Marcellus Shale & TENORM

PEMA EM Conference

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David J. Allard, CHP, Director
PA DEP, Bureau of Radiation Protection

(Rev. 9/23/2011)
Disclaimer -

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Legislative Authority

- Radiation Protection Act (Act 1984-147)
- Solid Waste Management Act (Act 1980-97)
- Appalachian States LLRW Compact Act (Act 1985-120)
- LLRW Disposal Act (Act 1988-12)
- LLRW Disposal Regional Facility Act (Act 1990-107)
PA Title 25 Environmental Protection

> Article V. Radiological Health*

- 217. Lic. of Radioactive Materials (RAM)
- 219. Standards for Protection Against Rad.
- 220. Notice, Instructions & Reports ....
- 221. X-rays in the Healing Arts
- 230. Packaging & Transport of RAM
- 236. LLRW Management & Disposal
- 240. Radon Certification

*Note: Partial list of Chapters; and on Nov. 2001 incorporated NRC regs in Title 10 CFR by reference
Feds in Rad / Nuc Protection
Radiation Protection

- Radiation exposure may have a risk
- Biological effects: acute or chronic (i.e., cancer)
- Justify, optimize (ALARA), limit dose
Biological Effects

Cancer – assume a linear no threshold (LNT) model

Dose-Response Relationships

- Probability of cancer vs. dose

Background incidence

Background dose

Customary Dose Limits

**Public** 100 mrem/yr; 500 mrem/yr;
25 mrem/yr any one source; 4 mrem/yr drinking water

**Patients** few dose limits; 300 mrad mammography

**Worker** 5,000 mrem/yr whole body
15,000 mrem/yr lens of eye
50,000 mrem/yr skin / extremity / organ

**Worker’s embryo / fetus** 500 mrem; and less than
50 mrem/month (patient’s fetus?)

*** Emergency Workers *** 5-25 rem (>25 rem, if planned for life
saving or major property)
PENNSYLVANIA CODE

• Title 25 Environmental Protection
  > Article VIII and IX Municipal and Residual Waste
    - 273. Municipal Waste Landfills
    - 277. Construction/Demolition Waste Landfills
    - 279. Transfer Facilities
    - 281. Composting Facilities
    - 283. Resource Recovery Facilities (RRF)
(There are also six RRFs in Central and SE PA.)
Landfill Under Construction

EPA RCRA “D” LF with liner and leachate collection
Regulations Applicable to Nuclear Medicine Procedures (cont.)

• DOT regulations in Title 49 CFR Section 173.401 Scope -
(b) This subpart does not apply to:
(3) Class 7 (radioactive) materials that have been injected into, ingested by, or are otherwise placed into, and are still in, human beings or live animals.
• CRCPD / DOT Exemption issued for detected RAM in scrap or waste
• DOT interpretation as “household waste”
SW Regulations – Basic Limitations

The following radioactive material controlled under specific or general license or order authorized by any federal, state or other government agency shall not be processed at the facility, unless specifically exempted from disposal restrictions by an applicable Pennsylvania or federal statute or regulation:

- NARM
- Byproduct material
- Source material
- Special nuclear material
- Transuranic radioactive material
- Low-level radioactive waste
The following radioactive material shall not be disposed / processed at the facility, unless approved in writing by the department and the disposal / processing does not endanger the health and safety of the public and the environment:

- Short lived radioactive material from a patient having undergone a medical procedure
- TENORM
- Consumer products containing radioactive material

The limitations in subsections ( ) and ( ) shall not apply to radioactive material as found in the undisturbed natural environment of the Commonwealth.
General Guidance for Action Plans

Definitions (RAM, NARM, NORM, TENORM, etc.)

- Background; reg drivers, sources, past events
- General Considerations
  - Personnel Training
  - Monitoring and detection of radiation
  - Awareness of items containing RAM
  - Initial response to detection
  - Notifications; internal/external (PA DEP)
  - Characterization
  - Disposition; reject, dispose / process onsite
  - Record keeping
Action Plans

• SW Facility must have a RP Action Plan
• Can have a disposal option for NM RAM, and small quantity of TENORM and consumer products
• Plan summary posted for facility personnel
• Facility personnel trained to Action Plan
• Monitoring equipment in place
• Proper response if monitors alarm
• Customer and waste hauler awareness
• Ensure that at least one trained person on duty
Trucks Being Monitored
SW Regs - Action Levels

• Below, average background* + 10 $\mu$R h$^{-1}$ (max) NO ACTION REQUIRED - treat waste in normal manner.

ACTION LEVEL 1

• Above average background + 10 $\mu$R h$^{-1}$ (alarm set point) shall cause an alarm, facility INVESTIGATES!

ACTION LEVEL 2

• Above 2 mR h$^{-1}$ in vehicle cab, 50 mR h$^{-1}$ on any other surface, or contamination – NOTIFY PaDEP / BRP and isolate waste and / or vehicle.

*Note: 10 $\mu$R h$^{-1}$ limit on instrument background.
Standard RP Program “Pancake”
Geiger Counter

“pancake” G-M

\[ \alpha \sim 3\% \quad \text{Th-230} \]
\[ \beta \sim 10\% \quad \text{Tc-99} \]
\[ \gamma \sim 3,500 \quad \text{cpm / mR/h} \quad \text{Cs-137} \]
MCAs Used For Characterization
## Guidance – Disposal Option

### Examples of Common Nuclear Medicine RAM *

<table>
<thead>
<tr>
<th>Isotope</th>
<th>T-1/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-131</td>
<td>8 days</td>
</tr>
<tr>
<td>Tc-99m</td>
<td>6 hours</td>
</tr>
<tr>
<td>TI-201</td>
<td>3.0 days</td>
</tr>
<tr>
<td>Ga-67</td>
<td>3.3 days</td>
</tr>
</tbody>
</table>

* Over 90% of alarms to date are from NM RAM and patient contaminated solid waste
DOT Exemption

• MoU between CRCPD and U.S. DOT
• DOT- E11406 for shipment of solid waste with low-levels of external radiation (expired April 2010)
• Approved by state radiation control official
• One-way transport exemption from certain DOT regs on packaging and labeling
• No contamination, < 50 mrem/hr on side
• In PA, add < 2 mrem/hr in vehicle cab
• If NM RAM and “household waste” no DOT Exemption needed, just a PA Transport Exemption Form
Cs-137 and Am-241
Well Logging Sources

Co-60 or Ir-192
Industrial Radiography Sources
December 2009 Ir-192 Tracer Proppant Detected at a PA Landfill
Early Flow-back with Ir-192 Tracer Proppant; Onsite *in situ* Decay Storage
Implementation Update (cont.)

• Hundreds of onsite radiation alarm responses
  ➢ ~ 90% NM RAM in household waste
  ➢ ~ 9% NORM or TENORM
  ➢ ~ 1% NM RAM in driver
  ➢ < 1% Regulated or controlled RAM

• DEP Fact Sheets on tritium and “orphan source” / LLRW disposal
Landfill Leachate Study - Tritium

Leachate Tritium Concentration

SAP ID

pCi/L
TENORM

• TENORM, surface dose rate < 50 $\mu$R h$^{-1}$
  @ 5 cm, combined radium activity < 5.0 pCi/g, and below 1 m$^3$ - facility can dispose / process without DEP approval

• Higher levels permitted with BRP Director approval, if pathways analysis demonstrates dose to maximum exposed person is less than 25 mrem yr$^{-1}$ from all exposure pathways (i.e., using “resident farmer” and RESRAD code)
TENORM -
RESRAD Code: “resident farmer” evaluation, public dose limit 25 mrem/yr, all pathways (i.e., radon, ground shine and drinking water), looking out 1000 years.
Implementation Update

- Over 170 SW facility permit modifications for RP Action Plans
- Over 140 initial onsite inspections
- Annual Reports being reviewed
- Hundreds of DOT Exemptions issued
- Official DOT “interpretation” on RAM in “household waste” in 2004 - not subject to hazmat regs in 49CFR

- RP Action Plans for POTWs / STPs / CWTs
Marcellus Shale
Uranium Concentrations

Source of data: U.S. Geological Survey Digital Data Series DDS-9, 1993
Uranium in PA

Uranium in Carbon, Lycoming, Sullivan and Columbia Counties, Pennsylvania

October 6 and 7, 1978
Hazleton, Pa.

Host: Pa. Geological Survey
Marcellus Shale Env. Concerns
Marcellus Shale
Marcellus Shale

NET FEET OF ORGANIC-RICH SHALE IN THE MARCELLUS FORMATION
(Modified from Pictrowski and Harper, 1979, Plate 4)
(See article on page 2.)

Bureau of Topographic and Geologic Survey
Department of Conservation and Natural Resources
3240 Schoolhouse Road
Middletown, PA 17057–3534
### Table 3.4
Survey Concentration Ranges and Typical U.S. Background Concentrations of Radionuclides in Soil, Fertilizer, and Common Building Materials (All values are in pCi/g-dry weight)

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Soil¹</th>
<th>Phosphate Fertilizer³</th>
<th>Building Materials³</th>
<th>Sludge Concentrations³</th>
<th>Ash Concentrations³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bi-212</td>
<td>0.1–3.5</td>
<td>0.1–4.6</td>
<td>0.1–3.7</td>
<td>0.1–13</td>
<td>0.3–16</td>
</tr>
<tr>
<td>Bi-214</td>
<td>0.1–3.8</td>
<td>4.0–140</td>
<td>2.5–5.0⁴</td>
<td>0.04–16</td>
<td>0.62–16</td>
</tr>
<tr>
<td>Cs-137</td>
<td>0.1–0.2³</td>
<td>NDA⁶</td>
<td>NDA</td>
<td>0–3.6</td>
<td>0–0.37</td>
</tr>
<tr>
<td>K-40*</td>
<td>2.7–19</td>
<td>32–160⁷</td>
<td>0.8–30</td>
<td>0–27</td>
<td>7.4–22</td>
</tr>
<tr>
<td>Pa-234m*</td>
<td>0.1–3.8</td>
<td>4.0–140</td>
<td>0.2–5.0⁴</td>
<td>0–15</td>
<td>0.36–15</td>
</tr>
<tr>
<td>Pb-212*</td>
<td>0.1–3.5</td>
<td>0.1–4.6</td>
<td>0.1–3.7</td>
<td>0.06–17</td>
<td>0.61–16</td>
</tr>
<tr>
<td>Pb-214*</td>
<td>0.1–3.8</td>
<td>4.0–140</td>
<td>0.2–5.0</td>
<td>0.06–0.09</td>
<td>0.1–0.8</td>
</tr>
<tr>
<td>Ra-223*</td>
<td>&lt;0.1–0.2</td>
<td>0.2–6.6</td>
<td>0.1–0.2⁴</td>
<td>0.2–12</td>
<td>0.4–4.9</td>
</tr>
<tr>
<td>Ra-224*</td>
<td>0.1–3.5</td>
<td>0.1–4.6</td>
<td>0.1–3.72</td>
<td>0–47</td>
<td>0–22</td>
</tr>
<tr>
<td>Ra-226*</td>
<td>0.1–3.8</td>
<td>0.1–24</td>
<td>0.1–3.5</td>
<td>0.14–38</td>
<td>0.65–30</td>
</tr>
<tr>
<td>Ra-228*</td>
<td>0.1–3.5</td>
<td>0.1–4.6</td>
<td>0.1–3.7¹</td>
<td>0–0.5</td>
<td>0.02–1.1</td>
</tr>
<tr>
<td>Th-227*</td>
<td>&lt;0.1–0.2</td>
<td>0.2–6.6</td>
<td>0.1–0.2</td>
<td>0.07–9</td>
<td>0.4–14</td>
</tr>
<tr>
<td>Th-228*</td>
<td>0.1–3.5</td>
<td>0.1–4.6</td>
<td>0.1–3.7</td>
<td>0.09–1.7</td>
<td>0.3–2.6</td>
</tr>
<tr>
<td>Th-230*</td>
<td>0.1–3.8</td>
<td>4.0–140</td>
<td>0.2–5.0</td>
<td>0.02–1.6</td>
<td>0.22–1.7</td>
</tr>
<tr>
<td>Th-232*</td>
<td>0.1–3.5</td>
<td>0.1–4.6</td>
<td>0.1–3.7¹</td>
<td>0–23</td>
<td>1–80</td>
</tr>
<tr>
<td>Th-234*</td>
<td>0.1–3.8</td>
<td>4.0–140</td>
<td>0.2–5.0</td>
<td>0.02–4.8</td>
<td>0.11–14</td>
</tr>
<tr>
<td>Th-238</td>
<td>0.1–3.8</td>
<td>4.0–140</td>
<td>0.2–5.0</td>
<td>0.18–26</td>
<td>1.2–91</td>
</tr>
<tr>
<td>U-234*</td>
<td>0.1–3.8</td>
<td>4.0–140</td>
<td>0.2–5.0</td>
<td>0–3.1</td>
<td>0.03–3.4</td>
</tr>
<tr>
<td>U-235*⁸</td>
<td>&lt;0.1–0.2</td>
<td>0.2–6.6</td>
<td>0.1–0.2</td>
<td>0.18–44</td>
<td>1.2–91</td>
</tr>
<tr>
<td>U-238*</td>
<td>0.1–3.8</td>
<td>4.0–140</td>
<td>0.2–5.0⁴</td>
<td>0.8–74</td>
<td>1.2–91</td>
</tr>
</tbody>
</table>

**Notes:**
The curie (Ci), or fractions of a curie (e.g., picocurie), is the unit for expressing a quantity of radioactivity. The unit normally used to describe the concentrations of radioactivity in the environment is picocuries per gram (pCi/g).
Figure 2. Correlation of Middle and Upper Devonian organic-rich shale facies and interbedded strata in three wells in Pennsylvania, based on gamma-ray log signatures (the jagged purple lines) and descriptions of well cuttings. Note that the black shales correspond in large part to higher-than-normal gamma-ray readings (radioactivity increases to the right in all log signatures).
U-238 Decay Chain

U-238 ~ 99.3% by wt, ~50% of radioactivity
Th-232 Decay Chain

Thorium ($^{232}$Th) Decay Series
Marcellus Shale

New techniques, better recovery

Two technologies relatively new to the Appalachian Basin are employed in wells drilled into the Marcellus formation.

The first, horizontal drilling, is one in which a vertical well is directed horizontally so that it penetrates a maximum number of vertical rock fractures.

The second is hydrofracing, a process in which a portion of a well is sealed and water is pumped in. This produces pressure that fractures the surrounding rock to form a reservoir.

6,000 to 8,000 feet deep

Well is turned horizontal

Marcellus shale

Source: Geology.com, Catskillmountainkeeper.org

Marcellus Shale area: New research shows an estimated 500 trillion cubic feet of natural gas lies within the rock.

Devonian Black Shale Succession: The Marcellus Shale comprises part of this large formation.
‘Fracking’ retrieves natural gas from the ground

Hydrofracturing or “fracking,” a method for extracting natural gas and oil from deep in underground shale, has environmentalists concerned because dangerous petroleum distillates are often found in the liquid mixture pumped into the wells. Some activists and property owners are concerned that the toxins may leak into drinking water.

Ohio part of deep ‘Marcellus’ shale deposit

The discovery of the natural gas deposits a mile beneath a four-state area has led to more high-pressure, high-volume fracking than ever. Hundreds of horizontal wells have drilled into the deposit, but only about two dozen in Ohio, officials said.

275,000 gas and oil wells have been drilled in Ohio since the 1880s.

A new way of drilling for natural gas

1. Drilling for maximum effect

The drilling turns horizontal at about 7,000 feet, hitting multiple fissures and increasing the volume of available natural gas.

SOURCES: Ohio Department of Natural Resources Division of Mineral Resources Management; geology.com

2. Putting the pressure on

A mixture of salt water, sand and chemicals is pumped under high pressure into the pipeline, which has small holes through which the brine water mixture is forced.

3. Increased gas flow

The small fissures are widened by the pressure. The brine water mixture is pumped back out of the well and natural gas follows back up the pipeline to the wellhead.
Marcellus Shale

- MS uranium content: 10-100 ppm
- MS U-238 content: ~3.4 - 34 pCi/g
- MS Ra-226 content: ~3.4 - 34 pCi/g
- MS frac H$_2$O Ra-226: 300 - 9,000 pCi/L
- DW MCL Ra-226 / gross α: 5 / 15 pCi/L
- Treated frac H$_2$O sludge: 6 - 250 μR/h
Frac Water Treatment

Frac H$_2$O with Ra-226 - no DOT placards on trucks!
Natural gas drilling: Polluted wastewater, partially treated, pours into Pa.

Wastewater from Pennsylvania’s natural gas wells, intensely salty and polluted with toxins like barium and strontium, is partially treated, diluted and then dumped into rivers and streams that supply public drinking water. Most states require natural gas drillers to get rid of the stuff by injecting it down shafts thousands of feet deep.

Click wastewater treatment plants to see nearest drinking water intakes downstream.
Frac Water Treatment

Sewage Treatment Plants (STP) that have become contaminated by TENORM - no land farming!

Table L.3  Radionuclides Most Likely to be Detected, Greater than 4 pCi/g for the 95th Percentile Concentration and High Percent of Samples

<table>
<thead>
<tr>
<th>Rank</th>
<th>Radionuclide</th>
<th>Concentration (pCi/g)</th>
<th>Percent Samples Detected</th>
<th>Probable Source</th>
<th>Half-life</th>
<th>Worker Loading</th>
<th>Onsite Resident (20 y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>U-131</td>
<td>51</td>
<td>246/311= 84</td>
<td>Medical, Pacific mountain, and 50-100 MGD</td>
<td>8 d</td>
<td>240</td>
<td>&lt;1</td>
</tr>
<tr>
<td>2.</td>
<td>Th-201</td>
<td>46</td>
<td>151/311= 49</td>
<td>Medical, Appalachian Highlands, 50-100 MGD</td>
<td>3 d</td>
<td>23</td>
<td>&lt;1</td>
</tr>
<tr>
<td>3.</td>
<td>Sr-89</td>
<td>20</td>
<td>68/98= 70</td>
<td>Medical</td>
<td>51 d</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>4.</td>
<td>U-234</td>
<td>17</td>
<td>92/92=100</td>
<td>U-processing Intermontane Plateaus</td>
<td>245x10^6 y</td>
<td>5</td>
<td>6.2</td>
</tr>
<tr>
<td>5.</td>
<td>Ra-226</td>
<td>13</td>
<td>289/311= 93</td>
<td>NORM, Atlantic &amp; Interior Plains, ground water</td>
<td>1600 y</td>
<td>550</td>
<td>1000</td>
</tr>
<tr>
<td>6.</td>
<td>U-238</td>
<td>12</td>
<td>92/92=100</td>
<td>Appalachian Highlands, Intermontane Plateaus</td>
<td>4.5x10^6 y</td>
<td>6.8</td>
<td>4.4</td>
</tr>
<tr>
<td>7.</td>
<td>K-40</td>
<td>12</td>
<td>308/311= 99</td>
<td>NORM, all geographic regions</td>
<td>1.3x10^6 y</td>
<td>27</td>
<td>23</td>
</tr>
<tr>
<td>8.</td>
<td>Be-7</td>
<td>9</td>
<td>263/311= 85</td>
<td>NORM, Appalachian Highlands</td>
<td>53 d</td>
<td>5.5</td>
<td>&lt;1</td>
</tr>
<tr>
<td>9.</td>
<td>Pa-234m</td>
<td>7</td>
<td>80/311= 85</td>
<td>U-238 decay</td>
<td>1 m</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>10.</td>
<td>Th-234</td>
<td>6.7</td>
<td>191/311= 29</td>
<td>U-238-decay, Intermontane Plateaus, Rocky Mt.</td>
<td>24 d</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>11.</td>
<td>Ra-228</td>
<td>5.1</td>
<td>271/311= 87</td>
<td>NORM, Interior Plains, ground water, &lt; 10 MGD</td>
<td>6 y</td>
<td>65</td>
<td>42</td>
</tr>
<tr>
<td>12.</td>
<td>H-3</td>
<td>5</td>
<td>111/158= 70</td>
<td>Academic/Medical Research, decay</td>
<td>12 y</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>13.</td>
<td>Th-228</td>
<td>4.1</td>
<td>92/92=100</td>
<td>NORM, Interior and Atlantic Plains, ground water, &lt; 10 MGD</td>
<td>2 y</td>
<td>1000</td>
<td>4.4</td>
</tr>
</tbody>
</table>
Carl Orso checked the progress as he offloaded wastewater from a natural gas drilling site at Eureka Resources, a wastewater treatment facility, in Williamsport, Penn.
Deep Well Injection

Marcellus shale Frac water Concentrates
The regulations for radionuclides are in the table below.

<table>
<thead>
<tr>
<th>Radionuclides</th>
<th>MCLG</th>
<th>MCL</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Adjusted) Gross Alpha Emitters</td>
<td>Zero</td>
<td>15 picoCuries per liter</td>
</tr>
<tr>
<td>Beta Particle and Photon Radioactivity</td>
<td>Zero</td>
<td>4 millirems per year</td>
</tr>
<tr>
<td>Radium 226 and Radium 228 (Combined)</td>
<td>Zero</td>
<td>5 picoCuries per liter</td>
</tr>
<tr>
<td>Uranium</td>
<td>Zero</td>
<td>30 micrograms per liter</td>
</tr>
</tbody>
</table>

The National Primary Drinking Water Regulations for radionuclides became effective in 1977 and were last revised in 2000 to include uranium. The Safe Drinking Water Act requires EPA to periodically review the regulation for each contaminant and revise it, if appropriate. EPA will review the radionuclides regulation again in 2015 or sooner if important information becomes available.

- More information on the Six Year Review of Drinking Water Standards.

States may set more stringent drinking water MCLGs and MCLs for radionuclides than EPA.
Administrative Manual – Part III
WATER QUALITY REGULATIONS

WITH AMENDMENTS THROUGH
JULY 16, 2008

18 CFR PART 410

Delaware River Basin Commission
DELAWARE · NEW JERSEY
PENNSYLVANIA · NEW YORK
UNITED STATES OF AMERICA

DELAWARE RIVER BASIN COMMISSION
P.O. BOX 7360, WEST TRENTON, NEW JERSEY 08628
(609) 883-9500 · www.drbc.net
Radon-222 in Natural Gas

Table 1. Radon-222 concentrations in natural gas at production wells

<table>
<thead>
<tr>
<th>Area</th>
<th>Radon-222 level, pCi/L</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Range</td>
</tr>
<tr>
<td>Colorado</td>
<td>25</td>
<td>0.2-160</td>
</tr>
<tr>
<td>New Mexico</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Texas, Kansas, Oklahoma</td>
<td>&lt;100</td>
<td>5-1450</td>
</tr>
<tr>
<td>Texas Panhandle</td>
<td>---</td>
<td>10-520</td>
</tr>
<tr>
<td>Colorado</td>
<td>25.4</td>
<td>11-45</td>
</tr>
<tr>
<td>Project Gasbuggy Area</td>
<td>15.8-19.4</td>
<td>---------</td>
</tr>
<tr>
<td>Project Gasbuggy Area</td>
<td>29.4</td>
<td>12-59</td>
</tr>
<tr>
<td>California</td>
<td>---</td>
<td>1-100</td>
</tr>
<tr>
<td>Gulf Coast (Louisiana, Texas)</td>
<td>5</td>
<td>---------</td>
</tr>
<tr>
<td>Kansas</td>
<td>100</td>
<td>---------</td>
</tr>
<tr>
<td>Wyoming</td>
<td>10</td>
<td>---------</td>
</tr>
<tr>
<td>Overall average</td>
<td>37</td>
<td></td>
</tr>
</tbody>
</table>

Action level: 4 pCi/L
Rad / Nuc Organizations

- Radiation Control
- Health Physics
- Medical Physics
- Nuclear Engineering
Reference URLs

- BRP  http://www.dep.state.pa.us/dep/deputate/airwaste/rp/rp.htm
- CRCPD  http://www.crcpd.org/
- HPS  http://www.hps.org/ http://hps.org/publicinformation/ate/
- AAPM  http://www.aapm.org/
- SNM  http://interactive.snm.org/index.cfm?pageid=10&rpid=1977
- NCRP  http://www.ncrp.com/
- ANS  http://www.ans.org/
- FEMA  http://www.fema.gov/hazards/nuclear/
- NRC  http://www.nrc.gov/
- EPA  http://www.epa.gov/
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Contact Information -

David J. Allard, CHP

PADEP / Bureau of Radiation Protection
PO Box 8469
Harrisburg, PA, 17105-8469

Tel.: 717-787-2480
Fax: 717-783-8965
E-mail: djallard@pa.gov
http://www.depweb.state.pa.us
“radiation”
Thank you!  Questions?