

## Environmental Water Quality BAE 452/552

Session 4  
Physical, chemical and biological  
properties of water

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## Chemical Characteristics (Organics)

Organic matter:

- Natural: decaying weeds, leaves, trees
- Anthropogenic: synthetic organic compounds
- Causes: color formation, taste and odor problems, oxygen depletion, interference with water treatment processes, formation of halogenated compounds when chlorine is added to disinfect water

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## Chemical Characteristics (Organics)

Natural organic compounds:

- Proteins in animal tissue (C, H, O, N, S); glycine  $C_2H_5NO_2$  or bacterial cells:  $C_5H_7NO_2$
- Carbohydrates in plant tissue (C, H, O); sugars, starches, cellulose, wood fiber; glucose  $C_6H_{12}O_6$
- Lipids in animal and plant tissue (not soluble in water); fats and oils, greases, waxes

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## Chemical Characteristics (Organics)

Synthetic organic compounds:

- More than 100,000 organic compounds since 1940
- Surfactants: soaps and detergents, nowadays biodegradable
- Pesticides and Ag Chemicals: disease and pest control (toxic to aquatic organisms, carcinogenic)

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## Chemical Characteristics (Organics)

Synthetic organic compounds (cont'd):

- Cleaning Solvents (hydrocarbons): suspected carcinogens, found more often in groundwater systems
- Examples: acetone, benzene, carbon tetrachloride, ethyl alcohol.

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## Chemical Characteristics (Organics)

Synthetic organic compounds (cont'd):

- Trihalomethanes (Cl, Br, I with organics): suspected carcinogens
- Examples: Chloroform ( $CHCl_3$ ), Bromodichloromethane ( $CHCl_2Br$ ), Chlorodibromomethane ( $CHCl_2Br$ ), and bromoform ( $CHBr_3$ )

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## Chemical Characteristics

(Organics)

Measurement of organic matter:

- Trace organics ( $10^{-12} - 10^{-13} \text{ g/m}^3$ ) using gas chromatography and mass spectroscopy
- Gross amounts ( $> 1 \text{ g/m}^3$ ) include COD, TOC, TOD, BOD

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## Chemical Characteristics

(Organics)

Measurement of organic matter (cont'd):

- COD (Chemical Oxygen Demand), a quick test determining the oxygen equivalent of the organic matter
- $\text{C}_a\text{H}_b\text{O}_c + \text{Cr}_2\text{O}_7^{-2} + \text{H}^+ \rightarrow \text{Cr}^{+3} + \text{CO}_2 + \text{H}_2\text{O}$  (adding heat and catalyst)
- Cannot differentiate between biologically oxidizable and inert organic matter

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## Chemical Characteristics

(Organics)

Measurement of organic matter (cont'd):

- TOC (Total Organic Carbon): for smaller amounts, using instrument
- TOD (Total Oxygen Demand): organic and some inorganic compounds converted to stable end products, using instrument

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## Chemical Characteristics

(Organics)

Measurement of organic matter (cont'd):

- BOD (Biochemical Oxygen Demand), principal mechanism in natural waters representing amount of  $\text{O}_2$  used in metabolism of biodegradable organics
- $\text{C}_a\text{H}_b\text{O}_c + \text{O}_2 + \text{nutrients} \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{nutrients} + \text{new cells} + \text{energy}$
- Based on stoichiometry and rate

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## Chemical Characteristics

(Organics)

BOD (cont'd):

- Fish example:
  - In clean bowl, respiration rate equals re-aeration rate
  - If we add OM or overfeed, fish and bacterial respiration rate  $>$  re-aeration rate
  - Depletion of oxygen in bowl results

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## Chemical Characteristics

(Organics)

BOD (cont'd):

- Carbonaceous BOD: biological oxidation of organic matter into  $\text{CO}_2$ ,  $\text{NH}_3$ , and  $\text{H}_2\text{O}$
- Nitrogenous BOD: biological oxidation of ammonia to nitrate (nitrification)

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## Biological Characteristics

- Micro-organisms
- Macro-invertebrates and fish

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## Biological Characteristics

(micro-organisms)

Effect on water quality

- Transmission of disease by pathogenic organisms
- Development of tastes and odor

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## Biological Characteristics

(micro-organisms)

What types?

- Bacteria (single cell)
- Fungi (multi-cellular)
- Algae (eucaryotic)
- Protozoa (single cell eucaryotic, w/out cell wall, sometime in oocyst or cyst)
- Worms
- Viruses (parasitic)

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## Biological Characteristics

(micro-organisms)

Enumeration:

- Bacteria: solid medium (plate count method, or liquid medium (gas-collection tube)
- Protozoa: microscopic counting (hemacytometer, flow cytometer)

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## Biological Characteristics

(micro-organisms)

Indicator organisms, the fecal coliform group:

- *Escherichia coli* in intestine of warm blooded animals
- *E. coli* are an indication of fecal matter in water and of possible pathogenic organisms
- Presumptive test (most probable number)
- Confirmed test (confirmation of *E. coli*)
- Completed test (further confirmation)

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## Biological Characteristics

(micro-organisms)

Indicator organisms, others in warm blooded animals:

- Fecal streptococci (e.g., *Streptococcus faecalis*)
- Clostridia (e.g., *Clostridium perfringens*)

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## Biological Characteristics (micro-organisms)

Human vs animal source:

- Ratio of Fecal Coliform (FC) to Fecal Streptococci (FS)
- If FC/FS > 4.0, human source
- If FC/FS < 1.0, animal source
- In between values indicate uncertainty

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## Biological Characteristics (micro-organisms)

Constraints in using FC/FS ratio:

- pH between 4 and 9 to exclude adverse effects
- At least 2 counts on each sample
- Minimize errors due to change in death rates by collecting samples within 24 hr of flow time from suspected contamination
- FC count at incubation temperature of 44 °C

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## Biological Characteristics (micro-organisms)

	FCx10 <sup>6</sup>	FSx10 <sup>6</sup>	Ratio
Human	13	3	4.4
Chicken	1.3	3.4	0.4
Cow	0.23	1.3	0.2
Pig	3.3	84	0.04
Sheep	16	38	0.4

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## Biological Characteristics (macro-invertebrates and fish)

Community structure, 2 view points:

- observed communities are the result of biotic forces acting to maintain communities at or near equilibrium
- communities are maintained by highly variable and unpredictable abiotic forces (nonliving aspects of the ecosystem), and that the species found together are those that could survive and thrive in the current conditions

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## Biological Characteristics (macro-invertebrates and fish)

Stream habitat:

- Determines species composition
- Determines species abundance
- Determines age/size structure

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## Biological Characteristics (macro-invertebrates and fish)

Index of Biotic Integrity (IBI):

- Ability of a stream to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region
- Developed by eco-region

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## Biological Characteristics

(macro-invertebrates and fish)

Index of Biotic Integrity (IBI):

- Correlation with other non-living aspects of the stream habitat: substrates, current velocity, depth, riparian condition, etc.
- Karr, J. R. & E. W. Chu (1999) *Restoring Life In Running Waters: Better Biological Monitoring*. Washington, D.C.: Island Press

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