=>

Conc

Time

Mass Balance:

Rate of j in- Rate of j out + Net Generation of j = Rate of accumulation of j

a) **Batch:** homogenous

No mixing => Q=0

Where rj\* is the volume average rate of formation of some species j. And Cj\* is the average concentration of j.

b) **Plug flow:** (=Moving batch reactor)

SS Condition =>

c) **CSTR**

Well mixed

5) Reaction kinetics

**Batch**

* Lakes are CSTR
* Rivers are Plug flow

**Batch**

*Focus on A*

&

Basic parallel reaction:

Same for S

Samefor S with K2

E= Activation energy

A= Frequency Factor

, dife V, diff

If they have same volume also same as one PF with volume Vs

=

Laminar Flow: In fluid dynamics, laminar flow is characterized by fluid particles following smooth paths in layers, with each layer moving smoothly past the adjacent layers with little or no mixing. At low velocities, the fluid tends to flow without lateral mixing, and adjacent layers slide past one another like playing card

Terminal velocity is the maximum velocity attainable by an object as it falls through a fluid

Settling velocity = terminal velocity

Where,

dP=particle diameter

vS=settling velocity

Ρl=density of liquid

Ρp= density of particle

μ= viscosity

CD= drag coeff,

Ideal mixing

Q

Q

C

CsTr wihtout reaction

Co

Cosconcentration of dye in tak at o+

MT mass of dye added.

Co dye concentration in influent

Mass balance on tank at tO+

ln

CCos =>lnC= ln Cos

slope

lnc

Rule; 3 residence time hlushing to hare 95%

C(10.95)Cos  t3T

Multiple well mixed tank with equal Ʈ

C0=0

Q

Q

Cn Cosn-1

Cn/Cos

n=4

n=2

n=1

n=4

Exponential Washout

C

t

**Ideal mixing plus kinetics**

lnt

T or T

t

C

**Mass of tracer recovered**

..........................................................................................................................

At this t, will capture 100% of MT

t

1

.....................................

.................................

...........................................................................

Fraction of tracer recovered by ti =

\*We want 100% removal

**Probability density:**

P(x) , probability, p(x)probability density

P(x) => , %

Eexit age of fluid packets

Fraction of fluid removed up to time t Fraction or percent (or probability!) of fluid with exit age t < tx (or 0 to t)

E (t) (t)

Time (t)

Exit age of a fluid packet at time t =

Fraction of fluid with exit age between t1 and t2

\*\*Ʈ= average hydraulic resident time and it is when p=0.5=

QS: what is T10? This is the youngest age of 10% of fluid

Answer: Area under E (t) vs t diagram till 10% or in cumulative E (t) vs t. point of 10% in probability axes and then you can find t on the other Axis.

**-collision rate**

Collision rate NijKijCiCjBijCiCj

Ci concentration of particle i

Kij βij f (particle size, density, fluid density, fluid mixing)

Collision efficiency => (usually we assume 1)

Nij Nij Nijrate of collision

-what coagulants do, is make 1. All collisions result in sticking.

-net rate of k-type particles Nkt NijKij Ai Aj

-Fick’s law:

Amount (moles, volume) of particles moving

Flux A= Net rate of particles moving throw an area

Diffiusion constant

Change in pressure (particles in over a distance a volume)

Flux

FluxJijDi

rradius of particles

Didiffusiry coefficient

Dj

KBozaman’s constant 1.3810-16

Tkelvin

Viscosity of water 0.01005 @20

1 Aggregate rate due to brown

NijKij ninj

Kij fluid shear

ninumber of i concentration motion

ddiameter of the particle

2 Aggregate due to fluid shear

Nij(didj)3G1 ninj

Kij fluid shear

3 Aggregate due to differential sedimentation

Nij |ri2rj2|

|vivj|

Cross section collision area

Ksed=Kij fluid shear due to differential sedimentation

**-units**

nnumber concentrations cm-3or L-1

Kij

NijKij ni njS-1 cm-3

* Which mechanism is important?

Depends on G value (mixing) & size of primary particles.

a)

for uniform particles: didj

Brownian motion would important one smaler particles

Fluid shear-good for large area.

b)

in a flocculator

1 always

Flouid shear is the only important.

-overall rate expressions.

* if we use radius instead of diameter we will have:

k

)3*G G()3*

* ( )*volume fraction concentration of particles.*

ratefrist order reaction.

* for constant floc volume =>

G and

Where flocculation constant

Frist order: G

Gmixing speed

Amount or dose of flocs

Rate (G, ,)

-density

-steady states means over time nothing would change.

-Ʈ=>for CSTR just like

-series CSTRs

Q

slope

G

G

1T

1

1

1

1)

Slope

Slope

Slope

(1)

G

1

Strategy

1. Floc shear curve known
2. Calculate ,T independanthy
3. Calculate slope.
4. Draw live until it interrupts
5. Find G value find intercept
6. Repeat for other CSTRs

Setting velocity:

(1)

-Reynolds number

1) Laminer region smoth 1

2) Transition zone: 1 0.34

3) Turbulent: 1000 0.44

-Terminal velocity if laminar flow (

a)

b) calc now

c) calc new

d) calc with (1)

e) is new done

? go bact to b

1) Design base for a single design particle

Dssign eq

Top surface area

1-Q given

2-calc

3-choose h2-3 m

4-calc

5-

6-V, h=> calc W, L

-removal is independent of depth.

-%removal

* Settling velocity distributions (continuous)
  + Batch settling test
  + Measure particle concentration (or mass or turbidity) at certain depth 8 over time.
  + Calculate velocity = and Fraction of particles. “F(v)” at each time point =Fraction of remaining.
  + Plot F(v) vs V on a graph.

\* we can say at t = x , F(v) percent of particles above Z have at that time.

- Fraction remaining at this velocity = F(vi)

- Fraction settled at this velocity = 1- F(v1)

1 – F(v)

Fraction that

Settles definitely

F(v): Fraction remained above Z

1.0

0

high

V(i)

V

low

Sand filter

* Evaluation of collector

Porosity of Sand = 0.3 – 0.4

Rate of approach =

Approach velocity

Total collector efficiency

\* We have a dead zone in design. (Poor performance)

If you want to improve performance:

-rc = Rate of particle removal from water per unit bed volume

rc = rate of particle generation in water per unit bed volume.

- Fraction of particles striking a collector which stick =

- Rate at which particles strike a single collector (rate of capture) =

* How the filter is designed
* Water quality

- Number of collectors per unit bed volume =

Vtot

porosity

- Mass balance on particles in water inside the filter.

Filter equation

first order

* For a non-spherical collector

S = shape factor =

* Decrease porosity due to particle build up which changes the filter coefficient.
* Particle accumulation stops when:

Rate of shearing = rate of attachment minimum porosity

* Particle accumulation rate:

Porosity as a function of deposit:

- Mass balance

Rate of volume particle that is lost from water = - rc

Integrate rate for any X , consider 1 X at a time

* Hydraulics of flow – throw porous media:

- Head loss due to friction.

Fair – hatch:

Density of liquid

**Equation to work with**

1. Particle removal rate from water
2. Particle accumulation rate on media
3. Porosity changes
4. λ will change and it’s not cte over t and X.
5. Fair – hatch equation

D = diffusion coefficient (table)

* Kinetics = very fast ⇒ reach equilibrium in seconds (no need to model)
* Slow kinetics – time to reach equilibrium. (reality, model)

**Gas transfer from gas phase to water phase:**

Hypothetical liquid film thickness

**Predict dissolve gas behavior**

\*You have to measure Kla for every type of compound and different waters different condition.

dif compound

Dif condition

Faster rate of diffusion

Henry’s law:

We should look at table and units

Dimensionless henry’s constant

If:

R = gas constant = 0.082

1. **Aeration in a CSTR:**

\*\*Most basins are CSTR.

All SCTR are steady states ⇒ accumulation =0

1. **Stripping in a CSTR:**

Steady state ⇒

Solubility of atmospheric oxygen in water at 25

1. **Aeration in a batch reactor:**

Design equation=

1. **Stripping in a batch reactor:**

Unsteady states داریم

Striping in first order decay.

**Steady states in batch**

CSTR with aeration and decoy (Ozonation)

Stripping tower design:

Max possible value of (best performance)

Contaminations are leaving water phase and enter the gas phase.

Fraction removed from water

Stripping factor

Air Stripping:

**Model 1: equilibrium control** (fastest kinetics, maximum possible removal)

**Model 2: mass transfer limitation** (not at equilibrium)

Slow transfer kinetics limit us

Steady states ⇒ accumulation = 0

NTU of transfer units

HTU = height of transfer unit

Height of tower

NTU×H TV

Rules:



How to do lab data and find k

**linear model:**

*q*

**Freudlich Model:** ⭢ non-liner behavior

*q*

assure: dif types of sites

**lungmuir Model:**

*q*

assure 1 type of site which has a maximum sorption Capacity

**sorption isotherms:**

*n*

:

**linearize lung muir:**

break through = no more clean bed

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| t | 1d | 3d | 5d |  |
| *t*  *et* |  |  |  | effluent |
| *x* |  |  |  | effluent |
|  | *5d* | | | midpoint |

1) Accumulation terms: advection + dispersion – Sorption – react

packed bed Reactor:

break through volume for certain mass of carbon

CUR= how much carbon is needed to treat certain volume of water.

sorbtion zone

saturation zone

C

Length of colum = Z

**Design:**

1. Do the test until
3. when