Environmental Water Quality
BAE 452/552

Session 16

Distributed Chemical Loads

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Distributed Phase Chemical Waste Loads (pesticides)

- Finding solid-phase and dissolved phase concentrations is complicated by dynamic processes (decay, decomposition and microbiological)
- Many pesticides are in use each with its own properties and characteristic behavior

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Distributed Phase Chemical Waste Loads (pesticides)

- Pesticide concentrations in runoff depend on relative timing of applications and storm events, and the adsorption and degradation properties of the pesticide
- We will use a simple equations to describe pesticide behavior for source areas with uniform soil, hydrologic and chemical characteristics (Haith, 1980)

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Pesticides Runoff Model

- A pesticide mass balance of surface centimeter of soil. On day t after a pesticide application P_0 (g ha^{-1}) to surface soil layer, the pesticide content P_t is:

$$P_t = P_0 e^{-k_s t} + \Delta P_t$$

- k_s = pesticide decay constant (day^{-1})
- ΔP_t = additional pesticide application (if any) on day t (g ha^{-1})

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Pesticides Runoff Model

- If a previous storm and/or pesticide application was made on some day τ prior to day t, then:

$$P_t = P_\tau^+ e^{-k_s (t-\tau)} + \Delta P_t$$

- P_t^+ = pesticide content after storm event and/or on day τ (g ha^{-1})

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Pesticides Runoff Model

- Total pesticide P_t is divided into adsorbed and dissolved forms using a linear adsorption coefficient, K_d:

$$P_t = A_t + D_t$$

- and

$$a_t = K_d d_t$$

Note: see Session 10 for similar notation

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Pesticides Runoff Model

$$P_t = A_t + D_t \qquad a_t = K_d d_t$$

where

A_t & D_t = adsorbed and dissolved pesticide in surface cm on day t (g $ha^{-1}cm^{-1}$), respectively

a_t & d_t = adsorbed and dissolved pesticide concentration on soil particles (mg kg^{-1}) and in soil water (mg L^{-1}), respectively

K_d = pesticide partition coefficient (L kg^{-1})

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Relationships

$$P_t = A_t + D_t \qquad a_t = K_d d_t$$

- $D_t = 100w\, d_t$

  $A_t = 100\rho_{dry}\, a_t$

where w is available water capacity (cm cm^{-1}), ρ_{dry} is dry bulk density (g cm^{-3}), and 100 is a conversion factor

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Available Water Capacity

$w = (\theta_{fc} - \theta_{wp})$ (cm cm^{-1})

where

θ_{fc} = volumetric moisture content at field capacity

θ_{wp} = volumetric moisture content at wilting point

Examples: 0.22 (silt loam), 0.14 (clay, clay loam, sandy loam), 0.19 (loam)

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Combining Relationships

$$P_t = A_t + D_t \qquad a_t = K_d d_t$$

$$D_t = 100w\, d_t \qquad A_t = 100\rho_{dry}\, a_t$$

$$A_t = \left[\frac{1}{1 + w / K_d \rho_{dry}}\right] P_t$$

$$D_t = \left[\frac{1}{1 + K_d \rho_{dry} / w}\right] P_t$$

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Pesticides Runoff Model

If runoff occurs on day t, portions of A_t and D_t will be removed by water and sediment movement. The solid-phase pesticide in runoff on day t (g ha^{-1}):

$$PX_t = (A_t / 100\rho_{dry}) X_t$$

where

- X_t = soil loss in runoff on day t (t ha^{-1})

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Pesticides Runoff Model

Dissolved pesticide losses are distributed into runoff, percolation and a residual which remains in the surface layer after a storm

Considering only events for precipitation > available water capacity, runoff loss of dissolved pesticide, PQ_t (g ha^{-1}), is:

$$PQ_t = [Q_t / (R_t + M_t)] D_t$$

where

- Q_t, R_t & M_t = runoff, rain and snowmelt on day t (cm), respectively

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Pesticides Runoff Model

If we assume the surface is dry prior to the event, percolation losses of dissolved pesticide from the layer is:

$$[(R_t + M_t - Q_t - w)/(R_t + M_t)]D_t$$

Dissolved pesticide remaining in the soil after the event: $[w/(R_t + M_t)]D_t$

Then, pesticide remaining in surface layer:

$$P_t^+ = P_t - PX_t - [(1-w)/(R_t + M_t)]D_t$$

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Solid-phase and Dissolved Loading

Similarities between solid-phase loading:

LS = $0.001 C_{sed} X$ using $a_t = C_{sed}$, and $a_t = A_t/100\rho_{dry}$

Similarities between dissolved phase loading:

LD = $0.1\ C_d\ Q$ using $C_d = D_t/(R_t + M_t)$ assuming good mixing with rain and snow

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Computational Steps

- Designate day of original pesticide application as t = 0
- Set P_0 equal to application to surface cm (g ha^{-1})
- Check each day for event (new application and/or precipitation above available water capacity)
- If an event occurs: $P_t = P_0 e^{-k_s t} + \Delta P_t$

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Computational Steps

If $R_t + M_t > w$, pesticide leaching occurs:

- calculated D_t and Q_t (CN method)
- $PQ_t = [Q_t/(R_t + M_t)]D_t$
- calculate A_t and X_t (RUSLE)
- $PX_t = (A_t/100\rho_{dry})X_t$
- Note: if $Q_t = 0$, all pesticide will be leaching downward and $PQ_t = PX_t = 0$; calculate P_t^+

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Data Needed

- Weather records
- RUSLE
- CN method
- Soil properties (w, n, ρ_{dry})
- Pesticide properties (K_d) (see handout with Session 11)
- See also Tables III-13 through III-17 in EPA document

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Example III-6 (EPA document)

- Pesticide Runoff

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