1. Indoor Air Quality
2. Industrial Hygiene: Assessment and Control of the Occupational Environment

Overview:

- Our occupational environment is regulated to provide a certainty the worker is minimally exposed to insult pollutants during his lifetime.
    - As an example, the manufacture of varnish requiring management of toluene and xylenes can lead to overexposure of these compounds, thereby potentially increasing the risk of cancer to those exposed.
- The regulation attempts to keep employers in check with up-to-date standards of exposure while ensuring that a 70 kg individual, exposed to a certain concentration of the insult pollutant for 40 hours a week for 40 years, will not develop cancer beyond $1/10^6$.
    - Mixtures of two or more chemicals are more complex to manage, but an acceptable procedure is available.
- In contrast, our indoor air such as in the home or in an office building, which is not regulated (guideline available), is typically rich in the same chemicals found in industrial settings, but typically at concentrations substantially below those in the industry.

- Air quality standards in a home or office cannot be extrapolated for use from the industrial regulatory levels.
    - The industrial regulatory levels are developed to provide provision for a 16 hour break away from the source of insult contaminant, thereby allowing the body to biotransform and hopefully eliminate the biotransformation products from the body.
- Indoor air, where the majority of the population spends more than 90-95% of their day is literally home to a broad range of issues.

Indoor Air

- The interiors of houses that were injected with UFFI (Urea Formaldehyde Foam Insulation) were later discovered to be relatively high in [HCHO].
    - HCHO is an A2 carcinogen, a mucous membrane irritant, a sensitizing agent, and others.
- From a regulated perspective, there is no need to remove the UFFI insulation, just that when an attempt is made to sell the house, that it includes HCHO testing to prove it is below a recommended level set out by the CMHC.

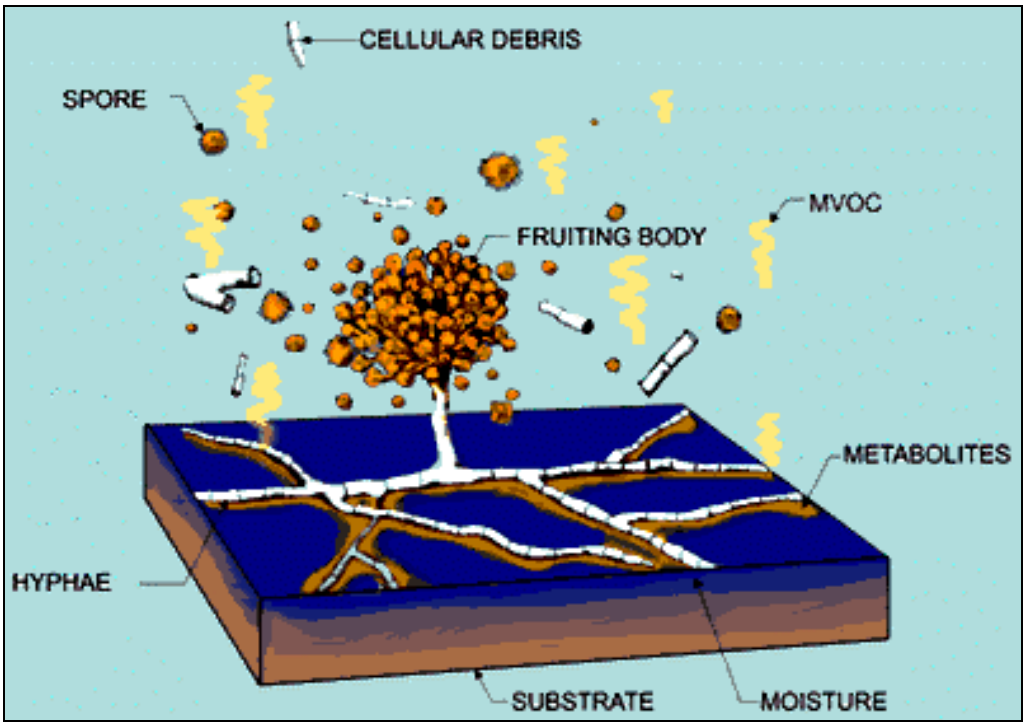
http://www.cmhc-schl.gc.ca/en/burema/gesein/abhose/abhose_ce06.cfm

    - "In the insulating process, a slight excess of formaldehyde was often added to ensure complete "curing" with the urea to produce the urea-formaldehyde foam. That excess was given off during

the curing, almost entirely within a day or two of injection. Properly installed, UFFI might not have resulted in any problem. Unfortunately, however, UFFI was sometimes improperly installed or used in locations where it should not have been. Enough complaints were received, particularly from people living in small, well-sealed homes, that Canadian authorities became concerned about possible health implications. The further use of UFFI was banned in 1980."

- Some of the major indoor air pollutants of concern are: asbestos and other friable materials, CO, HCHO, particulate matter (inhalable and respirable), NO_2, O_3, Rn (actually the progeny of Rn nuclide degradation), SO_2, and VOCs.
- Recently, considerable effort in the mitigation of mold and mycotoxins has led IAQ experts to include this parameter in the total health balance of the "building" occupants.

http://www.wbdg.org/design/env_iaq.php



- Molds are nasty, and need to be managed accordingly.

Pollutant	Indoor Source	*Guideline*
CO	Kerosene heaters, gas / wood stoves, fireplaces, smoking	10 mg/m³ for 8 hr, 40 mg/m³ for 1 hr
HCHO	Particleboard, plywood, hair gel, carpeting, ceiling tiles, UFFI…	<100 µg/m³
Particulate Matter	Smoking, vacuuming, wood stoves…	150-350µg/m³ for 24 hr
NO_2	Kerosene and gas heaters, gas stoves	100µg/m³ annual
O_3	Dry toner photocopier, electrostatic air cleaners	235 µg/m³/hr once a year
Rn (Pb)	Diffusion from soil, groundwater, building materials	0.01 working levels annual
SO_2	Kerosene space heaters	365 µg/m³ 24 hr 80 µg/m³ annual
VOCs	Everything else in the home…cooking, smoking, room deodorizers, cleaning sprays, paints, varnishes, solvents, carpets, furniture, flea collars, halogenated organics in your shower water, and from washing machines…	N/A

Radioactive Sources: Radon Gas in Indoor Air:

- **"Lung cancer** kills thousands of Americans every year. The untimely deaths of Peter Jennings and Dana Reeve have raised public awareness about lung cancer, especially among people who have never smoked. Smoking, radon, and secondhand smoke are the leading causes of lung cancer. Although lung cancer can be treated, the survival rate is one of the lowest for those with cancer. From the time of diagnosis, between 11 and 15 percent of those afflicted will live beyond five years, depending upon demographic factors. In many cases lung cancer can be prevented; this is especially true for radon".
    - http://www.epa.gov/radon/
- "Two studies show definitive evidence of an association between residential radon exposure and lung cancer. Two studies, a North American study and a European study, both combined data from several previous residential studies. These two studies go a step beyond earlier findings. They confirm the radon health risks predicted by occupational studies of underground miner's who breathed radon for a period of years. Early in the debate about radon-related risks, some researchers questioned whether occupational studies could be used to calculate risks from exposure to radon in the home environment. "These findings effectively end any doubts about the risks to Americans of having radon in their homes," said Tom Kelly, Director of EPA's Indoor Environments Division. "We know that radon is a carcinogen. This research confirms that breathing low levels of radon can lead to lung cancer."

http://www.consrv.ca.gov/cgs/minerals/hazardous_minerals/radon/

Radon Gas

- Rn gas is radioactive, with a relatively short half-life (~4 days).
- The source of ^{222}Rn is ^{226}Ra. The following scheme should help better understand:

$$^{226}Ra \rightarrow \mathbf{^{222}Rn} \rightarrow ^{218}Po \rightarrow ^{214}Pb \rightarrow ^{214}Bi \rightarrow ^{214}Po \rightarrow \mathbf{^{210}Pb}$$

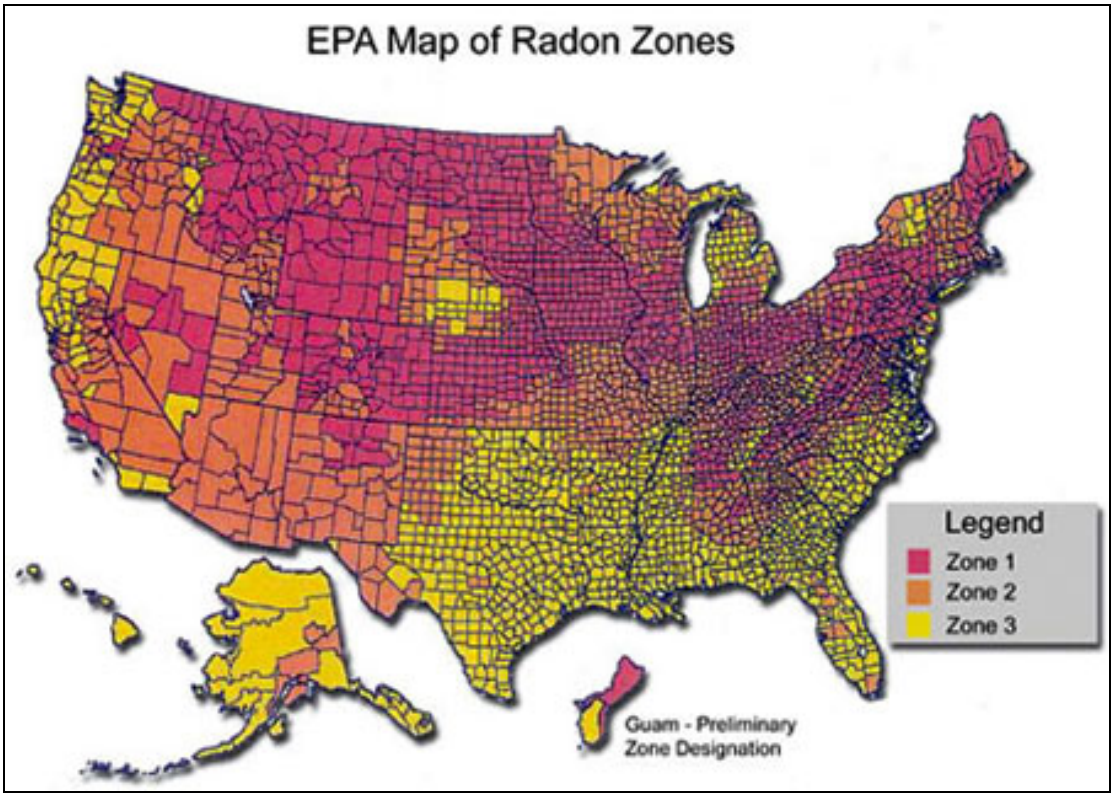
$$^{214}Bi \rightarrow ^{210}Tl \rightarrow \mathbf{^{210}Pb}$$

  - A decay such as $^{226}Ra \rightarrow \mathbf{^{222}Rn}$ is due to alpha particle loss (-4).
  - A decay such as $^{214}Pb \rightarrow ^{214}Bi$ is due to beta emission (-ve and +ve β emission)
    - $^{14}C \rightarrow ^{14}N$ is a common example
- The chances of inhaling and exhaling $\mathbf{^{222}Rn}$ intact are high.
  - Half-life of about 4 days
- But, there is a chance that upon inhalation it will decay while in the lungs.
  - Breaks down to radioactive products with half lives in the order of minutes to years
  - The half-life of $\mathbf{^{210}Pb}$ is about 20 years, but it is the decay to ^{214}Po which poses greatest concern
- If it does disintegrate while in the lungs, then the small particles can lodge in the cilia free regions of the lungs (points at and below 17th bronchial bifurcations). Now,

a direct radioactive source is focusing its energy, both α and β, directly on the surrounding tissue.

  - There is a larger risk of developing cancer associated with α particles – highly energetic, but unable to penetrate skin. Yet, when fixed and exposed directly to tissue…

- http://www.epa.gov/radon/pubs/devprot6.html
  - Radon gas monitoring systems
- http://www.epa.gov/radon/zonemap.html



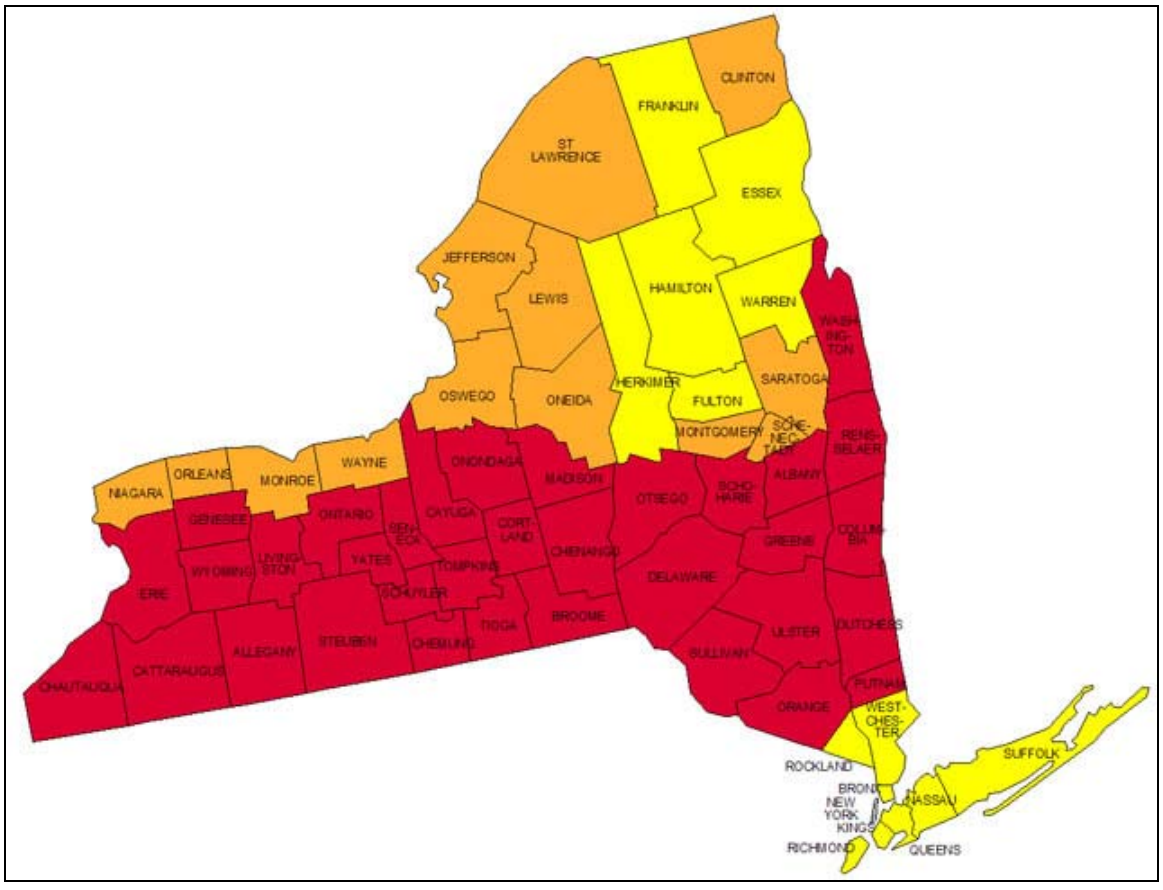
  - Hot spot information for Rn in USA
    - Zone 1 counties have a predicted average indoor radon screening level greater than 4 pCi/L (pico curies per liter) (red zones)

- Zone 2 counties have a predicted average indoor radon screening level between 2 and 4 pCi/L (orange zones)
- Zone 3 counties have a predicted average indoor radon screening level less than 2 pCi/L (yellow zones)

Zone 1 Highest Potential (greater than 4 pCi/L)

Zone 2 Moderate Potential (from 2 to 4 pCi/L)

Zone 3 Low Potential (less than 2 pCi/L)



New York

- Risks (US EPA)
  - http://www.epa.gov/radon/risk_assessment.html

Radon Level [a]	Lifetime Risk of Lung Cancer Death (per person) from Radon Exposure in Homes [b]		
pCi/L	Never Smokers	Current Smokers [c]	General Population
20	36 out of 1,000	26 out of 100	11 out of 100
10	18 out of 1,000	15 out of 100	56 out of 1,000
8	15 out of 1,000	12 out of 100	45 out of 1,000
4	73 out of 10,000	62 out of 1,000	23 out of 1,000
2	37 out of 10,000	32 out of 1,000	12 out of 1,000
1.25	23 out of 10,000	20 out of 1,000	73 out of 10,000
0.4	73 out of 100,000	64 out of 10,000	23 out of 10,000

- Factors
  - Underlying geology (uranium)
  - Soil porosity and permeability
  - Prevailing weather
  - Barometric pressure changes
  - Wind speed and direction
  - Chimney effect
  - Ventilation rate
  - Occupant behavior
  - Season
  - House idiosyncrasies
  - Heat distribution method
  - Domestic water Rn content

- 4 pCi ^{222}Rn/L air yields 0.02 WL.
- 0.02 WL continuous exposure
    - 8760 hours, 100% occupancy for 1 year yields 1.0 WL - month.
        - 1.0 WL - month yields 0.7 Rad absorbed dose.
- 0.02 WL yields an annual risk of 2×10^{-4}
- 0.02 WL per year over 45 years yields a lifetime risk of 9×10^{-3} (1%)