Organic Waste Recycling

Second Edition

Chongrak Polprasert

Environmental Engineering Program Asian Institute of Technology Bangkok Thailand

JOHN WILEY & SONS Chichester · New York · Brisbane · Toronto · Singapore

Contents

	Prefa	ix		
	Abbi	reviations and Symbols	xi	
1	INTRODUCTION			
-	1.1	Problems and need for waste recycling	1	
	1.2	Objectives and scope of organic waste recycling	5	
	1.3	Integrated technologies	· 7	
	1.4	Feasibility and social acceptance of waste recycling	13	
		References	14	
		Exercises	14	
2	CHA	ARACTERISTICS OF ORGANIC WASTES	17	
-	2.1	Human wastes	17	
	2.2	Animal wastes	23	
	2.3	Agro-industrial wastewaters	25	
	2.4	Pollution caused by human wastes and other wastewaters	47	
	2.5	Diseases associated with human and animal wastes	50	
	2.6	Waste minimization and clean technology	61	
		References	64	
		Exercises	66	
3	COMPOSTING			
	3.1	Objectives, benefits, and limitations of composting	70	
	3.2	Biochemical reactions	72	
	3.3	Biological succession	76	
•	3.4	Environmental requirements	76	
	3.5	Composting maturity	86	
	3.6	Composting systems and design criteria	88	
	3.7	Public health aspects of composting	102	
	3.8	Utilization of composted products	104	
		References	112	
		Exercises	113	
4	BIO	GAS PRODUCTION	115	
	4.1	Objectives, benefits, and limitations of biogas technology	115	
	4.2	Biochemical reactions and microbiology	118	
	4.3	Environmental requirements	124	
	4.4	Modes of operation, types of biogas digesters, and trouble shooting	129	
	4.5	Biogas production	149	

۷

vi _			Contents
	46	End-use of biogas and digested slurry	159
		References	163
		Exercises	165
5	ALC	GAE PRODUCTION	167
	5.1	Objectives, benefits, and limitations	167
	5.2	Algal production and high-rate algal ponds	172
	5.3	Algal harvesting technologies	186
	5.4	Utilization of waste-grown algae	192
	5.5	Public health aspects and public acceptance	195
		References	196
		Exercises	198
6	FISI	I PRODUCTION	201
	6.1	Objectives, benefits, and limitations	203
	6.2	Herbivores, carnivores and omnivores	205
	6.3	Biological food chains in waste-fed ponds	208
	6.4	Biochemical reactions in waste-fed ponds	209
	6.5	Environmental requirements and design criteria	211
	6.6	Utilization of waste-grown fish	228
	6.7	Public health aspects and public acceptance	229
		References	233
		Exercises	234
7	AOU	JATIC WEEDS AND THEIR UTILIZATION	237
	7.1	Objectives, benefits, and limitations	237
	7.2	Major types and functions	238
	7.3	Weed composition	246
	7.4	Productivity and problems caused by aquatic weeds	249
	7.5	Harvesting, processing and uses	252
	7.6	Feed and food potential	260
	7.7	Wastewater treatment using aquatic weeds	268
	7.8	Health hazards relating to aquatic weeds	300
		References	301
		Exercises	305
8	LAN	ND TREATMENT OF WASTEWATER	305
	8.1	Objectives, benefits, and limitations	305
	8.2	Wastewater renovation processes	306
	8.3	Wastewater renovation mechanisms	318
	8.4	System design and operation	324
	8.5	Land treatment—design equations	332
	8.6	System monitoring	343
	8.7	Public health aspects and public acceptance	348
		References	352
		Exercises	353

Cor	V				
9	LAND TREATMENT OF SLUDGE 9.1 Objectives, benefits, and limitations 9.2 Sludge transport and application procedures	355 358 359			
	9.3 System design and sludge application rates	360			
	9.4 Toxic compounds vs crop growth	374			
	9.5 Microbial aspects of sludge application on land	375			
	References	377			
	Exercises	377			
10	PLANNING, INSTITUTIONAL DEVELOPMENT AND				
10	REGULATORY ASPECTS	379			
	10.1 Planning for waste recycling programs	379			
	10.2 Guidelines for technology selection	383			
	10.3 Monitoring of facility performance	385.			
	10.4 Institutional arrangements	388			
	10.5 Regulatory aspects	392			
	References	404			
	Exercises	405			

Index

407

vii

Index

Acetoclastic bacteria 121 Acetogenic bacteria 121 Acid formation 120 Actinomycetes 73, 76 Advanced integrated wastewater pond system 180 Aerated static pile composting 99 Aeration requirements, in composting 84-85 Aerobic composting 69-70, 88-90 Agricultural reuses 5, 59 Agro-industrial wastes 25-47 Algal-bacterial symbiosis 49, 172, 203 Algal classification 167 Algal composition 171 Algal photosynthesis 49 Algal production, from wastewater 167-196 objectives and benefits 167-170 problems 170-172 Algal productivity 169, 181-187 Ammonia nitrogen, in waste-fed fish ponds 215, 217 Anaerobic composting 69–70, 88–89, 91–92 Anaerobic filter 143–146 Animal feed, from waste-grown fish 228-229 Animal unit (AU) 26 Animal wastes, quantity and characteristics 23-25 Aquacultural reuses 6, 59-60, 201 Aquatic processing units (APUs) 277, 278-279 Aquatic weed wastewater treatment systems 290-292, 294-295 Aquatic weeds, composition 246-249, 264 mineral content 247-249 protein content 247 water content 246-247 Aquatic weeds, major types 238-246 emergent 243-246, 249, 297 floating 242-245, 247-248, 251 submerged 238-240, 245-246, 249 Aquatic weeds, problems 252-253 Aquatic weeds, productivity 250-251 Aquatic weeds, wastewater treatment 268-300 bacteria and viruses removal 275-276

BOD₅ removal 270–271, 276 functions of aquatic plants 268–269 heavy metals removal 274–276 mechanisms of removal 270–276 nitrogen removal 272–273, 276 phosphorus removal 273–274, 276 refractory organic removal 276 solids removal 271–272, 276 Aquatic weeds, zonation in a water body 246 *Aspergillus* 76, 99–103 Assessment criteria, for recycling plans 384 Autoflocculation 191 *Azolla* 256–257

Bacillus bacteria, in composting 76 Bacteria, in biogas production 120-124 acetoclastic 121-122 acetogenic 121-122 acid forming 121 hydrogen-utilizing 121 methanogenic 120-121, 124 non-methanogenic bacteria 121, 123 Bag digester 137, 139-140 Bangalore composting 99 Beltsville aerated rapid composting (BARC) 92-96, 105-106 Beneficial land application, of sludge 355-356 Bio-accumulation 195, 208-210 Biochemical reactions, in biogas digesters 118-124 Biochemical reactions, in composting 72-75 Biochemical reactions, in waste-fed fish ponds 219-211 Bió-conversion, of solar energy 169 Biogas, from aquatic weeds 259-260 Biogas composition 115 Biogas digesters 130-147 attached-growth 143-147, 156 dispersed-growth 128 Biogas production 5-6, 115-163 drawbacks 117-118 objectives and benefits 115-117 Biogas promotion, in Nepal 390-392 Biogas purification 159, 161-162

Biogas yields, from waste materials 149. 154-155, 158 Biogas yields, from water hyacinth 250-260 Biological harvesting, of algae 191 Biological succession, in composting 76 Bio-magnification 196, 208-210 **Biomethanation** 122 **Biosolids 355** BOD loading, of HRAP 178 Brewery wastewaters, characteristics 40 Brewing industry 38, 40-41 Bulking materials, for composting 79-80 Bulrush 244, 297 C/N ratio, for anaerobic digestion 126-127 C/N ratio, for composting 77-79 C/N ratio, of excreta 18 Carbon dioxide (CO₂), in waste-fed fish ponds 217 Carnivorous fish 206 Cation exchange capacity (CEC) 320, 362-363, 365, 372 Cattail 244-245, 259, 297 Ceiling concentration limits, of heavy metals 363-364 Cell residence times 143, 145 Cesspools 18. Chemicals, from algae 194-195 Chinese composting pile 90-91, 93 Clean technology 17, 61-64 Clonorchis, in waste-fed fish ponds 231 CO₂ removal, from biogas 161-162 Coagulation-flocculation 189 Combined processes, wastewater land treatment 318-319 Common carp (Cyprinus carpio) 206-207 Compost, from aquatic weeds 257-258 Compost, from biogas slurry 163 Compost quality 108-111 Composting 69-112 definitions 69 drawbacks 72 levels of consumers 73-74, 76 objectives and benefits 70-72 Composting maturity 86-87 Composting systems 88-101 non-reactor type 99, 102 reactor type 100-101, 102 Composting toilets 88-90 Constraints, of waste recycling programs 381-382 Constructed wetlands 297-300 free water surface (FWS) 297-300 subsurface flow (SF) 297-300 Conventional biogas digester 140-142 Coontail 239-240

Critical concentration, of bacteria 230 Crop selection, for wastewater land treatment 331 Cumulative pollutant loading rates, of heavy metals 364 DANO composting system 96-98, 100 Data collection, for waste recycling programs 382-383 Denitrification, in wastewater land treatment 323-324 Depth, of HRAP 175-176 Depuration, of waste-grown fish 225, 228, 232 Design guidelines, for aquatic processing units 280-297 hydraulic application rate 283 hydraulic loading rate 283, 290-292 hydraulic retention time 280, 282, 290-292 nitrogen loading rate 283-285 organic loading rate 283, 290-292 process reliability 288 Design guidelines, for biogas digesters 141 Design guidelines, for composting systems 88-101 Design guidelines, for constructed wetlands 300 Design guidelines, for gas/solids separator 147, 149 Design guidelines, for HRAP 179 Design guidelines, for sludge land application 362, 365 Design guidelines, for UASB reactors 148 Design guidelines, for waste-fed fish ponds 221-227 Design guidelines, for wastewater land application 308 Dewatering, of aquatic weeds 254-255 Dissolved air flotation 190 Dissolved oxygen (DO), in waste-fed fish ponds 213-216, 221-223 Distribution system, for wastewater land treatment 310, 315, 317, 332 Diurnal changes, in waste-fed fish ponds 211-212 DO model, in fish ponds 221-223 Doubling time, of aquatic weeds 223 Emergent aquatic weeds 243-246, 249, 280, 297 End-uses, of biogas 159-163 of digested slurry 162-163 Energy, from algae 194

Energy demand 2-4

Environmental requirements, for anaerobic digestion 124-129 Environmental requirements, for composting 76-86 Environmental requirements, for waste-fed fish ponds 211–220 Epidemiology, of composting 104, 107 Excreta, quantity and characteristics 17-21 Fasciolopsis buski, in aquatic weeds 301 Fecal indicator 58 Feed, from algae 192-194 Fertilizer, from algae 194 Fertilizer, from compost 8, 105-109 First-order reaction, for constructed wetlands 297-298 Fish feed, from aquatic weeds 260-263 Fish feed, from biogas slurry 202 Fish feed, from compost 109, 111-112 Fish production, in waste-fed fish ponds 201-233 benefits and objectives 203-204 limitations 204-205 Fish sex 224 Fish stocking density 213, 217-219, 222-224, 226-227, 229 Fish yields, from composted nightsoil 111, 202 Fish yields, in waste-fed fish ponds 202 Fixed-dome (Chinese) digester 131-133, 135, 138 Floating aquatic weeds 240-243, 245-246, 249, 280 Floating gas holder (Indian) digester 133, 135, 138 Flood irrigation 311-313 Food, from algae 192-194 Food chains, in waste-fed fish ponds 208-209 Food conversion ratio, of fish 204, 230 Food potential, of aquatic weeds 208-209, 260-268 Forced-air aeration composting 92-96 Fruits and vegetables industry wastewater 48 Fruits industry 45-48 Gas/solids separator, for UASB reactor 145, 147, 149 Grass filtration 11 Green manure, from aquatic weeds 256-257 Groundwater quality 316, 344, 373 Groundwater recharge 314, 322 H₂S removal, from biogas 162-163

Harvesting, in constructed wetlands 298

Harvesting, of algae 171, 186–192 Harvesting, of aquatic weeds 252-254 Health hazards, from aquatic weeds 300-301 Heat value, of algae 176, 185 Heat value, of biogas 115 Herbivorous fish 205-206 High quality pollutant concentration limits, of heavy metals 363-364 High-rate algal ponds (HRAP) 172-181 Human food, from aquatic weeds 266 Human food, from waste-grown fish 228 Human wastes 17-23 Hydraulic retention time (HRT), of HRAP 176-177, 179 of biogas digesters 143, 145 of anaerobic filter 143, 145-147 Hydrilla 239 Hydrogen partial pressure 121-123 Hydrogen sulfide (H₂S), in waste-fed fish ponds 219-220 Hydrogen-utilizing methane bacteria 121 Illuminance, in algal photosynthesis 173–175 Indicator bacteria 364 Inhibition, of biomethanation 128 Input material changes, in waste minimization 64 Institutional arrangements, for waste recycling programs 388-392 government agency 389 municipality 389 non-government organization 390 private corporation 389-390 Integrated technologies, of organic waste recycling 7-13 Irradiance, in algal photosynthesis 173-175 Irrigation methods 311-313, 360-361 Irrigation process or slow rate 11, 306, 325-328, 333-334 Jersey composting system 98-102 Kamol Kij Co. Rice Mill Complex, Thailand 8-10 Kinetics of composting 75 Kirikan Farm, Thailand 8-11 Land filtration 11 Land treatment, of sludge 317–337 case study 371-374 Land treatment, of wastewater 305-352 Latrines, over-hanging 203

Latrines, ventilated improved pit (VIP) 88, 91 Legislation, waste recycling 392-404

Light intensity, in algal photosynthesis 173

_409

Limiting design parameter (LDP) 360, 362 Liquefaction 120 Livestock feed, from aquatic weeds 263-266 Loadings, to biogas digester 127 Mansonia mosquitoes, and aquatic weeds 301 Maturation, in composting 72-74, 102 Maya farms, the Philippines 9-10 Meat packing wastes, characteristics .46 Mechanisms, of wastewater land treatment 318-324 biological removal 321-324 chemical removal 320-321 physical removal 319 Mesophilic temperatures, in biogas digesters 125 Mesophilic temperatures, in composting 72-73,86 Methane formation 120-121 Methanogenic bacteria 120-121, 124 Microbiological criteria, for waste reuse 59-60 Microbiology, of anaerobic digestion 120-124 Microstraining 186-187 Mineralization, of organic nitrogen 366 Mixing, in HRAP 178 Moisture control, in composting 80-84 Monitoring, of sludge land application 371 Monitoring, of waste recycling programs 385-388 data evaluation, analysis, and documentation 387 equipments 387 objectives 386-387 organizational infrastructure 388 Monitoring, of wastewater land application 343-348 crop tissue 346 groundwater 344 soil 344 water quality 343 Mulch, from aquatic weeds 256 Nitrate in groundwater 348 Nitrification, in composting 73 Nitrification, in wastewater land treatment 319 Nitrobactor bacteria 73 Nitrosomonas bacteria 73 Non-methanogenic bacteria 121, 123 Nutrient uptake rates, for crops 323-324

Omnivorous fish 207

Operating practices, in waste minimization 63 Operation, of HRAP 179 Operational modes, of biogas digesters 129-130 Opisthorchis, in waste-fed fish ponds 231 Organic amendments, in composting 79-80 Organic fertilizer, from aquatic weeds 256 Organic loading rates, in biogas digesters 127-128 Organic wastes, characteristics 17-61 Organic wastes, chemical composition 85 Overland flow (OF) process 11, 306-309, 316-318, 330, 360-361 case study 347 design procedures 330 objectives and benefits 316 reliability 316 site selection 317-318 Oxygen release rates, from emergent plants 277, 280 Packing media, for anaerobic filters 143-145 Palm oil industry 30-35 Palm oil mill wastewaters, quantity and characteristics 34-37 Paper precoated belt filtration 187-188 Pathogen die-off, due to temperature 71, 107 Pathogen inactivation, in composting 71, 102 Pathogens, in algal ponds 170, 195 Pathogens, in anaerobic digestion 117-119 Pathogens, in human wastes 50-53 Pathogens, in sludge land application 375-376 Pathogens, in wastewater land application 349-352 Pathogens, passive transference 229 pH, in waste-fed fish ponds 216-217 Planning, for waste recycling program 379-383 Plug-flow digester 137, 139-140 Pollution effects, of organic wastes 47, 49, 52 Polychlorinated biphenyls (PCBs) 375 Population growth 1-3 Poultry processing wastewaters 46 Power alcohol, from aquatic weeds 259 Preapplication treatment, for wastewater land treatment 331 Primary pathogens, in composting 101-103, 104 Product changes, in waste minimization 64 Public acceptance, of composted products 107 Public acceptance, of waste-grown algae 196 Public acceptance, of waste-grown fish 232-233

Public acceptance, of waste recycling 13 Public acceptance, of wastewater land application 352 Public health aspects, of aquatic weed systems 300-301 Public health aspects, of composting 102-103, 104-107 Public health aspects, of sludge land application 375-376 Public health aspects, of waste-grown algae 195-196 Public health aspects, of waste-grown fish 229-233 Public health aspects, of wastewater land application 348-352 Pulp and paper, from aquatic weeds 258-259 Rapid infiltration (RI) process 306-309, 314-316, 328-330 case study 346 design procedures 328-330 objectives and limitations 314 reliability 315-316 site selection 316 Rate limiting steps, in biogas production 120 Rate limiting steps, in wastewater land treatment 323 Reclamation, of wastes 397-398 Recycling of organic wastes 5-7 methods 5-6 objectives 5 Red mud plastic digester 137, 139-140 Reeds (Phragmites) 297 Regulatory aspects, of waste recycling 392-404 Ridge and furrow irrigation 310-311, 313, 3640-361 Risk assessment, of sludge 362 Sanitation, coverage 1 Schistosomiasis, in waste-fed fish ponds 231 Secondary pathogens, in composting 101-102, 104 Separate gas holder digester 140-141 Septage, quantity and characteristics 19-21 Septic tanks 18-19 Sewerage systems 1-2 Sex reversal, of tilapia 224 Short-circuiting, in constructed wetlands 297 Silage 264-266 Single-cell protein, algae 167, 260 Slaughterhouse industry 40-46 Slaughterhouse wastes, characteristics 44-46 Slow rate (SR) process or irrigation 306-314 case study 346

design procedures 325-328, 334-343 objectives and limitations 309 reliability 311 site selection 311-314 Sludge application rates 365-377 Sludge characteristics 356-358, 372 Sludge land application procedures 359-361 Sludge land application systems 356, 365-367 Sludge loading to land, computation 367-371 Sludge production 317 Sludge transport 359-360 Small-bore sewers 22 Soakage pits 18 Sodium adsorption ratio (SAR) 321-322 Soil texture 306-307 Solar energy, irradiance 185 Solid waste legislation, in U.S.A. 399-400 Solid wastes, quantity and characteristics 22-23 Source reduction 61-64 Spirulina algae 169, 171, 196 Spray irrigation 310-311, 318, 361 Stocking density 213, 217-219, 222-224, 226-227, 229 Storage, for wastewater land treatment 332 Submerged aquatic weeds 238-240, 245-246, 249, 280 Sugar cane industry 35-39 Sugar industry wastewaters, quantity and characteristics 35-39 Sullage 21 Tapioca industry 25-30 Tapioca starch wastewaters, quantity and characteristics 29-31 Technology changes, in waste minimization 63 Technology selection 383-385 Temperature effects, on pathogen die-off 71, 107 Thermophilic temperatures, in biogas digesters 125 Thermophilic temperatures, in composting 72-73, 86 Threshold concentration, of bacteria and viruses 230-231 Tilapia (Oreochromis nilotica) 206-207 Tilapia growth model 223-224 Toxic substances, in algal ponds 195-196 Toxic substances, in biogas digesters 128 Toxic substances, in waste-fed fish ponds 220 Toxic substances, of sludge land application 374-375 Toxic substances, of wastewater land application 349

412 _

Trouble-shooting, for biogas digesters 147, 150–153 Trophic levels 208–210

Unit mass emission rate (UMER) 29–30
Upflow anaerobic sludge blanket (UASB) digester 145, 147–149
Utilization, of aquatic weeds 255–260
Utilization, of biogas 159–160
Utilization, of biogas slurry 162–163
Utilization, of composted products 104–112
Utilization, of waste-grown algae 192–195
Utilization, of waste-grown fish 228–229
Vacuum tanker, for septage removal 19
Vegetables industry 45–48
Vegetables industry, wastewater 48

Ventilated improved pit (VIP) latrines 88, 91

Waste minimization 17, 61–64

Waste recycling, in waste minimization 64
Waste reuses, in aquaculture 6, 201
Waste stabilization ponds 11
Wastewater, quantity and characteristics 21-22
Wastewater land treatment methods 306-318
Water hyacinth 241
Water lettuce 241-242
Water lily 243
Water quality standards 394-396, 401-403
Water spinach 242
Water supply, coverage 1
Werribee farm, Australia 10-13
Wetlands, see constructed wetlands
Windrow composting 92-96, 99

Zoonoses 50, 54–58 epidemiology 54–56 parasitic 57–58