TENORM – A Premier for Industrial Hygienists

HE SURVIVED THE WOLF, BUT THE TENORM GOT HIM!
Presentation Topics

- Cliff Notes Rad Fundamentals
- NORM and TENORM Definitions
- Impacted Industries
- Issues
- Work Practices and Measurement
- Tips for IHs
Radiological Descriptors

- **Activity**
  - The **rate** of the radioactive decay process.
  - dpm, pCi, Bq

- **Half Life**
  - The time it takes for one half of the radioactive atoms present to decay.
  - Can range from micro-seconds to 1E10 yrs

- **Dose**
  - Total amount of absorbed radiation (energy) in a material or tissue.
  - μrem, μSv
  - Exposure is totally different term—often confused - μR
Decay Chains

Radioactive Decay in Thorium and Uranium Series

Thorium Series
- Po-212 (0.3 μsec)
- Bi-212 (61 min)
- Pb-208 (3 min) (Stable)
- TI-208 (10.6 hr)
- Po-216 (0.15 sec)
- Rn-220 (55 sec)
- Th-228 (1.9 yr)
- Ra-224 (3.6 day) → Ac-228 (6.1 hr)
- Ra-228 (5.8 yr)
- Th-232 (1.4 x 10^10 yr)

Uranium Series
- Po-210 (138 day) → Bi-210 (160 μsec) → Po-214 (19.7 min) → Bi-214 (3 min) → Po-218 (3.8 day)
- Pb-206 (5 day) (Stable)
- Pb-210 (22 yr)
- Pb-214 (27 min)
- Rn-222 (1602 yr)
- Ra-226 (80,000 yr)
- Th-230 (24 day)
- Pa-234 (1.17 min)
- U-234 (4.5 x 10^8 yr)
- U-238 (250,000 yr)

Radioactive decay icon:
- Alpha Decay
- Beta Decay
- Gamma Emission
Equilibrium
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No not this!
Naturally Occurring Radioactive Material (NORM)

- Uranium and Decay Progeny
- Thorium and Decay Progeny
- Potassium-40
- Rhenium-187, Indium-115, Tellurium-128,130
- Cosmic (and man-made) Produced
  - Be-7, C-14, H-3
NORM – where is it found?
NORM in Consumer Products
NORM in the Earth and Air

- Monazite sands
- Grand Central Station
- Brick
- Reading Prong in USA
- Radon in Homes
TENORM

- Technologically Enhanced NORM
- Re-concentration of U or Th and Progeny
  - Natural High Concentration Bearing Minerals
  - Separation Processes Cause High Concentrations
  - Radon Progeny Build-up
  - Re-capture and Build-up of Low Concentrations
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Impacted Industries and Processes

- Metals Mining
- Rare Earth Extraction
- Phosphates/Fertilizer Production
- Oil and Gas Production
- Geothermal Production
- Coal Fired Energy Production
- Water Treatment Residuals
TENORM Sources in Oil and Gas Production

- Condensate $^{222}$Rn and particulate scale
- Particulate scale and $^{222}$Rn,

$^{222}$Rn, $^{210}$Pb, $^{210}$Po plates tubular

- Ra isotopes precipitate as mineral scale

$^{238}$U, $^{232}$Th

$^{222}$Rn migrates with gas

$^{226}$Ra, $^{228}$Ra, $^{224}$Ra, $^{222}$Rn

Mobilise with hydrocarbons and produced water
Components Contaminated with TENORM in the Oil and Gas Industry
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Regulations

- NRC
  - SNM, Source and Byproduct Materials
  - States
    - NARM and X-Ray generators
- EPA
  - Effluent Emissions, Waste Disposal, Remediation & Re-use
- OSHA
  - Worker Protection
- DOT
  - Most TENORM meets exemption criteria
- Canada
  - Provinces
  - Health Canada’s Naturally Occurring Radioactive Material Guidelines
States with Specific NORM Regulations

- Alabama
- Arkansas
- Georgia
- Louisiana
- Mississippi
- New Mexico
- Texas
- South Carolina
- West Virginia
Waste Disposal

- Decontamination
- Disposal Options
  - Landfills
  - Encapsulation
  - Deep Well Injection
  - Salt Cavern
  - Land Farming
- Special Issues
  - “Mixed Waste”
  - Legacy wastes and “bone yards”
- Transport
  - State Fees and Permits
  - Compact State Restrictions
Remediation Risk Assessment

- Parameters
- Scenario and Exposure Pathways
  - Farmer, Industrial, Recreational
  - Direct
  - Radon
  - Drinking Water
- Background
- Dose Constraint
  - NRC 25 mrem per year
  - EPA 15 mrem + 4 mrem water pathway
  - States - 10 mrem
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Principal Hazards

- Critical Radionuclides
  - Thorium and Uranium
  - Radium
  - Radon
  - Polonium
- External
- Internal
Worker Protection

- Whose guidance/rules are enforced
- Typically low dose rate fields
  - Variation between operation and shutdown
- Why?
  - TLD badges?
- Airborne Measurements
- Radon Complications
  - Measurement
  - Progeny Plate-out
- PPE
  - Dispersible contaminants
Exposure Limits

- Surface Contamination
  - ANSI vs. Reg Guide 1.86
    - 600 dpm/100 cm² vs 200 dpm/100 cm² for Ra-226
- Airborne Limits – The DAC
  - Ra-226: 3E-10 μCi/cc
  - Th-232: 1E-12 μCi/cc
  - Rn-222: 1E-08 μCi/cc
  - Po-210: 3E-10 μCi/c
- Dose limits
  - Workers – it depends
  - Public – 1 mSv/y (100 mrem/y)
External Exposure/Dose Rate Measurements
Contamination Detection
Air Sampling - Particulate
Air Sampling - Radon

- Lucas Cells
- E-PERMS
- Track Etch Badges
- Charcoal Canisters
- Air Particulate Filters

EPA Public - 4 pCi/L
WHO Public - 2.7 pCi/L
OSHA Workers - 100 pCi/L
NRC DAC - 30 pCi/L
3.3.11.3.1 Modified Tsivoglou Technique. The concentration, in picoCuries per liter (pCi/L), of each of the radon decay products (Po-218, Pb-214, and Po-214) can be determined by using the following calculations:

- \( C_2 = \frac{1}{FE} (0.16921 \times G_1 - 0.08213 \times G_2 + 0.07765 \times G_3 - 0.5608 \times R) \)
- \( C_3 = \frac{1}{FE} (0.001108 \times G_1 - 0.02052 \times G_2 + 0.04904 \times G_3 - 0.1577 \times R) \)
- \( C_4 = \frac{1}{FE} (-0.02236 \times G_1 + 0.03310 \times G_2 - 0.03765 \times G_3 - 0.05720 \times R) \)

It is important to note that the constants in these equations are based on a 3.04-minute half-life of Po-218. The working level (WL) associated with these concentrations can then be calculated using the following relationship:

Where:

- \( C_2 \) = concentration of Po-218 (RaA) in pCi/L;
- \( C_3 \) = concentration of Pb-214 (RaB) in pCi/L;
- \( C_4 \) = concentration of Po-214 (RaC') in pCi/L;
- \( F \) = sampling flow rate in liters per minute (Lpm);
- \( E \) = counter efficiency in counts per minute/disintegrations per minute (cpm/dpm);
- \( G_1 \) = gross alpha counts for the time interval of two to five minutes;
- \( G_2 \) = gross alpha counts for the time interval of six to 20 minutes;
- \( G_3 \) = gross alpha counts for the time interval of 21 to 30 minutes; and
- \( R \) = background counting rate in cpm.
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Odds and Ends of Radiation and Radioactivity Monitoring

- One meter doesn’t tell the whole story
- Calibrations can be tricky
- Don’t get too excited on a rainy day
- Nylon gloves on a plastic steering wheel will wreak havoc
- Polyester is both a bad dressing form but also a great way to catch radon particulate progeny
Odds and Ends Air Monitoring

- Typical alpha self-absorption on filters is 80% but can be at 90% for membrane filters
- Can measure radon using particulate by the Modified Tsivoglou Method
- Convert particulate in ug/m³ to uCi/cc by multiplying the ug/m³ by the soil concentration in pCi/g and then performing a units conversion
- Each DAC-Hr equals 250 uSv or 2.5 mrem
Media Sampling and Analysis

- EPA Methods 900 Series
  - for soil use 901.1M
  - for drinking water 903.1
  - method 900 for gross alpha and beta
  - Pb-210 by gas proportional or gamma spec
  - Polonium-210 by alpha spec
Standards and References

- CRC PD
  - Suggested Radiation Protection Regulations Part N – TENORM
- Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM)
- API Bulletin E-2
- ANSI – N13.53-2009
- ISCORS
Useful Links

- http://norm.igcc.state.ok.us/reg/dsp_state_tereg.cfm
- http://www.epa.gov/radiation/tenorm
- http://www.iscors.org/index.htm
- http://www.tenorm.com/
Useful Links

- http://emergency.cdc.gov/hazards-all.asp
Radon Spa
Thank You!

Questions?

Note to Pete – remember the answer to the banana question

Peter Collopy
pn collopy@yahoo.com
858—859-1944 (but only between 1000 and 1400)
15 min Qs are free—after that I have to charge you
<table>
<thead>
<tr>
<th>To convert from</th>
<th>To</th>
<th>Multiply by</th>
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<tbody>
<tr>
<td>Curies (Ci)</td>
<td>becquerels (Bq)</td>
<td>$3.7 \times 10^{10}$</td>
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<tr>
<td>millicuries (mCi)</td>
<td>megabecquerels (MBq)</td>
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<td>microcuries (μCi)</td>
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<td>millirads (mrad)</td>
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<tr>
<td>millirems (mrem)</td>
<td>microsieverts (μSv)</td>
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<td>milliroentgens (mR)</td>
<td>microcoulombs/kilogram (μC/kg)</td>
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<td>becquerels (Bq)</td>
<td>curies (Ci)</td>
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<td>millicuries (mCi)</td>
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<td>microcoulombs/kilogram (μC/kg)</td>
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### Uranium-238

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<thead>
<tr>
<th>Atomic No.</th>
<th>Radionuclide</th>
<th>Class</th>
<th>Table 1: Occupational Values</th>
<th>Table 2: Effluent Concentrations</th>
<th>Table 3: Releases to Sewers</th>
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<tbody>
<tr>
<td></td>
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<td></td>
<td>Col. 1 Oral Ingestion ALI (μCi)</td>
<td>Col. 2 Inhalation ALI (μCi)</td>
<td>Col. 3 DAC (μCi/ml)</td>
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<td>92</td>
<td>Uranium-238$^3$</td>
<td>D, see $^{230}$U</td>
<td>1E+1 Bone Surf</td>
<td>1E+0 Bone Surf</td>
<td>6E-10</td>
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<td></td>
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<td>(2E+1)</td>
<td>(2E+0)</td>
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<tr>
<td>W, see $^{230}$U</td>
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<td>8E-1</td>
<td>3E-10</td>
<td>1E-12</td>
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<tr>
<td>Y, see $^{230}$U</td>
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<td>4E-2</td>
<td>2E-11</td>
<td>6E-14</td>
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### Radium-226

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<tbody>
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<td></td>
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<td>Col. 1 Oral Ingestion ALI (μCi)</td>
<td>Col. 2 Inhalation ALI (μCi)</td>
<td>Col. 3 DAC (μCi/ml)</td>
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## Thorium-232

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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Col. 1 Oral Ingestion ALI (µCi)</td>
<td>Col. 2 Inhalation ALI (µCi)</td>
<td>Col. 3 DAC (µCi/ml)</td>
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<tr>
<td>90</td>
<td>Thorium-232</td>
<td>W, see $^{226}$Th</td>
<td>7E-1 Bone Surf</td>
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<td></td>
<td>(2E+0)</td>
<td>(3E-3)</td>
<td>-</td>
<td>4E-15</td>
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<tr>
<td></td>
<td></td>
<td>Y, see $^{226}$Th</td>
<td>-</td>
<td>3E-3 Bone Surf</td>
<td>1E-12</td>
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<td></td>
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<td>(4E-3)</td>
<td>-</td>
<td>6E-15</td>
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## Polonium-210

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<tr>
<th>Atomic No.</th>
<th>Radionuclide</th>
<th>Class</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Col. 1 Oral Ingestion ALI (µCi)</td>
<td>Col. 2 Inhalation ALI (µCi)</td>
<td>Col. 3 DAC (µCi/ml)</td>
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<tr>
<td>84</td>
<td>Polonium-210</td>
<td>D, see $^{203}$Po</td>
<td>3E+0</td>
<td>6E-1</td>
<td>3E-10</td>
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<tr>
<td></td>
<td></td>
<td>W, see $^{203}$Po</td>
<td>-</td>
<td>6E-1</td>
<td>3E-10</td>
</tr>
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</table>