Supplementary Data

This supplementary data is a part of a paper entitled "Preliminary Study on Leaching Capacity of Rare Earth Elements from Coal Fly Ash by Using Citric Acid Solution".

Data Read by ICP-OES on Cerium

The ICP-OES readings on cerium content in the nine data discussed in the paper can be seen in Table S1 below. The sample codes in Tables S1, S2, and S3 follow the X; Y; Z format, with X meaning the concentration of citric acid used in each running (in mol/L); Y meaning the liquid-to-solid (L/S) ratio used in each running (in mL/g); and Z meaning the temperature of the running (in °C).

Table S1. ICP-OES readings on cerium content in the nine samples

Sample codes	Cerium concentration (ppm)
0.01;5;30	0.024
0.01;10;30	0.024
0.01;15;30	0.017
0.01;5;50	0.027
0.01;10;50	0.026
0.01;15;50	0.021
0.01;5;80	0.035
0.01;10;80	0.048
0.01;15;80	0.036

About the sample codes, they are formatted as concentration of citric acid used (in mol/L); pulp density (in mL/g); temperature (in °C). The data read on the ICP-OES had been previously diluted 10 times with WaterOne.

Dilution Process

The samples that are shown in Table S1 are samples that were previously diluted ten times. The dilution process could be analyzed with Eq. (S1).

$$M_{diluted} \cdot V_{diluted} = C_{Ce,supernantant} \cdot V_{supernatant} \quad (S1)$$

Eq. (S1) explains the dilution process with WaterOne, as WaterOne is presumed to have zero concentration of rare earth elements (including cerium). $M_{diluted}$ is concentration of cerium in diluted samples in mg/L (written on Table (S1)), $V_{diluted}$ is the volume of diluted sample (presumed as 10 mL). $C_{Ce,supernatant}$ is concentration of cerium in concentrated samples in mg/L and $V_{supernatant}$ is the volume of concentrated sample (presumed as 1 mL). Concentrated sample is the liquid sample that was taken from leaching process, then centrifuged to take the supernatant, and the supernatant was later to be filtered and sampled

Leaching Capacity

Leaching capacity could be counted with equation (5) in the main article, thus the equation will not be written here. Aside of knowing the supernatant cerium concentration of the samples, amount of fly ash used in the leaching process should be known. The amount of fly ash could be seen on Table S2.

Table S2. Mass of fly ash used in each of the sample codes' run

Sample codes	Fly ash mass (g)
0.01;5;30	10.0173
0.01;10;30	5.0038
0.01;15;30	3.3340
0.01;5;50	10.0125
0.01;10;50	5.0062
0.01;15;50	3.3453
0.01;5;80	10.0106
0.01;10;80	5.0095
0.01;15;80	3.3369

From the data in Tables S1 and S2, with some information on cerium concentration in coal fly ash used and the amount of citric acid solution used in the leaching operation, cerium leaching capacity value could be counted and the counted values could be seen on Table S3.

Table S3. Mass of fly ash used in each of the sample codes' run

Sample codes	Cerium leaching capacity (%)
0.01;5;30	1.26
0.01;10;30	2.52
0.01;15;30	2.51
0.01;5;50	1.44
0.01;10;50	2.76
0.01;15;50	3.22
0.01;5;80	1.92
0.01;10;80	5.40
0.01;15;80	5.94

Example

The sample from a leaching operation that was run at 50 °C with citric acid concentration of 0.01 mol/L and pulp density of 15 mL/g (sample code 0.01;15;50) is used as the example for dilution with WaterOne water below.
Searching the supernatant concentration of sample code 0.01;15;50 with Eq. (S.1)

$M_{diluted} = 0.021\ mg/L$

$V_{diluted} = 10\ mL$

$V_{supernatant} = 1\ mL$

$M_{diluted} \cdot V_{diluted} = C_{Ce,supernatant} \cdot V_{supernatant}$

$0.021.10 = C_{Ce,supernatant} \cdot 1$

$C_{Ce,supernatant} = 0.21\ mg/L$

Searching the leaching capacity of sample code 0.01;15;50 with Eq. (S1)

$C_{Ce,sup\,erna\,tan\,t} = 0.21\ mg / L$

$Vs_{upernatant}$ = 50 mL (as 50 mL of citric acid had been added before the leaching process started, and assumed constant along the leaching process was running)

$V_{sup\,erna\,tan\,t} = 0.05\ L$

$C_{Ce,fly\ ash} = 83\ mg / kg$

$m_{fly\ ash} = 3.3454\ g$

$m_{fly\ ash} = 3.3453 \cdot 10^{-3}\ kg$

$$LC = \frac{(0.34 - 0.031) \cdot (0.05)}{83 \cdot \left(3.3453 \cdot 10^{-3}\right)} \cdot 100\%$$

$LC = 3.22\%$