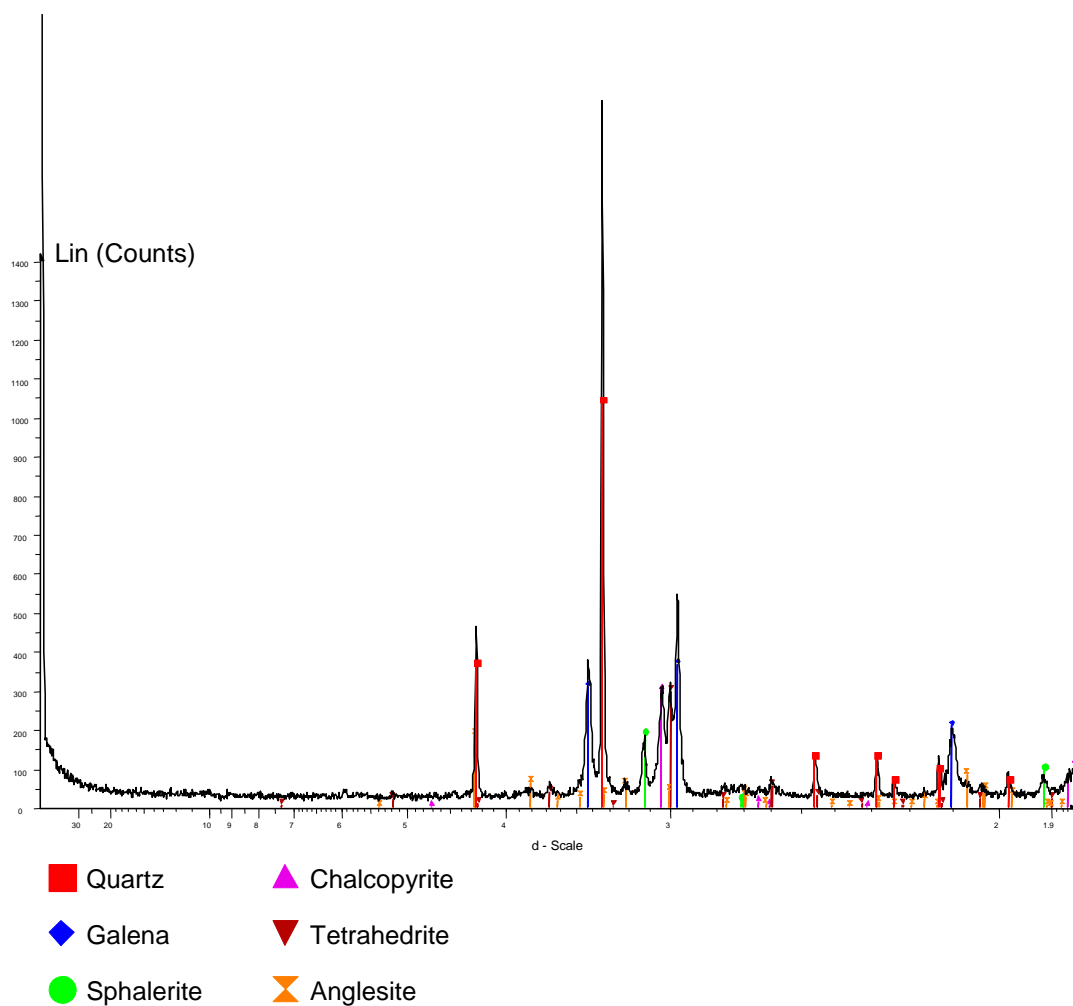

Appendix B1
**Characterisation of waste material used in
column leaching experiments**
Bulk XRF results

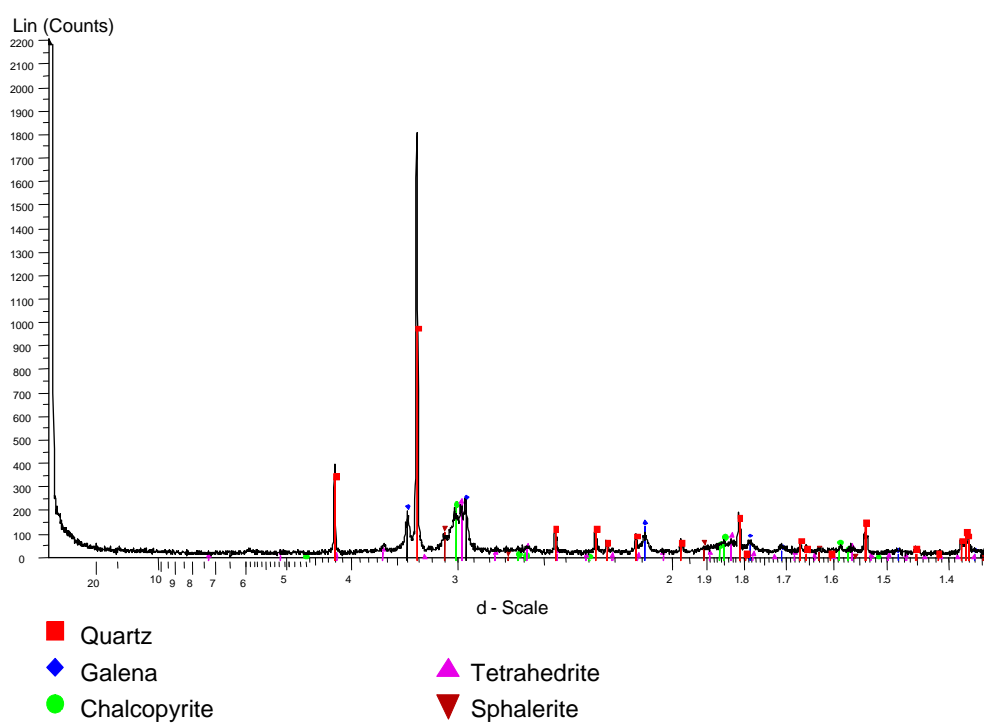
Element (weight%)	Experiment 1	Experiments 2 and 3
Ag	0.172	0.048
Al	1.150	3.230
As	0.707	0.464
Bi	0.027	0.014
Ca	0.014	0.011
Cd	0.021	0.007
Co	0.012	0.007
Cu	5.900	2.150
F	0.361	0.202
Fe	4.630	2.890
In	0.023	0.008
K	0.330	0.925
Mg	0.136	0.121
Mn	0.009	0.011
Na	b.d.	b.d.
O	39.800	46.700
P	0.036	0.074
Pb	8.180	4.590
S	13.500	6.360
Sb	1.960	0.545
Se	0.020	0.006
Si	20.300	29.300
Sn	0.404	0.110
Ti	0.077	0.148
W	0.040	0.011
Zn	2.040	1.900

b.d. – below detection.

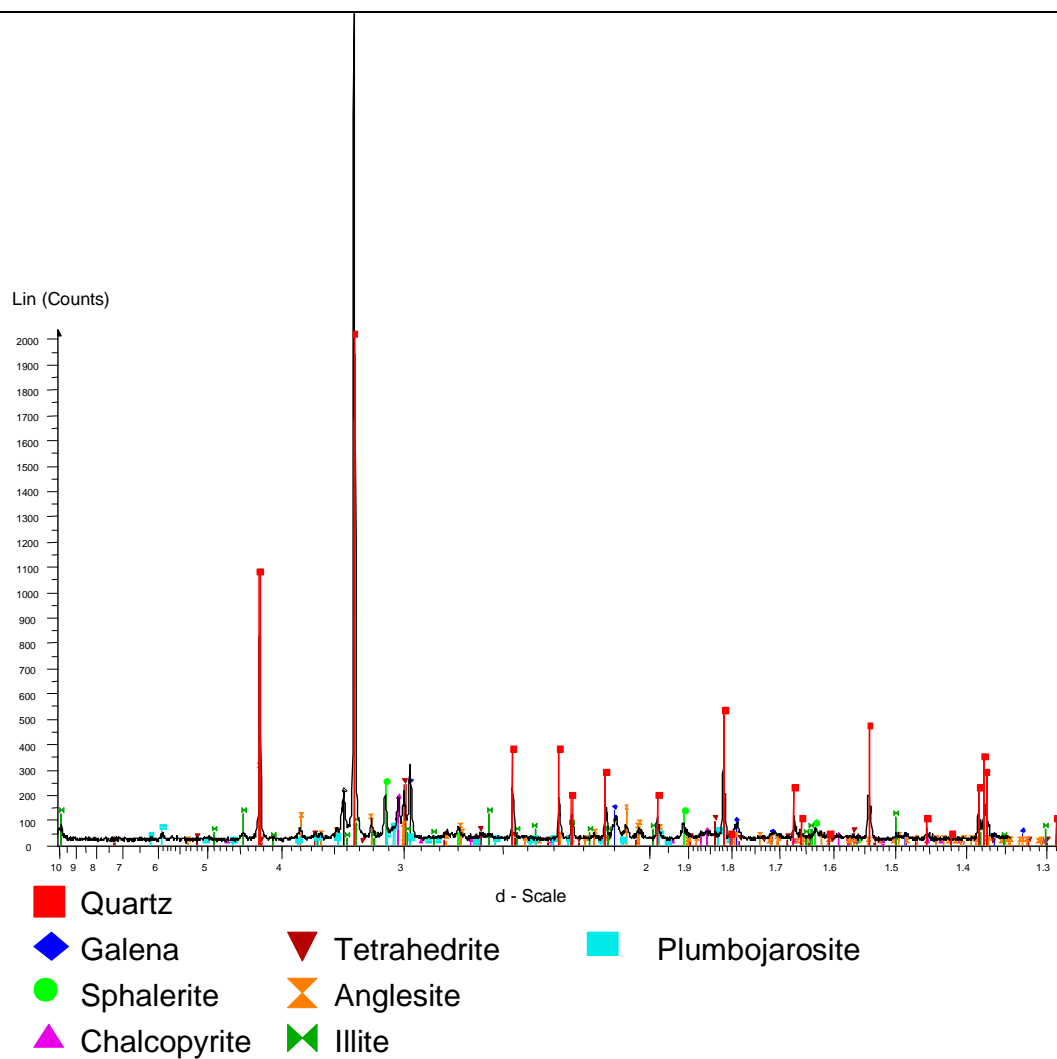
XRD traces



XRD trace of waste material used in experiment 1, pre-HCl leaching. Note presence of anglesite.



XRD trace of waste material used in experiment 1, post-HCl leaching. Note absence of anglesite.



XRD trace of waste material used in experiments 2 and 3.

Appendix B2

Phosphate stabilisation experiment 1

Coating stage pH and conductivity

Cumulative coating solution(ml)	Column A		Column B		Column C		Column D	
	pH	cond	pH	cond	pH	cond	pH	cond
200	5.39	n.r.	5.26	n.r.	5.24	n.r.	5.37	n.r.
400	5.25	29840	5.10	32440	5.22	32380	5.31	13000
600	5.26	30960	5.08	33800	5.06	34580	5.26	15470
800	5.37	30900	5.30	36320	5.23	34900	5.36	36120
1000	5.36	33080	5.18	51030	5.19	43710	5.32	39620
1200	5.39	35920	5.20	54180	5.18	56370	5.36	39800
1400	5.36	37900	5.17	63800	5.24	59700	5.29	47280
1600	5.63	38780	5.39	69840	5.37	71200	5.54	47250
1800	5.65	39600	5.40	74440	5.37	75160	5.56	46410
2000	5.63	39720	5.38	75760	5.35	75240	5.55	39360
2200	5.66	35650	5.42	58740	5.39	58110	5.58	37000
2400	5.64	34800	5.42	56970	5.40	52050	5.58	34860
2600	5.66	34540	5.44	56970	5.40	55200	5.59	34240
2800	5.64	34700	5.41	51930	5.39	53670	5.57	34260
3000	5.65	35860	5.42	55860	5.40	54330	5.58	34900
3200	5.64	34340	5.42	54780	5.38	53430	5.58	35960
3400	5.65	34460	5.17	54210	5.14	55500	5.58	37920
3600	5.64	35200	5.25	53550	5.26	54780	5.47	35440
3800	5.42	34620	5.20	56970	5.18	44730	5.39	35280
4000	5.38	35800	5.16	58020	5.13	54720	5.33	33760
4200	5.47	30700	5.22	52050	5.21	48030	5.39	30360
4400	5.39	31300	5.20	48480	5.38	44310	5.55	32520
4600	5.63	30620	5.39	46560	5.37	48780	5.56	30960
4800	5.61	30800	5.38	48000	5.36	45180	5.54	32320
5000	5.61	35240	5.37	58440	5.22	51660	5.42	33220

cond – conductivity reported in $\mu\text{S}/\text{cm}$ at 25 °C; n.r. – no result.

Dissolution stage pH and conductivity

Cumulative oxidising solution (ml)	Column A		Column B		Column C		Column D		Control	
	pH	cond	pH	cond	pH	cond	pH	cond	pH	cond
200	7.50	413	7.49	497	7.42	703	7.67	738	3.96	160
400	7.53	239	7.48	263	7.43	410	7.62	404	3.48	539
600	7.34	174	7.26	166	7.23	256	7.38	243	3.73	324
800	7.27	148	7.20	152	7.14	236	7.34	246	3.80	266
1000	7.20	114	7.13	113	7.12	172	7.27	181	3.93	184
1200	7.19	128	7.13	120	7.06	179	7.25	197	3.96	171
1400	7.16	98	7.11	86	7.07	127	7.24	139	4.08	136
1600	7.02	86	6.97	77	6.99	111	7.09	115	4.12	117
1800	7.02	91	6.94	86	6.96	122	7.09	139	4.15	115
2000	6.85	82	6.81	76	6.86	103	6.97	119	4.13	114
2200	6.86	91	6.79	86	6.83	121	6.97	139	4.08	114
2400	6.70	80	6.67	73	6.72	106	6.89	112	4.16	96
2600	6.71	91	6.68	81	6.76	110	6.89	125	4.09	104
2800	6.56	73	6.60	65	6.73	85	6.83	95	4.13	98
3000	6.60	79	6.58	73	6.71	98	6.83	115	4.10	104
3200	6.28	80	6.40	65	6.64	80	6.74	93	4.16	98
3400	6.35	90	6.47	73	6.62	92	6.74	112	4.07	110
3600	6.01	75	6.35	62	6.56	73	6.69	84	4.15	95
3800	6.04	78	6.34	67	6.55	83	6.68	97	4.13	97
4000	5.65	77	6.11	60	6.46	70	6.55	78	4.17	86
4200	5.80	78	6.10	68	6.43	87	6.55	98	4.10	91
4400	5.65	132	5.99	58	6.34	66	6.46	77	4.10	92
4600	5.44	85	5.95	63	6.32	74	6.51	88	4.08	91
4800	5.57	77	5.84	56	6.24	62	6.40	71	4.16	86
5000	5.48	73	5.86	64	6.31	72	6.44	88	4.13	92
5200	5.38	65	5.80	52	6.22	58	6.33	69	4.15	85
5400	5.43	71	5.82	59	6.20	68	6.36	83	4.08	94
5600	5.10	65	5.67	54	6.12	56	6.22	66	4.14	84
5800	5.32	77	5.75	59	6.16	66	6.28	79	4.15	84
6000	5.03	66	5.63	54	6.05	56	6.16	64	4.15	87
6200	5.16	70	5.56	59	6.00	67	6.12	80	4.13	90
6400	4.94	65	5.46	54	5.95	54	6.04	64	4.16	85
6600	5.11	69	5.53	59	5.93	63	6.04	74	4.14	83
6800	5.09	64	5.44	53	5.98	53	6.08	60	4.17	86
7000	5.11	71	5.47	58	5.93	62	6.01	73	4.19	88
7200	5.25	65	5.65	50	5.96	50	6.06	58	4.24	79
7400	5.06	68	5.56	55	6.00	60	6.00	70	4.20	85
7600	4.92	63	5.36	51	5.93	50	5.89	59	4.20	82
7800	4.90	69	5.42	55	5.87	58	5.86	69	4.18	83
8000	4.93	68	5.52	65	5.97	49	5.91	56	4.21	83
8200	4.94	69	5.40	55	5.85	59	5.86	68	4.16	84
8400	4.78	66	5.20	52	5.88	49	5.86	55	4.19	81
8600	4.82	73	5.40	55	5.84	58	5.81	68	4.18	82
8800	4.77	63	5.49	49	5.86	48	5.82	55	4.19	78
9000	5.00	65	5.58	54	5.75	57	5.75	68	4.17	82
9200	4.79	62	5.68	48	5.98	49	5.97	56	4.22	78

cond – conductivity reported in $\mu\text{S}/\text{cm}$ at 25 °C.

Coating stage leachate chemistry

	Column A			Column B			Column C			Column D		
	1200	3000	5000	1200	3000	5000	1200	3000	5000	1200	3000	5000
Cumulative coating solution (ml)												
Al	<100	<100	<100	152	197	179	<100	142	128	<100	<100	456
As	8690	3990	1690	8140	4240	1730	7200	3120	1280	6180	2340	1060
Ca	<100	<100	<100	122	<100	<100	<100	<100	108	<100	<100	869
Cd	15.5	15.6	10.5	38.2	39.7	36.2	50	58.7	53.5	77.9	55	60.3
Cu	3360	3240	2670	6190	6270	5280	11200	5960	5020	11400	5660	4690
K	6520	6890	6200	12100	13600	13500	11200	13600	12600	8000	6680	6380
Na	3950	4250	3790	3620	4180	3990	3290	4120	3820	4940	4120	3850
Pb	303	249	212	925	642	436	462	434	329	488	237	201
SO ₄ ²⁻	297	70	42	281	71	111	356	168	149	694	331	2116
Sb	1840	2270	1420	2130	2870	1450	3910	3730	2450	4570	4380	3210
Si	3.15	3.11	1.61	3.93	4.16	2.15	3.6	3.57	1.87	3.63	2.95	14.5
Zn	2580	2790	2080	6000	6320	5000	7580	6970	4930	10900	5890	4520

K, Na, SO₄²⁻ and Si values in mg/l, all other values in µg/l. Ag (<5), Fe (<100), In (<5), Mg (<10), Mn (<10) and Se (<100) below detection in all samples. Detection limits shown in brackets in µg/l.

Dissolution stage leachate chemistry**As**

Cumulative oxidising solution (ml)	Column A	Column B	Column C	Column D	Control
400	1950	2070	1410	1330	77
1600	573	456	505	481	55
2800	421	397	444	455	43
4000	307	308	353	361	35
5200	226	265	286	314	33
6400	208	230	243	250	14
7800	174	203	219	217	5
8800	141	170	193	182	3
9200	131	174	192	175	6

Concentrations in µg/l.

Cu

Cumulative oxidising solution (ml)	Column A	Column B	Column C	Column D	Control
400	1300	946	2270	2070	9730
1600	333	247	468	673	5850
2800	410	243	380	477	4290
4000	450	367	378	356	3610
5200	540	394	332	343	3270
6400	662	518	479	541	3670
7800	771	589	617	669	3020
8800	998	731	777	923	3230
9200	985	1000	1130	1200	3250

Concentrations in µg/l.

Fe

Cumulative oxidising solution (ml)	Column A	Column B	Column C	Column D	Control
400	550	800	698	454	908
1600	157	<100	<100	158	256
2800	156	<100	<100	<100	<100
4000	<100	<100	<100	<100	<100
5200	<100	<100	<100	<100	<100
6400	<100	<100	<100	<100	<100
7800	<100	<100	<100	<100	<100
8800	<100	<100	<100	<100	<100
9200	<100	122	223	<100	<100

Concentrations in µg/l.

Pb

Cumulative oxidising solution (ml)	Column A	Column B	Column C	Column D	Control
400	2580	1180	2520	2720	104000
1600	379	176	415	904	11800
2800	446	92.2	250	480	8040
4000	266	208	141	140	12500
5200	322	145	68.6	111	11400
6400	166	68	48.3	40.1	9710
7800	178	55.7	42.9	42	8200
8800	199	44.2	20.4	53.4	9580
9200	176	121	76	61.2	9240

Concentrations in µg/l.

SO₄²⁻

Cumulative oxidising solution (ml)	Column A	Column B	Column C	Column D	Control
400	78.38	86.93	98.33	91.56	11.47
1600	31.85	28.32	26.36	24.72	27.54
2800	26.97	24.15	21.09	22.91	29.60
4000	27.36	23.09	21.70	23.58	27.82
5200	24.97	21.02	18.92	20.91	27.04
6400	25.86	22.16	18.85	21.77	27.79
7800	25.19	20.41	18.24	21.55	27.47
8800	23.66	19.52	17.81	20.81	25.47
9200	24.23	20.41	18.28	21.16	25.79

Concentrations in mg/l.

Sb

Cumulative oxidising solution (ml)	Column A	Column B	Column C	Column D	Control
400	4210	3160	3760	5350	220
1600	1710	1320	1830	2260	211
2800	1130	954	1400	1880	100
4000	834	749	1160	1520	96
5200	687	626	925	1370	89
6400	565	548	747	1090	99
7800	488	491	672	944	91
8800	432	435	613	839	82
9200	415	435	609	813	85

Concentrations in µg/l.

Zn

Cumulative oxidising solution (ml)	Column A	Column B	Column C	Column D	Control
400	469	344	738	1060	2460
1600	157	112	149	368	2740
2800	271	167	162	276	3000
4000	486	366	232	280	2780
5200	862	527	293	351	2870
6400	1310	766	532	619	3370
7800	1740	1040	779	855	3040
8800	2440	1370	1150	1280	3560
9200	2430	1670	1400	1610	3670

Concentrations in µg/l.

Appendix B3

Phosphate stabilisation experiment 2

Coating stage pH and conductivity

Cumulative coating solution(ml)	Column A		Column B		Column C		Column D	
	pH	cond	pH	cond	pH	cond	pH	cond
200	5.51	19610	5.31	55560	5.32	36520	5.49	31460
400	5.42	29160	5.25	57330	5.25	37000	5.39	29920
600	5.51	27220	5.32	46980	5.33	51900	5.50	31800
800	5.53	28760	5.32	52460	5.34	47790	5.50	39100
1000	5.55	30400	5.34	44130	5.35	50640	5.52	31800
1200	5.54	34760	5.34	57870	5.33	57840	5.50	36340
1400	5.53	38240	5.35	54090	5.34	60000	5.51	34460
1600	5.52	38880	5.35	46050	5.32	62090	5.49	36060
1800	5.53	39780	5.37	57810	5.33	56350	5.51	36740
2000	5.53	38140	5.36	54900	5.33	68040	5.49	36720
2200	5.54	28600	5.40	43950	5.36	50040	5.53	28280
2400	5.57	27360	5.40	54690	5.37	46530	5.54	25040
2600	5.59	27220	5.41	54240	5.38	56550	5.56	25180
2800	5.60	26020	5.40	50880	5.38	49950	5.55	26780
3000	5.63	30960	5.43	64960	5.40	54660	5.58	30960
3200	5.65	35660	5.45	63700	5.42	50010	5.57	36960
3400	5.68	38940	5.49	56550	5.46	55620	5.62	39820
3600	5.70	50700	5.50	67200	5.47	67200	5.62	38860
3800	5.72	51780	5.53	65975	5.50	58590	5.64	50790
4000	5.74	51720	5.54	55405	5.51	56520	5.65	43320
4200	5.78	38040	5.59	58680	5.56	58470	5.70	39960
4400	5.57	32670	5.38	54510	5.35	58500	5.50	34880
4600	5.61	32140	5.40	56820	5.37	54270	5.53	34440
4800	5.60	30840	5.40	52680	5.38	55080	5.53	37260
5000	5.61	35100	5.41	55890	5.39	59520	5.54	33700

cond – conductivity reported in $\mu\text{S}/\text{cm}$ at 25 °C.

Coating stage leachate chemistry

Column	Cumulative coating solution (ml)	As	Cu	Pb	SO ₄ ²⁻	Sb	Zn
Column A	400	6.240	6.24	0.384	655.5	0.163	9.68
	2600	0.502	1.88	0.328	381.2	0.301	3.85
	5000	0.603	1.39	0.309	153.9	0.334	3.76
Column B	400	9.400	8.79	1.100	901.3	0.343	8.93
	2600	0.651	2.09	0.695	239.7	0.346	5.34
	5000	0.993	1.94	0.745	91.5	0.430	6.63
Column C	400	10.300	12.00	0.508	762.3	0.539	14.70
	2600	0.681	3.50	0.537	416.8	0.794	7.82
	5000	0.436	2.65	0.622	241.8	0.872	7.41
Column D	400	6.850	9.43	0.224	922.6	0.646	21.40
	2600	0.411	3.42	0.219	480.9	0.676	6.71
	5000	0.186	2.84	0.262	384.7	0.960	6.72

Concentrations in mg/l. Fe below detection (0.1 mg/l) in all samples.

Dissolution stage pH and conductivity

Cumulative oxidising solution (ml)	Column A		Column B		Column C		Column D		Control	
	pH	cond	pH	cond	pH	cond	pH	cond	pH	cond
200	7.25	908	7.13	1084	7.12	1157	7.21	1239	4.46	565
400	6.98	512	6.79	567	6.87	639	7.07	642	4.02	495
600	6.91	294	6.78	336	6.80	391	6.98	390	4.12	240
800	6.84	273	6.71	318	6.73	355	6.87	382	4.21	171
1000	6.78	186	6.69	204	6.71	249	6.86	272	4.15	136
1200	6.70	197	6.66	206	6.63	257	6.68	315	4.20	126
1400	6.93	150	6.89	157	6.86	193	6.96	235	4.16	112
1600	6.62	165	6.57	170	6.53	205	6.63	266	4.20	107
1800	6.63	126	6.59	133	6.60	160	6.63	198	4.15	97
2000	6.59	126	6.57	135	6.55	165	6.60	206	4.21	95
2200	6.66	110	6.57	117	6.57	139	6.57	168	4.18	89
2400	6.66	124	6.59	127	6.59	151	6.53	191	4.25	87
2600	6.55	107	6.51	112	6.48	131	6.48	160	4.16	86
2800	6.48	105	6.47	108	6.46	132	6.40	165	4.18	87
3000	6.43	93	6.46	94	6.46	115	6.35	136	4.11	83
3200	6.41	101	6.41	109	6.39	130	6.22	156	4.12	85
3400	6.40	84	6.40	89	6.36	106	6.24	124	4.13	82
3600	6.40	99	6.44	100	6.36	121	6.21	148	4.19	83
3800	6.51	103	6.43	94	6.44	106	6.27	123	4.14	82
4000	6.48	94	6.47	90	6.40	109	6.27	129	4.11	84
4200	6.43	76	6.44	76	6.37	95	6.29	105	4.07	87
4400	6.47	107	6.43	87	6.39	108	6.15	123	4.14	80
4600	6.23	119	6.25	75	6.23	89	6.00	97	4.06	81
4800	6.17	95	6.26	83	6.25	103	6.07	119	4.19	77
5000	6.21	75	6.23	82	6.27	91	6.10	96	4.17	77

cond – conductivity reported in $\mu\text{S}/\text{cm}$ at 25 °C.

Dissolution stage leachate chemistry

Al

Cumulative oxidising solution (ml)	Column A	Column B	Column C	Column D	Control
200	685	405	184	167	5330
800	1910	738	425	776	766
1600	1100	549	411	499	253
2000	753	433	355	1270	176
2600	444	376	302	n.r.	109
3200	283	302	211	537	189
3800	188	212	181	388	164
4400	151	133	105	247	129
5000	133	114	181	300	139

Concentrations in $\mu\text{g/l}$; n.r. – no result.

As

Cumulative oxidising solution (ml)	Column A	Column B	Column C	Column D	Control
200	557	558	515	327	9
800	243	310	278	230	12
1600	198	225	228	196	46
2000	165	194	203	172	44
2600	165	190	200	165	36
3200	140	166	173	149	39
3800	138	161	166	135	35
4400	117	137	151	130	28
5000	110	123	146	119	17

Concentrations in $\mu\text{g/l}$.

Cu

Cumulative oxidising solution (ml)	Column A	Column B	Column C	Column D	Control
200	88	52	87	148	39000
800	99	73	116	201	15300
1600	114	104	171	236	8330
2000	101	88	164	241	6950
2600	104	103	196	276	6050
3200	115	109	188	302	5710
3800	114	136	206	327	5260
4400	133	151	192	370	4920
5000	192	198	258	422	4230

Concentrations in $\mu\text{g/l}$.

Fe

Cumulative oxidising solution (ml)	Column A	Column B	Column C	Column D	Control
200	223	105	<100	<100	<100
800	1280	329	<100	313	<100
1600	635	240	111	176	<100
2000	456	186	97	233	<100
2600	239	159	<100	162	<100
3200	122	126	<100	103	<100
3800	<100	<100	<100	<100	<100
4400	<100	<100	<100	<100	<100
5000	<100	<100	<100	<100	<100

Concentrations in µg/l.

Pb

Cumulative oxidising solution (ml)	Column A	Column B	Column C	Column D	Control
200	26.8	11.3	4.55	15.5	3020.0
800	96.7	30.6	28.4	37.5	5130.0
1600	79.0	43.9	39.1	32.4	5010.0
2000	78.5	43.8	43.2	43.6	4320.0
2600	45.9	33.3	29.4	26.6	3720.0
3200	36.6	26.5	24.1	17.9	3390.0
3800	26.4	21.1	21.4	18.1	3170.0
4400	23.5	17.6	14.2	20.6	3060.0
5000	40.6	19.4	23.6	16.1	2890.0

Concentrations in µg/l.

Sb

Cumulative oxidising solution (ml)	Column A	Column B	Column C	Column D	Control
200	859	509	866	1000	46
800	406	403	490	629	67
1600	317	263	394	462	54
2000	254	235	360	414	49
2600	264	264	406	438	53
3200	205	209	314	360	50
3800	208	237	323	368	50
4400	174	179	261	306	50
5000	179	177	287	321	51

Concentrations in µg/l.

SO₄²⁻

Cumulative oxidising solution (ml)	Column A	Column B	Column C	Column D	Control
200	315	344	367	456	324
800	87	98	102	115	81
1600	53	53	59	83	43
2000	42	42	46	89	37
2600	33	34	35	50	32
3200	36	35	39	55	30
3800	30	31	30	47	30
4400	29	30	34	46	28
5000	25	25	27	33	28

Concentrations in mg/l.

Zn

Cumulative oxidising solution (ml)	Column A	Column B	Column C	Column D	Control
200	73	36	61	214	35000
800	104	67.2	118	405	9220
1600	115	88.8	164	617	5430
2000	123	106	202	714	4860
2600	150	130	255	818	4630
3200	185	171	281	1030	4780
3800	200	265	330	1100	4810
4400	295	352	366	1670	4940
5000	418	470	497	1690	4975

Concentrations in µg/l.