Radon Measurement Methods and Devices – An Overview

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Disclaimer

In no way does the inclusion in, or exclusion from, this presentation of any specific device indicate a recommendation, like or dislike, or any manner of opinion regarding any device.

Introduction

- Radon testing in homes and buildings not associated with licensed radiological operations should be done by trained and certified radon testers.
- All devices (evaluated and approved) for measuring radon in air have their pros and cons; none are perfect and none are worthless.

Six Categories

- "Passive" Devices:
  - Activated Carbon
    - Gamma spectroscopy
    - Liquid scintillation spectroscopy
  - Alpha-track devices
  - Electret ion chambers

Six Categories

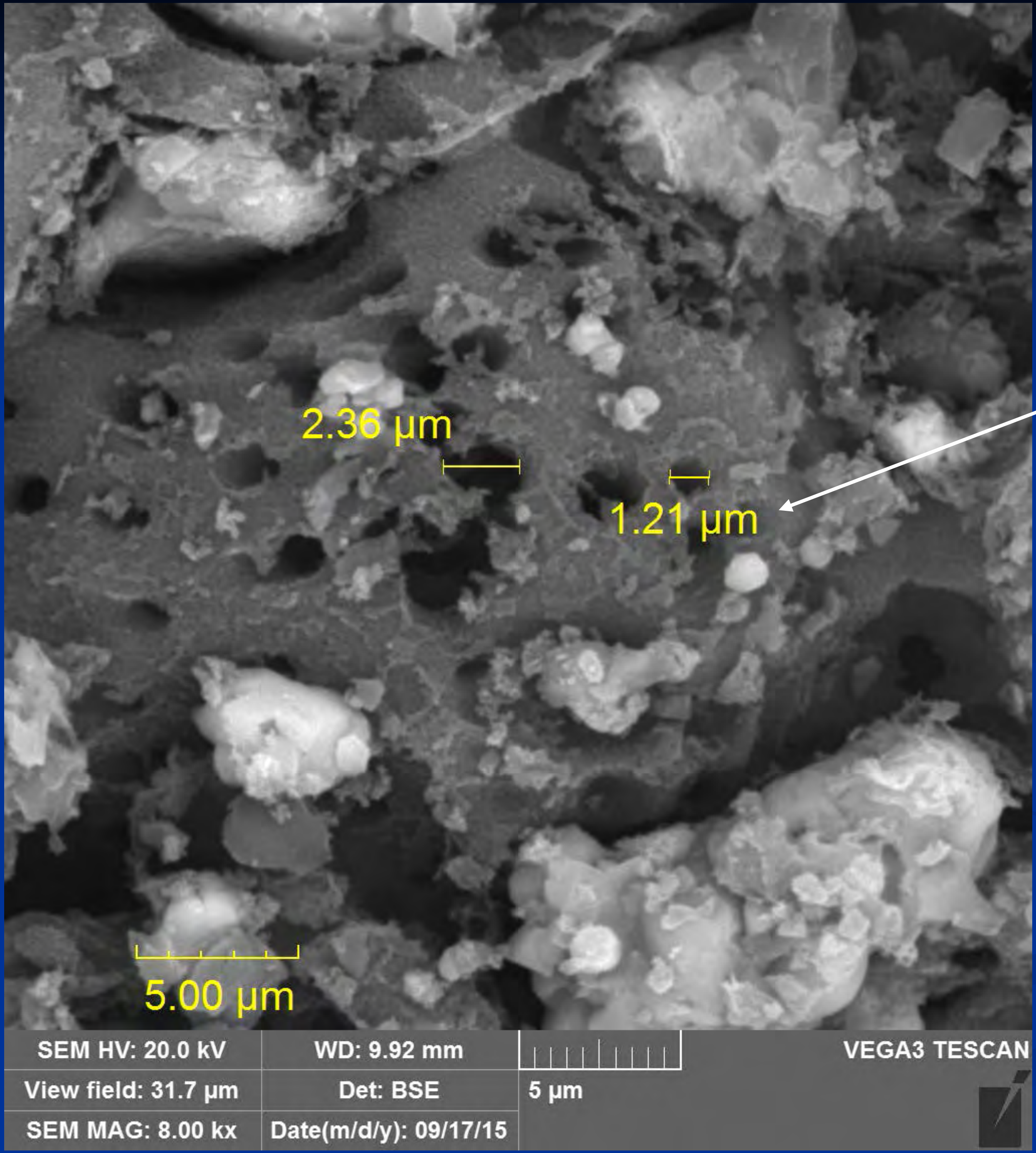
- "Active" Devices:
  - Scintillation cell
  - Ion chamber
  - Solid-state detector

“Passive” Devices

- Analyzed in laboratory after the measurement period; results not immediate
- One measurement; average over period
- Relatively inexpensive
- Devices not calibrated individually; process is calibrated by exposing groups of like devices in a radon chamber (similar to personal dosimeters)
- QC: blanks, duplicates & spikes

Activated Carbon

- The principle of operation is passive adsorption of radon from ambient air onto the carbon.
- Each grain of activated carbon has an enormous number of "adsorption sites."
- At typical indoor temperature, radon is not held strongly, so radon constantly adsorbs & desorbs.



About 3000 times the diameter of a Rn atom.

Activated Carbon

- Moisture competes with adsorption and is held more tightly than radon, thus the calibration is affected by humidity more or less so depending on the design of the device.
- Also, the higher the temperature in the surrounding air, the less radon is adsorbed.

Activated Carbon

- The activity of radon on the carbon tends toward an equilibrium condition with the concentration of radon in the surrounding air.
- If the radon concentration in the air changes, radon adsorbs or desorbs to seek equilibrium.

Activated Carbon

- Because the adsorbed radon constantly decays, the measurement is somewhat biased toward the last twelve or so hours of the exposure.
- Best results for achieving a good estimate of the average concentration is when the radon concentration is relatively constant or cycles consistently.

Activated Carbon

- Calibration: groups of devices exposed in a radon chamber to controlled conditions of temperature & humidity for several times periods.
- Calibration curves or equations developed to determine calibration factor, usually as a function of time of exposure and mass of moisture adsorbed during the exposure.

Activated Carbon

- Gamma-ray spectroscopy: Analysis is done by measuring gamma rays emitted by the radon progeny ^{214}Pb & ^{214}Bi.
- Liquid scintillation spectroscopy: The radon is transferred to a liquid scintillant; alpha particles emitted by ^{222}Rn, ^{218}Po & ^{214}Po, and perhaps beta particles emitted by ^{214}Pb & ^{214}Bi, are detected.

Examples: Activated Carbon Devices

Canisters, Bags, Trays: analyzed by gamma spectroscopy

Analyzed by liquid scintillation spectroscopy

Alpha-track Devices

- Alpha particles passing through some plastics cause damage, or a latent image, in the structure of the plastic.
- When the material is etched in a strong caustic solution, the damaged volume dissolves faster than the undamaged material, thus forming a track or pit.
- Tracks are visualized using a microscope and counted usually by automated scanning.

Alpha-track Devices

- The most common materials are cellulose nitrate (LR-115) and allyl diglycol carbonate (CR-39).
- The latter material is commonly used in a conductive housing or chamber, into which radon passively diffuses.
- Alpha particles from ^{222}Rn, ^{218}Po & ^{214}Po create tracks over an exposure period of several days to several months.

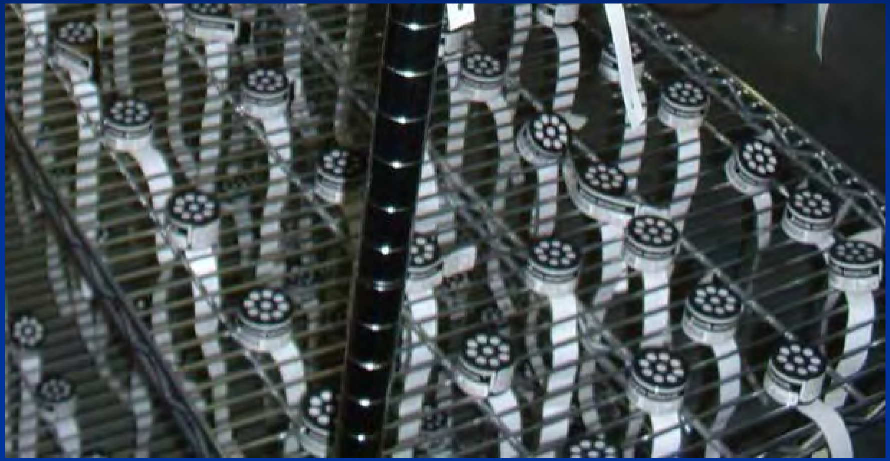
Alpha-track Devices

- The track density (tracks/mm^2) is directly related to $\int C\,dt$; the integral of radon concentration over time in Bq-h/m^3 (pCi-days/liter).
- For high exposures, overlapping tracks can get missed by scanning device, but a correction can be applied similar to a “dead time” correction.

Alpha-track Devices

- Calibration: like devices are exposed in a radon chamber for desired periods of time from days to weeks.
- Devices are not affected by temperature & humidity typically found in indoor environments.

Examples: Alpha-track Devices



Alpha Tracks in CR-39

Electret Ion Chambers

- An electret is a positively charged disk, typically of Teflon.
- The electret is attached to an electrically conductive enclosure or "chamber."
- Radon passively diffuses into the chamber and subsequently it and its progeny decay causing ionization in the air inside the chamber.
- Electrons are attracted to the electret and partially discharge it.

Electret Ion Chamber

- The potential (voltage) on the electret is measured before and after the exposure.
- Through calibration, the decrease in surface potential is related to the total exposure in Bq-h/m^3 (pCi-days/liter).
- The device also responds to ambient gamma, so this must be taken into consideration.

Examples: Electret Ion Chambers

“Active” Devices Continuous Radon Monitor (CRM)

- Measurements in real time
- Hourly measurements
- Relatively expensive
- Calibrated individually

CRM: Scintillation Cell

- A scintillation cell is a container, usually a cylinder, whose interior is coated with zinc sulfide (ZnS), except for the “end window.”
- When an alpha particle strikes ZnS, it scintillates.
- The end window is in contact with a photomultiplier tube which detects the scintillation, creates an electrical pulse and amplifies it.

CRM: Scintillation Cell

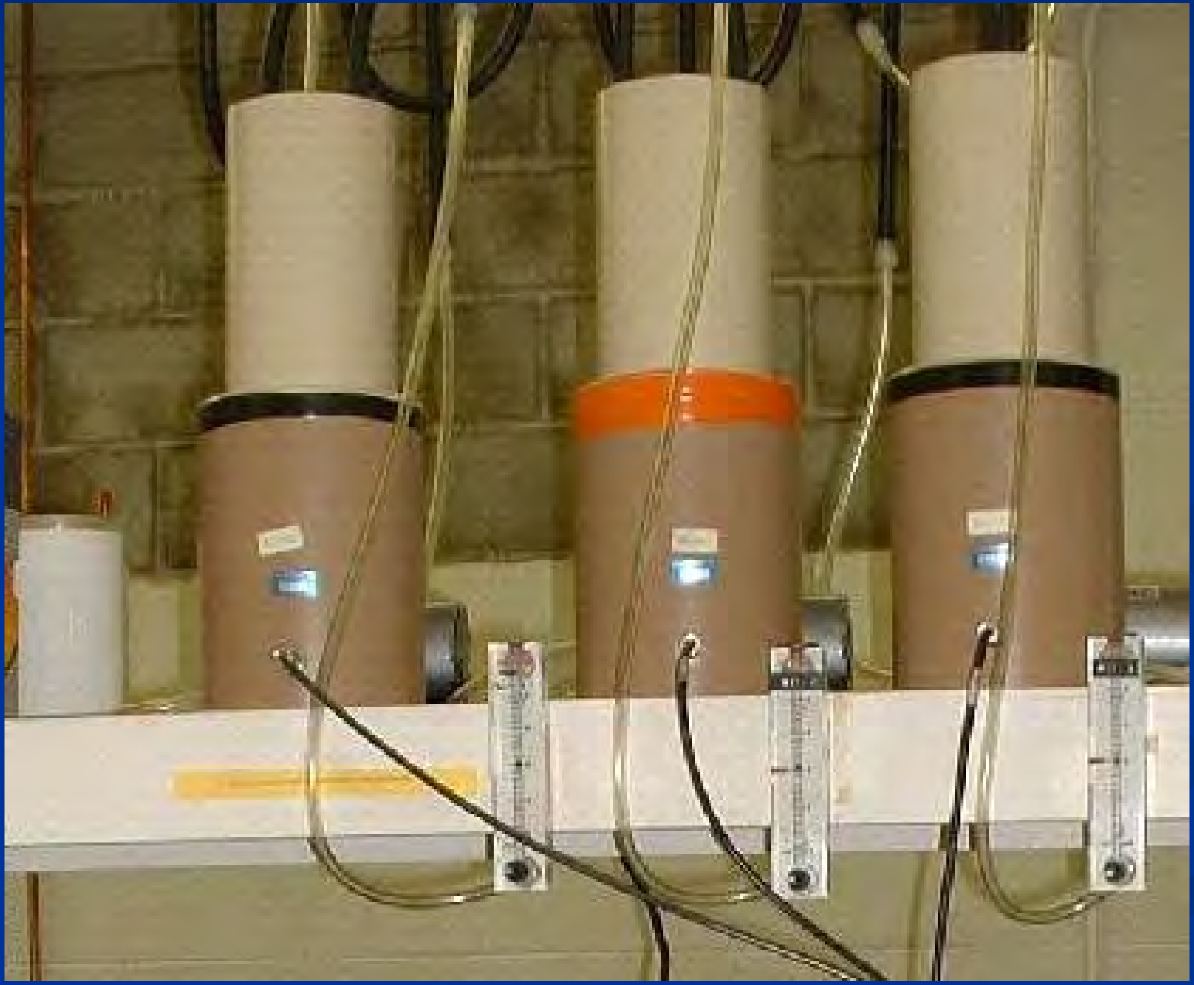
- Further electronics amplify and count the electrical pulses corresponding to alpha particles from ^{222}Rn, ^{218}Po & ^{214}Po striking the ZnS.
- The net count rate of these pulses is related to the concentration of radon in the scintillation cell.
- Radon can be pumped through the cell or it can passively diffuse into the cell depending on the design.

CRM: Scintillation Cell

- Calibration is accomplished by exposing the monitor to a known concentration of radon in a chamber, or pumping radon from such a chamber through the cell.
- Calibration typically done annually.
- The background count rate of the scintillation cell(s) may have to be evaluated more often than annually.
- Scintillation cell method also used for grab measurements.

Example of CRM with Scintillation Cell

Example of Custom CRM with Scintillation Cells



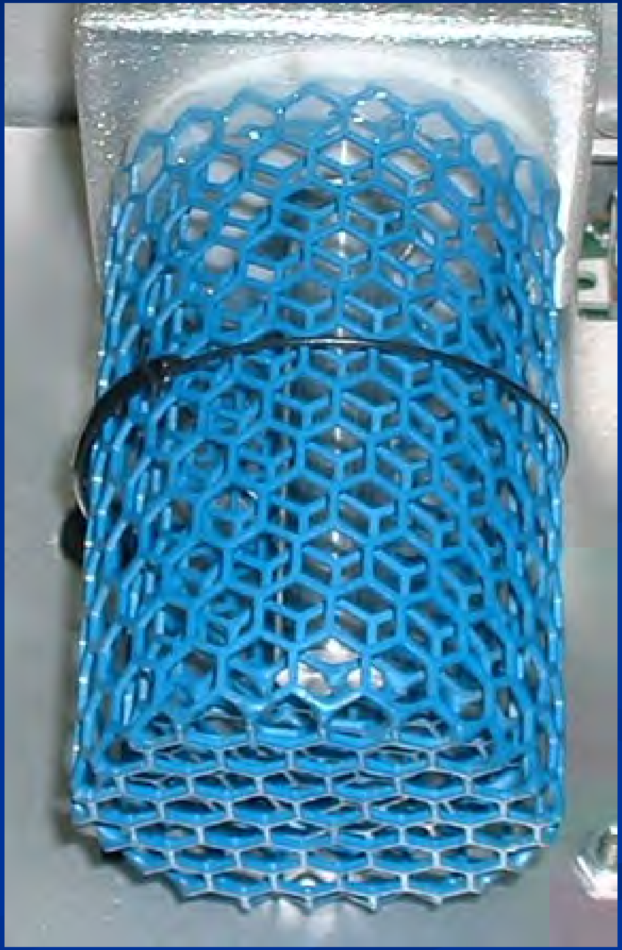
CRM: Ion Chamber

- An ion chamber is a metal enclosure, usually cylindrical, that defines a sensing volume.
- An electrode, usually in the form of a wire or rod, is in the middle of the chamber.
- An electrical potential is placed between the middle electrode and the wall of the chamber.
- When an alpha particle passes through the chamber, it ionizes the air.

CRM: Ion Chamber

- Positively charged ions are collected on the negative electrode, and negative electrons are collected on the positive electrode.
- This collection of ions is detected as an electrical pulse.
- Electronics shapes, amplifies and counts the pulses.
- The net count rate is related to the concentration of radon in the sensing volume.

Examples of Ion Chambers



Examples of Ion Chamber CRMs

CRM: Solid-state Detector

- Usually has some form of “chamber” with electrically conducting surface defining a sensing volume.
- Air can be pumped into chamber or may passively diffuse into chamber, depending on design.
- Usually has an electrical potential between the surface of the chamber and the detector.
- Detector may be a diode or diffused junction detector or something similar.

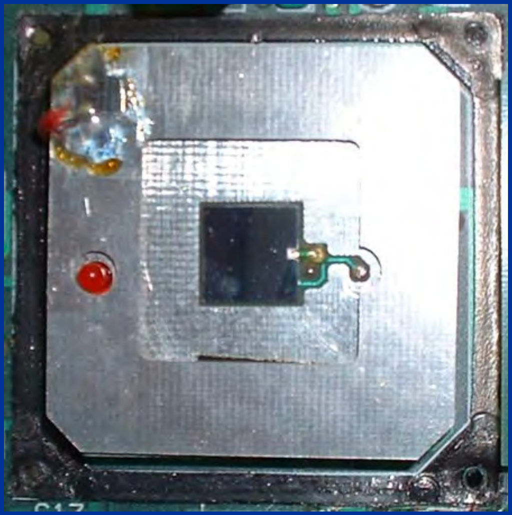
CRM: Solid-state Detector

- Radon in the chamber decays, creating positive charged ions of ^{218}Po.
- Positive ions are attracted to the surface of the detector which is negatively charged.
- The detector senses alpha particles from ^{218}Po & ^{214}Po, to a less extent from radon itself, that strike it.
- Electrical pulse is generated by the detector and then amplified, shaped and counted by the electronics.

CRM: Solid-state Detector

- The monitor stores and/or prints periodic measurements, usually hourly.
- Most models use "gross alpha" counting, no energy discrimination.
- Some use a high quality detector to determine energy of alpha particle, thus achieving alpha spectroscopy.
- Some require a desiccant to overcome humidity effects.

Example of Solid-state Detector



Examples of CRMs with Solid-state Detectors

Thank You for Your Attention

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