

Lecture 3: Water Pollution

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Objective: To introduce water pollutants (chemical, biological) and nutrients which might cause problems

Pathogenic Microorganisms

Typical Pathogens Excreted In Human Feces

Pathogen Group and Name	Associated Diseases
Virus	
Adenoviruses	Respiratory, eye infections
Enteroviruses	
Polioviruses	Aseptic meningitis, poliomyelitis
Echoviruses	Aseptic meningitis, diarrhea, respiratory infections
Coxsackie viruses	Aseptic meningitis, herpangina, myocarditis
Hepatitis A virus	Infectious hepatitis
Reoviruses	Not well known
Other viruses	Gastroenteritis, diarrhea
Bacterium	
<i>Salmonella typhi</i>	Typhoid fever
<i>Salmonella paratyphi</i>	Paratyphoid fever
Other salmonellae	Gastroenteritis
<i>Shigella</i> species	Bacillary dysentery
<i>Vibrio cholerae</i>	Cholera
Other vibrios	Diarrhea
<i>Yersinia enterocolitica</i>	Gastroenteritis

Pathogenic Microorganisms

Protozoan

<i>Entamoeba histolytica</i>	Amoebic dysentery
<i>Giardia lamblia</i>	Diarrhea
<i>Cryptosporidium</i> species	Diarrhea

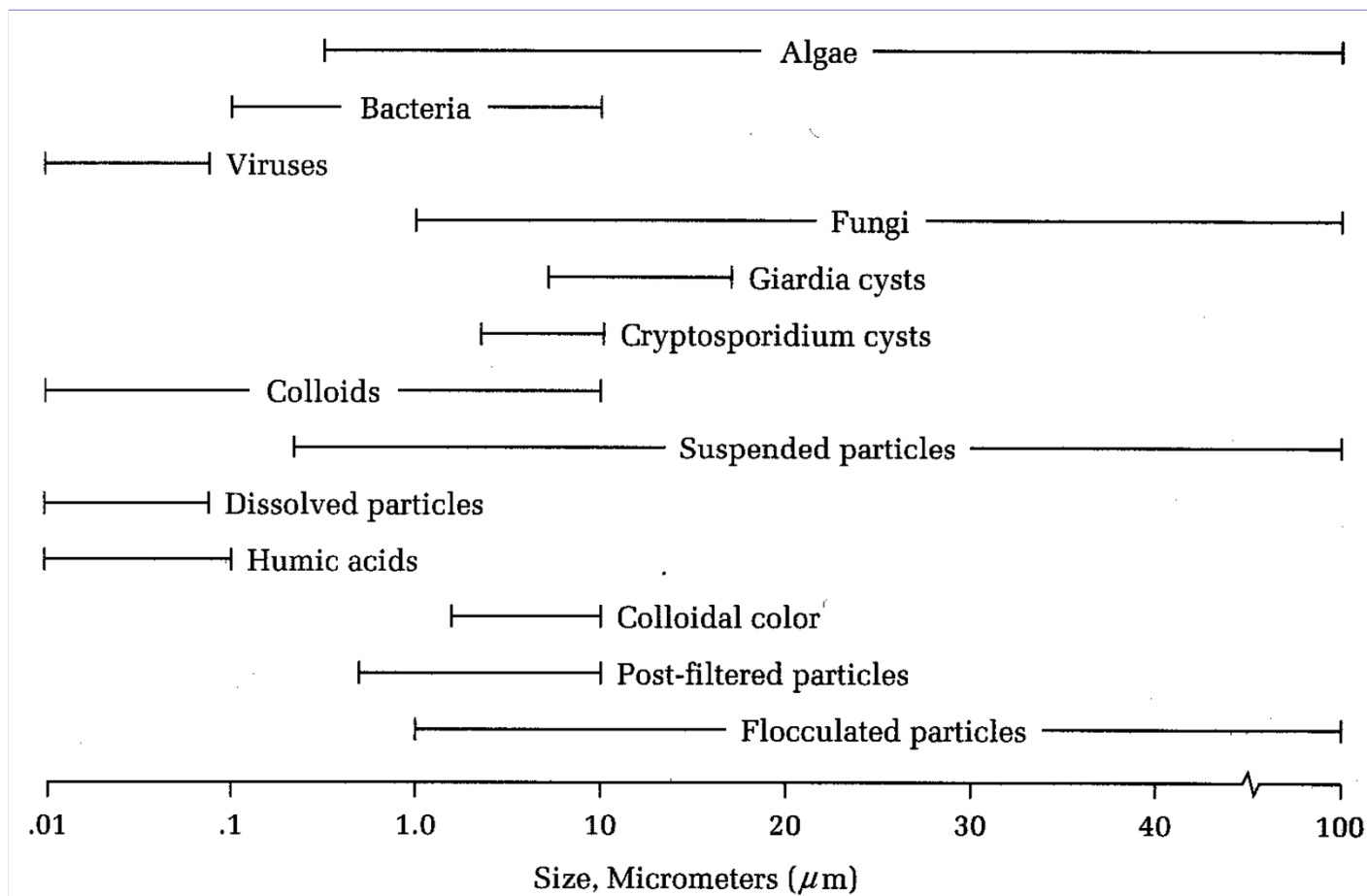
Helminth

<i>Ancylostoma duodenale</i> (hookworm)	Hookworm
<i>Ascaris lumbricoides</i> (roundworm)	Ascariasis
<i>Hymenolepis nana</i> (dwarf tapeworm)	Hymenolepiasis
<i>Necator americanus</i> (hookworm)	Hookworm
<i>Strongyloides stercoralis</i> (threadworm)	Strongyloidiasis
<i>Trichuris trichiura</i> (whipworm)	Trichuriasis

Q: Can you list sources which might give you exposure of pathogenic microorganisms?

Source: Hammer and Hammer, 1996.

Sizes of Microorganisms and Other Particles *(size influences removal through filtration method)*



Inorganic Pollutants

- Heavy Metals
- Arsenic
- Nitrates
- chromium
- Asbestos
- Other?

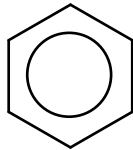
Effect = f(valency type, concentration)

For example: toxic effects of arsenate(AsIV)) and arsenite (As(III)) might be different.

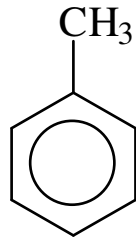
Q: Can you list sources which might give you exposure of these inorganic pollutants?

Volatile Organic Compounds (VOCs)

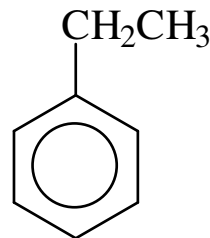
- Petroleum constituents:
 - benzene and substituted benzenes



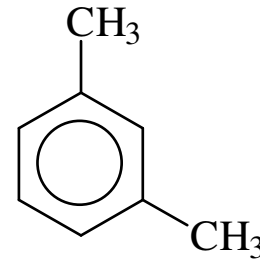
Benzene



Toluene



Ethylbenzene

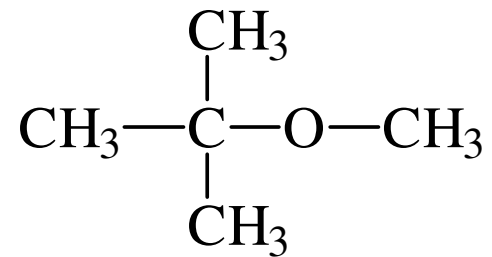


m-Xylene

- prevalent in gasoline, diesel fuel, heating oil
- most easily transported, slow degradation, toxic

Volatile Organic Compounds (VOCs)

- Oxygentated gasoline additives

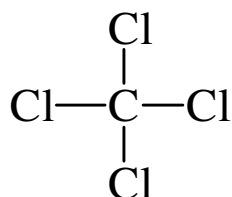


Methyl tertiary butyl ether (MTBE)

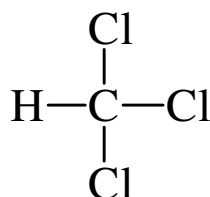
- added to gasoline to improve air quality
- very soluble, resistant to degradation, toxic
- attempt to solve one problem caused another (spills)

Volatile Organic Compounds (VOCs)

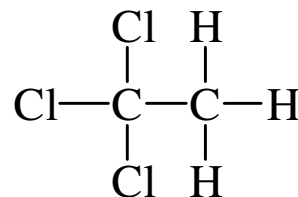
- Chlorinated solvents
 - C1 and C2 aliphatics



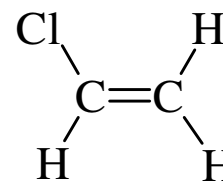
carbon tetrachloride



chloroform



1,1,1-trichloroethane



vinyl chloride

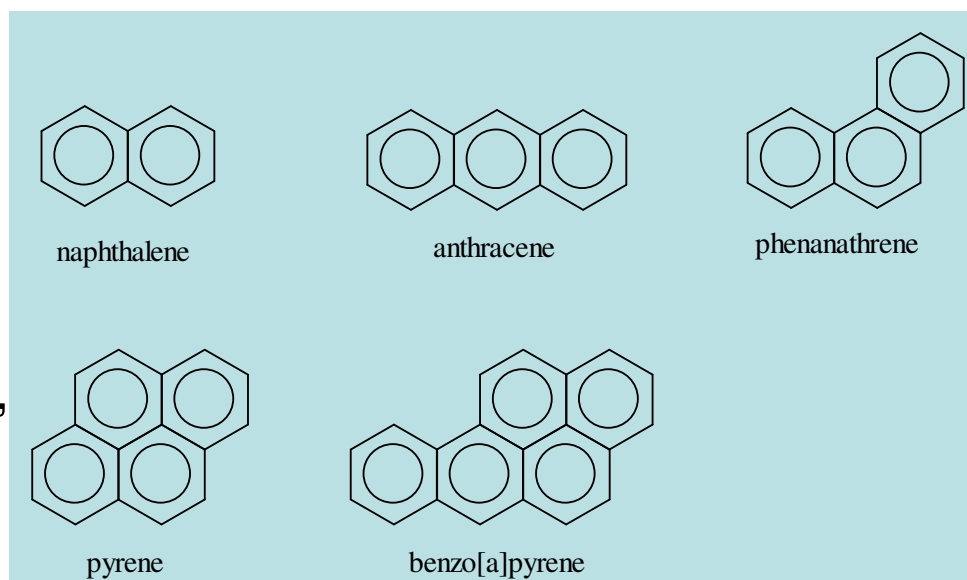
- widely used in degreasing, dry cleaning, extraction
- somewhat soluble, volatile, difficult to degrade

Pesticides (hydrophobic organic compounds)

- **Organochlorine Insecticides:** were commonly used in the past (e.g. DDT and chlordane).
- **Organophosphate Pesticides:** most are insecticides, some are very poisonous (they were used in World War II as nerve agents)
- **Carbamate Pesticides:** affect the nervous system
- **Pyrethroid Pesticides:** were developed as a synthetic version of the naturally occurring pesticide pyrethrin, which is found in chrysanthemums

Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are a group of over 100 different chemicals that are **formed during the incomplete burning** of coal, oil and gas, garbage, or other organic substances.



They are potent carcinogens, **hydrophobic organic compounds** and they tend to associate with particles.

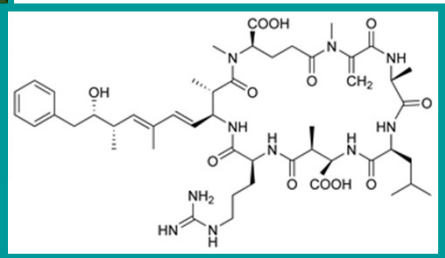
Polychlorinated biphenyls (PCBs)



- Polychlorinated biphenyls are mixtures of individual chlorinated compounds (known as congeners).
- PCBs are either oily liquids or solids that are colorless to light yellow.
- PCBs have been used as **coolants and lubricants** in transformers, capacitors, and other electrical equipment.
- The manufacture of PCBs was stopped in the U.S. in 1977.
- They are hydrophobic and they bio-accumulate in the food chain.

Other Organic Pollutants

- Fertilizers
- Surfactants
- Explosives, propellants
- Chlorination By-Products (e.g. trihalomethanes)
- Antibiotics
- Pharmaceuticals
- Personal care products
- Cyanobacterial toxins
- nanomaterials

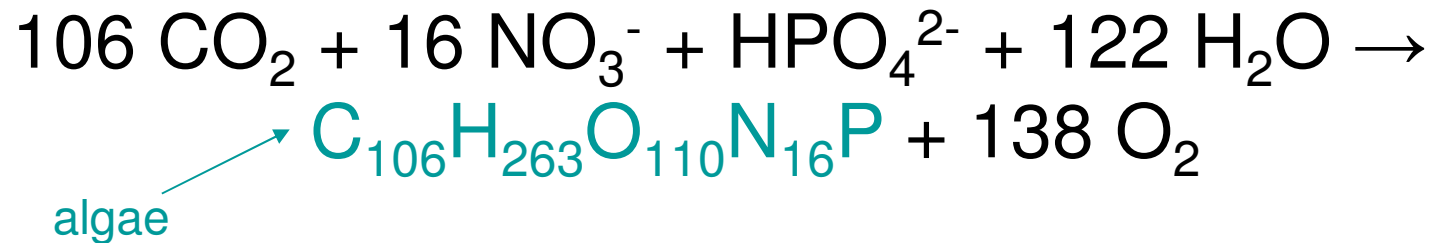


Microcystin-LR
(hepatotoxin)

Excess Nutrients

- Nitrogen and phosphorus are nutrients required by all living organisms. They are considered pollutants when they are in excess.
- Excessive nutrients often lead to large growths of algae which in turn become oxygen-demanding material when they die and settle.

Excess Nutrients



Nitrogen and phosphorus are typically the limiting factors

Phosphorus

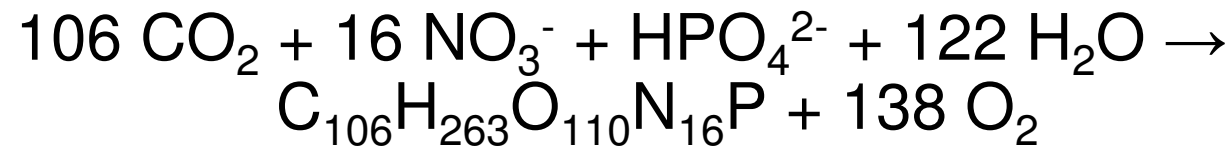
- Phosphorus is typically the limiting nutrient in lakes, and algae growth is linked to phosphorus inputs.
- P Sources
 - fertilizers
 - detergents
 - wastewater
- P can exist in a variety of chemical forms

Nitrogen

- Nitrogen is often the limiting nutrient in ocean waters and some streams
- Nitrogen can exist in numerous forms, but nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_3) are most commonly measured
- Sources are primarily from fertilizers and acid deposition

Factors Controlling Eutrophication

- Stoichiometry of photosynthesis (C,N,P, O & H)



$$\frac{\text{N}}{\text{P}} = \frac{16 \times 14}{1 \times 31} = 7.2$$

It takes ~ 7 times more N than P to produce a given mass of algae

- *Liebig's law of the minimum* – growth will be limited by the availability of the nutrient that is least available relative to the need
- Most fresh water systems are phosphorus limited

Salts

- Dissolved solids, or salts, may be present as any number of ions
 - cations: Na^+ , K^+ , Mg^{2+} , Ca^{2+}
 - anions: Cl^- , SO_4^{2-} , HCO_3^-
- Typically measures as *total dissolved solids* (TDS)
- Water classification
 - freshwater <1500 mg/L TDS
 - brackish water 1500 – 5000 mg/L
 - saline water >5000 mg/L
 - sea water 30-34 g/L

Salts

- Sources
 - industrial discharges
 - deicing
 - evaporative losses
 - minerals
 - sea water intrusion
- Effects
 - natural fresh water population threatened
 - limits use for drinking
 - crop damage/soil poisoning (cannot use for irrigation)

Suspended Solids

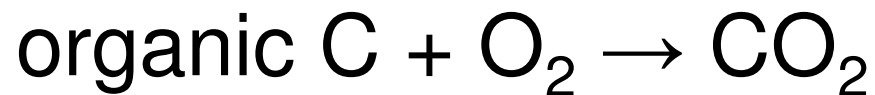
- Organic and inorganic particles in water are termed suspended solids
- May be distinguished from colloids, particles that do not settle readily

- Sources
 - storm water
 - wastes
 - erosion

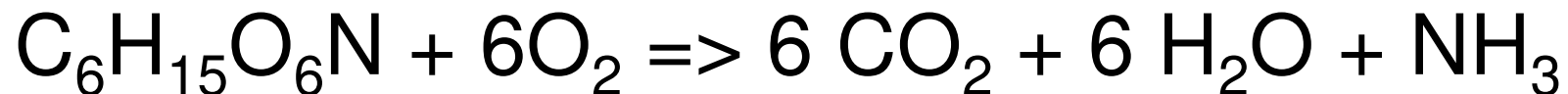
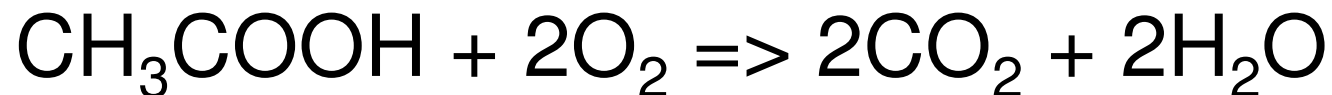
- Problems
 - sedimentation
 - may exert oxygen demand
 - primary transport mechanism for many metals, organics and pathogens
 - aesthetic
 - complicates drinking water treatment

Oxygen-Demanding Wastes

- When organic substances are broken down in water, oxygen is consumed



- For example:



Oxygen-Demanding Wastes

- High oxygen levels necessary for healthy stream ecology.
- For example:
 - trout require 5-8 mg/L dissolved oxygen (DO)
 - carp require 3 mg/L DO

Oxygen Demanding Wastes- measurement/estimation

- Estimated stoichiometrically by theoretical oxygen demand (ThOD)
- Measured by oxygen demand potential
 - biochemical oxygen demand (BOD)
 - Nitrogenous oxygen demand (NBOD)
 - chemical oxygen demand (COD)

Next class: tuesday