

# Index

Note: Page numbers in **bold** refer to tables and those in *italics* refer to figures

- Acoustic Doppler profiler flow meter  
 (ADFM), 137–139  
 principle, 137  
 schematic representation, 137, *137*  
 testing, 138–139
- Activated sludge, 162–163, 174–176  
 influent testing, 209, 210
- Activated Sludge Model no. 1 (ASM1),  
 163–164, *164*
- Agricultural irrigation *see* irrigation
- Algae  
 algal bloom, 220  
 biological monitoring, 80, 214  
 and human health, 314
- Alternating-activated-sludge (AAS)  
 WWTP, 254, *254*
- Alternative methods, 53–66  
 characteristics, 56–57, 60  
 compared with reference methods,  
 62–65, *63*  
 equivalence verification, 63  
 defined, 56–57  
 and emerging tools, 57  
 types of, 57–60  
 biosensing systems, 58  
 modelling, 58–59  
 optical sensors, 58  
 qualitative, 59  
 standard methods adapted, 57–58  
 toxicity evaluation, 59–60  
 uses, 60–62  
 biological monitoring tools, 61–62  
 field method, 60  
 handheld devices, 60–61  
 on-line sensors/analysers, 61  
 validation procedure, 63–64, *64*
- Ammonia/ammonium, **117**, 221  
 analysis, 55, *56*, 225–227  
 flow analysis, 233, **234**  
 methods listed, 225–226  
 sample preparation, 226–227  
 ecological impact, *277*  
 sample handling/preservation,  
 223–224
- Anaerobic digestion  
 interval observers, 260–261  
 mass-balance model, 257–258
- Analytic processes  
 improvement, 47–51  
 necessity, 67–69  
 normative requirements, 68  
 operation and maintenance, 68  
 research and development, 68  
 on-line sensors, 49–51  
 performance studies, 47–48, **49**  
 validation schemes, 48–49  
 interlaboratory studies, 48  
*see also* sampling
- Analytical results evaluation *see* Certified  
 Reference Materials (CRMs),  
 analytical results evaluation
- Antibodies, 70
- Area-velocity flow meters (AVFMs),  
 133–137  
 accuracy, 136, 137  
 data validity, 135–136

- Area-velocity flow meters (AVFMs) (*Cont.*)  
 evaluation, 135–136  
 narrow-beam Doppler, 134  
 principle, 133  
 wide-beam Doppler, 134
- ATP luminescence, 78
- Automated monitoring, 155–158  
 parameter measurement, 155–156  
 stations, 155–156, 155  
 control, 156–157  
 maintenance, 157  
 sensors, **156**
- Bacterial luminescence *see* bioluminescence
- Bacterial screening tests, 75
- Benthic ecology, 277, 284
- Biodegradation effect, 26
- Bioindicators, 285
- Biological monitoring, 77–80, 280–284  
 algae analysis, 80  
 microbiological contamination, 77–80  
 tools, 61–62, 77
- Biological oxygen demand (BOD), 180,  
 181–182  
 BOD<sub>5</sub>, 181–182, 192  
 determination, 42–43  
 microbial sensors, 74–75  
 online analysis, 74–75
- Bioluminescence, 210–211, 214–215  
 toxicity measurement, 280, 282
- Biosensors, 58, 67–77, 280–282, 354  
 applications, **69**  
 bioaffinity-based, 69, 70, 71, 79  
 biocatalytic-based, 69–70, 71  
 BOD analysis, 74–75  
 chemical substance detection, 76–77  
 defined, 69–70  
 effluent testing, 215  
 environmental applications, 72–77  
 field applications, 80–81  
 immunoassays, 70  
 immunosensors, 71  
 microbe-based, 69, 71  
 on-line monitoring, 280  
 optical methods, 72, 76, 280  
 parameters measured, 280, **281–282**  
 portable, 81  
 summarised, 73  
 toxicity analysis, 75–76  
 transducer links, 71
- Brenta River, 319  
 sampling, 319  
 TIN and IP mass loads, 320, 322,  
 323, 324  
 variables v. flow rate, 320, 321
- Capillary electrophoresis, 241
- Carbon *see* total organic carbon (TOC)
- CEN, 39
- Certified Reference Materials (CRMs),  
 84–109  
 analyte concentrations, **106–109**  
 analytical result evaluation, 102–105  
 errors, 102, 103, 104, 105  
 precision, 103, 104  
 standard deviation, 102, 103, 104  
 certification procedures, 94–100  
 expert laboratories, 100  
 interlaboratory, 97–98, **98**  
 ISO Guide, 94  
 single laboratory, 97  
 collection, 87  
 defined, 84–85  
 disadvantages, 85  
 element concentration, **99**  
 hierarchy, 100–101  
 homogeneity, 88, 91–92  
 parameters, 98  
 preparation, 86–89  
 producers, 105  
 repeatability, 102, 103  
 requirements, 86  
 stability control, 92–94  
 storage, 89–91  
 traceability, 100–101  
 transport, 89–91  
*see also* Reference Materials (RMs)
- Chemical oxygen demand (COD), 180  
 composition, 192–193  
 determination, 43–44, **43**  
 EKF estimation, 254–255  
 fractionation, 182–192, 183, 192,  
 193, 200  
 case study, 191–192  
 respirometric approach, 184–189,  
**184, 185**  
 using analytic monitoring data,  
 189–191, **189**  
 fractions in wastewater, 182–184  
 interval observers, 260

- Chemometrics, 367
- Chromatography, 227, 239–241
- Clean Water Act (CWA), 10–11, 13–15
  - disposal regulation, 14–15
  - effluent limitations, 13–14
  - main titles, 11
- Clean Water State Revolving Fund, 12
- Concentrated animal feeding operations, 17
- Contaminants *see* pollutants
- Continuous Perfectly Mixed Reactor (CPMR), 165, 166, 171, 172, 173
- COPANT, 39
  
- Dan Region (Israel) Reclamation Project, 344–346, 344
  - monitoring practice, 345–346, **345**
- Dangerous Substances Directive (DSD) (76/464/EEC), 3
- Data collection, 351–375
  - autonomous on-line instruments, 363, 364
  - biosensors, 354
  - cost-benefit analysis, 364
  - data quality standards, 356
  - discipline inputs, 358
  - disparate data, 359–361
  - and EU member states, 358
  - information sources
    - Micro and Nanotechnology (MNT) Network, 373–374
    - networked embedded systems, 372
    - Reconfigurable Ubiquitous Networked Embedded Systems (RUNES), 372–373
    - SENSCOPE, 373
    - Sensors for Water Industry Group (SWIG), 372
  - instrument supply industry, 355–356, 369–371
    - companies, 369, 370
    - future developments, 371
    - market characteristics, 370–371
    - market fragmentation, 370, 371
    - sale surges, 370
    - ‘maintenance’, 363
    - and management structures, 358–359
    - MCERTs, 356, 357
    - measurement choice, 354–355
    - measurement decisions, 362
    - measurements overlaid, 360, 361
    - ‘MicroRisk’ project (EU), 359–360
      - need for, 361, 374
      - requirements, 352
      - research and development support, 361–362
    - SCADA data, 359–360
    - sparse data, 359–361
    - standards, 364
    - system confidence, 360
    - techniques, 364–369
      - battery technology, 366
      - chemometrics, 367
      - communications, 368
      - developments, 365
      - Lab-on-Chip*, 369
      - miniaturisation, 366
      - portable instruments, 368
      - spectrometry, 367
      - test kits, 368
      - wireless technology, 368
    - users, 362–364
  - Data fractionation of COD, 189–191, **189**
    - biodegradable, 190
    - particulate fraction, 191
    - soluble biodegradable, 191
    - soluble nonbiodegradable, 190
  - Deflocculation, 209
  - Dender River, 148–155, 149
    - dry and wet periods, 305–306
    - ESWAT model, 149–155
    - fertiliser, 150, 151–152, **152**, 154
    - input information, 149, **152**, **153**
    - nitrate estimation, 304–306
    - nitrogen, 149–150
    - pollution, 148–149
    - sensitivity analysis, 151–152
      - linear regression, 151–152
    - uncertainty analysis, 152–153, 154–155
      - fertiliser, 152–153
      - rainfall, 153–154, 154
    - water quality modelling, 294, 298–299, 304–307
  - Denitrification, 211
  - Detergent residues, 194, 195
  - Direct toxicity assessment (DTA), 205
  - Discharge limits, 180–181
  - Discharge systems, 311–312
    - combined sewer overflow (CSO), 312
    - sewer system, 311
    - surface urban runoff, 311

- Discharges
  - ammonia, 277
  - biological monitoring, 280–284
  - biosensors, 280–282
  - chemical monitoring, 278–280
    - biosensors, 280
    - in-situ* methods, 278
    - on-line methods, 279
    - parameters, 278
    - physico-chemical measurement, **279**
  - colloids, 276
  - grain size distribution, 276
  - impact, 277
  - monitoring, 284
    - bioindicators, 285
    - early warning systems, 285
    - practical applications, 285
  - passive samplers, 284
  - pollutants, 278
  - quality survey, 275–287
  - residual constituents, **276**
  - stipulations, **37**
- Discharges from WWTPs
  - accuracy levels, 315–316
  - annual load, 317, 325
  - daily average load, 317
  - ecological effects, 312–314
  - errors, 316–317, 324, 325
  - example, 319–325
  - mass loading, 312–314, 325
    - calculations, 314–319, **318**
    - data use, **314**
    - sampling, 314
    - uncertainties, 315–317
  - on-line sensors, 319
  - public health effects, 314
  - sampling, 317
  - in sensitive receiving waters, 311–327
  - variables (pollutants), 312–314, **313**
  - see also* Brenta River
- DNA sequence sensors, 79–80
- Doppler AVFMs *see* area-velocity flow meters
- Early warning systems, 285, 343
- Electromagnetic flow meters, 132–133
  - advantages, 132
  - disadvantages, 133
- Emerging tools, 57
- Emission limit value (ELV), 14, 326
- Environmental Protection Agency (EPA), 10, 12
- Environmental quality standards (ESQs), 353
- European Committee for Standardisation (CEN), 39
- European Soil and Water Assessment Tool (ESWAT), 149–150
- ‘European Testing and Comparability of On-line Sensors (ETACS)’, 49–50
- ISO/CD 15839, 49, 51
  - overview, 51
- European Union
  - guidelines for monitoring, 146
  - wastewater regulation, 2–10
    - legislation, 2, 8–9
    - results, 10
- European Union Water Framework Directive (EU WFD) *see* Water Framework Directive (WFD)
- Eutrophication, 2, 220, 277
- Federal Water Pollution Control Act (FWPCA) *see* Clean Water Act
- Field measurement, 29–30
- Field method, 60
- Flow analysis techniques, 232–239, 232, **234**, 237
  - nitrogen, 233–238
  - phosphorus, 238–239
- Flow measurement *see* sewer flow measurement
- Flow rate, 116, 320, 321
  - variations, 170–172
- Flumes, 126–132
  - critical-flow flumes, 126, 130
    - modified, 131
  - flow computation principle, 127
  - measurement accuracy, 131–132
- Palmer-Bowlus flumes, 127–128, 128, 129
  - modified, 130–131
- Venturi flumes, 128, 130–131
  - modified, 131
- Fluorescence, 80, 280
- Genova WWTP, 315
- Groundwater recharge, 335–336
  - analysis, **335**

## Index

389

- Handheld devices, 60–61
- Hazard Assessment and Critical Control Points (HACCP) method, 31–32, 268–269, 337
- Hormones, 340
- Hypoxia, 220
- Immunoassays, 70, 79
- Immunoglobulins, 70
- In-line sensors, 173
- Industrial Pollution Prevention and Control Regulations Directive (IPPC) (96/61/EEC), 35
- Industrial wastewater, 265–272
  - accidental pollution, 270–272
  - characteristics, 266–268
  - monitoring, 268–269
    - critical control points, 268, 269
    - parameters, 268, 269
    - sampling campaigns, 268, 269
    - toxicity identification evaluation (TIE), 272
  - parameter concentrations, **267**
  - pretreatment stipulated, 265–266
  - source identification, 270–272
  - specific load, 266
  - spectrophotometry, 269, 270, 271, 279
  - TOD measurement, 271
  - variability, 266, 269–270
    - expression, 270
    - and sewer system, 269–270
- Integrated Pollution Prevention and Control Directive (IPPCD) (96/91/EC), 2, 3, 9
- International Standardisation Organisation (ISO), 38–39
- Irrigation, 331–333
  - microbial pathogens, 332–333
  - nutrients (excess), 333
  - pH, 333
  - reference international guidelines, 331–332
  - salinity, 332
  - scale deposits, 333
  - trace elements, 332
- ISO Guide 31, 99
- Kjeldahl nitrogen, 63, **64**, 229, 236
  - fractionation, 196–198, *197*, **198**
- Laboratory Reference Materials (LRMs), 85
- Manning's equation, 124–126
- Mass-balance model, 255–258, 262
- Mathematical modelling, 58–59
- Metallic compounds, 180, 198–199
  - treatability, 198–199
- Microbiological contamination analysis, 77–80
  - ATP luminescence, 78
  - DNA sequence sensors, 79–80
  - electric properties, 78–79
  - immunoassays, 79
- 'MicroRisk' project (EU), 359–360
- Modelling, 147–148, 289–309
  - and monitoring, 289–309
    - campaign guidelines, 307
    - uncertainties, 290
- Monitoring, 7
  - automated *see* automated monitoring
  - development, 55, 307
  - discharge, 284
  - and modelling, 147–148, 289–309
  - in rural areas, 145–159
    - Dender River, 148–155, *149*
    - uncertainties, 148
- Nanotechnology, 373–374
- National Pollutant Discharge Elimination System (NPDES), 11–12, 14, 15–21
  - compliance monitoring, 20–21
  - permitting systems, 17–18
    - technology based, 17
    - water quality based, 17–18
  - pollutant control, 19–20
  - programme areas, 15–17
  - quality control, 21
  - standards, 18
  - wastewater types, 19
  - watershed-based permits, 18–19, 21–22
- Nitrates, 221
  - analysis, 227–228
    - automated, 228
    - hydrazine reduction, 228
  - eutrophication, 277
  - flow analysis, **234**, 235–236
  - sample handling/preservation, 224
- Nitrification inhibition, 211–212

- Nitrite, 221  
 analysis, 227  
 chromatography, 227  
 flow analysis, 233–235  
 sample handling/preservation, 224
- Nitrogen, 196, 201, 219, 220–221, 333  
 analysis, 225–230, 233–238  
 categories, 197  
 as contaminant, 180  
 determination, 46  
 flow analysis, 236–238  
 fractionation, 196, 197, **198**  
 mass load, 320–324  
 organic *see* organic nitrogen  
 removal, 2, 211  
 sample handling/preservation, 223–224  
 total, 46, 229, 230, 236  
*see also* nitrogen compounds e.g. ammonia, nitrates
- Nutrients, 180, 196–198  
 analysis  
 capillary electrophoresis methods, 241  
 chromatographic methods, 239–241  
 flow analysis, 232–239  
 standard methods, 225–232  
 control, 219–245  
 defined, 219–220  
 sampling handling/preservation, 223–225  
 sources, 220  
*see also* nitrogen, phosphorus
- Observability, 249
- Observers, 248–262  
 definition, 250  
 discretization, 262  
 interval observers, 258–261  
 and anaerobic digester, 260  
 bounds, 258–259  
 improvements, 260–261  
 interval estimators, 259  
 real measurement applications, 261  
 for linear system, 251–255  
 applied to WWTP, 254  
 Extended Kalman Filter, 253–254, 262  
 Kalman filter, 252–253  
 Luenberger observer, 251  
 and nonlinear system, 252  
 mass-balance model, 255–258, 262  
 applied to anaerobic digester, 257–258  
 asymptotic observer, 257, 258  
 equation defined, 256  
 principle, 250  
 probabilistic observers, 259  
 properties, 250  
 uses in WWTPs, 248  
 validation, 262
- Oestrogens, 195
- On-line methods, 30, 68, 80  
 training, 383
- On-line sensors, 49–51, 52, 61, 173  
 discharges from WWTPs, 319  
 performance characteristics, **50**  
 in sewers, 113–114
- Optical methods, 58, 72, 76, 280, 353
- Organic aggregate parameters, 180, 181–192
- Organic micropollutants, 180, 192–196, 201  
 categories, 193–194  
 treatability, 194–195
- Organic nitrogen, 220–221  
 analysis, 229–230  
 flow injection, 230  
 Kjeldahl method, 229  
 persulfate method, 230  
 flow analysis, 236–238  
 high temperature combustion (HTC), 237–238  
 Kjeldahl method, 236  
 microwave oven use, 237  
 UV photooxidation, 236–237  
 sample handling/preservation, 224
- Organic trace contaminants, 340
- Pan American Standards Commission (COPANT), 39
- Passive samplers, 284
- Pesticide determination, 76–77
- Pharmaceuticals, 194, 195, 201, 278  
 in reused water, 340
- Phenols, 45–46, 77
- Phosphorus, 196, 219–220, 221–223  
 analysis, 222, 230–232  
 flow injection methods, 231–232  
 via molybdenum compounds, 230–231  
 oxidising digestion, 231  
 spectrophotometric methods, 238–239, 238  
 total phosphorus, 231–232  
 as contaminant, 180  
 determination, 46, 47  
 eutrophication, 277

- flow analysis, 238–239, **240**
  - electric techniques, 239
  - gel filtration techniques, 239
  - on-line pretreatments, 239
- mass load, 320–324
- occurrence, 221–222
- parameters, 222–223
- removal, 2
- sample handling/preservation, 224–225
- Plasticizing agents, 194, 195
- Pollutants, 179–201, 278, **313**
  - categories, 180
  - derivation, 179–180
- Polychlorinated biphenyls (PCBs), 193, 194
- Polychlorinated dibenzo-*p*-dioxins (PCDDs), 194
- Polychlorinated dibenzofurans (PCDFs), 194
- Polycyclic aromatic hydrocarbons (PAHs), 193, 194, 195
- Pretreatment programmes (POTWs), 16
  
- Quality control, 7–8, 21
- Quality Control Materials (QCMs), 85
  
- Ready-to-use method, 60
- Reclaim Water project, 340, **341**
- Reference Materials (RMs), 83–109
  - assigned values, 100
  - certification procedures, 94–100
  - collection, 87
  - defined, 84
  - hierarchy, 100–101
  - homogeneity, 88, 91–92, 93
  - preparation, 86–89
  - producers, 105
  - requirements, 86
  - sample treatment, 87–89, 88, 89
  - spiking, 89
  - stability control, 92–94, 95, 96
  - storage, 89–91, **90**
  - traceability, 100–101
  - transport, 89–91
  - types, 85
  - see also* Certified Reference Materials (CRMs)
- Registration, Evaluation, Authorisation and Restrictions of Chemicals (REACH) proposal, 205
- Regulation of wastewater, 1–22
- Remote sensing, 33, 113–114
  
- Residual constituents, **276**
- Respirometry, 182, 280, 282
  - oxygen uptake rate (OUR) tests, 182, 185–187, 212
  - toxicity detection, 212–213
- Respirometry fractionation of COD, 184–189
  - biodegradable fraction, 185–187
  - heterotrophic active biomass, 187–188
  - instrumentation, 186
  - nonbiodegradable, 188–189
  - particulate biodegradable fraction, 187
  - soluble biodegradable fraction, 187
- Rural areas, 145–159
  - automated monitoring, 155–158
  - case study, 148–155
  - characterised, 147
  - modelling and monitoring, 147–148
  - as nonpoint sources, 147
  - sensitivity analysis, 151–152
  - use of ESWAT, 149–151
  
- St André (Belgium) aquifer recharge project, 346–347, 346
  - monitoring practice, **347**
- Salinity, 332
- Sampling, 23–34, 223–225, 299–300
  - ageing, 25–26
  - compliance with European Directive, 28–29
  - critical control points, 31–32
  - field measurement, 29–30
  - importance, 23–24
  - and international standards, 29
  - location, 29
  - methods, 26–28, 51–52
    - automatic, 26, 27–28, 29, 33
    - grab sampling, 26, 27, 32
    - on-line, 30, 49–51, 52
    - remote, 33
  - nonoptimal, 300, **301**
  - procedure, 54
    - limits, 54–55
  - sample handling, 30–31
  - site choice, 31
  - see also* analytic processes
- Scale deposits, 333
- Sensitive waters, 311–327
- Sensors
  - and battery technology, 366
  - in WWTPs, 173
  - see also* observers

- Sewage
  - monitoring
    - analysis, 113
    - European directive, 111–112
    - measurement, 113
    - methodology, 112–114
    - nonparametric measurements, 115
    - objectives, 111–112
    - on-line devices, 113–114
    - parameters, 114–118
    - remote sensing, 113–114
    - sampling, 112–113
  - see also* wastewater
- Sewage evolution
  - biological factors, 117–118
    - aerobic/anaerobic conditions, 117
    - toxicity, 118
  - physical factors, 116
    - dilution, 116
    - flow rate ratio, 116
    - temperature, 116
  - physico-chemical factors
    - pH, 116–117, **117**
    - redox potential, 117
- Sewer flow measurement, 119–144
  - acoustic Doppler profiler flow meters, 137–139, 141
  - area-velocity meters, 133–137
  - electromagnetic meters, 132–133, 141
  - equipment, 121–122, 123
  - flumes, 126–132, 141
  - locations, 122–123
  - Manning's equation, 124–126, 141
    - Camp's distribution, 125, 125
    - Manning's roughness coefficient, 124, 125, 126
  - practical applications, 125–126
  - probes, 143
  - purposes, 120–121
  - quality assurance/control, 123–124
  - storm volume errors, **142**
  - techniques, 120
    - calibration, 141
    - compared, 139–141, **142**
    - hydrographs, 140
    - standard, 140
    - test site, 139
    - uncertainty, 141
- Sewer overflows, 16
- Sewers, 111–118, 268
  - see also* sewage
- Software sensors *see* observers
- Soil and Water Assessment Tool (SWAT), 149, 294
- Spectrofluorimetry, 80
- Spectrometry, 367
- Spectrophotometry, 58, 59
  - and industrial wastewater, 269, 270, 271, 279
  - in sewage analysis, 115
- Standard methodologies, 35–52
- Standards
  - defined, 36–38, 51
  - international organisations, 38–39
  - national organisations, 39, **40–41**
  - off-line techniques, 51–52
  - on-line methods, 49–50
  - parameter measurement, 42–47
    - biological oxygen demand, 42–43
    - chemical oxygen demand, 43–44, **43**
    - nitrogen, 46
    - phenols, 45–46
    - phosphorus, 46, 47
    - total organic carbon, 44–45, **44**
    - total suspended solids, 45
  - 'standard method', 38, 51
  - techniques, 51
  - types, 36–38
- State variables, 247–263
- Storm water overflows, 16
- Supervisory control and data acquisition (SCADA) system, 33, 359–360
- Surfactants, 194, 195
- Tienen (Belgium) water reuse scheme, 343
- Total Kjeldahl nitrogen (TKN) *see* Kjeldahl nitrogen
- Total maximum daily loads (TDML), 12, 14
- Total nitrogen, 46, 229, 230, 236
- Total organic carbon (TOC), **44**, 180
  - measurement, 44–45
- Total suspended solids (TSS), 45, 58
- Toxic shocks, 209, 210
- Toxic substances
  - lack of information on, 205
  - sources, 204, 207–208
    - domestic, 208
    - from treatment process, 208, 216

## Index

393

- identification, 208
- industrial, 208
- Toxicity
  - global, 280, 282
  - mitigation, 215–216
  - specific, 280, 282
- Toxicity evaluation *see* toxicity testing
- Toxicity identification evaluation (TIE), 272
- Toxicity testing, 59–60, 75–76, 203–218
  - biological tools, 280–282
  - biosensors, 75–76, 280–282
  - effluent, 206, 213–215
    - algae bioassays, 214
    - bacterial bioassays, 214–215
    - bioluminescence, 214–215
    - biosensors, 215
    - fish bioassays, 213–214
    - invertebrate bioassays, 214
  - future of, 204
  - influent, 206, 209–213, 216
    - bioluminescence, 210–211
    - nitrification inhibition, 211–212
    - respirometry, 212–213
  - methods, 209–215, **283**
  - need for, 204–205
  - units, 206–207
- Trace elements, 332
- Training, 377–383
  - courses, 378–379
    - on regulations, 381–382
    - on water chemistry, 380–381
    - on water quality characterisation, 382–383
  - in France, 378–379
  - institutes, 378–379
  - in New Zealand, 379
  - in North America, 379
  - on-line analysis, 383
  - students, 378
  - in UK, 379
- Treatability evaluation, 179–202
  - and COD fractions, 182–184
  - influent composition, 181
  - metallic compounds, 198–199
  - nutrients, 196–198
  - organic aggregates, 181–192
  - organic micropollutants, 194–196
  - respirometry, 182, 184–189
  - and WWTPs capacity, 181
- Trento (Italy), 319
- United States
  - implementation and control bodies, 12–13
  - ‘standard method’, 38
  - wastewater regulation, 10–22
- Urban areas, 161–177
- Urban Wastewater Treatment Directive (UWWTD) (91/271/EEC), 2, 3–8, 35–36, 203
  - deadline, 371
  - information and reporting, 6
  - monitoring, 6, 7
  - planning aspects, 4–5
  - pollutants, 7
  - quality control, 7–8
  - regulation, 5–6
  - stipulations, 265–266
  - types of wastewater covered, 4
- UV photooxidation, 236–237
- UV spectrophotometry *see* spectrophotometry
- Wastewater
  - composition, 24, **25**
  - discharges *see* discharges
  - flow rate variations, 170–172
  - heterogeneity, 24
  - hydrodynamics, 172
  - industrial *see* industrial wastewater
  - nondomestic pollution sources, 268
  - urban, 24
  - variability, 25, 170–172
    - COD, 170, 171
    - flow rate, 170–172
- Wastewater regulation
  - European Union, 2–10
  - United States, 10–22
- Wastewater treatment plants (WWTPs), 15, 162–176
  - activated sludge, 162–163, 174–176
    - influent testing, 209, 210
  - ASM1, 163, 164, 164
  - biokinetics, 163–164
  - biological process, 162–173

- Wastewater treatment plants (WWTPs) (*Cont.*)
- COD estimation, 254–255
  - COD fractionation, 182–192, 200
  - computer fluid dynamics, 170
  - contaminant removal, 180
  - control strategies, 174–176
    - actuator operations, 175
    - aeration control, 175, 175
    - bench-marking procedure, 174
    - control loops, 175–176
  - deflocculation, 209
  - discharge limits, 180–181
  - EKF application, 254–255
  - hydrodynamics, 167–170
    - characterisation, 168–169
      - Residence Time Distribution (RTD), 168–169, 169, 171
  - interval observers, 258–261
  - mass balance, 172–173
  - mass-balance models, 255–258
  - observers, 248–262
  - organic micropollutants, 194–196, 201
  - oxygen transfer, 164–167, 166
    - model, 165–166
    - profile, 166–167
  - pollution removal efficiency, 164–165, 169
  - process summarised, 162–163
  - reactors, 166, 167–168
    - Continuous Perfectly Mixed Reactor (CPMR), 167–168, 171, 172, 173
      - oxygen transfer, 165, 166
    - Plug Flow Reactor, 167, 168
  - remedial action, 215–216
  - sensors, 173
  - toxic shocks, 209, 210
  - toxicity mitigation, 215–216
  - see also* treatability evaluation
- Water Framework Directive (WFD)
- (2000/60/EC), 2, 36, 84, 290, 352, 371
  - guidelines, 146, 277
  - specification monitoring, 54
- Water quality modelling, 289–309
- calibration, 306
  - data needs, 293–294
    - ‘key variables’, 293
  - Dender River, 294, 298–299
  - dry and wet periods, 305–306
  - input monitoring, 302–307
    - uncertainty analysis, 302–303
    - uncertainty reduction, 303
  - integrated, 292–293
  - models
    - QUAL2E, 291–292, 293, 294
    - RWQM1, 292, 293–294
  - nitrate estimation, 304–306
  - optimal experimental design (OED), 294–295, 297, 307
    - D-optimal, 296
  - Fisher information matrix (FIM), 296, 298, 299–300, 301, 303
  - iterative, 296
  - model calibration, 297–298
  - problems, 295
  - sampling strategy, 296, 297, 299–300, 301–302, **301**
  - sequential, 295, 296
  - synthetic data series, 297
  - uncertainty evaluation, 300–301, **301**
  - sensitivity analysis, 304–305, **304**
  - see also* modelling
- Water reuse, 329–349
- case studies
    - agricultural irrigation, 344–346
    - drinking water, 346–347
    - industrial cooling, 343
  - classification, 330–331, 331
  - emergent technologies, 338–342
  - groundwater recharge, 335–336
  - HACCP, 337
  - industrial applications, 334
    - hierarchy, 334
  - irrigation, 331–333
  - monitoring, 337, 338, 340–342
    - and control strategy, 330
  - organic trace contaminants, 340
  - parameters, **339**, 342
  - pathogens, 332–333, 338–340, 343
  - pollutants, 338–342, **341**
    - hormones, 340
    - microbes, 332–333, 338–340
    - pharmaceuticals, 340
  - residential applications, 333
  - schemes (global), 336–337, 336
  - technology, 336–337
  - urban applications, 333
  - water quality, 330–336
- Water stress, 330
- Waters, sensitive, 311
- ‘Wet weather discharges’, 16
- Whole effluent testing (WET), 205