ENGR 202: Sustainable development and environmental stewardship

Jan. 16

1880: First basic legislation on emissions

1948: Donora smog, triggered clean-air movement in US

1963: First Clean Air Act

1970: Ammendment to Clean Air Act

1977, 1990: Further ammendments to Clean Air Act

Major pollutants:

- PM (particulate matter)
- SO_2
- CO
- NO_x
- O_3
- Pb → added later

Over 400 pollutants are recognized today

Particulate matter:

PM_{10} ← refers to size of particle

10 means less than 10 μm

PM_{10} is currently the largest size PM permitted to be emitted without penalty

Greatest source of PM: unpaved roads

In US, $PM_{2.5}$

Canada and UN is PM_{10}

SO_2:

Produced through metal smelting

When combined with NO_x, produces acid rain

Hilroy

CO:

colourless, odorless : very dangerous

produced by incomplete combustion

if inhaled, causes shortness of breath, dizziness, asphyxiation

large quantities of CO are released in transportation

NOx :

brown-red colour, easily identified

affects children first, significantly - blue babies

produced from cars - high temp. of combustion causes reaction

O_3:

two kinds - "good" and "bad" → "good" protects earth from harmful UV radiation from sun

extremely toxic, can eat through rubber

produced by various industrial activities

if O_3 meets VOC's, creates photochemical smog

Pb:

accumulates in blood

traditionally used in construction, water pipes, Pb is ingested through contaminated water

also found in gasoline

Jan. 23

Amount of toxins listed has increased with EPA
Canada uses EPA's list
- in 1990, 189 toxins were listed
- in 2010, 220 in total
- In the years to come, there will be over 1000

If in a year you are creating more than 10 tonnes of any toxic substance on the list, it must be controlled

Consequences of air pollution:
Acid rain: particular circumstances and pollutants ($NO_x + SO_2$) associate to create it, first case of acid rain in Sweden in 1960's
If pH of acid rain < 5, it will destroy
The good ozone (protective layer) protects earth from harmful ozone in the form of UV rays from sun

Hole in ozone layer above Antarctica
In the past, refrigerators used CFC's → chlorofluorocarbons
When refrigerators were disposed of, CFC's were released into atmosphere, fluorine reacted with ozone, destroying it
Process is repeated, fluorine remains in atmosphere

Montreal Protocol, 1987, banned the use of CFC's

Greenhouse effect: pollutants are trapped inside ozone layer, heat is reflected back
Two greenhouse gases: CO_2 (85%) and CH_4 (7-8%)
NO_2 is third largest in concentration, traces of others
CO_2 concentration is increasing, by 2100 it will double

1998: Kyoto Protocol

By 2012, CO_2 emissions would be reduced to certain levels

Different standards for each country based on circumstances

Signed by ~80 countries

US was supposed to cut emissions by 7%

Japan by 6%, Europe by 8%.

India and China did not sign, US did 3%, Canada did 2.5%

Entire thing is considered a failure

Current parties to the convention:

192 parties, 191 states

all UN members except Andorra, Canada, South Sudan, United States, EU

- Canada withdrew in 2011

Jan. 30

Two primary sources of water: surface water (70%)
ground water (30%)

Most of surface water is found in ocean, not freshwater

Ground water: springs and aquafers

Surface water is used for transportation, recreation, power production, sustaining aquatic life

Point-source pollution: pollution comes from single, manageable location

Non point-source pollution: come from runoff

Main water pollutants:

1. Pathogens: bacteria, viruses, worms, protozoa
   Transfer diseases, water-born diseases
   Affects entire populations, affilicted with epidemics
   Typhoid, cholera, skin diseases, respiratory diseases
   Protozoa are first level of life, can move, reproduce, eat
   As pathogens increase in size and complexity, diseases they can carry worsen

2. Organic matter
   Measured in how much oxygen is needed to break it down
   This oxygen is taken from water - organisms in water suffer if oxygen levels drop
   Oxygen levels are indicative of health of body of water

3. Nutrients : nitrogen, phosphorus

Vital to health of system, but not in excess

Excess comes from fertilizers, detergents

Produces algae, brings death of body of water

Phosphorus is the limiting nutrient

If drinking water has excess nutrients, pregnant women give birth to blue babies

4. Toxic organic chemicals

Produces cancer, mutagenicity,

Include DDT from WWI, DDE, chlorine : initially used without fear of side effects

Insecticides, switched to herbicides

VOC's, found abundantly in industrial areas

5. Toxic metals

72 metals characterized up until recently, a few more in last years

Groups of metals: harmless, slightly, very, extremely

Mercury, lead, arsenic are most toxic metals

So dangerous because of ability to bioaccumulate

6. Sediments / suspended soil

Accumulates on bottom of body of water, suffocates life

Depends on how high sediment is - Lac St. Louis, 1 meter

If sediment is resuspended, comes back into water collumn → eventually resettles

7. Acidity

Best is between 6 and 9 — African cichlids: 7.8 - 8.2

Acidic environment can help create toxic compounds

8. Salts

Not suitable for drinking purposes
Desalination: extremely expensive
One bottle of desalinated water = 3 bottles of wine
Presence of salts in irrigation water can be very harmful to crops

9. Heat

Can kill aquatic life
In hydro-electric plants, enormous quantities of hot water are produced - stored in cooling towers

Drinking water must be absolute highest quality
Can get water from sources: mountains, small streams
Can also get from lakes / rivers through intakes, send to water treatment plants, then to distribution center
If not, drinking water from groundwater
Intake must be protected: if it is contaminated, entire system is contaminated
Total coliforms, fecal coliforms, total streptococci
Fecal coliforms must be zero, can have some total coliforms
A single fecal coliform can kill, cause epidemics

Most common coliform: E. coli (fecal coliform)
Coliforms are indicators of other pathogenic organisms of fecal origin

assignment 1 due next week — feb. 27

midterm: chapters 1, 2, 12 → 13 short questions ← (1) some acronyms; (2) conceptual, few calculations

Feb. 6

Ground water - aquafers, springs
Very clean water, good quality, used for bottled water
Lots around Mirabel airport

Problems with groundwater:

1. underground storage tanks for gas stations. 1.2 million in USA
   20% are leaking, end up in groundwater
   Research and studies of tanks leaks is well-developed
   If tank leaks too much, must be replaced - gas station is closed temporarily

2. fertilizers, leak into groundwater
   issues: nitrates, phosphorus - blue babies!

Solid waste
Two groups: municipal solid waste, hazardous waste
Municipal waste: collected from people's houses, brought to facilities, recycled, reused, sorted, anything left is put in landfill or is incinerated

Each municipality has budget - half goes to waste management
Very important to optimize system

Hazardous waste: needs to be characterized
must have 4 properties: ignitibility
corrosivity
reactivity
toxicity

if it overpasses any of the 4 standards, classified as hazardous, dealt with differently (standards ← limits)

TCLP: toxicity ~~testing~~ characteristic leaching procedure
single test to check for hazardous waste

1200 sites contaminated in USA, takes lots of money and time to decontaminate
Not enough money to decontaminate all sites
Superfund: started in 80's, with 1.6 billion, realized not nearly enough
related to RCRA: resource conservation recovery act
cercla: main legislation behind superfund
comprehensive environmental response compensation and liability act
40-50 years estimated to decontaminate all sites, now at 30-40%.
canada has lots of contaminated sites, mostly in far-off areas
orphelin sites - abandoned by owners, contaminated sites
brown field - in central area, 2 on st-catherine's
3 or 4 sites under highways

Municipal waste: paper, plastic, glass, metals
more seperation is better
every plastic is numbered, known quantities in material
biggest problem with paper - de-inking
very expensive, very difficult

each person produces 2kg of waste each day
incinerator is preferred over landfill
both are used all over world
landfill is done in sanitary way. layer of waste, dirt, waste, dirt, etc
levels of gases produced are controlled - mostly methyl

Hilroy

~~so~~ a landfill done right can be very sanitary
most big cities don't have sanitary landfills
montreal landfill was bad, accepted foreign waste, poorly managed, closed few years ago
same issue in Toronto

one large incinerator in Montreal, opened and closed over the years

Radioactive waste:
Completely seperated group, distinct characteristics
1. Produces radiation, extremely harmful
2. Half-life: typical solid waste biodegrades after certain amount of time
radioactive waste have half-lives are hundreds, thousands of years

Radioactive waste associated with nuclear energy
started in 1945
first part: discovered nuclear power, used by people without other sources of power
places like Japan: nuclear energy is overused

nuclear power in Quebec: used to small extent, civilian and provincial applications
2000 kg of uranium ore = 1 kg of uranium
U-235: small quantities, very rich
U-238: larger quantities, needs to be enriched

Nuclear waste: 1. High-level waste
2. Low-level waste
3. Transuranic waste
4. Tailings (uranium)

1. By products are radioactive
Cannot have even smallest chance of leak
Some half-lives are incredibly high
waste must be stored with power plant
Since 1982, looking for solution to nuclear waste disposal

α - radiation can be stopped with barriers
β - radiation requires much more protection, can in some way be stopped
γ - radiation ~~also~~ goes through everything, cannot be stopped
can travel (from Japan to California)

from '82 to '87 - found 30 places to store waste
now: yucca mountains nuclear waste repository
hasn't been accepted by obama

Transuranic: atomic weights > 92
very unstable
less dangerous than HLW

Tailings: from 2000kg dug, 1 kg is used
1999 kg is left, some uranium
leaches, slowly

Hilroy

Feb. 13

Chapter 12: Global Warming and the greenhouse gas effect

Balanced greenhouse effect, ave. temp of earth = 15°C
Recent unbalance, increased temp. of earth
Caused mainly by human activity - emissions interfere with radiation's ability to return to space

Main greenhouse gases: CO_2 and CH_4
CO_2 = 85% of total
CH_4 = 7 - 11 %
Secondary greenhouse gases: many of them, small amounts

CO_2: comes from all combustion
CH_4: produced in wetlands, plant fields

N_2O (laughing gas): fertilizers
Halocarbons: refrigeration units, chlorine, fluorine
CF_4, SF_x

All above gases interfere with process
Affect climate - history of global conditions (at least 30 yrs)

Radiation: does not need a medium
Conduction: requires a medium (solids)
Convection: from solid to liquid or gas

Q_{max} =
heat flux = $\frac{\text{radiation}}{\text{area}}$

31% of radiation is reflected before hitting the earth
- called albido
rest is absorbed on earth

if $Q_{in} > Q_{out}$, net warming = greenhouse gases increase
if $Q_{in} < Q_{out}$, net cooling = greenhouse gases decrease

currently, over 100 greenhouse gases, each behave differently
new products create new emissions with unknown effects

effects of global warming:
- rise in sea levels
- more frequent, violent storms
- natural disasters

G.C.M: $\gamma = \frac{\Delta T_e}{\Delta F}$

March 6

Lifecycle analysis

Known as LCA, improves manufacturing processes by including environmental concerns
Production line used to be based entirely on profit
After many years - centuries - began to wonder if production was environmentally friendly
Now, "green" production is a necessity

Years ago, green design did not exist
After product was used, no concern about method of disposal
Raw materials used for construction was irrelevant
Now: are raw materials sustainable, how are they manufactured, how is disposal done
If green design is not followed now, repercussions: fines, loss of license

Enter change of mindset regarding design: Life Cycle Analysis
Mostly in developped countries

At every step of manufacturing process, LCA must be done
Raw materials: anything better, renewable, cost?
Spend money / resources on studies, determine best option

Step 1: Inventory analysis
collection of information - raw materials

Step 2: Impact analysis

Step 3: Improvement analysis

Inputs for each stage → Raw materials acquisition

↓

Manufacturing

↓

Use/ reuse / maintenance

↓

LCA is done on one part at a time, complicated items like computers and cars have thousands of LCA's

March 13

Chapter 10: Toxic metals

Metals have been very important to humans throughout history

Traditionally used for: tools (other than stone)
jewelry
various products - pots, tanks, etc.

Today, almost every product has metals in it

The history of metallurgy:

Stone Age: 6000 BC - 5000 BC
mostly stone up, starting realizing properties of metals by hitting them

Bronze Age: 3000 BC
smelting of copper + tin made much better products
start to distinguish between metals, value according to usefulness
1300 BC: map of gold mine in Egypt

Iron Age: 1000 BC
iron replaces bronze; quenching and carburizing of iron
isolation of mercury by greeks

Roman Empire: 200 BC
mix
value associated to silver and gold, currency
lead is used: pipes for aquifers, storage tanks, reservoirs

Dark Ages: 500 AD
no real changes, no increased knowledge

Middle Ages: 1000 AD
alchemists, trying different things, mixing, etc.

Renaissance: 1400 AD
distinguish between metals, make monuments, tools, jewelry, weapons
in England: use coal instead of charcoal

Industrial revolution: 1750 AD

study recognizing different metals (40 in all) in 1820

in 1900, 70 metals discovered

now, we have discovered 73.5

Era of the alloys: 1920's

combination of percentages of metals to make new properties

mix chromium and nickel, build airplane

today, thousands of combinations - endless?

1945: nuclear power

one of best alloys, used a lot for a long time: stainless steel

Grouping metals by toxicity: essential to life (in small quantities)

non-toxic

toxic, poisonous, bioaccumulation

4 ~~ways~~ ways to be in contact with metals:

air, water, food, dust (through skin)

need to find A_i = absorption rate

dependent on C_i = concentration of metal

U_i = uptake rate,

F_i = fraction absorbed into blood

$$A_i = C_i \cdot U_i \cdot F_i$$

different A for each method of ingestion

$$A_{total} = \sum A_i$$

Amount absorbed in blood is very important

Metals are grouped by whether they bioaccumulate in blood or not

Bioaccumulation: metals never leave, only way to remove is with special treatment

Increase in toxicity, no natural decrease

March 20

Chapter 14: Risk Assessment

Two sections: How we do risk assessment
Risk management / decision analysis

What are risks?
Risks are voluntary or not
Standards have been established by society for water, food. etc
Overpassing these limits is potentially dangerous - not safe level
Safe levels are constantly changing - usually getting stricter
These are voluntary risks

Environmental risks - changing, what we know now isn't "final answer"
Use tools we have now - math

Risks is the probability of a certain undesirable consequence
Main risk in environmental issues - death
1. Understanding of risk depends on personal judgement
2. Understanding of risk itself
3. Exposure to the risk

Most problems with risks are surprises

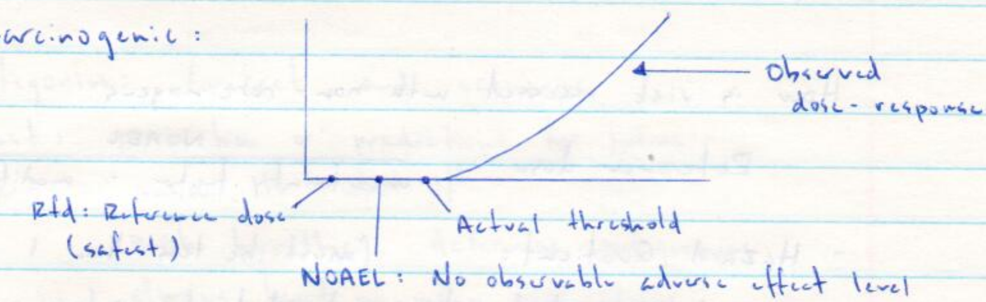
Risk assessment methodology

Hazard assessment
↓
Dose-responce assessment → Risk characterization ← Exposure assessment

Hazard assessment: done in labs, epidemiology
based on real observations

Dose-response assessment: linear or nonlinear (usually nonlinear)

Non carcinogenic:



Exposure assessment: how long someone has been exposed
when dealing with chronic exposure, very difficult to measure

Once risk has been assessed, if it is in fact a risk, we do:
Risk Management

Options for risk management:
- Reduce or eliminate source of contaminates
- Modify or eliminate exposure pathway
- Reduce or eliminate human exposure
- Treat or compensate damage from exposure

March 27

How is risk assessed with carcinogen

- C.D.I. : Chronic Daily Intake

can be calculated by average daily dose divided by weight of person

- P.F. : Potency Factor

how much cancer will be increased from C.D.I.

Increment of lifetime risk = C.D.I. · P.F.

Potency factor of every carcinogen is know

If increment of lifetime risk > 10^{-6}, it is dangerous, actions required

How is risk assessed with non-carcinogens

$$\text{Reference dose} = \frac{\text{NOAEL}}{\text{uncertainty factor} \cdot \text{modifying factor}}$$

- Hazard Quotient: (must be less than 1 to be acceptable)

average daily dose divided by reference dose

- Hazard Index:

sum of all hazard quotient

Chapter 15 : Environmental Forecasting

Proven to be very necessary, but risky, lots of uncertainty
Done according ~~the~~ to science, math, gut-feelings
In engineering, done with scientific models - mathematic simulations, statistic
Use models from today to predict future events and consequences
Lots of uncertainty - better than nothing
ex. Effect of air pollution in 5 years
Consequences of presence of toxic metals in 10 years

Attempt to predict future consequences to human health

Two categories: forecast and scenarios
- forecast: projection or predictions for future
- scenarios: answer to "what if"
  make hypothesis, determine consequences
  always based on many assumptions

In order to forecast or make scenarios, need time period:
< 10 years : near term
10 - 30 years : mid term
> 30 years : long term
Predictions are normally made for at least 30 years (one generation)

Three factors that influence accuracy of predictions / scenarios
population, G.D.P., technology

- population : in 2000, ~~pop~~ population was ≈ 6 billion
  less ressources, over production, current state of earth
  what will be pop. in 2020? 2050? 2100?

Hilroy

growth rate = birth rate - death rate ± immigration
fertility rate, infant mortility rate, other factors
accuracy of model increases with more factors
Europe fertility rate: 1.5 } must be included in calculations
Africa fertility rate: 7 } too big of impact to ignore

- Economic growth models
  information from past is necessary to make predictions
  most common factor: GDP of a country
  from GDP, get which countries are developped, non-developped, under developped
  with growth rate, can predict GDP in next years
  GDP is associated with energy consumption

- technology (technologic change)
  when will technological breakthroughs take place?
  electric car, nitrogen car, etc.
  "technological improvement"
  change depends on future use - usually depends on scenarios
  evaluating technologic change
  - rate of technological adoption
  → consumer choice models
  - new things are based on results

April 3

Chapter 3: Automobiles and the Environment

Most important development of 20th century: went from few thousand cars to almost 200 million

Tied to increase in population: many advantages tied to increase in numbers of cars

Focus will be on concerns, consequences

Disproportional development in 1st world countries, much more common in developed than in 3rd world countries

Development of car industry contributed greatly to economy

Advantages of cars:

- personal freedom
- convenience
- speed
- possibility of travelling

40,000 people killed by cars each years = 1 aircraft crash every day

Accidents are related to number of cars, quality of cars, quality of roads (transportation systems)

Traffic / congestion, very difficult to fix these issues

Air pollution, one of biggest contributors of CO_2 (20% of total)

CO: from incomplete combustion

Urban sprawl, urbanisation: expansion of cities is related to cars with cars, greater distances can be travelled easily, cities are free to expand

Focus of this class will be on air pollution

In 1940's and 1950's, no one really cared about air pollution related to cars

Started seeing phenomena of air pollution in big cities

ex: Los Angeles, photochemical smog - production of bad ozone also due to location and weather

In 50's and 60's, started seeing photochemical smog in other places around the world where conditions would permit

Manufacturing of cars and air control systems has evolved greatly from then until now: triple catalytic converter

Last two decades: electric cars, hybrids, hydrogen cars

LCA of a car: 20,000 parts

Improvement one part can make ~~one~~ big impact

Look to change quality of car, reduce emissions of car, number of cars

Changes in cars: weight has been reduced by half, shapes are more aerodynamic

Changes are not enough: air pollution by cars is still rapidly increasing

Way of life needs to change, not cars themselves

One of greatest achievements with cars is recycling: roughly 75% of car parts are recycled

Dumping places for tires, other parts

Potentially dangerous: one fire of tire pile can bring region back environmentally 100 years

Two streams of LCA for cars:

upstream, thinking about future models (look for improvement)

downstream, look at current models

Lobbying in car industry is very strong, very difficult to have "honest" battle about improvements

Similar to oil industry (EV1)

Ultimate goal: cars that are less polluting, less weight, more efficient

Also hope to reduce number of cars, but this is difficult

Characteristic graphs (memorize):

Figure 3.9, Figure 3.10

Alternative fuels

- diesel, ethanol, methanol, compressed natural gas

April 10

Chapter 5 : Electric Power Plants

One of most important technologies of 21st century
Almost impossible to imagine world without electricity

Thomas Edison, 1882, power stations
38% of world's energy is used in USA - disproportional

Electricity is supposedly environmentally green
Problem is source of energy
In most cases, electricity is created by burning fossil fuels
Must look at energy efficiency: E_{in} vs E_{out}
Most ressources for energy are non-renewal, limited amount

Electric power - kW
Electric energy - kW/h

52% of E_{tot} is from coal
18% of E_{tot} is from uranium
14% of E_{tot} is from natural gas
10% of E_{tot} is from hydroelectric
3% of E_{tot} is from oil
3% of E_{tot} is from other

where E_{tot} is total electricity (1997)

hydroelectricity + nuclear = $\frac{1}{3}$ of total

Fossil fuels : coal, oil, natural gas
Oil is produced by organic matter being pressured for thousands of years underground, same for coal and natural gas

Ratio of hydrogen to carbon : if 1 : 1, coal
if 2 : 1, oil
if 4 : 1, natural gas

This causes different heating values

Coal : 4 main types

1. Sub-bitumous
   - very soft
2. Bitumous
   - less soft than sub-bitumous
3. Anthracite
   - hard coal
4. Lignite
   - hard, brown

Burning breaks chemical bonds, creates energy

Oil

Brute, heavy, light, etc.

~ 50 different types

Lightest type of oil is gasoline

Main difference is refining process, to what stage oil is refined

Emissions from burning fossil fuels

SO_2, NO_x, CO_2, PM - most important 4

CO_2 : very important, keeps increasing

CO_2 from different fossil fuels is not the same

SO_2 : impurities in fossil fuels

burning fuel with sulphur inside: 95% is oxidized, 5% remains in ashes

eventually can become H_2SO_4 - very bad

PM: coal produces incredible amounts, oil and gas much less

NOx: very high for oil and coal, low for natural gas

All 4 pollutants must be limited as much as possible

Nuclear: digging for uranium, looking for U_3O_8 - uranium ore
0.25% is usable, rest is tailings
U_{235}: very little, usable
U_{238}: abundant, not usable
U_{236}: not stable, becomes U_{235} or U_{238}

All fossil fuels release heat when burned
Nuclear - release of radiation

Pu, weight 94, Pu_{239}: very high half-life
production of Pu_{239} releases α, β, γ radiation

By-products of nuclear power production: fuel rods
Fuel rods are more radioactive than what went in during process

1979, Three Mile Island nuclear accident, no new sites being built
Last 20 years, 60 power plants shut down
About 100 in operation in US

In Quebec, no need for nuclear, 95% of electricity is hydroelectric

Modern power plants have two turbines: gas and steam
Gas turbine: inject air with gas
reaction produces steam, turns turbine

To remove PM : electrostatic precipitators
To remove heat : cooling towers
To remove NOx : catalytic reduction converters

Another source of energy : biomass
others : fuel cells (electro-chemical technology)

FINAL EXAM :

13 questions, 12 + 1 bonus
1 question with acronyms
2/3 of questions from second part of course
3 problems with calculations, formulas given

Hilroy