ENV H 440/ENV H 545

Water treatment processes

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Water contaminants

- Chemicals
  - Inorganics
  - Organics
    - Synthetic organic compounds
    - Volatile organic compounds
- Microbes
  - Viruses
  - Bacteria
  - Protozoa parasites
  - Algae
  - Helminths

Water contaminants (I)

TABLE 1.9 USEPA National Primary Drinking Water Contaminant Standards

Contaminant	MCLG (mg/L)	MCL (mg/L)	Potential health effects	Sources of drinking water contamination
			Fluoride Rule[a]	
Fluoride	4.0	4.0	Skeletal and dental fluorosis	Natural deposits; fertilizer, aluminum industries; drinking water additive
			Phase I Volatile Organics[b]	
Benzene	Zero	0.005	Cancer	Some foods; gas, drugs, pesticide, paint, plastic industries
Carbon Tetrachloride	Zero	0.005	Cancer	Solvents and their degradation products
p-dichlorobenzene	0.075	0.075	Cancer	Room and water deodorants and "mothballs"
1,2-dichloroethane	Zero	0.005	Cancer	Leaded gas, fumigants, paints
1,1-dichloroethylene	0.007	0.007	Cancer, liver and kidney effects	Plastics, dyes, perfumes, paints
Trichloroethylene	Zero	0.005	Cancer	Textiles, adhesives and metal degreasers
1,1,1-trichloroethane	0.2	0.2	Liver, nervous system effects	Adhesives, aerosols, textiles, paints, inks, metal degreasers
Vinyl chloride	Zero	0.002	Cancer	May leach from PVC pipe; formed by solvent breakdown
			Surface Water Treatment Rule[c] and Total Coliform Rule[d]	
Giardia lamblia	Zero	TT[e]	Gastroenteric disease	Human and animal fecal wastes
Legionella	Zero	TT	Legionnaire's disease	Natural waters; can grow in water heating systems
Heterotrophic plate count	N/A	TT	Indicates water quality, effectiveness of treatment	
Total coliform	Zero	<5%+	Indicates gastroenteric pathogens	Human and animal fecal waste
Escherichia coli	Zero	TT	Gastroenteric disease	Human and animal fecal waste
Fecal coliforms	Zero	TT	Indicates gastroenteric pathogens	Human and animal fecal waste
Turbidity	N/A	TT	Interferes with disinfection	Soil runoff
Viruses	Zero	TT	Gastroenteric disease	Human and animal fecal waste
			Phase II Rule Inorganics[f]	
Asbestos (>10 μm)	7 MFL[g]	7 MFL	Cancer	Natural deposits; asbestos cement in water systems
Barium	2	2	Circulatory system effects	Natural deposits; pigments, epoxy sealants, spent coal
Cadmium	0.005	0.005	Kidney effects	Galvanized pipe corrosion; natural deposits; batteries, paints
Chromium (total)	0.1	0.1	Liver, kidney, circulatory disorders	Natural deposits; mining, electroplating, pigments

Water contaminants (II)

Mercury (inorganic)	0.002	0.002	Kidney, nervous system disorders	Crop runoff; natural deposits; batteries, electrical switches
Nitrate	10	10	Methemoglobulinemia	Animal waste, fertilizer, natural deposits, septic tanks, sewage
Nitrite	1	1	Methemoglobulinemia	Same as nitrate; rapidly converted to nitrate
Nitrate + Nitrite	10	10		
Selenium	0.05	0.05	Liver damage	Natural deposits; mining, smelting, coal/oil combustion
			Phase II Rule Organics[a]	
Acrylamide	Zero	TT	Cancer, nervous system effects	Polymers used in sewage/waste water treatment
Alachlor	Zero	0.002	Cancer	Runoff from herbicide on corn, soybeans, other crops
Aldicarb	Delayed	Delayed	Nervous system effects	Insecticide on cotton, potatoes, other crops; widely restricted
Aldicarb sulfone	Delayed	Delayed	Nervous system effects	Biodegradation of aldicarb
Aldicarb sulfoxide	Delayed	Delayed	Nervous system effects	Biodegradation of aldicarb
Atrazine	Remanded	Remanded	Mammary gland tumors	Runoff from use as herbicide on corn and noncropland
Carbofuran	0.04	0.04	Nervous, reproductive system effects	Soil fumigant on corn and cotton; restricted in some areas
Chlordane	Zero	0.002	Cancer	Leaching from soil treatment for termites
Chlorobenzene	0.1	0.1	Nervous system and liver effects	Waste solvent from metal degreasing processes
2,4-D	0.07	0.07	Liver and kidney damage	Runoff from herbicide on wheat, corn, rangelands, lawns
o-Dichlorobenzene	0.6	0.6	Liver, kidney, blood cell damage	Paints, engine cleaning compounds, dyes, chemical wastes
cis-1,2-dichloroethylene	0.07	0.07	Liver, kidney, nervous, circulatory system effects	Waste industrial extraction solvents
trans-1,2-dichloroethylene	0.1	0.1	Liver, kidney, nervous, circulatory system effects	Waste industrial extraction solvents
Dibromochloropropane	Zero	0.0002	Cancer	Soil fumigant on soybeans, cotton, pineapple, orchards
1,2-dichloropropane	Zero	0.005	Liver, kidney effects; cancer	Soil fumigant; waste industrial solvents
Epichlorohydrin	Zero	TT	Cancer	Water treatment chemicals; waste epoxy resins, coatings
Ethylbenzene	0.7	0.7	Liver, kidney, nervous system effects	Gasoline; insecticides; chemical manufacturing wastes
Ethylene dibromide	Zero	0.00005	Cancer	Leaded gas additives; leaching of soil fumigant
Heptachlor	Zero	0.0004	Cancer	Leaching of insecticide for termites, very few crops
Heptachlor epoxide	Zero	0.0002	Cancer	Biodegradation of heptachlor
Lindane	0.0002	0.0002	Liver, kidney, nervous system, immune system, and circulatory system effects	Insecticide on cattle, lumber, gardens; restricted in 1983

Water contaminants (III)

TABLE 1.9 USEPA National Primary Drinking Water Contaminant Standards (*Continued*)

Contaminant	MCLG (mg/L)	MCL (mg/L)	Potential health effects	Sources of drinking water contamination
			Phase II Rule Organics[h]	
Methoxychlor	0.04	0.04	Growth, liver, kidney, and nervous system effects	Insecticide for fruits, vegetables, alfalfa, livestock, pets
Pentachlorophenol	Zero	0.001	Cancer; liver and kidney effects	Wood preservatives, herbicide, cooling tower wastes
PCBs	Zero	0.0005	Cancer	Coolant oils from electrical transformers; plasticizers
Styrene	0.1	0.1	Liver, nervous system	Plastics, rubber, resin, drug damage industries; leachate from city landfills
Tetrachloroethylene	Zero	0.005	Cancer	Improper disposal of dry cleaning and other solvents
Toluene	1	1	Liver, kidney, nervous system and circulatory system effects	Gasoline additive; manufacturing and solvent operations
Toxaphene	Zero	0.003	Cancer	Insecticide on cattle, cotton, soybeans; cancelled in 1982
2,4,5-TP	0.05	0.05	Liver and kidney damage	Herbicide on crops, right-of-way, golf courses; cancelled in 1983
Xyenes (total)	10	10	Liver, kidney, nervous system effects	By-product of gasoline refining; paints, inks, detergents
			Lead and Copper Rule[i]	
Lead	Zero	TT#[j]	Kidney, nervous system damage	Natural/industrial deposits; plumbing solder, brass alloy faucets
Copper	1.3	TT##[k]	Gastrointestinal irritation	Natural/industrial deposits; wood preservatives, plumbing
			Phase V Inorganics[l]	
Antimony	0.006	0.006	Cancer	Fire retardents, ceramics, electronics, fireworks, solder
Beryllium	0.004	0.004	Bone, lung damage	Electrical, aerospace, defense industries
Cyanide	0.2	0.2	Thyroid, nervous system	Electroplating, steel, damage plastics, mining, fertilizer
Nickel	Remanded	Remanded	Heart, liver damage	Metal alloys, electroplating, batteries, chemical production
Thallium	0.0005	0.002	Kidney, liver, brain, intestinal effects	Electronics, drugs, alloys, glass
			Phase V Organics[m]	
Adipate (di(2-ethylhexyl))	0.4	0.4	Decreased body weight	Synthetic rubber, food packaging, cosmetics
Dalapon	0.2	0.2	Liver, kidney effects	Herbicide on orchards, beans, coffee, lawns, roads, railways
Dichloromethane	Zero	0.005	Cancer	Paint stripper, metal degreaser, propellant, extractant

Water contaminants (IV)

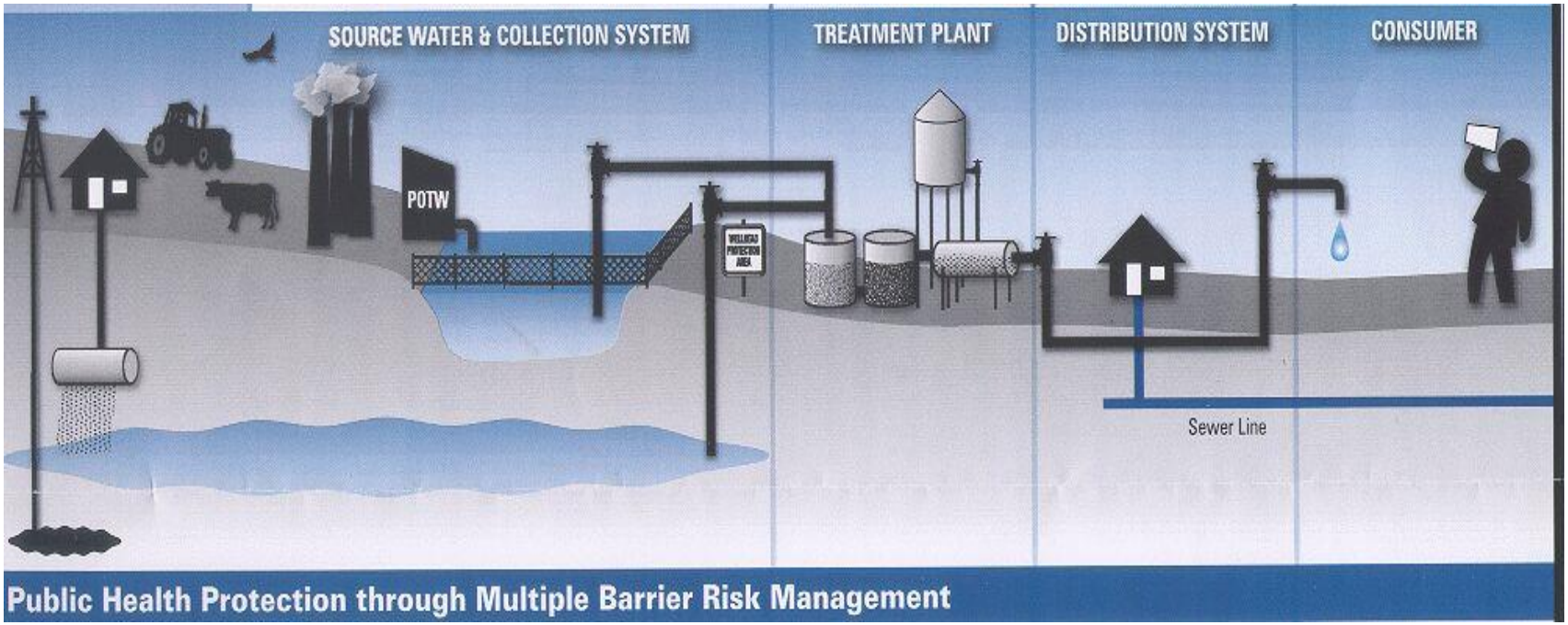
Dinoseb	0.007	0.007	Thyroid, reproductive organ damage	Runoff of herbicide from crop and noncrop applications
Diquat	0.02	0.02	Liver, kidney, eye effects	Runoff of herbicide on land and aquatic weeds
Dioxin	Zero	3×10^{-8}	Cancer	Chemical production by-product; impurity in herbicides
Endothall	0.1	0.1	Liver, kidney, gastrointestinal effects	Herbicide on crops, land/aquatic weeds; rapidly degraded
Endrin	0.002	0.002	Liver, kidney, heart damage	Pesticide on insects, rodents, birds; restricted since 1980
Glyphosate	0.7	0.7	Liver, kidney damage	Herbicide on grasses, weeds, brush
Hexachlorobenzene	Zero	0.001	Cancer	Pesticide production waste by-product
Hexachlorocyclo-pentadiene	0.05	0.05	Kidney, stomach damage	Pesticide production intermediate
Oxamyl (vydate)	0.2	0.2	Kidney damage	Insecticide on apples, potatoes, tomatoes
PAHs (benzo(a)-pyrene)	Zero	0.0002	Cancer	Coal tar coatings; burning organic matter; volcanoes, fossil fuels
Phathalate (di(2-ethylhexyl)	Zero	0.006	Cancer	PVC and other plastics
Picloram	0.5	0.5	Kidney, liver damage	Herbicide on broadleaf and woody plants
Simazine	0.004	0.004	Cancer	Herbicide on grass sod, some crops, aquatic algae
1,2,4-Trichlorobenzene	0.07	0.07	Liver, kidney damage	Herbicide production; dye carrier
1,1,2-Trichloroethane	0.003	0.005	Kidney, liver, nervous system damage	Solvent in rubber, other organic products; chemical production wastes
Interim (I) and proposed (P) standards for radionuclides[n] (USEPA 1976a, 1991e)				
Beta/photon emitters (I)	—	4 mrem/yr	Cancer	Natural and manmade deposits
Beta/photon emitters (P)	Zero	4 mrem/yr	Cancer	Natural and manmade deposits
Alpha emitters (I)	—	15 pCi/L	Cancer	Natural deposits
Alpha emitters (P)	Zero	15 pCi/L	Cancer	Natural deposits
Radium 226 +228 (I)	—	5 pCi/L	Bone cancer	Natural deposits
Radium 226 (P)	Zero	20 pCi/L	Bone cancer	Natural deposits
Radium 228 (P)	Zero	20 pCi/L	Bone cancer	Natural deposits
Uranium (P)	Zero	0.02	Cancer	Natural deposits
Disinfection by-products[o] (USEPA 1998g)				
Bromate	Zero	0.010	Cancer	Ozonation by-product
Bromodichloromethane	Zero	See TTHMs	Cancer, liver, kidney, and reproductive effects	Drinking water chlorination by-product
Bromoform	Zero	See TTHMs	Cancer, nervous system, liver and kidney effects	Drinking water chlorination by-product

Water contaminants (V)

TABLE 1.9 USEPA National Primary Drinking Water Contaminant Standards (*Continued*)

Contaminant	MCLG (mg/L)	MCL (mg/L)	Potential health effects	Sources of drinking water contamination
		Disinfection by-products[o] (USEPA 1998g)		
Chlorite	0.8	1.0	Developmental neurotoxicity	Chlorine dioxide by-product
Chloroform	Zero	See TTHMs	Cancer, liver, kidney, reproductive effects	Drinking water chlorination by-product
Dibromochloromethane	0.06	See TTHMs	Nervous system, liver, kidney, reproductive effects	Drinking water chlorination by-product
Dichloroacetic acid	Zero	See HAA5	Cancer, reproductive, developmental effects	Drinking water chlorination by-product
Haloacetic acids (HAA5)[p]	Zero	0.060 (stage 1)	Cancer and other effects	Drinking water chlorination by-products
Trichloroacetic acid	0.3	See HAA5	Liver, kidney, spleen, developmental effects	Drinking water chlorination by-product
Total trihalomethanes (TTHMs)	Zero	0.080 (stage 1)	Cancer and other effects	Drinking water chlorination by-products
		Interim Enhanced Surface Water Treatment Rule (USEPA 1998h)		
Cryptosporidium	Zero	TT	Gastroenteric disease	Human and animal fecal waste
		Other interim (I) and proposed (P) standards[q]		
Sulfate (P)	500	500[r]	Diarrhea	Natural deposits
Arsenic (I)	—	0.05	Skin, nervous system toxicity, cancer	Natural deposits; smelters, glass, electronics wastes; orchards

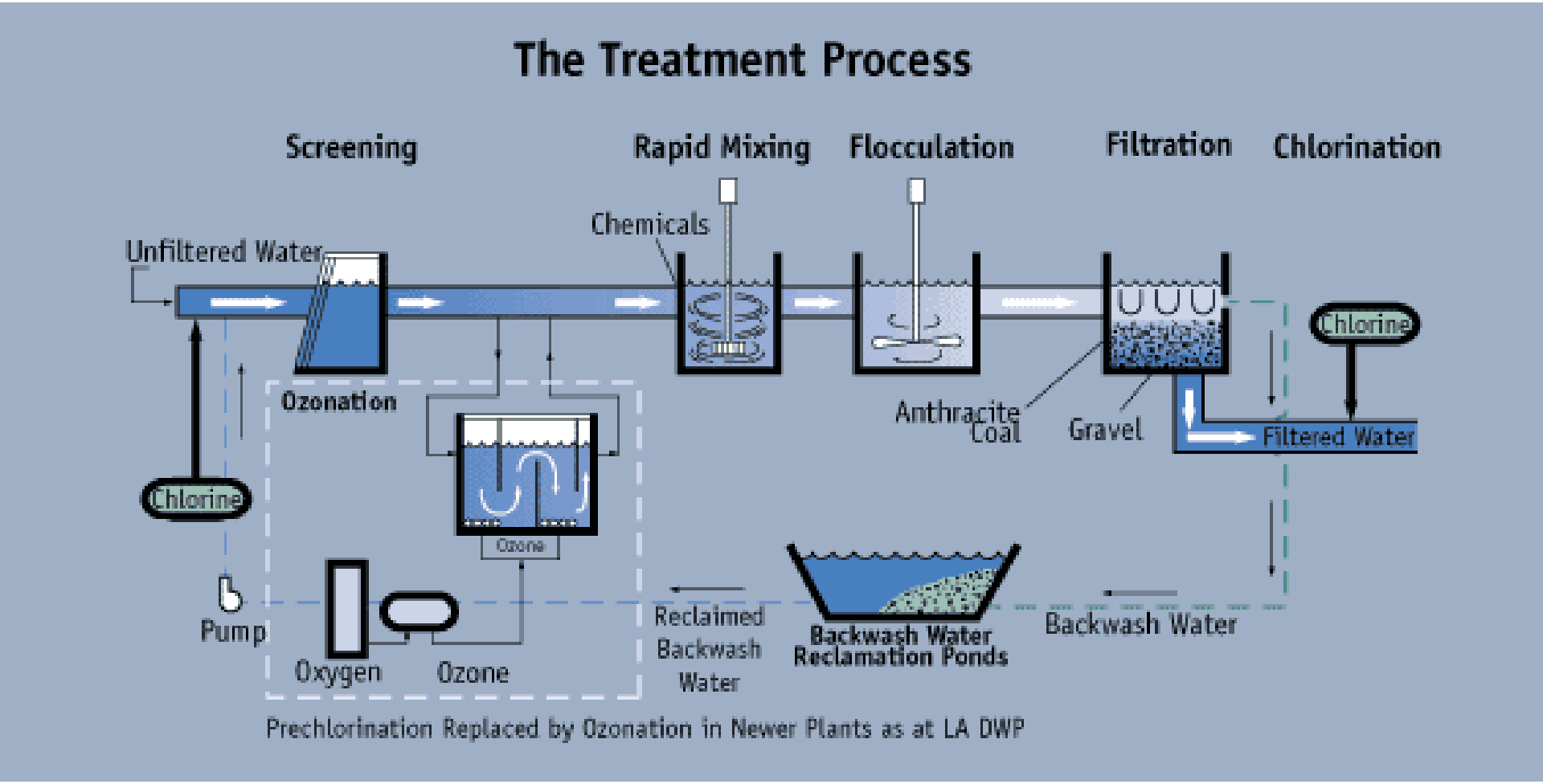
Multiple barrier concept for public health protection



Multiple Barrier Approach to Protect Public Health in Drinking Water

- Source Water Protection
- Treatment technology
- Disinfection
- Disinfectant residual in distribution system

Water treatment processes



Key points

- Purpose of the individual unit processes
- The typical operating conditions
- The outcome of the processes
- Microbial reduction of the processes

Oxidation

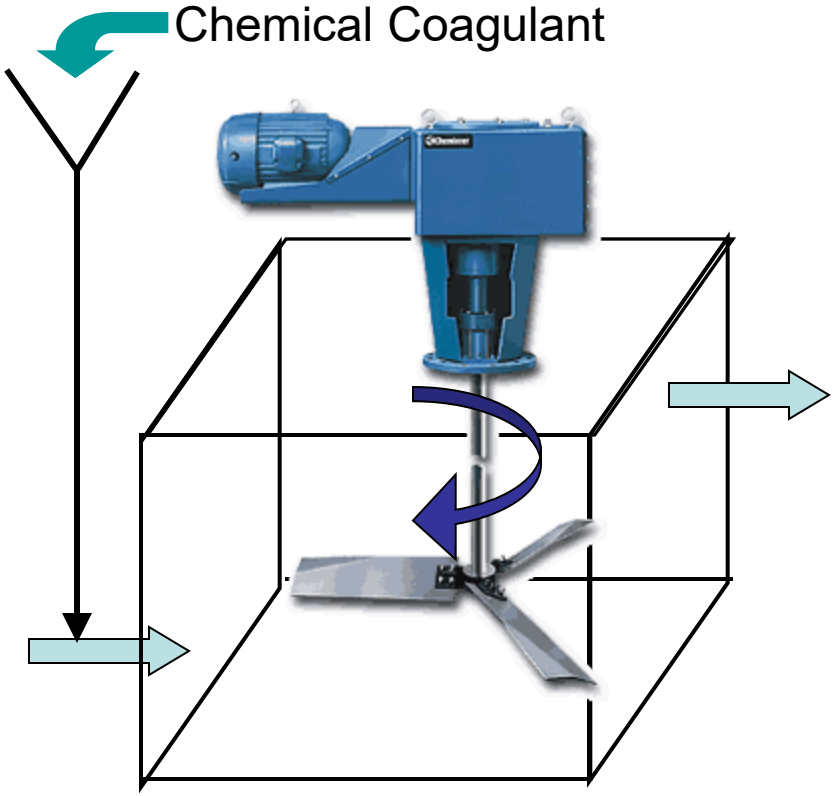
- To remove inorganics (Fe^{++}, Mn^{++}) and some synthetic organics
  - Cause unaesthetic conditions (brown color)
  - Promote the growth of autotrophic bacteria (iron bacteria): taste and order problem
- Free chlorine, chlorine dioxide, ozone, potassium permanganase
  - Fe^{++} + Mn^{++} + oxygen + free chlorine → $FeO_x \downarrow$ (ferric oxides) + $MnO_2 \downarrow$ (manganese dioxide)
  - $Fe(HCO_3)_2$ (Ferrous bicarbonate) + $KMnO_4$ (Potassium permanganase) → $Fe(OH)_3 \downarrow$ (Ferric hydroxide) + $MnO_2 \downarrow$ (manganese dioxide)
  - $Mn(HCO_3)_2$ (Manganese bicarbonate) + $KMnO_4$ (Potassuim permanganase) → $MnO_2 \downarrow$ (manganese dioxide)

Physico-chemical processes

- To remove particles (colloids and suspended solids) in water
- Coagulation/flocculation/sedimentation
- Filtration

Coagulation chamber

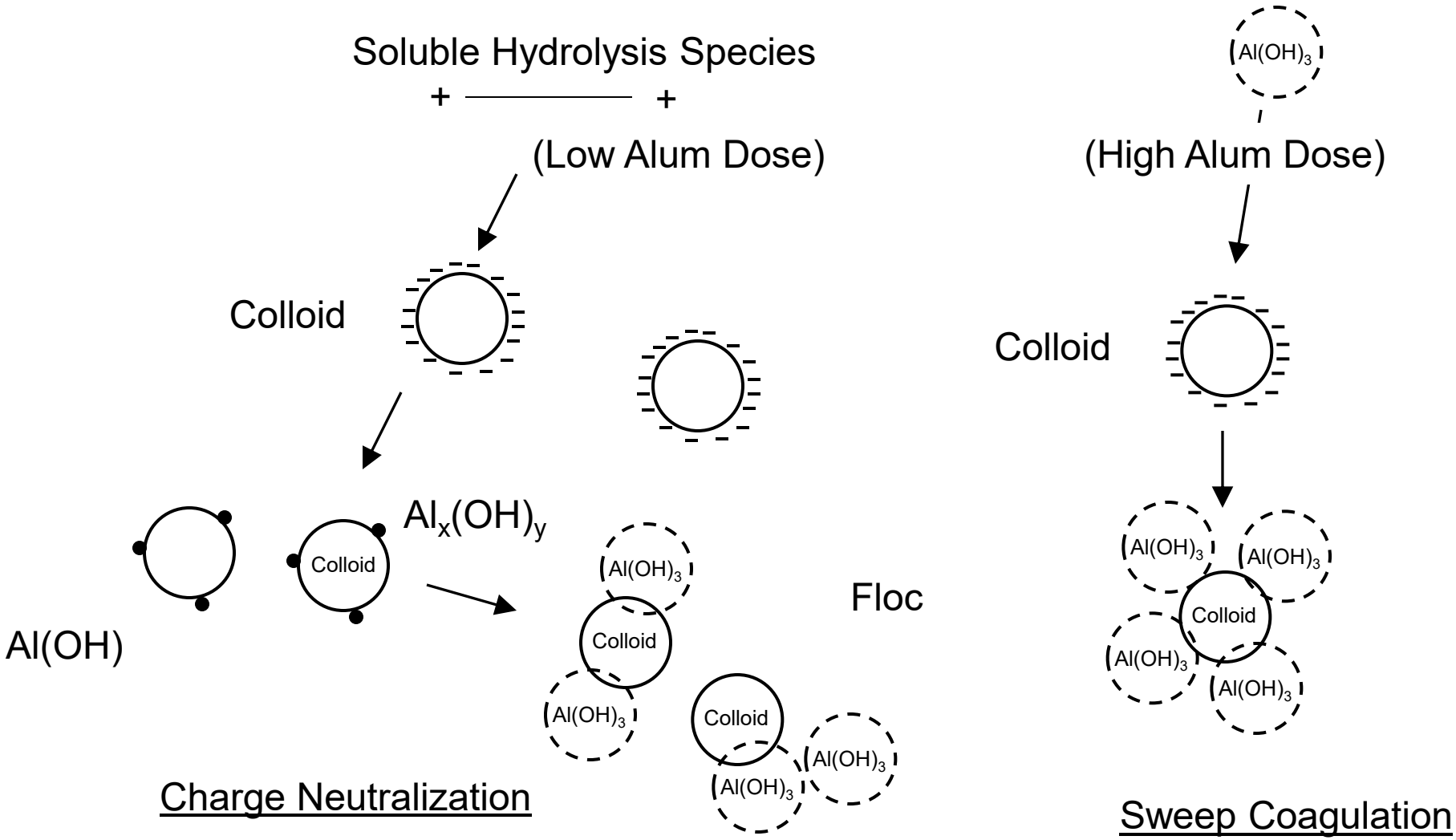
- Intense mixing of coagulant and other chemicals with the water
- Generally performed with mechanical mixers



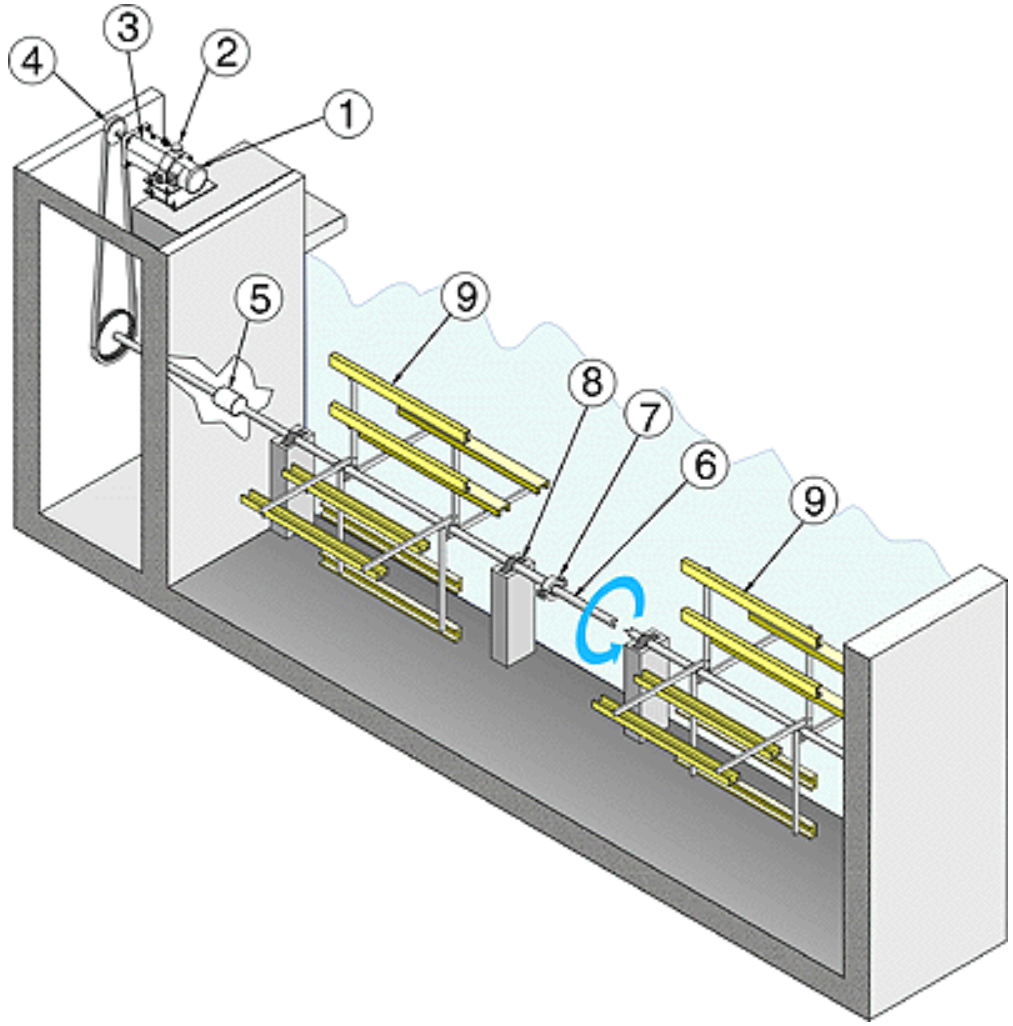
Major Coagulants

- Hydrolyzing metal salts
  - Alum ($Al_2(SO_4)_3$)
  - Ferric chloride ($FeCl_3$)
- Organic polymers (polyelectrolytes)

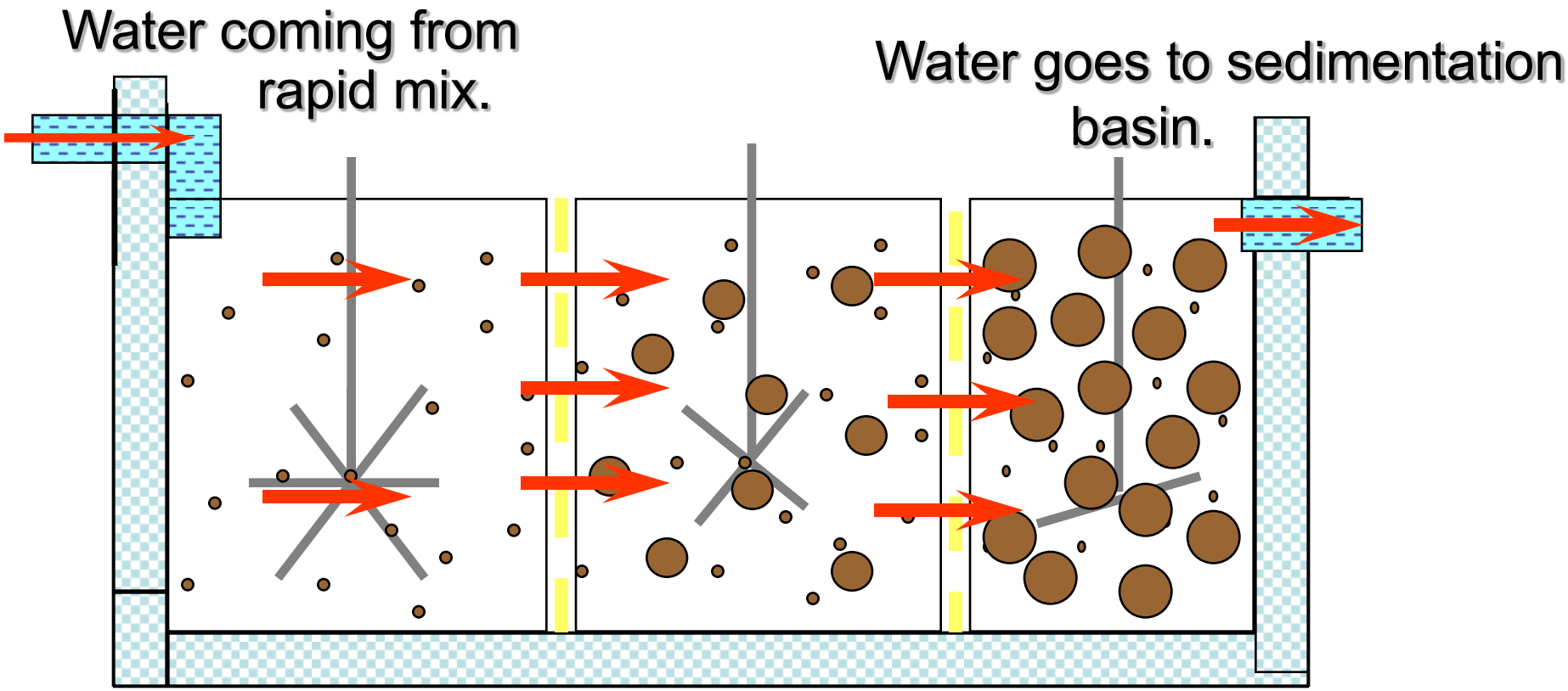
Coagulation with Metal Salts



Horizontal Paddle Flocculator

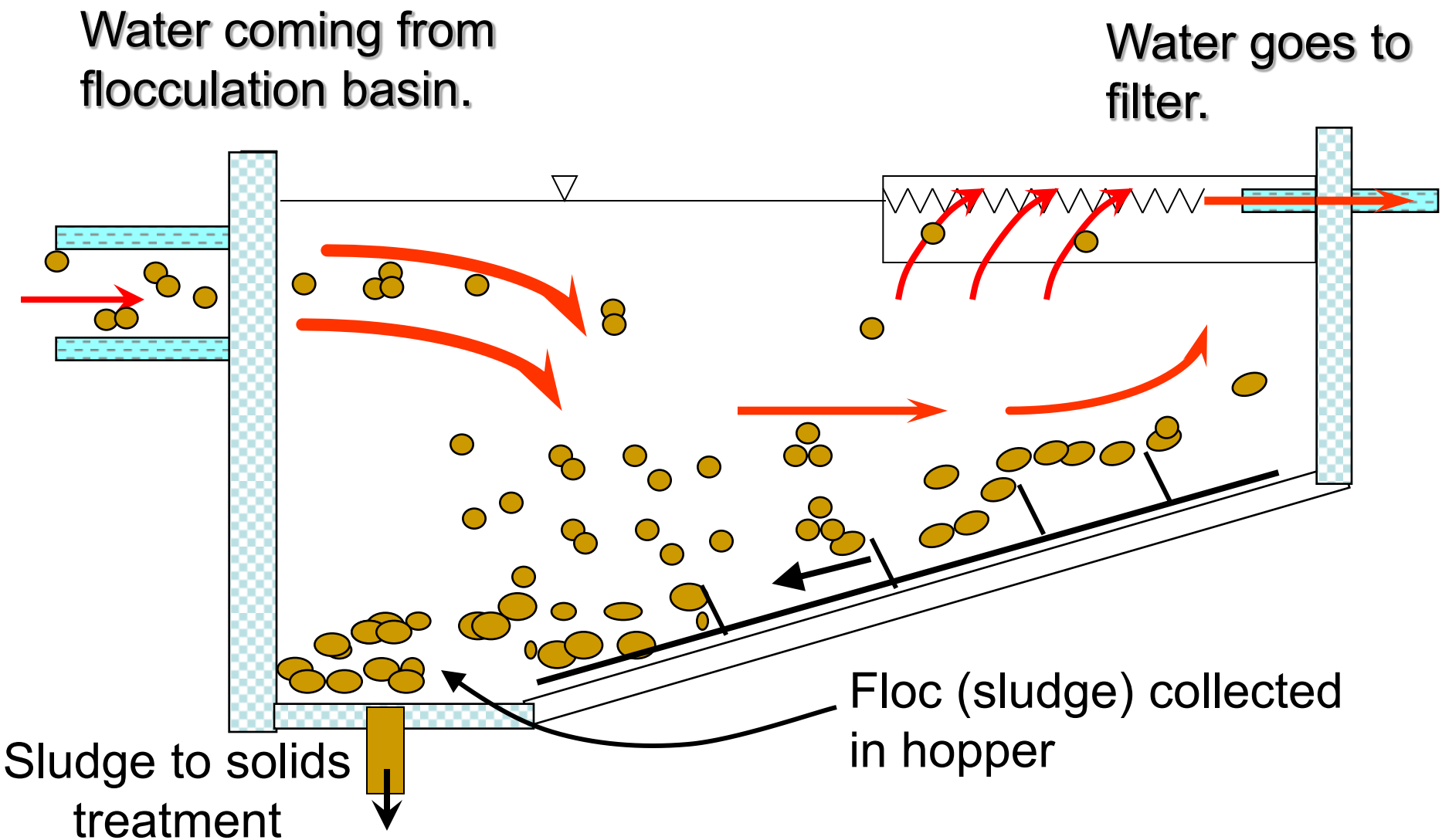


Flocculation process



Sedimentation Basin

Sedimentation Basin Example



Coagulation/flocculation/and sedimentation

- To remove particulates, natural organic materials in water
- Coagulation
  - 20 -50 mg/L of Alum at pH 5.5-6.5 (sweep coagulation)
  - rapid mixing: G values = 300-8000/second
- Flocculation:
  - Slow mixing: G values = 30-70/second
  - Residence time:10 -30 minutes
- Sedimentation
  - Surface loading: 0.3 -1.0 gpm/ft^2
  - Residence time: 1 – 2 hours
- Removal of suspended solids and turbidity: 60-80 %
- Reduction of microbes
  - 74-97 % of Total coliform
  - 76-83 % of fecal coliform
  - 88-95 % of Enteric viruses
  - 58-99 % of *Giardia*
  - 90 % of *Cryptosporidium*

Filtration

- To remove particles and floc that do not settle by gravity in sedimentation process
- Types of granular media
  - Sand
  - Sand + anthracite
  - Granular activated carbon
- Media depth ranges from 24 to 72 inches

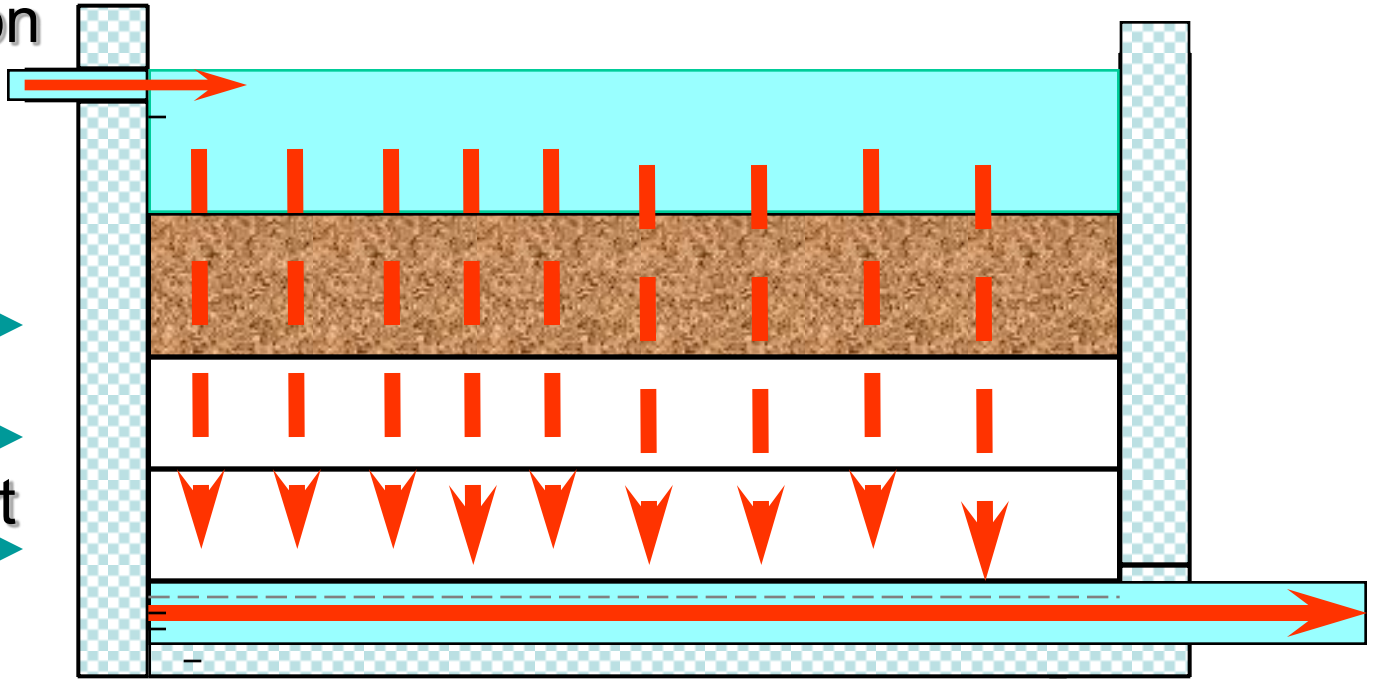
Filter Example

Water coming from sedimentation basin.

Anthracite

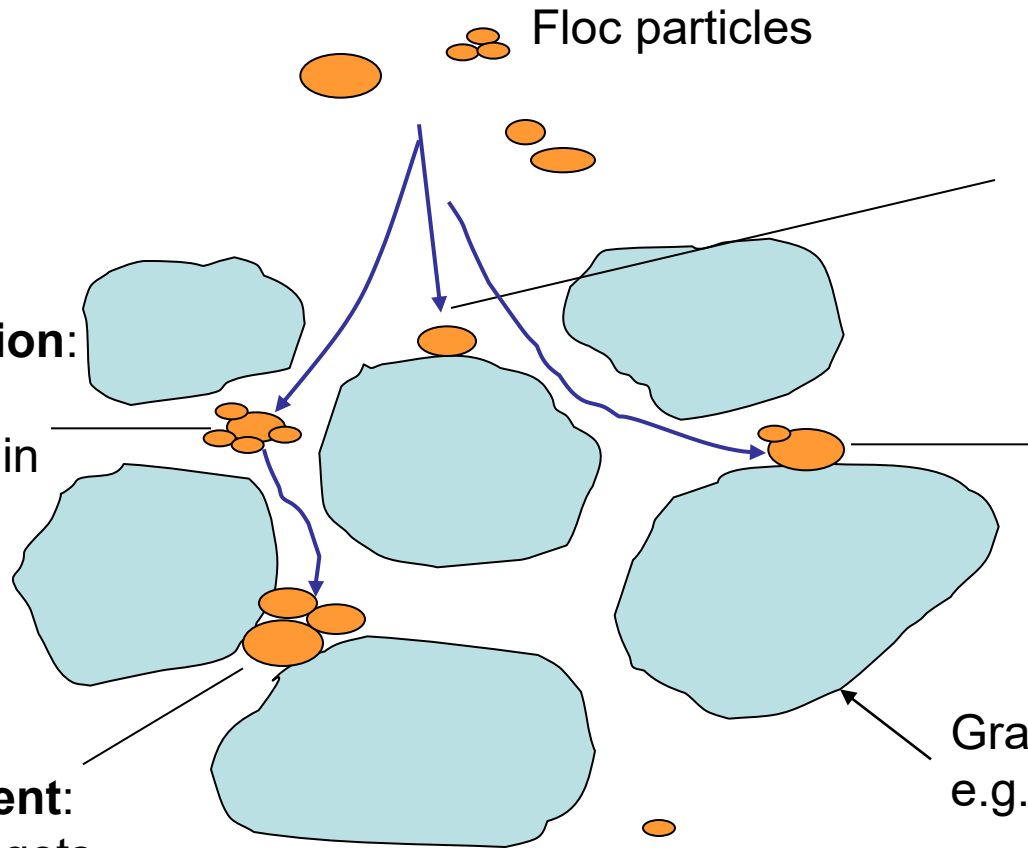
Sand

Gravel (support media)



Water going to disinfection

Mechanisms Involved in Filtration



Removal of bacteria, viruses and protozoa by a granular media filter requires water to be coagulated

Rapid filtration

- To remove particulates in water
- Flow rate: 2-4 gpm/ft^2
- Turbidity: < 0.5 NTU (often times < 0.1 NTU)
- Reduction of microbes
  - 50-98 % of Total coliform
  - 50-98 % of fecal coliform
  - 10-99 % of enteric viruses
  - 97-99.9 % of *Giardia*
  - 99 % of *Cryptosporidium*

Disinfection in water

- To inactivate pathogens in water
- Various types
  - Free chlorine
  - Chloramines
  - Chlorine dioxide
  - Ozone
  - UV

Trend in disinfectant use (USA, % values)

Disinfectant	1978	1989	1999
Chlorine gas	91	87	83.8
$NaClO_2$ (bulk)	6	7.1	18.3
$NaClO_2$ (on-site)	0	0	2
Chlorine dioxide	0	4.5	8.1
Ozone	0	0.4	6.6
Chloramines	0	20	28.4

Comparison between major disinfectants

Consideration	Disinfectants			
	Cl_2	ClO_2	O_3	NH_2Cl
Oxidation potential	Strong	Stronger?	Strongest	Weak
Residuals	Yes	No	No	Yes
Mode of action	Proteins/ NA	Proteins/ NA	Proteins/ NA	Proteins
Disinfecting efficacy	Good	Very good	Excellent	Moderate
By-products	Yes	Yes	Yes?	No

C^*t_{99} Values for Some Health-related Microorganisms (5 °C, pH 6-7)

Organism	Disinfectant			
	Free chlorine	Chloramines	Chlorine dioxide	Ozone
E. coli	0.03 – 0.05	95 - 180	0.4 – 0.75	0.03
Poliovirus	1.1 – 2.5	768 - 3740	0.2 – 6.7	0.1 – 0.2
Rotavirus	0.01 – 0.05	3806 - 6476	0.2 – 2.1	0.06-0.006
G. lamblia	47 - 150	2200	26	0.5 – 0.6
C. parvum	7200	7200	78	5 - 10

$I^*t_{99.99}$ Values for Some Health-Related Microorganisms

Organism	UV dose (mJ/cm2)	Reference
E.coli	8	Sommer et al, 1998
V. cholera	3	Wilson et al, 1992
Poliovirus	21	Meng and Gerba, 1996
Rotavirus-Wa	50	Snicer et al, 1998
Adenovirus 40	121	Meng and Gerba, 1996
C. parvum	< 3	Shin et al, 1999
G. lamblia	< 1	Shin et al, 2001

Ground Water Treatment

Major contaminants in groundwater

- Natural sources
  - Iron and manganese
  - Calcium and magnesium (Hardness)
  - Arsenic
  - Radionuclide
- Artificial sources
  - Nitrate (from infiltration of fertilizer and surface application of pesticides)
  - Synthetic and volatile organic compounds (from improper disposal of industrial wastewater)

Flow diagram of typical groundwater treatment systems

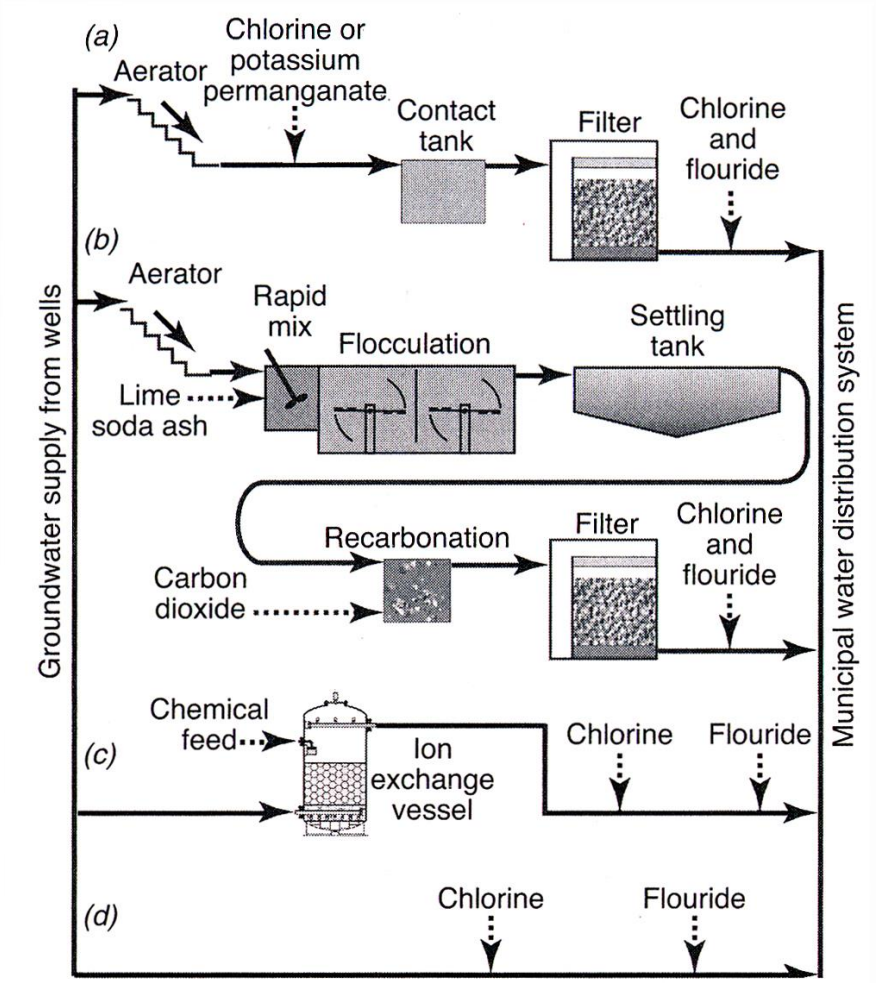


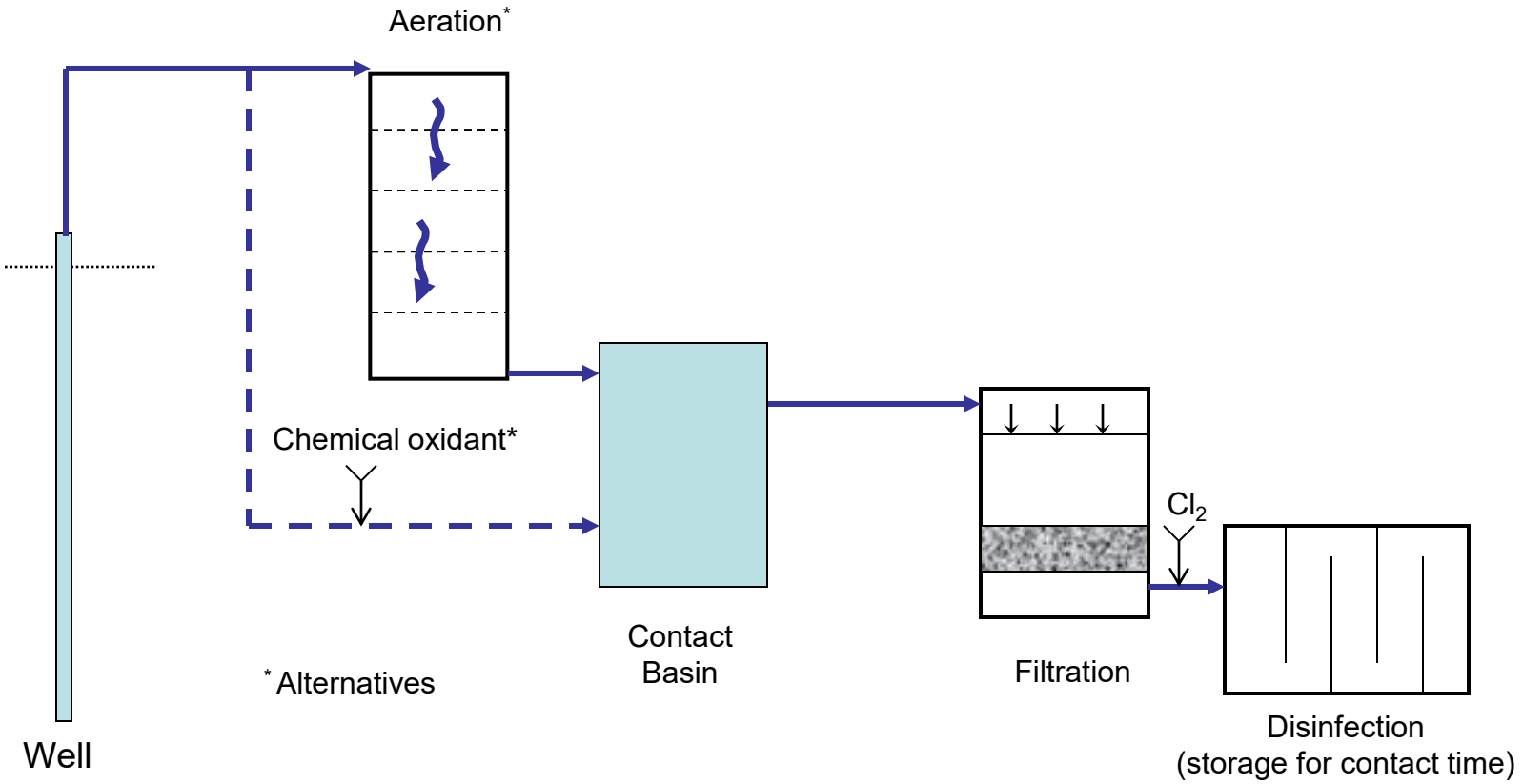
Figure 7–25

Flow diagrams of typical groundwater treatment systems. *(a)* Iron and manganese removal. *(b)* Precipitation softening. *(c)* Ion exchange. *(d)* Disinfection and fluoridation.

Iron and Manganese removal

- To remove Ferrous iron (Fe^{++}) and manganous manganese ion (Mn^{++})
- Aeration, sedimentation, and filtration
  - Fe^{++} + oxygen → FeO_x ↓ (ferric oxides)
- Aeration, chemical oxidation, sedimentation and filtration
  - Fe^{++} + Mn^{++} + oxygen + free chlorine → FeO_x ↓ (ferric oxides) + MnO2 ↓
  - Fe $(HCO_3)_2$ (Ferrous bicarbonate) + $KMnO_4$ (Potassium permanganase) → Fe $(OH)_3$ ↓ (Ferric hydroxide) + MnO_2 ↓ (manganese hydroxide)
  - Mn $(HCO_3)_2$ (Manganese bicarbonate) + $KMnO_4$ (Potassuim permanganase) → MnO_2 ↓ (manganese hydroxide)

Flow diagram of typical groundwater treatment plant for Fe & Mn removal



Hardness removal

- To remove Calcium (Ca++) and Magnesium (Mg++) ions
  - Interfere with laundering by causing excessive soap consumption
  - May produce scale in hot-water heaters and pipes
- Lime (CaO) and soda ash (Na_2CO_3)
  - Lime for carbonate hardness
  - Soda ash for noncarbonate hardness
- Equations in next slide

Hardness removal (equations)

$$CO_2 + Ca(OH)_2 = CaCO_3\downarrow + H_2O \qquad (7\text{–}19)$$

$$Ca(HCO_3)_2 + Ca(OH)_2 = 2CaCO_3\downarrow + 2H_2O \qquad (7\text{–}20)$$

$$Mg(HCO_3)_2 + Ca(OH)_2 = CaCO_3\downarrow + MgCO_3 + 2H_2O$$

$$MgCO_3 + Ca(OH)_2 = CaCO_3\downarrow + Mg(OH)_2\downarrow$$

$$Mg(HCO_3)_2 + 2Ca(OH)_2 = 2CaCO_3\downarrow + Mg(OH)_2\downarrow + 2H_2O \qquad (7\text{–}21)$$

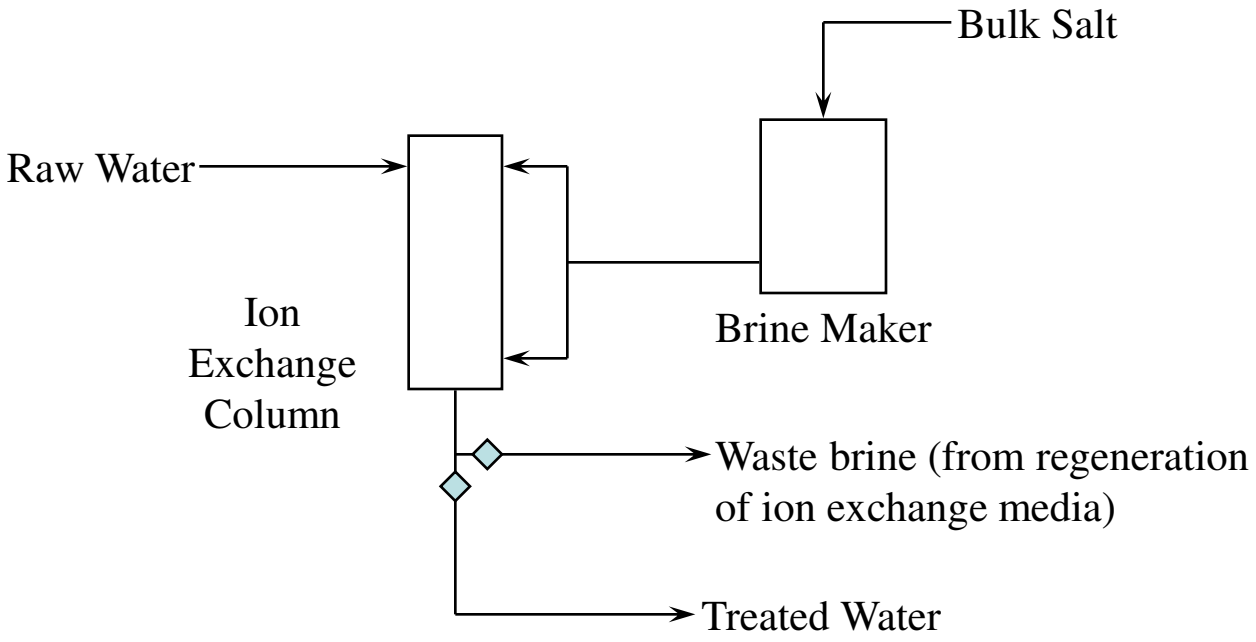
$$MgSO_4 + Ca(OH)_2 = Mg(OH)_2\downarrow + CaSO_4 \qquad (7\text{–}22)$$

$$CaSO_4 + Na_2CO_3 = CaCO_3\downarrow + Na_2SO_4 \qquad (7\text{–}23)$$

Ion exchange

- To remove anions such as nitrate, fluoride, arsenic, and other contaminants or cations such as calcium and magnesium
- Ion exchange vessel, a brine tank for regeneration, a storage tank for spent brine and backwash water, and piping for filtration and backwashing

Ion Exchange Process



Anion exchange for nitrate and arsenic removal

- Nitrate removal

$$2\overline{RCl} + NO_3^- \rightarrow \overline{RNO_3} + Cl^-$$

- Arsenic removal

$$2\overline{RCl} + HAs_4^{2-} \rightarrow \overline{R_2HAsO_4} + 2Cl^-$$

Advanced Treatment Processes

Activated Carbon

Activated carbon

- Manufacture
  - Usually made from either coal product (bituminous coal, lignite, or peat) or wood product (sawdust, coconut shells, or wood)
  - Converted to activated carbon by heating the materials to between 300^{o} and 1000^{o}C.
- The resulting activated carbon
  - Are approximately 1 millimeter sized carbon grains
  - Has large surface area (Handful of GAC has a larger surface area than ten football fields)
  - Adsorb particles and molecules to surface, usually due to molecular-level electrical forces.

Application of activated carbon (I)

- Taste and odor control
- Natural organic matters (NOM's)
- Disinfection-by-products (DBP's)
- Other artificial compounds
  - Volatile organic compounds (TCE, PCE, etc.)
  - MTBE
  - Metals

Application of activated carbon (II)

- Pressure filters

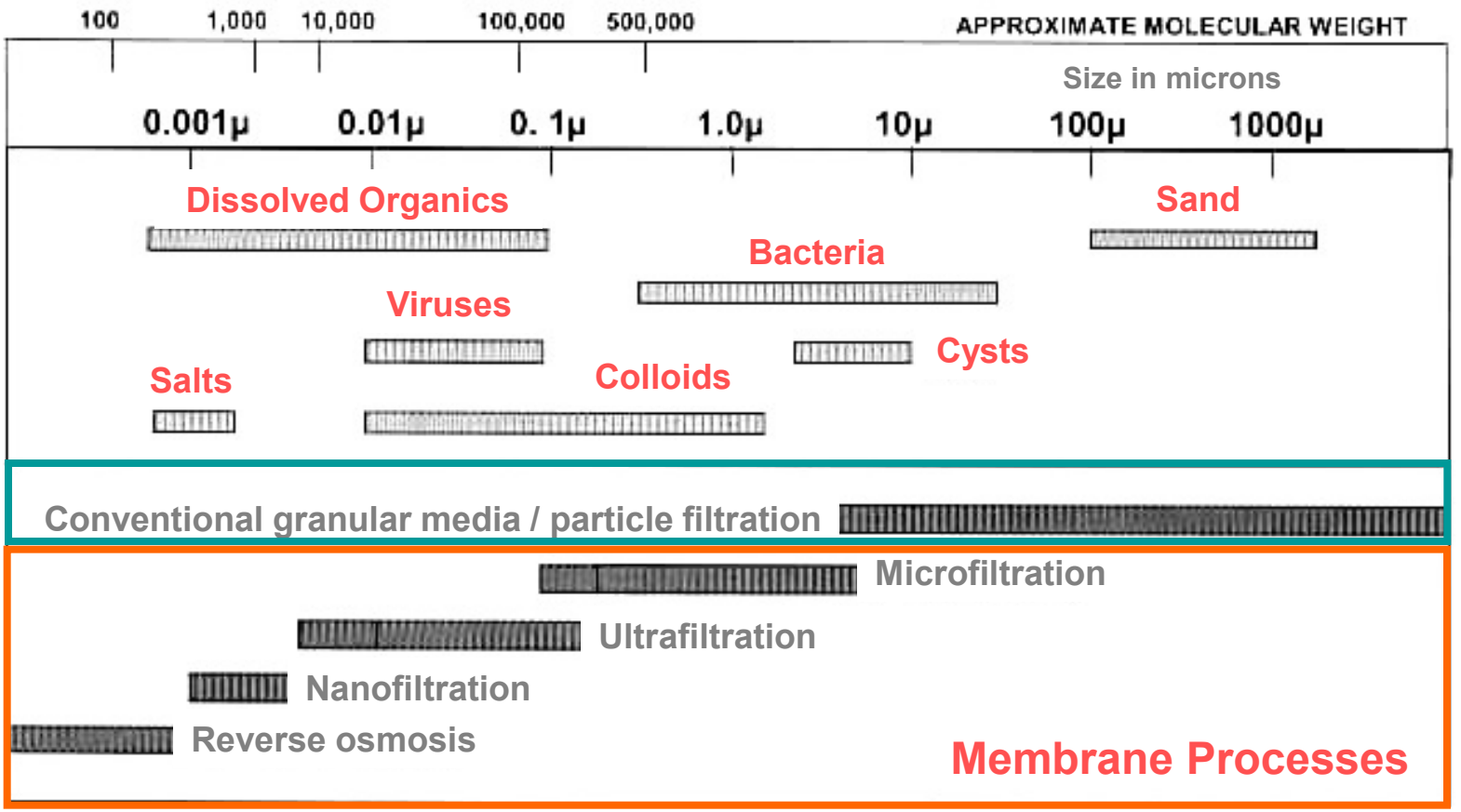
- Gravity filters

Membrane Filtration

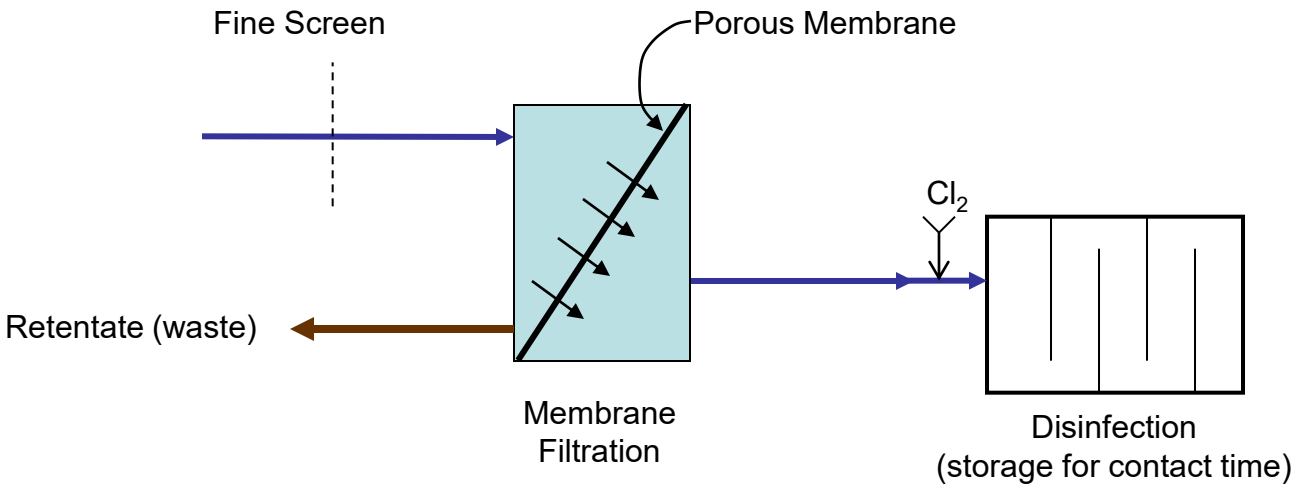
Membrane filtration

- To remove colloidal and particulate contaminants including microorganisms (microfiltration and ultrafiltration) or to separate dissolved salts, organic molecules, and metal ions (nanofiltration and reverse osmosis)
- Pore size
  - Microfiltration (0.7 – 7 μm)
  - Ultrafiltration (0.008 – 0.8 μm)
  - Nanofiltration (0.005 – 0.008 μm)
  - Reverse osmosis (0.0001 – 0.007 μm)

Membrane Filtration Processes



Flow diagram of Membrane Filtration Treatment Plant



Typical modules of membrane filtration

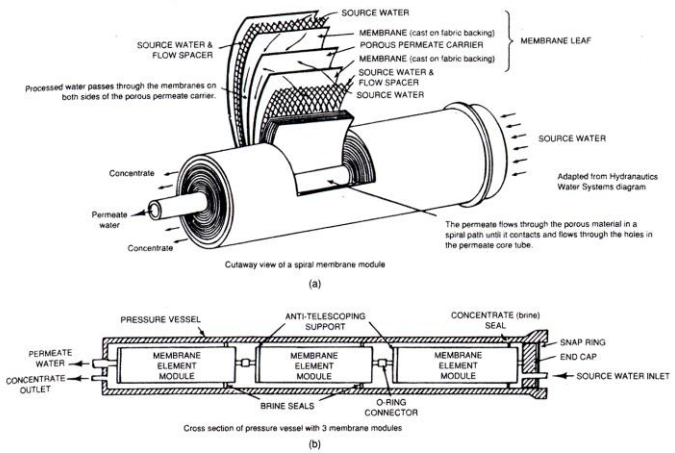


FIGURE 13.4 Typical spiral-wound RO membrane module for pressure-driven processes. Vessels with side ports near the end caps for feed and concentrate connections are also available. [*Adapted from* The U.S.A.I.D. Desalination Manual *(Buros et al., 1980) and is used courtesy of the U.S. Agency for International Development.*]

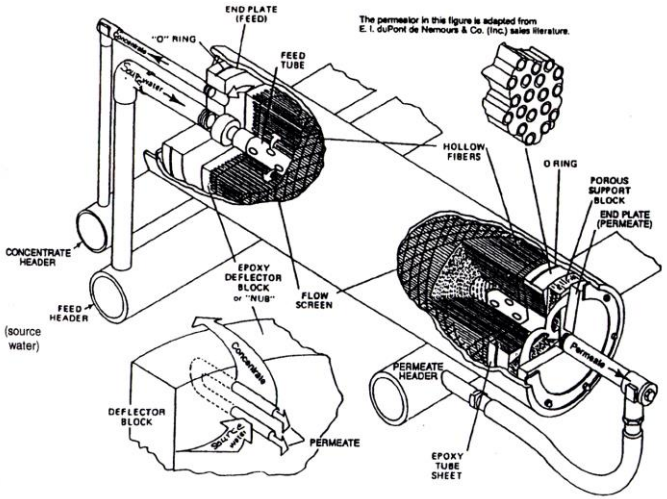


FIGURE 13.5 Typical hollow fine-fiber RO membrane module. [*Adapted from* The U.S.A.I.D. Desalination Manual *(Buros et al., 1980) and is used courtesy of the U.S. Agency for International Development.*]

Outside-in (vacuum) hollow fiber microfiltration module (install submerged in water)

Skid-mounted membrane unit

Flow diagram of a submerged membrane filtration process

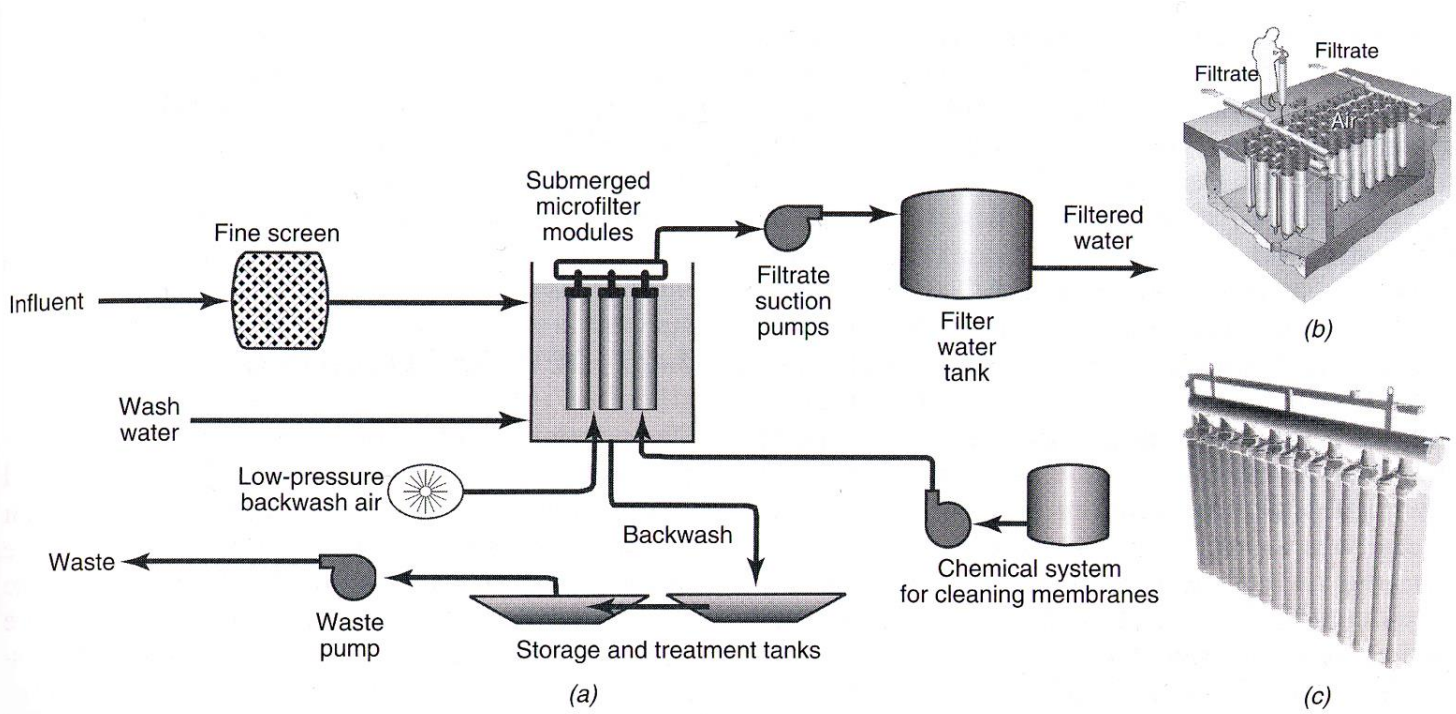
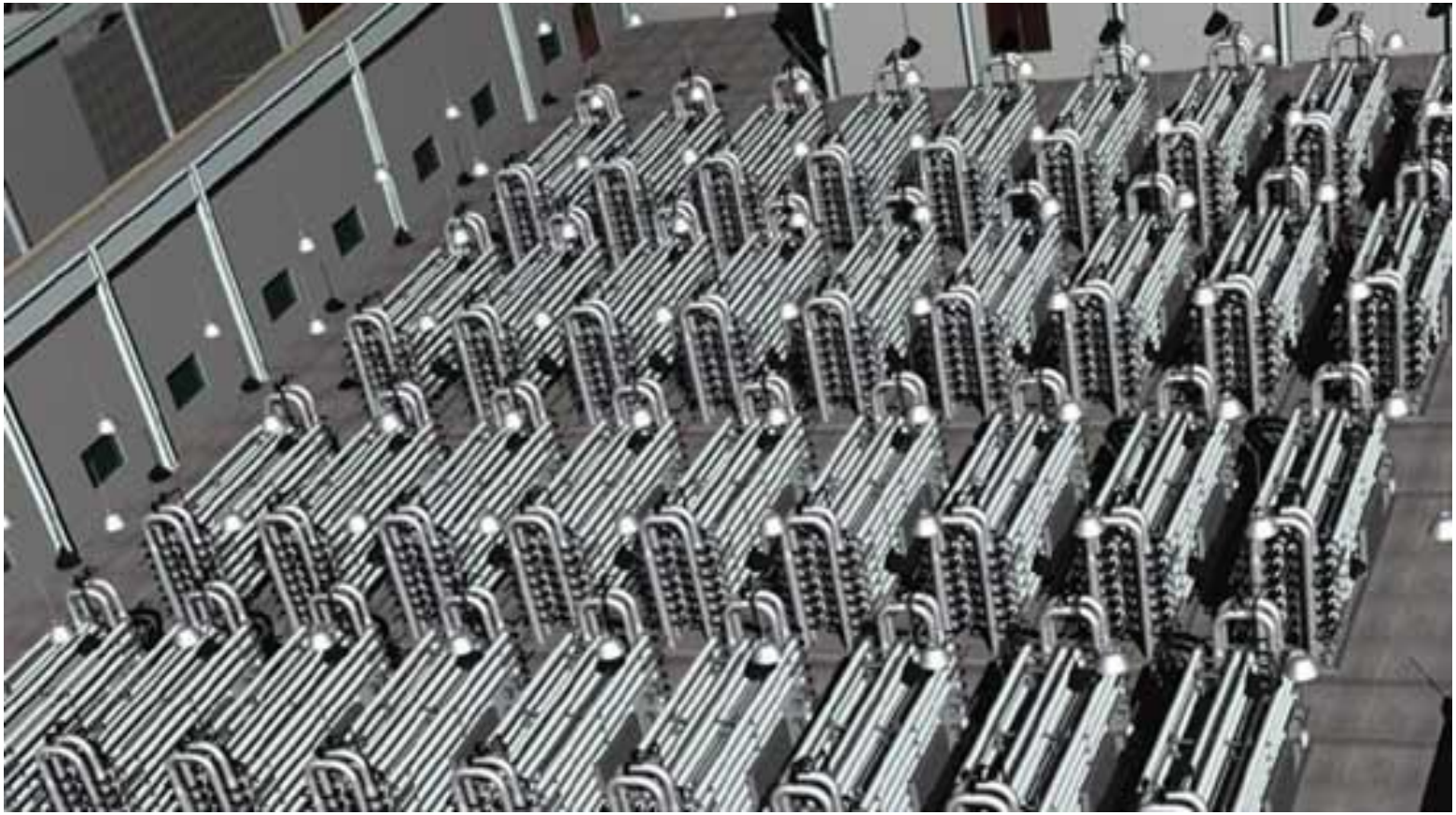


Figure 7–37

Memcor® continuous microfiltration-submerged (CMF-S) process. *(a)* Cell containing membrane modules and peripheral equipment including influent screen, filtration suction pumps, blowers for air scour, wash-water tank, chemical membrane cleaning system, and backwash processing. *(b)* Modules in a cell are grouped together in several manifolded assembles. *(c)* A manifold with suspended microfiltration modules.
(Courtesy of US Filter/Memcor.)

Multiple Membrane Units



Point-Of-Use devices

Point-of-Use Treatment Devices

Typical point-of-use treatment devices with filters and reverse osmosis units

Other POU devices

- Ion exchange
- UV
- All point-of-use devices are only as good as the maintenance provided (filter replacement, UV lamp cleaning and replacement, membrane cleaning and replacement)