

Solid Waste Management:

(Volume I)

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	xvii
------------------------	------

Part I - Principles of Solid Waste Management

CHAPTER I. INTRODUCTION	1
A. Definition of developmental status	1
B. Characteristics of solid waste in developing countries	1
C. Importance of a sound solid waste management program	2
C1. ENVIRONMENTAL and health impacts	3
C2. EPIDEMIOLOGICAL studies	3
D. Recovery and utilisation of resources	4
E. Scope and organisation of the book	4
F. References	6
CHAPTER II. FRAMEWORK FOR MANAGEMENT OF SOLID WASTE	7
A. Integrated waste management	7
A1. ELEMENTS of a waste management system	7
A2. WHAT is integrated waste management?	7
A3. IMPORTANCE of an integrated approach	8
A4. METHODS for integrating a waste system	8
A5. WASTE management hierarchy as a key element of 8 integrated solid waste management	8
B. Stakeholders	9
B1. RESIDENTIAL waste generators	9
B2. BUSINESS waste generators	9
B3. PUBLIC health and sanitation departments	10
B4. PUBLIC works departments	10
B5. NATURAL resource management agencies	10
B6. NATIONAL or state/provincial environmental ministries	10
B7. MUNICIPAL governments	10
B8. REGIONAL governments	10
B9. PRIVATE sector companies	10
B10. INFORMAL sector workers and enterprises	11
B11. NON-GOVERNMENTAL organisations	11
B12. COMMUNITY-BASED organisations	11
B13. POOR and residents of marginal and squatter areas	11
B14. WOMEN	11
C. Cost and cost recovery	12
C1. FEES and charges	12
C2. STRUCTURING financing for waste management systems	13

C3. STRATEGIES for cost containment and enhanced efficiency.....	13
D. Other important issues and strategies	15
D1. UNDERSTANDING characteristics of waste generated.....	15
D2. MAJOR differences between industrialised and developing countries.....	15
D3. IMPROVING management capabilities.....	16
D4. PUBLIC involvement.....	16
D5. SPECIAL wastes	16
D6. WASTE reduction	26
D7. SYSTEMS of waste reduction.....	28
D8. PRIORITIES for cities of developing countries.....	29
E. Summary.....	29
F. Reference.....	30
CHAPTER III. WASTE QUANTITIES AND CHARACTERISTICS	31
A. Introduction.....	31
B. Quantities and composition.....	32
B1. PROCEDURES	32
C. Other characteristics	39
C1. BULK density.....	39
C2. SIZE distribution	40
C3. CHEMICAL/thermal properties	43
C4. MECHANICAL properties.....	43
D. References.....	48
CHAPTER IV. STORAGE AND COLLECTION	51
A. Introduction.....	51
A1. LOW coverage in the provision of services	51
A2. APPLICATION of inappropriate technology	51
A3. TENDENCIES to acquire imported equipment	52
A4. INADEQUATE resource mobilisation.....	53
A5. INAPPROPRIATE methods of finance	53
B. Overview of present situation	53
C. Problems of storage and collection.....	55
D. Components of refuse collection.....	56
D1. SOURCES and characteristics of the refuse	57
D2. FREQUENCY of collection	59
D3. COMMUNAL storage.....	59
D4. HOUSE-TO-HOUSE collection.....	59
D5. COST	60
E. Methods of refuse storage	60
E1. DOMESTIC and commercial wastes	60
F. Communal storage methods.....	65
F1. DEPOTS.....	65
F2. ENCLOSURES	66
F3. FIXED storage bins.....	66
F4. SECTIONS of concrete pipe.....	67
F5. METAL drums	68
F6. PORTABLE bins	69
F7. CONCLUSIONS regarding communal waste containers	70
F8. CAPACITY margins.....	71

G. Collection vehicles	71
G1. HANDCARTS	72
G2. PEDAL tricycles.....	75
G3. ANIMAL carts.....	77
G4. MOTORIZED tricycles	77
G5. TRACTOR and trailer systems	78
G6. LIGHT commercial trucks	79
G7. FORE and aft tipper.....	80
G8. CONTAINER-HOIST	81
G9. VEHICLE standardisation.....	81
H. Access and point of collection.....	82
H1. DETACHED dwellings	82
H2. MULTI-FAMILY dwellings	83
H3. SINGLE-ROOM dwellings	83
H4. MARKETS	83
H5. ACCESS for trailer or container exchange	84
H6. NARROW paths/alleys	84
I. Basic collection systems	84
I1. COMMUNAL collection	85
I2. BLOCK collection	86
I3. KERBSIDE collection	86
I4. DOOR-TO-DOOR collection	86
I5. EVALUATION of basic systems	87
J. Primary and secondary collection.....	88
J1. SHORT-HAUL transfer.....	88
J2. COMPARATIVE labour and vehicle productivity	90
J3. SHORT-HAUL transfer station facilities	90
J4. LEVEL sites.....	91
J5. COMBINED transfer stations and district depots	91
K. Large-scale transfer stations	91
L. Transfer station planning and design	94
L1. SITE selection.....	94
L2. DESIGN of structures	94
L3. TRANSFER operations and plant layout.....	95
L4. CONCLUSIONS.....	107
M. Costs of solid waste collection.....	108
M1. SYSTEM costs.....	108
M2. COLLECTION from communal containers	111
M3. KERBSIDE and door-to-door collection.....	111
M4. OPERATION of collection vehicles in relay	113
M5. OPTIMISATION of vehicle routes	114
M6. COSTS of alternative systems	114
N. References.....	117
CHAPTER V. STREET CLEANING.....	119
A. Introduction.....	119
B. Types of street wastes	121
B1. WASTES generated by natural causes	121
B2. WASTES generated by traffic	121
B3. WASTES generated by the public	122

C. Manual street cleaning	122
C1. EQUIPMENT	122
D. Mechanical sweeping	123
E. Design of sweeping systems	125
E1. VEHICLES	125
E2. SCHEDULING	126
E3. ORGANISATION of manual sweepers.....	126
E4. TRANSFER facility	127
F. Litter bins.....	127
F1. DESIGN of litter bins.....	127
F2. SITING and emptying.....	128
G. Legislation	128
H. Reference	129

Part II - Processing and Treatment

CHAPTER VI. MATERIALS RECOVERY AND RECYCLING	131
A. Introduction.....	131
B. Manual separation	132
C. Mechanical separation	133
C1. SIZE reduction.....	133
C2. AIR classification	143
C3. SCREENING	146
C4. MAGNETIC separation.....	149
C5. ALUMINIUM and glass separation	152
C6. DRYING and densification	152
D. Design of processing facilities	152
D1. GENERAL design concepts	152
D2. FACILITY for processing source-separated MSW.....	159
D3. FACILITY for processing mixed waste	163
D4. CONCLUSIONS	165
E. Yard waste and food waste processing.....	166
E1. YARD waste	166
E2. FOOD waste.....	171
E3. COMPOSTING of mixtures of yard and food wastes	172
E4. PRECAUTIONS	173
F. Processing and recycling construction and demolition debris.....	173
F1. CONCRETE.....	174
F2. TECHNOLOGIES	174
F3. STATUS of concrete recycling.....	175
F4. REPRESENTATIVE projects.....	175
F5. SUMMARY and conclusions	179
G. References	180
CHAPTER VII. USE OF WASTE-DERIVED ORGANIC MATTER AS A SOIL AMENDMENT	183
A. Introduction.....	183
B. Utilisation of raw organic waste	183
B1. PREPARATION	183

B2. PARTICLE size	183
B3. DEHYDRATION	184
B4. EXAMPLE of direct application	184
C. Evaluation of direct application	185
C1. ADVANTAGES	185
C2. DISADVANTAGES.....	185
D. Economics	186
E. Use of composted waste	186
E1. DESCRIPTION of product	186
E2. APPEARANCE	187
E3. PRODUCT specifications	187
E4. GRADING the product	188
E5. METHOD of applying	189
E6. LOADING rate	189
F. Benefits from the application of compost to the soil	192
G. Limitations to the application of compost to the soil	193
G1. PUBLIC health	194
G2. TRANSPORT and application mechanics	194
H. References	195
CHAPTER VIII. COMPOSTING	197
A. Introduction.....	197
B. Definitions.....	197
B1. DEFINITION in the strict sense	197
B2. ECOLOGICAL definition	198
C. Active organisms.....	198
C1. VERMICULTURE	198
C2. INOCULUMS.....	199
D. Process factors.....	200
D1. NUTRITIONAL factors	200
D2. ENVIRONMENTAL factors.....	203
D3. AERATION.....	205
D4. OPERATIONAL parameters.....	207
E. Technology.....	213
E1. PRINCIPLES	213
E2. EQUIPMENT	213
E3. BIOFILTERS	214
E4. SYSTEM selection decision factors	216
F. Types of compost systems.....	216
F1. WINDROW systems	216
F2. IN-VESSEL reactors.....	225
G. Marketing and distribution of compost.....	229
G1. POTENTIAL markets	229
G2. SELLING price	230
G3. MARKET development.....	231
G4. PRODUCT distribution and transport.....	232
H. References	233

CHAPTER IX. SINGLE-CELL PROTEIN AND ETHANOL PRODUCTION.....	237
A. Introduction.....	237
A1. EXPLANATION of the concept	237
A2. HISTORICAL development.....	237
A3. APPLICABILITY to developing countries.....	238
B. Hydrolysis	238
B1. PRINCIPLES of hydrolysis	238
B2. ACID hydrolysis	239
B3. ENZYMATIC hydrolysis	240
B4. PRODUCTION system.....	243
C. Single-cell protein	244
C1. INDIRECT vs. direct production.....	246
C2. HARVESTING.....	249
C3. EQUIPMENT requirements and costs.....	250
D. Ethanol production.....	251
E. References.....	251
CHAPTER X. TYPES OF WASTE-TO-ENERGY SYSTEMS.....	253
A. Introduction.....	253
B. Incineration and refuse-derived fuel production.....	253
B1. FUEL characteristics	253
B2. INCINERATION.....	255
B3. REFUSE-DERIVED fuel production	256
C. Thermal gasification and biogasification	256
D. References.....	257
CHAPTER XI. BIOGASIFICATION	259
A. Introduction.....	259
B. Principles	259
B1. DEFINITIONS	259
C. Process description	260
C1. MICROBIAL ecology of the stages	261
D. Process rate limitation factors	263
D1. ENVIRONMENTAL factors.....	263
D2. PERFORMANCE factors.....	268
D3. FACTORS in the form of elements or compounds	268
E. Parameters.....	269
E1. GAS production and composition.....	269
E2. DESTRUCTION of volatile matter	272
E3. VOLATILE acid content	272
E4. HYDROGEN ion concentration	272
E5. BUFFERING capacity	273
E6. REMEDIAL measures	273
F. Operational procedures.....	273
F1. MIXING	273
F2. LOADING.....	276
F3. DETENTION time	276
F4. STARTING a digester.....	278

G. Digester construction design principles.....	279
G1. CONVENTIONAL digestion systems	279
G2. HIGH-RATE digestion systems	279
G3. “CONTACT” digestion systems	280
G4. HEATING the digester	280
G5. SMALL-SCALE digester design and construction.....	281
H. End products of the biogasification process.....	285
H1. PROPERTIES of the biogas	285
H2. BIOGAS purification.....	285
H3. USE of purified gas	287
I. Residues.....	287
I1. SUPERNATANT	287
I2. SLUDGE (biosolids).....	288
J. Feasibility considerations.....	289
J1. LARGE-SCALE undertakings	290
J2. SMALL-SCALE undertakings	291
K. References	292

CHAPTER XII. PRODUCTION OF REFUSE-DERIVED FUEL (RDF).....295

A. Background	295
B. RDF characteristics	298
C. Use of RDF.....	299
D. Presence of contaminants.....	299
E. Beneficiation of RDF.....	300
E1. HEATING value	300
E2. MOISTURE content	301
F. Precautions.....	301
G. Summary	301
H. References	302

CHAPTER XIII. INCINERATION AND THERMAL CONVERSION303

A. Incineration	303
A1. INTRODUCTION	303
A2. PRINCIPLES.....	303
A3. TYPES of incinerators.....	304
B. Pyrolysis.....	313
B1. PRODUCTS	314
B2. TECHNOLOGY	315
B3. PYROLYSIS-PRODUCED gas	317
C. Precautions	319
D. References.....	320

Part III - Final Disposal

CHAPTER XIV. SANITARY LANDFILL.....323

A. Introduction.....	323
B. Basic principles	323
B1. DEFINITION.....	323

B2. PLANNING for a landfill	324
C. Landfill processes	324
C1. PHYSICAL	324
C2. CHEMICAL	325
C3. BIOLOGICAL	325
C4. IN-PLACE density and settlement	327
D. Types of solid wastes.....	328
D1. SIGNIFICANCE of waste types	328
D2. ACCEPTABLE wastes.....	328
D3. UNACCEPTABLE wastes	329
D4. SPECIAL wastes	329
E. Quantity and composition of the wastes	329
F. Site selection.....	330
F1. INTRODUCTION.....	330
F2. USEFUL lifespan and area of site.....	330
F3. TOPOGRAPHY	333
F4. SOILS.....	334
F5. GEOLOGY	336
F6. HYDROGEOLOGY	336
F7. PHYSIOGRAPHIC setting	337
F8. GEOLOGY and soil characteristics	338
F9. VEGETATION	341
F10. SITE access and transport	342
F11. LAND use	342
F12. ECONOMIC considerations in site selection	343
F13. DECISION-MAKING process	343
G. Landfill technology	344
G1. INTRODUCTION	344
G2. CELL design and construction	345
G3. BOTTOM liner.....	348
G4. DAILY, intermediate, and final covers	348
G5. CUSTOMISED methods of construction and use after completion	354
G6. CO-DISPOSAL of special wastes	354
G7. HAZARDOUS wastes (secure landfill)	355
H. Development of the landfill.....	357
H1. TERRAIN upgrading.....	357
H2. ROADS.....	357
H3. MEASUREMENT of weight (scales)	358
H4. UTILITIES	359
H5. STRUCTURES.....	359
H6. FENCING.....	359
I. Operation	360
I1. INTRODUCTION	360
I2. GENERAL operating procedures	360
I3. SELF-HAUL	366
I4. SALVAGE/scavenging.....	367
I5. WASTE receipt and vehicle routing	368
I6. SPECIFIC operational procedures in a sanitary landfill.....	368
J. Water management	375
J1. SURFACE water.....	375
J2. GROUNDWATER	375
J3. WATER balance and the formation of leachate	376

K. Liners	380
K1. SOIL liners	380
K2. FLEXIBLE membrane liners	383
L. Leachate collection and treatment	384
L1. INTRODUCTION	384
L2. PREREQUISITES	384
L3. LEACHATE collection systems	385
L4. DESIGN of the leachate collection system.....	386
L5. REMOVAL and storage of the leachate	386
L6. LEACHATE management alternatives.....	387
L7. EVAPORATION	387
L8. RECIRCULATION and recycling.....	387
L9. TREATMENT	388
M. Management of landfill gas	390
M1. ORIGIN, composition, and volume of gases.....	390
M2. GAS generation.....	390
M3. VOLUME (yield).....	392
M4. DISPOSITION of the landfill gas.....	394
M5. COLLECTION, upgrading, and utilisation of landfill gas	395
M6. USE of landfill gas in some developing countries.....	399
M7. ECONOMIC feasibility factors associated with landfill gas recovery.....	400
N. Equipment	400
N1. BASIC concepts	400
N2. FACTORS	401
N3. FUNCTIONS served by equipment	402
N4. EQUIPMENT types: descriptions and specifications	403
N5. INSPECTION and maintenance.....	409
O. Provision for material recovery	410
O1. INTRODUCTION	410
O2. PROBLEMS due to scavenging	410
O3. ESTABLISHMENT of scavenging site	410
O4. MANAGEMENT of scavenging activity	411
O5. SUPERVISION and procedures.....	411
P. Environmental monitoring	412
P1. GROUNDWATER.....	412
P2. SURFACE water	415
P3. LANDFILL gas and migration.....	416
Q. Uses of completed landfills	416
Q1. GEOTECHNICAL problems	416
Q2. POTENTIAL hazards	417
Q3. RECOMMENDATIONS for construction on completed fills	418
Q4. POTENTIAL uses	419
Q5. REHABILITATION of existing facilities.....	420
R. Economics	421
R1. BACKGROUND	421
R2. LANDFILL costs vs. total cost of solid waste disposal	422
R3. EFFECT of processing on cost of waste disposal	422
R4. CAPITAL and operating costs.....	423
R5. LANDFILL cost models.....	423
R6. LANDFILL equipment costs	426
S. Public participation	427
S1. INTRODUCTION.....	427

S2. PRINCIPLES of public participation.....	428
S3. DISSIPATION of opposition.....	428
S4. OBJECTIVES of public participation.....	430
S5. ADVANTAGES associated with public participation.....	430
S6. PARTICIPANTS.....	431
S7. EXTENT of public input in relation to stage of project development.....	431
S8. CONCLUSIONS.....	431
T. References.....	432

Part IV - Key Non-Technical Considerations

CHAPTER XV. REGULATORY AND ECONOMIC INSTRUMENTS FOR SOLID WASTE MANAGEMENT.....	439
--	------------

A. Introduction.....	439
B. Responsibility for regulatory and economic instruments.....	440
B1. NECESSARY conditions.....	440
B2. NEEDED research.....	440
C. Useful regulatory and economic mechanisms.....	441
C1. REGULATORY mechanisms.....	441
C2. ECONOMIC mechanisms.....	443
D. References.....	446

CHAPTER XVI. FINANCIAL ARRANGEMENTS FOR SOLID WASTE MANAGEMENT.....	447
--	------------

A. Introduction.....	447
B. Financing capital investment costs.....	447
B1. RESERVES.....	447
B2. BONDS.....	447
B3. LOANS/grants.....	448
B4. DONATIONS.....	449
C. Financing operating and maintenance costs.....	449
C1. FINANCING methods.....	449
C2. COSTS of solid waste service.....	450
C3. RESPONSIBILITY for service delivery.....	451
D. Financing waste management services for marginal areas.....	451
D1. SERVICE alternatives.....	452
E. The role of the private sector.....	453
E1. CONTRACTING.....	453
E2. FRANCHISE.....	454
E3. OPEN competition.....	455
E4. VENDOR/operator equity investment.....	455
F. Financing considerations and requirements.....	455
F1. SELECTION of financing method.....	455
F2. VIABILITY of the project.....	455
F3. RELIABILITY of waste supply.....	456
F4. SERVICE agreement.....	456
F5. SALES of materials and/or energy.....	456
F6. AVAILABILITY of final disposal site.....	456
F7. LEGAL authority.....	456

F8. PERMITS	456
F9. AGREEMENTS	456
F10. FINANCING process	457
F11. OWNERSHIP	457
G. The impact of resource recovery on financing	457
H. References	458

CHAPTER XVII. POLICY ALTERNATIVES FOR IMPROVING SOLID WASTE MANAGEMENT

A. Introduction.....	461
B. Decision-making.....	461
C. Financial aspects	461
C1. BUDGETARY issues	461
C2. BUDGETARY reform.....	462
C3. DEVELOPMENT of a financial base.....	462
C4. EFFECTS of financial resources	463
C5. DATABASE needs	463
C6. COST containment via design of collection service	464
C7. PROCUREMENT.....	464
C8. EQUIPMENT bid document: preparation and precautions.....	465
C9. COSTS apportionment.....	465
D. Human resources	466
D1. PERSONNEL requirements	466
D2. FIELD supervision of collection service personnel	466
D3. ATTITUDE, morale, and motivation of personnel	466
D4. PUBLIC health inspectors.....	467
E. Political issues.....	467
E1. AUTHORITY	467
E2. PUBLIC education.....	468
E3. STATUS and resulting problems.....	468
E4. POLITICAL factor.....	469
E5. ROLES of the political leadership	469
E6. CENTRALISED policy coordination	470
F. Conclusions	470
G. References	471

CHAPTER XVIII. MANAGEMENT INFORMATION SYSTEMS.....

A. Introduction.....	473
B. Evaluation of performance	474
C. Indicators.....	475
C1. GENERATION.....	475
C2. ONSITE storage.....	476
C3. COLLECTION and transport	476
C4. PROCESSING and resource recovery.....	476
C5. FINAL disposal	476
C6. ADMINISTRATION.....	477
D. Establishment of the management information system	477
D1. ORGANISATION	477
D2. DATA collection	478
D3. STORAGE and processing.....	478

E. Conclusions.....	479
F. References.....	479

Appendices

APPENDIX A. PUBLIC HEALTH ASPECTS.....	481
APPENDIX B. CHARACTERISTICS OF COMPOSTED YARD WASTE.....	493
APPENDIX C. PERFORMANCE INDICATORS FOR SOLID WASTE SERVICES.....	495
APPENDIX D. COSTS OF SOLID WASTE MANAGEMENT TECHNOLOGIES.....	503
BIBLIOGRAPHY.....	505
GLOSSARY	515