

**PLS 209 – Environmental Politics**  
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**Topic: Water Quality**

**Terms and Definitions**

- *Watershed* is a bowl-shaped catchment basin where runoff precipitation (mainly rain and snowmelt) collects.
  - Some of this precipitation evaporates, some is stored in soils and vegetation, some recharges groundwater (which itself may discharge to surface waters), and the rest runs off to nearby surface waters (e.g., streams, lakes, rivers, estuaries, or oceans)
  - Runoff transports dissolved and suspended materials (soils, metals, pesticides, nutrients, etc.) and can cause soil erosion
  - Soil erosion can add soils, nutrients, minerals, and other pollutants to receiving waters
- *Estuary* is a semi-enclosed body of water that has a free connection to the ocean within which seawater is measurably diluted by freshwater from land drainage (e.g., rivers) and groundwater discharge.
  - Estuaries are generally productive biological ecosystems that provide critical habitat for a large diversity of fish and wildlife
  - They serve as nurseries for many young finfish and shellfish
  - Provide for navigation/transportation
  - Provide flood control
  - Often used for waste disposal (e.g., sewage, urban runoff)
- *Hydrologic cycle*: the process by which water moves through the earth's ecosystems by evaporation, atmospheric transport, precipitation, runoff, infiltration, and re-evaporation
  - Evaporation occurs when solar energy causes water molecules from surface waters or soil to escape into the air
  - Transportation of water by plants because of evaporation and transpiration (evapotranspiration) also releases water vapor
  - As water vapor rises, clouds form and atmospheric water can be transported from one place to another
  - Eventually precipitation occurs which enters the ground (and recharges groundwater) or surface water
  - Fallen water finds itself in groundwater or works its way to rivers, lakes, estuaries, or the ocean
  - On average, a water molecule spends 9 days in the atmosphere from the time it evaporates until it falls as precipitation
  - 97% of water is in seawater or estuaries
  - 2% is in glaciers, ice caps, ice fields
  - 1% is freshwater (97% of this is groundwater; 3% is surface water)
  - See Figure 3.5
- Estuarine resources
  - *Wetlands* are bogs, swamps, river deltas, and marshes, whose soils are periodically flooded or water-saturated most of each growing season. They are typically defined by

- specialized species of water-loving plants (hydrophytic plants) and specialized soil types (hydric soils).
- *Submerged aquatic vegetation* such as eelgrasses and sea grasses provide photosynthesis, benthic habitats for invertebrates, finfish fry, and shellfish larvae. They can stabilize bottoms.
  - *Anadromous fish* spend most of their life cycle in marine and estuarine waters but migrate to freshwaters to spawn and reproduce. Examples are the striped bass and salmon.
  - *Catadromous fish* spend the greater part of their life cycle in estuarine and freshwaters but migrate to ocean waters to spawn and reproduce. Example is the eel.
  - *Shellfish* such as clams, oysters, blue crabs, etc.
  - Migratory and nonmigratory birds and major nesting areas.
  - *Desalination* is a process by which sea water is turned into drinking water
    - Desalination projects have become increasingly feasible and common with more than 130 small plants in southern Florida and around 19 plants operating or under construction in California.
    - Because an enormous amount of energy is needed, it is costly and often is cost-prohibitive when it comes to agricultural or industrial uses
    - Can themselves be a polluter due to elevated water temperatures or very saline water

### 1972 Federal Water Pollution Control Act (Clean Water Act)

- Directed congress to set uniform, national limits on effluents for all major sources of discharges into water
  - Effluent guidelines are similar to New Source Performance Standards (NSPS) under the CAA
- Goals of the CWA
  - Eliminate all discharges of pollutants into navigable waters of the United States by 1985
  - Make all waters “fishable and swimmable” by the middle of 1983
- Limited use of ambient standards to define goals and limits on dischargers
  - Nothing equivalent to the CAA’s health-based, nationally uniform National Ambient Air Quality Standards (NAAQS)
- Earlier versions of water pollution control legislation made states set water quality standards for specific waterbodies and draft plans for meeting them. Standards varied depending on the state’s decisions about the “designated use” of the waters. The 1972 CWA continued this program with more federal oversight.
  - Anti-degradation policy prevents states from relaxing water quality standards
- Contained a system of technology-based effluent guidelines which include numerical effluent limits
  - Nonmunicipal sources are required to have technological controls that met the following criteria:
    - “Best practicable control technology” by July 1979
    - “Best available technology” by July 1983
  - Municipal sources
    - All sewage treatment plants in existence on July 1, 1977 had to have “secondary treatment levels” and all facilities regardless of age were required to have the “best practical treatment technology” by July 1983.

- EPA was also required to establish special standards for the discharge of toxic substances. EPA was also required to establish pretreatment standards
- Effluent guidelines apply to all new sources, even if the receiving water meets the local water quality standards
- Act also contained three levels of planning
  - Section 303 statewide water quality management plans
  - Section 208 areawide waste treatment planning
  - Section 205 facility planning
- Construction Grants Program
  - Provided more than \$60 billion in federal funding for the construction of municipal sewage treatment systems.
  - Phased out with the state revolving loan program where the federal government provided funding to states to create a revolving loan program. When loans are repaid the money is lent to other communities to fund other improvements.
- 1987 Water Quality Act - Latest Reauthorization of the CWA
  - Section 319 Nonpoint Source Management Program
  - National Estuary Program
  - NPDES Stormwater Permits require certain industries to begin addressing their stormwater runoff
  - NPDES municipal stormwater permits require local governments of a certain size (gradually phased in to smaller communities) to get permits to ensure they are addressing their city/county's stormwater runoff
  - NPDES erosion and sediment control permits require states to start regulating erosion and sediment runoff from large construction sites
  - Expanded pretreatment requirements
  - Shifted from construction grants to state revolving loans
- Implementation of the CWA has been shaped by several factors
  - States given a strong role
    - States decided on the designated uses of a water body
    - Once delegated the authority to implement the state program, states have considerable influence over standards and enforcement

**General Categories of pollution sources addressed by the CWA**

- *Point sources*: identifiable sites such as a sewage treatment plant, smoke stack, or industrial discharge
- *Nonpoint sources (NPS)*: diffuse sources of pollution generated by such things as erosion, stormwater runoff, marinas, hydromodifications, habitat alteration
- Distinction is in how these sources are defined in federal pollution control laws

### Indicators of Water Quality Problems

- *Eutrophication* is the excessive nutrient loadings that result in excessive growth of algae and weeds that leads to the loss of water clarity (turbidity), low dissolved oxygen (DO), and changes in fish and wildlife.
  - *Natural eutrophication* is slow aging of surface waters, especially in lakes. It results from the gradual addition of soil and nutrient runoff from undisturbed watersheds. No rapid or dramatic changes in water quality, fish populations, or aquatic wildlife occurs
  - *Cultural eutrophication* is rapid aging of surface waters usually resulting from human, agricultural, or cultural activities. It often leads to turbidity (loss of clarity), excessive growth of algae and weeds, and changes in fish and wildlife
- *Dissolved oxygen (DO)* is the amount of oxygen gas dissolved in water
  - The higher the temperature the less oxygen dissolves in water because heat increases molecular motion
  - Increased salinity also decreases DO because salts compete for hydrogen bonding sites in water
  - *DO saturation* is the maximum concentration of oxygen gas that typically dissolves in an aquatic system and depends mainly on temperature and salinity
    - 9 to 14 mg DO/L in freshwater
    - 7 to 11 mg DO/L in marine waters
  - DO is important because most aquatic plants and animals require oxygen for aerobic respiration
    - Most fish require at least 5 mg DO/L to survive (salmon 6 to 8 mg DO/L)
  - *Anoxic* waters have no dissolved oxygen and cannot support plant and animal life, which can lead to fish kills.
  - *Hypoxia* results when DO falls to 2 ppm or less and can potentially be harmful to finfish and shellfish
- *Biological Oxygen Demand (BOD)* is the demand for DO brought about by increasing numbers of bacteria and other decomposers as they assimilate organic matter. Technically, it is the mg of oxygen needed to the organic matter in 1 L of a water sample
  - *Organic matter* including human and animal waste is biodegradable and is broken down by decomposers such as bacteria and fungi. Adding organic matter increases the populations of the decomposers, which require oxygen
- *Turbidity* is a measure of the suspended solids in water and the corresponding water clarity. It can also be measured in terms of the *total suspended solids (TSS)* in the water column, a measure of possible problems due to siltation and soil erosion.
  - The greater the turbidity the greater the decline in water clarity. This reduces the depths to which light can penetrate. This can lead to the loss of sea grass beds and other valuable submerged aquatic vegetation that serves as habitat
  - A sign of excessive sedimentation which causes the water to be murky, muddy, or cloudy
  - A sign of excessive nutrient loadings that stimulate algae growth that reduces water clarity
  - Filter feeders such as clams, oysters, and mussels are nature's way of controlling turbidity by filtering out plankton
  - In terms of drinking water, increased turbidity can make it more difficult to effectively filter water and can interfere with chlorine disinfection.

- *Nitrates (nitrogen compounds) and phosphates (phosphorous compounds)*
  - Nitrate contamination is often common in rural agricultural areas as a result of fertilizer application and in areas with dense concentrations of onsite sewage disposal systems (OSDSs) or septic systems.
  - Nitrates tend to be more mobile in soils than phosphates.
  - High levels of nitrates in drinking waters can pose human health problems. 10 mg of N per L is the EPA's standard for drinking water
  - *Limiting nutrients principle*: research has shown that in most freshwaters phosphorous is the limiting nutrients and in ocean waters nitrogen is often the limiting nutrient. Estuaries are more complex and both nitrogen and phosphorus can function as the limiting nutrients in different parts of the estuary at different times of the year.
- *Salinity* is a measure of the saltiness of the ocean. It is due primarily to dissolved minerals such as sodium chloride and is reported in parts per thousand or g/kg of water.
  - Ocean waters have an average salinity of 35 g/kg
  - Estuaries typically fall between 10 – 25 g/kg
  - Red sea is 40 g/kg
- *Coliform bacteria* is often used as the main indicator of potential bacterial contamination
  - Often increases as a result of stormwater runoff and other nonpoint sources (OSDSs) and point sources
  - Shellfish areas are closed to shellfishing when high bacterial loadings are present. Because shellfish are filter feeders, they can accumulate bacteria and viruses.
  - One problem is that it doesn't distinguish human bacteria from animal bacteria. Thus, high bacterial loadings could be due to large animal or bird populations
  - *Viruses* can be present in wastewater and can pose human health problems. Typically, there is no monitoring and government officials rely on fecal coliform bacteria as a proxy
- *Hydrocarbons* are organic chemicals composed of the elements of hydrogen and carbon.
  - They are derived principally from fossilized plant matter that has been transformed over geologic time into methane (natural gas), crude oils (petroleum), and waxy solids like paraffin
- *Heavy metals* such as mercury, cadmium, lead, and chromium used in different industries such as electroplating.
  - Heavy metals are often bioaccumulated in fish. Populations that are heavily reliant on fish in their diet can be at risk.
    - Minimata, Japan: Example of mercury poisoning as a result of contaminated fish
  - Lead levels in sediments declined dramatically with the introduction of lead free gasoline
- *Pesticides* such as herbicides, insecticides, fungicides, and other pest-control agents can work their way into the water column and harm fish or aquatic vegetation
- *Temperature*: some species are very sensitive to temperatures.
- *Assimilative capacity* is the ability to biodegrade (assimilate) the organic wastes discharged into them.
  - Unpolluted aquatic environments are therefore able to purify themselves up to a point
- *Biomonitoring*: certain species can be used as biomonitors, or indicators of water quality.
  - Ex: Salmon and trout are good biomonitors because they require DO levels of 6 mg DO/L or greater

- Declining seagrass beds: Sea grass declines can be due to changing salinity/climate patterns, excessive nutrient loadings which cause excessive turbidity and reduces light penetration, introduction of chemical herbicides
- Declines in shellfish such as the oysters which is often due to declining water quality as well as disease and overharvesting

### CWA Terminology

- Clean Water Act (1972) was last amended in 1987
  - Goal is that all waters will be fishable and swimmable and meet their designated uses
  - Waters have designated uses
  - Quantitative and narrative water quality criteria
  - Oriented towards antidegradation such that waters that are fishable and swimmable are prevented from deteriorating
- Beneficial uses include
  - Aquatic life support
  - Fish consumption
  - Shellfish harvesting
  - Drinking water supply
  - Primary contact recreation – swimming
  - Secondary contact recreation
  - Agriculture
  - Groundwater recharge Wildlife habitat
  - Culture
- EPA classifications
  - *Fully supporting all uses*: Water quality condition is good and it meets its designated use criteria
  - *Threatened for one or more uses*: Water quality condition is good and supports its beneficial uses now but may not support one or more of these uses in the future unless action is taken
  - *Impaired for one or more uses*: Water quality condition is impaired and fails to meet designated use criteria at times. Water quality might be defined as fair (partially supporting) or poor (not supporting)
  - *Not attainable*: The jurisdiction has performed a use-attainability analysis and demonstrated that use support is not attainable due to one of the six biological, chemical, physical, or economic/social conditions specified in the code of federal regulations (CFR)
- Pollution Source Categories
  - *Industrial*: pulp and paper, chemical manufacturers, steel plants, metal process and product manufacturers, textile makers, food processors, etc.
  - *Municipal*: sewage treatment plants
  - *Combined sewer overflows (CSOs)*: single facilities treating both sanitary and stormwater that become overloaded during storm events
  - *Storm sewers/urban runoff*: runoff from impervious surfaces including streets, parking lots, roofs, and other paved areas
  - *Agricultural*: crop production, livestock, pastures, etc.
  - *Silviculture*: forestry activities

- *Construction*: land development and road construction and associated erosion and sedimentation
- *Resource extraction*: Mining, petroleum drilling, runoff from mine tailing sites
- *Land disposal*: Leachate or discharge from OSDs (septic systems), land fills, and hazardous waste sites
- *Hydrologic modifications*: Channelization, dredging, dam construction, flow regulation
- *Habitat modification*: removal of riparian vegetation, streambank modification, drainage/filling of wetlands

### **Leading Causes of Water Quality Impairment**

- Rivers
  - Siltation
  - Nutrients
  - Bacteria
  - Oxygen-depleting substances
  - Pesticides
  - Habitat alteration
  - Suspended solids
  - Metals
- Lakes
  - Nutrients
  - Metals
  - Siltation
  - Oxygen-depleting substances
  - Noxious aquatic plants
  - Suspended solids
  - Toxics
- Estuaries
  - Nutrients
  - Bacteria
  - Priority toxic organic chemicals
  - Oil and Grease
  - Salinity
  - Habitat alterations

### **Leading Causes of water quality impairment related to human activities**

- Rivers
  - Agriculture
  - Municipal point sources
  - Hydrologic modification
  - Habitat modification
  - Resource extraction
  - Urban runoff/storm sewers
  - Removal of streamside vegetation

- Industrial point sources
- Lakes
  - Agriculture
  - Unspecified nonpoint sources
  - Atmospheric deposition
  - Urban runoff/storm sewers
  - Municipal point sources
  - Hydromodification
  - Construction
  - Land disposal
- Estuaries
  - Industrial discharges
  - Urban runoff/storm sewers
  - Municipal point sources
  - Upstream sources
  - Agriculture
  - CSOs
  - Land disposal of wastes

### **Managing Point and Nonpoint Sources of Water Pollution**

- *Primary waste treatment* is the simplest and least costly approach to dealing with sewage and other waste matter
  - Screen out debris and grind solids that might interfere with plant operations
  - Allow suspended solids to settle to the bottom forming a primary sludge, which is then incinerated or transferred to a landfill. Goal is to reduce suspended solids by 85%
  - Disinfect effluent using chlorination prior to discharging into receiving waters
  - Reducing BOD is not a principal objective but it does occur when suspended solids settle out
- *Secondary waste treatment* is often required to produce effluents that can be safely be discharged to receiving waters. It is mandated by the CWA
  - The goal is typically and 85% reduction in BOD typically through aeration during the sludge process to introduce oxygen to break down organic matter
  - To further reduce suspended solids
  - Disinfect effluent using chlorination prior to discharging into receiving waters
- *Tertiary or advanced waste treatment* is often oriented towards removing nutrients from the wastewater using various processes before discharging it to surface waters
  - Focused on removing phosphorus and/or nitrogen through aerobic and anaerobic processes
  - Sometimes filtered through plant matter
  - Helps eliminate harmful algae blooms



- *Combined sewer overflows (CSOs)* result when storm sewers are combined with sanitary sewers and during heavy rainfall events, sewage treatment plants cannot handle the runoff so the overflow, including raw sewage, is discharged
  - Addressing CSOs often involves constructing large detention and storage areas where overflows can be stored and pumped into the sewage treatment plant during dry periods. This helps remove floating debris, raw sewage, and bacteria.
  - Boston Harbor Project conducted by the Massachusetts Water Resources Authority (MWRA) was estimated to cost approximately \$6 billion and involved building primary and secondary treatment plants and a controversial 9.5 mile, 24-foot diameter tunnel to discharge treated waters in the deeper portion of Massachusetts Bay. Project should be completed in 2001.
  - Chicago is building a huge system of tunnels and three huge reservoirs to remove the 500 CSOs and discharge the water back into the treatment plant. It is expected to cost around \$3 Billion dollars.
- *Pretreatment* often involves working with industries to remove pollutants such as metals from the waste stream before they are discharged to sewage treatment plants
  - Concept can also be applied to the formulation of products such as low phosphate detergents
  - Concept can be applied to reusing compounds and reusing water such that there are no discharges to sewer systems
- *Best management practices (BMPs)* are typically used to address nonpoint source problems. These include specific actions targeted at reducing specific pollutants in storm runoff
  - Constructing a detention pond to allow sediments to settle and combining it with other techniques such as oil and grease separators
  - Installing silt fence and other BMPs at a construction site to reduce runoff
  - Building a manure storage shed
  - Developing a nutrient management plan for a farm
  - Installing a denitrification septic system or reducing the density of septic systems

### Groundwater

- It accounts for about 97% of all freshwater and approximately half of all Americans rely on groundwater while approximately 95% of farm families rely on it for their drinking water
  - Groundwater is usually cleaner than surface water because the soil filters out most of the bacteria, suspended materials, and other contaminants
  - Estimates are that most rivers receive as much of their flow from groundwater seepage as from surface runoff
  - Safe Drinking Water Act requires monitoring of public wells and community wells but not private wells. Thus, many homeowners don't know if their water is contaminated
  - Over half of the reported waterborne disease outbreaks in the US between 1971 and 1994 were traced to microbially-tainted groundwater
- *Aquifers* are underground sources of freshwater
  - Water infiltrates soils and maintains groundwater resources in porous sand, gravel, and rock formations
  - Often tapped for drinking water, irrigation, and industrial needs

- Ogallala aquifer is the largest groundwater resource in North America and supplies a vast area from southern South Dakota to northwestern Texas
- About 50% of all drinking water in the U.S. is drawn from wells drilled in relatively shallow aquifers less than 30 meters deep
- *Shallow, unconfined (water table) aquifers* are repeatedly recharged by precipitation which makes them vulnerable to contamination by various pollutants such as gasoline, solvents, and pesticides
- *Relatively deep, confined aquifers* lie below layers of clay, which makes them better protected and are recharged by precipitation falling at distant sites
- *Natural recharge area*: the area of land, which, because of its permeable soils, is the main source of groundwater inflow. This recharge area can be many miles from the point at which water is pumped.
- Most significant sources of groundwater contamination include
  - *Waste storage, treatment, or disposal facilities*: Unplanned seepage from open dumps, landfills, waste ponds, underground storage tanks, even graveyards.
    - Petroleum products leaking from underground storage tanks are the leading source of groundwater pollution in most states
    - Landfill seepage is the second leading cause of groundwater pollution
  - *Onsite sewage disposal systems (OSDSs) or septic systems* serve about 30% of US households and can be a significant source of bacteria, viruses, nitrogen, and other chemicals
    - Third most common source of groundwater contamination
  - *Pipes, materials transport, transfer operations*: unintentional leakage from sewers or pipelines or other accidental spills during the transport or transfer of materials
  - *Nonpoint sources* such as irrigation practices, mine drainage, de-icing of highways, urban street runoff, etc.
- Ensuring Adequate Water Resources
  - Increase supply (e.g., construct new reservoirs)
  - Demand management (water conservation) includes
    - Reducing overall use of water
    - Reducing wastage of water
    - Recycling used water (water reuse)
  - Elements of an effective water conservation program
    - Rational water pricing
    - Leak detection/correction programs
    - Installing water saving plumbing devices
    - Altering landscape practices