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The biogeochemistry of tropical lakes: A case study from Lake Matano, Indonesia

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Web Appendix 1: Numerical description of reaction–transport model

Assuming that eddy diffusion is the dominant mode of transport, the profile of Fe(II) can be described at steady state by (Taillefert and Gaillard 2002):

$$\frac{1}{A_z}\frac{d}{dz}\left(A_z K_z \frac{d[\mathrm{Fe(II)}]}{dz}\right) + R_{\mathrm{Fe}}(z) = 0 \qquad \text{(A1)}$$

where A_z is the lateral surface area (m^2) at each depth z (m), K_z is the vertical eddy diffusion coefficient, [Fe(II)] is the concentration (mol L^{-1}) of dissolved Fe(II), and R_{Fe} (z) (mol L^{-1} yr^{-1}) is the rate at which Fe(II) is released to the water by Fe reduction. As the Fe(II) concentration in the epilimnion is close to zero (owing to rapid oxidation kinetics) and the Fe(II) concentration in the deep water is constant, the boundary conditions for Eq. A1 are

$$[\mathrm{Fe(II)}]\,(z=0) = 0; \quad \left.\frac{d[\mathrm{Fe(II)}]}{dz}\right|_{z=L} = 0 \qquad \text{(A2)}$$

where $z = 0$ corresponds to the pycnocline (100-m depth) and $z = L$ corresponds to the deep water (590 m). The rate $R_{Fe}(z)$ is likely proportional to both the particulate Fe(III) (hydr)oxides and the reductant (organic carbon) concentrations. In turn, the rate of their consumption is largely proportional to $R_{Fe}(z)$. Therefore, the decrease in $R_{Fe}(z)$ with depth is typically exponential (e.g., Katsev et al. 2006*a*):

$$R_{\mathrm{Fe}}(z) = R_{\mathrm{Fe}}(0)e^{(-\alpha z)}. \qquad \text{(A3)}$$

Assuming, for simplicity, that K_z does not vary significantly below the pycnocline and neglecting the gradient in A_z because of the steep morphology of Lake Matano, we obtain the following solution to Eqs. A1–A3:

$$[\mathrm{Fe(II)}](z) = \frac{R_{\mathrm{Fe}}(0)}{K_z\alpha^2}\left[1 - \exp(-\alpha z) - \alpha z \exp(-\alpha L)\right]. \qquad \text{(A4)}$$

Table A1.1. Representative physical data.

Depth (m)	Temperature (°C)		Conductivity (μS)		Density (kg m^{-3})	
	2004	2005	2004	2005	2004	2005
0	27.8	28.4	193	191	996.5	996.3
20	27.7	28.4	192	191	996.5	996.3
40	27.6	28.4	192	192	996.5	996.3
60	27.6	27.8	192	193	996.5	996.5
80	27.6	27.6	192	194	996.5	996.5
100	27.4	27.4	205	201	996.6	996.6
120	26.8	26.8	229	229	996.7	996.8
140	26.5	26.4	254	254	996.9	996.9
160	26.2	26.1	278	277	997.0	997.0
180	25.9	25.9	294	290	997.0	997.0
200	25.8	25.8	303	302	997.1	997.1
250	25.6	25.6	314	311	997.1	997.1
300	25.6	25.6	318	317	997.1	997.1
350	25.6	25.6	320	318	997.1	997.1
400	25.6	25.6	321	319	997.1	997.1
450	25.6	25.6	321	319	997.1	997.1
500	25.6	25.6	321	319	997.1	997.1
550	25.6	25.6	321	319	997.1	997.1

Table A1.2. Representative chemical data.

Depth (m)	pH 2004	pE 2004	O_2 (μmol L^{-1}) DL* 5		Mn (μmol L^{-1}) DL 0.003		Fe (μmol L^{-1}) DL 0.02		P (μmol L^{-1}) DL 0.05		Cr (nmol L^{-1}) DL 30		Ni (nmol L^{-1}) DL 8		Co (nmol L^{-1}) DL 0.15	
			2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
0	7.72	10.3	249	208						DL	187	179	84	63	1.6	0.6
1				206												
5			246	205												
10			243	205								183		59		0.4
15			239	206												
20	8.19	9.86	239	206	0.2		2			DL	181		78		1.1	
25			240	203												
30			238	203								188		60		0.3
35			238	204												
40	8.25	9.09	235	204	0.2		2				183		80		1.6	
45			237	204												
50			235	201	0.2		2			DL		177		60		0.4
55			196	199								178		62		0.3
60	8.26	9.48	184	200	0.5		2				171	169	72	62	1.2	0.3
65			171	202												
70			164	199												
75			159	202												
80	8.26	9.53	141	202	0.5		2				180		78		1.3	
85			132	200												
90			116	200	0.4		2		DL	DL		144	96	57	5.5	0.3
95			73	189												
96			59													
97			46													
98			38													
99			30													
100	7.57	10.1		119	1.3		2		DL	0.8	125	95	107	48	4.4	0.3
105				35												
110	7.24	5.0	DL	DL	8.5	9.2	27	2	DL	0.9	DL	DL	85	215	19	25
120	7.15	5.0	DL	DL	7.7	9.5	34	34	DL	0.4	DL	DL	36	28	14	9
140					8.0	8.1	58	67		2.9	DL	DL	39	32	22	20
150	7.0	5.22	DL	DL	7.8	8.2	74	68		2.9	DL	DL	36	28	29	22
160					7.8	8.0	78	88	3.4	4.7	DL	DL				
180						7.3		103		5.9	DL	DL	51	41	51	39
200	6.97	5.23	DL	DL		7.4	110	118	6.5	7.1	DL	DL		42		44
225						6.5		122		7.5		DL		42		42
250						6.7		132		8.3		DL		43		38
275						6.5		134		8.6		DL		42		38
300	6.99	5.08	DL	DL	6.1	6.2	115	132	7.2	8.2	DL	DL	46	42	35	39
350						6.5		140		9.0		DL		43		35
400	6.99	5.16	DL	DL	6.2	6.4	126	137	8.4	8.7	DL	DL	51	44	40	33
450						6.4		140		8.6		DL		42		33
500	6.99	4.99	DL	DL	6.5	6.4	149	141	9.6	8.4	DL	DL	50	40	36	33
525	6.99	4.70				6.4		141		8.3		DL		40		30

* DL is the analytical detection limit. Concentrations reported as DL are at or below the detection limits.