Anaerobic processes
Tertiary treatment

Anaerobic fermentation & oxidation

- **Applications**
  - Treatment of waste sludge & high-strength organic wastes
  - Pretreatment step for conventional biological treatment

- **Advantage**
  - Low biomass yield
  - Energy production in the form of methane (of recent interest!)
    - WWTP -- ~3% of total energy cost in USA
    - Target on energy positive treatment of wastewater

- **Disadvantage**
  - Effluent quality usually not as good as aerobic treatment

Anaerobic fermentation & oxidation

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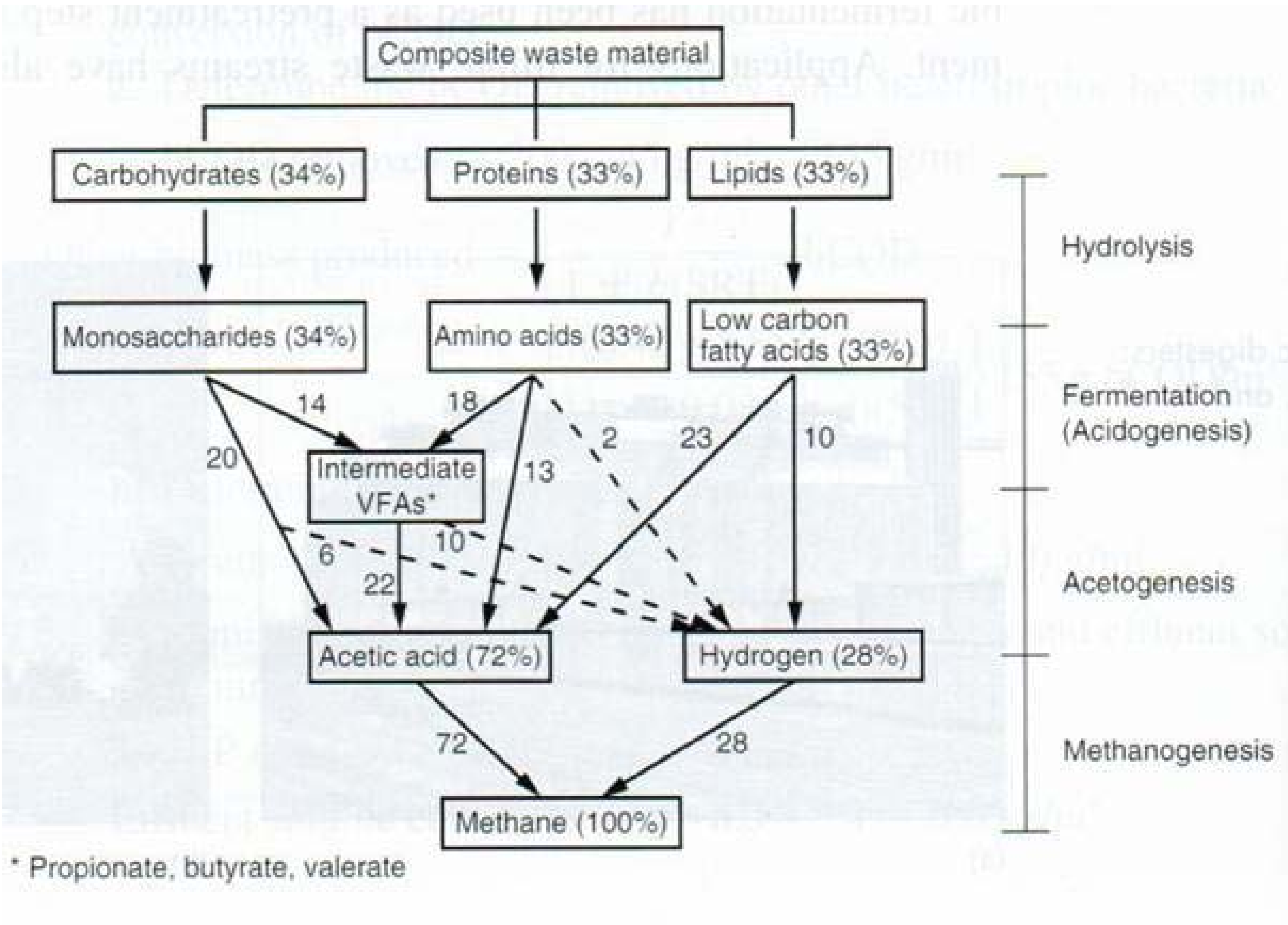
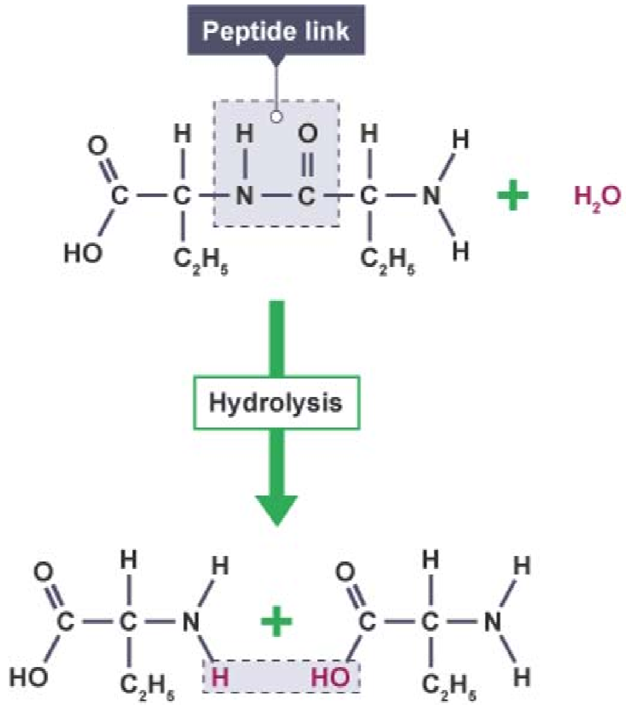


Anaerobic fermentation & oxidation

- **Hydrolysis**
  - Particulates - - - -→ Soluble molecules - - - -→ Monomers
  - By extracellular enzymes



- **Acidogenesis (fermentation)**
  - Use: sugars, amino acids, fatty acids (both e- donor & acceptor)
  - Produce: VFAs, CO_2, H_2

- **Acetogenesis**
  - Use: VFAs other than acetate
  - Produce: acetate, H_2, CO_2

Anaerobic fermentation & oxidation

- **Methanogenesis**
  - By methanogens (belongs to domain **Archaea**)
  - Two groups of methanogens
    - *aceticlastic* methanogens: acetate → $CH_4 + CO_2$
    - *hydrogenotrophic* methanogens: $H_2 + CO_2$ → CH_4
  - In anaerobic digestion process, ~72% methane from acetic acid & ~28% from H_2 (→ gas production of ~65% CH_4 & ~35% CO_2)

- **Syntrophic relationship**
  - Methanogens – acidogens & acetogens
    - Acidogens & acetogens: produce H_2, acetate, etc.
    - Methanogens: cleans up the acido/acetogenesis end products
  - *"Interspecies hydrogen transfer"*

COD balance for anaerobic process

(COD utilized) = (Biomass COD) + (Methane COD)

- No e^- acceptor consumed!
- COD of methane = 2.86 g COD/L CH_4 (@ 0°C, 1 atm)

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Process kinetics

- Low yield coefficients
  - Low energy gain by chemical transformation
  - Fermentation: Y ~ 0.06 g VSS/g COD; b ~ 0.02 d^{-1}
  - Methanogenesis: Y ~ 0.03 g VSS/g COD; b ~ 0.008 d^{-1}

- Consider two steps:
  - Hydrolysis
  - Soluble substrate utilization for fermentation and methanogenesis
    - Methanogenesis the rate-limiting step

- High SRT is needed (around 40 d) due to slow degradation rate

Process stability

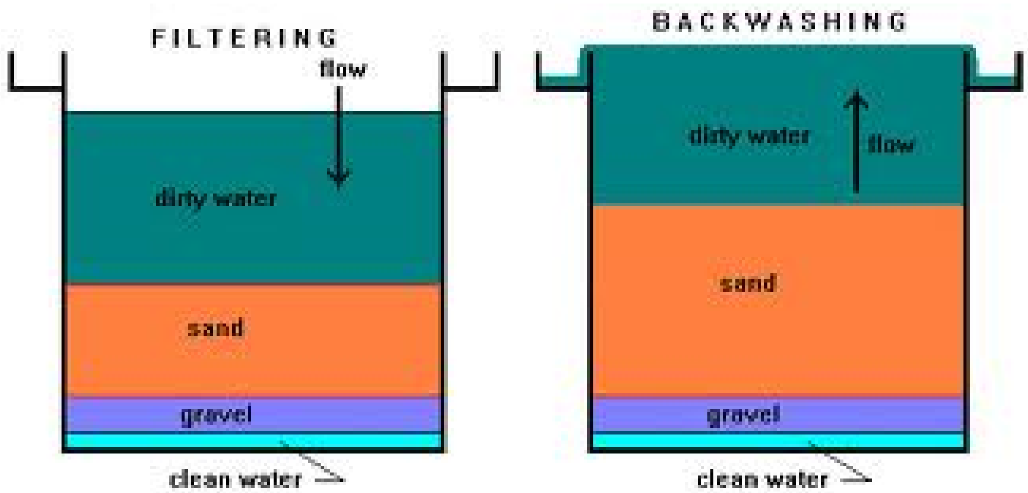
- Kinetics of VFA production is faster than utilization (methanogenesis)
- At steady state, sufficient methanogen population is established to maintain low VFA concentration (<200 g/m^3) & pH≥7.0
- Unstable digester operation may develop under transient loading conditions (VFA production > utilization): VFA accumulation & pH drop
- Low pH leads to decline in methanogenic activity: process failure
- Methanogenic inhibition can also occur by acetate accumulation (acetate conc. > 3000 g/m^3)

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

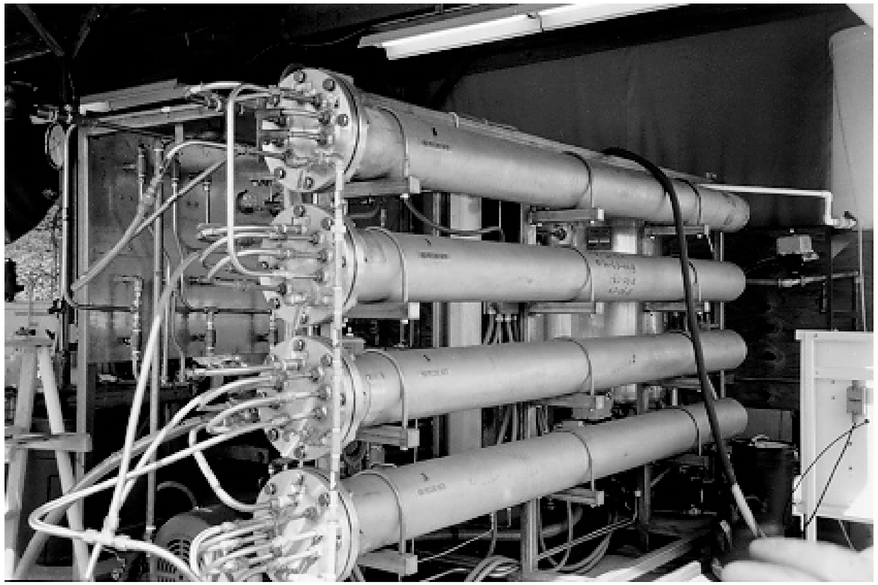
- Additional removal of SS
- Sand is most frequently used
- Backwash needed when effluent quality degrades or the filter clogs



http://www.rpi.edu

Tertiary – Membrane filtration

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



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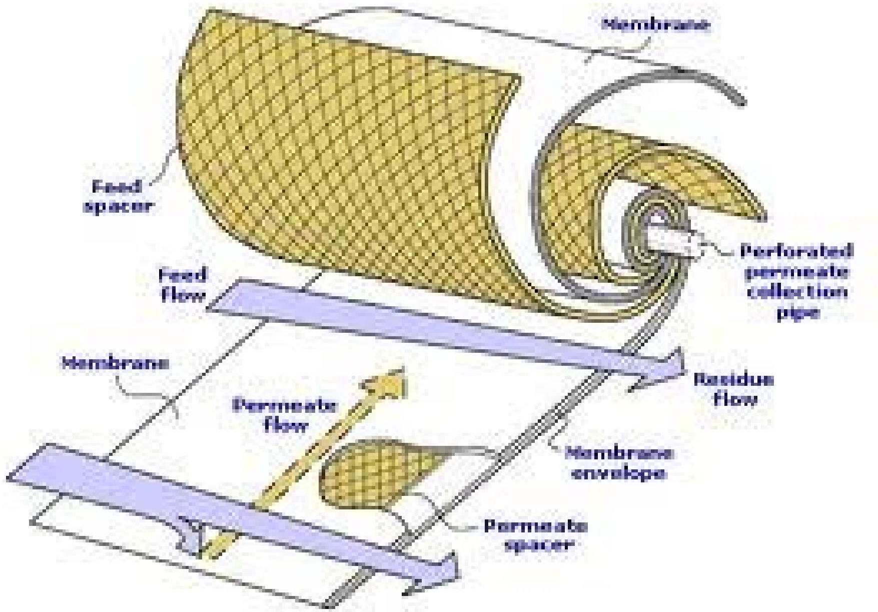
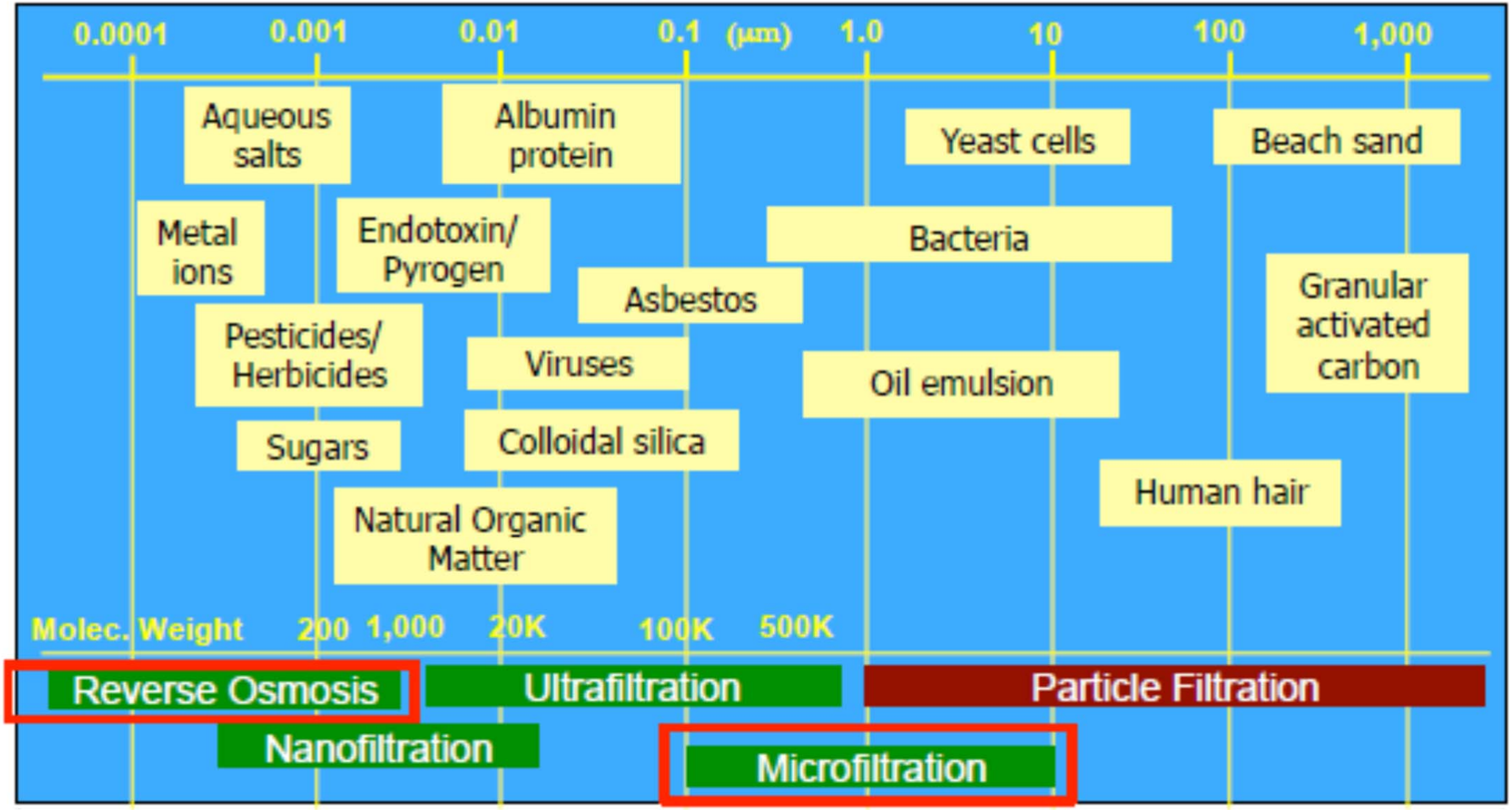


http://www.onlinembr.info

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

http://www.chemvironcarbon.com