Air quality in offices and homes

Note: Attempts at energy conservation are contributing factors to poor indoor air quality

gases can build up in a well-sealed building

Building ventilation rates

- For a pollutant being emitted at rate R (text, p. 115), then under steady state conditions

$$c(\text{inside}) = c(\text{outside}) + R/kV$$

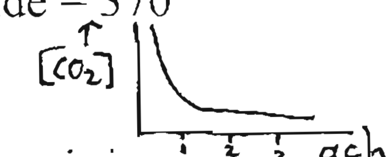
Often: $c(\text{inside}) \approx R/kV$
or rearranging $R = k_i [c_i] V$ — assumes c(out) is zero

k is the rate constant for air exchange (air changes per hour (ach)); when V is in m^3 and R is in mg/h then c is in mg/m^3
vol. of building

This analysis applies to both homes and workplaces. k is a combination of natural ventilation (open doors and windows, drafts) and mechanical ventilation. As $k \longrightarrow 1$ and less, emitted pollutants will build up inside
i.e. 1 air change per hour
See Figure 4.2 text p116

- "Energy efficient" homes and offices (R2000) have k in the range 0.2 to 0.6; emitted gases tend to be trapped inside

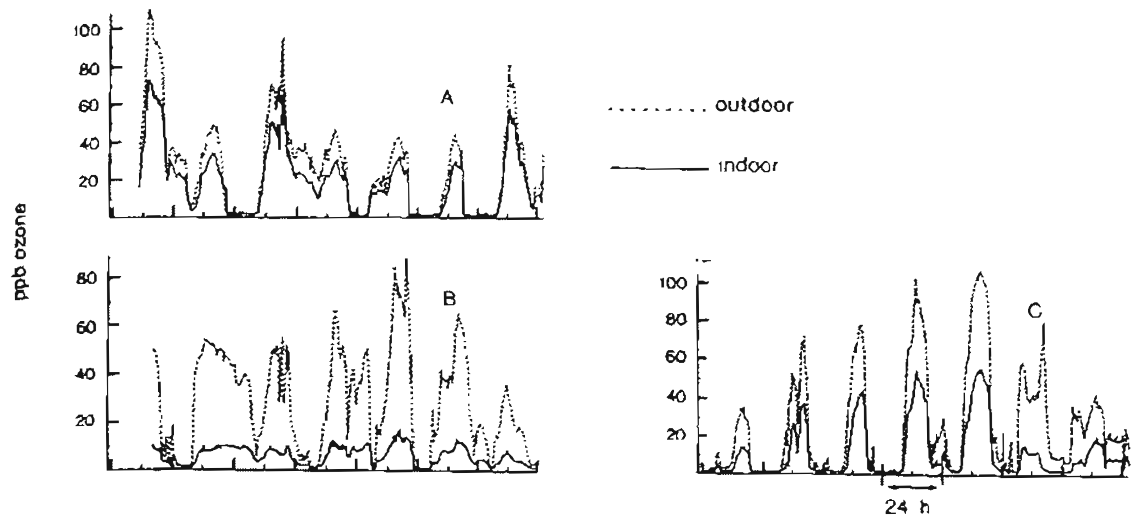
- "Sick building syndrome" often associated with excessive CO_2 (TLV 9000 mg/m^3 or 5000 ppmv: outside = 370 ppmv)

Fig 4.2.


- Sometimes (*e.g.*, ozone episodes) the outdoor air is more polluted; reducing the ventilation rate lowers pollution indoors

Note: rates of emission, ventilation and exchange may be different in different parts of the building.

How infiltration affects the concentration of ozone during an air pollution episode



Building A, $k = 8.2\ h^{-1}$; B, $k = 0.6\ h^{-1}$; C, $k = 4.0\ h^{-1}$

Building A, which exchanges efficiently with outdoor air, has indoor ozone concentrations closely tracking concentrations outdoors

Building B, which has low exchange rates with outside, maintains low indoor concentrations even when the outside air is highly contaminated

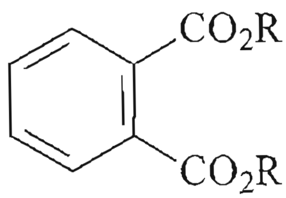
So, when air quality is bad outside, keep all windows and doors shut.

Building C is intermediate.

Indoor emissions

- From synthetic materials (carpets, plywood, urea-formaldehyde foams) —> $CH_2=O$; plasticizers, especially dialkyl phthalates. Especially a problem with mobile homes.

- Regulations in Sweden require complete ventilation (no recycling) in new office building for the first 6 months of occupancy



R = butyl, octyl, 2-ethylhexyl

- From cooking and heating activities: NO_x, CO, including woodstoves, car fumes from garages

- "New car smell" = mixture of VOCs, total *c* —> 64 mg/m^3 (new buildings 20-40 mg/m^3) including toluene and other alkylbenzenes, styrene, acetone, C_5 to C_{12} alkanes (*Chem. Eng. News*, May 20, 2002, p. 45)

- Recent issue: polybrominated flame retardants in indoor air: computer monitors, cushions and mattresses, automobile upholstery: *more discussion later in the course*

- Smoking ... "a single cigarette may release more than 100 mg of CO into the room" text p125.
  + the other chemicals, HCN, PAHs, and particulates will get you!

Radioisotopes in the environment

- **Toxicological aspects of ionizing radiation**

Primary Source: International Commission on Radiological Protection (ICRP) Publication #60, 1990

Definitions: bequerel

Actually a small amount of radioactivity.

Activity { 1 Bq ≡ 1 disintegration per second (irrespective of energy)
1 Ci ≡ 3.7 × 10^{10} Bq ← a large amount of radioactivity
(Curie) ← older unit

Mega (10^6)

Emission	Identity	Energy, MeV	Range in air	Range in water
	2 neutrons 2 protons			
α i.e. $^{4}_{2}He$	He^{2+}	3-9	< 10 cm	< 0.1 mm
β	e^-	0-3	up to 10 m	several mm
γ	photon	0.01-10	up to 100 m	several cm
x-ray	photon	0.001-1	up to 10 m	up to 1 cm
neutron	neutron	0-10	up to 100 m	up to 1 m

α emission = bare He nucleus, energetic but poorly penetrating
β emission = high energy electron: penetration depends on energy; β from ^{3}H cannot penetrate skin; β from ^{31}P requires about 1 cm of Plexiglas
γ emission = high energy electromagnetic radiation: highly penetrating, requires lead shielding
neutrons - do not themselves produce ionisation but transfer energy to other atoms which do cause ionisation
Notice that for α or β released <u>inside the body</u>, almost all the energy is absorbed: this is why radon is dangerous.

Remember

$^{A}_{Z}M$ — A ← mass no. = Z + N (N = no. neutrons); Z = no. protons ← atomic no.

e.g. $^{238}_{92}U \longrightarrow {}^{234}_{90}Th + {}^{4}_{2}He$

decays by ejection of α particle

Ionizing radiation means that ions are formed: e.g.:

$$H_2O + \underset{\gamma \text{ or X-ray}}{\overset{\alpha, \beta \text{ particles}}{\text{energy}}} \rightarrow H^+ + OH^{\cdot} + e^-$$

Water is the most important target molecule because it is most abundant in living tissue. Ionised DNA / proteins cannot carry out their normal functions ⇒ cancers

Both $OH^{\cdot}$ and e^- can damage biological macromolecules and therefore tissues by non-specific mechanisms: reductions of reducible functional groups (e^-) and hydrogen abstraction from lipids ($OH^{\cdot}$) initiating peroxidation and causing membranes to become leaky.

Energetics

Usual units for radioactive disintegration are MeV, where 1 MeV ~ 10^8 kJ mol^{-1}; the important concepts are **dose** and **dose rate**. One nuclear disintegration can cause thousands of ionization events, because the energies of covalent bonds are in the hundreds of kJ mol^{-1}.

Absorbed
Dose (D) = Absorbed energy:
1 Gray (Gy) ≡ 1 J kg^{-1}

Older unit "rad"
1 rad ≡ 0.01 J kg^{-1}
Hence 100 rad = 1 Gray

An acute dose of about 4 Gy will cause death over the next several days to weeks (data from Japanese A-bomb victims).

Because some forms of radiation (especially γ) are penetrating, the absorbed dose may be much less than the total energy released upon nuclear disintegration.

Radiation weighting factors (W_R)

The extent of damage from radiation depends on both the absorbed dose and the type of radiation involved.

Radiation type	$\mathbf{W_R}$
photons (γ and x-rays)	1
electrons (β rays)	1
neutrons	5-20 depending on energy*
α particles	20 ← most damaging

* most damaging near 1 MeV

Tissue weighting factor (W_T)

For living tissue, a tissue weighting factor (W_T) takes account of the variation of biological sensitivity of different organs.

Tissue	$\mathbf{W_T}$
Gonads	0.20
Bone marrow, colon, lung, stomach	0.12 each
Bladder, breast, liver, esophagus, thyroid	0.05 each
Skin, bone surface	0.01 each
All others	0.05
Total =	1.00

W_T apportions the whole body dose among the various organs. This would be appropriate for external radiation sources, but not for (e.g.) inhaled radon or iodine isotopes, which localize to specific tissues

Older unit, "rem"
100 rem = 1 Sievert (98)

Effective Dose (E), J kg^{-1}, has the special name Sievert (Sv).

Effective dose = $\Sigma(D \times W_R \times W_T)$

absorbed dose

accounts for the difference in radiation weighting

summed over all tissues

The effective dose is a function of:

- radiation intensity, Bq
- type of radiation
- energy of radiation, MeV
- how easily radiation is absorbed
- the tissue into which the energy is deposited

Ionizing radiation in the environment

- natural radioisotopes ^{40}K; ^{235}U; ^{238}U and daughters such as ^{222}Rn
- radioisotopes formed by cosmic rays ← high energy atomic nuclei (mainly protons)

In atmosphere, 2y radiation, ⇒ α, e^-, neutrons etc.

$$^{14}N + n \longrightarrow {}^{14}C + p^+$$

neutron ← proton

Hence radiocarbon dating since $t_{1/2}$ = 5500 years

- medical x-rays
- fall-out from nuclear testing
- nuclear industry: see below

Typical exposure to ionizing radiation = 1-2 mSv/year mostly from cosmic radiation

~55% from radon in indoor and outdoor air
~8% from cosmic rays from outer space
~8% from rocks and soils
~11% from natural radioactive isotopes (e.g. ^{40}K, ^{14}C) of elements that are present in our bodies
~18% from anthropogenic sources (mainly medical X-rays)