

INTRODUCTION	XVI
STUDY GOAL AND OBJECTIVES	XVI
REASONS FOR DOING THE STUDY	XVI
CONTRIBUTIONS OF THE STUDY AND FOR WHOM.....	XVII
SCOPE AND FORMAT	XVII
METHODOLOGY	XVII
INFORMATION SOURCES.....	XVII
RELATED BCC WORK CREDENTIALS	XVIII
BCC ONLINE SERVICE	XVIII
INTERNET	XVIII
AUTHOR'S CREDENTIALS	XIX
DISCLAIMER	XIX
 SUMMARY.....	 XX
SUMMARY TABLE VALUE OF THE U.S. MARKET FOR ADVANCED MUNICIPAL WATER TREATMENTS TECHNOLOGIES, THROUGH 2008 (\$ MILLIONS).....	XXI
SUMMARY FIGURE VALUE OF THE U.S. MARKET FOR ADVANCED MUNICIPAL WATER TREATMENTS TECHNOLOGIES, 2000-2008 (\$ MILLIONS)	XXI
 OVERVIEW	 1
MARKET FORCES	1
QUANTITY.....	1
QUALITY.....	1
AGING INFRASTRUCTURE	1
CONGRESSIONAL SPENDING.....	2
EPA Gap Analysis	2
WIN Proposes Increased Federal Funding.....	3
UTILITIES' PLANS FOR PLANT UPGRADES	3
WATER AVAILABILITY AND USAGE IN THE U.S.	4
PUBLIC SUPPLY.....	4
TABLE 1 DISTRIBUTION OF PUBLIC SUPPLY WATER BY USE.....	4
FIGURE 1 DISTRIBUTION OF PUBLIC SUPPLY WATER BY USE (%).....	5
THE PRICE OF IMPROVED WATER QUALITY	5
HISTORY OF DRINKING WATER TREATMENT	5
TABLE 2 A BRIEF HISTORY OF DRINKING WATER TREATMENT	6
TABLE 2 (CONTINUED).....	7
OVERVIEW OF ADVANCED MUNICIPAL WATER TREATMENT TECHNOLOGIES.....	7
EPA SPENDING FORECASTS.....	7
TABLE 3 INVESTMENT NEEDED FOR WATER TREATMENT BY CONTAMINANT (\$ BILLIONS).....	8
FIGURE 2 INVESTMENT NEEDED FOR WATER TREATMENT BY CONTAMINANT (%)	8
ENVIRONMENTAL TECHNOLOGY VERIFICATION	9
TABLE 4 ETV DRINKING WATER SYSTEMS EVALUATIONS.....	9
TABLE 4 (CONTINUED).....	10

DRINKING WATER TREATMENT REQUIREMENTS.....	11
Particle Filtration.....	11
Disinfection	11
Disinfection Byproducts.....	12
Trihalomethanes	12
Haloacetic Acids	12
Alternate Forms of Chlorine.....	12
Alternatives to Chlorine	13
Ozone.....	13
Ultraviolet Light	13
TABLE 5 COMPARISON OF DISINFECTION METHODS	13
Membrane Filtration	14
CONTINUED RELIANCE ON CHLORINE.....	14
TABLE 6 DISINFECTION METHODS USED BY WATER TREATMENT PLANTS.....	14
FIGURE 3 DISINFECTION METHODS USED BY WATER TREATMENT PLANTS	
(%).....	15
TABLE 7 FORMS OF CHLORINE USED AT DRINKING WATER PLANTS (%).....	15
FIGURE 4 FORMS OF CHLORINE USED AT WATER TREATMENT PLANTS (%)	16
THE MULTI-BARRIER APPROACH	16
REGULATORY CLIMATE.....	17
SAFE DRINKING WATER ACT	17
TABLE 8 NATIONAL PRIMARY DRINKING WATER REGULATIONS	18
TABLE 8 (CONTINUED).....	19
TABLE 8 (CONTINUED).....	20
TABLE 8 (CONTINUED).....	21
TABLE 9 NATIONAL SECONDARY DRINKING WATER REGULATIONS.....	21
TABLE 9 (CONTINUED).....	22
Statutory Requirements of the SDWA, through 2005	22
TABLE 10 STATUTORY REQUIREMENTS IN THE SAFE DRINKING WATER ACT	
AMENDMENTS OF 1996.....	22
Arsenic.....	22
Small System Compliance.....	23
Cryptosporidium	24
Groundwater Rule	24
Drinking Water Contaminant Candidates	25
TABLE 11 THE DRINKING WATER CONTAMINANT CANDIDATE LIST	25
TABLE 11 (CONTINUED).....	26
Emerging Pathogens.....	27
Adenoviruses	27
Caliciviruses	27
Coxsackieviruses	27
Echoviruses.....	27
Helicobacter pylori	28
Aeromonas hydrophila.....	28
Mycobacterium avium complex	28
Microsporidia.....	29
Emerging Inorganic Contaminants.....	29

Perchlorate.....	29
Emerging Organic Contaminants	30
MTBE.....	30
Endocrine Disrupters, Pharmaceuticals and Other Organic Contaminants	30
INDUSTRY STRUCTURE	31
THE URGE TO MERGE.....	31
WHY MERGE?	31
TABLE 12 MERGERS AND ACQUISITIONS IN THE WATER TREATMENT INDUSTRY (SINCE 1996)	32
ENGINEERING FIRMS ACTIVE IN MUNICIPAL WATER TREATMENT	32
TOP ENGINEERING FIRMS IN WATER.....	33
TABLE 13 ENGINEERING FIRMS INVOLVED IN WATER SUPPLY AND SALES, 2001 (\$ MILLIONS).....	33
TABLE 13 (CONTINUED).....	34
Earth Tech	34
Black & Veatch	34
Montgomery Watson Harza	35
CH2M Hill.....	36
Camp Dresser & McKee	37
AECOM Technology	38
URS Corp.	38
Malcolm Pirnie.....	38
Tetra Tech.....	39
Henningson, Durham and Richardson (HDR)	40
PBS&J.....	40
The Dewberry Companies	40
Dewberry-Goodkind, Inc.....	41
Dewberry & Davis, Inc.	41
Jacobs Engineering Group	41
Carollo Engineers	41
CSA Group	42
Parsons Corp.....	43
Hazen and Sawyer.....	43
Boyle Engineering	43
Gannett Fleming.....	44
Michael Baker Corp.....	44
PATENT TRENDS.....	44
BY TECHNOLOGY	45
TABLE 14 PATENTS INVOLVING ADVANCED WATER TREATMENT TECHNOLOGIES (OCTOBER 22, 2000 TO OCTOBER 22, 2002).....	45
TABLE 14 (CONTINUED).....	46
TABLE 14 (CONTINUED).....	47
FIGURE 5 PATENTS BY TECHNOLOGY (%).....	48

BY COMPANY	48
FIGURE 6 PATENTS BY COMPANY, OCTOBER 22, 2000 TO OCTOBER 22, 2002 (%).....	49
MEMBRANE FILTRATION.....	50
MARKET SIZE AND GROWTH.....	50
Market Size and Growth (Continued)	51
TABLE 15 SALES AND PROJECTIONS FOR THE U.S. MEMBRANE FILTRATION	
MARKET IN MUNICIPAL WATER TREATMENT, THROUGH 2008 (\$ MILLIONS).....	52
FIGURE 7 SALES AND PROJECTIONS FOR THE U.S. MEMBRANE FILTRATION	
MARKET IN MUNICIPAL WATER TREATMENT, 2000-2008 (\$ MILLIONS).....	53
OVERVIEW	53
Rejected Contaminants	53
Membrane Configurations	54
Flux	54
Other Process Parameters	54
Modes of Filtration	54
Membrane Fouling	55
Filtration Processes	55
TABLE 16 CAPACITY OF MEMBRANE TECHNOLOGY BY PROCESS, INSTALLED	
AND PROPOSED PROJECTS, 2002 (%).....	55
FIGURE 8 INSTALLED CAPACITY OF MEMBRANE TECHNOLOGY BY PROCESS,	
INSTALLED AND PROPOSED PROJECTS, 2002 (%).....	56
FIGURE 9 COMPARISON OF MEMBRANE PROCESSES	56
REVERSE OSMOSIS (RO)	57
RO Membranes	57
Membrane Cost.....	57
UF as RO Pretreatment	58
MF as RO Pretreatment.....	58
Advantages and Disadvantages.....	58
Advantages.....	58
Disadvantages.....	59
Brine	59
Manufacturers and Products	59
TABLE 17 RO MEMBRANE PRODUCTS.....	60
Installed Capacity.....	61
TABLE 18 FULL SCALE RO DRINKING WATER INSTALLATIONS IN THE U.S.	
(COMPLETED AND PROPOSED, 2002).....	61
TABLE 18 (CONTINUED).....	62
TABLE 18 (CONTINUED).....	63
TABLE 18 (CONTINUED).....	64
TABLE 18 (CONTINUED).....	65
TABLE 18 (CONTINUED).....	66
ELECTRODIALYSIS REVERSAL (EDR).....	66
Advantages and Disadvantages.....	67
Advantages.....	67
Disadvantages.....	67
EDR Membranes/Systems.....	67
Installed Capacity.....	68
TABLE 19 FULL-SCALE EDR DRINKING WATER INSTALLATIONS IN THE U.S.....	68

<i>TABLE 19 (CONTINUED)</i>	69
MF	69
Advantages and Disadvantages	70
Advantages.....	70
Disadvantages.....	70
MF Membranes/Systems	71
<i>TABLE 20 MF PRODUCTS</i>	71
Installed Capacity.....	71
<i>TABLE 21 FULL-SCALE MF DRINKING WATER INSTALLATIONS IN THE U.S.</i> <i>(COMPLETED AND PROPOSED, 2002)</i>	71
<i>TABLE 21 (CONTINUED)</i>	72
<i>TABLE 21 (CONTINUED)</i>	73
UF73	
UF Membranes/Systems	74
<i>TABLE 22 UF PRODUCTS</i>	74
Installed Capacity.....	74
<i>TABLE 23 FULL-SCALE UF DRINKING WATER INSTALLATIONS IN THE U.S.</i> <i>(COMPLETED AND PROPOSED, 2002)</i>	75
NANOFILTERS (NF).....	76
NF Membranes/Systems	76
<i>TABLE 24 NF MEMBRANE PRODUCTS</i>	76
<i>TABLE 24 (CONTINUED)</i>	77
Installed Capacity.....	77
<i>TABLE 25 FULL-SCALE NF DRINKING WATER INSTALLATIONS IN THE U.S.</i> <i>(COMPLETED AND PROPOSED, 2002)</i>	77
<i>TABLE 25 (CONTINUED)</i>	78
COST, EFFECTIVENESS OF MEMBRANE FILTRATION	78
<i>TABLE 26 TYPICAL MEMBRANE SYSTEM SPECS (10-MGD SYSTEM)</i>	79
INDUSTRY PARTICIPANTS	79
<i>TABLE 27 COMPANIES SELLING MEMBRANE TECHNOLOGY FOR DRINKING</i> <i>WATER TREATMENT</i>	79
Pall Corp.	80
Asahi Kasei	80
Microza	80
<i>TABLE 28 ASAHI MICROZA ELEMENTS</i>	81
Dow Liquid Separations/Filmtec	81
Koch Membrane Systems	82
RO Elements	82
UF Elements	83
NF Elements	83
<i>TABLE 29 KOCH NF PRODUCTS</i>	83
Osmonics	84
RO Membrane Elements	84
<i>TABLE 30 OSMONICS DESAL SERIES A</i>	84
<i>TABLE 31 OSMONICS' CA DESAL ELEMENTS</i>	85
NF Membrane Elements	86
MUNI Packaged Systems	86
<i>TABLE 32 OSMONICS MUNI SYSTEMS</i>	86

<i>TABLE 33 INSTALLED OSMONICS' MUNI RO/NF PLANTS</i>	87
Ionics/Norit	87
Norit UF Technology.....	88
Hydranautics/Nitto Denko	89
RO Membrane Elements	89
NF Membrane Elements	89
HYDRAcap	89
USFilter	90
USFilter/Memcor	91
Aquasource/Ondeo	91
TriSep.....	92
Spiral Wound Backflushable UF Element.....	92
Toray Industries	93
Zenon Environmental.....	93
ZeeWeed	93
PCI Membranes	94
MARKET SHARE	95
<i>TABLE 34 MEMBRANE FILTRATION PERCENTAGE MARKET SHARE BY</i> <i>COMPANY, 2002</i>	95
<i>FIGURE 10 MEMBRANE MARKET SHARE BY COMPANY, 2002 (%)</i>	96
OZONE	96
MARKET SIZE AND GROWTH.....	96
<i>TABLE 35 SALES AND PROJECTIONS FOR THE U.S. OZONE DISINFECTION</i> <i>MARKET IN MUNICIPAL WATER TREATMENT, THROUGH 2008 (\$ MILLIONS)</i>	97
<i>FIGURE 11 SALES AND PROJECTIONS FOR THE U.S. OZONE DISINFECTION</i> <i>MARKET IN MUNICIPAL WATER TREATMENT, 2000-2008 (\$ MILLIONS)</i>	97
OVERVIEW	98
Mechanisms of Ozone Disinfection	98
Other Contaminants Oxidized	98
Generating O ₃	99
Dispersing the Gas	99
Ozone with Hydrogen Peroxide.....	100
DRAWBACKS AND BENEFITS	100
Advantages	100
Disadvantages.....	100
Bromate.....	101
INSTALLED CAPACITY	101
<i>TABLE 36 U.S. OZONE INSTALLATIONS (EXISTING AND PROPOSED)</i>	101
<i>TABLE 36 (CONTINUED)</i>	102
<i>TABLE 36 (CONTINUED)</i>	103
<i>TABLE 36 (CONTINUED)</i>	104
<i>TABLE 36 (CONTINUED)</i>	105
<i>TABLE 36 (CONTINUED)</i>	106
<i>TABLE 36 (CONTINUED)</i>	107
<i>TABLE 36 (CONTINUED)</i>	108
<i>TABLE 36 (CONTINUED)</i>	109
COST, EFFECTIVENESS OF OZONE TREATMENT	109

TABLE 37 TYPICAL OZONE SYSTEM SPECS (10-MGD INSTALLATION).....	110
INDUSTRY PARTICIPANTS	110
PCI-WEDECO.....	110
Effizon Technology.....	111
GSO/GSA Series.....	111
TABLE 38 PCI-WEDECO GSO/GSA SERIES GENERATORS	112
SMO/SMA Series	112
TABLE 39 PCI-WEDECO SMO/SMA SERIES GENERATORS	112
PDO/PDA Series	113
Ozonia	113
OZAT Packaged Plants.....	113
TABLE 40 OZAT OZONE PLANT SPECS.....	114
OZAT Skids	114
TABLE 41 SPECIFICATIONS FOR OZAT SKIDS.....	114
TABLE 41 (CONTINUED).....	115
Engineered AT Systems	115
Praxair Trailigaz	115
Osmonics	116
HC Series Ozone Generators.....	116
TABLE 42 OSMONICS HC SERIES OZONE GENERATORS.....	117
USFilter	117
MARKET SHARE	118
TABLE 43 OZONE DISINFECTION PERCENTAGE MARKET SHARE BY COMPANY, 2002.....	118
FIGURE 12 OZONE DISINFECTION PERCENTAGE MARKET SHARE, BY COMPANY, 2002 (%)	118
ULTRAVIOLET LIGHT	118
MARKET SIZE AND GROWTH.....	118
TABLE 44 SALES AND PROJECTIONS FOR THE U.S. UV RADIATION MARKET IN MUNICIPAL WATER TREATMENT, THROUGH 2008 (\$ MILLIONS).....	119
FIGURE 13 SALES AND PROJECTIONS FOR THE U.S. UV RADIATION IN MUNICIPAL WATER TREATMENT, 2000-2008 (\$ MILLIONS).....	120
OVERVIEW	120
UV Lamps	121
Reactor Types	121
Advantages and Disadvantages.....	121
Advantages.....	121
Disadvantages.....	122
UV EQUIPMENT.....	122
TABLE 45 UV MANUFACTURERS AND PRODUCTS	122
INSTALLED CAPACITY	123
TABLE 46 U.S. UV DRINKING WATER INSTALLATIONS (EXISTING AND PROPOSED).....	123
COST, EFFECTIVENESS OF UV IRRADIATION	123
TABLE 47 TYPICAL UV SYSTEM SPECS (10-MGD INSTALLATION).....	124
INDUSTRY PARTICIPANTS	124
Trojan Technologies.....	124
UVSwift System.....	125

UVLogic System.....	125
<i>TABLE 48 UVLOGIC SYSTEM SPECS.....</i>	<i>125</i>
<i>TABLE 48 (CONTINUED).....</i>	<i>126</i>
UV8000 System.....	126
WEDECO-Ideal Horizons.....	127
Spektrotherm Lamps.....	127
B-Series.....	127
<i>TABLE 49 WEDECO B-SERIES UV SYSTEMS.....</i>	<i>128</i>
K-Series.....	128
<i>TABLE 50 WEDECO K SERIES SYSTEMS.....</i>	<i>128</i>
Aquionics.....	129
Calgon Carbon Corp.	129
Sentinel System.....	130
Rayox System.....	130
Severn Trent/UltraDynamics.....	131
UltraDynamics Equipment.....	131
<i>TABLE 51 ULTRADYNAMICS LIGHT INDUSTRIAL SYSTEMS.....</i>	<i>132</i>
Severn Trent/Hanovia.....	132
FrontLine.....	132
Pulsar UV Technologies.....	133
Ondeo Degrement.....	133
Wallace & Tiernan/USFilter.....	134
<i>TABLE 52 BARRIER UV SYSTEM SPECS.....</i>	<i>134</i>
Lightstream Technologies.....	134
MARKET SHARE.....	135
<i>TABLE 53 U.S. UV DISINFECTION MARKET PRECENTAGE SHARE, BY</i> <i>COMPANY, 2002.....</i>	<i>135</i>
<i>FIGURE 14 U.S. UV DISINFECTION MARKET PERCENTRAGE SHARE, BY</i> <i>COMPANY, 2002 (%).....</i>	<i>136</i>
NOVEL TREATMENTS.....	136
MARKET SIZE AND GROWTH.....	136
Market Size and Growth (Continued).....	137
<i>TABLE 54 SALES AND PROJECTIONS FOR U.S. NOVEL TECHNOLOGIES IN</i> <i>MUNICIPAL WATER TREATMENT, THROUGH 2008 (\$ MILLIONS).....</i>	<i>138</i>
<i>FIGURE 15 SALES AND PROJECTIONS FOR U.S. NOVEL TECHNOLOGIES IN</i> <i>MUNICIPAL WATER TREATMENT, 2000-2008 (\$ MILLIONS).....</i>	<i>138</i>
OVERVIEW.....	138
Hypochlorites.....	139
Chloramines.....	139
<i>TABLE 55 PLANTS DISINFECTING WITH CHLORAMINE.....</i>	<i>140</i>
Chlorine Dioxide.....	140
Chlorite/Chlorate.....	140
NDMA.....	141
On-Site Sodium Hypochlorite Generation.....	141
Disinfection with Chloramine.....	142
On-Site Chlorine Dioxide Production.....	142
Mixed Oxidant Disinfection.....	142

COST, EFFECTIVENESS OF NOVEL TREATMENTS.....	143
<i>TABLE 56 ADVANCED OXIDIZING AGENTS COMPARED (TYPICAL 10-MGD PLANT)</i>	143
INDUSTRY PARTICIPANTS	144
Wallace & Tiernan.....	144
Chlorine Dioxide System	144
Direct-Feed Ammoniator	144
Ionics	145
<i>TABLE 57 CLOROMAT SYSTEM SPECIFICATIONS</i>	145
Severn Trent/ClorTec	146
ClorTec Systems.....	146
Severn Trent/Biochem	146
Sterling Pulp Chemicals.....	147
ERCO R101 Generator	147
CDG Technology	148
Gas:Solid System	148
OXI Company.....	148
OXI-2B.....	149
MIOX Corp.....	149
<i>TABLE 58 MIOX MIXED OXIDANT DISINFECTION INSTALLATIONS</i>	150
Electrolytic Technologies.....	150
<i>TABLE 59 KLORIGEN SYSTEM SPECIFICATIONS</i>	151
INTERNATIONAL ASPECTS	151
<i>FIGURE 16 WORLD ACCESS TO CLEAN WATER</i>	152
WORLD ACCESS TO WATER	152
WORLD BANK WATER PROJECTS.....	153
WWEMA FORECASTS.....	153
DEPARTMENT OF COMMERCE PROJECTIONS.....	153
AWWA Inks Trade Pact	154
Water/Wastewater Markets of 12 “Best Prospect” Countries	154
<i>TABLE 60 WATER/WASTEWATER MARKETS OF 12 “BEST PROSPECT” COUNTRIES</i>	154
Australia.....	155
China	155
Egypt	155
India	156
Japan	156
Mexico.....	157
South Korea.....	157
Saudi Arabia	158
Spain.....	158
Taiwan.....	158
United Kingdom.....	159
EXPENDITURES FOR POTABLE WATER TREATMENT	159

<i>TABLE 61 U.S. EXPORTS OF POTABLE WATER TREATMENT EQUIPMENT (\$</i>	
<i>MILLIONS, 1999)</i>	160
MAJOR PLAYERS IN GLOBAL WATER TREATMENT	160
Major Players in Global Water Treatment (Continued)	161
APPENDIX I	162
MANUFACTURERS DIRECTORY	162
MANUFACTURERS DIRECTORY (CONTINUED)	163
MANUFACTURERS DIRECTORY (CONTINUED)	164
MANUFACTURERS DIRECTORY (CONTINUED)	165
MANUFACTURERS DIRECTORY (CONTINUED)	166
MANUFACTURERS DIRECTORY (CONTINUED)	167
MANUFACTURERS DIRECTORY (CONTINUED)	168
MANUFACTURERS DIRECTORY (CONTINUED)	169
MANUFACTURERS DIRECTORY (CONTINUED)	170
MANUFACTURERS DIRECTORY (CONTINUED)	171
APPENDIX II	172
GLOSSARY	172
GLOSSARY (CONTINUED)	173