Environmental Science Midterm Review

Introduction to Environmental Science

I. Environmental Science - the study of the interactions between human beings and the earth's living and nonliving components.

A. Major Environmental Problems

1. Human population growth
2. Excessive and wasteful resource use
3. Wildlife extinction
4. Habitat destruction
5. Pollution - global climate change

B. Root Causes of our Environmental Problems

1. Emergence of Homo Sapiens
   - Easter Island Analogy

C. Solution to our Environmental Crisis = Sustainability and Stewardship

Water Resources

I. The Blue Planet: Earth - water covers 70% of its surface average depth of the ocean is ~ 13,000 feet, or 2.5 miles.

A. Water: The Extraordinary Molecule

II. The Hydrologic Cycle - The "circular" path in which water moves through ecosystems.

Watershed – the total land area drained by a body of water.

Groundwater - is fresh water that has percolated through the soil, and accumulates below the ground.

1. Zone of Saturation — the area where water saturates the pore spaces in soil, gravel, and rock.

2. Water Table — the upper layer of the zone of saturation. The water table fluctuates depending on local conditions.

3. Aquifer - large storehouses of groundwater held in porous rock like limestone, glacial till, and sandstone

III. Water Shortage - With most of the planet being covered with water, how could there be *a* water shortage?

Agriculture - Food production requires great quantities of water. 2/3 of all freshwater use in the world is used for agriculture.

Industry - Water is consumed in countless industries at staggering rates mainly paper, chemical, petroleum, and metal processes.

Population – Growth of human population puts a strain on water resources. Average U.S. family consumes about 60 gallons per day.

Unequal Distribution – different geographic locations have differing amounts of water.

Pollution – most surface water in the United States and around the world is contaminated in some way.

IV. Major Water Issues (naturally occurring)

A. Drought - a drought is classified when an area's rainfall falls below 30% for a period of 21 days or longer.

B. Floods - annual flood events can cause widesprrad damage.

1. Flood Control Methods

V. Irrigation - the act of conveying water to agricultural land to use to grow crops. 2/3 of all water used in the world is for agriculture.

A. Methods of Irrigation: Sheet (Flood), Furrow, Sprinkler, Drip

B. Problems with Irrigation

1. Evaporation - loss of water to the atmosphere.

2. Salinization - excessive evaporation causes mineral salts to be left behind in soil greatly increasing the salinity of the soil.

3. Groundwater Depletion- loss of groundwater which cannot be rapidly replaced. Also the threat of subsidence occurring in areas where groundwater is rapidly depleted

VI. Standing Water Ecosystems

A. Standing Water Resources:
Lakes and Ponds, Marshes, Swamps, Bogs, Prairie potholes

B. Standing Water Life Zones

1. Littoral Zone – Nutrient rich shallow water next to shoreline. Sunlight reaches the bottom.

2. Limnetic Zone -Top layer of water receives sunlight for photosynthesis (Photic Zone)

3. Profundal Zone - Deep water where no light penetrates (Aphotic Zone)

4. Benthic Zone - Bottom of the aquatic ecosystem

Life Stage of Lakes – Oligotrophic, Mesotrophic, Eutrophic

Hedges Lake = Meromictic Lake

Seasonal Lake Turnover

VII. Flowing Water Ecosystems - water that is constant flow (Streams and Rivers)

A. Watershed - the total amount of land area that is drained by a river system.

B. Stream Features - meandering or the S-like curve of a river results when water dissipates its energy.

C. Floodplain - the flat outer flood zone of a flowing body of water.

D. Discharge Rate - the total amount of water flowing past a particular point in a river or stream. Usually expressed in cubic feet per second.

VIII. Water Conservation

A. Reduce evaporation (Irrigation), Drip Irrigation, Improve Industrial Use of Water, Desalinization of Seawater, Genetically Modified Plants?, Home Water Conservation:

Long Distance Transport of Water - transport water in using pipes, canals, aqueducts.
1. New York City Water Supply, California Water Project, Aral Sea

Water Pollution

I. Water Pollution – the contamination of water that lessens its value to living organisms.

A. Point Pollution - water pollution that has a well defined source.

B. Non-Point Pollution - water pollution spread over a wide area.

C. Input Control -method used to prevent water pollutants from entering environment.

D. Output Control - removing pollutant after it enters into the environment.

II. Types of Water Pollutants

A. Sediment Pollution - the clouding of water with soil sediments. Is the most widespread form of water pollution.

1. sediment pollution blocks photosynthesis, clogs fish gills, damages water intake machinery, washes toxic metal into water, clogs boating channels, covers fish eggs.

2. Causes of Sediment Pollution -

- Runoff - caused by accelerated erosion as a result of construction, agriculture, poor logging practices, and mining.

3. Control of Sedimentation

- Input Controls - Proper soil management (cover crops, contour farming), gully reclamation, hydroseeding, diversion ditches on roads, vegetative buffers.

- Output Controls - redirect water flow into wetlands (constructed wetland), sediment control ponds, silt fence, dredging, dams.

B. Nutrient Pollution (Cultural Eutrophication) - the enrichment of plant fertilizers in an aquatic ecosystem. Mainly in the form of Nitrates (NO_3^-) and Phosphates (PO_4^+).

1. Cultural Eutrophication and Algal Blooms - Increased nutrient input (Mainly in the form of Nitrates and Phosphates) into water resources causes rapid growth of algae. The high populations of algae die and settle to the bottom of the water where they are decomposed by aerobic bacteria which greatly depletes the dissolved oxygen levels of the lake. - Biological Oxygen Demand (BOD)

3. Sources of Nutrients
- Agricultural Fertilizers - Runoff from farms, home lawns and gardens, recreational facilities.
- Domestic Sewage - Detergents, and waste.
- Animal and Livestock Waste- Manure runoff, and pet waste.

4. Nutrient Pollution Input Controls

- Controlled Animal Feeding Operation (CAFO) - legislation that regulates animal feed lots, manure runoff, manure spreading.

- Phosphate free detergents

- Vegetative buffer strips - 50 feet or more buffer to absorb nutrients.

- collection ponds/artificial wetlands

- Applying fertilizers at the right time!

- Wastewater Treatment Plants

5. Nutrient Pollution Output Controls

- Tertiary Treatment for Wastewater to remove nitrates and phosphates.
- Herbicides
- Aquatic Plant Harvest

C. Thermal Pollution - the increase or decrease of water temperature as a result of human activity. Mainly affects the dissolved oxygen level of the water, but can also adversely affect aquatic organisms (Thermal Shock).

1. Causes of Thermal Pollution - Industrial use, and power generation utilize water for cooling.

V. Disease Causing Organisms - water that is contaminated by microorganisms that cause water borne illness. This was a major threat to human health for thousands of years.

1. Bacteria - Cholera, Typhoid, E-Coli
2. Microorganisms - single celled protozoans and amoebae can cause water borne illness.
- Amoebic dysentery, Giardia, Cryptosporidiosis

3. Viruses - Deadly viruses can also be found in wastewater and sewage that can spread disease. - Hepatitis

4. Blue-Green Algae – Anabaena secretes a neurotoxin.

5. Input and Output Controls - Disinfection of water by chlorination, ozonation, ultra-violet radiation, or boiling.

V. Toxic Organic Compounds - (Organic = Carbon containing) Synthetic compounds used in industry, medicine, and agriculture that have contaminated water.

1. PCB's (Polychlorinated Biphenyls,

- Bioaccumulation - the increase in the concentration of a chemical in the tissue of an organism

Biomagnification – the increase in the concentration of a toxin as it moves up through the food chain. Upper levels of consumers can accumulate toxic concentrations of chemicals.

3. Organochlorides - many chlorinated compounds are used in industry that can cause adverse health effects. trichloroethylene (TCE) used for cleaning metal parts and carbon tetrachloride used in many manufacturing.

4. Petroleum - crude oil can have many adverse health effects when spilled into the environment (oil spills).

5. Input and Output controls for Toxic Organic Compounds

Input Controls - Water treatment (carbon filtration) and safe disposal of waste water containing toxins (Incineration or sanitary landfill disposal). Safe transportation of crude oil (double hull tankers), or lessening dependence on crude oil!!!

Output Controls - Dredging, extraction wells, water purification, oil spill clean-up.

Bioremediation - the use of living organisms to clean-up toxins. Microorganisms that can degrade toxins, or plants that can remove toxins from the soil (hyperaccumulators)

Plastics Pollution!!!!

VI. Heavy Metal and Toxic Inorganic Water Pollutants

1. Heavy Metals - Arsenic, Zinc, Mercury, Copper, and Lead.
2. Nitrates – Blue baby syndrom
3. Input/Output Controls - Water filtration/purification

VII. Common Water Quality Tests

Nitrate (NO_2^-), pH, Dissolved Oxygen (DO), Temperature, Alkalinity/Hardness ($CaCO_3$), Phosphate (PO_4^+), Turbidity, Total Dissolved Solids (TDS), Coliform Bacteria

Ocean Acidification – a decrease in the pH of the ocean due to increased levels of carbon dioxide dissolving into the ocean.

Water Quality Index – a method of determining the quality of water that can be used in many parts of the country.

VIII. Groundwater Pollution - Groundwater contamination is probably the worst form of water pollution due to the fact that groundwater is not visible, and can easily be contaminated by a number of sources, and can travel long distances.

1. Leaching - the process of water moving into something, dissolving it, and carrying it away as a result of groundwater flow.
2. Lechate - contaminated groundwater exposed at the surface.
3. Plume - a well defined area of polluted groundwater.
5. Groundwater Pollution Remediation

- Identify source of groundwater pollutant, and stop it.

- Stop recharge and infiltration at the site (cap with impermeable barrier)

- Identify location of plume, and its direction of movement (monitoring wells, local topography and geology of region)
- Stop movement of plume by constructing containment walls (only possible for shallow plumes)

Use of Permeable Reactive barriers (PRB's) – a wall built below ground, made of a reactive material to neutralize polluted groundwater. Common substance include charcoal, limestone, or iron.

- Drill extraction wells to remove polluted water and treat at the surface.

- Construct interceptor or collection trenches to collect polluted groundwater and treat at the surface.

The Love Canal Groundwater Pollution

IX. Clean Water Act

A. The United States Congress passed the Federal Water Pollution Control Act Amendments of 1972, and it became known as the Clean Water Act after Congress passed amendments to it in 1977. The law was further amended in 1987 (Safe Drinking Water Act).

- Main Objective: To restore and maintain the chemical, biological, and physical integrity of the Nation's water (surface waters only until 1987).

- achieve a level of water quality that provides for the protection and propagation of fish, shellfish, and wildlife.

- to improve water quality for recreation in and on the water.

- eliminate or control the discharge of pollutants into surface waters

- prohibit discharge of pollutants without a permit.

- the act also prohibits potentially harmful spills of oil and certain hazardous substances, and requires clean up.

2. Other important Acts of Congress used to protect water:

- Rivers and Harbors Act (1899) - protects nation's waters to promote commerce.

- Water Pollution Control Act (1948) - provides federal funding to States to promote efforts to protect water quality.

- Marine Protection, Research, and Sanctuaries Act (1972) - prevents unacceptable dumping in the ocean.

- The Ocean Dumping Ban Act (1988) - complete ban on ocean dumping after Dec. 31 1991.

Wastewater and Wastewater Treatment

I. Wastewater - used water that contains dissolved or suspended matter, that is produced by homes, factories, farms and other places where water is used.

A. Types of Wastewater

1. Domestic Wastewater- wastewater produced by humans in their daily lives. It comes from homes and other non-manufacturing sources. It is composed of urine, feces, and gray water.

a. Gray water - wastewater produced by bathing, cooking, or cleaning clothes or dishes. It is usually high in detergent pollutants and bacteria from skin, food, teeth or clothing.

3. Sewage- wastewater produced by residential and commercial sources. The major components of sewage are human body wastes and gray water. Other chemicals or oils may also be present in sewage.

1. Remove or destroy disease causing organisms.
2. Reduce or remove dissolved or suspended material.
3. Remove or reduce organic materials.
4. Remove or reduce potential nutrient pollutants.

IV. Wastewater Treatment Systems

A. Municipal Wastewater Treatment – used in areas of large populations where wastewater is treated in one or more central locations.

1. Collection – a network of pipes and pump stations to collect wastewater and transport it to the treatment facility.

2. Primary Treatment – Screening of large suspended material, and sedimentation of smaller suspended solids in settling tanks.

Products of Primary Treatment – Scum and sludge (biosolids)

3. Secondary Treatment - Biological filtration utilizes microorganisms to breakdown dissolved organic material and toxic ammonia in human waste into Nitrates (NO_3^-), and Phosphates (PO_4^-).

Methods of Secondary Treatment – Sub Aeration and trickling filters.

Biological Contactor – medium used for bacterial growth

4. Tertiary Treatment –(optional in many cases, but becoming more widespread) – the removal of nitrates and phosphates produced by secondary treatment.

- Anoxic Denitrification (Bioreactors) – D.O levels below 0.5 ppm causeanaerobic bacteria to disassociate Nitrates into N_2 and O_2.

~ Solar Aquatic Tertiary Treatment (The Living Machine) – the use of plants to remove excess phosphates and nitrates.

5. Disinfection – The killing of microorganisms present in the effluent. Chlorination, Ozonization, Ultraviolet Radiation.

6. Sludge Removal and Disposal – (biosolids) The by product of both primary and secondary treatment is disposed of by:

Land application (~ 50%) - Landfills (~ 25%) Incineration (~ 25%)

-In NY 55% of all sludge was dumped into the ocean until 1992 when the Ocean Dumping Act took effect.

B. Alternatives to Municipal Wastewater Treatment

1. The Living Machine
2. Constructed Wetlands

C. Septic Systems – small scale wastewater treatment used mostly by small rural communities. 25% of homes in the U. S. utilize this form of wastewater treatment.

1. Septic systems consist of a septic tank, distribution box, and leach field.

2. Anaerobic Digestion – heavy biosolids that collect in the septic tank are broken down by the anaerobic bacteria. The by product of anaerobic digestion are nitrates, phosphates, and methane gas.

- Approximately 50% of the biosolids in the septic tank are broken down by anaerobic bacteria, the remaining 50% must be removed.

3. Septic System Regulations:

Must be 50 feet away from surface water, and 100 feet from wells

Chemistry of Wastewater Treatment

Aerobic bacteria converts proteins and carbohydrates into mainly NO_3 and CO_2

Anaerobic bacteria utilize anaerobic decomposition to convert proteins and carbohydrates into Methane (CH_4), Carbon Dioxide, and small amounts of hydrogen sulfide gas.

50 to 70% of biogas consists of methane and 30 to 50% carbon dioxide.

Weather, Climate, and Climate Change

Two gases make up the bulk of the earth's atmosphere: nitrogen (N2), which comprises 78% of the atmosphere, and oxygen (O2), which accounts for 21 %. Various trace gases make up the remainder. Trace gases (1%)

Based on temperature, the atmosphere is divided into four layers: the troposphere, stratosphere, mesosphere, and thermosphere.

Weather and Climate

The earth's climate is generally defined as the average weather over a long period of time.

How does climate differ from weather?

Weather - is the current atmospheric conditions, including temperature, rainfall, wind, and humidity at a given place.

Climate - is the general weather conditions over a long period of time. Climates are usually classified by annual temperature and precipitation values, (Arid, Humid, Polar, Tropical)

Ocean currents and global winds play a significant role in transferring heat around the planet.

Paleoclimates (Ancient Climates)

Studying past climates and climate changes help us to better understand our current climate and what may happen in the future. Several techniques are used for measuring past climates, including:

Extracting deep ice cores from glaciers and the polar ice caps, examining growth rings on trees, coral reef cores, sediment cores can all reveal clues to past climates.

- Examining fossil and pollen records

Vostok Ice Core – deep ice core drilled into Antarctica (10,230 feet)use gases = direct relationship in the past

Why the Increasing Trend in Temperature? Fossil fuel use

What Causes Climate Change?

- Greenhouse Gases – Gases present in the atmosphere that absorb infrared radiation given off by the Earth's Surface causing atmospheric temperature to rise.

They include: Carbon Dioxide (CO_2), Methane (CH_4), Water Vapor, CFC's

- Ice House gases – Gases or particulates in the atmosphere that reflect sunlight back into space, causing temperatures to decrease.

They include: Sulfur Dioxide (SO_2) and Dust

Annual Greenhouse Gas Index (AGGI)- a measure of the total influence of greenhouse gases on the Earth's climate

Based on the Radiative Forcing of each gas. Radiative forcing is a measure of how much energy is absorbed by a greenhouse gas and is expressed in watts/square meter.

The Greenhouse Effect – Incoming short wave, visible light radiation from the sun penetrates the atmosphere and heats the Earth's surface. The surface then re-radiates this energy as long wave, infrared radiation which is absorbed by gases in the atmosphere, causing temperatures to rise. Thus the Earth's atmosphere acts like the glass in a greenhouse.

What Can Result if the Earth's Temperature Rises?

Climate Shift – Change in the location and area of world Biomes.

Sea-Level Rise – Melting glacial ice will add water to the ocean, and the increase in ocean temperature will also cause thermal expansion of the oceans.

Global Cooling – Melting glacial ice may interrupt warm ocean currents causing changes in local climates. Cool, low density fresh water may cap warm, more dense salt water in the Gulf Stream. This may lead to cooling the climate of Europe.

THE KYOTO PROTOCOL

Global Warming and Disease- changes in climate could also lead to the spread of disease to new areas. Migration and increasing populations of insects, higher temperatures, increased moisture.

Ozone Destruction – Human created gases used as refrigerants like chlorofluorocarbons (CFC's), commonly known as Freon and Methyl Bromide a soil fumigant, have escaped into the atmosphere and have risen up into the stratosphere. It is there that the Sun's radiation destroys the CFC molecule, therefore freeing up reactive chlorine molecules. The chlorine then bonds with the free oxygen atoms that make up the ozone layer, and therefore decreases the amount of ozone in the stratosphere.

The Ozone Hole – The loss of ozone over the poles has created very thin or no areas of ozone. The formation of the ozone hole is linked to the formation of polar stratospheric clouds.

<u>Negative Effects of Stratospheric Ozone Depletion</u> – the loss of ozone causes more UV radiation to reach the Earth's surface. This can damage cells leading to cancer. In humans the result is an increased risk of Melanoma, or skin cancer.

THE MONTREAL PROTOCOL