Water quality

Water quality

- Sources of water pollutants
- Types of water pollutants
- Oxygen demand: ThOD, COD, BOD
- Modeling BOD
- Water quality in rivers: DO modeling
- Groundwater quality

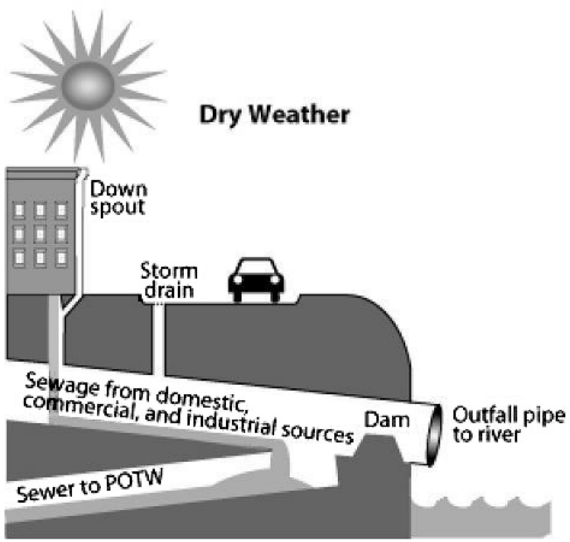
Sources of water pollutants

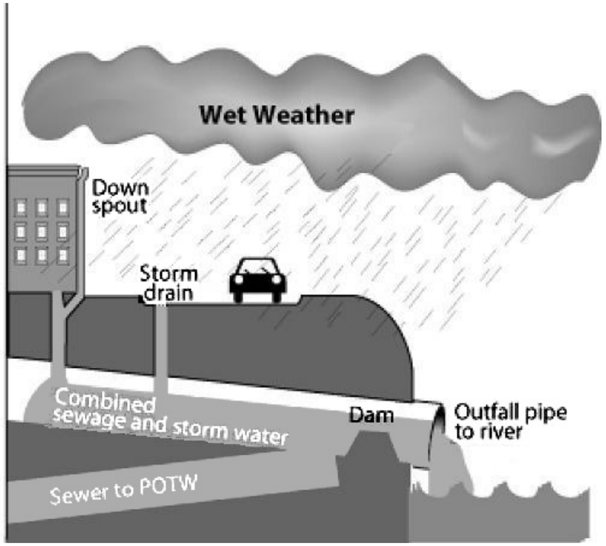
- **Point sources**: collected by a network of pipes of channels and conveyed to a single point of discharge
  - ex: domestic sewage, industrial wastewater

- **Nonpoint sources**: have multiple and diffuse discharge points
  - ex: urban and agricultural runoff

Combined sewer overflow (CSO)

- A nonpoint pollution problem
- Combined sewer system (↔ separate sewer system)
  - The sewage mixed with the storm water may go directly to the river (**C**ombined **S**ewer **O**verflow)
  - Generally no longer constructed in the developed world, but old cities may still have the combined sewer





USEPA (2004)

Types of water pollutants

- **Oxygen-demanding material**
  - Any substances that can be oxidized in the water resulting in the consumption of dissolved molecular oxygen (DO)
  - Mostly biodegradable organic matter, but also includes inorganics (ex: ammonia)
  - Low DO poses a threat to fish and other higher forms of aquatic life that requires oxygen
  - Major source: human waste, food residue, industry (esp. food-processing & paper industries)

Types of water pollutants

- **Nutrients**
  - Nitrogen & phosphorus
  - Excessive nutrients → excessive algal growth
  - Major source: agricultural runoff, human and animal excrement, P-based detergents, fertilizers, food-processing wastes
  - Agricultural runoff may cause significant nutrient loadings to the water

Types of water pollutants

- **Pathogens**
  - Bacteria, viruses, protozoa, and helminthes
  - Excreted by diseased persons or animals
  - Occurrence of pathogens in drinking water may cause outbreaks of gastrointestinal infections

Types of water pollutants

1993 Milwaukee Cryptosporidiosis outbreak

The 1993 Milwaukee Cryptosporidiosis outbreak was a significant distribution of the Cryptosporidium protozoan in Milwaukee, Wisconsin, and the largest waterborne disease outbreak in documented United States history. The Howard Avenue Water Purification Plant was contaminated, and treated water showed turbidity levels well above normal. It was one of two water treatment plants for Milwaukee. The root cause of epidemic was never officially identified; initially it was suspected to be caused by the cattle genotype due to runoff from pastures. It was also thought that melting ice and snowmelt carrying *Cryptosporidium* may have entered the water treatment plants through Lake Michigan. MacKenzie et al. and the CDC showed that this outbreak was caused by *Cryptosporidium* oocysts that passed through the filtration system of one of the city's water-treatment plants, arising from a sewage treatment plant's outlet 2 miles upstream in Lake Michigan.

Types of water pollutants

1993 Milwaukee Cryptosporidiosis outbreak (continued)

This abnormal condition at the water purification plant lasted from March 23 through April 8, after which, the plant was shut down. Over the span of approximately two weeks, 403,000 of an estimated 1.61 million residents in the Milwaukee area (of which 880,000 were served by the malfunctioning treatment plant) became ill with the stomach cramps, fever, diarrhea and dehydration caused by the pathogen. At least 104 deaths have been attributed to this outbreak, mostly among the elderly and immunocompromised people, such as AIDS patients.

(*Wikipedia, 2014*)

Types of water pollutants

- **Suspended solids (SS)**
  - Particles carried by water
  - When the water flow slows down, most SS settle down, but colloidal particles do not settle readily
  - Cause turbidity in water and may destroy habitat for benthic organisms

Types of water pollutants

- **Salts**
  - Often measured as total dissolved solids (TDS): measure the weight remaining after evaporating a filtered water sample
  - Evaporation of water from reservoirs, canals, and during application to plants increases salinity
  - Increased salinity causes reduction in crop yield & threats to aquatic life

Types of water pollutants

- **Pesticides**
  - Herbicides, insecticides, fungicides, …
  - Kills herbs, insects, fungi, … → why not toxic to humans?
  - Migrates to surface water by runoff; to groundwater by infiltration

Types of water pollutants

- **Pharmaceuticals and personal care products (PPCP)**
  - Of recent interest
  - Substances used by humans and pets for health or cosmetic reasons and the products used to boost growth or health of livestock
  - Sources: human activity, residues from manufacturing, residues from hospitals, illegal drugs, drug use to animals (antibiotics and steroids)

Types of water pollutants

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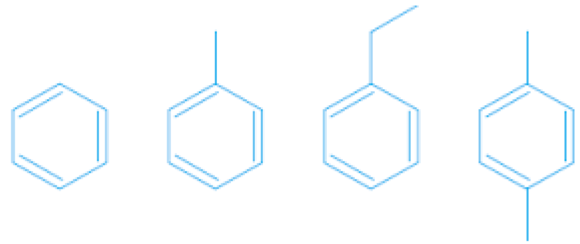
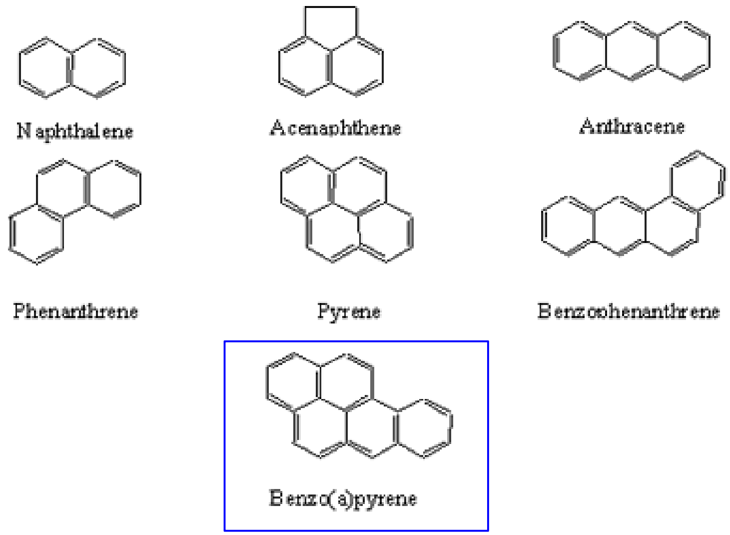
- **Endocrine disrupting chemicals (EDCs)**
  - Compounds mimicking hormones
  - example:
    - polychlorinated biphenyls (PCBs): coolant, insulator, plasticizer
    - atrazine: pesticide
    - phthalates: plasticizer
    - bisphenol A (BPA): making plastics
    - natural and synthetic estrogen
      - contraceptive pills: 17α-ethynylestradiol (EE2)
  - May cause adverse effects at relatively low concentrations
  - Can interfere with the regulation of reproductive and developmental processes or alter the normal physiological function of the endocrine system

Types of water pollutants

- Other toxic organic chemicals
  - **BTEX**

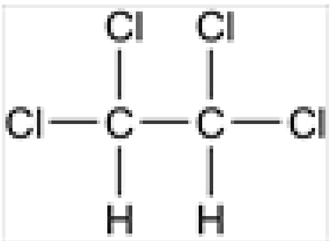


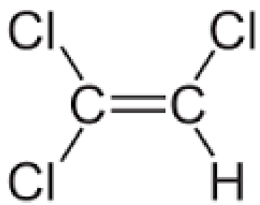
    - <u>B</u>enzene, <u>T</u>oluene, <u>E</u>thylbenzene, <u>X</u>ylene
    - Spills from gasoline and other petroleum products
  - **Polycyclic aromatic hydrocarbons (PAHs)**
    - Compounds with two or more fused benzene rings
    - Some are carcinogenic
    - Incomplete combustion, petroleum

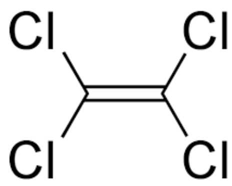


Types of water pollutants

- Other toxic organic chemicals
  - **Chlorinated ethenes and ethanes**
    - Tetrachloroethane (**TCA**), trichloroethylene (**TCE**), tetrachloroethylene (**PCE**)
    - Solvents for dry cleaning and metal washing







perchloroethylene

Types of water pollutants

- **Arsenic**
  - Neither metal nor non-metal, but metalloid
  - Source: mineral dissolution from weathered rocks and soils, mainly from iron oxides or sulfide minerals → arsenic contamination is often **a naturally occurring problem**
  - Human carcinogen
  - Significant groundwater contaminant in many regions of the world (ex: 33-77 million of Bangladesh's 125 million people are at risk of As poisoning from groundwater)
  - Exist in quite high levels in Korea as well!

Types of water pollutants

- **Toxic metals**
  - Cadmium (Cd), Chromium (Cr), Copper (Cu), Nickel (Ni), Lead (Pb), Mercury (Hg)
  - Sources: industrial waste, wastewater treatment plants, stormwater runoff, mining operations, smokestack emissions, etc.
  - Some heavy metals bioaccumulate and biomagnify (ex: mercury in tuna)

Types of water pollutants

- **Toxic metals**
  - **Acid mine drainage (AMD)**
    - Water in mine operations gets acidic by a series of geochemical and microbial reactions
    - Generally metal solubility increases as pH lowers
    - Water contamination, ecosystem destruction, corrosion of infrastructure
  - Outbreaks: recall from your middle school class!
    - Minamata, Japan – mercury
    - Toyoma, Japan – cadmium (itai-itai disease)

Types of water pollutants

- **Heat**
  - Water used as coolants is discharged to the receiving waters
  - May destroy the aquatic ecosystem
  - Temperature increases → decrease in oxygen solubility and enhanced microbiological activity → oxygen depletion in rivers

Types of water pollutants

- **Nanoparticles**
  - Particles having a dimension < 100 nm
  - Naturally occurring humic material; TiO_2 particles in paints, varnishes, paper, plastics, creams, etc.; carbon nanoparticles in tires, tennis rackets, video screens, etc.; protein-based nanomaterials in the production of soaps, shampoos, and detergents
  - Rapidly increasing production
  - Toxicity and fate not well known

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Reading assignment

Textbook Ch 9 p. 378-392

Oxygen demand

Theoretical oxygen demand (ThOD)

Oxygen demand

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Oxygen demand

Chemical oxygen demand (COD)

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Oxygen demand

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BOD Measurement

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* , %5

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The expected BOD of the diluted sample should be 2-6 mg/L.

** saturation DO concentration at 20ÁC: 9.17 mg/L*

BOD Measurement

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0 %

$DO_{b,t}$ **8** *t*

$DO_{s,t}$ **8** *t*

Oxygen demand

ThOD ≥ COD > BOD

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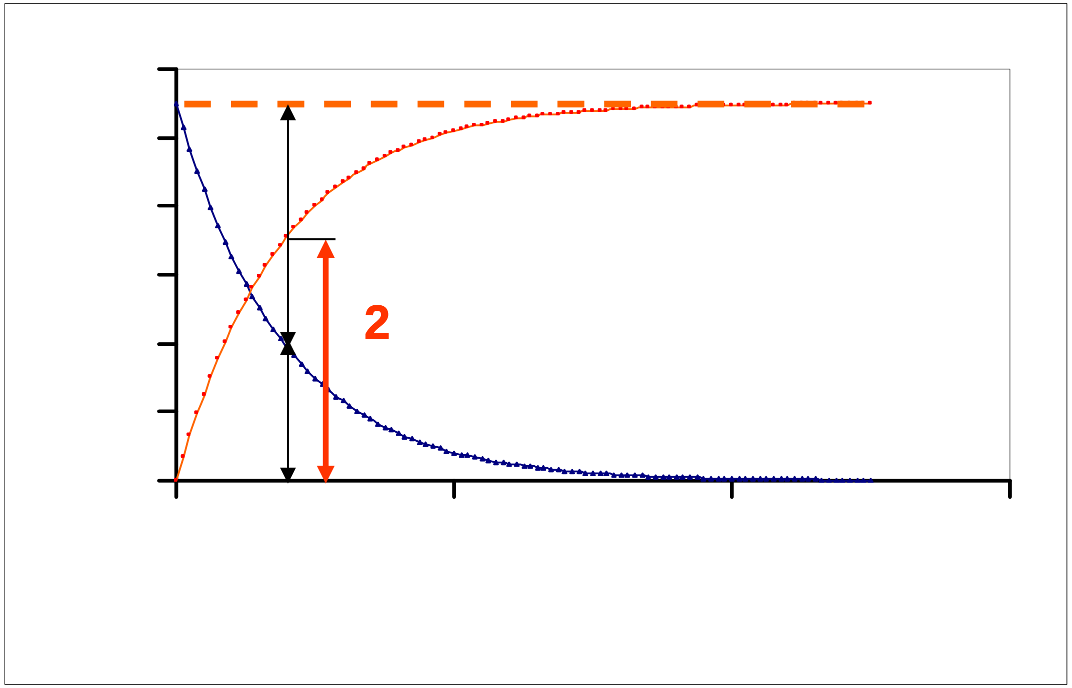
Modeling BOD



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Modeling BOD

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Modeling BOD

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Modeling BOD

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Nitrogenous BOD

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Nitrogenous BOD

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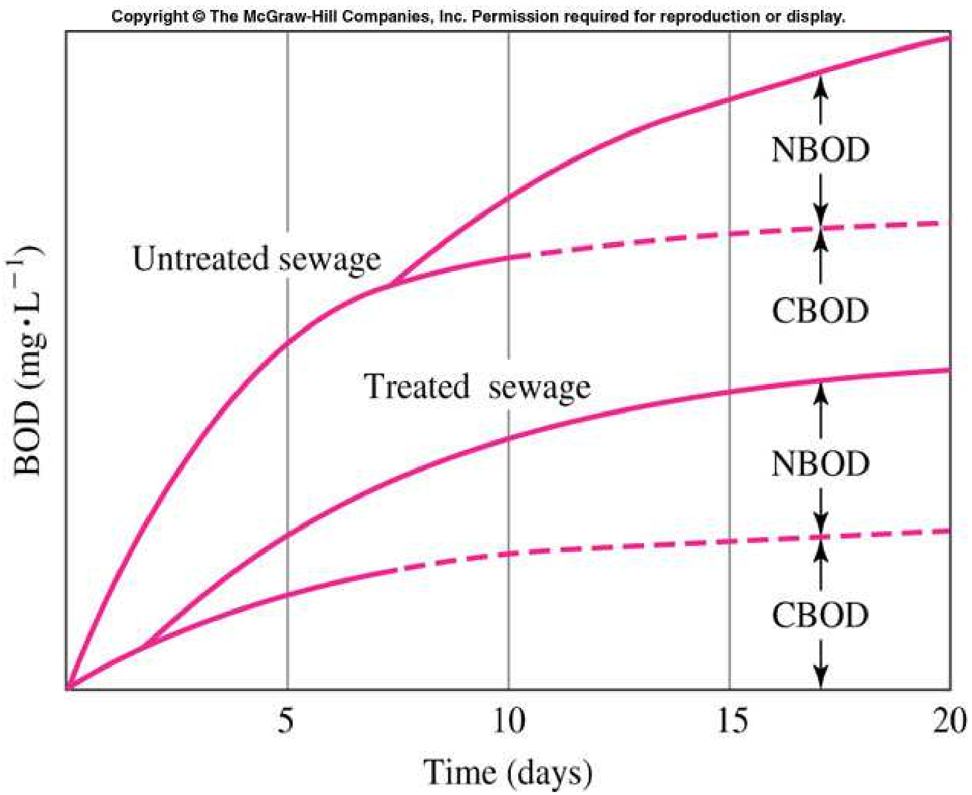

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Reading assignment

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