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|  | C = bulk Cs = equilibrium with bulk Ci = interfaceIf liquid film resistance dominates If gas film resistance dominates |
| Batch reactor  | Zeroth order | First order | Second order |
| CMFR | Zeroth order | First order | Second order |
| PFR  | Zeroth order  | First order | Second order  |

Ci, Q into CMFR 🡪 C1, Q into PFR 🡪 C2,Q (both first order)

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Dispersion is concentrations spread out in space. Diffusivity: big↓, small↑, water ↓, air ↑, low T ↓, high T ↑

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| Molecular diffusion: D [=] m2/s | Turbulent diffusion: [=] m2/s | Advection: |

**Adsorption**- surface uptake **Absorption**- distributed uptake **Sorption**- either one or both

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Dissolution of ammonium chloride involving a phase change:

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|  | Dc critical oxygen deficit or min DO concentration. xc critical distance or distance downstream at which Dc occurs. |

DOmin content of water to support higher life: 2 mg/L abs lower limit, 4 mg/L game fish maintain Dc (DOsat-DO) small so that DO>DOmin

To reduce Dc- biological treatment (reduce in waste) increase flow of BOD-free water increase river aeration- k2

*oligotrophic* - low nutrients, low productivity *mesotrophic* - intermediate nutrients and productivity *eutrophic* - high nutrients, high productivity

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|  | *epilimnion* - warm surface layer *thermocline* - ΔT zone *hypolimnion* - cool, lower layer **Summer** - stable stratification: warm water (lower density) on top, cool water (higher density) on bottom, little mixing between upper and lower layer**Autumn** **turnover**- epilimnion cools, reduced solar heating, lower air temperature, cooling surface water sinks to thermocline, if epilimnion cools to hypolimnion temperature 🡪 complete mixing of lake **Winter stratification**- surface water freezes, slow heat transfer through lake by conduction**Stably stratified- coupled CMFR unstratrified- single CMFR**  **Eutrophication** promotes excessive growth of **algae** and **phytoplankton****Ground water**- **unsaturated zone (vadose zone) air-filled porous media saturated zone (aquifer) water-filled porous media** |

Hazardous water landfills and sanitary landfills are two major sources of GW contamination. An estuary is where a river meets the ocean and the resulting water body is affected by the tidal action of a sea. All of the water that falls on land and runs off into the oceans passes through estuaries. Mixing influenced by T and salinity.

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|  | River tends to flow *onto* the water contained in an estuary, leading to a stable stratification. Oscillating tidal flow disrupts the stratification by pushing salt water into the river’s mouth**. Issues of concern**: saltwater intrusion, municipal sewage discharge, toxic materials from industry, runoff with storm water.**Ocean outfall**- Municipal sewage of coastal cities is discharged to oceans.  |

WW treatment- **physical, chemical, biological. Primary**- application of physical and/or chemical. **Secondary**- BOD removal. **Advanced**

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|  |  Settling distance during transit = vL/U = H’ fraction removed

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| 0.3~1000 |  |
| 1000~35000 |  |

 |

**backwashing**- force water upwards through filter bed, lift sand grains, liberate trapped particles, discharge backwash water, or return to head of treatment plant

**Reverse osmosis**- force water at high-pressure through fine-pore membrane, desalination of seawater, water softening, wastewater reuse, rejects ionic components

**Electrodialysis**- removal of ions through membranes by transverse electric field, unlike RO, ions cross membranes rather than water, ineffective against nonionic species

Reaction at the cathode: at the anode:

**Disinfection**-

on a log log plot, pick a C and the corresponding tc. calculate k based on tc, divide by C to get k’ (a constant). multiply by new C to get new k, calculate tc.

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|  | HOCl is an oxidant Formation of chloramines Ineffective products: *free residual Cl:* [HOCl] + [OCl-] *combined available Cl:* [NH2Cl] + [NHCl2] + [NCl3] *Cl residual:* [HOCl] + [OCl-] + [NH2Cl] + [NHCl2] + [NCl3] |
|  | Add coagulant mix vigorously (flash mix) to form charged species and precipitates (coagulation), stir gently to increase rate of collision (flocculation), separate solids from water by settling(I) not enough coagulant ⇒ negatively charged particles(II) stoichiometric coagulant dose ⇒ neutral particles(III) too much coagulant ⇒ positively charged particles(IV) sweep floc ⇒ physical capture of particles by Al(OH)x polymer |
| Electroneutrality, Ionic strength, **Hardness**, the sum of the normalities of all multivalent cations. Main cations, Compute total harness (TH) computeIf CH = Nc NCH = TH-CH If CH = TH NCH = 0Convert meq/L hardness to mg/L as CaCO3 1meq/L = 50mg/L as CaCO3Alk – capacity to neutralize acids , meq/LLime treatment- To decrease Ca2+, increase CO32-. To decrease Mg 2+, increase OH-. Incrase pH, decrease Mg2+, decrease Ca2+ if enough ALK is present (H2CO3🡪HCO3-🡪CO32-)

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|  | Na2CO3 required | Ca(OH)2 required |
|  | None  | TH + 2 [Mg2+] + 2[H2CO3\*] + 0.00125 eq/L |
|  |  | Alk + 2 [Mg2+] + 2[H2CO3\*] + 0.00125 eq/L |

If Mg2+ not present, drop Mg2+ and 0.00125. Final step add CO2 to bring pH down to neutral level | Particle concentration – mass (#) particles per fluid volumeParticle density – mass of particle per particle volume |
|  | Activated sludge- Separate cells because cells are sources of BODRecycle cells to maintain high cell residence time relative to hydraulic residence time ()Not recycle in order to bleed off dead cellsS- concentration of biodegradable organic matter (BOD) X = concentration of active biomass (VSS)km- the maximum substrate degradation rate (g BOD / g VSS / d) Ks- half saturation degradation rate (g BOD/m3) Y- cell-yield coefficient (g VSS / g BOD) |

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OD in reactor- oxidation of BOD to CO2 and H2O, conversion of BOD to cell mass if all BOD oxidized, OD=BODin-BODout=Qin(Sin-S)

Steady-state O2 requirement =

O3, NO2,CO, Pb, SO2, PM – **criteria air pollutants**

**Fine** **PM** formed by combustion (fires and diesel engines), atm transform (chemical rxn 🡪 products with low Pvap so products condense onto pre-existing PM or form new PM).

**Coarse** **PM** formed by evaporation of sea spray (NaCl), wind-blown soil (Si, Ca, Al, Fe), brake wear (metals), fly ash

**Primary PM**- directly emitted (CO, Pb,SO2, NO2, PM 10, PM 2.5)

**Secondary PM**- formed in atm (O3, NO2, PM2.5)

 ***VOC*** (combustion + evaporation of fuels + natura l sources) + ***sunlight*** 🡪 ***secondary organic aerosol*** (SoA, high MW organic compounds)