CHAPTER 10. KINETICS OF BIODEGRADATION IN SOIL

1. p.243. Kinetics-
   - (a) concentration of chemical remaining at time t
   - (b) prediction of concentration at future time t_f
   - (c) assessment of whether a chemical will be eliminated before it is transported to human or environmental receptor

2. Models representing kinetics of biodegradation
   - (a) first-order
   - (b) Michaelis-Menten
   - (c) zero-order

3. Power rate model (empirical): $-dC / dt = kC^n$
   - $n = 1$ ---> first-order kinetics
   - $n = 0$ ---> zero-order kinetics

   Class - be able to integrate these equations to determine concentration of a chemical as a function of time.

4. p.250. Models based on processes lined to growth $v = \frac{V_{max} S}{K_m + S}$ [14]
   where $v = dC / dt$
   - (a) case I, when $S >> K_m$, $v = V_{max}$ zero-order reaction
   - (b) case II, when $S = K_m$, $v = V_{max} / 2$
   - (c) case III, when $S << K_m$, $v = [V_{max} / K_m] (S)$ first-order reaction

5. p. 253. First-order kinetics:
   - (a) half-life kinetics
   - (b) commonly used in environmental fate models

6. p.256. Biodegradation kinetics in complex environments
   - (a) diffusion barriers
   - (b) sorption to clays
   - (c) other organics present
   - (d) other factors, e.g., Oxygen, may govern rate of growth
   - (e) multiple species acting simultaneously
   - (f) protozoa role
   - (g) low solubilities in water
   - (h) sorbed bacteria
   - (i) acclimation phenomenon

7. Diffusion and Adsorption
   - (a) sorption usually treated as rapid equilibrium process, but is a two-phase process
   - (b) diffusion and Adsorption control bioavailability of organic substances
   - (c) diffusion of chemicals into and out of soil pores may be factor in controlling rate of mineralization
   - (d) rate of biodegradation governed by rate od desorption of diffusion of substrate from inaccessible micropores to sites containing active microorganisms.

   p.259 (e) Figure 10-4. Diffusion controls rate of biodegradation at high concentration

8. p. 260. Cometabolism

9. skip section 10-2.4, p. 263-264, and read section 10-3: Fungal Processes

10. Read page 266, last paragraph end Chapter 10

CHP-10

P.243 Power Rate model $-\frac{dc}{dt} = kC^n$ [1]

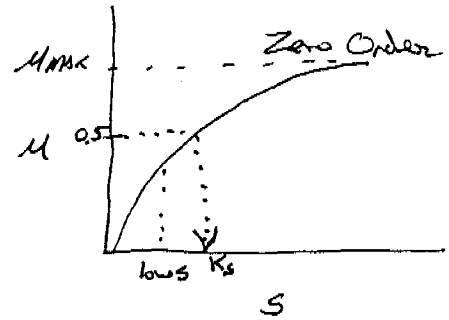
P.245 Monod (1949)
Microbial Growth & Substrate conc.

$$\mu = \frac{\mu_{max} S}{K_S + S} \quad [2]$$

(1) high S $\Rightarrow \mu = \frac{\mu_{max} S}{K_S + S} = \mu_{max}$

(2) low S; $S << K_S \Rightarrow \mu = \frac{\mu_{max} S}{K_S + S} = \frac{\mu_{max}}{K_S}(S)$

1st order w/ S



(3) $S = K_S \Rightarrow \mu = \frac{\mu_{max} S}{S + S} = \frac{\mu_m S}{2S} = \frac{\mu_m}{2}$

P.246 $\frac{dN}{dt} = kN \Rightarrow \frac{dN}{N} = k\,dt \Rightarrow \ln N \Big|_{N_0}^{N} = kt \Big|_{t_0}^{t} \Rightarrow \boxed{\ln N - \ln N_0 = kt}$ [4]

P.249 Haldane Modification of Monod Eq
for toxic organics

$$\mu = \frac{\mu_{max} S}{K_S + S + (S^2/K_I)} \quad [13]$$

P.250 10-2.2 Biodegradation by NON-GROWING MICROORGANISMS ←

Michaelis-Menten Eq $\nu = \frac{V_{MAX} S}{K_m + S}$ [14]

$\nu \equiv \frac{dS}{dt} = \frac{V_{max} S}{K_S + S} = \frac{k_2 S}{K_S + S}$ [17]

(1) high S $\Rightarrow \frac{dS}{dt} = V_{max} \Rightarrow \frac{dS}{dt} = k_2$ [19]

(2) low S $\Rightarrow \frac{dS}{dt} = \frac{V_{MAX} S}{K_S}. \Rightarrow \frac{dS}{dt} = \frac{V_{MAX}}{K_S} S = k_1 S$ [15]

(3) $S = K_S \Rightarrow \frac{dS}{dt} = \frac{V_{MAX} S}{2S} = \frac{1}{2} V_{MAX}$

Zero and First order power rate models - frequently used in studies of the degradation of organic chemicals in soil systems

Zero Order $dC/dt = -k$

On Integration becomes: $\underline{C_t = C_o - kt}$

Define half-life, when $C_t = C_o/2$

Therefore, $C_o/2 = C_o - kt_{1/2}$

and $C_o - C_o/2 = kt_{1/2}$

and $(2C_o - C_o)/2 = kt_{1/2}$

and $C_o/2 = kt_{1/2}$

so $\underline{C_o/2k} \quad \underline{= t_{1/2}}$

First Order $dC/dt = -kC$

On Integration becomes: $\ln (C_t/C_o) = -kt$ ------> find k

Or $\underline{C_t = C_o e^{-kt}}$

Define half-life, when $C_t = C_o/2$

Therefore, $\ln(1/2) = -kt_{1/2}$

and $-0.693 = -kt_{1/2}$

so $\underline{0.693/k = t_{1/2}}$

Considerations for measuring (bio)degradation reactions:

- Loss of parent compound
  - Mass balance (volatilzation, leaching correction)
- Mineralization - production of CO_2, NH_3 or NO_3^-, PO_4
- Abiotic controls
- Transformations
  - Cooxidation, cometabolism
- Detoxification
  - cellular toxicity
  - mutagenicity