

# **Low-Cost Urban Sanitation**

**Duncan Mara**

*Department of Civil Engineering, University of Leeds,  
U.K.*

**JOHN WILEY & SONS**

Chichester · New York · Brisbane · Toronto · Singapore

---

# Contents

<b>Preface</b>	xiii
<b>Acknowledgements</b>	xiv
<b>Copyright Acknowledgements</b>	xvi
<b>1 Urban Sanitation Needs</b>	1
1.1 Global Needs in Urban Sanitation	1
1.2 Technological Options for Sanitation	3
1.2.1 Communal or individual sanitation?	4
1.3 Complementary Inputs	6
1.4 Integrated Urban Development	6
1.5 Further Reading and Information	7
<b>2 Sanitation and Health</b>	11
2.1 The Improvement of Public Health	11
2.2 The Environmental Classification of Excreta-related Diseases	11
2.2.1 Excreted infections	12
2.2.2 Categories of excreta-related diseases	17
2.3 Excreta-related Disease Control	27
2.3.1 Control of Category I and II infections	27
2.3.2 Control of Category III–V infections	28
2.3.3 Control of Category VI and VII infections	28
2.4 Further Reading	29
<b>3 Ventilated Improved Pit Latrines</b>	31
3.1 Description	31
3.1.1 Odour control	31
3.1.2 Fly and mosquito control	33
3.1.3 Component parts	37
3.2 The Latrine Pit	38
3.2.1 Single pits	39
3.2.2 Alternating twin pits	39
3.2.3 Wet pits	41
3.3 The Coverslab and Foundation	42
3.4 The Superstructure and Vent Pipe	45
3.4.1 In-house VIP latrines	47
3.5 Operation and Maintenance	48

3.6	Groundwater Pollution	49
3.7	Further Reading and Information	51
3.8	Design Example	52
3.8.1	Single-pit VIP latrine	52
3.8.2	Alternating twin-pit latrine	53
<b>4</b>	<b>Pour-flush Toilets</b>	<b>55</b>
4.1	Description	55
4.1.1	Conversion to cistern-flush operation	59
4.1.2	Advantages	61
4.2	Leach Pit Design	63
4.2.1	Prevention of groundwater pollution	65
4.3	Further Reading and Information	66
4.4	Design Example	66
4.4.1	Infiltration	67
4.4.2	Solids storage	67
<b>5</b>	<b>Sullage Disposal</b>	<b>69</b>
5.1	Sullage Volumes	69
5.2	Sullage Disposal Alternatives	70
5.3	Further Reading	71
<b>6</b>	<b>Septic Tanks</b>	<b>73</b>
6.1	Description	73
6.2	Appropriateness	73
6.3	Tank Design	74
6.3.1	Scum storage	74
6.3.2	Sedimentation	74
6.3.3	Digestion	75
6.3.4	Sludge storage	76
6.3.5	Overall design capacity	77
6.3.6	Two-compartment septic tanks	78
6.3.7	Community septic tanks	78
6.3.8	Design details	78
6.3.9	Upflow filter	80
6.4	Tank Desludging	81
6.4.1	White towel test	82
6.5	On-site Effluent Disposal	83
6.6	Further Reading	83
6.7	Design Example	84
6.7.1	Tank design	84
6.7.2	Drainfield design	85
<b>7</b>	<b>Emptying</b>	<b>87</b>
7.1	Manual or Mechanical Emptying?	87
7.2	Vacuum Tankers	87
7.3	Sludge Disposal	89
7.4	Institutional Aspects	90

7.5 Emptying Costs	91
7.6 Further Reading and Information	92
<b>8 Settled Sewerage</b>	<b>93</b>
8.1 Description	93
8.2 Appropriateness	94
8.3 Design	95
8.3.1 Interceptor tank	95
8.3.2 System layout	95
8.3.3 Peak flow estimation	96
8.3.4 Hydraulic design	97
8.4 Construction and Maintenance	99
8.4.1 Sewer appurtenances	99
8.4.2 Lift stations	100
8.4.3 Sewage treatment	103
8.4.4 Operation and maintenance	103
8.5 Further Reading	103
8.6 Design Example	104
8.6.1 Solution	104
<b>9 Simplified Sewerage</b>	<b>109</b>
9.1 Description	109
9.2 Appropriateness	111
9.3 Hydraulic Design	111
9.3.1 Properties of a circular section	112
9.3.2 Design based on minimum self-cleansing velocity	115
9.3.3 Design based on minimum tractive tension	121
9.3.4 Hydrogen sulphide control	125
9.3.5 Sewer gradient and ground slope	126
9.3.6 Number of households served	128
9.4 Construction and Maintenance	131
9.4.1 Sewer appurtenances	131
9.4.2 Sewage treatment	131
9.4.3 Operation and maintenance	131
9.5 Costs	133
9.6 Further Reading	134
9.7 Design Examples	136
9.7.1 Example 1	136
9.7.2 Example 2	138
9.7.3 Example 3	138
<b>10 Sewage Treatment</b>	<b>141</b>
10.1 Introduction	141
10.2 Waste Stabilization Ponds	141
10.2.1 Anaerobic ponds	143
10.2.2 Facultative ponds	144
10.2.3 Maturation ponds	148
10.3 Agricultural Reuse	150
10.4 Effluent Storage Reservoirs	152

10.5 Aquacultural Reuse	154
10.5.1 Fish yields	157
10.6 Further Reading	158
10.7 Design Example	159
10.7.1 Solutions	159
10.7.2 Summary	163
<b>11 Sociocultural Aspects</b>	<b>165</b>
11.1 Introduction	165
11.2 Privacy	165
11.3 Posture, Cleansing and Orientation	166
11.4 Gender and Age	167
11.5 Maintenance	169
11.6 Further Reading	169
<b>12 Socioeconomic Aspects</b>	<b>171</b>
12.1 Economic Costing	171
12.1.1 Inclusion of <i>all</i> relevant costs	172
12.1.2 Shadow pricing	173
12.1.3 Mutually consistent assumptions	176
12.2 Financial Costing	179
12.3 Household Decisions	181
12.4 Further Reading	181
12.5 Worked Examples	182
12.5.1 Example 1	182
12.5.2 Example 2	183
12.5.3 Example 3	184
12.5.4 Example 4	187
12.5.5 Example 5	188
12.5.6 Example 6	189
<b>13 Technology Selection and Upgrading</b>	<b>193</b>
13.1 Technology Selection	193
13.2 Technology Upgrading	194
13.2.1 Upgrading a VIP latrine	195
13.2.2 Upgrading a pour-flush toilet	195
13.2.3 Planned sanitation sequences	195
<b>14 Hygiene Education</b>	<b>201</b>
14.1 Introduction	201
14.2 Disease Education	202
14.3 Handwashing	203
14.4 Sanitation Education	203
14.5 Communication	204
14.6 Educating Children	205
14.7 Further Reading	206

---

<b>15</b>	<b>Institutional Aspects</b>	<b>207</b>
15.1	Organizations and Responsibilities	207
15.2	Sanitation Planning	208
15.2.1	The Kalbermatten model	208
15.2.2	Operation and maintenance planning	210
15.3	Sanitation Promotion	211
15.3.1	Demonstration facilities	211
15.3.2	Selecting communities	212
15.4	Community Participation and Management	212
15.5	Subsidies or Loans?	213
15.5.1	Subsidies	214
15.5.2	Loans	214
15.6	Monitoring and Evaluation	217
15.7	Further Reading	218

<b>Index</b>	<b>221</b>
--------------	------------