Wastewater treatment processes overview

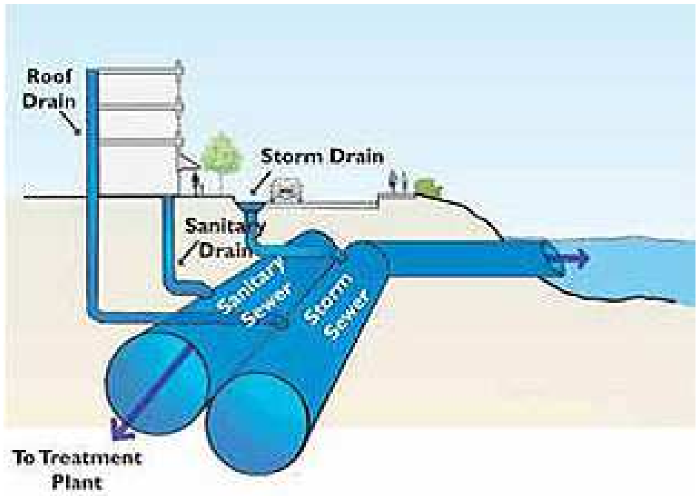
Today's lecture

- Sewer networks
- Municipal wastewater treatment systems
  - Overview
  - Pretreatment: Screens, Grit chamber, flow equalization
  - Primary treatment
  - Secondary treatment
  - Tertiary (advanced) treatment

Sewer networks

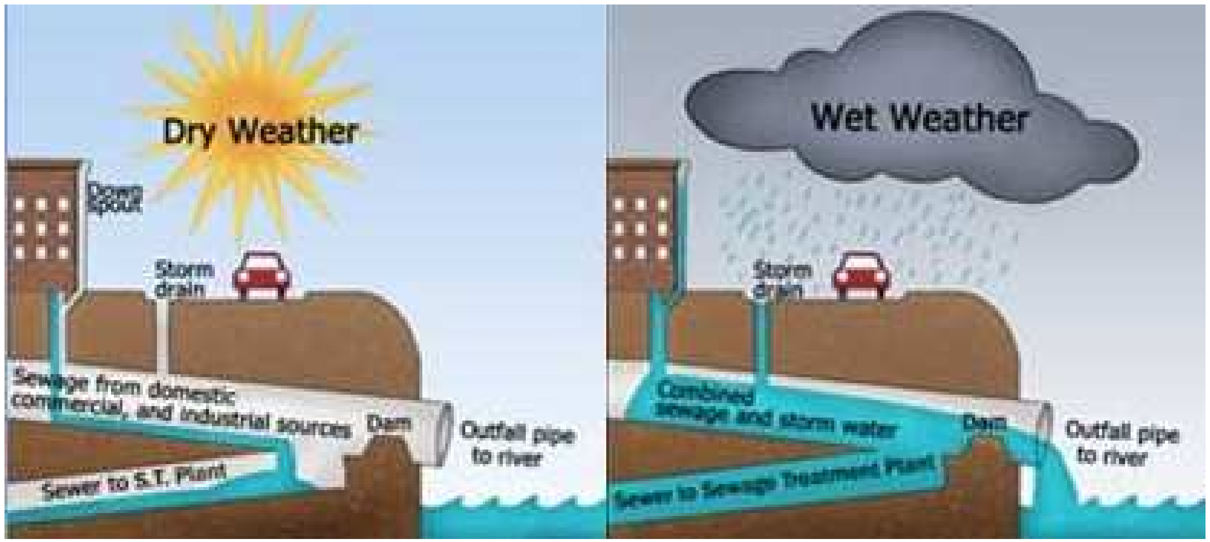
- Combined sewer
  - Sewage and stormwater are collected by a single pipeline
  - Usually for old cities
- Separate sewer
  - Dual pipeline system to collect sewage and stormwater separately
  - New constructions usually adopt separate sewer

#1



Combined sewer overflow (CSO)

- Some diluted wastewater flows directly to the water body during storm events
- Constant CSO in some cases (release of CSO w/o dilution!) due to exceedance of design sewage flowrate



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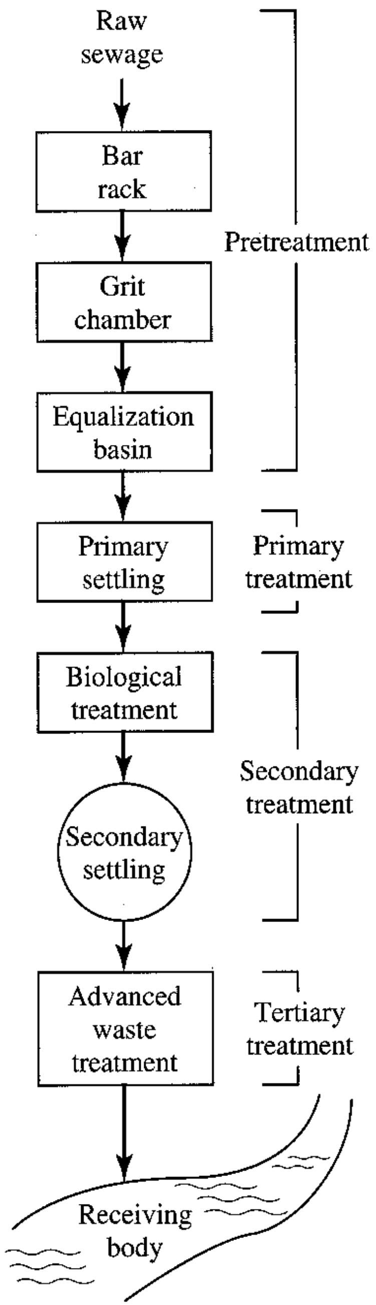

Municipal wastewater treatment systems

- Pretreatment: removes materials that can cause operational problems, equalization optional
- Primary treatment: remove ~60% of SS and ~35% of BOD
- Secondary treatment – remove ~85% of BOD and SS; N/P removal
- Advanced (tertiary) treatment – more BOD and/or SS removal, N/P removal, refractory organics, or others

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Bar racks (screens)

- Purpose: to remove large objects that would damage or foul pumps, valves, and other mechanical equipment

Manually-cleaned bar screen

#4

Mechanically-cleaned bar screen

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Grit chamber

- Grits: inert dense materials such as sand, broken glass, silt, and pebbles
- Purpose: to remove grits that can abrade pumps and other mechanical devices

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Rectangular horizontal flow grit chamber

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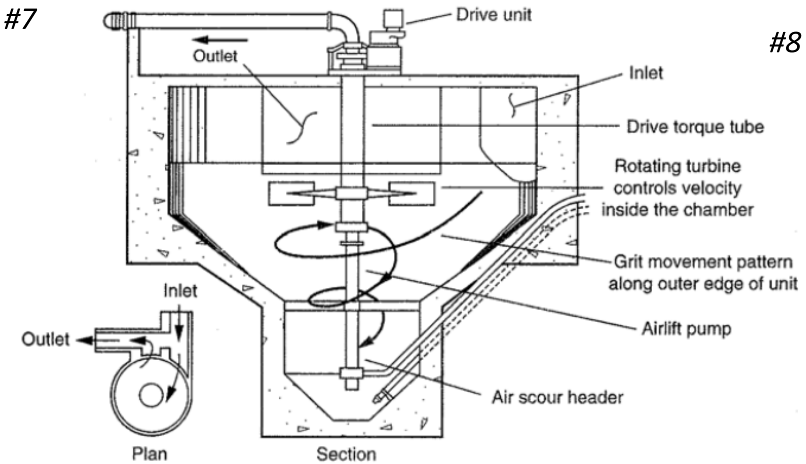


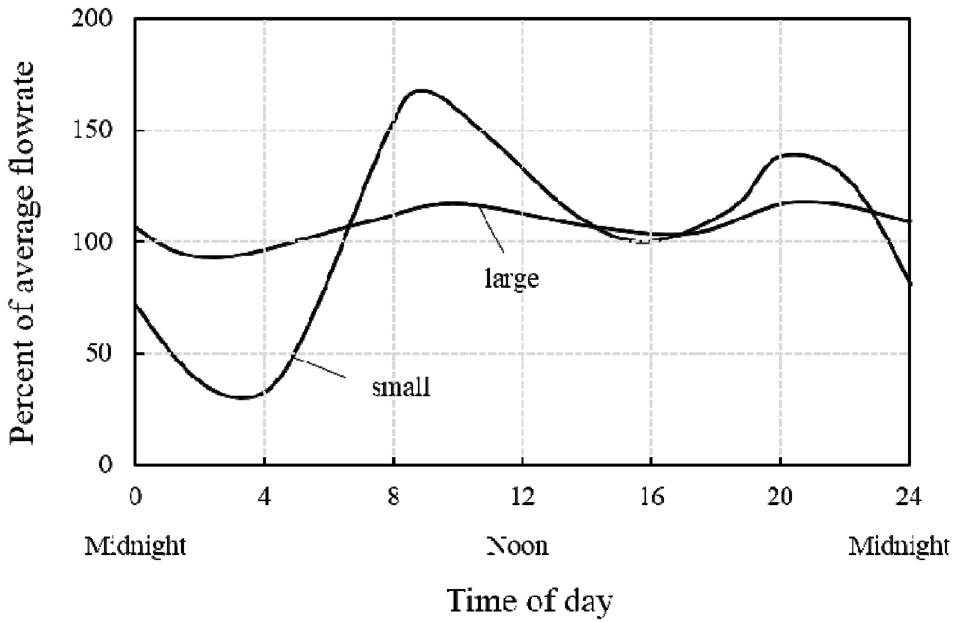
Vortex-type grit chamber

Flow equalization

- **Daily variations**
  - Significant daily variations of flowrate especially for small collections systems

  ** note the lag time for wastewater to reach the treatment plant*

  - Constituent concentration also varies over time



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Flow equalization

- Purpose: dampen flowrate variations (and concentration variations) to
  - i) overcome the operational problems caused by flowrate variations
  - ii) improve the performance of the downstream processes
  - iii) reduce the size and cost of downstream treatment facilities

Flow equalization

- **Method of application: in-line or off-line**
  - In-line: can achieve dampening of constituent concentration in addition to the dampening of flowrate
  - Off-line: pumping requirements are minimized

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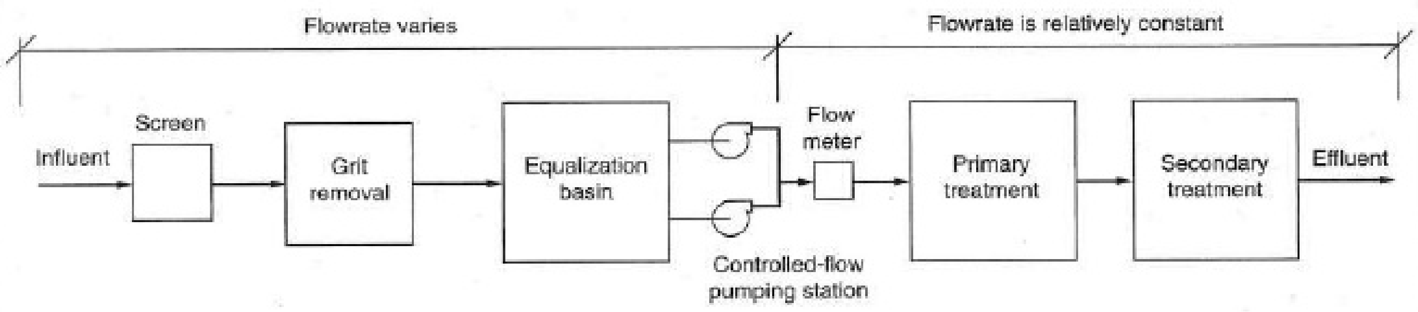
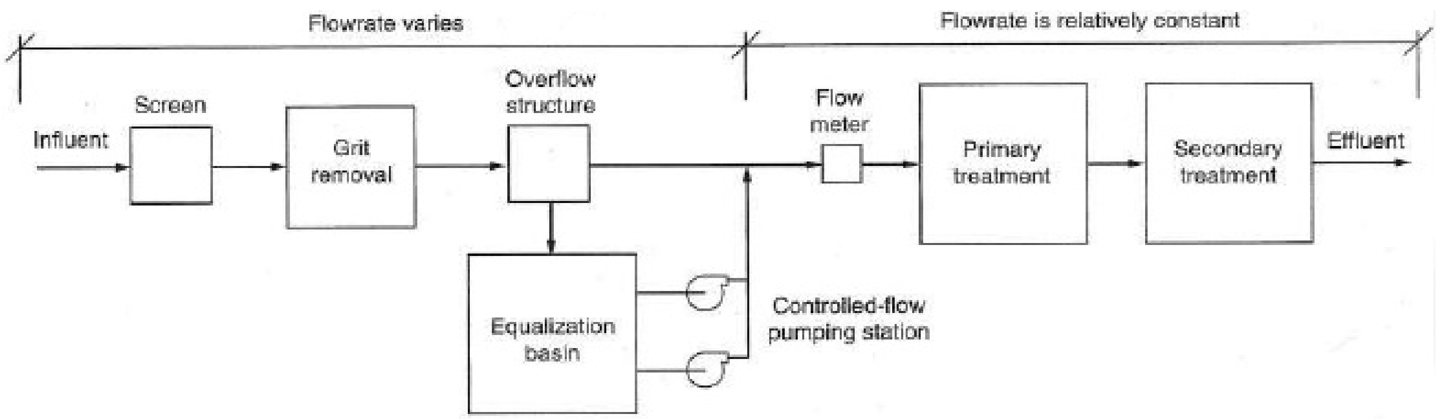
[In-line]



[Off-line]



Primary sedimentation basins

- Removal of suspended solids by settling
- This removes some BOD as well!
- Removes ~60% of SS and ~35% of BOD
- Sludge settled at the bottom and collected by mechanical devices
- Floating materials such as oil and grease are also removed

Primary sedimentation basins

- Design parameters
  - Retention time: ~2 hr
  - Overflow rate, v_0: determines particle removal efficiency

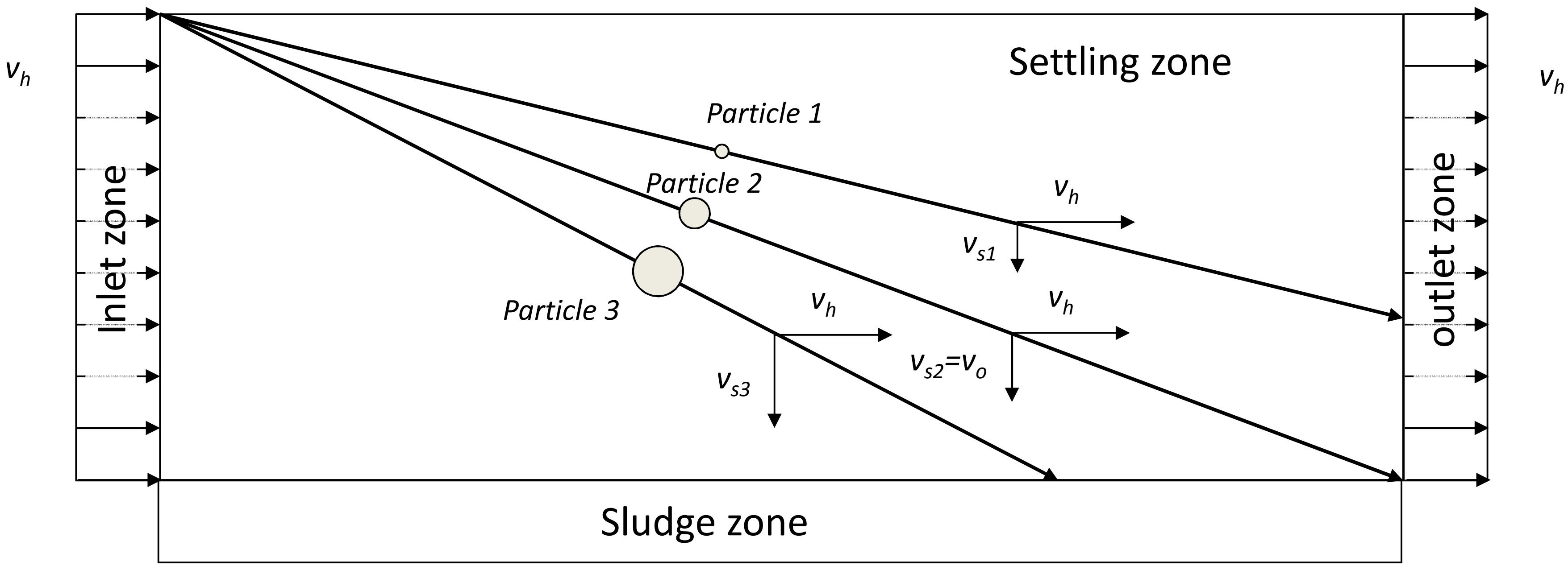
$$v_o = \frac{Q}{A_c}$$

Q = water flow rate (m^3/s)

A_c = surface area of the sedimentation basin (m^2)

Removal of particles in sedimentation basins

Assume a rectangular sedimentation basin:



particle 1: $v_{s1} < v_o$ → partial removal

particle 2: $v_{s2} = v_o$ → 100% removal

particle 3: $v_{s3} > v_o$ → 100% removal

Removal of particles in sedimentation basins

From the diagram in the previous slide,

(time for water to flow through the settling zone) [1]

= (settling zone length, L) / (horizontal velocity, v_h)

(time for particle with settling vel. of v_o entering at the top to settle) [2]

= (settling zone height, H) / (settling velocity, v_o)

Equating [1] and [2], $\frac{L}{v_h} = \frac{H}{v_o}$

⇨ $$v_o = \frac{Q}{A_c}$$

v_o = **overflow rate** *(m/s)*

A_c = surface area of the basin (m^2)

For particles with settling velocity (v_s) greater than v_o, 100% removed;

For particle with v_s smaller than v_o, removal efficiency is v_s/v_o x 100 (%)

Primary sedimentation basins

- Rectangular or circular

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#12

Secondary treatment

- Goal: provide BOD removal beyond what is achieved in primary treatment
  - Removal of soluble BOD
  - Additional removal of SS
- How: by providing favorable conditions for microbial activities
  - Availability of high density of microorganisms
  - Good contact between organisms and wastes
  - Favorable temperature, pH, nutrients, carbon source (food)
  - Oxygen (or other electron acceptors)
  - No or little toxic chemicals present

Secondary treatment - bioreactors

#13

suspended growth

#14

attached growth

We'll learn further later!

Tertiary (advanced) treatment

- Goal: to improve the quality of the secondary treatment effluent
- Many of the Korean wastewater treatment plants now have advanced treatment process
- Further BOD and SS removal, nutrient removal, TDS removal, or the removal of refractory organic compounds
- Different processes can be used depending on the major target

Tertiary – Granular filtration

- Additional removal of SS
- Sand is most frequently used
- Backwash needed when effluent quality degrades or the filter clogs

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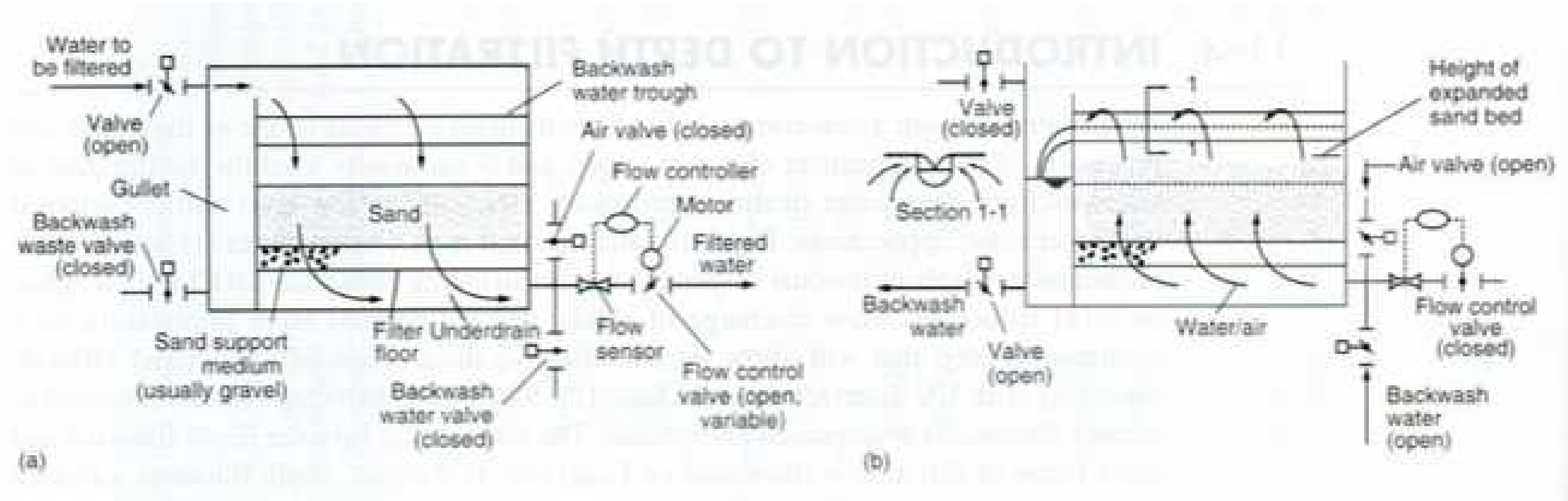
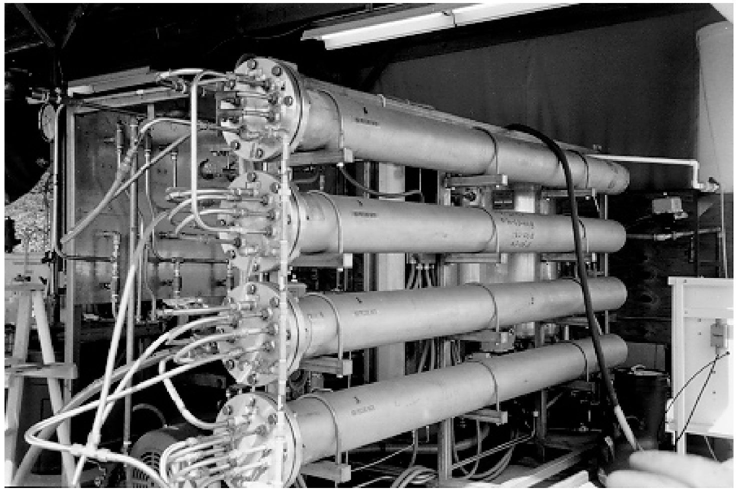


<Filtration> <Backwash>

Tertiary – Membrane filtration

- Additional removal of SS
- Getting economically viable by advances in membrane techniques



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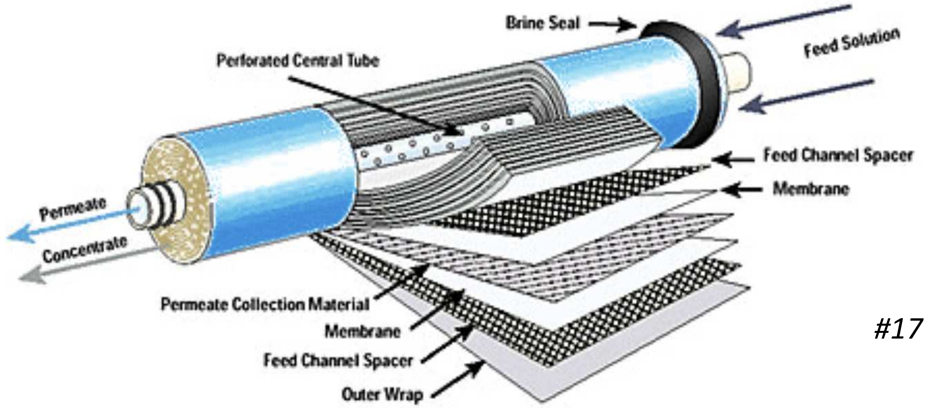

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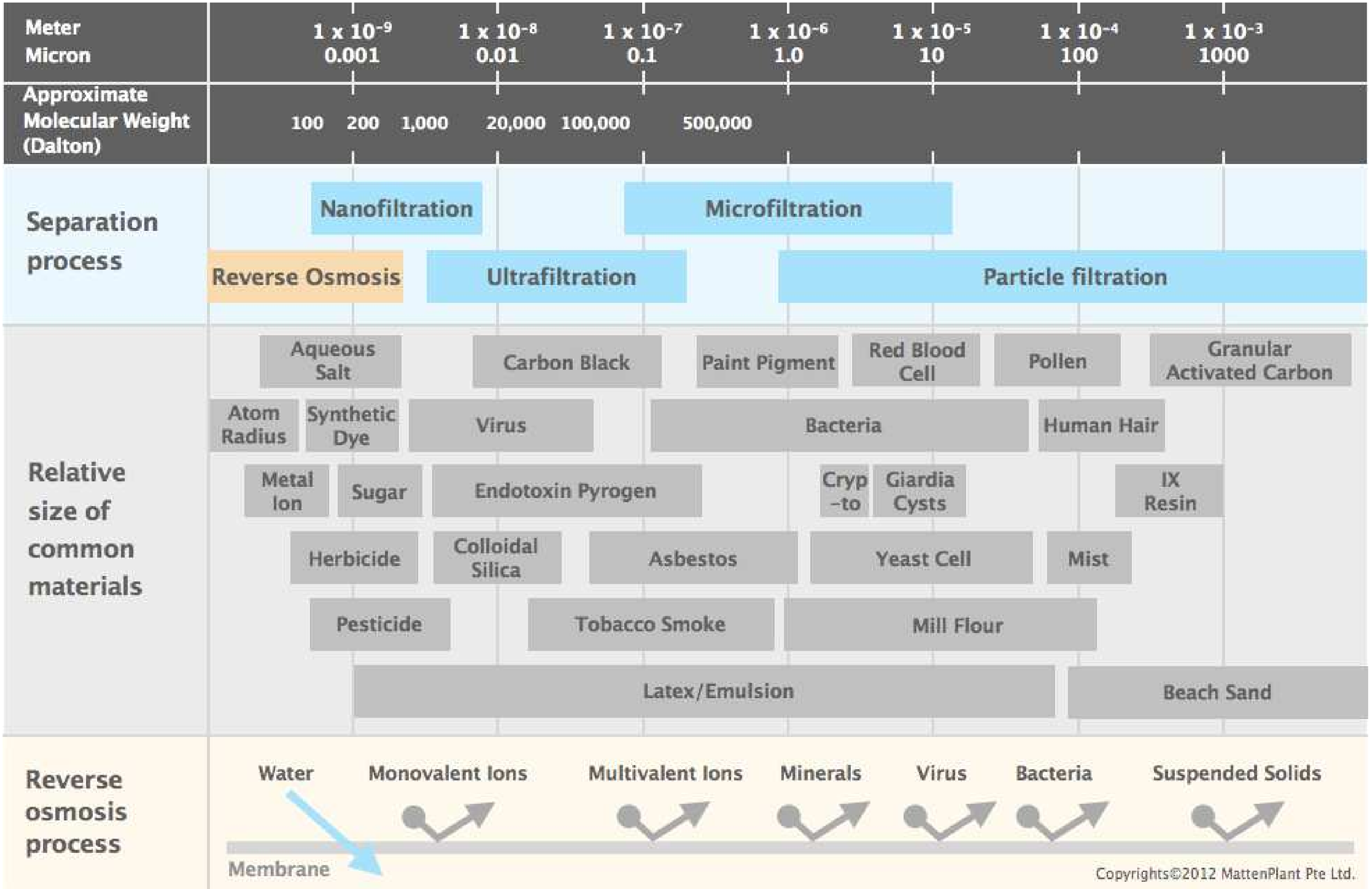
Tertiary – Membrane filtration



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Tertiary – Chemical P removal

- Use chemicals (ferric chloride, alum, lime, …) to precipitate P from secondary effluent
  - Using ferric chloride:

    $$FeCl_3 + HPO_4{}^{2-} \rightleftharpoons FePO_4 \downarrow + H^+ + 3Cl^-$$

  - Using alum

    $$Al_2(SO_4)_3 + 2HPO_4{}^{2-} \rightleftharpoons 2AlPO_4 \downarrow + 2H^+ + 3SO_4{}^{2-}$$

  - Using lime:

    $$5Ca(OH)_2 + 3HPO_4{}^{2-} \rightleftharpoons Ca_5(PO_4)_3OH \downarrow + 3H_2O + 6OH^-$$

Tertiary – Granular activated carbon adsorption

- Removal of refractory organic compounds

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