Supplementary Information

Adsorption of rare earth metals (Sr^{2+} and La^{3+}) from aqueous solution by Mg-aminoclay-humic acid [MgAC-HA] complexes in batch mode

Young-Chul Lee,[a] Arunkumar Rengaraj,[b] Taegong Ryu,[c] Hyun Uk Lee,[d] Ha-Rim An,[d] Kug-Seung Lee,[e] Go-Woon Lee,[e] Jun Yeong Kim,[b] Jungho Ryu,[c] Byoung-Gyu Kim*,[c] and Yun Suk Huh*,[b]

[a]Department of BioNano Technology, Gachon University, 1342 Seongnamdaero, Sujeong-gu, Seongnam-si, Gyeonggi-do 461-701, Republic of Korea

[b]Department of Biological Engineering, College of Engineering, Inha University, Incheon 402-751, Republic of Korea

[c]Mineral Resources Research Division, Korea Institute of Geoscience and Mineral Resources (KIGAM), Daejeon 305-350, Republic of Korea

[d]Advanced Nano-Surface Research Group, Korea Basic Science Institute (KBSI), Daejeon 305-806, Republic of Korea

[e]Pohang Accelerator Laboratory (PAL), Pohang 790-784, Republic of Korea

[f]Quality Management Team, Korea Institute of Energy Research (KIER), 152 Gajeongro, Yuseong-gu, Daejeon 305-343, Republic of Korea

*Corresponding authors:

Dr. Byoung-Gyu Kim, Tel.: +82-42-868-3608, Fax: +82-42-868-3645, Email address: kgbkim@kigam.re.kr (B-G. Kim)

Prof. Yun Suk Huh, Tel.: +82-32-860-9177, Fax: +82-32-872-4046, Email address: yunsuk.huh@inha.ac.kr (Y.S. Huh)

Table S1. Acidic functional groups of [HA] and [MgAC-HA] complexes by titration method.

(0.2g sample)	**Amount of acid pipette**	**Volume of 0.1M NaOH consumed**	**Phenol group (ml)**	**Phenol group (mmol/g)**	**Lactone group (ml)**	**Lactone group (mmol/g)**
[HA] - 0.1 M NaOH		44				
[HA] – 0.1 M Na_2CO_3		53				
[HA] – 0.1 M $NaHCO_3$		57				
			9	2.54	4	8.8
[MgAC-HA] complexes - 0.1 M NaOH	(15 mL) 0.1M HCl	40				
[MgAC-HA] complexes – 0.1 M Na_2CO_3		45				
[MgAC-HA] complexes – 0.1 M $NaHCO_3$		43				
			5	1.1	2	4.4

Table S2 Sr3d binding energy with O and N in Sr^{2+} adsorbed onto [MgAC-HA] complexes.

Sr3d	O		N	
position	134.8	136.8	133.1	135.1
FWHM	1.46	2.5	1.23	2.41
Area	419.8	79.56	536.8	140.82

Table S3 Sr3d binding energy with O and N in mixture of Sr^{2+} and La^{3+} adsorbed onto [MgAC-HA] complexes.

Sr3d	O		N	
position	134.8	136.8	133.2	135.1
FWHM	1.35	2	1.32	2
Area	134.13	10.54	125.81	26.2

Table S4 La3d binding energy with O and N in Sr^{2+} adsorbed onto [MgAC-HA] complexes.

La3d	O		N		Satellite (O)		Satellite (N)	
position	836.2	853.9	835.1	852.1	840.02	857.42	838.4	855.6
FWHM	1.62	2	2.33	2.2	1.62	2	2.33	2.2
Area	67.76	75.34	169.27	266.36	56.99	88.44	258.82	272.16

Table S5 La3d binding energy with O and N in mixture of Sr^{2+} and La^{3+} adsorbed onto [MgAC-HA] complexes.

La3d	O		N		Satellite (O)		Satellite (N)	
position	836.5	853.2	834.9	851.6	839.1	856.2	838.3	855.2
FWHM	2	2.2	1.82	1.42	2	2.2	1.82	1.42
Area	903.95	923.12	1312.62	653.37	1060.07	837.13	745.49	492.39

Table S6 Summary of EXAFS fitting for Sr K-edge and La L3-edge absorption spectra.

Edge element	Sample	Sr-O	N	R (Å)	σ^2 (Å^2)	R-factor (%)
Sr K	Sr^{2+}	Sr-O1	3	2.491(8)	0.007(1)	0.6
		Sr-O2	4	2.643(10)	0.008(1)	
		Sr-Sr1	5	3.864(20)	0.019(5)	
		Sr-Sr2	3	3.986(20)	0.019(5)	
	Mixture of Sr^{2+} and La^{3+}	Sr-O1	4	2.498(3)	0.003(1)	2.4
		Sr-O2	5	2.631(5)	0.004(1)	
		Sr-Sr1	4	3.647(194)	0.036(18)	
		Sr-Sr2	4	3.769(194)	0.036(18)	
La L_3	La^{3+}	La-La	3	2.090(53)	0.015(3)	0.5
		La-O1	5	2.609(15)	0.006(2)	
		La-O2	4	3.267(42)	0.008(4)	
	Mixture of Sr^{2+} and La^{3+}	La-La	3	2.499(83)	0.0350	2.3
		La-O1	5	2.624(38)	0.0130	
		La-O2	4	3.495(45)	0.0197	

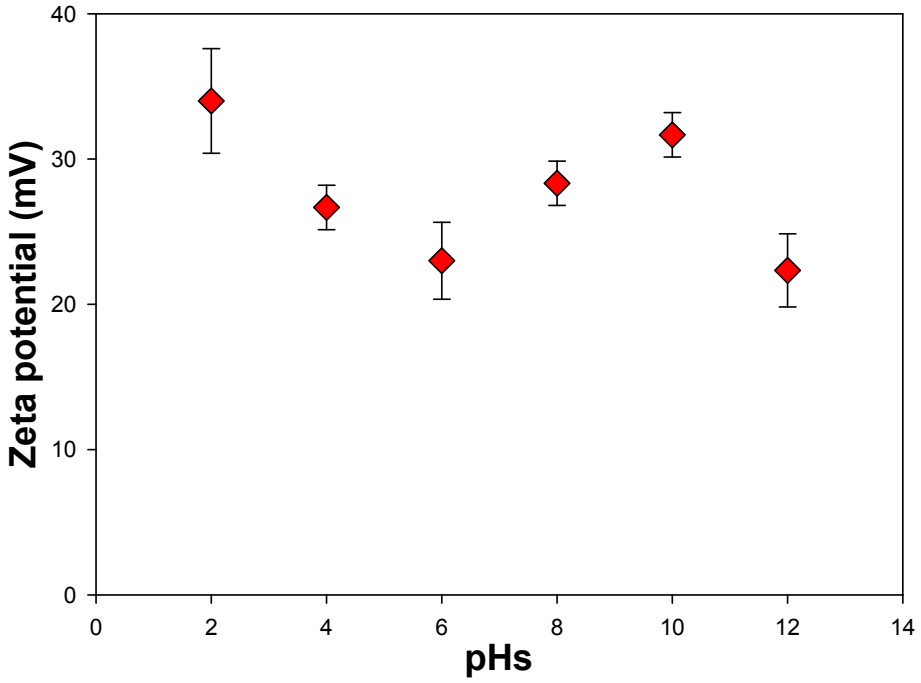

Figure S1. Zeta potential of [MgAC] at 1.0 g/L in aqueous solution according to pHs.

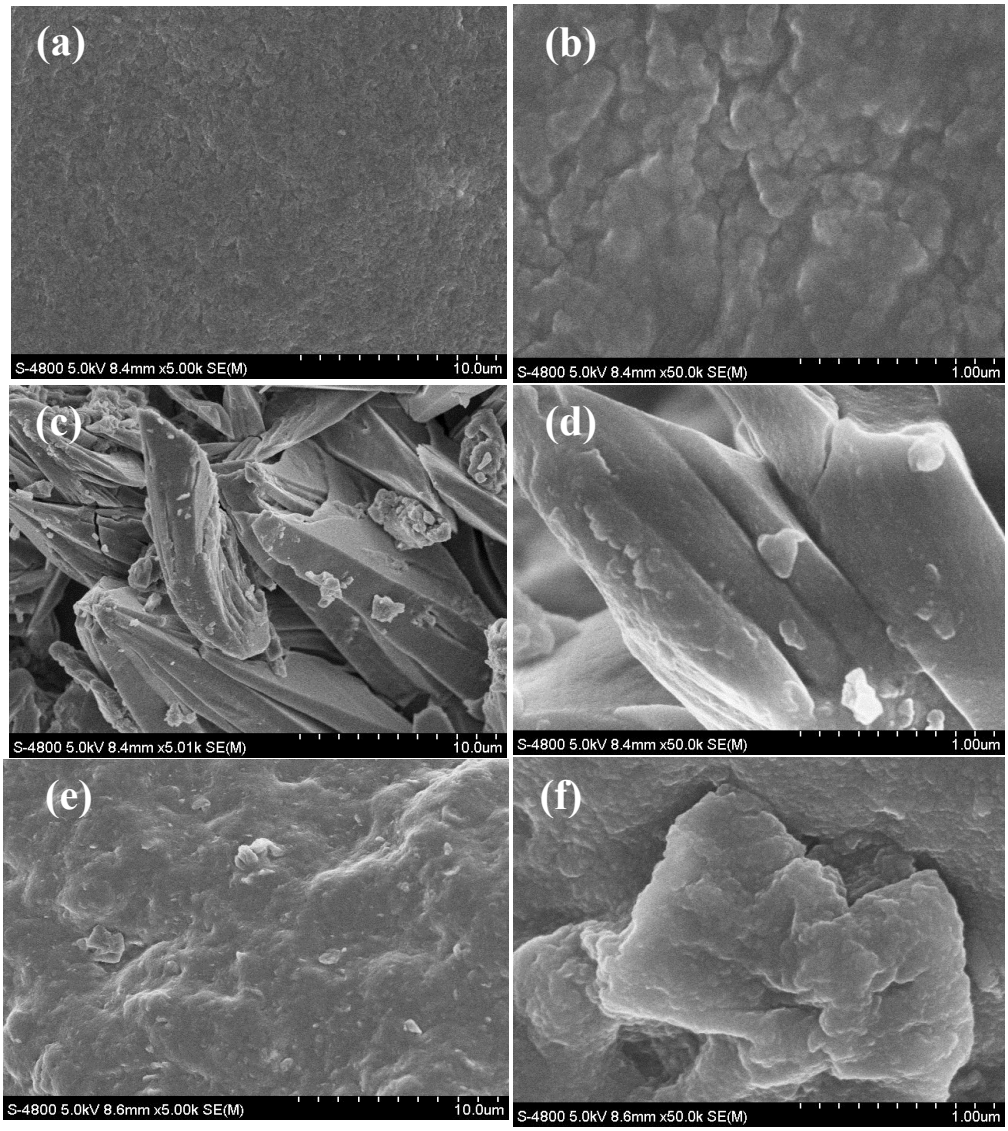

Figure S2. Scanning electron microscopic images of [MgAC] (a, b), [HA] (c, d), and [MgAC-HA] complexes (e, f).

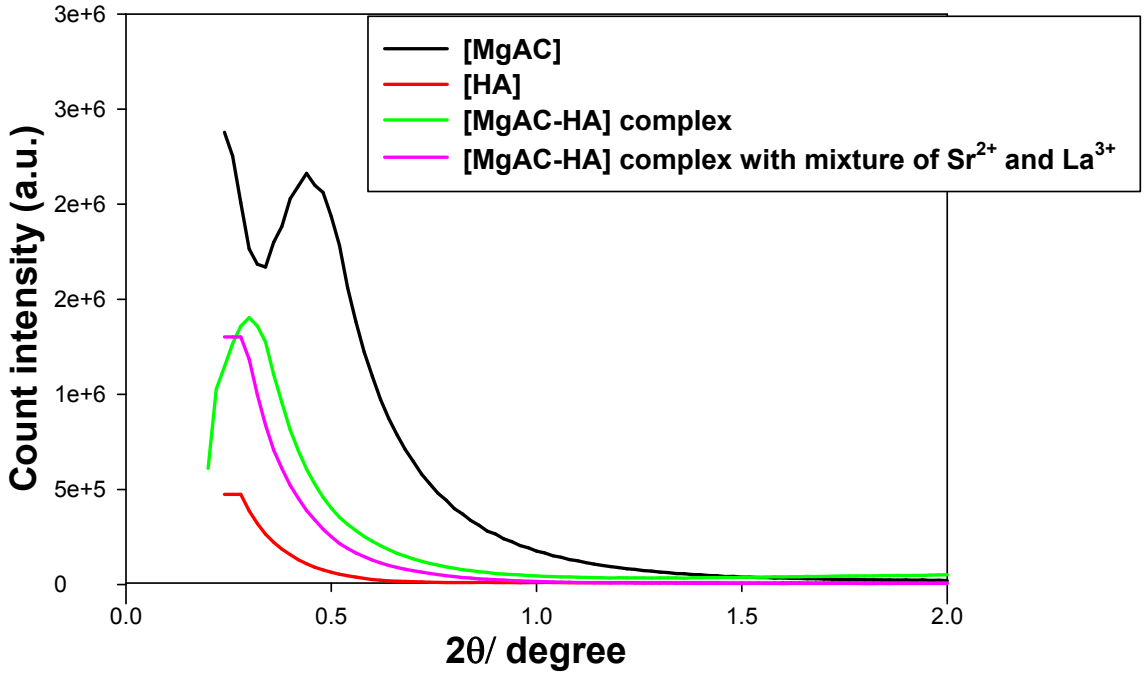

Figure S3. Small angle X-ray scattering (SAXS) spectra of [MgAC], [HA], [MgAC-HA] complexes, and [MgAC-HA] complexes with mixture of Sr^{2+} and La^{3+}.

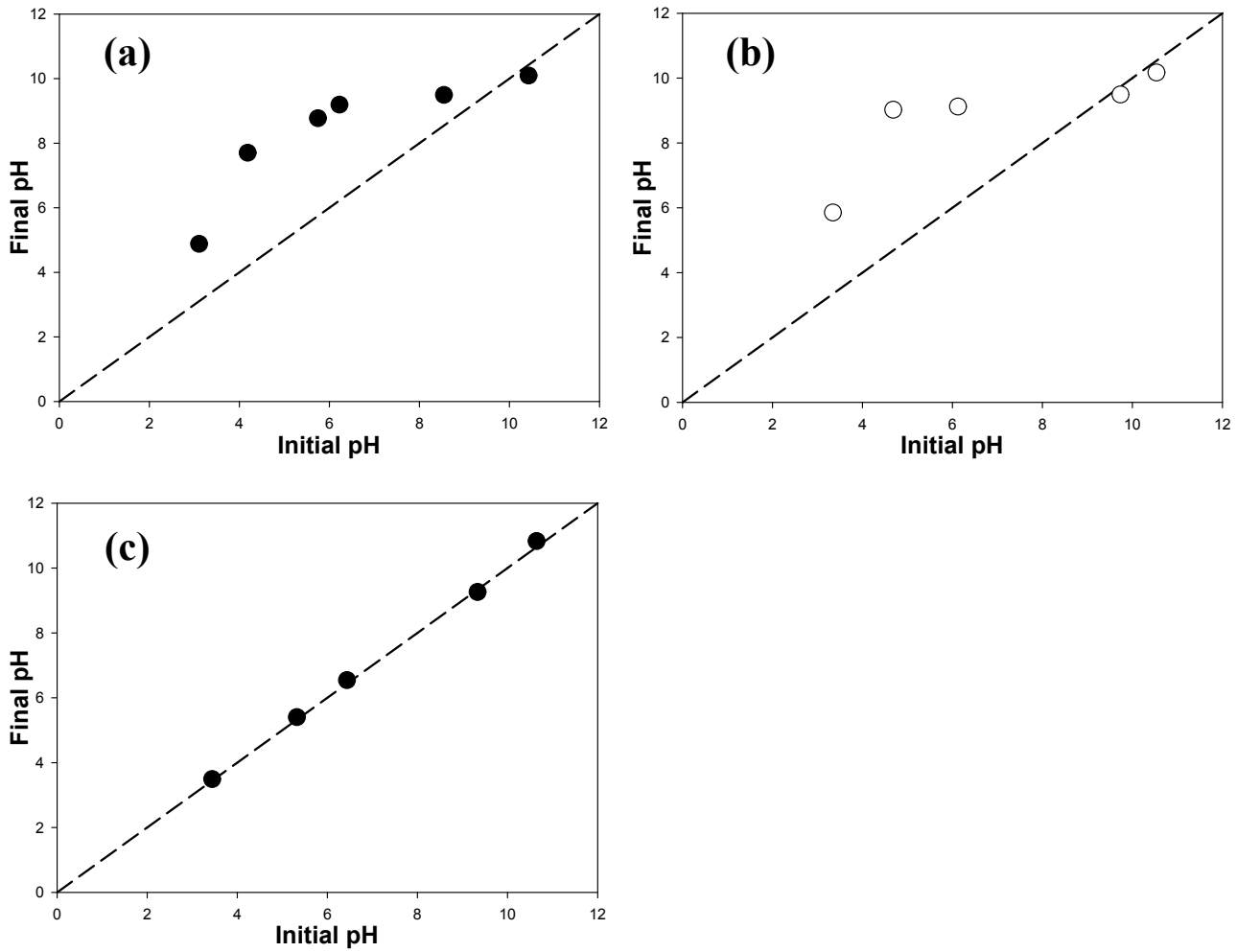

Figure S4. pH variations after injection [MgAC] for Sr^{2+} (a) and La^{3+} (b) adsorption, and after [HA] injection for Sr^{2+} or La^{3+} (c).

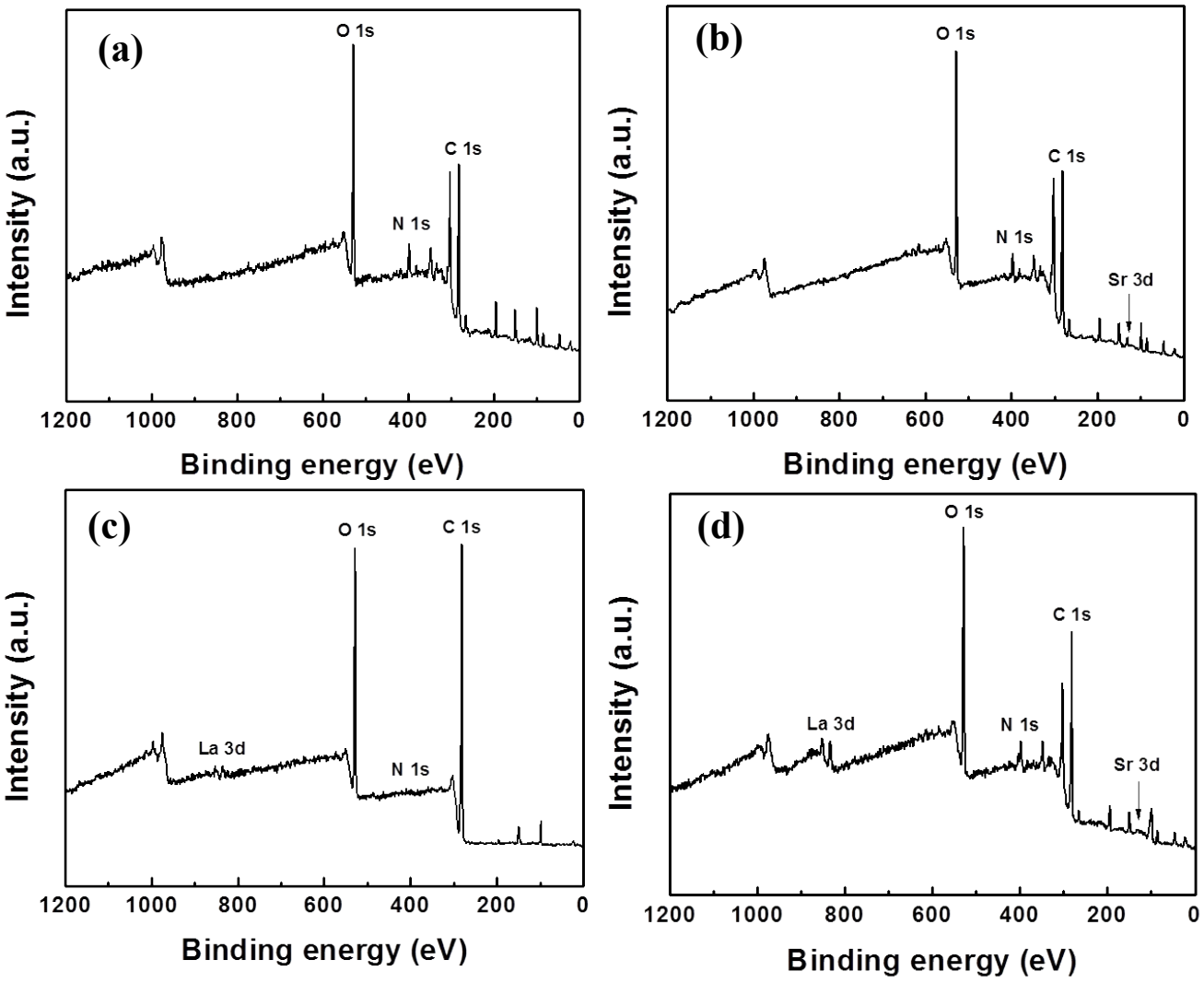

Figure S5 Survey scans of XPS in [MgAC-HA] complexes (a), Sr^{2+} adsorbed onto [MgAC-HA] complexes (b), La^{3+} adsorbed onto [MgAC-HA] complexes (c), and mixture of Sr^{2+} and La^{3+} adsorbed onto [MgAC-HA] complexes (d).

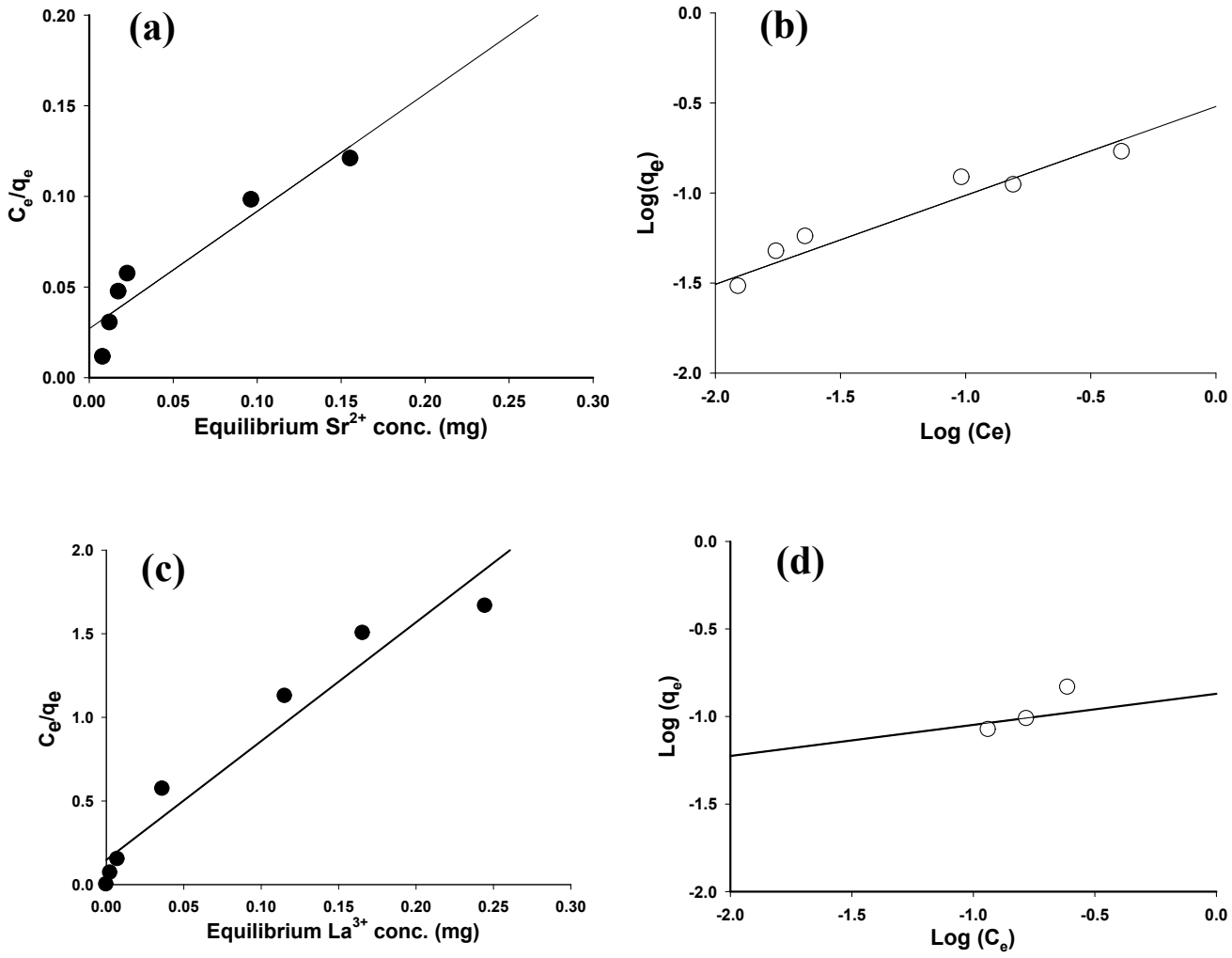

Figure S6 Langmuir (a,c) and Frenudlich (b,d) plots in [MgAC] adsorption of single Sr^{2+} and La^{3+} respectively.

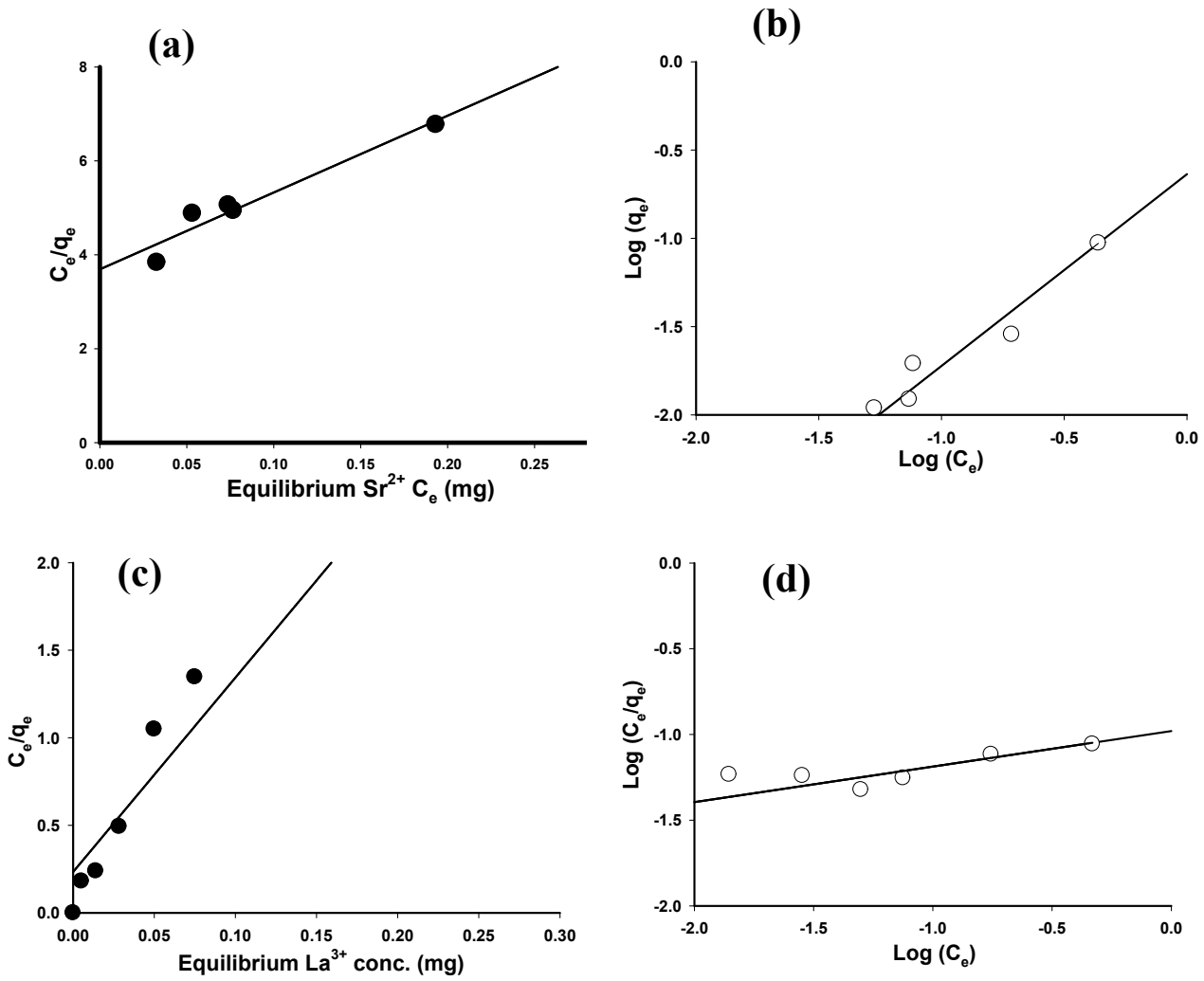

Figure S7 Langmuir (a,c) and Freundlich (b,d) plots in [HA] adsorption of single Sr^{2+} and La^{3+} respectively.

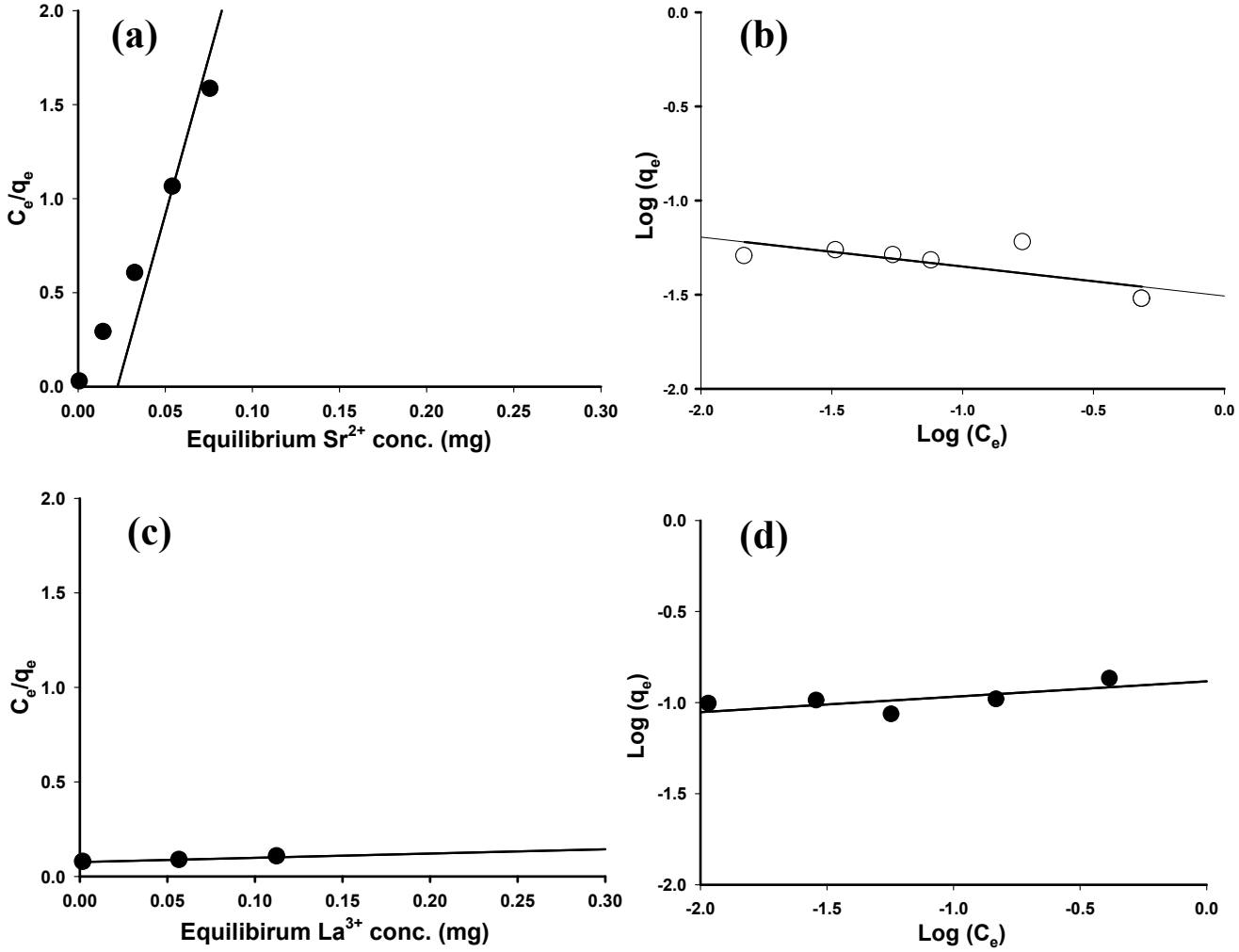

Figure S8 Langmuir (a,c) and Frenudlich (b,d) plots by [MgAC-HA] complexes adsorption of single Sr^{2+} and La^{3+} respectively.

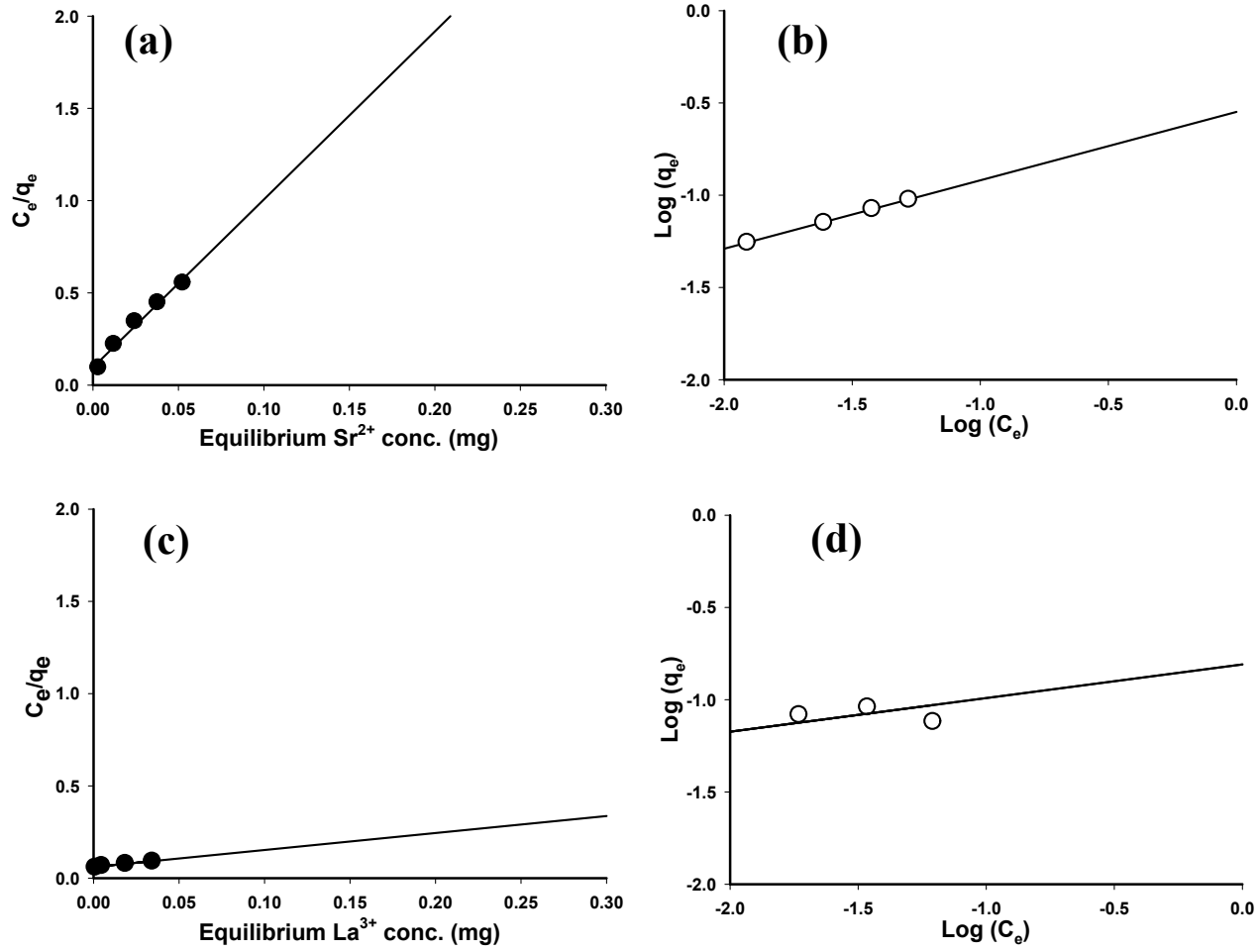

Figure S9 Langmuir (a,c) and Freundlich (b,d) plots of Sr^{2+} and La^{3+} by [MgAC-HA] complexes adsorption in mixture of Sr^{2+} and La^{3+}.