Importance of EFM:

Why do we care about fate and transport and what species are we interested in?

Generally, it comes down to 3 issues:

1. Toxicology: we know what concentrations are harmful, so we design engineering projects to avoid/minimize occurrence of such concentrations.

2. Nutrition/Life Support: organisms need chemicals to survive and we must predict the occurrence of these chemicals to predict population growth (e.g. of phytoplankton, algae, zooplankton).

3. Climate Change: Combination of above.

Example species of interest:

- **O₂**: required for respiration.
- **CO₂**: required for photosynthesis; greenhouse gas.
- **PO₄**: important freshwater nutrient.
- **CFC**: ozone-depleting chemical.
- **Fe²⁺**: heavy metal – toxic in large doses.
- **Ar**: Poison.

Others: PCB, MTBE, NOₓ, CO, pH, heat.

As engineering practice leaves a bigger footprint on the environment, it is necessary to predict impact at design stage and mitigate impact in clean-up stage. This is role of EFM.
Example Problems we will cover in this class:

1. Industrial exhaust gases:

   ![Diagram of industrial exhaust gases]
   instantaneous C-profile.

2. River discharge:
   Plan view:

   ![Diagram of river discharge]
   average C-profile.

3. Accidental spills:
   Plan view:

   ![Diagram of an oil spill]


   ![Diagram of oxygen concentration profile]

See pictures on web site "Related Resources". Think of an example you've encountered somewhere.
Concentration:

Concentration is a measurement that lets us keep track of our substance of interest. It also lets us compare intensities.

Definition: Concentration expresses the measure of the amount of a substance in a mixture.

Three concentration measures:

1. **Concentration**: mass of the substance in a unit volume of a mixture.

   \[ C = C(x, y, z, t) = C(\vec{x}, t) \]

   "field representation".

   At a point at a given time:

   \[ C = \lim_{\Delta V \to 0} \frac{\Delta M}{\Delta V} \]

   \( \Delta M \): tracer mass
   \( \Delta V \): volume.

   - averaged over a small volume, but not too small so that it contains a large \( \# \) of molecules.
   - called "continuum hypothesis".
   - \( \Theta(10^{-7}) \) mm is average spacing of molecules in water.

   For finite \( V \) of uniform concentration:

   \[ C_i = \frac{M_i}{V} \]

   \( C_i \): concentration of species \( i \)
   \( M_i \): mass of species \( i \)
   \( V \): volume of mixture.

   units: \( \frac{M}{L^3} \) eg. \( \frac{mg}{m^3} \), \( \frac{kg}{m^3} \), etc.
(2) **Relative concentration or mass fraction:** mass of the substance in a unit mass of a mixture.

\[ \chi = \frac{M_i}{M} \]

- \( M_i \): mass of species i.
- \( M \): mass of mixture.

**Units:** \( \frac{M}{M} \) \( \rightarrow \) unitless.

Sometimes use mixed units: ppm, ppb, etc.

(3) **Molar concentration:** number of molecules of the substance in a unit volume of a mixture.

\[ \theta = \frac{N_i}{V} \]

- \( N_i \): number of moles of i.

**Units:** \( \frac{\#}{V} \) eg. \( \frac{\text{mol}}{L}, \frac{\text{nmol}}{\mu L}, \text{etc.} \)

Recall \( 1 \text{ mol} = 6.022 \times 10^{23} \) molecules.

**Other related quantities:**

- **Dilution:** the ratio of the volume of a mixture to the volume of effluent contained in a mixture.

\[ S = \frac{V}{V_e} \]

- \( V_e \): volume of effluent from source i.

**Units:** \( S \) \( \rightarrow \) unitless.

\( S = 1 \) ... undiluted effluent.

\( S = \infty \) ... pure ambient water.

- **Density:** Mass of a substance per unit volume.

\[ S_i = \frac{M_i}{V_i} \]

- **Specific Gravity:** \( S_i / S_{water} \).