Index

activated sludge process (ASP) 183, 184–188
  common problems in 187
  process requirements for 184
    balancing tank 186
  UASB versus 190
adsorption 197–198
  using GAC 197
aeration 177–178
aerobic processes
  anaerobic processes and 183
  attached growth system 183
  suspended growth system 183
agricultural water needs 6–8
air-conditioning and refrigeration systems 117–118
air-cooled chillers and condensers 124–127
  advantages 125
  disadvantages 125–126
algae 42, 112
alkalinity 28–29
  measurement 29
  pH and 29
  polymerisation and 333
  types 28
alternative heat rejection systems 123–130
  air-cooled chillers and condensers 124–127
    see also separate entry
  combination cooling systems 127–129
  geothermal cooling systems 129–130
  hybrid cooling towers 125–127
alternative water sources 101–104
  comparison 102
  maximum allowable concentrations 101–104
alternatives to wet cooling towers 117–130
  air-conditioning and refrigeration systems 117–118
  alternative heat rejection systems 123–130
    see also separate entry
  energy conservation = water conservation 118–123
    see also separate entry ammonia (NH_3) 29
anaerobic processes 182, 188–189
  performance 190
aquatic treatment-lagoon technology 183
Australia
  Australian drinking water guidelines 31
  water consumption 7–22

bacteria 40–41, 112
  classification 186
  Salmonella 40–41
basic water chemistry 25–44
  common substances in water 26–44
  solubility principles 26
benchmarking water and energy consumption 237–240
  energy consumption 238–240
  water consumption 237–238
biochemical oxygen demand (BOD) 39
biodegradable organics (BOD) removal 180–192
  activated sludge process (ASP) 183, 184–188
    see also separate entry
  aerobic and anaerobic processes 183
  biological treatment methods 182
  membrane bioreactors (MBR) 191–192
biofouling 111–113
blending 333–334
blowdown (BD) 91–92
  control 150
    automatic blowdown control installation to 153
    by improving boiler feedwater quality 154
    treatment programme to 153–154
    ways to 153

boilers
classification by application 139
classification by configuration 139
firetube boilers 139–140
industrial fired watertube boilers, guidelines 142
waste heat recovery boilers 143
watertube boilers 140–142
boron 37
brine streams disposal 217
business sector water usage 11–15
consumption reduction, reasons for 15–22
cost reduction 18–20
counter-measure for future water price increase 20
drives innovation 20–21
improved staff awareness and morale 21
increasing investor confidence 16–17
minimising value chain related risk 18
production efficiency 20
societal entitlement 15–16
tax relief and rebates 21–22

cadmium 43
calcium 32–35
calcium carbonate scaling 106
California
water usage in
commercial sectors 14
industrial sectors 14
carbon dioxide, in water 28–29
cartridge-type waterless urinals 247–249
disposable cartridge type 248
cash flows
computing 226–228
one-time cash flows 226
operating cash flow 227–228
working-capital cash flows 227–228
centrifugal compressor and chiller 119
chelation 197
chemical oxygen demand (COD) 39
chemical precipitation 193–196
flocculation step 193, 196
precipitation step 194–195
pretreatment step 193–194
settling step 194, 196
sulphide precipitation 194
chlorides 35–36
chromium 42–43
clean-in-place (CIP) technology 316–317
internal recycling 318
optimising CIP programmes 320
single use CIP skid system 318
closed circuit cooling systems 84
coagulation 172–173
coking 333
colour 38–39
combination cooling systems 127–129
advantages 128
disadvantages 129
commercial buildings, hospitals and institutional buildings 267–288
correctional centers 285–288
water conservation opportunities 286–288
water usage benchmarks 286
hospitals 275–285
see also under hospitals, water usage in
office and retail 267–274
energy consumption 270–271
industry structure and water usage 267–269
shopping centers 271–272
water-usage benchmarks 269–272
water-saving opportunities 272–274
compound meter 75
condensates
carbonic acid and oxygen contaminating 150
condensate corrosion inhibitors 150
process fluids contaminating 150–151
strategies to recover 148–151
conductivity
total dissolved solids (TDS) and 30–32
see also under total dissolved solids (TDS) cooling towers
types 92–94
forced draught wet cooling towers 94
induced draught counter-flow cooling towers 93–94
induced draught cross-flow cooling towers 93
mechanical draught 92
natural draught 92
cooling water systems 83–115
cooling towers *see separate entry*
critical factors affecting 105
percentage of water used in 84
for recirculating water systems 104–114
types of 84–92
closed circuit cooling systems 84
comparison 85
once-through systems 84
open recirculating 84
see also separate entry

cooling water systems (*continued*)
typical concentrations in 103
water conservation opportunities 94–101
see also under water conservation
corrosion 109–111
assessment guidelines 111
in cooling systems, types 109
dezincification 110
galvanic corrosion 110
general corrosion 110
pitting corrosion 109–110
stress corrosion cracking 110
principal factors contributing to 111
principal factors governing 110
costs of water visible and invisible 19
crude distillation 332
cyanide 38

dataloggers 80–82
dealkalisation 136
demineralisation 136
desalting 332
dezincification 110
disc tube technology (DTM) 211
disinfection methods
types 112
non-oxidising biocides 112–113
oxidising biocides 112
ultraviolet disinfection 112
dissolved air flotation (DAF) 177
design and operating parameters 179
factors affecting 178–179
dissolved gases 28–30
ammonia (NH_3) 29
carbon dioxide 28–29
hydrogen sulphide (H_2S) 30
oxygen (O_2) 29
dissolved ions removal, membranes for 198–219
advantages 199
brine streams disposal 217
dead-end and cross-flow filtration 201–202
electrodialysis (ED) 219
electrodialysis reversal (EDR) process 219
fouling, membrane 213–214
membrane configurations 207–213
disc tube technology 211–213
hollow fibre 207–208
plate and frame 209–213
spiral wound 207
tubular membranes 208–209
VSEP system 210–212
membrane performance monitoring 213–217
common failure mechanisms 214
scaling tendencies, assessment 213–215
Silt Density Index (SDI) 214–215
membrane structure 206
membrane systems selection, considerations 217–218
membrane types 202–206
comparison 203–204
flux (throughput per unit area) 206
microfiltration (MF) 202
nanofiltration (NF) 202, 205–206
reverse osmosis (RO) 206
ultrafiltration (UF) 205
tangential filtration chart 200
dissolved ions 30–38
cations 30
less common anions 30
removal *see under* dissolved ions removal, membranes fordissolved oxygen (DO) 187
Doppler-type meters 78
drift (DR) 87
duck bill waterless urinals 250
dynamic loggers 81

economy air cycle 121
electrodialysis (ED) 136, 219
electrodialysis reversal (EDR) process 219
electromagnetic meters 78
emulsified FOG removal 176–180
by aeration 177–178
by air flotation 177–179
dissolved air flotation (DAF) 177
induced air flotation (IAF) 177
types 177
flotation, types 178
ultrafiltration 179–180
energy conservation = water conservation 118–123
rules in
building insulation, improving (Rule 6), 121
chillers sizing (Rule 8), 121
energy efficient chillers and refrigeration systems installation (Rule 7), 121
free cooling mode (Rule 9) 121
increase building reflection (Rule 5) 121
lighting load reduction (Rule 4) 120
operate at the highest chilled water temperature (Rule 11) 122

operate at the lowest condensing water temperature (Rule 10) 122
over-cooling elimination (Rule 2) 120
recover waste heat (Rule 13), 123
system operation (Rule 1) 119–120
timely maintenance (Rule 3) 120
variable drive speed fans to the cooling tower (Rule 12), 122–123
evaporative condensers 94

facultative lagoons 183
fats, oils and greases (FOG)
removal 175–180
emulsified FOG removal 176–180
see also separate entry
free FOG removal, skimming 176
sources of 175–176
filtration techniques
automatic self-cleaning filters 99–100
granular media filtration 99
sidestream filtration 99–100
for suspended solids 173–175
dual media 173
multimedia 173–174
single media 174
financially sound business case, in water saving 221–235
computing cash flows 226–228
see also under cash flows
conventional cost accounting 224
identifying hidden costs 224–226
conventional production costs 225
project implementation costs 225
regulatory 224–225
voluntary costs 225
making a good business case 222–226
management functions 222
project profitability assessment 228–233
discounted cash flow analyses 230–231
internal rate of return (IRR) 233
net present value (NPV) analyses 231–232
payback method 228–230
Return on Investment (ROI) method 230
project risk assessment 233–235
financial risk 235
regulatory risk 235
technical risk 235
risk matrix 223
fixed orifice condensate discharge traps (FOCDT) 145–146
flow and consumption, measuring 73–82
chemical methods 82
dataloggers 80–82
flow measurement 73–75
see also flowmeters flowmeters
classification 75
compound meter 75
open-channel meter 75
positive displacement meter 75
proportional meter 75
V100 piston-type volumetric meter 76
velocity meters 76–79
see also separate entry
desirable characteristics 74
types 75–79
positive displacement meters (volumetric) 75–76
food processing and beverage industry 300–328
benchmarking water usage 307–310
poultry processing 308
process and place of water usage 306–308
water and energy usage 301–306
energy usage 303–306
water usage 301–303
water minimisation measures 310–328
in amenities blocks 325
avoiding water usage 310–312
in clean-in-place 316–320
see also separate entry
in evaporative condensers and cooling towers 325
reusing water 326–327
by spray nozzles usage 312–315
see also under spray nozzles
in steam systems 326
using liquid ring vacuum pumps 320–324
in washing 316
forced draught wet cooling towers 94
fouling 109, 209
membrane fouling 213
France, agricultural water needs in 6–8
fungi 42, 112

galvanic corrosion 109
geothermal cooling systems 129–130
global warming impacts 9
global water resources
availability 2–3
global water challenge 5
grease trap 176

H2Zero™ cube traps 249
Hardness
calcium and magnesium 32–35
scaling potential and 33

Hazen units (HU) 38
heavy metals 42–44
  cadmium 43
  chromium 42–43
  removal 192–197
    by chemical precipitation 193–196
      see also separate entry
    ion exchange 196–197
      advantages 197
      costs of 197
heavy metals removal 192–197
helminths 42
holding time index (HTI) 113
hospitality sector 236–265
  benchmarking water and energy consumption 237–240
  see also separate entry
  guest awareness programmes 264–265
  staff awareness programmes 264
  steps to achieve water savings 240–263
  see also under water savings, steps to achieve hospitals, water usage in 275–285
  benchmarking energy consumption 277–278
  benchmarking water usage 276
  major water-consuming areas 275–276
  water conservation opportunities 278–285
    air-conditioning and refrigeration systems 279
    food preparation 280
    hemodialysis units 284
    in-house laundries 280
    medical equipment 281–285
    medical pumps and liquid ring vacuum pumps 284
    monitor leakage 278
    pre-vacuum sterilizers 282
    steam sterilizers 282
    steam systems 279
    taps, toilets and urinals 279–280
hybrid cooling towers (HCTs) 125–127
  advantages 126
  Baltimore Aircoil HXI cooler 126–127
  dry mode 126
  evaporative cooling mode 126
  evaporative pre-cooled mode 126
hydrocyclones 170–171, 176
hydrogen sulphide (H_2S) 30
hydrotreating 333
hypothetical refinery 335
improvement opportunities identification, in WMP 55–67
  management systems assessment 55–56
    one-2-five water® rating 55–58
  technical assessment 56–67
    flow verification 64–65
    regulatory standards 60–62
    water audit 62–65
    water balance development 65
    water losses and its cost 63
    water-saving potential, estimating 59–60
induced air flotation (IAF) 177
induced draught counter-flow cooling towers 93–94
induced draught cross-flow cooling towers 93
industrial water reuse technologies 157–219
  adsorption 197–198
  biodegradable organics (BOD) removal 180–192
  see also under biodegradable organics (BOD) removal
  dissolved ions removal, membranes for 198–219
  see also separate entry
  fats, oils and greases removal 175–180
  see also under fats, oils and greases (FOG)
  heavy metals removal 192–197
  see also under heavy metals
  industrial process water-quality requirements 162
  in a manufacturing plant 158
  reuse streams, pollutants found in 164–165
  see also under pollutants found in reuse streams
  step-by-step approach to 159–164
    establishing the goals of the study 160
      goals 160
      project boundaries 160
    gather the data 161
    identify the project 161–164
    implementation 164
    technical assessment 164
  suspended solids, removal of 167–174
  see also under suspended solids
  wastewater contaminants by industry 166–167

involuntary water loss reduction 95–96
drift loss 96
leakage from pipes, joints and pump glands, reducing 96
by minimising overflow of water 95
by piping configuration correcting 96
splash 96
ion exchange processes
sodium cation ion exchange resin 136
types 134
iron 36

kitchens, water saving in 252–258
Asian wok stoves 254
design and behavioral patterns 252
dish washers 255
types and water usage 258
low flow pre-rinse spray valves, water and energy savings from 253
sinks 252
waterless wok stoves 254–255

Langelier Scaling Index (LSI) 107
rules for interpreting 107
laundries 343–355
alkalies in 346
benchmarking 348
bleaching chemicals in 345
industry structure 344
large and small on-premise laundries 344
large commercial laundries 344
large hospital laundries 344
laundry equipment types 345–348
continuous batch washers (CBW) systems 347–348
washer-extractor 346
phosphoric, citric acids in 346
surfactants in 344
water conservation 343–355
ozone disinfection 353
reuse for rinse water quality 351
reuse for wash water quality 350
VSEP nanofiltration membrane in 352
water and energy reuse 349
lead 42
Liquid Ring Vacuum Pumps (LRVPs) 320–325
working principle 321

magnesium 32–35
magnetic flowmeter 78
manganese 36
membrane bioreactors (MBR) 191–192
external recirculation MBR 191
submerged MBR 191
membranes for dissolved ions removal
see under dissolved ions removal, membranes for mercury 44
micro-organisms 40–42, 112
categories 40
non-pathogens 40
pathogens 40
see also algae; bacteria; fungi; helminths; protozoa
microbial growth 111–113
microbiological control 112, 113
microfiltration (MF) 202
mobile telephone networks 82

nanofiltration (NF) 202, 205
Nephelometric Turbidity Units (NTU) 38
nitrates 37
nitrification 187
non-oxidising biocides 112

oil contamination 151
oil refining 330–342
hypothetical refinery 335
oil refining processes 332–334
alkylation and polymerisation 333
blending 333
coking 333
desalting, crude distillation and vacuum distillation 332
hydrotreating 333
reforming 333
thermal and catalytic cracking 332–333
refinery, flowchart 334
water conservation opportunities 339–342
options for 339
water consumption reduction 341–342
water-quality matrix 340
water usage 335–342
cooling water systems 335
energy usage 338–339
refinery wastewater sources 338
steam systems 335–337
wastewater quality and effluent limits 338
wastewater systems 337
once-through cooling systems 84
one-2–five water® diagnostic tool 56
open-channel meter 75
open recirculating cooling systems 84–92
basic concepts 88–92
ambient wet bulb temperature, T_{wb} 89
approach temperature ($T_{cw} - T_{wb}$) 89–90

open recirculating cooling systems (*continued*)
blowdown 91
calculating the heat load Q 88
cooling range ($T_{hw} - T_{cw}$) 89
cooling water requirement 89
cycles of concentration 91
evaporation rate 90
make-up water required 91
system losses 92
operational principles 86–88
basis of 87
organics in water
soluble organics 39
synthetic organic chemicals 39
oxidising biocides 112
oxygen (O_2) 29
ozone disinfection 353–355

permeate stream 201
pH 26–27
pH scale 27
see also alkalinityphosphates 27
piston meters 76
pitting corrosion 109
pollutants found in reuse streams 164–165
removal of 165–167
order of removal 167
positive displacement meter 75
Practical Scaling Index (PSI) 107
pre-treatment systems 134–138
for common impurities 137
effluent quality from 138
proportional meter 75
protozoa 41
public amenities, water saving in 244–262
air-cooled condensers 260
cooling tower, air-conditioning and refrigeration 258
costs and savings 251
H2Zero™ Cube traps 249
ice-making machines 259–261
water conservation tips for 260
kitchens 252–258
see also separate entry
laundry 259
staff rooms 262
swimming pools 262
taps 244
urinals 244
water-cooled condenser models 260
waterless urinals 246
see also separate entry
zip industries 245
public switched telephone network 81

radio networks 82
radionuclides 44
reforming 331
reject stream 201
reverse osmosis (RO) 136, 202, 206
Ryznar Scaling Index (RSI) 107

safe drinking water, human need for 3–6
salinity of irrigation water, guidelines 32
sand filters 294
high rate sand filters 294
rapid sand filters 294
sanitation, human need for 3–6
satellite telephone networks 82
scaling 105–108
calcium carbonate scaling 106
control methods 108
acid addition 108
chemical inhibitors 108
scaling indices 107–108
Langelier Scaling Index (LSI) 107
Practical Scaling Index (PSI) 107
Ryznar Scaling Index (RSI) 107
scaling tendencies, assessment 215
screening 168–169
coarse screening 168
contra-shear design 169
fine screens 168
rotating screens 168
screening media 168
static screens 168
static wedge/curved screens 168
vibrating screens 169
weave wire screens 169
sedimentation 170–171
Sequencing Batch Reactor (SBR) process 187
silica 37
Silt Density Index (SDI) 214
slop oil 176
sodium 36
softening 134–136
spray nozzles
maintenance of 314
for water minimisation 312–315
benefits 312
steam systems 132–155
in an industrial plant 135
principles 133–146
ion exchange processes 134
see also separate entry
pre-treatment 134–138
steam and energy conservation opportunities 146–154

maximise condensate recovery 148–151
minimising boiler water BD 151–154
see also under blowdown (BD)
repair steam leaks 147
steam distribution system 143–146
steam generation 139–143
see also boilers
steam traps *see separate entry* "true"
cost of steam, calculating 154
steam traps
fixed orifice condensate discharge traps (FOCDT) 145–146
types 144
F&T steam trap 144
mechanical traps 144
thermodynamic traps 144
thermostatic traps 144
step-by-step guide, to WMP 50–51
baseline data and review usage gathering (step 3) 52–55
improvement opportunities, identifying, (step 4) 55–67
see also separate entry
preparing the plan prioritising the opportunities (step 5), 67–68
report the results (step 6) 68–71
seek senior management commitment (step 1), 50–51
water conservation manager, appointing (step 2) 51–52
stress corrosion cracking 110
suspended solids
classification of 167
removal of 167–174
by chemically aided settling 172
by filtration 173
see also under filtration techniques
by screening 168–169
see also separate entry
sedimentation 170–171
settling 171–172
turbidity and 38
sustainable water management plan (WMP) 46–50
minimising evaporation 296–299
automatic pool covers 298
bubble covers for 297
pool covers for 297
sand filters 294
high rate sand filters 294
rapid sand filters 294
swimming pool benchmarks 291–292
water conservation opportunities 292–299
optimising filter backwash cycles 294–295
reducing leakage 293
water-efficient fixtures 293–294
Sydney 13
Sydney water customer usage profile 54
water usage in 13

telemetry systems 81
thermal and catalytic cracking 332–333
total dissolved solids (TDS)
conductivity and 32
see also under conductivity
conversion factors 32
total suspended solids (TSS) 177
trade in water 7
transit time meters 78
trickling filter 183
turbidity 38
Nephelometric Turbidity Units (NTU) 38
turbine meters 77

ultrafiltration (UF) 179–180, 202
ultrasonic meters 78
ultraviolet disinfection 112
United Kingdom, agricultural water needs in 6–8
Upflow Anaerobic Sludge Blanket (UASB) 189

V100 piston-type volumetric meter 76
vacuum distillation 332
velocity meters 76–79
mechanical meters 77–78
non-mechanical meters 78–79
selection 80
Vibratory Shear Enhanced Processing (VSEP) system 210–211
virtual water 7–8
in traded crops 9
viruses 40
voluntary water loss, reducing 96–100
by flowmeters installation 98
increasing cycles of concentration 97–98
by operating BD in continuous mode 98–99
by sidestream filtration installation 99–100
VSEP (vibratory shear enhanced membrane process) 179–180

water
common substances in 26–44
impurities in, types 26
water chemistry *see under* basic water chemistry

water (*continued*)
water minimisation hierarchy 158
water sources, alternative *see under* alternative water sources
water usage/metrics 61
water conservation
business sector water usage 11–15
see also separate entry
China water facts 12
climate change impact on 8–10
global water resources availability 2–3
by improving operating practices 100–101
process leaks minimisation 101
shut off the unit when not in operation 100
as a priority for business 1–22
opportunities 94–101
involuntary water loss reduction 95–96
see also separate entry
key areas 94
voluntary water loss, reducing 95–96
see also separate entry
water treatment contractors role in 114–115
water management plan (WMP) 46–50
benefits of 47–50
step-by-step guide to 50–51
see also separate entry
traditional approach to 47
WMP alignment with corporate strategy 48
see also sustainable water management plan (WMP) water savings, steps to achieve 240–263
gathering and metering consumption and billing data 241
identifying the best opportunities 241–263
guest rooms 241–244
public amenities 244–252
see also under public amenities, water saving in
taps 243
toilets 242–243
sustainable water management plan 46–50
see also separate entry
water management policy 240–241
water-saving potential, estimating 59–60
in industrial plants 61
waterless urinals 246
bacterial blocks 249
benefits 246
cartridge type 247–249
H2Zero™ cube traps 249
mechanical working traps, trap with duck bill 250
technologies in 247
wet cooling towers, alternatives to *see under* alternatives to wet cooling towerswindage 87