NORM/TENORM Management:
Measurement, Exposure Assessment and Controls

John Snawder/Chad Hyman
What is NORM/TENORM?

• Naturally Occurring Radioactive Materials existing in nature that have a potential to cause health hazards when concentrated and allowed to enter the body
  – Parent Isotopes of NORM – Uranium-238 (4.47 billion years) and Thorium-232 (14.05 billion years)
  – Make up 60% of the earths crust
  – Decay produces three primary isotopes of NORM
    • Radium 226
    • Radium 228
    • Radon 222
How Does NORM Reach the Surface?

• The primary isotopes move into reservoirs through diffusion
• The primary isotopes attach themselves to larger compounds such as Sulfates, Carbonates, and Chlorides (*Piggy Backing*)
• NORM is carried to the surface by produced fluid
TENORM Production

- Three primary changes cause the “particulates” to precipitate out of the solution and produce scale
  - Temperature
  - Pressure
  - Turbulence
- If you can remove the material, then you remove the hazard
TENORM Production

- **Radium-226** 1,600 Years
  - Gives off Alpha Particle and Gamma Ray
    - 4.8 MeV alpha particle; 0.186 MeV gamma energy

- **Radium-228** 5.8 Years
  - Gives off Beta Particle and Gamma Ray
    - 0.017 MeV beta particle; <0.001 MeV gamma energy

- **Radon-222** 3.8 Days
  - Gives off Alpha Particle and Gamma Ray
    - 5.5 MeV alpha particle; <0.001 MeV gamma energy
Radiation Safety

• Why is TENORM a concern?
  – These materials emit radiation
    • Alpha radiation: Potential internal hazard (e.g., swallowed, inhaled, absorbed through wounds). Not external hazard
    • Beta radiation: Short range particles- Potential internal and/or external hazard
    • Gamma radiation: Penetrating, potential external hazard
Measuring Methods
Radiation Units

• **Roentgen** *(pronounced Rankin)* — *R* (µR/hr)
  – A unit of measurement used to identify the amount of radiation (energy) emitted for gamma rays and X-ray

• **Roentgen Equivalent Man** — *REM* (mR)
  – Measure of the dose of any ionizing radiation to body tissue in terms of its estimated biological effect
Think of a Speedometer

- MPH is the dose rate (µR/hr)
- Odometer is the “dose” (mR)
- GOAL IS TO KEEP ANNUAL DOSE (miles traveled) below:
  100 mR/year. Service workers are not radiation workers!
Analytical Highlights – No Controls

Radiation Doses and Regulatory Limits (in Millirems)

- Dose limit from NRC-licensed activity
- Radiation doses

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Doses (millirems)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual nuclear worker doses limit (NRC)</td>
<td>0</td>
</tr>
<tr>
<td>Whole body CT</td>
<td>1,000</td>
</tr>
<tr>
<td>Average US annual dose</td>
<td>620</td>
</tr>
<tr>
<td>Annual public dose limit (NRC)</td>
<td>310</td>
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<tr>
<td>From your body</td>
<td>100</td>
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<tr>
<td>Cosmic rays</td>
<td>40</td>
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<tr>
<td>Chest X-rays</td>
<td>30</td>
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<tr>
<td>Safe drinking water limit (EPA)</td>
<td>10</td>
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<tr>
<td>Trans-Atlantic flight</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>2.5</td>
</tr>
</tbody>
</table>
NORM Accumulation

- Must understand the process to identify the risk
- Most likely areas to find NORM accumulation:
  - Bends, turn, corners, valves, and changes in pipe diameter
  - Areas with slowed flow or material storage
  - Equipment that leaves a residual material after the emptying process
NORM Management Strategy

• Worker Protection and Training

• NORM Monitoring

• Control of Contaminated Equipment

• Control of NORM Waste
Survey Guidelines

• Persons conducting surveys must possess appropriate training as defined by the local laws and regulations (8-40 h training)
  – Baseline Surveys
  – Routine Assessment
  – Surveys Prior to Service and Maintenance
  – Legacy Contamination Surveys

• Anything 2X the background is referenced as a hot spot

• Hot spots and readings over 50 µR/hr should always be assessed for potential risk to workers and environment.
ALARA
As Low As Reasonably Achievable
The ALARA Principle was set forth to help in the minimization of risk relating to radioactive exposure of both workers and the general public

- **Time**
  - Limit time near identified sources
- **Distance**
  - Increase distance from sources
- **Shielding**
  - Barrier in front of source
Exposure Reducing Tools- Time

- Radiation exposure decreases linearly with a decrease in the amount of time near a source
  - $100 \, \mu R/hr \times 0.5 \, \text{hours} = 50 \, \mu R$
Exposure Reduction Tools - Distance

- Dose rate is inversely proportionate to the distance squared from the source
  - 100 µR/hr @ 3 feet = 25 µR/hr @ 6 feet
Exposure Reduction Tools-Shielding

- Shielding materials can provide a half value layer and decrease the intensity of gamma rays by factor of two
  - 100 μR/hr through 1HVL = 50 μR/hr
NORM/TENORM Study Design
July 3-7, 2017
Workover Rigs NORM/TENORM Study

• NIOSH and industry partners are working to obtain results of exposure to TENORM during maintenance operations and assess external and internal dose from operations

• Based on company radiation survey data, approximately 1 in 10 wells is determined to be “high NORM” (vessels exceed external dose rate of 45 \( \mu R/hr \))
July 3 and 5, GM Alice NORM Level of Well

- Well was moderately high. Average count on the 4 heater treaters was about 800 µR/hr
- Tubing and rods checked were at background levels <45 µR
- Workers carried the radiation dosimeter to estimate dose
- July 3, pulling and inspecting tubing
- July 5, tripping rods and installing pump
GM Alice Dosimeter Readings

![Bar chart showing NORM mR readings for different positions: Operator, Floor hand, Inspection Hand, Ground hand, and Area. The chart compares readings from 3-Jul and 5-Jul.]
July 7, EM Fretheim NORM Level of Well

- Well was low. Average count on the 4 heater treaters was background or below < 45 µR/hr
- Tubing and rods checked were at background levels <45 µR
- Workers carried the radiation dosimeter to estimate dose
- July 7, removed well head, installed BOP and pulled and inspected tubes
EM Fretheim Dosimeter Reading

![Bar chart showing NORM mR readings for Operator, Floor hand, Inspection Hand, and Ground hand.]
5 October-4 November, 2016 and Spring-Summer 2017
Service and Maintenance NORM/TENORM Study

• NIOSH and partners collaborating to obtain results of exposure to TENORM during maintenance operations and assess external and internal dose from operations

• Based on company radiation survey data, approximately 1 in 10 wells is determined to be “high NORM” (vessels exceed external dose rate of 45 µR/hr); however, these wells are typically covered by the most experienced team (highest exposed workers)
NORM/TENORM Study Design

• Company followed routine radiation survey practices. Recorded the following data for each location: date of survey, type of vessel, initial dose rate (mR/hr) at the bottom (belly) of the vessel.

• Workers from the ‘highest exposure team’ were provided Model 2501 Personal Radiation Monitors and recorded the following data for each location: date of survey, time on the job in hours, background dose away from vessel (mR), personal doses for each worker at the end of the shift (mR), and an area dose in sheds containing the vessel (mR).
Worker Exposures

Dose of Worker 1 Versus Vessel Belly Dose

Dose of Worker 2 Versus Vessel Belly
Worker Exposures

![Bar chart showing average doses for Worker 1 and Worker 2 at Separator and Treater locations. The chart indicates higher average doses at the Treater compared to the Separator for both workers.](image)
Worker Dose 7 Months

Worker Dose (cumulative 43 days at NORM wells)

Worker 1: Dose mR
Worker 2: Dose mR
Conclusions NORM/TENORM Study

- Preliminary external dose estimates predict the highest exposed workers will not exceed 100 mR/year
- Paired worker results track well with each other and in general with the pre-job survey
- Wipes of worker hands/PPE no external alpha and beta contamination concerns
- Preliminary evaluation of sludge and water samples show easily measured $^{226}\text{Ra}$ and $^{232}\text{Th}$ progeny and confirm disequilibrium of progeny in process materials
Up Next...Breakout Sessions 11:30am-12:15pm

1. RAGAGEP: OSHA Wants Me to Do What?? – Mike Marshall, Room 335-A
2. A Multi-State Initiative to Examine Workers’ Compensation Claims For Oil and Gas Extraction Workers – Kyla Retzer & Dr. Kyle Moller, Room 335-B
3. Investigations the H&P Way (The SIF Model) – Wade Deer, Room 335-C
4. Driving Transformation: How to Actively CARE – Mark Crelia, Room 336-AB
5. Heater Burner Automation Reduces Operator Injury Risk – Ron Truelove, Room 337-AB
8. The Impact of Safety Performance Metrics on Contractor Behavior – Phillip Crawley, Room 343-AB
9. Release for Unrestricted Use and Transfers Involving NORM Contamination – Geri Blanchard, Room 346-AB
Up Next…Tuesday

Lunch
- Grand Ballroom 12:15pm – 1:45pm
  - Speaker: Kola Fagbayi, Vice President of HSE & Technology BP
  - Keynote Speaker: Johnny “Joey” Jones, Combat-wounded Staff Sergeant (Ret.), Motivational Speaker

CEUs
- Receive 1.3 CEUs (13 hours) for attending conference
- Submit form at Customer Service Desk at the conclusion of the conference

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