Wastewater treatment processes overview

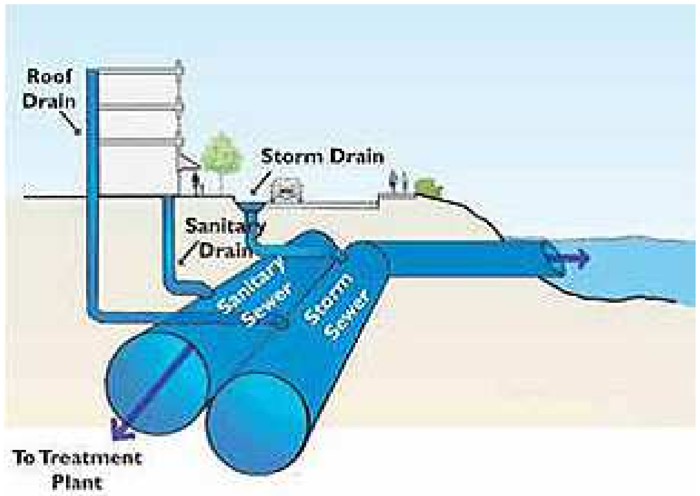
Today's class

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

Sewer networks

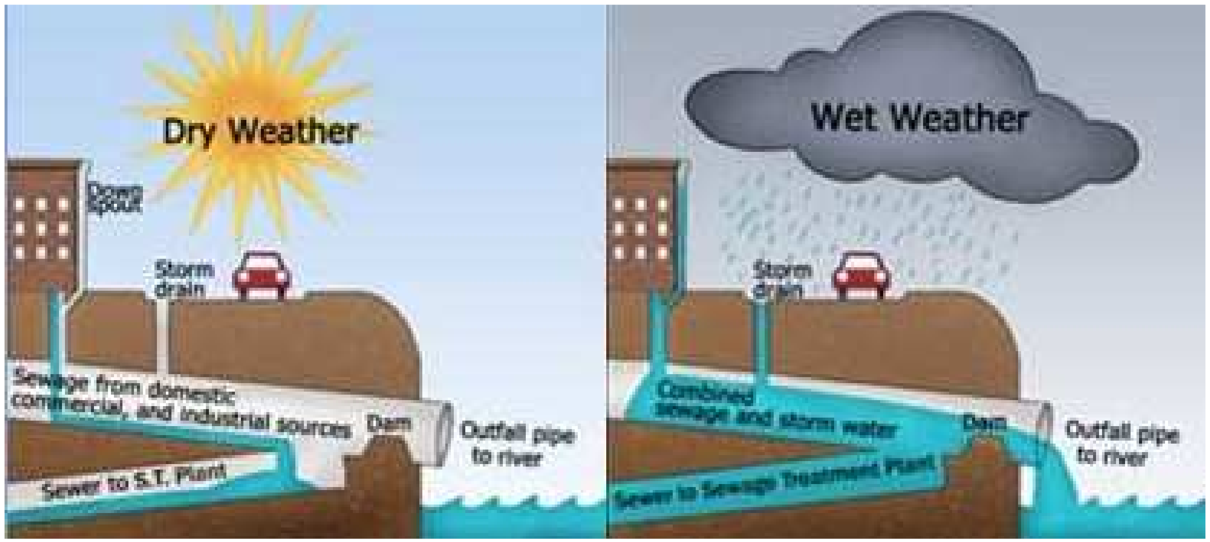
- Combined sewer
  - Sewage and stormwater are collected by a single pipeline
  - Usually for old cities

- Separate sewer
  - Dual pipeline system to collect sewage and stormwater separately
  - New constructions usually adopt separate sewer

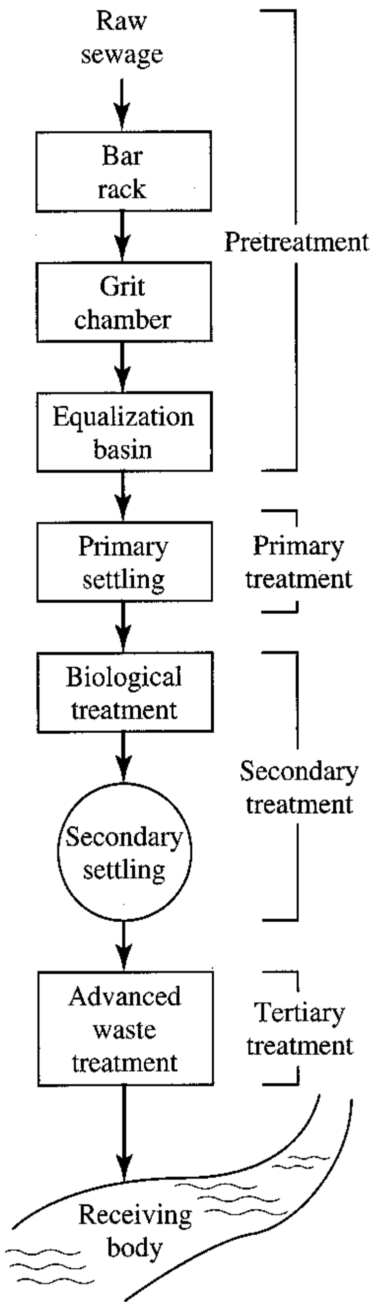


Combined sewer overflow (CSO)

- 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



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

Bar racks (screens)

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

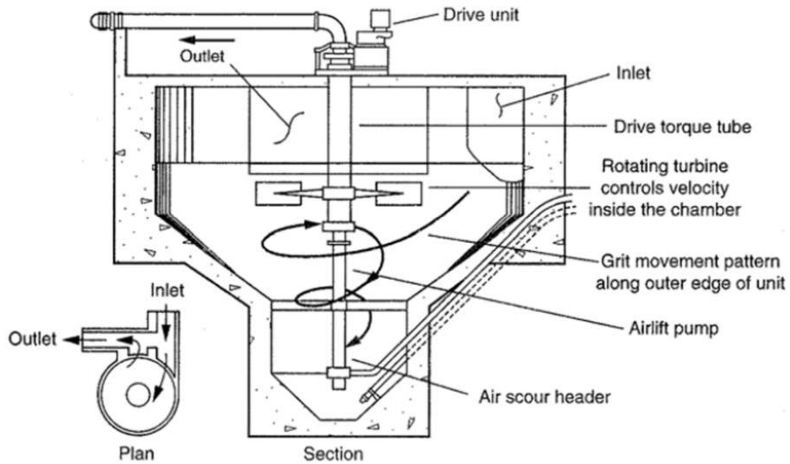
Manually-cleaned bar screen

Mechanically-cleaned bar screen

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

Rectangular horizontal flow grit chamber



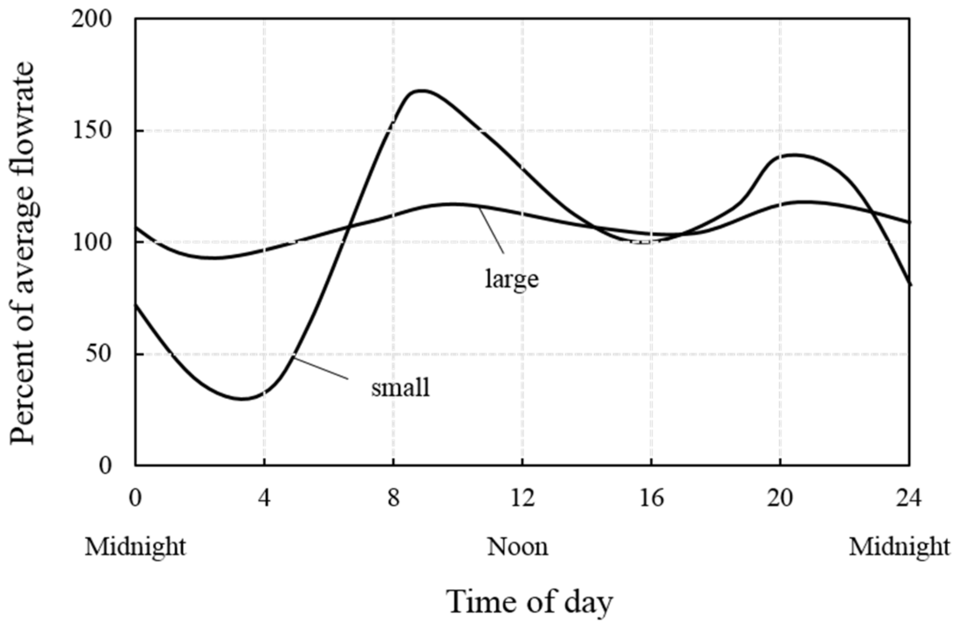
Vortex-type grit chamber

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



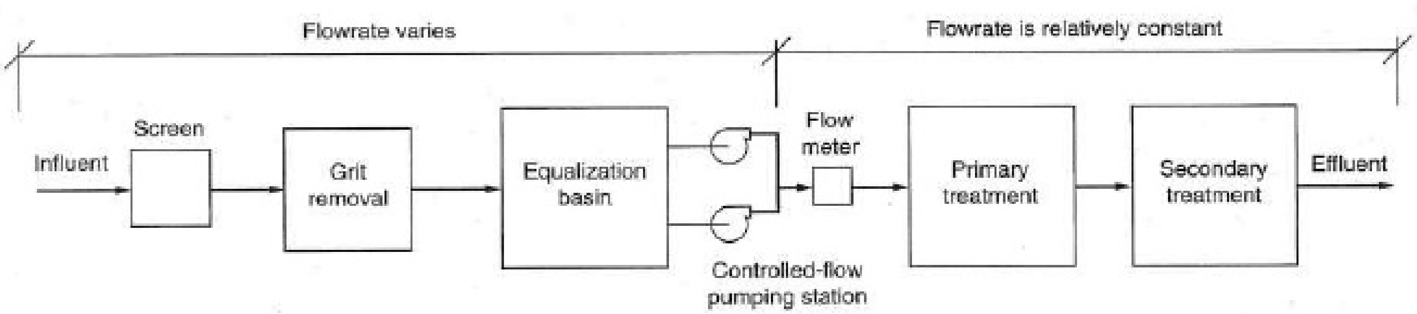
Flow equalization

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

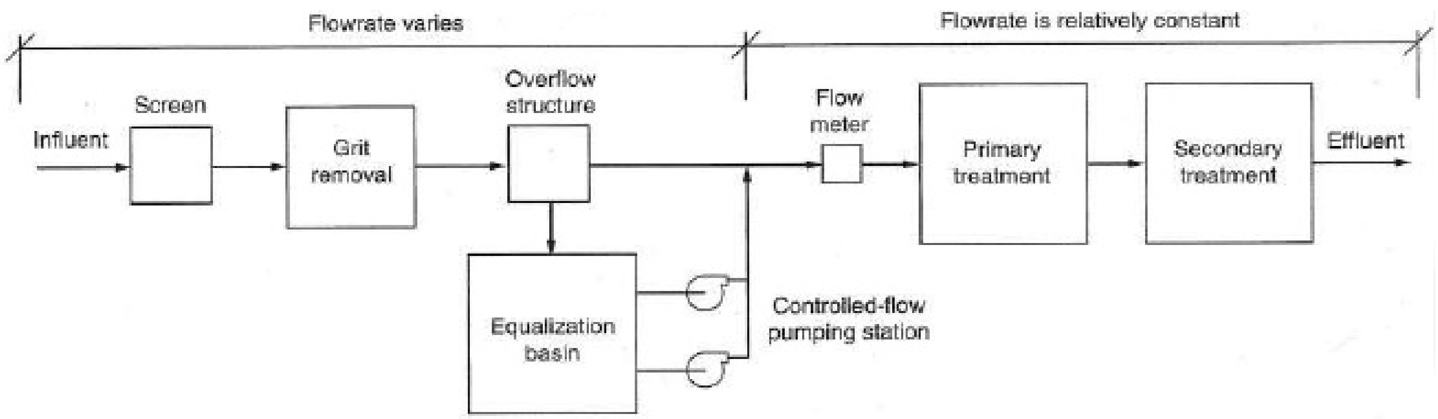
Flow equalization

- **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

[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

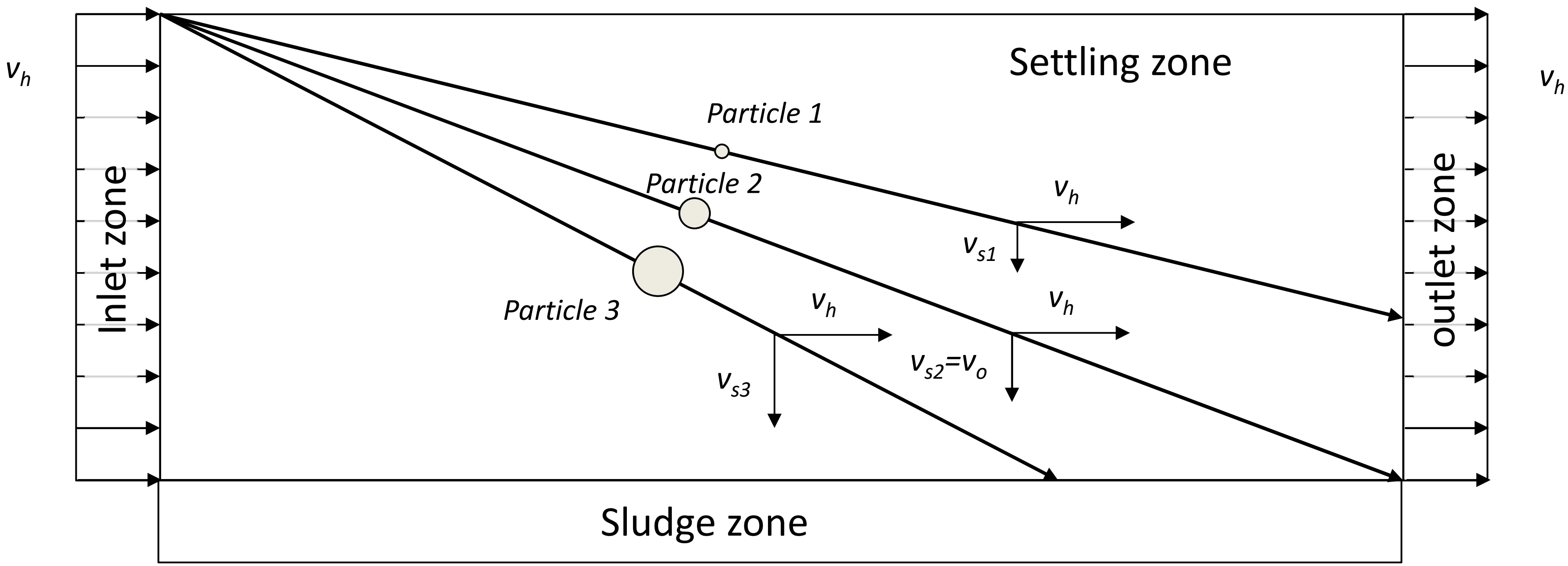
$$v_o = \frac{Q}{A_c}$$

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

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

suspended growth

attached growth

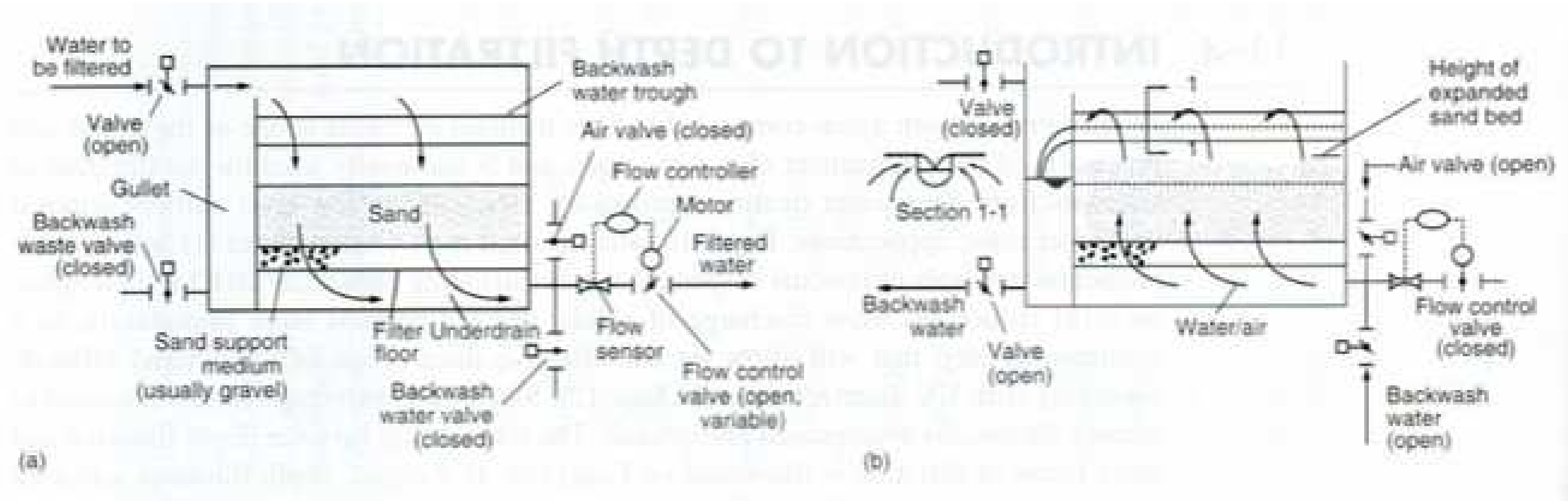
We'll learn further later!

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

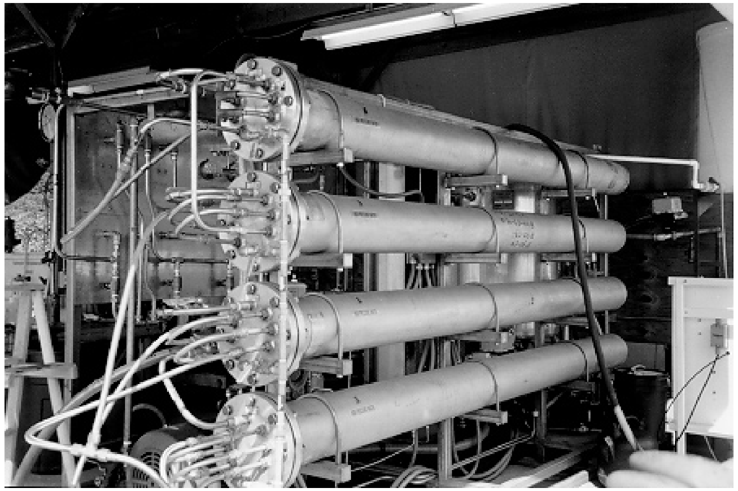
- Additional removal of SS
- Sand is most frequently used
- Backwash needed when effluent quality degrades or the filter clogs

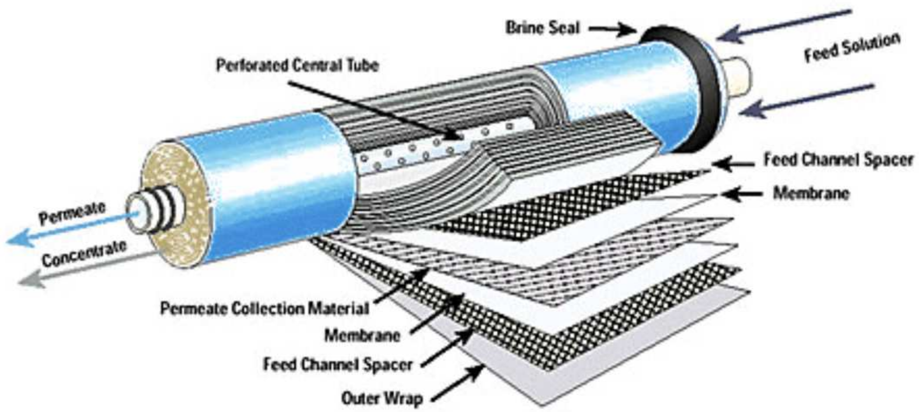


<Filtration> <Backwash>

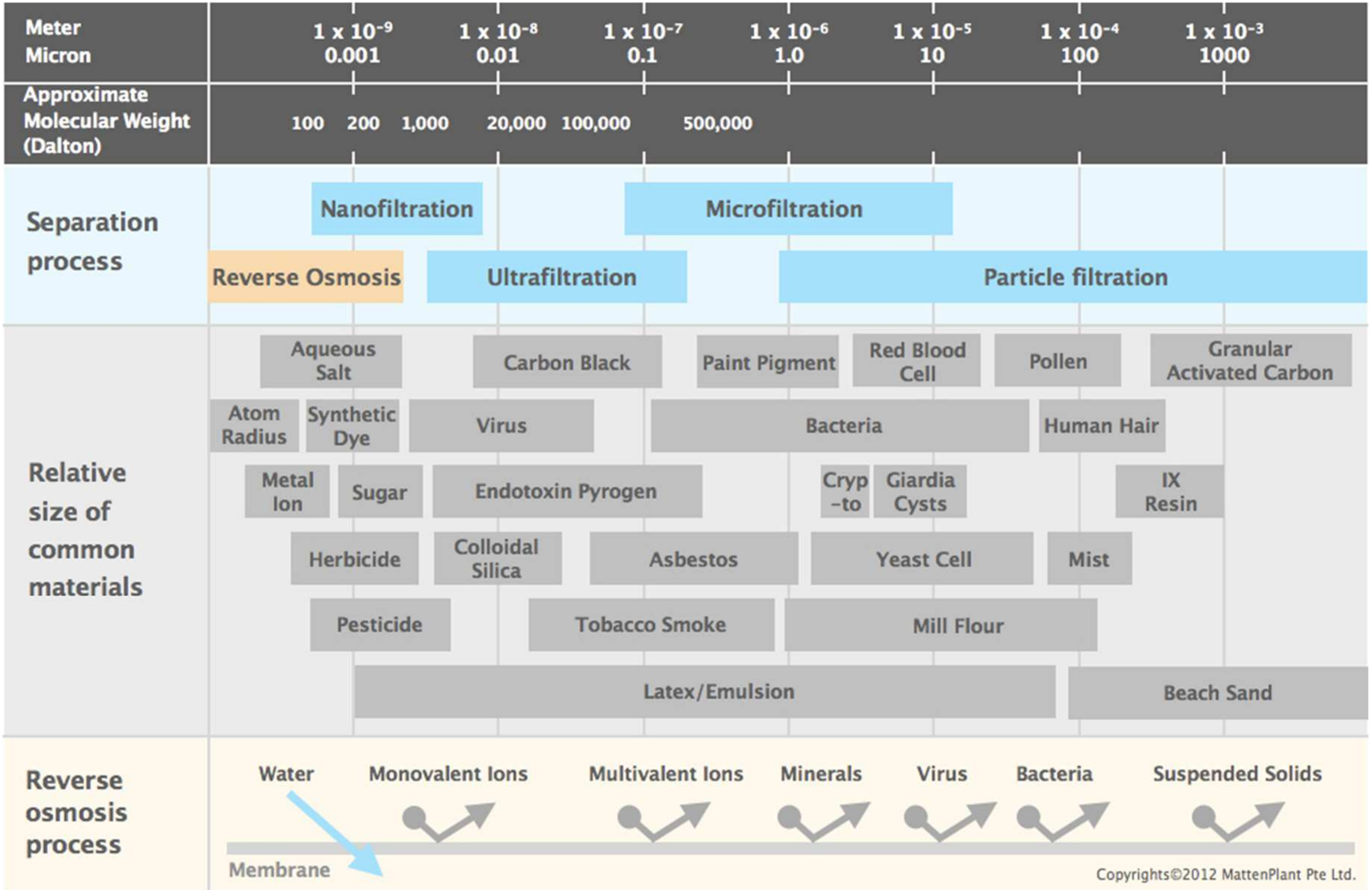
Tertiary – Membrane filtration

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





Tertiary – Membrane filtration



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