Impact of sodium silicate on lead release from lead(II) carbonate

Supplementary Material

Bofu Li[a,*], Benjamin F. Trueman[a], Javier M. Locsin[a], Yaohuan Gao[a,b] , Mohammad Shahedur Rahman[a,c], Yuri Park[d], and Graham A. Gagnon[a]

[a]Centre for Water Resources Studies, Department of Civil & Resource Engineering, Dalhousie University, 1360 Barrington St., Halifax, Nova Scotia, Canada B3H 4R2

[b]School of Human Settlements and Civil Engineering, Xi'an Jiaotong University, No.28, Xianning West Road, Xi'an, Shaanxi, 710049, P.R. China

[c]Civil Engineering Department, College of Engineering, Al Imam Mohammad Ibn Saud Islamic Univeristy, Riyadh, Saudi Arabia

[d] Department of Separation Science, School of Engineering Science, Lappeenranta-Lahti University of Technology LUT, Mikkeli, Finland

*Corresponding author: Bofu Li
E-mail: bofu.li@dal.ca
Tel: 902.494.6070
Fax: 902.494.3105

Table S1. Summary of thermodynamic data used in equilibrium solubility modeling (Schock et al., 1996).

Phase	Equation	log K
-	$Pb^{+2} + H_2O = PbOH^+ + H^+$	-7.22
-	$Pb^{+2} + 3H_2O = Pb(OH)_3^- + 3H^+$	-28.08
-	$Pb^{+2} + 4H_2O = Pb(OH)_4^{-2} + 4H^+$	-39.72
-	$Pb^{+2} + 2H_2O = Pb(OH)_2 + 2H^+$	-16.91
-	$2Pb^{+2} + H_2O = Pb_2OH^{+3} + H^+$	-6.36
-	$3Pb^{+2} + 4H_2O = Pb_3(OH)_4^{+2} + 4H^+$	-23.86
-	$4Pb^{+2} + 4H_2O = Pb_4(OH)_4^{+4} + 4H^+$	-20.88
-	$6Pb^{+2} + 8H_2O = Pb_6(OH)_8^{+4} + 8H^+$	-43.62
-	$Pb^{+2} + CO_3^{-2} = PbCO_3$	7.10
-	$Pb^{+2} + 2CO_3^{-2} = Pb(CO_3)_2^{-2}$	10.33
-	$Pb^{+2} + CO_3^{-2} + H^+ = PbHCO_3^+$	12.59
-	$Pb^{+2} + PO_4^{-3} + H^+ = PbHPO_4$	15.41
-	$Pb^{+2} + PO_4^{-3} + 2H^+ = PbH_2PO_4^+$	21.05
-	$Pb^{+2} + SO_4^{-2} = PbSO_4$	2.73
-	$Pb^{+2} + 2SO_4^{-2} = Pb(SO_4)_2^{-2}$	3.50
-	$Pb^{+2} + Cl^- = PbCl^+$	1.59
-	$Pb^{+2} + 2Cl^- = PbCl_2$	1.80
-	$Pb^{+2} + 3Cl^- = PbCl_3^-$	1.71
-	$Pb^{+2} + 4Cl^- = PbCl_4^{-2}$	1.43
Cerussite	$PbCO_3 = Pb^{+2} + CO_3^{-2}$	-13.11
Hydrocerussite	$Pb(OH)_2{:}2PbCO_3 + 2H^+ = 3Pb^{+2} + 2CO_3^{-2} + 2H_2O$	-18.00
Hydroxylpyromorphite	$Pb_5(PO_4)_3OH + H^+ = 5Pb^{+2} + 3PO_4^{-3} + H_2O$	-62.83

Table S2. Linear model coefficients, p-values, and 95% confidence intervals (lower and upper bounds).

Filter pore size (μm)	Term	Coefficient	p-value	Lower bound	Upper bound
0.2	(Intercept)	78.78	0.00	65.69	94.48
0.2	Polyphosphate	23.49	0.00	17.15	32.18
0.2	Orthophosphate	0.03	0.00	0.02	0.05
0.2	Silicate	1.23	0.08	0.97	1.56
0.2	50 mg C/L	0.62	0.00	0.45	0.84
0.2	pH 9	0.49	0.00	0.36	0.67
0.2	Polyphosphate : 50 mg C/L	1.60	0.05	0.99	2.59
0.2	Orthophosphate : 50 mg C/L	14.11	0.00	8.72	22.82
0.2	Silicate : 50 mg C/L	0.82	0.34	0.53	1.26
0.2	Polyphosphate : pH 9	1.90	0.01	1.18	3.07
0.2	Orthophosphate : pH 9	6.31	0.00	3.90	10.20
0.2	Silicate : pH 9	1.33	0.18	0.87	2.06
0.2	50 mg C/L : pH 9	5.73	0.00	3.54	9.27
0.2	Polyphosphate : 50 mg C/L : pH 9	0.06	0.00	0.03	0.13
0.2	Orthophosphate : 50 mg C/L : pH 9	0.21	0.00	0.11	0.43
0.2	Silicate : 50 mg C/L : pH 9	0.49	0.04	0.25	0.96
0.45	(Intercept)	122.93	0.00	101.36	149.10
0.45	Polyphosphate	15.92	0.00	11.40	22.24
0.45	Orthophosphate	0.04	0.00	0.03	0.05
0.45	Silicate	1.00	0.99	0.78	1.29
0.45	50 mg C/L	0.47	0.00	0.34	0.66
0.45	pH 9	0.35	0.00	0.25	0.49
0.45	Polyphosphate : 50 mg C/L	2.07	0.01	1.24	3.45
0.45	Orthophosphate : 50 mg C/L	18.27	0.00	10.97	30.44
0.45	Silicate : 50 mg C/L	1.21	0.39	0.77	1.92
0.45	Polyphosphate : pH 9	2.60	0.00	1.56	4.34
0.45	Orthophosphate : pH 9	7.37	0.00	4.42	12.28
0.45	Silicate : pH 9	1.80	0.01	1.14	2.85
0.45	50 mg C/L : pH 9	7.60	0.00	4.56	12.66
0.45	Polyphosphate : 50 mg C/L : pH 9	0.06	0.00	0.03	0.13
0.45	Orthophosphate : 50 mg C/L : pH 9	0.12	0.00	0.06	0.26
0.45	Silicate : 50 mg C/L : pH 9	0.36	0.01	0.18	0.74

Table S3. Ratio of geometric mean lead release in the inhibitor group to the corresponding control group.

Filter pore size (μm)	Inhibitor	pH	DIC (mg C/L)	Ratio (inhibitor:control)
0.2	Polyphosphate	7.5	5	23.49
0.2	Polyphosphate	7.5	50	37.68
0.2	Polyphosphate	9	5	44.65
0.2	Polyphosphate	9	50	4.60
0.2	Orthophosphate	7.5	5	0.03
0.2	Orthophosphate	7.5	50	0.47
0.2	Orthophosphate	9	5	0.21
0.2	Orthophosphate	9	50	0.63
0.2	Sodium silicate	7.5	5	1.23
0.2	Sodium silicate	7.5	50	1.01
0.2	Sodium silicate	9	5	1.64
0.2	Sodium silicate	9	50	0.66
0.45	Polyphosphate	7.5	5	15.92
0.45	Polyphosphate	7.5	50	32.96
0.45	Polyphosphate	9	5	41.48
0.45	Polyphosphate	9	50	5.37
0.45	Orthophosphate	7.5	5	0.04
0.45	Orthophosphate	7.5	50	0.67
0.45	Orthophosphate	9	5	0.27
0.45	Orthophosphate	9	50	0.62
0.45	Sodium silicate	7.5	5	1.00
0.45	Sodium silicate	7.5	50	1.21
0.45	Sodium silicate	9	5	1.80
0.45	Sodium silicate	9	50	0.79

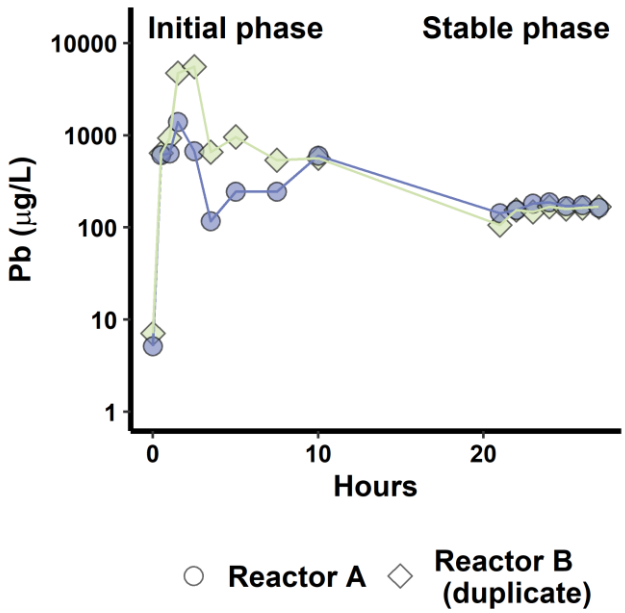

Figure S1. Lead in effluent from CSTRs with 1 g/L lead(II) carbonate as a function of operational times. Hydraulic residence time of 30 min at pH 7.5 and dissolved inorganic carbon of 5 mg C per L

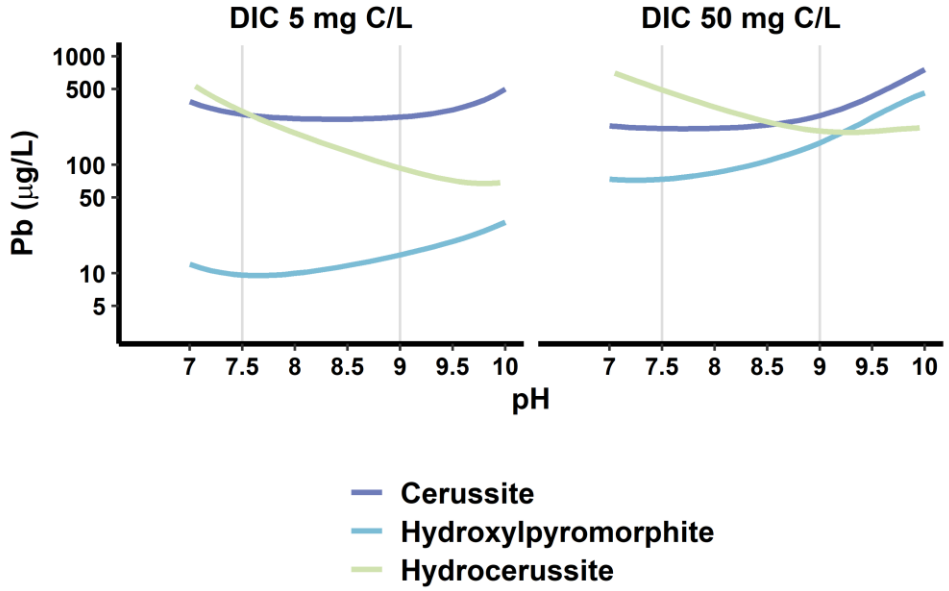

Figure S2. Equlibirium solubility of cerussite, hydrocerussite, and hydroxylpyromorphite at DIC 5 and 50 mg C per L. Grey lines indicated experimental pH condition (7.5 or 9) in this study. Thermodynamic data are due to Schock et al. (1996) and solubility calculations were made with *tidyphreeqc* (Dunnington, 2020).

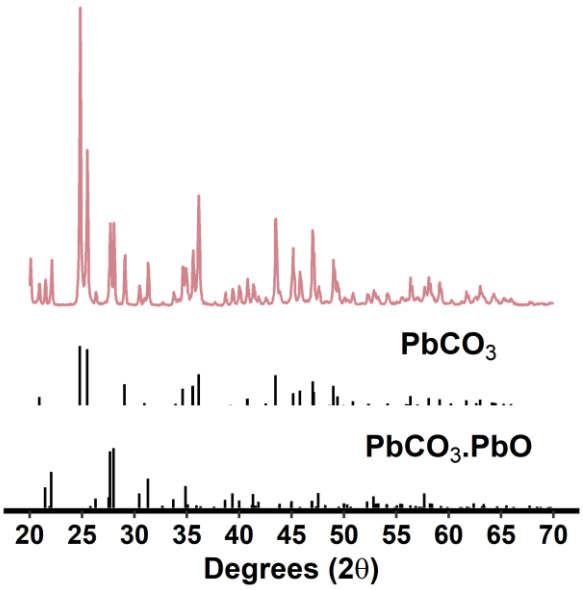

Figure S3. X-ray diffraction (XRD) patterns representing the lead carbonate solids before reaction.

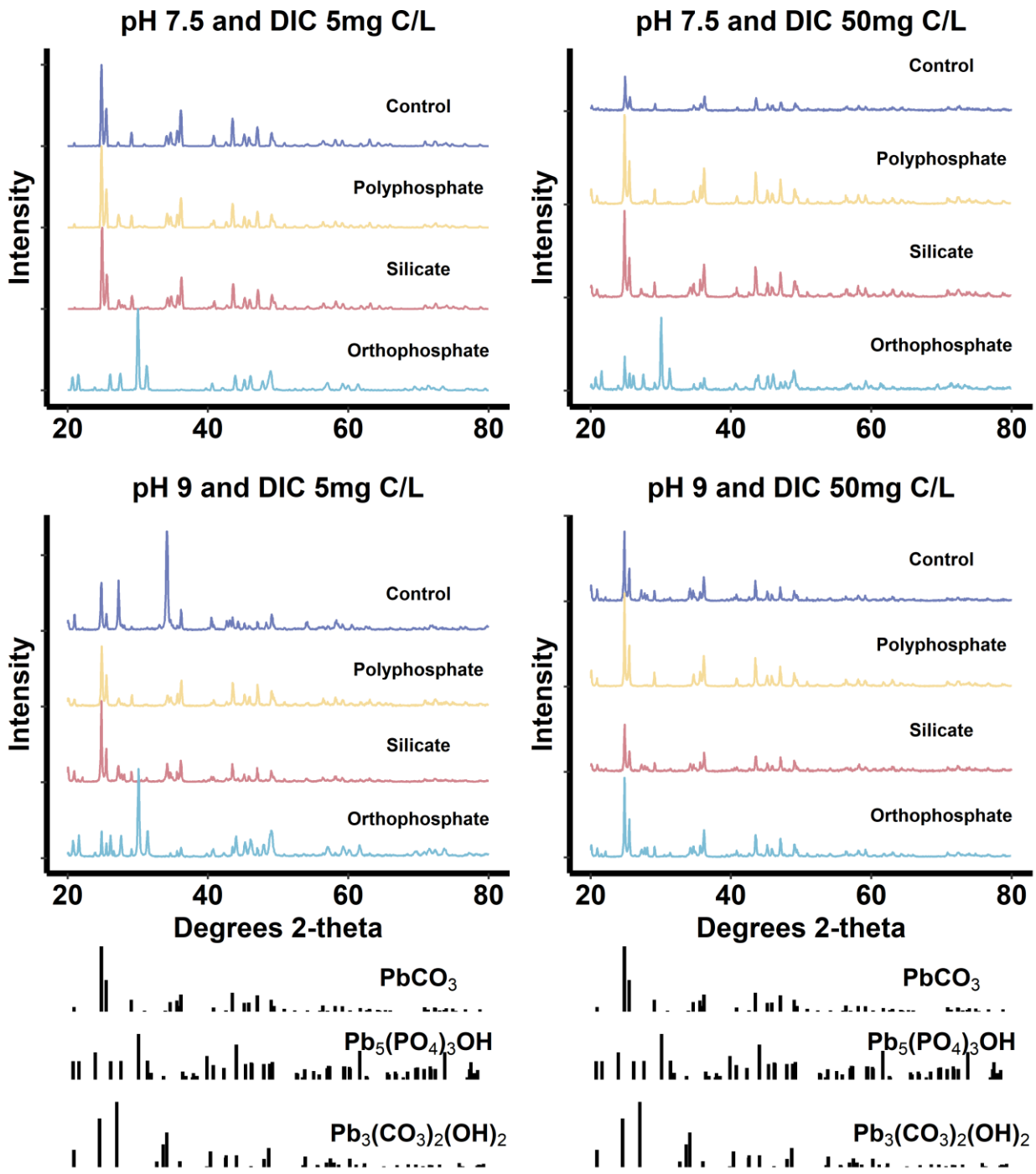

Figure S4. X-ray diffraction (XRD) patterns characterizing cerrusite particles after reaction with orthophosphate, polyphosphate, or sodium silicate at two pH (7.5 and 9) and DIC levels (5 and 50 mg C per L)

Table S4. Stable phase lead release data.

Inhibitor	pH	DIC (C mg/L)	Filtrate (μm)	Date	Column	Time (hour)	Pb (μg/L)
Polyphosphate	7.5	5	0.2	2018-08-06	A	24.0	1944.00
Polyphosphate	7.5	5	0.2	2018-08-06	A	25.0	1942.00
Polyphosphate	7.5	5	0.2	2018-08-06	A	26.0	1970.00
Polyphosphate	7.5	5	0.2	2018-08-06	B	24.0	1787.90
Polyphosphate	7.5	5	0.2	2018-08-06	B	25.0	1739.45
Polyphosphate	7.5	5	0.2	2018-08-06	B	26.0	1736.30
Polyphosphate	7.5	5	0.45	2018-08-06	A	23.0	2071.00
Polyphosphate	7.5	5	0.45	2018-08-06	A	24.0	2092.00
Polyphosphate	7.5	5	0.45	2018-08-06	A	25.0	2072.00
Polyphosphate	7.5	5	0.45	2018-08-06	A	26.0	2071.00
Polyphosphate	7.5	5	0.45	2018-08-06	A	27.0	2057.00
Polyphosphate	7.5	5	0.45	2018-08-06	B	23.0	1883.00
Polyphosphate	7.5	5	0.45	2018-08-06	B	24.0	1882.00
Polyphosphate	7.5	5	0.45	2018-08-06	B	25.0	1831.00
Polyphosphate	7.5	5	0.45	2018-08-06	B	26.0	1790.00
Polyphosphate	7.5	5	0.45	2018-08-06	B	27.0	1858.00
Polyphosphate	7.5	50	0.2	2019-08-22	A	28.0	1744.00
Polyphosphate	7.5	50	0.2	2019-08-22	A	29.0	1804.00
Polyphosphate	7.5	50	0.2	2019-08-22	A	30.0	1832.00
Polyphosphate	7.5	50	0.2	2019-08-22	A	31.0	1784.00
Polyphosphate	7.5	50	0.2	2019-08-22	A	32.0	1763.00
Polyphosphate	7.5	50	0.2	2019-08-23	B	29.0	1886.00
Polyphosphate	7.5	50	0.2	2019-08-23	B	30.0	1893.00
Polyphosphate	7.5	50	0.2	2019-08-23	B	31.0	1882.00
Polyphosphate	7.5	50	0.2	2019-08-23	B	32.0	1816.00
Polyphosphate	7.5	50	0.45	2019-08-22	A	28.0	1895.00
Polyphosphate	7.5	50	0.45	2019-08-22	A	29.0	1895.00
Polyphosphate	7.5	50	0.45	2019-08-22	A	30.0	1897.00
Polyphosphate	7.5	50	0.45	2019-08-22	A	31.0	1906.00
Polyphosphate	7.5	50	0.45	2019-08-22	A	32.0	1847.00
Polyphosphate	7.5	50	0.45	2019-08-23	B	28.0	2000.00
Polyphosphate	7.5	50	0.45	2019-08-23	B	29.0	1930.00
Polyphosphate	7.5	50	0.45	2019-08-23	B	30.0	1894.00
Polyphosphate	7.5	50	0.45	2019-08-23	B	31.0	1884.00
Polyphosphate	7.5	50	0.45	2019-08-23	B	32.0	1892.00
Polyphosphate	9.0	5	0.2	2018-11-06	A	26.5	1730.00
Polyphosphate	9.0	5	0.2	2018-11-06	A	28.5	1703.00
Polyphosphate	9.0	5	0.2	2018-11-06	A	30.5	1732.00
Polyphosphate	9.0	5	0.2	2018-11-06	A	31.5	1836.00
Polyphosphate	9.0	5	0.2	2018-11-06	A	32.5	1966.00

Polyphosphate	9.0	5	0.2	2018-11-06	B	26.5	1684.00
Polyphosphate	9.0	5	0.2	2018-11-06	B	28.5	1740.00
Polyphosphate	9.0	5	0.2	2018-11-06	B	30.5	1631.00
Polyphosphate	9.0	5	0.2	2018-11-06	B	31.5	1567.00
Polyphosphate	9.0	5	0.2	2018-11-06	B	32.5	1735.00
Polyphosphate	9.0	5	0.45	2018-11-06	A	26.5	1793.00
Polyphosphate	9.0	5	0.45	2018-11-06	A	28.5	1762.00
Polyphosphate	9.0	5	0.45	2018-11-06	A	30.5	1816.00
Polyphosphate	9.0	5	0.45	2018-11-06	A	31.5	1950.00
Polyphosphate	9.0	5	0.45	2018-11-06	A	32.5	2050.00
Polyphosphate	9.0	5	0.45	2018-11-06	B	26.5	1788.00
Polyphosphate	9.0	5	0.45	2018-11-06	B	28.5	1802.00
Polyphosphate	9.0	5	0.45	2018-11-06	B	30.5	1681.00
Polyphosphate	9.0	5	0.45	2018-11-06	B	31.5	1643.00
Polyphosphate	9.0	5	0.45	2018-11-06	B	32.5	1800.00
Polyphosphate	9.0	50	0.2	2019-08-01	A	28.0	754.40
Polyphosphate	9.0	50	0.2	2019-08-01	A	29.0	728.80
Polyphosphate	9.0	50	0.2	2019-08-01	A	30.0	731.30
Polyphosphate	9.0	50	0.2	2019-08-01	A	31.0	754.90
Polyphosphate	9.0	50	0.2	2019-08-01	A	32.0	749.00
Polyphosphate	9.0	50	0.2	2019-10-20	B	28.0	603.20
Polyphosphate	9.0	50	0.2	2019-10-20	B	29.0	534.40
Polyphosphate	9.0	50	0.2	2019-10-20	B	30.0	606.00
Polyphosphate	9.0	50	0.2	2019-10-20	B	31.0	546.50
Polyphosphate	9.0	50	0.2	2019-10-20	B	32.0	591.10
Polyphosphate	9.0	50	0.2	2019-10-21	B	28.0	544.20
Polyphosphate	9.0	50	0.2	2019-10-21	B	29.0	567.90
Polyphosphate	9.0	50	0.2	2019-10-21	B	30.0	567.60
Polyphosphate	9.0	50	0.2	2019-10-21	B	31.0	615.20
Polyphosphate	9.0	50	0.2	2019-10-21	B	32.0	606.00
Polyphosphate	9.0	50	0.45	2019-08-01	A	28.0	814.60
Polyphosphate	9.0	50	0.45	2019-08-01	A	29.0	819.20
Polyphosphate	9.0	50	0.45	2019-08-01	A	30.0	767.00
Polyphosphate	9.0	50	0.45	2019-08-01	A	31.0	823.80
Polyphosphate	9.0	50	0.45	2019-08-01	A	32.0	796.10
Polyphosphate	9.0	50	0.45	2019-10-20	B	28.0	873.00
Polyphosphate	9.0	50	0.45	2019-10-20	B	29.0	910.00
Polyphosphate	9.0	50	0.45	2019-10-20	B	30.0	870.00
Polyphosphate	9.0	50	0.45	2019-10-20	B	31.0	865.90
Polyphosphate	9.0	50	0.45	2019-10-20	B	32.0	833.50
Polyphosphate	9.0	50	0.45	2019-10-21	B	28.0	888.20
Polyphosphate	9.0	50	0.45	2019-10-21	B	29.0	890.00

Polyphosphate	9.0	50	0.45	2019-10-21	B	30.0	710.90
Polyphosphate	9.0	50	0.45	2019-10-21	B	31.0	869.70
Polyphosphate	9.0	50	0.45	2019-10-21	B	32.0	806.80
Control	7.5	5	0.2	2018-08-02	A	23.0	71.93
Control	7.5	5	0.2	2018-08-02	A	24.0	73.18
Control	7.5	5	0.2	2018-08-02	A	25.0	70.76
Control	7.5	5	0.2	2018-08-02	A	26.0	67.79
Control	7.5	5	0.2	2018-08-02	A	27.0	68.55
Control	7.5	5	0.2	2018-08-02	B	23.0	87.66
Control	7.5	5	0.2	2018-08-02	B	24.0	79.98
Control	7.5	5	0.2	2018-08-02	B	25.0	85.51
Control	7.5	5	0.2	2018-08-02	B	26.0	82.14
Control	7.5	5	0.2	2018-08-02	B	27.0	83.40
Control	7.5	5	0.2	2018-10-03	A	29.5	82.30
Control	7.5	5	0.2	2018-10-03	A	31.0	87.10
Control	7.5	5	0.2	2018-10-03	A	32.0	75.43
Control	7.5	5	0.2	2018-10-03	A	33.0	80.80
Control	7.5	5	0.2	2018-10-03	B	29.5	82.44
Control	7.5	5	0.2	2018-10-03	B	31.0	82.73
Control	7.5	5	0.2	2018-10-03	B	32.0	77.63
Control	7.5	5	0.2	2018-10-03	B	33.0	78.90
Control	7.5	5	0.45	2018-08-02	A	23.0	181.50
Control	7.5	5	0.45	2018-08-02	A	24.0	188.40
Control	7.5	5	0.45	2018-08-02	A	25.0	170.80
Control	7.5	5	0.45	2018-08-02	A	26.0	174.60
Control	7.5	5	0.45	2018-08-02	A	27.0	163.60
Control	7.5	5	0.45	2018-08-02	B	23.0	147.20
Control	7.5	5	0.45	2018-08-02	B	24.0	167.30
Control	7.5	5	0.45	2018-08-02	B	25.0	158.80
Control	7.5	5	0.45	2018-08-02	B	26.0	163.20
Control	7.5	5	0.45	2018-08-02	B	27.0	167.20
Control	7.5	5	0.45	2018-10-03	A	29.5	93.61
Control	7.5	5	0.45	2018-10-03	A	31.0	91.40
Control	7.5	5	0.45	2018-10-03	A	32.0	94.35
Control	7.5	5	0.45	2018-10-03	A	33.0	90.68
Control	7.5	5	0.45	2018-10-03	B	29.5	90.28
Control	7.5	5	0.45	2018-10-03	B	31.0	85.10
Control	7.5	5	0.45	2018-10-03	B	32.0	87.45
Control	7.5	5	0.45	2018-10-03	B	33.0	87.62
Control	7.5	50	0.2	2018-11-17	A	28.0	43.26
Control	7.5	50	0.2	2018-11-17	A	29.0	50.58
Control	7.5	50	0.2	2018-11-17	A	30.0	49.00

Control	7.5	50	0.2	2018-11-17	A	31.0	50.27
Control	7.5	50	0.2	2018-11-17	A	32.0	49.62
Control	7.5	50	0.2	2018-11-17	B	28.0	50.40
Control	7.5	50	0.2	2018-11-17	B	29.0	47.83
Control	7.5	50	0.2	2018-11-17	B	30.0	46.03
Control	7.5	50	0.2	2018-11-17	B	31.0	48.23
Control	7.5	50	0.2	2018-11-17	B	32.0	50.04
Control	7.5	50	0.45	2018-11-17	A	28.0	56.39
Control	7.5	50	0.45	2018-11-17	A	29.0	57.58
Control	7.5	50	0.45	2018-11-17	A	30.0	58.10
Control	7.5	50	0.45	2018-11-17	A	31.0	58.99
Control	7.5	50	0.45	2018-11-17	A	32.0	60.15
Control	7.5	50	0.45	2018-11-17	B	28.0	52.90
Control	7.5	50	0.45	2018-11-17	B	29.0	55.60
Control	7.5	50	0.45	2018-11-17	B	30.0	59.80
Control	7.5	50	0.45	2018-11-17	B	31.0	59.30
Control	7.5	50	0.45	2018-11-17	B	32.0	59.20
Control	9.0	5	0.2	2018-08-29	A	28.0	36.09
Control	9.0	5	0.2	2018-08-29	A	29.0	39.31
Control	9.0	5	0.2	2018-08-29	A	30.0	37.58
Control	9.0	5	0.2	2018-08-29	A	31.0	39.04
Control	9.0	5	0.2	2018-08-29	A	32.0	38.02
Control	9.0	5	0.2	2018-08-29	B	28.0	41.76
Control	9.0	5	0.2	2018-08-29	B	29.0	42.39
Control	9.0	5	0.2	2018-08-29	B	30.0	35.65
Control	9.0	5	0.2	2018-08-29	B	31.0	39.33
Control	9.0	5	0.2	2018-08-29	B	32.0	38.66
Control	9.0	5	0.45	2018-08-29	A	28.0	10.15
Control	9.0	5	0.45	2018-08-29	A	29.0	50.81
Control	9.0	5	0.45	2018-08-29	A	30.0	48.82
Control	9.0	5	0.45	2018-08-29	A	31.0	49.36
Control	9.0	5	0.45	2018-08-29	A	32.0	46.00
Control	9.0	5	0.45	2018-08-29	B	28.0	56.04
Control	9.0	5	0.45	2018-08-29	B	29.0	55.54
Control	9.0	5	0.45	2018-08-29	B	30.0	53.67
Control	9.0	5	0.45	2018-08-29	B	31.0	52.58
Control	9.0	5	0.45	2018-08-29	B	32.0	48.57
Control	9.0	50	0.2	2019-07-12	A	28.0	137.00
Control	9.0	50	0.2	2019-07-12	A	29.0	135.80
Control	9.0	50	0.2	2019-07-12	A	30.0	139.60
Control	9.0	50	0.2	2019-07-12	A	31.0	138.90
Control	9.0	50	0.2	2019-07-12	A	32.0	137.00

Control	9.0	50	0.2	2019-07-16	B	28.0	130.00
Control	9.0	50	0.2	2019-07-16	B	29.0	136.40
Control	9.0	50	0.2	2019-07-16	B	30.0	136.40
Control	9.0	50	0.2	2019-07-16	B	31.0	137.30
Control	9.0	50	0.2	2019-07-16	B	32.0	137.20
Control	9.0	50	0.45	2019-07-12	A	28.0	153.90
Control	9.0	50	0.45	2019-07-12	A	29.0	157.10
Control	9.0	50	0.45	2019-07-12	A	30.0	153.10
Control	9.0	50	0.45	2019-07-12	A	31.0	152.90
Control	9.0	50	0.45	2019-07-12	A	32.0	153.90
Control	9.0	50	0.45	2019-07-16	B	28.0	158.10
Control	9.0	50	0.45	2019-07-16	B	29.0	152.80
Control	9.0	50	0.45	2019-07-16	B	30.0	158.40
Control	9.0	50	0.45	2019-07-16	B	31.0	158.90
Control	9.0	50	0.45	2019-07-16	B	32.0	155.20
Orthophosphate	7.5	5	0.2	2018-10-11	A	35.0	2.94
Orthophosphate	7.5	5	0.2	2018-10-11	A	36.0	2.15
Orthophosphate	7.5	5	0.2	2018-10-11	A	37.0	2.33
Orthophosphate	7.5	5	0.2	2018-10-11	A	38.0	2.04
Orthophosphate	7.5	5	0.2	2018-10-11	B	35.0	3.10
Orthophosphate	7.5	5	0.2	2018-10-11	B	36.0	2.64
Orthophosphate	7.5	5	0.2	2018-10-11	B	37.0	3.16
Orthophosphate	7.5	5	0.2	2018-10-11	B	38.0	2.77
Orthophosphate	7.5	5	0.45	2018-10-11	A	35.0	5.02
Orthophosphate	7.5	5	0.45	2018-10-11	A	36.0	3.57
Orthophosphate	7.5	5	0.45	2018-10-11	A	37.0	3.90
Orthophosphate	7.5	5	0.45	2018-10-11	A	38.0	3.76
Orthophosphate	7.5	5	0.45	2018-10-11	B	35.0	4.70
Orthophosphate	7.5	5	0.45	2018-10-11	B	36.0	4.74
Orthophosphate	7.5	5	0.45	2018-10-11	B	37.0	6.28
Orthophosphate	7.5	5	0.45	2018-10-11	B	38.0	4.84
Orthophosphate	7.5	50	0.2	2019-08-20	A	28.0	11.47
Orthophosphate	7.5	50	0.2	2019-08-20	A	29.0	19.08
Orthophosphate	7.5	50	0.2	2019-08-20	A	30.0	23.40
Orthophosphate	7.5	50	0.2	2019-08-20	A	31.0	24.61
Orthophosphate	7.5	50	0.2	2019-08-20	A	32.0	40.76
Orthophosphate	7.5	50	0.2	2019-08-21	B	28.0	21.46
Orthophosphate	7.5	50	0.2	2019-08-21	B	29.0	27.00
Orthophosphate	7.5	50	0.2	2019-08-21	B	30.0	28.97
Orthophosphate	7.5	50	0.2	2019-08-21	B	31.0	21.55
Orthophosphate	7.5	50	0.2	2019-08-21	B	32.0	19.27
Orthophosphate	7.5	50	0.45	2019-08-20	A	28.0	39.58

Orthophosphate	7.5	50	0.45	2019-08-20	A	29.0	36.29
Orthophosphate	7.5	50	0.45	2019-08-20	A	30.0	36.52
Orthophosphate	7.5	50	0.45	2019-08-20	A	31.0	39.54
Orthophosphate	7.5	50	0.45	2019-08-20	A	32.0	36.10
Orthophosphate	7.5	50	0.45	2019-08-21	B	28.0	41.62
Orthophosphate	7.5	50	0.45	2019-08-21	B	29.0	40.81
Orthophosphate	7.5	50	0.45	2019-08-21	B	30.0	39.44
Orthophosphate	7.5	50	0.45	2019-08-21	B	31.0	41.84
Orthophosphate	7.5	50	0.45	2019-08-21	B	32.0	37.85
Orthophosphate	9.0	5	0.2	2018-11-17	A	28.0	11.85
Orthophosphate	9.0	5	0.2	2018-11-17	A	29.0	11.60
Orthophosphate	9.0	5	0.2	2018-11-17	A	30.0	10.43
Orthophosphate	9.0	5	0.2	2018-11-17	A	31.0	18.27
Orthophosphate	9.0	5	0.2	2018-11-17	A	32.0	10.15
Orthophosphate	9.0	5	0.2	2019-06-28	A	28.0	6.02
Orthophosphate	9.0	5	0.2	2019-06-28	A	29.0	5.31
Orthophosphate	9.0	5	0.2	2019-06-28	A	30.0	5.44
Orthophosphate	9.0	5	0.2	2019-06-28	A	31.0	4.80
Orthophosphate	9.0	5	0.2	2019-06-28	A	32.0	5.44
Orthophosphate	9.0	5	0.45	2018-11-17	A	28.0	15.99
Orthophosphate	9.0	5	0.45	2018-11-17	A	29.0	14.16
Orthophosphate	9.0	5	0.45	2018-11-17	A	30.0	12.06
Orthophosphate	9.0	5	0.45	2018-11-17	A	31.0	17.33
Orthophosphate	9.0	5	0.45	2018-11-17	A	32.0	11.59
Orthophosphate	9.0	5	0.45	2019-06-28	A	28.0	12.23
Orthophosphate	9.0	5	0.45	2019-06-28	A	29.0	10.05
Orthophosphate	9.0	5	0.45	2019-06-28	A	30.0	8.83
Orthophosphate	9.0	5	0.45	2019-06-28	A	31.0	9.89
Orthophosphate	9.0	5	0.45	2019-06-28	A	32.0	9.04
Orthophosphate	9.0	50	0.2	2019-08-16	A	28.0	74.58
Orthophosphate	9.0	50	0.2	2019-08-16	A	29.0	82.71
Orthophosphate	9.0	50	0.2	2019-08-16	A	30.0	83.92
Orthophosphate	9.0	50	0.2	2019-08-16	A	31.0	95.08
Orthophosphate	9.0	50	0.2	2019-08-16	A	32.0	74.73
Orthophosphate	9.0	50	0.2	2019-08-16	A	34.0	86.06
Orthophosphate	9.0	50	0.2	2019-08-16	B	28.0	91.33
Orthophosphate	9.0	50	0.2	2019-08-16	B	29.0	77.57
Orthophosphate	9.0	50	0.2	2019-08-16	B	30.0	95.10
Orthophosphate	9.0	50	0.2	2019-08-16	B	31.0	95.19
Orthophosphate	9.0	50	0.2	2019-08-16	B	32.0	86.85
Orthophosphate	9.0	50	0.2	2019-08-16	B	34.0	90.57
Orthophosphate	9.0	50	0.45	2019-08-16	A	28.0	85.52

Orthophosphate	9.0	50	0.45	2019-08-16	A	29.0	92.43
Orthophosphate	9.0	50	0.45	2019-08-16	A	30.0	95.28
Orthophosphate	9.0	50	0.45	2019-08-16	A	31.0	103.20
Orthophosphate	9.0	50	0.45	2019-08-16	A	32.0	85.34
Orthophosphate	9.0	50	0.45	2019-08-16	A	34.0	96.55
Orthophosphate	9.0	50	0.45	2019-08-16	B	28.0	99.10
Orthophosphate	9.0	50	0.45	2019-08-16	B	29.0	87.54
Orthophosphate	9.0	50	0.45	2019-08-16	B	30.0	106.30
Orthophosphate	9.0	50	0.45	2019-08-16	B	31.0	105.00
Orthophosphate	9.0	50	0.45	2019-08-16	B	32.0	98.72
Orthophosphate	9.0	50	0.45	2019-08-16	B	34.0	95.40
Silicate	7.5	5	0.2	2018-09-12	A	31.0	116.40
Silicate	7.5	5	0.2	2018-09-12	A	32.0	60.01
Silicate	7.5	5	0.2	2018-09-12	A	33.0	56.60
Silicate	7.5	5	0.2	2018-09-12	B	31.0	87.90
Silicate	7.5	5	0.2	2018-09-12	B	32.0	55.41
Silicate	7.5	5	0.2	2018-09-12	B	33.0	101.00
Silicate	7.5	5	0.2	2018-09-28	A	28.0	147.10
Silicate	7.5	5	0.2	2018-09-28	A	30.0	137.30
Silicate	7.5	5	0.2	2018-09-28	A	33.0	145.00
Silicate	7.5	5	0.2	2018-09-28	A	34.0	114.10
Silicate	7.5	5	0.2	2018-09-28	B	28.0	145.70
Silicate	7.5	5	0.2	2018-09-28	B	30.0	30.30
Silicate	7.5	5	0.2	2018-09-28	B	33.0	109.20
Silicate	7.5	5	0.2	2018-09-28	B	34.0	127.30
Silicate	7.5	5	0.2	2018-10-15	A	35.0	116.60
Silicate	7.5	5	0.2	2018-10-15	A	36.0	117.40
Silicate	7.5	5	0.2	2018-10-15	A	37.0	107.50
Silicate	7.5	5	0.2	2018-10-15	A	38.0	109.10
Silicate	7.5	5	0.2	2018-10-15	B	35.0	93.58
Silicate	7.5	5	0.2	2018-10-15	B	36.0	114.00
Silicate	7.5	5	0.2	2018-10-15	B	37.0	116.30
Silicate	7.5	5	0.2	2018-10-15	B	38.0	104.60
Silicate	7.5	5	0.45	2018-09-12	A	23.0	63.54
Silicate	7.5	5	0.45	2018-09-12	A	26.0	96.76
Silicate	7.5	5	0.45	2018-09-12	A	27.0	120.10
Silicate	7.5	5	0.45	2018-09-12	A	29.0	134.50
Silicate	7.5	5	0.45	2018-09-12	A	31.0	134.70
Silicate	7.5	5	0.45	2018-09-12	A	32.0	65.03
Silicate	7.5	5	0.45	2018-09-12	A	33.0	67.34
Silicate	7.5	5	0.45	2018-09-12	B	23.0	109.50
Silicate	7.5	5	0.45	2018-09-12	B	26.0	99.80

Silicate	7.5	5	0.45	2018-09-12	B	27.0	95.42
Silicate	7.5	5	0.45	2018-09-12	B	29.0	122.00
Silicate	7.5	5	0.45	2018-09-12	B	31.0	100.20
Silicate	7.5	5	0.45	2018-09-12	B	32.0	61.81
Silicate	7.5	5	0.45	2018-09-12	B	33.0	113.90
Silicate	7.5	5	0.45	2018-09-28	A	28.0	160.30
Silicate	7.5	5	0.45	2018-09-28	A	30.0	166.00
Silicate	7.5	5	0.45	2018-09-28	A	33.0	167.50
Silicate	7.5	5	0.45	2018-09-28	A	34.0	141.90
Silicate	7.5	5	0.45	2018-09-28	B	28.0	173.50
Silicate	7.5	5	0.45	2018-09-28	B	30.0	79.24
Silicate	7.5	5	0.45	2018-09-28	B	33.0	154.30
Silicate	7.5	5	0.45	2018-09-28	B	34.0	156.60
Silicate	7.5	5	0.45	2018-10-15	A	35.0	139.20
Silicate	7.5	5	0.45	2018-10-15	A	36.0	138.80
Silicate	7.5	5	0.45	2018-10-15	A	37.0	133.10
Silicate	7.5	5	0.45	2018-10-15	A	38.0	124.20
Silicate	7.5	5	0.45	2018-10-15	B	35.0	136.20
Silicate	7.5	5	0.45	2018-10-15	B	36.0	135.00
Silicate	7.5	5	0.45	2018-10-15	B	37.0	131.20
Silicate	7.5	5	0.45	2018-10-15	B	38.0	131.80
Silicate	7.5	50	0.2	2019-08-14	A	28.0	125.40
Silicate	7.5	50	0.2	2019-08-14	A	29.0	50.84
Silicate	7.5	50	0.2	2019-08-14	A	30.0	37.86
Silicate	7.5	50	0.2	2019-08-14	A	31.0	31.33
Silicate	7.5	50	0.2	2019-08-14	A	32.0	44.09
Silicate	7.5	50	0.2	2019-08-15	B	28.0	47.69
Silicate	7.5	50	0.2	2019-08-15	B	29.0	42.50
Silicate	7.5	50	0.2	2019-08-15	B	30.0	48.09
Silicate	7.5	50	0.2	2019-08-15	B	31.0	46.76
Silicate	7.5	50	0.2	2019-08-15	B	32.0	49.79
Silicate	7.5	50	0.45	2019-08-14	A	28.0	79.96
Silicate	7.5	50	0.45	2019-08-14	A	29.0	65.03
Silicate	7.5	50	0.45	2019-08-14	A	30.0	67.70
Silicate	7.5	50	0.45	2019-08-14	A	31.0	67.39
Silicate	7.5	50	0.45	2019-08-14	A	32.0	66.26
Silicate	7.5	50	0.45	2019-08-15	B	28.0	73.74
Silicate	7.5	50	0.45	2019-08-15	B	29.0	72.50
Silicate	7.5	50	0.45	2019-08-15	B	30.0	69.02
Silicate	7.5	50	0.45	2019-08-15	B	31.0	69.58
Silicate	7.5	50	0.45	2019-08-15	B	32.0	71.62
Silicate	9.0	5	0.2	2018-11-13	A	28.0	64.27

Silicate	9.0	5	0.2	2018-11-13	A	29.0	61.29
Silicate	9.0	5	0.2	2018-11-13	A	30.0	63.72
Silicate	9.0	5	0.2	2018-11-13	A	31.0	59.21
Silicate	9.0	5	0.2	2018-11-13	A	32.0	70.45
Silicate	9.0	5	0.2	2018-11-13	B	28.0	62.08
Silicate	9.0	5	0.2	2018-11-13	B	29.0	68.08
Silicate	9.0	5	0.2	2018-11-13	B	30.0	57.33
Silicate	9.0	5	0.2	2018-11-13	B	31.0	60.26
Silicate	9.0	5	0.2	2018-11-13	B	32.0	71.12
Silicate	9.0	5	0.45	2018-11-13	A	28.0	83.49
Silicate	9.0	5	0.45	2018-11-13	A	29.0	74.66
Silicate	9.0	5	0.45	2018-11-13	A	30.0	74.05
Silicate	9.0	5	0.45	2018-11-13	A	31.0	71.60
Silicate	9.0	5	0.45	2018-11-13	A	32.0	77.48
Silicate	9.0	5	0.45	2018-11-13	B	28.0	88.53
Silicate	9.0	5	0.45	2018-11-13	B	29.0	87.36
Silicate	9.0	5	0.45	2018-11-13	B	30.0	71.41
Silicate	9.0	5	0.45	2018-11-13	B	31.0	73.11
Silicate	9.0	5	0.45	2018-11-13	B	32.0	86.30
Silicate	9.0	50	0.2	2019-08-10	A	28.0	79.05
Silicate	9.0	50	0.2	2019-08-10	A	29.0	98.11
Silicate	9.0	50	0.2	2019-08-10	A	30.0	100.00
Silicate	9.0	50	0.2	2019-08-10	A	31.0	100.50
Silicate	9.0	50	0.2	2019-08-10	A	32.0	98.21
Silicate	9.0	50	0.2	2019-08-11	B	28.0	82.37
Silicate	9.0	50	0.2	2019-08-11	B	29.0	84.59
Silicate	9.0	50	0.2	2019-08-11	B	30.0	84.48
Silicate	9.0	50	0.2	2019-08-11	B	31.0	88.13
Silicate	9.0	50	0.2	2019-08-11	B	32.0	82.98
Silicate	9.0	50	0.45	2019-08-10	A	28.0	131.20
Silicate	9.0	50	0.45	2019-08-10	A	29.0	127.00
Silicate	9.0	50	0.45	2019-08-10	A	30.0	127.10
Silicate	9.0	50	0.45	2019-08-10	A	31.0	125.00
Silicate	9.0	50	0.45	2019-08-10	A	32.0	122.40
Silicate	9.0	50	0.45	2019-08-11	B	28.0	124.00
Silicate	9.0	50	0.45	2019-08-11	B	29.0	117.90
Silicate	9.0	50	0.45	2019-08-11	B	30.0	123.00
Silicate	9.0	50	0.45	2019-08-11	B	31.0	116.60
Silicate	9.0	50	0.45	2019-08-11	B	32.0	117.40

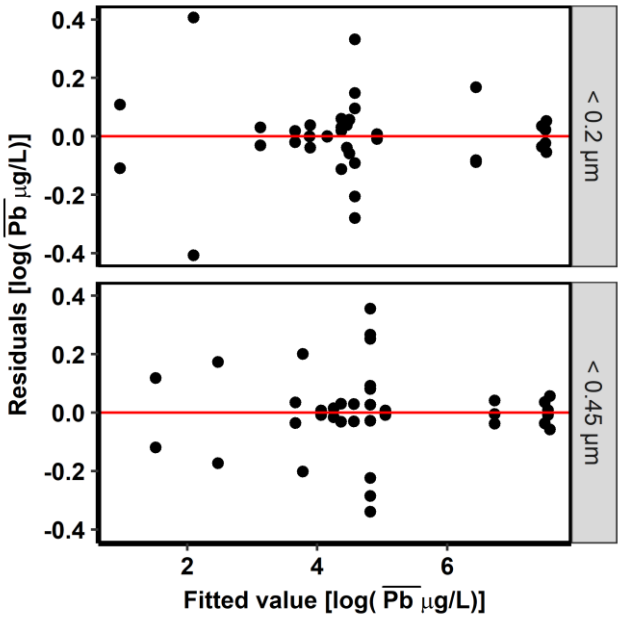

Figure S5. Variance of the model residuals was approximately constant across the range of fitted values.

Statistical analysis in R

The linear model was fitted using the data in Table S4 (the column names have been abbreviated to improve code readability).

```
## # A tibble: 373 x 8
##    inhibitor        ph dic_ppm filtrate date       column_a_b_ time_h
pb_ppb
##    <fct>         <dbl>   <dbl> <fct>    <date>     <chr>        <dbl>
<dbl>
##  1 Polyphosphate   7.5       5 0.2      2018-08-06 A               24
1944
##  2 Polyphosphate   7.5       5 0.2      2018-08-06 A               25
1942
##  3 Polyphosphate   7.5       5 0.2      2018-08-06 A               26
1970
##  4 Polyphosphate   7.5       5 0.2      2018-08-06 B               24
```

```
1788.
##  5 Polyphosphate   7.5       5 0.2      2018-08-06 B               25
1739.
##  6 Polyphosphate   7.5       5 0.2      2018-08-06 B               26
1736.
##  7 Polyphosphate   7.5       5 0.45     2018-08-06 A               23
2071
##  8 Polyphosphate   7.5       5 0.45     2018-08-06 A               24
2092
##  9 Polyphosphate   7.5       5 0.45     2018-08-06 A               25
2072
## 10 Polyphosphate   7.5       5 0.45     2018-08-06 A               26
2071
## # ... with 363 more rows
```

The following code reproduces the linear model described in the paper and in Table S2:

```
library("tidyverse") # load the tidyverse
options(dplyr.summarise.inform = FALSE)

table_s4 %>% # data in Table S4
  group_by(inhibitor, ph, dic_ppm, column_a_b_, date, filtrate) %>%
  # calculate geometric mean lead release for each run:
  summarize(pb_ppb = prod(pb_ppb) ^ (1 / length(pb_ppb))) %>%
  ungroup() %>%
  select(-date, -column_a_b_) %>%
  mutate_at(vars(-matches("pb")), factor) %>%
  # set control system as the reference state:
  mutate(inhibitor = relevel(inhibitor, ref = "Control")) %>%
  group_by(filtrate) %>% # group data by filtrate (<0.45 and <0.2 µm)
  nest() %>%
  ungroup() %>%
  mutate(
    # log-transform lead concentration and apply linear regression:
```

```
    model = map(
      data,
      ~ lm(log(pb_ppb) ~ inhibitor * dic_ppm * ph, data = .x)
    ),
    # summarize the model:
    tidied = map(
      model,
      ~ broom::tidy(.x) %>%
        bind_cols(broom::confint_tidy(.x))
    ),
    # convert model estimates to ratios in the original units:
    transformed = map(
      tidied,
      ~ .x %>%
        mutate_at(vars(estimate, conf.low, conf.high), exp) %>%
        select(term, estimate, conf.low, conf.high, p.value)
    )
  ) %>%
  unnest(transformed)
```

Log-transformation yields a multiplicative model in the original units

We provide a simple example:

$$Pb = \beta_0 + \beta_1 X_{inhibitor} + \beta_2 X_{pH} + \beta_3 X_{inhibitor} X_{pH}$$

Where Pb is lead concentration, the X are 0/1 dummy variables where X = 0 is the reference state ($X_{inhibitor}$: 0 = control, 1 = orthophosphate treatment; X_{pH} : 0 = pH 7.5, 1 = pH 9), and β_j are the linear regression coefficients.

For the orthophosphate-treated system at pH 9, the estimated lead concentration is:

$$Pb = \beta_0 + \beta_1 \times 1 + \beta_2 \times 1 + \beta_3 \times 1 \times 1$$

For orthophosphate-treated system at pH 7.5, the estimated lead concentration is:

$$Pb = \beta_0 + \beta_1 \times 1 + \beta_2 \times 0 + \beta_3 \times 1 \times 0$$

Thus, the β_j are additive constants.

To better conform to the ordinary least squares regression assumptions, lead concentrations here were log-transformed:

$$log(Pb) = \beta_0 + \beta_1 X_{inhibitor} + \beta_2 X_{pH} + \beta_3 X_{inhibitor} X_{pH}$$

The estimated lead concentration after back-transformation in the orthophosphate-treated system at pH 9 is:

$$Pb = e^{(\beta_0 + \beta_1 \times 1 + \beta_2 \times 1 + \beta_3 \times 1 \times 1)} = e^{(\beta_0)} \times e^{(\beta_1)} \times e^{(\beta_2)} \times e^{(\beta_3)} = \beta_0' \times \beta_1' \times \beta_2' \times \beta_3'$$

Where the β_j' are the multiplicative coefficients shown in Figure 2b and Table S2.

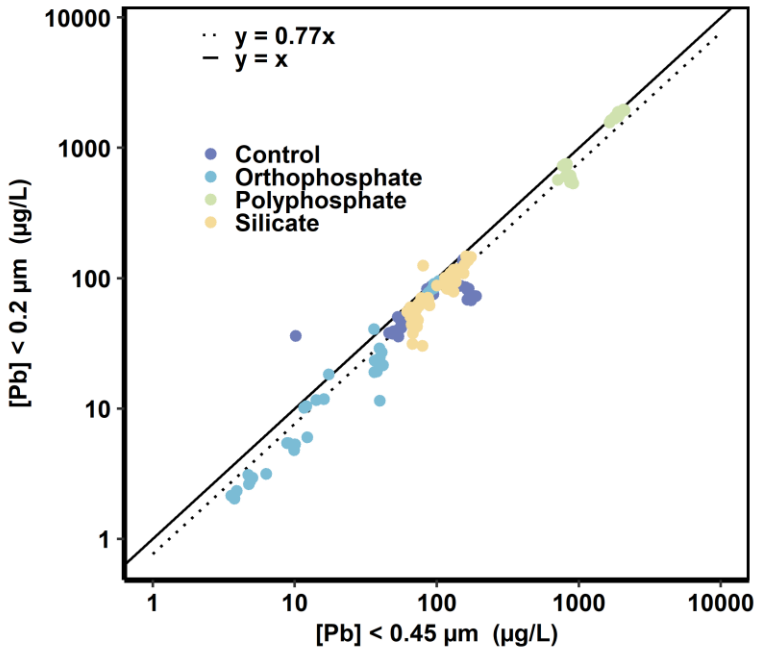

Figure S6. Considering the complete dataset, an estimated 77% of lead in 0.45 µm filtrate was present in 0.2 µm filtrate (Hodges-Lehman estimate).

References

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