Career Services and Fundamental Concepts in Environmental Engineering

CIEG -125 Introduction to Civil Engineering

Fall 2005

Lecture 6

Today

- Career Services
- Ethics – Groups 10, 11 and 12
- Fundamental Concepts in Environmental Engineering
- Scheduling the Final Exam

Fundamental Concepts in Environmental Engineering Outline

- Important Dimensions and Units
  - density
  - concentration
  - flow rate
  - residence time
- Mass balance w/one material

Density

- Mass divided by unit volume

$$\rho = M/V$$

ρ = density (kg/m^3, lb$_M$/ft^3)

M = mass

V = volume

- $\rho_{water} = 1 \times 10^3$ kg/m^3 = 1 g/cm^3 = 62.4 lb$_M$/ft^3

Concentration

- Gravimetric definition: mass of material A in a unit volume of material consisting of material A and other materials B.

$$C_A = M_A / (V_A + V_B)$$

C_A = concentration of A (kg/m^3, mg/L used in EE)

M_A = mass of material A

V_A = volume of material A

V_B = volume of material B

Example

Plastic beads with a volume of 0.04 m^3 and a mass of 0.48 kg are placed in a container and 100 L of water are poured into the container.

What is the concentration of plastic beads in mg/L?

C_A = $M_A / (V_A + V_B)$

= (0.48 kg) / (0.04 m^3 + 100L(1 m^3 / 1000L))

= 3.43 kg/ m^3

= 3.43 kg/ m^3 (10^6 mg/kg) / (10^3 L/m^3)

= 3420 mg/L

Example 2

Plastic beads with a volume of 0.04 m^3 and a mass of 0.48 kg are placed in a 100 L container into which water is poured filling the container to the brim.. What is the concentration of plastic beads in mg/L?

$$V_A + V_B = 100 \text{ L}$$

$$\begin{aligned} C_A &= M_A / (V_A + V_B) \\ &= 0.48 \text{ kg} / 100\text{L} \\ &= 0.0048 \text{ kg/ L} \\ &= 0.0048 \text{ kg/ L} \ (10^6 \text{ mg/kg}) \\ &= 4800 \text{ mg/L} \end{aligned}$$

Concentration: ppm

- Another measure of concentration is ppm or *parts per million*
- If the fluid is water (ρ = 1 g/cm^3) :

$$\begin{aligned} 1 \text{ mg/L} &= (0.001 \text{ g})/1000 \text{ mL} \\ &= (0.001 \text{ g})/1000 \text{ cm}^3 \\ &= (0.001 \text{ g})/1000 \text{ g} \\ &= 1 \text{ g} / 10^6 \text{ g} = 1 \text{ ppm} \end{aligned}$$

Concentration: percentage

- Some material concentrations are expressed as percentages, by mass:

$$\Phi_A = 100 * M_A / (M_A + M_B)$$

- The percentage can also be expressed by volume:

$$\Phi_A = 100 * V_A / (V_A + V_B)$$

Example

A wastewater sludge has a solids concentration of 10,000 ppm. Express this concentration in percent solids (mass basis), assuming that the density of the solids is 1 g/cm^3.

$$10{,}000 \text{ ppm} = 10^4 \text{ g} / 10^6 \text{ g} = 1/100 = 1 \%$$

Pollution Concentrations in Air

- In air pollution, concentrations are usually expressed in μg/m^3 of air
- 1 microgram (μg) = 10^{-6} g
- Sometimes, concentrations are expressed in terms of ppm, by volume
- Conversion of μg/m^3 to ppm (Volume/Volume) requires knowledge of the gram molecular weight of the gas

Moles and GMW of Gases

- 1 mole is made up of 6.02 x 10^{23} molecules
- 1 mole is the amount of a gas in grams numerically equivalent to its molecular weight
- 1 mole of CO_2 weighs:
  - 12 + 16 + 16 = 44 g CO_2
  - A.k.a. gram molecular weight (GMW)
- At standard condition (0°C and 1 atm of pressure), 1 mole of any gas occupies 22.4 L

Converting μg/m^3 to ppm

ppm (V/V) = (1 m^3 of pollutant / 10^6 m^3 of air)

X μg/m^3 = (X μg of pollutant / 1 m^3 of air)

= [X μg of pollutant * (1 g / 10^6 μg) * (1 mole / GMW g) * (22.4 L/mole)] / [1 m^3 of air * (10^6 / 10^6)]

= [X μg of pollutant * (1 g / 10^6 μg) * 10^6 * (1 mole / GMW g) * (22.4 x 10^{-3} m^3/mole)] / [10^6 m^3 of air]

= [(X * 22.4 x 10^{-3} / GMW) m^3 of pollutant] / [10^6 m^3 of air]

= [X * 22.4 x 10^{-3} / GMW] ppm

= [X * 22.4 / (GMW * 1000)] ppm

Example: Gaseous Pollution

- If a concentration of 600 μg/m^3 of sulfer dioxide is in air at standard conditions, what is the ppm of this pollutant?

Sulfer dioxide (SO_2) has one sulfer atom and two oxygen atoms

GMW = (32 + 16 + 16) g/mole = 64 g/mole

ppm = [(600 * 22.4) / (64 * 1000)] = m^3/mol)

= 0.21 ppm

Flow Rate

- Flow Rate can either be:
  - gravimetric (mass) flow rate (kg/s or lb_M/s); or
  - volumetric (volume) flow rate (m^3/s or ft^3/s)
  - dependent quantities because:

    [mass] = [density] x [volume]
- Mass flow rate, Q_M, is the amount of mass passing a point during a unit of time
- Volume flow rate, Q_V, would be the volume of that same mass of material passing

Flow rate, con't

- $Q_M = Q_V * \rho$
- Suppose that we have a volumetric flow of materials A and B, $Q_{V(A+B)}$, and we know the concentration of A, C_A.
- The mass flow rate of A is:

  $Q_{MA} = C_A * Q_{V(A+B)}$
- This is different from first equation, which is only applicable for one material.

Example

A wastewater treatment plant discharges a flow of 1.5 m^3/s (water plus solids) at a solids concentration of 20 mg/L (20 mg of solids per liter of flow, solids plus water). How much solid material is the plant discharging per day?

$Q_{M\text{-}SOLIDS} = C_{SOLIDS} * Q_{V(WATER + SOLIDS)}$

= [20 mg/L * (10^{-6} kg/mg)] * [(1.5 m^3/s) * (10^3 L/ m^3) * (86,400 s/day)]

= 2592 kg/day

Example

A drinking water treatment plant adds fluorine at a concentration of 1 mg/L and the average daily demand is 18 million gallons. How many pounds of fluorine must the community purchase?

$Q_{M\text{-}FLOURINE}$

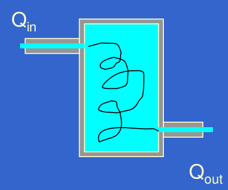
= $C_{FLOURINE} * Q_{WATER}$

= (1 mg/L) * (3.79 L/gal) * (2.2 x 10^{-6} lb/mg) * (18 x 10^6 gal/day)

= 150 lb/day

Residence Time

When a fluid flows through a container, how long does the average particle of fluid stay in the container?



Called residence time, detention time or retention time.

Residence Time

- If the volume of the container is V (m3)
- the flow rates $Q_{out} = Q_{in} = Q$ (m^3/s) , then the average residence time is:

$$t_{avg} = V/Q$$

- Note that residence time can be increased by increasing the volume of the tank or reducing the flow rate.

Example

A lagoon has a volume of 1500 m^3 and the flow into the lagoon is 3 m^3/hour. What is the residence time in the lagoon?

$T = V/Q = (1500\ m^3)/(3\ m^3/hour) = 500$ hours

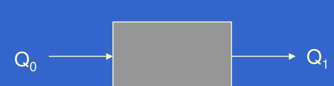
Why do you think we might be concerned about residence time?

Mass Balances w/ Single Material

- Except for processes involving nuclear reactions, a pound of any material in the beginning of a process will yield a pound of that material in the end, albeit in a different form.
- In other words, mass is conserved.
- Because mass is conserved, we can do a mass balance before/after a process

Mass Balance using Black Boxes

- We do mass balances by:
  - drawing a boundary around a process (or set of processes), called a black box
  - identifying all input mass flows to and output mass flows from this process

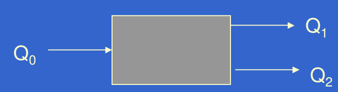


Conservative, Steady-State Systems

- If the process inside the black box does not create or destroy material; and
- The flows in/out do not change (i.e., the system is at steady-state),
- The system is said to be a steady-state conservative system.
- For such systems, $Q_0 = Q_1$
- Thus, mass in = mass out.

Splitting Single Material Flows

- Suppose we have two output mass flows instead of one?

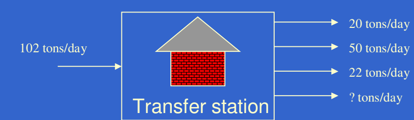


- If the system is still steady-state and conservative, then $Q_0 = Q_1 + Q_2$

Example

A city generates 102 tons/day of refuse, all of which goes to a transfer station. At the transfer station, the refuse is split into four flow streams headed for three incinerators and one landfill. If the capacity of the incinerators is 20, 50 and 22 tons/day, how much refuse must go to the landfill?

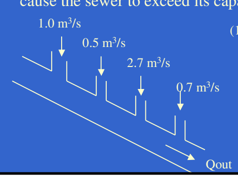
If we draw a black box around the transfer station



Landfill flow (tons/day) = 102 - (20 + 50 + 22) = 10 tons/day

Example 2

A trunk sewer has a flow capacity of 4 m^3/s. If the flow to the sewer is exceeded, it will not be able to transmit the sewage through the pipe and backups will occur. Currently, three neighborhoods contribute to the sewer, and their maximum (peak) flows are 1.0, 0.5 and 2.7 m^3/s. A builder wants to construct a development that will contribute a maximum flow of 0.7 m^3/s to the trunk sewer. Would this addition cause the sewer to exceed its capacity?



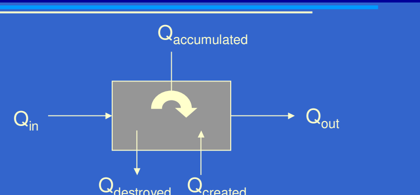
$(1.0 + 0.5 + 2.7 + 0.7)\ m^3/s = Q_{out} = 4.9\ m^3/s > 4.0\ m^3/s$

Thus, the builder should not be permitted to use this trunk sewer. In fact, the current situation is not good in that if all three communities use the sewer at peak, backup will occur.

Complex Mass Balances w/ 1 material

- What if we do not have a conservative, steady state system?
  - If a system is not conservative, that means that material may be created or destroyed
  - If the system flows are not in steady state, then material can be accumulated within or flushed out of the system.

Mass Balance Equation (1 material)



$Q_{accumulated} = Q_{in} - Q_{out} + Q_{created} - Q_{destroyed}$

Rate of mass accumulated = rate of mass input - rate of mass output + rate of mass created - rate of mass destroyed

Mass Balance for > 1 Material

- The process is more complicated when flows may carry several different materials
- However, the same form of mass balance equation can be used for each material.

Summary

- Concentration is the amount of material by mass or volume in a unit volume of many materials
- Flow rate is the mass or volume of a material passing a fixed point in a flow over a unit of time
- Mass balance is a tool we can use to analyze a system based on the conservation of mass.

Scheduling the Final Exam

- Considering: ENGL 110, MATH 241, MATH 242, CHEM 104, PSYC 100, ECON 151
- Propose:
  - Tuesday Dec 13
  - Wed Dec 14 (afternoon)

Next Week

- Mid term Exam
  - 50 minutes at beginning of class
  - Covers everything up to and including last week – 10/10/05
  - Open book / Open notes
  - Review homework and notes, make a summary sheet of key points
  - Practice midterm given today – questions will be similar. Solutions on class website
- Guest lecture – Professor Dom DiToro – Environmental Engineering and Water Resources