APPENDIX

Appendix A: Data for EDS analysis of different regions on the oxidized granulated slag sample of size range 106-425μm, in figure 3.3.4.

Part 1	Atom%	Mg	Al	Si	Ca	Ti	Mn	Fe
Ed dk	"	1.35	2.02	1.06	-	91.29	1.38	4.26
Ed lgt	"	3.44	4.28	7.17	0.42	62.33	3.89	16.94
Cendk	"	1.50	2.42	1.33	-	89.01	1.79	4.99
Cenlgt	"	2.41	2.92	2.58	-	79.69	2.29	10.10
Part 2								
Ed dk	"	-	1.72	1.27	-	95.37	-	2.27
Ed lgt	"	3.51	4. 43	5.36	-	66.99	3.65	16.06
Cendk	"	1.53	2.12	1.70	0.26	92.55	1.17	2.51
Cenlgt	"	3.12	4.39	6.30	0.47	67.04	3.57	14.77

Appendix B: Data for EDS analysis of different regions on the oxidized granulated slag sample of size range 1700-2360μm.

	Atom%	Mg	Al	Si	Ca	Ti	Mn	Fe
Part 1	"							
Ed dk	"	0.71	1.99	0.50	0.10	93.21	0.42	3.05
Ed lgt	"	1.78	3.47	4.95	0.56	73.61	2.92	11.70
Cen dk	"	0.45	1.58	0.73	0.00	94.18	0.59	2.49
Cen lgt	"	2.04	3.70	7.28	0.58	65.54	4.24	16.63
Part. 2	"	Mg	Al	Si	Ca	Ti	Mn	Fe
Ed dk	"	1.03	1.85	1.72	0.11	91.64	0.73	2.94
Ed lgt	"	3.30	3.87	2.89	0.41	76.37	2.97	10.24
Cen dk	"	0.48	1.87	0.54	0.04	92.96	0.59	3.42
Cen lgt	"	3.24	3.21	0.66	0.03	79.91	2.34	10.64

Appendix C: Data for EDS analysis of different regions on the oxidized granulated slag sample of size range > 4750μm, in figure 3.3.5.

Part 1	Atom%	Ti	Fe	Mn	Al	Si	Mg	Ca
Ed dk	"	92.95	2.93	0.23	1.97	1.02	0.79	0.12
Ed lgt	"	74.13	11.85	3.43	3.37	3.40	3.03	0.31
Cen dk	"	89.56	4.17	0.97	2.71	0.40	2.19	0.03
Cen lgt	"	75.54	12.48	2.84	3.62	3.20	1.99	0.35
Part 2								
Ed dk	"	93.69	2.95	0.26	1.92	0.54	0.57	0.09
Ed lgt	"	76.93	11.57	2.61	3.62	1.64	3.64	0.00
Cendk	"	87.75	5.31	1.17	2.66	0.45	2.64	0.04
Cenlgt	"	84.06	7.95	2.47	3.21	0.08	2.15	0.08
Part 3								
Ed dk	"	94.06	3.11	0.18	1.60	0.44	0.48	0.16
Ed lgt	"	77.86	11.11	2.79	3.34	2.27	2.47	0.16
Cendk	"	86.04	6.42	1.37	2.82	0.47	2.68	0.13
Cenlgt	"	73.02	12.75	3.68	3.10	4.48	2.30	0.39

Appendix D: EDS analysis of unoxidized block route slag, as in figure 3.3.6.

	Atom%	Mg	Al	Si	Ca	Ti	Mn	Fe
Part. 1								
Edge	"	3.56	1.51	0.00	0.00	75.80	1.54	17.60
Centre	"	3.93	1.22	0.00	0.00	78.19	"	16.66
Part. 2								
Edge	"	2.46	1.20	0.20	0.10	79.90	2.60	17.40
Centre	"	1.60	1.30	0.30	0.00	80.00	2.50	16.80

Appendix E1: EDS analysis of black particles of granulated slag of size range 425-600μm chlorinated for 15 minutes, as seen in figure 4.4.3a .

Pt1	Fe	Ti	Mn	Si	Mg	Al	Ca
Bk -Dk	5.90	87.00	1.20	2.10	1.80	1.40	0.60
Bk- Lt	18.70	66.70	2.40	3.80	5.30	2.90	0.30
P2;Bk-Dk	1.30	95.60	0.20	1.40	0.00	1.10	0.30
Bk-Lgt	25.70	53.60	3.30	6.80	6.30	3.50	0.90

Appendix E2: EDS analysis of light particles of granulated slag of size range 425-600μm chlorinated for 15 minutes, as seen in figure 4.4.3c

Pt1	Fe	Ti	Mn	Si	Mg	Al	Ca
Lgt –Ed	0.10	97.50	0.10	1.10	0.40	0.60	0.20
Lgt- Cen	1.40	92.40	0.10	0.50	3.60	1.90	0.10
Pt 2;Lt-Ed	0.00	97.60	0.00	1.20	0.10	0.90	0.20
Lgt-Cen	0.60	97.70	0.20	0.20	0.50	0.70	0.10
Pt3;Lt-Ed	0.30	98.90	0.10	0.30	0.10	0.20	0.10
Lgt-Cen	1.50	92.70	0.00	0.80	3.40	1.40	0.10

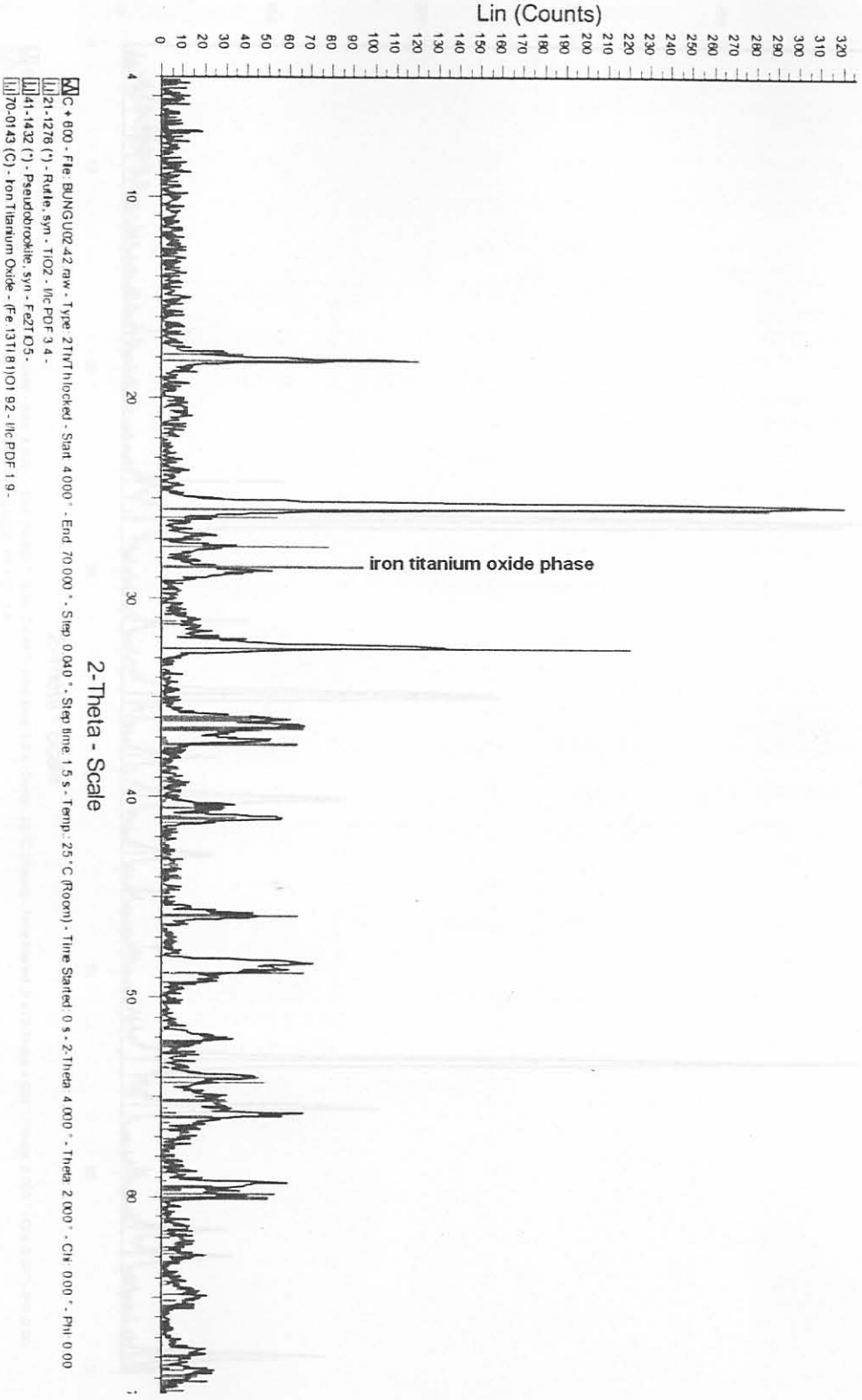
Appendix E3: EDS Analysis of granulated slag of size range 1700-2360μm chlorinated for 15 minutes, as seen in figure 4.4.3d

Pt1	Fe	Ti	Mn	Si	Mg	Al	Ca
Lgt –Ed	0.00	97.00	0.10	1.80	0.30	0.60	0.20
Lgt- Cen	0.30	97.30	0.00	0.20	1.40	0.70	0.10
Pt 2;Lt-Ed	0.00	94.10	0.10	2.50	1.40	1.60	0.30
Lgt-Cen	0.10	97.80	0.00	0.40	0.70	0.80	0.20
Pt3;Lt-Ed	0.10	96.60	0.00	1.80	0.30	0.70	0.50
Lgt-Cen	0.00	97.40	0.00	0.40	1.20	0.90	0.20

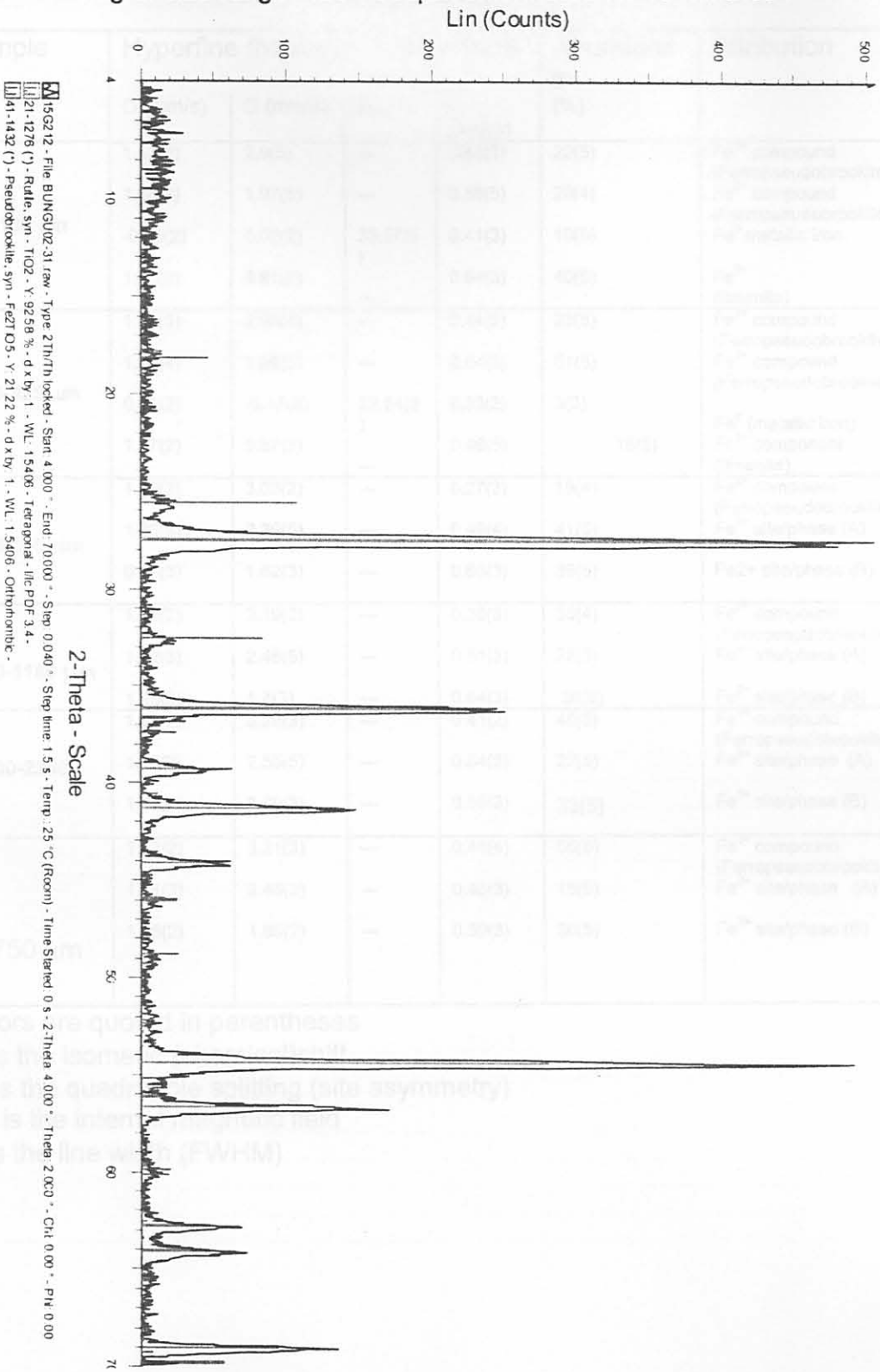
Appendix E4: EDS analysis of block route slag chlorinated for 5 minutes, as seen in figure 4.4.3e

Pt1	Fe	Ti	Mn	Si	Mg	Al	Ca
Brs –Ed	0.10	98.20	0.00	1.00	0.20	0.40	0.00
Brs – Cen	1.40	87.70	0.10	0.30	0.10	0.50	0.30
Pt2;Bs-Ed	0.10	98.90	0.00	0.30	5.70	1.80	0.20
Brs –Cen	3.60	85.60	0.50	0.40	7.80	2.20	0.00
Pt3;Bs-Ed	0.20	98.30	0.00	0.50	0.30	0.60	0.20
Brs –Cen	7.70	86.50	0.50	0.20	3.00	2.00	0.10

Appendix F: XRD spectra showing the prominent peak at 28.74^{O} corresponding to an iron titanium oxide solid solution in granulated slag of size range 600-1180μm.



Appendix G: XRD spectra showing the phases present in granulated titania slag of size range 425 - 600μm chlorinated for 15 minutes .



Appendix H: Hyperfine interaction parameters of the different size ranges of granulated slag (Mössbauer analysis).

Sample	Hyperfine Interaction Parameters				Abundance (%)	Attribution
	□ (mm/s)	□ (mm/s)	B_{hf} (T)	□ (mm/s)		
+75-106 μm	1.13(2)	2.9(5)	---	0.45(3)	22(5)	Fe^{2+} compound (Ferropseudobrookite, site-1)
	1.06(3)	1.97(5)	---	0.58(5)	28(4)	Fe^{2+} compound (Ferropseudobrookite, site-2)
	-0.45(2)	0.02(2)	33.57(5)	0.41(3)	10(5)	Fe^{0} metallic iron
	1.05(3)	0.81(2)	---	0.54(3)	40(5)	Fe^{2+} (Ilmenite)
+106-425 μm	1.09(3)	2.95(4)	---	0.44(2)	28(5)	Fe^{2+} compound (Ferropseudobrookite,site-1)
	1.04(4)	1.99(5)	---	0.64(3)	51(5)	Fe^{2+} compound (Ferropseudobrookite, site-2)
	0.00(2)	-0.17(3)	32.54(5)	0.33(3)	3(3)	Fe^{0} (metallic iron)
	1.07(2)	0.87(3)	---	0.46(5)	18(5)	Fe^{2+} component (Ilmenite)
+425-600 μm	1.09(2)	3.03(2)	---	0.27(3)	19(4)	Fe^{2+} compound (Ferropseudobrookite site-1)
	1.00(3)	2.39(5)	---	0.49(4)	41(5)	Fe^{2+} site/phase (A)
	0.99(3)	1.62(3)	---	0.60(3)	39(5)	Fe2+ site/phase (B)
+600-1180 μm	1.13(2)	3.19(2)	---	0.36(3)	36(4)	Fe^{2+} compound (Ferropseudobrookite site-1)
	1.12(3)	2.46(5)	---	0.51(3)	28(5)	Fe^{2+} site/phase (A)
	1.09(3)	1.7(3)	---	0.64(3)	36(3)	Fe^{2+} site/phase (B)
+1700-2360 μm	1.18(2)	3.29(3)	---	0.41(2)	45(5)	Fe^{2+} compound (Ferropseudobrookite site-1)
	1.16(3)	2.55(5)	---	0.54(3)	22(5)	Fe^{2+} site/phase (A)
	1.14(3)	1.89(3)	---	0.59(3)	33(5)	Fe^{2+} site/phase (B)
+4750 μm	1.18(2)	3.31(3)	---	0.44(4)	55(5)	Fe^{2+} compound (Ferropseudobrookite site-1)
	1.01(3)	2.46(3)	---	0.43(3)	15(5)	Fe^{2+} site/phase (A)
	1.15(2)	1.85(2)	---	0.59(3)	30(5)	Fe^{2+} site/phase (B)

Errors are quoted in parentheses
δ is the isomeric (chemical)shift
Δ is the quadrupole splitting (site asymmetry)
B_{hf} is the internal magnetic field
Γ is the line width (FWHM)

Appendix I: Chlorination parameters and results obtained.

Minimum fluidization velocity = 5.7l/min
Maximum fluidization velocity = 17.84l/min
Atmospheric pressure =86kPa
Total pressure that could be tolerated = 108-115 kPa at a flowrate of 16.5l/min at 22.5^{O}C
Reaction temperature = 1000 ^{O}C
Particle size range used: 425 - 600μm.

Gas mixture used :

Rotameter reading	Gas	Flowrate(l/min)	%
100	CO	2.75	20.75
20	Cl_2	4.00	30.19
30	N_2	6.50	49.06
Total		13.25	100.00

EXPT 1

Block route slag (BRS)

Name of sample	5BRS
Mass of sample(g)	25.02
Room temperature(^{O}C)	20.00
Reaction pressure(kPa)	89.06
Reaction time(mins)	5.00
Mass of product(g)	21.49
Reduction in mass(g)	3.53
Name of sample	10BRS
Mass of sample(g)	25.00
Room temperature(^{O}C)	21.00
Reaction pressure(kPa)	89.32
Reaction time(mins)	10.00
Mass of product(g)	21.25
Reduction in mass(g)	3.76
Name of sample	15BRS
Mass of sample(g)	25.00
Room temperature(^{O}C)	20.00
Reaction pressure(kPa)	112.05
Reaction time(mins)	15.00
Mass of product(g)	21.00
Reduction in mass(g)	4.00

EXPT 2

Block route slag of the campaign (BSC)

Name of sample	5BSC
Mass of sample(g)	25.00
Room temperature(^{O}C)	22.00
Reaction pressure(kPa)	90.92
Reaction time(mins)	5.00
Mass of product(g)	21.65
Reduction in mass(g)	3.35
Name of sample	10BSC
Mass of sample(g)	25.00
Room temperature(^{O}C)	22.00
Reaction pressure(kPa)	89.46
Reaction time(mins)	10.00
Mass of product(g)	21.34
Reduction in mass(g)	3.66
Name of sample	15BSC
Mass of sample(g)	25.00
Room temperature(^{O}C)	21.00
Reaction pressure(kPa)	88.52
Reaction time(mins)	15.00
Mass of product(g)	21.15
Reduction in mass(g)	3.85
Name of sample	20BSC
Mass of sample(g)	25.00
Room temperature(^{O}C)	21.00
Reaction pressure(kPa)	91.00
Reaction time(mins)	20.00
Mass of product(g)	20.75
Reduction in mass(g)	4.25

EXPT 3

Granulated slag of size range 1700 - 2360μm

A

Name of sample	5C1700
Mass of sample(g)	25.01
Room temperature(^{O}C)	20.50
Reaction pressure(kPa)	89.46
Reaction time(mins)	5.00
Mass of product(g)	22.32
Reduction in mass(g)	2.69
Name of sample	10C1700
Mass of sample(g)	25.01
Room temperature(^{O}C)	19.50
Reaction pressure(kPa)	88.79
Reaction time(mins)	10.00
Mass of product(g)	22.09
Reduction in mass(g)	2.92
Name of sample	15C1700
Mass of sample(g)	25.01
Room temperature(^{O}C)	21.00
Reaction pressure(kPa)	88.26
Reaction time(mins)	15.00
Mass of product(g)	22.00
Reduction in mass(g)	3.00

B

Name of sample	5C1700
Mass of sample(g)	25.02
Room temperature(^{O}C)	26.00
Reaction pressure(kPa)	102.00
Reaction time(mins)	5.00
Mass of product(g)	22.38
Reduction in mass(g)	2.64
Name of sample	10C1700
Mass of sample(g)	25.04
Room temperature(^{O}C)	26.20
Reaction pressure(kPa)	101.00
Reaction time(mins)	10.00
Mass of product(g)	22.24
Reduction in mass(g)	2.80
Name of sample	15C1700
Mass of sample(g)	25.00
Room temperature(^{O}C)	26.00
Reaction pressure(kPa)	140.00
Reaction time(mins)	15.00
Mass of product(g)	22.00
Reduction in mass(g)	3.00

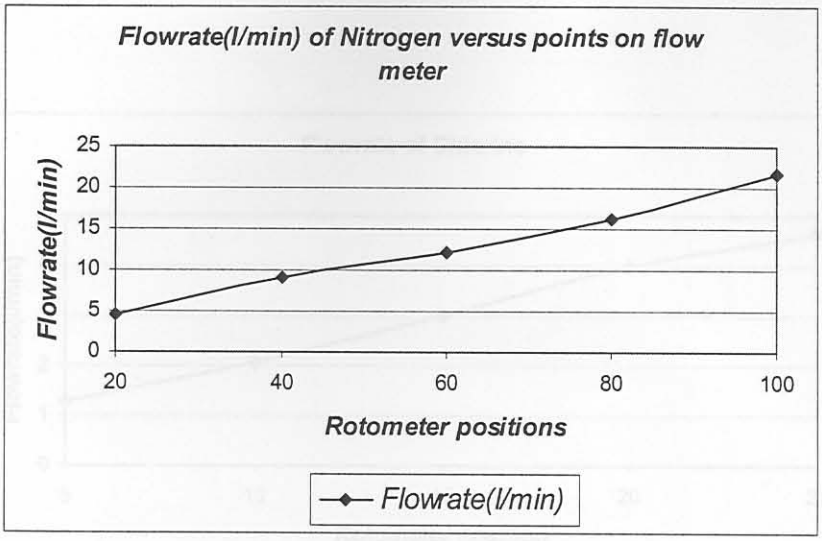
EXPT 4	
Granulated slag of size range 425 - 600μm	
A	
Name of sample	5C425
Mass of sample(g)	25.03
Room temperature(^{O}C)	24.00
Reaction pressure(kPa)	101.00
Reaction time(mins)	5.00
Mass of product(g)	22.88
Reduction in mass(g)	2.16
Name of sample	10C425
Mass of sample(g)	25.00
Room temperature(^{O}C)	27.00
Reaction pressure(kPa)	113.00
Reaction time(mins)	10.00
Mass of product(g)	22.73
Reduction in mass(g)	2.28
Name of sample	15C425
Mass of sample(g)	25.00
Room temperature(^{O}C)	27.00
Reaction pressure(kPa)	120.00
Reaction time(mins)	15.00
Mass of product(g)	22.07
Reduction in mass(g)	2.93

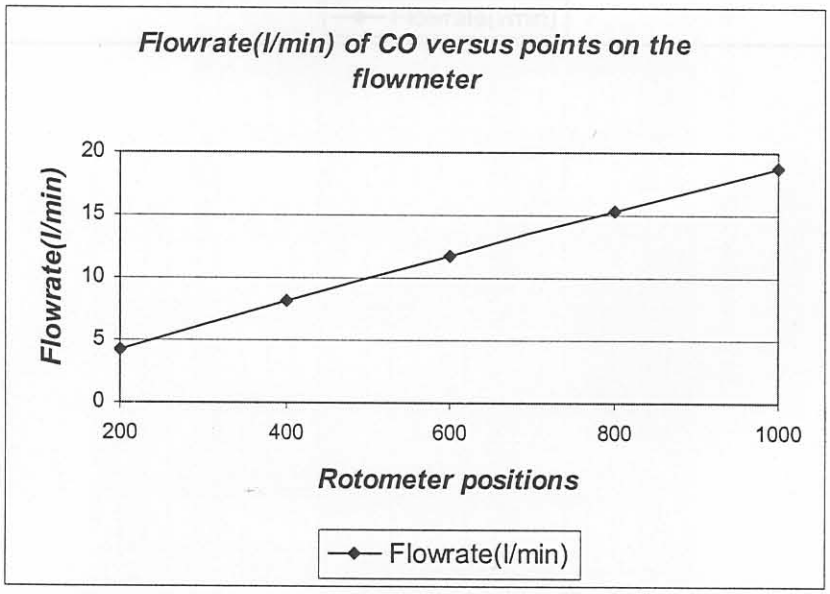
B	
Name of sample	5C425
Mass of sample(g)	25.02
Room temperature(^{O}C)	24.90
Reaction pressure(kPa)	100.00
Reaction time(mins)	5.00
Mass of product(g)	22.86
Reduction in mass(g)	2.15
Name of sample	10C425
Mass of sample(g)	25.03
Room temperature(^{O}C)	27.00
Reaction pressure(kPa)	100.00
Reaction time(mins)	10.00
Mass of product(g)	22.32
Reduction in mass(g)	2.71
Name of sample	15C425
Mass of sample(g)	25.00
Room temperature(^{O}C)	27.00
Reaction pressure(kPa)	114.00
Reaction time(mins)	15.00
Mass of product(g)	22.09
Reduction in mass(g)	2.91

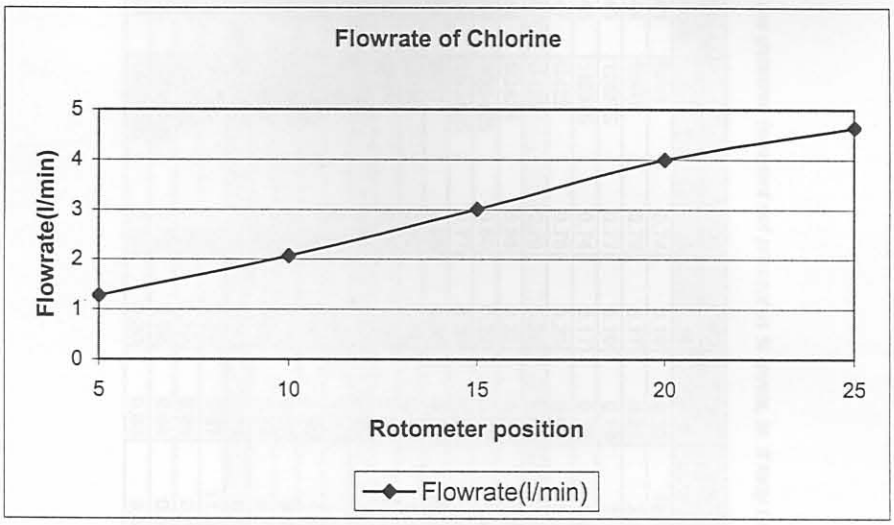
C	
Name of sample	5C425
Mass of sample(g)	25.00
Room temperature(^{O}C)	27.00
Reaction pressure(kPa)	101.00
Reaction time(mins)	5.00
Mass of product(g)	22.08
Reduction in mass(g)	2.92
Name of sample	10C425
Mass of sample(g)	25.01
Room temperature(^{O}C)	27.00
Reaction pressure(kPa)	101.00
Reaction time(mins)	10.00
Mass of product(g)	22.53
Reduction in mass(g)	2.48
Name of sample	15C425
Mass of sample(g)	25.01
Room temperature(^{O}C)	25.00
Reaction pressure(kPa)	15.00
Reaction time(mins)	99.00
Mass of product(g)	21.98
Reduction in mass(g)	3.03

D	
Name of sample	5C425
Mass of sample(g)	25.01
Room temperature(^{O}C)	27.00
Reaction pressure(kPa)	133.00
Reaction time(mins)	5.00
Mass of product(g)	22.49
Reduction in mass(g)	2.52
Name of sample	10C425
Mass of sample(g)	25.01
Room temperature(^{O}C)	27.00
Reaction pressure(kPa)	100.00
Reaction time(mins)	10.00
Mass of product(g)	22.64
Reduction in mass(g)	2.37
Name of sample	15C425
Mass of sample(g)	25.01
Room temperature(^{O}C)	27.50
Reaction pressure(kPa)	101.00
Reaction time(mins)	15.00
Mass of product(g)	21.77
Reduction in mass(g)	3.24

Appendix J: Calibration curves of the three gases used during chlorination.







Appendix K: XRF analysis of both the chlorinated and unchlorinated slag samples

*nd: not detected (element not present in % levels, ie. It may be absent or present in trace amounts)

Reference number		Al2O3 %	CaO %	Cr2O3 %	Fe2O3t %	K2O %	MgO %	MnO %	Na2O %	P2O5 %	SiO2 %	TiO2 %	V2O5 %	Zr2O %	Total %
DB443	BRS	0.74	0.19	0.20	16.99	nd	1.47	1.13	nd	nd	1.21	81.37	0.45	0.20	103.95
DB444	5BRS	0.79	0.17	0.21	2.30	nd	1.22	0.10	nd	nd	1.39	93.29	0.11	0.24	99.84
DB445	10BRS	0.77	0.19	0.19	2.10	nd	1.09	0.09	nd	nd	1.49	93.39	0.09	0.25	99.65
DB446	15BRS	0.74	0.17	0.18	1.79	nd	0.98	0.09	nd	nd	1.45	93.90	0.08	0.25	99.61
DB447	G425	0.75	0.20	0.07	11.22	nd	1.06	1.21	nd	nd	1.28	85.04	0.46	0.22	101.52
DB447QC	G425	0.76	0.20	0.07	11.21	nd	1.12	1.21	nd	nd	1.26	85.47	0.46	0.23	102.00
DB448	5G425	0.85	0.22	0.07	2.31	nd	1.06	0.18	nd	nd	1.51	92.96	0.12	0.25	99.53
DB449	10G425	0.80	0.22	0.06	1.97	nd	0.88	0.17	nd	nd	1.47	93.72	0.10	0.25	99.64
DB450	15G425	0.77	0.20	0.05	1.64	nd	0.66	0.16	nd	nd	1.50	94.43	0.08	0.25	99.73
DB451	BSC	0.98	0.08	0.11	13.62	nd	1.02	1.53	nd	nd	1.04	85.13	0.44	0.15	104.11
DB452	1BSC	0.92	0.06	0.10	1.89	nd	0.57	0.22	nd	nd	1.24	94.53	0.11	0.18	99.82
DB453	2BSC	0.86	0.06	0.09	1.68	nd	0.45	0.19	nd	nd	1.22	94.83	0.08	0.18	99.65
DB453QC	2BSC	0.88	0.07	0.09	1.68	nd	0.50	0.20	nd	nd	1.29	95.00	0.08	0.18	99.96
DB454	5BSC	0.86	0.07	0.07	1.60	nd	0.47	0.19	nd	nd	1.30	95.09	0.08	0.19	99.91
DB455	10BSC	0.78	0.06	0.06	1.17	nd	0.39	0.15	nd	nd	1.20	95.36	0.06	0.18	99.39
DB456	15BSC	0.83	0.08	0.07	0.96	nd	0.36	0.13	nd	nd	1.48	95.47	0.04	0.19	99.60
DB457	20BSC	0.81	0.08	0.04	0.75	nd	0.30	0.08	nd	nd	1.49	96.15	0.03	0.19	99.92
DB457QC	20BSC	0.80	0.07	0.04	0.75	nd	0.26	0.07	nd	nd	1.41	96.28	0.03	0.19	99.90
DB458	G1700	0.79	0.20	0.07	11.21	nd	1.11	1.22	nd	nd	1.38	86.66	0.47	0.22	103.34
DB459	5G1700	0.77	0.19	0.05	0.61	nd	0.66	0.05	nd	nd	1.57	95.72	0.06	0.26	99.94
DB460	10G1700	0.72	0.20	0.04	0.54	nd	0.58	0.05	nd	nd	1.54	95.61	0.04	0.25	99.57
DB461	15G1700	0.73	0.20	0.03	0.41	nd	0.55	0.03	nd	nd	1.58	95.66	0.03	0.25	99.47

APPENDIX M: Composition of various phases in titania slags (in wt%). Fe, Mn, O, Ti, and V by WDS, other elements by EDS;

C4346 – Chlorinated black particles of size 425-600 μm,

C4349 – FeO-containing rutile in unchlorinated slag of size 425 - 600μm

C4350 – FeO-containing rutile in unchlorinated slag of size 2360 - 3350 μm

No.	Al	Ca	Fe	Mg	Mn	O	Si	Ti	V	Total	Label
3	0.50	0.00	2.00	0.20	0.20	39.20	0.10	58.20	0.00	100.40	C4350 P001
4	0.40	0.00	1.70	0.10	0.20	38.40	0.10	58.00	0.00	98.90	C4350 P002
5	0.90	0.00	2.90	0.80	0.40	36.00	0.10	58.20	0.20	99.50	C4350 P003
6	1.00	0.00	3.50	0.80	0.50	35.30	0.10	57.40	0.10	98.70	C4350 P004
8	0.30	0.00	2.00	0.10	0.30	38.60	0.20	57.70	0.00	99.20	C4350 P006
9	0.30	0.00	1.90	0.00	0.30	38.30	0.10	58.30	0.00	99.20	C4350 P007
10	0.40	0.00	1.70	0.10	0.20	38.30	0.10	58.30	0.00	99.10	C4350 P008
11	0.40	0.00	1.80	0.10	0.20	38.80	0.20	58.30	0.10	99.90	C4350 P009
12	0.40	0.00	2.00	0.10	0.30	38.20	0.10	57.80	0.00	98.90	C4350 P010
13	0.40	0.10	1.70	0.10	0.20	39.10	0.10	58.40	0.00	100.10	C4350 P011
14	0.40	0.00	1.70	0.10	0.30	39.10	0.10	57.80	0.00	99.50	C4350 P012
18	0.30	0.00	25.50	2.50	3.50	36.50	0.10	33.10	0.10	101.60	C4346 P015
20	0.60	0.00	22.40	2.40	2.40	36.30	0.10	36.10	0.20	100.50	C4346 P017
21	0.40	0.10	22.40	2.40	3.90	36.50	0.40	34.50	0.30	100.90	C4346 P018
22	0.60	0.00	22.00	2.30	3.50	36.60	0.20	36.00	0.20	101.40	C4346 P019
23	0.40	0.00	16.20	2.60	2.50	40.30	0.20	42.30	0.10	104.60	C4346 P020
24	0.80	0.10	22.10	2.20	3.10	36.60	0.80	33.70	0.10	99.50	C4346 P021
25	0.90	0.10	22.80	2.20	2.90	37.40	0.90	33.90	0.20	101.30	C4346 P022
26	1.00	0.30	19.20	2.00	2.40	39.20	1.10	37.80	0.10	103.10	C4346 P023
27	0.70	0.10	19.30	2.00	2.90	38.30	0.50	38.00	0.30	102.10	C4346 P024
28	1.00	0.10	25.20	1.70	1.90	40.30	0.40	34.70	0.00	105.30	C4346 P025
29	0.10	0.00	0.20	0.00	0.00	40.20	0.10	59.10	0.00	99.70	C4346 P026
30	0.50	0.00	1.50	0.20	0.20	38.20	0.10	58.40	0.20	99.30	C4349 P027
31	0.60	0.00	2.00	0.20	0.30	38.30	0.10	57.90	0.50	99.90	C4349 P028