

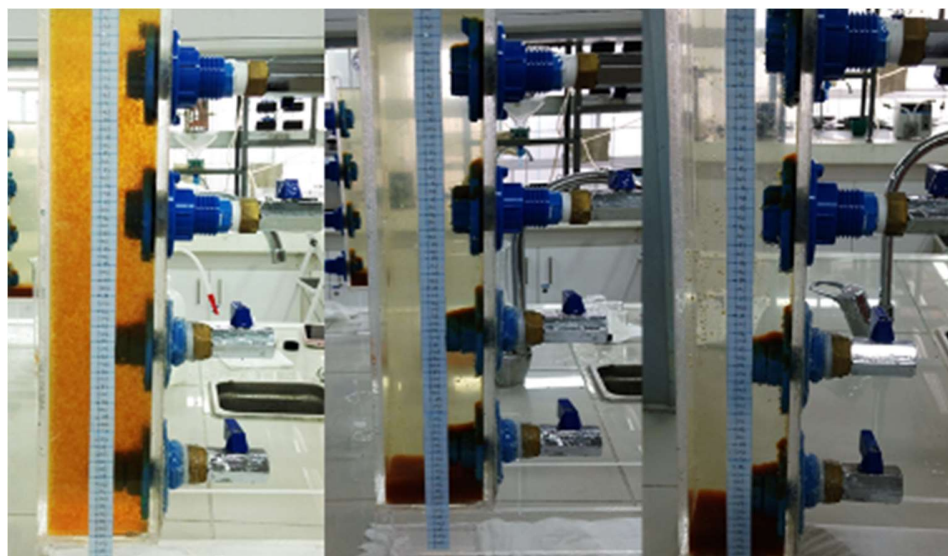
SUPPLEMENTARY MATERIAL

Section S1. Synthetic acid drainage solutions composition

Ion (g/L)	100 mgFe/L	100 mgAl/L	100 mgFe/L + 100 mgAl/L	50 mgFe/L	50 mgAl/L	50 mgFe/L + 50 mgAl/L
Al ³⁺	-	0.10	0.10	-	0.05	0.05
Fe ³⁺	0.10	-	0.10	0.05	-	0.05
Na ⁺	1.5	1.5	1.5	1.0	1.0	1.0
Cl ⁻	2.5	2.3	2.5	1.6	1.5	1.6
SO ₄ ²⁻	2.4	2.4	2.4	2.4	2.4	2.4

Section S2. Photographs of settling experiments

Solution 1: Fe = 100 mg L⁻¹. pH = 5.5

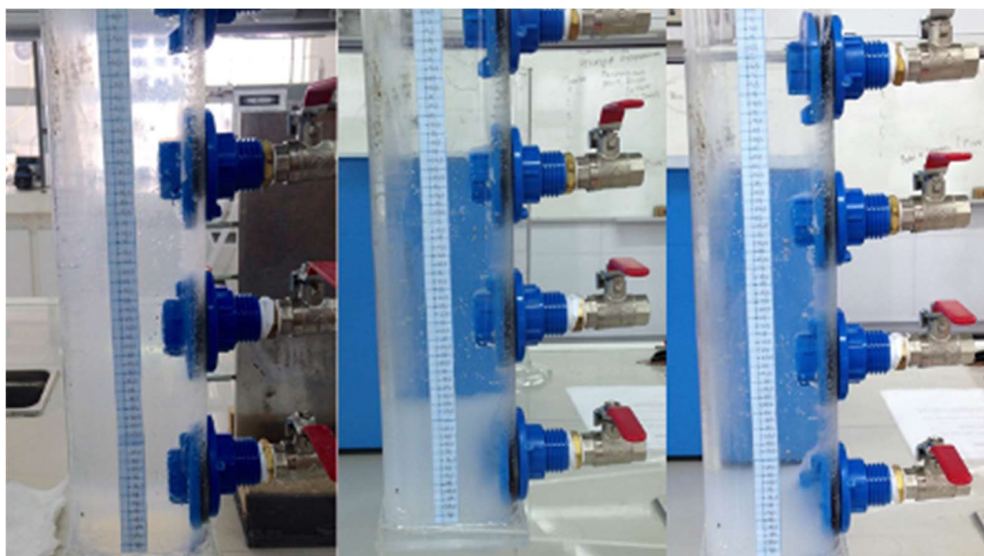


(a) 0 minutes

(b) 30 minutes

(c) 120 minutes

Solution 2: $\text{Al} = 100 \text{ mg L}^{-1}$. $\text{pH} = 5.5$

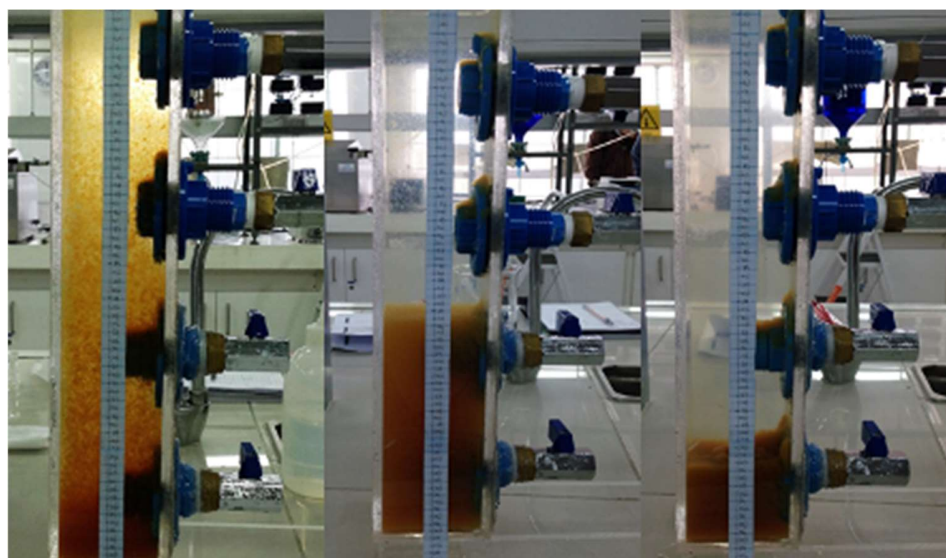


(a) 0 minutes

(b) 30 minutes

(c) 120 minutes

Solution 3: $\text{Al} = 100 \text{ mg L}^{-1} + \text{Fe} = 100 \text{ mg L}^{-1}$. $\text{pH} = 6.5$

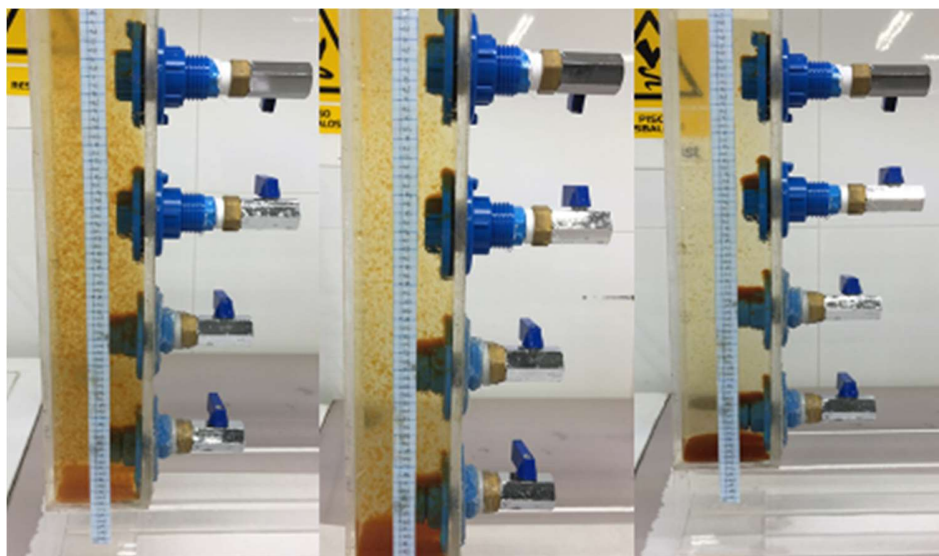


(a) 0 minutes

(b) 30 minutes

(c) 120 minutes

Solution 4: $\text{Fe} = 50 \text{ mg L}^{-1}$. $\text{pH} = 4.5$

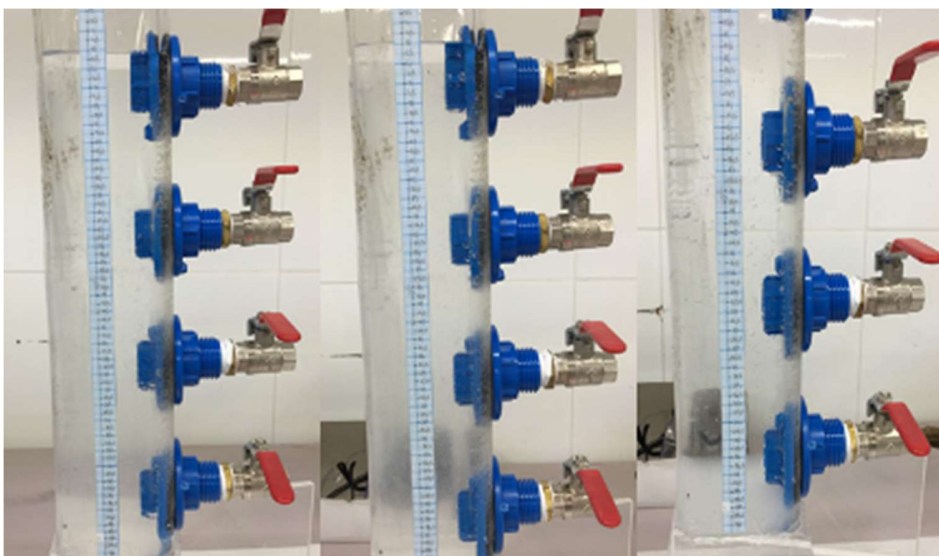


(a) 0 minutes

(b) 30 minutes

(c) 120 minutes

Solution 5: $\text{Al} = 50 \text{ mg L}^{-1}$. $\text{pH} = 4.5$

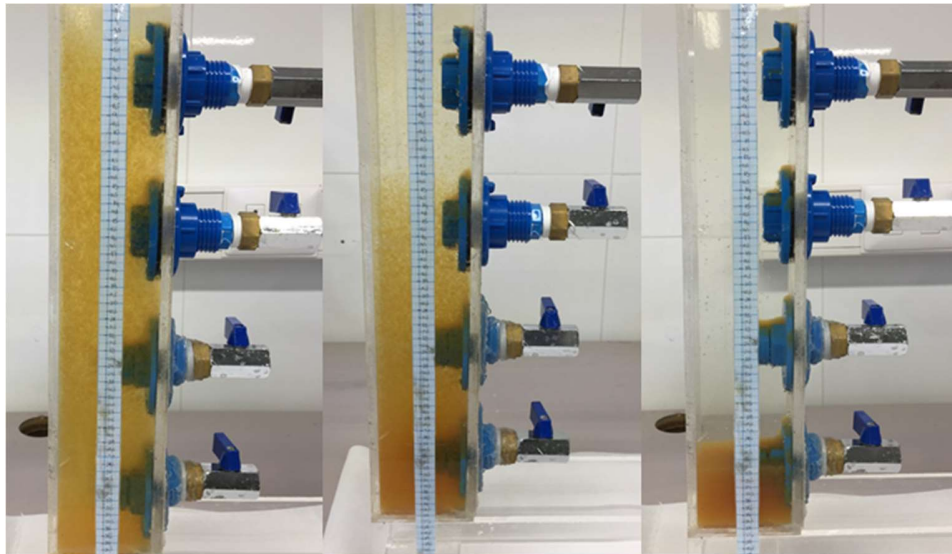


(a) 0 minutes

(b) 30 minutes

(c) 120 minutes

Solution 6: Al = 50 mg L⁻¹ + Fe = 50 mg L⁻¹. pH = 6.5



(a) 0 minutes

(b) 30 minutes

(c) 120 minutes

Section S3. PHREEQC Code

PHASES

Schwermannite

$\text{Fe}_8\text{O}_8(\text{SO}_4)1.26(\text{OH})5.48 + 21.48\text{H}^+ = 8\text{Fe}^{+3} + 1.26\text{SO}_4^{-2} + 13.48\text{H}_2\text{O}$

log_k 18.5

Hydrobasaluminnite

$\text{Al}_4\text{SO}_4(\text{OH})_{10}(\text{H}_2\text{O})_{15} + 10\text{H}^+ = 4\text{Al}^{+3} + \text{SO}_4^{-2} + 25\text{H}_2\text{O}$

log_k 23.9

$\text{Fe}(\text{OH})_3(\text{a})$

$\text{Fe}(\text{OH})_3 + 3\text{H}^+ = \text{Fe}^{+3} + 3\text{H}_2\text{O}$

log_k 3.0

$\text{Al}(\text{OH})_3$

$\text{Al}^{+3} + 3\text{H}_2\text{O} = \text{Al}(\text{OH})_3 + 3\text{H}^+$

log_k -16.9

SOLUTION 1 Solution base

#Composition can be changed according to values in Table 1

temp 20

pH 1.3 charge

pe 5

redox pe

units g/l

density 1

Cl 2.504

Fe(3) 0.1

Al 0.1

Na 1.500

S(6) 2.422
-water 1 # kg

SOLUTION 2
temp 20
pH 7 charge
pe 4
redox pe
units mol/l
density 1.08
Na 2
-water 1 # kg

EQUILIBRIUM_PHASES 1
CO2(g) -3.5
O2(g) -0.679
Schwermannite 0 0
Fe(OH)3(a) 0 0
Hydrobasaluminnite 0 0
Al(OH)3 0 0

SELECTED_OUTPUT 1
-reset false
-pH true
-pe true
-ionic_strength true
-totals Al Cl Fe Na S(6)
-equilibrium_phases Schwermannite Fe(OH)3(a) Hydrobasaluminnite Al(OH)3

END

#USE SOLUTION 1
#USE SOLUTION 2
MIX
1 0.999
2 0.001

END

#USE SOLUTION 1
#USE SOLUTION 2
MIX
1 0.998
2 0.002

USE EQUILIBRIUM_PHASES 1

END

#USE SOLUTION 1
#USE SOLUTION 2
MIX
1 0.997
2 0.003

USE EQUILIBRIUM_PHASES 1

END

#USE SOLUTION 1

#USE SOLUTION 2

MIX

1 0.996

2 0.004

USE EQUILIBRIUM_PHASES 1

END

#USE SOLUTION 1

#USE SOLUTION 2

MIX

1 0.995

2 0.005

USE EQUILIBRIUM_PHASES 1

END

#USE SOLUTION 1

#USE SOLUTION 2

MIX

1 0.994

2 0.006

END

Section S4. Settling tests - raw data

Solution type 1: Fe=100 mg L⁻¹

pH = 4.5

Time (min)	Height (cm)
0.0	35.0
2.5	34.5
5.0	14.0
10	3.6
15	2.8
20	2.2
30	2.0
40	1.8
50	1.7
60	1.6
70	1.6
80	1.6
90	1.5
120	1.5

Time (min)	Height (cm)
0.0	35.0
2.5	34.5
5.0	31.7
10	4.5
15	3.1
20	2.7
30	2.1
40	2.0
50	2.0
60	1.9
70	1.8
80	1.7
90	1.6
120	1.6

pH = 5.5

Time (min)	Height (cm)
0.0	35.0
2.5	34.5
5.0	14.6
10	3.5
15	2.3
20	2.0
30	1.9
40	1.8
50	1.7
60	1.7
70	1.7
80	1.7
90	1.7
120	1.7

Time (min)	Height (cm)
0.0	35
2.5	34
5.0	14
10	3.6
15	3
20	2.6
30	2.6
40	2.3
50	2
60	2
70	2
80	2
90	2
120	2

pH = 6.5

Time (min)	Height (cm)
0.0	35.0
2.5	33.0
5.0	22.0
10	3.7
15	3.0

Time (min)	Height (cm)
0.0	35.0
2.5	34.0
5.0	28.0
10	3.0
15	2.4

Time (min)	Height (cm)
20	2.5
30	2.2
40	2.0
50	2.0
60	2.0
70	2.0
80	2.0
90	2.0
120	2.0

Time (min)	Height (cm)
20	2.1
30	2.0
40	1.8
50	1.8
60	1.8
70	1.8
80	1.8
90	1.8
120	1.8

Solution type 2: Al = 100 mg L⁻¹

pH = 4.5

Time (min)	Height (cm)
0.0	40.0
2.5	39.9
5.0	38.4
10	34.0
15	6.4
20	6.0
30	6.0
40	5.5
50	5.5
60	5.5
70	5.5
80	5.5
90	5.5
120	5.5

Time (min)	Height (cm)
0.0	40.0
2.5	39.5
5.0	38.5
10	35.0
15	6.2
20	6.0
30	5.8
40	5.6
50	5.6
60	5.6
70	5.6
80	5.6
90	5.6
120	5.6

pH = 5.5

Time (min)	Height (cm)
0.0	40.0
2.5	38.5
5.0	34.5
10	25.0
15	18.9
20	13.7
30	11.7
40	11.0
50	9.5

Time (min)	Height (cm)
0.0	40.0
2.5	39.0
5.0	35.0
10	27.0
15	23.2
20	20.1
30	13.1
40	11.7
50	11.0

Time (min)	Height (cm)
60	9.2
70	9.2
80	9.2
90	9.0
120	8.5

Time (min)	Height (cm)
60	10.5
70	10.2
80	9.8
90	9.8
120	9.3

pH = 6.5

Time (min)	Height (cm)
0.0	40.0
2.5	39.0
5.0	35.0
10	27.0
15	20.5
20	14.0
30	12.0
40	10.8
50	10.1
60	9.6
70	9.5
80	9.5
90	9.0
120	9.0

Time (min)	Height (cm)
0.0	40.0
2.5	39.5
5.0	36.0
10	28.0
15	21.5
20	19.4
30	12.5
40	11.0
50	10.7
60	10.3
70	10.0
80	9.6
90	9.5
120	8.7

Solution type 3: Fe = 100 mg L⁻¹ + Al = 100 mg L⁻¹

pH = 4.5

Time (min)	Height (cm)
0.0	35.0
2.5	34.5
5.0	23.0
10	9.0
15	6.8
20	5.8
30	4.5
40	3.5
50	3.1
60	3.0
70	2.9
80	2.9
90	2.9

Time (min)	Height (cm)
0.0	35.0
2.5	34.5
5.0	31.0
10	6.5
15	5.0
20	4.3
30	3.5
40	2.7
50	2.5
60	2.4
70	2.3
80	2.3
90	2.3

Time (min)	Height (cm)
120	2.9

Time (min)	Height (cm)
120	2.0

pH = 5.5

Time (min)	Height (cm)
0.0	35.0
2.5	34.0
5.0	31.5
10	22.5
15	16.0
20	12.8
30	9.7
40	7.9
50	7.8
60	7.5
70	6.9
80	6.6
90	5.5
120	5.5

Time (min)	Height (cm)
0.0	35.0
2.5	34.2
5.0	31.5
10	24.3
15	17.1
20	14.5
30	10.4
40	8.7
50	8.0
60	7.7
70	7.3
80	6.8
90	6.3
120	6.3

pH = 6.5

Time (min)	Height (cm)
0.0	35.0
2.5	33.6
5.0	31.0
10	25.3
15	18.4
20	16.0
30	11.7
40	9.4
50	8.9
60	5.7
70	5.7
80	5.7
90	5.7
120	5.7

Time (min)	Height (cm)
0.0	35.0
2.5	34.0
5.0	32.0
10	25.1
15	18.5
20	15.6
30	11.5
40	9.2
50	8.7
60	8.2
70	7.8
80	7.4
90	7.0
120	6.2

Solution type 4: Fe = 50 mg L⁻¹

pH = 4.5

Time (min)	Height (cm)
0.0	35.0
2.5	34.7
5.0	32.0
10	1.3
15	1.3
20	1.2
30	1.1
40	1.1
50	1.1
60	1.1
70	1.1
80	1.1
90	1.1
120	1.1

Time (min)	Height (cm)
0.0	35.0
2.5	34.7
5.0	32.5
10	1.3
15	1.3
20	1.3
30	1.3
40	1.2
50	1.2
60	1.1
70	1.1
80	1.1
90	1.1
120	1.1

pH = 5.5

Time (min)	Height (cm)
0.0	35.0
2.5	34.7
5.0	31.5
10	1.5
15	1.3
20	1.2
30	1.2
40	1.2
50	1.2
60	1.2
70	1.2
80	1.2
90	1.2
120	1.2

Time (min)	Height (cm)
0.0	35.0
2.5	34.5
5.0	31.0
10	1.2
15	1.2
20	1.2
30	1.2
40	1.2
50	1.2
60	1.2
70	1.2
80	1.2
90	1.2
120	1.2

pH = 6.5

Time (min)	Height (cm)
0.0	35.0
2.5	34.5

Time (min)	Height (cm)
0.0	35.0
2.5	34.5

Time (min)	Height (cm)
5.0	28.0
10	1.2
15	1.2
20	1.2
30	1.1
40	1.1
50	1.1
60	1.1
70	1.1
80	1.1
90	1.1
120	1.1

Time (min)	Height (cm)
5.0	29.0
10	1.0
15	1.0
20	1.0
30	1.0
40	1.0
50	1.0
60	1.0
70	1.0
80	1.0
90	1.0
120	1.0

Solution type 5: Al = 50 mg L⁻¹

pH = 4.5

Time (min)	Height (cm)
0.0	40.0
2.5	39.5
5.0	39.0
10	6.5
15	6.3
20	6.0
30	5.7
40	5.5
50	5.5
60	5.5
70	5.5
80	5.5
90	5.5
120	5.5

Time (min)	Height (cm)
0.0	40.0
2.5	39.5
5.0	39.0
10	9.5
15	7.6
20	7.2
30	6.7
40	6.4
50	6.2
60	6.2
70	6.2
80	6.2
90	6.0
120	6.0

pH = 5.5

Time (min)	Height (cm)
0.0	40.0
2.5	39.0
5.0	34.5
10	9.1
15	8.3
20	7.7

Time (min)	Height (cm)
0.0	40.0
2.5	39.5
5.0	36.0
10	11.5
15	9.6
20	8.8

Time (min)	Height (cm)
30	7.2
40	7.0
50	6.8
60	6.7
70	6.7
80	6.7
90	6.7
120	6.7

Time (min)	Height (cm)
30	8.0
40	7.5
50	7.3
60	7.1
70	7.0
80	7.0
90	7.0
120	7.0

pH = 6.5

Time (min)	Height (cm)
0.0	40.0
2.5	38.5
5.0	37.0
10	14.0
15	8.5
20	7.9
30	7.8
40	7.0
50	6.8
60	6.8
70	6.7
80	6.5
90	6.5
120	6.5

Time (min)	Height (cm)
0.0	40.0
2.5	39.0
5.0	36.5
10	8.5
15	7.6
20	7.3
30	7.0
40	6.7
50	6.6
60	6.5
70	6.5
80	6.5
90	6.5
120	6.5

Solution type 6: Fe = 50 mg L⁻¹ + Al = 50 mg L⁻¹

pH = 4.5

Time (min)	Height (cm)
0.0	35.0
2.5	32.0
5.0	25.0
10	6.2
15	5.1
20	4.3
30	3.3
40	2.7
50	2.6
60	2.5

Time (min)	Height (cm)
0.0	35.0
2.5	34.0
5.0	30.5
10	5.6
15	4.2
20	3.5
30	2.8
40	2.4
50	2.2
60	2.1

Time (min)	Height (cm)
70	2.4
80	2.3
90	2.3
120	2.2

Time (min)	Height (cm)
70	2.1
80	2.0
90	2.0
120	2.0

pH = 5.5

Time (min)	Height (cm)
0.0	35.0
2.5	34.0
5.0	28.5
10	8.5
15	5.4
20	1.3*
30	4.2
40	3.5
50	3.2
60	3.0
70	2.9
80	2.8
90	2.8
120	2.8

Time (min)	Height (cm)
0.0	35.0
2.5	34.5
5.0	29.0
10	13.5
15	8.2
20	6.8*
30	5.7
40	4.5
50	4.1
60	3.9
70	3.5
80	3.5
90	3.5
120	3.5

*These measurements are not presented in the graphs.

pH = 6.5

Time (min)	Height (cm)
0.0	35.0
2.5	34.0
5.0	30.0
10	7.0
15	5.6
20	4.7
30	3.9
40	3.4
50	3.1
60	3.0
70	3.0
80	2.8
90	2.7
120	2.7

Time (min)	Height (cm)
0.0	35.0
2.5	33.5
5.0	29.5
10	10.0
15	6.9
20	6.0
30	4.9
40	3.9
50	3.6
60	3.4
70	3.3
80	3.2
90	3.2
120	3.2

Summary of calculated settling velocity

Solution	Vs (mm/s)					
	pH = 4.5		pH = 5.5		pH = 6.5	
	R1	R2	R1	R2	R1	R2
Al 50	1.61	1.43	1.16	1.11	1.04	1.32
Al 100	1.39	1.31	0.34	0.32	0.32	0.29
Fe 50	1.47	1.50	1.42	1.41	1.22	1.29
Fe 100	1.89	1.27	1.83	1.83	0.90	1.13
Fe 50 + Al 50	0.82	1.14	0.85	0.61	1.04	0.84
Fe 100 + Al 100	1.12	1.01	0.34	0.28	0.27	0.25

Section S5. Results of PHREEQC simulations

See Excel spreadsheet.

Section S6. Zeta potential data

pH	Zeta potential (mV)					
	50 mgFe/L		50 mgAl/L		50 mgFe/L + 50 mgAl/L	
	R1	R2	R1	R2	R1	R2
4.5	-2.98	-2.64	-5.9	-5.78	-6.1	-5.7
5.5	-3.3	-3.12	-9.26	-9.13	-7.34	-7.81
6.5	-5.46	-5.71	-13.54	-14.01	-12.45	-13.01
7.5	-5.57	-6.4	-16.89	-17.12	-15.21	-15.73
8.5	-9.97	-10.2	-21.88	-20.56	-16.29	-16.95

