American Lung Association of the Upper Midwest

Title: Radon and Lung Cancer

RADON

AMERICAN LUNG ASSOCIATION of the Upper Midwest

In partnership with: IDPH

Some Questions

- So What! Why do we care!
- What is radon?
- What is the science? Is there enough proof?
- What does the scientific evidence show?
- How does radon damage the body?
- What difference does the house make?
- How do you test for radon?
- How do you remove (mitigate) radon?

2

Lung Cancer

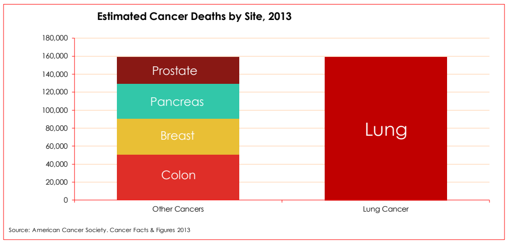
- Lung cancer is the leading cause of death in the United States for both men and women, accounting for an estimated 158,683 deaths and 203,536 new diagnoses in 2007 (Source: Center for Disease Control and Prevention – Lung Cancer Statistics).

- Lung cancer is responsible for:
  - ✓29% of all cancer deaths in males
  - ✓26% of all cancer deaths for females

  Source: American Cancer Society – Cancer Facts and Figures 2010

3

Lung cancer is the deadliest cancer



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Celebrity Lung Cancer Deaths

- Desi Arnaz, actor, 69
- Yul Brenner, actor, 65
- Nat King Cole, singer, 45
- Walt Disney, producer, 65
- Chuck Connors, actor, 71
- Pat Nixon, first lady
- Joe DiMaggio, baseball player
- Gary Cooper, actor, 60
- Everett Dirkson, senator, 75
- Eddie Rabbit, singer, 56
- George Harrison, musician, 58
- George Peppard, actor
- Audrey Meadows, actress, 71
- Bette Grable, actress, 56
- Duke Ellington, composer, 75

- John Wayne, actor, 72
- Robert Mitchum, actor, 79
- Jim Varney, actor, comedian, 50
- Carl Wilson, Beach Boys , 51
- Jean Simmons, actress, 72

- You might recognize many of these celebrity names. Back in the old days of Hollywood, smoking was very glamorous and almost everyone smoked but even today, celebrities like Peter Jennings, 67, reporter, die from lung cancer.

5

Even Wayne McLaren, the Marlboro Man, died of Lung Cancer at the age of 51

Photo from the California Department of Health Services

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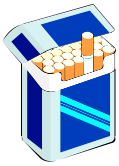
Lung Cancer and Tobacco

Since the Surgeon General's warning came into effect in the late 1960's and was placed on cigarette packs – we are all aware that the majority of lung cancer deaths are due to cigarette smoking.



SURGEON GENERAL WARNING:
Smoking Causes Lung Cancer, Heart Disease, Emphysema, and May Complicate Pregnancy

Smoking cigarettes is a VOLUNTARY act, but because of the magnitude of lung cancer incidence and poor survival rates, even secondary causes present a major concern, these include:

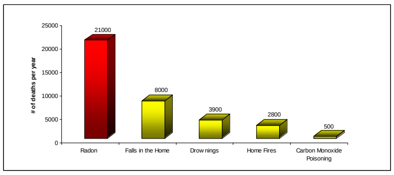
- Air pollution (outdoor and indoor)
- Lung diseases
- Family genetics and predisposition
- Asbestos
- Passive smoking, and
- RADON

Radon and Lung Cancer

The EPA ranks Radon in the highest classification of cancer causing substances – Group A. This category ONLY includes those substances that show sufficient evidence that it causes cancer in humans.

- EPA's Classification of Cancer Causing Agents:
- **Group A: Known Human Carcinogen - RADON**
- Group B: Probable carcinogenic
- Group C: Possibly carcinogenic
- Group D: Not classifiable (no data) and
- Group E: Evidence of non-carcinogenicity

Radon and Lung Cancer



More likely to die from radon than from home accidents, drowning, or accidental fires

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Radon and Lung Cancer

Radon is the leading cause of Lung Cancer in non-smokers and claims approximately 21,000 lives each year

The survival rate is one of the lowest for those with cancer. Approximately 85% of patients diagnosed will not live beyond 5 years

11

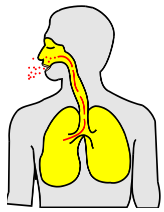
Radon and Lung Cancer

- Radon is a gas, Radon decay products are solid particles.
- These particles become suspended in the air when they are formed.
- Some of these particles "plate out" (attach to surfaces) or even "pit' surfaces.
- Some of these particles attach themselves to aerosols/dust/smoke particles floating in the air.

12

Radon and Lung Cancer

- Radon and Radon Decay Products (RDPs) are inhaled; Radon is exhaled.
- RDPs remain in lung tissue and are trapped in the bronchial epithelium.
- RDPs emit alpha particles which strike individual lung cells and may cause physical and/or chemical damage to DNA.



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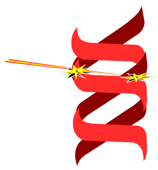
Radon and Lung Cancer

- Risk of lung cancer is based on <u>concentration</u> and <u>exposure</u> time
- Genetic disposition
- Generally, 10 to 20 year incubation period is required



Double Strand Breaks

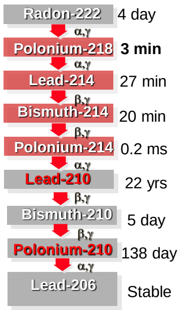
14

Radon and Smoking

- Radon binds to aerosols, dust particles, or cigarette smoke
- Indoor smoke increases the amount of dust in a room as much as **600** times
- Normally Radon decay products attach themselves to walls and surfaces, when dust and tobacco smoke is present, they attach to the particles
- Health effects - multiplied with cigarette smoke

15

Radon & Tobacco Leaves



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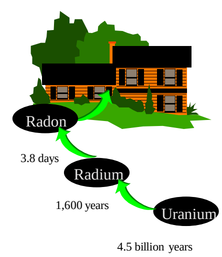
What is Radon?



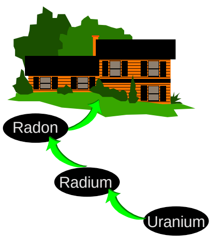
- Natural deposits of uranium in the soil
- Radioactive decay of uranium in rock soil and water
- Found everywhere in the world – therefore any building has the potential for elevated levels of radon
- Naturally occurring (not man-made)
- Tasteless
- Odorless
- Colorless

18

Where is Radon?

19

Radon



- Radon is a gas that can move up through the soil and when it enters a building constructed on top of this soil, it can build up.
- Once it enters the building it moves upward in the structure where it can be diluted with fresh outdoor air.
- This is why radon is typically at it's highest concentration in the lower portion of a building.

20

Why the Concern?

- Once radon enters a building, it is easily dispersed through the air. It then begins a radioactive decay process that leads to the creation of radon decay products (radon progeny).
- Radon gas itself is relatively harmless until it decays into these decay products which in turn release damaging energy particles.

21

Action Level

The potential adverse health effects from radon decay product (progeny) exposure prompted the U.S. Environmental Protection Agency (EPA) to adopt an Indoor Action Level for radon of:
4 picocuries per liter (abbreviated pCi/L)

22

World Health Organization

- International organization
- No mandatory impact on US & State Programs (at this time)
- Published Who Handbook on Indoor Radon Sept 09
- Recommended that reference level for radon be reduced down to 2.7 piC/L (100 Bq/m3)
- USEPA will review this recommendation

23

Scientific Evidence for Radon

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Scientific Evidence

- The role of residential radon and radon decay products and its relationship to lung cancer has been the subject of controversy for the last 20 years.
- Available data linking radon to lung cancer.
- The health risks associated with radon are based on epidemiological studies that have been carried out world-wide for over 50 years.
- Epidemiologists use gathered data to make educated and informed statements about causal relationships and radon's contribution.

Epidemiology

- Study of how disease occurs in populations/groups
- Identifies risk factors for public health planning
- Does **NOT** address cause of disease/condition
- Uses gathered data and statistical models to make educated statements about whether certain conditions contribute to the situation,
i.e. **DOES A CONTRIBUTE TO B?**

The health risks associated with radon are based on epidemiological studies that have been carried out world-wide for over 50 years.

Epidemiology

- Ecologic study – county mortality versus radon disease
- Cohort study – study group with data collection
- Case control study
  - ✓Comparison of those with radon versus without radon
  - ✓Pooling of data
  - ✓Odds-ratio

4

Underground Miner Studies

- Mines
  - ✓found throughout the world
- Uranium/Radon
  - ✓at elevated levels
- Studies of miners
  - ✓association between radon exposure and lung cancer
- Early miner studies
  - ✓estimate risks from radon exposure

5

Underground Miner Studies

- Early miner studies - primary basis for estimating the risks from radon exposure (including indoor exposures) today.
- Monitoring miner exposure to radon decay products
  - ✓collecting working level month (WLM) data
  - ✓correlates to the average number of hours worked by miners per month.

6

Underground Miner Studies

STUDY	ORE	WORKERS	DATE
China	Tin	13649	1972
Czechoslovakia	Uranium	4320	1961
Colorado Plateau	Uranium	3347	1969
Ontario	Uranium	21346	1968
Newfoundland	Fluorspar	1751	1978
Sweden	Iron	1294	1976
New Mexico	Uranium	3457	1990
Beaverlodge (Saskatchewan)	Uranium	6895	1982
Port Radium (Northwest Territories)	Uranium	1420	1960
Radium Hill (Australia)	Uranium	1457	1961
France	Uranium	1769	1983
TOTAL		60705	

Underground Miner Studies

All studies showed a markedly increased risk of lung cancer.

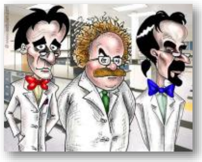
STUDY	LUNG CANCER	MEAN WLM
China	936	286
Czechoslovakia	701	196.8
Colorado Plateau	334	578.6
Ontario	385	31
Newfoundland	112	388.4
Sweden	79	80.6
New Mexico	68	110.9
Beaverlodge (Saskatchewan)	56	21.2
Port Radium (Northwest Territories)	39	243
Radium Hill (Australia)	31	7.6
France	45	59.4
TOTAL	**2686**	**182.1**

Miner Studies

- Radon decay products - cause of lung cancer: in radon-rich environments of uranium and other miners.
- Does radon poses a similar risk of causing lung cancer in men, women and children exposed at generally lower levels found in homes.
- Over the last few decades, mining practices have improved and there has been a sharp reduction in uranium mining. Therefore, current interests focus on the general publics exposure to radon in homes and other buildings.

BEIR Committee

- EPA worked with National Academy of Sciences and the National Research Council
- Biologic Effects of Ionizing Radiation (BEIR) Committee
- 13 scientists with expertise in radon, analyzed the data from the 11 miner studies
- Developed models to estimate the risk of exposure to radon in homes



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BEIR VI Report

Several reports - Latest findings in 1999…

1. Home exposure is expected
   - ✓cause of lung cancer in the general population
2. 11,000 lung cancer deaths each year
   - ✓1/4 are radon related (in never-smokers)
3. Uncertainty (at **low levels** of exposure)
4. Radon is the second leading cause of lung cancer after cigarette smoking.

Radon is the leading cause of cancer in non-smokers

11

BEIR VI Report

5. Radon cannot be entirely eliminated from homes - it is naturally occurring.
6. Of all deaths attributable to radon (smoking and non-smoking) perhaps 1/3 could be avoided by reducing radon in homes that are above the EPA action level.
7. Most of the radon-related deaths could have been avoided if person was non-smoker.

12

BEIR VI Report

Converting risks - mines to homes

- Miners subject to greater exposures levels
- Majority of miners were smokers
- All miners inhaled dust /other pollutants
- Miners were almost all men

13

Studies in the U.S.

- U.S., 5 major case studies - lung cancer risk from prolonged residential radon exposure (Between 1982 and 1996).
- Studies have been conducted in: New Jersey; Iowa (1993)
- Two studies have been conducted in Missouri:
- And a combined study was conducted in: Connecticut; Utah; So Idaho
- Design of each U.S. study varied by case selection, subject residency, exposure windows of interest, dosimetry methods (calculating the amount of exposure to radiation) and analytical analysis, so results must be interpreted cautiously.
- Overall, these studies produced a positive association between prolonged radon exposure and lung cancer.

14

Iowa Study

- Iowa has the highest average radon concentration in the U.S.
- National Cancer Institute SEER Cancer Registry used to identify and register lung cancer patients
- Controls – general population
- Cases were participants with lung cancer; 15 year exposure at levels equal to 4.0 pCi/L

Red Zone Counties - predicted average indoor radon screening level greater than 4 pCi/L

15

Iowa Study

- An independent pathological review confirming that participants had lung cancer
- Radon measurements with strict QAQC protocol
- Home occupancy at least for the last 20 years
- Only <u>women</u> were allowed
  - More time at home
  - Agricultural (less relocation)
  - Less occupational exposure
  - Supplement miner studies

16

Iowa Study

Total Controls & Cases →

- Nearly statistically significant (>50% chance)

Cases w/ Interviews (excluded deceased subjects to minimize bias from second-hand accounts from relatives) →

- Statistically significant
- >83% chance
- Radon exposure is a significant risk factor for lung cancer in women

60% of all homes tested had radon levels above the USEPA Action Level.

17

Spain Case-Control Study

- Study period from 1992 – 1994 & published in 2002
- Risk of lung cancer associated with exposure to radon in the home
- Examine both HIGH and LOW levels of radon exposure

18

Spain Case-Control Study

- Santiago De Compostela
- Population - 500,000
- Rural & urban coastal zones
- Porous, granite local subsoil
- Minimum of 35 years old
- Lived > 5 years, uninterrupted, in their current home with no with major structural alterations
- Removed participants - history of respiratory disease or cancer

19

Spain Case-Control Study

All detectors placed in the home:

- Minimum of 90 days or 3 months
- Average of 152 days or 5 months

In 22.2% of all the homes in this study the radon concentrations met or exceeded the U.S. EPA action level

20

Spain Case-Control Study

- Questionnaire was used to obtain information:
  - ✓ age, sex, smoking habit, lung cancer family history, employment type, age & type of dwelling, construction material of dwelling, and daily number of hours spent at home
- Controls (general population) questioned by two trained interviewers
- Cases (Lung Cancer population)
- Closest surviving cohabitants were interviewed if death occurred

21

Spain Case-Control Study

In this study, the "odds ratio" is the probability that lung cancer will occur in a case versus a control.

Radon Concentration (pCi/L)	# Cases	# Controls	Analysis	Risk of Lung Cancer
0.0 – 0.9	28	73	1.0 OR	Risk case = Risk control
1.0 – 1.4	43	54	**2.73 OR**	Risk case > Risk control (3 times)
1.5 – 3.9	46	64	**2.48 OR**	Risk case > Risk control (3 times)
≥ 4.0	42	46	**2.96 OR**	Risk case > Risk control (3 times)

NOTE: Analysis figures adjusted for age, sex, family history, & lifetime tobacco use

22

Spain Case-Control Study

- The risk of lung cancer is 46 times higher for smokers exposed to radon at levels > 1 pCi/L.
- Remember that the EPA Action Level is 4 pCi/L.

Lifetime Tobacco Use	Radon Concentration (pCi/liter)	# Cases	# Controls	Analysis	Risk of Lung Cancer
Non Smoker	0.0 – 0.9	2	28	1.0 OR	Risk case = Risk control
	≥ 1.0	11	76	1.81 OR	Risk case > Risk control (2 times)
Smoker	0.0 – 0.9	24	43	**20.16 OR**	Risk case > Risk control (20 times)
	≥ 1.0	118	85	**46.45 OR**	Risk case > Risk control (46 times)

NOTE: Analysis figures adjusted for age, sex, family history, & lifetime tobacco use

23

Conclusion

In general, findings from the Miner Studies, BEIR Report, U.S. Studies and the Spain Study support the conclusion:

- After cigarette smoking, prolonged residential radon exposure is the 2nd leading cause of lung cancer in the general population (non-smokers).

24

Chemical & Radiologic Characteristics

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1

Who is Stanley Watrus?

- Stanley Watrus was a construction engineer at the newly built Limerick Nuclear Power Plant in Pottstown, PA.
- In December 1984, Stanley Watrus set off radiation alarms.
- This was 2 weeks before the plant was activated – no nuclear radiation.
- He had radon in his home.

2

What were the levels of radon?

Home radon levels of:

- ✓ 4400 pCi/L in the basement
- ✓ 3200 pCi/L in the living room
- ✓ 1800 pCi/L in the bedrooms

MEDIA	BACKGROUND CONCENTRATION
Outdoor air	0.2 pCi/L
Indoor air	1-2 pCi/L
Soil gas	100 – 3M pCi/L

- Radon is measured in picocuries per liter (pCi/L).
- U.S. EPA Action level is 4.0 pCi/L.
- Technology based level – no level is considered SAFE.

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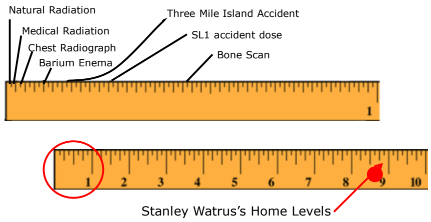
Calculated Exposure Risk



Equivalent to smoking 135 packs of cigarettes every day

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Characteristics of Radon

Radon occurs naturally in most rock and soils. At room temperatures it is:

- Naturally Occurring
- Colorless
- Odorless
- Tasteless
- Soluble in cold water
- Heaviest Noble Gas
- Radioactive

Radon cannot be detected by man and cannot be created artificially

5

Naturally Occurring

- The earth has always been radioactive.
- The natural radioactivity - is about the same today as it was more than 10 thousand years ago.
- Our bodies have measurable amounts of radioactivity over our lifetime.
- Most radioactive substances enter our bodies as part of air, water or food.
  - ✓About half is from potassium (a nutrient important for the brain and muscles) and the rest is from radioactive carbon and hydrogen.

6

Soluble in water

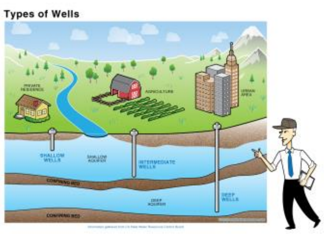
- Radon is soluble in water, *meaning it dissolves in water. This does not inactivate radon*.
- Homes using surface water (lakes, rivers, streams, reservoirs) usually do not have high radon levels because the radon is able to escape into the air.
- Aeration (or residual time) is part of drinking water processing in municipal systems which removes or reduces radon.

7

Soluble in water

- When well water is used, Radon may contribute to the home.
- These small public water works and private domestic wells often have closed systems and short transfer times. Radon is unable to escape into the air or decay.

About ½ of U.S. drinking water comes from groundwater wells



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Soluble in water

- The EPA does not currently regulate radon in drinking water (no need).
- EPA recommendations includes testing well water if radon concentrations in the occupied dwelling continue to be over 4 pCi/L and an active mitigation system cannot remove air-borne radon.

10,000 pCi/L of radon in water contributes to roughly 1 pCi/L of airborne radon.

9

Heaviest Noble Gas

The table lists the six Noble Gases and their uses. For example, Neon glows in distinctive colors when used inside lighting tubes. Radon has few uses - it's presence in groundwater appears to provide a possible means of predicting earthquakes.

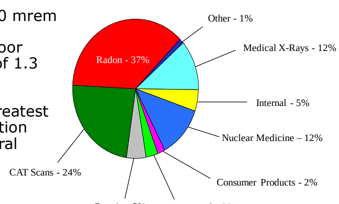
Gas	Applications
Argon	filament light bulbs
Helium	blimps/balloons
Krypton	lasers for eye surgery
Neon	neon lights
Radon	has few uses
Xenon	flash tubes for cameras

Radioactive

- Radon is radioactive – it gives off radiation.
- Radiation is defined as energy released in the form of particles or electromagnetic waves.

Sources of Radiation Exposure (2009)

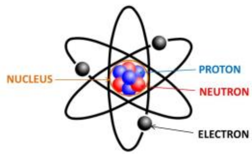
- Average Exposure 360 mrem
- Assumes average indoor radon concentration of 1.3 pCi/L.
- Radon is by far the greatest single source of radiation exposure to the general public.



Source: National Council on Radiation Protection (NCRP Report 160)

The Atom

- Nucleus contains positively charged protons and electrically neutral neutrons
- The electron cloud surroundin the nucleus is made up of negatively charged electrons

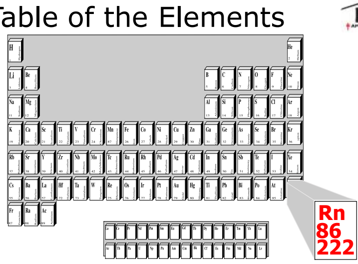


Radon (Radon- 222)

- Protons: 86
- Neutrons: 136
- Electrons: 86

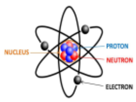
Atomic mass : 86+136=**222**
Atomic number: **86**

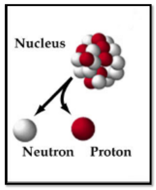
Periodic Table of the Elements



Radiation

- Sometimes the nucleus (center of an atom) has too much energy in it.
- Unstable - An atom cannot hold this energy forever.
- Sooner or later it must get rid of the excess energy.





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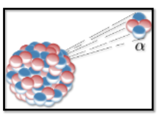
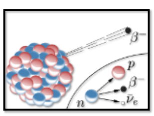
Radiation

- When the atom gives off radiation to get rid of excess energy it can be released in the form of particles - alpha particles or beta particles

alpha OR beta





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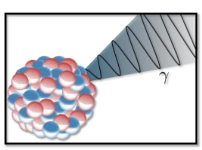
Radiation

- Or excess energy it can be released in the form of waves – gamma waves

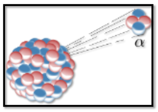
gamma



18

Alpha Radiation (α)

- Alpha particle released when the nucleus kicks out 2 neutrons and 2 protons (mass number changes by 4 and atomic number changes by 2).
- Alpha particle
  - Relatively massive
  - Relatively slow
  - Total charge of +2



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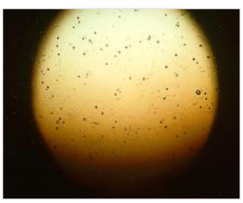
Alpha Particles Strong Enough To Pit Plastic



- Plastic chip from passive radon test (alpha track)
- Magnified only 100 times

20

Beta Radiation

- Nucleus changes a neutron into a proton and a beta particle is released (atomic number remains unchanged).
- Beta particle
  - Relatively small mass
  - Relatively fast moving
  - Total charge of -1

21

Gamma Radiation

- Gamma radiation is pure energy
- Released from the nucleus whenever an alpha or beta particle is emitted.
- Gamma particle (ray)
  - Small mass
  - Move at the speed of light
  - No charge

22

Types of Radiation

Energy in the form of waves is called Electromagnetic Radiation and in addition to Gamma rays also includes:

- Radar
- Radio waves
- Microwave radiation
- Ultraviolet radiation
- Medical x-rays

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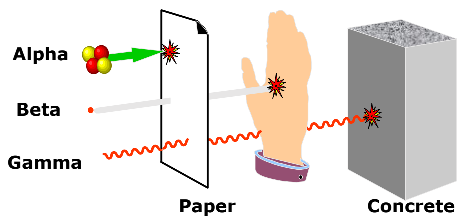
Types of Radiation

- Gamma rays and x-rays are virtually identical except that x-rays are produced artificially rather than coming from the atomic nucleus.

24

Penetration Levels



25

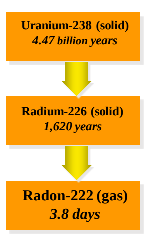
Uranium Decay Chain

In the case of radon the elements in a series change (through decay), after a sufficiently long time, from radioactive elements into it's final form of LEAD which is STABLE and will not change. This series of change is called the Uranium Decay Chain.

A decay chain is a natural, spontaneous process in which an atom of one element decays or breaks down to form another element by loosing atomic particles.

26

Abbreviated Uranium-238 Decay Series

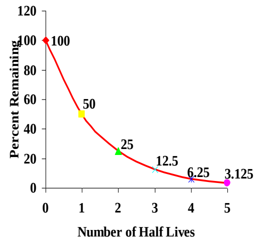


- Uranium decays to Radium and then to Radon.
- Uranium and Radium as solids are trapped in soil, but radon gas can move.
- The decay rate is called "half life."

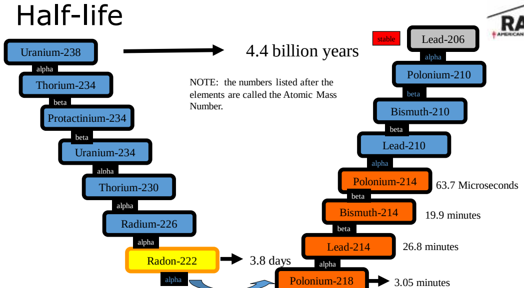
27

The Meaning of Half Life

- Half Life is the time required for half of the atoms to decay.
- It is not the time for all of the atoms to decay.



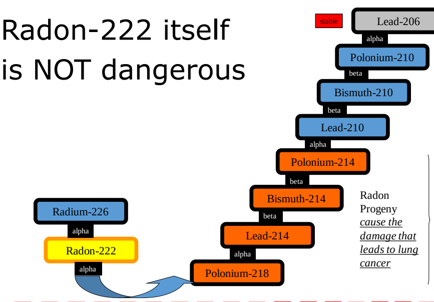
Half-life



Uranium Decay Chain

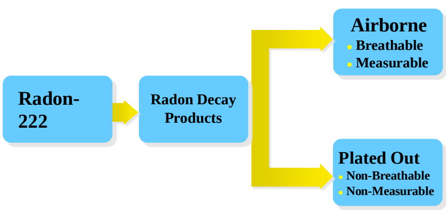
- Radon Decay Products (Polonium-218, Lead-214, Bismuth-214, & Polonium 214, NOT Radon Gas deliver the actual radiation dose to the lung tissues.
- The radiation released during the subsequent decay of the alpha-emitting decay products Polonium- 218 and Lead- 214 delivers a radiological significant dose to the lungs that can damage respiratory epithelium (the cells that line the insides of the lungs).

Radon-222 itself is NOT dangerous



31

Fate of Indoor Radon



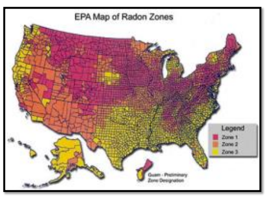
32

Radon Sources of Exposure and Entry

1

Radon Exposure

EPA identified areas of the U.S. that have the potential to produce elevated levels of radon based on soil surface geology, aerial radioactivity, soil permeability and foundation type (1993).

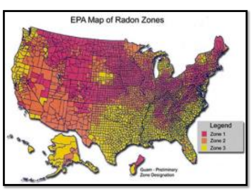


2

Zone 1 counties have a predicted average indoor radon screening level greater than 4 pCi/L (red zones) Highest Potential.

Zone 2 counties have a predicted average indoor radon screening level between 2 and 4 pCi/L (orange zones) Moderate Potential.

Zone 3 counties have a predicted average indoor radon screening level less than 2 pCi/L (yellow zones) Low Potential.

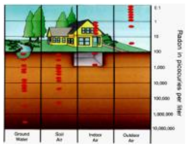


3

Radon Exposure

MEDIA	RANGE	AVERAGE
Outdoor air	0.1 to 30 pCi/L	0.2 pCi/L
Indoor air	1.0 to 3,000 pCi/L	1.0 to 2.0 pCi/L
Soil	20 pCi/L to 100,000 pCi/L	200 to 2,000 pCi/L
Groundwater	100 to 3,000,000 pCi/L	

Radon in water moves slower than radon in air. The distance that radon moves before most of it decays is less than 1 inch in water-saturated rocks or soils, but it can be more than 6 to 10 feet through dry rocks or soils



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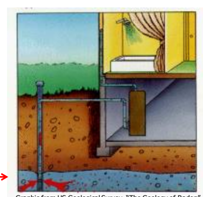
Radon Exposure

It takes about 10,000 pCi/L of radon in water to raise the radon in indoor air by 1 pCi/L.



Graphic from US Geological Survey, "The Geology of Radon"

5

Radon Levels in Buildings

Radon levels in buildings depend on:

(1)the concentration of uranium and radium in the soil or underlying geology

(2)how easily the radon can be transported into the building thru the soil permeability, pathways and openings into the building

Strength of radon source

Ease of transport into building

6

Radon Levels in Buildings

(3) the pressure differentials created by nature – the cool temperature of the soil verses the warmer temperature inside a building

(4) and to a lesser degree, the ventilation rate of the building

Pressure differentials

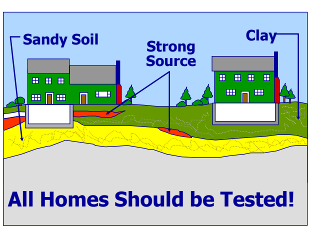
Ventilation rate

Radon Sources

Strength of radon source

- Natural soils and rock near or beneath building.
  - ✓Granites, shales, and corals, etc. can have slightly elevated levels of uranium (approx. 5 pCi/g)
- Contaminated soils from uranium processing mills and contaminated building materials.
  - ✓This is relatively rare and well-known in local areas.
- Groundwater supplies directly from wells.

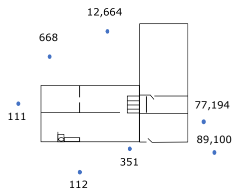
Radon Levels Vary Building to Building



Varying Soil Concentrations

Within short distances, depending on:

- Radium concentration
- Airflow through soil
- Readings can be misleading

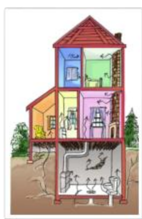


10

Radon Sources

The major factor influencing movement of radon into a home is the uranium and radium concentrations beneath the home.

95% comes from rock & soil



11

Radon Sources: Potential Factors

- Radium Content
- Size of Particles
  - The smaller the particles the more surface area
- Porosity of Soil
  - The ease of soil gas movement into the building
- Forces pulling or pushing soil gas through soil

12

Ease of Transport

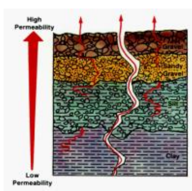
- Natural
  - ✓Pores/void space in soil - permeability of underlying soils
  - ✓Cracks, fissures in underlying geology
- Manmade
  - ✓Loose fill beneath foundation
  - ✓Along utility line trenches
  - ✓Along & into water drainage systems (e.g., sumps)

Ease of transport into building

13

Soil Permeability

- Radon moves more rapidly through permeable soils, such as course sand and gravel than through impermeable soils like clay.
- Fractures allow radon to move quickly through soil and rock.
- Radon moving through soil spaces and rock fractures usually escape into the atmosphere.

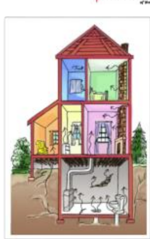


Graphic from US Geological Survey, "The Geology of Radon"

14

Soil Permeability

- If a house sits on top of soil with radon, soil air often flows toward the foundation.
- Older homes may have lower radon levels, because the soil surrounding an older home may be more compacted.



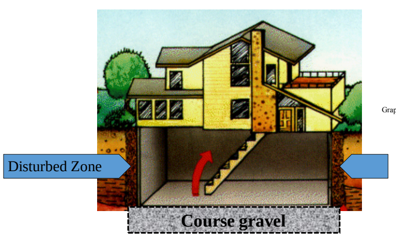
15

Disturbed Zone

- The gap between the basement walls and the ground consisting of fill material more permeable than the undisturbed surrounding soil.
- Radon travels easily through the disturbed zone and gravel under the foundation to entry pathways to enter the home.
- Materials used to fill the disturbed zone may contain and release radon.

16

Disturbed Zone



Graphic from US Geological Survey, "The Geology of Radon"

17

Ease of Transport

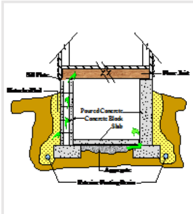
Radon will move by diffusion from its source

- Area of high concentration to an area of low concentration (concentration gradient).
- Where radon can enter a building (directly beneath an entry point) the soil gas concentration may be low.
- Meaning radon can diffuse even through tight soils to a point where it will be drawn in by convective transport (eg hot pot).

18

Foundation Type: Basement Poured and Block Walls

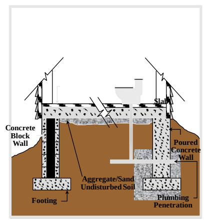
- Cracks and penetrations in poured floors/walls.
- Blocks can be hollow, radon enters through sides and top row.
- Excavation makes soil more permeable.



19

Foundation Type: Slab-on-Grade Foundation Walls

- Many openings:
  - ✓ Cracks,
  - ✓ Penetrations,
  - ✓ Joints,
  - ✓ Cold, expansion
- Hollow blocks



20

Foundation Type: Crawlspace Over Enclosed Earthen Area

- Large opening where vacuum from house is applied.
- Crawl vents are little help, especially in winter.
- Floor insulation is not a radon barrier.

21

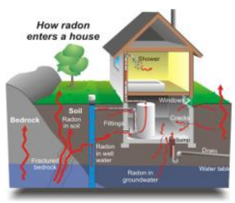
Foundation Type:Pier Building on "Stilts"

- Generally open to outside air, however on hills the side may be bermed in.
- Mobile homes are set on piers which can be skirted and insulated.

22

Radon Entry Pathways

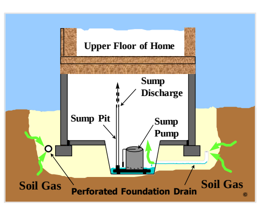
- Exposed Soil (Dirt floors)
- Cracks in foundations
- Pores and cracks in concrete
- Sump holes
- Floor drains
- Floor-wall joints
- Loose fitting pipe penetrations
- Building materials (rare)



23

Entry Pathways

- Water drainage systems
- Radon can pass through porous drainage beds or "French Drains" towards home.
- Frequently routed to interior sumps.



24

Radon from Building Materials

Typical building materials, may contain some radium, but do not contribute significantly to indoor radon levels. These products may include:

- concrete block,
- brick,
- stone,
- granite, and
- sheet rock.

25

Radon from Surface Materials

- Rocks and building materials can contain uranium and radium.
- Radon created on surface emitted into room.
- Rate depends on radium content and surface area.
- Typically dissipated by normal ventilation.

26

Radon from Granite Countertops

- Periodic concerns - granite countertops – high levels of radiation
- Although radioactive - the amount is not enough to pose a health threat.
- Granite is very dense & not friable
- Only radon gas near the surface would escape into the indoor environment.
- Trace minerals found inside the brown or black minerals, know *as biotite,* having some uranium content.
- With proper resealing, the radon emanation can be further reduced.

27

Radon Transport Through Soil to Building Requires:

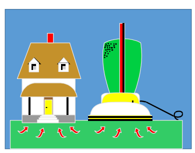
- A radon source (covered above)
- A pathway to the home (covered above)
  - ✓High soil porosity, or utility trenches, etc.
- Openings in the foundation (covered above)
  - ✓Joints, cracks, earthen areas, utility penetrations, etc.

Driving force -A force that draws or pushes the radon toward the building

28

Driving Force: Induced Soil Suction

- Buildings can create vacuums that will draw in soil gas.
- These vacuums are very small and are referred to as air pressure differentials.



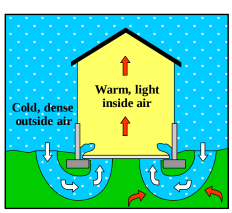
Pressure differentials

29

Driving Force: Temperature Induced Pressure Differentials

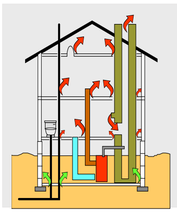
The Stack Effect

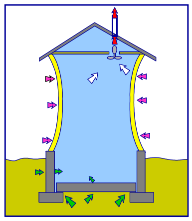
- Cold outside air is denser than inside - causes inside air to leave home.
- This difference in pressure causes the home to act like a vacuum, drawing radon in through entry pathways.



30

Driving Force





31

Radon Varies Constantly

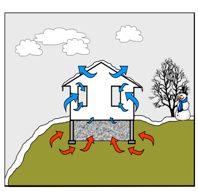
Lowest Level

Highest Level

32

Radon Varies Constantly

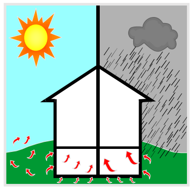
- Frost can "cap" the soil so negative pressure of building is exerted on larger area.
- Asphalt aprons around large buildings can have the same effect.



33

Radon Varies Constantly

Rain can…
- "cap" the soil.
- displace and force soil gas into building.
- change barometric pressure.

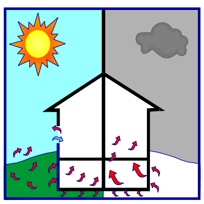


34

Radon Varies Constantly

Opening & closing windows can…

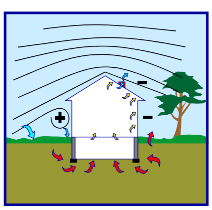
- Reduce vacuum and thereby reduces radon entry into building.
- Increase natural ventilation and radon dilution.



35

Radon Varies Constantly

Wind Effects
- Structure negative - Bernoulli effect, and down-wind openings.
- Structure positive with upwind openings.
- Soil positive - Wind pushing beneath.



36

Ventilation

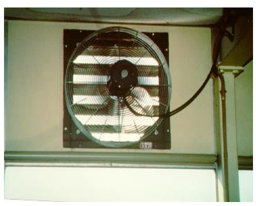
Ventilation rate

- Radon concentration indoors - influenced by household ventilation.
- Change radon concentration by increasing ventilation:
  - ✓opening windows and doors,
  - ✓operating bathroom & kitchen fans
  - ✓operating clothes dryers
  - ✓By pulling more radon from the soil through lower parts of the home.
- Heating systems - cause negative pressure or the vacuum/stack effect.

37

Ventilation

Spot exhausts in large buildings can cause localized high readings.



38

Ventilation

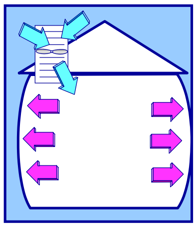
Unit ventilators can introduce fresh air.

39

Ventilation

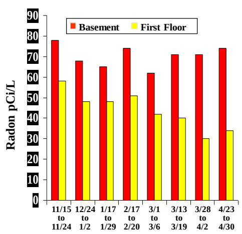
Addition of outside air can affect radon concentrations.

- Pressurization of building.
- HVAC Balancing.
- Evaporative cooler.
- Dilution of radon.



40

Radon Levels Are Typically Higher in Lower Levels of Home

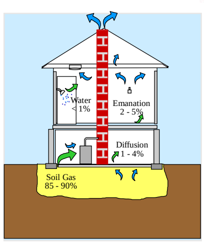


Higher radon in upper floors, versus lower floors, can indicate unusual entry mechanisms.

41

Total Contribution to the Home

These are averages and each home can be different!



42

Radon Measurement Devices

Why perform a radon measurement?

- Do I have a radon problem?
- Ready to sell my home
- I haven't tested in 4 years!
- I remodeled
- Is my mitigation system working?
- I want to know my average radon level

2

Radon Measurement Devices

- Passive -Do not require external power to operate
- Active - Require power to function
  (i.e. batteries, DC adaptors, or electricity from outlet)

<u>SHORT TERM</u>

- Any test lasting between 48 hours and 90 days
- Typically used for real estate transactions

<u>LONG TERM</u>

- Any test lasting between 90 days and 1 year
- Provides a more accurate indication of the annual average radon level in a home.

3

Passive Measurement Devices

4

Activated Charcoal (AC)

- Open and placed in the area for 2 to 7 days.
- Radon gas enters passively into the envelope/charcoal and remains trapped along with subsequent radon decay products.
- At the end of sampling period, it is sealed and sent for analysis.
- The lab counts the decay from the radon adsorbed to the charcoal on a gamma detector and a calculation based on calibration information is used to calculate the radon concentration.

5

AC Protocol

Advantages:	Disadvantages:
Inexpensive	Should be analyzed by laboratory as soon as possible after removal from house
Does not require power to operate	Highly sensitive to humidity
Can be sent through the mail	No way to detect tampering
Can be deployed by anyone	Results biased towards last 24 hours of testing period
Accurate	

6

Charcoal Liquid Scintillation (LS)

- LS samples are collected in a small plastic vial with a screw cap, and uses charcoal as a collection medium.
- Radon gas enters, or diffuses, into the charcoal and remains trapped along with the subsequent radon decay products.
- The exposure period is 2 to 7 days, depending on design.
- The vial sealed and sent to lab.
- Analysis is different –the charcoal is treated with a scintillation fluid, then analyzed using a scintillation counter, and the radon concentration determined by converting from counts per minute.

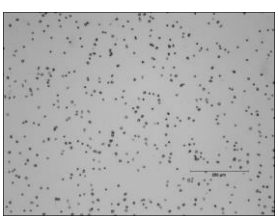
7

Alpha Track Detectors (AT)

- Radon gas enters the device through small openings covered by a filter and begins to decay.
- The small particles produced during the radon decay process hit the plastic detector(s) and cause a tiny dent (tracks) on the plastic surface.
- At the end of the sampling period the AT is sealed and returned to lab for analysis.
- The plastic detector is treated to enhance the damaged tracks, and then the tracks are counted using a microscope or optical reader.
- The number of tracks is used to extrapolate the radon concentration.
- Long-term: 90 days to 12 months

8

Alpha Track Detectors (AT)



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Electret Ion Chamber (ES)(EL) Protocol

EL (long-term device – deployed 1 to 12 months)
ES (short-term device – deployed 2 to 7 days)

These devices are made of plastic - larger than AC devices.

- Include plunger, ion chamber and paper filter

Detectors contain a charged Teflon disk (called an electret) located inside the main (ion) chamber.

10

ES/EL Protocol

- The plunger at the top opens and closes the device; with the plunger open the radon gas enters the main chamber through a filter.
- The radon gas decays in the chamber creating electrically charged particles, which reduces the voltage on the disc by small increments.
- A Measurement Professional or Technician will read the voltage of the disk before and after deployment – the difference between the two readings is used to calculate radon exposure.
- The EL can be exposed at shorter intervals if radon levels are sufficiently high.
- The ES can be exposed at longer intervals if radon levels are sufficiently low.

11

Overview of passive devices

<u>Passive Devices:</u>

- Activated Charcoal Adsorption (AC)
- Charcoal Liquid Scintillation (LS)
- Alpha Track Detection (AT) (filtered)

} Can be deployed by homeowners and Licensed Measurement Professionals & Technicians

- Electret Ion Chambers

} Can ONLY be deployed by Licensed Measurement Professionals & Technicians

12

Active Device Protocol

13

Continuous Radon Monitor (CR)

- One type of active monitor measuring radon gas is an Continuous Radon Monitor.
- These devices record real-time continuous measurements.
- There are a variety of this type of monitor on the market.

14

Continuous Radon Monitor (CR)

- Some CRs will monitor their own vital signs or environmental factors to insure that it is operating within it's specified operating parameters, including:
  - ✓Temperature
  - ✓Humidity
  - ✓Barometric pressure
  - ✓Physical movement
- Advanced monitors utilize infrared detection systems to sense movement of external bodies to ensure test validity and detect tampering.

15

CR Protocol

Advantages

- Increased accuracy (record at least once every hour)
- This level of detail also guards against tampering
- Can help to identify variances, which can help identify radon in water problems

Disadvantages

- Expensive
- Must be operated by Licensed Measurement Professionals or Technicians
- Require power to operate

16

Which device?!

- Jeff's neighbor tested for radon and his test results were over 4.0 pCi/L. Jeff wants to know his radon level. Which testing device would you recommend?
- It is spring and Cindy's radon test results came back at 3.7 pCi/L. She has read that radon levels can be at their highest in the winter. She is already concerned that the level is close to 4.0 pCi/L. What device could she use that will provide a more accurate annual average?

17

Which device?!

- Which *passive* device can only be deployed by licensed measurement professionals and technicians?
- Betsy is selling her home and moving into a nursing home. Her daughter did a radon test right before they put the house on the market. Results= 3.2 pCi/L The Daniels are interested in buying because their 2 teenagers can live in the basement. Betsy discloses that the test was done on the first floor. Should the Daniels request a test to be done in the basement?

18

Radon Measurement Protocol

1

Purpose of Radon Testing

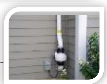
- Home testing to determine "highest concentration"
- Home testing to verify first testing - "follow-up test"
- Home testing to determine "average levels"
- Home testing to determine if "mitigation system works"
- Home testing to determine if "mitigation system continues to work"
- Apartment testing
- School testing
- Large building testing

2

Testing Examples

- Home (not real estate) – below
- Real Estate Transaction – below
- New Construction – below
- Post Mitigation – below
- Multi-family Building – not included
- School/Commercial Building – not included



3

Radon Measurement in Homes

Rn radon

4

Radon Measurements

The U.S. EPA “recommends that initial measurements be short-term tests placed in the lowest lived-in level of the home, and performed under closed-building conditions”.

- (lived in VS livable VS lowest)

Source: EPA’s Protocols for Radon and Radon Decay Product Measurements in Homes

5

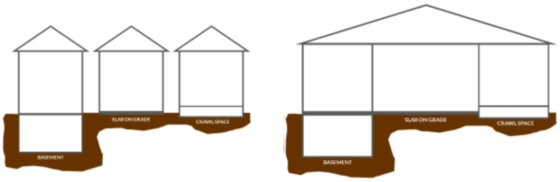
Radon Measurement in Homes

Measurement Location:

- For short-term or long-term tests, take measurements in each lowest structural area suitable for occupancy at the same time. For example, in a split-level building with a basement, a slab-on-grade room (converted garage) and a room over a crawl-space you would take measurements in each of the foundation types.

5

Radon Measurements



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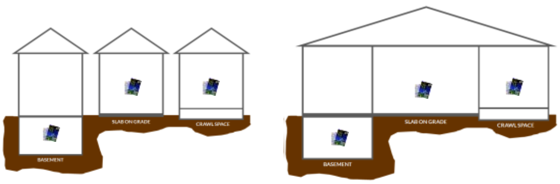
Radon Measurements



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Home testing for “Highest Concentration”

Short-term measurement

Long-term measurement

8

Short and Long-Term Measurements

Short-Term

- Short-term measurements range from 48 hours to 90 days, under closed building conditions.

Long-Term

- 91 days to 12 months

9

Measurement Protocol

Closed-Building Conditions – 12 hours prior to testing

- Important for short-term testing
- Close and keep windows on all levels shut
- Keep external doors closed (except normal use)
- Structural defects need to be repaired prior to testing
- Permanently installed HVAC systems may be operated

10

Measurement Protocol

- Operation of dryers, range hoods, bathroom fans and other mechanical systems that draw air out should not be used (if possible)
- If a radon mitigation system is in place, it should be functioning during test
- Air conditioning systems that recycle interior air may be operated
- Whole-house fans may not be used

11

Measurement Protocol

- Window air conditioning units operated in a re-circulating mode and must be > 20 feet from the detector
- Ceiling fans, portable humidifiers, dehumidifiers and air filters must be > 20 feet from detector
- Portable window fans must be removed (sealed in place)
- Fireplaces or combustion appliances (except for water heaters/cooking appliances) may not be used unless they are the primary source of heat for building

Measurement Protocol

Weather

- Severe weather will affect the measurement results
- High wind will increase variability of radon concentration because of wind-induced difference in air pressure between the building interior and exterior.
- Rapid changes in barometric pressure increase the chance of a large difference in the interior and exterior air pressures that can change the rate of radon influx.

Measurement Protocol

Weather

- No testing should be done during severe storms or periods of high winds.
- Severe storm (National Weather Service) is one that:
  - ✓generates winds of 58 mph and/or
  - ✓¾ inch diameter hail and
  - ✓may produce tornadoes

Measurement Protocol

- The HVAC system in operation throughout the measurement interval
- Maintained in the normal range of 72 degrees Fahrenheit + / - 5 degrees

Measurement Protocol

- Don't test during renovation of a building, especially those involving structural changes of the HVAC systems that disturb the normal airflow of the building.
- For planned renovations, test prior to and immediately after completion of renovations.

Measurement Locations

- Measurement Location - Rooms regularly occupied include
  - ✓Family rooms
  - ✓Living rooms
  - ✓Dens
  - ✓Playrooms
  - ✓Bedrooms
- Charcoal canisters shall not be placed in
  - ✓Bathrooms
  - ✓Kitchens
  - ✓Laundry rooms
  - ✓Spa rooms
  - ✓Areas of high humidity

Measurement Locations

- When the level of the home being test is over 2000 square feet, an additional test is required for each additional 2000 square feet.
- Measurements made in closets, cupboards, sumps, crawlspaces or nooks within the foundation are not to be used as a representative measurement and are not to be the basis on whether or not to mitigate.

Measurement Device Placement

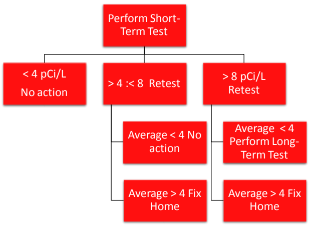
Measurement devices - placed in the general breathing zone and must be:

- 20 inches to 6 feet from floor
- Undisturbed during measurement period
- At least 3 feet from exterior doors, windows to outside, or ventilation ducts;
- Out of direct flow of air from ventilation duct(s)
- At least 1 foot from exterior walls
- At least 4 inches away from other objects horizontally/vertically above device
- At least 4 feet from heat (fireplaces, furnaces, out of direct sunlight, etc.)
- At least 1 foot below the ceiling.

Things to Remember

- Measurements should not be made if temporary radon reduction measures have been implemented.
- A permanent radon reduction system should be fully operational for at least 24 hours prior to testing and during the testing to determine the system's effectiveness.

Results



21

Follow-up Measurements

- Provide the homeowner with information to make an informed decision on whether to mitigate or not.
- Provides additional confirmation of the level.
- Radon levels fluctuate over time and when the follow-up measurement is averaged with the initial measurement a more representative reading is given.
- There is a small chance an error occurred during analysis, the follow-up measurement is a check.
- Should be done in the same location as the initial measurement.

22

Documentation/Records

- Follow-up measurements must be conducted in the same locations as the initial measurements (unless they were not performed per protocol).
- Use the results of the initial & follow-up measurements.
- The average is considered the basis of the need for mitigation.
- You can perform a Long-Term test any time a better understanding of the year-round average would give a clearer understanding of the radon measurement.

23

New Construction

- Don't test new construction until ALL of the following is complete
  - ✓ Insulation
  - ✓ Exterior doors/hardware
  - ✓ Windows
  - ✓ Fireplaces/dampers
  - ✓ Ceiling covers
  - ✓ Interior trim/cover for exterior walls
  - ✓ Exterior siding, weatherproofing & caulk
  - ✓ Interior/exterior structural components
  - ✓ Heating, air conditioning & plumbing appliances
- Any interior or exterior work that may adversely affect the measurement validity must be complete before testing.
- Unoccupied homes must be tested with the HVAC system set and operating in the normal range (example 72 degrees Fahrenheit plus or minus 5 degrees).

Post Mitigation

Post mitigation testing - determine the mitigation system's effectiveness

- Protocol
  - ✓Conduct > 24 hours but < 30 days after activating mitigation system.
  - ✓Operate the System normally and continuously during measurement.
  - ✓DO NOT conduct measurements if temporary radon reduction measures are in use.

General Principles of Radon Mitigation Systems

RADON
AMERICAN LUNG ASSOCIATION.
of the Upper Midwest

1

Radon Mitigation Techniques

- Radon concentrations in homes can be cost effectively reduced regardless of initial concentration.
- Methods that reduce/prevent radon entry via soil gas into the house are called MITIGATION TECHNIQUES.
- The difficulty is not whether radon can be reduced, but instead utilizing mitigation techniques without compromising aesthetics, building integrity, occupant health and safety, as well as ensuring cost effectiveness.

2

As Low As Reasonably Achievable

- Historically, the industry practice has been to design a radon reduction system that reduces radon to less than the USEPA guideline of 4.0 pCi/L in the lowest potentially livable location of a home.

Levels below 4.0 pCi/L still present a risk and further reduction may be necessary to reduce this risk to the occupants.

3

As Low As Reasonably Achievable

- The USEPA's Indoor Radon Abatement Act of 1988 states that "indoor radon concentrations should approach or equal outdoor radon concentrations."
  - The ambient outdoor concentrations averages from 0.1 to 0.4 pCi/L. Meeting this ambient goal may not always be practicable due to higher costs.

USEPA uses the phrase, "as low as reasonably achievable (ALARA)," as a goal for indoor radon concentrations.

4

Radon Reduction Methods

There are 4 methods by which indoor radon levels can be reduced:

1. Preventing/reducing radon entry into the house
2. Removing the radon/radon decay products after entry
3. Removing the source of radon
4. Removing radon/radon decay products with the use of air cleaners

5

Radon Reduction Methods

Methods 3 & 4 have not been demonstrated to be effective because:

- The removal of the source of radon cannot be achieved since it is impossible to remove all the soil.
- The removal of radon and radon decay products with the use of air cleaners may decrease the concentrations of airborne particulates and the radon decay products attached to those particulates; however, the devices will not decrease unattached decay products.

6

Radon Reduction Methods

This leaves **TWO** effective radon reduction methods:

METHOD 1	Preventing/reducing radon entry into the house
METHOD 2	Removing the radon/radon decay products after entry

7

Radon Reduction Methods

Method 1:

Reduces radon levels in the home by collecting radon gas prior to building entry and discharging it to a safe location.

How it works:

- Modifying building pressure differentials and reversing the soil gas flow away from the house through Active Soil Depressurization
- Sealing all opening and cracks

8

Radon Reduction Methods

Method 2:

Reduces radon concentrations entry by dilution using increased ventilation, and/or filtering radon and RDPs from the air.

How it works:

- As radon enters a building it quickly mixes with the indoor air and is diluted to concentrations of which building occupants are exposed.
- The more air that can be mixed in will lower the final breathable radon concentration

9

Mitigation Systems

Active soil depressurization techniques.

- Active sump/drain tile depressurization
- Active block wall depressurization
- Active sub slab depressurization
- Active sub membrane depressurization in crawl spaces

10

Active Soil Depressurization

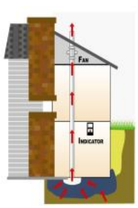
- The fan suction system creates a low pressure field underneath the slab floor or soil gas retarder.
- The low pressure field beneath the slab draws radon out of the soil, up the pipe, and exhausts it outdoors before it ever enters the building.
- Some sub-slab material (i.e tightly packed soil or course gravel) may not allow the pressure field to extend to all areas of the soil surrounding the foundation. This could allow radon to enter the home where the pressure field does not exist. Adding additional suction points to the system helps extend the pressure field.

11

Basics of ASD: Sub-Slab

General Information:

- Most common and efficient in houses with a slab foundation or concrete covered basement
- Sub-slab radon mitigation systems consist of:
  - Suction point;
  - Suction pit;
  - Vent pipe;
  - Vent fan; and
  - Sealing of visible openings, cracks, and holes.



12

Basics of ASD: Sub-Slab

Suction Point(s):

- Consists of one or more holes in floor slab of which suction pipes are inserted into suction pit.
  - The pipe(s) may also be inserted below the concrete slab from outside the house.
  - The number and location of suction pipes needed depends on how easily air can move through the crushed rock or soil AND the strength of the radon source.

13

Basics of ASD: Sub-Slab

Suction Pit:

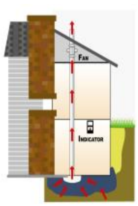
- A hole created by removing ~ 5 gallons sub-slab aggregate material.
- Dug directly below where suction point penetrates slab.
- Vent pipe extends from this pit to outside.

14

Basics of ASD: Sub-Slab

Vent Pipe:

- Pipe extending from inside the suction pit with an exhaust point on the outside of the house.
- Exhaust point should be located above the eave line of the roof.
- Mitigation professionals should avoid creating an exhaust point allowing the re-entry of radon gas into the home through open windows, doors, or back draft through chimney's.
- Exhaust points need to be away from windows, doors or any entry point into the home that has conditioned space.



15

Vent Pipe Examples

16

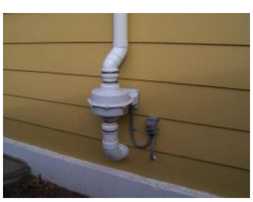
Basics of ASD: Sub-Slab

Vent Fan:

- A radon vent fan connected to the suction pipe(s) draws the radon gas from below the house and releases it into the outdoor air while simultaneously creating a negative pressure (vacuum) beneath the slab.
- Common locations for the vent fan include unconditioned house and garage spaces, such as attics and the exterior of the house.

17

Common Fan Locations



18

Basics of ASD: Sub-Slab

Sealing:

- Sealing limits the flow of radon into the home thereby reducing the loss of conditioned air.
- All cracks and other openings in the foundation should be sealed as part of radon reduction to maintain pressure field.
- Sealing and caulking has not been shown to lower radon levels by itself and is NOT a stand alone solution.

19

Basics of ASD: Sub-Membrane

General Information:

- Most common and efficient in houses with a dirt floor crawlspace or basement foundation.
- Sub-membrane radon mitigation systems should consists of:
  - Soil gas retarder;
  - Vent pipe;
  - Vent fan; and
  - Sealing of visible openings, cracks, and holes.

20

Basics of ASD: Sub-Membrane

Soil Gas Retarder:

- A high-density plastic sheet used to cover any earth floor.
- A minimum of 6 mil plastic, heavier plastic is needed if the crawl is used for storage.
  - A mil is the term used to specify the thickness of plastic sheeting, 1 mil is a milli-inch or a thousandth of 1 inch.
- Seams must overlap and be sealed and plastic must be sealed to piers and walls.

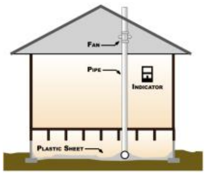
21

Basics of ASD: Sub-Membrane

Vent Pipe:
- Same purpose, appearance, and requirements as SSD, BUT extends from underneath the soil gas retarder instead of slab floor.

Vent Fan:
- Same purpose, appearance, and requirements as SSD.

Sealing:
- Same purpose, appearance, and requirements as SSD.



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Basics of ASD: Drain Tile

Drain Tile Depressurization: adding a suction point on drain tiles or perforated pipe directing water away from the foundation can be effective in reducing radon levels.

- One variation of sub-slab and drain tile suction is sump hole suction – a sump hole used to remove unwanted water is capped, so it can continue to drain water and serve as the location for a radon suction pipe.

23

Basics of ASD: Block Wall

Block Wall Depressurization: Used in basements with hollow block foundation walls by sealing the top of these walls and adding a suction point(s).

- This method removes radon, depressurizes the block wall, and is often used in combination with sub-slab suction.

24

Basics of ASD

Examples of multiple suction point systems:

2 suction pipes routed to fan on the exterior

2 suction pipes routed thru garage to a fan in attic/ loft

2 suction pipes routed thru interior to fan on in the attic

25

ASD Added Benefits

Negative pressure in the soil not only prevents soil based radon from entering but also anything else in the soil. This has many additional benefits to homeowners including

- Moisture reduction – makes basement drier and the de-humidifier runs less
- Odors elimination – often times basement odors disappear after a radon system is installed
- Mold elimination
- Removal of chemicals left in the soil

26

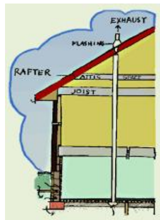
Additional Information

- Utility costs are low, basically the same electricity needed for a 100 watt light bulb.
- There is very little noise, if installed properly.
- System failure is detected by an electric meter or pressure gauge (u-tube manometer).
- Building/home should be retested every 2 years to ensure system properly operating.
- The vent fan should NEVER be turned off.
- A radon contractor should be consulted before any remodels or structural changes with regards to system warranties and reducing radon levels during construction.

27

Radon Resistant Construction

- Type of radon mitigation system installed in a building during initial construction.
- Passive new construction system relies solely on the convective flow of air upward in the vent pipe for sub-slab depressurization.



28

Radon Resistant Construction

- A skeletal system is a system that is designed for the installation of a vent fan and may consist of multiple vent pipes.
- It includes vertical and angled runs that may be joined to a single termination above the roof or may be terminated separately above the roof.

29

Radon Resistant Construction

- Radon resistant homes are being built in Iowa.
- Active mitigation systems should be installed by a licensed mitigation professional or technician.

30

Radon Resistant Construction

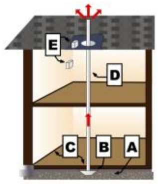
A. Gas Permeable Layer – (usually 4 inches clean gravel)placed beneath the slab or flooring system to allow the soil gas to move freely underneath the house.

B. Plastic Sheeting – placed on top of the gas permeable layer and under the slab. To help prevent the soil gas from entering the home. In crawl spaces, the sheeting is placed over the crawlspace floor.

C. Sealing & Caulking - all openings in the concrete foundation floor to reduce soil gas entry into the home.

D. Vent Pipe - 3-4 inch gas-tight or PVC pipe (commonly used for plumbing) runs from under the gas permeable layer through the house to the roof to safely vent radon and other soil gases above the house.

E. Junction Box - an electrical junction box is installed IN CASE an electric venting fan is needed later.



31

Radon Resistant Construction

Advantages to RRC installation:

- Helps block radon from entering home.
- Easy to upgrade if a fan is needed.
- More cost-effective to install while building a home.
- May improve the home’s energy-efficiency.
- New home contractor may install the basic elements without a mitigation licensee - A licensee is needed with the installation of a fan.

32