Marcellus Shale & TENORM

PEMA EM Conference

September 24, 2011

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(Rev. 9/23/2011)

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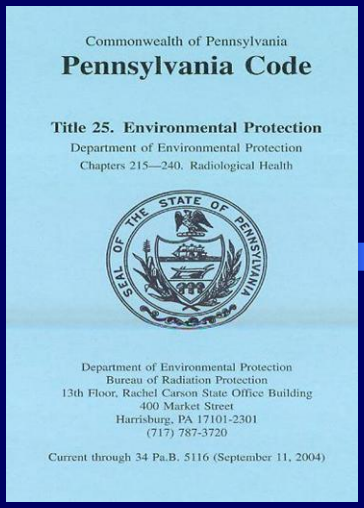
Legislative Authority

- 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 RP Regulations



PA Title 25 Environmental Protection

> Article V. Radiological Health*

- 215. General Provisions

- 217. Lic. of Radioactive Materials (RAM)

- 219. Standards for Protection Against Rad.

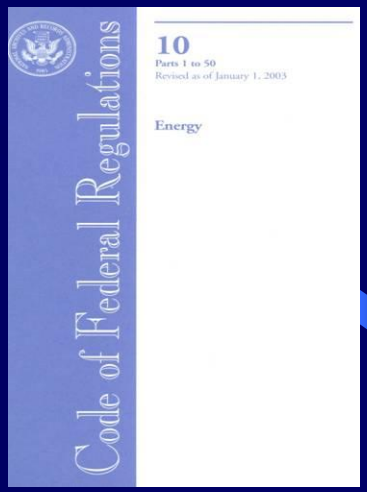
- 220. Notice, Instructions & Reports ….

- 221. X-rays in the Healing Arts

- 230. Packaging & Transport of RAM

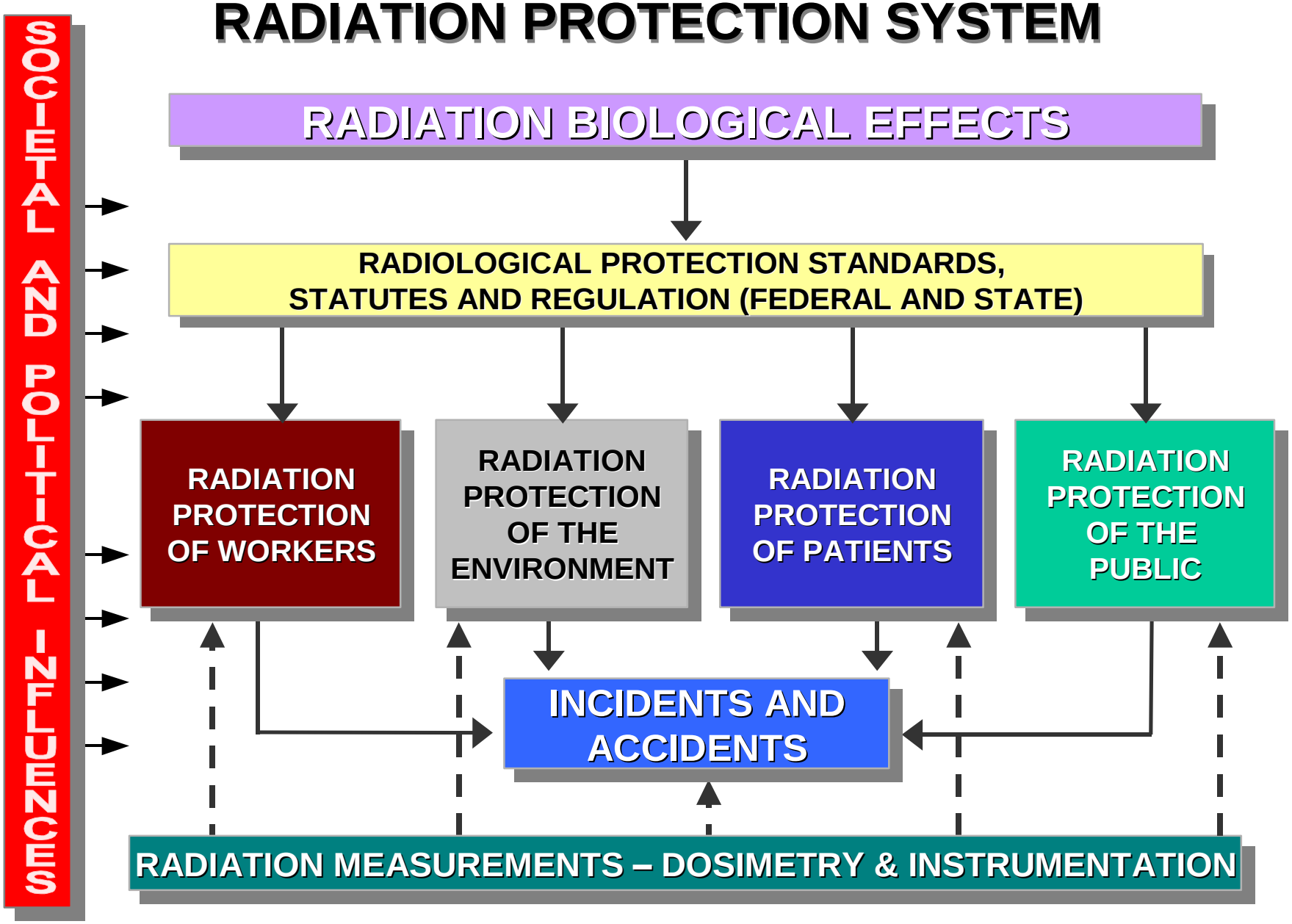
- 236. LLRW Management & Disposal

- 240. Radon Certification



***Note: Partial list of Chapters; and on Nov. 2001 incorporated NRC regs in Title 10 CFR by reference**

RADIATION PROTECTION SYSTEM



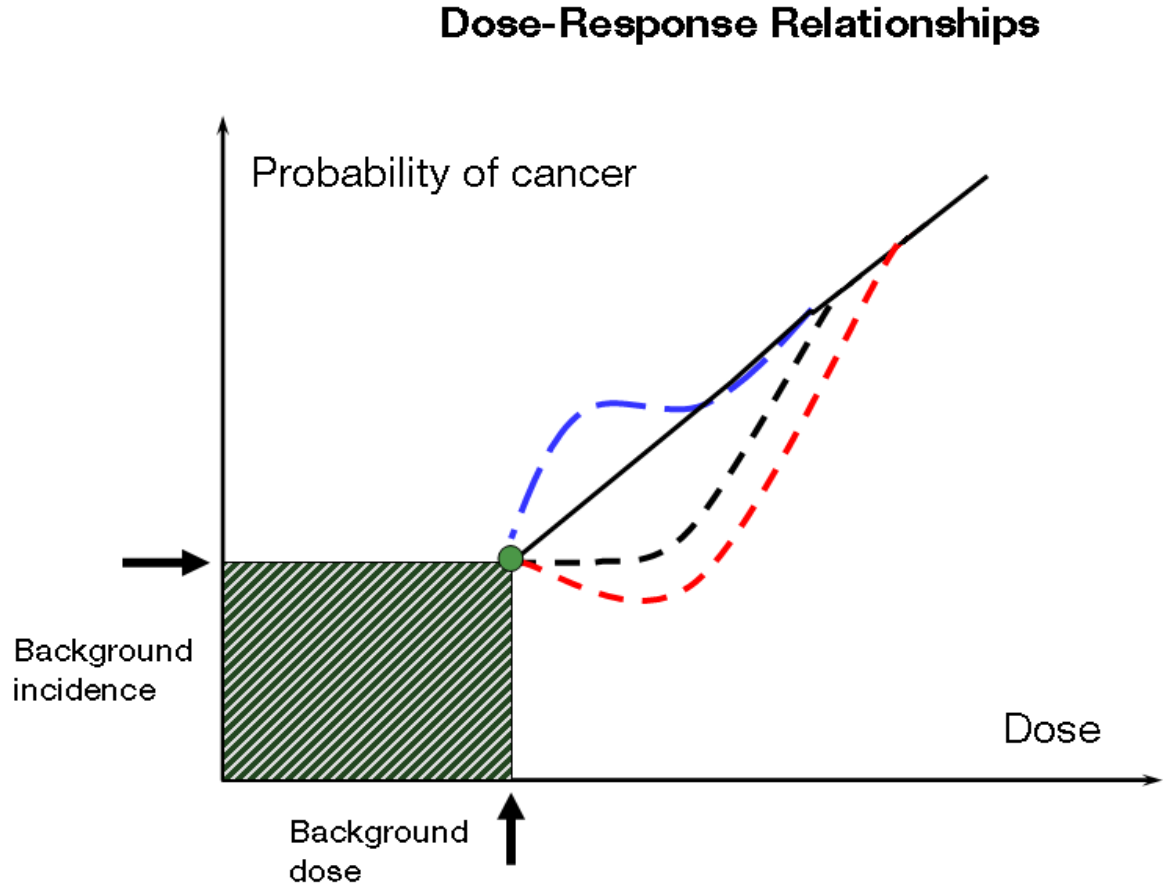
Feds in Rad / Nuc Protection

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



See NCRP Report No. 136 (2001) for a detailed description of the contrasting types of dose-response relationships.

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

  - 271. Municipal Waste Management – General Provisions

  - 273. Municipal Waste Landfills

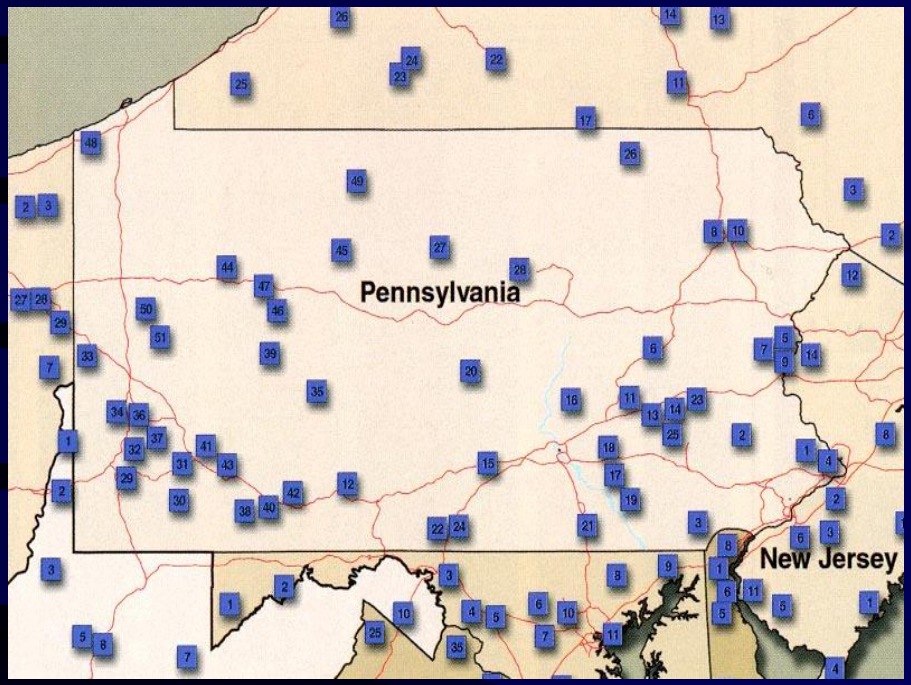
  - 277. Construction/Demolition Waste Landfills

  - 279. Transfer Facilities

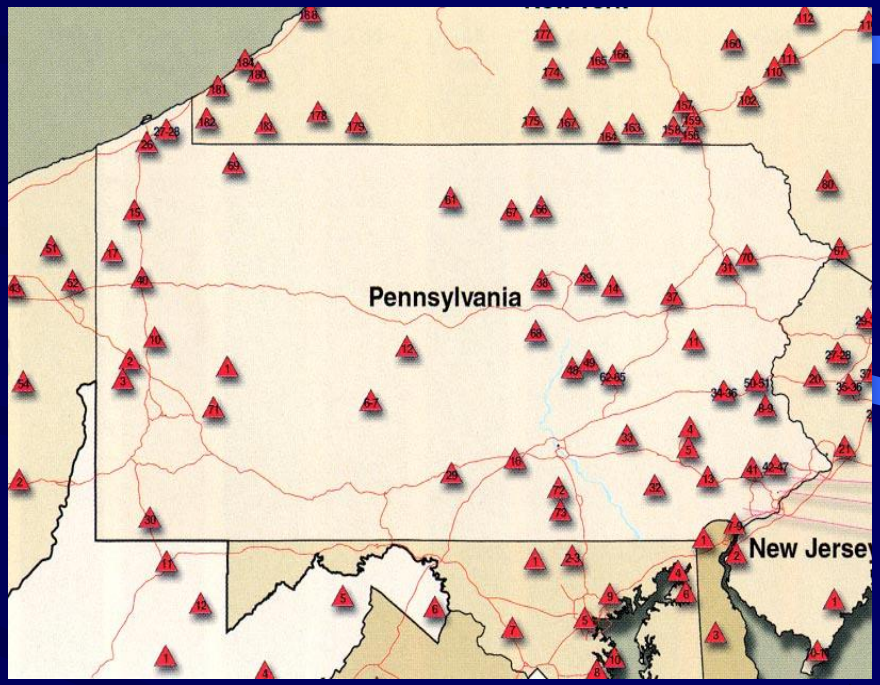
  - 281. Composting Facilities

  - 283. Resource Recovery Facilities (RRF)

LANDFILLS



TRANSFER STATIONS



(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**

SW Regulations – Basic Limitations (cont.)

- **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 μR h^{-1} (max) NO ACTION REQUIRED - treat waste in normal manner.**

ACTION LEVEL 1

- **Above average background + 10 μR 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 μR h^{-1} limit on instrument background.**

Standard RP Program "Pancake" Geiger Counter

"pancake" G-M

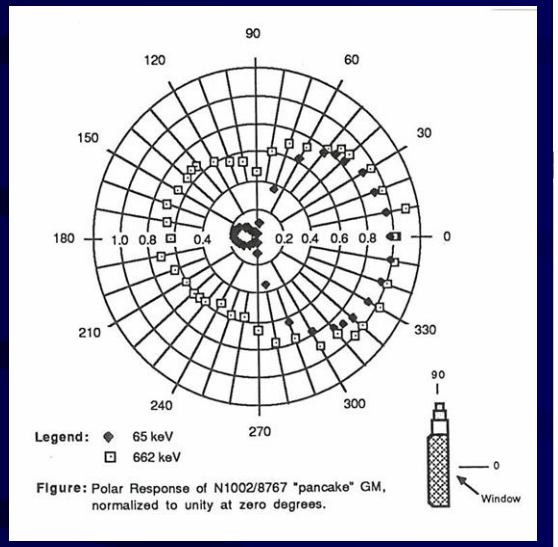


Figure: Polar Response of N1002/8767 "pancake" GM, normalized to unity at zero degrees.

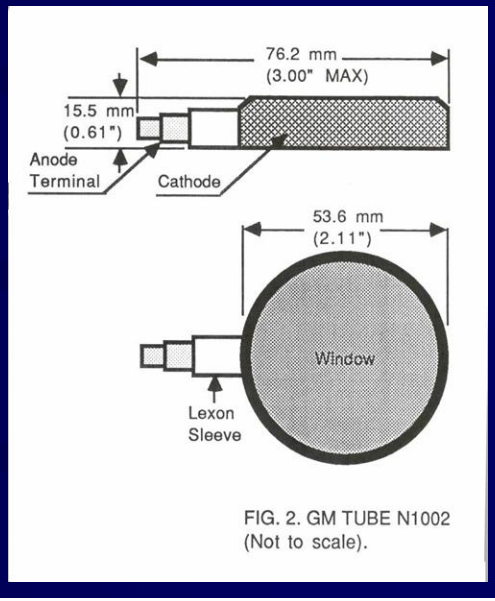
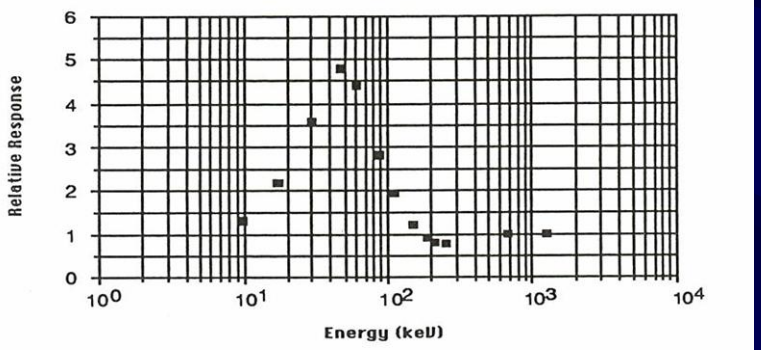


FIG. 2. GM TUBE N1002
(Not to scale).

α ~3%
Th-230

β ~10%
Tc-99

γ~3,500
cpm / mR/h
Cs-137



Legend: ■ Beam perpendicular to detector window (with a 2 mm plastic cap for Cs-137 and Co-60).

Figure: Photon Energy Response of N1002/8767 "pancake" GM, normalized to 662 keV.

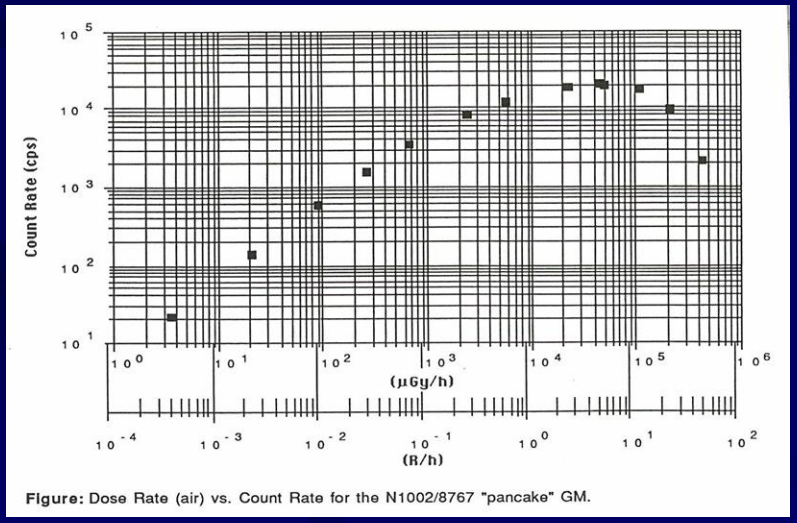


Figure: Dose Rate (air) vs. Count Rate for the N1002/8767 "pancake" GM.

MCAs Used For Characterization

Guidance – Disposal Option

Examples of Common Nuclear Medicine RAM *

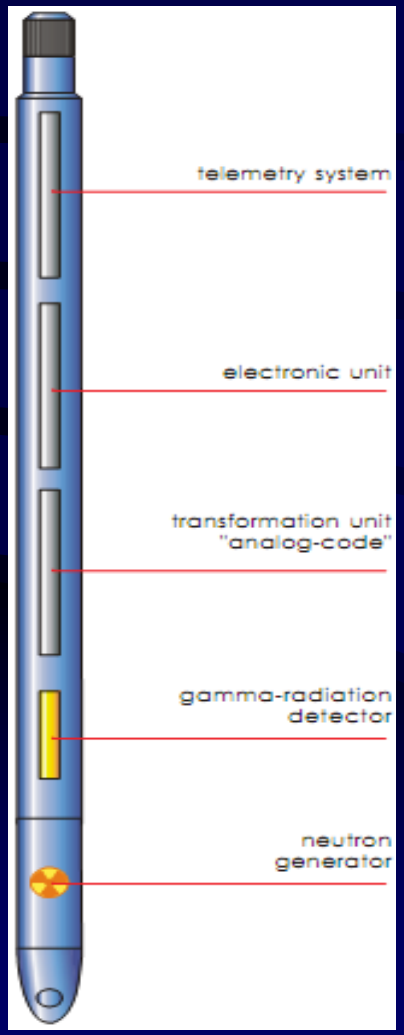
Isotope	T-1/2
I-131	8 days
Tc-99m	6 hours
Tl-201	3.0 days
Ga-67	3.3 days

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

DOT Exemption

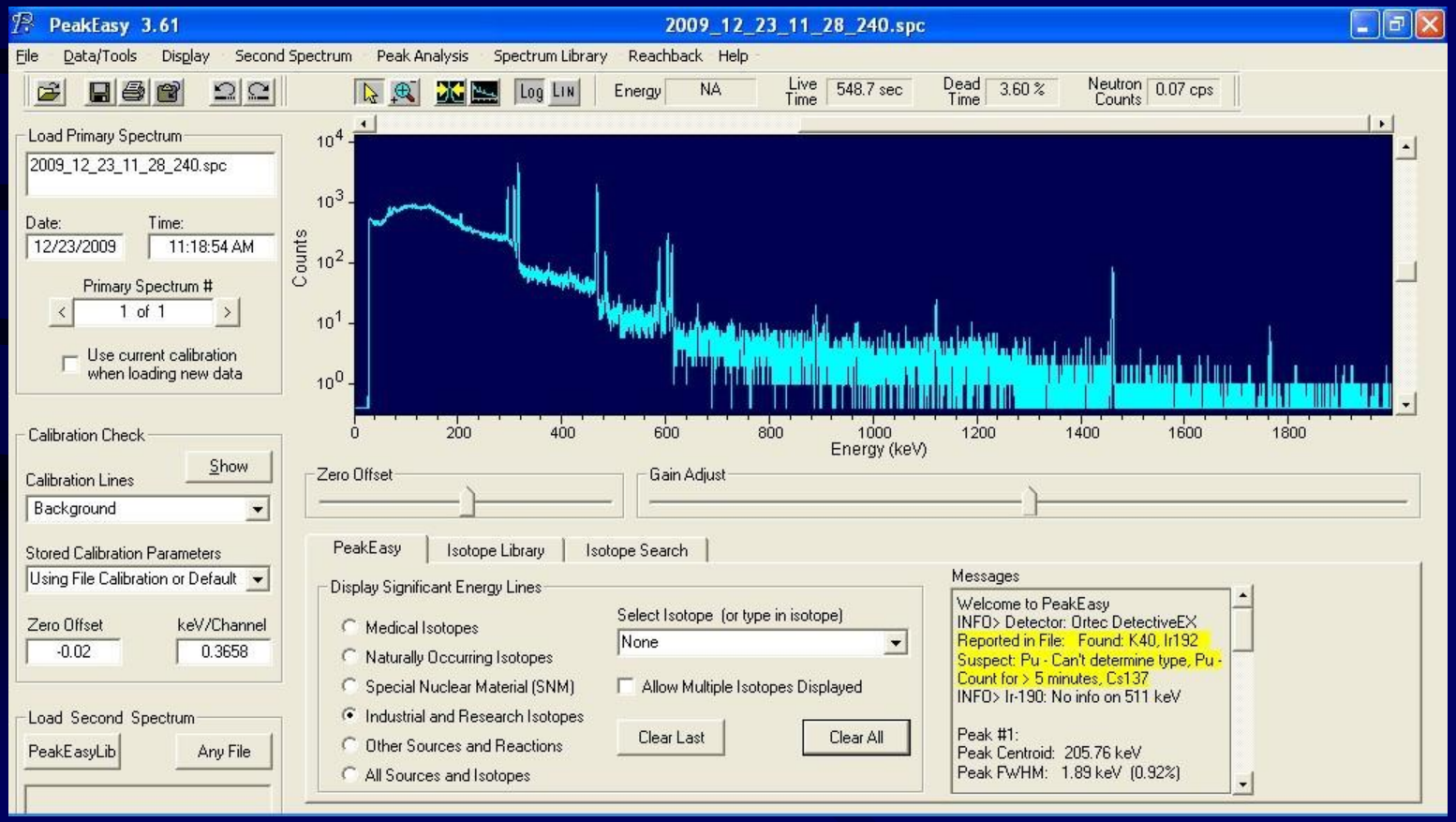
- MoU between CRCPD and U.S. DOT
- DOT- E11406 for shipment of solid waste with low-levels of external radiation (expired April 2010)
- Approved by state radiation control official
- One-way transport exemption from certain DOT regs on packaging and labeling
- No contamination, < 50 mrem/hr on side
- 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



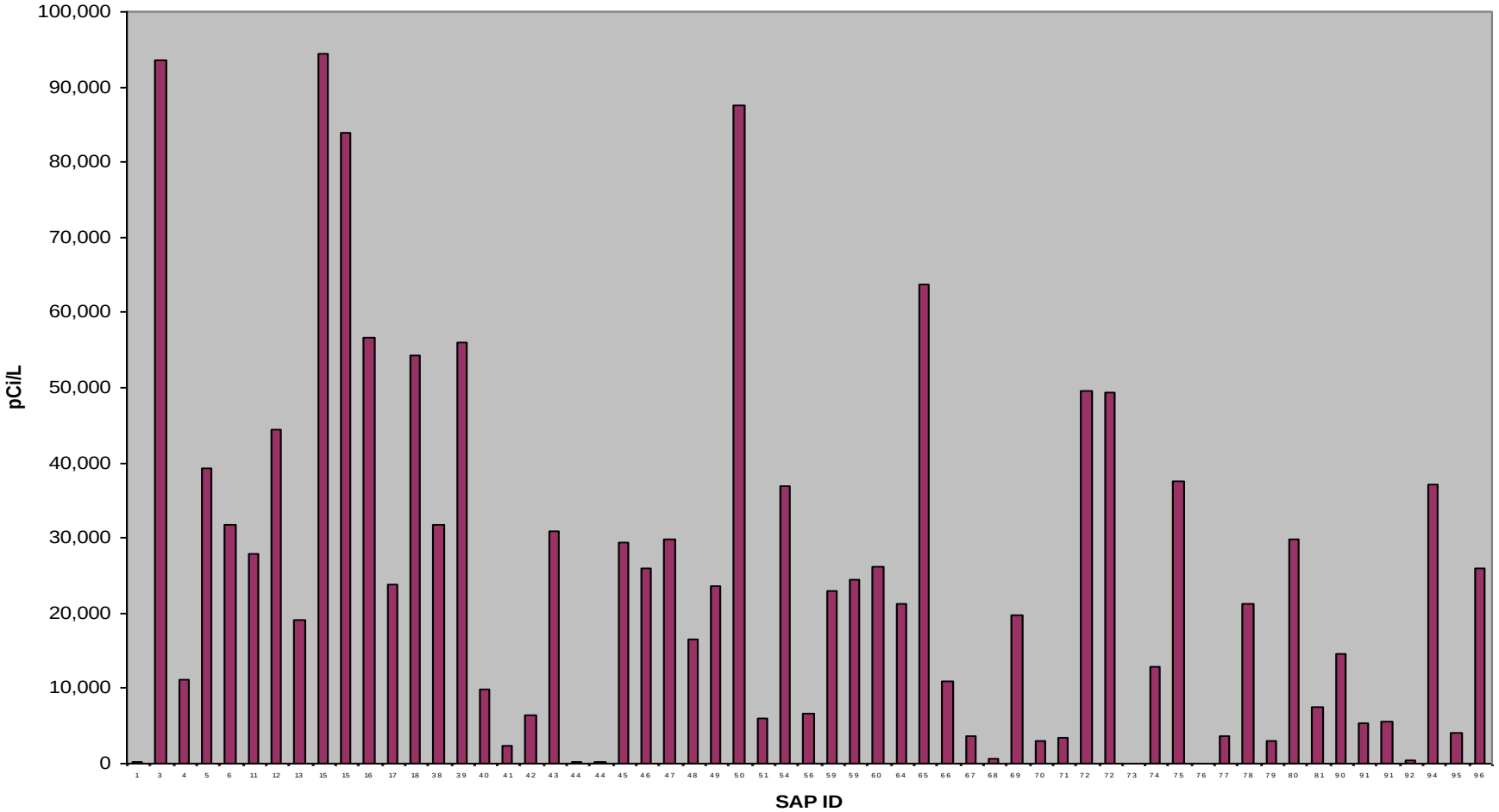
Early Flow-back with Ir-192 Tracer Proppant; Onsite *in situ* Decay Storage

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



Guidance - Disposal Option (cont.)

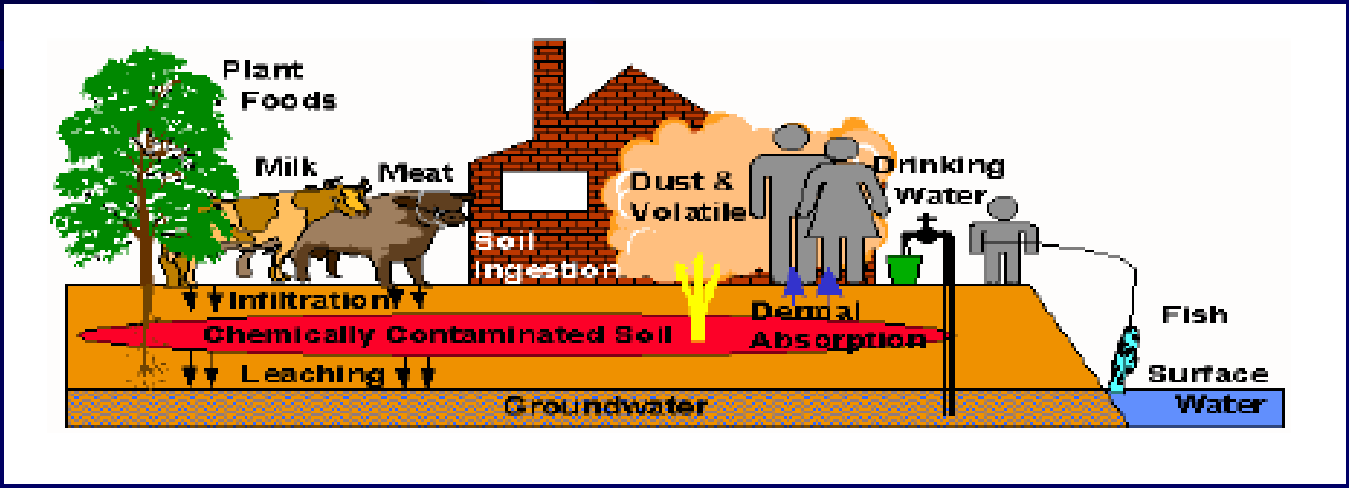
TENORM

- **TENORM, surface dose rate < 50 μR 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)**

Guidance - Disposal Option (cont.)

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

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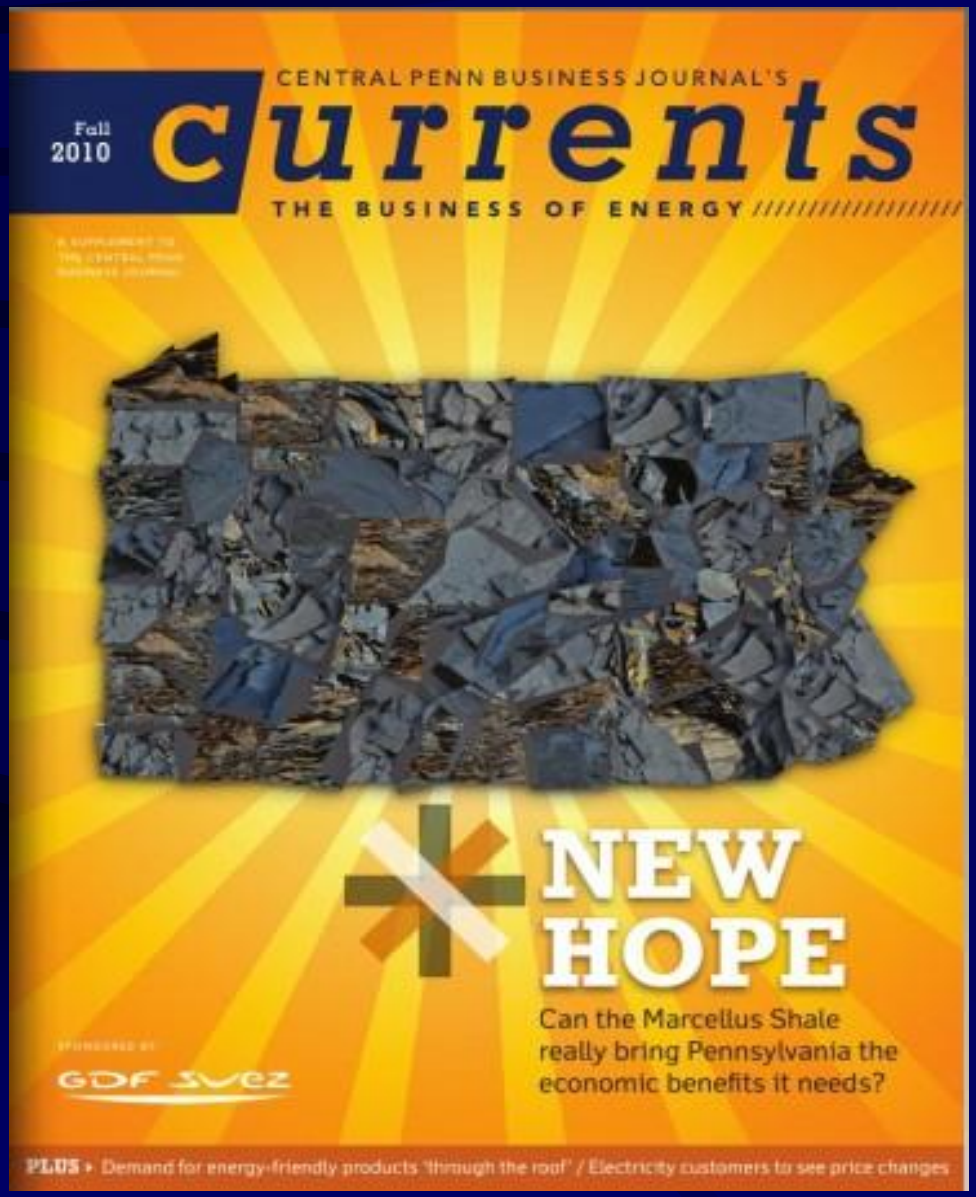
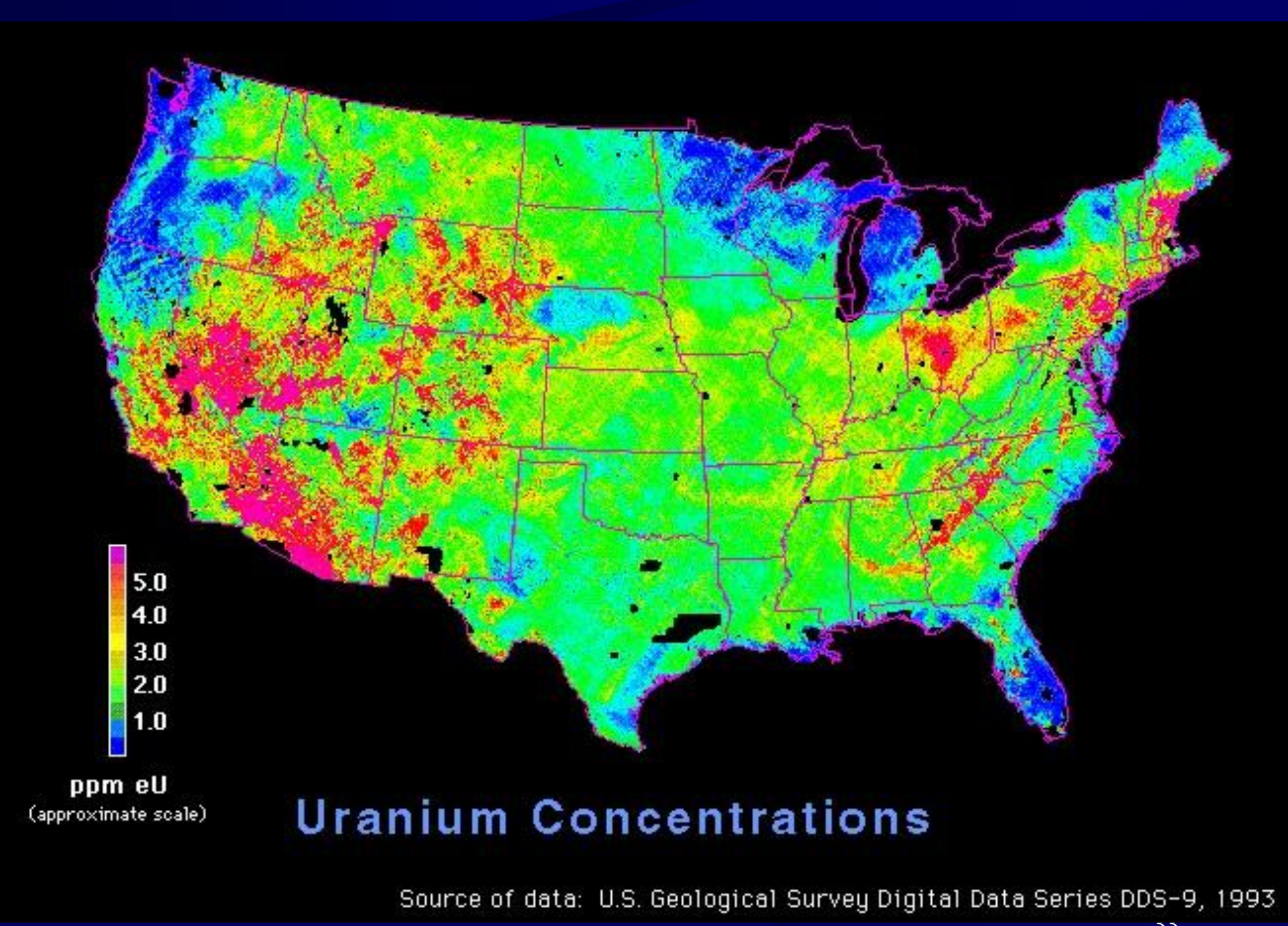
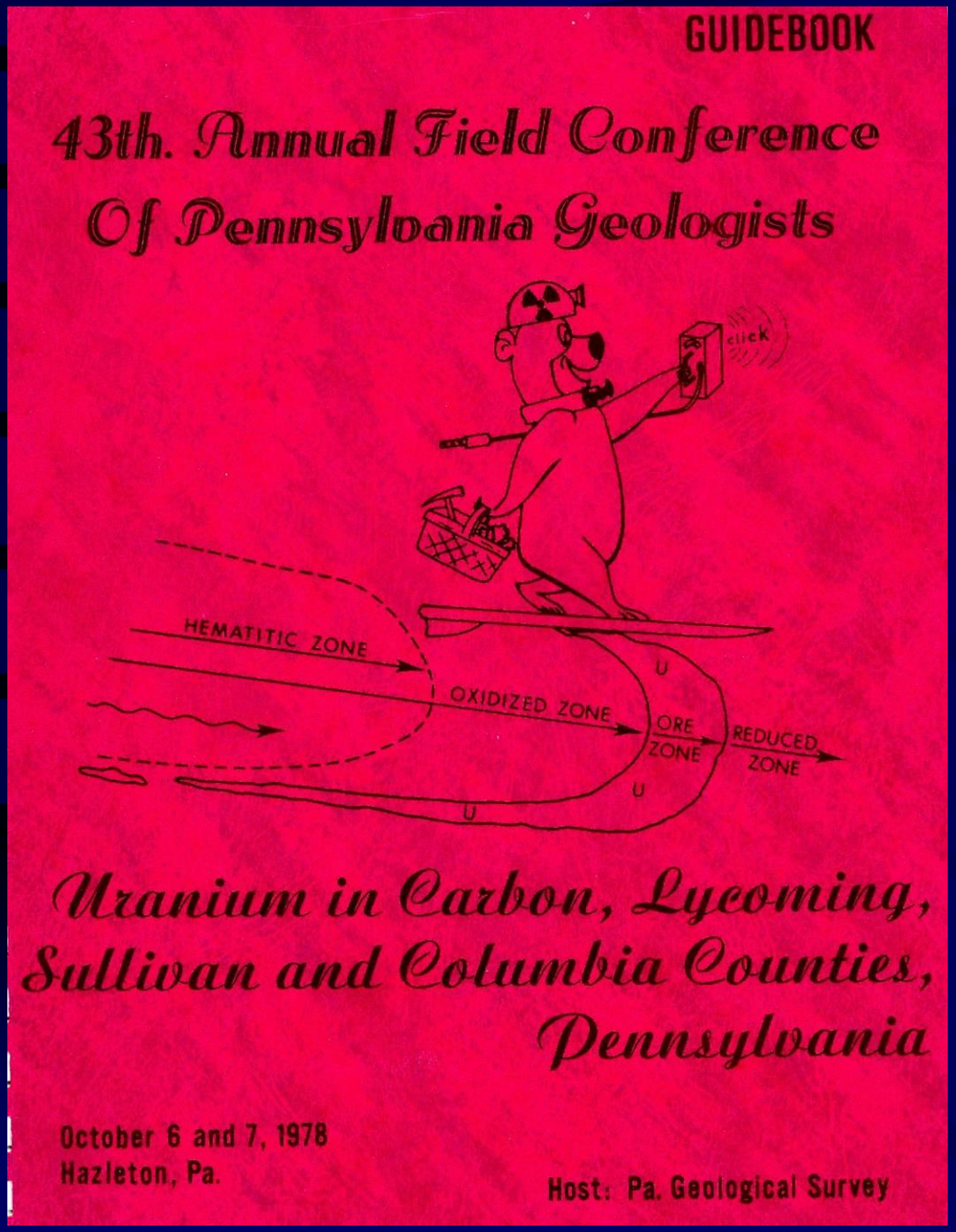
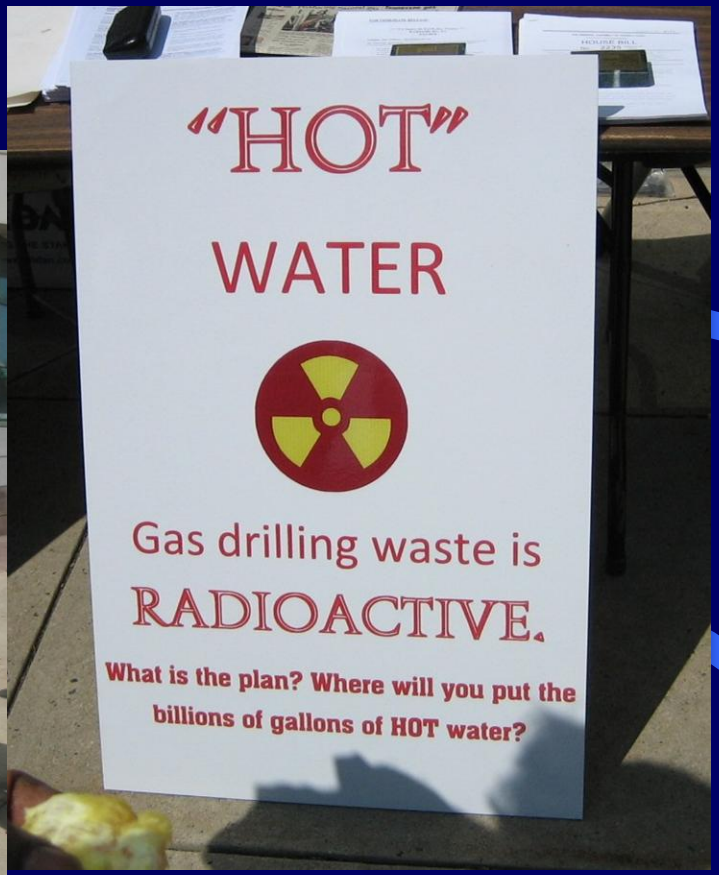



5.0
4.0
3.0
2.0
1.0
ppm eU
(approximate scale)
Uranium Concentrations
Source of data: U.S. Geological Survey Digital Data Series DDS-9, 1993

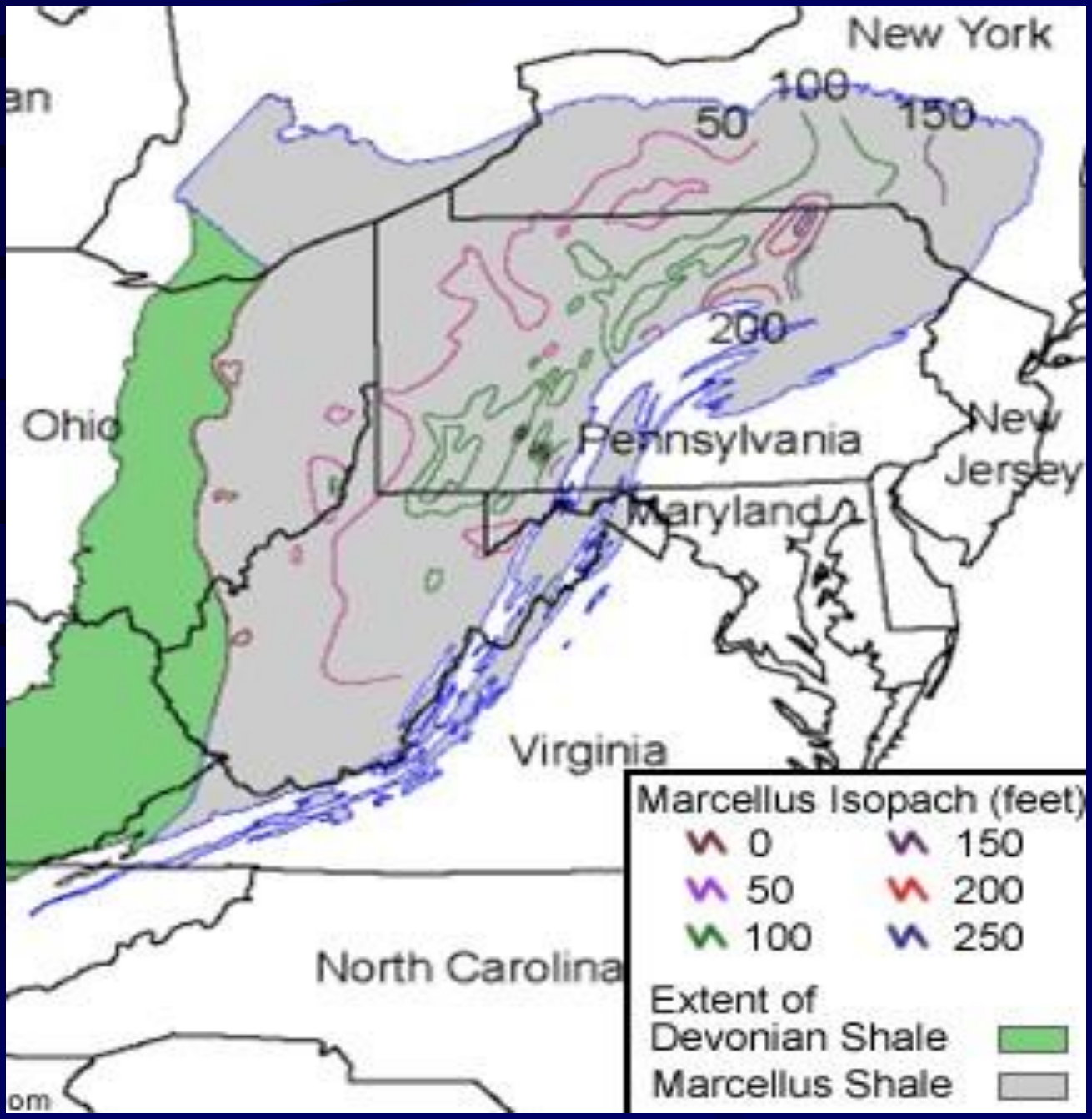
Uranium in PA



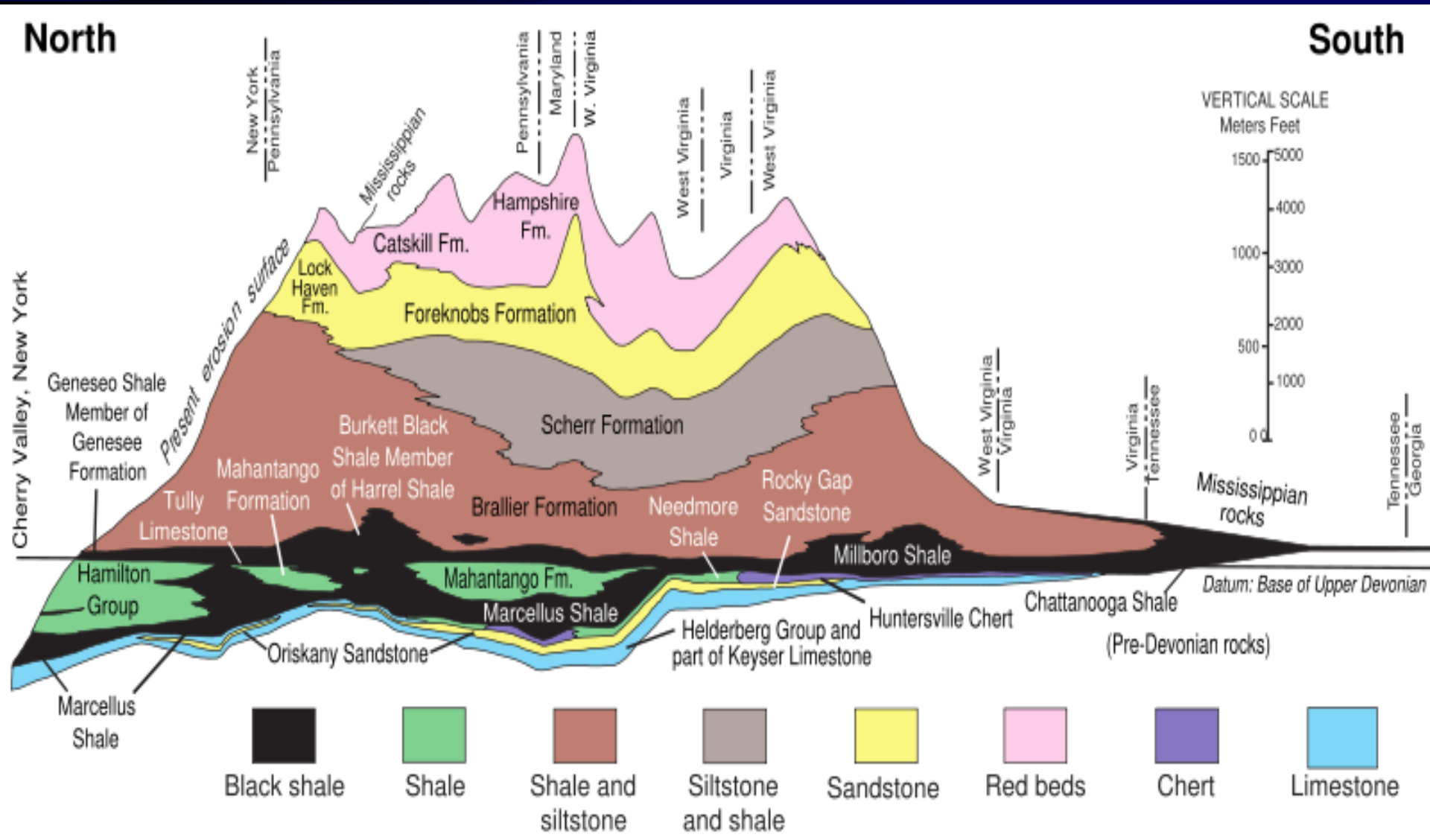
Marcellus Shale Env. Concerns



Patriot News


New York
50
100
150
200
Ohio
Pennsylvania
New Jersey
Maryland
Virginia
North Carolina
Marcellus Isopach (feet)
0
50
100
150
200
250
Extent of Devonian Shale
Marcellus Shale

Marcellus Shale



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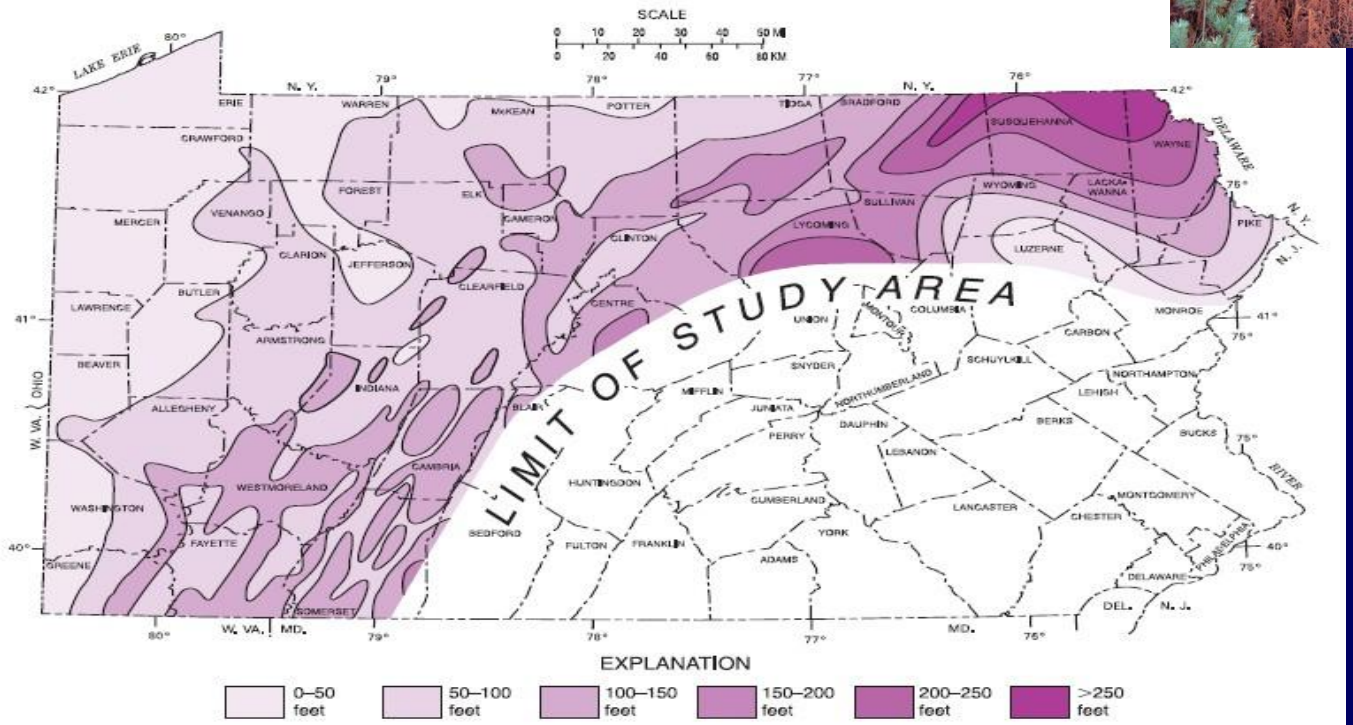
NET FEET OF ORGANIC-RICH SHALE IN THE MARCELLUS FORMATION

(Modified from Piotrowski 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

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Background NORM / TENORM

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)**

Radio-nuclide	Soil[1]	Phosphate Fertilizer[3]	Building Materials[3]	Sludge Concentrations[3]	Ash Concentrations[3]
Bi-212	0.1–3.5	0.1–4.6	0.1–3.7	0.1–13	0.3–16
Bi-214	0.1–3.8	4.0–140	2.5–5.0[4]	0.04–16	0.62–16
Cs-137	0.1–0.2[5]	NDA[6]	NDA	0–3.6	0–0.37
K-40*	2.7-19	32–160[7]	0.8–30	0.3–26	7.4–22
Pa-234m*	0.1–3.8	4.0–140	0.2–5.0[4]	0–27	1–77
Pb-212*	0.1–3.5	0.1–4.6	0.1–3.7	0–15	0.36–15
Pb-214*	0.1–3.8	4.0–140	0.2–5.0	0.06–17	0.61–16
Ra-223*	<0.1–0.2	0.2–6.6	0.1–0.2[4]	0.06–0.09	0.1–0.8
Ra-224*	0.1–3.5	0.1–4.6	0.1–3.72	0.2–12	0.4–4.9
Ra-226*	0.1–3.8	0.1–24	0.1–3.5	0–47	0–22
Ra-228*	0.1–3.5	0.1–4.6	0.1–3.7[1]	0.14–38	0.65–30
Th-227*	<0.1–0.2	0.2–6.6	0.1–0.2	0–0.5	0.02–1.1
Th-228*	0.1–3.5	0.1–4.6	0.1–3.7	0.07–9	0.4–14
Th-230*	0.1–3.8	4.0–140	0.2–5.0	0.09–1.7	0.3–2.6
Th-232*	0.1–3.5	0.1–4.6	0.1–3.7[1]	0.02–1.6	0.22–1.7
Th-234*	0.1–3.8	4.0–140	0.2–5.0	0–23	1–80
Tl-208*	0.1–3.5	0.1–4.6	0.1–3.7	0.02–4.8	0.11–14
U-234*	0.1–3.8	4.0–140	0.2–5.0	0.18–44	1.2–91
U-235*[8]	<0.1–0.2	0.2–6.6	0.1–0.2	0–3.1	0.03–3.4
U-238*	0.1–3.8	4.0–140	0.2–5.0[4]	0.18–26	0.8–74

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).

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URANIUM 238 (U238) RADIOACTIVE DECAY

type of radiation	nuclide	half-life
	uranium-238	4.47 billion years
α	thorium-234	24.1 days
β	protactinium-234m	1.17 minutes
β	uranium-234	245000 years
α	thorium-230	8000 years
α	radium-226	1600 years
α	radon-222	3.823 days
α	polonium-218	3.05 minutes
α	lead-214	26.8 minutes
β	bismuth-214	19.7 minutes
β	polonium-214	0.000164 seconds
α	lead-210	22.3 years
β	bismuth-210	5.01 days
β	polonium-210	138.4 days
α	lead-206	stable

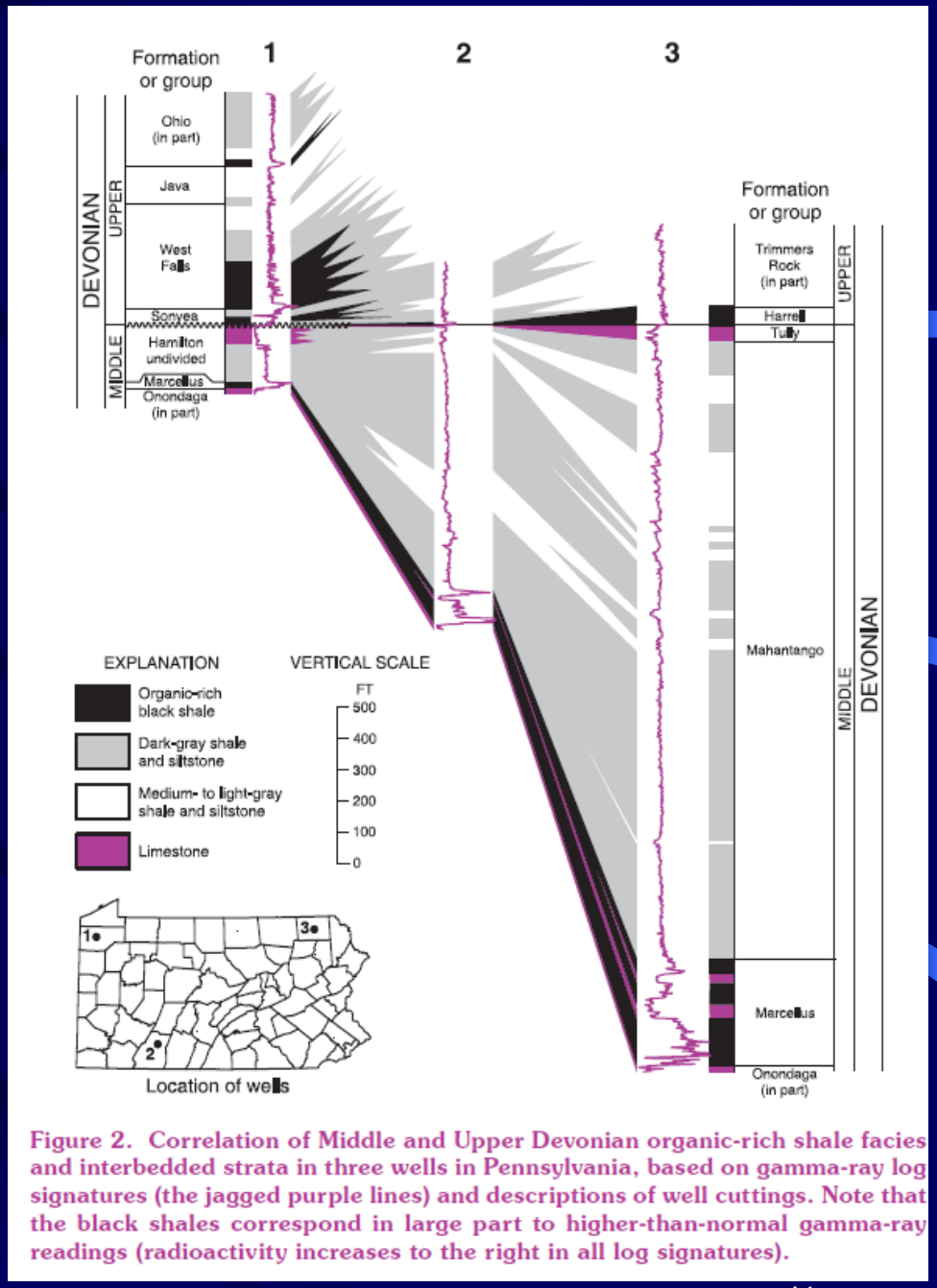
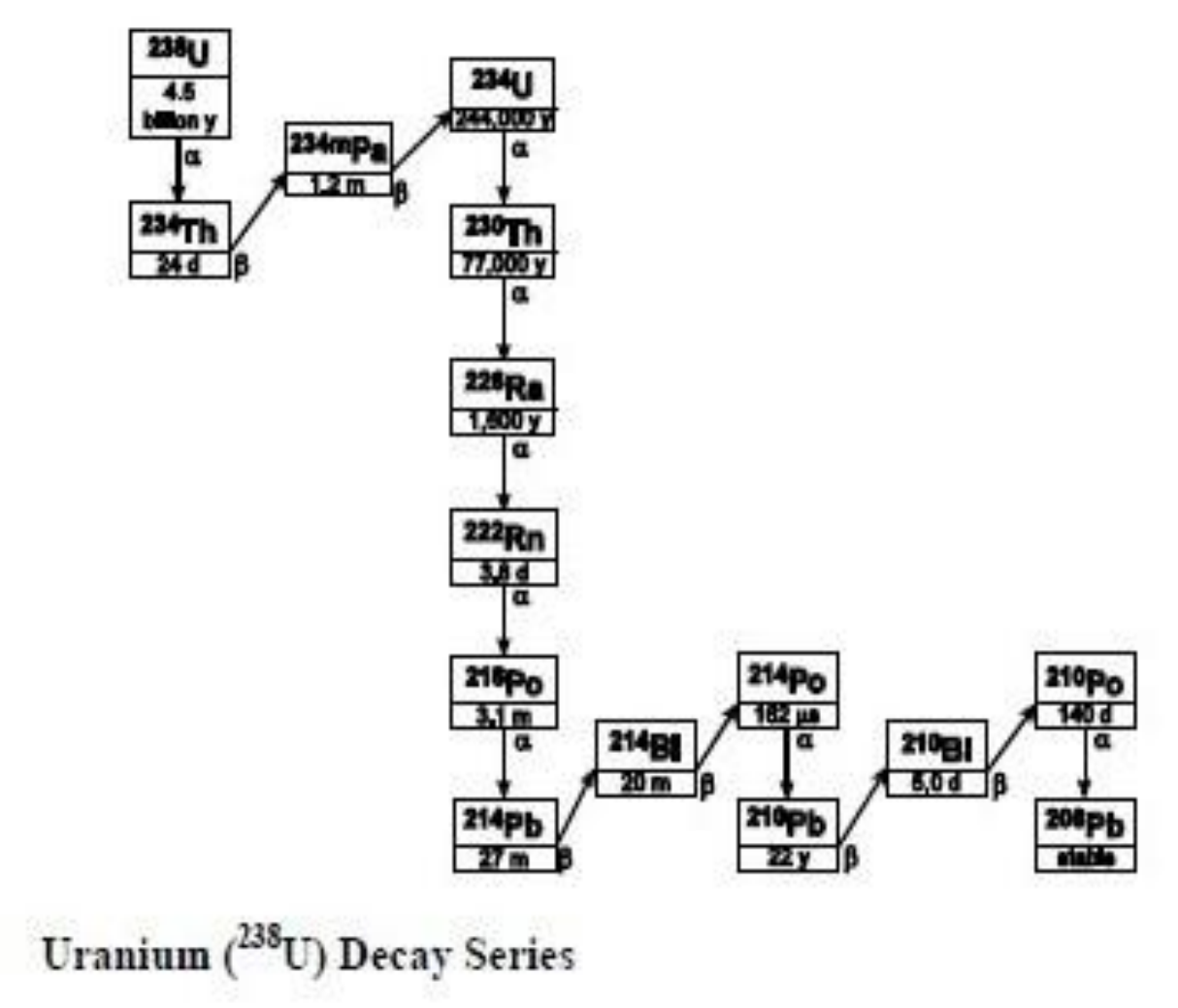


Figure 2. Correlation of Middle and Upper Devonian organic-rich shale facies and interbedded strata in three wells in Pennsylvania, based on gamma-ray log signatures (the jagged purple lines) and descriptions of well cuttings. Note that the black shales correspond in large part to higher-than-normal gamma-ray readings (radioactivity increases to the right in all log signatures).

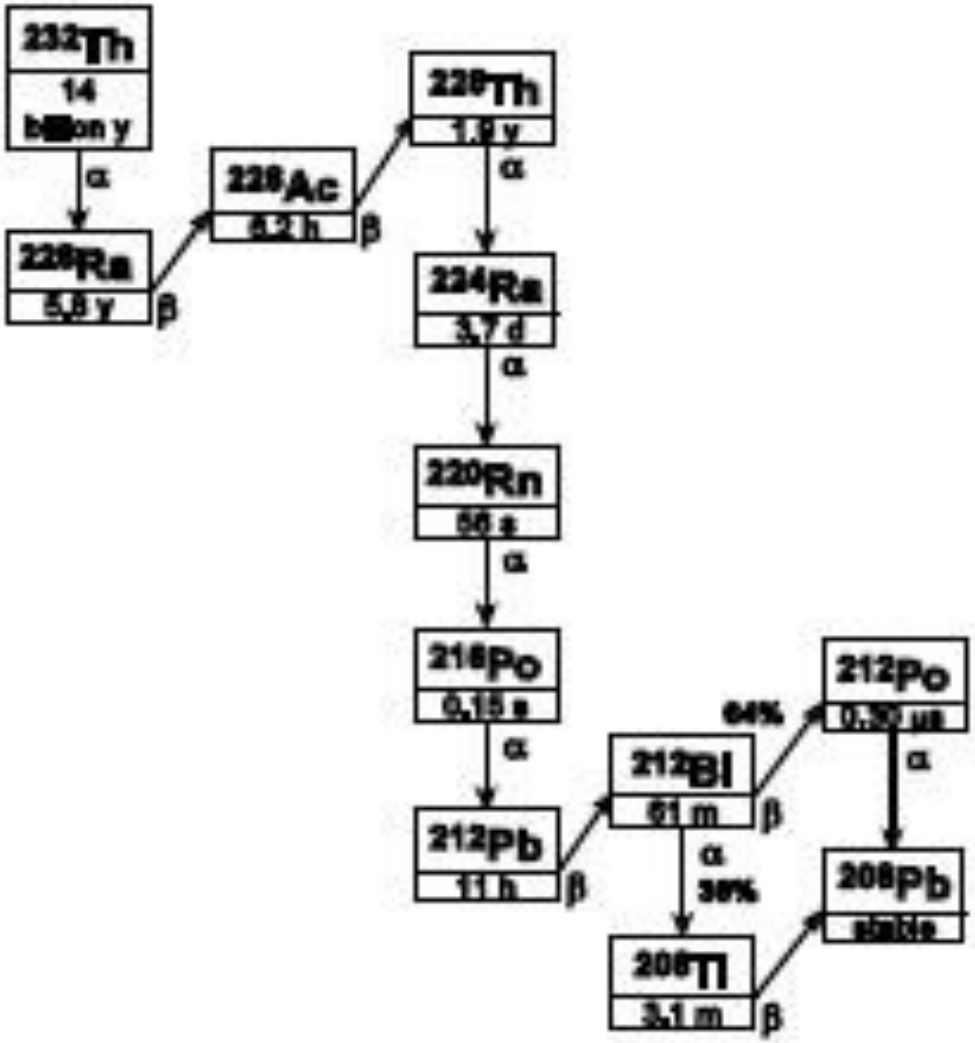
U-238 Decay Chain

U-238 ~ 99.3% by wt, ~50% of radioactivity



Uranium (^{238}U) Decay Series

Th-232 Decay Chain



Thorium (^{232}Th) Decay Series

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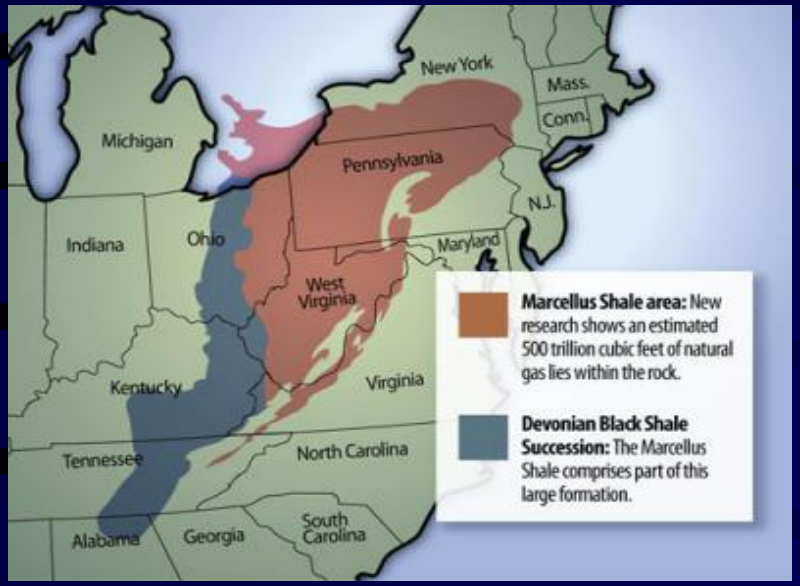
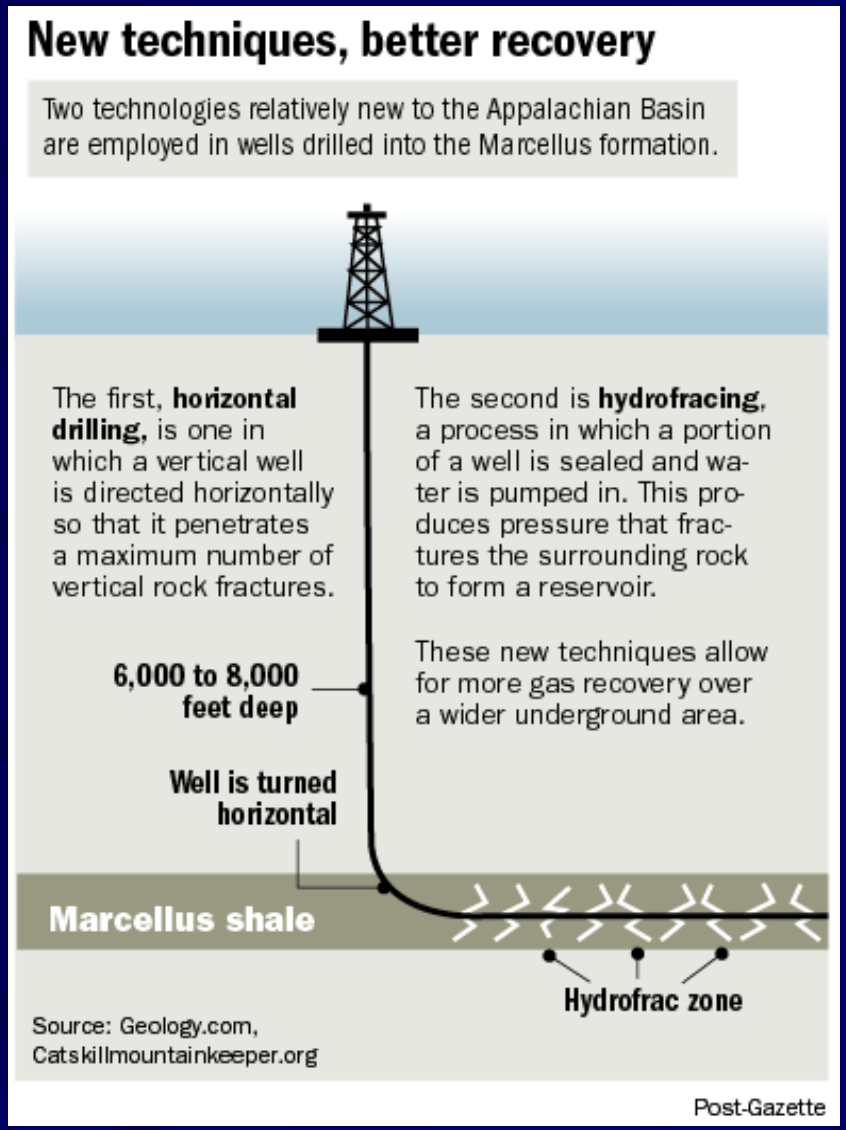
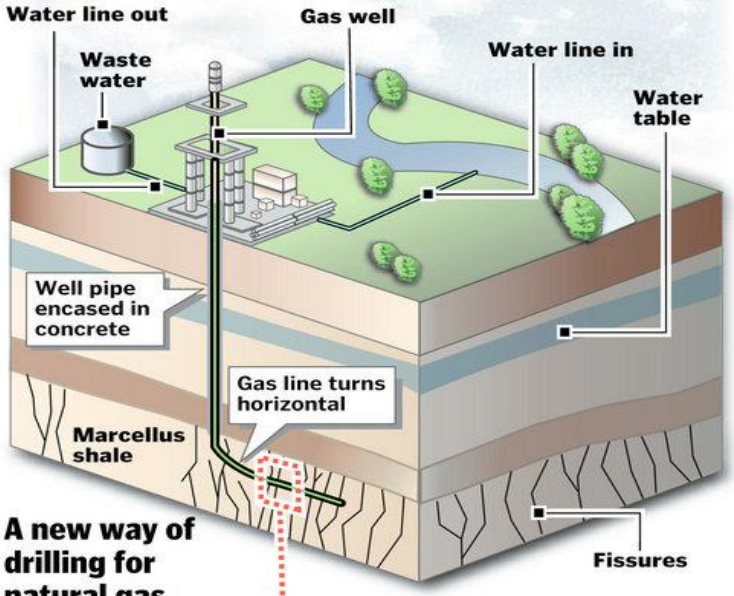




‘Fracking’ retrieves natural gas from the ground

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.

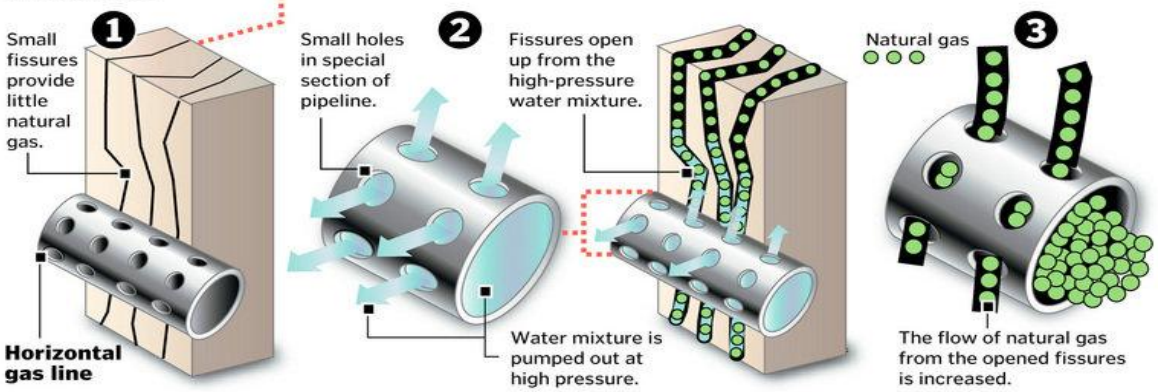


Ohio part of deep ‘Marcellus’ shale deposit

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.

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.

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

MICHAEL SCOTT, JAMES OWENS | THE PLAIN DEALER

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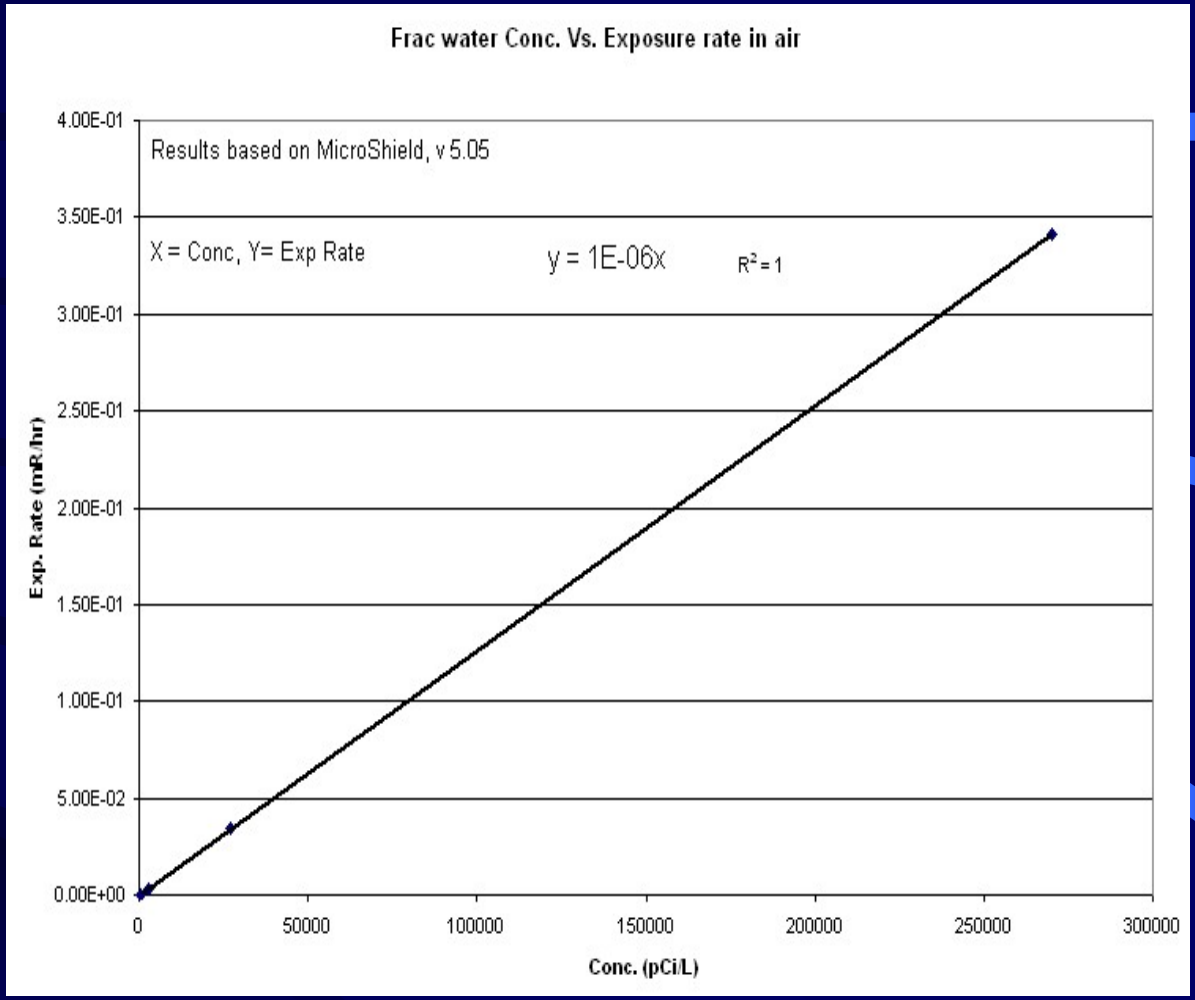
- MS uranium content: 10-100 ppm
- MS U-238 content: ~3.4 - 34 pCi/g
- MS Ra-226 content: ~3.4 - 34 pCi/g
- MS frac H_20 Ra-226: 300 - 9,000 pCi/L
- DW MCL Ra-226 / gross α: 5 / 15 pCi/L
- Treated frac H_20 sludge: 6 - 250 μR/h

Frac Water Treatment

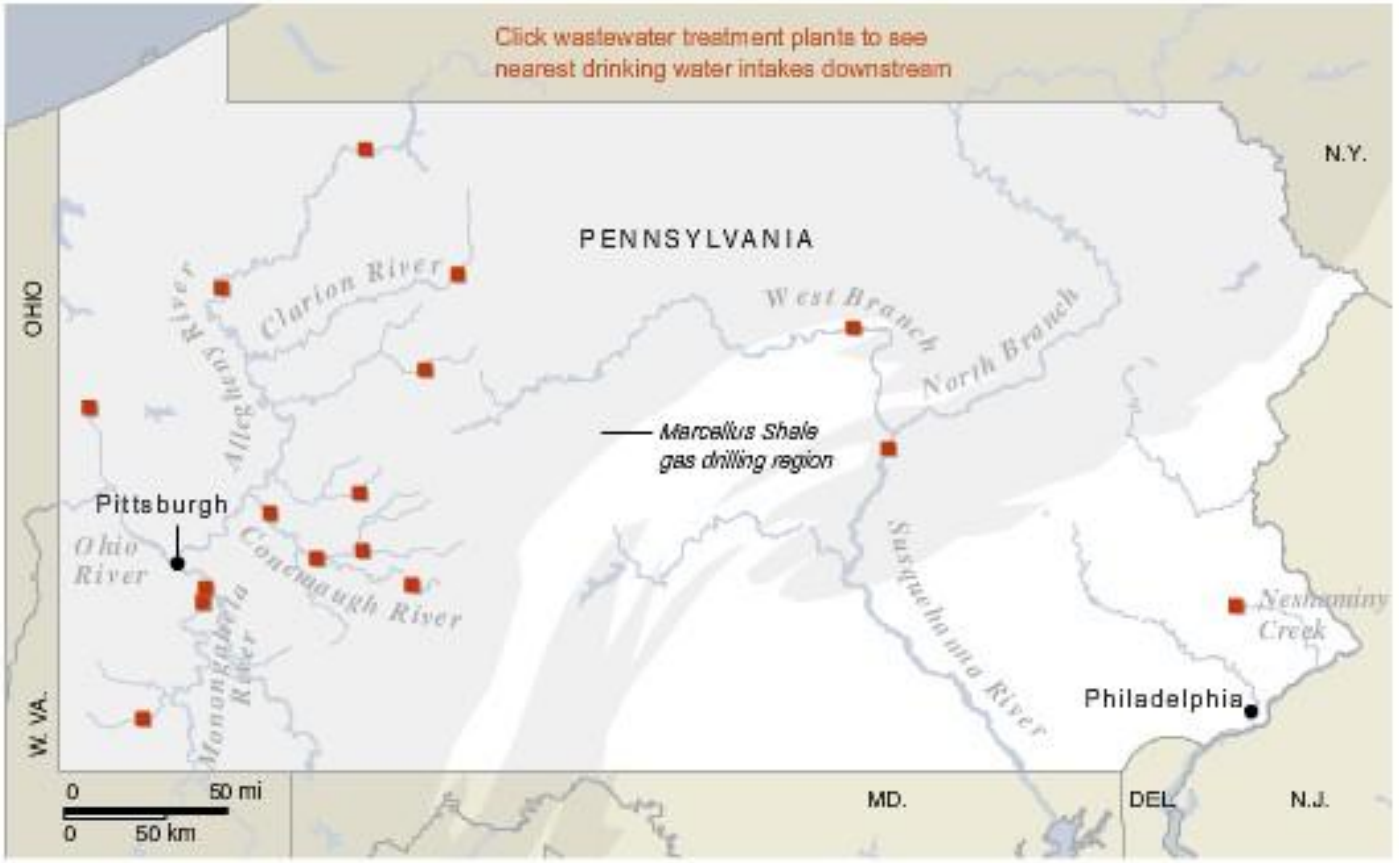
Frac H_2O with Ra-226 - no DOT placards on trucks!



NY Times

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.



Frac Water Treatment

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

United States Department of Energy | United States Environmental Protection Agency | DOE/EH-0668 EPA 832-R-03-002B

Interagency Steering Committee on Radiation Standards

Final Report

ISCORS Assessment of Radioactivity in Sewage Sludge: Recommendations on Management of Radioactive Materials in Sewage Sludge and Ash at Publicly Owned Treatment Works

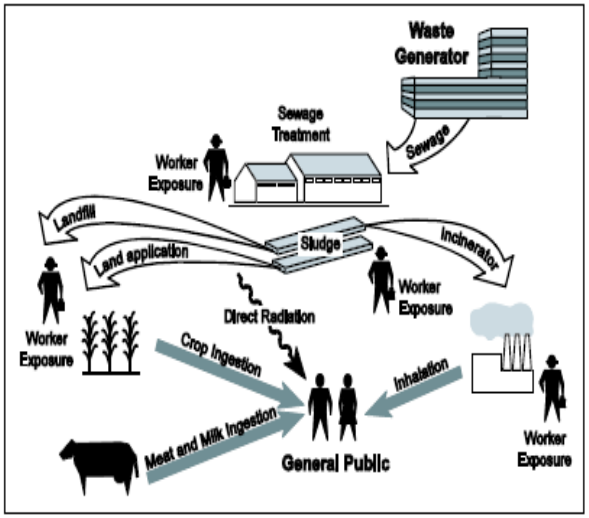


Figure 3.2 Primary Pathways for Radiation Exposure due to POTW Operations

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

They are ranked in decreasing order of concentration. The maximum concentration, percent of samples detected, probable source and half-life are also listed. Finally, the Relative Contribution to the dose of a Worker Loading at a POTW (air exchange rate = 3 per hour, room height = 4 meters, and time exposed to sludge = 1000 hours per year) at the 95% peak dose is listed next to the Relative Contribution of an Onsite Resident at the 95 % peak dose after 20 years of application.

Rank	Radio-nuclide	Concentration (pCi/g)		Percent Samples Detected	Probable source	Half-life	Relative contribution, 95%-ile	
		95%-tile	Max				Worker Loading	Onsite Resident (20 y)
1.	I-131	51	840	246/311= 84	Medical, Pacific mountain, and 50–100 MGD	8 d	240	<1
2.	TL.201	46	241	151/311= 49	Medical, Appalachian Highlands, 50–100 MGD	3 d	23	<1
3.	Sr-89	20	70	68/98= 70	Medical	51 d	<1	<1
4.	U-234	17	44	92/92=100	U-processing Intermontane Plateaus	245×10^3 y	5	6.2
5.	Ra-226	13	47	289/311= 93	NORM, Atlantic & Interior Plains, ground water	1600 y	550	1000
6.	U-238	12	26	92/92= 100	Appalachian Highlands, Intermontane Plateaus	4.5×10^9 y	6.8	4.4
7.	K-40	12	26	308/311= 99	NORM, all geographic regions	1.3×10^9 y	27	2.3
8.	Be-7	9	22	263/311= 85	NORM, Appalachian Highlands	53 d	5.5	<1
9.	Pa-234m	7	27	80/311= 86	U-238 decay	1 m	<1	<1
10.	Th-234	6.7	23	191/311= 29	U-238-decay, Intermontane Plateaus, Rocky Mt.	24 d	<1	<1
11.	Ra-228	5.1	38	271/311= 87	NORM, Interior Plains, ground water, < 10 MGD	6 y	65	42
12.	H-3	5	8	111/158= 70	Academic/Medical/Research	12 y	<1	<1
13.	Th-228	4.1	9	92/92= 100	NORM, Interior and Atlantic Plains, ground water, < 10 MGD	2 y	1000	4.4

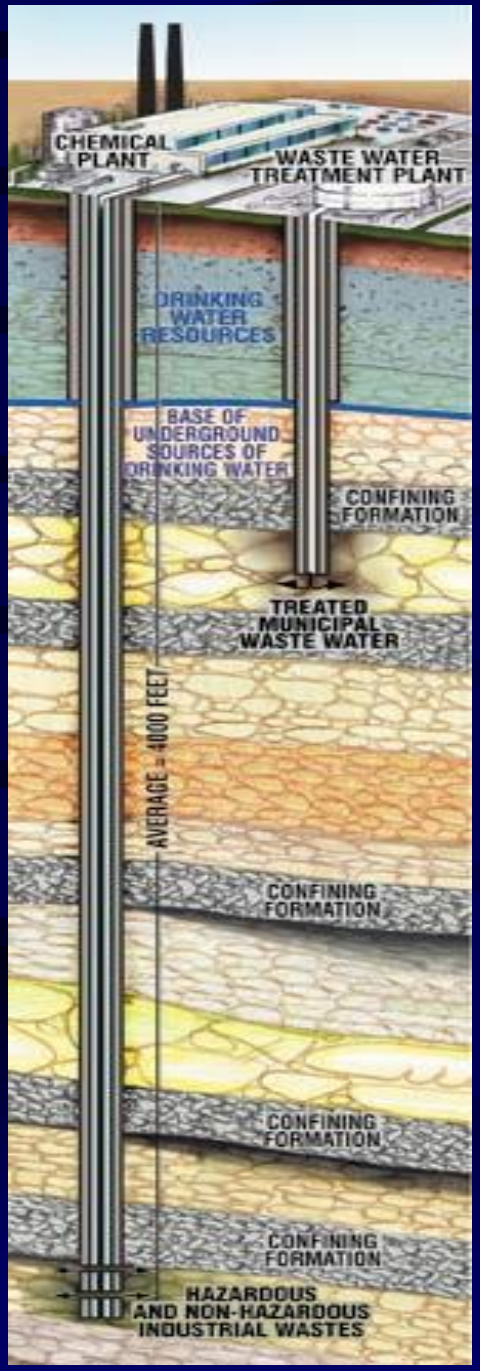
NY Times

The New York Times March 1, 2011

Jessica Kourkounis for The New York Times

RECOMMEND

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

EPA DW MCLs

The regulations for radionuclides are in the table below.

Radionuclides	MCLG	MCL
(Adjusted) Gross Alpha Emitters	Zero	15 picoCuries per liter
Beta Particle and Photon Radioactivity	Zero	4 millirems per year
Radium 226 and Radium 228 (Combined)	Zero	5 picoCuries per liter
Uranium	Zero	30 micrograms per liter

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.

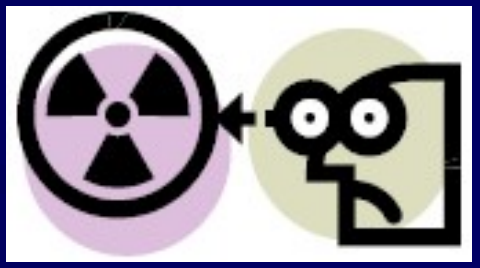
Administrative Manual – Part III
WATER QUALITY REGULATIONS

WITH AMENDMENTS THROUGH
JULY 16, 2008

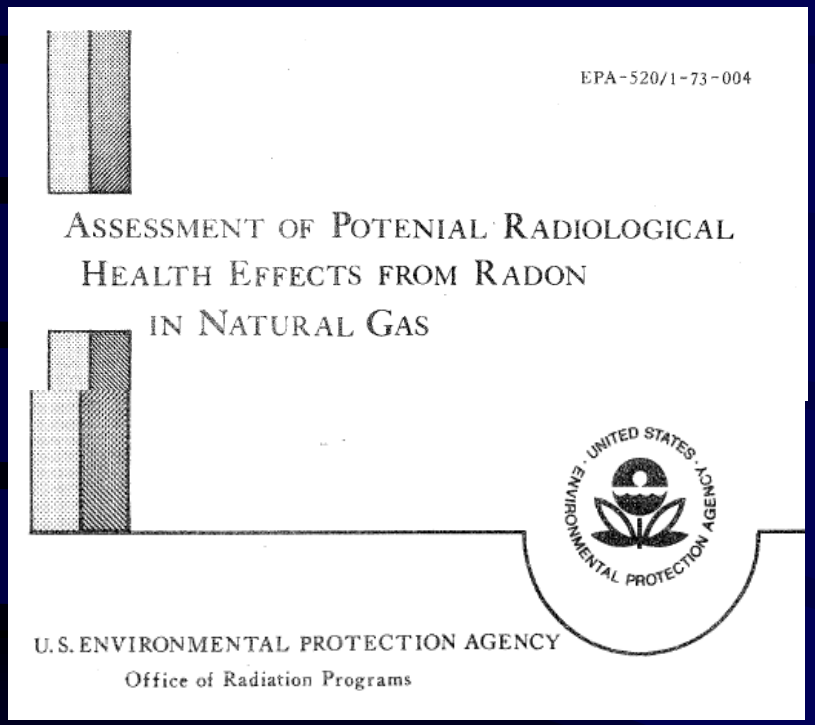
18 CFR PART 410

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



EPA-520/1-73-004

ASSESSMENT OF POTENIAL RADIOLOGICAL HEALTH EFFECTS FROM RADON IN NATURAL GAS

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Radiation Programs

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

Area	Radon-222 level, pCi/l Average	Range	Reference
Colorado New Mexico	25	0.2-160	1
Texas, Kansas, Oklahoma	<100	5-1450	2
Taxas Panhandle	---	10-520	3
Colorado	25.4	11-45	5-7
Project Gasbuggy Area	15.8-19.4	--------	7
Project Gasbuggy Area	29.4	12-59	8
California	---	1-100	10
Gulf Coast (Louisiana, Texas)	5	--------	11
Kansas	100	--------	11
Wyoming	10	--------	11
Overall average	37		

Action level: 4 pCi/L

Rad / Nuc Organizations

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

CRCPD

AAPM

ANS

HPS

Reference URLs

- BRP http://www.dep.state.pa.us/dep/deputate/airwaste/rp/rp.htm
- CRCPD http://www.crcpd.org/
- CDC http://www.bt.cdc.gov/radiation/index.asp
- HPS http://www.hps.org/ http://hps.org/publicinformation/ate/
- AAPM http://www.aapm.org/
- ACR http://www.acr.org/departments/educ/disaster_prep/dp_primer.html

- 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/
- IAEA http://www-pub.iaea.org/MTCD/publications/PDF/P074_scr.pdf

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“radiation”

Thank you!

Questions?