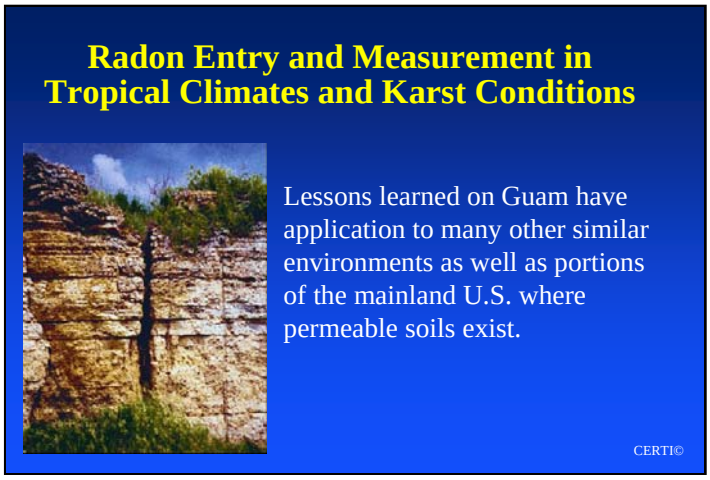

Key Points

A course designed to equip radon professionals to interpret radon and radon decay product measurements made during the unique entry conditions found on the Island of Guam.

Unique Entry Patterns and Building Conditions

- Soil pressure driven entry – environmental effects such as:
  - Rain effects
  - Wind effects
  - Tidal fluctuations
- Extremely tight buildings
  - Steel reinforced concrete
  - Low air exchange rate
- Low equilibrium fractions
  - High internal air circulation due to forced air, air conditioning
  - Clean ambient air

Application to Other Locations

- Areas with Karst geology
  - Limestone geologies like northern Alabama and parts of Tennessee
- Highly porous soil
  - Mountainous areas with porous decomposed granite
- Areas where socio economic changes alter building practices
  - Over the last 20 years a significant change has occurred on Guam where building construction changed from open ventilation to enclosed structures with air conditioning.
- Marine environments and locations where clean outdoor air significantly impacts equilibrium factor and hence how overall health risk exposure is determined as a function of radon measurements.

Section 1

Key Points

Course Based Upon:

EPA, *Indoor Radon & Radon Decay Product Measurement Protocols*, July 1992

EPA, *Protocols for Radon & Radon Decay Product Measurements in Homes*, June 1993

EPA, *Radon Mitigation Standards*, April 1994

EPA, *Home Buyer's and Seller's Guide to Radon*, July 2000

EPA, *A Citizen's Guide to Radon*, (fourth edition), May 2002

Program

All course materials and online coursework available at **www.certi.us**

Video and audio played from computer with slides

Resource Materials

Guam specific brochures

Research papers

Homework and Quizzes

Homework and Quizzes are designed to reinforce the material. Successful completion of the quizzes is required to obtain a Course Certificate.

Continuing Education Credits:

After completing the Course, download your certificate and send in with renewal application.

Guam Certification:

For Measurement Only Providers (if you will not be providing Mitigation Services)

Arrange for Guam Specific Measurement Exam through Guam Community College
(671) 735-5516

For Measurement and Mitigation or Mitigation only Providers

Complete the Guam Specific Mitigation Course then arrange for the Guam Specific Mitigation Exam (which includes the Measurement Portion) through Guam Community College
(671) 735-5516

Section 2

History and Overview of Radon on Guam

- Source found in areas with Limestone
- Radon enters because of soil pressures
  - Rain
  - Wind
- Very high potential
- Highly variable

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Key Points

History

1989 -1990	DOD testing revealed elevated concentrations and initiated radon program
	(As of May 2000, 755 of the 1,390 housing units on Anderson AFB had been mitigated for radon) Source: ATSDR
August 1991	Guam DOE testing of schools
	Residential survey
	Laboratory established
1993 – 1994	Guam Public Building Survey
	Investigation of entry factors
1998	Re-survey selected air conditioned DOE facilities
	Survey of mitigation systems
1998 – 2006	Numerous surveys and mitigation efforts at military installations
2007	Guam Community College opens Pacific Training Facility

Conclusions to Date

Buildings constructed over native limestone have the highest potential for elevated radon concentrations if the building is not well ventilated.

Where radon potential exists beneath a building (constructed over limestone), the radon entry is not only caused by interior negative pressures, but often soil pressures caused by rain and wind.

Where air conditioning systems exist within a building, the lack of fresh air make-up and unbalanced ducting systems associated with central air handlers can affect radon entry and final concentrations.

Other than the effects of central Heating Ventilation and Air Conditioning (HVAC) systems, the primary difference between radon entry on Guam and the mainland U.S. is that radon often enters Guam structures due to pressures in the sub-grade rather than vacuums within the structures.

Air handling systems can reduce the amount of radon decay products in the air due to higher air circulation rates and possibly from outdoor air having fewer suspended particulates.

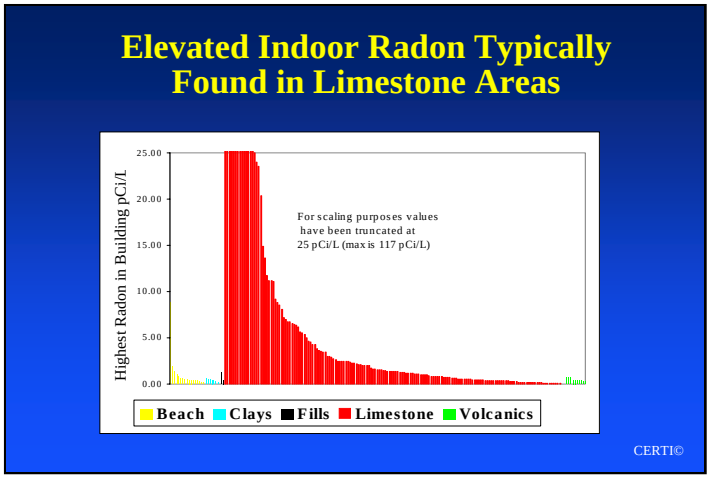
Guam EPA estimates that **1 in 3** homes have elevated indoor radon levels.

Health Effects

There are buildings on Guam that have exhibited very high indoor radon levels

Effects of radon exposure is no worse on Guam than in the U.S. Mainland, it is just very prevalent in certain areas of the Island.

Section 3

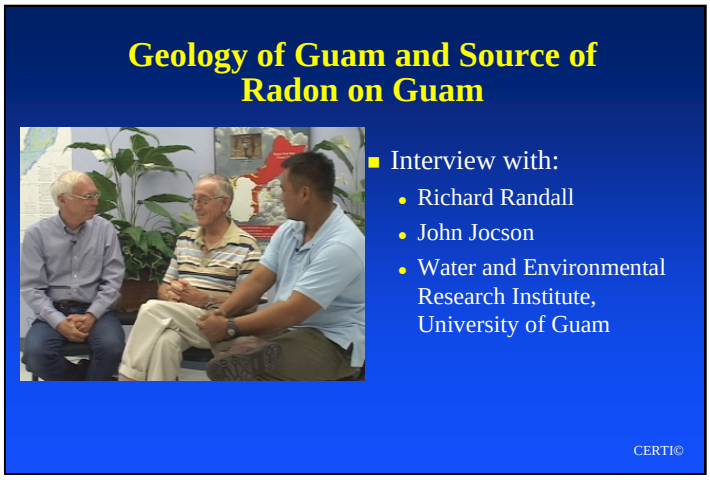


Key Points

- The above chart is a histogram showing the highest radon levels observed within buildings during the school, residential, and public building surveys conducted in the 1990s. The tests were conducted under closed building conditions.
- These measurements do not indicate long-term averages, but rather the radon potential of the building as can be obtained with short-term measurements.
- Through the investigation of US Geological Survey maps, the underlying geology was determined for each building.
- The histogram correlates the radon potential to the underlying geology, or fill, in the case of structures known to be constructed over large amounts of fill such as on the Cabras peninsula.
- The histogram clearly points out that the highest potential for finding elevated radon concentrations can be found in buildings constructed over native limestone.
- Note that the "Y," or vertical axis, has been limited to 25 pCi/L for illustrative purposes. Short-term radon measurements were observed in excess of 100 pCi/L.

- High radon potential is associated with the soil above limestone areas due to atmospheric deposition of uranium bearing dusts from Asia over millenniums
- The use of limestone from quarries for building materials is not a cause for concern
- The uranium deposits leading to radon are **not** associated with atmospheric bomb testing in the Pacific during the 1940's and 50s.

Reading assignment: Download and review the two papers regarding geological origin of radon on Guam



Key Points

General Geology of Guam

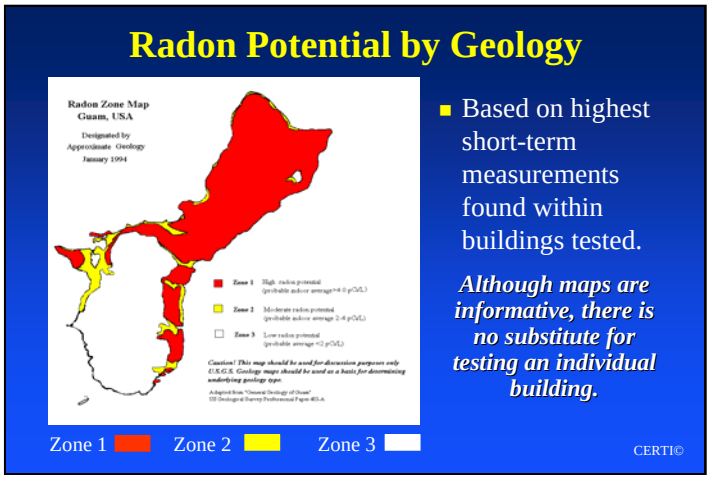
- Guam is roughly 33 million years old and was formed from the release of magma from the earth's crust as were other islands in the Marianas Chain
- Basement rocks are volcanic from underwater eruptions and underlies the entire island.
- When volcanic rises near the surface of the ocean coral reefs begin to form, which led to the limestone formations found on Guam and other similar tropical islands.
- Most limestone found on surface of Guam were laid down during the Miocene and Pleistocene area.
- The northern plateau has risen almost 500 feet.
- No surface drainage on limestone deposits in the northern portion of Guam, which means rainfall easily passes down, causing any deposits on limestone to be captured within limestone cavities
- Southern portion of the island is volcanic and there is surface drainage, causing any deposits to wash off the surface and not accumulate within the underlying structures.

Source:

- Radon source is naturally occurring and not from atmospheric bomb testing
- Volcanic dusts and dusts from other areas within Asia containing Uranium 238 over millions of years.
    - Deposits can be retained in the limestone areas since it is porous
    - Deposits are not retained in volcanic areas where there is surface drainage
    - Causes higher radon potential where soil covers limestone deposits (northern portion and some coasts)

Soil Gas Movement

- Definitions:
    - **Vadose Zone**: area between the water table and the ground surface above. Air moves through this area.
    - **Karst:** Limestone geology that is very porous due to cavities caused by rainwater soaking down and dissolving the limestone.
- Rain acts like a hydraulic piston that displaces soil gas in limestone cavities up and into homes.
- Rainfall can cause water table to increase as much as 5 feet, which means a tremendous volume of radon laden soil gas can be forced up to the surface through porous limestone geology and into buildings.
- Tide can also cause the water table to move up and down and push radon laden soil gas up.
- There are enough variations in source potential that it is recommended that all homes be tested.
- Rain and wind can cause the underlying Vadose Zone to be pressurized and force radon laden soil gas to the surface and into buildings. The variability of radon entry is closely associated to these environmental effects.



Key Points

Given the high correlation between indoor radon and the underlying limestone geology, a radon potential map was constructed on the basis of known limestone formations as well as the results of short-term radon measurement surveys conducted by Guam EPA and its consultants.

The map above divides Guam into three radon potential zones. It was created from data gathered under conditions of short-term, closed-building conditions with test devices on the ground floor of buildings, where radon levels would be expected to be the highest.

Zone 1: High potential of short-term test result being above 4 pCi/L

Zone 2: High potential of short-term test result being between 2 and 4 pCi/L

Zone 3: High potential of short-term test result being less than 2 pCi/L

When predicting radon potential in coastal areas, caution should be taken since not all coastal areas are identified on the map as being limestone formations. Runoff from limestone formations may lead to elevated radon in coastal and beach areas.

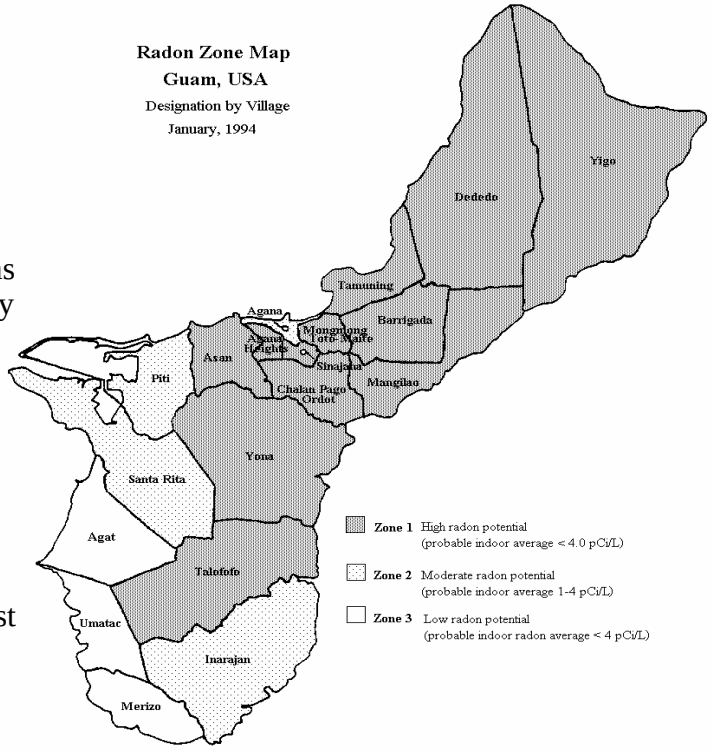
Zone Map by Village

The radon potential readings have been overlaid onto a map of Village Boundaries as a means of recommending what villages may be the most prone to having elevated indoor radon levels.

This does not mean that every home, school or office building in the shaded areas (Zone 1) will be elevated

It does however mean that there is a high enough potential to suggest that:

- Citizens in these areas should definitely test their homes
- New homes should be constructed with radon resistant features



Proximity to Surface Can Impact Radon Potential

GCC JFK Satellite (South)

	Room 123	Room 122		Room 121	Room 120
Average Radon pCi/L	1.67	2.05		21.64	11.15

Native soil line

Imported fills can act as barriers to entry from native surfaces.

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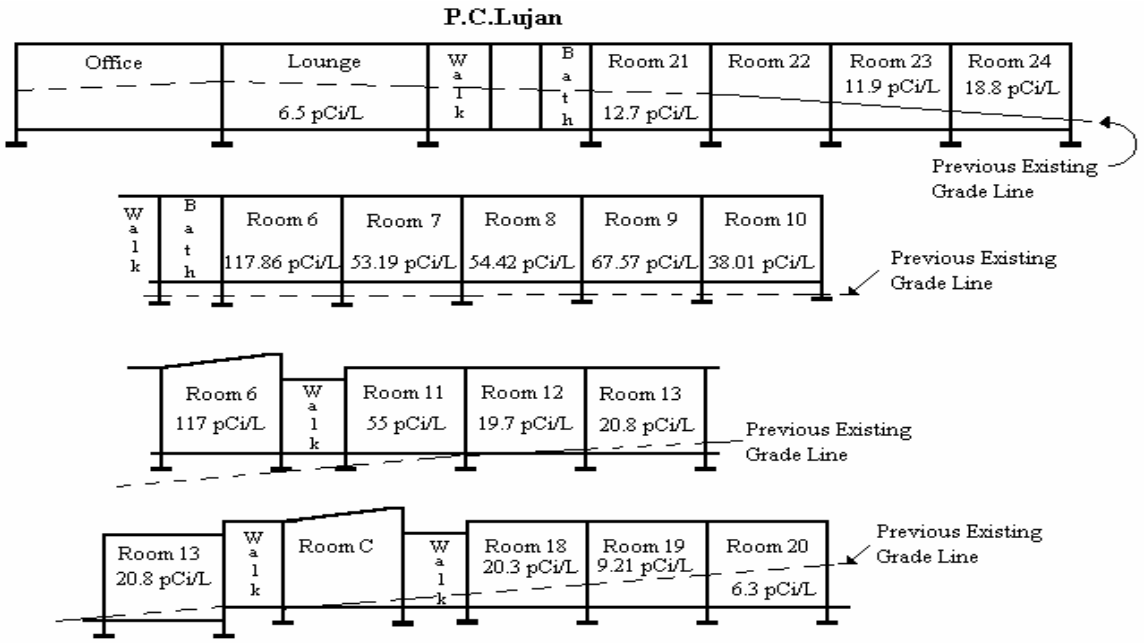
Key Points

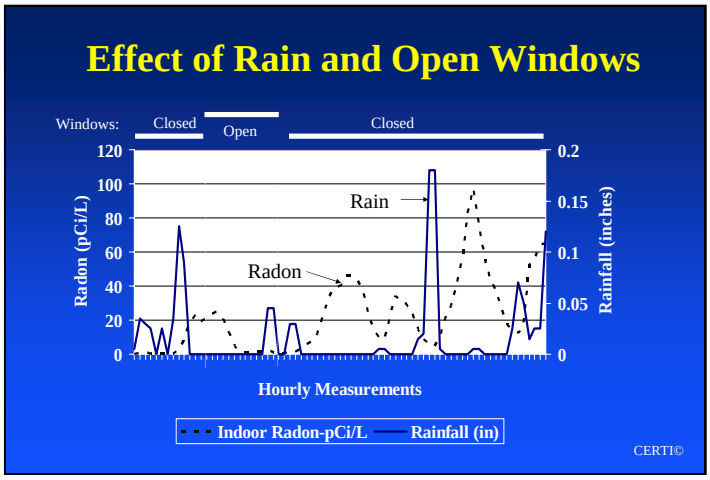
- Radon is emanating from soils on the surface of limestone deposits and being pushed into buildings
- If there is sufficient distance between the native soil and there is low uranium bearing materials in it, the radon may not enter a building.
- If the native soils have been removed during the grading of the lot during construction, the source may also have been removed. (see correlation between cut and fill lines for the school diagrammed below and the radon readings in the rooms above)

It is important to test all ground floor rooms when testing larger buildings such as schools and office buildings



Elevation Sketches Showing Previous Existing Grade Lines and Short-Term Radon Measurements from Aug. 1991

Note correlation between high radon readings and where the native soil grade line is near slab of room, but also where levels fall off if a significant amount of native soil was removed.



Key Points

- The data shown in this graph was collected on an hourly basis. Both radon and rainfall was measured, as well as the position of the louvered windows to the outdoor air.
- When the windows were closed, there was an increase in indoor radon during rainfall. Each rainfall occurrence was followed by an increase in indoor radon (provided the exterior windows were closed).
- There was a sharp decrease in radon when the windows were open and there was a negligible effect from the rain on indoor radon when the windows were open.

The graph shows the significant impact that closing or sealing windows can have on radon levels.

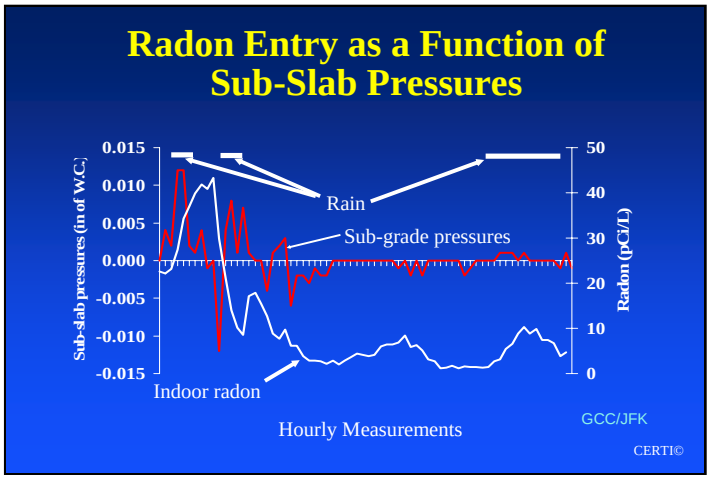
- It is best to conduct a short-term test with louvers closed.
- If the homeowner typically opens louvers for fresh air be sure to do a long-term test
- If the homeowner plans to add air conditioning and seal windows (***recommend retest***)
- The short-term test estimates what the radon levels could be after adding A/C
- Be sure to recommend adding fresh air when sealing building

Traditionally Guam structures have been constructed to allow for significant cross-ventilation

Louvered windows are very common in older structures to allow in light and fresh air, but can be closed during inclement weather or after hours

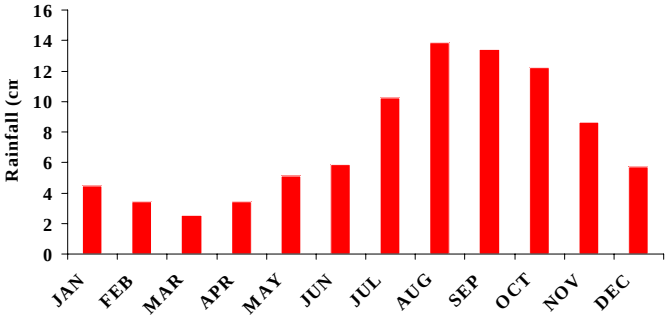
As air conditioning is becoming more common, many of these louvered windows are covered with a clear plastic to allow light to enter but not fresh air.

In high radon potential areas, the addition of air conditioning without adding fresh air make-up can significantly increase indoor radon levels.



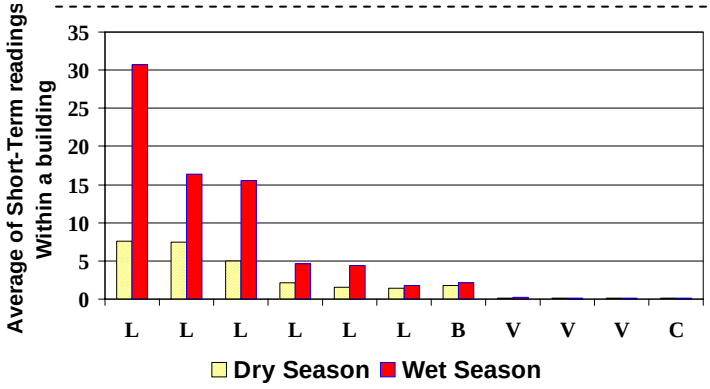
Key Points

- The above graph shows hourly measurements of indoor radon and sub-grade pressures. Periods of rain are also indicated on the graph.
- During periods of rain-induced, sub-grade pressures, radon-laden soil gas is forced into the structure. Such sub-grade pressures are most noticeable during short bursts of rainfall, as is indicated during the early period of the test (left hand side).
- The rainfall that occurred during the latter portion of the test was a more sustained rain, which did increase sub-slab pressures (and hence indoor radon concentrations), but the increase was not as dramatic as with the earlier cloudbursts.
- The amount of sub-slab pressure is also a function of the accompanying wind (if any) and also the direction of the wind.
- Soil pressures can force soil gases into a building and if there is a radon source, such as in the underlying soil in limestone areas, radon can sharply increase.



Guam receives a great deal of rainfall that translates to strong radon entry driving forces and variable indoor radon readings

Rainfall in Guam
Annual Average: 89 in. Max: 139 in. Min: 58 in
Source: Guam NAS, Monthly
Mean from 1948 to 2004



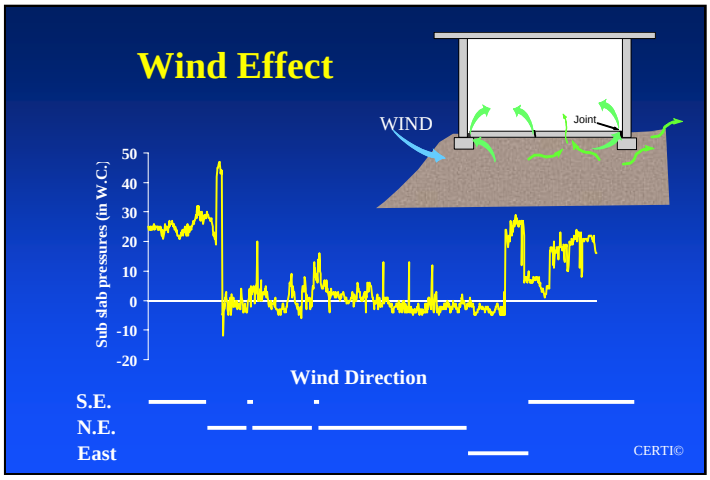
•L = Limestone, B = Beach, V = Volcanic, C = Clay

A comparison of short-term radon measurements conducted in the same rooms of schools, both in the dry season and the rainy season shows:

- Much higher levels in locations over limestone in the rainy season (high radon source)
- Insignificant changes in non-limestone areas (low radon source)

Order of Preference:

1. Long-term tests (Year long preferred)
2. Average of short-term test results from dry season and wet season
3. Single short-term test



Key Points

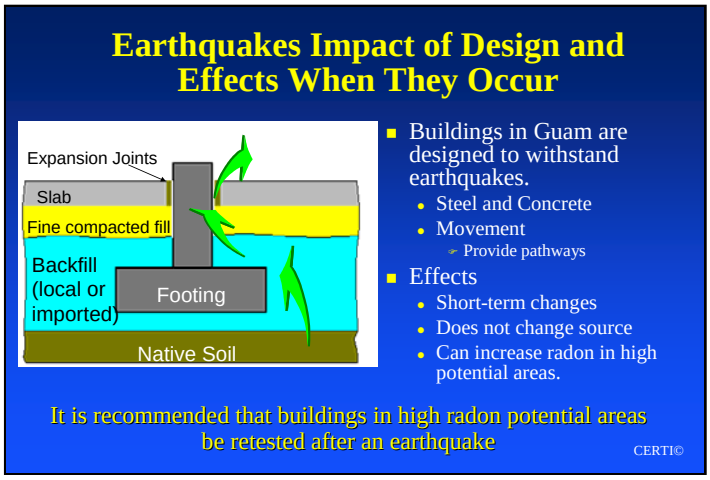
Wind striking the face of a cliff or a hill can exert pressures in the underlying geology. Where the underlying geology is porous, wind and soil pressures can force soil gases into a structure. If radon is being created in the soil or in the geology beneath the structure, soil gases entering the structure can bring radon with them. This in turn can cause short-duration increases (spikes) in indoor radon concentrations.

The above graph shows sub-slab pressures as a function of time. As these measurements were made, the predominant wind direction was noted. Not only can the force of the wind have an effect on soil pressures, but likewise the direction of the wind. In this case, winds from the southeast blew against the side of the hill that the structure was built upon, thereby increasing soil pressures.

	
Cliffs and hills can provide a surface upon which wind can exert soil pressures	Porous limestone or karst geology can provide large pathways for soil gases to move to the surface

"Karst" is a geological term for porous cavities formed by water percolating down through the soil. This process is common in all limestone, including the limestone in Guam.

Wind can cause extreme spikes in indoor radon levels, but only in areas where the radon potential is high

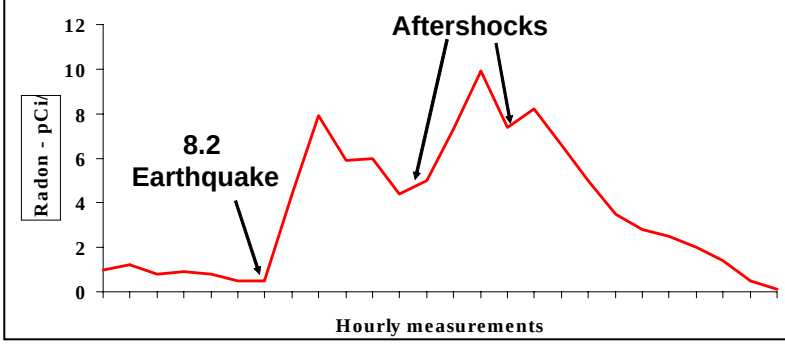


Key Points

Guam buildings are constructed to withstand earthquakes

- Lots of steel and concrete
- Movement of building which allows for many small pathways

Short-Term Effect of Earthquake



The graph on the left provides hourly radon measurements that were made in a room during and shortly after an 8.2 Richter scale earthquake.

The room previously had a low short-term test result.

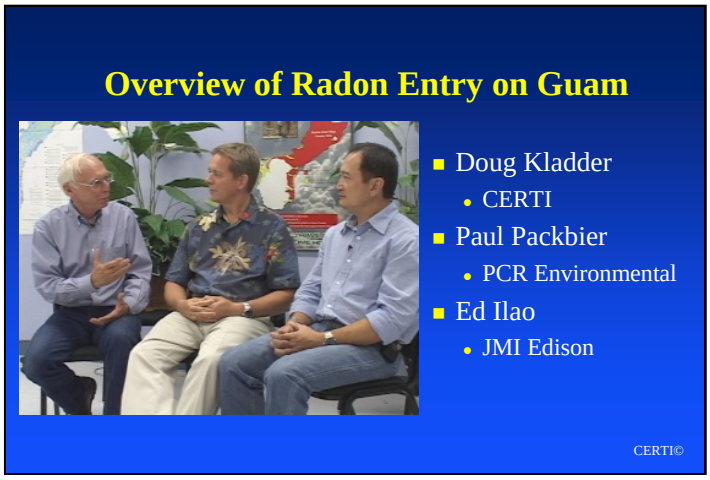
There were sharp increases in radon associated with the initial quake and after shocks. After the quake, indoor levels returned to low levels.

Long-Term Effect of Earthquake

- Short-term radon tests were conducted in several Gov Guam buildings before and after 8.2 Richter scale earthquake
- Buildings constructed over limestone (i.e. high radon potential)
  - Rooms that were elevated before quake remained elevated after quake, unless repair work included upgrading HVAC system with additional fresh air supplied to rooms
  - Several rooms that had not exhibited high radon levels, were elevated after the quake. That is increased radon pathways and entry points
- Buildings not constructed over limestone (i.e. low radon potential)
  - No increase in indoor radon levels due to quake.
  - Quake did not alter the radon source in the underlying soil or geology.

An earthquake does not alter the radon source beneath the building but can change pathways

It is recommended that buildings in high radon potential areas be retested after an earthquake



Key Points

Interesting Stories:

- The cap of a 12 inch wide exploratory well that went down roughly 500 feet was removed. Air from within the well blew out of well with such a high force that it blew one's hair back. "It was like the air pushed from a subway tunnel as the train is coming" The well was ½ mile inland from coast.
- With a micromanometer measuring the pressure differential across a slab, one could see pressure spikes whenever the wind blew

Variability of Radon Measurements

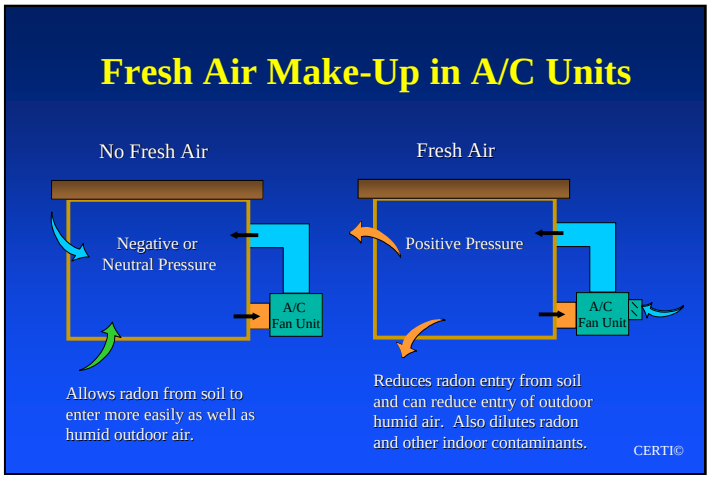
- In same subdivision – wide ranges from near zero up to over 300 pCi/L, with same style of home construction.
- Primarily environmental factors causing soil pressures via natural pathways, although mechanical systems can cause entry as well

Pathways & Construction:

- Radon laden soil gas follows path of least resistance. i.e. limestone solution cavities
- Buildings are constructed with highly compacted fill beneath slabs. However, utility lines and conduit are typically laid into a trench before compaction and since contractors do not want to break these lines during compaction they typically do not compact the fill within these trenches as much as other parts of the sub-grade. Consequently, these trenches that typically are around the perimeter of the home provide a pathway for radon movement, but also a place where the application of an active soil depressurization system may be the most effective.
- Floor drains also can be an entry point if they communicate with the soil and especially if the P-traps dry up. Floor drains that connect to septic tanks with dry traps can not only be a pathway for sewer gases but also radon, since the tank is connected to a leach field.

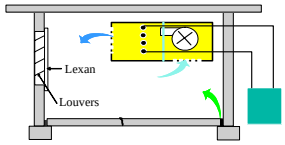
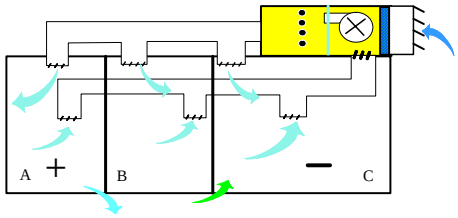
Can radon be reduced?

- Can homes with even 200-300 pCi/L can they be fixed? ***"Yes, most definitely!"***



Key Points

- Buildings on Guam are either operated with many windows fully open (other than in inclement weather) or have air conditioning.
- Buildings on Guam are very tight (0.1 air change per hour or less)
- A small amount of fresh air make-up can significantly reduce radon
- Unbalanced systems or where exhaust fans withdraw air without make-up air can increase radon

 **Split Units**	 **Central Units for Large Buildings**	 **External Package**
• Coil and fan treat individual rooms • Typically no fresh air provided	• Treat several rooms • Typically provide fresh air • Air flows can be unbalanced causing one room to elevated where another is not • All ground floor rooms of large buildings with central A/C should be tested simultaneously	• Package unit outside • Can be provided with fresh air make-up • Condition of ductwork can impact radon

Advantages of Fresh Air Make-up

- Radon
  - Retards radon entry by pressurizing building
  - Dilutes radon
- Moisture
  - If buildings are under negative pressure due to exhaust fans, etc., outside air will enter structure
    - Water from moist outdoor air will condense on interior surfaces cooled by A/C
    - Can lead to mold
  - If air is brought in through air conditioning system, moisture is removed prior to entry because it is passed over A/C coils and can reduce mold potential.

Impact of Closing or Disabling Fresh Air Make-up Inlets

Damper Closed

Inlet Sealed

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Key Points

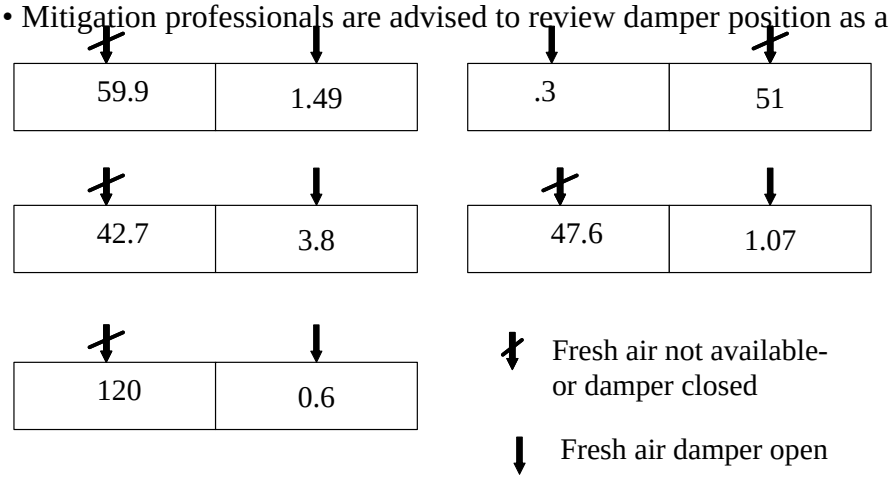
- Fresh air inlets and dampers are sometimes shut
  - Belief that it will reduce energy bills, but more outdoor air will infiltrate increasing interior condensation and potential mold problems
  - Temporarily during typhoons and then not opened afterwards
  - A/C unit is undersized and occupant wants maximum cooling.
  - Become clogged with debris

Clogged Inlet

Impact of disabling fresh air make-up

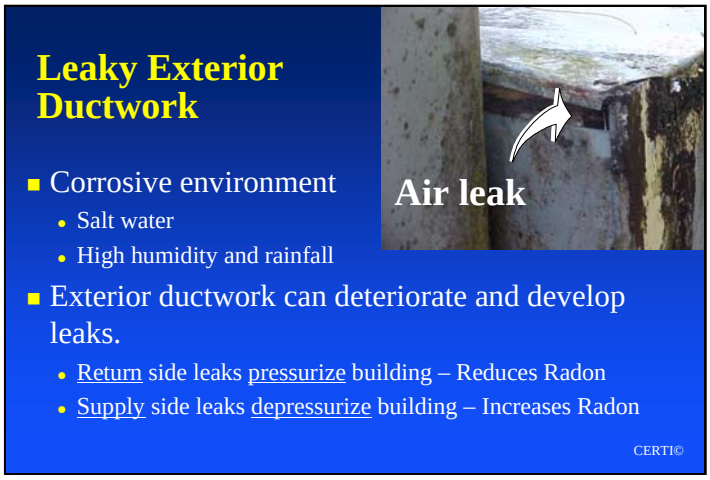
The figure below is of five buildings located over high radon potential limestone formations.

- Each building consisted of two adjacent duplexes built identically and resting upon the same soils.
- Radon measurements for each of the duplexes are shown in each box in units of pCi/L.
- The position of the fresh air damper is indicated by the arrows. If the damper was closed there is a hash mark through the arrow.
- There is a dramatic difference in radon measurements between adjacent units as a direct function of the position of the damper.
- Measurement professionals are advised to note positions of dampers, if they exist when conducting measurements.
- Mitigation professionals are advised to review damper position as a part of their diagnostic exercise.



Important Note:

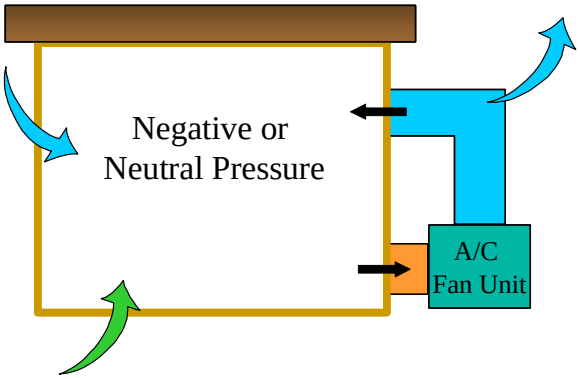
If one tested a building in a high radon area and the result was low because of a properly opened damper, radon levels could sharply increase in the future if the occupant closes the damper or it becomes clogged with debris.



Key Points

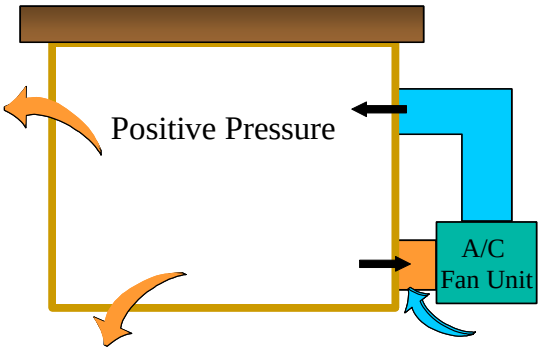
Leaks in Supply Ductwork

- Ductwork that supplies conditioned air to building
- Causes building air to be exhausted outside
- Creates severe negative pressure inside, increasing radon entry
- Causes loss of conditioned air and additional entry of moist outdoor air into building leading to mold concerns.
- Leaks can be at:
  - Ductwork seams and edges
  - Boots connecting air handler to ductwork.



Leaks in Return Ductwork

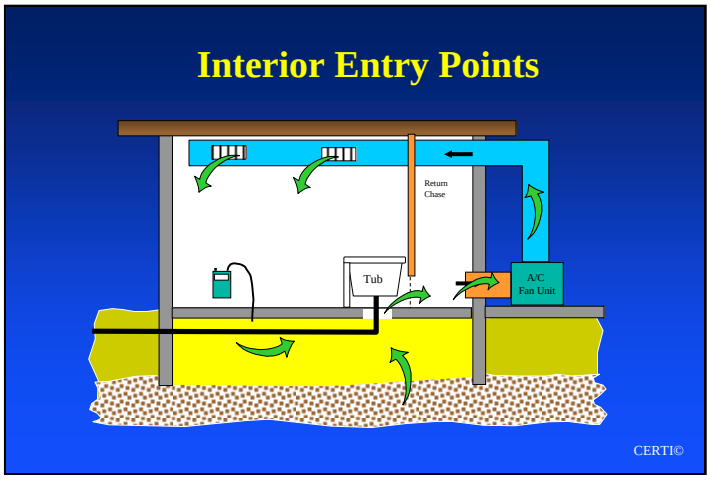
- Ductwork that extracts air from building and returns it to the air conditioning unit
- Draws outdoor air in
- Can pressurize the building thereby reducing radon entry and dilution
- Can increase load on air conditioner
- Leaks can be at:
  - Ductwork seams and edges
  - Boots connecting air handler to ductwork.



Important Notes

Radon levels in a building with ductwork that deteriorates could significantly change in the future if ductwork deteriorates after test or if ductwork that was deteriorated at the time of the test is later fixed. Recommend re-testing periodically and after ductwork repairs are made in buildings with exterior ductwork and located in high radon potential areas.

Deteriorated supply ductwork could negatively impact the effectiveness of an active soil depressurization system.



Key Points

- Slabs are not always poured continuously without openings to the soil (often hidden behind walls)
- Block-outs are provided for:
  - Tubs and showers
  - Plumbing lines, etc.
- Soil pressures can force radon laden soil gas up through these openings
- If return of interior A/C unit communicates with slab opening radon can be drawn in.

Block out for tub shown during construction

View of gap under bathtub viewed through return air duct chase

- Openings in slab provide entry point.
- If return air side of air conditioner is in chase area which communicates to these potions of the slab, radon can be extracted and supplied into the building.

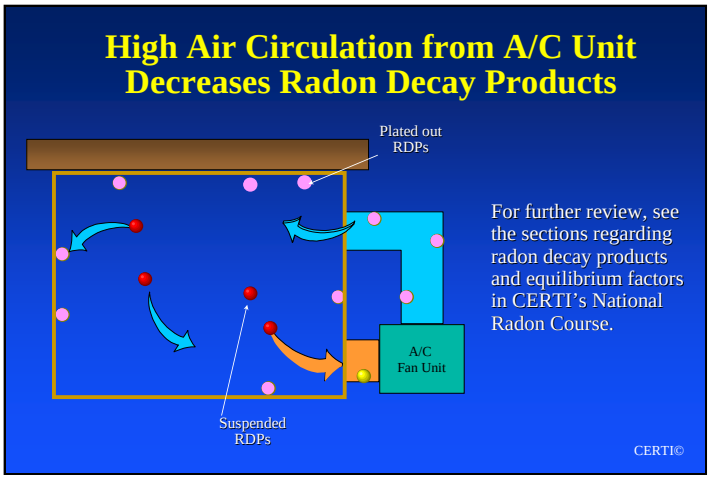
Important Notes:

Measurement Professionals:

- Radon levels could change as a function of the frequency of operating an A/C unit
- When testing a vacant house, the A/C unit should be turned on to identify these concerns.

Mitigation Contractors:

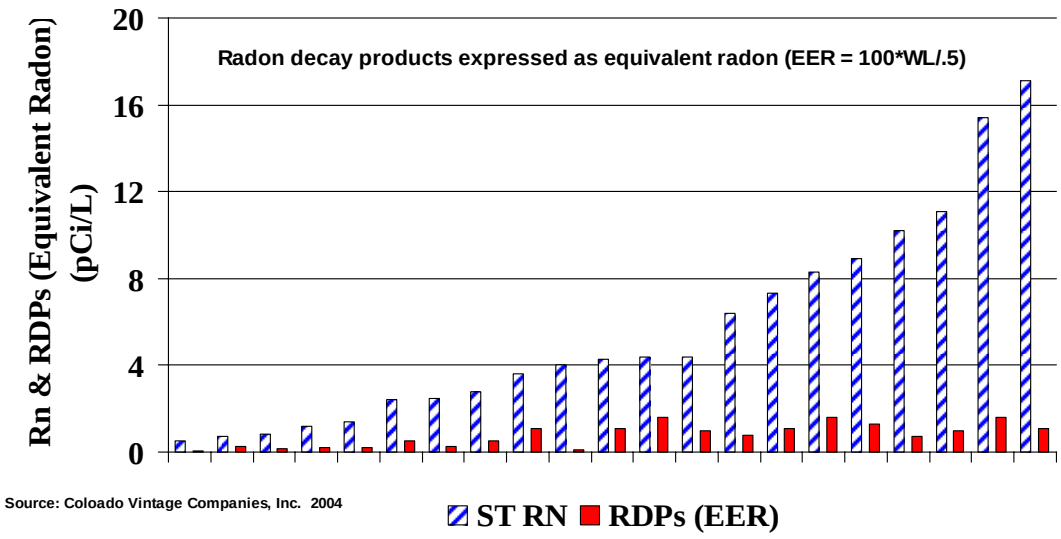
- An active soil depressurization system may not be able to overcome entry from these locations IF the return side of the A/C unit is drawing upon them.
- These openings should be sealed as a part of new home construction



Key Points

- Radon decay products represent the actual risk associated with elevated indoor radon
- The percentage of radon decay products **(RDPs)** actually available for inhalation is expressed as the equilibrium factor.
    - In the mainland U.S. it is assumed that the percentage of RDPs is 40-50%
    - Air circulation and the absence of air borne particles will reduce the percentage of RDPs in the air and hence the actual exposure health risk for a given level of radon gas.
        - Note that although overall risk goes down as the equilibrium factor decreases, the risk reduction may not be reduced proportionately due to higher unit risk factors associated with smaller size ranges of radon decay products attached to small aerosols (sometimes referred to as unattached fraction)
- In Guam windows are either open most of the time (low radon), or air conditioning systems operate essentially continuously. This increases plate-out of radon and hence (low radon decay products)
- The following graph depicts the results of simultaneous short-term measurements of radon and radon decay products in Guam .
    - RDPs are significantly reduced by operation of A/C units and cleaner ambient air (tropical area -- no smokestack industry).

Simultaneous Radon & Radon Decay Product Measurements
(Conducted in 21 Guam Residences



Source: Coloado Vintage Companies, Inc. 2004

Measuring Radon and Radon Decay Products

- Simultaneous deployment of
  - Radon measurement device (pCi/L)
  - Radon Decay Product Measurement Device (WL)
    - Available at Guam EPA
- Conduct test with A/C ON.
- Limited to short-term testing
  - Experimental devices available for long-term, passive measurements

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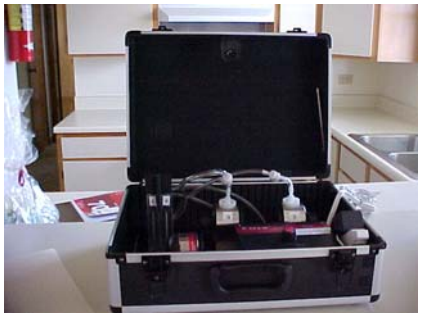
Key Points

Instrumentation:

Co-located continuous radon monitor (CRM) and continuous radon decay product measurement device (CWLM)

Provides hourly readings



Electret Radon Progeny Integrating Sampling Unit (ERPISU)

Provides average results of radon and RDPs for 2-3 day test

Long-term Electret (Radon) with LR-115 (Radon Decay Products).

Provides long-term average of Radon and RDPs.

Experimental!

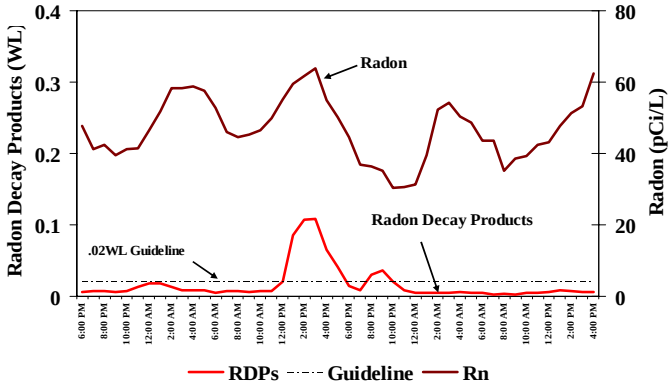
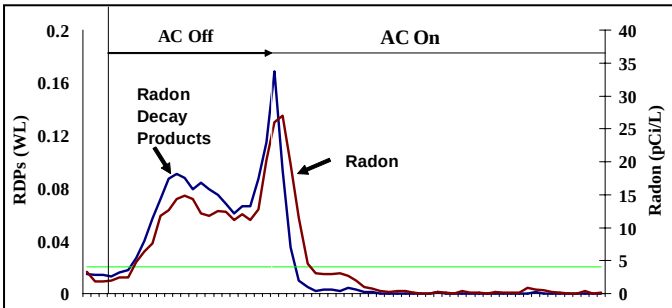


Illustration of Low RDPs

- Hourly measurements of radon and RDPs.
- RDPs much lower than expected
- Spike was due to vacuuming carpet
- Radon: 46.9 RDPs: 0.017 EF: 4%



Effect of Fresh Air make-up and Circulation on RDPs

Radon and RDPs with A/C ON and OFF

	RN (pCi/L)	RDPs (WL)	% RDPs (EF)
A/C OFF	10.8	0.1	59%
A/C ON	0.8	0.001	9.0%

Key Points

Air Conditioning Systems can have a significant impact on indoor radon!

Major Lifestyle/Building Changes

- Since late 1980s air conditioning has become very common. Even though A/C was provided with fresh air, many users close fresh air dampers with false understanding that this would reduce energy cost
- More recently, split A/C units are being installed with no provision for fresh air
- The incidence of radon induced lung cancer may increase, now that more Air Conditioning is being installed in a manner that significantly reduces natural ventilation.

What are implications of closing off fresh air make-up?

- Moisture laden air still enters building where it can condense on surfaces and lead to mold growth
- Closing off fresh air does not decrease cooling costs.

Interesting Story:

- Highest levels of radon were found in the second story bedroom and during occupied periods. Air conditioning was only turned on when occupants were present. Radon spikes correlated with Air Conditioning system being on (determined by use of Continuous Radon Monitor)
- *Finding:* Return duct of air conditioning system was within a plumbing chase that had exposed soil at its base. Leaks in return duct drew radon laden soil gas into ductwork and supplied it to the upstairs bedrooms, when A/C was on.

Other Sources of Radon?

- Building materials and radon from water, to date, **have not** presented themselves as significant sources of indoor radon. Radon laden soil gas is the primary source of indoor radon

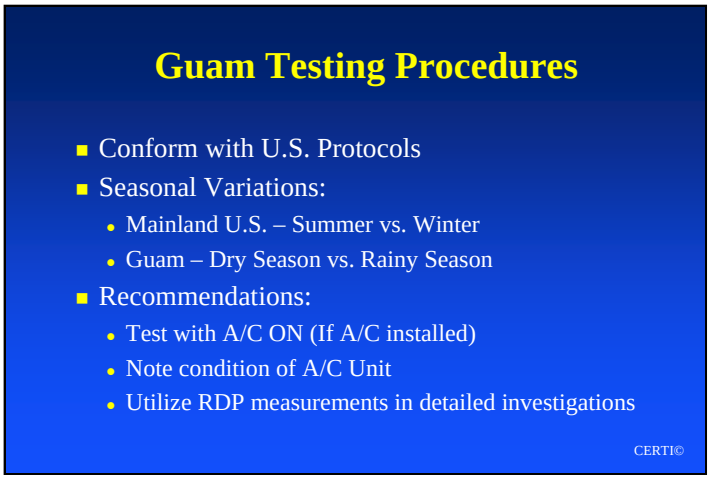
Radon Decay Products

- Clean air and almost constant use of forced air conditioning systems reduce equilibrium factor
- 10% equilibrium factors are common on Guam, as determined when simultaneously measuring radon and radon decay products.

Measurement Approaches

- Conduct short-term tests with air conditioning on.
- Fresh air make-up damper closed presents an worst case scenario. If fresh air damper is closed during test, note this in report and recommend that it be opened, or conduct a second test with it open to provide a comparison.

1



Key Points

Follow Mainland U.S. Protocols

- **Short-term Testing**
  - All exterior doors and windows closed other than normal entry and exit.
  - If no air conditioning this will be difficult – consider long-term testing under normal lived in conditions
  - If results are obtained with long-term tests and open windows, advise client that they should retest if A/C is added
  - Recommend second short-term test in opposite season as first one.
    - Average wet season and dry season results, or preferably do a long-term test.
- **Long-term Testing**
  - Preferred over short-term due to high variability of radon levels
- **Interpreting Measurements**
  - Radon entry is highly variable on Guam
    - Be cognizant of weather conditions during test – especially short-tem
    - Re-test if test was conducted during power outages, typhoons, tropical storms
  - Suggest retesting after:
    - Earthquakes
    - Modifications of
      - Building
      - HVAC system
      - Addition of A/C
      - Repair of A/C
- **Radon Decay Product Measurement**
  - Measure radon and radon decay products simultaneously
  - Radon indicates potential
  - RDPs indicate actual exposure
  - Look for reasons why RDPs may be low such as A/C, air cleaners, etc.

Key Points

Interpreting Radon Measurements on Guam

- **Short-Term Testing**
  - Really only reflects the radon potential
  - Better to average short-term results from two tests, with one test being conducted in the wet season and the other during the dry season
    - 1994 study showed average short-term radon measurement during dry season were 49% lower than measurements conducted in the same locations during the wet season.
  - Note there can be rain spikes even in dry season, when short downpours occur
  - Used for real estate transactions, but with two collocated passive devices with results averaged.
- **Long-Term Testing**
  - Preferred unless time is of the essence
  - Good practice to recommend long-term after a short-term test indicates elevated potential
- **Guam EPA Technical Resources**
  - Analytical Equipment: activated charcoal lab, E-Perm system, radon decay product measurement devices

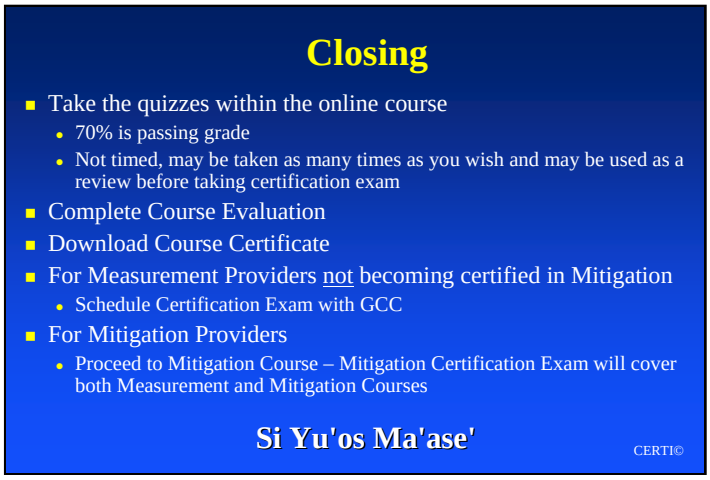
- **Guam EPA Listing Requirements**
  - Initial
    - Obtain national certification for radon measurement and/or mitigation
    - Complete this Guam specific course and pass exams for measurement and/or mitigation
  - Maintain Guam EPA Listing:
    - Provide quarterly reports to GEPA
      - Test results
      - Mitigation (existing or RRNC)
      - Provide pre and post results
      - Indicate village but not street address (maintains client confidentiality)
    - Maintain national certification including continuing education as required by certifying body

Key Points

- **Military Testing**
  - Military periodically retests housing units - Many housing units on base have radon mitigation systems
- **Private Sector**
  - Demand is often associated with public outreach efforts by Guam EPA - Support GEPA outreach efforts!
- **Testing at the Time of Real Estate Transactions (Moe Cotton – Century 21)**
  - Currently, there no legal requirements to test a home at the time of sale
  - Radon included in Environmental Concerns Class that Guam realtors must attend
  - If buyer wants a house tested for radon, then the buyer can request it.
  - Radon would be included as an environmental hazard on the property disclosure form
  - Architects and builders are starting to voluntarily provide passive radon systems in new homes
  - *"If I was a buyer I would request a test so I would know the house is safe"*
  - Long-Term test is preferred but with timing of real estate transaction may not be practical:
    - Conduct two side-by-side short-term measurements
    - Follow-up with long-term measurement and perhaps consider escrowing funds for mitigation to be released based upon results of long-term test
  - For those planning to conduct radon measurements and mitigation on Guam, the real estate community is a key part of your market.
    - Get to know the real estate community - Realtors® - Lenders - Relocation firms
    - Be a problem solver
    - Be prepared to answer many of the questions that Mr. Cotton asked during the interview.
    - Clean air in Guam is a selling feature and helps reduce radon decay product exposure.

Key Points

- Radon is definitely a concern on Guam
- It is estimated that roughly 27% of homes on Guam are at or above the Guam EPA's and the U.S. EPA's recommendation for long-term exposure of 4 pCi/L.
- Several homes have been found on Guam that are several times higher than the 4.0 pCi/L guidance.
- Indoor radon levels are predominantly associated with buildings constructed over limestone, but it is recommended that all homes be tested regardless of their location.
- The source of radon found in surface deposits is not from atmospheric bomb testing or other manmade occurrences
    - Source materials predate nuclear era
    - Source has resulted from millions of years of surficial deposition
    - Uranium 234 vs. 238 (i.e., totally different form of uranium than would be found from nuclear activities)
- Radon levels can be extremely high vary significantly as a function of weather
- Radon entry is due to pressures in the soil caused by rain and wind
- Air conditioning systems can have a very significant impact on indoor radon levels (both good and bad).
- High air circulation caused by presence of A/C units can beneficially reduce radon decay products, even when the indoor radon levels may be elevated.
- U.S. EPA protocols are still utilized
    - Need to interpret effects of:
        - Environmental factors
        - Air Conditioning system



Key Points

To conduct the online coursework, do the following:

- Go to **www.certi.us**
- Click on "Radon Training"
- Click on "*CERTI University – Conduct Coursework*"
- Log in with your Username and Password provided when you purchased the course
- Click on the course title
- Review Case Studies and Resource Materials
- Complete Quizzes
- Download your Course Certificate

Measurement Providers:

If you are planning to become certified as a Measurement Provider only – not providing Mitigation services – Schedule your Certification Exam through Guam Community College

Mitigation Providers:

If you are planning to become certified either as both a Measurement and Mitigation Provider or just a Mitigation Provider – Proceed to the Guam Specific Mitigation Course. The Guam Specific Mitigation Exam will cover both the Measurement and Mitigation Courses.

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Special thanks to:

Guam EPA for research they have sponsored since the early 1990s that has led to the understanding we have of radon entry factors and mitigation approaches for Guam.

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Si Yu'os ma'ase'