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 L

C_A = $M_A / (V_A + V_B)$
= 0.48 kg / 100L
= 0.0048 kg/ L
= 0.0048 kg/ L (10^6 mg/kg)
= 4800 mg/L

Concentration: ppm

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

1 mg/L = (0.001 g)/1000 mL
= (0.001 g)/1000 cm^3
= (0.001 g)/1000 g
= 1 g / 10^6 g = 1 ppm

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 ppm = 10^4 g / 10^6 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/m³ 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 * (10^3 / 10^3)]

= [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?

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

= [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?

$Q_{M\ FLUORINE}$

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

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

= 150 lb/day