WATER TREATMENT

SKAA 2912

WATER QUALITY PARAMETERS (CHEMICAL – ORGANIC & INORGANIC)

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ORGANIC COMPOUNDS

- All organic compounds contain carbon in combination with one or more elements
- Sources:
  - Nature:
    - Breakdown of naturally occurring materials
    - The greatest source are from fibers, vegetable oils, animal oils and fats, cellulose, starch, sugar
    - Serve as precursors for disinfectant-by-products (DBPs) formation
  - Synthetic:
    - A wide variety of compounds and materials prepared by manufacturing processes (man-made chemicals from domestic and commercial activities)
  - Fermentation:
    - Alcohols, acetone, glycerol, antibiotics, acids

ORGANIC COMPOUNDS

- General effects
  - Deplete dissolved oxygen in water → destroy aquatic life and damage ecosystem
  - Some can cause cancer (e.g. DBPs – carcinogenic compounds formed when chlorine is employed as a disinfectant in water and wastewater treatment plants)

ORGANIC COMPOUNDS

- Man-made organic compounds:-
  - Volatile organic compounds
  - Pesticides
  - Emerging drinking water contaminants
  - Chemicals in treatment additives, linings and coatings

ORGANIC COMPOUNDS

- Volatile organic compounds (VOCs)
  - Characteristics
    - Evaporative
    - Slightly soluble in water
    - Easily volatilize from hot water (other exposure route besides ingestion: inhalation)
    - Lipophilic (can enter via skin absorption → enter brain from blood)
  - Effects
    - Dizziness, nausea and cardiac depression
    - Toxic to liver and kidney after chronic exposure and some can cause cancer
  - Divided into three broad groups:
    - Petroleum products (aromatic compounds in fuel oil and gasoline tanks)
    - Halogenated VOCs (used as solvents and degreasers in industrial and commercial)
    - **Chlorinated organic DBPs, particularly THMs**

ORGANIC COMPOUNDS

- Disinfectant by-products
  - Organic DBPs are formed through the reaction of disinfectants with organic matter in source waters
  - Regulated disinfectants are:
    - Chlorine

      Possess mutagenic potential to bacteria and mamalian cells; < 4 mg/L
    - Chlorine dioxide: < 0.8 mg/L (dissociate into Chlorite (ClO^-) and Chlorate ($ClO3^-$))

      Chlorite (ClO^-): Decrease red blood cells and growth rate; delay neurodevelopment (< 1.0 mg/L)

      Chlorate ($ClO3^-$): Increase thyroid and pancreatic tumor
    - Chloramines

      Affect dialysis patient by denaturing the red blood cells; < 4 mg/L

ORGANIC COMPOUNDS

- Disinfectant by-products
  - Regulated DBPs are:
    - Trihalomethanes (THMs): human carcinogen; volatile compounds that can be exposed during showering and other household uses of water
    - Haloacetic acids (HAAs): human carcinogen, develop abnormal sperm, decrease sperm count and motility, liver toxicity and tumors,
    - Bromate: human carcinogen
    - Nitrosamines: Nitrisodimethylamine (NDMA) – human carcinogen

ORGANIC COMPOUNDS

- Pesticides
  - Include insecticides, herbicides, nematicides, rodenticides and fungicides
  - Characteristics
    - Water soluble
    - Canbind tightly to organic material in soil and particles
    - Mostly are chlorinated
  - Effects
    - Short-term exposure: liver and kidney damage, major interference with nervous, interfere with immune and reproductive system functions; less severe would be dizziness, nausea and fatigue
    - Long-term exposure: risk of birth defects and cancer risk

ORGANIC COMPOUNDS

- Emerging drinking water contaminants
  - Found in the range of ng/L to µg/L in finished drinking water
  - Endocrine disruptors
    - Affect endocrine systems (thyroid and steroid hormones) - interfere with the development and reproduction in wildlife
    - Enter via wastewater treatment plants or agricultural runoff
  - Pharmaceuticals and personal care products
    - Enter via wastewater treatment plants

ORGANIC COMPOUNDS

- Emerging drinking water contaminants
  - Perfluorinated chemicals
    - Highly water soluble
    - Used to produce water- and stain-resistant products (e.g cookware, clothing, fire fighting foam)
    - Do not degrade in the environment
    - Cause adverse effects on liver and immune system; likely to be human carcinogens
  - Nanoparticles
    - Used in consumer products (washing liquidss, clothing, washing machines, drug delivery systems for pharmaceuticals)

ORGANIC COMPOUNDS

- Chemicals in Treatment Additives, Linings and Coatings
  - Acrylamide
    - Sources: polyacrylamide flocculants; also used as grouting agents in the construction of drinking water reservoir
    - Effects: toxic effects to central nervous systems particularly damaging the nerves in arms or legs; carcinogenic
  - Epichlorohydrin
    - Sources: used as flocculants in drinking water treatment plants and as a solvent for lacquers to coat the interiors of water tanks and pipe
    - Effects: carcinogenic
  - Polycyclic Aromatic Hydrocarbons (PAHs)
    - Sources: leaching of tar or asphalt linings of distribution pipelines but their solubility is limited
    - Effects: toxicity vary and can cause cancer

INORGANIC COMPOUNDS

- When placed in water, inorganic compounds dissociate into electrically charged atoms referred to as ions
- All atoms linked in ionic bond
- Can be classified into two:
  - Metal
    - Toxic (As^{3+}, As^{5+}, Ba^{2+}, Cd^{2+}, Pb^{2+}, Hg^{2+})

      Source: Human activities (e.g. mining and industries)

      Effects: Dangerous diseases such as cancer, abortion and deformation of new born babies; stored up in food chain
    - Non-toxic (Ca^{2+}, Mn^{2+}, Na^{+}, Fe^{2+}, Mg^{2+}, Al^{3+}, Cu^{2+}, Zn^{2+}, SO_4^{2-})

      Source: Mineral available in the natural environment

      Effects: Color, odor, taste and turbidity; Deteriorate health at high concentration
  - Non-metal (halogens, nutrients and hardness)
    - Source: Mineral
    - Effects: Diseases (NO_2^-: baby blue syndrome); aesthetic (Si^{4+}: turbidity); F^-: not good for health if it is taken at high concentration, < 1 mg/L good for the growth of children's teeth but concentration higher than 1 mg/L can cause color on teeth and problem in bone growth

INORGANIC COMPOUNDS

- Arsenic (As^{3+}, As^{5+})
  - Arsenic present in organic arsenical forms in fish and shellfish much less toxic than inorganic arsenic. Daily intake is 50 µg and only 1-20 µg is in inorganic form
  - Effects of chronic exposure to human: systemic toxicity (dermatological toxicity: hyperpigmentation, keratoses; peripheral vascular disease: blackfoot disease; increase the risk of cardiovascular disease; diabetes; gastroenterological disease) and cancer
  - Lethal dose in drinking water: 1 to 4 mg/kg (USEPA, 2000)
  - Minimum contaminant level (MCL) in drinking water: 10 µg/L (USEPA, 2001)

INORGANIC COMPOUNDS

- Cadmium (Cd^{2+})
  - Enter tap water by corrosion of galvanized pipe and solder used in hot water heaters
  - Can cause kidney dysfunction, hypertension, anemia and altered liver functions; human carcinogens
  - MCL: 5 µg/L (USEPA, 1985, 1991)

INORGANIC COMPOUNDS

- Lead (Pb^{2+})
  - Sources: Corrosion of lead pipe and lead solder, especially in areas with soft or acidic water
  - More toxic in children than adults (more readily absorb in young children than older children and young adults)
  - Effects:
    - Accumulates in bones
    - Impairs neurodevelopment (delay in mental and physical development, decrease in intelligence)

INORGANIC COMPOUNDS

- Mercury (Hg^{2+})
  - Sources: burning of fossil fuels, incineration of products containing mercury, leaching of organic mercury from antifungal outdoor paints
  - Inorganic mercury is poorly absorbed by human but if in the form of methylmercury, it is readily absorbed
  - Methylmercury → neurotoxic: can result in mental and motor dysfunctions or death. For pregnant women, can cross placenta barrier

REFERENCES

- American Water Works Association (2011). *Water Quality and Treatment: A Handbook on Drinking Water 6th Edition*, James K. Edzwald (Ed.), McGraw-Hill: USA
- Benjamin, M.M. (2002). *Water Chemistry,* McGraw-Hill: Singapore
- Sawyer, C.N., McCarty, P.L. & Parkin, G.F. (1994). *Chemistry for Environmental Engineering,* McGraw-Hill: Singapore
- USEPA (1985). National Primary and Secondary Drinking Water Regulations; Synthetic Organic Chemicals, Inorganic Chemicals and Microorganisms. *Federal Register*, 50: 46936-47022.
- USEPA (1991). National Primary and Secondary Drinking Water Regulations; Synthetic Organic Chemicals and Inorganic Chemicals; Monitoring for Unregulated Contaminants; National Primary Drinking Water Regulations Implementation; National Secondary Drikning Water Regulations. *Federal Register*, 56: 3526-3599.
- USEPA (2000). National Primary Drinking Water Regulations: Arsenic and Clarifications to Compliance and New Source Contaminants Monitoring. *Federal Register*, 65: 3887-38983.
- USEPA (2001). National Primary Drinking Water Regulations: Arsenic and Clarifications to Compliance and New Source Contaminants Monitoring. *Federal Register*, 66: 6957-7066.