



pennsylvania

DEPARTMENT OF ENVIRONMENTAL PROTECTION

Bureau of Radiation Protection



PA TENORM Study Overview

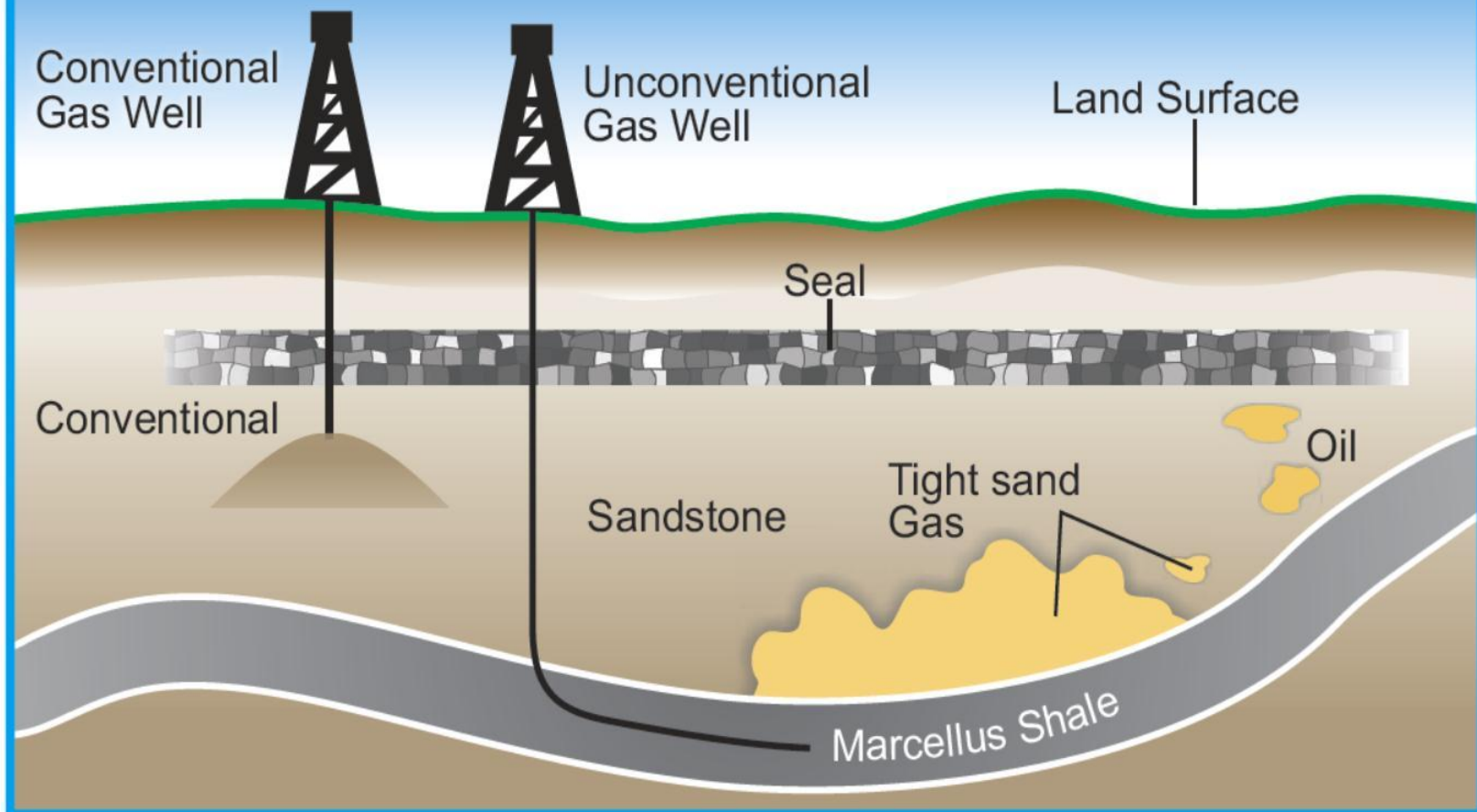
David J. Allard, CHP

ASCC Meeting

November 6, 2015

O&G Well Types

Conventional and Unconventional Gas Wells



TENORM & NORM Defined

Technologically Enhanced Naturally Occurring Radioactive Material

- *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

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

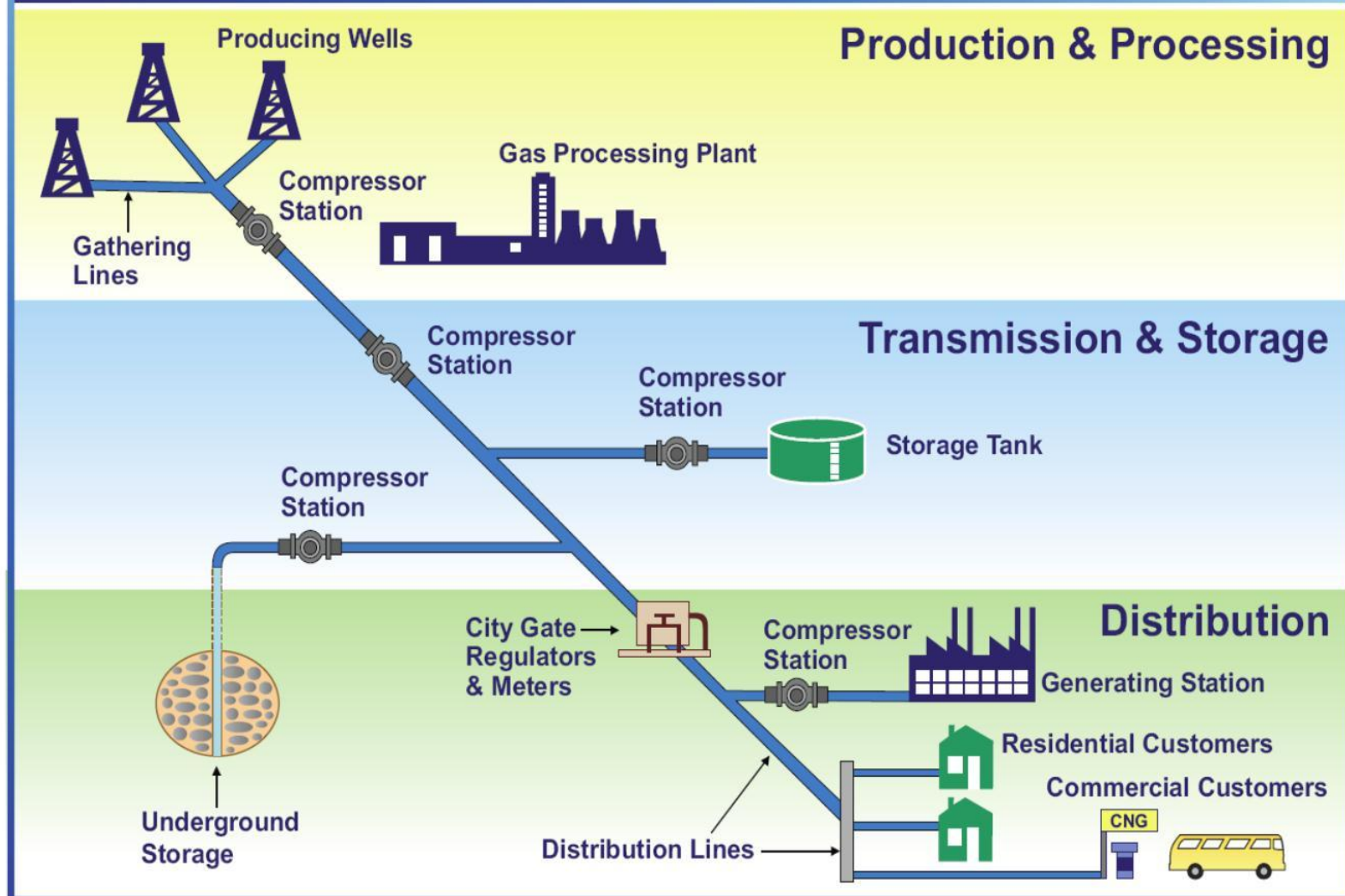


Study Schedule

- Scope, Field Sampling Plan and QAP in 2012
- Work began April 2013 and was completed in August 2014
- Sample analysis, data analysis and report preparation was through fall 2014
- Internal DEP final review thru early winter
- Peer review over winter 2014 holidays
- Final study report posted January 2015
- O&G industry sample data being reviewed now

Natural Gas Production & Use

Natural Gas Operations



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., $\mu\text{R/h}$, direct surface $\text{dpm}/100\text{ cm}^2$)
- 'Smear' samples for removable radioactivity

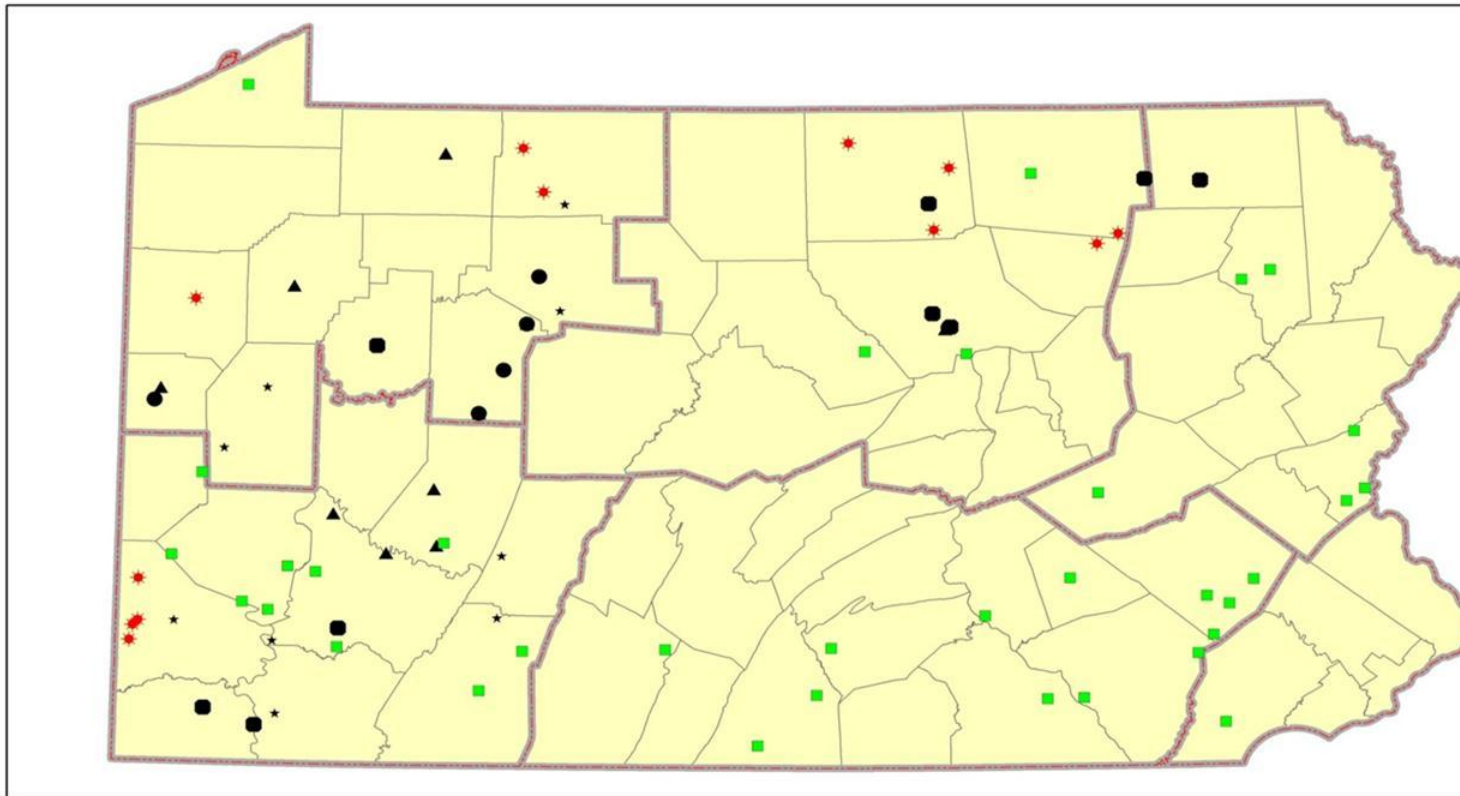
Sample Analysis

- 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

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

Field Work - Locations



Legend

- ★ Well Pads
- Leachate
- ▲ Centralized Waste Treatment Facility
- Publicly Owned Treatment Works
- Zero Liquid Discharge
- ★ Landfills

- County Boundaries
- PA DEP Regional Boundaries

Study Results

Well Sites and Pads

Vertical Cuttings -

Ra-226: 0.7 to 17 (2.8 ave.) pCi/g [g-spec]

U-238: 0.5 to 4.5 (1.5 ave.) pCi/g [XRF & calc]

MS Horizontal Cuttings

Ra-226: 0.1 to 13 (5.2 ave.) pCi/g [g-spec]

U-238: 2.0 to 17 (8.6 ave.) pCi/g [XRF & calc]

Study Results

Well Sites and Pads

Hydro Frac Fluid -

Ra-226: 64 to 21,000 (5,290 ave.) pCi/L [g-spec]

Ra-228: 4.5 to 1,640 (469 ave.) pCi/L [g-spec]

Flowback Water -

Ra-226: 551 to 25,500 (8,490 ave.) pCi/L [g-spec]

Produced Water -

Ra-226: 41 to 26,600 (5,880 ave.) pCi/L [g-spec]

Study Results

Well Sites and Pads

Ambient Radon: 'background' 0.2 to 0.7 pCi/L

Radon in Natural Gas: 3.0 to 148 (48 ave.) pCi/L

Drill Muds Ra-226: 0.66 to 3.7 (2.3 ave.) pCi/g

Proppant Ra-226: 0.17 to 0.36 (0.24 ave.) pCi/g

Contamination: 'potential w spills'

Study Results

POTW, Impacted & Non-impacted

Filter Cake -

[POTW-I] Ra-226: 20.1 ave. pCi/g

[POTW-N] Ra-226: 8.89 ave. pCi/g

Radon: 0.2 to 8.7 pCi/L

Ambient gamma: 5 to 36 μ R/h [max 63 mrem/y]

Contamination: some fixed, little removable

Study Results

Centralized Wastewater Treatment Plants

Filter Cake -

Ra-226: 3.38 to 294 (108 ave.) pCi/g

Radon indoor areas: 2.0 pCi/L (ave.)

Soils: BG to 500 pCi/g

Ambient gamma: max 24 μ R/h [max 38 mrem/y]

Contamination: mostly fixed, some removable

Study Results

Zero Liquid Discharge Plants

Filter Cake -

Ra-226: 3.08 to 480 (112 ave.) pCi/g

Radon indoor areas: 2.3 pCi/L (ave.)

Ambient gamma: max 43 μ R/h [max 76 mrem/y]

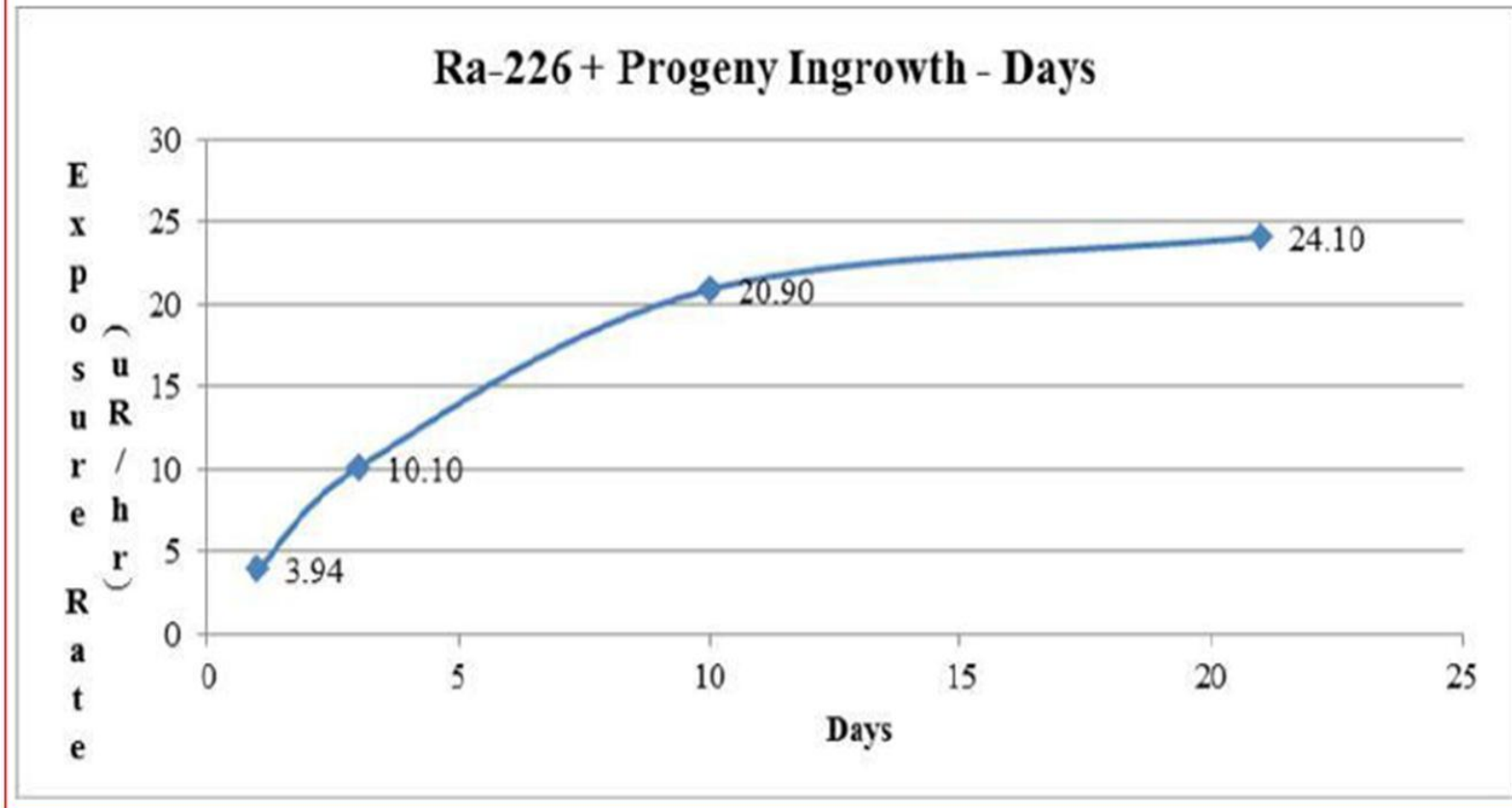
Contamination: mostly fixed, some removable

Wastewater truck driver: < 1 mrem/y

Study Results

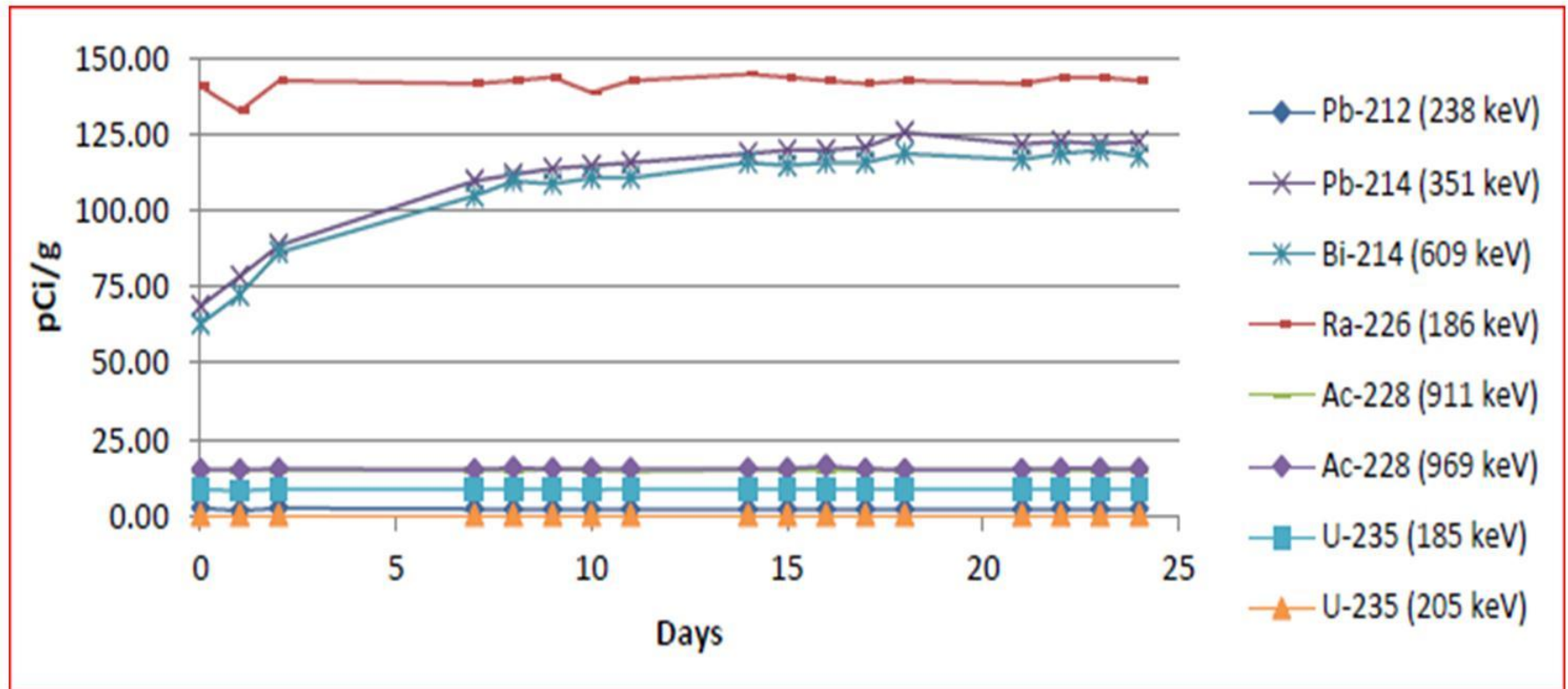
Rn-222 [+d] Ingrowth vs. $\mu\text{R/h}$

Figure 5-1. Ra-226 Progeny Ingrowth (Days Post Removal) versus Exposure Rate from 13.34 pCi/g Ra-226



Study Results

Radiochem of Filter Cake vs. Time



Study Results

Landfills

Leachate -

Ra-226: 54 to 416 (112 ave.) pCi/L

Radon local environs: 'BG' 0.2 to 0.9 pCi/L

Ambient gamma: 5 to 13.5 μ R/h [max 17 mrem/y]

Surface Contamination: minimal from gamma drive-overs

Study Results

Radon

Underground Storage -

Gas in: 20 to 30 pCi/L

Gas out: 5.1 to 11 pCi/L

Radon at well head: 3.0 to 148 (48 ave.) pCi/L

Ambient Rn Compressor Station: 0.1 to 0.8 pCi/L

Ambient Rn Power Plant: 0 to 0.4 pCi/L

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 study
- ~25 % of TENORM sludge over DOT Class 7 limits
- Long-term Ra in LF leachate monitoring needed

DEP BRP Conclusions

- Sludge from wastewater treatment not in equilibrium between Ra-226 and Rn-222 decay products
- We are review O&G industry data on samples taken during DEP study
- Landfill TENORM disposal protocols developed circa 2002 need to be re-examined
- Follow-up needed at gas processing plants and pipeline cleaning operations to assess potential worker exposure to Pb-/Po-210

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

Acknowledgements

DEP Staff -

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Questions?