

	PAGE NO
Executive Summary .....	i
Acknowledgements.....	xi
Table of Contents .....	xii
List of Figures .....	xvii
List of Tables .....	xviii
Abbreviations and Glossary.....	xx
<b>1 INTRODUCTION .....</b>	<b>1</b>
1.1 Project Objectives .....	2
<b>2 LITERATURE REVIEW .....</b>	<b>5</b>
2.1 Introduction .....	5
2.2 Ozone .....	6
2.3 Advanced Oxidation Processes .....	8
2.4 Ultraviolet Irradiation .....	9
2.5 Peracetic Acid .....	11
2.6 Membrane Filtration .....	11
2.7 Bromine .....	14
<b>3 LABORATORY AND PILOT PLANT INVESTIGATION.....</b>	<b>17</b>
3.1 Introduction .....	17
3.2 Results and Discussion .....	20
3.2.1 Chlorine.....	20
3.2.2 Ozone.....	22
3.2.3 Ultraviolet Irradiation.....	32
3.2.3.1 UV unit with lamp immersed in effluent.....	32

3.2.3.2	UV unit with lamp positioned above effluent.....	36
3.2.3.3	Medium pressure UV.....	37
3.2.3.4	Multiwave UV.....	42
3.2.4	Peracetic Acid and Peracetic Acid / Hydrogen Peroxide.....	45
3.2.5	Bromine.....	50
3.2.6	Mixed Oxidant Generator.....	52
3.2.7	Klor-Free.....	53
3.2.8	Ozone Combinations.....	53
3.2.8.1	Ozone and UV.....	53
3.2.8.2	Ozone and Chlorine.....	54
3.2.8.3	Ozone and Peracetic Acid.....	56
3.2.8.4	Ozone and Bromine.....	57
3.2.9	Ultraviolet Irradiation Combinations.....	57
3.2.9.1	UV and Chlorine.....	57
3.2.9.2	UV and Peracetic Acid.....	59
3.2.9.3	UV and Bromine.....	60
3.2.10	Membranes.....	60
3.2.11	<i>Cryptosporidium</i> and <i>Giardia</i> Results.....	60
3.3	Summary.....	62
4	<b>GUIDELINES FOR WASTEWATER DISINFECTION.....</b>	<b>63</b>
4.1	Cost Assessment.....	63
4.2	Ozone.....	64
4.3	Medium Pressure UV.....	64
4.4	Peracetic Acid.....	65
4.5	Bromine.....	66
4.6	Recommendations for Future Research.....	66
4.7	Status in Terms of <i>Cryptosporidium</i> and <i>Giardia</i> .....	66
4.8	Conclusions.....	67
5	<b>REFERENCES.....</b>	<b>69</b>

	APPENDIX.....	79
6	<b>ANALYTICAL METHODOLOGY</b> .....	80
6.1	<b>Microbiological Analyses</b> .....	80
6.1.1	Coliform / <i>E. coli</i> Organisms .....	80
6.1.2	Faecal Streptococci.....	80
6.1.3	Coliphages .....	80
6.1.4	Colony Counts.....	80
6.1.5	<i>Cryptosporidium</i> and <i>Giardia</i> .....	80
6.2	<b>Chemical Analyses</b> .....	81
6.2.1	pH and Temperature .....	81
6.2.2	Turbidity .....	81
6.2.3	Conductivity .....	81
6.2.4	Alkalinity.....	81
6.2.5	Calcium, Magnesium and Total Hardness .....	81
6.2.6	Iron.....	81
6.2.7	Manganese .....	82
6.2.8	Total Dissolved Solids.....	82
6.2.9	Suspended Solids.....	82
6.2.10	Chemical Oxygen Demand.....	82
6.3	<b>Organic Analyses</b> .....	82
6.3.1	Total Organic Carbon, Dissolved Organic Carbon and Biodegradable Dissolved Organic Carbon Analysis.....	82
6.3.2	Trihalomethane Formation Potential.....	83
6.3.3	Ultraviolet Absorbance.....	83
6.4	<b>Determination of Chlorine, Bromine, Ozone, Hydrogen Peroxide and Peracetic Acid</b> .....	84
6.4.1	Iodometric Titration for the Determination of Chlorine .....	84
6.4.2	Iodometric Titration for the Determination of Bromine .....	84
6.4.3	Iodometric Titration for the Determination of Ozone.....	84
6.4.4	Indigo Colorimetric Method for the Determination of Ozone.....	85
6.4.5	Iodometric Titration for the Determination of Hydrogen Peroxide.....	85

6.4.6	Iodometric Titration for the Determination of Peracetic Acid...	86
6.5	<b>Materials and Procedures</b> .....	86
6.5.1	Seeding and Viability of the Protozoa.....	86
6.5.1.1	Viability Assays.....	86
6.5.1.2	Materials and Procedures.....	87
6.5.2	Assessment of Disinfection Efficacy .....	88
6.5.3	Chlorine Demand Tests and Assessment of Chlorine Disinfection .....	88
6.5.4	Ozone Requirement/Demand Tests and Assessment of Ozone Disinfection.....	89
6.5.5	Disinfectant Demand Tests.....	90
6.5.6	Operation of Low Pressure UV Unit with Lamp Positioned above Effluent.....	91
6.5.7	Operation of Low Pressure UV Unit with Lamp Immersed in Effluent.....	91
6.5.8	Operation of Low Pressure UV Unit in Laboratory Batch Tests .....	91
6.5.9	Medium Pressure UV Unit .....	92
6.5.10	Multiwave UV Unit.....	92
6.5.11	Peracetic Acid and Peracetic Acid with Hydrogen Peroxide ....	92
6.5.12	Bromine .....	93
6.5.13	Mixed Oxidant Generator.....	93
6.5.14	Klor-Free .....	94
6.5.15	Pilot Plant .....	94
6.5.16	Tracer Tests .....	96
7	<b>PHOTOGRAPHS</b> .....	97
7.1	Laboratory Ozonation Equipment.....	97
7.2	Pilot-Plant .....	97
7.3	Medium Pressure UV Unit .....	98
7.4	Ozone Generator and Destructor .....	98
7.5	<i>Cryptosporidium</i> Oocysts Following In Vitro Excystation Viewed Under DIC.....	99
7.6	<i>Cryptosporidium</i> Oocysts Following In Vitro Excystation Viewed Under DIC.....	99

7.7	FITC Stained <i>Giardia</i> Cysts and a <i>Giardia</i> Cyst viewed Under DIC .....	100
7.8	TMR-FDA Stained <i>Giardia</i> Cysts.....	101
7.9	SEM of a <i>Cryptosporidium</i> Oocyst .....	101
7.10	SEM of a <i>Giardi</i> Cyst.....	102