Assessing options for remediation of contaminated mine site drainage entering the River Teign, Southwest England

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Figure S1. Steps outlining the kinetics experiment to determine analyte adsorption rates.

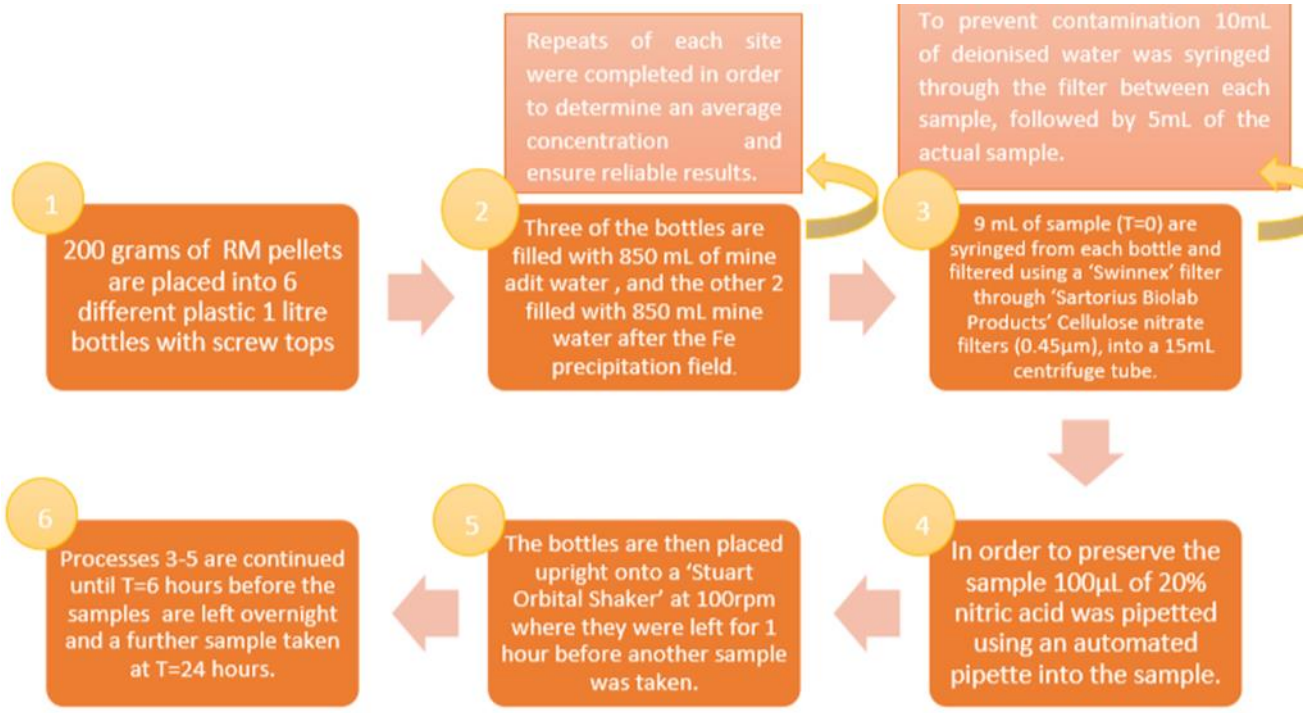
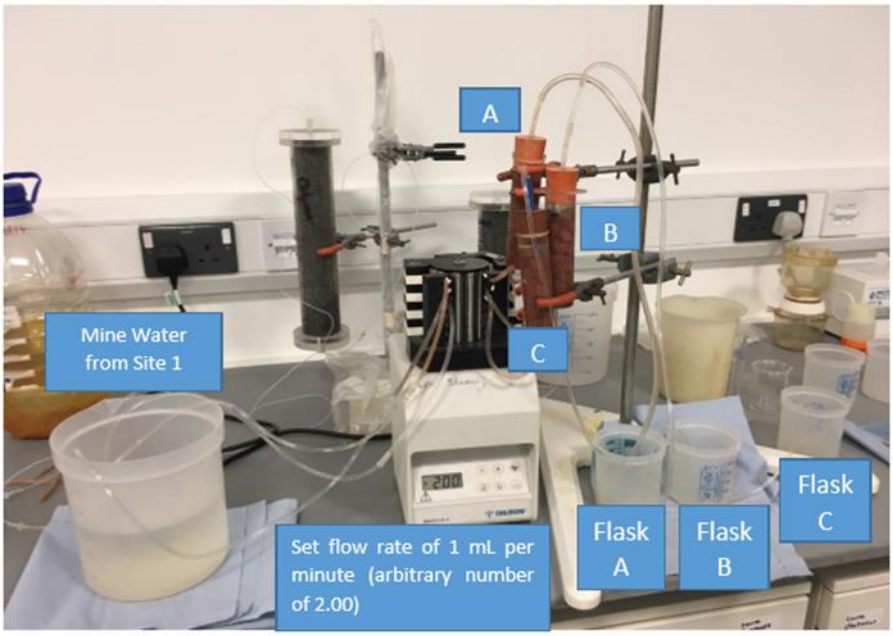


Figure S2. Steps outlining column experiment.



The plunger from a plastic 60mL syringe was removed and the syringe inverted and a rubber bung with a plastic tube inserted. This was done as the 1 litre plastic columns used by Hill (2016) were too large for the time constraints presented in determining capacity.

Mine adit water was used as the high concentration of Zn previously measured suggested the pellets could be exhausted in a relatively short time but still enough time to identify the "break-through" point. Using adit water from Bridford maintained a realistic context for this project.

Three repeats were completed for the mean to be calculated ensuring reliable results. Each of the columns were filled in small batches of FP and shaken, ensuring the maximum dry weight of the pellets, this was done up to the 50mL line. The weight of the pellets in each column was variable due to their rigid shape, the CP had a weight of 589g, the FP 410g.

Tubing and a pump (Miniplus 3 Gilson) were set up to a speed of 1 mL per minute, the flow rate of each individual column was determined, by measuring the volume of water in a 100mL measuring cylinder within a given time.

Figure S3. Environment Agency sampling points for the River Teign.

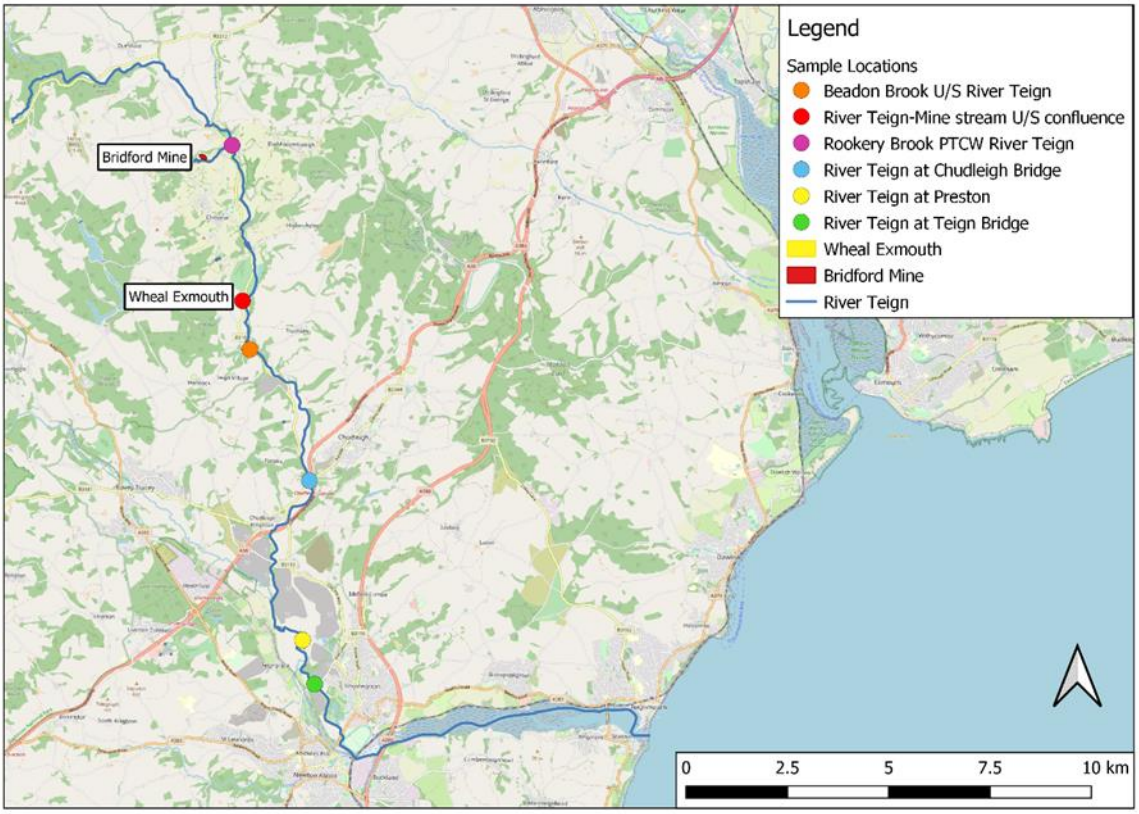


Table S1. Removal efficiencies for Zn, Cd and Pb at 2, 24 and 53 hours *(Turner 2017; Hill 2016).*

Duration	Zinc removal %			
	Compressed	Fired	FAE	New
2 hours	73.7	22	25.6	23.3
24 hours	99.5	99.3	97.2	94.7
53 hours	99.8	99.9	-	-

Duration	Cadmium removal %			
	Compressed	Fired	FAE	New
2 hours	94.4	25.3	28.2	27.6
24 hours				
53 hours	99.5	99.9		
Duration	**Lead removal %**			
	Compressed	Fired	FAE	New
2 hours	99.2	92.7	64	96.3
24 hours				
53 hours	99.9	99.8		

Table S2. Field scale trial at Bridford mine. Percentage removal of Zn, Cd and Pb over a 3-month period *(Comber 2015).*

Day	% removal Zn		% removal Cd		% removal Pb	
	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered
3	91	84	94	94	99	99
9	81	80	91	91	99	99
20	77	78	87	86	99	98
26	63	62	75	74	97	95
33	45	39	56	48	85	51
38	36	31	45	43	74	68
44	28	28	44	42	66	58
51	24	24	39	36	68	53
58	27	22	41	37	66	60
67	31	24	40	35	46	36
72	37	34	51	42	43	39
79	28	31	45	48	73	51
89	26	23	38	39	73	43
104	36	19	57	36	79	58

Table S3. Biochar removal efficiency results for Zn, Cd and Pb at 550°C and 700°C *(Roberts 2018).*

Removal efficiency (%) 2 hrs						
Biochar	550°C			700°C		
	zinc	cadmium	lead	zinc	cadmium	lead
Forestry waste	5	-1	18	8	0	62
Municipal waste	9	0.023	60	17	19	76
Rice husk	28	43	100	9	20	98
Miscanthus straw pellet	21	35	97	50	62	100
Wheat straw pellet	80	86	94			
Oil seed rape	80	88	91	81	90	100

Table S4. Environment Agency monitoring data from 2000-2020 available at.

https://environment.data.gov.uk/water-quality/view/landing

All units µg/l

Beadon brook								
	Zn EQS	Dissolved zn	bio zn	Cd EQS	mean Cd	Pb EQS	mean Pb	bio Pb
2012	13.8	145		0.08	1.99	7.2	2.15	
2013	13.8	203		0.08	2.47	7.2	2.28	
2014	13.8	61		0.08	0.98	7.2	2	
2015	13.8	176	120	0.08	2.02	7.2	1.15	0.72
2016	13.8	358	325	0.08	3.69	7.2	2.80	2.28
2017	13.8	249	211	0.08	2.76	7.2	1.95	1.34
2018	13.8	200	168	0.08	1.92	7.2	1.42	0.84
2019	13.8	138	107	0.08	1.64	7.2	1.72	0.74

RT at Preston	Zn EQS	Dissolved Zn	bio zn	Cd EQS	mean Cd	Pb EQS	mean Pb
2000	13.8	21.5		0.08	0.11	7.2	1.06
2001	13.8	30.9		0.08	0.08	7.2	1.25
2002	13.8	19.4		0.08	0.01	7.2	1.0
2003	13.8	20.3		0.08	0.09	7.2	2.09
2004	13.8	19.0		0.08	0.09	7.2	2.57
2005	13.8	21.1		0.08	0.09	7.2	2
2006	13.8	16.4		0.08	0.08	7.2	2.02
2007	13.8	16.1		0.08	0.10	7.2	2
2008	13.8	15.9		0.08	0.10	7.2	2
2009	13.8	15.8		0.08	0.105	7.2	2
2010	13.8	18.5		0.08	0.107	7.2	2
2011	13.8	15.0		0.08	0.100	7.2	2
2012	13.8	16.8		0.08	0.103	7.2	2
2013	13.8	15.9		0.08	0.107	7.2	2
2014	13.8	17.2		0.08	0.101	7.2	2
2015	13.8	13.8	9.19	0.08	0.0763	7.2	2
2016	13.8	16.9	8.90	0.08	0.0763	7.2	0.535
2017	13.8	16.7	10.90	0.08	0.0684	7.2	1.05
2018	13.8	18.4	9.74	0.08	0.0847	7.2	1.12
2019	13.8	16.3	10.13	0.08	0.0823	7.2	1.12

Table S5. continued.

RT at Chudleigh bridge	Zn EQS	Dissolved zn	bio zn	Cd EQS	mean Cd	Pb EQS	mean Pb
2011	13.8	17.4	8.4	0.08	0.1	7.2	2
2012	13.8	28.	15.7	0.08	0.103	7.2	2
2013	13.8	31.5	16.5	0.08	0.175	7.2	2.83
2014	13.8	23.8	12.9	0.08	0.19	7.2	2
2018	13.8	39.9	18.6	0.08	0.219	7.2	2.00
2019	13.8	42	18.1	0.08	0.191	7.2	2.65

Rookery Brook PTCW RT	Zn EQS	Dissolved zn	bio zn	Cd EQS	mean Cd	Pb EQS	mean Pb
2011	13.8	551		0.08	1.85	7.2	19
2012	13.8	453		0.08	1.98	7.2	21.6
2013	13.8	368		0.08	1.7	7.2	27.3
2016	13.8	407		0.08	1.36	7.2	20

Ambient data to used to calculate metals bioavailability at Chudleigh bridge *(Environment Agency water quality archive):*

RT at Chudleigh bridge			
Year	**pH**	**DOC (mg/l)**	**Hardness (Total a $CaCO_3$) mg/l**
2019	7.57	3.81	34.8
2018	7.33	4.46	34.1
2014	7.41	3.09	32.4
2013	7.49	2.88	36.8
2012	7.33	3.2	37.3
2011	7.17	4.775	24.2

Figure S4. Screenshot of Biomet tool, used to calculate the bioavailable concentrations of Zn at Chudleigh bridge, using pH, hardness and DOC.

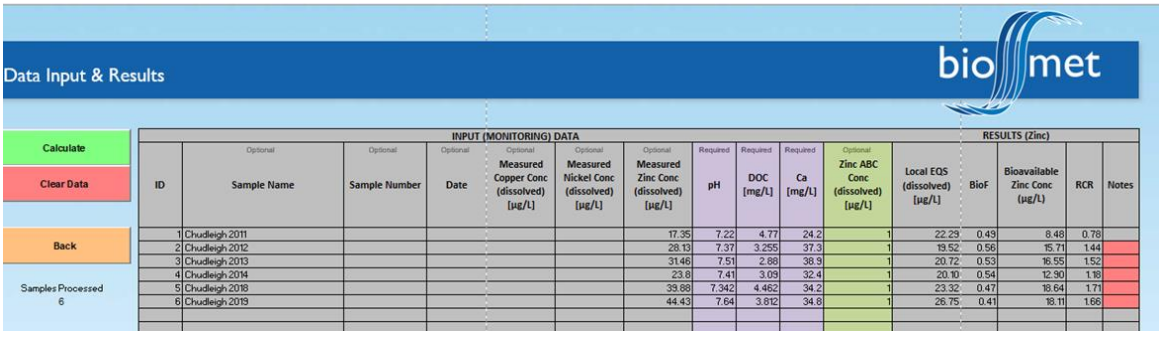


Figure S5. Screenshot of Real World Application model, used to calculate the amount of pellets/biochar needed to reduce Zn levels below the EQS at Chudleigh.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Metal	EQS	Metal Conc. In water body (µg/l)	Metal Conc. In water body (mg/l)	Amount above EQS (ug/l)	Amount above EQS (mg/l)	Flow (m3/s) (annual avg.)	Flow m3/s into l/s	Flow (l/s) x 60 = l/min	Flow (l/min) x 60 = l/hour	Flow (l/hr) x 24 = l/day	Flow l/day x 365 = l/yr	Exceedance (mg/l) x flow (l/yr) = (load) mg/yr	Load into kg/year	Capacity of pellets* (mg/kg)	g/kg	kg/kg	Load (kg/yr) / adsorption capacity (kg/kg) = kg of pellets for 1year to reach EQS in water body	Tonnes of pellets a year required to reach EQS in water body	So, kg/yr of pellets / 586* = m3 required for amount of pellets
2	Zinc	10.9	18.1	0.01811	7.2	0.007	5.3200	5320	319200	19152000	459648000	1.678E+11	1209632659	1210	395.8	0.40	0.0004	3056171	3056	5215
3	Cadmium	0.08	0.2	0.00019	0.1	0.000	5.3200	5320	319200	19152000	459648000	1.678E+11	18454867.2	18	1.56	0.00	0.0000	11830043	11830	20188
4	Lead	7.2	2.7	0.00265	-4.6	-0.005	5.3200	5320	319200	19152000	459648000	1.678E+11	-763360416	-763	2089	2.09	0.0021	-365419	-365	-624
5																				
6																				
7																				
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13																				*From laboratory, 586kg in 1m3