

LIST OF CONTENT

1.1	The geographic and legislative context.....	1
1.1.1	Water regulation.....	1
1.1.2	Current disposal practices.....	2
1.1.3	A new strategy.....	3
1.1.4	A survey in the KwaZulu-Natal province.....	4
1.2	Anaerobic biotechnology for industrial wastewater.....	6
1.2.1	Co-digestion.....	7
1.2.2	Industrial wastewater.....	8
1.3	Project outline.....	11
2.1	The anaerobic digestion process.....	14
2.1.1	Biochemistry and microbiology.....	14
2.1.2	Physico-chemical processes.....	16
2.1.3	Thermodynamics and self-regulation.....	16
2.2	Co-digestion.....	18
2.3	Characterisation of effluents: biodegradability, activity, inhibition.....	21
2.3.1	Volumetric methods.....	23
2.3.2	Manometric methods.....	24
2.4	The serum bottle method.....	26
2.5	The pH-stat titration method.....	28
2.5.1	General layout of the instrument.....	29
2.5.2	The first application to the nitrification process.....	29
2.5.3	The denitrification process.....	30
2.5.4	The aceticlastic methanogenesis process.....	31
3.1	Apparatus.....	33
3.1.1	The serum bottle method.....	35
3.1.1.1	Assessing the biodegradability of the test material.....	36
3.1.1.2	Assessing the toxicity of the test material.....	37
3.1.2	The pH-stat titration method.....	37
3.1.3	The laboratory-scale reactors.....	40
3.1.4	The pilot-scale reactor.....	41
3.2	Analytical methods.....	45

3.2.1	Determination of solids	45
3.2.2	Determination of organic carbon.....	46
3.2.2.1	Experimental determination of the organic carbon content of the sludge	47
3.2.3	Determination of the pH.....	48
3.2.4	Determination of the alkalinity and volatile acids concentration.....	49
3.2.5	Determination of the gas volume and composition.....	50
3.2.5.1	Determination of the gas volume for serum bottle assays.....	50
3.2.5.2	Determination of the gas volume for laboratory- and pilot-scale digesters.....	50
4.1	Screening tests	54
4.1.1	Conventional toxicity and biodegradability assays	54
4.1.1.1	Toxicity assessment of landfill leachates	58
4.1.1.2	Biodegradability assessment of landfill leachates	60
4.1.1.3	Toxicity assessment of textile effluents	63
4.1.1.4	Biodegradability assessment of textile effluents	67
4.1.1.5	Conclusions	72
4.1.2	Improved toxicity and biodegradability assay.....	73
4.1.3	Modified anaerobic activity tests.....	79
4.1.3.1	Test No 1 – individual components.....	79
4.1.3.2	Test No 2 – individual components.....	86
4.1.3.3	Test No 3 – co-digestion.....	94
4.1.3.4	Test No 4 – co-digestion.....	104
4.1.3.5	Test No 5 – co-digestion.....	110
4.1.3.6	Summary of the findings on the biodegradability of the test materials.....	120
4.2	Laboratory-scale experiments	123
4.2.1	What information can a serum bottle activity test provide for the start-up of a semi(continuous) experiment ?	126
4.2.2	Anaerobic digestion of the distillery effluent.....	128
4.2.2.1	Batch phase.....	132
4.2.2.2	Semi-continuous phase.....	135
4.2.2.3	Assessing the methanogenic activity of the sludge	148
4.3	A mathematical model for a two-unit pH-stat titration sensor.....	153

4.3.1	Specific features of Aquasim.....	154
4.3.2	The mathematical model	156
4.3.3	The hydraulics	157
4.3.4	The titration unit	158
4.3.5	The selection of equilibrium vs. dynamic state variables.....	159
4.3.6	Setting the initial conditions.....	160
A.1	The evaluation protocol.....	182
A.1.1	Characterisation of the test material and preparation of the seed sludge.	182
A.1.2	Quick toxicity assessment	183
A.1.3	Confirmatory assessment.....	183
A.1.3.1	Data interpretation.....	184
A.1.4	Laboratory-scale simulation	184
A.1.5	Monitoring.....	185
B.1	Test preparation.....	188
B.2	Execution of the activity test	191
B.3	Data interpretation.....	195
B.3.1	Interpreting biodegradability test.....	196
B.3.2	Interpreting toxicity test.....	197
B.3.3	How does the frequency of re-equilibration affect the calculation of activity ?.....	199
C.1	Preparation of the components	202
C.2	Instrument preparation.....	203
C.3	Data interpretation.....	209
D.1	Operation of an anaerobic (CSTR) digester	213
D.2	Monitoring a digestion process	216
D.2.1	Gas production.....	216
D.2.1.1	Set-up of the gas line	217
D.2.2	Gas composition	217
D.2.3	pH, alkalinity and VFAs concentration	218
D.2.4	COD concentration	218
D.2.5	Solids concentration	218
D.2.6	Evaluation of the stability of an anaerobic digester	219
D.2.7	Calculating the performance of the process	220

D.3	controlling a digestion process	222
F.1	Nutrients and Mineral Salts medium.....	229
F.2	Gas-chromatographic determination of gas composition.....	231
F.3	Two-point titration method	234
F.3.1	The accuracy of alkalinity and VFA determination through titration	234
F.4	Stoichiometric calculations	236
F.4.1	Organic carbon content.....	236
F.4.2	Biogas composition	237
G.1	Serum bottle tests	239
G.1.1	Conventional toxicity and biodegradability tests on landfill leachates	240
G.1.1.1	Toxicity assays	242
G.1.1.2	Biodegradability assays	245
G.1.2	Conventional toxicity and biodegradability tests on textile effluents	247
G.1.2.1	Toxicity assays	249
G.1.2.2	Biodegradability assays	253
G.1.3	Improved activity test: synthetic dye effluent	254
G.1.4	Modified anaerobic activity tests: test No 1	256
G.1.5	Modified anaerobic activity tests: test No 2	261
G.1.6	Modified anaerobic activity tests: test No 3	267
G.1.7	Modified anaerobic activity tests: test No 4	271
G.1.8	Modified anaerobic activity tests: test No 5	277
G.1.9	Evaluating the reproducibility of an anaerobic activity test	289
G.1.10	The accurate determination of the gas volume for an activity test.....	293
G.2	Laboratory-scale tests: final experiment.....	295
G.2.1	Batch phase.....	295
G.2.2	Accuracy of the liquid displacement gas measuring system	295
G.2.3	Off-line activity tests	297
I.1	Theses.....	347
I.2	Courses	347
I.3	Co-operations	348
I.4	Linkage with other WRC projects.....	348