

Contents

Preface	17
Introduction – Cleaner Production	19
1 Industrial Impacts on the Environment	27
1.1 Industrial Use of Natural Resources	27
1.1.1 Resource Availability and Use	27
1.1.2 Bulk Material, Minerals and Biotic Resources	28
1.1.3 Energy	29
1.1.4 Water	29
1.2 Environmental Impacts – The Atmosphere	30
1.2.1 Global Warming.....	30
1.2.2 Policies to Reduce Emissions of Greenhouse Gases	31
1.2.3 Stratospheric Ozone Depletion.....	32
1.2.4 Ozone-destroying Substances	33
1.2.5 Reduction of Ozone-depleting Substances and the Montreal Protocol	34
1.3 Industrial Air Pollution	34
1.3.1 Air Pollution	34
1.3.2 Acidification	35
1.3.3 Sulphur Oxides.....	35
1.3.4 Nitrogen Oxides	36
1.3.5 Convention on Reduction of Air Born Long-Range Transboundary Pollution, LRTP	36
1.3.6 Tropospheric Ozone.....	36
1.3.7 Particulate Pollutants.....	37
1.3.8 Radioactivity	39
1.4 Industrial Water Pollution	39
1.4.1 Organic Pollution	39
1.4.2 Nutrients.....	40
1.4.3 Salts	41
1.5 Pollution by Toxic Substances	41
1.5.1 Pollution by Heavy Metals	41
1.5.2 The Heavy Metals.....	41
1.5.3 Persistent Organic Pollutants.....	42
1.5.4 Pesticides	44
1.5.5 Industrial Chemicals and By-products.....	44
1.5.6 Measures to Control the Use of Chemicals	45
Study Questions, Abbreviations, Internet Resources	45

2 Development of Pollution Abatement Methods.....	47
2.1 Searching for Solutions to the Pollution Problem.....	47
2.1.1 Introduction.....	47
2.1.2 Remediation Measures – Can We Clean Up the Environment?.....	48
2.1.3 The Long-term Perspective	49
2.2 Avoiding the Problem – Let Nature Handle it.....	50
2.2.1 The Philosophy of Dilution	50
2.2.2 Site Selection	50
2.2.3 Chimneys are Not Enough	51
2.3 The End-of-pipe Approach	51
2.3.1 External Cleaning	51
2.3.2 The Filter Strategy	52
2.3.3 Waste as a Resource	52
2.4 Process Integrated Solutions.....	53
2.4.1 A Promising Case – the Pulp and Paper Industry	53
2.4.2 Changed Technology	53
2.4.3 The Substitution of Raw Materials	54
2.4.4 Integration and Environmental Audits	54
2.5 Recycling	54
2.5.1 Levels of Recycling.....	54
2.5.2 Organising Production to Decrease Emissions	55
2.5.3 Legal Measures	56
2.6 The Long-term Solution – Reorganise Society	56
2.6.1 Products or Functions.....	56
2.6.2 Changing Production or Consumption?	57
2.6.3 Eco-development rather than Environmental Protection	57
Study Questions, Abbreviations, Internet Resources	58
3 Industry in the Baltic Sea Region.....	59
3.1 Baltic Sea Region Industrial History.....	59
3.1.1 Natural Resources and Early Industrialisation.....	59
3.1.2 Industrialisation Gains Momentum – late 1800s and early 1900s.....	59
3.1.3 Changes in the late 20 th Century.....	60
3.2 The Major Branches of Industry	61
3.2.1 The Classification of Industrial Economy	61
3.2.2 Agriculture, Forestry and Fishing.....	61
3.2.3 Coal, Petrol, Oil shale and Gas.....	61
3.2.4 Iron and Metal Mining	62
3.2.5 Stone, Mineral and Cement	63
3.2.6 Textile Clothing; Leather	63
3.2.7 Pulp and Paper	63
3.2.8 The Chemical Industry.....	64
3.2.9 Manufacturing of Machinery, Electrical and Optical Equipment, Car Industry	65
3.2.10 The Power Industry	66
3.2.11 Construction	66
3.3 Industrial Structure and Restructuring	66
3.3.1 Industry Restructuring	66

3.3.2 Economy versus Environment.....	67
3.3.3 The Change to a Post-industrial Society	69
Study Questions, Abbreviations, Internet Resources	69
4 Cleaner Production Assessment.....	71
4.1 Cleaner Production Assessment Methodologies.....	71
4.1.1 UNEP/UNIDO Methodology	71
4.2 Planning and Organising Cleaner Production	72
4.2.1 Obtain Management Commitment	72
4.2.2 Establish a Project Team.....	72
4.2.3 Develop Environmental Policy, Objectives and Targets	72
4.2.4 Plan the Cleaner Production Assessment.....	72
4.3 Pre-assessment	73
4.3.1 Company Description and Flow Chart.....	73
4.3.2 Walk-through Inspection.....	73
4.3.3 Establish a Focus	74
4.4 Assessment	75
4.4.1 Collection of Quantitative Data	75
4.4.2 Material Balance	76
4.4.3 Identify Cleaner Production Opportunities	78
4.4.4 Record and Sort Options.....	80
4.5 Evaluation and Feasibility Study.....	81
4.5.1 Preliminary Evaluation	81
4.5.2 Technical Evaluation.....	81
4.5.3 Economic Evaluation.....	81
4.5.4 Environmental Evaluation.....	84
4.5.5 Select Viable Options	84
4.6 Implementation and Continuation.....	84
4.6.1 Prepare an Implementation Plan	84
4.6.2 Implement Selected Options.....	85
4.6.3 Monitor Performance	85
4.6.4 Sustain Cleaner Production Activities	85
Abbreviations, Study Questions, Internet Resources	86
5 Tracking Environmental Performance	87
5.1 Environmental Performance Evaluation	87
5.1.1 Environmental Performance is Difficult to Assess.....	87
5.1.2 Environmental Performance Evaluation, EPE	87
5.1.3 The EPE Process	88
5.2 Environmental Performance Indicators	88
5.2.1 What is an Environmental Performance Indicator?.....	88
5.2.2 Core Principles of Environmental Performance Indicators.....	89
5.2.3 Selecting Environmental Performance Indicators.....	89
5.2.4 Approaches to Data Collection	89
5.3 Types of Environmental Indicators	90
5.3.1 Absolute and Relative Environmental Indicators.....	90
5.3.2 Corporate, Site and Process Related Environmental Indicators.....	90
5.3.3 Quantity and Cost-related Environmental Indicators.....	90

5.4 Classification of Indicators	91
5.4.1 Performance and Condition Indicators	91
5.4.2 Environmental Performance Indicators	91
5.4.3 Management Performance Indicators	91
5.4.4 Operational Performance Indicators	91
5.4.5 Environmental Conditions Indicators	92
5.5 Establishing Environmental Performance Indicators	93
5.5.1 Selecting Indicators for EPE	93
5.5.2 Starting the Process	93
5.5.3 Collecting Data	94
5.6 How to Use Environmental Indicators	94
5.6.1 The Roles of Indicators	94
5.6.2 Identifying Weak Points and Potential for Improvements	95
5.6.3 Determining Quantifiable Environmental Objectives and Targets	95
5.6.4 Documenting Continuous Improvement	95
5.6.5 Communicating Environmental Performance	95
Abbreviations, Study Questions, Internet Resources	96
6 Energy Conservation	97
6.1 Energy – the Basis of Life and Society	97
6.1.1 World Energy Development	97
6.1.2 The Development in the EU and the Baltic Sea Region	98
6.1.3 Environmental Issues and World Energy Use	99
6.1.4 Implementing the Kyoto Protocol	99
6.2 Improving Energy Use in Society	100
6.2.1 Energy for Transport – Alternatives	100
6.2.2 Electric Energy – More Efficient Lighting, Motors and Processes	100
6.2.3 Heating Energy – Saving, Upscaling and Downscaling	101
6.2.4 Integrated Solutions	101
6.3 Power Generation	102
6.3.1 Kinds of Energy Sources	102
6.3.2 Power Plants	103
6.3.3 Cogeneration	103
6.3.4 Trigeneration	104
6.4 Saving Electric Energy	104
6.4.1 Strategic Choices	104
6.4.2 Power Factor Improvement	105
6.4.3 Load Factor Improvements	106
6.5 Saving Thermal Energy – Heating Systems	106
6.5.1 Boilers	106
6.5.2 Heat Recovery Systems	108
6.5.3 Pinch Technology	108
6.5.4 Heat Pumps	109
6.5.5 Insulation	110
6.6 Saving Thermal Energy – Cooling Systems	110
6.6.1 Choosing the Right Source of Cold Temperature	110
6.6.2 Cooling Towers	110
6.6.3 Absorption Refrigeration	111

6.6.4 Mechanical Refrigeration.....	111
6.6.5 District Cooling	111
6.6.6 Insulation	111
Study Questions, Abbreviations, Internet Resources	111
7 Water Conservation.....	113
7.1 Water Management in Society.....	113
7.1.1 A Global Water Perspective.....	113
7.1.2 Water Consumption in Industry	113
7.1.3 Integration of Industrial and Municipal Water Management	114
7.1.4 Provision of Water to Industry	115
7.2 Measures to Reduce Water Consumption.....	115
7.2.1 Strategic Choices	115
7.2.2 Separation of Different Kinds of Wastewater	115
7.2.3 Process Water	116
7.2.4 Cooling Water	116
7.2.5 Sanitary Wastewater	116
7.2.6 Storm Water	116
7.2.7 Elimination of Intermittent Emissions	117
7.3 Process Changes	117
7.3.1 Process Changes to Reduce Water Consumption	117
7.3.2 Cases of Water Conservation.....	118
Study Questions, Abbreviations, Internet Resources	119
8 Water Pollution Reduction	121
8.1 Measures to Decrease Pollutants in Water Streams	121
8.1.1 A Range of Strategies	121
8.1.2 Exchange of Raw Material and Support Chemicals	121
8.1.3 Modifying the Process	122
8.1.4 Modifying the Equipment	122
8.1.5 Improved Process Control, Reliability of Operation	122
8.1.6 Avoiding Accidental Spills.....	123
8.1.7 Separation and Extraction of By-products	123
8.1.8 Equalisation of Wastewater Flow	124
8.1.9 Choice of Products and Product Design.....	124
8.2 Separation Unit Operations for Cleaner Production	124
8.2.1 A Range of Methods	124
8.2.2 Adsorption	125
8.2.3 Ion Exchange	125
8.2.4 Membrane Separation.....	126
8.2.5 Extraction.....	127
8.2.6 Stripping.....	128
8.3 Adsorbents	128
8.3.1 Types of Adsorbents.....	128
8.3.2 Activated Carbon	129
8.3.3 Polymer Adsorbents.....	129
8.3.4 Molecular Sieves	129
8.3.5 Silica Gel	130
8.3.6 Activated Alumina	130

8.4 Membrane Processes	130
8.4.1 A Range of Membrane Processes	130
8.4.2 Membrane Technologies	132
8.5 Choosing Separation Processes	132
8.5.1 Separate Treatments for Different Wastewater Streams	132
8.5.2 Which Method is Right	132
8.5.3 Column or Batch-wise Separation	132
Study Questions, Abbreviations, Internet Resources	133
9 Air Pollution Reduction	135
9.1 Character and Origins of Air Pollutants	135
9.1.1 Strategies for Reducing Air Pollution	135
9.1.2 Decreasing Dust	135
9.1.3 Removing Liquid Mists and Aerosols	136
9.1.4 Limiting Polluting Gases and Vapours	136
9.2 Cleaner Production Strategies for Reducing Air Pollutants	137
9.2.1 Changes in Raw Materials	137
9.2.2 Changes in Process Technology	138
9.2.3 Changing the System	138
9.3 Unit Operations for Separating Gaseous Air Pollutants	139
9.3.1 Condensation	139
9.3.2 Adsorption	140
9.3.3 Absorption	140
9.3.4 Membrane Separation	141
9.3.5 Biological Methods	141
9.4 Unit Operations for Separating Particulate Air Pollutants	142
9.4.1 Removal of Suspended Particles	142
9.4.2 Dynamic Separation	142
9.4.3 Scrubbers	143
9.4.4 Electrostatic Precipitators and Filters	143
Study Questions, Abbreviations, Internet Resources	144
10 Waste Reduction	145
10.1 The Waste Concept	145
10.1.1 The Waste Concept	145
10.1.2 How to Produce Less Waste	145
10.1.3 The Formal Definition of Wastes	147
10.1.4 Industrial Solid Waste	147
10.2 Waste Management Strategies	147
10.2.1 The Waste Hierarchy	147
10.2.2 Waste Minimisation or Source Reduction	148
10.2.3 Recycling	148
10.2.4 Waste Treatment	149
10.2.5 Land Filling	152
10.3 Reducing Waste through Cleaner Production Methods	152
10.3.1 Mining Waste	152
10.3.2 Recycling Polluted Residue	153

10.3.3 Efficient use of Materials	153
10.3.4 Resource Conservation	153
10.4 Future Developments	153
Study Questions, Abbreviations, Internet Resources	154
11 Green Engineering	155
11.1 Green Engineering	155
11.1.1 Green Design	155
11.1.2 Corporate Strategies	156
11.1.3 The Strategies of Green Engineering	156
11.2 Industrial Ecology	157
11.2.1 The Kalundborg Case	157
11.2.2 Energy Cooperative Systems	157
11.2.3 Water Recycling in Kalundborg	158
11.2.4 Gas and Inorganic Material Recycling	158
11.2.5 Biomass Recycling	159
11.3 Product Design	159
11.3.1 Ecodesign or Design for Environment (DfE)	159
11.3.2 New Concept Development	160
11.3.3 Dematerialising Products and Services	160
11.3.4 Extending the Life of a Product	160
11.3.5 Making Products Recyclable	160
11.3.6 Reducing Impact During Use	161
11.4 Materials Management	161
11.4.1 Choosing Material	161
11.4.2 Recycled Materials	162
11.5 Production Design	162
11.5.1 Cleaner Production Strategies	162
11.5.2 Distribution and Transport	163
11.5.3 Supply Chain Management	163
11.5.4 Optimising the End-of-life System	163
Study Questions, Abbreviations, Internet Resources	164
12 Green Chemistry	165
12.1 The Principles of Green Chemistry	165
12.1.1 What is Green Chemistry	165
12.1.2 The History of Green Chemistry	166
12.1.3 Green Chemistry Methodologies	166
12.2. Selecting Raw Materials	167
12.2.1 Criteria for Green Chemicals	167
12.2.2 Selecting Raw Materials	167
12.2.3 Hydrogen and Fuel Cells vs Fossil Fuels and Combustion	168
12.2.4 Production of Hydrogen Based on Fossil Raw Materials	168
12.2.5 Hydrogen Production Using Renewable Raw Materials	169
12.2.6 Alternatives to Heavy Metals	170
12.3 Auxiliary Materials	170
12.3.1 Solvents	170

12.4 Reaction Pathways	171
12.4.1 Finding Alternatives to Chemical Reactions	171
12.4.2 Finding Alternatives to Chemical Processes	174
12.5 Biotechnology	174
12.5.1 The Promises of Biotechnology	174
12.5.2 The Components of Biotechnology	175
12.5.3 Textiles and Leather – Chromium vs Enzymatic Tanning	175
12.5.4 Use of Enzymes for Leather Tanning	176
Study Questions, Abbreviations, Internet Resources	177
13 Promoting Cleaner Production	179
13.1 Supporting Cleaner Production	179
13.1.1 The Origin	179
13.1.2 Capacity Building	180
13.1.3 Promotion	180
13.2 Promotion of Cleaner Production	180
13.2.1 UNEP's International Declaration on Cleaner Production	180
13.2.2 Networks and Partnerships for CP Promotion	180
13.2.3 International Organisations	182
13.2.4 National Cleaner Production Centres	183
13.3 Policy Instruments to Promote Cleaner Production	184
13.3.1 Policy Frameworks	184
13.3.2 Regulatory Instruments	184
13.3.3 Legislation	185
13.3.4 Specified and Negotiated Compliance	185
13.3.5 Market-Based Instruments	185
13.3.6 Cleaner Production Investments	186
13.3.7 Information-Based Strategies	186
13.4 Stakeholder Involvement	186
13.4.1 The Stakeholders	186
13.4.2 Educational Institutions	187
13.4.3 Production Chain Stakeholders	187
13.5 The Barriers to CP Implementation	187
13.5.1 Character of the Obstacles	187
13.5.2 Leadership Commitment	188
13.5.3 Employees and Partners	188
13.5.4 Partnership Development	189
13.5.5 Education and Training for Employees	189
13.6 Links between Cleaner Production and Other Tools	190
13.6.1 Integration of Cleaner Production and ISO 14001/EMS	190
13.6.2 Cleaner Production and Environmental Policies	190
Abbreviations, Study Questions, Internet Resources	191
References	193

Introduction	201
Descriptions	202
1 – Dairy Industry	205
1. Background	205
2. Dairy Processing	206
3. Cleaner Production Opportunities	207
2 – Pulp and Paper Industry	211
1. The Pulp and Paper Industrial History	211
2. Main Process Technologies	212
3. The Most Important Cleaner Production Measures	214
4. The Raw Materials	215
3 – Textile Industry	219
1. Introduction	219
2. Industrial Processes	220
3. Environmental Impacts	222
4. Cleaner Production Opportunities	223
4 – Glass Industry	228
1. Glass Production	228
2. The Technologies	229
3. Cleaner Technologies Options	231
4. Techniques for Controlling Emissions to Air	232
5. Energy Saving	233
5 – Chlor-Alkali Manufacturing Industry	236
1. The Chlor-Alkali Industry	236
2. Processes and Techniques	237
3. Environmental Impacts	240
4. Cleaner Production Opportunities	242
6 – Cement Manufacturing Industry	246
1. The Cement Industry	246
2. Production Technologies	246
3. Consumption and Emission Levels	250
4. Technology Development and Cleaner Production Opportunities	252

Case Study 1 – Vernitas Textile Company Ltd, Lithuania	
Vernitas Textile Company – From Environmental Disaster to Environmental Recognition.....	259
Case Study 2 – Klaipėdos Baldai, Lithuania	
Klaipėdos Baldai Furniture Manufacturing.....	269
Case Study 3 – Greenchem Programme, Sweden	
Greenchem Programme – Wax Esters as Wood Coating Material.....	277
Case Study 4 – Meat Processing Industry, Russia	
Energy Management in a Meat Processing Company	285
Case Study 5 – SCA Pulp and Paper mills, Sweden	
Pulp and Paper Industry in Sweden – An Ideal Case for Cleaner Production	291
Case Study 6 – Assa Abloy Metallurgic Industry, Sweden	
Surface Treatment Processes in a Metallurgic Industry	297
Index	303