

# Index

Note: *f.* indicates figure; *t.* indicates table.

- Acid solubility test, 198
- Air binding, 94, 95*f.*, 116, 117*f.*  
 correction of, 95
- Air scour, 117, 118*f.*  
 combined with water wash, 123, 124,  
 124*t.*, 125  
 followed by water wash, 123, 124, 127
- Algae  
 control by circulation of reservoir water,  
 106–107  
 control by copper sulfate, 106  
 filamentous, 108  
 and raised pH in source water, 102  
 in raw water, 106  
 removal by clarification and filtration,  
 107–108  
 removal from filter walls, 206  
 and slow sand filtration, 213  
 and taste and odor, 105–106
- Alkalinity  
 in filtration quality control, 164  
 of raw water as guide to coagulation, 29
- Alum, 3  
 and caustic, 40  
 and cold water, 46, 109–110  
 and fluoride, 40
- Anthracite  
 effect of chemical cleaning, 205, 205*f.*  
 fluidization velocity for mean sizes, 121,  
 122*t.*  
 lumps, 175, 177*f.*  
 temperature correction factors for large  
 grain sizes, 121–123, 123*t.*
- Aquarion Water Company (Connecticut),  
 29–30
- Arsenic, and prechlorination, 8–9
- Atmospheric oxygen, 8
- AWWA Standard B100-01, *Filtering  
 Material*, 71, 198, 204
- AWWA Standard B101-01 *Precoat Materials*,  
 229
- AWWA Standard B604-05, *Granular  
 Activated Carbon*, 71
- Bacillus*, 160–161
- Backwashing, 115, 132  
 addition of coagulant or polymer to  
 backwash water near end of backwash,  
 137–138  
 air scour followed by water wash, 123, 124,  
 127  
 assessing effectiveness, 192–199  
 calculating media size range, 121, 122*t.*  
 clean-bed head loss trend analysis,  
 197–198  
 cleaning media and restratifying filter bed,  
 125–126  
 combined air scour and water wash, 123,  
 124, 124*t.*, 125  
 complexity of, 115–116  
 concluding with subfluidization rise rate,  
 135–137, 136*t.*  
 and cone of depression from loss of nozzle,  
 118, 120*f.*  
 controlling media loss and disruption,  
 126–129  
 desired conditions after, 119  
 effect on residuals holding and treatment  
 facilities, 131  
 effect on wash-water supply, 130  
 and filter bed expansion, 127–128,  
 192–194, 194*f.*  
 and filter boil, 117–118, 118*f.*, 119*f.*  
 floc retention analysis, 195–197, 198*f.*  
 fluidization velocity for mean sizes of  
 anthracite, sand, and garnet, 121,  
 122*t.*  
 improved, and rapid sand filtration, 2

- influence on other filters, 129–130
- influence on plant production, 131–132
- managing and monitoring, 125–132
- methods, 123–124
- monitoring backpressure on underdrain systems, 127
- and observation of air scour, 117, 118*f*.
- observing backwash, 116–119
- pre-backwash detection of air binding, 116, 117*f*.
- pre-backwash detection of cracks in filter bed, 116, 117*f*.
- pre-backwash detection of hills and valleys, 116
- pre-backwash detection of mudballs, 116, 117*f*.
- remnant particles, 134–135
- rise rate increase and head loss, 119–121, 120*f*.
- scheduling, 129–132
- spent wash-water turbidity monitoring, 194–195
- stopping and starting filters without, 95–98, 97*t*.
- surface wash, 123–124, 125
- surface wash and detection of problems, 116, 117*f*.
- temperature and viscosity, 121
- temperature correction factors, 121–123, 123*t*.
- and uniform rise rate of water, 117, 118*f*.
- wash-water trough baffles, 128–129, 129*f*.
- and wash-water trough design, 128–129, 129*f*.
- water wash only, 123
- water wash with surface wash, 123
- See also* Return to service after backwashing
- Bacteria**
  - in clay removal by slow sand filtration, 215
  - removal by slow sand filtration, 214
  - total coliform removal by precoat filtration, 243, 244, 244*t*.
- Baylis turbidimeter, 3
- Baylis, John, 2
- Box inspection, 183
- Calcium Carbonate Chemical Balance or Stability Test, 36
- Caldwell–Lawrence diagrams, 35–36
- Chelsea Water Works Company (London, England), 211
- Chemical feed, 39
  - accumulator in compensation for pulsed flow from diaphragm pumps, 41
  - checking feed rates, 42
  - dosage issues related to pumps, 40
  - feeding low dosages for low water flow, 41 and handling of lime, 43
  - inspecting and maintaining pumps, 42–43
  - location of addition points, 40–42
  - pumps, 39
  - and quality control, 170–171, 171*f*.
- Chemical mixing, 39, 43
  - backmix reactor and motorized mixer, 44, 44*f*, 46
  - for coagulation, 44–46, 44*f*, 45*f*, 46*f*.
  - high-shear chemical induction mixers, 44, 46*f*.
  - hydraulic jump mixers, 44, 45*f*.
  - inadequate, 47
  - in-line motorized mixers, 44, 45*f*.
  - inspection and maintenance of rapid mixers, 48
  - for lime softening, 47
  - rapid, 44
  - static mixers, 44, 45*f*.
- Chippis, Michael, 149
- Chlorination, 2
- Chlorine dioxide, 10–11
- Cincinnati, Ohio, 212
- Clarification, 1, 39, 70
  - and algae, 64
  - ballasted flocculation clarifiers, 62–64, 62*f*, 69
  - contact adsorption clarifiers, 60–62, 61*f*, 62*f*, 63, 68, 69
  - conventional sedimentation basins, 55, 68
  - dissolved air flotation, 65–68, 65*f*, 66*f*, 69
  - effect of high wind on large sedimentation basins, 55

- energy requirements for ballasted and DAF processes, 69
- flotation concept, 55
- high rate sedimentation processes, 55–58, 56*f*.
- ideal settling (Hazen), 54–55, 54*f*.
- management and maintenance of clarifiers, 64–65
- monitoring clarifier performance, 68–69
- plate settlers, 60, 61*f*.
- and plug flow, 64
- and sand recirculation equipment, 63
- sedimentation concepts, 53–55
- and sludge, 64–65
- tube settlers, 58–60, 59*f*.
- Clean-bed head loss, 148–149
- restoring in slow sand filtration, 224–225, 225*f*.
- trend analysis, 197–198
- Coagulation, 1, 11–12, 39, 230
- adding extra coagulant on returning filter to service after backwashing, 137
- chemical mixing for, 44–46, 44*f*., 45*f*., 46*f*.
- cleaning media, 204–206, 205*f*.
- and cold water, 109–110
- dilution and overfeeding or underfeeding of metal coagulants and polymers, 31
- dosage determination, evaluation, and monitoring, 15–32, 32*t*.
- and high color with low turbidity in source water, 102–103
- and high turbidity with high color/high NOM in source water, 103–104, 104*f*.
- historical chemical dosing charts, 16–18, 101
- jar tests, 18–24, 18*f*.
- and microbiological contaminants, 14
- and NOM, 14–15
- NOM as guide to chemistry of, 29–31, 30*t*.
- overdilution of dry coagulants, 40
- pH and alkalinity as guide to, 29
- and pilot filters, 26–28, 27*f*.
- and pulsed flow from diaphragm pumps, 41
- and slow sand filtration, 220
- source water influence on chemistry of, 13–15
- and streaming current measurements, 24, 25–26
- sweep flow, 46
- and turbidity, 14
- and variable pH in source water, 102
- and variable turbidity in source water, 101–102
- visual observation of dosage results, 15–16
- and zeta potential testing, 24–25
- Coagulation dosage charts, 16–17
- limitations, 17–18
- Color, in filtration quality control, 164
- Colorado State University, 3, 215, 218, 243
- Conley, Walter, Jr., 2, 12
- Core samples, 190–192, 193*f*.
- Cryptosporidium*
- inactivation by ozone, 9, 10
- and particle counters, 157–158
- removal by precoat filtration, 229, 243–244, 244*t*.
- and slow sand filtration, 212, 214
- and stopping and starting filters without backwashing, 96
- DAF. *See* Dissolved air flotation
- Depth filtration, 80
- Design and Operation Guidelines for Optimization of the High-Rate Filtration Process*, 101
- Diatomaceous earth filtration
- and *Giardia* removal, 3
- See also* Precoat filtration
- Diatomaceous Earth Filtration for Safe Drinking Water*, 250
- Diatomite. *See* Precoat filtration
- Diatoms
- in raw water, 106
- removal by clarification and filtration, 107–108
- Direct filtration, 39
- coagulant mixing for, 46
- jar tests for, 21

- Dissolved air flotation (DAF)  
 clarification, 65–68, 65*f*, 66*f*, 69  
 in clarification of algae and diatoms, 107  
 coagulant mixing for, 46  
 engineering considerations, 67  
 float, 67–68  
 and floc sinking, 67  
 jar tests, 23, 23*f*, 67  
 maintenance, 68  
 valve adjustment, 68
- Dissolved organic carbon (DOC), 14
- Dual-media filtration, 2
- Effective size (ES), 73
- Elevation of media surface, 185
- Endamoeba histolytica*, 3, 229, 243
- Environmental Protection Agency (EPA).  
*See* US Environmental Protection Agency
- Excavation boxes, 187–190, 189*f*
- False floor uplift, 175, 176*f*
- Ferric coagulant, 40
- Filter beds  
 cracks in, 116, 117*f*, 184  
 expansion of, 127–128  
 hills and valleys in, 116  
 influence of bed depth and media size on  
 particle removal ( $L/d$  ratio), 80–81,  
 81*f*  
 mudballs in, 116, 117*f*  
 particle removal mechanisms, 79–80  
 pore spaces, 79, 79*f*  
 porosity, 77  
 restratification in backwash, 125–126
- Filter boil, 117–118, 118*f*, 119*f*
- Filter cycle, 81–82
- Filter Evaluation Procedures for Granular Media*, 182
- Filter inspection, 175–178, 209  
 acid solubility test, 198  
 anthracite and sand lumps, 175, 177*f*  
 assessing backwash effectiveness, 192–199  
 box, 183  
 checking valve integrity, 198–199  
 clean-bed head loss trend analysis,  
 197–198  
 core samples, 190–192, 193*f*  
 and cracks in filter bed, 184  
 elevation of media surface, 185  
 excavation boxes, 187–190, 189*f*  
 false floor uplift, 175, 176*f*  
 and filter bed expansion, 192–194, 194*f*  
 filter piping, 183  
 floc retention analysis, 195–197, 198*f*  
 gravel surface profiles, 187  
 information review, 178  
 material removed from pressure filter, 175,  
 177*f*  
 materials and equipment, 180, 181*t*  
 media, 184  
 mounds, 175, 177*f*  
 and mudballs, 184  
 pipe organ bed expansion tool, 193–194,  
 194*f*  
 planning, 180  
 preparing for, 178–180  
 pressure filters, 208–209  
 probing filter media, 185–187, 186*f*, 188*f*  
 quick, 180, 184*t*  
 recommended procedures, 180, 183*t*  
 safety and sanitation considerations,  
 178–179  
 spent wash-water turbidity monitoring,  
 194–195  
 support materials, 184  
 time intervals, 180, 182*t*  
 troughs, 183–184  
 underdrain failure, 175, 176*f*  
 underdrains, 184
- Filter maintenance, 209  
 chemical cleaning of media and  
 underdrains, 200–206  
 cleaning media at coagulation plants,  
 204–206, 205*f*  
 cleaning media at iron and manganese  
 removal plants, 204–206, 205*f*  
 cleaning media at lime softening plants,  
 203–204

- eliminating mudballs, 199–200, 199*f*, 201*f*, 202*f*.
- keeping filter vessels clean, 206–208
- preparations for chemical cleaning, 201–203
- Filter Maintenance and Operations Guidance Manual*
- on clean-bed head loss, 149
  - on delayed start, 140
  - on difficult water conditions, 101
  - on floc and filtration rate, 93
  - on initial turbidity spike, 143
- Filter piping inspection, 183
- Filter Surveillance Video*, 190
- Filters
- and air binding, 94–95, 95*f*.
  - biological growth in off-line units, 90
  - more filters for greater operational flexibility, 89
  - number of, 90–91
  - stopping and starting without backwashing, 95–98, 97*t*.
- See also* Return to service after backwashing
- Filtration, 230
- and innovation, 3–4
  - and low turbidity for virus removal, 2–3
  - 19th century developments, 1–2
  - 20th century developments, 2–3
- “Filtration Processes—A Distinguished History and a Promising Future,” 2
- Filtration rate, 98
- constant rate control, 91–92
  - declining rate control, 91
  - and design of settled water collection troughs, 94
  - and effluent quality, 82–87, 83*f*., 84*f*., 85*t*., 86*f*.
  - equal rate modes, 91–92
  - flexibility in, 93–94
  - gradual increases, 83, 93
  - management of, 92–93
  - minimizing effects of increases in, 87–89
  - modes of control, 91–92
  - more filters for greater operational flexibility, 89
  - and number of filters, 89–91
  - pumping flexibility and water storage in mitigation of increases in, 88, 94
  - and sedimentation basins as equalization basins, 89
  - and stopping and starting filters without backwashing, 95–98, 97*t*.
- Flexibility, 4
- Flocculation, 39, 48
- baffled, 49–50
  - baffling with mechanical flocculators, 51, 52*f*.
  - ballasted, and jar testing, 24
  - concepts, 48–49
  - and energy input (*Gt*), 49, 51
  - floc and resistance to turbidity
    - breakthrough, 83–85, 84*f*., 86*f*., 93
  - inspection and maintenance of equipment
    - and basins, 53
  - mechanical, 49, 50, 51
  - monitoring, 52–53
  - paddle wheel flocculators, 49, 50, 50*f*., 53
  - polymer conditioners, 2
  - and residence time, 51
  - and slow sand filtration, 220
  - and temperature, 49
  - types of, 49–50
  - vertical shaft, multispeed hydrofoil flocculators, 50, 53
  - visual observation of floc to assess dosage, 15–16, 16*f*.
- FlocMonitor, 52–53
- Flow rate
- monitoring in pilot filters, 28
  - and quality control, 171–173, 172*f*.
- Free chlorine, 8–9
- Fuller, George, 1, 11, 53–54
- GAC. *See* Granular activated carbon
- GAC Sandwich filter, 221
- Garnet, 121, 122*t*.
- Giardia*
- and coagulation, 12
  - and floc resistance to turbidity
    - breakthrough, 84, 85–87, 86*f*.

- and particle counters, 157–158
- removal by diatomaceous earth filtration, 3
- removal by precoat filtration, 229, 243, 244*t*.
- removal by slow sand filtration, 3
- and slow sand filtration, 212, 214, 220
- Granular activated carbon (GAC)
  - for NOM removal, 78
  - with slow sand filtration, 221, 222*f*.
  - for taste and odor control, 78
  - and taste and odor in source water, 105–106
- Granular media filter materials, 71
  - chemical cleaning of, 200–206
  - density, 77–78
  - durability, 78
  - effective size (ES), 73
  - hardness, 78
  - influence of size on filter performance, 74, 75*f*.
  - inspection, 184
  - porosity, 76–77
  - probing, 185–187, 186*f*, 188*f*.
  - shape, 76
  - sieve analysis, 72, 73*f*.
  - size and uniformity, 71–74, 73*f*.
  - standards, 71
  - types, 71
  - uniformity coefficient (UC), 73–74
- Gravel surface profiles, 187
- Hanford, Washington, 2, 12
- Hardness
  - in filtration quality control, 164
  - of granular media filter materials, 78
- Hazen, Allen, 11–12, 217–218
- Head loss
  - and backwash rise rate increase, 119–121, 120*f*.
  - clean-bed, 148–149, 197–198
  - at depths within filter bed, 148
  - monitoring, 28
  - in monitoring filter performance, 148–150
  - in precoat filtration, 238
  - and quality control, 173
  - rate of increase, 150
  - total, 148
- Hudson, Herbert, 2
- In-line filtration, 39
- Indianapolis, Ind., 212
- Infiltration galleries, 1
  - with slow sand filtration, 220
- “Integration of the Clarification Process,” 12
- Interim Enhanced Surface Water Treatment Rule (IESWTR), 133
- Iron
  - and aeration, 111
  - cleaning media at iron and manganese removal plants, 204–206, 205*f*.
  - and prechlorination, 8–9
  - sources, 110–111
- Jar tests, 18, 101
  - alternative procedures, 22–24
  - apparatus, 18*f*.
  - and ballasted flocculation, 24
  - calibration to treatment plant, 18–19
  - chemical reactions with contaminants, 19–20
  - and coagulant dosage, 19
  - coagulated water flocculated in jar, 22
  - and color or TOC removal, 20
  - data to record, 21–22
  - for direct filtration, 21
  - dissolved air flotation test, 23, 23*f*.
  - documentation, 20
  - and floc behavior, 19
  - and inorganic coagulants, 20
  - maintaining representative samples, 20
  - and polymers, 20
  - premeasurement of chemicals, 20
  - quality control checks, 21
  - recommended practices, 20–21
  - residence time and overflow rate of sedimentation basin, 21
  - and RoboJar, 24
  - and sedimentation, 19
  - separate addition of chemicals, 20

- settling times and clarifier overflow rates,  
20, 21*t*.  
uses, 19–20
- Kirkwood, James P., 1, 211
- Lake Mead, Nevada  
chlorine and ammonia to reduce bromate  
formation from ozonation, 10  
and ozone feed interruption, 9–10  
prechlorination and filtration, 9
- Lawrence, Mass., 214, 217–218
- L/d* ratio, 80–81, 81*f*
- Lime softening, 32–33  
assessing treatment chemistry, 34  
and Calcium Carbonate Chemical Balance  
or Stability Test, 36  
calcium carbonate precipitate, 33  
and calcium carbonate precipitation on  
filter media and infrastructure, 35  
with calcium oxide or calcium hydroxide, 33  
chemical handling and feed, 43  
chemical mixing for, 47  
and chemical stabilization of water, 35–36  
cleaning media, 203–204  
dosage determination, 33  
magnesium hydroxide precipitate, 33  
monitoring results, 34–35  
with sodium carbonate or sodium  
bicarbonate, 33  
split treatment, 33–34
- Los Angeles, California, 9
- Louisville, Ky., 212
- Lumps, anthracite and sand, 175, 177*f*.
- Manganese  
and chlorination, 111  
cleaning media at iron and manganese  
removal plants, 204–206, 205*f*.  
conditioning filters for removal of, 206,  
207–208  
and ozone, 9  
sources, 110–111
- Microorganisms, and coagulation, 14
- Microscopic particulate analysis (MPA), 161
- Moh hardness, 78
- Monitoring  
backpressure on underdrain systems, 127  
backwash, 125–132  
clarifier performance, 68–69  
coagulation, 15–32, 32*t*.  
flocculation, 52–53  
lime softening, 34–35  
pilot filter head loss and flow rate, 28  
precoat filtration, 248–249
- Monitoring filter performance, 147–148,  
162  
clean-bed head loss, 148–149  
filtrate turbidity, 151–157, 154*f*, 155*f*,  
156*f*.  
filtration rate, 150  
head loss, 148–150  
head loss at depths within filter bed, 148  
inspection of membrane and cartridge  
filters, 161  
microbiological sampling, 159–161  
particle counts, 157–159, 159*f*, 160*f*.  
rate of increase of head loss, 150  
total head loss, 148  
water production by filters, 151
- Mounds, 175, 177*f*.
- Mudballs  
eliminating, 199–200, 199*f*, 201*f*, 202*f*.  
and filter inspection, 184  
pre-backwash detection of, 116, 117*f*.
- Municipal water supplies (19th century), 1
- Natural organic matter (NOM)  
and chlorine dioxide, 10–11  
and coagulation, 14–15  
as guide to coagulation chemistry, 29–31,  
30*t*.  
and ozone, 9, 14  
and prechlorination, 8  
and UV absorbance, 14
- Nozzle, loss of, 118, 120*f*.
- Occupational Safety and Health  
Administration (OSHA) regulations,  
179

- Operational Control of Coagulation and Filtration Processes* (M37), 15, 163
- Ozone  
 and bromate formation, 10  
 and NOM, 9, 14  
 as preoxidant, 9–10  
 preozonation with slow sand filtration, 216–217, 220–221, 222*f*.
- PAC. *See* Powdered activated carbon
- Particle counters  
 and excessive data, 159  
 in filtration quality control, 168–169  
 in monitoring filter performance, 157–159, 159*f*, 160*f*  
 particle counts in filtration quality control, 164–165  
 and turbidimeters, 152
- Particles, 12–13  
 colloidal, 13  
 and zeta potential, 13
- Partnership for Safe Water, 133
- pH  
 in filtration quality control, 164, 170  
 of raw water as guide to coagulation, 29  
 and variability in raw water, 102
- Pilot filters, 26–28, 27*f*.  
 and head loss monitoring, 28  
 maintenance, 28  
 and rate of flow monitoring, 28
- Pilot-plant filters, 26
- Pipe organ bed expansion tool, 193–194, 194*f*.
- Polymers  
 adding extra on returning filter to service after backwashing, 137  
 effectiveness decreased by excess dilution, 40  
 filter performance as indicator of effectiveness, 28–29  
 and metal coagulants, 40–42
- Potassium permanganate, 11
- Poughkeepsie, N.Y., 211
- Powdered activated carbon (PAC)  
 and taste and odor in source water, 105–106  
 and turbidimeters, 152
- Prechlorination, 7–9
- Precoat filtration, 229, 252  
 addition of filter aid to influent, 230, 232*f*.  
 aluminum hydroxide in modification of diatomite, 241  
 appropriate source water quality, 241–242  
 auxiliary facilities and equipment, 238–239  
 body feed, 239, 240, 247–248, 248*f*.  
 causes of short filter runs, 240, 251–252  
 and cleaning, 249  
 cleaning filter leaves, 236, 237*f*, 249  
 concepts, 229–230, 240  
 defined, 229  
 development of, 229  
 diatomite, 240–241  
 diatomite and perlite as abrasives, 238, 252  
 diatomite grades, 241, 242*t*.  
 diatomite or perlite as filter medium (filter aid), 229, 230  
 disposal of spent filter aid, 249–250  
 evaluating filter aids, 245  
 filter leaves (elements), 230, 232*f*, 235–236, 235*f*, 236*f*.  
 filtration rate, 237  
 and head loss, 238, 247, 249  
 inspection and maintenance, 252  
 performance monitoring, 248–249  
 perlite, 240–241  
 precoat, 230, 232*f*.  
 precoating apparatus, 239  
 precoating procedure, 246  
 pressure filters, 230, 231*f*, 233, 234*f*.  
 pretreatment, 242–243  
 pumps and piping, 238–239  
 rate of flow control, 237  
 recommended operating procedures, 245–252  
 schematics, 230, 231*f*.  
 soda ash in calcining of diatomite, 241  
 steps in, 245  
 storage and handling, 238  
 troubleshooting, 250–252

- vacuum filters, 230, 231*f.*, 233–235, 236*f.*  
vessels, 230
- Precoat Filtration* (M30), 229, 238, 239
- Preoxidation, 7–8  
with atmospheric oxygen, 8  
with chlorine dioxide, 10–11  
with free chlorine, 8–9  
with ozone, 9–10  
with potassium permanganate, 11
- Pressure filters, inspection of, 208–209
- Pretreatment, 7, 36–37  
chemical coagulation, 11–12  
filter performance in assessing, 28–29  
and particles in water, 12–13  
raw water quality as guide to chemistry of, 29–31  
and source water influence on coagulation chemistry, 13  
*See also* Coagulation; Lime softening; Preoxidation
- Problem Organisms in Water* (M7), 106
- Pump calibration curves, 42
- Quality control, 163, 173  
chemical and microbiological analyses, 163–164  
head loss instrumentation, 173  
instrumentation concepts, 165  
laboratory, 163–165  
measurement of physical aspects of water quality, 164–165  
measuring treatment chemical flows, 170–171, 171*f.*  
measuring water flow, 171–173, 172*f.*  
online pH instruments, 170  
online turbidimeters, 166–168, 167*f.*  
particle counters, 168–169  
sample extract location, 164, 165*f.*  
streaming current instruments, 169–170  
treatment plant concerns, 165–173
- Rapid sand filtration, 1–2  
and improved backwashing, 2  
surface wash, 2
- Raw water conditions, 101, 113  
algae and diatoms, 106–108  
cold water, 109–110  
extreme situations requiring intake closure, 112  
high color and low turbidity, 102–103  
high turbidity and high color/high NOM, 103–104, 104*f.*  
iron and manganese, 110–111  
taste and odor, 105–106  
variable pH, 102  
variable turbidity, 101–102
- Recommended Standards for Water Works*, 158, 227
- Report on the Filtration of River Waters, for the Supply of Cities, as Practiced in Europe*, 1
- Return to service after backwashing, 133–134, 145  
and addition of chemical to filter influent as filter box refills at end of backwash, 138–139, 139*t.*, 140*t.*  
and addition of coagulant or polymer to backwash water near end of backwash, 137–138  
and addition of extra coagulant or polymer, 137  
and backwash remnant particles, 134–135  
and concluding backwash with subfluidization rise rate, 135–137, 136*t.*  
delayed start, 139–141  
filter ripening, 134–135  
and filter-to-waste procedure, 141–143, 142*f.*  
minimizing high turbidity, 135–144  
and potential for regulatory consequences, 133  
and sources of particles causing turbidity, 134, 134*f.*  
starting at low filtration rate with gradual increase, 143  
and turbidity, 133  
and turbidity spike, 133, 143, 144*t.*
- Robeck, Gordon, 2–3

- RoboJar, 24
- Roughing filters with slow sand filtration, 220, 221, 222*f*.
- Safety Practices for Water Utilities* (M3), 179
- Salem, Oregon, 220
- Sand
- effect of chemical cleaning, 205, 205*f*.
  - fluidization velocity for mean sizes, 121, 122*t*.
  - lumps, 175, 177*f*.
  - temperature correction factors for large grain sizes, 121–123, 123*t*.
- Schmutzdecke, 213–214
- Sedimentation, 1, 2, 68
- basins as equalization basins, 89
  - blanket clarifiers, 56*f*, 57–58, 68–69
  - concepts, 53–55
  - conventional basins, 55, 68
  - design of settled water collection troughs and influence on filtration rate, 94
  - effect of high wind on large basins, 55
  - floc density and operation of solids contact and sludge blanket clarifiers, 57
  - flocculation clarifiers, 56–57, 56*f*.
  - high rate processes, 55–58
  - ideal settling (Hazen), 54–55, 54*f*.
  - plate settlers, 60, 61*f*.
  - and slow sand filtration, 220
  - solids contact clarifiers, 56, 57, 68, 69
  - tube settlers, 58–60, 59*f*.
- Simpson, James, 211
- Slow sand filtration, 211, 227
- and algae, 213–214
  - avoiding stop–start operation, 214, 223
  - bacteria in clay removal, 215
  - bacteria removal, 214
  - bed depth and filter performance, 217, 218
  - biodegradability and removal of dissolved organic matter, 215–217
  - and biological activity, 212–213
  - chemical coagulation, flocculation, and sedimentation as emergency pretreatment, 220
  - cleaning to restore clean-bed head loss, 224–225, 225*f*.
  - cold water and efficiency decline, 214–215
  - covered filters for cold regions, 219, 219*f*.
  - design basics, 212–213, 213*f*.
  - effluent rate control, 213*f*.
  - filter as demonstration filter, 211
  - filtration rate and filter performance, 218 and *Giardia* removal, 3
  - and good source water quality for filters used alone, 219–220
  - history of, 211–212
  - infiltration galleries or wells as pretreatment, 220
  - influent rate control, 217*f*.
  - introduction to U.S., 1
  - maintenance, 223–227
  - maturation period, 222
  - mechanisms of, 212–217
  - media size and filter performance, 217–218
  - minimizing rate increases, 223
  - modification (GAC Sandwich filter) for pesticide removal, 221
  - modifications for treatment of poorer quality source water, 220–221
  - operating to waste after resanding, 227
  - operational differences from rapid rate filtration, 221–222
  - organisms in, 213–214
  - performance monitoring, 223, 224*f*.
  - placing new filter into service, 222
  - preozonation for improved biodegradability, 216–217, 220–221
  - pretreatment with ozone and roughing filter plus posttreatment with GAC filter, 221
  - pretreatment with ozone, roughing filter, and GAC filter, 221, 222*f*.
  - rate control, 216–217
  - removal of inorganic particles, 215
  - removal of microorganisms, 214–215
  - replacing sand when bed level reaches minimum depth, 225–227, 226*f*.
  - roughing filters as pretreatment, 220

- schematics, 213*f.*, 217*f.*, 222*f.*  
schmutzdecke, 213–214  
trenching procedure, 225–226, 226*f.*  
water temperature and filter performance, 218  
and worms, 214
- Specific ultraviolet light absorbance (SUVA), 14
- Standard Method* 2130, 152  
*Standard Method* 2560, 157  
*Standard Method* 9216, 159  
*Standard Method* 9218, 160  
*Standard Methods for the Examination of Water and Wastewater*, 151  
on quality control, 163
- Streaming current, 13, 101  
instruments in filtration quality control, 169–170  
measurements, 24, 25–26, 26*f.*
- Surface wash, 2, 123–124, 125  
rotary sweep for, 3
- Surface Water Treatment Rule (SWTR)  
and coagulation, 11  
and lime softening, 33–34
- Synechocystis minuscula*, 107
- Taste and odor  
and algae, 105–106  
and GAC, 78, 105–106  
and ozone, 9  
and PAC, 105–106
- Temperature, in filtration quality control, 164
- Thames Water Utilities, 213, 221
- THMs. *See* Trihalomethanes
- Total head loss, 148
- Total organic carbon (TOC)  
in filtration quality control, 164  
and jar tests, 20
- Trihalomethanes, 7–8
- Trough inspection, 183–184
- Turbidimeters  
online, in filtration quality control, 166–168, 167*f.*  
and PAC, 152  
and particle counters, 152
- Turbidity, 3–4  
breakthrough, 82–84  
and coagulation, 14  
in filtration quality control, 164, 166–168, 167*f.*  
in monitoring filter performance, 151–157, 154*f.*, 155*f.*, 156*f.*  
removal by precoat filtration, 243, 244*t.*  
and variability in raw water, 102
- Typhoid fever, 2
- Underdrain systems  
chemical cleaning of, 200–206  
failure, 175, 176*f.*  
inspection, 184  
monitoring backpressure on, 127
- Uniformity coefficient (UC), 73–74
- US Environmental Protection Agency, 3
- Valves  
adjustment for DAF, 68  
checking integrity, 198–199
- Vermont, and slow sand filters, 219, 219*f.*
- Wash-water trough design, 128–129, 129*f.*  
*Water Analysis Handbook*, 164  
Water piezometers, 223, 224*f.*  
*Water Quality & Treatment*, 107  
Water wash, 123  
with surface wash, 123
- Waterloo, University of, 221
- Wells, with slow sand filtration, 220
- Whatman #40 filter paper, 21
- Worms, 214
- Zebra mussels, 8, 11
- Zeta potential, 13, 101  
measurements, 24–25