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| --- | --- | --- | --- | --- |
|  | | C = bulk Cs = equilibrium with bulk Ci = interface  If 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   |  |  | | --- | --- | |  |  | | 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) compute  If CH = Nc NCH = TH-CH If CH = TH NCH = 0  Convert meq/L hardness to mg/L as CaCO3 1meq/L = 50mg/L as CaCO3  Alk – capacity to neutralize acids , meq/L  Lime 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-)   |  |  |  | | --- | --- | --- | |  | 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 volume  Particle density – mass of particle per particle volume | |
|  | | Activated sludge-  Separate cells because cells are sources of BOD  Recycle cells to maintain high cell residence time relative to hydraulic residence time ()  Not recycle in order to bleed off dead cells  S- 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)