United States early 1970's created EPA-> Environmental Protection Agency.

The National Environmental Policy Act (NEPA) is a United States environmental law that promotes the enhancement of the environment and established the President's Council on Environmental Quality

Under president Nixon

Biggest environmental agency

- Water/air/soil/noise were the basic environmental issues in the 70's
- Waste management , toxicity, environmental impacts only came later ,80's,90's
- Now our environmental issues are everything (buildings, roads, plants... etc.) the whole Ecosystem.
- Environmental Stewardship->responsible use and protection of the natural environment through conservation and sustainable practices. (actions done effects on environment)

Using resources creates a byproduct (pollution)

The biggest pollutants are Foresting, Agriculture, Urbanization

Green Engineering -> Green design, pollution prevention, Industrial ecology

The design, commercialization, and use of processes and products that minimize pollution, promote sustainability, and protect human health without sacrificing economic viability and efficiency

Industrial Ecology -> Industrial systems with the goal of finding ways to lessen their environmental impact. Learn how industries are using industrial ecology to reduce the use of natural resources and generate less waste

Sustainable development -> The development that meets the needs of the present without compromising the ability of future generations to meet their own needs

Air is a priority factor (air, water,food ect.)

Difficulty of impacts - Death

- Severe illness
- Illness
- Annoyance

Acute impact -> Easy to identify (short term)

Chronic Impact -> Takes years, difficult to assess

- Knowledge of long term effect is very limited
- Ex: Pharmaceuticals create new chemicals, do not know long term effects

80's, 90's approach -> What is carcinogenic? Toxic? (put in categories, groups)

Not just tested for humans but the whole ecosystem

The key is not to impair future generations (prevention)

CHP2

3 Main groups -> Air, Water, Soil

1.AIR

1880's in the US, first understanding of air pollution

1948 (Pennsylvania, air issues, lots of death) .Research done on emissions causing this * industrial complex .Proper legislation on Air Pollution

1963-70, Clean Air act (CAA) creates a more complete legislation

- Identified 5 primary Air pollutants
- In 1978, a 6 pollutant was added to the list

1. PM (Particulate Matter)

- Dust/Haze
- Fine particles suspended in air solid/liquid
- In micrometers
- Comes mostly from combustion, industrial and manufacturing processes
- Effects on humans are Respirations and Cardiovascular
- PM 50 was standard, then PM 25, then PM 20, then PM 10
- 1997 – PM 2.5 STANDARD (USA) , CANADA STILL PM 10
- Roads are source of PM (paved roads = low pm, asphalt = high pm)

2. Sulfur Dioxide (SO_2) Sulfur Oxides

- Burning of fossil fuels (coal, oil)(combustions) creates SO2
- Metal smelters emit a lot of SO2

- Associated with acid rain ($SO_2 + NO_2$)
- Causes respiratory illness's
- Graphs shows it has went down 35% even though coal has gone up in electric plants

3. Carbon Monoxide (CO)
- Colorless/Odorless gas
- When fossil fuel is not completely combusted
- Effects to humans are shortness of breath, dizziness headache, asfixiation
- Cars emit most CO
- Graph shows it has went down very slightly since the 1970's act

4. Nitrogen dioxide (NO_2) Nitrogen oxides (NO)
- A reddish-brown gas that is toxic in high concentrations
- Can cause respiratory problems at low concentrations
- It comes primarily from combustions
- Can cause acid rain with SO_2

5. Ozone
- Air pollutant ozone at ground level -> Bad Ozone
- Bad Ozone involves chemicals reactions involving nitrogen oxides(NO_x), hydrocarbon gasses = VOC = Volatile Organic Compounds or said ROG (reactive organic gasses)
- Ozone in stratosphere -> Good Ozone
- Ozone belongs to class of chemicals known as Oxidants
- Ground level ozone causes respiratory problems and interferes with crops
- Los Angeles high level of ozone,
- (VOC'S have gone down over the years)

6. Lead
- A heavy metal that can cause neurological damage and adverse effects on organs such as the liver and kidneys.
- When lead is absorbed, it is not easily reversible
- Biggest emissions were from automobile using leaded gasoline
- Now they use unleaded gasoline
- Lead smelting, manufacturing processes are major sources of lead in the USA.
- Graph shows Lead emissions have nearly gone down to 0

AIR TOXICS

Clean Air Act also targeted substances called hazardous air pollutants (HAPS)

- 189 listings of hazardous air pollutants.
- Cannot emmit more than 10 tons per year
- Toxic release Inventory (TRI) - 650 chemicals, they are the second list which has not enough evidence to be as concerning, but still needs to be monitored.

Acid Deposition

Acid rain is the fallout of acidic particles or any type of precipitation that is more acidic than the norm. (lower PH)(base ph =7)

- It gained attention in the 1960s when Sweden noticing a decline in fish populations in lakes.
- It was observed that the tall chimeneys shooting SO2 into the atmosphere traveled miles away.This formed a new concern: long-distance transport of air pollution
- These acidic particles reached the earth in wet or dry form, causing variety of effects.
- Deposition of nitrate species also contributed to acid loadings
- NO2+SO2 = Acid rain.
- This acidity in lakes affects aquatic organisms, soil life, and buildings made of limestone or marble.
- First phase of S02 Emission reductions was achieved in 1995
- Second phase in 2000. (legislation / cap on S02 production)

Stratospheric Ozone Depletion

The good Ozone , which is O3, up in the stratospehere, protects us from solar radiation.

- It absorbs most UV-B rays which damage protein and DNA
- If there is a hole in the ozone , more radiation comes in
- 1970-80, worldwide decreases in stratopheric ozone levels . South Pole, Antartica 40% less ozone, more radiation comes in, very damaging to human health., kill organisms.
- Culprit of ozone tear are CFCs which are Chlorofluorocarbons
- CFCs are used in refrigeration, AC units, aerosol. ex: FREON
- CFC molecules remain in the air many years and go to the stratosphere, which break down and create reactions with the ozone.
- Montreal protocol on substances that deplete the ozone layer in 1987
- Ban of CFC'S, by the year 2000.
- Recovering of ozone layer as agreement has been in effect.

Greenhouse Gases

- Gaseous emissions that trap heat in the atmosphere.
- Solar energy comes in UV rays, which is partially absorbed by the earths surface. It is then shot back into space as Infared radiation.
- This balance determines the Temperature of the planet
- H20 and Co2 (carbon dioxide) absorb outgoing energy. Less energy escapes , heats up the planet
- GHG (Green House Gases) are causing global warming.
- Primary GHG CO2 CARBON DIOXIDE from oil,gas,coil. About 85% of US green house emissions
- Second is CH4 , METHANE, N20 nitrous oxide, halocarbons, which include CFCS, Perfluorocarbons (PFCS) and sulfur hexafluoride (sF6).
- Problems with global warming, climate change, sea level rise, tusnami's, floods, droughts. Plant and animal disruption due to sudden changes in climate.
- In 1992, accord signed between 150 nations to reduce future growth of greenhouse gas emissions.
- In 1998, Kyoto agreement signed by 84 countries. Climate change treaty by 2012. China and India did not sign accord. And change after 2012 were minimal
- 2016, Paris agreement on climate change

Sources and Uses of Water

- Surface Water -> lakes, streams,rivers,oceans cover about 70% of earth surface
- Ground Water -> underground water sources, springs, aquifers
- Clean water -> lakes rivers
- Saline water -> salted water, aka oceans
- Biggest portion is saline water

Major Water Contaminants

- Surface water and ground water become polluted in a variety of ways.
- Point sources -> discharge points outfall pipe from factory, or wastewater treatment plant
- Non point sources -> erosions from mining, construction activities, runoff from argiculutural lands, and fallout from the atmosphere

- 9 priority pollutants

1.Pathogens

- Disease causing agents in order of less developed to more developed. Virus, bacteria, protozoa, and parasitic worms called helminths
- Microorganisms found in infected people or animals, excreted in feces into water system
- Water born disease
- Can cause human illness from life-threatening diseases ex: cholera, gastro intestinal, respiratory etc..

2. Organic Wastes

- Main source of oxygen depletion substances in surface water.
- It lowers oxygen levels in water, (kills aquatic life)
- Large quantities make it very hard for the water to oxidize back to higher levels
- Organic waste includes, human and animal excrements, food, organic residuals
- The demand for oxygen by bacteria is called biological oxygen demand (BOD)
- Substances that trigger chemical reactions are referred to as chemical oxygen demand (COD)

3.Nutrients

- Nitrogen->(fertilizers) and Phosphorus->(detergent) are two essential nutrients to support vegetation and other forms of life.
- Over enrichment of these nutrients in lakes rivers or streams due to fertilizers and household detergents is called eutrophication.
- Can kill aquatic life and soil
- Decomposition under insufficient oxygen is called anaerobic conditions
- Trophic states(nitrate levels in lakes, rivers) : - oligotrophic (low), mesotrophic (medium), eutrophic (high), hypereutrophic (very high)

4.Toxic Organic Chemicals

- Oil spills are perhaps biggest example of water contamination by organic compounds
- DDT'S(non-biodegradable) And VOC'S are also dangerous high risk chemicals that reach water sources, can hit shores.

5.Toxic Metals

- Mercury, Lead and Arsenic are the most toxic metals that can effect vital organs or even kill.
- There are 73 metals
- Mercury-> bioaccumulates in tissue of fish and other organisms. Humans affected by consumption of fish, suffering damage to the brain.

6.Sediments and Suspended Solids

- They consists of soil particles that enter a water body and settle to the bottom.
- 70% human sediments, polluting the quality of water

7.Acidity

- Neutral PH=7
- Acidic= Lower
- Basic= Higher
- Most fish species cannot survive in waters with a ph below 5.0
- Industrial processes generating acidic wastewater that contaminates surface water. Ex: Drainage and runoff from mining operations are a major source.
- Need to neutralize to bring back to neutral PH

8,Salts

- Salt tend to dissolve easily in water measured in TDS (Total Dissolved Solids)
- Human drinking water and crops rely on low TDS levels, high TDS will make saline water undrinkable and severely affect crop production

9.Heat

- Thermal pollution, waste heat from electric power plants primarily.
- Detrimental to fish and plant life.
- Require cooling to release waste heat to the atmosphere rather than dumping hot water

Drinking Water Quality

- 1974 Safe Water Drinking Act (SWDA) established maximum MCL levels (maximum contaminant levels.

Surface water quality clean water act CWA, of 1977, EPA identified 126 priority toxic pollutants

Groundwater Quality/Contaminents

- Highest priority problem is petroleum compounds from underground storage tanks from petroleum gas stations, etc. that leak through and impact the groundwater quality
- Second is Nitrates, causes high levels, mostly from agricultural fertilizers.

Solid and Hazardous Waste

- Must manage waste, incinerate or land field waste
- Two classes, hazardous waste and non-hazardous waste (RCRA, Resource Conservation and Recovery Act,1976)
- Hazardous waste
- 1 of the four properties are hazardous waste
- Ignitibility
- Corrosivity (corrode metals)
- Reactivity (explosion, reactions)
- Toxicity (water/health)
- TCLP (Toxic Characteristic Leaching Procedure), test for toxicity
- Getting rid of waste appropriately, in the 1960's, industries berried hazardous waste, leaking in soil etc.. While now it is engineered to prevent leakage or exposure.
- 1980, Superfund (CERCLA, Comprehensive environmental response compensation and liability act) To clean dangerous and abandoned waste sites, and hold liable the parties who caused it. (Causing a lot of legal battles, very expensive)
- Non-Hazardous waste
- Most common trash, garbage.
- Components of municipal solid waste (MSW), glass paper, food etc.
- Brownfields are properties that may have hazardous substances, pollutants or contaminants present.

Radioactive Waste

- Harmful effects on living organisms by radiation
- Radioactive waste remains dangerous up to hundreds of thousands of years
- Military and civilian use of nuclear energy which produce waste through the whole cycle whether nuclear energy or weaponry
- AEC (Atomic Energy Act) taken over by NRC (Nuclear Regulatory Commission) and Department of Energy (DOE)
- Need to separate uranium , enrich it and fusion which create waste
- High Level Waste
- The most dangerous, spent fuel from reactors, also liquids.solids from reprocessing of spent fuel for plutonium and uranium
- Requires permanent isolation.
- Alpha, beta and gamma radiation from unstable uranium which is very dangerous. It can destroys tissue, give mutations, cancer and even death
- It has a very long half-life which is decaying half its mass which could go up to 24,000 years
- Nuclear Waste Policy Act of 1982, (NWPA) called for such waste to be buried in deep geological formation not to be disturbed.
- We have yet to have approved a location, But yuca mountain in Nevada is the debate

Transuranic Wastes

- Transuranic waste (TRU), is the result of weapon productions, separation of plutonium and recycling. It includes heavier elements than uranium, greater than 92 atomic number, and emits radiation at a specific level but not as radioactive as high level waste

Uranium Mill Tailings

- Largest volume of radioactive waste, reside from processing uranium ore

Low-Level Waste (LLW)

- Any radioactive waste not considered any of the above is considered low-level waste
- It is the responsibility of the state government, subject to federal, while high level etc. is the federal government. (for the disposal)

CHP12

Greenhouse Gas

- Greenhouse gasses in the atmosphere cause the balance of the natural process of the suns energy and the earth to be affect
- Change in temperature causes sea levels, change in climate, glacier melting, tsunamis
- Priority greenhouse gasses
- CO_2 -> Carbon dioxide
- Cutting of forest, vegetation, fossil fuels
- CH_4-> Methane
- Wetlands, landfills
- N_2o (laughing gas)-> fertilizers, lawns
- Halocarbons->CFC's, chlorine, fluorine bromine
- Perl halogens-> CF_4 SF_6

Climate is the average weather while weather is day to day.

Global climate system -> Atmosphere, oceans, ice, rivers, lakes , land surface etc.. That influence that atmosphere and the climate.

Radiative heat exchange between earth and the sun

- 3 ways of transferring heat
- Radiation -> immediate no medium
- Conduction-> Heat through solid substance
- Convection -> heat from solid to liquid

Sun called a black body -> perfect emitter

Sun emits solar radiation, which some is absorbed by the earth surface, and the rest is sent back to space.

Most solar radiation coming to earth is in UV (short wavelength)

The outgoing radiation from earth's surface is mostly IR (long wavelength)

The shorter the wavelengths the greater the energy

The troposphere is the lowest layer in the atmosphere above the earth's surface, and it contains most of the atmospheric gases.

The Atmosphere is made of

- Nitrogen (N2)
- Oxygen (O2)
- Remaining gases, water vapor, CO2 (Various greenhouse gases), CO,O3
- Referred to in PPM, or PPB, parts per million/billion
- Even though traces are small can have substantial effects

H20, C02,CH4 absorb outgoing surface radiation, CFCS and other gases too small a scale

O3, O2 absorb UV coming into the earth from the stratosphere

Atmospheric Window-> very low level of absorption occurs between 8-12 UM, radiation passes directly through to space

Heat is redirected towards earth hence the greenhouse effect

Heat flux calculated with surface area

y= Climate sensitivity factor -> net change in radiative forcing caused by greenhouse gases to the resulting change in the earth's average surface temps.

o= Stefan-Boltzmann equation -> rate at which energy in form of heat can be radiated by a body at a given temp

Climate Change predictions

- Observe, measure
- Use climate models, predict
- Best way to predict is using scenarios(graphs), make best scenario and worst scenario
- Both scenarios are problematic

Paleo Climatology-> study of past climates

Biggest station in Antarctica

Drill in ice-corps, take samples by analyzing the bubbles inside the ice looking for C02, CH4

Can estimate past climates dating back 420,000 years

If we reduce 60-70% it will even out by 2100

Reducing Greenhouse gas emissions

- Factors
- Population growth
- GDP per capita-> a person's affluence,
- Energy Intensity

Carbon Cycle

- Carbon Cycle is the circulation and transformation of carbon back and forth between living things and the environment
- We release carbon from the earth's crust, and form it into CO2 during combustion into the atmosphere
- CO2 is very stable non reacting chemical

Rio de Janeiro , 1992 -> worldwide awareness of global warming problem. Efforts to address the problem

Kyoto protocol,1997->Leaders of major industrialized countries agreed to reduce their overall emission of CO2,CH4, N20 to an average 5.2% below. Different countries have different limitations

- It did not include INDIA, CHINA, which are growing contributors to greenhouse gases

CHP 7

Life cycle analysis -> assess environmental impacts associated with all the stages of a product's life from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling

- 3 steps
- Inventory analysis -> Input/output raw materials, process, manufacturing, distribution, use repair and maintenance, disposal recycling.
- Impact analysis -> effects on the environment for each input and output. Impact on health, ecosystem ect.
- Improvement analysis -> Improvements on identified impact in inventory/analysis

CHP 10

Human exposure to toxic metals

- Metals are Vital to human civilization for centuries. Used for jewelry, tools in ancient times to computers, spaceships today.
- Stone age -> copper, gold, lead, silver to make ornaments 6000 BC. Smelting -> to make jewelry, buttons, weapons.
- Bronze age -> smelting copper/tin to make bronze for weapons, tools ornaments. (3000-1000 BC)
- Iron age -> Gradually iron replaced bronze, more durable. Iron requires carburizing -> heating in the presence of carbon such as charcoal. And quenching -> reduce heat quickly. Iron used extensively in Europe.(1000-500 BC)
- Roman Empire -> Greeks isolated mercury. Romans advanced manufacture of iron and steel for tools,farming,weapons,ships,anchors,chains. Ornaments/coins using gold/silver. Lead for water pipes etc..(200-500 AD)
- Dark ages -> Fall of roman empire, decline and use of metals such as iron and other metals.
- Middle ages -> Metal increased once again. Rise of alchemists, attempts to turn lead into gold.(1000-1400 AD) also alloying, casting, separating, plating metals.
- Renaissance -> Lead/gold used for decoration, Bronze used for monuments. Silver/gold jewelry, Iron/steel used for farming, tools, weapons. Iron used for horse harness(1400-1500 AD)
- Industrial revolution -> use coke instead of charcoal to smelt iron. Spark of industrial revolution. High quality iron used in steam engines, Iron/steel used for bridges, rail transport, boats. By 1820, rapid increase in metals (40 known). By early 1900's, 70 metals were known.
- 1920's -> new era, combining metals. ex: alloy of aluminum, alloys of nickel and chromium. has transformed the industry.(aircraft, electrical etc...)

73 metals into groups -> non toxic, mildly toxic, high toxicity.

Low concentrations of metals found are referred to as trace metals. (Due to mining, smelting, manufacturing)

Human exposure to trace metals four principle routes

- Inhalation of Air, Ingestion of Water, Ingestion of Food, Ingestion of Dust
- Can be deadly to humans depending on amount.

Absorption rate body/time = A = Ci x Ui x Fi

- I = air, water, food , soil/dust
- C= concentration
- U= uptake rate
- F= fraction absorbed by bloodstream

All metals found in the environment. Human activity increases these concentrations. Trace metals contamination is common.

Trace metals in air

Three particle diameter

- Nuclei mode -> tiny particles, not very stable 0.01um
- Accumulation mode -> stable size particle, from nuclei mode particles. 0.2-0,5um
- Coarse particle mode -> large particles 10um.

Respiratory system

Divided into three regions

- Nasopharyngeal
- Tracheobronchial
- Pulmonary

If particles reach the pulmonary region, specifically the alveary sacs where the oxygen transfers to the bloodstream, toxic material can be absorbed into the bloodstream.

Trace Metals in water

certain pesticides/fertilizers, lead pipes can add metals to drinking water supply.

Trace Metals in food

Dust, Soldered Cans, Air can land on food.

Total exposure -> Ai= Ci x Ui x Fi of air, water, food, dust add each Ai for A= total absorption rate

Total dose of absorbed metals

Total amount absorbed is known as the dose.

D total= A total x T

T= time of exposure

A= total absorption rate

Doses in population

PbB -> Blood lead concentration

Pdf = Probability density function -> pbb concentration/population, graph to show population pbb at which different concentration they are. (lead in blood)

Normal distribution - > curve statistic (ex pbb and pdf) to find mean value -> value of x at peak of curve inflection point-> A point where the curves changes direction.

CDF = cumulative density function also used as a dose response-curve. Threshold level-> maximum safe level below which there are no effects.

NAAQS -> National ambient air quality standard, set in place after the CAA of 1970, that lead concentrations will not exceed the standards.

CHP 14

Risk assessment and Decision Analysis

Examine the concept of risk as applied to environmental pollutants.

Risk involves a chance of injury or loss (death)

Risk -> probability of a specific undesired consequence

When Several kinds or magnitudes of injury or loss may occur risk is defined as

Risk -> (probability of an undesired consequence) x (size of the loss)

People have personal judgment and a different understanding of the risk then people who have been exposed to the risk. Therefore, criteria's and regulations were set in place. 0 risk is impossible but small levels of chemicals might be free of harmful consequences or might pose risk that are so small they are accepted by society. (public opinion -> involvement of public)

Risk assessment methodology

A four step process for risk assessment was defined in 1983 by the National Research Council -----> NRC and these steps have been widely adopted by government agencies and others.

- Hazard Assessment
- Dose-response assessment
- Exposure assessment
- Risk characterization

1. Hazard assessment

Its purpose is to determine whether exposure to a given chemical can cause an observable increase in some illness or health condition. (laboratory studies, animal studies, epidemiological studies)

2. Dose-Response assessment

If the hazard assessment establishes that a chemical can cause some type of health effect the next step is to assess the dose, mass(ingested or received) and response/adverse effect.

Carcinogenic Effects

Tested on animals. If significantly more tumors develop the chemical is clearly a carcinogen. But Very hard to assess on humans, Information on exposure to chemicals due to accidents or workers at chemicals plants ect can help but most data is animal data.

Dose response assessment -> dose/probability of cancer (risk) graph. Any exposure to a carcinogenic substance is considered to increase the lifetime risk of cancer, regardless of dosage. Typically a linear dose-response is assumed with no threshold. Risk can only be zero if exposure is zero as well.

Non carcinogenic Chemical Effects

Chemicals that do not induce tumors in test animals even at high dosages are judged noncarcinogenic. Other types of adverse health effects might occur such as kidney/liver damage, nerve damage, diabetes. Animal testing are again the major source of data for dose-response relationships. Dose-response assessment relationship for non-carcinogenic chemicals have a dosage threshold, were below that level there is no observable adverse effect. Above the threshold, risk is involved such as disease. This is very different than carcinogenic were there is a zero threshold.

3. Exposure assessment

Purpose is to measure or estimate the frequency, intensity and duration of human exposure to a chemical agent in the environment. From this total exposure can be determined.

Exposure due to air, water, land, food ect. (chp 10)

Factors for exposure -> Land use at or near site, exposure pathway, daily intake, exposure frequency, exposure duration, body weight.

4. Risk Characterization

To combine the results of the exposure assessment with the dose-response function for each chemical of concern. It then yields the expected incidence of the adverse health effects for carcinogenic (cancer) or non carcinogenic (adverse health effects)

Assessing risk for carcinogens

Chronic Daily intake (CDI) -> the average daily dose of a chemical of the lifetime of an individual. (average daily dose of chemical by water air ect, divided by Body weight)

Ex: (concentration x intake rate/ body weight)   (4.6 mg/L) (5L) / 70 kg

If over a period of time

Ex: (concentration x intake rate/ body weight) x (total exposure time/ total lifetime)

[(4.6 mg/L) (5L) / (70kg)] x [(4h x 450d x 10y)/(70 y x 365d x 24h)]

Potency Factor (PF) -> To calculate the resulting risk of cancer from a given exposure CDI is multiplied by the potency factor. This factor is based on the dose-response curve for the chemical and exposure.

Incremental Risk -> CDI X PF

Level of acceptable risk -> EPA concluded that a lifetime risk of 1 in million or less can be regarded as acceptable or inconsequential.

Assessing risk for noncarcinogens

The dosage of a chemical below which there is no adverse health effects observed is called the no observable adverse effect level -> NOAEL

Reference Dose (RfD) - > it is a key parameter used in risk assessment to characterize the safe dose of a non carcinogenic chemical. RfD = NOAEL / (UF X MF)

UF -> uncertainty factor, which increases for each following conditions, extrapolation NOAEL data from animals to humans, data from subchronic exposures, variable responses in the affected population and lack of NOAEL data.

MF -> Modifying factor, judgment about the quality and uncertainties of data. (usually 1.0)

Metric used in risk assessment to compare an actual dose of chemical to the reference dose(HQ)

Hazard Quotient (HQ) -> Average daily dose(ADD) divided by the Reference dose (RfD)

HQ= ADD/RFD   example : HQ(1)= (2 mg/L)(2L)/70 kg   Consumption 2L , weight 70kg.

Hazard Index -> HI

HI= Sum of HQ'S (different chemicals)   if <1 acceptable risk

Risk management

Used to describe the process for defining an acceptable risk in the context of a particular situation and deciding the appropriate action to reduce, control or eliminate an unacceptable risk.

It is there to try and achieve a balance between public health/environmental and economic and technological resources.

Options for dealing with unacceptable risk falls into four categories.

- Reduce or eliminate source of contaminants
- Modify or eliminate exposure pathway
- Reduce or eliminate human exposure
- Treat or compensate damage from exposure

Most environmental risk management lies in dealing with hazardous waste disposal sites, including storage tanks containing fuel/chemicals. A general criticism of risk-based approaches to environmental management is that they are more likely to result in a decision to leave contaminants in place, compared to the more conservative approach to treat/remove any contaminants.

Decision Analysis

It is a tool for structuring and identifying information relevant to the decision at hand.

Influence diagram -> A way of visualizing the important connections among different elements of a problem. Diagram representing key variables that can influence a decision, or an outcome.

Decision Trees

First there is a decision node with multiple options to chose from. (explore the consequences of choosing either branch, think of a branch splitting into multiple options)

Then you have the chance nodes with multiple outcomes, which are the multiple uncertainties about the outcome that can happen when picking a decision node.

Solving decision tree -> Collapse the branches of each chance node into a single branch that represents the *expected value* of the uncertain outcomes. This is known as *folding back the tree*

EV = P(1) x V(1) + P(2) x V(2) ect...

EV= expected value

P= probability of each branch

V= Value of each branch

Chp 15

Environmental Forecasting

We examine how mathematical models can lend insight about the future to help guide actions and policy decisions about environmental laws, regulations, guidelines and standards.

What exactly would we like to predict? The general need is to estimate future levels of environmental quality.

Forecasting -> what will happen tomorrow, in a week, next month. Prediction/projection same connotation as forecast, which is trying to determine as accurately as possible an outcome at some future time.

Scenario -> describe a range of possible outcomes that logically follow from different assumptions about key factors or events that affect outcome. "what if"

Time period -> near-term, midterm, long-term used to denote different periods of interest. Different time frames dictate the type of models appropriate for a given analysis.

Spatial scale -> local area, regional, national, global level.(different pollution scales depending on localization) Geographic scales to be more accurate on environmental analysis.

Drivers of environmental Change

Three major factors affecting environmental change

- Population growth
- Economic growth
- Technology change

Population growth models

Annual growth rate model -> Population over time on a compound annual growth.

$P=Po (1 +r)^{(t)}$

T= time

R= rate

Po= initial population

P= final population

Exponential growth model -> Continuous growth, change in population proportional to the total population at that moment. Tends to grow more rapidly as time goes on compared to annual growth model.

$P= (Po)(e)^{rt}$

Logistic growth model -> It is in a sigmoidal shape -> S-shape curve. Population grows exponentially, but over time the rate gradually slows until it reaches zero. (population stabilizes at limit Pmax known as the carrying capacity of the environment -> equilibrium where demand in population food, water, natural resources are in balance, with the supply of the environment.)

Demographic models -> Population statistics, size, age , gender , distribution ect.

The growth rate = (birth rate) - (death rate) + (immigration rate). (population dynamics)

Crude rates -> Apply to population as a whole. (age-specific rates by gender are more useful than crude rates for overall population).

Fertility rates -> total fertility rate of women. Replacement rate is average number of live births needed to replace each female. If fertility rates exceed the replacement rate, they create a population momentum that leads to increase in population.

Economic Growth Models

Suppose you want to estimate the total mass of pollutant emissions from automobiles 25 years from now.

Most common measure is using GDP -> Gross domestic product, annual value of all good and services produced. And GDP per capita -> average affluence of population

If GDP grows faster than total population, GDP per capita also rises.

Economic growth and energy use- > As GDP per capita increases, energy per capita also increases.

Input-Output Models -> accounts for all of the indirect impacts as well as the direct impacts.

Macroeconomic Models -> explain economic activity in terms of behavior of three economic factors: firms, households, government.

Factors contributing to economic growth GNP (gross national product)

$G= P K^{(0.3)} L^{(0.7)}$

G= real GNP (billions)

P= annual productivity factor

K= annual value of all capital goods

L= size of labor force

CHP 3

Automobiles and the Environment

The car is arguably the most important technological development of the 20th century. from 8000 in the 1900's to 135 million today.

pros

It is convenience, speed and ease of travel that is unmatched. Economic growth

Cons

Traffic accidents, adverse environmental impacts.

Environmental impacts of the automobile

- 3 to 4 million miles of paved road since the 1900's

Air pollution -> NOx, HC, and CO pose serious problems, which come from the exhaust of the car. Emissions has since dropped significantly due to federal regulations.

Still, even though they reduced 90% and up on emissions, there are still multiple factors making cars an environmental threat.

- Increasing vehicle population
- Departure from federal standards
- Greater use of light trucks

Co2 emissions (greenhouse gas), coming from cars means that alternatives must be burning less fossil fuel or using alternative sources.

Cars have become lighter and use better material than they did in the 1950's but there are over 20,000 individual parts in a car and impacts occur for each of those from raw materials, transport, processing ect.

Retired cars are also gutted of all recyclable material then crushed into a landfill (waste)

Other environmental Impacts

- Lead emissions
- CFC emissions (AC)
- Waste motor oil
- Other life cycle impacts (materials)

A car needs power/energy for cruising, climbing and acceleration. Energy also must pass through the drivetrain to the wheels to get power and most of the fuel energy is lost as waste heat from the engine, and to friction in the drivetrain components.

Cars release 20% of the total CO_2 into the atmosphere.

Engineering cleaner cars

Automotive standards for energy efficiency (CAFE) -> Corporate average fuel economy. (1975)

In exam air fuel

CO and Hydrocarbons (HC), are the end product of incomplete combustions. The motor has a effective Air-Fuel ratio which controls the amount of gasoline to air in the mixture that is burned.

- Stoichiometric amount -> theoretical proportions of air and fuel needed to complete a chemical reaction (low amount of CO/HC)
- Fuel rich mixture -> low amounts of air to fuel (high CO/HC, old cars)
- Fuel lean mixture -> high amount of air to fuel

NOx(nitrous oxides) cannot be readily avoided because they are a normal product of most combustion reactions.

Each phase of a typical four-stroke engine

- Intake stroke (mixture drawn to chamber)
- Compression stroke (upward moving of piston)
- Powerstroke (after spark plug fires, combustion and expansion happens and piston goes downward)
- Exhaust stroke (exhaust valve opens, releases combustion gases.)

Alternative fuels

Battery-powered electric vehicles

- Pros
- Zero emission
- Consume less energy
- Cons
- Limited driving range
- Higher initial cost
- Battery life cycle (toxic metals)
- Recharging

Hybrid vehicles

- Runs on gasoline and electric
- Pros
- Increases driving range
- Can offer zero emissions depending on operation (urban use only electric motor)

Fuel cells

Gas-powered electrochemical battery that takes hydrogen and oxygen and mixes them to produce electricity. The byproduct is water. Very expensive.