

Table 1. Mineralogical composition of tailings and natural soil nearby tin-mining areas

Profile/ Depth cm	Type of minerals												Sum
	Op	Zr	Qtd	Qtp	Wm	Rf	Or	Sn	Gr	Ep	Tm	Rt-At	
	-----%-----												
TBB1 Tailing profile dominated by grayish and yellowish sand, initial soil derived from sandstone													
0-12	6	7	26	44	nd	nd	nd	nd	6	<1	10	1	100
12-28	7	6	27	45	nd	nd	nd	nd	5	<1	9	1	100
28-39	5	4	29	51	<1	nd	nd	nd	4	<1	7	<1	100
39-59	4	2	32	54	<1	nd	nd	nd	3	<1	5	<1	100
59-75	2	3	33	56	<1	nd	nd	nd	1	<1	4	1	100
75-105	3	<1	34	57	1	nd	nd	nd	<1	<1	5	<1	100
105-125	1	1	36	59	<1	nd	nd	nd	1	<1	2	<1	100
TBB2 Tailing profile dominated by grayish and redish sand, initial soil derived from sandstone													
0-15	<1	2	41	50	<1	nd	nd	nd	4	<1	3	<1	100
15-25	1	1	36	52	<1	nd	nd	nd	5	<1	4	1	100
25-60	4	<1	35	53	<1	nd	nd	nd	3	<1	5	<1	100
60-89	1	1	33	58	<1	nd	nd	nd	5	<1	2	<1	100
89-112	2	2	29	60	1	nd	nd	nd	2	<1	3	<1	100
112-130	3	3	28	61	<1	nd	nd	nd	1	<1	4	<1	100
TBB3 Spoil profile with a mixture of initial soil and sandy tailing derived from sandstone													
0-30	5	3	38	43	2	3	nd	nd	3	<1	2	1	100
30-54	5	2	36	45	3	4	nd	nd	2	-	3	<1	100
54-79	3	2	39	44	4	2	nd	nd	2	1	2	1	100
79-120	5	3	35	41	6	4	nd	nd	3	<1	3	<1	100
TBB4 Natural soil profile under rubber plantation derived from sandstone, adjacent to tin mining													
0-17	5	4	43	38	3	<1	nd	nd	2	1	3	1	100
17-31	5	3	46	35	4	1	nd	nd	3	1	2	<1	100
31-63	3	4	47	37	3	<1	nd	nd	1	1	3	1	100
63-110	4	3	45	36	4	1	nd	nd	1	2	2	2	100
TBB5 Natural soil profile under oil palm derived from granite, nearby tin-mining areas													
0-15	6	2	41	37	3	1	nd	<1	1	2	5	2	100
15-42	4	3	42	35	5	<1	nd	1	1	1	7	1	100
42-65	6	2	40	38	5	1	nd	<1	1	1	6	<1	100
65-105	6	2	42	35	2	<1	nd	<1	2	2	8	1	100
105-133	7	1	43	37	4	nd	nd	nd	1	1	6	<1	100
133-163	5	1	44	36	4	<1	nd	nd	<1	2	7	1	100
TBB6 Tailing profile with grayish sand, derived from granite and had been reclaimed with Acacia													
0-16	11	3	29	33	1	nd	nd	nd	6	nd	16	1	100
16-42	6	3	30	35	3	<1	2	1	4	nd	14	2	100
42-65	10	2	32	36	1	<1	2	<1	3	nd	12	2	100
65-110	11	<1	34	39	1	1	1	<1	2	nd	9	1	100
TBB7 Tailing profile with grayish sand, derived from granite, and had been reclaimed but re-mined													
0-20	14	5	30	18	6	<1	3	1	2	<1	20	<1	100
20-30	10	4	32	19	4	<1	4	nd	3	nd	22	1	100
30-40	15	3	33	23	3	<1	1	<1	4	nd	17	<1	100
40-60	9	4	36	23	5	<1	1	nd	3	nd	18	1	100
60-83	14	2	37	25	4	1	<1	nd	1	nd	14	2	100
83-120	9	1	39	28	5	nd	2	<1	2	<1	13	<1	100

Notes: Op: opaque, Zr: zircon, Qtd: turbid quartz, Qtp: transparent quartz, Wm: weathered minerals, Rf: rock fragment, Or: orthoclase, Sn: sanidine, Gr: garnet, Ep: epidote, Tm: tourmaline, Rt-At: rutile-anatase

Table 2. Total major elemental oxide composition of selected layers of tailing and natural soil profiles

Profile /	Major elemental oxide content											LOI
	Ca											
Depth	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	O	MgO	Na ₂ O	K ₂ O	P ₂ O ₅	SO ₃	
cm	----- % -----											
TBB1 Tailing profile dominated by grayish and yellowish sand, initial soil derived from sandstone												
0-12	96.40	0.10	1.97	0.55	0.01	0.02	0.06	0.37	0.03	0.01	0.01	0.04
28-39	95.94	0.07	2.33	0.47	0.00	0.01	0.06	0.57	0.05	0.01	0.01	0.36
105-125	95.68	0.09	2.46	0.55	0.01	0.02	0.07	0.38	0.05	0.01	0.01	0.29
TBB3 Spoil profile with a mixture of initial soil and sandy tailing derived from sandstone												
0-30	43.07	1.31	36.02	4.72	0.01	0.03	0.27	1.01	0.93	0.05	0.08	12.42
30-54	93.49	0.19	3.89	0.71	0.00	0.02	0.11	0.48	0.13	0.01	0.01	0.85
TBB4 Profile of natural soil derived from sandstone adjacent to tin mining areas												
0-17	70.15	0.48	13.82	3.78	0.01	0.03	0.27	1.23	0.12	0.12	0.07	9.05
63-110	67.55	0.58	17.26	6.11	0.00	0.03	0.22	1.18	0.12	0.05	0.07	6.15
TBB5 Natural soil profile under oil palm derived from granite, nearby tin-mining areas												
0-15	76.18	0.11	12.90	1.43	0.01	0.05	0.12	0.94	0.14	0.04	0.05	6.86
65-105	73.38	0.12	21.39	1.51	0.01	0.02	0.11	1.41	0.13	0.02	0.05	5.62
TBB6 Tailing profile with grayish sand, derived from granite and had been reclaimed with Acacia												
0-16	85.62	0.06	10.00	0.65	0.01	0.02	0.07	0.90	0.18	0.01	0.04	2.28
65-110	92.23	0.04	5.20	0.57	0.01	0.02	0.07	0.46	0.25	0.01	0.01	1.05
TBB7 Tailing profile with grayish sand, derived from granite, and had been reclaimed but re-mined												
0-20	94.06	0.03	3.68	0.49	0.01	0.01	0.05	0.58	0.21	0.01	0.01	0.75
83-120	93.02	0.04	4.45	0.51	0.01	0.01	0.05	0.70	0.09	0.01	0.01	0.98
G-Rock	74.60	0.05	12.90	1.40	0.04	0.28	0.16	4.31	5.15	0.02	0.01	0.64

G-Rock: Granite rock

Table 3. Total minor elemental oxide and heavy metal composition of selected layers of tailing and natural soil profiles

Profile/	Minor elemental oxide content												
Depth	ZnO	PbO	ZrO ₂	CuO	V ₂ O ₅	Cr ₂ O ₃	Cl	Rb ₂ O	Ga ₂ O ₃	Y ₂ O ₃	Nb ₂ O ₅	SnO	F
cm	----- mg kg ⁻¹ -----												
TBB1 Tailing profile dominated by grayish and yellowish sand, initial soil derived from sandstone													
0-12	nd	nd	nd	nd	nd	277	382	nd	nd	59	nd	nd	3390
28-39	nd	nd	nd	nd	nd	257	707	nd	nd	28	nd	nd	nd
105-125	nd	nd	nd	nd	nd	286	370	nd	nd	37	nd	nd	2890
TBB3 Spoil profile with a mixture of initial soil and sandy tailing in the topsoil, derived from sandstone													
0-30	61	105	651	36	212	137	970	60	54	56	52	172	nd
30-54	nd	nd	186	20	nd	219	485	nd	nd	23	nd	nd	nd
TBB4 Profile of natural soil derived from sandstone, adjacent to tin mining areas													
0-17	44	nd	597	16	130	190	1290	nd	19	26	nd	418	nd
63-110	31	nd	673	nd	188	171	1380	nd	20	nd	nd	260	nd
TBB5 Natural soil profile under oil palm derived from granite, nearby tin-mining areas													
0-15	36	nd	nd	nd	41	128	1270	23	21	70	42	203	nd
65-105	41	nd	nd	nd	47	149	1330	26	28	62	52	180	nd
TBB6 Tailing profile with grayish sand, derived from granite and had been reclaimed with Acacia													
0-16	24	nd	nd	nd	nd	223	908	37	nd	29	25	nd	nd
65-110	22	nd	nd	18	nd	207	438	56	nd	34	nd	153	nd
TBB7 Tailing profile with grayish sand, derived from granite, and had been reclaimed but re-mined													
0-20	nd	nd	nd	nd	30	216	577	nd	nd	nd	nd	95	nd
83-120	21	nd	nd	nd	nd	204	685	nd	nd	23	nd	152	nd
G-Rock	nd	48	nd	nd	nd	89	663	879	32	152	46	nd	1600

G-Rock: Granite rock; nd = not detected

Table 4. Availability of heavy metals in post-tin mining soils and nearby natural soils in the study areas

Profile/ Depth	Type of heavy metals								
	Pb	Cd	Cr	Co	Ni	As	Sn	Se	Hg
cm	----- mg kg ⁻¹ -----								µg kg ⁻¹
TBB1 Tailing profile	dominated by grayish and yellowish sand, initial soil derived from sandstone								
0-12	0.19	nd	0.09	nd	nd	nd	nd	nd	3.35
28-39	0.27	nd	0.12	nd	nd	nd	nd	nd	nd
105-125	0.27	nd	0.10	nd	nd	nd	nd	nd	1.46
TBB2 Tailing profile	dominated by grayish and reddish sand, initial soil derived from sandstone								
0-15	0.20	nd	0.11	nd	nd	nd	nd	nd	2.71
60-89	0.18	nd	0.12	nd	nd	nd	nd	nd	2.72
TBB3 Spoil profile with a mixture of initial soil and sandy tailing,	initial soil derived from sandstone								
0-30	0.20	nd	0.12	nd	nd	0.92	nd	nd	2.50
30-54	0.19	nd	0.12	nd	nd	nd	nd	nd	1.94
TBB4 Natural soil profile under rubber crops derived from sandstone, near by tin mining									
0-17	0.19	nd	0.10	nd	nd	0.79	nd	nd	3.55
63-110	0.19	nd	0.09	nd	nd	nd	nd	nd	nd
TBB5 Natural soil profile under oil palm derived from granite, nearby tin-mining areas									
0-15	0.25	nd	0.10	nd	nd	nd	nd	nd	2.62
65-105	0.29	nd	0.08	nd	nd	0.54	nd	nd	5.72
TBB6 Tailing profile with grayish sand, derived from granite and had been reclaimed with Acacia									
0-16	0.37	nd	0.10	nd	nd	nd	nd	nd	2.14
16-42	1.03	nd	0.11	nd	nd	nd	nd	nd	2.72
42-65	1.08	nd	0.09	nd	nd	0.62	nd	nd	2.51
65-110	1.19	nd	0.10	nd	nd	nd	nd	nd	nd
TBB7 Tailing profile with grayish sand, derived from granite, and had been reclaimed but re-mined									
0-20	0.50	nd	0.09	nd	nd	nd	nd	nd	nd
20-30	0.52	nd	0.10	nd	nd	0.62	nd	nd	4.59
40-60	0.46	nd	0.12	nd	nd	0.55	nd	nd	3.76
83-120	0.34	nd	0.12	nd	nd	nd	nd	nd	1.25

Notes: nd = not detected

Table 5. Particle size, pH, organic matter, P and K of tailings and spoil in post-tin mining areas

Profile/ Depth	Particle size			pH	Organic matter		C/N	Potential		Bray 1
	Sand	Silt	Clay	H ₂ O	C	N		P ₂ O ₅	K ₂ O	P ₂ O ₅
cm	----- % -----				----- % -----			mg 100 g ⁻¹		mg kg ⁻¹
TBB1 Tailing profile dominated by grayish and yellowish sand, initial soil derived from sandstone										
0-12	94	4	2	5.4	0.10	0.01	10	2.7	0.6	2.6
12-28	95	4	1	5.5	0.09	0.01	9	2.3	1.0	2.4
28-39	95	2	3	5.4	0.17	0.02	9	2.6	1.0	3.3
39-59	96	1	3	6.3	0.11	0.01	11	2.6	1.0	3.7
59-75	92	1	7	6.1	0.09	0.01	9	2.6	1.0	3.5
75-105	93	2	5	6.1	0.10	0.01	10	2.6	1.0	3.3
105-125	96	2	2	5.5	0.12	0.01	12	2.9	1.0	0.2
TBB2 Tailing profile dominated by grayish and reddish sand, initial soil derived from sandstone										
0-15	91	2	7	6.1	0.16	0.02	8	2.9	1.0	4.6
15-25	90	4	6	6.1	0.13	0.01	13	3.3	0.5	5.4
25-60	91	5	4	5.5	0.12	0.01	12	2.9	1.0	4.3
60-89	91	3	6	5.3	0.11	0.01	11	2.9	1.0	4.4
89-112	92	4	4	5.5	0.15	0.01	15	2.9	1.0	5.4
112-130	94	1	5	5.3	0.13	0.01	13	3.3	1.0	3.9
TBB3 Spoil profile with a mixture of initial soil and sandy tailing, derived from sandstone										
0-30	81	5	14	4.8	0.44	0.04	11	6.1	1.0	4.4
30-54	92	0	8	5.3	0.16	0.02	8	3.3	1.0	4.6
54-79	92	1	7	5.1	0.18	0.02	9	3.3	0.7	4.4
79-120	95	3	2	5.5	0.15	0.01	15	2.6	0.5	6.1
TBB4 Natural soil profile under rubber crops derived from sandstone, nearby tin mining										
0-17	69	2	29	4.7	1.80	0.13	14	14.8	2.2	26.7
17-31	69	4	27	4.8	1.49	0.10	15	13.2	2.0	24.3
31-63	64	3	33	5.0	0.59	0.05	12	6.3	1.1	6.6
63-110	61	2	37	5.0	0.35	0.03	12	5.8	0.9	4.5
TBB5 Natural soil profile under oil palm derived from granite, nearby tin-mining area										
0-15	64	8	28	5.2	0.97	0.08	12	6.0	3.0	10.0
15-42	59	6	35	4.8	0.38	0.03	13	4.4	2.2	5.2
42-65	62	6	32	4.8	0.28	0.02	14	4.7	2.0	2.8
65-105	58	8	34	5.0	0.23	0.02	12	5.0	1.7	3.0
105-133	57	5	38	5.1	0.17	0.02	9	4.9	1.7	2.2
TBB6 Tailing profile with grayish sand, derived from granite and had been reclaimed with Acacia										
0-16	82	6	12	4.9	0.22	0.02	11	3.3	2.0	3.9
16-42	83	3	14	5.0	0.17	0.02	9	3.3	2.0	3.3
42-65	89	3	8	5.2	0.12	0.01	12	3.3	1.0	3.2
65-110	85	5	10	5.3	0.10	0.01	10	2.9	1.2	4.1
TBB7 Tailing profile with grayish sand, derived from granite, and had been reclaimed but re-mined										
0-20	91	1	8	5.4	0.09	0.01	9	2.9	0.6	3.2
20-30	90	2	8	5.3	0.08	0.01	8	2.9	1.2	4.1
30-40	90	0	10	5.2	0.08	0.01	8	2.9	2.0	2.8
40-60	91	1	8	5.3	0.08	0.01	8	2.9	2.0	3.5
60-83	89	1	10	5.2	0.08	0.01	8	2.9	2.0	3.9
83-120	87	1	12	5.2	0.08	0.01	8	2.9	2.0	3.0

Table 6. Exchangeable cations and Al, and cation exchange capacity of tailings and spoil in post-tin mining areas

Profile/ Depth	Exchangeable cation				Sum	CEC [†]	BS [§]	Exch.
cm	Ca	Mg	K	Na				Al
	----- cmol _c kg ⁻¹ -----						%	cmol _c kg ⁻¹
TBB1 Tailing profile dominated by grayish and yellowish sand, derived from sandstone								
0-12	0.52	0.20	0.01	0.04	0.77	1.21	64	0.12
12-28	0.47	0.17	0.01	0.02	0.67	1.24	54	0.04
28-39	0.47	0.19	0.01	0.05	0.72	1.25	58	0.10
39-59	0.49	0.19	0.02	0.04	0.74	1.32	32	0.04
59-75	0.42	0.17	0.02	0.02	0.63	1.34	47	0.04
75-105	0.43	0.19	0.01	0.07	0.70	1.17	60	0.00
105-125	0.43	0.18	0.01	0.03	0.65	1.37	47	0.10
TBB2 Tailing profile dominated by grayish and reddish sand, derived from sandstone								
0-15	0.42	0.17	0.01	0.03	0.63	1.20	53	0.08
15-25	0.41	0.16	0.00	0.03	0.60	1.00	60	0.04
25-60	0.46	0.18	0.01	0.02	0.67	0.99	68	0.06
60-89	0.44	0.18	0.01	0.01	0.64	1.03	62	0.04
89-112	0.43	0.17	0.02	0.02	0.64	1.15	56	0.06
112-130	0.45	0.17	0.01	0.06	0.69	1.14	61	0.10
TBB3 Spoil profile with a mixture of initial soil and tailing, derived from sandstone								
0-30	0.50	0.20	0.02	0.02	0.74	2.28	32	0.54
30-54	0.44	0.18	0.01	0.02	0.65	1.14	57	0.10
54-79	0.33	0.17	0.01	0.01	0.52	1.13	46	0.20
79-120	0.49	0.19	0.01	0.04	0.73	0.99	74	0.06
TBB4 Natural soil profile derived from sandstone, nearby tin mining areas								
0-17	0.49	0.25	0.04	0.05	0.83	6.82	12	1.16
17-31	0.51	0.22	0.03	0.03	0.79	5.77	14	0.92
31-63	0.47	0.21	0.02	0.04	0.74	4.55	16	0.67
63-110	0.53	0.23	0.01	0.04	0.81	5.30	15	0.54
TBB5 Natural soil profile derived from granite, nearby tin-mining areas								
0-15	0.81	0.37	0.05	0.02	1.25	4.32	29	0.57
15-42	0.52	0.29	0.04	0.23	1.08	3.84	28	1.20
42-65	0.53	0.27	0.03	0.14	0.97	5.06	19	1.22
65-105	0.51	0.24	0.02	0.09	0.86	4.07	21	1.11
105-133	0.45	0.19	0.01	0.01	0.66	4.48	15	1.37
TBB6 Tailing profile derived from granite and had been reclaimed with Acacia								
0-16	0.47	0.22	0.03	0.02	0.74	2.16	34	0.68
16-42	0.42	0.20	0.02	0.03	0.67	1.99	34	0.68
42-65	0.39	0.18	0.02	0.03	0.62	1.56	40	0.52
65-110	0.51	0.21	0.02	0.02	0.76	1.65	46	0.46
TBB7 Tailing profile derived from granite, and had been reclaimed but re-mined								
0-20	0.42	0.16	0.01	0.01	0.60	1.07	56	0.36
20-30	0.43	0.17	0.01	0.04	0.65	1.15	57	0.34
30-40	0.48	0.18	0.02	0.07	0.75	1.08	69	0.20
40-60	0.57	0.23	0.03	0.05	0.88	1.25	53	0.22
60-83	0.49	0.21	0.02	0.04	0.76	1.24	61	0.28
83-120	0.51	0.22	0.03	0.03	0.79	1.41	56	0.26

[†] = cation exchange capacity; [§] = base saturation; Exch = exchangeable