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DEPARTMENT OF ENVIRONMENTAL PROTECTION

Bureau of Radiation Protection

PA TENORM Study & Regulatory Framework

David J. Allard, MS, CHP

Shale Network Workshop at PSU

May 19, 2017

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The author has no conflicts of interest.

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D. Allard [2013], adopted from an IRPA 11 meeting graphic

RADIATION PROTECTION SYSTEM

RADIATION BIOLOGICAL EFFECTS

RADIOLOGICAL PROTECTION STANDARDS, STATUTES AND REGULATION (FEDERAL AND STATE)

RADIATION MEASUREMENTS –INSTRUMENTATION & DOSIMETRY

RADIATION PROTECTION OF WORKERS

RADIATION PROTECTION OF THE ENVIRONMENT

RADIATION PROTECTION OF PATIENTS

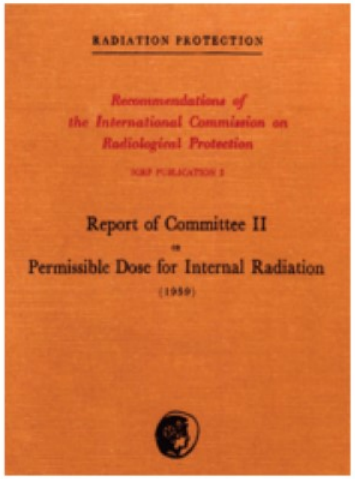
RADIATION PROTECTION OF THE PUBLIC

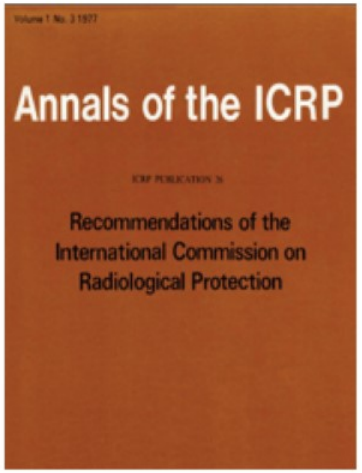
BASIC & APPLIED RESEARCH, INCIDENTS, ACCIDENTS AND ANALYSIS

SOCIETAL AND POLITICAL INFLUENCES

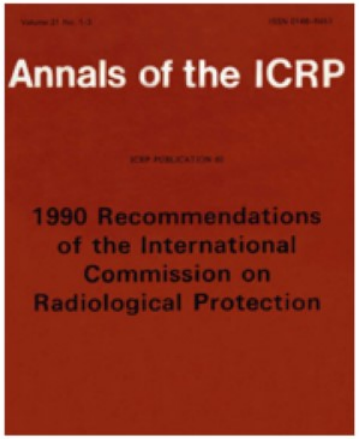
Radiation Protection Recommendations

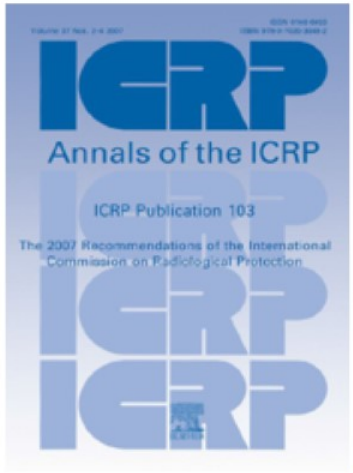
- Justification
- Optimization [ALARA]
- Limitation



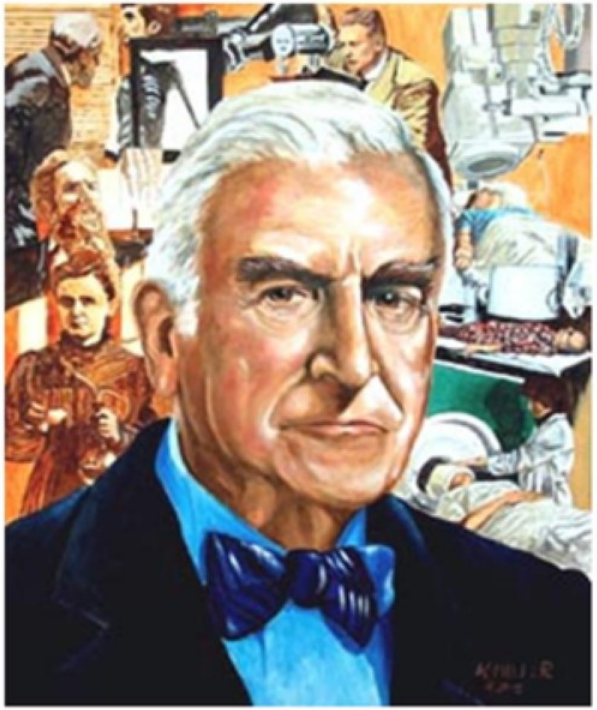


- Existing Conditions
- Planned Scenarios
- Emergencies





NCRP - Lauriston S. Taylor



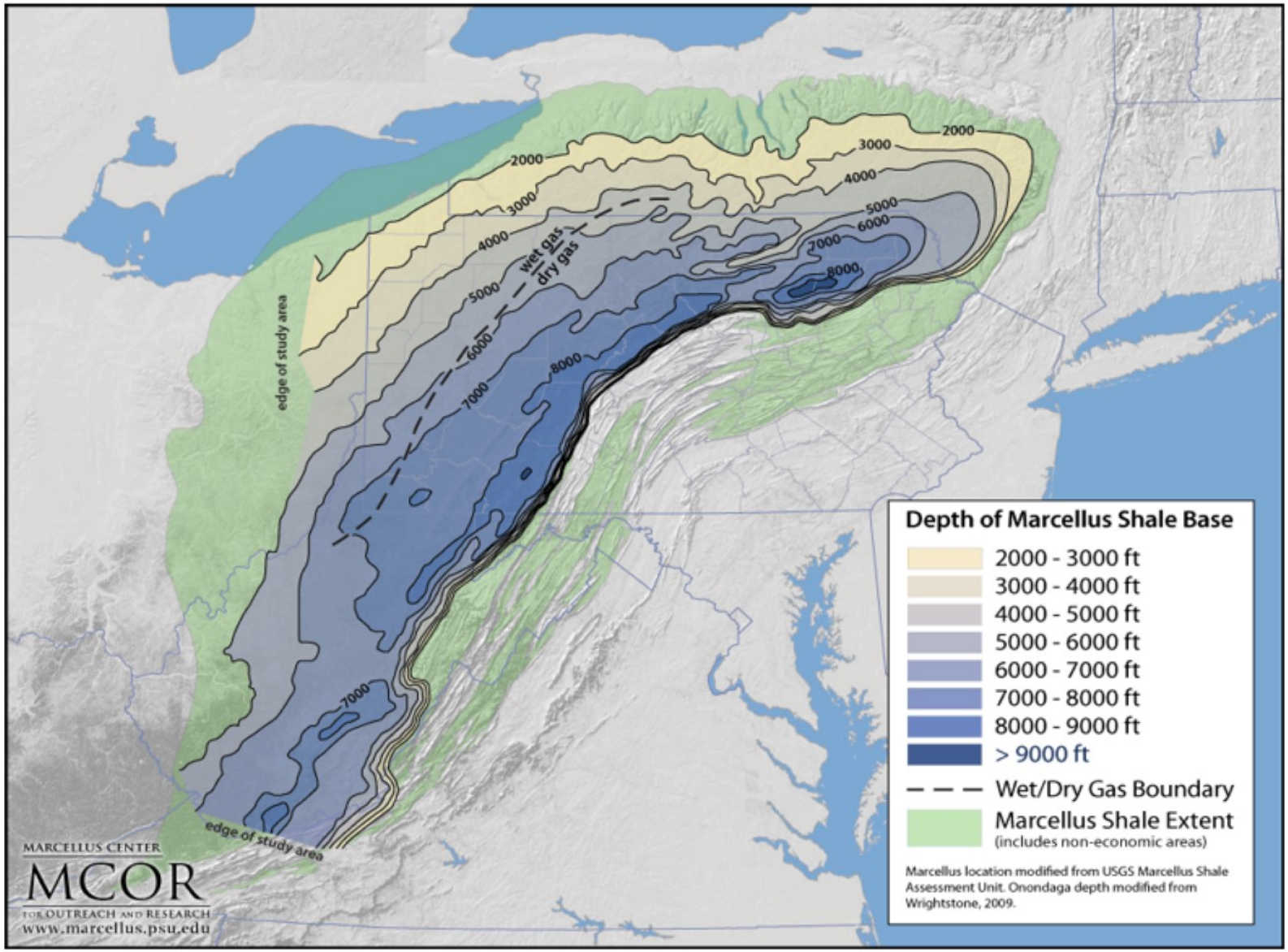
Taylor painting by Ken Miller

"Radiation protection is not only a matter of science. It is a problem of philosophy, and morality, and the utmost wisdom."

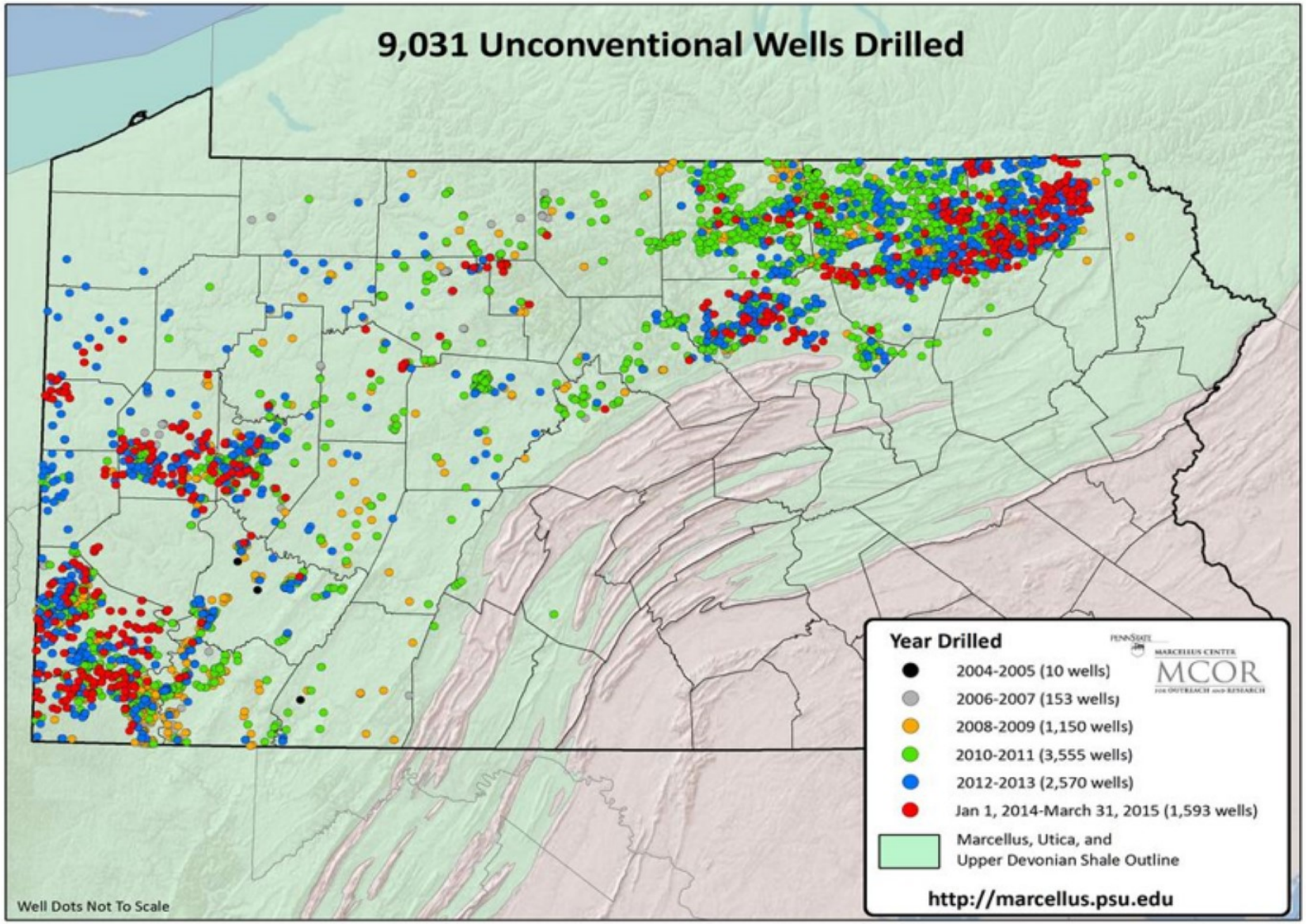
(L.S. Taylor, 1956)

NCRP
National Council on Radiation Protection & Measurements

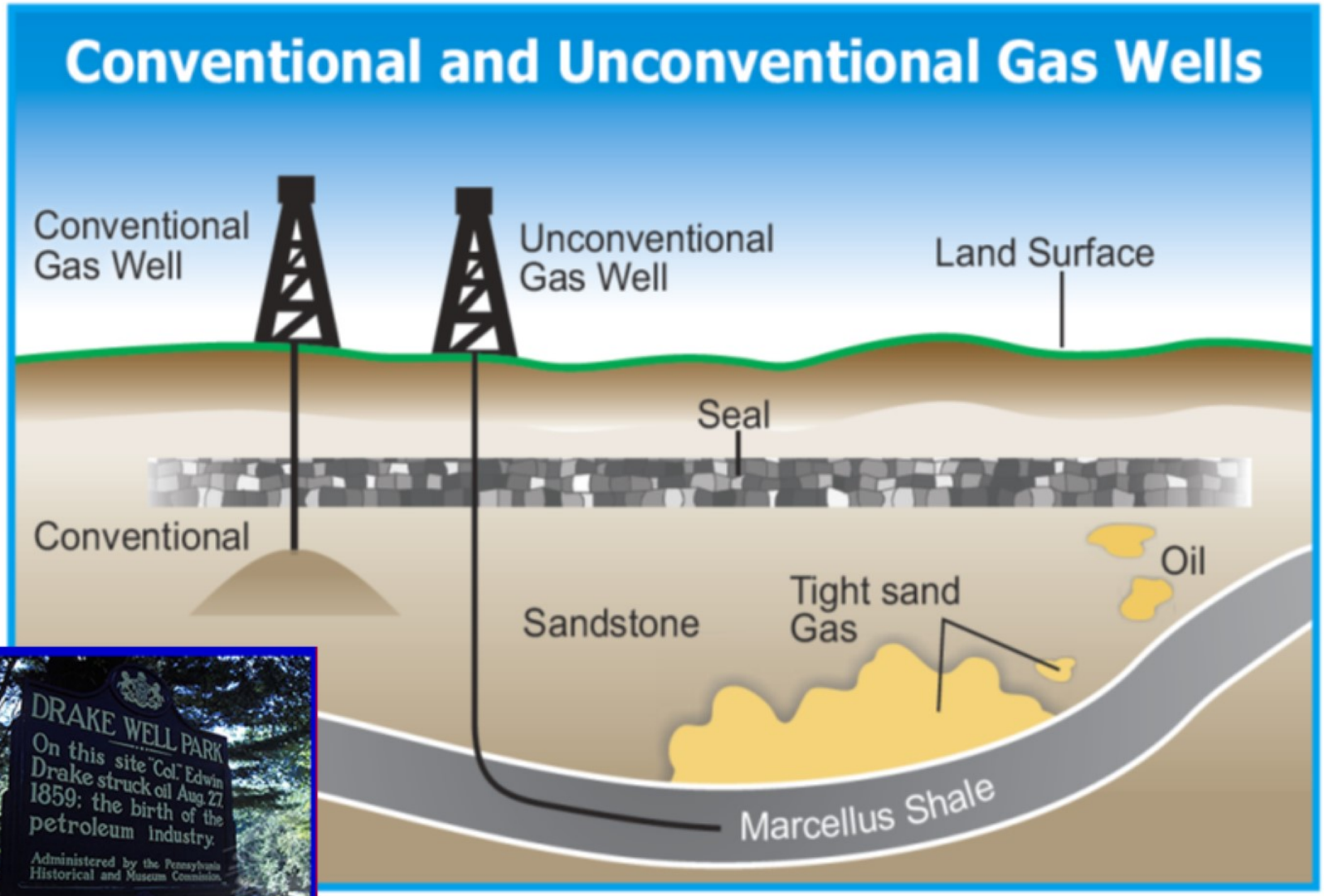
MS - Wet vs. Dry Gas

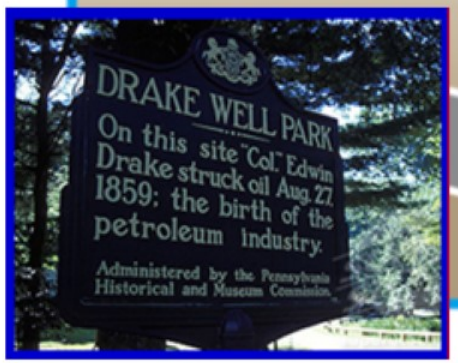


MS Gas Wells Thru 2015



O&G Well Types





Marcellus Shale

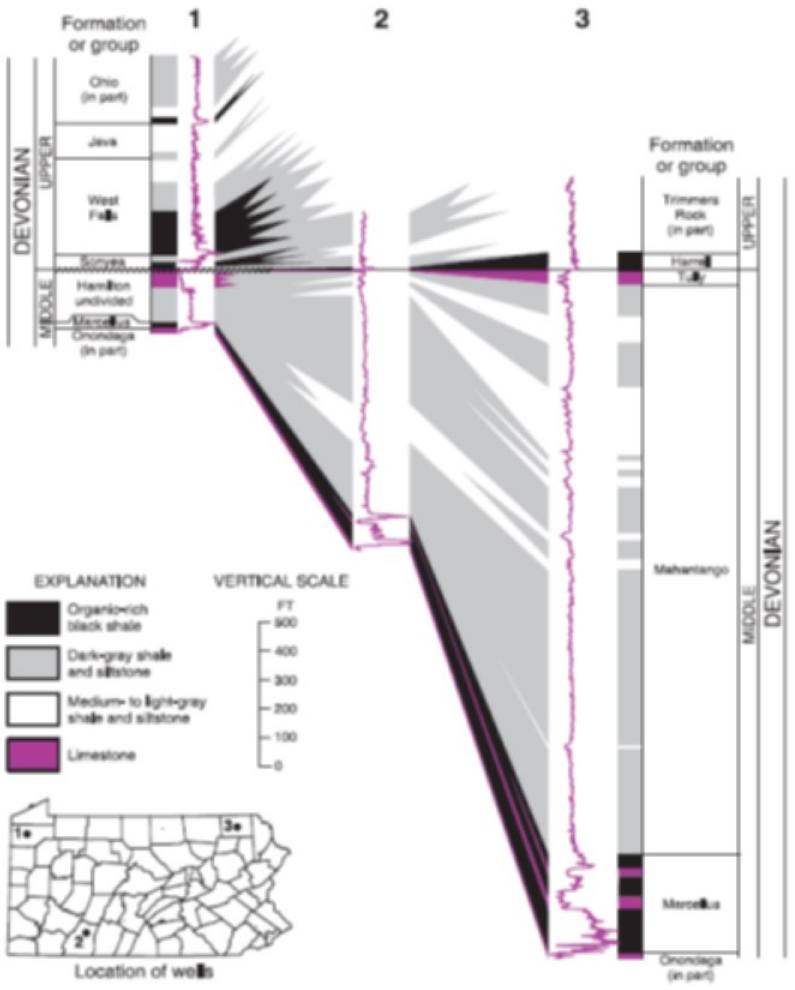


Figure 2. Correlation of Middle and Upper Devonian organic-rich shale facies and interbedded strata in three wells in Pennsylvania, based on gamma-ray log signatures (the jagged purple lines) and descriptions of well cuttings. Note that the black shales correspond in large part to higher-than-normal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

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

TENORM & NORM Defined

Technologically **E**nhanced **N**aturally **O**ccurring **R**adioactive **M**aterial

- *TENORM*, a naturally occurring radioactive material not subject to regulation under the laws of the Commonwealth or the Atomic Energy Act of 1954, whose radionuclide concentrations or potential for human exposure have been increased above levels encountered in the natural state by human activities.
- *NORM - Naturally occurring radioactive material* - NORM is a nuclide, which is radioactive in its natural physical state - that is, not man-made - but does not include source or special nuclear material.

PA DEP Regulations, Title 25, Chapter 271

TENORM Regulatory Framework

- Environmental Protection Agency (EPA)
- Nuclear Regulatory Commission (NRC)
- Dept. of Energy (DOE)
- Dept. of Labor - Occupational Safety & Health Administration (OSHA)
- Dept. of Transportation (DOT)
- States (e.g., Pennsylvania)

DOT - Shipping RAM

RAM Class 7, Transport under 49CFR

ERG2004 — RADIOACTIVE MATERIALS (LOW LEVEL RADIATION) — GUIDE 161

EMERGENCY RESPONSE

FIRE

- Presence of radioactive material will not influence the fire control processes and should not influence selection of techniques.
- Move containers from fire area if you can do it without risk.
- Do not move damaged packages; move undamaged packages out of fire zone.

Small Fires

- Dry chemical, CO_2, water spray or regular foam.

Large Fires

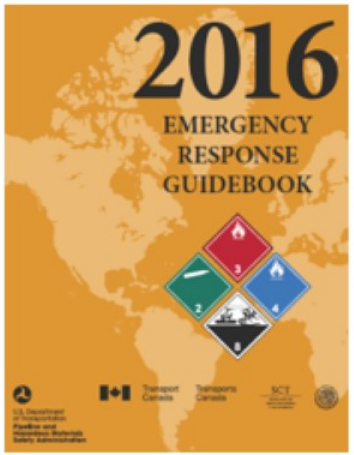
- Water spray, fog (flooding amounts).

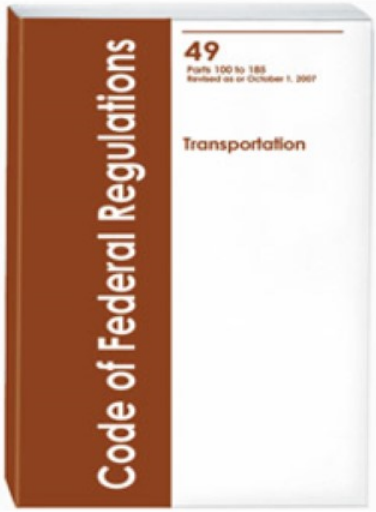
SPILL OR LEAK

- Do not touch damaged packages or spilled material.
- Cover liquid spill with sand, earth or other non-combustible absorbent material.
- Cover powder spill with plastic sheet or tarp to minimize spreading.

FIRST AID

- Medical problems take priority over radiological concerns.
- Use first aid treatment according to the nature of the injury.
- Do not delay care and transport of a seriously injured person.
- Give artificial respiration if victim is not breathing.
- Administer oxygen if breathing is difficult.
- In case of contact with substance, immediately flush skin or eyes with running water for at least 20 minutes.
- Injured persons contaminated by contact with released material are not a serious hazard to health care personnel, equipment or facilities.
- Ensure that medical personnel are aware of the material(s) involved, take precautions to protect themselves and prevent spread of contamination.





PA TENORM Waste Issues

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SHIPPING OF TECHNOLOGICALLY ENHANCED NATURALLY OCCURRING RADIOACTIVE MATERIAL UNDER THE U.S. DOT HAZARDOUS MATERIAL TRANSPORTATION REGULATIONS

Safe and proper shipment of radioactive materials occurs routinely on Pennsylvania roads. This includes nuclear medicine materials, industrial test equipment and manufactured products. This fact sheet focuses on the shipment of technologically enhanced naturally occurring radioactive material (TENORM).

Most soils and rocks contain some level of naturally occurring radioactive material (NORM). This NORM is often affected by physical or chemical actions resulting in TENORM. Examples of TENORM-containing materials include fire brick, water and wastewater treatment residuals (sludge), and decorative polished rock (e.g., granite and marble) commonly used in building or home construction. It is also common for the native rock formations encountered by the oil and gas (O&G) extraction industry during drilling to contain levels of NORM, specifically uranium, thorium and their decay products. Consequently, drill cuttings from these formations may be classified as TENORM. In addition, sediment, water and wastewater residuals, sludges and solid filter cakes resulting from the recycling or processing of "produced water" (e.g., brines or flowback) may also contain TENORM.

This fact sheet is intended to alert generators of TENORM-containing materials in all industry sectors that, at high concentrations, the TENORM may be classified as a hazardous material as defined by the U.S. Department of Transportation (USDOT). The USDOT has regulatory authority and responsibility for safety in the transportation of all hazardous materials, including radioactive material. There are nine hazardous material classifications, with radioactive material being Class 7.

FEDERAL REGULATION

It is important to note that this fact sheet is not intended to provide complete guidance on the packaging and shipment of radioactive material under USDOT Hazardous Materials Regulations (HMR) contained in Title 49, Code of Federal Regulations (49 CFR) Parts 100-178. However, the first step when moving materials is to determine if levels of radioactive materials meet the USDOT HMR definition of Class 7 radioactive material, as defined in 49 CFR 173.436. In the case of radium-226 (Ra-226), for example, any shipment that is offered for transport in commerce having a Ra-226 concentration greater than 270 picocuries per gram and a total activity above 0.27 microcuries would be subject to the USDOT HMR regulations. If those thresholds are met, then the other USDOT HMR regulations related to proper shipment name (e.g., low specific activity), manifesting as hazardous material on shipping papers, proper packaging, and marking and placarding as "radioactive" must be evaluated and implemented.

U-238 w Series Geochem

From: IAEA TCS No. 40 May 2010

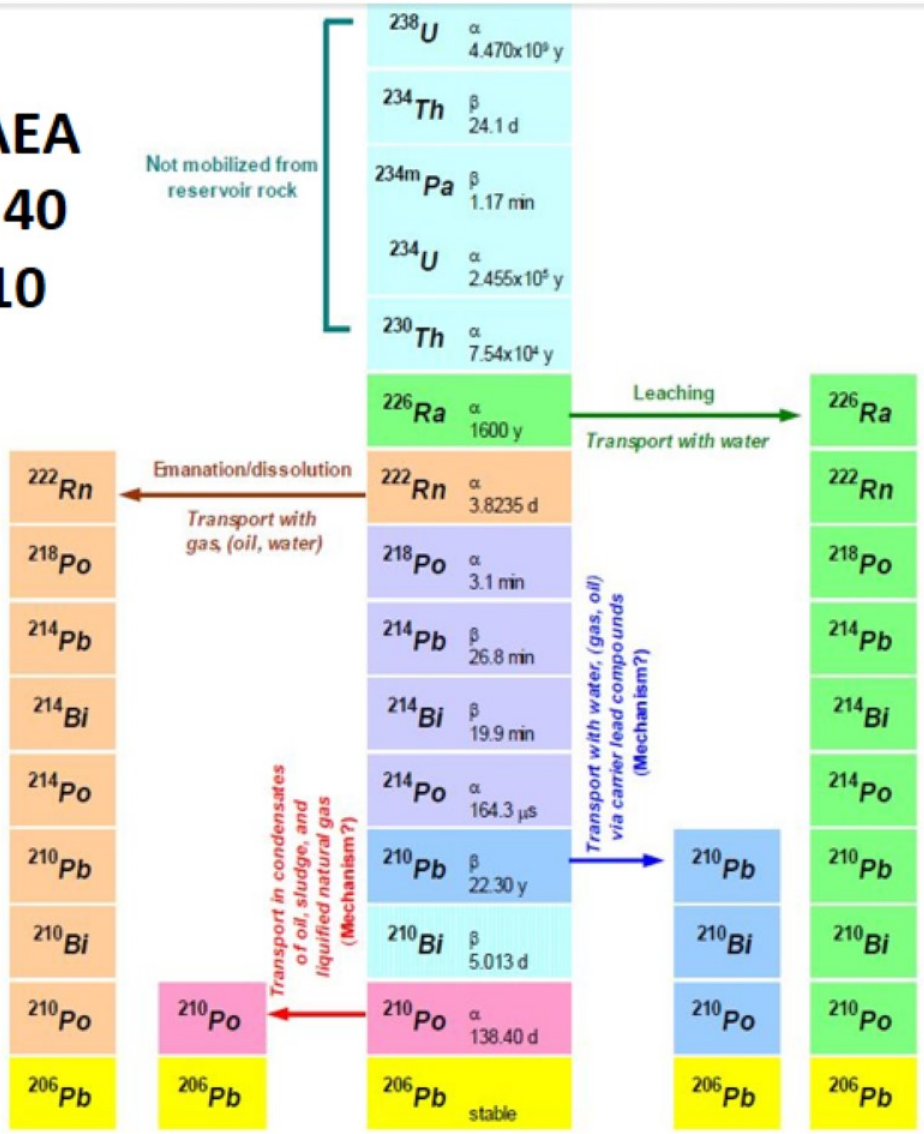
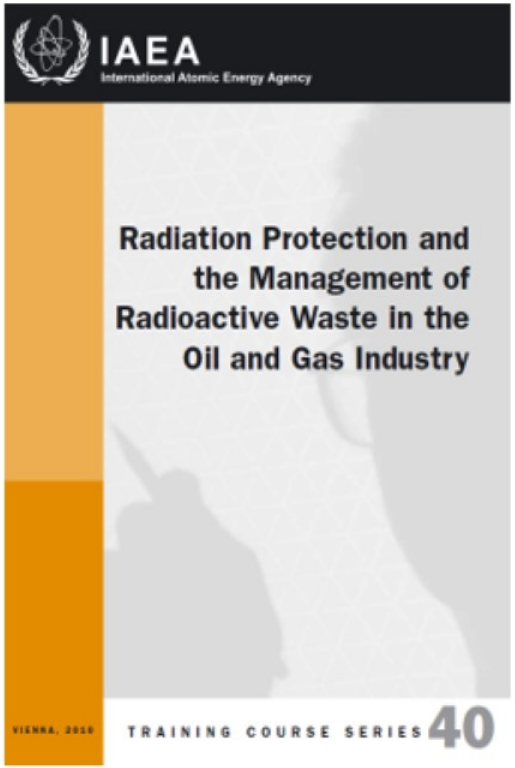


FIG. 41. Transport of ^{238}U progeny in oil and gas production



PA DER Study c1991

NORM Survey Summary [1]

The radium-226 in the brine samples ranged from 3.29 pCi/l to 2,575 pCi/l with one at 4,685 pCi/l. The average was 742 pCi/l. Radium-228 in the brine samples ranged from 7.17 pCi/l to 2,196 pCi/l. The average was 676 pCi/l. Following is a listing of the results by well type.

		Radium 226 (pCi/l)			Radium 228 (pCi/l)		
Well Type	#	Avg.	High	Low	Avg.	High	Low
All	38	742	4,685	8.34	676	2,196	12.06
Deep Gas	9	1,243	4,685	203	1,475	2,110	499
Shallow Gas	17	946	2,575	20	665	2,196	13
Shallow Oil	12	86	275	8.34	94	456	12.06

Study Background

Generation of TENORM waste had increased significantly. This was mainly due to the expansion in unconventional natural gas exploration and production in the Commonwealth.

In 2013 DEP determined several issues with O&G TENORM needed to be addressed.

These issues include:

- Potential Worker Radiation Exposure
- Possible Public Radiation Exposure
- Unknown Environmental Contamination
- Waste Disposal

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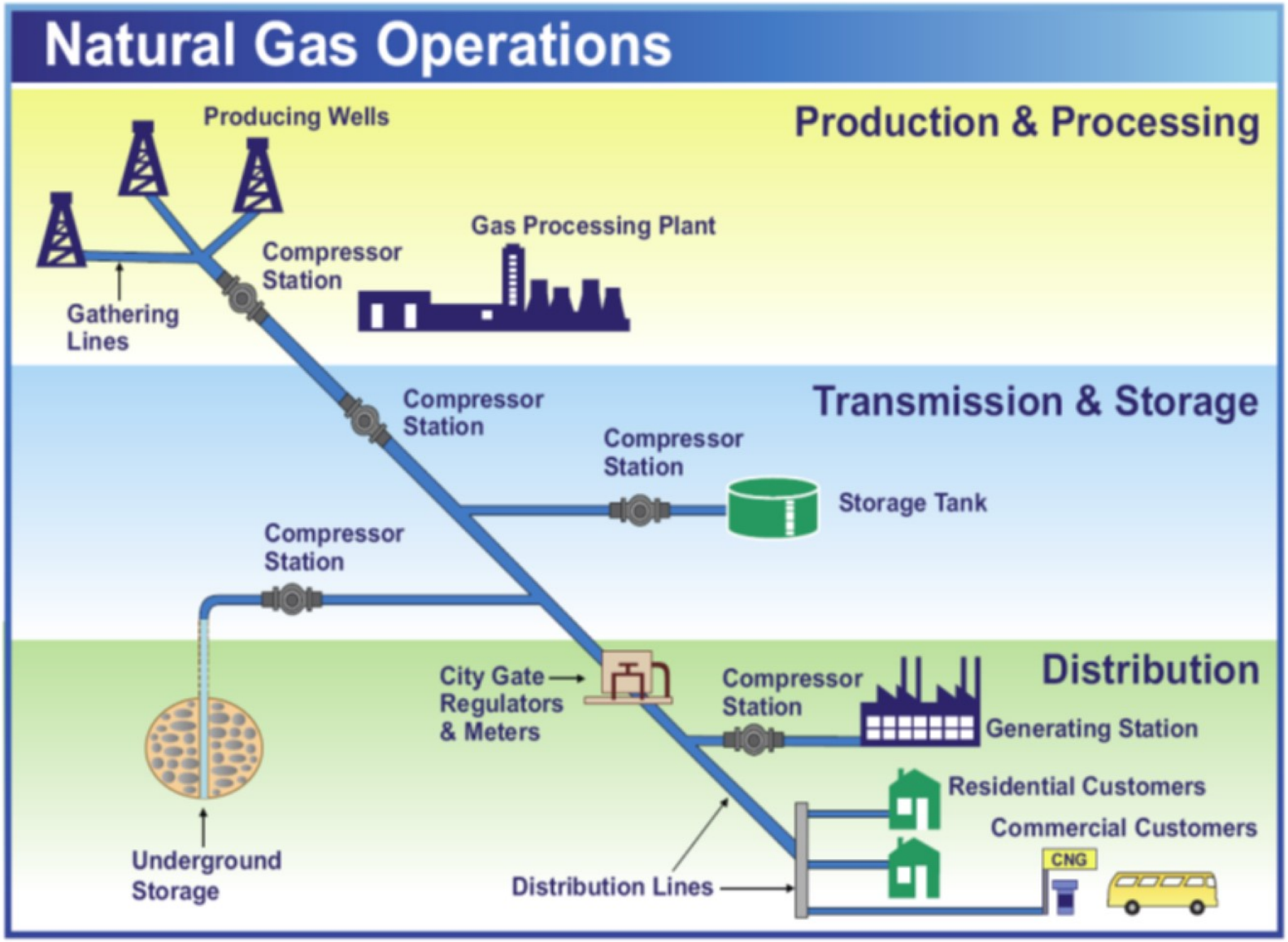
Natural Gas Production & Use



Site Categories for Sampling

- Well pads
- Waste water treatment plants (WWTPs)
- Waste sludge loads to landfills
- Landfills
- Underground natural gas storage sites
- Gas-fired electricity generating facilities
- Compressor stations
- Gas processing facility
- Beneficial use sites (e.g., roads)
- Decommissioned well casings

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Sample Types

- Solid samples (i.e., drill cuttings, muds, proppant, sludge, soils and sediment)
- Liquid samples (i.e., pre-frac, flowback and produced water)
- Natural gas samples
- Radiation surveys (i.e., µR/h, direct surface dpm/100 cm^2
- 'Smear' samples for removable radioactivity

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Sample Analysis

- The samples were analyzed for the presence of alpha, beta and gamma radiation (gross counting and spectroscopy)
- Some solid and liquid sample analyzed by XRF, ICP-MS and neutron activation
- The gas was sampled for radon-222 concentrations

Field Work

MS Well pad [Patriot News photo]

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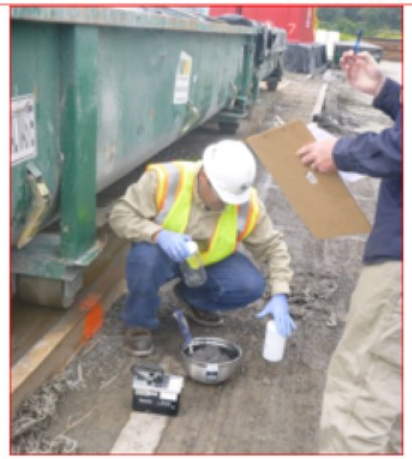
Field Work



Drilling Operations rock cuttings

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Field Work

Frac-water, proppant and flowback sampling at a well pad

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Field Work

Radon testing at a gas storage and electrical generator facilities

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Field Work

Beneficial Use of brine on roads

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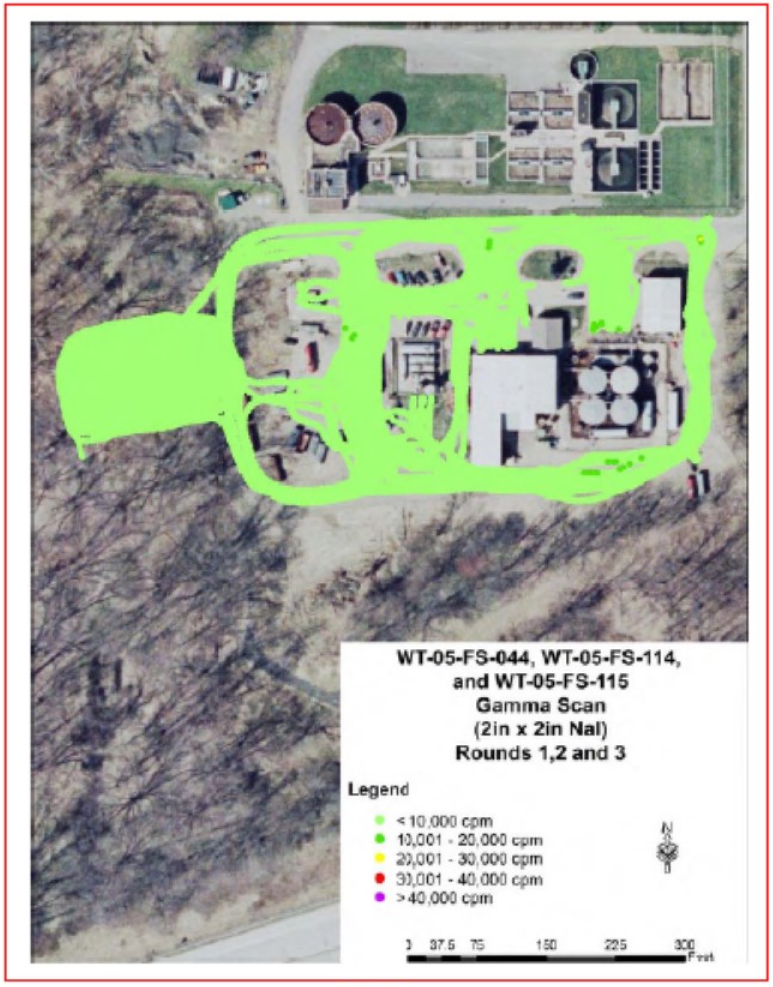
Field Work

Wastewater Treatment

Field Work



Wastewater Treatment Facilities

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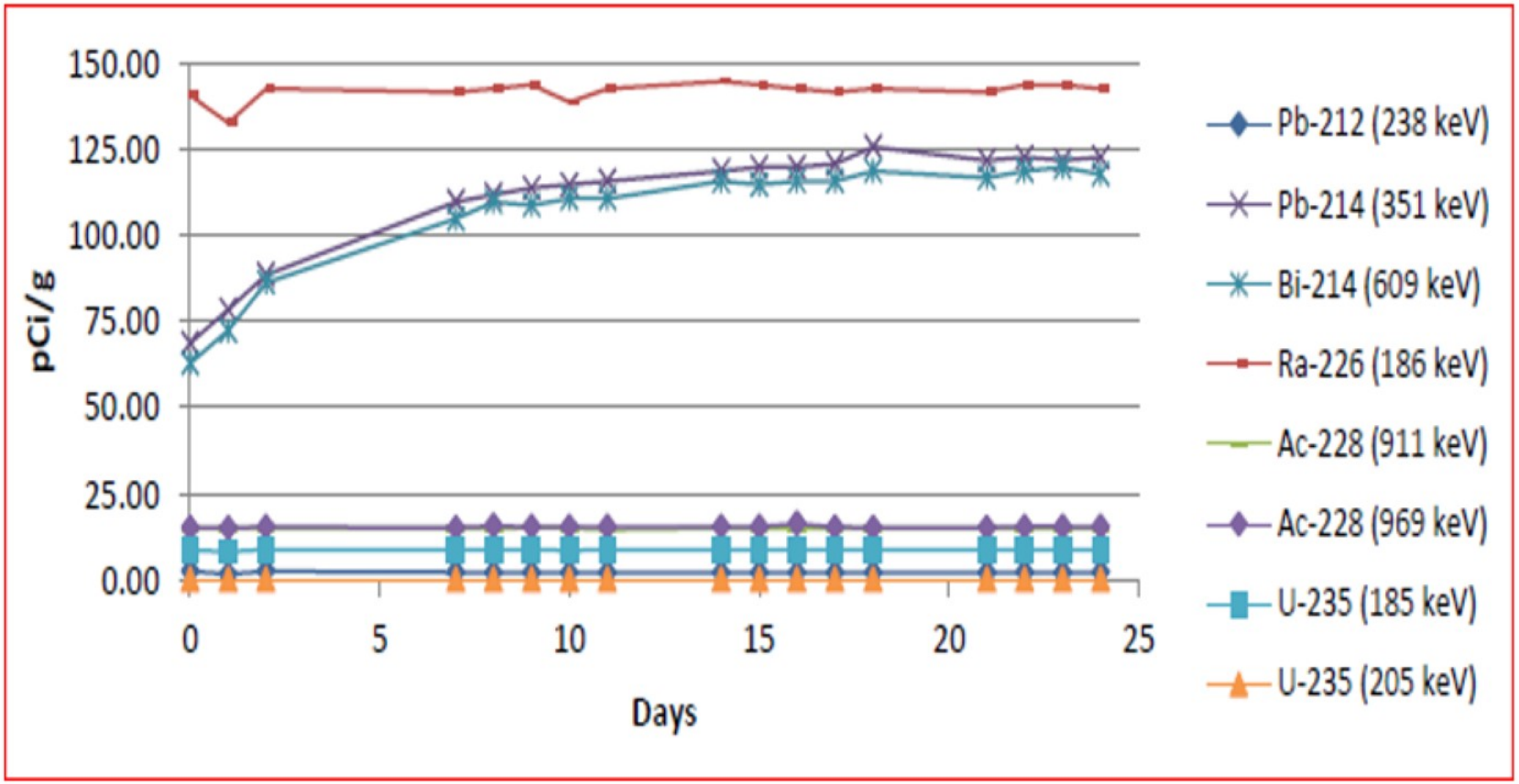
Study Results

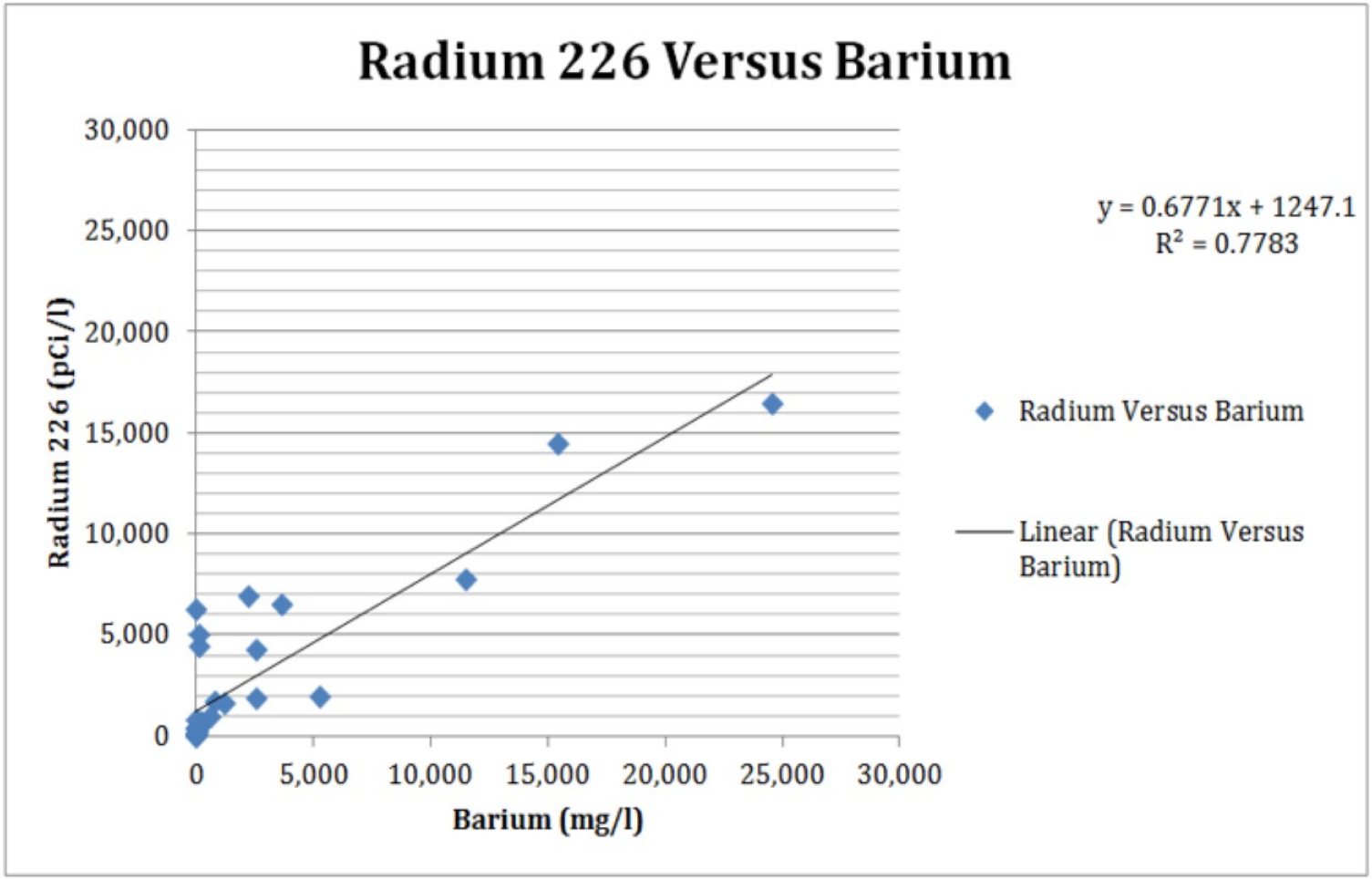
Radiochem of Filter Cake vs. Time



Study Results

Non-Rad Chem. Data on Flow-back H2O

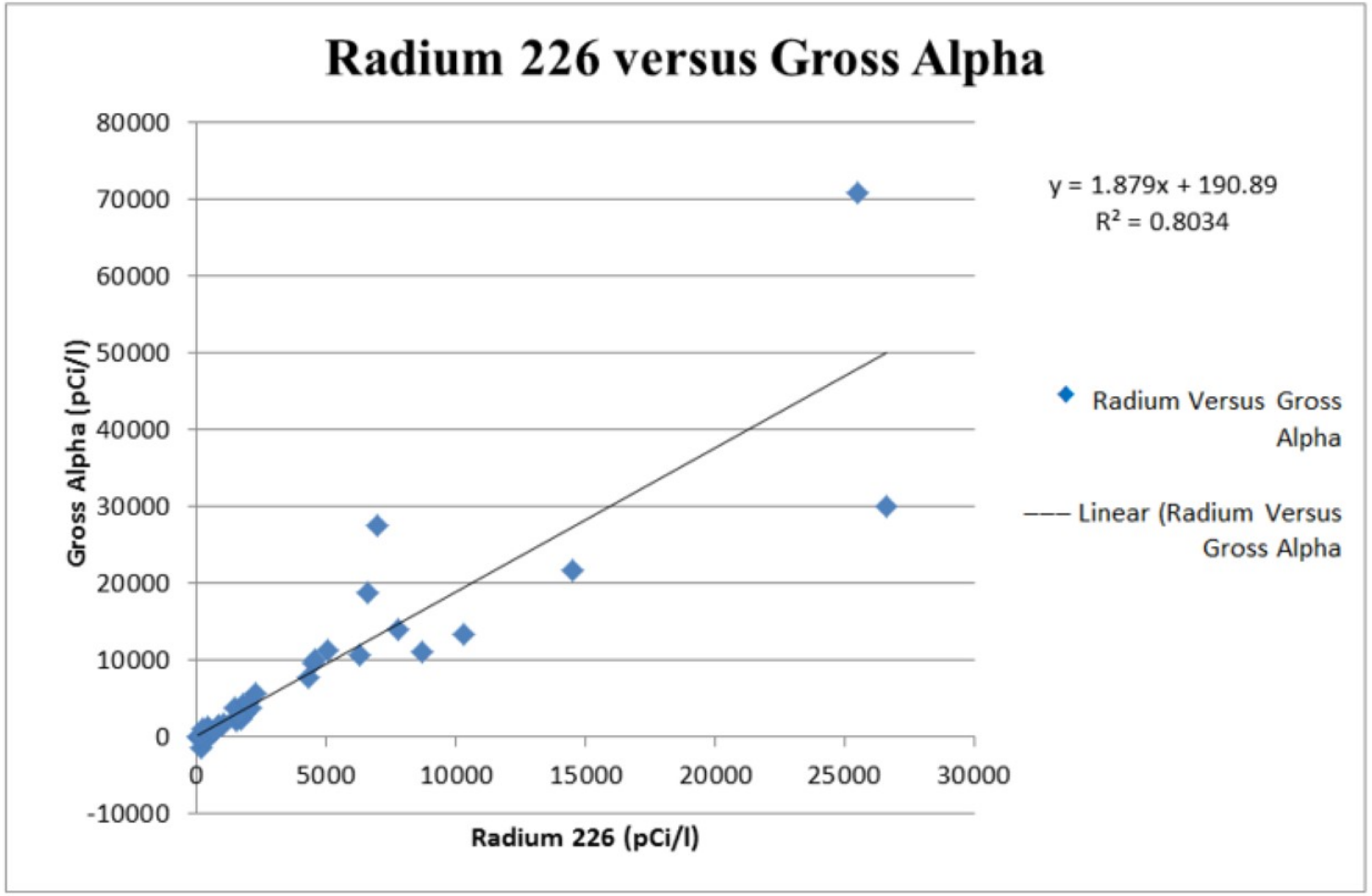
Figure M-11. Ra-226 X-Y Scatter Plot versus Barium – Outlier Removed



Study Results

Non-Rad Chem. Data on Flow-back H2O

Figure M-19. Ra-226 X-Y Scatter Plot versus Gross Alpha – Outlier Removed



DEP BRP Conclusions

- Study one of the most comprehensive to date
- Well sites and pads have low worker exposure
- O&G well frac and produced water high in Ra
- Potential for environmental impact with spills
- Unclear impact with the use of brines on roads
- Several wastewater treatment plants and environs require follow-up for clean-up
- ~25 % of TENORM sludge over DOT Class 7 limits
- Long-term Ra in LF leachate monitoring needed

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DEP BRP Conclusions

- Sludge from wastewater treatment not in equilibrium between Ra-226 and Rn-222 decay products
- O&G industry data on samples taken during DEP study in-line with our data
- Landfill TENORM disposal protocols developed circa 2002 need to be re-examined
- Follow-up needed on 'pigging' and gas processing plants for potential worker Pb-/Po-210 exposure

TENORM Study Information

- Study-related documents are available at www.dep.state.pa.us Keyword "TENORM"
- Overview of Study is being provided to the appropriate DEP advisory committees and other stakeholders
- Overview of Study also being presented at various scientific meetings and conferences

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TENORM Study - Acknowledgements

> DEP Staff

Dan Husted (FOs)

Bob Lewis (Radon Div.)

CO & RO BRP Staff

Taru, Janelle & Tom, et al. (BoLs)

Ken, Sharon & Ali (Dep. Sec's Office)

> PermaFix Staff -

Andy Lombardo, Jason, Allan, Tony, Anita, et al.

> GEL Lab Staff -

Bob Seyer, et al.

> Many O&G Firms' Staff

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State Regs TENORM Disposal

For example, ND's New Regs – 50 pCi/g [Dec. 2014]

NORTH DAKOTA DEPARTMENT of HEALTH

State	Disposal Limit (picocuries per gram)	Radionuclide	Type of Limit
California	1800	total picocuries/gram	landfill permit
Colorado	2000	total picocuries/gram	landfill permit
Idaho	1500	Ra-226 and Ra-228	landfill permit
Illinois	200	Ra-226	state rule for drinking water treatment sludge
Louisiana	30	Ra-226	state rule
Michigan	50	Ra-226 and Ra-228	state rule
Minnesota	30	Ra-226	state rule for drinking water treatment sludge
Mississippi	30	Ra-226 and Ra-228	state rule
Montana	30	Ra-226 and Ra-228	state policy
New Mexico	30	Ra-226 or Ra-228	state rule - landspreading
Texas	30	Ra-226 or Ra-228	state rule - landspreading
Utah	10000	Ra-226 and Ra-228	landfill permit
Washington	10000	Ra-226 and Ra-228	landfill permit
Wyoming	50	Ra-226 and Ra-228	state policy

Health Physics Society & TENORM

ANSI/HPS N13.53-2009

Approved: March 2009

ANSI American National Standards Institute

Control and Release of Technologically Enhanced Naturally Occurring Radioactive Material (TENORM)

HPS Position Statement

Adopted January 1992

The Health Physics Society believes the current regulatory framework for establishing and enforcing regulatory radiation safety standards results in inconsistent, inefficient, and unnecessarily expensive public health protection policies regarding radiation safety. Therefore, the Society advocates the establishment of a regulatory framework with the following requirements:

1. A single, independent U.S. federal agency (herein called the Agency) shall have the responsibility and authority to establish all ionizing radiation safety standards for all controllable sources[1] of occupational and public exposures.

HPS
Health Physics Society
Specialists in Radiation Safety

HEALTH PHYSICS SOCIETY

COMPATIBILITY IN RADIATION SAFETY REGULATIONS

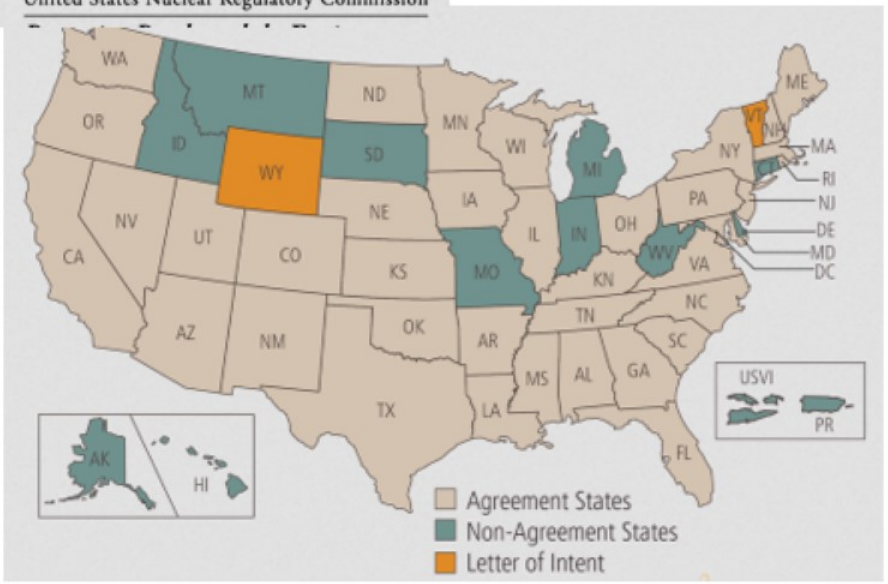
POSITION STATEMENT OF THE HEALTH PHYSICS SOCIETY*

Adopted: January 1992
Revised: August 2000
Reaffirmed: July 2007

TENORM RP Regulatory Framework

U.S.NRC
United States Nuclear Regulatory Commission

- States / OAS / CRCPD



http://www.crcpd.org/

June 2015

E-42 TASK FORCE REPORT

REVIEW OF TENORM IN THE OIL & GAS INDUSTRY

New E-45 WG

SR-N [now active]

SSRCR Volume I - April 2004

PART N

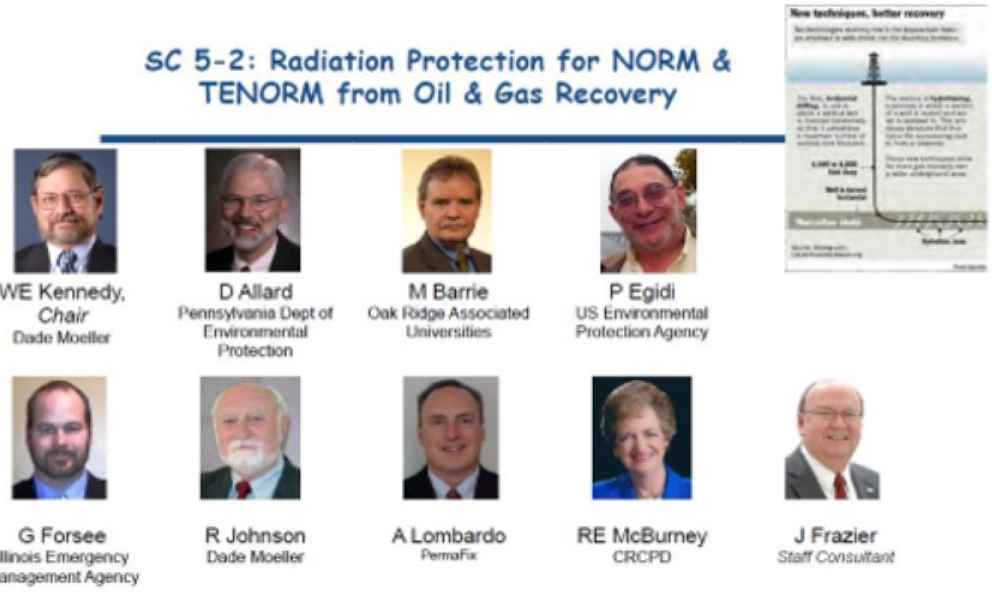
REGULATION AND LICENSING OF TECHNOLOGICALLY ENHANCED NATURALLY OCCURRING RADIOACTIVE MATERIAL (TENORM)

TENORM RP Regulatory Framework

"Current TENORM regs in the USA are fragmented !!"

John Boice

But we're hopeful… a new NCRP Scientific Committee has been stood-up to review TENORM waste disposal.



PA Solid Waste & Metal Recyclers

Radiation Monitoring

PA SW Regs and TENORM

PA DEP's NEW MUNICIPAL AND RESIDUAL WASTE RADIATION MONITORING AND RESPONSE REGULATIONS
Title 25. Environmental Protection

NOTE: THE FOLLOWING TITLE 25 CHAPTER SECTIONS HAVE APPLICABLE REQUIREMENTS RELATED TO RADIATION MONITORING OF SOLID WASTE

Chapter 271 – Municipal Waste Management – General Provisions

§ 271.1 DEFINITION
§ 271.114 TRANSITION PERIOD

Chapter 273 – Municipal Waste Landfills

§ 273.133 MAP AND GRID REQUIREMENTS
§ 273.140a RADIATION PROTECTION ACTION PLAN
§ 273.201 BASIC LIMITATIONS
§ 273.223 RADIATION MONITORING AND RESPONSE
§ 273.311 DAILY OPERATIONAL RECORDS
§ 273.313 ANNUAL OPERATION REPORT

PA SW Regs and TENORM

(m) The following radioactive material may not be disposed at the facility, unless approved in writing by the Department, and the disposal does not endanger the environment, facility staff or public health and safety:

(1) Short-lived radioactive material from a patient having undergone a medical procedure.

(2) TENORM.

(3) Consumer products containing radioactive material.

(n) The limitations in subsections (l) and (m) do not apply to radioactive material as found in the undisturbed natural environment of the Commonwealth.

PA SW Regs and TENORM

§ 273.140a. Radiation protection action plan.

(a) An application shall contain an action plan specifying procedures for monitoring for and responding to radioactive material entering the facility, as well as related procedures for training, notification, recordkeeping and reporting.

(b) The action plan shall be prepared in accordance with the Department's Guidance Document on *"Radioactivity Monitoring at Solid Waste Processing and Disposal Facilities,"* Document Number 250-3100-001, or in a manner at least as protective of the environment, facility staff, and public health and safety and which meets all statutory and regulatory requirements.

(c) The action plan shall be incorporated into the landfill's approved waste analysis plan, under § 271.613 (relating to waste analysis plan).

PA SW Regs and TENORM

DEPARTMENT OF ENVIRONMENTAL PROTECTION
Bureau of Radiation Protection and
Bureau of Land Recycling and Waste Management

DOCUMENT NUMBER:	250-3100-001
TITLE:	Final Guidance Document on Radioactivity Monitoring at Solid Waste Processing and Disposal Facilities.
EFFECTIVE DATE:	January 2, 2004
AUTHORITY:	Solid Waste Management, Act of July 7, 1980, P.L., No. 97, as amended, 35 P.S. Sections 6018.101-6018.1003; Radiation Protection Act, Act of July 10, 1984, P.L. 688, No. 147, 35 P.S. Sections 7110.101-7131.1101; The Administrative Code of 1929, Section 1917-A, 71 P.S. Section 510-17; Solid Waste Regulations, 25 Pa. Code Chapters 273, 277, 279, 281, 283, 284, 288, 289, 293, 295 and 297; Radiological Health Regulations, 25 Pa. Code Chapters 215-240.
POLICY:	To protect the environment and the public health, safety and welfare from the possible dangers of radioactive material that is delivered to solid waste processing and disposal facilities.
APPLICABILITY:	This guidance document applies to all owners and operators of solid waste processing and disposal facilities that are required by regulation to monitor for radiation from incoming loads of waste, and to those facilities that choose to monitor even though not required. This guidance document also applies to all Department personnel and activities involved with waste facility permitting, operations and enforcement, radiation protection, grants, monitoring, administration and emergency response.
DISCLAIMER:	The policies and procedures outlined in this guidance are intended to supplement existing requirements. Nothing in the policies or procedures shall affect regulatory requirements.

Solid Waste Radiation Monitoring

PA RCRA D landfill

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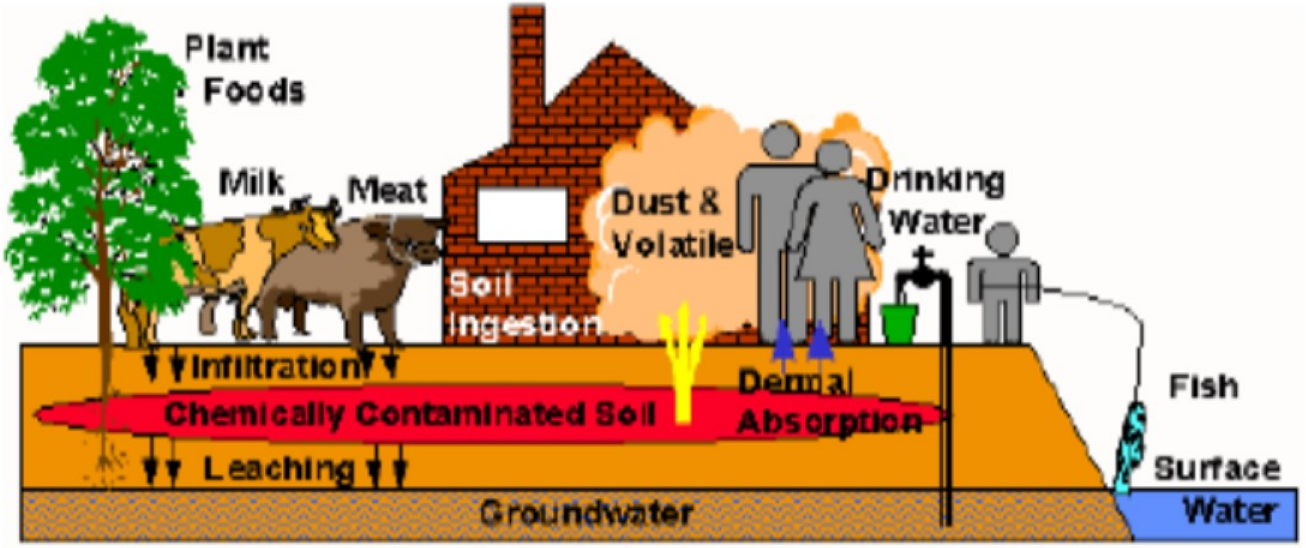
TENORM Waste Disposal

TENORM -

RESRAD code runs circa 2002 : "resident farmer" evaluation, public dose limit 25 mrem/yr, all pathways (i.e., radon, ground shine and drinking water), looking out 1000 years.



PA TENORM Waste Issues

- O&G sludge, rock cuttings and 'other' (e.g., zircons)
- Numerous sludge samples exceeded DOT criteria for Ra-226 and Ra-228
- Initial disposal RESRAD modeling performed c2002
- Additional c2004 MicroShield® calculations assumed Ra-226 / Rn-222 decay product equilibrium for μR/h
- PA TENORM Study data has informed DEP for the need to update our approach for TENORM disposal

PA TENORM Waste Issues

2017 TENORM MONTHLY DISPOSAL BALANCE

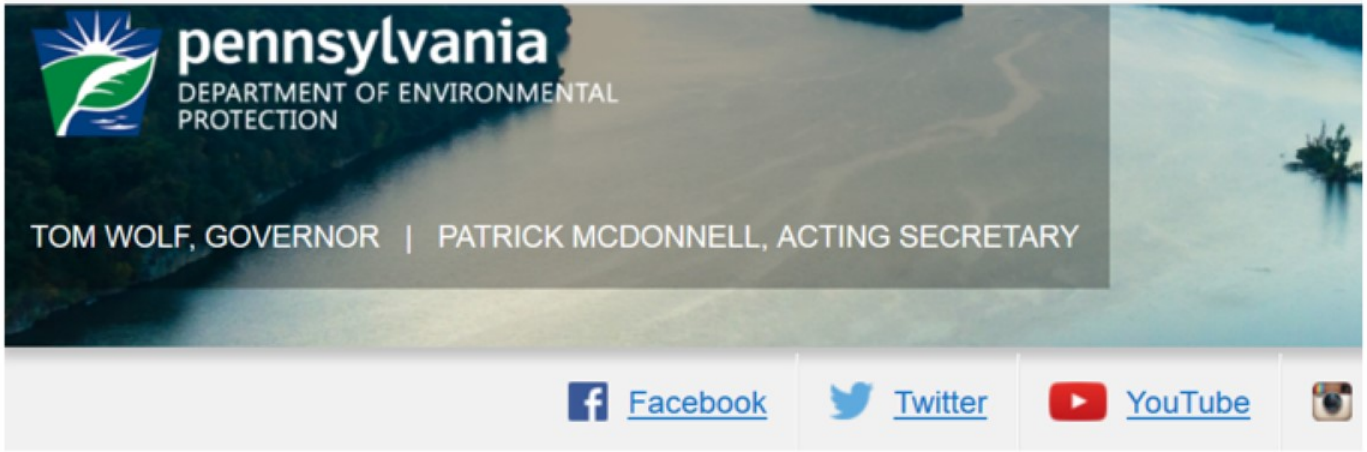
Landfill Name:
County:
Township:
Month

ACCEPTANCE CRITERIA		
2014 Collected Tonnage:		ENTER 2014 COLLECTED TONNAGE HERE
2015 Collected Tonnage:		ENTER 2015 COLLECTED TONNAGE HERE
2016 Collected Tonnage:		ENTER 2016 COLLECTED TONNAGE HERE
3-Year Collected Tonnage Average:		-
Allowed Source Term Loading (ASTL):		-
Monthly Source Term Allocation (MSTA):		-

MSTA = A mathematical Expression Which Will Calculate The Remaining Amount of TENORM That Can Be Accepted Based On The Blanket TENORM Authorization.

								Actual Reading From Handheld Device							
								RIGHT SIDE	LEFT SIDE						
								Center-Line	Center-Line				Load	MSTA	
		Form U			Waste Origin If Transported Directly			Mid-Point	Mid-Point				Source Term	Remaining	
	Ticket	Approval	Waste		To A Landfill From an Oil or Gas Well Site			Dose Rate	Dose Rate	Isotope	TENORM				Additional
Date	Number	Number	Code	Generator	Well Name	Municipality	County	(µR/Hr)	(µR/Hr)		Tonnage	Multiplier	(pCi/g)*Tons)	(pCi/g)*Tons)	Comments
	Use The Rows Below To Enter TENORM Information									Use The Rows Below To Enter TENORM Information				-	
														More Information Needed	One or more parameters necessary for source term calculation are needed.
														More Information Needed	One or more parameters necessary for source term calculation are needed.

PA O&G Regs and TENORM



DEP > Businesses > Energy > Oil and Gas Programs > Office of Oil and Gas Management > I
Regulations

OIL AND GAS SURFACE REGULATIONS

On October 8, 2016, Pennsylvania's Environmental Quality Board (EQB) published a final-form rulemaking in the Pennsylvania Bulletin regarding surface activities related to unconventional gas well development. The Pennsylvania Bulletin publication includes the final-form rulemaking language in plain text (Annex A) and an Order describing the regulations. The publication document is available as an html document here and as a pdf document here.

PA O&G Regs and TENORM

RULES AND REGULATIONS

Title 25—ENVIRONMENTAL PROTECTION

ENVIRONMENTAL QUALITY BOARD

[25 PA. CODE CHS. 78 AND 78a]

Environmental Protection Performance Standards at Oil and Gas Well Sites

PENNSYLVANIA BULLETIN, VOL. 46, NO. 41, OCTOBER 8, 2016

§ 78a.58. Onsite processing

The amendments establish provisions regarding wastewater processing at well sites, codifying the Department's current approval process for onsite oil and gas waste processing. Subsection (a) allows operators to process fluids generated by oil and gas wells at the well site when the fluids were generated or at the well site when all of the fluid is intended to be beneficially used to develop, drill or stimulate a well upon Department approval. Subsection (b) lists specific activities that do not require Department approval, including mixing fluids with freshwater, aerating fluids or filtering solids from fluids. These activities shall be conducted within secondary containment. Subsection (d) requires an operator processing oil and gas fluids onsite to develop a radiation protection action plan which specifies procedures for monitoring and responding to radioactive material or technologically enhanced naturally occurring radioactive materials (TENORM) produced by the treatment process. This subsection also requires procedures for training, notification, recordkeeping and reporting to be implemented. Subsection (e) specifies that drill cuttings may only be processed at the well site where those drill cuttings were generated, if approved by the Department. Subsection (g) allows for using approved processing facilities at subsequent well sites.

PA O&G Regs and TENORM

(c) Activities described in subsection (b) shall be conducted within secondary containment.

(d) An operator processing fluids or drill cuttings generated by the development, drilling, stimulation, alteration, operation or plugging of oil or gas wells shall develop an action plan specifying procedures for monitoring for and responding to radioactive material produced by the treatment processes, as well as related procedures for training, notification, recordkeeping and reporting. The action plan shall be prepared in accordance with the Department's *Guidance Document on Radioactivity Monitoring at Solid Waste Processing and Disposal Facilities*, Commonwealth of Pennsylvania, Department of Environmental Protection, No. 250-3100-001, as amended and updated, or in a manner at least as protective of the environment, facility staff and public health and safety and which meets all statutory and regulatory requirements.




pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Bureau of Radiation Protection

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Questions?