

Supplementary Material

Characterization and Leaching Kinetics of Rare Earth Elements from Phosphogypsum in Hydrochloric Acid

Qingjun Guan^{1,2*}, **Ying Sui**², **Chufeng Liu**², **Yongjie Wang**², **Chuxiong Zeng**²,
Weijian Yu^{1,2}, **Zhiyong Gao**³, **Zhenyue Zang**^{4*}, and **Ru-an Chi**^{4,5}

¹ Hunan Province Key Laboratory of Coal Resources Clean-Utilization and Mine Environment Protection, Hunan University of Science and Technology, China

² School of Resource Environment and Safety Engineering, Hunan University of Science and Technology, China

³ School of Minerals Processing and Bioengineering, Central South University, China

⁴ School of XingFa Mining Engineering, Wuhan Institute of Technology, China.

⁵ Hubei Three Gorges Laboratory, Yichang 443007, China

Correspondence: guanqingjun1@126.com; zyzxm@wit.edu.cn

S1. The sequential chemical extraction (SCE) results

Table S1-1 Distribution of REEs and calcium in different fractions of the PG sample according to the SCE procedure. Unit: ppm

REEs Fraction	La				Ce				Y			
	Duplicate 1	Duplicate 2	Duplicate 3	Average	Duplicate 1	Duplicate 2	Duplicate 3	Average	Duplicate 1	Duplicate 2	Duplicate 3	Average
Ion-exchangeable	3.5	3.4	3.5	3.5	2.3	2.3	2.4	2.3	5.2	5.0	5.1	5.1
Carbonate	2.1	2.5	2.1	2.2	1.4	1.7	1.4	1.5	3.7	4.6	3.6	4.0
Metal oxide	16.7	18.7	17.1	17.5	9.9	11.2	10.3	10.5	30.3	33.3	29.9	31.2
Organic matter	7.1	7.8	9.7	8.2	4.4	4.8	5.3	4.8	12.0	12.9	15.6	13.5
Residual	13.2	13.4	15.8	14.1	8.5	8.8	9.6	9.0	22.9	23.1	24.8	23.6
Total	42.6	45.7	48.3	45.5	26.5	28.8	29.1	28.1	74.0	78.9	79.1	77.4
Bulk analysis	46.0				32.0				74.0			
R_{SCE}(%)	92.6	99.4	104.9	99.0	82.9	90.0	90.9	87.9	100.0	106.7	106.9	104.5

R_{SCE}(%): recovery of SCE which is calculated by the data of the sum of five forms divided by the bulk chemical analysis result; **The bulk chemical analysis result** was obtained by analyzing the PG solid sample after digestion with the mixed acid through ICP-OES.

Table S1-2 Distribution of REEs and calcium in different fractions of the PG sample according to the SCE procedure. Unit: ppm

Fraction	Nd				Σ REE				Ca			
	Duplicate 1	Duplicate 2	Duplicate 3	Average	Duplicate 1	Duplicate 2	Duplicate 3	Average	Duplicate 1	Duplicate 2	Duplicate 3	Average
Ion-exchangeable	2.1	2.1	2.3	2.2	13.0	12.8	13.3	13.0	21504.1	21147.8	19167.5	20606.5
Carbonate	1.4	1.7	1.6	1.6	8.6	10.5	8.8	9.3	21815.8	22115.7	17870.1	20600.5
Metal oxide	9.6	10.6	10.5	10.2	66.5	73.8	67.8	69.4	11259.7	12172.7	10465.5	11299.3
Organic matter	4.4	4.7	6.1	5.1	27.9	30.2	36.8	31.6	41854.7	43049.7	41194.1	42032.9
Residual	8.1	8.1	10.7	9.0	52.6	53.4	60.9	55.7	126353.4	124593.5	114589.5	121845.5
Total	25.5	27.3	31.1	28.0	168.6	180.7	187.6	179.0	222787.8	223079.3	203286.8	216384.6
Bulk analysis	30.0				182.0				209363.0			
R_{SCE}(%)	85.0	90.9	103.7	93.2	92.7	99.3	103.1	98.3	106.4	106.6	97.1	103.4

R_{SCE}(%): recovery of SCE which is calculated by the data of the sum of five forms divided by the bulk chemical analysis result; **The bulk chemical analysis result** was obtained by analyzing the PG solid sample after digestion with the mixed acid through ICP-OES.

The sequential chemical extraction (SCE) test was repeated three times, and the experimental results were shown as Table S1. The accuracy of the extraction procedure was evaluated by comparing the bulk chemical analysis with the sum of the five individual associations. As shown in Table S1, the recovery of REEs and calcium for the SCE process varied from 82.9% to 106.9%, which was in the acceptable range of 70-130% [1, 2].

References

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2. Fu B.; Liu G.; Sun M.; Hower J.C.; Hu G.; Wu D. A comparative study on the mineralogy, chemical speciation, and combustion behavior of toxic elements of coal beneficiation products. *Fuel* 2018, 228, 297-308.