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DEPARTMENT OF ENVIRONMENTAL PROTECTION

Bureau of Waste Management

2016 TENORM Disposal Protocol And Supplemental Waste Tracking Update

November 19, 2015

INTRODUCTION

The following slides present historical information and relevant background information used in the derivation of the TENORM Disposal Protocol.

The original protocol was developed by modeling a standard roll-off container full of TENORM using the software program MicroShield to determine the micro-Roentgen per hour (µR/hr) exposure rate measured on the outside of a roll-off container based on TENORM activity concentration in pico-Curies per gram (pCi/g) on the inside.

INTRODUCTION continued…

The activity concentration was then modeled inside a large generic landfill model using RESRAD dose assessment software to determine the future dose to the critical group, due to TENORM disposed of in the landfill.

Many assumptions were made during the original assessments. The following slides detail key inputs and assumptions used and which we have learned through experience are different or have changed.

INTRODUCTION continued…

Key input and assumptions used in the original derivation:

- 2% of the total waste disposed of in a year will be TENORM.
- The TENORM waste disposed of would contain:
  - 13.3 pCi/g of the Uranium Natural Decay Series including Ra-226.
  - 2.22 pCi/g of the Thorium Natural Decay Series including Ra-228
- The roll-off container was filled with the same activity concentrations. *Both series were assumed to be in equilibrium, meaning all progeny were at the same activity concentration.*

INTRODUCTION continued…

Since the original inputs and assumptions were used to derive the protocol we have learned:

- The majority of TENORM waste is wastewater treatment sludge which contains only Ra-226 and progeny from the uranium series and Ra-228 and progeny from the thorium series.
- The progeny, originally assumed to be in equilibrium, are not in equilibrium

Summary of RESRAD Assessments from 2002 to 2015 - Non Default Input Parameters

Parameter	2015 Landfill "A'	2012 Landfill "A"	2002 Blanket Auth. Generic Landfill	RESRAD Default Values
Contaminated Zone Area (m2)	3.60E+04	4.07E+04	2.02E+06	1.00E+04
Contaminated Zone Thickness (m)	1.9	2.15	106.7	2
Ra-226 Activity (pCi/g)	0.28	0.91	0.267	0
Ra-228 Activity (pCi/g)	0.046	0.151	0.0445	0
Cover Thickness (m)	0.9144	0.9144	0	0
Rn-222 Emanation Rate (-)	0.25	0.25	0.05	0.25
% of Total Waste	0.2	1.23	2	N/A
Max Dose (mrem)	20	69	30	N/A
tdose (year of max dose)	0	0	1,000	N/A

Summary of RESRAD Assessments from 2002 to 2015 - Non Default Input Parameters

Notes:

- The higher radium activity concentration in Landfill “A” in 2012 (0.91 versus 0.28 pCi/g of Ra-226) compared to Landfill “A” in 2015 accounts for the higher resulting dose (69 versus 20 mrem).

- The radium activity concentrations for Landfill “A” 2015 and the 2002 Generic Landfill are essentially equal. The higher dose result for the Generic Landfill (30 versus 20 mrem) is due to the much larger contaminated zone area and thickness.

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Theoretical Ra-226 Progeny Ingrowth

Parameter	Day 1	Day 3	Day 10	Day 21	BA used
Ra-226 (pCi/g)	13.3	13.3	13.3	13.3	13.3
Rn-222 (pCi/g)	2.21	5.59	11.5	13.3	13.3
Po-218 (pCi/g)	2.20	5.59	11.5	13.3	13.3
Pb-214 (pCi/g)	2.15	5.55	11.5	13.3	13.3
Bi-214 (pCi/g)	2.11	5.52	11.5	13.3	13.3
Po-214 (pCi/g)	2.11	5.52	11.5	13.3	13.3
Pb-210 (pCi/g)	8.8E-05	7.56E-04	7.03E-03	3.00E-02	13.3
Bi-210 (pCi/g)	3.8E-06	9.69E-05	2.81E-03	2.22E-02	13.3
Po-210 (pCi/g)	4.6E-09	3.74E-07	4.45E-05	1.22E-03	13.3
Exp Rate (uR/hr):	3.94	10.1	20.9	24.1	35
uR/hr / Ra-226 pCi/g:	0.30	0.76	1.57	1.81	2.63
Ra-226 pCi/g / uR/hr:	3.38	1.32	0.64	0.55	0.38

Theoretical Ra-226 Progeny Ingrowth

Notes:

1. Blanket Authorization (BA) also modeled 13.3 pCi/g of the U-238 series and 2.22 pCi/g of the Th-232 series resulting in 35 μR/hr.

2. BA assumed all Ra-226 progeny in equilibrium, i.e. Day 21 resulting in a 0.38 Ra-226 pCi/g / μR/hr conversion.

3. 2012 and 2015 assessments assumed no equilibrium, i.e. Day 1, resulting in a 3 Ra-226 pCi/g / μR/hr factor used to convert exp. rate measurements to pCi/g of Ra-226 in sludge.

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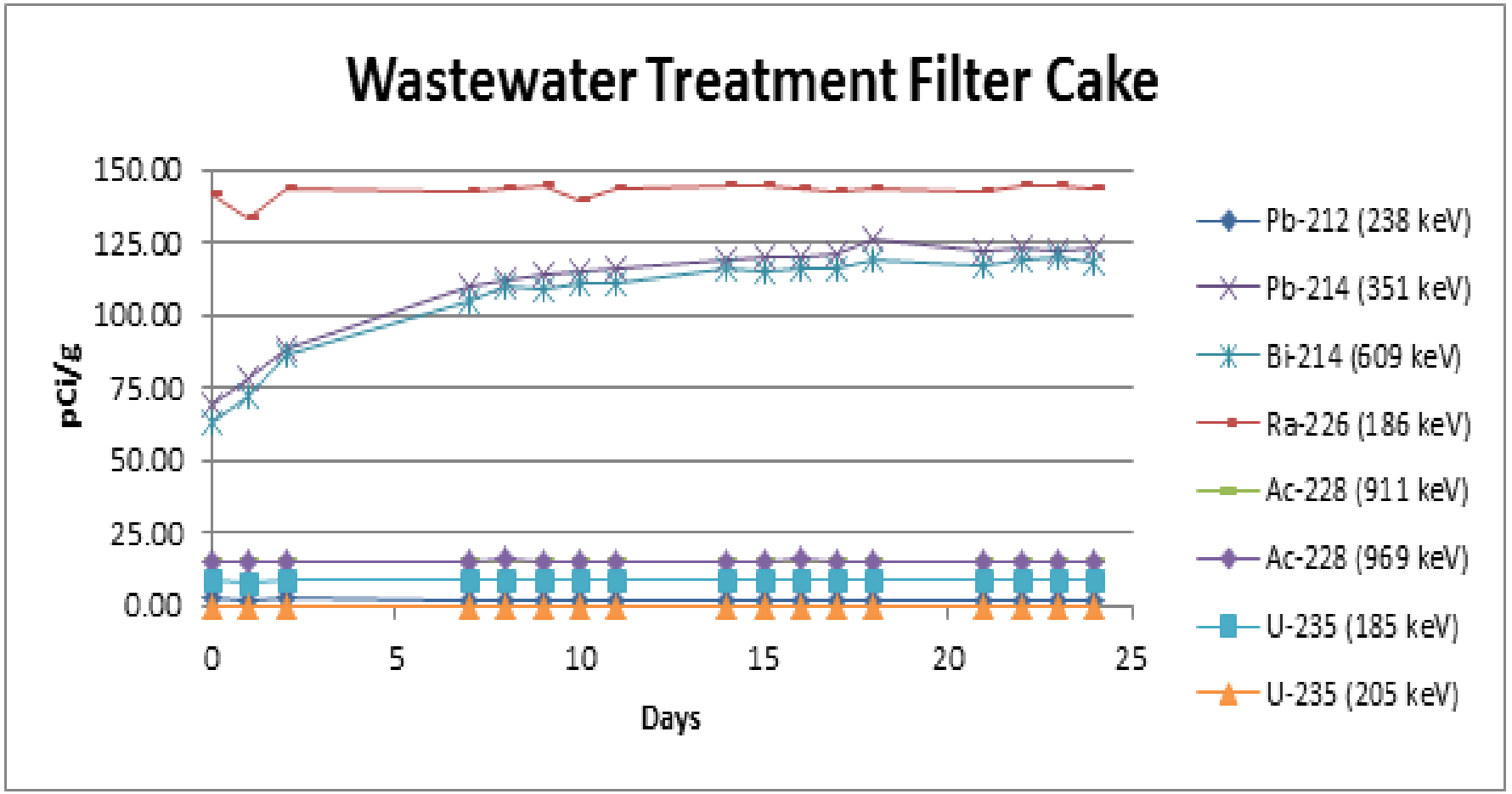
Actual Ra-226 Progeny Ingrowth (sample and analysis results)



Actual Ra-226 Progeny Ingrowth (sample and analysis results)

Notes:

1. MicroShield was used to determine exp rate based on day actual values, i.e. 140 pCi/g of Ra-226 and 70 pCi/g of progeny, as well as the 15 pCi/g of Ra-228 identified in the sample. The result was a conversion factor of 0.83 Ra-226 pCi/g / μR/hr.

2. An additional run was performed reducing the density of the material from 1.5 g/cc to a more sludge appropriate value of 1.1 g/cc and a value of 1.1 Ra-226 pCi/g / μR/hr results.

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Summary of Evaluations of Exposure Rate due to TENORM Activity within Roll-Off Container

Source Term	Activity (pCi/g)	Rolloff Exposure Rate (μR/hr)	RESRAD Dose (mrem)	Dose per Exp. Rate (mrem / μR/hr)	Dose per Activity (mrem / pCi/g)	Ra-226 pCi/g per μR/hr
Uranium (U-238 + progeny and U-235 + progeny)	13.33	24.79	19.33	0.78	1.45	0.54
Thorium (Th-232 + progeny)	2.23	11.27	0.739	0.07	0.33	
Radium (Ra-226 + progeny and Ra-228 + progeny)	13.33	35.48	12.74	0.36	0.96	0.38
Ra-226 (Ra-226 + progeny)	13.33	24.21	12.74	0.53	0.96	0.55
Ra-226 (10 day in growth, 86% progeny)	13.33	20.9	12.74	0.61	0.96	0.64
Ra-226 (3 day in growth, 41% progeny)	13.33	10.1	12.74	1.26	0.96	1.32
Ra-226 (1 day in growth, 16% progeny)	13.33	3.94	12.74	3.23	0.96	3.38
Total (Original parents plus progeny)	13.33	36.05	20	0.55	1.50	0.37

Additional Sources of Variability (Error) in Estimating Ra-226 pCi/g from Exposure Rate measurements:

1. Moisture content of sludge samples analyzed dry (> 50%) over estimates activity concentration.
2. Operator error and detection geometry error on exposure rate measurement at landfill.
3. Status of Ra-226 equilibrium at time of exposure rate reading.
4. Variability in source term, i.e. ratio of Ra-226 to Ra-228.

Distribution Ra-226 pCi/g / μR/hr Empirical Sample Results

Ra-226 pCi/g / μR/hr	Frequency
>0-0.5	1
>0.5-1.0	17
>1.0 - 1.5	15
>1.5 - 2.0	20
>2.0 - 2.5	21
>2.5 - 3.0	9
>3.0-3.5	13
>3.5-4.0	7
>4.0-4.5	5
>4.5-5.0	5
>5.0-5.5	2
>5.5-6.0	3
>6.0	0

Average:	2.39
Stdev.:	1.27
Median:	2.13
Min.:	0.43
Max.:	5.72
Count:	119

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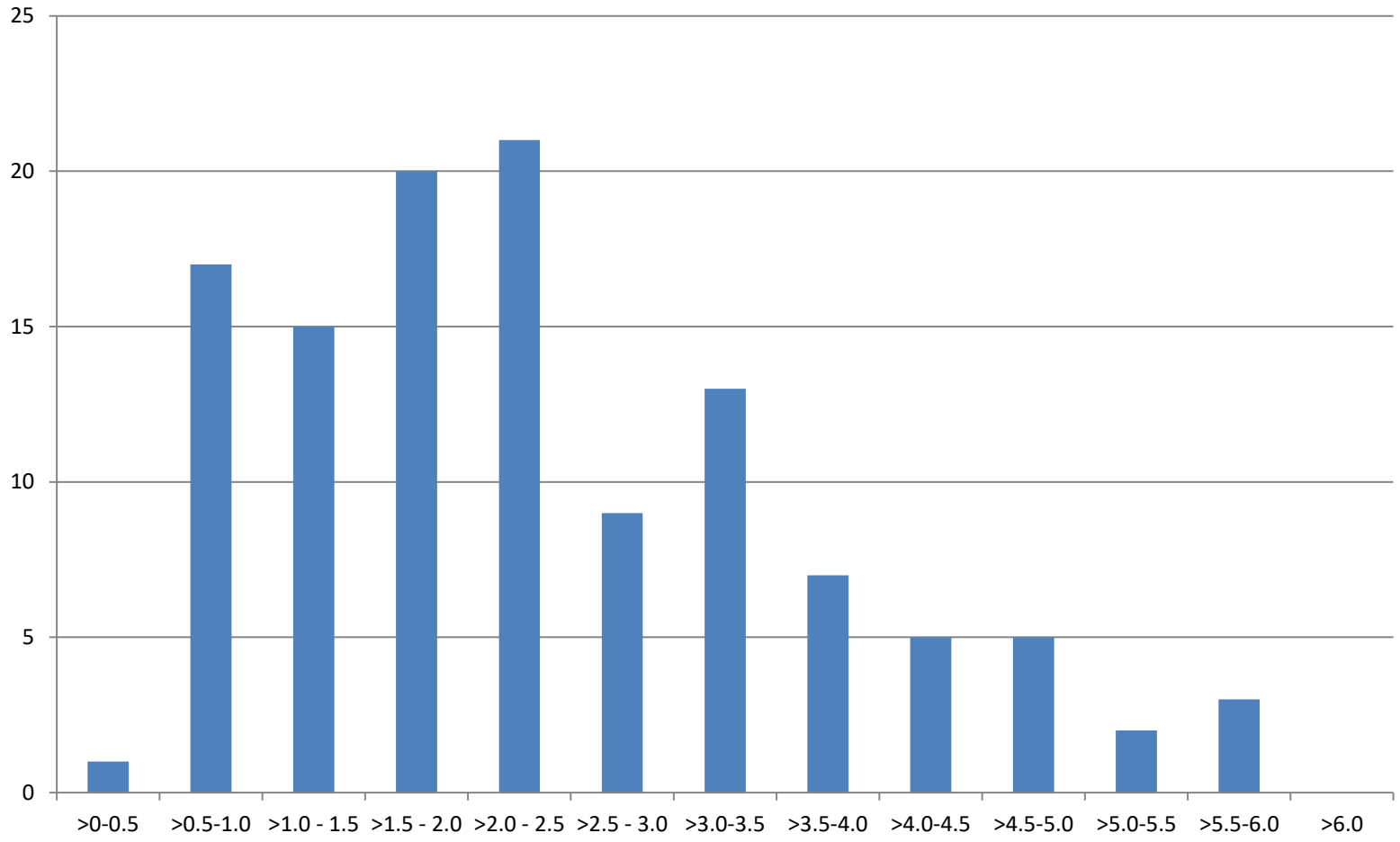
Distribution Ra-226 pCi/g / μR/hr Empirical Sample Results



Distribution Ra-226 pCi/g / μR/hr Empirical Sample Results

Notes:

1. Since the distribution is skewed towards the left and the median is less than the average value, the median should be considered.

2. Since the samples sent to the lab are dried and ground prior to analysis, the reported activity is about double the actual activity at 50% moisture content.

3. Correcting for moisture content the actual value of Ra-226 pCi/g per μR/hr is about 1.

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Conclusions

1. The conversion factor used in the solid waste spreadsheets to convert from exposure rate on the outside of roll-off containers to Ra-226 activity should be reduced from 3 to 1.5 Ra-226 pCi/g / mR/hr.
   - Concurs with conclusion in MSC and PIOGA's TENORM Study: multiplier of approximately 1.6

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Landfill Source Term Allocation Calculation

- As previously stated, the Blanket Authorization modeled a known concentration 13.3 pCi/g, which resulted in a 35 µR/hr dose rate

  - The original assumption was also that all Ra-226 progeny is in equilibrium; we now know freshly generated sludges aren't in equilbrium

    - Adjusted the Landfill Monthly TENORM tracking spreadsheets to account for the disequilibrium by adding a 3x multiplier and converting the annual source term allocation (STA) to a monthly STA.

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Landfill Source Term Allocation Calculation

- RESRAD Modeling indicated that the mrem/yr for the landfills accepting TENORM dropped from an average of 54.6 in 2012 to 23.8 in 2015.
  - However, 8 out of 21 landfills are still exceeding the 25 mrem/yr design criteria (compared to 13 out of 14 landfills in 2012) according to our extrapolated 2015 RESRAD Model

*The resulting mRem/yr for each landfill represents the estimated dose that would be measured in an occupied establishment constructed on top of the landfill 1,000 years in the future. These landfills do not pose an immediate, acute hazard to the public or to facility employees

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Landfill Source Term Allocation Calculation

- Determined there is an issue with the source term allocation calculation
  - Since 2012:
    - Prior years cold waste/collected waste tonnage was multiplied by 0.7 to provide the source term allocation

Acceptance Criteria	
2011 Collected Tonnage	100,000
Allowed Source Term Loading (ALST) A mathematical expression which will calculate the remaining tons of TENORM that can be accepted based on the Blanket TENORM Authorization	70,000

Landfill Source Term Allocation Calculation

- The 0.7 conversion factor was used based on the Blanket Authorization:
  - Landfills could accept TENORM on a sliding scale to meet the mrem/yr design criteria
    - 2% of total landfill volume at 35 µR/hr
    - 1% of total landfill volume at 70 µR/hr
    - 0.5% of total landfill volume at 140 µR/hr
      - 0.02 tons * 35 µR/hr = **0.7**
      - 0.01 tons * 70 µR/hr = **0.7**
      - 0.005 tons * 140 µR/hr = **0.7**

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Landfill Source Term Allocation Calculation

- The problem was that the 0.7 conversion factor was based off of µR/hr (35 µR/hr from blanket auth.)
  - With the 3x multiplier, µR/hr for sludge (804) is converted to pCi/g, but the STA is still based in µR/hr
  - Conversion factor calculation:
    - 2% of total waste volume at 13.3 pCi/g
      - 0.02 * 13.3 pCi/g = **0.266**

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Landfill Source Term Allocation Calculation

- Additionally…
  - Variability between the amount of cold waste received from one year to the next
    - Source Term Allocation will now be based off of the average cold waste from the prior 3 calendar years

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Conclusions

2. The estimate of TENORM volume calculated each year based on the previous years total volume should be corrected to reflect the 13.3 pCi/g of Ra-226 originally used in Blanket Authorization in lieu of the value of 35 µR/hr used previously. The conversion factor should be corrected from 0.7 to 0.266

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Multiplier for Non-Sludge Loads

- Adjusted the sludge multiplier to accurately convert µR/hr to pCi/g
- Adjusted the STA so it's based off of pCi/g instead of µR/hr
- Need to adjust all other non-sludge TENORM loads to be converted to pCi/g

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Multiplier for Non-Sludge Loads

- MicroShield modeled a known concentration 13.3 pCi/g, which resulted in a 35 µR/hr dose rate
  - This was for TENORM waste in equilibrium (essentially everything except sludges)
  - 13.3 pCi/g ⟶ 35µR/hr = 0.38x multiplier (pCi/g per µR/hr)

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Multiplier for Non-Sludge Loads

- Now:
  - the STA is calculated using a factor based on pCi/g, and
  - the source term for each TENORM waste load (sludge and non-sludge) is calculated using pCi/g converted from µR/hr

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Conclusions

3. The multiplier for non-sludge TENORM waste loads will be changed from 1x to 0.38x
   - Landfills can continue accepting non-sludge loads in the same amount they have been in 2015 (a net wash)
   - Sludge loads with a 1.5x multiplier and a 0.266 STA factor will reduce the STA by a greater percentage

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Conclusions

4. Complexities involved with allowing pCi/g data from a 901.1 analysis with sludge loads instead of using µR/hr measurements to determine the source term for a load
   - Ability to enter pCi/g data for TENORM loads will not be incorporated into TENORM monthly spreadsheets for landfills in 2016

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Questions?

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Supplemental Waste Tracking

- Rejected Waste Tracking Protocol will remain the same for the 2016 calendar year
  - Provides the Department with a record for every rejected waste load

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Supplemental Waste Tracking

- The Supplemental Waste Tracking Form will remain the same
  - Will be providing a flowchart with “Reason for Rejection” options the landfill can choose from
    - Will provide more accurate and definitive data to the Department

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Supplemental Waste Tracking

- As of September 30th, 2015, the Department had received a total of 224 SWTFs for loads rejected from PA Landfills

  – 22 were rejected because a landfill filled its STA for the month

    * In the month of March, two operators continued to send TENORM waste loads for disposal to a landfill after the landfill's monthly allocation was reached, amounting to an additional 35 rejections. These loads are not included in the total.

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Supplemental Waste Tracking

- If the 2016 TENORM Protocol (1.5x multiplier for sludge, 0.38x for other TENORM, 0.266 STA factor) were implemented in 2015:
  - 119 additional TENORM loads (1,281 tons) would have been rejected due to STA
    - Still capacity in other landfills

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Supplemental Waste Tracking

- Only 4 landfills would have had more than 10 additional rejections (21 currently accepting TENORM)

- No landfill filled its STA during **every** month in 2015

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Questions?

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