Site Characterization and Remedial Design for Surface Impoundments Containing Technologically Enhanced Naturally Occurring Radioactive Material (TENORM)

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INTRODUCTION

- TENORM is an emerging regulatory issue with evolving requirements
- It affects several categories of large-volume manufacturing by-products and industrial waste
- Project characterized one type of manufacturing waste for the purpose of facility decommissioning and closure
  - *Showed importance of potentially underappreciated analytical issue that can significantly impact the results and the dose*
- A radiological site characterization was completed to inform closure strategy
- Dose modeling showed that modest and low-cost remedy will meet the local regulatory standard; however, O&M will need to be performed in perpetuity

NORM/TENORM BASICS

Naturally **O**ccurring **R**adioactive **M**aterial – **NORM**

- Examples of NORM: bauxite (aluminum ore), phosphate ore, granite rock, ceramic products, radon, some foods
- NORM is exempt from regulation…for the most part (exception: drinking water MCLs)

Technologically **E**nhanced NORM - **TENORM**

- Primarily a byproduct of processing mineral ores containing NORM
- Others: oil drilling waste, fly ash for coal plants, water treatment sludge
- Generally a waste material
- Exempt from Federal regulation but regulated in some states

RADIOACTIVE WASTE REGULATORY OVERSIGHT

- NRC
  - Regulates the civilian use of civilian radioactive materials: power plants, mining, industrial, academic and medical use.
- Agreement States
  - Regulate materials within their borders (not HLW)
  - Approval to administer licensing, inspection, etc.
  - Most states are Agreement States
- TENORM is regulated by the States
  - Approximately 13 states have TENORM-specific regulations, although what aspect is regulated varies
  - Several states are currently developing new regulations

WHEN/WHERE IS TENORM A PROBLEM?

"That depends on where you find it and when, where, and whom you talk to!"

"*State Regulations and Policies for Control of Naturally-Occurring and Accelerator Produced Radioactive Materials (NARM) and Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM)*"

(Association of State and Territorial Solid Waste Management Officials' [ASTSWMO's] Radiation Focus Group, December 2014)

http://www.astswmo.org/Files/Policies_and_Publications/Materials_Management/State%20Statutes%20and%20Regulations%20on%20TENORM%20Final%20Dec2014.pdf

ALUM PROCESS RESIDUE (APR)

- Uses of aluminum sulfate ("**alum**")
  - Water treatment coagulant
  - Paper and pulp manufacturing
- Source material is **bauxite**
  - NORM
  - Composition varies, including radionuclides
- Large-volume waste slurry ("**APR**")
  - High aluminum and silica content
  - Usually buffered with sodium hydroxide prior to disposal
  - pH can vary widely depending on buffering
  - Historically disposed in unlined "mud ponds" or low-lying areas
  - APR is *not* red mud

ALUM PRODUCTION PROCESS

$$2Al(OH)_3 + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 6H_2O$$

\+ **sulfuric acid** ⟶

+/- NaOH buffer ⇢

BAUXITE (NORM) VS APR (TENORM)

Bauxite

- Uranium (^{238}U) and decay products
- Thorium (^{232}Th) and decay products
- Potassium (^{40}K)
- ^{232}Th range: 0.6 – 28 pCi/g; avg: 6.2 pCi/g
- ^{238}U range: 0.8 – 13 pCi/g; avg: 4.1 pCi/g

(Von Philipsborn and Kuhnast 1992; FNCA 2005; Cooper 2005; IAEA 1996 Georgescu et al in IAEA 2005; Grant et al 2005; Abbady 2006; Adams & Richardson 1960)

APR

- Radionuclide concentrations generally higher
- Highest activity decay products:
  - ^{232}Th - range: 5 - 70 pCi/g
  - ^{238}U - range: 2 – 12 pCi/g
  - ^{228}Ra – range: 8 – 48 pCi/g

ONGOING TENORM INVESTIGATIONS

Former Alum Facility

- Unlined 6-acre APR pond
- APR up to 19-feet deep
- 130,000 cubic yards of APR
- High-density industrial area; nearby residential
- Unconfined sole-source aquifer

SITE INVESTIGATION

GOALS

- Radiological characterization
- Volume estimate, physical properties

APPROACH

- Drilling: sampling/analytical

METHODS

- Field: track-mounted Geoprobe drilling rig, isolation barrier; gamma walk-over survey
- Analytical: Standard EML HASL-300

CHALLENGES

- Rigorous health-and-safety requirements
- Representative radiological data!

FIELD WORK CHALLENGES

- More stringent H&S requirements
- Minimize contact to equipment and workers
- Disturbance triggers air-permitting reqmnts

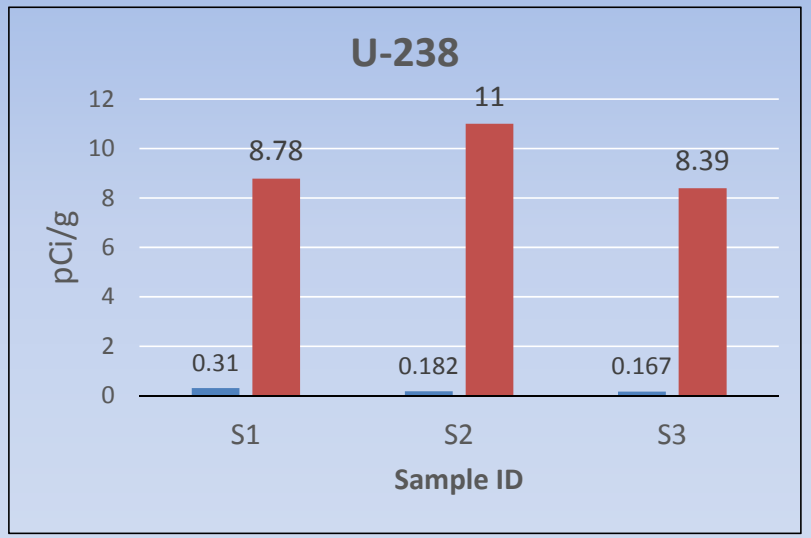
ANALYTICAL CHALLENGES

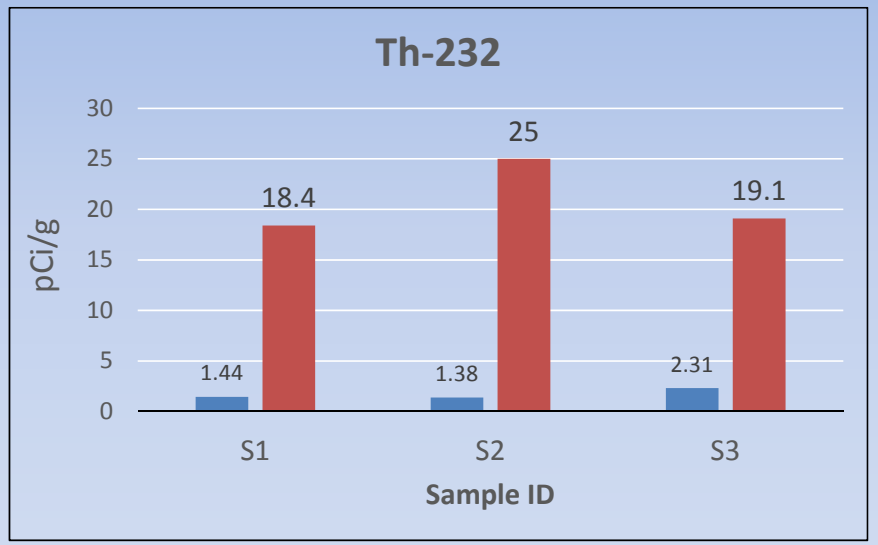
- Standard methods based on DOE Environmental Measurements Laboratory procedures manual HASL-300.

  https://www.orau.org/PTP/PTP%20Library/library/DOE/eml/hasl300/HASL300TOC.htm

- Laboratory methods do not specify sample preparation method – lab's will use their SOPs unless instructed otherwise.
- Initial testing sample preparation by finely grinding the material in a ball mill followed by an acid leaching procedure.
- Ran subset duplicates (different lab) using alternate more aggressive persulfate fusion preparation.
- Significant difference in results between the two preparation procedures!

Effect of Sample Preparation on Results





- Comparison indicated that for APR
  - Concentrations after the fusion process about one order of magnitude higher
  - Grind and acid-rinse method likely only extracted constituents from the surface of the sample particles
  - The fusion process liberated constituents in the mineral matrix of the material
  - Background in the range of 1 to 2 pCi/g for both radionuclides

REMEDIAL OPTIONS

- **Clean Closure -** Excavation and offsite landfill disposal
- **Beneficial reuse –** Excavation and offsite transportation to cement kiln, site restoration
- **Closure in place –** Isolation cap

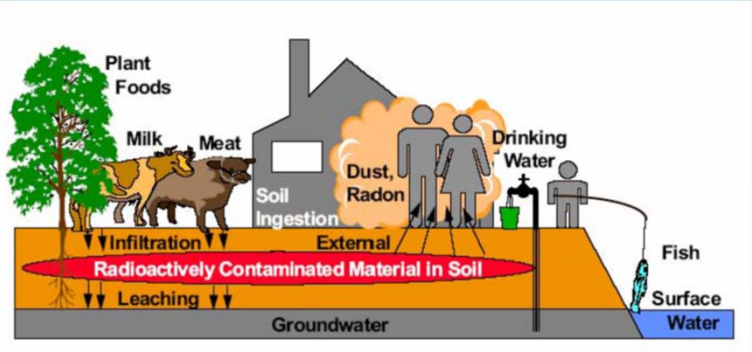
PRIMARY CLOSURE REQUIREMENTS

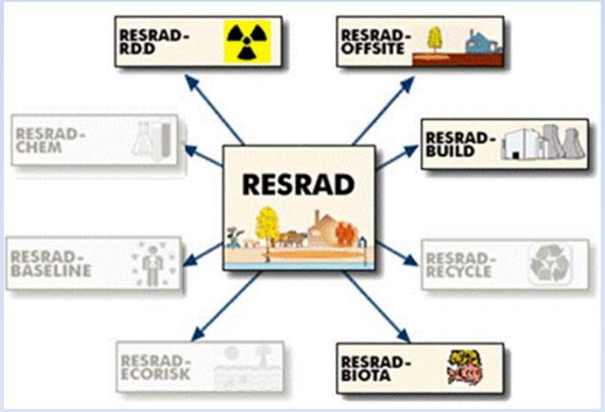
- Unrestricted Use
  - Residual radioactivity reduced to ALARA
  - Dose <25 mrem/year to critical group
- Restricted Use
  - ALARA
  - Institutional controls to achieve dose <25 mrem/year
  - Dose less that 100 mrem/year without institutional controls
  - Numerous additional criteria

Note: *Average annual dose from natural sources = 310 mrems/year*
https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/bio-effects-radiation.html

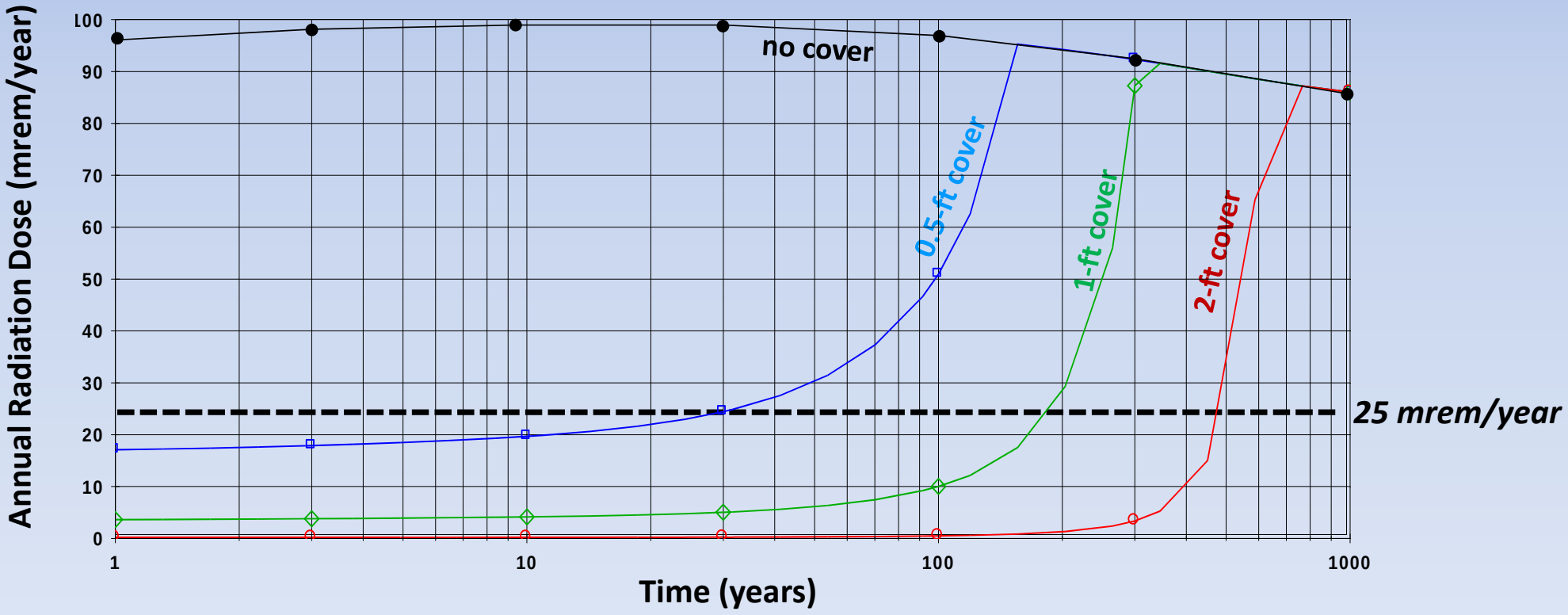
RESRAD Dose Modeling

- RESidual RADioactivity (RESRAD) – a set of computer codes used to predict future dose (developed by Argonne National Laboratory)
- Standard model to guide decommissioning and waste management
- Numerous environmental pathways may be considered (direct exposure, inhalation of particulates and radon, and ingestion of plant foods, etc.)
- Calculates the annual radiation dose from residual radionuclides
- Useful for analyzing scenarios to aid in remedial design, e.g., cap properties, thickness

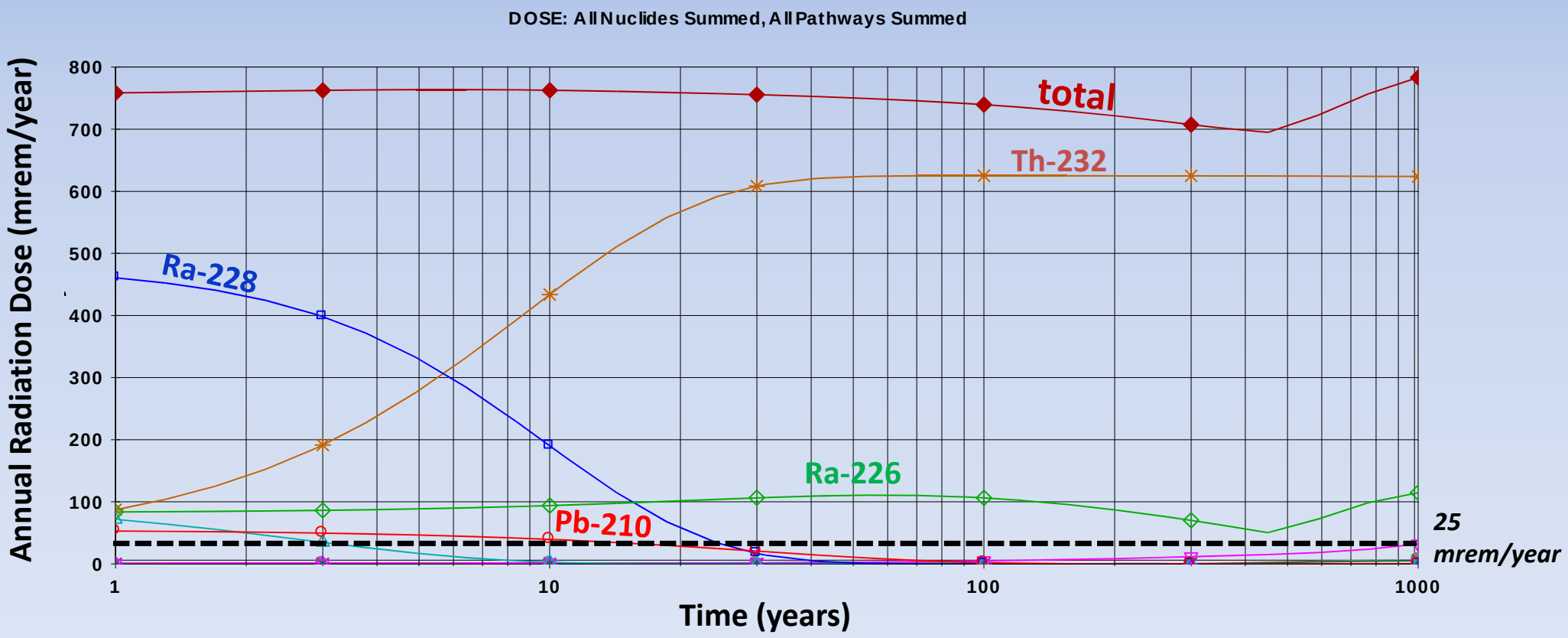




RESRAD Model: Soil Cover Thickness Sensitivity Analysis
Restricted Use Scenario



RESRAD MODEL: UNRESTRICTED USE SCENARIO, NO SOIL COVER



RESRAD MODELING CONCLUSIONS

- Without capping, dose exceeds regulatory criterion
- Thin (6 inch) soil cover adequate to reduce dose below regulatory criteria under **restricted use** (land use scenario => pathways => exposure)
- Modeling default duration is 1,000 years; cap maintenance required in perpetuity

WRAP UP

- Regulatory environment
  - Requirements vary by jurisdiction and are evolving (or not)
  - Vague and varied agency positions, policy lacking
  - Likely affect remedial options
  - Multi-agency oversight in some jurisdictions
- Public involvement
  - Radiological risk likely not well understood by community
  - Local opposition may effect remedial strategy
- O&M in perpetuity for in-place closure alternative
- TENORM can be a “re-opener” at toxics cleanup sites; potential significant cost increases
  - Work delays, slower approvals, additional H&S requirements
  - Revisions to remedial planning documents

Thank You!

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