Contaminant Fate and Transport in the Environment EOH 2122; Lecture 6, Transport in Surface Waters

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Physical Transport in Surface Waters-Gravity Driven Advection

- Gravity driven advection is the dominant transport process in rivers no matter their size.
- The gravitational energy of river flow-gained by flow down slope must either be dissipated by friction against the bottom, sides or air or be kinetic energy (associated with velocity).
- Equations exist for modeling channel flow (uniform) based on the hydraulic radius and slope and a frictional coefficient (factors in the roughness of the bed).
- *Hydraulic Radius R =*cross sectional area of flowing river/wetted perimeter (bottom+ 2* depth). That is the cross-sectional area divided by the wetted perimeter.
- *These models are most useful in human engineered situations like drainage ditches and man made canals.*

Simple Gravity Driven Advection Continued

- Chezy Equation [2-1]

$V=C\ (RS)^{1/2}$ where V is the velocity, C is the Chezy friction coefficient $[L^{1/2}/T]$,R is the hydraulic radius [L] and S is the (slope dimensionless).

- Manning Equation
- $V=1.49(R^{2/3}S^{1/2})/n$ where n is the Manning Roughness Coefficient as shown on page72, Table 2-1.

Example 2-1

- First calculate the hydraulic radius R

$$R = \frac{(2\ m * 3.281\ ft/m)\ (8in*1ft/12in)}{(2\ m * 3.281\ ft/m) + 2\ (8in*1ft/12in)} = .55ft$$

$$V(ft/sec) = 1.49\ (0.55^{2/3} * 0.001^{1/2}) /\ 0.013 = 2.4\ ft/sec$$

Physical Transport-Surface Water

- Travel time (refer to Figure 2.4)

T = L/V where L is the river reach or control volume under study.

An estimate of travel time is important to water engineers to determine time of spills to inlets but also useful if there is loss of contaminant through volatilization or bacterial transformation.

Q, Discharge

- Definition-The total volume of water passing any given point on the river.*Q*

$Q = A * V$, Q is in $[L^3/T]$; A is the cross sectional area and V is the water velocity.

- *Flux or Mass/Time transported past a river point is $\longrightarrow$ $J=QC$ where Q is the discharge $A * V$ and C is the mean concentration. Although C could be in median or mode dependant on what you are trying to predict.*
- *Review figure 2.5 velocity distribution and measured velocity by depth.*

Fickian Mixing River

- Mass of a chemical spreads out as it moves downriver according to velocity sheer (dispersion) and turbulent diffusion (think about river mining).
- Distribution of chemical mass will elongate in the direction of river flow due to water moving slower near the banks, bottom and surface
- The greater the spatial variability in Velocity and the greater the turbulence the greater the mixing of chemical mass (contrast rapids at Ohiopyle and the Yough below Connellsville).

Fickian Mixing Results In Essentially Normally Distributed Concentrations at any River Location, L

- A Gaussian Distribution ideally describes longitudinal dispersion
- C (x, t)=M/ $(4\mu DlT)^{1/2}\, e^{-[(x-Vt)2/(4Dxt)} e^{-kt})$
- Where C is concentration, M is mass per cross-sectional area, x is longitudinal direction, V is river velocity, t is time and Dl is the Fickian mixing coefficient—the last exponential term is only relevant if the contaminant is being removed by a first order decay process.

- Refer to 2-4 lower panel and notice that when a chemical pulse is added to a river the mass at any distance L is normally distributed around Cmax.
- As the pulse moves downriver Cmax decreases but the σ of the distribution of C increases. The fickian mixing coefficient D, can then be determined by:
- $D = \sigma^2$ (the variance of the chemical distribution)/2t
- It follows that the portion of the river lying one std dev above and below Cmax is 68% of the total mass and that the chemical concentration one standard deviation from Cmax is Cmax* 0.61.

Pollution is usually not uniform but from a Point

- A certain distance must be traveled before an effluent discharge is has a uniform concentration across the river-this is defined as the ***Transverse Mixing Zone.***
- This length is given by $L \sim w^2V/2D$ because:

$\sigma = (2Dt)^{1/2} \sim w$ where the std dev is the lateral std dev of the chemicals concentration distribution to the width of the river.

Lakes

- The average time that water remains in a lake is called the HYDRAULIC RESIDENCE TIME-it is defined as the ratio of the lake volume to the rate of water loss by all processes (outflow, seepage, evaporation, anthropogenic activity {letting water out of a reservoir or using for drinking water}.
- Chemical agents may be uniformly distributed in small ponds-probably cross-sectionally uniform in canals of low flow but in large lakes there is multiple input flow and significant wind driven advection leading to complicated current (fig 2.6)

Lakes Continued

- Turbulent Diffusion in a Lake requires modeling in at least two dimensions so that
- $C (x, y, t)=M/4\pi t (DxDy)^{1/2} e^{-[(x-Vt)2/(4Dxt)+(y-Vt)2/4Dyt)]}(e^{-kt})$
- Small changes in water temperature due to temperature fluctuations and differences in solute concentration lead to stratification in large lakes.

Lakes

- In winter we have reverse stratification as temperature moves below freezing for some time---When water is a 4 degrees centigrade it sinks to bottom and the top of the lake freezes
- Define Thermocline, Epilimnium and Hypolimnion.

Homework

- Read sections on particle settling and 2.3.
- For next class do problems in Chapter 2, entire problem 1.