

Managing O&G TENORM Waste in Pennsylvania, Cradle to Grave

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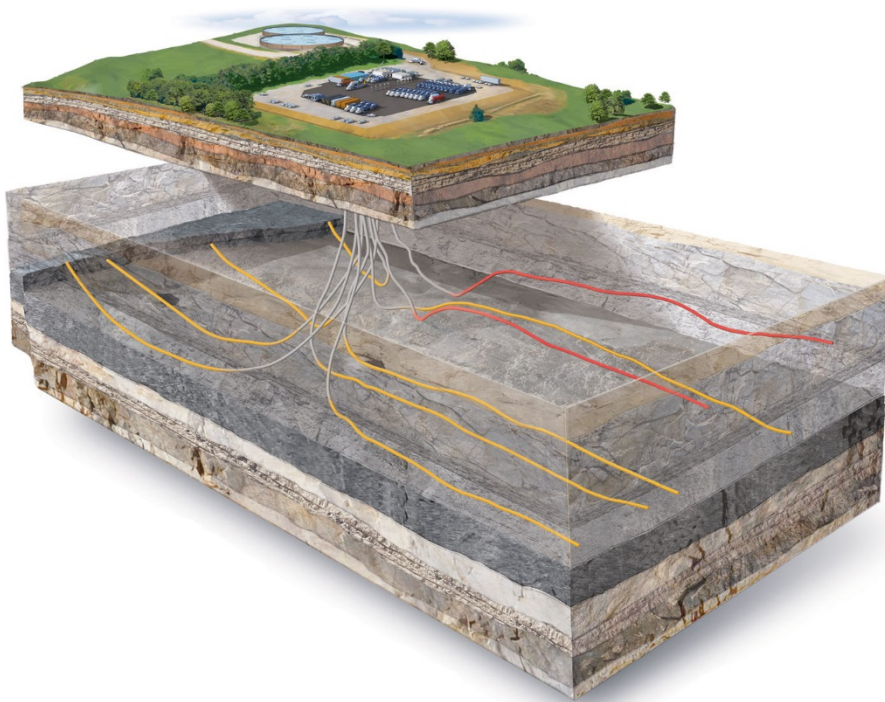
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Overview

- Waste Generation Process
- Characterization of Waste
- Regulations
 - Radiation Protection Action Plans
 - Transportation Requirements
 - Disposal Options
- Risk Mitigation and Worker/ Public Safety Measures



Radioactivity: Natural



- Oil and gas deposits exist in geologic formations that contain naturally-occurring radioactive materials (NORM)
 - Uranium (U-238)
 - Parent + 13 radioactive progeny
 - Alpha, beta, gamma radiation
 - Thorium (Th-232)
 - Parent + 10 radioactive progeny
 - Alpha, beta, gamma radiation
 - Secular Equilibrium in the rock (drill cuttings)

Radioactivity: NORM & TENORM

Drill Cuttings

^{238}U
^{234}Th
$^{234\text{m}}\text{Pa}$
^{234}U

Fluids

^{226}Ra
^{222}Rn
^{218}Po
^{214}Pb
^{214}Bi
^{214}Po
^{210}Pb
^{210}Bi
^{210}Po
^{206}Pb

Uranium Decay Series

^{238}U	$4.5 \times 10^9 \text{ y}$	α
^{234}Th	24.0 d	β, γ
$^{234\text{m}}\text{Pa}$	1.2 m	β, γ
^{234}U	$2.5 \times 10^5 \text{ y}$	α, γ
^{230}Th	$7.7 \times 10^4 \text{ y}$	α, γ
^{226}Ra	$1.6 \times 10^3 \text{ y}$	α, γ
^{222}Rn	3.83 d	α
^{218}Po	3.1 m	α
^{214}Pb	27 m	β, γ
^{214}Bi	20 m	β, γ
^{214}Po	$1.6 \times 10^{-4} \text{ s}$	α, γ
^{210}Pb	22.3 y	β, γ
^{210}Bi	5.01 d	β
^{210}Po	138 d	α
^{206}Pb	Stable	none

Drill Cuttings

Fluids

^{228}Ra
^{228}Ac
^{228}Th
^{224}Ra
^{220}Rn
^{216}Po
^{212}Pb
^{212}Bi
^{212}Po
^{208}Tl
^{208}Pb

Thorium Decay Series

^{232}Th	$1.4 \times 10^{10} \text{ y}$	α
^{228}Ra	5.7 y	β
^{228}Ac	6.1 h	β, γ
^{228}Th	1.9 y	α, γ
^{224}Ra	3.7 d	α, γ
^{220}Rn	55.6 s	α
^{216}Po	0.15 s	α
^{212}Pb	10.6 h	β, γ
^{212}Bi	61 m	α, β, γ
^{212}Po	$3 \times 10^{-7} \text{ s}$	α
^{208}Tl	3.1 m	β, γ
^{208}Pb	Stable	none

Radioactivity: TENORM

- **Technologically-enhanced NORM (TENORM)**
- Sludge
 - Produced/Flowback fluids
 - Water treatment- metals extraction inadvertently concentrates radium in filter cake sludge
 - Tank clean-out material
 - Filter socks
- Scale
 - Group IIA elements (barium, strontium, calcium, radium) form pipe / tank scales
 - Acidity, temperature, and pressure contribute to scale build-up
 - Gas transportation (radon)



A&M Hibbard Centralized Treatment Facility

- Located in Susquehanna County, Pennsylvania
- Cabot owned (WMGR123 permit); operated by third party contractor
- Treatment of primarily Flowback/Produced fluids for reuse in Cabot's operations in NE PA
- Fluid Treatment Strategy
 - Removal of targeted metals and other potential scale builders
- Capacity to treat ~**22,000** bbls per day
- Treated ~**10,000,000** bbls for reuse since 2012



A&M Hibbard Centralized Treatment Facility

Filter Cake – TENORM WASTE

- **Dewatered solids are collected from the filter press**
- **Immediately placed into 96 CF IP-certified supersacks**
- **Characterized via onsite assay**
 - Additional samples collected for analysis by third party laboratory
- **Moisture readings are collected onsite**
- **Adhere to site Radiation Protection Action Plan (RPAP)**
- **Qualified individual onsite collects necessary dose readings and/or smear samples**
- **Shipping papers are prepared (Class 7 – Radioactive Waste)**
 - Most waste generated at the facility is greater than 270 pCi/g
 - PADEP TENORM Shipping Factsheet
- **TENORM waste is disposed offsite**
 - Truck – Transload - Rail
 - EnergySolutions Clive Disposal Site in Utah
 - US Ecology Idaho Disposal Facility



TENORM Waste Characterization

- Total Radium (Ra-226/228) typical analytical sample process:
 - Collect sample
 - Ship to lab
 - Lab dries/grinds sample material, containerizes, and seals sample
 - **21-day** ingrowth of radium progeny
 - Analysis using gamma spectroscopy (EPA 901.1)
 - Additional parameters required in PA - gross alpha/gross beta, Th-232 and U-238
 - Typical turnaround time of **~45 days**

Problem:

- Adds significant cost to the operator to stage waste during lab analysis
- Waste storage space is limited

TENORM Waste Characterization

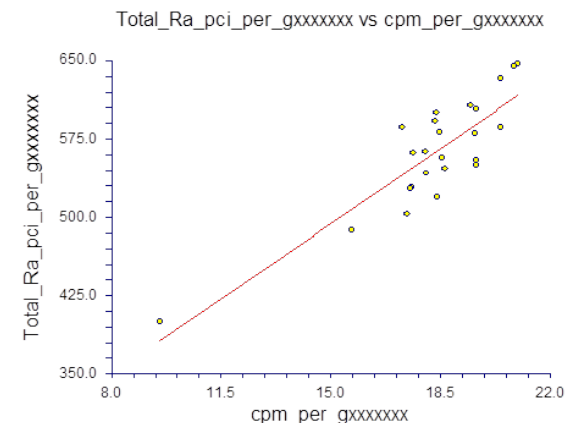
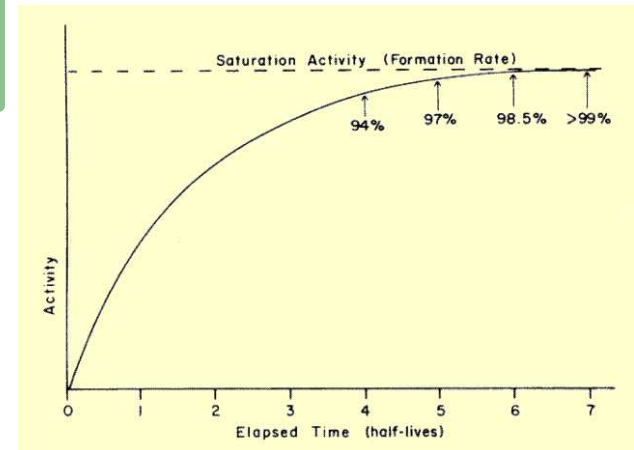
Solution:

Developed an Accurate / Simple Onsite Approach to Characterize Samples

Benchtop NaI Detector

- Fixed Geometry
 - Identical sample containers
 - Fixed sample count position
 - Fixed sample count time
 - Background correction
- Filter cake samples collected onsite and counted at $t = 0$ and $t = 3$ days
- Data analysis was performed to determine the optimal onsite sample count window (~3-days of ingrowth)
- Confirmation samples sent offsite for 3-day and 21-day analysis at multiple laboratories
- Using analytical results, a correlation between onsite and offsite results was established by plotting a best-fit line with statistical software
- Standardized meter operation / sample analysis by developing an SOP for WWTF operator

$$A_d(t) \approx A_p(1 - e^{-\lambda_d t})$$

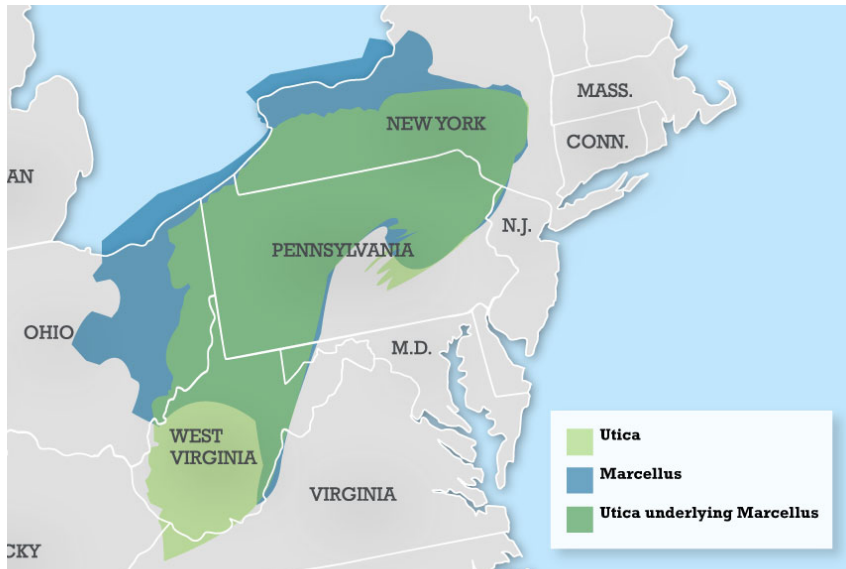


Linear Regression Plot

Regulations - National

- The U.S. Nuclear Regulatory Commission (NRC) does not regulate or license NORM and TENORM
- Authority falls to the 50 individual states and miscellaneous federal agencies
- U.S. Department of Transportation regulates the packaging, labelling, and transportation of NORM- or TENORM- containing materials
- U.S. Environmental Protection Agency (EPA) regulates radioactivity in drinking water
- U.S. Occupational Safety and Health Administration (OSHA) regulates employee exposure to radioactive material
- States that have entered into an agreement with the NRC allow states to have their own radiation protection regulations
 - 37 Agreement States

Regulations - Pennsylvania



- Agreement state
- Except for transportation, NORM & TENORM is under regulatory control of the PA Dept. Of Environmental Protection
- Disposal options in PA do exist for some low-level NORM-containing wastes
 - Based on landfill specifics, require dose modelling and PA DEP approval
 - Each landfill has monthly concentration volumetric limits

Regulations - Pennsylvania

Radiation Protection Action Plans (RPAP)

- **PA DEP DOCUMENT NUMBER:** 250-3100-001
- **TITLE:** “Final Guidance Document on Radioactivity Monitoring at Solid Waste Processing and Disposal Facilities”
- Action Plans will be part of the solid waste facility permit by modification, and must be approved by the Department

Regulations - Pennsylvania

Hibbard A&M Centralized Treatment Facility RPAP

- Key Components:
 - Responsible personnel
 - Radiation detection instruments
 - Annual calibration
 - Daily checks
 - Radiation surveys of outgoing material
 - Action Levels
 - Levels and responses
 - Training
 - Documentation
 - ALARA Program

RADIATION PROTECTION ACTION PLAN

CABOT OIL & GAS CORPORATION
A&M HIBBARD CENTRALIZED TREATMENT FACILITY
DIMOCK TOWNSHIP, PENNSYLVANIA

Prepared for:



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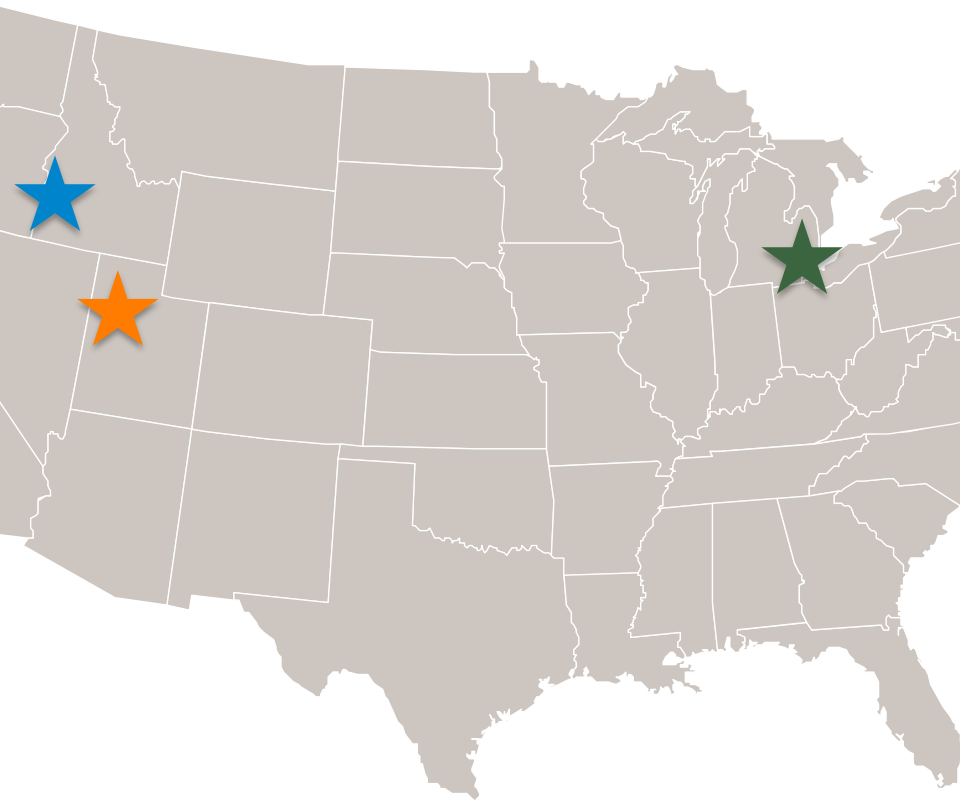
Transportation of TENORM Waste

- **PADEP TENORM Shipping Fact Sheet**
 - >270 pCi/g must be DOT Class 7 waste
- **Class 7 – Radioactive Waste**
 - Must be properly manifested
 - Qualified individuals must complete shipping papers
 - Drivers must have Haz Mat endorsement on license
 - Conveyances must be properly placarded/labeled
 - Must maintain shipping records
- **Know your transportation route**
 - Public sensitivity



Disposal of TENORM Waste

- PA landfills have pre-determined allotment of monthly TENORM tons (landfill specific)
- TENORM tons calculated from dose (issues with multiplier)
- What is the landfill-specific waste acceptance criteria (WAC)
- What other constituents are in the waste (i.e. Barium)?



ENERGY SOLUTIONS

~Class A LLRW, NORM / TENORM, Class A Mixed LLRW (radioactive and hazardous)

~Waste Acceptance: Ra-226 up to 10,000 pCi/g

Location: Clive, UT

US ECOLOGY IDAHO

~RCRA / TSCA, NORM / TENORM

~Waste Acceptance: Ra-226 + Ra-228 up to 1,500 pCi/g

Location: Grand View, ID

US ECOLOGY MICHIGAN

~RCRA / TSCA, NORM / TENORM

~Waste Acceptance: Ra-226 up to 50 pCi/g

Location: Belleville, MI

Risk Mitigation

RPAP Requirements

- ALARA Policy (As Low As Reasonably Achievable)
- Training
- Documentation
- Surveys of outgoing waste loads
- Etc.

WORKER PROTECTION

True Worker Protection (Risk Management) Requires More Than Just RPAP Compliance



Risk Mitigation

WORKER PROTECTION

Evaluate Potential and Actual Radiation Exposures (Dose)

- Initial facility exposure rate assessment
- Periodic exposure rate assessments, quarterly Health Physics audits
 - Walk-around dose rate and gross gamma rate surveys
 - Removable alpha and beta radiation surveys
 - Worker interviews
 - Documentation review
- Dosimetry- WWTF Operator administers dosimetry program
- Multiple radon evaluations at the facility
- 3-month continuous air monitoring campaign for alpha/beta
- Personal air monitoring during tank cleaning



Radiation Hazards and Monitoring Results

■ Radiation Hazards

- Typical Radiation Exposure Levels at WWTF
 - ~5 to 20 $\mu\text{rem/hr}$ (0.005 – 0.02 mrem/hr)
- Typical Radiation Exposure Levels of TENORM waste containers
 - ~20 to 500 $\mu\text{rem/hr}$ (0.02 – 0.5 mrem/hr)
- Typical TENORM concentrations
 - ~200 to 600 pCi/g total Ra (Ra-226 + Ra-228)

■ Radiation Monitoring

- Dosimetry
 - < 100 mrem/yr
- Air Monitoring
 - ~ Background
- Radon Monitoring
 - ~ Background
- Contamination
 - ≤ 20 dpm/100cm² alpha removable following decontamination
 - Reg. Guide 1.86 criteria

Risk Mitigation

WORKER PROTECTION

- PPE Evaluation- Initial and continuous
- Worker Training
 - All workers receive NORM Awareness Training
 - RPAP Supervisors receive extensive NORM and RPAP Training
- Radiological Controls
 - Postings
 - Access Controls
 - Equipment
 - Develop and Implement SOPs

SOPs

- Filter Cake Sample Collection / Analysis
- Operation of Radiation Survey Instruments
- Equipment Decontamination
- Production Tank Clean-out
- TENORM Loading, Transportation and Contingency
- Filter Cake DOT Communication Compliance
- Supersack Loading
- Adding Absorbent to Supersacks
- Filter Press Operation
- Solids Testing – Filter Press Cake
- Railcar Inspection
- Conveyance Inspection

Risk Mitigation

REDUCE ENVIRONMENTAL LIABILITIES

- Baseline Survey
 - Walkover gamma survey performed to document the baseline conditions prior to initiating water treatment activities
 - Results will be compared to future surveys
- HAZMAT Incident Training
- Radiation Fact Sheet (public communication - external affairs)
- Documentation!!!

Summary & Conclusions



- Hydraulic fracturing for oil and gas has brought radiological issues into the spotlight
- Consider applicability of federal and state regulations that may apply
 - RPAP requirement
 - Transportation and disposal
 - Markings, labels, paperwork
 - Local or transcontinental disposal
 - Worker annual dose limits
 - Public or OSHA occupational
- Implementing a robust NORM/TENORM Management Program:
 - Basic radiation safety practices
 - Reduce occupational and public exposures
 - Reduce environmental liability
 - Reduce long-term costs



A **decade** of progress and perseverance in the Marcellus Shale.