.3	Na	1035	71.9
B	27	1.9	Nb	12	0.8
Ba	383	26.6	Nd	31	2.2
Be	87	6.1	Ni	628	43.6
Bi	54	3.8	P	613	42.6
Br	193	13.5	Pb	989	68.7
Ca	1132	78.7	Pd	8	0.6
Cd	800	55.6	Pr	27	1.9
Ce	53	3.7	Pt	7	0.5
Cl	924	64.5	Rb	41	2.8
Co	161	11.2	Rh	8	0.6
Cr	879	61.1	S	926	64.4
Cr(VI)	4	0.3	Sb	263	18.3
Cs	26	1.8	Sc	31	2.2
Cu	964	67.0	Se	199	13.8
Dy	26	1.8	Si	1008	70
Er	24	1.7	Sm	26	1.8
Eu	25	1.7	Sn	195	13.6
F	58	4.0	Sr	249	17.3
Fe	1040	72.3	Ta	8	0.6
Ga	18	1.3	Tb	16	1.1
Gd	25	1.7	Te	11	0.8
Ge	10	0.7	Th	33	2.3
Hf	27	1.9	Ti	608	42.3
Hg	234	16.3	Tl	35	2.4
Ho	10	0.7	Tm	13	0.9
I	2	0.1	U	32	2.2
In	17	1.2	V	136	9.5
Ir	2	0.1	W	30	2.1
K	1037	72.1	Y	34	2.4
La	42	2.9	Yb	22	1.5
Li	17	1.2	Zn	1063	73.9
Lu	13	0.9	Zr	83	5.8

** The information is referred to the collected raw data, without any cleaning or pretreatment.*

Table S2 Missing rates of elements after data cleaning

Element	Missing counts	Missing rate(%)	Zero counts	Available counts
Ca	152	11.70	0	1147
Al	229	17.63	1	1070
K	248	19.09	0	1051
Fe	263	20.25	3	1036
Na	265	20.40	1	1034
Si	276	21.25	0	1023
Zn	292	22.48	0	1007
Mg	305	23.48	1	994
Pb	355	27.33	0	944
Cu	362	27.87	0	937
Cl	371	28.56	1	928
S	379	29.18	0	920
Cr	443	34.10	0	856
Cd	512	39.41	0	787
Ni	685	52.73	0	614
Ti	689	53.04	0	610
P	691	53.19	1	608
Mn	832	64.05	0	467
As	848	65.28	1	451

Table S3 Random Forest imputation validation results with 20% hold-out

Element	n_train	n_test	R^2	R^2_log$_{10}$	RMSE	RMSE_log$_{10}$	MAPE
Ca	917	229	0.257	0.156	96158.5	0.341	165.6%
Al	856	214	0.667	0.688	13958.7	0.274	87.7%
K	840	210	0.419	0.472	17027.7	0.296	99.3%
Fe	828	207	0.433	0.262	9724.4	0.343	256.7%
Na	827	207	0.318	0.141	28429.4	0.446	401.6%
Si	818	205	0.813	0.761	23273.2	0.213	41.2%
Zn	805	201	0.396	0.325	5158.8	0.310	90.5%
Mg	795	199	0.295	0.218	5623.4	0.286	88.8%
Pb	755	189	0.578	0.367	1244.5	0.372	302.9%
Cu	749	187	0.392	0.390	639.1	0.283	78.4%
Cl	742	186	0.641	0.419	50748.1	0.401	278.8%
S	736	184	0.145	0.180	13139.5	0.294	84.1%
Cr	684	171	0.164	0.212	234.5	0.411	363.6%
Cd	373	93	0.582	0.691	296.9	0.195	39.3%
Ni	491	123	0.461	0.411	49.3	0.307	87.8%
Ti	488	122	0.486	0.571	2644.5	0.270	74.1%
P	486	122	0.554	0.621	3195.3	0.229	49.1%
Mn	373	93	0.582	0.691	296.9	0.195	39.3%
As	360	90	0.147	0.047	56.4	0.604	2293.5%

*Given the relatively low imputation accuracy for As and Cd, correlation results involving these elements should be interpreted with caution.

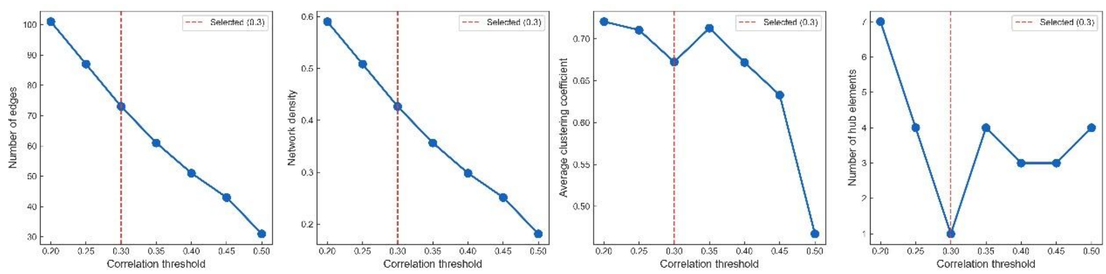

Figure S1 Sensitivity analysis of the selection of correlation thresholds.

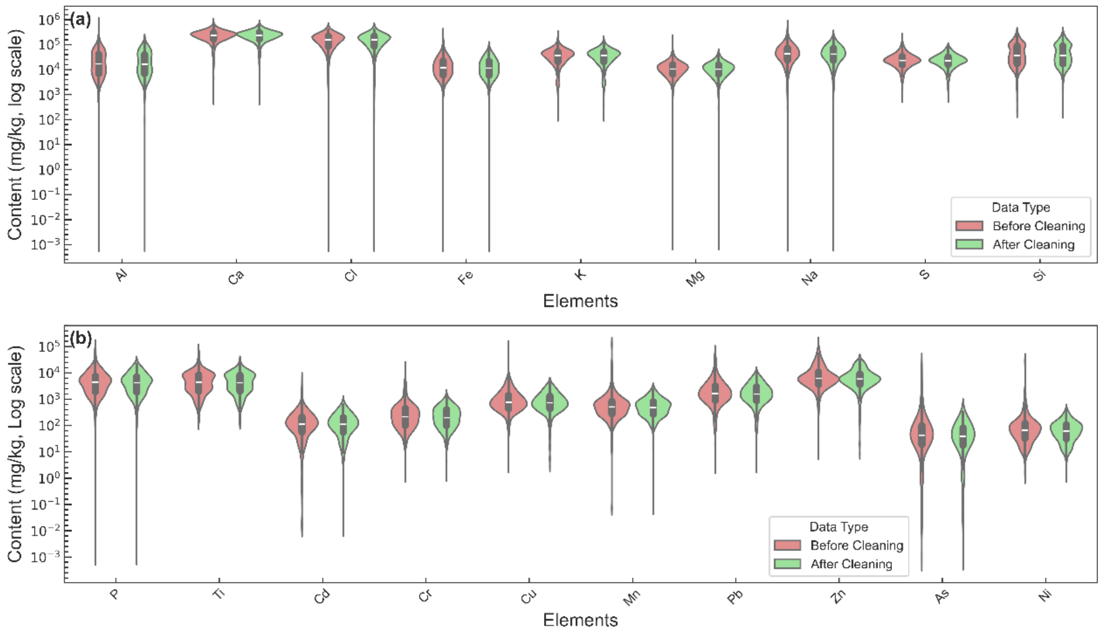

Figure S2 Ranges of elemental contents in MSWI fly ash samples before and after outlier removal. (a) Major elements; (b)Minor and trace elements

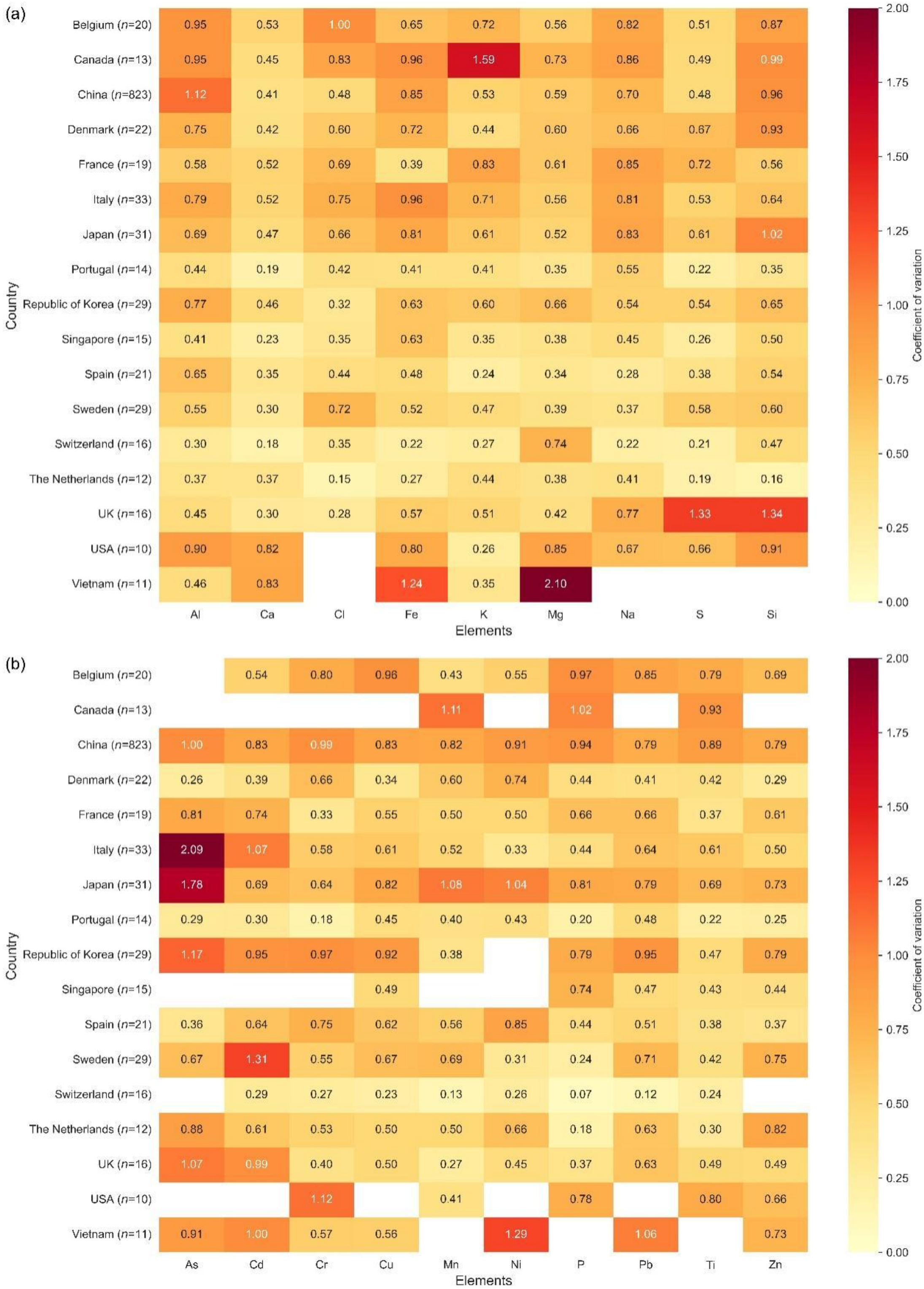

Figure S3 Coefficients of variation of elements among countries. The sample size for each region is shown in parentheses following the country name (e.g., China (n=823)).

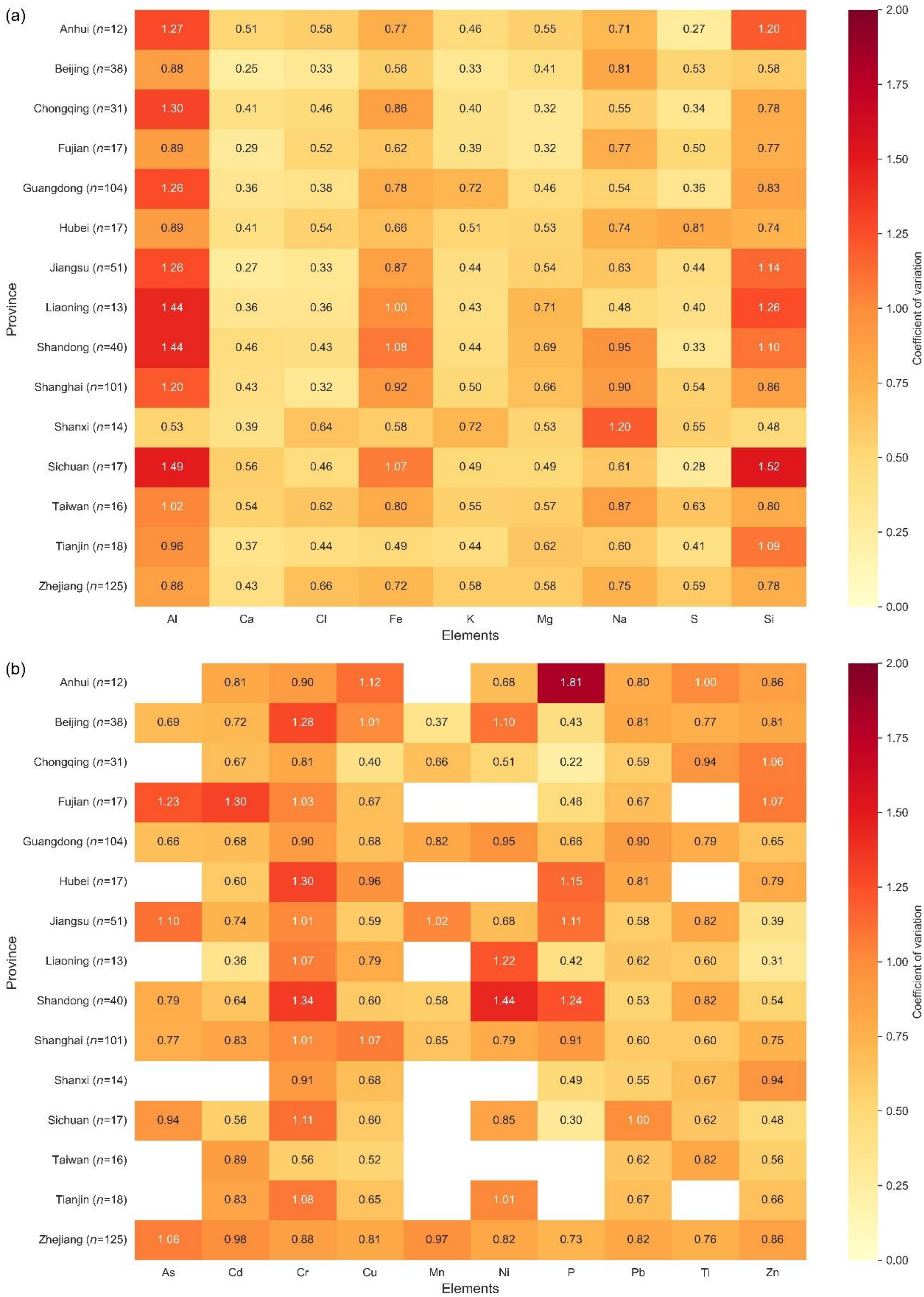

Figure S4 Coefficients of variation of elements among provinces. The sample size for each region is shown in parentheses following the province name (e.g., Zhejiang (n=125)).

Table S4 Results of one-way analysis of variance (ANOVA) among countries[1]

Elements	F value	Original *p* value	Corrected *p* value	η^2	Significance
S	18.89	3.00E-36	5.70E-35	0.226	***
Pb	16.41	1.12E-33	1.07E-32	0.209	***
Zn	16.47	1.19E-29	7.52E-29	0.175	***
Cu	11.03	5.80E-22	2.75E-21	0.152	***
K	10.04	3.33E-21	1.27E-20	0.134	***
Cd	10.85	1.56E-18	4.93E-18	0.155	***
Ti	10.01	1.93E-16	5.23E-16	0.191	***
Cl	8.52	2.47E-15	5.86E-15	0.115	***
Na	6.01	8.35E-11	1.76E-10	0.08	***
Ca	5.36	5.97E-10	1.13E-09	0.07	***
Al	5.11	8.02E-09	1.39E-08	0.068	***
Si	4.92	6.56E-08	1.04E-07	0.064	***
Cr	3.69	1.03E-05	1.50E-05	0.063	***
Mg	3.97	1.18E-05	1.60E-05	0.05	***
Fe	2.82	0.0006	0.0007	0.04	***
Mn	1.6	0.1124	0.1334	0.04	ns
Ni	1.43	0.1633	0.1792	0.028	ns
As	1.52	0.1698	0.1792	0.026	ns
P	1.26	0.2461	0.2461	0.028	ns

[1]17 countries with more than 10 samples were analyzed, including China, Italy, Japan, Sweden, Republic of Korea, Spain, Belgium, France, Switzerland, UK, Singapore, Denmark, Portugal, Canada, the Netherlands, Vietnam, and USA.

***: corrected $p<0.001$; **: corrected $p<0.01$; *: corrected $p<0.05$; ns: not significant

Table S5 Results of one-way analysis of variance (ANOVA) among Chinese provinces[1]

Elements	**F value**	**Original *p* value**	**Corrected *p* value**	η^2	**Significance**
Al	7.17	1.19E-13	2.26E-12	0.166	***
Si	6.14	2.99E-11	2.84E-10	0.156	***
Ti	19.9	4.56E-11	2.89E-10	0.264	***
Cl	6.29	3.15E-10	1.33E-09	0.158	***
Mg	5.64	3.50E-10	1.33E-09	0.141	***
Fe	5.55	6.04E-10	1.91E-09	0.141	***
P	9.75	2.68E-08	7.28E-08	0.205	***
K	4.48	3.13E-07	7.44E-07	0.109	***
Zn	4.51	1.12E-05	2.36E-05	0.085	***
S	3.8	1.68E-05	3.19E-05	0.101	***
Ca	3.22	6.52E-05	0.0001	0.077	***
Cd	4.6	0.0002	0.0003	0.082	***
Cu	3.17	0.001	0.0014	0.067	**
Mn	4.95	0.001	0.0014	0.134	**
Cr	2.65	0.0056	0.0071	0.065	**
Ni	3.22	0.0077	0.0092	0.062	**
Pb	2.43	0.0108	0.0121	0.051	*
As	1.82	0.1118	0.118	0.046	ns
Na	1.18	0.2849	0.2849	0.032	ns

[1]15 Chinese provinces with more than 10 samples were analyzed, including Zhejiang, Shanghai, Guangdong, Jiangsu, Beijing, Chongqing, Shandong, Hubei, Sichuan, Tianjin, Fujian, Taiwan, Shanxi, Liaoning, Anhui.

***: corrected $p<0.001$; **: corrected $p<0.01$; *: corrected $p<0.05$; ns: not significant

Table S6 Results of Kruskal-Wallis test among countries[1]

Elements	H value	Original *p* value	Corrected *p* value	Significance
Pb	128.33	4.49E-21	8.52E-20	***
S	119.57	7.52E-20	7.14E-19	***
Zn	112.45	5.93E-19	3.76E-18	***
K	109.15	8.16E-17	3.88E-16	***
Cu	101.81	7.39E-16	2.81E-15	***
Ti	95.56	1.35E-15	4.26E-15	***
Cl	94.95	5.39E-15	1.46E-14	***
Cd	89.63	1.97E-14	4.67E-14	***
Na	86.37	6.87E-13	1.45E-12	***
Al	85.21	1.14E-12	2.17E-12	***
Ca	86.74	1.56E-12	2.70E-12	***
Si	65.57	2.14E-09	3.39E-09	***
Cr	62.38	1.96E-08	2.87E-08	***
Mg	35.37	0.0002	0.0003	***
As	24.97	0.0003	0.0004	***
Ni	27.75	0.002	0.0023	**
Fe	32.29	0.0022	0.0024	**
P	21.84	0.0256	0.027	*
Mn	16.83	0.0515	0.0515	ns

[1]17 countries(regions) with more than 10 samples were analyzed, including China, Italy, Japan, Sweden, Republic of Korea, Spain, Belgium, France, Switzerland, UK, Singapore, Denmark, Portugal, Canada, the Netherlands, Vietnam, and USA.

***: corrected p<0.001; **: corrected p<0.01; *: corrected p<0.05; ns: not significant

Table S7 Results of Kruskal-Wallis test among Chinese provinces[1]

Elements	H value	Original *p* value	Corrected *p* value	Significance
Zn	63.02	3.50E-10	6.65E-09	***
Mg	71.94	8.59E-10	8.16E-09	***
Si	70.14	1.82E-09	1.15E-08	***
Cl	61.92	1.01E-08	4.79E-08	***
Al	63.76	2.55E-08	9.69E-08	***
S	57.5	6.41E-08	2.03E-07	***
Ca	57.96	2.66E-07	7.23E-07	***
K	54.77	4.43E-07	1.05E-06	***
Cd	39.3	6.24E-07	1.32E-06	***
Fe	55.46	7.22E-07	1.37E-06	***
Ti	27.87	3.87E-06	6.68E-06	***
Cu	40.38	6.49E-06	1.03E-05	***
Pb	32.01	0.0002	0.0003	***
P	20.56	0.001	0.0013	**
Ni	17.24	0.0041	0.0051	**
Na	29.09	0.0102	0.0114	*
Cr	21.67	0.01	0.0114	*
Mn	12.06	0.0169	0.0178	*
As	10.34	0.0661	0.0661	ns

[1]15 Chinese provinces with more than 10 samples were analyzed, including Zhejiang, Shanghai, Guangdong, Jiangsu, Beijing, Chongqing, Shandong, Hubei, Sichuan, Tianjin, Fujian, Taiwan, Shanxi, Liaoning, Anhui.

***: corrected p<0.001; **: corrected p<0.01; *: corrected p<0.05; ns: not significant

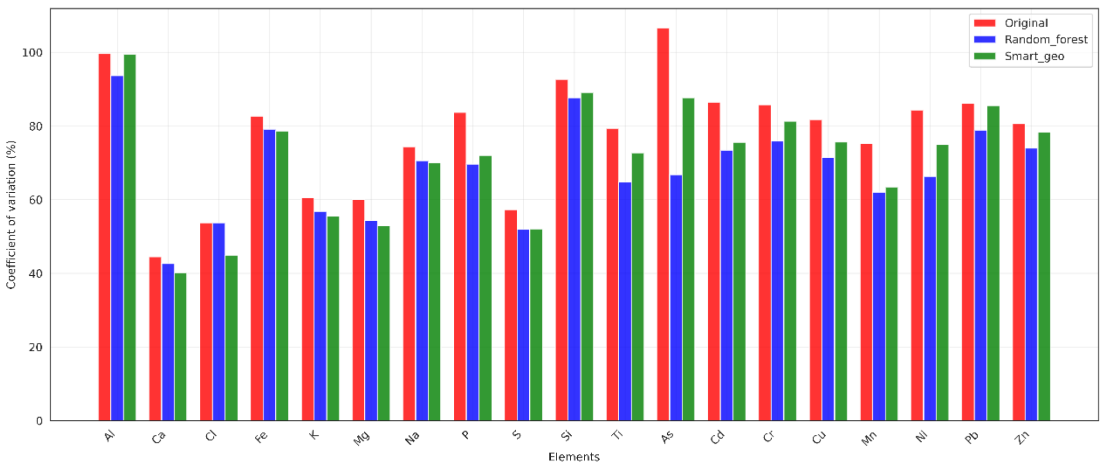

Figure S5 Coefficients of variation (CVs) before and after imputation.

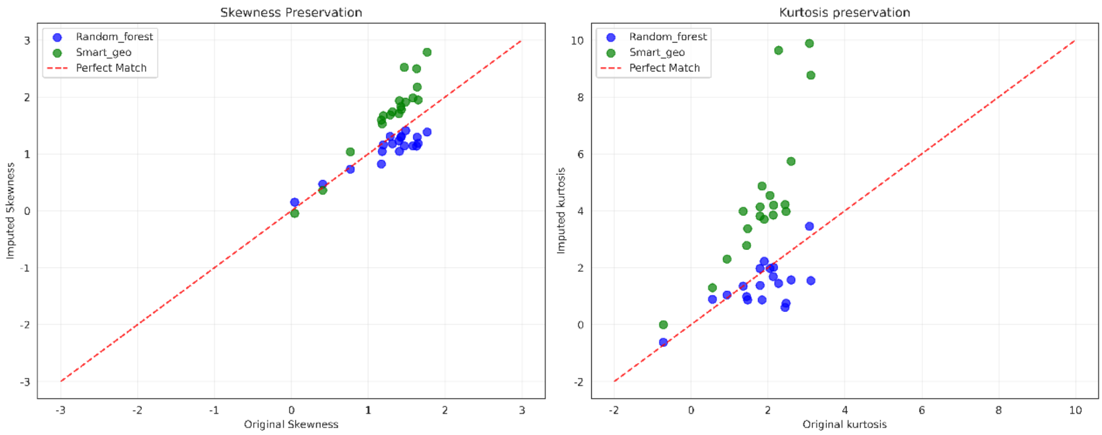

Figure S6 Skewness and kurtosis preservation after imputation.

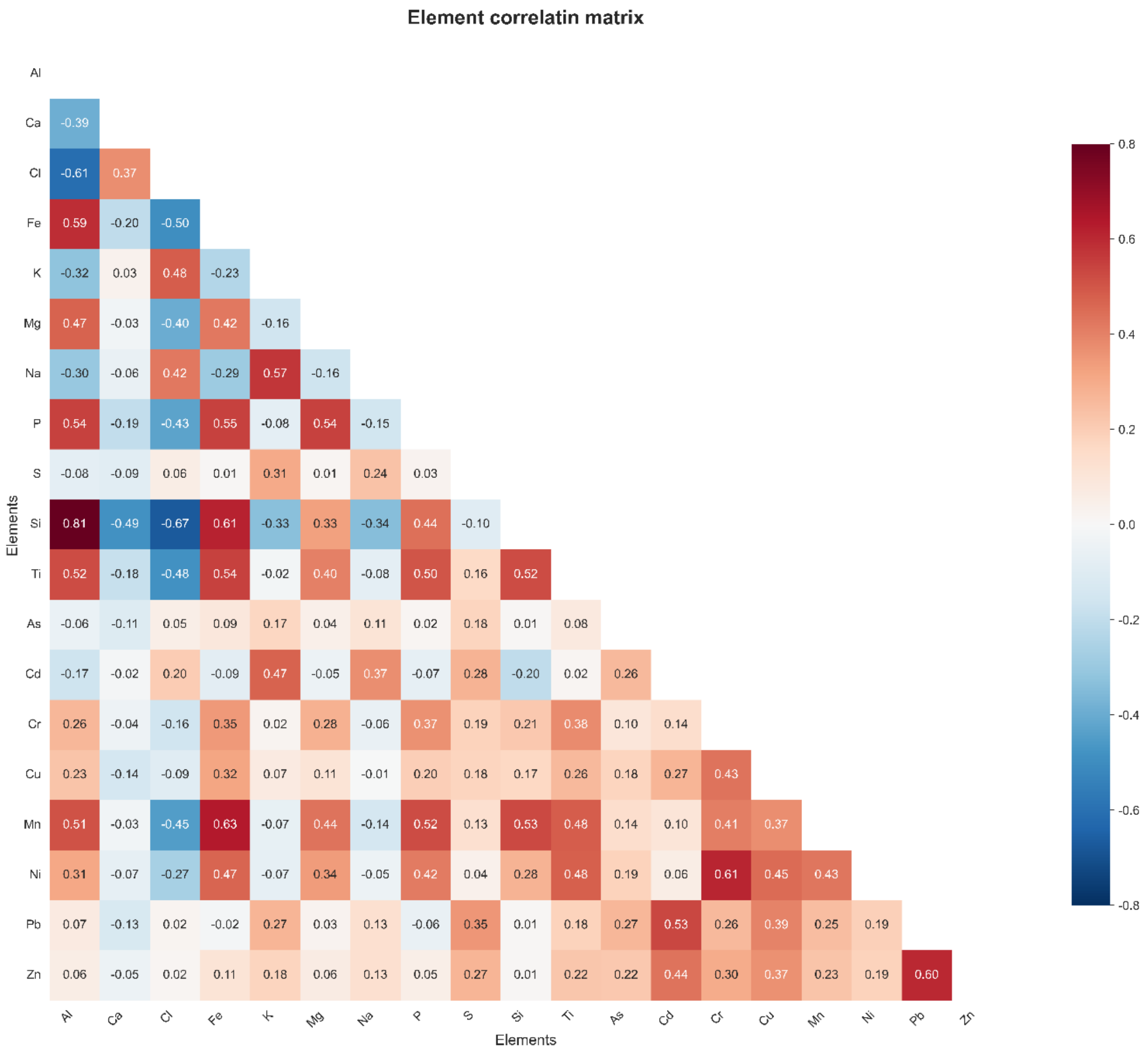

Figure S7 Elemental correlation in original dataset. The values are Pearson correlation coefficients between the elements in both axes.

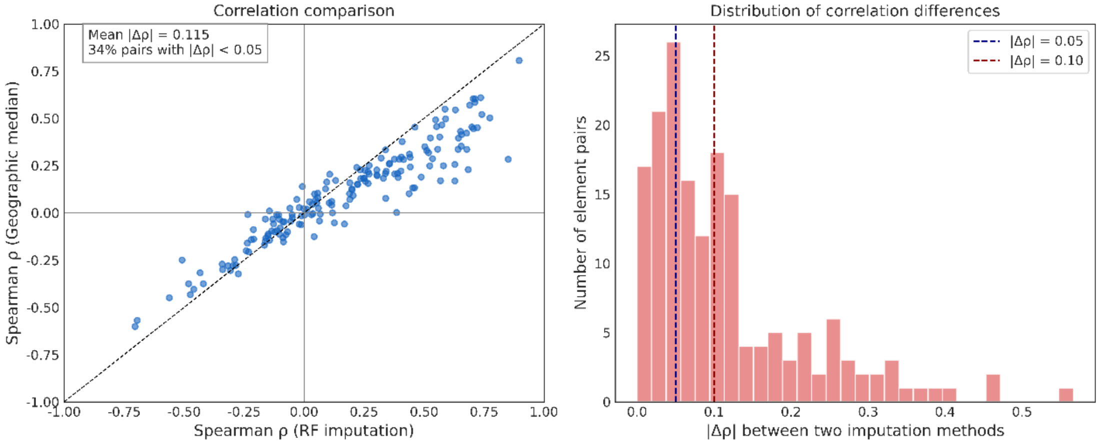

Figure S8 Sensitivity check of Random Forest and smart geographic grouping imputation

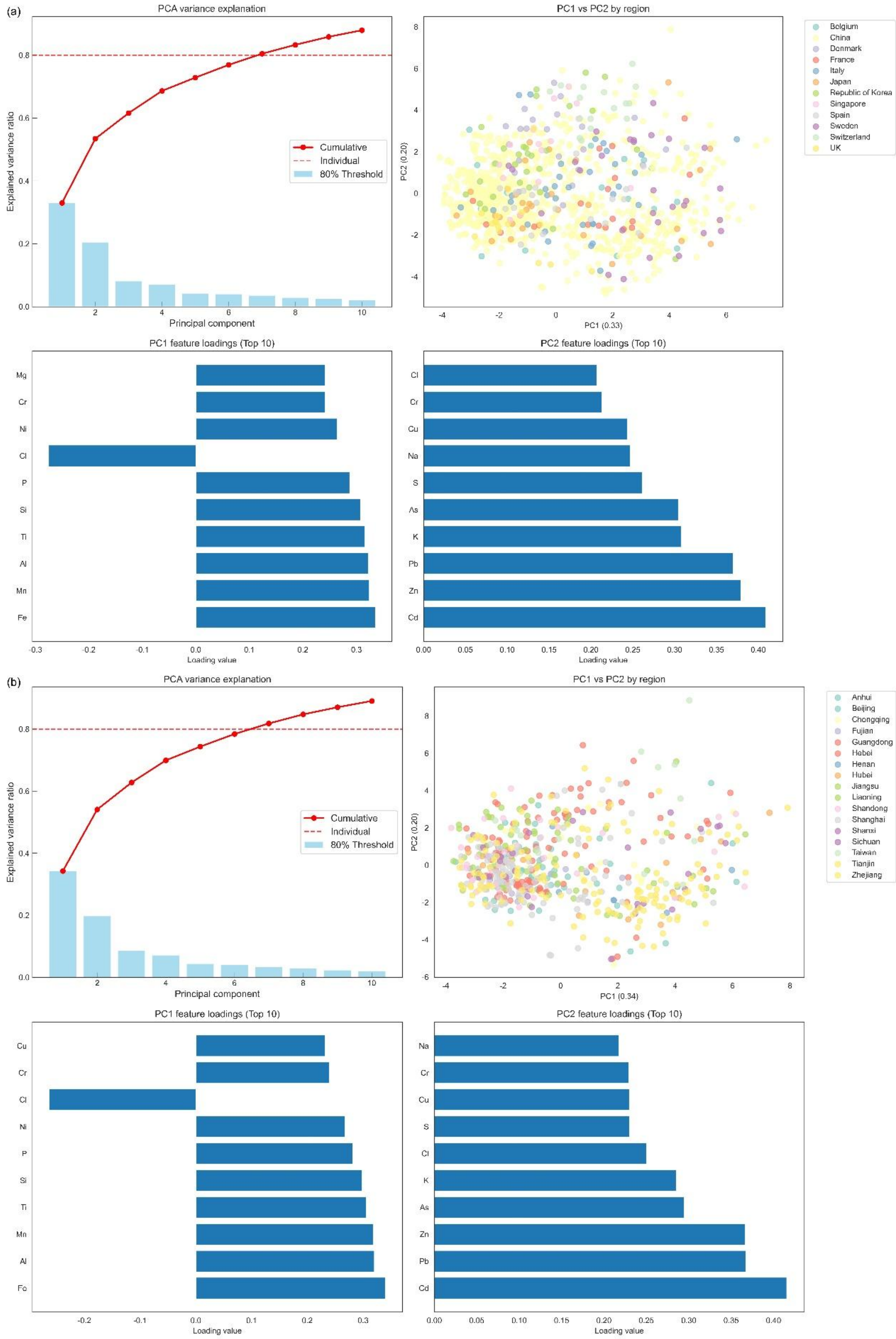

Figure S9 PCA analysis of elemental content in fly ash at (a) country level and (b) Chinese province level.

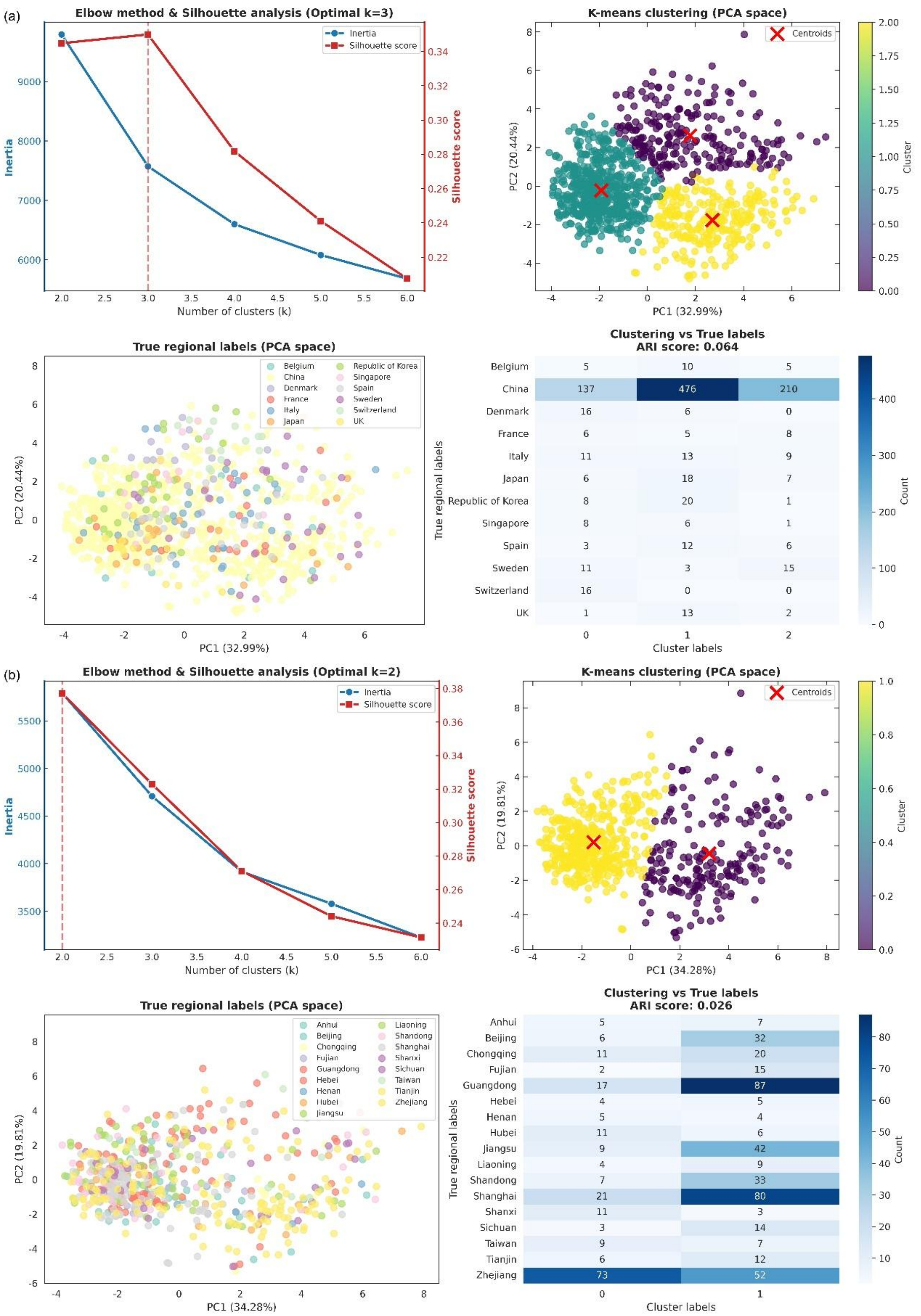

Figure S10 Clustering results at the (a) country level and (b) Chinese province level using five primary components.

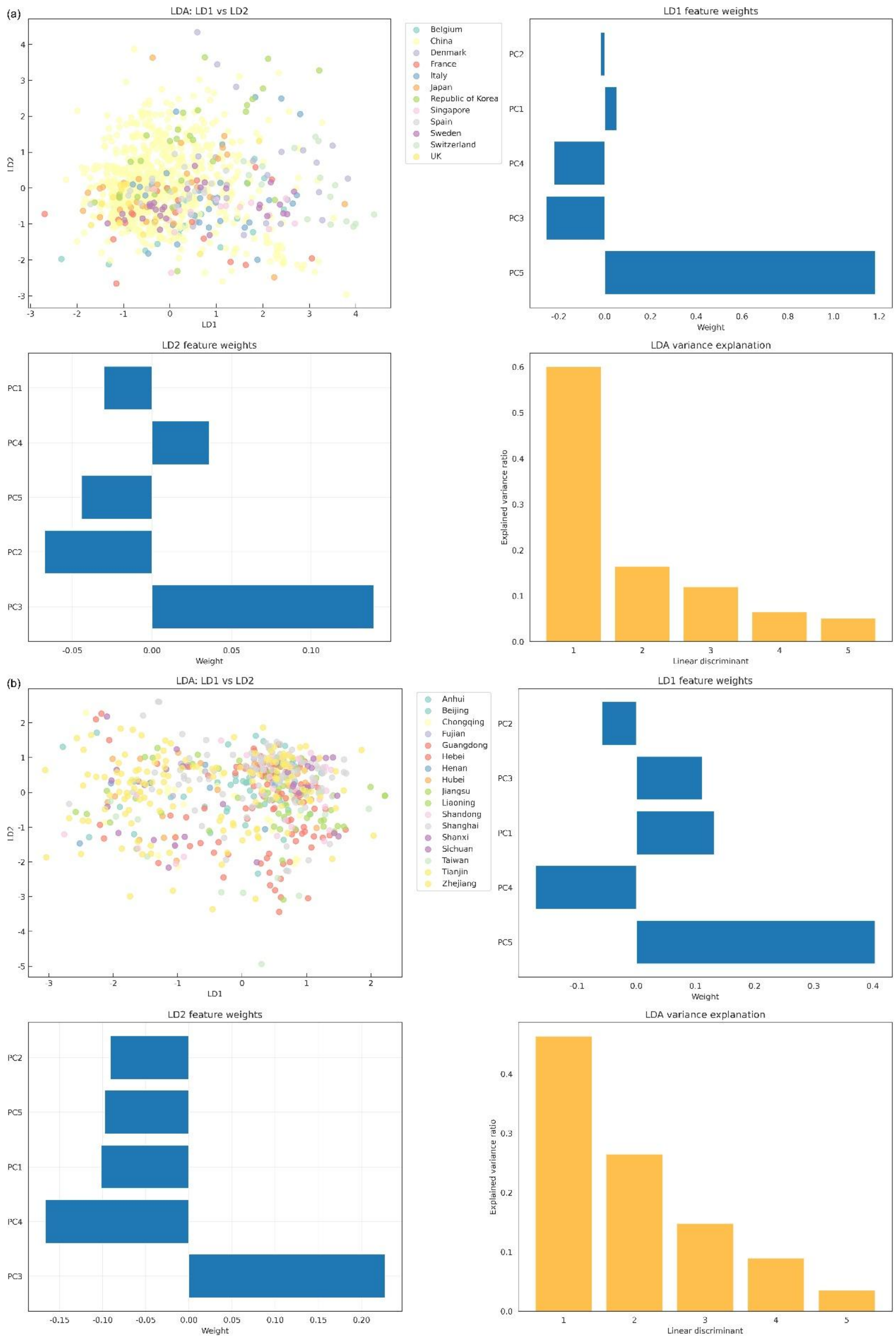

Figure S11 Results of linear discriminant analysis (LDA) at the (a) country level and (b) Chinese province level.

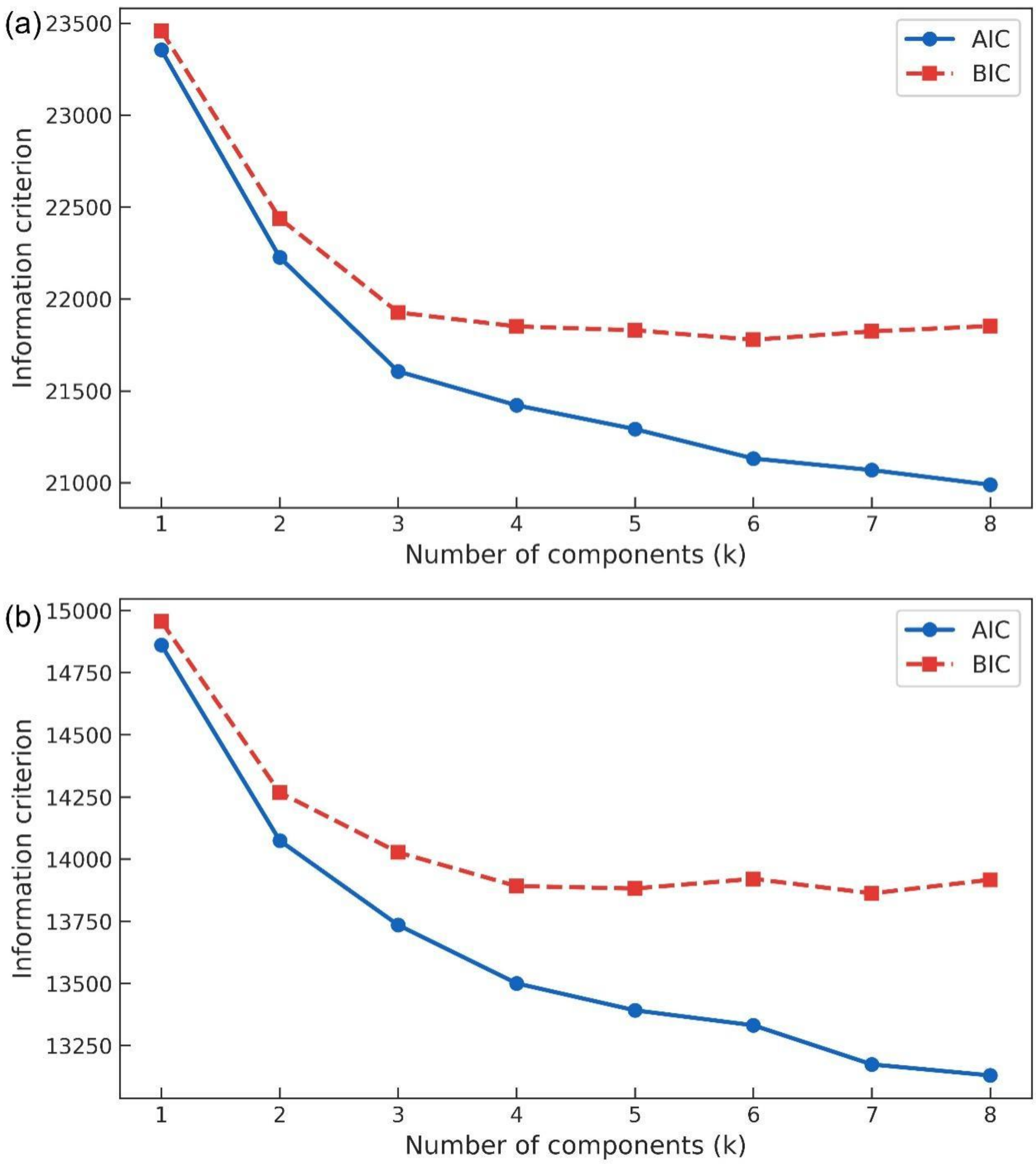

Figure S12 Gaussian Mixture Model (GMM) model selection results for country-level and Chinese province-level datasets. GMM was fitted to the first five principal components of the PCA-reduced dataset for k = 1–8 components. Akaike Information Criterion (AIC, blue solid line) and Bayesian Information Criterion (BIC, red dashed line) are shown as a function of the number of Gaussian components k. Lower values indicate better model fit; a clear minimum indicates the preferred number of discrete components. The absence of a BIC minimum and the flattening of both curves beyond k = 3–4 indicate that no strongly preferred discrete cluster number exists, supporting a continuous compositional spectrum rather than discrete geographic categories.

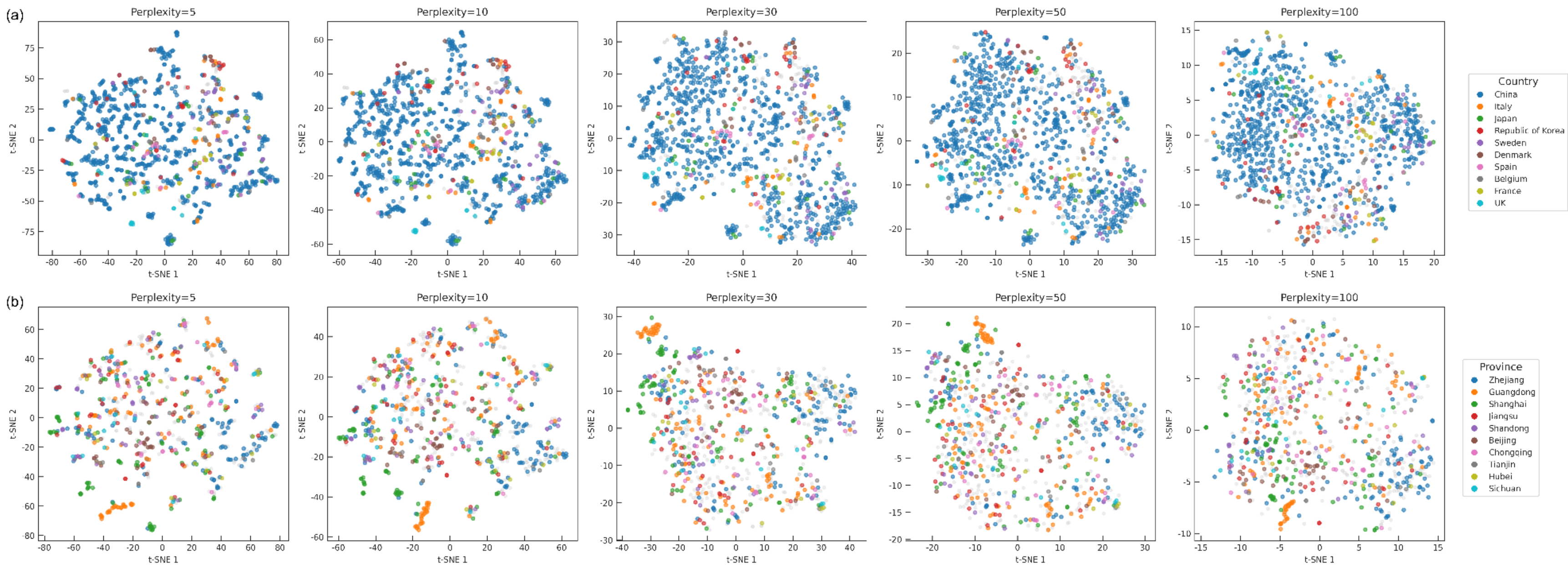

Figure S13 Sensitivity of t-Distributed Stochastic Neighbor Embedding (t-SNE) visualization to the perplexity hyperparameter at (a) country level and (b) Chinese province level. t-SNE was performed at perplexity values of 5, 10, 30, 50, and 100 on the standardized elemental dataset. Node colors indicate geographic region. The extensive overlap between regions is consistent across all perplexity settings, confirming that the absence of geographically coherent clusters reflects genuine compositional continuity rather than an artifact of the perplexity parameter choice.

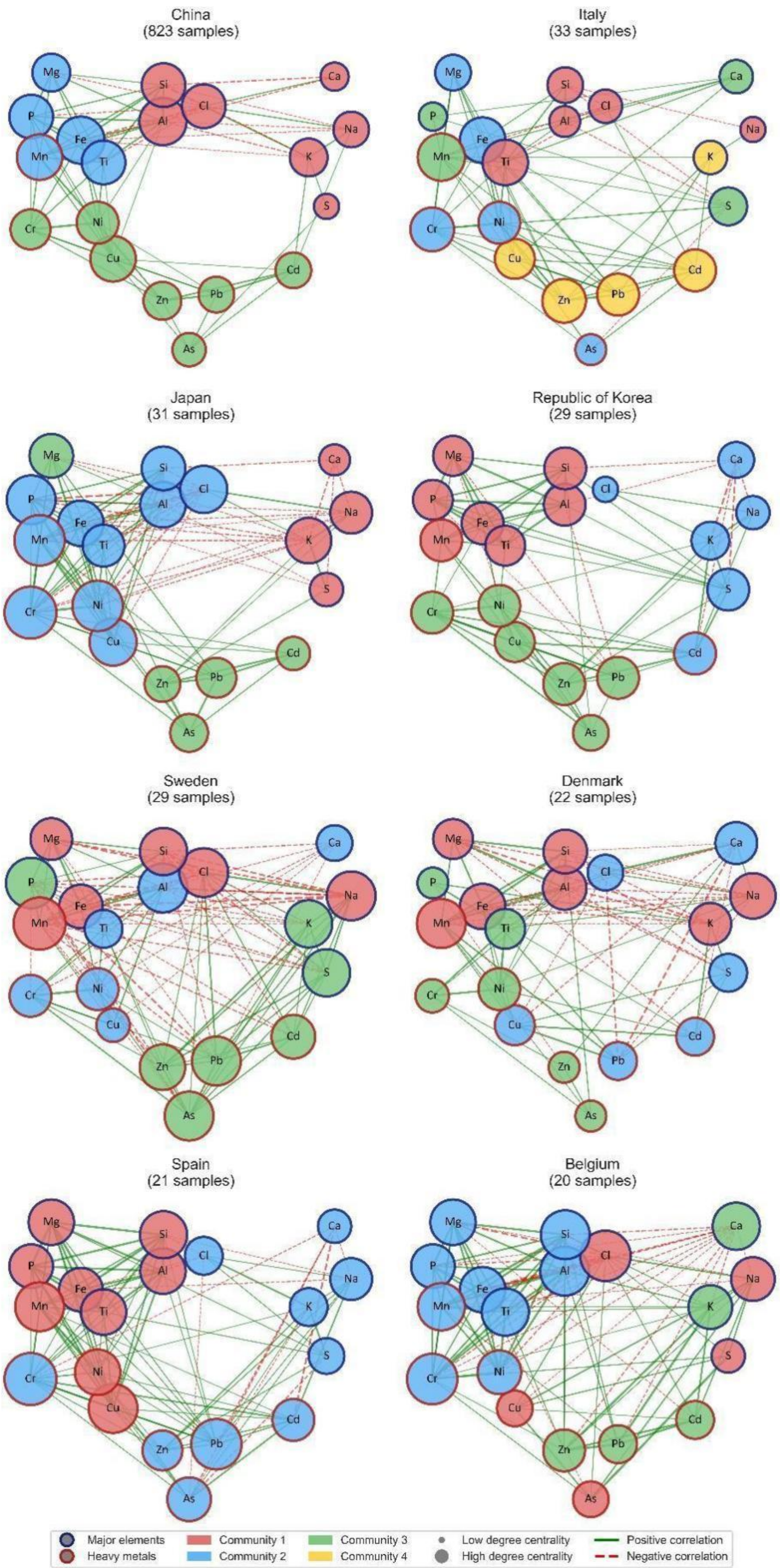

Figure S144 Element correlation network in countries with ≥ 20 samples. All subplots share a fixed node layout computed from the global network to facilitate cross-regional comparison. Node fill color indicates community membership detected by the Louvain algorithm (fixed seed = 42); node border color distinguishes major elements (dark blue border) from heavy metals (dark red border); node size is proportional to degree centrality. Green solid lines represent positive correlations and red dashed lines represent negative correlations; edge width is proportional to the absolute Pearson correlation coefficient. Only element pairs with $|r| \geqslant 0.3$ and $p < 0.05$

(Benjamini–Hochberg corrected) are shown. Sample sizes are indicated in parentheses below each country name. Note that community colors are assigned independently for each regional network and do not represent the same community across subplots.

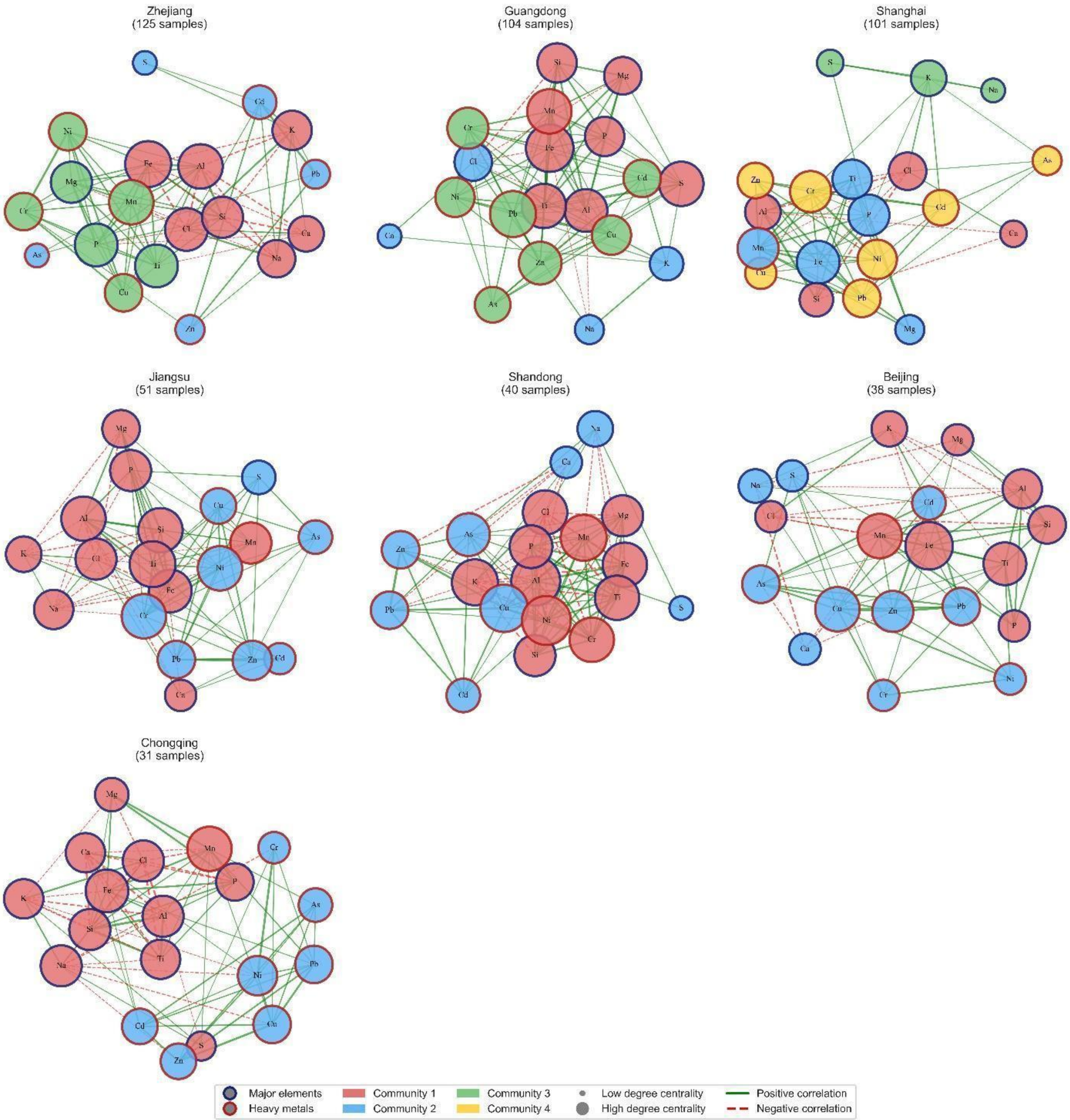

Figure S15 Element correlation network in provinces with ≥20 samples. All subplots share a fixed node layout computed from the China-wide network. Visual encoding follows the same conventions as Figure S14 (country-level networks). Community detection was performed independently for each provincial network using the Louvain algorithm (fixed seed = 42); community colors are therefore not directly comparable across subplots.

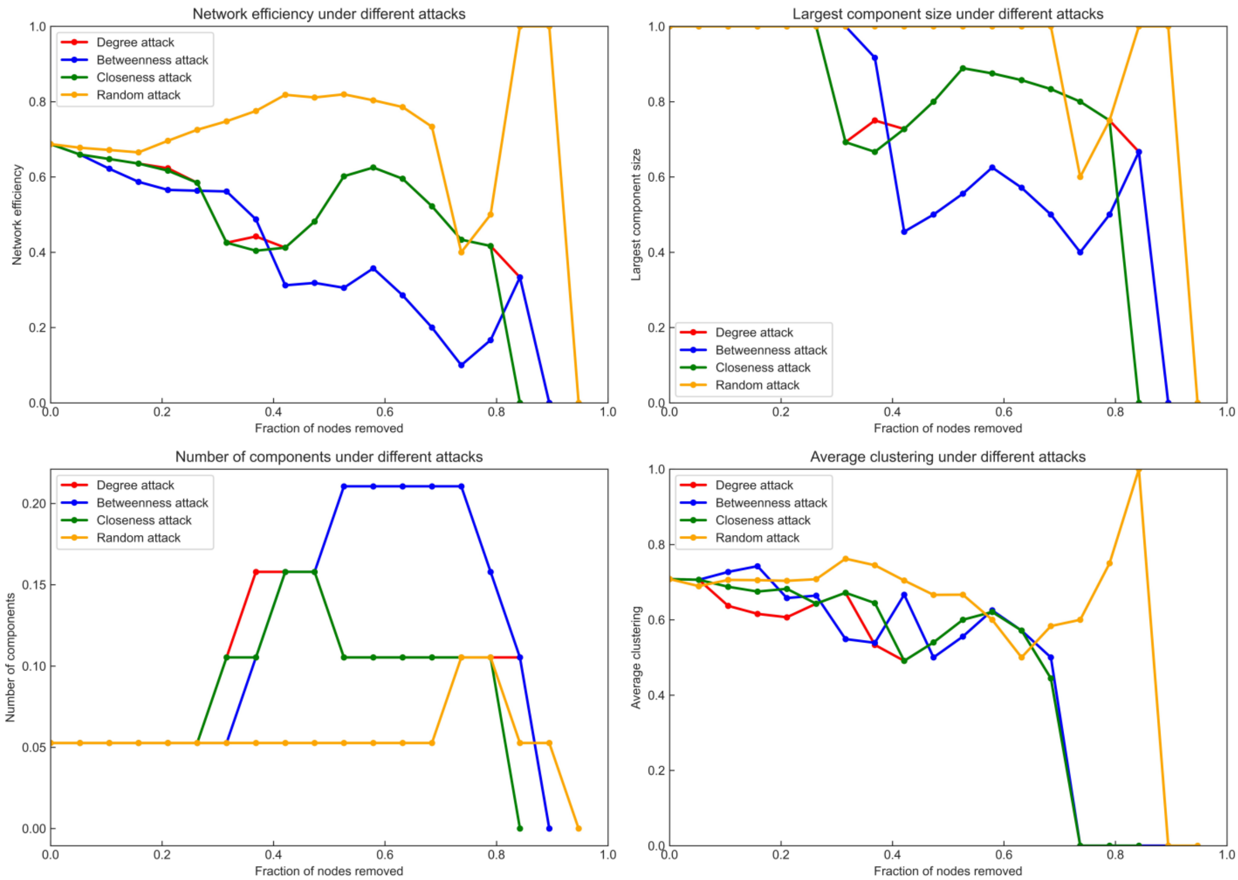

Figure S16 Network robustness analysis in the global level.

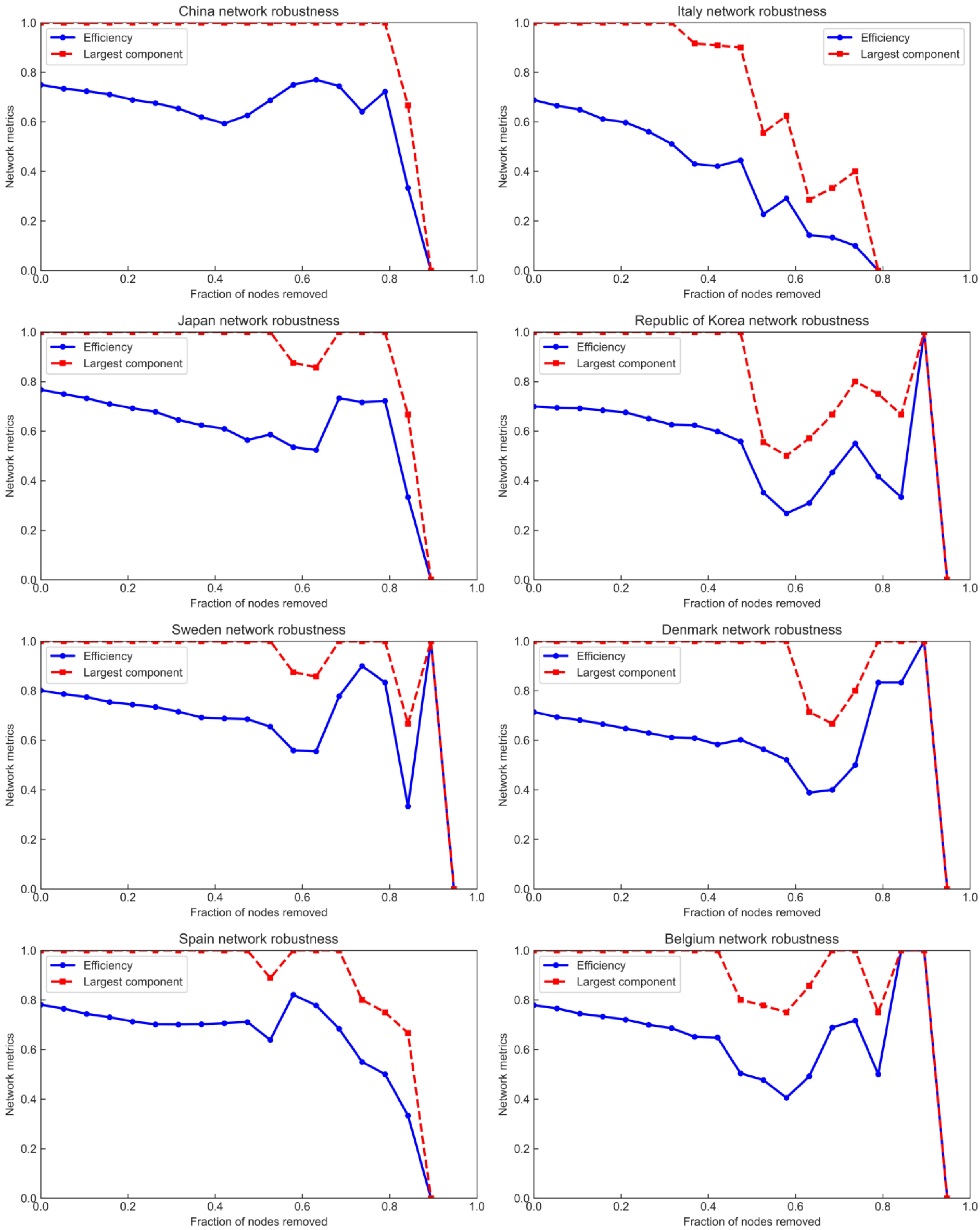

Figure S17 Network robustness analysis of countries with most samples.

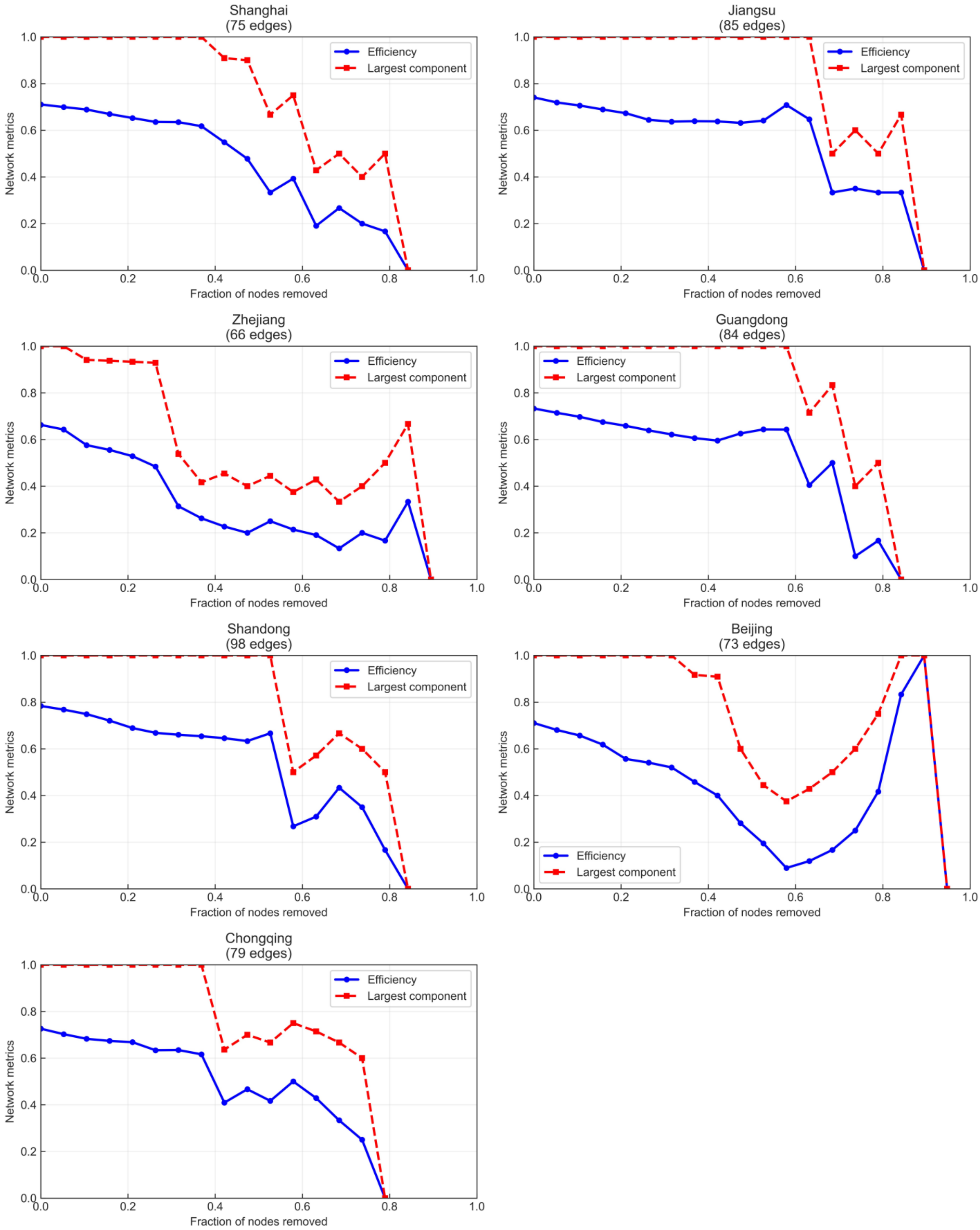

Figure S18 Network robustness analysis of provinces with most samples.

Text S2: List of literature used in the dataset

The journal publications, thesis, and reports used for the construction of the dataset are listed below. The thesis is labeled with “[D]”.

Abdi E, Asadollahfardi G, Salehi A, et al. (2024). Using municipal Solid-Waste Incinerator fly ash, wash water, and propylene fibers in Self-Compacting repair mortar, greenhouse gas emissions potential. International Journal of Concrete Structures and Materials, 18: 57. https://doi.org/10.1186/s40069-024-00694-9

Aghabeyk F, Chen B, Van Zijl M B, et al. (2025). Physicochemical characterization and resource recovery potential of hazardous municipal solid waste incineration (MSWI) fly ash and air pollution control (APC) residues in the Netherlands. Journal of Environmental Management, 384: 125579. https://doi.org/10.1016/j.jenvman.2025.125579

Alba N, Gassó S, Lacorte T, et al. (1997). Characterization of municipal solid waste incineration residues from facilities with different air pollution control systems. Journal of the Air & Waste Management Association, 47(11): 1170–1179. https://doi.org/10.1080/10473289.1997.10464059

Alba N, Vázquez E, Gassó S, et al. (2001). Stabilization/solidification of MSW incineration residues from facilities with different air pollution control systems. Durability of matrices versus carbonation. Waste Management, 21(4): 313–323. https://doi.org/10.1016/s0956-053x(00)00082-9

Almalkawi A T, Balchandra A, Soroushian P. (2019). Potential of using industrial wastes for production of geopolymer binder as green construction materials. Construction and Building Materials, 220: 516–524. https://doi.org/10.1016/j.conbuildmat.2019.06.054

Andreola F, Barbieri L, Hreglich S, et al. (2007). Reuse of incinerator bottom and fly ashes to obtain glassy materials. Journal of Hazardous Materials, 153(3): 1270–1274. https://doi.org/10.1016/j.jhazmat.2007.09.103

Arikibe J E and Cieślik B M. (2025). Assessing metal distribution in diverse incineration ashes: Implications for sustainable waste management in case of different incineration facilities. Water Air & Soil Pollution, 236: 81. https://doi.org/10.1007/s11270-024-07686-1

Ashraf M S, Ghouleh Z, Shao Y. (2019). Production of eco-cement exclusively from municipal solid waste incineration residues. Resources Conservation and Recycling, 149: 332–342. https://doi.org/10.1016/j.resconrec.2019.06.018

Assi A, Bilo F, Zanoletti A, et al. (2019). Zero-waste approach in municipal solid waste incineration: Reuse of bottom ash to stabilize fly ash. Journal of Cleaner Production, 245: 118779. https://doi.org/10.1016/j.jclepro.2019.118779

Atanes E, Cuesta-García B, Nieto-Márquez A, et al. (2019). A mixed separation-immobilization method for soluble salts removal and stabilization of heavy metals in municipal solid waste incineration fly ash. Journal of Environmental Management, 240: 359–367. https://doi.org/10.1016/j.jenvman.2019.03.122

Aubert J, Husson B, Vaquier A. (2003). Use of municipal solid waste incineration fly ash in concrete. Cement and Concrete Research, 34(6): 957–963. https://doi.org/10.1016/j.cemconres.2003.11.002

Auer S, Kuzel H, Pöllmann H, et al. (1995). Investigation on MSW fly ash treatment by reactive calcium aluminates and phases formed. Cement and Concrete Research, 25(6): 1347–1359. https://doi.org/10.1016/0008-8846(95)00127-x

Bai J J, Zhang Z Q, Yan D H, et al. (2012). Study on the removal of chlorine and heavy metals in incineration fly ash during water-washing process. Environmental Engineering, 2012, 30(02): 104–108. https://doi.org/10.13205/j.hjgc.2012.02.032.

Bai J J. (2012). Study on the pretreatment technology of municipal solid waste incineration fly ash prior to co-processing in cement kilns . Yulin: Northwest A & F University.

Bai Y Y. (2023). Preparation and impact resistance of municipal solid waste incineration fly ash based low carbon composite materials . Qinhuangdao: Yanshan University.

Bayuseno A P and Schmahl W W. (2011). Characterization of MSWI fly ash through mineralogy and water extraction. Resources Conservation and Recycling, 55(5): 524–534. https://doi.org/10.1016/j.resconrec.2011.01.002

Bernasconi D, Caviglia C, Destefanis E, et al. (2021). Influence of speciation distribution and particle size on heavy metal leaching from MSWI fly ash. Waste Management, 138: 318–327. https://doi.org/10.1016/j.wasman.2021.12.008

Bernasconi D, Caviglia C, Destefanis E, et al. (2025). Steam washing for MSWI-FA treatment. Waste Management, 195: 10–21. https://doi.org/10.1016/j.wasman.2025.01.031

Bernasconi D, Viani A, Zárybnická L, et al. (2023). Reactivity of MSWI-fly ash in Mg-K-phosphate cement. Construction and Building Materials, 409: 134082. https://doi.org/10.1016/j.conbuildmat.2023.134082

Bie R, Chen P, Song X, et al. (2015). Characteristics of municipal solid waste incineration fly ash with cement solidification treatment. Journal of the Energy Institute, 89(4): 704–712. https://doi.org/10.1016/j.joei.2015.04.006

Bodénan F and Deniard P. (2003). Characterization of flue gas cleaning residues from European solid waste incinerators: assessment of various Ca-based sorbent processes. Chemosphere, 51(5): 335–347. https://doi.org/10.1016/s0045-6535(02)00838-x

Bogush A A, Stegemann J A, Zhou Q, et al. (2020). Co-processing of raw and washed air pollution control residues from energy-from-waste facilities in the cement kiln. Journal of Cleaner Production, 254: 119924. https://doi.org/10.1016/j.jclepro.2019.119924

Bogush A, Stegemann J A, Wood I, et al. (2014). Element composition and mineralogical characterisation of air pollution control residue from UK energy-from-waste facilities. Waste Management, 36: 119–129. https://doi.org/10.1016/j.wasman.2014.11.017

Cai S X. (2025). The preparation of calcium carbonate from MSW incinerator fly ash via indirect carbonization and the harmless treatment of by-products . Qingdao: Qingdao University of Technology.

Cai W Y and Su C L. (2023). Experimental study on optimization of fly ash washing technology for domestic waste incineration. Electric Power Survey and Design, (09): 34–39+55. https://doi.org/10.13500/j.dlkcsj.issn1671-9913.2023.09.007.

Cao L L, Liu K, Zeng J R, et al. (2014). Elemental composition and microstructural characteristics of municipal solid waste incineration ash in Shanghai. Nuclear Techniques, 37(06): 8–16.

Cao L, Zuo Y, Liang S, et al. (2023). Geopolymerization of MSWI fly ash and coal fly ash for efficient solidification of heavy metals: Insights into stabilization mechanisms and long-term leaching behavior. Construction and Building Materials, 411: 134359. https://doi.org/10.1016/j.conbuildmat.2023.134359

Cao Y N, Luo J J, Sun S Q. (2021). Characteristics of MSWI fly ash with acid leaching treatment. Journal of Fuel Chemistry and Technology, 49(08): 1208–1218.

Carignan J, Libourel G, Cloquet C, et al. (2005). Lead Isotopic Composition of Fly Ash and Flue Gas Residues from Municipal Solid Waste Combustors in France: Implications for Atmospheric Lead Source Tracing. Environmental Science & Technology, 39(7): 2018–2024. https://doi.org/10.1021/es048693x

Chai X L, Wang D Y, Takahashi F, et al. (2012). Physicochemical characteristics of typical fly ashes of solid waste incineration plants in China. Journal of Tongji University (Natural Science), 2012, 40(12): 1857–1862.

Chang F and Wey M. (2006). Comparison of the characteristics of bottom and fly ashes generated from various incineration processes. Journal of Hazardous Materials, 138(3): 594–603. https://doi.org/10.1016/j.jhazmat.2006.05.099

Chang W, Jiang X G, Qiu Q L, et al. (2015). Performance of non-fired brick making from fly ash in a purely burning municipal solid waste circulating fluidized bed incinerator. Acta Scientiae Circumstantiae, 35(07): 2224–2232. https://doi.org/10.13671/j.hjkxxb.2014.0995.

Chang W. (2016). Study on the washing process and recycling of MSWI fly ash. Hangzhou: Zhejiang University.

Chen J M, Li W, Li Y L. (2025). Effect of entrained flow gasification fine slag on melting temperature and harmlessness of municipal solid waste incineration fly ash. Coal Conversion, 48(02):101–110.

Chen J. (2022). Study on the influence of municipal solid waste incineration fly ash on the preparation of ceramsite in conjunction with coal fly ash. Chongqing: Chongqing University of Science and Technology.

Chen K. (2025). The study of washing of water-soluble chloride salts in municipal solid waste fly ash. Sichuan Building Materials, 51(08): 54–56.

Chen L, Wang L, Cho D, et al. (2019). Sustainable stabilization/solidification of municipal solid waste incinerator fly ash by incorporation of green materials. Journal of Cleaner Production, 222: 335–343. https://doi.org/10.1016/j.jclepro.2019.03.057

Chen P, Zhang Q S, Chen Y. (2023). Study on influencing factors of melting and vitrification process of municipal solid waste incineration fly ash at high temperature. Guangdong Chemical Industry, 50(11): 136–140.

Chen P, Zheng H, Xu H, et al. (2019). Microbial induced solidification and stabilization of municipal solid waste incineration fly ash with high alkalinity and heavy metal toxicity. PLoS ONE, 14(10): e0223900. https://doi.org/10.1371/journal.pone.0223900

Chen Q, Wang Q F, Li Y, et al. (2019). Research on physicochemical characteristics and heavy metal speciation in fly ash from a MSW incineration plant in South China. Environmental Sanitation Engineering, 27(04): 13–18.

Chen Q. (2022). Zeolite fabrication from MSWI fly ash by modified hydrothermal methods and the applications. Hangzhou: Zhejiang University.

Chen T, Chen Y, Dai M, et al. (2021). Stabilization-solidification-utilization of MSWI fly ash coupling CO_2 mineralization using a high-gravity rotating packed bed. Waste Management, 121: 412–421. https://doi.org/10.1016/j.wasman.2020.12.031

Chen W X, Ren G J, Li N, et al. (2024). Effects of different curing conditions on compressive strength and microstructure of alkali-activated MSWI fly ash/bottom ash cementitious materials. Journal of Hebei Normal University of Science & Technology, 38(04): 66–72.

Chen W, Wang Y, Hu M, et al. (2022). Controlling reactions during heavy metal leaching from municipal solid waste incineration fly ash. Journal of the Serbian Chemical Society, 88(1): 83–95. https://doi.org/10.2298/jsc220505065c

Chen W. (2021). Numerical simulation of industrial sludge blending and detection analysis in a new incinerator. Wuhan: Huazhong University of Science and Technology.

Chen X, Bi Y, Zhang H, et al. (2016). Chlorides removal and control through water-washing process on MSWI fly ash. Procedia Environmental Sciences, 31: 560–566. https://doi.org/10.1016/j.proenv.2016.02.086

Chen X, Xu Z, Yao Z, et al. (2020). Preparation of non-sintered lightweight aggregates through co-mechanochemical treatment of oil-contaminated drill cuttings, circulation fluidized bed combustion fly ash, and quicklime. Environmental Science and Pollution Research, 27(17): 20904–20911. https://doi.org/10.1007/s11356-020-08522-9

Chen Y, Xu Y, Feng Y Y. (2014). Optimizing extraction process of heavy metals in fly ash using saponins by response surface methodology. CIESC Journal, 65(02): 701–710.

Chen Z L. (2019). Mechanism study of mechanochemistry on PCDD/Fs degradation and on heavy metals stabilization in MSWI fly ash. Hangzhou: Zhejiang University.

Cheng T. (2003). Combined glassification of EAF dust and incinerator fly ash. Chemosphere, 50(1): 47–51. https://doi.org/10.1016/s0045-6535(02)00396-x

Chi D H and Liu Z H. (2004). Experimental study on leaching of heavy metals in incineration fly ash with NaAc (pH=3) buffer solution. Yunnan Environmental Science, (04): 27–29.

Chimenos J, Fernández A, Cervantes A, et al. (2005). Optimizing the APC residue washing process to minimize the release of chloride and heavy metals. Waste Management, 25(7): 686–693. https://doi.org/10.1016/j.wasman.2004.12.014

Chuai X, Yang Q, Zhang T, et al. (2022). Speciation and leaching characteristics of heavy metals from municipal solid waste incineration fly ash. Fuel, 328: 125338. https://doi.org/10.1016/j.fuel.2022.125338

Colangelo F, Messina F, Cioffi R. (2015). Recycling of MSWI fly ash by means of cementitious double step cold bonding pelletization: Technological assessment for the production of lightweight artificial aggregates. Journal of Hazardous Materials, 299: 181–191. https://doi.org/10.1016/j.jhazmat.2015.06.018

Cristelo N, Segadães L, Coelho J, et al. (2020). Recycling municipal solid waste incineration slag and fly ash as precursors in low-range alkaline cements. Waste Management, 104: 60–73. https://doi.org/10.1016/j.wasman.2020.01.013

Cui J, Xie S, Jia G, et al. (2024). Utilizing microbial-induced carbonate precipitation technology and carbonation for recycling municipal solid waste incineration fly ash in the production of bricks. Construction and Building Materials, 420: 135458. https://doi.org/10.1016/j.conbuildmat.2024.135458

Cui Y C. (2024). Study on preparation of waste incineration fly ash solid brick and performances by microbial mineralization and calcium carbide slag. Taiyuan: Taiyuan University of Technology.

Cyr M, Idir R, Escadeillas G. (2012). Use of metakaolin to stabilize sewage sludge ash and municipal solid waste incineration fly ash in cement-based materials. Journal of Hazardous Materials, 243: 193–203. https://doi.org/10.1016/j.jhazmat.2012.10.019

De Boom A and Degrez M. (2012). Belgian MSWI fly ashes and APC residues: A characterisation study. Waste Management, 32(6): 1163–1170. https://doi.org/10.1016/j.wasman.2011.12.016

Del Valle-Zermeño R, Formosa J, Chimenos J, et al. (2012). Aggregate material formulated with MSWI bottom ash and APC fly ash for use as secondary building material. Waste Management, 33(3): 621–627. https://doi.org/10.1016/j.wasman.2012.09.015

Deng F and Qian G. (2008). MSWI fly ash based novel solidification/stabilization matrices for heavy metals. Journal of Wuhan University of Technology (Materials Science Edition), 23(06): 955–960.

Deng F, Gui Y, Liao Y S, et al. (2019). Study on the effects of municipal solid waste incineration fly ash on cement hydration process. China Concrete and Cement Products, (12): 94–97. https://doi.org/10.19761/j.1000-4637.2019.12.094.04.

Deng S J. (2024). EDTA and citric acid water washing for removal of heavy metals from waste incineration fly ash. Nanchang: East China Jiaotong University.

Deng X, Jian R, Chen S, et al. (2023). Killing two birds with one stone: Preparation of ceramsite high-strength lightweight aggregate via co-sintering of dredged sediment and municipal solid waste incinerated fly ash. Construction and Building Materials, 409: 134039. https://doi.org/10.1016/j.conbuildmat.2023.134039

Deng Y, Li S Y, Wang J Q, et al. (2021). Heavy metals removal from municipal solid waste incineration fly ashes by electric field enhanced washing with citric acid/ammonium citrate. Chinese Journal of Environmental Engineering, 15(04): 1451–1457.

Derie R. (1996). A new way to stabilize fly ash from municipal incinerators. Waste Management, 16(8): 711–716. https://doi.org/10.1016/s0956-053x(97)00013-5

Desai Y, Srivastava R R, Srivastava V K, et al. (2023). Hydrometallurgical recovery of critical metals from an incinerated fly ash of municipal solid waste from western India. Geosystem Engineering, 26(5): 208–217. https://doi.org/10.1080/12269328.2023.2201296

Diaz-Loya E I, Allouche E N, Eklund S, et al. (2012). Toxicity mitigation and solidification of municipal solid waste incinerator fly ash using alkaline activated coal ash. Waste Management, 32(8): 1521–1527. https://doi.org/10.1016/j.wasman.2012.03.030

Diliberto C, Meux E, Diliberto S, et al. (2018). A zero-waste process for the management of MSWI fly ashes: production of ordinary Portland cement. Environmental Technology, 41(9): 1199–1208. https://doi.org/10.1080/09593330.2018.1525434

Ding S M. (2007). Pollution properties of heavy metals in municipal solid waste incineration fly ash in Chongqing. Chongqing: Chongqing University.

Ding Z W. (2022). Study on thermal volatilization of heavy metals in waste incineration fly ash based on carbothermal reduction. Nanjing: Nanjing Normal University.

Dong G H, Zuo W, Zhao R B, et al. (2023). Migration and transformation of Pb and Zn during co-processing of municipal solid waste incineration fly ash by cement kiln. Chinese Journal of Environmental Engineering, 17(01): 250–258.

Duan Y, Liu X, Hong W, et al. (2023).Leaching behavior and comprehensive toxicity evaluation of heavy metals in MSWI fly ash from grate and fluidized bed incinerators using various leaching methods: A comparative study. Science of the Total Environment, 914: 169595. https://doi.org/10.1016/j.scitotenv.2023.169595

Ebert B A R, Steenari B, Geiker M R, et al. (2020). Screening of untreated municipal solid waste incineration fly ash for use in cement-based materials: chemical and physical properties. Discover Applied Sciences, 2: 802. https://doi.org/10.1007/s42452-020-2613-7

Ebert B A, Geiker M R, Kunther W, et al. (2021). Impact of electrodialytic remediation of MSWI fly ash on hydration and mechanical properties of blends with Portland cement. Construction and Building Materials, 309: 125193. https://doi.org/10.1016/j.conbuildmat.2021.125193

Eighmy T T, Eusden J D, Krzanowski J E, et al. (1995). Comprehensive approach toward understanding element speciation and leaching behavior in municipal solid waste incineration electrostatic precipitator ash. Environmental Science & Technology, 29(3): 629–646. https://doi.org/10.1021/es00003a010

Elomaa H, Seisko S, Lehtola J, et al. (2019). A study on selective leaching of heavy metals vs. iron from fly ash. Journal of Material Cycles and Waste Management, 21(4): 1004–1013. https://doi.org/10.1007/s10163-019-00858-w

European Conformity (EC). (2003). Council Decision 2003/33/EC of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC, Official Journal of the European Communities L: 27–49.

Fan C C, Wang B M, Wang X J. (2023). Study on physical and chemical characteristics and heavy metal leaching behavior of MSWI fly ash. China Environmental Science, 43(S1): 149–159.

Fan C, Wang B, Ai H, et al. (2021). A comparative study on characteristics and leaching toxicity of fluidized bed and grate furnace MSWI fly ash. Journal of Environmental Management, 305: 114345. https://doi.org/10.1016/j.jenvman.2021.114344

Fan C, Wang B, Ai H, et al. (2021). A comparative study on solidification/stabilization characteristics of coal fly ash-based geopolymer and Portland cement on heavy metals in MSWI fly ash. Journal of Cleaner Production, 319: 128790. https://doi.org/10.1016/j.jclepro.2021.128790

Fan J F. (2020). Effect on sintering process by adding fly ash from municipal solid waste incineration. China Metallurgy, 30(10): 84–86. https://doi.org/10.13228/j.boyuan.issn1006-9356.20200176.

Fan S, Xing H Z, Niu X C, et al. (2025). Research on factors influencing LIBS detection of heavy metals in MSWI fly ash. Clean Coal Technology: 1–13. https://link.cnki.net/urlid/11.3676.TD.20250507.1945.

Fedje K K and Andersson S. (2020). Zinc recovery from Waste-to-Energy fly ash – A pilot test study. Waste Management, 118: 90–98. https://doi.org/10.1016/j.wasman.2020.07.017

Fedje K K, Ekberg C, Skarnemark G, et al. (2009). Removal of hazardous metals from MSW fly ash—An evaluation of ash leaching methods. Journal of Hazardous Materials, 173(1–3): 310–317. https://doi.org/10.1016/j.jhazmat.2009.08.094

Feng D L, Zheng J S, Luo Z C, et al. Experimental study on dynamic mechanical responses of concentrated solution sludge solidified by alkali-activated GGBS and

MSWI fly ash. China Civil Engineering Journal: 1–16. https://doi.org/10.15951/j.tmgcxb.24090727.

Feng W L. (2022). High-value utilization of waste incineration fly ash to prepare zeolite-like hydrogenation catalyst. Lhasa: Tibet University.

Forestier L L and Libourel G. (1998). Characterization of flue gas residues from municipal solid waste combustors. Environmental Science & Technology, 32(15): 2250–2256. https://doi.org/10.1021/es980100t

Fu G S. (2023). Study on the preparation and long-term mechanical properties of municipal solid waste incineration fly ash-based filling material. Liaoning: Liaoning Technical University.

Funari V, Mäkinen J, Salminen J, et al. (2016). Metal removal from municipal solid waste incineration fly ash: A comparison between chemical leaching and bioleaching. Waste Management, 60: 397–406. https://doi.org/10.1016/j.wasman.2016.07.025

Gao J. (2021). Study on a low-energy-consumption melting solidification method of municipal solid waste incineration fly ash. Beijing: North China Electric Power University.

Gao L. (2022). Study on the extraction and application characteristics of valuable components of fly ash incineration of municipal solid waste. Ma'anshan: Anhui University of Technology.

Gao T. (2021). Study on the distribution law of carbon and dioxin and the method of flotation separation in municipal solid waste incineration fly ash. Xuzhou: China University of Mining and Technology.

Gao X, Wang W, Ye T, et al. (2007). Utilization of washed MSWI fly ash as partial cement substitute with the addition of dithiocarbamic chelate. Journal of Environmental Management, 88(2): 293–299. https://doi.org/10.1016/j.jenvman.2007.02.008

Gao Z H. (2021). Research on the influence of municipal solid waste incineration fly ash alkali metals on leaching toxicity and resource utilization. Chongqing: Chongqing University.

Garcia-Lodeiro I, Carcelen-Taboada V, Fernández-Jiménez A, et al. (2015). Manufacture of hybrid cements with fly ash and bottom ash from a municipal solid waste incinerator. Construction and Building Materials, 105: 218–226. https://doi.org/10.1016/j.conbuildmat.2015.12.079

Gastoł W, Shalomieiev V A, Tabunschyk G V, et al. (2025). Evaluation of the possibility of preparing geopolymer materials based on slags and fly ashes from the thermal treatment of municipal waste. Materialwissenschaft Und Werkstofftechnik, 56(5): 757–769. https://doi.org/10.1002/mawe.202400387

Geng C, Liu J, Wu S, et al. (2019). Novel method for comprehensive utilization of MSWI fly ash through co-reduction with red mud to prepare crude alloy and cleaned slag. Journal of Hazardous Materials, 384: 21315. https://doi.org/10.1016/j.jhazmat.2019.121315

Geysen D, Vandecasteele C, Jaspers M, et al. (2004). Comparison of immobilisation of air pollution control residues with cement and with silica. Journal of Hazardous Materials, 107(3): 131–143. https://doi.org/10.1016/j.jhazmat.2003.12.001

Ghouleh Z and Shao Y. (2018). Turning municipal solid waste incineration into a cleaner cement production. Journal of Cleaner Production, 195: 268–279. https://doi.org/10.1016/j.jclepro.2018.05.209

Ginés O, Chimenos J, Vizcarro A, et al. (2009). Combined use of MSWI bottom ash and fly ash as aggregate in concrete formulation: Environmental and mechanical considerations. Journal of Hazardous Materials, 169(1–3): 643–650. https://doi.org/10.1016/j.jhazmat.2009.03.141

Goh C C, Show K Y, Cheong H K. (2003). Municipal solid waste fly ash as a blended cement material. Journal of Materials in Civil Engineering 15: 513–523. https://doi.org/10.1061/(asce)0899-1561(2003)15:6(513).

Gong Y F. (2022). Study on the effect of co-incineration of general industrial solid waste on fly ash stabilization in municipal solid waste incineration plants. Cleaning World, 38(11): 53–56+83.

Gu Q, Wang T, Wu W, et al. (2021). Influence of pretreatments on accelerated dry carbonation of MSWI fly ash under medium temperatures. Chemical Engineering Journal, 414: 128756. https://doi.org/10.1016/j.cej.2021.128756

Gu Y, Liu W, Cao Z, et al. (2023). Effect of particle size of NanoSiO_2 on cement-based stabilization/solidification of municipal solid waste incineration fly ash. Construction and Building Materials, 411: 134311. https://doi.org/10.1016/j.conbuildmat.2023.134311

Guan Y Y, Wang X N, Zhao C D, et al. (2023). Stabilization effect and environmental risk assessment of heavy metals in MSWI fly ash by different organic chelating agents. Environmental Engineering, 41(12): 304–311. https://doi.org/10.13205/j.hjgc.202312038.

Guo F L. (2022). Research on disposal of heavy metals in fly ash from domestic waste incineration. Ma'anshan: Anhui University of Technology.

Guo X and Zhang T. (2019). Utilization of municipal solid waste incineration fly ash to produce autoclaved and modified wall blocks. Journal of Cleaner Production, 252: 119759. https://doi.org/10.1016/j.jclepro.2019.119759

Guo X, Hu W, Shi H. (2014). Microstructure and self-solidification/stabilization (S/S) of heavy metals of nano-modified CFA–MSWIFA composite geopolymers. Construction and Building Materials, 56: 81–86. https://doi.org/10.1016/j.conbuildmat.2014.01.062

Guo X, Shi H, Hu W, et al. (2013). Durability and microstructure of CSA cement-based materials from MSWI fly ash. Cement and Concrete Composites, 46: 26–31. https://doi.org/10.1016/j.cemconcomp.2013.10.015

Guo Y W, Wang W, Qiao W, et al. (2006). Pollution characteristics of heavy metals in hazardous waste incineration fly ash. Journal of University of Science and Technology Beijing, (01): 17–21. https://doi.org/10.13374/j.issn1001-053x.2006.01.004.

Guo Z and Liu Z M. (2020). Thermodynamic calculation and energy cost of plasma melting system for MSW incineration fly ash with suspension preheating. Thermal Power Generation, 49(04): 12–18. https://doi.org/10.19666/j.rlfd.201912260.

Haberl J and Schuster M. (2019). Solubility of elements in waste incineration fly ash and bottom ash under various leaching conditions studied by a sequential extraction procedure. Waste Management, 87: 268–278. https://doi.org/10.1016/j.wasman.2019.02.001

Han S, Ju T, Meng Y, et al. (2021). Evaluation of various microwave-assisted acid digestion procedures for the determination of major and heavy metal elements in municipal solid waste incineration fly ash. Journal of Cleaner Production, 321: 128922. https://doi.org/10.1016/j.jclepro.2021.128922

Han X, Zhang P, Zheng Y, et al. (2023). Utilization of municipal solid waste incineration fly ash with coal fly ash/metakaolin for geopolymer composites preparation. Construction and Building Materials, 403: 133060. https://doi.org/10.1016/j.conbuildmat.2023.133059

Hao Q, Jiang C, Tang Q, et al. (2010). characteristic and leaching behavior of heavy metals from municipal solid wastes incineration (MSWI) fly ash in Chongqing, China. Chengdu: 2010 4th International Conference on Bioinformatics and Biomedical Engineering, 2010, pp. 1–3. http://doi.org/10.1109/ICBBE.2010.5516733.

Hartmann S, Koval L, Škrobánková H, et al. (2015). Possibilities of municipal solid waste incinerator fly ash utilisation. Waste Management & Research, 33(8): 740–747. https://doi.org/10.1177/0734242x15587545

Hashem M. (2021). Using eco-cement made from municipal solid waste incineration residues as a mineral additive for concrete[D].

He H. (2022). Study on emission characteristics of dioxins from iron ore sintering co-treating MSW incineration fly ash. Hangzhou: Zhejiang University.

He W Z. (2024). Study on the evolution of heavy metals and chlorides in ceramsite prepared from secondary aluminum dross. Qingdao: Qingdao University of Technology.

He X H, Hou H B, Zhang D J. (2006). Study on cement solidification of municipal solid waste incineration fly ash. Environmental Pollution and Control, (06): 425–428.

He Y H. (2022). Study on safe disposal of fly ash from municipal solid waste incineration in Lhasa. Lhasa: Tibet University.

He Z X, Luo L T, Li R T. (2025). Study on the performance of geopolymer mortar based on municipal solid waste incineration fly ash, waste glass powder, and metakaolin. Chongqing Architecture, 24(02): 58–63.

Heuss-Aßbichler S, Magel G, Fehr K. (2010). Abiotic hydrogen production in fresh and altered MSWI-residues: Texture and microstructure investigation. Waste Management, 30(10): 1871–1880. https://doi.org/10.1016/j.wasman.2010.02.015

Hjelmar, O. (1996). Disposal strategies for municipal solid waste incineration residues. Journal of Hazardous Materials, 47(1–3): 345–368. https://doi.org/10.1016/0304-3894(95)00111-5

Hoy M, Tonueng C, Horpibulsuk S, et al. (2024). Enhancing concrete pavement performance using refuse derived fuel fly ash as a sustainable cementitious material. International Journal of Pavement Engineering, 25(1): 2431601. https://doi.org/10.1080/10298436.2024.2431601

Hsieh Y, Chen W, Zhu J, et al. (2018). Characterization of polychlorinated dibenzo-P-dioxins and dibenzofurans of the flue gases, fly ash and bottom ash in a municipal solid waste incinerator. Aerosol and Air Quality Research, 18(2): 421–432. https://doi.org/10.4209/aaqr.2017.12.0564

Hu C C, Wang L A, Zhan X Y, et al. (2019). Preparation of ceramsite with MSWI fly ash and electrolytic manganese residues. Chinese Journal of Environmental Engineering, 13(01): 177–185.

Hu H Y, Liu H, Zhang Q, et al. (2016). Sintering characteristics of CaO-rich municipal solid waste incineration fly ash through the addition of Si/Al-rich ash residues. Journal of Material Cycles and Waste Management, 18: 340–347. https://doi.org/10.1007/s10163-014-0341-z

Hu M, Xu P C, Wang Y G, et al. (2022). Study on effects of additives on the process and products of plasma vitrification of municipal solid waste incineration fly ash. Industrial Heating, 51(10): 9–13.

Hu Y, Zhang P, Chen D, et al. (2011). Hydrothermal treatment of municipal solid waste incineration fly ash for dioxin decomposition. Journal of Hazardous Materials, 207-208: 79–85. https://doi.org/10.1016/j.jhazmat.2011.05.068

Hu Y. (2021). Research on solidification/stabilization of cement-based materials and mechanism of heavy metals in municipal solid waste incineration fly ash. Shanghai: East China University of Science and Technology.

Huang F. (2016). Research of alkali-activated material dual solidification heavy metals in MSWI fly ash. Jiaozuo: Henan Polytechnic University.

Huang J L. (2023). Study on promotion mechanism of chlorination volatilization of heavy metals in municipal solid waste incineration fly ash during sintering process. Guangzhou: South China University of Technology.

Huang J. (2017). Study on volatilization characteristics of heavy metals in co-processing of municipal solid waste incineration fly ash in cement kilns. Cement, (06): 12–15.

Huang K L, Gao J C, Xu G Q. (2022). Research on the technology of preparing ceramsite from waste incineration fly ash mixed with sludge and industrial waste residues. Shandong Chemical Industry, 51(18): 10–12+15.

Huang L and Xu Z H. (2021). Discussion on environmental management of crystalline salt from cement kiln co-disposal of fly ash pretreatment products. Cement, (03): 19–22.

Huang T, Zhang S, Liu L. (2018). Immobilization of trace heavy metals in the electrokinetics-processed municipal solid waste incineration fly ashes and its characterizations and mechanisms. Journal of Environmental Management, 232: 207–218. https://doi.org/10.1016/j.jenvman.2018.11.051

Huang Y. (2022). Study on resource utilization of municipal solid waste incineration fly ash. Wuhan: Huazhong University of Science and Technology.

Huber F, Herzel H, Adam C, et al. (2017). Combined disc pelletisation and thermal treatment of MSWI fly ash. Waste Management, 73: 381–391. https://doi.org/10.1016/j.wasman.2017.12.020

Huber F, Laner D, Fellner J. (2017). Comparative life cycle assessment of MSWI fly ash treatment and disposal. Waste Management, 73: 392–403. https://doi.org/10.1016/j.wasman.2017.06.004

Hyat H. (2025). Exploration of the electrical properties of municipal solid waste incinerated fly ash and bottom ash with minimal pretreatment.

IAWG (International Ash Working Group: Chandler, A J, Eighmy T T, Hartlén O, et al). (1997). Municipal solid waste incinerator residues. Studies in Environmental Science, vol. 67, Elsevier Science, Amsterdam.

Ibrahim N M, Amat R C, Rahim M A, et al. (2021). Reclamation and reutilization of incinerator ash in artificial lightweight aggregate. Archives of Metallurgy and Materials, 67: 269–275. https://doi.org/10.24425/amm.2022.137501

Ibrahim N M, Amat R C, Rahim N L, et al. (2022). A properties of municipal solid waste incineration fly ash (IFA) and cement used in the manufacturing of new inventive blended cement. International Journal of Integrated Engineering, 14(9): 215–221. https://doi.org/10.30880/ijie.2022.14.09.027

Irshidat M R, Al-Nuaimi N, Rabie M. (2021). Potential utilization of municipal solid waste incineration ashes as sand replacement for developing sustainable cementitious binder. Construction and Building Materials, 312: 125488. https://doi.org/10.1016/j.conbuildmat.2021.125488

Irshidat M R, Al-Nuaimi N, Rabie M. (2022). Sustainable alkali-activated binders with municipal solid waste incineration ashes as sand or fly ash replacement. Journal of Material Cycles and Waste Management, 24(3): 992–1008. https://doi.org/10.1007/s10163-022-01374-0

Izumikawa C. (1996). Metal recovery from fly ash generated from vitrification process for MSW ash. Waste Management, 16(5–6): 501–507. https://doi.org/10.1016/s0956-053x(96)00092-x

Jahromy S S, Jordan C, Azam M, et al. (2019). Fly ash from municipal solid waste incineration as a potential thermochemical energy storage material. Energy & Fuels, 33(7): 5810–5819. https://doi.org/10.1021/acs.energyfuels.8b04106

Jang K, Choi W Y, Lee D, et al. (2021). Purification of landfill gas by extracted calcium ions from municipal solid waste incineration fly ash. Science of the Total Environment, 807: 150729. https://doi.org/10.1016/j.scitotenv.2021.150729

Jara-Echeverría D, Sánchez-Redondo I, Rivas-Seijas J, et al. (2025). Two-stage separation-immobilization method for municipal solid waste incineration fly ash treatment. Process Safety and Environmental Protection, 219: 272–282. https://doi.org/10.1016/j.cherd.2025.06.009

Ji Y X. (2023). Experimental study on the preparation of lime sulphur from MSW fly ash. Modern Chemical Research, (11): 96–98.

Jiang J, Wang J, Xu X, et al. (2004). Heavy metal stabilization in municipal solid waste incineration fly ash using heavy metal chelating agents. Journal of Hazardous Materials, 113(1–3): 141–146. https://doi.org/10.1016/j.jhazmat.2004.05.030

Jiang J, Xu X, Wang J, et al. (2007). Investigation of basic properties of fly ash from urban waste incinerators in China. Journal of Environmental Sciences, 19(4): 458–463. https://doi.org/10.1016/s1001-0742(07)60076-x

Jiang Y H, Xi B D, Li M X, et al. (2009). Leaching characteristics of fly ash from municipal solid waste incineration. Research of Environmental Sciences, 22(12): 1478–1481. https://doi.org/10.13198/j.res.2009.12.128.jiangyh.019.

Jiang Y H, Xi B D, Li X J, et al. (2006). Influence of additive on characteristic of slag during the process of melting fly ash from municipal solid waste incinerator. Environmental Sciences, (11): 2288–2292. https://doi.org/10.13227/j.hjkx.2006.11.027.

Jiang Y H, Xi B D, Li X J, et al. (2007). Effect of different extractants on leaching characteristics of the fly ash from municipal solid waste incinerator. Environmental Science, (10): 2400–2403. https://doi.org/10.13227/j.hjkx.2007.10.036.

Jiao F, Zhang L, Dong Z, et al. (2016). Study on the species of heavy metals in MSW incineration fly ash and their leaching behavior. Fuel Processing Technology, 152: 108–115. https://doi.org/10.1016/j.fuproc.2016.06.013

Jiao G, Wei Y, Liao Q, et al. (2024). A systematic comparison of salt removal efficiency in washing treatment by using fly ashes from 13 MSWI plants in China. Journal of Environmental Management, 358: 120831. https://doi.org/10.1016/j.jenvman.2024.120831

Jin L Z. (2023). Research on mechanochemical modification and utilization technology of municipal solid waste incineration fly ash as building materials. Hangzhou: Zhejiang University.

Jin M T, Sun X, Dong H L, et al. (2012). Research on anti-corrosion of thiobacillus for the geopolymer solidification MSWI fly ash. Environmental Sciences,33(09): 3272–3278. https://doi.org/10.13227/j.hjkx.2012.09.022.

Jin M, Zheng Z, Sun Y, et al. (2016). Resistance of metakaolin-MSWI fly ash based geopolymer to acid and alkaline environments. Journal of Non-Crystalline Solids, 450: 116–122. https://doi.org/10.1016/j.jnoncrysol.2016.07.036

Jin Y, Ma X, Jiang X, et al. (2012). Effects of hydrothermal treatment on the major heavy metals in fly ash from municipal solid waste incineration. Energy & Fuels, 27(1): 394–400. https://doi.org/10.1021/ef3015525

Joumblat R A, Masri Z A B A, Absi J, et al. (2022). Investigation of using municipal solid waste incineration fly ash as alternative aggregates replacement in hot mix asphalt. Road Materials and Pavement Design, 24(5): 1290–1309. https://doi.org/10.1080/14680629.2022.2071756

Joumblat R, Elkordi A, Khatib J, et al. (2022). Characterisation of asphalt concrete mixes with municipal solid waste incineration fly ash used as fine aggregates substitution. International Journal of Pavement Engineering, 24(2): 2099855. https://doi.org/10.1080/10298436.2022.2099855

Joumblat R, Kassem H A, Masri Z A B A, et al. (2023). Performance evaluation of hot-mix asphalt with municipal solid waste incineration fly ash using the stress sweep rutting test. Innovative Infrastructure Solutions, 8(10): 261. https://doi.org/10.1007/s41062-023-01230-6

Jung C, Matsuto T, Tanaka N, et al. (2003). Metal distribution in incineration residues of municipal solid waste (MSW) in Japan. Waste Management, 24(4): 381–391. https://doi.org/10.1016/s0956-053x(03)00137-4

Juntarasakul O, Roongcharoen P, Tabelin C B, et al. (2024). Municipal solid waste incineration (MSWI) fly ash as a potential adsorbent for phosphate removal. Sustainability, 16(20): 8869. https://doi.org/10.3390/su16208869

Kalmykova Y and Fedje K K. (2013). Phosphorus recovery from municipal solid waste incineration fly ash. Waste Management, 33(6): 1403–1410. https://doi.org/10.1016/j.wasman.2013.01.040

Kamon M, Katsumi T, Sano Y. (2000). MSW fly ash stabilized with coal ash for geotechnical application. Journal of Hazardous Materials, 76(2-3): 265–283. https://doi.org/10.1016/s0304-3894(00)00203-x

Kan L, Shi R, Zhao Y, et al. (2020). Feasibility study on using incineration fly ash from municipal solid waste to develop high ductile alkali-activated composites. Journal of Cleaner Production, 254: 120168. https://doi.org/10.1016/j.jclepro.2020.120168

Kang D, Yoo Y, Park J. (2020). Stabilization of heavy metals in municipal solid waste incineration fly ash via CO_2 uptake procedure by using various weak acids. Journal of Industrial and Engineering Chemistry, 94: 472–481. https://doi.org/10.1016/j.jiec.2020.11.019

Kang J, Choi M K, Park K, et al. (2024). Applicability assessment of a plasma melting technology for a fly ash recycling system in the Republic of Korea. Environmental Technology, 46(4): 601–612. https://doi.org/10.1080/09593330.2024.2364307

Kang Z J, Liu Z Y, Xu X X, et al. (2018). Research on preparation of grass planting tiles with MSWI fly ash. Environmental Pollution and Control, 40(09): 1019–1022+1062.

Katsuura H, Inoue T, Hiraoka M, et al. (1996). Full-scale plant study on fly ash treatment by the acid extraction process. Waste Management, 16 (5/6): 491–499. https://doi.org/10.1016/S0956-053X(96)00091-8

Keppert M, Pavlík Z, Tydlitát V, et al. (2012). Properties of municipal solid waste incineration ashes with respect to their separation temperature. Waste Management & Research, 30(10): 1041–1048. https://doi.org/10.1177/0734242x12448511

Kępys W. (2024). Pierwiastki śladowe w pozostałościach z termicznego przekształcania odpadów komunalnych, osadów ściekowych i odpadów niebezpiecznych. Gospodarka Surowcami Mineralnymi - Mineral Resources Management: 29–46. https://doi.org/10.24425/gsm.2024.150824

Kim H, Purev O, Cho K, et al. (2022). Removal of inorganic salts in municipal solid waste incineration fly ash using a washing ejector and its application for CO_2 capture. International Journal of Environmental Research and Public Health, 19(4): 2306. https://doi.org/10.3390/ijerph19042306

Kim J and Kim H. (2003). Glass-ceramic produced from a municipal waste incinerator fly ash with high Cl content. Journal of the European Ceramic Society, 24(8): 2373–2382. https://doi.org/10.1016/j.jeurceramsoc.2003.08.001

Kim S, Tanaka N, Matsuto T, et al. (2005). Leaching behaviour of elements and evaluation of pre-treatment methods for municipal solid waste incinerator residues in column leaching tests. Waste Management & Research, 23(3): 220–229. https://doi.org/10.1177/0734242x05055322

Kirkelund G M and Jensen P E. (2018). Electrodialytic treatment of Greenlandic municipal solid waste incineration fly ash. Waste Management, 80: 241–251. https://doi.org/10.1016/j.wasman.2018.09.019

Kitamura H, Ueshima M, Back S, et al. (2021). Impact of diatomite addition on lead immobilization in air pollution control residues from a municipal solid waste incinerator. Environmental Science and Pollution Research, 29(15): 21232–21243. https://doi.org/10.1007/s11356-021-17349-x

Koppelman L E Tanenbaum E G. (1993). The potential for beneficial use of waste-to-energy facility ash: volume 4, engineering properties. USA: New York State Energy Research and Development Authority.

Kuang W, Zhong S, Chen M L, et al. (2012). Pollution characteristics of heavy metals in MSWI fly ash. Environmental Science & Technology, 2012, 35(08): 143–148.

Kuasakul T, Chernpimy C, Tabyang W, et al. (2025). Durability against sulfate attack of cement and municipal solid waste incineration fly ash stabilized marginal lateritic soil under wet and dry cycles. Transportation Infrastructure Geotechnology, 12: 85. https://doi.org/10.1007/s40515-025-00548-1

Kuboňová L, Langová Š, Nowak B, et al. (2013). Thermal and hydrometallurgical recovery methods of heavy metals from municipal solid waste fly ash. Waste Management, 33(11): 2322–2327. https://doi.org/10.1016/j.wasman.2013.05.022

Kumar V, Baral A, Roesler J R, et al. (2024). Reducing PB and CL mobility in Waste-to-Energy fly ashes via chlorellestadite formation. ACS ES&T Engineering, 4(5): 1193–1205. https://doi.org/10.1021/acsestengg.3c00597

Lam C H K, Barford J P, McKay G. (2011). Utilization of municipal solid waste incineration ash in Portland cement clinker. Clean Technology and Environmental Policy, 13: 607–615. https://doi.org/10.1007/s10098-011-0367-z

Lancellotti I, Kamseu E, Michelazzi M, et al. (2009). Chemical stability of geopolymers containing municipal solid waste incinerator fly ash. Waste Management, 30(4): 673–679. https://doi.org/10.1016/j.wasman.2009.09.032

Lane D J, Sippula O, Koponen H, et al. (2019). Volatilisation of major, minor, and trace elements during thermal processing of fly ashes from waste- and wood-fired power plants in oxidising and reducing gas atmospheres. Waste Management, 102: 698–709. https://doi.org/10.1016/j.wasman.2019.11.025

Lee J, Nam M, Park D, et al. (2025). Recycling municipal solid waste incineration fly ash as a functional foaming agent in slag-based geopolymer. Construction and Building Materials, 492: 142839. https://doi.org/10.1016/j.conbuildmat.2025.142839

Lee T, Chang C, Rao M, et al. (2010). Modified MSWI ash-mix slag for use in cement concrete. Construction and Building Materials, 25(4): 1513–1520. https://doi.org/10.1016/j.conbuildmat.2010.08.007

Lei C Q. (2021). The leaching behavior of rare earth elements in fly ash of waste incineration and the effect of tail gas emission on rare earth elements and phosphorus in surrounding soil. Guilin: Guangxi Normal University.

Lei M. (2022). Study on the cement kiln co-processing of waste incineration fly ash. Tianjin: Hebei University of Technology.

Li B, Gao L, Ru C Y, et al. (2023). Simulation of MSWI fly ash washing process and calculation of washing loss rate. Environmental Sanitation Engineering, 31(06): 80–84.

Li C L. (2021). Experimental study on resource utilization of municipal solid waste incineration fly ash based on geopolymerization. Industrial Safety and Environmental Protection, 47(02): 97–100.

Li C W. (2023). Immobilization of heavy metals in municipal solid waste incineration fly ash using glass-ceramic. Chongqing: Chongqing University.

Li H, Yang J, Wei X Z, et al. (2022). Study on the effect of magnesium oxychloride cement on the solidification of fly ash from domestic waste incineration and its influencing factors. Energy Environmental Protection, 36(06): 38–46.

Li J R, Liu R Q, Tang B M, et al. (2022). Improvement effect of polyester fiber on TSR of MSWI fly ash/asphalt mixture. Journal of Highway and Transportation Research and Development, 39(01): 17–23+39.

Li J S, Xue Q, Wang P, et al. (2016). Leaching characteristics of chlorine from municipal solid waste incineration fly ash by up-flow percolation column tests. Environmental Earth Sciences, 75: 31. https://doi.org/10.1007/s12665-015-4772-1

Li J X, Yan J H, Chi Y, et al. (2004). Analysis on the contents and leaching characteristics of heavy metals in MSWI fly ash. Acta Scientiae Circumstantiae, (01): 168–170. https://doi.org/10.13671/j.hjkxxb.2004.01.033.

Li J, Teng G, Zhang S, et al. (2024). The leaching behavior of hazardous element under different leaching procedure utilizing slag-fly ash-based agent: Chromium, antimony, and lead. Science of the Total Environment, 919: 170782. https://doi.org/10.1016/j.scitotenv.2024.170782

Li J, Zhou B, Yi X J, et al. (2016). Treatment efficiencies of heavy metals in municipal solid waste incineration fly ash with stabilization agents. Chinese Journal of Environmental Engineering, 10(06): 3242–3248.

Li K. (2025). Research on the preparation and properties of geopolymer from municipal solid waste incineration fly ash. Jinan: Qilu University of Technology.

Li M, He X L, Feng Y P, et al. (2022). Recovery of calcium carbonate after extracting calcium salt from fly ash of municipal solid waste incineration. Environmental Engineering, 40(11): 182–188+198. https://doi.org/10.13205/j.hjgc.202211026.

Li M, Hu S, Xiang J, et al. (2003). Characterization of fly ashes from two Chinese municipal solid waste incinerators. Energy & Fuels, 17(6): 1487–1491. https://doi.org/10.1021/ef030092o

Li M. (2022). Research on recovery technology of calcium and copper from municipal solid waste incineration fly ash. Chengdu: Southwest Jiaotong University.

Li M. (2025). The occurrence characteristics and leaching behavior of pollutants and recoverable elements in MSWI fly ash. Qingdao: Qingdao University of Technology.

Li P and Shimaoka T. (2024). Recovery of Zn and Cu from municipal solid waste incineration fly ash by integrating ammonium leaching and ammonia removal. Waste Management, 178: 115–125. https://doi.org/10.1016/j.wasman.2024.02.036

Li P F, Zhao W Q, Yang F L, et al. (2023). Melting process characteristics and energy saving optimization of waste incineration fly ash mixed with coke powder. Clean Coal Technology, 29(S2): 483–493. https://doi.org/10.13226/j.issn.1006-6772.22051102.

Li P F. (2021). Study on melting and solidification of heavy metals from fly ash of municipal solid waste incineration. Taiyuan: Shanxi University.

Li Q, Chen W L, Wang K H, et al. (2025). Optimization of process parameters for chlorine removal from fly ash of municipal solid waste incineration. Non-Metallic Mines, 48(02): 41–44.

Li R D, Li Y L, Wang L, et al. (2007). Migration characteristics of heavy metals during pilot melting process of incineration fly ash. Environmental Sciences, (12): 2873–2876. https://doi.org/10.13227/j.hjkx.2007.12.020.

Li R D, Nie Y F, Wang L, et al. (2004). Trace pollutants in MSW incinerator fly ash: Heavy metals and dioxins. Combustion Science and Technology, (06):479–483.

Li R, Li Y, Yang T, et al. (2015). A new integrated evaluation method of heavy metals pollution control during melting and sintering of MSWI fly ash. Journal of Hazardous Materials, 289: 197–203. https://doi.org/10.1016/j.jhazmat.2015.02.055

Li R, Zhang B, Wang Y, et al. (2018). Leaching potential of stabilized fly ash from the incineration of municipal solid waste with a new polymer. Journal of Environmental Management, 232: 286–294. https://doi.org/10.1016/j.jenvman.2018.11.036

Li S C and Zhu C J. (2023). Study on vitrification technology of fly ash from domestic waste incineration by electric melting. Glass Enamel & Ophthalmic Optics, 51(02): 7–12+6.

Li S C and Zhu C J. (2024). Research on the production technology of rock wool by electric melting method of domestic waste incineration fly ash. Glass Enamel & Ophthalmic Optics, 52(10):13–20.

Li T and Wang B. (2023). Effect and mechanism of nano-alumina on early hydration properties and heavy metals solidification/stabilization of alkali-activated MSWI fly ash solidified body. Journal of Hazardous Materials, 452: 131327. https://doi.org/10.1016/j.jhazmat.2023.131327

Li T R. (2024). Solidification properties and mechanism of nanomaterials for heavy metals in alkali-activated MSWI fly ash solidified body. Dalian: Dalian University of Technology.

Li W H, Ma Z Y, Yang E Q, et al. (2019). Characteristics of electrostatic precipitator ash and bag filter ash froma circulating fluidized bed municipal solid waste incinerator. Proceedings of the CSEE, 39(05): 1397–1405. https://doi.org/10.13334/j.0258-8013.pcsee.181110.

Li W J. (2022). Development and heavy metal ions solidification mechanism study of UHPC including municipal solid waste incineration fly ash. Qingdao: Qingdao University of Technology.

Li W, Gu K, Yu Q, et al. (2020). Leaching behavior and environmental risk assessment of toxic metals in municipal solid waste incineration fly ash exposed to mature landfill leachate environment. Waste Management, 120: 68–75. https://doi.org/10.1016/j.wasman.2020.11.020

Li W, Sun Y, Huang Y, et al. (2019). Evaluation of chemical speciation and environmental risk levels of heavy metals during varied acid corrosion conditions for raw and solidified/stabilized MSWI fly ash. Waste Management, 87: 407–416. https://doi.org/10.1016/j.wasman.2019.02.033

Li X, Bertos M F, Hills C D, et al. (2006). Accelerated carbonation of municipal solid waste incineration fly ashes. Waste Management, 27(9): 1200–1206. https://doi.org/10.1016/j.wasman.2006.06.012

Li X, Chen Q, Zhou Y, et al. (2014). Stabilization of heavy metals in MSWI fly ash using silica fume. Waste Management, 34(12): 2494–2504. https://doi.org/10.1016/j.wasman.2014.08.027

Li X. (2024). Study on co-sintering for aluminum extraction from secondary aluminum dross and preparation of glass-ceramics from leaching residue. Guangzhou: South China University of Technology.

Li Y H. Research on the removal effect and mechanism of MSW incineration fly ash on high phosphorus wastewater. Hangzhou: Zhejiang University, 2021.

Li Y L, Chen W F, Wang Y G, et al. (2023). Physicochemical properties and risk assessment of heavy metals in the incinerated municipal solid waste fly ash. Energy Research and Information, 39(01): 1–8.

Li Y, Chen W, Hu M. (2022). Characterization of solid waste incineration fly ashes and their heavy metal leaching behavior. Pollution, 9(1): 392-400. http//doi.org/10.22059/POLL.2022.348489.1624

Li Y, Min X, Ke Y, et al. (2018). Preparation of red mud-based geopolymer materials from MSWI fly ash and red mud by mechanical activation. Waste Management, 83: 202–208. https://doi.org/10.1016/j.wasman.2018.11.019

Li Z C, Yang Y B, Ma Z Z, et al. (2022). Preparation of entirely waste-based glass-ceramics from municipal solid waste incineration fly ash. Chinese Journal of Environmental Engineering, 16(06): 1925–1932.

Li Z C. (2022). Preparation of glass-ceramics from waste incineration fly ash and mechanism of heavy metal solidification. Tianjin: Hebei University of Technology.

Liang D, Tao L, Wang F, et al. (2023). Synthesis of geopolymers using municipal solid waste incineration fly ash and construction and demolition waste: Mechanical and thermal activation. Journal of Environmental Chemical Engineering, 11(6): 111249. https://doi.org/10.1016/j.jece.2023.111249

Liang M, Li X B, Liu H W, et al. (2014). Characteristics and stabilization of fly ash from domestic waste incineration. Environmental Sanitation Engineering, 22(03):1–3.

Liang S H, Wang J, Wang Y X, et al. (2024). Experimental study on solidification/stabilization of leachate sludge by sulfoaluminate cement and MSWI fly ash. Journal of Building Materials, 1–11.

Liao S K, Wu Z E, Shen Y H. (2023). Application of cold sintering process for stabilizing heavy metals in municipal solid waste incineration fly ash. Sustainability, 15(19): 14110. https://doi.org/10.3390/su151914110

Lima A T, Kirkelund G M, Ntuli F, et al. (2022). Screening dilute sources of rare earth elements for their circular recovery. Journal of Geochemical Exploration, 238: 107000. https://doi.org/10.1016/j.gexplo.2022.107000

Lima A, Ottosen L, Pedersen A, et al. (2007). Characterization of fly ash from bio and municipal waste. Biomass and Bioenergy, 32(3): 277–282. https://doi.org/10.1016/j.biombioe.2007.09.004

Lin J X. (2022). Research of a new process for the treatment of waste incineration fly ash by pickling – Comprehensive utilization of flue gas and fly ash. Xiamen: Xiamen University.

Lin K and Chang C. (2006). Leaching characteristics of slag from the melting treatment of municipal solid waste incinerator ash. Journal of Hazardous Materials, 135(1-3): 296–302. https://doi.org/10.1016/j.jhazmat.2005.11.064

Liu B R X. (2024). Application of biodegradation in municipal solid waste incineration fly ash composite cementitious materials. Kunming: Yunnan University.

Liu F, Liu J, Yu Q, et al. (2005). Leaching characteristics of heavy metals in municipal solid waste incinerator fly ash. Journal of Environmental Science and Health Part A, 40(10): 1975–1985. https://doi.org/10.1080/10934520500184707

Liu G W. (2018). Research on chemical stabilization of heavy metals from municipal solid waste incineration. Guangzhou: University of Chinese Academy of Sciences (Guangzhou Institute of Geochemistry).

Liu H, Huang S B, Wang X L, et al. (2020). Study on preparation of ceramsite from MSWI fly ash and waste glass. Biological Chemical Engineering, 6(06): 51–53.

Liu H, Liu Y, Zhang S, et al. (2010). Experimental study on the solidification of contaminated bottom sludge utilizing municipal solid waste incineration fly ash. Journal of Tianjin Institute of Urban Construcion,16(01): 29–32.

Liu H. (2023). Research and application on stabilization of MSWI fly ash by mechanochemical method and its utilization in preparation of biofilm fillers. Nanchang: Nanchang University.

Liu J, Hu L, Tang L, et al. (2020). Utilisation of municipal solid waste incinerator (MSWI) fly ash with metakaolin for preparation of alkali-activated cementitious material. Journal of Hazardous Materials, 402: 123451. https://doi.org/10.1016/j.jhazmat.2020.123451

Liu L, Luo Y D, Qing M X, et al. (2023). Solidification characteristics of heavy metals in fly ash from domestic waste incineration. Journal of Central South University (Science and Technology), 54(10): 3852–3864.

Liu S C, Jiang C S, Li Q L, et al. (2013). Analysis of heavy metal content and leaching toxicity of municipal solid waste incineration fly ash in Chongqing. Journal of Southwest China Normal University (Natural Science Edition), 38(01): 101–107. https://doi.org/10.13718/j.cnki.xsxb.2013.01.013.

Liu W. (2021). Research on resource utilization of municipal solid waste incineration fly ash. Changzhou: Changzhou University.

Liu X Y, Cao H L, Weng L Q, et al. (2023). Delicate characterization of MSWI fly ash and study on stabilization mechanism of heavy metals with sintering solidification. China Environmental Science, 43(S1):160–169

Liu X Y. (2023). Preparation and properties of recycled ceramsite from municipal solid waste incineration fly ash. Harbin: Harbin Institute of Technology.

Liu X, Zhao X, Yin H, et al. (2018). Intermediate-calcium based cementitious materials prepared by MSWI fly ash and other solid wastes: hydration characteristics and heavy metals solidification behavior. Journal of Hazardous Materials, 349: 262–271. https://doi.org/10.1016/j.jhazmat.2017.12.072

Liu Y, Fang H, Min L R, et al. (2024). Study on mechanical properties of filling body prepared by co-disposal of municipal solid waste incineration fly ash and bottom ash. Mining R & D, 44(06): 95–103.

Liu Z C. (2023). Research on preparation and property of high ductility municipal solid waste incineration fly ash-cementitious rapid repair materials. Taiyuan: Taiyuan University of Technology.

Liu Z J, Chen L Z, Zhang J L, et al. (2020). Metallurgical treatment for municipal solid waste incineration fly ash. Journal of Iron and Steel Research, 32(07): 601–609. https://doi.org/10.13228/j.boyuan.issn1001-0963.20200062.

Loginova E, Proskurnin M, Brouwers H. (2019). Municipal solid waste incineration (MSWI) fly ash composition analysis: A case study of combined chelatant-based washing treatment efficiency. Journal of Environmental Management, 235: 480–488. https://doi.org/10.1016/j.jenvman.2019.01.096

Long J S and Yao T. (2022). Investigation on physicochemical properties and PCDD/Fs distribution patterns of MSWI fly ash during water washing process. Environmental Sanitation Engineering, 30(03): 41–45.

Long L, Jiang X, Lv G, et al. (2021). Comparison of MSWI fly ash from grate-type and circulating fluidized bed incinerators under landfill leachate corrosion scenarios: the long-term leaching behavior and speciation of heavy metals. Environmental Science and Pollution Research, 29(10): 15057–15067. https://doi.org/10.1007/s11356-021-16618-z

Long L, Zhao Y, Lv G, et al. (2022). Improving stabilization/solidification of MSWI fly ash with coal gangue based geopolymer via increasing active calcium content. The Science of the Total Environment, 854: 158594. https://doi.org/10.1016/j.scitotenv.2022.158594

Long L. (2023). Mechanism study on solidification and stabilization of municipal solid waste incineration fly ash via coal gangue and blast furnace slag. Hangzhou: Zhejiang University.

Long Q. (2024). Preparation and performance study of artificial aggregates from municipal solid waste incineration fly ash. Jingzhou: Yangtze University.

Long W, Peng J, Gu Y, et al. (2021). Recycled use of municipal solid waste incinerator fly ash and ferronickel slag for eco-friendly mortar through geopolymer technology. Journal of Cleaner Production, 307: 127281. https://doi.org/10.1016/j.jclepro.2021.127281

Lu F J. (2024). Low-temperature preparation and properties of high-active melting vitreous products from municipal solid waste incineration fly ash. Beijing: Chinese Building Materials Academy.

Lu J. (2015). Study on the physicochemical characteristics and heavy metal stabilization of incineration fly ash. Qingdao: Qingdao Technological University.

Lu S L, Ding X M, Luo Q, et al. (2024). Mechanical properties and toxic leaching characteristics of alkali-activated chelated municipal solid waste incinerator fly ash. Bulletin of the Chinese Ceramic Society, 43(10): 3765–3771.

Lü X L, Wei L, Liu Y S, et al. (2012). Effect of chlorine-containing compounds on evaporation of heavy metals in secondary gasification of fly ash from municipal solid waste incinerator. Acta Scientiarum Naturalium Universitatis Pekinensis, 48(01):133–138. https://doi.org/10.13209/j.0479-8023.2012.017.

Lü Z J. (2021). Analysis of characteristics of fly ash from typical municipal solid waste incineration and study on stabilization effect of heavy metals. Qingdao: Qingdao University of Technology.

Lundtorp K, Jensen D, Sørensen M, et al. (2003). On-site treatment and landfilling of MSWI air pollution control residues. Journal of Hazardous Materials, 97(1-3): 59–70. https://doi.org/10.1016/s0304-3894(02)00243-1

Luo C. (2024). Study on the effect of chlorine on lead and cadmium leaching toxicity in fly ash of domestic waste incineration. Shandong Chemical Industry, 53(20): 266–268.

Luo G P. (2024). Research on ultra-low emission flue gas purification process based on fly ash reduction. Hangzhou: Zhejiang University.

Luo J Y, Hu D J, Shao H P, et al. (2019). Dynamic analysis of physicochemical characteristics of fly ash from municipal waste incineration. Zhejiang Chemical Industry, 50(07): 41–46.

Luo S M. (2022). Study on solidification effect of heavy metals in waste incineration fly ash. Nanchang: East China Jiaotong University.

Luo W and Li Y. (2018). Stabilization of heavy metals in municipal solid waste incineration fly ash by organic chelating agents. Sichuan Environment, 37(05): 19–24.

Luukkonen T, Yu Y, Adhikary S K, et al. (2024). Metallic aluminium in municipal solid waste incineration fly ash as a blowing agent for porous alkali-activated granules. Royal Society Open Science, 11(8): 240598. https://doi.org/10.1098/rsos.240598

Ma B G, Su H W, Li X G, et al. (2013). Research on pretreatment technology of municipal solid wastes incineration fly ash. Journal of Wuhan University of Technology, 35(04): 22–26.

Ma Q, Chen Y F, Jin T, et al. (2018). Immobilization of heavy metals in fly ash from municipal solid waste incineration power generation. Ecology and Environmental Sciences, 27(09): 1716–1723.

Ma W, Chen D, Pan M, et al. (2019). Performance of chemical chelating agent stabilization and cement solidification on heavy metals in MSWI fly ash: A comparative study. Journal of Environmental Management, 247: 169–177. https://doi.org/10.1016/j.jenvman.2019.06.089

Ma W, Fang Y, Chen D, et al. (2017). Volatilization and leaching behavior of heavy metals in MSW incineration fly ash in a DC arc plasma furnace. Fuel, 210: 145–153. https://doi.org/10.1016/j.fuel.2017.07.091

Ma W, Shi W, Shi Y, et al. (2020). Plasma vitrification and heavy metals solidification of MSW and sewage sludge incineration fly ash. Journal of Hazardous Materials, 408: 124809. https://doi.org/10.1016/j.jhazmat.2020.124809

Ma Y F, Bai L, Li X D, et al. (2020). Analysis on physicochemical characteristics of fly ash along the heating surfaces of typical MSW grate incineration boiler. Environmental Sanitation Engineering, 28(03): 1–7.

Mai N T, Tham T T, Thuy H N T, et al. (2024). Residual, sequential extraction, and ecological risk assessment of some metals in ash from municipal solid waste incineration, Vietnam. Green Processing and Synthesis: 13(1). https://doi.org/10.1515/gps-2023-0234

Mangialardi T. (2001). Sintering of MSW fly ash for reuse as a concrete aggregate. Journal of Hazardous Materials, 87(1-3): 225–239. https://doi.org/10.1016/s0304-3894(01)00286-2

Mangialardi T. (2003). Disposal of MSWI fly ash through a combined washing-immobilisation process. Journal of Hazardous Materials, 98(1-3): 225–240. https://doi.org/10.1016/s0304-3894(02)00359-x

Mao Y, Wu H, Wang W, et al. (2019). Pretreatment of municipal solid waste incineration fly ash and preparation of solid waste source sulphoaluminate cementitious material. Journal of Hazardous Materials, 385: 121580. https://doi.org/10.1016/j.jhazmat.2019.121580

Mao Z J, Wang Z Y, Luo J J, et al. (2013). Using wet process to remove heavy metals from waste incineration fly ash. Environmental Sanitation Engineering, 21(02): 6–8+10.

Marieta C, Guerrero A, Leon I. (2020). Municipal solid waste incineration fly ash to produce eco-friendly binders for sustainable building construction. Waste Management, 120: 114–124. https://doi.org/10.1016/j.wasman.2020.11.034

Mizutani S, Yoshida T, Sakai S, et al. (1996). Release of metals from MSWI fly ash and availability in alkali condition. Waste Management, 16(5–6): 537–544. https://doi.org/10.1016/s0956-053x(96)00095-5

Mohamedzein Y E, Al-Aghbari M Y, Taha R A. (2006). Stabilization of desert sands using municipal solid waste incinerator ash. Geotechnical and Geological Engineering, 24(6): 1767–1780. https://doi.org/10.1007/s10706-006-6806-7

Mokrzycki J, Baran P, Gazda-Grzywacz M, et al. (2023). Decarbonatization of energy sector by CO_2 sequestration in waste incineration fly ash and its utilization as raw material for alkali activation. Materials, 16(18): 6094. https://doi.org/10.3390/ma16186094

Mu Y, Saffarzadeh A, Shimaoka T. (2018). Influence of ignition of waste fishbone on enhancing heavy metal stabilization in municipal solid waste incineration (MSWI) fly ash. Journal of Cleaner Production, 189: 396–405. https://doi.org/10.1016/j.jclepro.2018.03.301

Muthuraja R, Pombhejara C N, Ganesan S, et al. (2024). Assessment and classification of different ashes from waste incinerators in Thailand. Results in Engineering, 24: 103325. https://doi.org/10.1016/j.rineng.2024.103325

Nag M and Shimaoka T. (2022). A novel and sustainable technique to immobilize lead and zinc in MSW incineration fly ash by using pozzolanic bottom ash. Journal of Environmental Management, 329: 117036. https://doi.org/10.1016/j.jenvman.2022.117036

Nag M, Labira D, Shimaoka T, et al. (2023). Utilization of size-fractionated pozzolanic bottom ash to immobilize heavy metals in MSW incinerator fly ash. Journal of Environmental Chemical Engineering, 11(5): 110394. https://doi.org/10.1016/j.jece.2023.110394

Nag M, Labira D, Shimaoka T. (2025). Resource recovery from MSW incineration residues through the 'Ash-by-Ash Treatment Method' (AATM): optimization of water and bottom ash contents. Environmental Technology, 46(19): 3804–3821. https://doi.org/10.1080/09593330.2025.2478179

Nag M, Saffarzadeh A, Nomichi T, et al. (2020). Enhanced Pb and Zn stabilization in municipal solid waste incineration fly ash using waste fishbone hydroxyapatite. Waste Management, 118: 281–290. https://doi.org/10.1016/j.wasman.2020.08.026

Narenkumar J, Sathishkumar K, Das B, et al. (2023). An integrated approach of bioleaching-enhanced electrokinetic remediation of heavy metals from municipal waste incineration fly ash using Acidithiobacillus spp. Frontiers in Environmental Science, 11: 1273930. https://doi.org/10.3389/fenvs.2023.1273930

Natal A P S. (2023). Production of geopolymers from fly ash for wastewater treatment[D].

Nedkvitne E N, Borgan Ø, Eriksen D Ø, et al. (2021). Variation in chemical composition of MSWI fly ash and dry scrubber residues. Waste Management, 126: 623–631. https://doi.org/10.1016/j.wasman.2021.04.007

Ngo T M, Hoang V H, Van H T, et al. (2024). Insights into the composition and properties of fly ash emissions from a municipal solid waste power plant. Environmental Research Communications, 6(2): 025004. https://doi.org/10.1088/2515-7620/ad23f2

Nguyen T H, Pham Q V, Nguyen T P M, et al. (2022). Distribution characteristics and ecological risks of heavy metals in bottom ash, fly ash, and particulate matter released from municipal solid waste incinerators in northern Vietnam. Environmental Geochemistry and Health, 45(5): 2579–2590. https://doi.org/10.1007/s10653-022-01335-4

Nguyen T T, Tsai C K, Horng J J. (2022). Sustainable recovery of valuable nanoporous materials from high-chlorine MSWI fly ash by ultrasound with organic acids. Molecules, 27(7): 2289. https://doi.org/10.3390/molecules27072289

Ni H F, Dan Z, Zhou W W, et al. (2022). Characteristics analysis and risk assessment of heavy metals of waste incineration fly ash in Lhasa. Environmental Engineering, 40(03): 89–93+131. https://org.doi/10.13205/j.hjgc.202203014.

Ni H F. (2022). Experimental study on characteristics and stabilization of heavy metals in fly ash from municipal solid waste incineration in Lhasa. Lhasa: Tibet University.

Ni P, Xiong Z, Tian C, et al. (2017). Influence of carbonation under oxy-fuel combustion flue gas on the leachability of heavy metals in MSWI fly ash. Waste Management, 67: 171–180. https://doi.org/10.1016/j.wasman.2017.05.023

Ning G P. (2024). Research on chlorination removal and hydrothermal stability of heavy metals from waste incineration fly ash. Jingdezhen: Jingdezhen Ceramic University.

Nowak B, Rocha S F, Aschenbrenner P, et al. (2011). Heavy metal removal from MSW fly ash by means of chlorination and thermal treatment: Influence of the chloride type. Chemical Engineering Journal, 179: 178–185. https://doi.org/10.1016/j.cej.2011.10.077

Oehmig W N, Roessler J G, Blaisi N I, et al. (2015). Contemporary practices and findings essential to the development of effective MSWI ash reuse policy in the United States. Environmental Science & Policy, 51: 304–312. https://doi.org/10.1016/j.envsci.2015.04.024

Oehmig W N, Roessler J, Saleh A M, et al. (2021). Comparison of trace element mobility from MSWI ash before and after plasma vitrification. Waste Management & Research the Journal for a Sustainable Circular Economy, 40(2): 227–235. https://doi.org/10.1177/0734242x211011543

Oh K, Ma H, Yi H, et al. (2022). Structural parts based on Municipal-Solid-Waste incineration ashes. Waste Management, 150: 185–190. https://doi.org/10.1016/j.wasman.2022.07.004

Ou Z. (2025). Study on the methods and mechanisms of utilizing clayey tailings for the solidification/stabilization treatment of municipal solid waste incineration (MSWI) fly ash. Guangzhou: Guangdong University of Technology.

Ouyang C, Zhang R N, Bi Z J, et al. (2015). Characteristics of heavy metals in fly ash from domestic waste incineration plants. Environmental Sanitation Engineering, 2015, 23(05): 35–38.

Pan J R, Huang C, Kuo J, et al. (2007). Recycling MSWI bottom and fly ash as raw materials for Portland cement. Waste Management, 28(7): 1113–1118. https://doi.org/10.1016/j.wasman.2007.04.009

Pan X C, Yan J H, Ma Z Y, et al. (2008). Experimental study on vitrification of fly ashes from municipal solid waste incinerator. Power Engineering, (02): 284–287+313.

Pan Y, Wu Z, Zhou J, et al. (2013). Chemical characteristics and risk assessment of typical municipal solid waste incineration (MSWI) fly ash in China. Journal of Hazardous Materials, 261: 269–276. https://doi.org/10.1016/j.jhazmat.2013.07.038

Pan Z. (2021). Study on the salts removal from municipal solid waste incineration fly ash via concentrated leachate solution. Anshan: University of Science and Technology Liaoning.

Park K, Hyun J, Maken S, et al. (2004). Vitrification of municipal solid waste incinerator fly ash using Brown's gas. Energy & Fuels, 19(1): 258–262. https://doi.org/10.1021/ef049953z

Park Y J and Heo J. (2002). Vitrification of fly ash from municipal solid waste incinerator. Journal of Hazardous Materials, 91(1-3): 83–93. https://doi.org/10.1016/s0304-3894(01)00362-4

Peceño B, Luna-Galiano Y, Varela F, et al. (2024). Study of a fire-resistant plate containing fly ashes generated from municipal waste incinerator: Fire and mechanical characteristics and environmental life cycle assessment. Materials, 17(8): 1813. https://doi.org/10.3390/ma17081813

Pedersen A J. (2002). Evaluation of assisting agents for electrodialytic removal of Cd, Pb, Zn, Cu and Cr from MSWI fly ash. Journal of Hazardous Materials, 95(1-2): 185–198. https://doi.org/10.1016/s0304-3894(02)00138-3

Peng X, Jiao B Q, Yu L, et al. (2011). Enhanced electrokinetic removal of heavy metals in MSWI fly Ash assisted by cation exchange membranes. Applied Mechanics and Materials, 84–85: 626–630. https://doi.org/10.4028/www.scientific.net/amm.84-85.626

Perumal P and Illikainen M. (2023).Feasibility study of one-part alkali activated material with MSWI fly ash. In: Escalante-Garcia J I, Castro Borges P, Duran-Herrera A. Proceedings of the 75th RILEM Annual Week 2021. RILEM Bookseries, vol 40. Springer, Cham. https://doi.org/10.1007/978-3-031-21735-7_63

Phongphiphat A, Ryu C, Finney K N, et al. (2010). Ash deposit characterisation in a large-scale municipal waste-to-energy incineration plant. Journal of Hazardous Materials, 186(1): 218–226. https://doi.org/10.1016/j.jhazmat.2010.10.095

Piantone P, Bodénan F, Derie R, et al. (2003). Monitoring the stabilization of municipal solid waste incineration fly ash by phosphation: mineralogical and balance approach. Waste Management, 23(3): 225–243. https://doi.org/10.1016/s0956-053x(01)00058-7

Pietrzak A, Ulewicz M, Kozień E, et al. (2025). Application of a mixture of fly ash and solid waste from gas treatment from municipal solid waste incineration in cement mortar. Materials, 18(3): 481. https://doi.org/10.3390/ma18030481

Polettini A, Pomi R, Sirini P, et al. (2001). Properties of Portland cement — stabilised MSWI fly ashes. Journal of Hazardous Materials, 88(1): 123–138. https://doi.org/10.1016/s0304-3894(01)00292-8

Pu K. (2023). Study on ceramic production technology using waste incineration fly ash as resource. Hangzhou: Zhejiang Gongshang University.

Qian G, Cao Y, Chui P, et al. (2005). Utilization of MSWI fly ash for stabilization/solidification of industrial waste sludge. Journal of Hazardous Materials, 129(1-3): 274–281. https://doi.org/10.1016/j.jhazmat.2005.09.003

Qian G, Song Y, Zhang C, et al. (2006). Diopside-based glass-ceramics from MSW fly ash and bottom ash. Waste Management, 26(12): 1462–1467. https://doi.org/10.1016/j.wasman.2005.12.009

Qian X F, Cai X, Han X, et al. (2016). Experimental study on the disposal of MSW incinerator fly ash through flotation and acid pickling. Energy Engineering, (05): 39–43+73. https://doi.org/10.16189/j.cnki.nygc.2016.05.007.

Qiao J G, Han M M, Li Z G. (2018). Experimental study on rheological properties of municipal solid waste incineration fly ash in asphalt mortar. Highway Engineering, 43(05): 53–56+137.

Qiao J G, Han M M, Wang Y, et al. (2019). Pavement performance of municipal solid waste incineration fly ash asphalt mixture. Journal of Materials Science & Engineering, 37(02): 291–295+237.

Qiu Q, Jiang X, Chen Z, et al. (2017). Microwave-assisted hydrothermal treatment with soluble phosphate added for heavy metals solidification in MSWI fly ash. Energy & Fuels, 31(5): 5222–5232. https://doi.org/10.1021/acs.energyfuels.6b02516

Qiu Q, Jiang X, Lv G, et al. (2016). Stabilization of heavy metals in municipal solid waste incineration fly ash in circulating fluidized bed by microwave-assisted hydrothermal treatment with additives. Energy & Fuels, 30(9): 7588–7595. https://doi.org/10.1021/acs.energyfuels.6b01431

Qiu Q, Jiang X, Lv G, et al. (2018). Adsorption of heavy metal ions using zeolite materials of municipal solid waste incineration fly ash modified by microwave-assisted hydrothermal treatment. Powder Technology, 335: 156–163. https://doi.org/10.1016/j.powtec.2018.05.003

Qiu Y F, Chen P, Zheng K Q, et al. (2022). Treatment of MSWI fly ash by using indigenous microorganism and the investigation of its promising utilization. China Environmental Science, 42(05): 2220–2228.

Quina M J, Almeida M A, Santos R, et al. (2014). Compatibility analysis of municipal solid waste incineration residues and clay for producing lightweight aggregates. Applied Clay Science, 102: 71–80. https://doi.org/10.1016/j.clay.2014.10.016

Quina M J, Santos R C, Bordado J C, et al. (2007). Characterization of air pollution control residues produced in a municipal solid waste incinerator in Portugal. Journal of Hazardous Materials, 152(2): 853–869. https://doi.org/10.1016/j.jhazmat.2007.07.055

Quina, M J, Bordado J C, Quinta-Ferreira R M. (2007). Treatment and use of air pollution control residues from MSW incineration: An overview. Waste Management, 28(11): 2097–2121. https://doi.org/10.1016/j.wasman.2007.08.030

Rani D A, Boccaccini A, Deegan D, et al. (2008). Air pollution control residues from waste incineration: Current UK situation and assessment of alternative technologies. Waste Management, 28(11): 2279–2292. https://doi.org/10.1016/j.wasman.2007.10.007

Rémond S, Pimienta P, Bentz D. (2002). Effects of the incorporation of municipal solid waste incineration fly ash in cement pastes and mortars. Cement and Concrete Research, 32(2): 303–311. https://doi.org/10.1016/s0008-8846(01)00674-4

Ren L W, Ye Z, Liu Q, et al. (2022). Research on enhanced pretreatment of domestic waste incineration fly ash. Guangdong Chemical Industry, 49(06): 148–151.

Ren X, Song K, Liu D, et al. (2022). Leaching characteristics of sulfates and chlorides from fly ash produced by municipal solid waste incineration. Desalination and Water Treatment, 273: 180–189. https://doi.org/10.5004/dwt.2022.28882

Ribbing C. (2007). Environmentally friendly use of non-coal ashes in Sweden. Waste Management, 27(10): 1428–1435. https://doi.org/10.1016/j.wasman.2007.03.012

Righi C, Lancellotti I, Barbieri L, et al. (2022). Benefits of pre-treating MSWI fly ash before alkali-activation. Sustainable Chemistry and Pharmacy, 27: 100671. https://doi.org/10.1016/j.scp.2022.100671

Rissler J, Fedje K K, Klementiev K, et al. (2024). Zinc speciation in fly ash from MSWI using XAS - novel insights and implications. Journal of Hazardous Materials, 477: 135203. https://doi.org/10.1016/j.jhazmat.2024.135203

Rissler J, Klementiev K, Dahl J, et al. (2020). Identification and quantification of chemical forms of Cu and Zn in MSWI ashes using XANES. Energy & Fuels, 34(11): 14505–14514. https://doi.org/10.1021/acs.energyfuels.0c02226

Romero M, Rincón J, Rawlings R, et al. (2001). Use of vitrified urban incinerator waste as raw material for production of sintered glass-ceramics. Materials Research Bulletin, 36(1–2): 383–395. https://doi.org/10.1016/s0025-5408(01)00501-3

Ruan Y. (2019). Co-hydrothermal processing to stabilize fly ash of different waste incinerators and its mechanism. Hangzhou: Zhejiang University.

Sabour M R, Hatami A M, Nikravan M, et al. (2024). Optimization of chloride removal from fly ash: A step towards sustainable waste management. International Journal of Environmental Science and Technology, 22(5): 3149–3162. https://doi.org/10.1007/s13762-024-05940-x

Saikia N, Kato S, Kojima T. (2006). Production of cement clinkers from municipal solid waste incineration (MSWI) fly ash. Waste Management, 27(9): 1178–1189. https://doi.org/10.1016/j.wasman.2006.06.004

Saikia N, Mertens G, Van Balen K, et al. (2015). Pre-treatment of municipal solid waste incineration (MSWI) bottom ash for utilisation in cement mortar. Construction and Building Materials, 96: 76–85. https://doi.org/10.1016/j.conbuildmat.2015.07.185

Saqib N and Bäckström M. (2015). Chemical association and mobility of trace elements in 13 different fuel incineration fly ashes. Fuel, 165: 193–204. https://doi.org/10.1016/j.fuel.2015.10.062

Sarmiento L M, Clavier K A, Paris J M, et al. (2019). Critical examination of recycled municipal solid waste incineration ash as a mineral source for Portland cement manufacture – A case study. Resources Conservation and Recycling, 148: 1–10. https://doi.org/10.1016/j.resconrec.2019.05.002

Schlumberger S and Bühler J. (2013). Metallrückgewinnung aus Filterstäuben der thermischen Abfallbehandlung nach dem FLUREC-Verfahren. In: Thomé-Kozmiensky, Aschen – Schlacken – Stäube aus Abfallverbennung und Metallurgie. TK Verlag Karl Thomé-Kozmiensky, Neuruppin, Germany, pp. 377–396.

Scholz P, Vogel C, Schuck G, et al. (2024). Speciation of copper and zinc compounds relevant for the hazard property (HP) 14 classification of municipal solid waste incineration bottom and fly ashes. Waste Management, 189: 421–426. https://doi.org/10.1016/j.wasman.2024.09.001

Sekito T, Dote Y, Onoue K, et al. (2014). Characteristics of element distributions in an MSW ash melting treatment system. Waste Management, 34(9): 1637–1643. https://doi.org/10.1016/j.wasman.2014.04.009

Shan C, Jing Z, Pu L, et al. (2012). Solidification of MSWI ash at low temperature of 100 °C. Industrial & Engineering Chemistry Research, 51(28), 9540–9545. https://doi.org/10.1021/ie203040d

Shang N, Wang H Y, Wu H N, et al. (2016). Study of compressive strength and leachability of cement mortars containing municipal solid waste incineration fly ash. Chinese Journal of Environmental Engineering, 10(06): 3207–3214.

Shao N, Wei X, Monasterio M, et al. (2021). Performance and mechanism of mold-pressing alkali-activated material from MSWI fly ash for its heavy metals solidification. Waste Management, 126: 747–753. https://doi.org/10.1016/j.wasman.2021.04.003

Shao Y. (2014). Immobilization mechanisms of solidified municipal solid waste incineration fly ash using blast furnace slag based cementitious material. Wuhan: Wuhan University.

Sharifikolouei E, Baino F, Salvo M, et al. (2020). Vitrification of municipal solid waste incineration fly ash: An approach to find the successful batch compositions. Ceramics International, 47(6): 7738–7744. https://doi.org/10.1016/j.ceramint.2020.11.118

Shen D S, Zheng Y G, Yao J, et al. (2011). Analysis of pollution characteristics of solid waste incinerator fly ash in Zhejiang Province. Environmental Sciences, 32(09): 2610–2616. https://doi.org/10.13227/j.hjkx.2011.09.020.

Sheng N, Sun X L, Zhang W, et al. (2022). Stabilization and mechanism of heavy metals in municipal solid waste incineration fly ash by co-hydrothermal processing with coal fly ash. Journal of Combustion Science and Technology, 28(05): 605–616.

Sheng Y, Jian L, Li HJ, et al. (2014). Study on characteristics and chemical speciation of heavy metals from municipal solid waste incineration fly ash of Haikou. Environmental Science and Management, 39(12): 95–98.

Shevtsova M, Malaiškienė J, Škamat J, et al. (2025). Influence of different binders on the municipal solid waste incineration fly ash granulation-based stabilization process. Sustainability, 17(10): 4573. https://doi.org/10.3390/su17104573

Shi H and Kan L. (2009). Characteristics of municipal solid wastes incineration (MSWI) fly ash–cement matrices and effect of mineral admixtures on composite system. Construction and Building Materials, 23(6): 2160–2166. https://doi.org/10.1016/j.conbuildmat.2008.12.016

Shi H S, Li X, Wu K. (2019). Influence of municipal incineration fly ash on performance of magnesium phosphate cement. New Building Materials, 46(05): 37–40+45.

Shi J J. (2009). Property analysis of secondary pollutants in Shanghai Jiangqiao domestic waste incineration plant. Environmental Sanitation Engineering, 17(05): 49–50+53.

Shi W F. (2024). Research on preparation, performance and application of ecological cement-based materials based on solid waste resource utilization. Nanjing: Nanjing Forestry University.

Shi Y J. (2022). Theoretical and experimental study on solidification of heavy metals by plasma melting of MSWI fly ash/red mud. Tianjin: Tianjin University.

Shim Y, Rhee S, Lee W. (2005). Comparison of leaching characteristics of heavy metals from bottom and fly ashes in Korea and Japan. Waste Management, 25(5): 473–480. https://doi.org/10.1016/j.wasman.2005.03.002

Singh D and Kumar A. (2017). Performance evaluation and geo-characterization of municipal solid waste incineration ash material amended with cement and fibre. International Journal of Geosynthetics and Ground Engineering, 3: 16. https://doi.org/10.1007/s40891-017-0094-6

Song G, Kim K, Seo Y, et al. (2003). Characteristics of ashes from different locations at the MSW incinerator equipped with various air pollution control devices. Waste Management, 24(1): 99–106. https://doi.org/10.1016/s0956-053x(03)00073-4

Song J N. (2024). Status and stabilization mechanism of arsenic and selenium in municipal solid waste incineration fly ash. Dalian: Dalian Maritime University.

Song L J, Zhao Y C. (2003). Formation mechanism of heavy metals in municipal solid waste incineration fly ash. Shanghai Environmental Sciences, 22(S2): 140–142+199.

Song Y P. (2024). Preparation and properties of municipal solid waste incineration fly ash based foamed geopolymers. Qinhuangdao: Yanshan University.

Song Z J. (2023). Research on waste incineration fly ash synchronous preparation of ceramsite and recycling chlorine salt process. Hengyang: University of South China.

Sørensen M, Mogensen E, Lundtorp K, et al. (2001). High temperature co-treatment of bottom ash and stabilized fly ashes from waste incineration. Waste Management, 21(6): 555–562. https://doi.org/10.1016/s0956-053x(00)00113-6

Soylu E, Lode S, Silva C M, et al. (2025). Comprehensive characterization of solid waste incineration fly ash before and after salt washing: Evaluating analytical methods for sustainable waste management. Resources Conservation & Recycling Advances, 27: 200268. https://doi.org/10.1016/j.rcradv.2025.200268

Staničić I, Backman R, Cao Y, et al. (2021). Fate of trace elements in oxygen carrier aided combustion (OCAC) of municipal solid waste. Fuel, 311: 122551. https://doi.org/10.1016/j.fuel.2021.122551

Stanmore, B. (2003). The formation of dioxins in combustion systems. Combustion and Flame, 136(3): 398–427. https://doi.org/10.1016/j.combustflame.2003.11.004

Stegemann J, and Buenfeld N. (2002). Prediction of unconfined compressive strength of cement paste containing industrial wastes. Waste Management, 23(4): 321–332. https://doi.org/10.1016/s0956-053x(02)00062-4

Sun C, Li M, Gau S, et al. (2011). Improving the mechanical characteristics and restraining heavy metal evaporation from sintered municipal solid waste incinerator fly ash by wet milling. Journal of Hazardous Materials, 195: 281–290. https://doi.org/10.1016/j.jhazmat.2011.08.040

Sun J, Tan X, Ji T. (2021). Effects of typical components of MSWI fly ash on its melting characteristics. Environmental Sanitation Engineering, 29(04): 59–63+72.

Sun J, Tan X, Zhang S G, et al. (2021). Composition and melting characteristics of fly ash from 14 MSWI plants in China. Environmental Engineering, 39(10):124–128. https://doi.org/10.13205/j.hjgc.202110017.

Sun L J, Zhu R R, Huang Y, et al. (2024). Effect of cooperative incineration of sludge on the physical properties of fly ash. Clean Coal Technology, 30(S1): 198–203. https://doi.org/10.13226/j.issn.1006-6772.24041701.

Sun L, Wu X, Liu DJ, et al. (2017). Stabilization of heavy metals in municipal solid waste incineration fly ash using thermal treatment with silica-based material. Chemical Industry and Engineering Progress, 36(09): 3514–3522. https://doi.org/10.16085/j.issn.1000-6613.2017–0141.

Sun Y T, Yao K, Zheng Y Q, et al. (2021). Research on one-dimensional semi-dynamic leaching behavior of heavy metals in fly ash-based alkali-activated gelling materials. Environmental Science and Technology, 44(01): 24–31.

Sun Y, Zheng J, Zou L, et al. (2010). Reducing volatilization of heavy metals in phosphate-pretreated municipal solid waste incineration fly ash by forming pyromorphite-like minerals. Waste Management, 31(2): 325–330. https://doi.org/10.1016/j.wasman.2010.10.011

Szarek Ł, Falaciński P, Drużyński P. (2023). Possibilities of using ash from thermal treatment of municipal solid waste in hardening slurries. Archives of Environmental Protection, 49(2): 76–84. https://doi.org/10.24425/aep.2023.145899

Tabyang W, Suksiripattanapong C, Phetchuay C, et al. (2021). Evaluation of municipal solid waste incineration fly ash based geopolymer for stabilised recycled concrete aggregate as road material. Road Materials and Pavement Design, 23(9): 2178–2189. https://doi.org/10.1080/14680629.2021.1959385

Tabyang W, Suksiripattanapong C, Wonglakorn N, et al. (2022). Utilization of municipal solid waste incineration fly ash for Non-Bearing masonry units containing coconut fiber. Journal of Natural Fibers, 19(16): 12522–12535. https://doi.org/10.1080/15440478.2022.2073313

Takasuga T, Makino T, Tsubota K, et al. (2000). Formation of dioxins (PCDDs/PCDFs) by dioxin-free fly ash as a catalyst and relation with several chlorine-sources. Chemosphere, 40(9-11): 1003–1007. https://doi.org/10.1016/s0045-6535(99)00345-8

Tan B. (2022). Effect of in-situ formed nano-calcite particles on hydration and properties of cement-based materials[D].

Tan J, De Vlieger J, Desomer P, et al. (2022). Co-disposal of construction and demolition waste (CDW) and municipal solid waste incineration fly ash (MSWI FA) through geopolymer technology. Journal of Cleaner Production, 362: 132502. https://doi.org/10.1016/j.jclepro.2022.132502

Tan W F, Wang L A, Huang C, et al. (2013). Municipal solid waste incineration fly ash sintered lightweight aggregates and kinetics model establishment. International Journal of Environmental Science and Technology, 10: 465–472. https://doi.org/10.1007/s13762-012-0111-1

Tan Y J, Zhang X W, Zhang Y H, et al. (2024). Detoxification co-treatment of municipal solid waste incineration fly ash and dehydrated sludge using vacuum carbon thermal reduction. Journal of University of South China (Science and Technology), 38(05):17–24.

Tan Y J. (2024). Research on vacuum carbothermal reduction detoxification and resource utilization of municipal solid waste incineration fly ash. Hengyang: University of South China.

Tang G C, Liu M, Yuan T X. (2016). Research on the distribution and migration rule of heavy metals in waste incineration in Guizhou city. Ecology and Environmental Sciences, 25(04): 686–691.

Tang J and Steenari B. (2015). Solvent extraction separation of copper and zinc from MSWI fly ash leachates. Waste Management, 44: 147–154. https://doi.org/10.1016/j.wasman.2015.07.028

Tao S. (2024). Study on leaching experiments and influencing mechanisms of mercury and cadmium in fly ash from municipal solid waste incineration. Hangzhou: Zhejiang University.

Terrones-Saeta A, Terrones-Saeta J M, Suárez-Macías J, et al. (2025). Development and mechanical analysis of geopolymers formed with mining residue and fly ash from municipal solid waste incineration obtained after the neutralisation stage. Polymers, 17(12): 1704. https://doi.org/10.3390/polym17121704

Tian S L. (2021). Study on concentration technology of water washing solution of municipal solid waste incineration fly ash. Hebei: Hebei University of Technology.

Tian X, Rao F, León-Patiño C A, et al. (2019). Effects of aluminum on the expansion and microstructure of alkali-activated MSWI fly ash-based pastes. Chemosphere, 240: 124986. https://doi.org/10.1016/j.chemosphere.2019.124986

Tian X, Rao F, León-Patiño C A, et al. (2020). Co-disposal of MSWI fly ash and spent caustic through alkaline-activation: Immobilization of heavy metals and organics. Cement and Concrete Composites, 114: 103824. https://doi.org/10.1016/j.cemconcomp.2020.103824

Tian Y. (2022). Characterization, stabilization, and utilization of waste-to-energy residues in civil engineering applications[D]

Tokgoz D D G, Ozerkan N G, Antony S J. (2023). Untreated municipal solid waste incineration ashes for cement replacement. Journal of Engineering Research, 11(3): 34–39. https://doi.org/10.1016/j.jer.2023.100129

Trinh M M and Chang M B. (2020). Catalytic pyrolysis: New approach for destruction of POPs in MWIs fly ash. Chemical Engineering Journal, 405: 126718. https://doi.org/10.1016/j.cej.2020.126718

Tu H B. Study on the heavy metals distribution characteristics in MSW fly ashes[D]. Hangzhou: Zhejiang University, 2010.

Tzanakos K, Mimilidou A, Anastasiadou K, et al. (2014). Solidification/stabilization of ash from medical waste incineration into geopolymers. Waste Management, 34(10): 1823–1828. https://doi.org/10.1016/j.wasman.2014.03.021

Ubbriaco P and Calabrese D. (1998). Solidification and stabilization of cement paste containing fly ash from municipal solid waste. Thermochimica Acta, 321(1-2): 143–150. https://doi.org/10.1016/s0040-6031(98)00453-5

Valentim B, Guedes A, Kuźniarska-Biernacka I, et al. (2024). Variation in the composition of municipal solid waste incineration ash. Minerals, 14(11): 1146. https://doi.org/10.3390/min14111146

Valizadeh B, Abdoli M A, Dobaradaran S, et al. (2024). Risk control of heavy metal in waste incinerator ash by available solidification scenarios in cement production based on waste flow analysis. Scientific Reports, 14: 6252. https://doi.org/10.1038/s41598-024-56551-y

Van Truong T, Perumal P, Kokko M, et al. (2024). Two-step process to recover metal and mineral residues from municipal solid waste incinerated (MSWI) ashes. Construction and Building Materials, 456: 139341. https://doi.org/10.1016/j.conbuildmat.2024.139341

Varaprasad B J S, Joga J R, Joga S R. (2020). Reuse of municipal solid waste from incinerated ash in the stabilization of clayey soils. Slovak Journal of Civil Engineering, 28(4): 1–7. https://doi.org/10.2478/sjce-2020-0024

Viader RP, Jensen PE, Ottosen LM. (2016). Electrodialytic remediation of municipal solid waste incineration residues using different membranes. Chemosphere, 169: 62–68. https://doi.org/10.1016/j.chemosphere.2016.11.047

Viet D B, Chan W, Phua Z, et al. (2020). The use of fly ashes from waste-to-energy processes as mineral CO_2 sequesters and supplementary cementitious materials. Journal of Hazardous Materials, 398: 122906. https://doi.org/10.1016/j.jhazmat.2020.122906

Vogel C, Scholz P, Kalbe U, et al. (2024).Speciation of antimony and vanadium in municipal solid waste incineration ashes analyzed by XANES spectroscopy. Journal of Material Cycles and Waste Management, 26(4): 2152–2158. https://doi.org/10.1007/s10163-024-01954-2

Wan S. (2022). Study on the chlorine fixation of activated waste incineration fly ash and the mechanism of heavy metal solidification. Wuhan: Wuhan University.

Wan X Y. (2023). Experimental study on the solidification of heavy metals by co-pyrolysis of municipal sludge and waste incineration fly ash. Lhasa: Tibet University.

Wan X, Wang W, Ye T, et al. (2005). A study on the chemical and mineralogical characterization of MSWI fly ash using a sequential extraction procedure. Journal of Hazardous Materials, 134(1-3): 197–201. https://doi.org/10.1016/j.jhazmat.2005.10.048

Wang B T, Dong S H, Liu T C. (2022). Detection of physicochemical properties and leaching toxicity test of a certain waste incineration fly ash. Journal of Safety and Environment, 22(02): 988–995. https://doi.org/10.13637/j.issn.1009-6094.2021.0237.

Wang F, Wang W, Wan X. (2008). Acid neutralizing capacity and elements leaching behavior from MSWI fly ash under static pH condition. Environmental Science, (02): 2529–2534. https://doi.org/10.13227/j.hjkx.2008.02.034.

Wang F, Zhang F, Chen Y, et al. (2015). A comparative study on the heavy metal solidification/stabilization performance of four chemical solidifying agents in municipal solid waste incineration fly ash. Journal of Hazardous Materials, 300: 451–458. https://doi.org/10.1016/j.jhazmat.2015.07.037

Wang J B and Qin R X. (2013). Organic chelator for the stabilization of heavy metals in fly ash. Environmental Science & Technology, 36(09): 139–143.

Wang J. (2024). Experimental study on solidification/stabilization of high-salt concentrated sludge by alkali-activated GGBS combined with MSWI fly ash. Guangzhou: Guangdong University of Technology.

Wang K, Lin K, Huang Z. (2001). Hydraulic activity of municipal solid waste incinerator fly-ash-slag-blended eco-cement. Cement and Concrete Research, 31(1), 97–103. https://doi.org/10.1016/s0008-8846(00)00423-3

Wang K, Wu X, Liang C, et al. (2020). Experimental study on the stabilization/solidification of MSWI fly ash by geopolymerization based on secondary aluminum dross. China Environmental Science, 40(10): 4421–4428.

Wang L, Jin Y Y, Nie Y F. (2009). Accelerated carbonation of high Ca content municipal solid waste incineration fly ash and impact on leaching of heavy meal. Environmental Sciences, 30(11): 3399–3404. https://doi.org/10.13227/j.hjkx.2009.11.011.

Wang L, Jin Y Y, Nie Y F. (2009). Accelerated carbonation of municipal solid waste incineration fly ash. China Environmental Science, 29(10): 1111–1116.

Wang L, Jin Y, Nie Y, et al. (2010). Recycling of municipal solid waste incineration fly ash for ordinary Portland cement production: A real-scale test. Resources Conservation and Recycling, 54(12): 1428–1435. https://doi.org/10.1016/j.resconrec.2010.06.006

Wang M F, Liu J H, Ma M S. (2022). Study on plasma melting of municipal solid waste and incineration fly ash co-disposal. Environmental Science and Technology,35(04): 11–15+21.

Wang M L, Wang Q H, Wang X N, et al. (2019). Experimental study on removal of chlorine and heavy metals from domestic waste incineration fly ash by its leachate. Environmental Engineering, 37(09): 144–148. https://doi.org/10.13205/j.hjgc.201909026.

Wang Q H. (2024). Synthesis of layered double hydroxides from municipal solid waste incineration fly ash and its application. Hangzhou: Zhejiang University.

Wang Q X, Guo Y P, Han F, et al. (2022). Study on phosphate-induced soluble chlorine stabilization of municipal solid waste incineration fly ash. Journal of Engineering Thermophysics, 43(12): 3393–3401.

Wang Q, Yan J, Chi Y, et al. (2009). Application of thermal plasma to vitrify fly ash from municipal solid waste incinerators. Chemosphere, 78(5): 626–630. https://doi.org/10.1016/j.chemosphere.2009.10.035

Wang Q, Yang J, Wang Q, et al. (2008). Effects of water-washing pretreatment on bioleaching of heavy metals from municipal solid waste incinerator fly ash. Journal of Hazardous Materials, 162(2–3): 812–818. https://doi.org/10.1016/j.jhazmat.2008.05.125

Wang R N. (2022). Numerical simulation and experimental study on thermal plasma melting furnace for municipal solid waste incineration fly ash. Beijing: China University of Mining and Technology.

Wang W, Ye T M, Wang Q, et al. (2007). Extraction procedure for leaching toxicity of fly ash from municipal solid waste incinerators under co-disposal scenario in landfill. Environmental Sciences, (12): 2867-2872. https://doi.org/10.13227/j.hjkx.2007.12.028.

Wang X, Jiao Y, Xu B, et al. (2010). Characteristics of Heavy Metals Partition during Melting Process of MSWI Fly Ash. Chengdu: 2010 Asia-Pacific Power and Energy Engineering Conference, pp. 1–5. https://doi.org/10.1109/APPEEC.2010.5448430.

Wang X, Jin B, Xu B, et al. (2017). Melting characteristics during the vitrification of MSW incinerator fly ash by swirling melting treatment. Journal of Material Cycles and Waste Management, 19: 483–495 https://doi.org/10.1007/s10163-015-0449-9

Wang X, Li A, Zhang Z. (2016). The effects of water washing on cement-based stabilization of MWSI fly ash. Procedia Environmental Sciences, 31: 440–446. https://doi.org/10.1016/j.proenv.2016.02.095

Wang XT, Jiao YZ, Jin BS. (2007). Analysis of basic characteristics of fly ash from waste incineration in East China. Thermal Power Generation, (05): 38–42. https://doi.org/10.19666/j.rlfd.2007.05.011.

Wang Y J, Li K Q, Ni W, et al. (2019). Study on solidification of heavy metal ions from garbage incineration fly ash using slag-based cementitious materials. Metal Mine, (07): 194–198.

Wang Y T. (2021). Solidification/stabilization treatment and assessment methods of heavy metals in municipal solid waste incineration fly ash. Shanghai: East China University of Science and Technology.

Wang Y X, Zhao W, Guo J X, et al. (2024). Effect of coal ash on melting and vitrification characteristics of municipal solid waste incineration fly ash. Chemical Engineering (China), 52(09): 1–7.

Wang Y, Lin F, Chen P, et al. (2024). Experimental study on EICP stabilization of MSW incineration fly ash. Acta Scientiae Circumstantiae, 44(08): 416–425. https://doi.org/10.13671/j.hjkxxb.2024.0039.

Wang Y, Ma J, Qing L, et al. (2023). Accelerated carbonation pretreatment of municipal solid waste incineration fly ash and its conversion to geopolymer with coal fly ash. Construction and Building Materials, 383: 131363. https://doi.org/10.1016/j.conbuildmat.2023.131362

Wang Z Y. (2007). Compound stabilization of MSW incineration fly ash with copper salt and cement. Shanghai: Tongji University.

Wehrung Q, Bernasconi D, Destefanis E, et al. (2024). Aqueous carbonation of waste incineration residues: Comparing BA, FA, and APCr across production scenarios. Minerals, 14(12): 1269. https://doi.org/10.3390/min14121269

Wei B Y, Zhang G L, Huang L, et al. (2019). Experimental study on physical and chemical characteristics and washing characteristics of municipal solid waste incineration fly ash in Beijing. Environmental Engineering, 37(04): 163–166. https://doi.org/10.13205/j.hjgc.201904031.

Wei C, Liu Q, Wen J. (2009). Distribution of heavy metals from iron bath-melting separation process applied to municipal solid waste incineration fly ash. Environmental Technology, 30(14): 1503–1509. https://doi.org/10.1080/09593330903241938

Wei N. (2015). Leachability of heavy metals from lightweight aggregates made with sewage sludge and municipal solid waste incineration fly ash. International Journal of Environmental Research and Public Health, 12(5): 4992–5005. https://doi.org/10.3390/ijerph120504992

Wei X Z, Su M T, Zha S M, et al. (2022). Experimental study on stabilization of heavy metals in municipal solid waste incineration fly ash. Modern Chemical Research, (21): 86–88.

Wei Y and Cheng C. (2016). Determination of total Cl in incinerator fly ashes utilized as cement raw materials. Construction and Building Materials, 124: 544–549. https://doi.org/10.1016/j.conbuildmat.2016.07.132

Wei Y M, Yao R X, Chen S, et al. (2021). Removal of chloride from MSWI fly ash: A comparison of accelerated carbonation and water flushing. China Environmental Science, 41(09): 4184–4192.

Wei Y M, Yao R X, Liu S J, et al. (2021). Effect of intrinsic property of MSWI fly ash on dechlorination: Illustrated by two ash samples from Chongqing and Tianjin. Acta Scientiae Circumstantiae, 41(12): 4986–4994. https://doi.org/10.13671/j.hjkxxb.2021.0158.

Weibel G, Eggenberger U, Kulik D A, et al. (2018). Extraction of heavy metals from MSWI fly ash using hydrochloric acid and sodium chloride solution. Waste Management, 76: 457–471. https://doi.org/10.1016/j.wasman.2018.03.022

Weibel G, Eggenberger U, Schlumberger S, et al. (2016). Chemical associations and mobilization of heavy metals in fly ash from municipal solid waste incineration. Waste Management, 62: 147–159. https://doi.org/10.1016/j.wasman.2016.12.004

Weibel G, Zappatini A, Wolffers M, et al. (2021). Optimization of metal recovery from MSWI fly ash by acid leaching: Findings from laboratory- and industrial-scale experiments. Processes, 9(2): 352. https://doi.org/10.3390/pr9020352

Wen Y L and Wang J J. (2024). Study on the effect of co-incineration of aged refuse on fly ash stabilization in municipal solid waste incineration plants. Cleaning World, 40(04): 47–50.

Wen Z Y, Yan D H, Li W S, et al. (2023). Effect of oxygen content on low temperature pyrolysis of dioxins in fly ash from MSWI. Environmental Sanitation Engineering, 31(S1): 66–71.

Wilewska-Bien M, Lundberg M, Steenari B, et al. (2006). Treatment process for MSW combustion fly ash laboratory and pilot plant experiments. Waste Management, 27(9): 1213–1224. https://doi.org/10.1016/j.wasman.2006.09.011

Wolffers M, Eggenberger U, Schlumberger S, et al. (2021). Characterization of MSWI fly ashes along the flue gas cooling path and implications on heavy metal recovery through acid leaching. Waste Management, 134: 231–240. https://doi.org/10.1016/j.wasman.2021.08.022

Wolffers M, Weibel G, Eggenberger U. (2021). Waste wood fly ash treatment in Switzerland: Effects of co-processing with fly ash from municipal solid waste on Cr(VI) reduction and heavy metal recovery. Processes, 9(1): 146. https://doi.org/10.3390/pr9010146

Wu C Q, Wen H J, Ye H, et al. (2024). Effect of horizontal ball milling on dioxin removal from municipal solid waste incineration fly ash under medium temperature. Chinese Journal of Environmental Engineering, 18(09):2550–2555.

Wu H and Ting Y. (2005). Metal extraction from municipal solid waste (MSW) incinerator fly ash—Chemical leaching and fungal bioleaching. Enzyme and Microbial Technology, 38(6): 839–847. https://doi.org/10.1016/j.enzmictec.2005.08.012

Wu K, Shi H, De Schutter G, et al. (2011). Preparation of alinite cement from municipal solid waste incineration fly ash. Cement and Concrete Composites, 34(3): 322–327. https://doi.org/10.1016/j.cemconcomp.2011.11.016

Wu K, Shi H, De Schutter G, et al. (2012). Experimental study on alinite ecocement clinker preparation from municipal solid waste incineration fly ash. Materials and Structures, 45(8): 1145–1153. https://doi.org/10.1617/s11527-012-9822-5

Wu L M and Ren X. (2020). Effects of domestic waste incineration fly ash on the characterization of cement stabilized macadam. Shandong Jiaotong Keji, (01): 41–43+55.

Wu S Y. (2024). Study on solidification mechanism and working performance of heavy metals in fly ash based backfill of municipal solid waste incineration. Fuxin: Liaoning Technical University.

Wu S, Xu Y, Sun J, et al. (2015). Inhibiting evaporation of heavy metal by controlling its chemical speciation in MSWI fly ash. Fuel, 158: 764–769. https://doi.org/10.1016/j.fuel.2015.06.003

Wungsumpow C, Pochalard S, Piriyakul K. (2025). Utilizing fly ash from municipal solid waste and polypropylene fiber to improve the flexural properties of compacted cement sand. Discover Sustainability, 6(1): 726. https://doi.org/10.1007/s43621-025-01626-7

Wunsch P, Greilinger C, Bieniek D, et al. (1996). Investigation of the binding of heavy metals in thermally treated residues from waste incineration. Chemosphere, 32(11): 2211–2218. https://doi.org/10.1016/0045-6535(96)00123-3

Xi Z M. (2022). Application and research of waste incineration in ultra-high-performance concrete. Zhengzhou: Henan University of Technology.

Xia DZ. (2015). Research on stabilization of heavy metals in MSWI fly ash through segmented hydrothermal treatment. Wuhan: Huazhong University of Science & Technology.

Xia M and Wang Q Q. (2022). Study on the erosion of refractory materials by municipal solid waste incineration fly ash and CaO. Refractories, 56(06): 519–522.

Xiang Y X. (2023). Study on gaseous pollutants generation characteristics of MSWI fly ash and solid wastes of steel smelting with collaborative thermal treatment. Nanjing: Southeast University.

Xie C J, Hou Y J, Ma L J, et al. (2023). Research progress on harmless and resource treatment of MSW fly ash. Applied Chemical Industry, 52(06): 1896–1901.

Xie C J. (2023). Study on microwave-hydrothermal treatment of MSW incineration fly ash and its adsorption performance. Shijiazhuang: Hebei University of Science and Technology.

Xie J X, Yin J, Chen J J, et al. (2010). Study on solidification of municipal solid waste incineration fly ash by geopolymer. Chinese Journal of Environmental Engineering, 4(04): 935–939.

Xie Q L, Wang D D, Liang G J, et al. (2022). Separation of inorganic chlorine salts from municipal solid waste incineration fly ash. Mining and Metallurgical Engineering, 42(01): 81–84+89.

Xie S H. (2022). Study on the performance of municipal solid waste incineration (MSWI) fly ash bricks based on bacteria mineralization to recycle MSWI fly ash. Taiyuan: Taiyuan University of Technology.

Xie S X, Kang C X, Xiong J, et al. (2024). Analysis of physicochemical characteristics and heavy metal speciation of incineration fly ash from a municipal solid waste incineration plant in East China. Journal of Pingxiang University, 41(06): 107–112.

Xie Y and Zhu J. (2013). Leaching toxicity and heavy metal bioavailability of medical waste incineration fly ash. Journal of Material Cycles and Waste Management, 15: 440–448. https://doi.org/10.1007/s10163-013-0133-x

Xiong Y, Zhu F, Zhao L, et al. (2014). Heavy metal speciation in various types of fly ash from municipal solid waste incinerator. Journal of Material Cycles and Waste Management, 16: 608–615. https://doi.org/10.1007/s10163-014-0274-5

Xu P C, Hu M, Xu J Y, et al. (2022). Study on the transformation characteristics of chlorine during plasma vitrification of municipal solid waste incineration fly ash. Journal of Engineering Thermophysics, 43(07): 1969–1975.

Xu P, Zhao Q L, Qiu W. (2020). Environmental safety assessment of alkali-activated bricks produced by waste incineration fly ash. Journal of Harbin Institute of Technology, 52(11): 40-45.

Xu P, Zhao Q, Qiu W, et al. (2019). Microstructure and strength of Alkali-Activated bricks containing municipal solid waste incineration (MSWI) fly ash developed as construction materials. Sustainability, 11(5): 1283. https://doi.org/10.3390/su11051283

Xu S S, Liu Y T, Liu D, et al. (2024). Experimental study on stabilization of heavy metals in solidified body of municipal solid waste incineration fly ash. Guangzhou Chemical Industry, 52(22): 138–140+196.

Xu T, Wang L, Zeng Y, et al. (2018). Characterization of typical heavy metals in pyrolysis MSWI fly ash. Environmental Technology, 40(26): 3502–3511. https://doi.org/10.1080/09593330.2018.1480663

Xu W H, Fu P F, Fang G W, et al. (2021). Study on the performance of metallurgical slag-based cementitious material for solidification of municipal solid waste incineration fly ash. Conservation and Utilization of Mineral Resources, 41(03): 10–16.

Xue C. (2021). Study on the optimization of solidification/stabilization treatment process of lead and cadmium in municipal solid waste incineration fly ash and stability effects. Shanghai: East China University of Science and Technology.

Xue J, Wang W, Wang Q, et al. (2010). Removal of heavy metals from municipal solid waste incineration (MSWI) fly ash by traditional and microwave acid extraction. Journal of Chemical Technology & Biotechnology, 85(9): 1268–1277. https://doi.org/10.1002/jctb.2426

Yan D, Peng Z, Yu L, et al. (2018). Characterization of heavy metals and PCDD/Fs from water-washing pretreatment and a cement kiln co-processing municipal solid waste incinerator fly ash. Waste Management, 76: 106–116. https://doi.org/10.1016/j.wasman.2018.03.006

Yan J H, Li J X, Chi Y, et al. (2004). Characteristic analysis of heavy metals evaporation of MSWI fly ash. Environmental Science, (02): 170–173. https://doi.org/10.13227/j.hjkx.2004.02.035.

Yan J H, Peng W, Li X D, et al. (2004). Leaching characteristics of heavy metals in municipal solid waste incineration fly ash. Journal of Fuel Chemistry and Technology, (01): 65–68.

Yang C N, Zhang J B, Qu J S, et al. (2020). Research on physicochemical characteristics and leaching toxicity of fly ash from a MSW incinerator in Northwest China. Clean Coal Technology, 26(06): 64–69. https://doi.org/10.13226/j.issn.1006-6772.EP20082401.

Yang F L, Li P F, Ren L, et al. (2021). Influence of ultra-high temperature plasma gasification and melting on municipal solid waste incineration fly ash. Clean Coal Technology, 27(03): 268–274. https://doi.org/10.13226/j.issn.1006-6772.20090801.

Yang G Y, Ren Q Q, Li P P, et al. (2022). Co-melting characteristics of MSWI fly ash and rice husk ash. Journal of Combustion Science and Technology, 28(05): 617–624.

Yang J, Xiao B, Boccaccini A R. (2009). Preparation of low melting temperature glass–ceramics from municipal waste incineration fly ash. Fuel, 88(7): 1275–1280. https://doi.org/10.1016/j.fuel.2009.01.019

Yang W C. (2023). Microwave hydrothermal dechlorination coupled with geopolymer solidification for disposal of municipal solid waste incineration fly ash and durability assessment. Shenzhen: Shenzhen University.

Yang Y and Kong Z J. (2019). Study and practice on stabilization technology of the treatment of fly ash from MSW incineration by chelating agent. Energy Saving of Nonferrous Metallurgy, 35(04): 55–59.

Yang Z, Ji R, Liu L, et al. (2017). Recycling of municipal solid waste incineration by-product for cement composites preparation. Construction and Building Materials, 162: 794–801. https://doi.org/10.1016/j.conbuildmat.2017.12.081

Yao Q M. (2025). Research on the effects of co-melting characteristics of municipal solid waste incineration fly ash and fine slag from coal gasification/coal gangue. Huainan: Anhui University of Science and Technology.

Yao Q. (2024). One-step synthesis of zeolite by mechanochemical method of fly ash and its life cycle assessment. Hangzhou: Zhejiang University.

Yao R X. (2021). Study on dechlorination pretreatment of MSWI fly ash with the purpose of promoting its resource utilization. Chongqing: Chongqing University.

Ye G, Deng Y Q, Wu H, et al. (2023). Solidification of heavy metals in waste incineration fly ash by sodium sulfide ball milling reaction. Non-Metallic Mines, 46(01): 40–42+46.

Ye N, Chen Y, Yang J, et al. (2016). Co-disposal of MSWI fly ash and Bayer red mud using an one-part geopolymeric system. Journal of Hazardous Materials, 318: 70–78. https://doi.org/10.1016/j.jhazmat.2016.06.042

Ye S, Yong R O, Kouk Q Y, et al. (2024). Accelerated carbonation of incineration fly ash (IFA) and its impact on inhibiting heavy metals leaching and removal of soluble salts. Waste Management Bulletin, 2(2): 153–160. https://doi.org/10.1016/j.wmb.2024.04.005

Ye T M, Wang W, Gao X B, et al. (2007). Characterization and heavy metals leaching toxicity of fly ash from municipal solid waste incinerators in China. Environmental Science, (11): 2646–2650. https://doi.org/10.13227/j.hjkx.2007.11.030.

Yi L S, Liu T, Wu Q, et al. (2021). Preparation of porous thermal insulation material with MSWI fly ash and coal ash. Mining and Metallurgical Engineering, 41(01): 124–127.

Yu F. (2024). Preparation and failure characteristics of waste incineration fly ash based paste filling material and application. Fuxin: Liaoning Technical University.

Yu J, Sun L, Xiang J, et al. (2013). Physical and chemical characterization of ashes from a municipal solid waste incinerator in China. Waste Management & Research, 31(7): 663–673. https://doi.org/10.1177/0734242x13485793

Yu L, Xie Y D, Ji H B, et al. (2016). Influence of heavy metal leaching in domestic garbage fly ash. Environmental Science and Management, 41(08): 107–110.

Yu S, Du B, Baheiduola A, et al. (2020). HCB dechlorination combined with heavy metals immobilization in MSWI fly ash by using n-Al/CaO dispersion mixture. Journal of Hazardous Materials, 392: 122510. https://doi.org/10.1016/j.jhazmat.2020.122510

Yuan B, Hu H, Huang Y, et al. (2022). Effect of hydrated lime on the migration behavior of selenium in the MSWI plants: Experimental and theoretical study. Chemical Engineering Journal, 433: 134603. https://doi.org/10.1016/j.cej.2022.134603

Yuan Q, Robert D, Mohajerani A, et al. (2022). Utilisation of waste-to-energy fly ash in ceramic tiles. Construction and Building Materials, 347: 128475. https://doi.org/10.1016/j.conbuildmat.2022.128475

Yuan R, Fan X, Gan M, et al. (2023). Facile treatment of municipal solid waste incineration fly ash by one-step microwave hydrothermal method: Hazards detoxification and tobermorite synthesis. Journal of Environmental Chemical Engineering, 11(3): 109768. https://doi.org/10.1016/j.jece.2023.109768

Yuan S. (2013). Study on the leaching of heavy metals of solid waste incineration fly ash. Chongqing: Chongqing University.

Yuan Z P, Li X Y, Chen Q Y, et al. (2012). Geopolymerisation of municipal solid waste incineration fly ash and solidification of heavy metals. Environmental Engineering, 30(06): 91–94+7. https://doi.org/10.13205/j.hjgc.2012.06.029.

Yue S Y. (2023). Changes in the occurrence characteristics of incineration fly ash heavy metals in the low-temperature flue gas purification process. Guangzhou: South China University of Technology.

Záleská M, Pavlík Z, Pavlíková M, et al. (2025). Towards immobilization of heavy metals in low-carbon composites based on magnesium potassium phosphate cement, diatomite, and fly ash from municipal solid waste. Construction and Building Materials, 470: 140621. https://doi.org/10.1016/j.conbuildmat.2025.140621

Zhai J, Burke I T, Stewart D I. (2021). Beneficial management of biomass combustion ashes. Renewable and Sustainable Energy Reviews, 151: 111555. https://doi.org/10.1016/j.rser.2021.111555

Zhan X and Kirkelund G M. (2021). Electrodialytic remediation of municipal solid waste incineration fly ash as pre-treatment before geopolymerisation with coal fly ash. Journal of Hazardous Materials, 412: 125220. https://doi.org/10.1016/j.jhazmat.2021.125220

Zhan X, Wang L, Hu C, et al. (2018). Co-disposal of MSWI fly ash and electrolytic manganese residue based on geopolymeric system. Waste Management, 82: 62–70. https://doi.org/10.1016/j.wasman.2018.10.014

Zhang B, Zhou W, Zhao H, et al. (2016). Stabilization/solidification of lead in MSWI fly ash with mercapto functionalized dendrimer Chelator. Waste Management, 50: 105–112. https://doi.org/10.1016/j.wasman.2016.02.001

Zhang C and Wang S. (2019). Experimental study on melting treatment of fly ash from MSW incineration. Journal of Liaoning Shihua University, 39(06): 31–35.

Zhang C F, Hu Y T, Zhang J D, et al. (2022). Study on the effect of mineral compositions on the melting characteristics of fly ash from MSW incineration. Environmental Sanitation Engineering, 30(06): 64–69.

Zhang C F, Zhu B F, Hu Y T, et al. (2022). Study on basic physical and chemical characteristics of fly ashes from two municipal solid waste incinerators. Environmental Science and Technology, 35(05): 8–13.

Zhang C P, Qian K Z, Liu Z J, et al. (2023). Characteristics of bottom residue and heavy metal solidification of fly ash from domestic waste incineration after co-incineration of organic industrial waste. Guangzhou Chemical Industry, 51(08):134–136.

Zhang D S, Wang J, Yue Z B, et al. (2024). Experimental study on preparation of lightweight low-silicon-aluminum ceramsite from municipal solid waste incineration fly ash in conjunction with bottom ash. Environmental Pollution and Control, 46(01):32–37.

Zhang F, Wang F H, Hao H T, et al. (2014). Research on solidification and stability of heavy metals in municipal solid waste incineration fly ash by using SGA. Chinese Journal of Environmental Engineering, 8(02): 709–715.

Zhang H S. (2022). Study on preparation and properties of geopolymer composites containing municipal solid waste incineration fly ash. Zhengzhou: Zhengzhou University.

Zhang H Y. (2023). Study on mineralogical component and phase transformation of sintered brick made with MSWI fly ash as an admixture. Journal of Applied Technology, 23(03): 227–231.

Zhang H, Zhao Y, Qi J. (2006). Study on use of MSWI fly ash in ceramic tile. Journal of Hazardous Materials, 141(1): 106–114. https://doi.org/10.1016/j.jhazmat.2006.06.100

Zhang J Z. (2023). Preparation of iron-containing sulfoaluminate cementitious materials via multi-phase cooperative strengthening pretreatment of waste incineration fly ash. Jinan: Shandong University.

Zhang J, Mao Y, Wang W, et al. (2022). A new co-processing mode of organic anaerobic fermentation liquid and municipal solid waste incineration fly ash. Waste Management, 151: 70–80. https://doi.org/10.1016/j.wasman.2022.07.016

Zhang J, Zhang H, Yuan C, et al. (2023). Chelating effect of heavy metals in MSWI fly ash with several kinds of stabilizing agents. Environmental Engineering, 41(S1): 430–434.

Zhang L, Su X, Zhang Z, et al. (2014). Characterization of fly ash from a circulating fluidized bed incinerator of municipal solid waste. Environmental Science and Pollution Research, 21: 12767–12779. https://doi.org/10.1007/s11356-014-3241-9

Zhang M, Guo M, Zhang B, et al. (2020). Stabilization of heavy metals in MSWI fly ash with a novel dithiocarboxylate-functionalized polyaminoamide dendrimer. Waste Management, 105: 289–298. https://doi.org/10.1016/j.wasman.2020.02.004

Zhang N T. (2024). Study on the hydration and microstructure of solid waste-based non-sintered ceramsite. Qinhuangdao: Yanshan University.

Zhang P, Peng L, Tian W, et al. (2023). Pollution characteristics of heavy metals in treatment products of municipal solid waste incineration fly ash and environmental risk assessment. Environmental Science and Management, 48(11): 189–194.

Zhang Q, Tian K, Yue Y P, et al. (2019). Preparation of waste incineration fly ash reference material for analysis of heavy metal elements. Environmental Chemistry, 2019, 38(12):2682–2689.

Zhang R C. (2022). Leaching behavior of chlorine and heavy metals during carbonated washing of MSWI fly ash. Changsha: Central South University.

Zhang S, Ghouleh Z, Shao Y. (2020). Use of eco-admixture made from municipal solid waste incineration residues in concrete. Cement and Concrete Composites, 113: 103725. https://doi.org/10.1016/j.cemconcomp.2020.103725

Zhang T. (2022). Study on the effect and influencing mechanism of water washing and hydrothermal oxidation treatment of municipal solid waste incineration fly ash. Nanjing: Nanjing Normal University.

Zhang W, Xie G, Hu J, et al. (2023). Hazardous wastes used as hybrid precursors for geopolymers: Cosolidification/stabilization of MSWI fly ash and Bayer red mud. Chemical Engineering Journal, 474: 145966. https://doi.org/10.1016/j.cej.2023.145966

Zhang Y X, Lu Q M, Wang Z, et al. (2022). Experimental research on microwave sintering behavior of composite waste incineration ash. Environmental Pollution and Control, 44(07): 862–867+872.

Zhang Y X, Wang Z, Lu Q M, et al. (2024). Experimental research on the preparation of expansion cementitious materials using municipal solid waste incineration fly ash. Journal of Environmental Engineering Technology, 14(02): 538–544.

Zhang Y, Cetin B, Likos W, et al. (2016). Impacts of pH on leaching potential of elements from MSW incineration fly ash. Fuel, 184: 815–825. https://doi.org/10.1016/j.fuel.2016.07.089

Zhang Y, Huang T, Huang X, et al. (2017). Study on electro-kinetic remediation of heavy metals in municipal solid waste incineration fly ash with a three-dimensional electrode. RSC Advances, 7(45): 27846–27852. https://doi.org/10.1039/c7ra01327b

Zhang Y, Zhu X, Ma B, et al. (2024). Insights into microstructural alterations in alkali-activated materials incorporating municipal solid waste incineration fly ash. Construction and Building Materials, 425: 136129. https://doi.org/10.1016/j.conbuildmat.2024.136129

Zhang Y. (2005). The leaching behavior of heavy metals from MSWI fly ash and experimental study on solidification of MSWI fly ash. Hangzhou: Zhejiang University.

Zhang Y. (2016). Experimental study on fly ash characteristics and chemical stabilization of waste power plant in Kaifeng City . Kaifeng: Henan University.

Zhang Z K, Wang J, Li H T, et al. (2019). Water-washing dechlorination and cement solidification of municipal solid waste incineration fly ash. Science Technology and Engineering, 19(35): 395–401.

Zhao A R. (2021). Study on the characteristics of improved reaction during melting of municipal solid waste incineration fly ash with solid waste. Beijing: University of Chinese Academy of Sciences (Institute of Engineering Thermophysics).

Zhao C D, Guan Y Y, Zhang Z, et al. (2023). Effect of fly ash incorporation on hydration mechanism and heavy metal solidification/stabilization effect of slag-based backfilling cementitious materials. Environmental Engineering, 41(12): 213–220+189. https://doi.org/10.13205/j.hjgc.202312026.

Zhao F W, Ma X D, Da Y Q, et al. (2023). Physicochemical characteristics and heavy metal leaching toxicity of incineration fly ash from different waste incinerators. Clean Coal Technology, 29(S2): 524–529. https://doi.org/10.13226/j.issn.1006-6772.22091301.

Zhao G J, Gong B X, Cao X Y, et al. (2005). Study on melting characteristics of MSWI fly ash. Acta Scientiae Circumstantiae, (05):670–674. https://doi.org/10.13671/j.hjkxxb.2005.05.018.

Zhao G J, Li H B, Zhao Z L, et al. (2005). Study on basic characteristics of municipal solid waste incineration fly ash. Journal of Fuel Chemistry and Technology, (02): 184–188.

Zhao H. (2022). Mechanism of chlorine and heavy metals removing from municipal solid waste incineration fly ash by electric field enhanced washing . Mianyang: Southwest University of Science and Technology.

Zhao M M, Lang Z X, Liu Y F, et al. (2024). Direct wet mineralization and carbon sequestration performance of municipal solid waste incineration fly ash. Petroleum Processing and Petrochemicals, 55(04):95–104.

Zhao S, Gong L, Guo G, et al. (2023).Selenium leaching behaviors from MSWI fly ash and its control. Journal of Industrial and Engineering Chemistry, 134: 163–168. https://doi.org/10.1016/j.jiec.2023.12.047

Zhao S, Liu B, Ding Y, et al. (2020). Study on glass-ceramics made from MSWI fly ash, pickling sludge and waste glass by one-step process. Journal of Cleaner Production, 271: 122674. https://doi.org/10.1016/j.jclepro.2020.122674

Zhao S, Muhammad F, Yu L, et al. (2019). Solidification/stabilization of municipal solid waste incineration fly ash using uncalcined coal gangue–based alkali-activated cementitious materials. Environmental Science and Pollution Research, 26(25): 25609–25620. https://doi.org/10.1007/s11356-019-05832-5

Zhao S, Zhang S, Liang X, et al. (2024). Transformation and environmental chemical characteristics of hazardous trace elements in an 800 t/d waste incineration thermal power plant. The Science of the Total Environment, 918: 170693. https://doi.org/10.1016/j.scitotenv.2024.170693

Zhao X, Li J, Huang Y, et al. (2015). Partitioning characteristics of nine heavy metals in a municipal solid waste incinerator in Guangdong. Environmental Pollution and Control, 37(06): 18–23.

Zhao Y X, She K L, Yao G Y, et al. (2022). Analysis of the leaching effect of heavy metals from fly ash under different leaching standards. Journal of Jilin Jianzhu University, 39(06): 41–46.

Zhao Y, Song L, Li G. (2002). Chemical stabilization of MSW incinerator fly ashes. Journal of Hazardous Materials, 95(1-2): 47–63. https://doi.org/10.1016/s0304-3894(02)00002-x

Zheng P, Liu J G, Liu F, et al. (2007). Effects of phosphoric acid washing on immobilization of heavy metals in municipal solid waste incineration fly ash. Chinese Journal of Environmental Engineering, (01): 121–125.

Zheng Y, Li J J, Zhang Y F, et al. (2024). Heavy metal leaching toxicity of typical grate furnace/fluidized bed furnace waste incineration fly ash and their chelated products. Chemical Industry and Engineering Progress, 43(03):1630–1636. https://doi.org/10.16085/j.issn.1000-6613.2023-0502.

Zhong S, Wang L A, Liu Y Y, et al. (2009). Kinetics of concentrated phosphates removal by municipal solid waste incineration fly ash. Journal of Civil and Environmental Engineering, 31(05): 117–121.

Zhou M, Yang J K, Xiao M D, et al. (2007). Study on leaching properties and immobilization of municipal solid waste incineration fly ash. Chinese Journal of Environmental Engineering, (02): 119–123.

Zhou Q. (2023). Synthesis of Na-P1 zeolite from MSWI fly ash by microwave-assisted hydrothermal method and adsorption capacity of the product . Hangzhou: Zhejiang University.

Zhou R C and Lü S J. (2023). Study on melting characteristics of domestic garbage and hazardous waste incineration fly ash and their coupling under oxygen-enriched atmosphere. Energy Conservation Technology, 41(04): 345–348.

Zhou S S. (2024). Study on municipal solid waste incineration fly ash treated by melting and vacuum melting . Mianyang: Southwest University of Science and Technology.

Zhou X, Hu B, Tong J, et al. (2020). Mechanism of heavy metal stabilization by red mud-based geopolymer. Chinese Journal of Geotechnical Engineering, 42(S1): 239–243.

Zhu J M, Li M Y, Zheng D C, et al. (2018). Distribution and chemical stabilization of heavy metals in municipal solid waste incineration fly ash of Chongqing. Environmental Chemistry, 37(04): 880–888.

Zhu J, Zhao L, Chen M, et al. (2011). Removal of heavy metals from hazardous waste incinerator fly ash by vacuum-aided heat treatment. Environmental Engineering Science, 28(10): 743–748. https://doi.org/10.1089/ees.2010.0314

Zhu L X, Cai J J, Wu H, et al. Effects of slaked lime on heavy metal stabilization in municipal solid waste incineration fly ash. Energy Environmental Protection, 1–11. https://doi.org/10.20078/j.eep.20250209.

Zhu S H. (2023). Experimental study on the effect of chloride ions in fly ash from domestic waste incineration in Lhasa on ceramic granules. Lhasa: Tibet University.

Zhu X L and Shi J Y. (2023). Study on hydration heat generation of municipal solid waste incineration fly ash. China Energy and Environmental Protection, 45(03): 183–187+193.

Zhu Y X, Ye Z, Ren L W, et al. (2023). Study on ceramsite sintering from municipal solid waste incineration fly ash combined with construction waste soil. Environmental Engineering, 41(12): 206–212+130. https://doi.org/10.13205/j.hjgc.202312025.

Zhu Y X. (2023). Research on harmless treatment of MSWI fly ash by wet pretreatment combined with sintering and mechanical milling. Hangzhou: Zhejiang University.

Zhu Z, Guo Y, Zhao Y, et al. (2022).Carbon reclamation from biogas plant flue gas for immobilizing lead and neutralizing alkalis in municipal solid waste incineration fly ash. Chemical Engineering Journal, 435: 134812. https://doi.org/10.1016/j.cej.2022.134812

Zimar Z, Robert D, Giustozzi F, et al. (2024). Use of industrial wastes for stabilizing expansive clays in pavement applications: durability and microlevel investigation. Acta Geotechnica, 19(9): 6259–6287. https://doi.org/10.1007/s11440-024-02298-9

Zimar Z, Robert D, Sidiq A, et al. (2022). Waste-to-energy ash for treating highly expansive clays in road pavements. Journal of Cleaner Production, 374: 133854. https://doi.org/10.1016/j.jclepro.2022.133854

Zucha W, Weibel G, Wolffers M, et al. (2020). Inventory of MSWI fly ash in Switzerland: Heavy metal recovery potential and their properties for acid leaching. Processes, 8(12): 1668. https://doi.org/10.3390/pr8121668