VULNERABILITY TO POLLUTION

GEOG/ENST 2271 – Lecture 12

Turco: Chapter 7

Last lecture

- Sources and receptors
- Dispersion
- Climate and pollutants
  - Effects of atmospheric stability and inversions

Air Quality: a History of Coal

- Coal formed during the Carboniferous period (360-290 million years ago):
  - Solar energy converted to plant material
  - Vegetation decomposing in swamps
  - 20 m of vegetation compressed to 1 m of coal

- Recent release of an enormous backlog of solar energy

Coal in Britain

- First developed by the Romans
- 11th century widespread use of 'sea coal'
- 1285 Edward I complains that coal had 'infected and corrupted the air'
- 1306 coal banned in London
- Expanding population and lack of forests encourages coal use once again
- John Evelyn 1661
- Backbone of the Industrial Revolution (1800s)

Coal in the USA

- Largest coal reserve in the world (eastern United States)
- Industry developed in 1800s and was the backbone to American economic success

History of Coal in China

- Used in China for 6,000 years
  - Prevalent use in the 11th century
  - 1300 Marco Polo notes coal use in China
- Second largest reserves in the world

Current use of Coal in China

Widely used to fuel economic growth in 21th Century

- In 2015 75% of electrical power generation come from coal burning plants
- Produces twice as much coal annually as US
  - Still much less on a per capita basis

Coal and Health

- Smog in China's cities
  - Major environmental issue
  - Estimated annual mortality of 1,000,000 per year
- Tens of thousands for USA
- 1,800 for Ontario

Haze in Wuhan, China

Many ways of not being good for you

- Toxic
  - Directly damages all or part of an organism
- Carcinogenic (or mutagenic)
  - Attacks or mutates DNA
  - Causes cancer
- Teratogenic
  - Causes birth defects

Exposure

- Acute exposure
  - Large dose for a short period of time
- Chronic exposure
  - Small dose for an extended period
  - More insidious

Dosages

- Dose: exposure per unit mass

$$D = \frac{Cft}{m}$$

C ~ concentration of toxin, $\mu g/m^3$

f ~ flow rate into lungs, m^3/s

t ~ time, s

m ~ mass of receptor, in kg

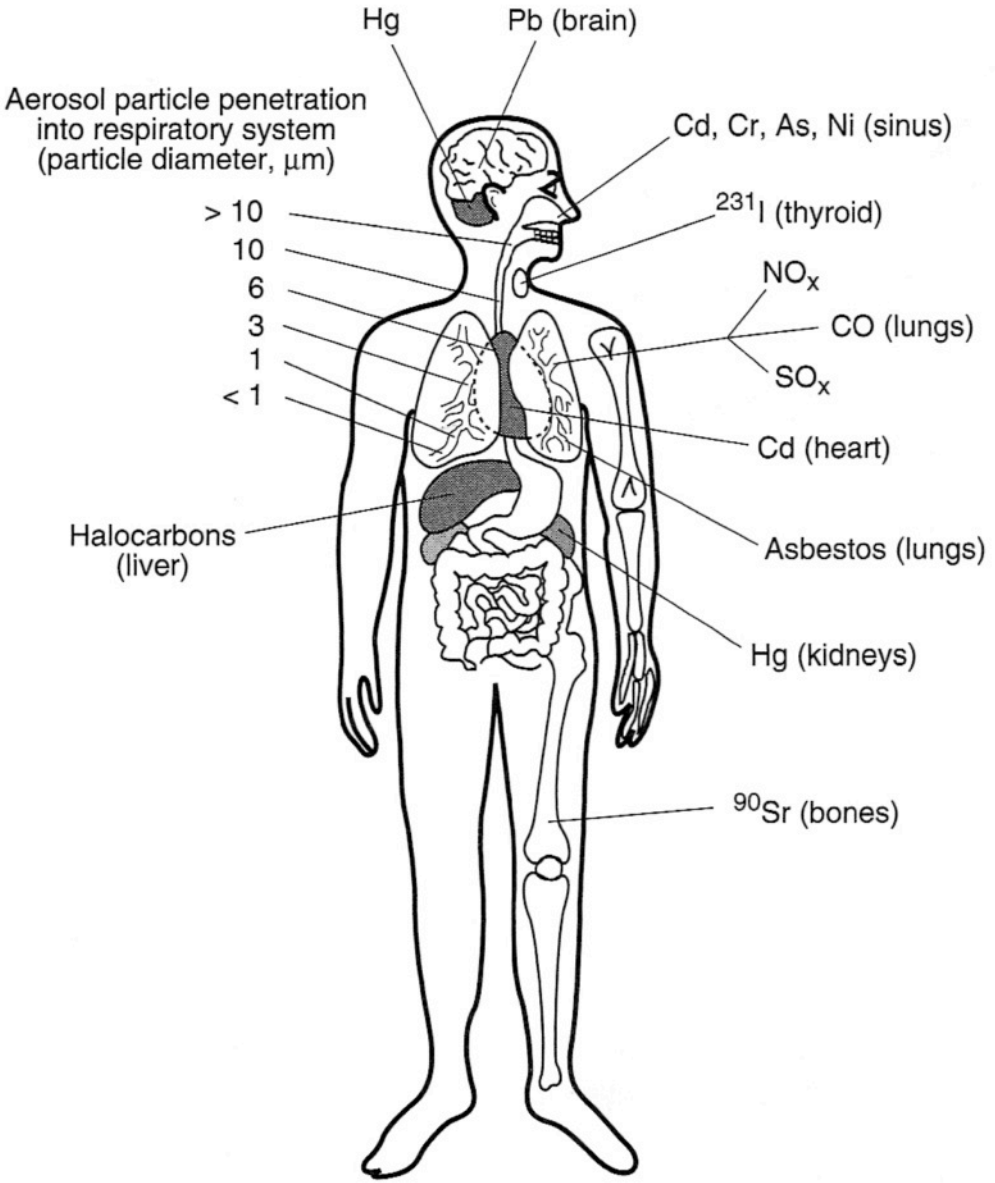
- At rest, typical breathing is about 0.001 m^3/s

Dosages

- Typically calculated per unit of body mass
  - E.g. mg/kg, μg/kg
- D_{50}
  - Causes harmful effects in 50% of exposed population
- LD_{50}
  - Causes death to 50%

Internal Receptors

- Vulnerabilities
  - Lungs
  - Liver
  - Kidneys
  - Central nervous system



Turco: Fig. 7.1

Particulate Matter

- Definitions
  - TSP – total suspended particulate matter
  - PM_{10} – all particulate matter, 10 µm or less in size
    - Also called respirable suspended particulate (RSP)
  - $PM_{2.5}$ – all particulate matter, 2.5 µm or less

- Environmental Concerns
  - Linked to health concerns, especially $PM_{2.5}$
  - Direct damage to respiratory tract

Particulate Matter

- PM is the solid phase of pollutants
- Main sources
  - Coarse PM (> 2.5 μm)
    - Dust, ash, pollen, sulfates, nitrates, soot
  - Fine PM (< 2.5 μm)
    - Soot, smoke, VOCs
  - Active area of research

Heavy metals (toxic particulates)

Table 7.1 Toxic Heavy Metals

Metal	*Concentration* (ppmm)	*Effects*[a]
Arsenic (As)	0.5	Cancer of the lungs, liver, and skin; teratogenic; poisonous in large doses
Cadmium (Cd)	0.2	Accumulation in the kidneys, lungs, and heart; symptoms like Wilson's disease; 50 ppmm fatal within 1 hour; carcinogenic
Chromium (Cr)	1.0	Skin rashes, lung cancer (after continued exposure); carcinogenic
Iron (Fe)	10.0	Siderosis, or red lung disease
Lead (Pb)	0.15	Brain damage; red blood cell anemia; paralysis of limbs
Manganese (Mn)	5.0	Aching limbs and back; drowsiness; loss of bladder control; nasal bleeding
Mercury (Hg)	0.05	Central nervous system attack; tremors and neuropsychiatric disturbance
Nickel (Ni)	1.0	Skin rashes, cancer of the sinus and lungs (after continued exposure); exposure to 0.001 ppmm of nickel carbonyl leads to nausea, vomiting, and possible death
Vanadium (V)	0.5	Acute spasm of the bronchi; emphysema
Zinc (Zn)	5.0	Fever, muscular pain, nausea, and vomiting

Carbon Monoxide (CO)

- Displaces oxygen in the bloodstream
- Effect increases with length of exposure
  - Can recover over time
- Effects:
  - Headaches
  - Drowsiness
  - Death

Acids

- Nitrogen Dioxide (NO_2)
  - Forms nitric acid in the lungs
- Sulphur Dioxide (SO_2)
  - Forms sulphuric acid in lungs
- Effects:
  - Damaged tissues
  - Bronchitis
  - Increased risk of infections

Ozone (O_3)

- Oxidizes tissue
  - Effect is similar to a burn
- Restricted air flow
- Build up of scar tissue in the lungs

Airborne toxins and harmful concentrations

Table 7.2 Human Response to Pollutant Exposure

CO	10–30 ppmm	Time distortion (typical urban)
	~100	Throbbing headache (freeways, 100 ppmm)
	300	Vomiting, collapse (tobacco smoke, 400 ppmm)
	600	Death
NO_2	0.06–0.1	Respiratory impact (long-term exposure promotes disease)
	1.5–5.0	Breathing difficulty
	25–100	Acute bronchitits
	150	Death (may be delayed)
O_3	0.02	Odor threshold
	0.1	Nose and throat irritation in sensitive people
	0.3	General nose and throat irritation
	1.0	Airway resistance, headaches
		Long-term exposure leads to premature aging of lung tissue
SO_2	0.3	Taste threshold (acidic)
	0.5	Odor threshold (acrid)
	1.5	Bronchiolar constriction, respiratory infection

Turco: Table 7.2

Volatile organic compounds (VOCs)

- Benzene and other polycyclic aromatic hydrocarbons (PAH)
  - Respiratory irritation, dizziness
  - Carcinogenic
- Solvents (TCE, PCE, MEK)
  - Moderate toxicity at low doses
  - Liver, nerve damage
- Toluene (gasoline additive)
  - Teratogenic, toxic to liver, nerve cells

Dioxins

- Extremely carcinogenic category of VOCs
- Created by burning plastics, PCBs
  - Incineration of municipal waste
  - Accidents (explosions)

- Soot is generally high in carcinogenic organic compounds

Lead

- Gasoline additive (no more)
  - Turco: before unleaded gasoline, 500 tPb/yr deposited into Los Angeles coastal waters
- Paint (no more, but old paint still in place)
- Industrial processes
- Concentrations found in blood:
  - Urban: 20 μg/100 g
  - Rural: 10 μg/100 g
  - Harmful: 60 μg/100 g

Asbestos

- Millions of tonnes used for insulation and fireproofing
- Fibres are extremely fine
- Exposure can cause serious lung damage and cancer
- Banned in many developed countries

- ***Canada remains a leading exporter***

Radioactivity

- A subatomic problem…

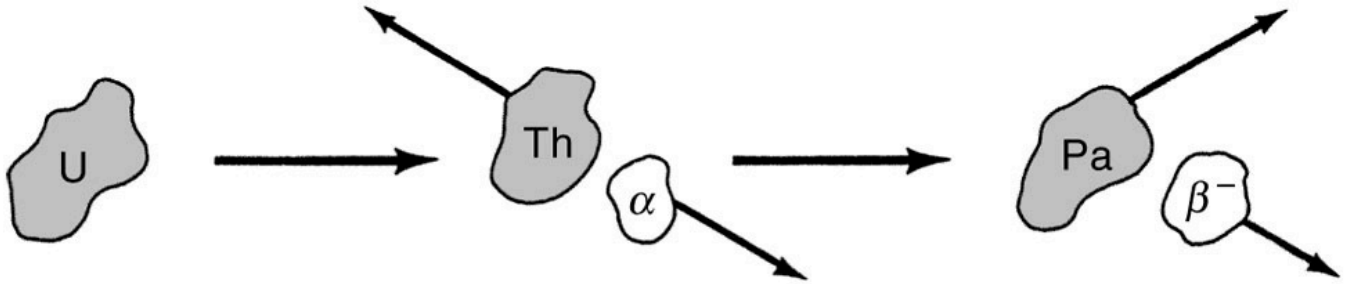
- Nucleus of atoms made up of protons and neutrons
- Type of element determined by number of protons
  - E.g. Oxygen has 8 protons, Carbon has 6
- Some kinds of atoms are unstable (radioactive)
  - Especially heavy ones, e.g. Uranium
  - Spontaneously *decay* by emitting a subatomic particle
  - Mass and energy released

Ionizing Radiation

- Alpha decay
  - Emission from the nucleus of a 2 proton, 2 neutron particle (α particle)
- Beta decay
  - Conversion of a proton to neutron or neutron to proton
  - Emission of an electron/positron (β particle)
- Gamma radiation
  - Electromagnetic waves produced by either form of decay (γ ray)

Transmutation

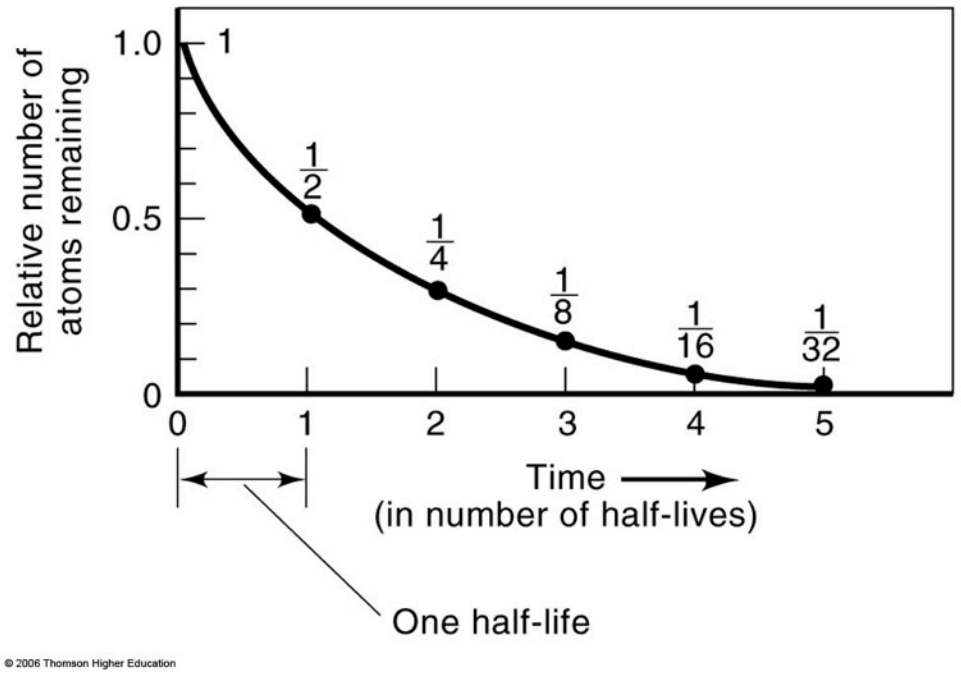
- Atom changes from one element to another
  - Number of protons has changed
- May be part of a series of nuclear decays ending in a stable atom
  - "Decay chain"



H&K: Figure 13.9

Half-life

- The length of time it takes for half of the original number of atoms to decay
- $\tau_{1/2}$



Half-life

- Decay is random; no way of knowing when an individual atom will decay
- Other half isn't partially decayed; it's exactly the same as it was before, with the same chance of future decay
- ^{238}U: $\tau_{1/2} = 4.5$ billion years
- Radon (^{222}Rn): $\tau_{1/2} = 4$ days
- Astatine (^{218}At): $\tau_{1/2} = 1.5$ s

Nuclear radiation

Table 13.1 PROPERTIES OF NUCLEAR RADIATIONS	
Type of Radiation	Range
α particles	a sheet of paper, a few centimeters of air, or thousandths of a centimeter of biological tissue
β particles	a thin aluminum plate or tenths of a centimeter of biological tissue
γ rays	several centimeters of lead or meters of concrete

H&K: Table 13.1

Exposure

- External
  - Exposed to radiation from decaying material
  - Sometimes intentional
- Internal
  - Radioactive material absorbed by the body
    - Decays over time
    - E.g. Plutonium, Iodine

Cells and ionizing radiation

- Cell death
- Genetic damage
  - Inhibits cell repair
  - Messes with cell division (reproduction)
- Cancer
  - Uncontrolled cell division
  - May result from a combined effort of radiation and viruses

Radiation ‘poisoning’

- Acute:
  - “Radiation sickness”
  - Skin lesions
  - Eventual organ failure or haemorrhaging leading to death
  - LD_{50} is 450-600 rem
  - Teratogenic in smaller doses
- Chronic:
  - Carcinogenic
  - Risk appears to accumulate over a lifetime

Radiation sources

- Natural exposure
  - Radioactive sources in the Earth's crust
- Nuclear weapons
  - Limited Test Ban Treaty, 1963
    - Last atmospheric test by China in 1980
  - Comprehensive Test Ban Treaty, 1996
    - India, Pakistan: 1998; North Korea: 2006, 2009, 2013 and 2016
    - Nuclear reactors
  - Minimize radioactivity of released material

Radiation sources (more)

- Medical treatment
  - X-Rays
  - Cancer diagnosis and treatment
- Built environment
  - Concrete, stonework, basements

Ionizing radiation exposure

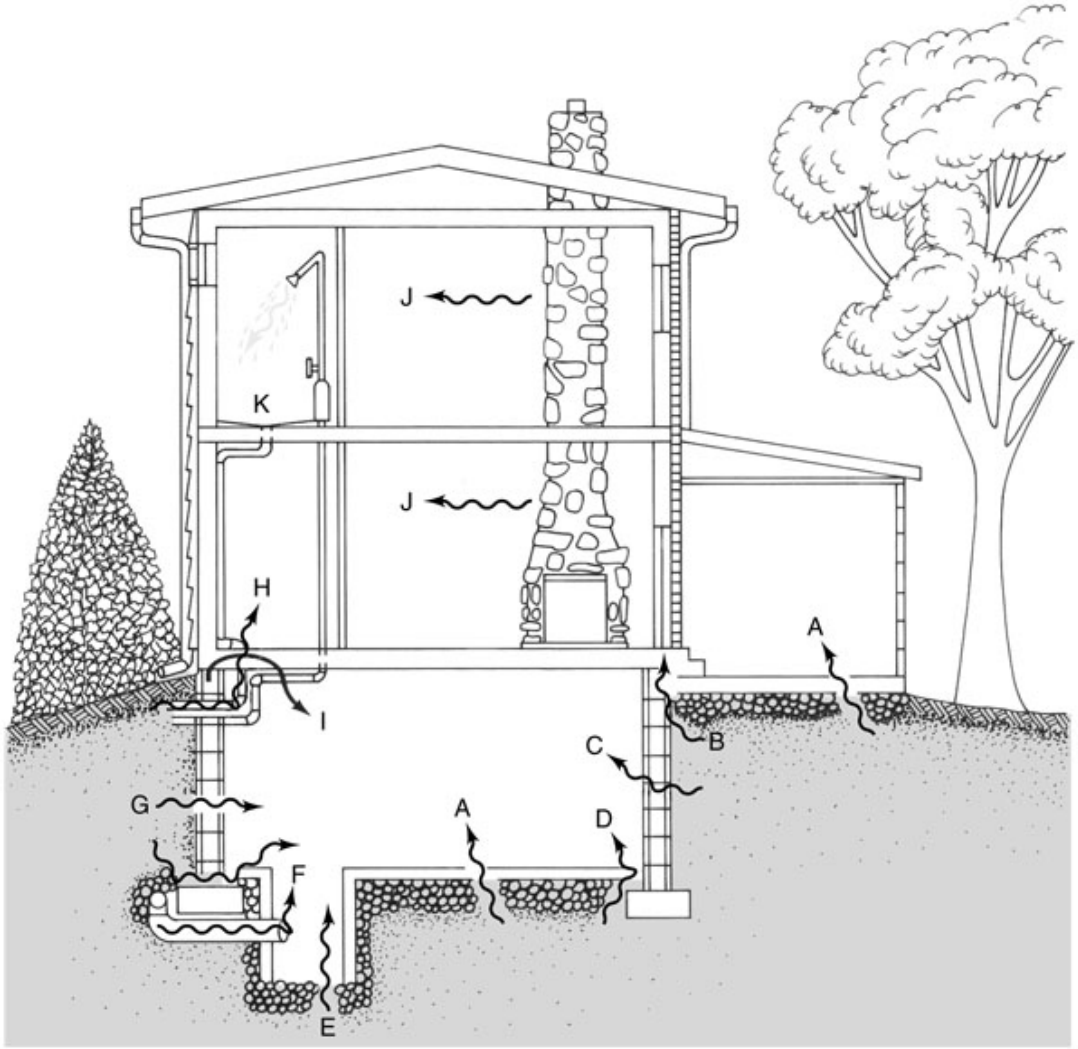
Table 15.5 AVERAGE ANNUAL RADIATION DOSE RECEIVED BY INDIVIDUALS IN THE UNITED STATES

Source	Effective Dose Equivalent (mrem/y)
Natural sources	
Inhaled radon daughters	200
Cosmic rays	30
Terrestrial	30
Internal natural radionuclides	40
Artificial Sources	
Medical, dental X-rays	39
Nuclear medicine	14
Consumer products	9
All other sources (including occupational, fallout, nuclear fuel cycle)	<3
Rounded Total	**360**

H&K: Table 15.5

Radon (Rn)

- Gaseous at normal temperatures and pressure
- Part of uranium and thorium decay chains
  - Half-life of 4 days
- "Daughter" elements are solid
  - Latch on to dust particles
  - Inhaled
- Estimated to be second-largest cause of lung cancer in US
  - 10-15%



A. Cracks in concrete slabs
B. Spaces behind brick veneer walls that rest on uncapped hollow-block foundation
C. Pores and cracks in concrete blocks
D. Floor–wall joints
E. Exposed soil, as in a sump
F. Weeping (drain) tile, if drained to open sump
G. Mortar joints
H. Loose-fitting pipe penetrations
I. Open tops of block walls
J. Building materials, such as some rock
K. Water (from some wells)

After Reading Week

- MIDTERM Feb. 24
- Urban air quality Feb. 26