CE 326 Principles of Environmental Engineering - Spring 2008

I. Water Treatment

Worldwide Water and Sanitation Conditions

- c_____ drinking water has the greatest impact on human health for > _____% of world's population
- worldwide deaths due to contaminated drinking water are approximately 14,000 - 25,000 per day
- 25% of hospital beds occupied by people infected with waterborne illnesses
- currently the world's population that lack's access to "safe" drinking water is 18% or 1.1 billion (Johannesburg World Summit on Sustainable Development, 2002)
- _____ million are without proper sanitation

- More than 5 million people die each year from diseases caused by unsafe drinking water, lack of sanitation, and insufficient water for hygiene. In fact, over 2 million deaths occur each year from water-related diarrhea alone. At any given time, almost half of the people in developing countries suffer from water-related diseases.
- Insufficient supplies of water and sanitation disproportionately affect women, children, and the poor. The majority of deaths from water-related diarrhea are among children under 15, and women. At any given time, almost _____ of the people in developing countries suffer from water-related diseases

- Agriculture accounts for more than _____ percent of global water consumption. The inefficient use of water for i_____ has led to depletion of groundwater resources in many of the world's most important agricultural regions, and is the primary source of groundwater pollution in parts of Europe, the United States, and Asia.
- During the 1990s, about ____ million people in developing countries gained access to improved drinking water, demonstrating the possibility for major improvements in safe water access worldwide.
- At the Millennium Summit in September 2000, world leaders agreed to the goal of halving, by 2015, the proportion of people without access to safe drinking water and sanitation. To meet this goal, an additional ____ billion people will need access to adequate water, and ___ billion will need improved sanitation. The annual investment required to meet the goal is estimated to be $___ billion, nearly twice the current level of investment.

- Within ____ years, half the world's population could have trouble finding enough fresh water for drinking and irrigation (BBC News, Wednesday, 15 December, 1999). The study was carried out at Colorado University, which surveyed river basins all over the planet to identify those under most pressure.
- It found a third of the world's people already live in regions considered to be "water-stressed" - where there is not enough, or barely enough water to go around.
- **Areas at risk.** Waterways under most pressure included China's Yellow River basin, the Zambezi River in Africa, and the rivers that lead into the Aral Sea in Central Asia.
- Most of the water from those sources is used for irrigation, not drinking, according to the study's leading author, Kenneth Strzepek. He says that with rising populations, half the world's people will find it hard to get enough water for crops and livestock within _____ years, and still have enough left to drink themselves.

A. U.S.A.

- In the U.S.A. approximately _____ billion gallons of water is withdrawn from surface and groundwater supplies daily.
- About ___ of this amount (32 bgd) is used for p_____ w_____ s_____.
- Approximately 50,000 c_____ water systems supply 80 to 90% of the U.S. population.
- On average, Americans use _____ gal/person/day. (This includes industrial uses and system losses).
- About _____ people do not have running water in their homes.
- The split between surface water and well water is about _____ .
- In rural areas _____ of the population uses groundwater.
- 20% of all public water supply wells and 29% of wells in urban areas have detectable levels of at least one v_____ o_____ c_____.[1]
- At least 13 organic chemicals that are confirmed animal or human c_____ have been detected in drinking water wells.[1]
- Toxic organics were found in some wells in almost every state east of the Mississippi, t_____ (TCE) was the most prevalent.[1]
- 1000 public drinking water systems that serve 12 million people in the U.S. exceed n_____ levels at least some of the time. 8.7 million of these people are in California.[2]

B. Iowa

- In Iowa, _____ of our drinking water comes from groundwater supplies.
- Iowans use an average of _____ gal/person each day.
- Farms lose _____ tons of soil each year. Soil runoff is the leading pollutant in Iowa's waterways.
- Iowa has lost over _____ of its wetlands.
- Iowans apply more f_____ than all states except Illinois.
- In 1996 there were _____ fish killed from manure and chemical spills.
- About _____ of public water systems had excessive bacterial counts.
- Trihalomethanes were detected in over _____ of samples over a seven year period. Only 10% of samples exceed drinking water standards.
- High nitrate levels were found in _____ of private wells and 2% of public water systems.
- The herbicide atrazine was found in _____ of drinking water samples. Only 1% of samples exceed drinking water standards.

II. Water Quality Characteristics

A. Hardness and Trace Metals[3]

- life expectancy for white males over 45 years of age hasn't changed much since 1900 (mainly due to little progress in the control of c_____ disease)
- in 1959 researchers noticed a large discrepancy between rates of cardiovascular heart disease depending on g_____ location
- significant negative correlations were found between m_____ from cardiovascular heart disease and magnesium, calcium, bicarbonate, sulfate, fluoride, dissolved solids, specific conductance, and pH
- most significant negative correlation was for h_____
- mortality from cardiovascular heart disease in hard water areas has been shown to be h_____ that in soft water areas
- t_____ metals may be an important factor
- c_____ of water may be an improtant factor
- studies in Texas have shown a relationship between the levels of l_____ in groundwater and incidence of schizophrenia, psychosis, neurosis, personality problems, and homocidal tendencies.

U. S. Geological Survey Classification of Hardness

Classification	Hardness, mg/L as $CaCO_3$
Soft	0 - 55
Slightly Hard	55 - 100
Moderately Hard	100 - 200
Very Hard	> 200

1. In *Major Environmental Issues Facing the 21st Century*, by Theodore & Theodore. Prentice Hall, 1996.
2. In a report by the Environmental Working Group. AWWA is preparing a rebuttal to these claims.
3. Hoadley, A. (1978) "Public Health Aspects of Water Supplies," In *Water Treatment Plant Design*, R. L. Sanks (Ed.) Ann Arbor, Stoneham, Mass. 17.

Four Water Quality Characteristics

1. **P**_____ characteristics relate to quality of water for domestic use: e.g., color, turbidity, temperature, and taste and odor.

2. **C**_____ characteristics are often evidenced by observed reactions: e.g., hardness of water.

3. **B**_____ characteristics are important for public health reasons: e.g., pathogens.

4. **R**_____ factors must be considered where there is possibility of contact with radioactive substances: e.g., radon in groundwater.

I. Physical Characteristics.

A. **Turbidity.** Presence of s_____ m_____ in water. Measured by refraction of light (Nephelometric Turbidity Units, NTU). Not necessarily a health concern, but may be an indication of contamination.

B. **Color.** Dissolved organic material from decaying vegetation may cause color in water. Color is a concern from the standpoint of aesthetics and it often indicates the presence of h_____ substances which are precursors of t____h_____m_____, THMs, formed during chlorination.

C. **Taste and Odor.** Taste and odor in water is caused by o_____ c_____, i_____ s_____, or d_____ g_____. Objectionable tastes and odors should be removed from drinking water.

D. **Temperature**. Consistently cool drinking water is most desirable (_____ - _____ °C).

II. Chemical Characteristics.

A. Inorganic Substances.

1. **Chloride.** All waters contain some chloride due to leaching of m_____ s_____ d_____, infiltration of sea water, or industrial and agricultural influence. Concentrations in excess of _____ mg/L may cause noticeable taste.

2. **Copper.** Found in some natural waters, particularly around ore deposits and mines. Small quantities are not considered a problem, but may cause a undesirable t_____ in water.

3. **Fluorides.** Some waters contain natural fluorides. Good in preventing t_____ d_____ when concentration is between 0.7 and 1.2 mg/L. Higher concentrations can lead to f_____, a discoloration and pitting of teeth in children.

4. **Iron**. Usually present in small amounts, especially in groundwater. High levels of iron are objectionable because they leave a b_____ c_____ on laundry and impart taste and odor to the water.

5. **Lead**. Dangerous even in small quantities. Cumulative p_____. Poorly absorbed by adults (5 - 7%) but highly absorbed by children (up to 40%). Stored in the bone and slowly released into the bloodstream. Lead poison can cause brain and nerve damage, kidney damage, anemia, and porphyrinuria (excretion of hemoglobin precursors in the urine). Problem in drinking water due to lead solder, lead pipes, and lead cores in drinking water fountains.

6. **Manganese.** Imparts a b_____ color to water and laundry, flavors coffee and tea.

7. **Nitrate**. Causes methemoglobinemia (b_____ b_____) in infants given formula containing high concentrations of nitrate and breast fed babies whose mothers drink high levels of nitrate. The babies blood absorbs nitrate instead of oxygen resulting in oxygen depletion. Nitrates are found in water contaminated from wastewaters or fertilizers.

8. **Sodium**. Concern for people with heart, kidney, or circulatory ailments. Most home w_____ s_____ use sodium, replacing the calcium and magnesium ions with sodium ions.

9. **Sulfate**. Waters containing high sulfate concentrations from contact with natural deposits of magnesium or sodium sulfate may act as a l_____.

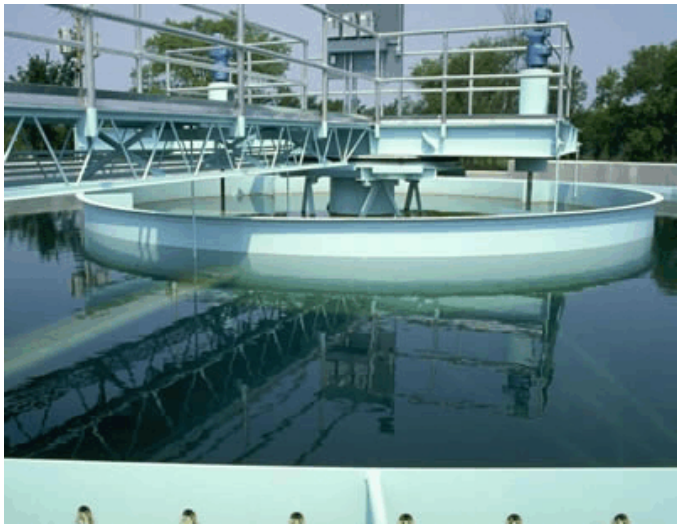
10. **Zinc**. Zinc in water supplies (usually near zinc ore mines) will give an undesirable t_____.

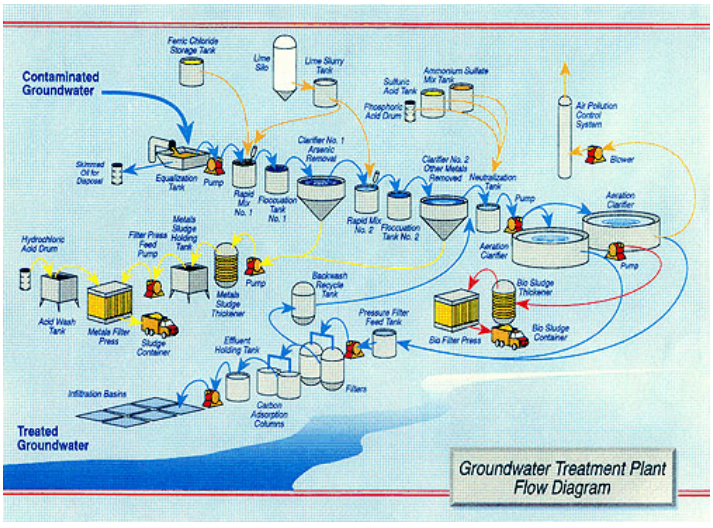
Maximum Contaminant Levels for Inorganic Compounds

Contaminant	Existing MCL (mg/L)	MCLG (mg/L)
Arsenic	0.01	0
Asbestos	7 million fibers/L	7 million fibers/L
Barium	2.0	2.0
Cadmium	0.005	0.005
Chromium	0.1	0.1
Lead	0.015 TT	0
Mercury	0.002	0.002
Nitrate (as N)	10.0	10.0
Nitrite (as N)	1.0	1.0
Selenium	0.05	0.05
Thallium	0.0005	0.002

B. Organic Substances.

1. **Volatile Organic Compounds.** Compounds which are characterized by high v_____ are classified as volatile organic compounds (VOCs). VOCs may have particular adverse health effects. They are a result of industrial, commercial, and agricultural activity. Many are s_____ or additives (e.g., paint thinners).
2. **Synthetic Organic Compounds**. Organic chemicals of an a_____ origin are termed synthetic organic compounds (SOCs). Like VOCs, SOCs may have particular adverse health effects and are a result of industrial, commercial, and agricultural activity. Many SOCs are h_____, p_____, or i_____.
3. **Disinfection Byproducts.** During disinfection of drinking water, chemical oxidants kill disease causing organisms (p_____), but can also create toxic organic compounds. These are termed disinfection byproducts (DBPs). The most common source of DBPs is c_____ or b_____ of water containing organic matter. This often results in trihalomethanes (THMs), the most common of which are:
    1. Chloroform ($CHCl_3$)
    2. Bromoform ($CHBr_3$)
    3. Bromodichloromethane ($CHBrCl_2$)
    4. Dibromochloromethane ($CHBr_2Cl$)





III. Legislation

A. SDWA of 1974

- The S_____ D_____ W_____ A_____ (SDWA) was signed into law by President Gerald Ford in 1974.
- It established minimum national standards for drinking water to protect public health.
- The act established p_____ standards which specified maximum contaminant levels (MCLs) for individual contaminants suspected of having an adverse affect on public health.
- The act also established s_____ standards relating to tastes, odors, and appearance of drinking water.
- SDWA set a timeline for the promulgation of standards with a review every three years.

B. SDWA Amendments of 1986

- By the 1980s, a number of contaminants had yet to be regulated, and on June 19, 1986 President Reagan signed into law the 1986 Amendments to the SDWA.
- Major aspects of the 1986 Amendments to the SDWA included:
    - C_____ revisions to drinking water regulations in a timely fashion.
    - Definition of a t_____ t_____ for each contaminant regulated.
    - Requirement of a treatment technique where it is not feasible to ascertain the level of a r_____ c_____.
    - F_____ r_____ for surface waters (Surface Water Treatment Rule, SWTR).
    - D_____ of all water supplies.
    - Prohibition on the use of l_____ products on conveyance systems.
    - Requirement for the protection of g_____ sources.
- The SDWA directed EPA to set up several classes of compounds for which regulations are to be developed and to establish a timeline for development of the regulations.

C. SDWA Amendments of 1996

- On November 29, 1996, the Senate passed a bill to r_____ the SDWA. This bill contained several amendments to the regulations which would lessen some of the regulatory burden on water utilities, especially small systems. This bill passed the House on June 25, 1996 and both houses on August 2, 1996. These amendments locked EPA into a 1998 deadline for issuing a DBP rule and enhanced SWTR. Subsequent review and revisions to current standards is required every six years.
- Currently, EPA has drinking water regulations for more than 90 contaminants. The SDWA required EPA to maintain a list of unregulated contaminants. EPA uses this list to prioitize reseach and data collection efforts to determine whether to regulate a given contaminant.
- In February 2005, EPA published its second list of contaminants, the contaminant candidate list (CCL). Currently EPA is soliciting nominations for CCL3.
- For the current list of standards see: http://www.epa.gov/safewater/contaminants/index.html for the time line of promulgation, see:

  http://www.epa.gov/safewater/contaminants/pdfs/contam_timeline.pdf

  for the contaminant candidate list see: http://www.epa.gov/safewater/ccl/ccl2.html

  for nominating a contaminant to the CCL see: http://www.epa.gov/safewater/ccl/ccl3.html