

**Supplemental Information:****Table S1 XRF measures fly ash composition after alkaline washing (wt%)**

<b>Sample number</b>	<b>SiO<sub>2</sub></b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>K<sub>2</sub>O</b>	<b>TiO<sub>2</sub></b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>CaO</b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>MnO</b>
FA-1-1	57.390	30.530	3.580	2.250	0.857	2.100	1.440	1.230	0.149	0.036
FA-1-2	56.700	29.790	3.510	2.480	0.825	2.890	1.420	1.190	0.144	0.034
FA-1-3	56.200	30.270	3.630	2.470	0.828	2.940	1.380	1.230	0.156	0.035
FA-1-4	56.510	30.090	3.750	2.500	0.842	2.680	1.340	1.240	0.153	0.036
FB-1-1	48.650	30.170	1.980	1.390	0.904	1.100	0.539	0.498	0.042	0.014
FB-1-2	45.610	29.440	1.760	1.440	0.869	1.050	0.501	0.439	0.040	0.013
FB-1-3	49.780	33.290	2.040	3.500	0.967	3.950	0.562	0.495	0.046	0.013
FB-1-4	46.230	31.500	2.030	5.040	0.935	7.230	0.546	0.473	0.044	0.013

**Table S2 The Cs<sup>+</sup> removal ratio and magnetized zeolite recovery ratio**

Magnetized zeolite recovery ratio: $W_r / W_0$ (%)			
	Coarse soil	Medium soil	Fine soil
Coarse zeolite (1-3 mm)	95.09	94.55	96.36
Medium zeolite (60-80 mesh)	92.00	90.46	77.55
Fine zeolite (120 mesh)	89.82	66.19	85.36
Cs <sup>+</sup> removal ratio ( $g/g$ , $C_{Cs}$ ) (%)			
	Coarse soil	Medium soil	Fine soil
Coarse zeolite (1-3 mm)	99.84	99.8	99.63
Medium zeolite (60-80 mesh)	99.91	99.92	99.87
Fine zeolite (120 mesh)	99.48	99.74	99.7

**Table S3 The Cs<sup>+</sup> removal efficiency compare to literature**

	method	Cs concentration	Addition ratio	Cs removal efficiency (%)	reference
1	PEI-Fe <sub>3</sub> O <sub>4</sub>	1630 Bq/kg	0.015:1	73.5	Kim (2021)
2	aminopolycarboxylate chelators (APCs)	40mg/kg	10:1	46	Sawai (2017)
3	washing-electrokinetic	10 Bq/kg	-	97.4	Kim (2012)
4	weathered biotite	-	-	45	Honda (2017)
5	Indian mustard	13.4 Bq/kg	-	50	Fuhrmann (2002)
6	K based washing	1.47 mg/kg	20:1	81.3	Song(2023)
7	hydrothermal treated clay	269 mmol/kg		96	Yin (2018)
8	PB/Fe <sub>3</sub> O <sub>4</sub> /GO	-	-	80	Yang (2014)
9	supercritical CO <sub>2</sub>	-	-	95	Leybros (2016)
10	A.Thiooxidans sp bacteria	-	-	96	kim (2021)
11	magnetized zeolite (current study)	10 mg/g	0.5:1	99.92	Zhang (2023)