

# Environmental Water Quality BAE 452/552

## Session 6 Eutrophication

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## Where are we?

### Receiving Water Impacts:

- Physical, chemical, biological characteristics of water
- The oxygen problem
- Eutrophication←
- Water quality criteria/standards
- Water quality monitoring

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## Aquatic Ecosystem

- In water quality, our goal is to restore, protect, and enhance the ecosystem or ecology
- Ecosystem: biotic or abiotic, in dynamic equilibrium with inputs and surroundings.
- If one input is changed, the ecosystem will adjust to a new equilibrium
- Examples: rivers, lakes, wetlands, estuaries, soils.

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## Aquatic Ecosystem

- Primary input: sun energy
- Secondary input: organics and waste heat
- Elements: nutrients (food) for growth of biotic components; toxics that retard growth, damage or kill organisms
- Biotic components: producers, consumers, and decomposers

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## Eutrophication

- When lakes, streams and estuaries are over fertilized, excessive production of aquatic organic matter can become a water quality problem
- Eutrophication: a process by which a body of water progresses from its origin to its extinction. This process happens in stages.
- If human influences: 'cultural eutrophication'

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## Eutrophication

### Negative effects:

- Quantity: plant growth decreases water clarity, clog filters or water ways
- Chemistry: DO, CO<sub>2</sub> levels => pH
- Biology: Species composition: algae, taste, odor, toxics

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## Trophic Levels

- Oligotrophic (poorly nourished)
- Mesotrophic (moderately nourished)
- Eutrophic (well-nourished)
- Hypereutrophic (over-nourished)

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## Trophic Status of Lakes

Water Quality	Oligotrophic	Mesotrophic	Eutrophic
Total P ( $\mu\text{g/L}$ )	<10	10-20	>20
Chlorophyll-a ( $\mu\text{g/L}$ )	<4	4-10	>10
Secchi depth (m)	>4	2-4	<2

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## Eutrophication

How it works:

- Inorganic nutrients that serve as raw materials from which plant biomass is synthesized, 'the building blocks'
- Macronutrients: C, O, N, P, S, Si, Fe
- Micronutrients: Mg, Co, Zn

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## Phosphorus

- Phosphorus (P) is essential to all life (genetic systems, storage and transfer of cell energy)
- P is in short supply relative to other macronutrients:
  1. Not abundant in earth's crust; minerals not soluble
  2. Not in gaseous form, so no atmospheric source
  3. Strongly sorbs to fine-grained particles

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## Phosphorus (P)

- Human activity => discharge to water bodies:
  1. Detergent P
  2. Agriculture
  3. Urban

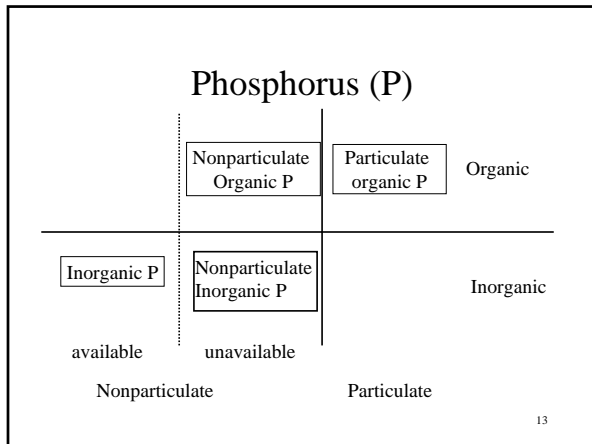
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## Phosphorus (P)

Phosphorus (P) forms in natural waters:

1. Soluble Reactive P (SRP) or orthophosphate or soluble inorganic P: readily available to plants ( $\text{H}_2\text{PO}_4^-$ ,  $\text{HPO}_4^{2-}$ ,  $\text{PO}_4^{3-}$ )
2. Particulate organic P: living plants, animals
3. Non-Particulate organic P: dissolved or colloidal => decomposition of particulate organic P
4. Non-Particulate inorganic P: detergents

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### Phosphorus (P)

Phosphorus (P) forms (alternative terminology):

1. Dissolved Phosphorus (DP)
2. Particulate Phosphorus (PP)
3. Total Phosphorus (TP)

Availability of P is important in water quality!

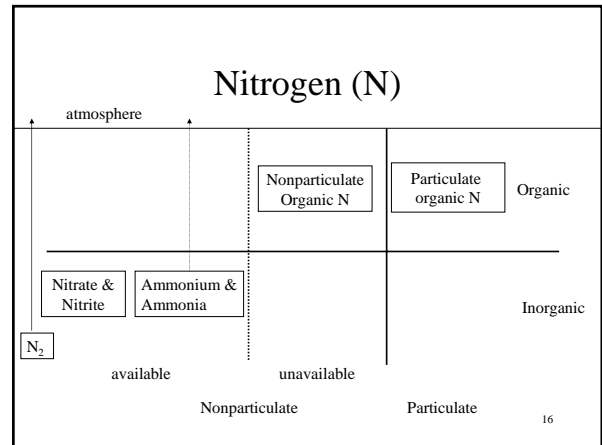
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### Nitrogen

Nitrogen (N) forms in relation to natural waters :

- Free nitrogen ( $N_2$ )
- Ammonium ( $NH_4$ )
- Ammonia ( $NH_3$ )
- Nitrite ( $NO_2^-$ )
- Nitrate ( $NO_3^-$ )
- Organic N

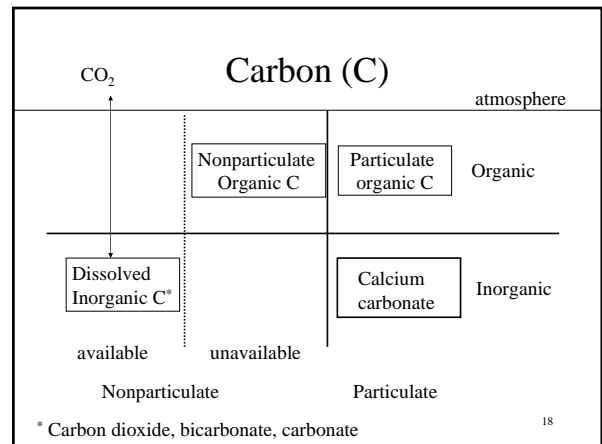
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### Carbon

- Nutrient function, but not limiting for algae growth
- Measure of biomass
- Pollutant: organic carbon decomposition affects oxygen, toxics associate with organic matter, naturally produced organic carbon can be transformed into toxic compounds (chlorine + C => trihalomethanes)

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## Silicon

- Significance in dynamics of phytoplankton as a structural element in the cells of diatoms (dissolved reactive silicon  $[\text{Si}(\text{OH})_4]$  to build frustule or ‘glass wall’ surrounding the cells
- Since the frustules are not available to other diatoms, low concentrations of silicon can limit algae growth

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## N and P: “The Limiting Nutrient”

- In management it is often important to identify which nutrient used for plant nutrition controls the level of plants in water bodies: ‘the limiting nutrient’
- It is however not a rule that management should focus only on the limiting nutrient if that nutrient source is difficult to control (e.g., groundwater)

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## Stoichiometry: Algae Growth

- Production of organic matter (say algae):
- $106\text{CO}_2 + 16\text{NH}_4^+ + \text{HPO}_4^{2-} + 108\text{H}_2\text{O} \leftrightarrow \text{C}_{106}\text{H}_{263}\text{O}_{110}\text{N}_{16}\text{P}_1 + 107\text{O}_2 + 14\text{H}^+$   
“algae”
- Mass ratios of C:N:P  $\Rightarrow$  1272:224:31, and including 1% P in protoplasm, we obtain:
- 40:7.2:1

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## N and P: “The Limiting Nutrient”

- Comparison of nutrients in water to stoichiometry can show which nutrient is the limiting nutrient
- If the N:P ratio  $< 7.2$ , then N is limiting
- If the N:P ratio  $> 7.2$ , then P is limiting

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## N and P Export Rates for NPS

Nutrient (kg/ha yr)	Forest	Ag	Urban	Atmosphere
N	3	5	5	24
P	0.4	0.5	1	1
Ratio	7.5	10	5	24

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