10.1071/MF06057_AC

ISSN 1323-1650

Marine and Freshwater Research, 2006, **57**(8), 775–788.

Sulfidic materials in dryland river wetlands

S. Lamontagne[A,C,D], *W. S. Hicks*[B,C], *R. W. Fitzpatrick*[A,C] *and S. Rogers*[A,C]

[A]CSIRO Land and Water, Private Mail Bag No. 2, Glen Osmond, SA 5064, Australia.

[B]CSIRO Land and Water, GPO Box 1666 Canberra, ACT 2601, Australia.

[C]CRC LEME, CSIRO Exploration and Mining, PO Box 1130, Bentley, WA 6102, Australia.

[D]Corresponding author. Email: sebastien.lamontagne@csiro.au

Abstract. Due to a combination of river regulation, dryland salinity and irrigation return, lower River Murray floodplains (Australia) and associated wetlands are undergoing salinisation. It was hypothesised that salinisation would provide suitable conditions for the accumulation of sulfidic materials (soils and sediments enriched in sulfides, such as pyrite) in these wetlands. A survey of nine floodplain wetlands representing a salinity gradient from fresh to hypersaline determined that surface sediment sulfide concentrations varied from <0.05% to ~1%. Saline and permanently flooded wetlands tended to have greater sulfide concentrations than freshwater ones or those with more regular wetting–drying regimes. The acidification risk associated with the sulfidic materials was evaluated using field peroxide oxidations tests and laboratory measurements of net acid generation potential. Although sulfide concentration was elevated in many wetlands, the acidification risk was low because of elevated carbonate concentration (up to 30% as $CaCO_3$) in the sediments. One exception was Bottle Bend Lagoon (New South Wales), which had acidified during a draw-down event in 2002 and was found to have both actual and potential acid sulfate soils at the time of the survey (2003). Potential acid sulfate soils also occurred locally in the hypersaline Loveday Disposal Basin. The other environmental risks associated with sulfidic materials could not be reliably evaluated because no guideline exists to assess them. These include the deoxygenation risk following sediment resuspension and the generation of foul odours during drying events. The remediation of wetland salinity in the Murray–Darling Basin will require that the risks associated with disturbing sulfidic materials during management actions be evaluated.

Table A1. Description and morphology for Lower River Murray floodplain wetland sediment samples

Additional details in Lamontagne *et al*. (2004)

Sample code	Colour (Munsell)	Texture[A]	HCl fizz[B]	Consistence[C]	Structure[D]
BBU1	10YR5/6	CS	NE	S	m
BBU2	5Y5/2; 10YR4/4	ZCL	NE	S	m
BBU3	5Y6/2; 2.5Y5/4	LC	NE	MH	m
BBU4	2.5Y5/2;7.5YR5/6	MC	NE	VH	m
BBL1	10YR4/2	LS	NE	L	sg
BBL2	5Y6/1; 2.5Y 6/6	MC	NE	HA	m
CL1	5Y5/1	LC	NE	HA	abk
CL2	5Y4/1	LC	NE	HA	abk
CL3	5Y4/2	MC	NE	HA	abk
ML1	2.5Y5/2	CS	NE	S	m
ML2	5Y6/2	SCL	NE	S	m
ML3	5Y6/2; 10YR4/4	HC	NE	EH	m
WL1	5Y5/1	ZL	SL	S	m
WL2	2.5Y4/1	ZCL	SL	S	m
WL3	5Y5/2	MC	VS	SH	m
WL4	5Y4/2	ZCL	VS	S	m
WL5	5Y5/1	MC	NE	SH	m
WL6	2.5Y5/2	MC	NE	SH	m
WL7	5Y5/2	HC	NE	VH	m
RL1	2.5Y5/2	LS	VS	L	sg
RL2	2.5Y6/2	CS	NE	S	sg
RL3	2.5Y5/2	SL	NE	S	m
RL4	5Y5/2	MC	VS	SH	m
HL1	5Y4/1	ZLC	SL	SH	m
HL2	5Y4/1	ZLC	SL	SH	m
HL3	5Y5/1	ZLC	VS	SH	m
RA1.1	5Y6/2	ZCL	ST	S	m
RA1.2	5Y5/2	ZCL	SL	SH	m
RA1.3	5Y5/2	MC	VS	SH	m
RA1.4	5Y5/2	MC	NE	SH	m
RA1.5	5Y6/2	MC	NE	SH	m
RA2.1	5Y5/2	LS	ST	L	sg
RA2.2	5Y6/2	LS	ST	L	sg
RA2.3	5Y5/2	LS	VS	L	sg
RA2.4	5Y6/2	LS	NE	L	sg
RA2.5	5Y5/2	LC	NE	SH	m
RA2.6	5Y5/2	LC	NE	SH	m
RA2.7	5Y5/2	LC	NE	SH	m
BEB1	5Y3/1	LC	VE	SH	m
BEB2	5Y5/3	HC	VE	VH	m
LV1.1	5Y8/2	(salt)			pl
LV1.2	5Y8/1	(salt)			pl
LV1.3	5Y5/2	LC	VE	EH	m
LV1.4	5Y4/1	LC	VE	EH	m
LV1.5	5Y4/1	MC	VE	EH	m
LV1.6	5Y4/1	MC	VS	EH	m
LV1.7	5Y5/1	MC	VS	EH	m
LV1.8	5Y4/1	MC	VS	EH	m
LV2.1	5Y6/3	LC	VE	SH	pl
LV2.3	5Y6/3	LC	SL	SH	pl
LV2.4	5Y4/1	LC	NE	MH	m
LV3.1	5Y4/2	LC	VE	MH	m
LV3.2	5Y4/1	MC	VS	MH	m
LV3.3	5Y4/1	MC	NE	MH	m

[A]Using the Australian Soil and Land Survey: Field Handbook: McDonald et al. (1990). Where: S=Sand, LS=Loamy Sand, CS=Clayey Sand, SL=Sandy Loam, L=Loam, ZL=Silty loam, ZCL= Silty Clay Loam, SCL=Sandy Clay Loam, ZLC= Silty Light Clay, LC=Light Clay, MC=Medium Clay, HC=Heavy clay. Taken from dried subsamples.

[B]Reaction or fizz to 1N HCl: NE = non-effervescent; VS = Very slightly effervescent; SL – Slightly effervescent; ST = Strongly effervescent; VE = Violently effervescent.

[C]Consistence: L=Loose; S=Soft; SH= Slightly Hard; MH= Moderately Hard; HA = Hard; VH=Very Hard; EH= Extremely Hard; R= Rigid; VR= Very Rigid.

[D]Structure: gr=Granular; abk=Angular blocky; sbk=Subangular blocky; pl=Platy; weg=wedge; sg= single grain; m=Massive; pr=Prismatic; cpr=Columnar; po=Polyhedral;

Table A2. Laboratory sediment tests for Loveday, Berri, Ramco and Hart disposal basins

(See Table 3 for details on sample codes.) Data as % sediment dry weight unless otherwise shown

Sample code	1:5 EC (dS m^{-1})	1:5 pH	S_{tot}	S_{Cr}	$S_{ox + org}$	C_{tot}	C_{carb}	C_{org}
LV1.1	4.9	8.1	1.7	0.33	1.4	7.4	3.9	3.5
LV1.2	3.2	8.1	1.1	0.49	0.61	6.3	1.9	4.4
LV1.3	17	8.0	0.92	0.46	0.46	4.6	1.6	3.0
LV1.4	4.5	7.8	0.86	0.45	0.41	3.8	1.2	2.6
LV1.5	4.5	7.8	0.91	0.52	0.39	3.3	1.1	2.2
LV1.6	1.3	8.6	0.72	0.72	<0.01	2.5	0.14	2.4
LV1.7	0.54	9.2	0.28	0.28	<0.01	1.0	<0.012	1.0
LV1.8	0.83	9.0	0.21	0.15	0.06	0.62	0.072	0.55
LV2.1	68	8.6	3.5	0.78	2.7	7.9	1.1	6.8
LV2.3	71	8.7	1.4	0.43	0.97	5.8	1.5	4.3
LV2.4	3.4	8.9	0.21	0.19	0.02	0.85	0.022	0.83
LV3.1	38	8.4	1.1	0.27	0.83	2.4	0.54	1.9
LV3.2	15	8.3	1.0	0.97	0.03	2.1	0.07	2.0
LV3.3	2.1	8.8	0.33	0.36	<0.01	1.5	0.06	1.4
RA1.1	33	8.4	0.53	0.02	0.51	1.6	0.65	0.95
RA1.2	5.8	8.9	0.12	0.13	<0.01	0.33	0.028	0.30
RA1.3	3.0	9.2	0.18	0.19	<0.01	0.21	<0.012	0.20
RA1.4	2.3	9.5	0.02	<0.01	0.02	0.15	0.014	0.14
RA1.5	2.0	9.5	0.02	<0.01	0.02	0.11	<0.012	0.10
RA2.1	25	8.6	0.28	0.04	0.24	1.1	0.43	0.67
RA2.2	6.4	8.9	0.16	0.11	0.05	0.52	0.15	0.37
RA2.3	4.0	8.8	0.16	0.14	0.02	0.59	0.08	0.51
RA2.4	2.2	9.3	0.10	0.09	0.01	0.33	0.014	0.32
RA2.5	1.9	9.4	0.19	0.18	0.01	0.38	<0.012	0.37
RA2.6	1.9	9.4	0.08	0.08	<0.01	0.20	<0.012	0.19
RA2.7	1.8	9.4	0.02	0.01	0.01	0.17	<0.012	0.16
BEB1	47	8.4	1.4	0.29	1.1	4.6	2.3	2.3
BEB2	44	8.4	1.3	0.47	0.83	5.1	2.2	2.9
HL1	24	8.8	0.36	0.22	0.14	1.4	0.33	1.1
HL2	22	8.5	0.24	0.06	0.18	1.3	0.40	0.90
HL3	6.0	8.6	0.18	0.19	<0.01	0.50	0.035	0.47

Table A3. Laboratory sediment tests for Ross, Woolpolool, Merreti, Clover and Bottle Bend wetlands

(See Table 3 for details on sample codes.) Data as % sediment dry weight unless otherwise shown

Sample code	1:5 EC (dS m^{-1})	1:5 pH	S_{tot}	S_{Cr}	$S_{ox + org}$	C_{tot}	C_{carb}	C_{org}
RL1	12	9.4	0.14	0.02	0.12	0.38	0.061	0.32
RL2	3.6	9.1	0.02	<0.01	0.02	0.18	0.014	0.17
RL3	3.3	8.9	0.03	<0.01	0.03	0.35	0.014	0.34
RL4	2.5	9.4	0.14	0.10	0.04	0.31	0.05	0.26
WL1	4.0	8.5	0.32	0.07	0.25	1.8	0.27	1.5
WL2	5.0	8.3	0.36	0.09	0.27	2.6	0.33	2.3
WL3	5.5	8.6	0.33	0.04	0.29	0.57	0.014	0.56
WL4	1.9	8.3	0.25	0.08	0.17	3.2	0.22	3.0
WL5	1.5	8.4	0.14	0.04	0.10	0.78	<0.012	0.77
WL6	0.60	8.6	0.02	0.01	0.01	0.40	0.014	0.39
WL7	0.87	8.7	0.04	0.01	0.03	0.30	<0.012	0.29
ML1	0.59	7.6	0.02	0.01	0.01	0.42	0.014	0.41
ML2	0.40	7.2	0.01	0.01	<0.01	0.27	0.013	0.26
ML3	0.31	7.2	0.01	<0.01	0.01	0.15	0.013	0.14
CL1	7.8	6.6	0.04	0.01	0.03	0.82	0.028	0.79
CL2	9.0	6.8	0.28	0.01	0.27	0.57	0.028	0.54
CL3	8.5	7.0	0.27	<0.01	0.27	0.36	0.028	0.33
BBL1	1.2	5.8	0.12	0.09	0.03	1.1	0.014	1.1
BBL2	0.82	5.0	0.03	0.02	0.01	0.66	0.014	0.65
BBU1	3.4	5.7	0.03	0.01	0.02	0.57	<0.012	0.56
BBU2	6.4	6.2	0.39	0.35	0.04	2.8	0.014	2.8
BBU3	1.8	5.0	0.05	0.03	0.02	0.31	<0.012	0.30
BBU4	11	5.8	0.11	0.03	0.09	1.9	<0.012	1.9

Table A4. Field sediment tests

A final pH < 3.5 following peroxide addition ($pH_{peroxide}$) indicates a potential acid sulfate soil. Eh values relative to the Standard Hydrogen Electrode

Wetland	Site/pit or core	Depth (cm)	Field pH	$pH_{peroxide}$	Eh (mV)
Loveday	Site 1 Pit 1	1–5	7.2	6.9	–
		5–12	7.3	6.6	–
		12–20	7.3	6.7	–
		20–30	7.3	6.2	–40
		30–40	7.7	6.2	–3
		40–50	8.6	7.9	–
	Site 2 Pit 1	0–1	8.6	7.3	–12
		0–3	8.1	6.6	50
		1–20	8.1	6.6	–180
		20–30	8.5	2.6	–85
	Site 2 Pit 2	0–5	7.9	6.1	270
		5–30	8.0	3.2	180
		30–40	7.8	2.0	40
Ramco	Core 1	2	7.2	7.5	550
		5	7.3	6.6	430
		10	7.2	6.4	410
		20	7.5	7.1	360
	Core 2	2	7.2	7.3	320
		5	7.3	7.5	260
		10	7.5	6.3	220
		15	7.0	5.8	110
		20	7.7	4.7	90
		25	7.7	7.9	180
Berri	Pit 1	0–5	6.9	–	–
	Pit 2	0–5	6.3	–	–
Hart	Pit 1	0–5	6.9	7.1	230
	Pit 2	0–5	7.4	7.8	270
		5+	7.2	5.9	200
Ross	Pit 1	0–10	6.9	6.2	–81
	Pit 2	0–10	6.6	5.9	–65
		15–25	6.6	5.8	55
		25+	7.1	7.2	150
Woolpolool	Core 1	1	7.7	7.2	–240
		6–10	–	6.2	–130
	Core 2	1	7.3	6.4	–310
		3+	–	6.1	–150
Merreti		0–5	6.1	4.6	270
		5–10	6.1	5.4	340
		10–20	5.8	6.5	400
Clover		0–10	5.9	–	–
Bottle Bend	Site 2, Core 1	5	6.4	2.9	50
		15	6.2	2.1	110

Table A5. Mineralogical composition of sediments from selected samples estimated by XRD analysis

Results are semi-quantitative for the mineral and give a compositional range

Sample code	Q	Mi	Al	Or	Ka	Sm	Ha	Py	Ca	Ar	Gy	Do	Un	Dominant S form	
														Reduced	Organic + oxidised
BBU1	D	M	M	M	T	T	T	?T	–	–	–	–	–	Pyrite	
BBU2	D	M	M	M	T	T	T	–	–	–	–	–	–		
BBU3	D	SD	M	M	T	T	T	–	–	–	–	–	–		
BBU4	CD	CD	T	T	M	CD	T	–	–	–	T	–	–		Gypsum
BBL1	D	M	M	M	T	–	T	?T	–	–	–	–	–	Pyrite	
BBL2	CD	CD	T	T	M	CD	T	?T	–	–	–	–	–	Pyrite	
WL4	D	M	M	M	T	M	T	?T	T	–	–	–	–	Pyrite	Organic
WL6	D	SD	M	M	T	M	T	?T	T	–	–	–	–	Pyrite	
WL7	D	SD	T	T	T	M	–	–	T	–	–	–	–		
HL1	D	M	M	T	T	T	M	–	M	?T	–	–	–		Organic
RA1.3	D	SD	M	M	T	M	T	?T	–	–	–	–	–	Pyrite	
RA2.1	D	M	M	M	T	T	M	?T	T	–	–	–	–	Pyrite	Organic
RA2.3	D	M	M	M	T	T	T	?T	T	–	–	–	–	Pyrite	
RA2.5	D	M	M	M	T	T	T	?T	–	–	–	–	–	Pyrite	
BEB1	CD	M	T	T	T	M	CD	–	M	CD	T	–	–		Gypsum
BEB2	CD	M	T	T	T	M	CD	–	M	CD	T	–	–		Gypsum
LV1.1	CD	M	T	T	T	T	T	T	CD	CD	M	–	–		
LV1.2	CD	M	T	T	T	M	M	T	CD	–	T	–	–	Pyrite	Gypsum
LV1.3	D	M	T	T	T	SD	T	T	SD	–	T	–	–		
LV1.4	D	M	T	T	T	M	T	T	SD	–	T	?T	–		
LV1.5	D	M	T	T	T	M	–	T	T	–	–	–	–	Pyrite	
LV1.6	D	M	T	T	T	M	–	T	–	–	–	–	–	Pyrite	
LV1.7	D	M	T	T	T	T	–	T	–	–	–	–	–		
LV2.1	M	M	T	T	T	T	D	–	M	–	T	–	M		Gypsum
LV2.3	M	M	T	T	T	T	D	–	M	–	T	–	T		Gypsum
LV2.4	D	M	T	T	T	M	T	T	T	–	–	–	–	Pyrite	
LV3.1	D	M	T	T	T	T	M	?T	M	–	T	–	–	Pyrite	Gypsum
LV3.2	D	M	T	T	T	M	M	T	T	–	–	–	–	Pyrite	
LV3.3	D	M	T	T	T	M	T	T	T	–	–	–	–	Pyrite	
LV efflorescence 1	M	–	T	–	–	T	–	–	CD	CD	T	–	–		
LV efflorescence 2	SD	M	T	T	T	M	–	T	D	–	T	–	–		
LV efflorescence 3	M	T	–	–	T	T	T	–	CD	M	CD	–	–		

Q=Quartz, Mi=Mica, Al=Albite, Or=Orthoclase, Ka=Kaolin, Sm=Smectite, Ha=Halite, Py=Pyrite, Ca=Calcite, Ar=Aragonite, Gy=Gypsum, Do=Dolomite, Un=Unidentified
D=Dominant (>60%), CD=co-dominant (sum of phases >60%), SD=sub-dominant (20-60%), M=minor(5-20%), T=trace (<5%).