Lecture 15. Indoor air pollutants.

Objectives:
1. What are indoor air pollutants?
2. Radon.
3. Formaldehyde.
4. Tobacco smokes.
5. EPA recommendations.

Readings: Turco: p. 223-257; Brimblecombe: p. 167-173

1. What are indoor air pollutants?

Indoor air pollution can be considered to consist of any airborne material in a living or working space (home, office, school, etc.) that may irritate people or affect their health.

Major indoor air pollutants:

1. smoke from combustion processes (heating and cooking);
2. carbon monoxide (CO);
3. tobacco smoke;
4. formaldehyde;
5. radon;
6. asbestos;
7. lead;
8. some volatile organic vapors.

- Environmental Protection Agency (EPA) studies of human exposure to air pollutants indicate that indoor levels of pollutants may be 2-5 times, and occasionally more than 100 times, higher than outdoor levels. These levels of indoor air pollutants are of particular concern because it is estimated that most people spend about 90% of their time indoors.

Table 15.1 Sources and indoor pollutants.

Sources	Pollutants
Soil and ground water	**radon**
Building materials (carpeting, paint, varnish, adhesives)	**formaldehyde** **asbestos** **vinyl chloride** **organic fumes** **lead**
Personal activities and hobbies	**cigarette smoke** **fireplace smoke** **solvent and glue fumes**
Appliances, cooking, and heating	**carbon monoxide** **natural gas** **cooking odors** **boiler and heater fumes**
Household chemicals (bleach, oven cleaner, insect sprays, nail polish, hair spray)	**ammonia** **hydrogen chloride** **pesticides** **organic fumes** **aerosols**
Pets	**hair** **feces** **proteins** **dust**
Plants	**pollen** **hydrocarbons**

- The concentrations of indoor pollutants are affected by the structure of buildings, the ventilation, the indoor generation of contaminants, and the intrusion from outside.
- Various indoor pollutants affect health in different ways.
- It is often that definition of indoor air pollution is extended to include noise, electromagnetic fields, etc.

2. Radon is a natural radioactive element formed in soils all over the world. It is colorless, odorless, tasteless gas.

- Radon is particularly hazardous in areas where soil contains large abundance of the uranium, thorium, and radium. These elements decay by radioactive fragmentation in the soil, releasing radon as a gas.

Radioactive decay is a process when unstable nucleus breaks in to two or more pieces releasing the large amount of energy. Typical radioactive decay products are alpha particles (α), beta particles (β) and gamma rays (γ).

Alpha particles are the nucleus of helium, consisting of two protons and two neutrons and caring a positive charge (2+) associated with protons. Their penetrating ability is low.

Beta particles are high velocity electrons that carry negative charge (1-). Their penetrating ability is moderate.

Gamma rays are high energy electromagnetic radiation with very short wavelengths. They don't carry charges. Their penetrating ability is very high.

NOTE: recall Lecture 5 on electromagnetic radiation.

Units of radioactivity:

Curie (Ci): **1 Ci = 3.7×10^{10}** decays per second

SI system: Becquerel (Bq): **1 Ci = 3.7×10^{10}** Bq

NOTE: further discussion of radioactivity is given in Lecture 16.

Half-life of a radioactive species is the time it would take for half the existing atoms to decay.

Steps of radon production:

1. Uranium-238 (^{238}U), which is present since the Earth formed 4.5 billion years ago in solid minerals in the soil, decays (with half-life time of 4.5 billion years) to form radium-226 (^{226}Ra).
2. Radium-226 (^{226}Ra), existing in mineral form, decays to form radon-222 (^{222}Ra) which is gaseous.
3. Radon-222 (^{222}Ra) molecules diffuse through the soil, escaping into the atmosphere or dissolving in the ground water.
4. Radon accumulates in closed space (basement, mine shafts, etc.).
5. Radon-222 decays (with half-life time of about 3.8 days) emitting alpha particles.
6. Polonium-218 (^{218}Po) and the other species that evolve from the radon over the short time (about an hour) stick onto walls, floors, and dust particles.
7. Polonium-218 (^{218}Po), lead-214 (^{214}Pb), bismuth-214 (^{214}Bi), polonium-214 (^{214}Po) are inhaled with air in the respiratory system..
8. These elements decay (with half-life time less than 30 minutes) emitting alpha and beta particles directly into lung tissue causing lung cancer.

Risk assessment is performed to assess actual concentration of radon using its measurements and some modeling.

- A simple technique to measure radon is to use activated charcoal, which absorbs radon from the air.
- A box model is often used to assess radon concentration in the building.

NOTE: recall a box model introduced in Lecture 10.

Radon concentration, q_{Rn}, in the building can be estimated under steady-state conditions:

sum of source rates = sum of sink rates

$$S_{Rn} + S_v = L_v + L_d$$

where

S_{Rn} is the radon sources, which typically lies in a well-defined range of values (between about 0.01 and 10 pCi/liter/hour) with mean value of 0.5 pCi/liter/hour; (NOTE: 1 pCi = 1×10^{-12} Ci). S_v is the radon source due to ventilation of building with air outside,

$S_v = q^0_{Rn} / \tau_v$

here q^0_{Rn} is the background radon concentration (typical value is 0.2 pCi/liter) and τ_v is the ventilation time;

L_v is the radon sink due to ventilation of building with air outside, $L_v = q_{Rn} / \tau_v$;

L_d is the radon sink due to decay, $L_d = q_{Rn} / \tau_{Rn}$; where τ_{Rn} is the radon half-life (91 hours);

Thus, $S_{Rn} + q^0_{Rn} / \tau_v = q_{Rn} / \tau_v + q_{Rn} / \tau_{Rn}$

or

$$q_{Rn} = (q^0_{Rn} + \tau_v S_{Rn}) / (1 + \tau_v / \tau_{Rn})$$

or in simplified form

$$q_{Rn} \sim q^0_{Rn} + \tau_v S_{Rn}$$

For typical values we have **q_{Rn} = 0.7 pCi/liter or about 1 pCi/liter**

This means that in average home, roughly two radon-decay events occur every minute in each liter of air.

Working level (WL) is a common unit that is used to measure the exposure to radon.

1 WL = 100 pCi/liter (or often **1 WL = 200 pCi/liter)**

Working level can be estimates as **WL = q_{Rn} / 200**

- **Safe level of exposure to radon is 4 pCi/liter, or 0.02 WL.**

3. Formaldehyde is a volatile organic compound (HCHO) which is often used in the building materials (for instance, in resins and adhesives). It is colorless with strong pickle-like order gas.

NOTE: place to smell formaldehyde is a funeral home

Table 15.2 Formaldehyde emissions.

Product	**Range of emission rates (10^{-6} g per g material per day)**
Particleboard	**0.4 - 8.1**
Plywood	**0.03 - 9.2**
Imitation wood paneling	**0.8 - 2.1**
Fiberglass insulation	**0.3 - 2.3**
Clothing	**0 - 0.06**
Carpeting	**0.03 - 0.4**

- Concentrations of formaldehyde in homes can vary widely with the season, the construction of the home, and life-style of the residents.

Table 15.3 Formaldehyde concentrations.

Location	Measured concentration range (ppmv)
Ambient air	**0.00040 - 0.08 (0.01 average)**
Non-UFFI[a] home	**0.01 - 0.08 (0.03 average)**
UFFI home	**0.01 - 3.4 (0.12 average)**
Mobile home	**0.01 - 2.9 (0.38 average)**
Textile plant	**< 0.1 - 1.4**
Fertilizer plant	**0.2 - 1.9**
Bronze foundry	**0.12 - 8.0**
Iron foundry	**<0.02 - 18.3**
Plywood industry	**1.0 - 2.5**
Hospital autopsy room	**2.2 - 7.9**
STANDARTS FOR EXPOSURE	
Indoor air, USA	**0.1 (maximum)**
Indoor air, Sweden (old structures)	**0.7 (maximum)**
Occupation air	**1.0 - 5.0**

[a]Urea-Formaldehyde-Foam Insulation

NOTE: In ambient air, methane oxidation annually generates several hundred times more formaldehyde than is manufactured worldwide each year. However formaldehyde generated from methane is greatly diluted in the atmosphere and it has a very short lifetime (a few hours). Thus, formaldehyde in ambient air can not accumulated to any substantial degree to cause a problem.

- Because formaldehyde is quite soluble in water, up to 95% of the vapor that is inhaled can be absorbed in the upper respiratory tract (the nose, mouth, and throat).
- Formaldehyde can react with amino acids, proteins, and DNA, thereby damaging cells.

Table 15.4 Health effects of formaldehyde.

Concentration (ppmv)	Exposure time (min)	Health effects
0.01	**5**	**Eye irritation**
0.05	**1**	**Odor threshold**
0.08	**1**	**Cerebral cortex affected**
0.2	**60**	**Eye, nose, and throat irritation**
0.8	**10**	**Brain alpha-wave rhythm and autonomous nervous system changes**
4.0	**1**	**Unbearable without respiratory protection**

4. Tobacco smokes consist of a mixture of gases and particles.

Tobacco smoke gases are by-products of tobacco combustion intermixed with components of the air (for instance, carbon monoxide, hydrogen chloride, acetone, formaldehyde).

Tobacco smoke particles are tars, nicotine, and a variety of organics.

Nicotine, a major active component of tobacco smoke, is a strong stimulant and very addictive.

- Health agencies have estimated that up to several hundred people currently die each year of diseases related to, or exacerbated by, smoking.

Secondhand smoke has two major sources:

1. The sidestream smoke that escapes from the burning tobacco ash.
2. The air that smokers exhale.

Table 15.5 Some components of cigarette smoke.

Component	Emission (mg/ cigarette) Mainstream smoke	Sidestream smoke
Tar	**10.2 - 20.8**	**34.5 - 44.1**
Nicotine	**0.46 - 0.92**	**1.27 - 1.69**
Carbon monoxide	**18.3**	**86.3**
Ammonia	**0.16**	**7.4**
Hydrogen cyanide	**0.24**	**0.16**
Acetone	**0.58**	**1.45**
Phenols	**0.23**	**0.60**
Formaldehyde	**-**	**1.44**
Toluene	**0.11**	**0.60**
Acrolein	**0.084**	**0.825**
NOx	**0.014**	**0.051**
Polonium-210 (pCi)	**0.07**	**0.13**
Fluoranthenes	7.7×10^{-4}	1.6×10^{-3}
Benzofluorenes	2.5×10^{-4}	1.0×10^{-3}
Pyrenes	2.7×10^{-4}	1.5×10^{-3}
Chrysene	1.9×10^{-4}	1.2×10^{-3}
Cadmium	1.3×10^{-4}	4.5×10^{-4}
Perylenes	4.8×10^{-5}	1.4×10^{-4}
Dibenzanthracenes	4.2×10^{-5}	1.4×10^{-4}
Anthanthrene	2.2×10^{-5}	3.9×10^{-5}

Table 15.6 Disorders related to tobacco.

Organs	*Diseases*
Mouth, nose, and throat	**Cancer of the mouth and tongue; Cancer of the sinus and larynx; Lost of sensitivity to taste and smell.**
Pulmonary tract	**Lung cancer, emphysema; Coughing; Asthma attacks.**
Gastrointestinal tract	**Cancer of the stomach, colon, rectum, and pancreas.**
Cardiovascular system	**Heart diseases, strokes; Restricted blood supply to internal organs.**
Nervous system	**Strokes; Accelerated onset of senility.**
Skeletal and connective tissue	**Enhanced osteoporosis; Premature aging and wrinkling of the skin**
Urinary tract	**Prostate cancer.**

5. EPA recommendations:

Indoor Air Hazards to Watch For :

Moisture and biologicals (like molds, mildew and dust mites).

Sources include excessive humidity levels, poorly maintained humidifiers and air-conditioners, inadequate ventilation and animal dander.

Health effects: Allergic reactions are the most common health problems associated with biological pollutants. Symptoms often include watery eyes, runny nose and sneezing, nasal congestion, itching, coughing, wheezing and difficulty breathing, headache, dizziness and fatigue. Dust mites have been identified as the single most important trigger for asthma attacks.

Combustion products including carbon monoxide. They include gases or particles that come from smoking and the burning of fuels--natural gas, propane, wood, oil, kerosene and coal. The resulting harmful gases include carbon monoxide, nitrogen dioxide, sulfur dioxide, particulates and excess water vapor.

Sources include unvented fossil-fuel space heaters, unvented gas stoves and ovens, and "backdrafting" from furnaces and water heaters.

Health effects: Carbon monoxide, an odorless gas, can be fatal. Nitrogen dioxide can damage the respiratory tract, and sulfur dioxide can irritate the eyes, nose and respiratory tract. Smoke and other particulates irritate the eyes, nose and throat, and can cause lung cancer. Too much water vapor can lead to moisture problems in the home, including the growth of mold.

Formaldehyde is an organic gas.

Sources include durable press drapes and other textiles, particle-board products such as cabinets and furniture framing, and adhesives.

Health effects: It is a strong irritant that causes watery eyes and in low doses, causes burning sensations in the eyes, nose and throat. Wheezing and coughing, fatigue, skin rashes, headaches, loss of coordination and nausea are other symptoms. Larger doses can cause asthma attacks as well as damage to the liver, kidneys and the central nervous system. Some people are highly sensitive and react to formaldehyde concentrations that don't bother most people. Formaldehyde has been shown to cause cancer in laboratory animals, but there is limited evidence that it causes cancer in humans.

Radon is an odorless radioactive gas that results from the breakdown of uranium.

Sources: soil and rock beneath and around the foundation, ground water wells and some building materials.

Health effects: Radon gas decays into radioactive particles that can get trapped in your lungs when you breathe. These particles release bursts of energy that can damage lung tissue and lead to lung cancer.

VOCs from household products and furnishings.

Sources: These include volatile organic compounds from paints, solvents, air fresheners, hobby supplies, dry cleaned clothing, aerosol sprays, adhesives and fabric additives used in carpeting and furniture.

Health effects: Short-term effects include eye, nose and throat irritation, and headaches. Long-term exposure can cause loss of coordination; nausea; and damage to liver, kidneys and the central nervous system. Some organics can cause cancer in animals and are suspected of causing cancer in humans.

Asbestos. Most homes more than 20 years old are likely to have asbestos.

Sources include deteriorating, damaged or disturbed pipe insulation, fireproofing or acoustical material and floor tiles.

Health effects: Inhaled asbestos particles become lodged deep in the lungs and remain there for a lifetime. Asbestos can causes a serious deteriorate disease of the lungs, asbestosis.

Lead is a metal.

Sources include lead-based paint, dust from removing paint by sanding, scraping and burning.

Health effects: Young children (up to about six years old) are especially at risk of ingesting lead contaminated dust or paint chips. Small amounts of lead dust, consumed regularly, can cause delayed development, reading and learning problems, lowered IQ, hyperactivity and discipline problems. Larger doses can cause high blood pressure, anemia, and kidney and reproductive disorders in both kids and adults. Lead accumulates in the body and its effects are irreversible. The disease associated with lead poisining is called plumbism.

Be alert for these signs:

- unusual and noticeable odors, stale or stuffy air;
- noticeable lack of air movement;
- dirty or faulty central heating or air conditioning equipment;
- damaged flue pipes or chimneys;
- unvented combustion air sources for fossil fuel appliances;
- excessive humidity;
- tightly constructed or remodeled home;
- presence of molds and mildew;
- health reaction after remodeling, weatherizing, using new furniture, use of household or hobby products, or moving into a new home;
- feeling noticeably healthier outside the home.