Ch. 17 Notes: Water Pollution and Its Prevention

17.1 Notes

a) Water Pollution

A. Pollution essentials

1) **pollutant**
   a) something causing unclean and impure conditions
   b) a substance *posing threats to organisms' health and the environment*
2) **water pollutant**—*any chemical, biological, or physical change in water quality that has a harmful effect on living organisms and makes water unsuitable for desired uses* (Miller book)
3) **biodegradable**—can be broken down by detritus feeders and decomposers
4) **nonbiodegradable**—will not be decomposed naturally

B. Gulf of Mexico hypoxia

1) **hypoxia** ("Low oxygen")—*"dead zone" in a body of water due to lack of oxygen*
2) Gulf of Mexico hypoxia first detected in 1974
3) causes
   (quotes from http://www.enviroliteracy.org/article.php/1128.html)
   a) *nitrogen runoff* from fertilizers

large amounts of nitrogen →
growth of phytoplankton →
phytoplankton die and sink →
consumed by bacteria, which use up oxygen

   b) **stratification**—the tendency of fresh water flowing out from the Mississippi river to sit atop the heavier salt water from the Gulf
   c) *human-made changes* to the Mississippi River and its tributaries,
      i. "**Channelization** (the practice of *dredging the river bottom* to make passage easier and safer for cargo ships)
      ii. Channelization, along with wetland drainage, contributes to hypoxia by increasing the speed of river flow. Faster-moving waters spend less time subjected to biological processes in which nitrogen is metabolized."

Mississippi River/Gulf of Mexico Watershed Nutrient Task Force https://www.epa.gov/ms-htf

4) **eutrophication**—*natural "enrichment" or overfertilization of a body of water* (a harmful process)
   - **cultural eutrophication**—*human activities accelerating input of nutrients* (more in section 2)

C. Water Pollution: sources, types, criteria

1) sources of water pollution
   a) **point sources**
      i. *specific sites of pollution discharge* (pipes, ditches, sewers)
      ii. fairly easy to locate and monitor
   b) **nonpoint sources**
      i. broad, scattered; *can't be traced to one site* (large land areas, runoff, surface flow)
      ii. harder to control

2) types of water pollution
   a) **pathogens** *(disease-causing agents) such as bacteria, viruses, and parasites* from human and animal waste
   b) **organic wastes**
      i. leaves, grass clippings, trash
      ii. *oxygen-demanding wastes*—organic wastes that can be decomposed by aerobic bacteria which depletes oxygen
      iii. threatens human, animal, and aquatic plant life
   c) **chemical pollutants**
      i) *water-soluble inorganic materials*
         - water-soluble nitrates and phosphates
         - heavy metals (including Pb, Hg, Cd, and Ni)
         - sulfuric acid (H_2SO_4), nitric acid (HNO_3)
         - road salts ($NaCl$, $CaCl_2$)
         - can cause excessive growth of algae and other aquatic plants that die and deplete the O_2 content, killing fish
      ii) *organic materials*— oil, gas, plastic, petroleum products, pesticides, detergents, industrial chemicals
      iii) *water-soluble radioactive isotopes*
         - accumulate in tissues and organs
         - cause birth defects, cancer and genetic damage
      iv) **sediments** or *suspended matter (largest class)*
         - soil, sand, silt, clay, gravel, dust
         - particles stay suspended in water, making water cloudy
         - **bed load**—*sand and silt gradually washed along the bottom of a body of water*
         - reduces photosynthesis and disrupts food webs
         - clogs harbors, reservoirs, channels and artificial lakes
   d) nutrients (see #3 water quality for details)
      i. phosphorus
      ii. nitrogen
   e) *TDS (total dissolved salts, total dissolved solids)* a measure of the ions dissolved in a sample of water
      i. electrical conductivity (EC) estimates TDS
      ii. unit of EC: microSiemens per centimeter (µS/cm)
      iii. can be from specific rock types, urban runoff, sewage plant wastewater, septic system wastewater, high evaporation rate, some bacteria
   f) *thermal pollution*
      i. rise in water temp from heat absorbed to cool power plants
      ii. lowers water level and makes organisms more vulnerable to disease
   g) *genetic pollution*
      i. deliberate or accidental addition of nonnative species
      ii. disrupts aquatic systems and crowd out natives

iii. reduces biodiversity
iv. principal way they are introduced: intake and ballast from ships

3) water quality
a) **DO (dissolved oxygen)**
info from http://www.state.ky.us/nrepc/water/wcpdo.htm
i. *a measure of the amount of gaseous oxygen (O_2) dissolved in an aqueous solution*
ii. O_2 dissolved by diffusion from the air, by water movement, and from photosynthesis
iii. Environmental Impact:

"…Fish in waters containing excessive dissolved gases may suffer from 'gas bubble disease'; however, this is a very rare occurrence. The bubbles or emboli block the flow of blood through blood vessels causing death. *External bubbles (emphysema)* can also occur and be seen on fins, on skin and on other tissue. Aquatic invertebrates are also affected by gas bubble disease but at levels higher than those lethal to fish.

Adequate dissolved oxygen is necessary for good water quality. Oxygen is a necessary element to all forms of life. Natural stream purification processes require adequate oxygen levels in order to provide for aerobic life forms. *As dissolved oxygen levels in water drop below 5.0 mg/L, aquatic life is put under stress. The lower the concentration, the greater the stress. Oxygen levels that remain below 1-2 mg/L for a few hours can result in large fish kills.*"

b) **Biological (or biochemical) oxygen demand (BOD)**—*amount of dissolved oxygen needed by aerobic decomposers to break down over 5 day period @ 20ºC (68ºF)*

from http://purdue.edu/

"The first step in measuring BOD is to obtain equal volumes of water from the area to be tested and dilute each specimen with a known volume of distilled water which has been thoroughly shaken to insure oxygen saturation.

After this, an *oxygen meter* is used to determine the concentration of oxygen within one of the vials. The remaining vial is than sealed and placed in darkness and tested five days later. BOD is then determined by subtracting the second meter reading from the first.

The range of possible readings can vary considerably: water from an exceptionally clear lake might show a BOD of less than 2 mg/L of water. Raw sewage may give readings in the hundreds and food processing wastes may be in the thousands."

c) **Chemical Oxygen Demand (COD)**
i. *a measure of the oxygen consumed when organic matter is broken down chemically rather than naturally*
ii. can be determined much more quickly than BOD
iii. more accurately reflects the amount of organic matter in a water sample

d) *chlorides (Cl^-)*
from http://www.state.ky.us/nrepc/water/wcparint.htm
i. importance

"'*Chloride' is a salt compound resulting from the combination of the gas chlorine and a metal. Some common chlorides include sodium chloride (NaCl) and magnesium chloride*

($MgCl_2$). Chlorine alone as Cl_2 is highly toxic, and it is often used as a disinfectant. In combination with a metal such as sodium it becomes essential for life. Small amounts of chlorides are required for normal cell functions in plant and animal life."

ii. environmental impact

"Chlorides are not usually harmful to people; however, the sodium part of table salt has been linked to heart and kidney disease. Sodium chloride may impart a salty taste at 250 mg/L; however, calcium or magnesium chloride are not usually detected by taste until levels of 1000 mg/L are reached. *Public drinking water standards require chloride levels not to exceed 250 mg/L*."

"Chlorides can corrode metals and affect the taste of food products. Therefore, water that is used in industry or processed for any use has a recommended maximum chloride level. Chlorides can contaminate freshwater streams and lakes. Fish and aquatic communities cannot survive in high levels of chlorides."

iii. sources

- rocks containing chlorides
- agricultural runoff
- wastewater from industries
- oil well wastes
- effluent wastewater from wastewater treatment plants

e) *total iron (Fe^{2+}, Fe^{3+})*

from http://www.state.ky.us/nrepc/water/wcparint.htm

i. importance

"Iron is the fourth most abundant element, by weight, in the earth's crust. Natural waters contain variable amounts of iron despite its universal distribution and abundance. Iron in groundwater is normally present in the *ferrous or bivalent form [Fe^{++}]* which is a soluble state. It is easily oxidized to *ferric iron [Fe+++]* or insoluble iron upon exposure to air. Iron is a trace element required by both plants and animals. *It is a vital oxygen transport mechanism in the blood of all vertebrate and some invertebrate animals*."

ii. environmental impact

"Iron in water may be present in varying quantities depending upon the geological area and other chemical components of the waterway. Ferrous (Fe++) and ferric (Fe+++) ions are the primary forms of concern in the aquatic environment. Other forms may be in either organic or inorganic wastewater streams. *The ferrous form Fe++ can persist in water void of dissolved oxygen and usually originates from groundwater or mines that are pumped or drained. Iron in domestic water supply systems stains laundry and porcelain. It appears to be more of a nuisance than a potential health hazard. Taste thresholds of iron in water are 0.1 mg/L for ferrous iron and 0.2 mg/L ferric iron, giving a bitter or an astringent taste*. Water used in industrial processes usually contains less than 0.2 mg/L iron. Black or brown swamp waters may contain iron concentrations of several mg/L in the presence or absence of dissolved oxygen, but this iron form has little effect on aquatic life. *The current aquatic life standard is 1.0 mg/L based on toxic effects."*

f. *Nitrate / Nitrite / Nitrogen*

from http://www.state.ky.us/nrepc/water/wcparint.htm

i. importance

"Nitrogen is one of the most abundant elements. About 80 percent of the air we breathe is nitrogen. It is found in the cells of all living things and is a major component of proteins. *Inorganic nitrogen may exist in the free state as a gas N_2, or as nitrate NO_3^-, nitrite NO_2^-, or* *ammonia NH_3. Organic nitrogen is found in proteins and is continually recycled by plants and animals."*

ii. environmental impact

"Nitrogen-containing compounds act as nutrients in streams and rivers. *Nitrate reactions [NO_3^-] in fresh water can cause oxygen depletion. Thus, aquatic organisms depending on the supply of oxygen in the stream will die. The major routes of entry of nitrogen into bodies of water are municipal and industrial wastewater, septic tanks, feed lot discharges, animal wastes (including birds and fish) and discharges from car exhausts. Bacteria in water quickly convert nitrites [NO_2^-] to nitrates [NO_3^-].*

Nitrites can produce a serious condition in fish called "brown blood disease." Nitrites also react directly with hemoglobin in human blood and other warm-blooded animals to produce methemoglobin. Methemoglobin destroys the ability of red blood cells to transport oxygen. This condition is especially serious in babies under three months of age. It causes a condition known as methemoglobinemia or "blue baby" disease. *Water with nitrite levels exceeding 1.0 mg/L should not be used for feeding babies. Nitrite/nitrogen levels below 90 mg/L and nitrate levels below 0.5 mg/L seem to have no effect on warm water fish."*

g) water temperature

from http://www.state.ky.us/nrepc/water/wcparint.htm

"Human activities should not change water temperatures beyond natural seasonal fluctuations. To do so could disrupt aquatic ecosystems. Good temperatures are dependent on the type of stream you are monitoring. Lowland streams, known as "warmwater" streams, are different from mountian or spring fed streams that are normally cool.

In a warmwater stream temperatures should not exceed 89 degrees (Fahrenheit). Cold water streams should not exceed 68 degrees (Fahrenheit). Often summer heat can cause fish kills in ponds because high temperatures reduce available oxygen in the water."

h) pH

from http://www.state.ky.us/nrepc/water/wcparint.htm

i. importance

"*pH is a measure of the acidic or basic (alkaline) nature of a solution.* The concentration of the hydrogen ion [H^+] activity in a solution determines the pH… $pH = -\log [H^+]$

A pH range of 6.0 to 9.0 appears to provide protection for the life of freshwater fish and bottom dwelling invertebrates."

ii. environmental impact

"*The most significant environmental impact of pH involves synergistic effects*. Synergy involves the combination of two or more substances which produce effects greater than their sum. *This process is important in surface waters*. Runoff from agricultural, domestic, and industrial areas may contain iron, aluminum, ammonia, mercury or other elements. The pH of the water will determine the toxic effects, if any, of these substances. For example, 4 mg/L of iron would not present a toxic effect at a pH of 4.8. However, as little as 0.9 mg/L of iron at a pH of 5.5 can cause fish to die.

Synergy has special significance when considering water and wastewater treatment. The steps involved in water and wastewater treatment require specific pH levels. In order for coagulation (a treatment process) to occur, pH and alkalinity must fall within a limited range. Chlorination, a disinfecting process for drinking water, requires a pH range that is temperature dependent."

Limiting pH Values		
Minimum	Maximum	Effects
3.8	10.0	Fish eggs could be hatched, but deformed young are often produced
4.0	10.1	Limits for the most resistant fish species
4.1	9.5	Range tolerated by trout
---	4.3	Carp die in five days
4.5	9.0	Trout eggs and larvae develop normally
4.6	9.5	Limits for perch
---	5.0	Limits for stickleback fish
5.0	9.0	Tolerable range for most fish
---	8.7	Upper limit for good fishing waters
5.4	11.4	Fish avoid waters beyond these limits
6.0	7.2	Optimum (best) range for fish eggs
---	1.0	Mosquito larvae are destroyed at this pH value
3.3	4.7	Mosquito larvae live within this range
7.5	8.4	Best range for the growth of algae

i) total phosphorus

from http://www.state.ky.us/nrepc/water/wcparint.htm

i. importance

"Phosphorus is one of the key elements necessary for growth of plants and animals. *Phosphorus in elemental form is very toxic and is subject to bioaccumulation.* Phosphates PO_4^{3-} are formed from this element. Phosphates exist in three forms: orthophosphate, metaphosphate (or polyphosphate) and organically bound phosphate. Each compound contains phosphorous in a different chemical formula. Ortho forms are produced by natural processes and are found in sewage. Poly forms are used for treating boiler waters and in detergents. In water, they change into the ortho form. Organic phosphates are important in nature. Their occurrence may result from the breakdown of organic pesticides which contain phosphates. They may exist in solution, as particles, loose fragments, or in the bodies of aquatic organisms."

ii. environmental impact

"Rainfall can cause varying amounts of phosphates to wash from farm soils into nearby waterways. Phosphate will stimulate the growth of plankton and aquatic plants which provide food for fish. This increased growth may cause an increase in the fish population and improve the overall water quality. However, *if an excess of phosphate enters the waterway, algae and aquatic plants will grow wildly, choke up the waterway and use up large amounts of oxygen. This condition is known as eutrophication or over-fertilization of receiving waters. The rapid growth of aquatic vegetation can cause the death and decay of vegetation and aquatic life because of the decrease in dissolved oxygen levels.* Phosphates are not toxic to people or animals unless they are present in very high levels. Digestive problems could occur from extremely high levels of phosphate."

j) fecal coliform bacteria

(rom http://www.state.ky.us/nrepc/water/wcparint.htm

i. importance of testing

"Total coliform bacteria are a collection of relatively harmless microorganisms that live in large numbers in the intestines of man and warm- and cold-blooded animals. They aid in the digestion of food. A specific subgroup of this collection is the fecal coliform bacteria, the most common member being *Escherichia coli*. These organisms may be separated from the total coliform group by their ability to grow at elevated temperatures and are associated only with the fecal material of warm-blooded animals."

ii. environmental impact

"*The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of man or other animals.* At the time this occurred, the source water may have been contaminated by pathogens or disease producing bacteria or viruses which can also exist in fecal material. *Some waterborne pathogenic diseases include typhoid fever, viral and bacterial gastroenteritis and hepatitis A.* The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to this water. *Fecal coliform bacteria may occur in ambient water as a result of the overflow of domestic sewage or nonpoint sources of human and animal waste*."

List of common water "criteria pollutants":
from http://www.epa.gov/ost/criteria/wqcriteria.html

Antimony	Selenium	Chloroethane
Arsenic	Silver	Dichlorobromomethane
Beryllium	Thallium	1,1-Dichloroethane
Cadmium	Zinc	Ethylbenzene
Chromium (III)	Cyanide	Methyl Bromide
Chromium (VI)	Asbestos	Methylene Chloride
Copper	2,3,7,8-TCDD (Dioxin)	Vinyl Chloride
Lead	Benzene	Polychlorinated Biphenyls
Mercury	Carbon Tetrachloride	
Methylmercury	Chlorobenzene	
Nickel	Chlorodibromomethane	

3) government programs
   a) **EPA: National Pollutant Discharge Elimination System (NPDES)** http://cfpub.epa.gov/npdes/
      i. focuses on point source pollution
      ii. industrial applications
   b) **EPA: Total Maximum Daily Loads (TMDL)** http://www.epa.gov/owow/tmdl/
      i. analysis of point/ nonpoint source pollutants
      ii. can search by state

17.2 Notes

from http://ufl.edu

WATER CHEMISTRY and WATER QUALITY

"*Water chemistry is 'what's in' the water and is a specific term based on scientific measurements.* All waters everywhere contain naturally-occurring elements (chemicals) dissolved in the water. Most of the elements dissolved in Florida freshwaters are beneficial or benign to humans, animals and plants. A very few elements, such as lead and mercury, and man-made chemicals such as certain pesticides, are harmful to humans, animals and plants at some levels.

Water quality is 'what the water's like' and is a less specific term which may be based as much on personal knowledge, perceptions and beliefs as on scientific measurements. Qualities of water may include color, clarity and so on. One person may judge a lake as having 'poor water quality,' while another person may judge the same lake as having 'good water quality,' depending on their knowledge, interests and concerns."

II. **Eutrophication**

A. background info

1) natural nutrient enrichment of lakes
2) **cultural eutrophication**—*human activities which accelerate eutrophication* (sewage treatment plants, runoff of fertilizers, accelerated erosion of topsoil)
3) general consequences
   a) *leads to excessive algal growth*
   b) *affects quantity and type of plants*
   c) *affects water quality*
   d) *affects water clarity and depth*
   e) *affects fisheries*
   f) can lead to **hypoxia**
4) affected by water **turbidity** (*cloudiness)*
   a) *caused by suspended matter such as clay, silt, and organic matter*
   b) *plankton and other microscopic organisms*
   c) *increased turbidity decreases light penetration through water*

B. different kinds of aquatic plants

1) **benthic plants**—vegetation on the *bottom* of a body of water
2) **SAV—submerged aquatic vegetation—***usually underwater*
   - increased turbidity decreases available light
   - nutrients absorbed through roots
3) **emergent vegetation**—*lower parts submerged, upper parts exposed*
4) *phytoplankton*
   - *microscopic photosynthetic organisms*
   - they live floating in the water
   - examples: diatoms, dinoflagellates, coccolithophores, phytoflagellates, photosynthetic bacteria

MAIN CLASSIFICATIONS BY SIZE

Megaplankton, 20-200 cm
Macroplankton, 2-20 cm
Mesoplankton, 0.2 mm-2 cm
Microplankton, 2 -200 μm

Nanoplankton, 2-20 μm
Picoplankton, 0.2-2 μm, mostly bacteria
Femtoplankton, smaller than 0.2 μm, consisting of marine virus

C. impacts of nutrient enrichment

1) **oligotrophic** water
   a) *clear water*
   b) *low in nutrients*
   c) *limited growth of phytoplankton*
   d) *ample DO*
2) eutrophication – main steps

nutrient enrichment →
growth of phytoplankton →
death of phytoplankton →
accumulation of detritus →

growth of bacteria →
depletion of DO →
suffocation of higher organisms

3) eutrophication of shallow lakes and ponds (< 6-ft. deep) – main steps
   - impedes boating, fishing, and swimming

nutrient enrichment →
SAV grows high enough to be above the surface →
SAV blocks light from going beneath it →
as SAV dies, the debris sinks (accumulation of detritus) →
growth of bacteria →
depletion of DO →
suffocation of higher organisms

4) "trophic states"or "trophic status" of Florida's lakes
   from http://ufl.edu
   a) *oligotrophic lakes* (~12%)
   b) *mesotrophic lakes* (~31%)
   c) *eutrophic lakes* (~41%)
   d) *hypereutrophic lakes* (~16%)

5) natural vs. cultural eutrophication
   a) *natural eutrophication* occurs on its own, over time
   b) **cultural eutrophication** is caused by human activities

D. combating eutrophication
1) attacking the symptoms
   a) *herbicides*
      - examples: $CuSO_4$, diquat, 2,4-D, glyphosate
      - can kill fish and aquatic animals
      - can't use water right away for fishing, irrigation, etc.
      - contributes to the "pesticide treadmill"
   b) *artificial aeration* by plastic tubes with microscopic holes
   c) *harvesting aquatic weeds* in shallow lakes and ponds
   d) *drawing water down by damming*
   e) *planting vegetation along streambeds* to slow erosion
   f) *controlling application & timing of fertilizer*
   g) *controlling runoff* from feedlots, golf courses, & fields
   h) *use of biological control agents* such as denitrification
2) getting at the root causes
   a) control strategies for point sources
      - regulation of sewage-treatment plant wastes
      - upgrading sewage-treatment plant systems
      - restriction or banning use of detergents with phosphates
      - monitoring dishwashing detergent labels for phosphates (these are not regulated)
   b) control strategies for nonpoint sources

- responsibility of the individual property owners

3) recovery through **BMPs (best management practices)**

- agriculture: animal waste management, contour farming, strip cropping, crop rotation, IPM…
- construction: limiting areas of work, runoff retention…
- urban: flood storage, porous pavements, runoff retention, street cleaning…
- forestry: log removal, ground maintenance, pesticide management…
- mining: water diversion, underdrains…
- multicategory: sediment traps, burrer strips, increased infiltration devices…

from http://www.bmpdatabase.org

"In the 1990's as required by the Clean Water Act the U.S. Environmental Protection Agency (USEPA) mandated that *most municipalities in the United States with populations larger than 10,000 obtain a stormwater runoff discharge permit. One of the requirements of this permit program is the use of non-structural and structural best management practices (BMPs) appropriate to reduce pollutants to the Maximum Extent Practicable (MEP).* In response to this program, communities need to know which types of BMPs are appropriate for them (e.g., which BMPs function best in cold climates or in areas of heavy rainfall) and how to monitor the performance of the BMPs they select to ensure they function properly."

17.3 Notes

III. Sewage Management and Treatment

A. development of collection and treatment systems

info from http://www.nau.edu

1) nomadic tribes (~10,000 B.C.E.) – the earth received the wastes directly; sometimes wastes were buried
2) Ur (3500 B.C.E.) – sewage was swept into the street
3) Indus Valley (present day Pakistan) – (2500 to 1500 B.C.E.) – refuse bins throughout some cities, home chutes for garbage, simple toilets
4) Jerusalem (~1300 B.C.E.) – some streets were washed daily
5) Crete (1500-1700 B.C.E.) – advanced plumbing, organic waste disposal sites, capital city courtyard with baths
6) Greeks (~500 B.C.E.) – first dumps established in Athens
7) *Western Roman Empire* (31 B.C.E. – C.E. 476) – *very advanced technology, focused on efficiency and purity*
   a) *aqueducts* (some still being used!)
   b) water used for baths, fountains, cleaning sewers, etc.
   c) sewage disposal to nearby rivers and dumping wastes outside the city still caused health concerns
8) *Middle Ages* (500 C.E. to 1500 C.E.)
   a) *reverting to more primitive methods*
   b) *outhouses, chamber pots, open trench disposal*…
   c) improper drainage, widespread mudholes of wastes
   d) *rats, ticks, flea infestations*
   e) examples of diseases: "*dysentery*, *typhus* (which comes from bad sanitation and is highly contagious), and *typhoid fever* (from human feces and urine)"

f) post-Black Plague (1349) reforms
- "scavenger system" of people removing carcasses and refuse from the streets
- banning of throwing waste products into bodies of water

9) Renaissance (1400 – 1600)
   a) cesspools invented
   b) water issues, health issues more important
   c) slaughterhouse regulations

10) more modern times…
   a) 1800s – major changes in waste disposal
   b) 1860 – Louis Moureas invented the *septic tank*
   c) 1868 – Edward Frankland developed trickling sand filter technology
   d) *cholera* pushed improvements in technology and practices

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B. general terms
   1) **raw sewage (raw wastewater)**—completely *untreated* sewage
   2) **storm drain**—*collection* and draining of waste
   3) **sanitary sewer**—*destination* for the wastewater
   4) **effluent**— *water that is not reused after flowing out of any wastewater treatment facility or other works used for the purpose of treating, stabilizing, or holding wastes.*
   5) **potable water**— *water fit for consumption by humans and animals; "drinking water"*

C. pollutants in raw sewage
   1) general components according to the textbook
      a) *debris/grit*
      b) *particulate organic material*
      c) *colloidal/dissolved organic material*
      d) *dissolved inorganic material*
   2) more specific components
      a) *beneficial or neutral organisms* (bacteria, protozoa, and worms)
      b) *pathogens* (bacteria, protozoa, and worms)
      c) *organic matter* (from plants, animals, or synthetic organic compounds)
      d) oil and grease
      e) *inorganic materials* (inorganic minerals, metals, and compounds; examples: Na, K, Ca, Mg, Cd, Cu, Pb, Ni, Zn)
      f) *nutrients* (nitrate and phosphate)
      g) *solids* (settlable, suspended, dissolved)
      h) *gases* (CH_4, NH_3, H_2S)

D. removing pollutants from raw sewage
(extra info and quotes from http://ohioline.osu.edu/)
   1) **preliminary treatment** – *removal of debris and grit*
      a) *screening out debris*
         i. purpose: *to protect the pumping and other equipment*
         ii. parts

- **bar screen**
- comminutor or *sewage grinder*, a large version of a garbage disposal

iii. destination: debris is usually deposited in a *landfill*

b) *settling of grit*

i. purpose: *to protect the pumping and other equipment*

ii. main part

- **grit chamber**, a *large pool* with slow-moving wastewater

iii. destination: grit is usually deposited in a *landfill*

2) **primary treatment** – *removal of particulate organic material*

a) purpose: *to separate suspended solids and grease from wastewater*

b) procedure

i. wastewater is held in a **primary clarifier** (quiet tank) for several hours

ii. particles will sink and grease will float

iii. "the solids drawn off the bottom and skimmed off the top receive further treatment as **raw sludge**

iv. *clarified wastewater* flows on to the next stage of wastewater treatment

v. *clarifiers* and *septic tanks* are usually used to provide primary treatment"

3) se**condary treatment (biological treatment)** – *removal of colloidal and dissolved organic material*

a) purpose: *to break down raw sludge further*

b) procedure

i. sewage *microorganisms* (*natural detritus feeders/decomposers*) are cultivated and added to the wastewater

ii. microorganisms use organic matter from sewage as food, producing CO_2 and H_2O

iii. O_2 is added

c) types of systems

i. *fixed film systems*

"Fixed film systems gro*w microorganisms on substrates* such as rocks, sand or plastic. The wastewater is spread over the substrate, allowing the wastewater to flow past the film of microorganisms fixed to the substrate. As organic matter and nutrients are absorbed from the wastewater, the film of microorganisms grows and thickens. **Trickling filters**, rotating biological contactors, and sand filters are examples of fixed film systems."

ii. *suspended film systems*

"Suspended film systems *stir and suspend microorganisms in wastewater*. As the microorganisms absorb organic matter and nutrients from the wastewater they grow in size and number. After the microorganisms have been suspended in the wastewater for several hours, they are settled out as a sludge (and clumps called *floc*). Some of the sludge is pumped back into the incoming wastewater to provide "seed" microorganisms. The remainder is wasted and sent on to a sludge treatment process. **Activated sludge**, extended aeration, oxidation ditch, and sequential batch reactor systems are all examples of suspended film systems." **Activated sludge systems** use an *aeration tank* and a **clarifier tank.**

iii. *lagoon systems*

> "Lagoon systems are *shallow basins which hold the waste-water for several months to allow for the natural degradation of sewage*. These systems take advantage of natural aeration and microorganisms in the wastewater to renovate sewage."

4) **biological nutrient removal (BNR) –** *removal of dissolved inorganic material*
   a) sometimes called **tertiary treatment**
   b) natural **denitrification** uses *denitrifying bacteria*
   c) setup
      i. intake (from primary treatment, or sent back through the cycle)
      ii. zone 1: *anaerobic (no oxygen) zone*
         - *anaerobic bacteria fermentation*
         - organic acids and $(NH_4)^+$ formed
      iii. zone 2: *anoxic (highly oxygen-deficient) zone*
         - *$(NO_3)^-$ recycled from zone 3 →→ N_2 gas*
         - $(PO_4)^{3-}$ and more $(NH_4)^+$ formed
      iv. zone 3: *oxygen-rich zone*
         - $(PO_4)^{3-}$ absorbed by bacteria
         - removed with excess sludge
      v. secondary clarifier
      vi. output of clarified water

5) final cleansing and disinfection
   a) purpose: *to remove pathogens from wastewater*
   b) examples
      i. *adding chlorine (Cl_2 gas or NaClO)*
      ii. *uv treatment*

> "High levels of chlorine may be harmful to aquatic life in receiving streams. Treatment systems often add a chlorine-neutralizing chemical to the treated wastewater before stream discharge."

6) *advanced treatment*
   a) purpose: *to remove phosphorus and/or nitrogen (nutrients) from wastewater*
   b) procedures
      i. chemical addition
      ii. coagulant addition to remove P
      iii. air stripping to remove NH_3

From http://ohioline.osu.edu/

E. sludge treatment
   1) types of sludge
      a) *primary sludge*
         i. "material that settles out during primary treatment
         ii. often has a strong odor
         iii. requires treatment prior to disposal"

iv. ~97% water

b) *secondary sludge*—"extra microorganisms from the biological treatment processes"

2) treatment goals
   a) *"to stabilize the sludge and reduce odors*
   b) *to remove some of the water and reduce volume*
   c) *to decompose some of the organic matter and reduce volume*
   d) *to kill disease causing organisms*
   e) *to disinfect the sludge"*

3) types of treatment
   a) **anaerobic digestion**—*bacteria breaking down detritus in the absence of oxygen*
      i. raw sludge is p[laced into tanks called **sludge digesters**
      ii. products = CO_2, H_2O, CH_4 *(methane)…* **biogas**
      iii. process takes 4-6 weeks
      iv. **treated sludge (biosolids)—**mixture of organic material and water
         - similar to humus; good fertilizer; water can be squeezed out to form a **sludge cake**
         - sludge cakes can be used as manure
   b) **composting** *(aerobic digestion)*
      i. raw sludge mixed with wood shavings to absorb excess water
      ii. placed in **windrows**—*long, narrow piles*
      iii. *organic matter is broken down by naturally-occurring bacteria and fungi*
      iv. aeration is all the microorganisms need to thrive

   c) *removal of excess water* (target: 50-80% water)

settling and decanting, drying bed, vacuum filter, filter press, centrifuge

> "Wastewater treatment processes require careful management to ensure the protection of the water body that receives the discharge. Trained and certified treatment plant operators measure and monitor the incoming sewage, the treatment process and the final effluent."

F. alternate treatment systems http://www.nesc.wvu.edu/subpages/septic.cfm

1) *individual septic systems*
   a) treat household wastewater onsite
   b) less disruptive to the environment than sewer systems
   c) parts of a *septic tank*
      - *fiberglass or concrete watertight box*
      - inlet and outlet pipes
      - *tank holds wastewater so layers separate* (oils, wastewater, sludge)
      - *bacteria break down sludge* (what isn't broken down remains until the tank is pumped periodically)
      - clarified wastewater flows to the drain field, often through a distribution setup
   d) *drain field* (leachfield, disposal field, soil absorption system)
      - trenches

- gravel or sand-lined bed
- 1-3 ft. below surface
- perforated pipes for distribution

"The drainfield treats the wastewater by allowing it to slowly trickle from the pipes out into the gravel and down through the soil. The gravel and soil act as biological filters."

SEPTIC TIPS from http://www.nesc.wvu.edu/subpages/septic.cfm

1) "Do not drive over the absorption field with cars, trucks, or heavy equipment.
2) Do not plant trees or shrubbery in the absorption field area, because the roots can get into the lines and plug them.
3) Do not cover the absorption field with hard surfaces, such as concrete or asphalt. Grass is the best cover, because it will help prevent erosion and help remove excess water.
4) Divert surface runoff water from roofs, patios, driveways, and other areas away from the absorption field.

Take care not to flush the following: hair combings, coffee grounds , dental floss , disposable diapers , kitty litter, sanitary napkins and tampons, cigarette butts, paper towels, gauze bandages, fat, grease, or oil… and NEVER flush chemicals that could contaminate surface and groundwater, such as paints, varnishes, thinners, waste oils, photographic solutions, and pesticides."

2) using effluents for irrigation
   a) can be used to water golf courses, parks, crops, etc.
   b) effluent water must be free from toxic chemicals

3) reconstructed waste systems: *artificial (constructed) wetlands*

from https://wrrc.arizona.edu/

"If properly built, maintained and operated, constructed wetlands can effectively remove many pollutants associated with municipal and industrial wastewater and stormwater. Such systems are especially efficient at removing contaminants such as suspended solids, nitrogen, phosphorus, hydrocarbons, and even metals. They are used to treat municipal effluent, industrial and commercial wastewater, agricultural runoff, stormwater runoff, animal wastes, acid mine drainage and landfill leachates."

from http://www.dep.state.fl.us/water/wastewater/dom/oreastwet.htm

"The Orlando Easterly Wetlands is an effort by the City of Orlando, Florida to reuse highly treated reclaimed water from its 40-million-gallon-per-day (mgd) Iron Bridge Regional Water Reclamation Facility for environmental enhancement. The project began in the mid-1980s… Recognizing that aquatic ecosystems can be used to naturally remove nitrogen and phosphorus, the city created a large-scale wetland treatment system on an active cattle pasture that had been a wetland many years ago. Earthen berms were constructed throughout the site, and 2.1 million aquatic macrophytes were planted to create 17 cells that further "polish" the reclaimed water piped in from the Iron Bridge facility and discharge it with no adverse impact into the environmentally sensitive St. Johns River system.

After more than a decade of demonstrated performance, the Orlando Easterly Wetlands reclamation project has proven to the world that large-scale, created wetlands can be used on a long-term basis - and with resounding success - for both the advanced treatment of wastewater and beneficial reuse."

17.4 Notes

IV. Public Policy

from http://www.epa.gov/r5water/cwa.htm

A. **CWA: Clean Water Act of 1972**

1) history

a) (1972) Federal Water Pollution Control Act Amendments

b) (amended in 1977) Clean Water Act

c) revised in 1981, 1987…

d) affected by newer laws

2) provisions

a) established the basic structure for regulating discharges of pollutants into U.S. waters

b) gave the EPA authority to implement pollution control programs

c) continued requirements to set water quality standards for all contaminants in surface waters

d) made it unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a permit was obtained under its provisions

e) funded the construction of sewage treatment plants under the construction grants program and recognized the need for planning to address the critical problems posed by nonpoint source pollution

f) Revisions in 1981 streamlined the municipal construction grants process, improving the capabilities of treatment plants built under the program

g) Changes in 1987 phased out the construction grants program, replacing it with the State Water Pollution Control Revolving Fund, more commonly known as the Clean Water State Revolving Fund. This new funding strategy addressed water quality needs by building on EPA-State partnerships.

> "Over the years, many other laws have changed parts of the Clean Water Act. Title I of the Great Lakes Critical Programs Act of 1990, for example, put into place parts of the Great Lakes Water Quality Agreement of 1978, signed by the U.S. and Canada, where the two nations agreed to reduce certain toxic pollutants in the Great Lakes. That law required EPA to establish water quality criteria for the Great Lakes addressing 29 toxic pollutants with maximum levels that are safe for humans, wildlife, and aquatic life. It also required EPA to help the States implement the criteria on a specific schedule."

B. Search current legislation on http://thomas.loc.gov/