Reply to NIOSH "Metals and Controls Corp. Thorium and Welding Exposure Model"

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To the Advisory Board on Radiation and Worker Health's Work Group on Metals and Controls Corporation

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Internal exposures to thorium inhalation

- Background
  - Aerosols generated from soil disturbed during subsurface remediation in Building 10
  - Soil contaminated by leakage of pipe residues
- Thorium concentrations
  - NIOSH white paper (April 8, 2019)
    - Cited inventory of uranium and thorium prepared for assessment of financial liability
    - NIOSH performed pairwise comparison of U:Th ratios in soil samples but did not utilize results in estimating doses from thorium intakes
    - Model of onsite ^{232}Th concentrations assumed a 1:1 U:Th mass ratio

Inventory of special nuclear materials at M&C (January 1, 1962) (kg)

Material	Commission	License	Commission + License
93% Enr. U	1,264	18	—
20% Enr. U	—	71	—
3.2% Enr. U	—	1,449	—
2.2% Enr. U	—	3,932	—
1.8% Enr. U	—	363	—
Normal U	61	192	—
Depleted U	158	346	—
Total U	1,483	6,371	7,854
Thorium	198	46	244
U:Th	7.49	138.50	32.19

SC&A review (July 26, 2019)

- Inventory of uranium and thorium indicates U:Th mass ratios = 7.5 to 138.5
- Measurements of onsite ^{232}Th concentrations not utilized in estimating Th intakes

Data used by SC&A for modeling ^{232}Th concentrations in pipe residues

- ^{232}Th and ^{238}U concentrations in 88 borehole soil samples from Building 12 burial area measured by Sowell (1985) under contract to NRC
  - 88 measured concentrations of ^{232}Th
  - 80 measured concentrations of ^{238}U, plus eight assays below the lower limit of detection (LOD)
- ^{238}U concentrations measured by Weston (1996) in pipe sediments under Building 10
  - ^{238}U concentrations in 18 pipes or pipe segments
  - Volume of sediment in each pipe or pipe segment

SC&A model of ^{232}Th concentrations

- Assume ratio of ^{232}Th in pipes to ^{232}Th in soil = ratio of ^{238}U in pipes to ^{238}U in soil:

$$\frac{[^{232}Th_p]}{[^{232}Th_s]} = \frac{[^{238}U_p]}{[^{238}U_s]}$$

  - where
    - $[^{232}Th_p]$ = concentration of ^{232}Th in pipe residues (pCi/g)
    - $[^{232}Th_s]$ = concentration of ^{232}Th in soil (pCi/g)
    - $[^{238}U_p]$ = concentration of ^{238}U in pipe residues (pCi/g)
    - $[^{238}U_s]$ = concentration of ^{238}U in soil (pCi/g)

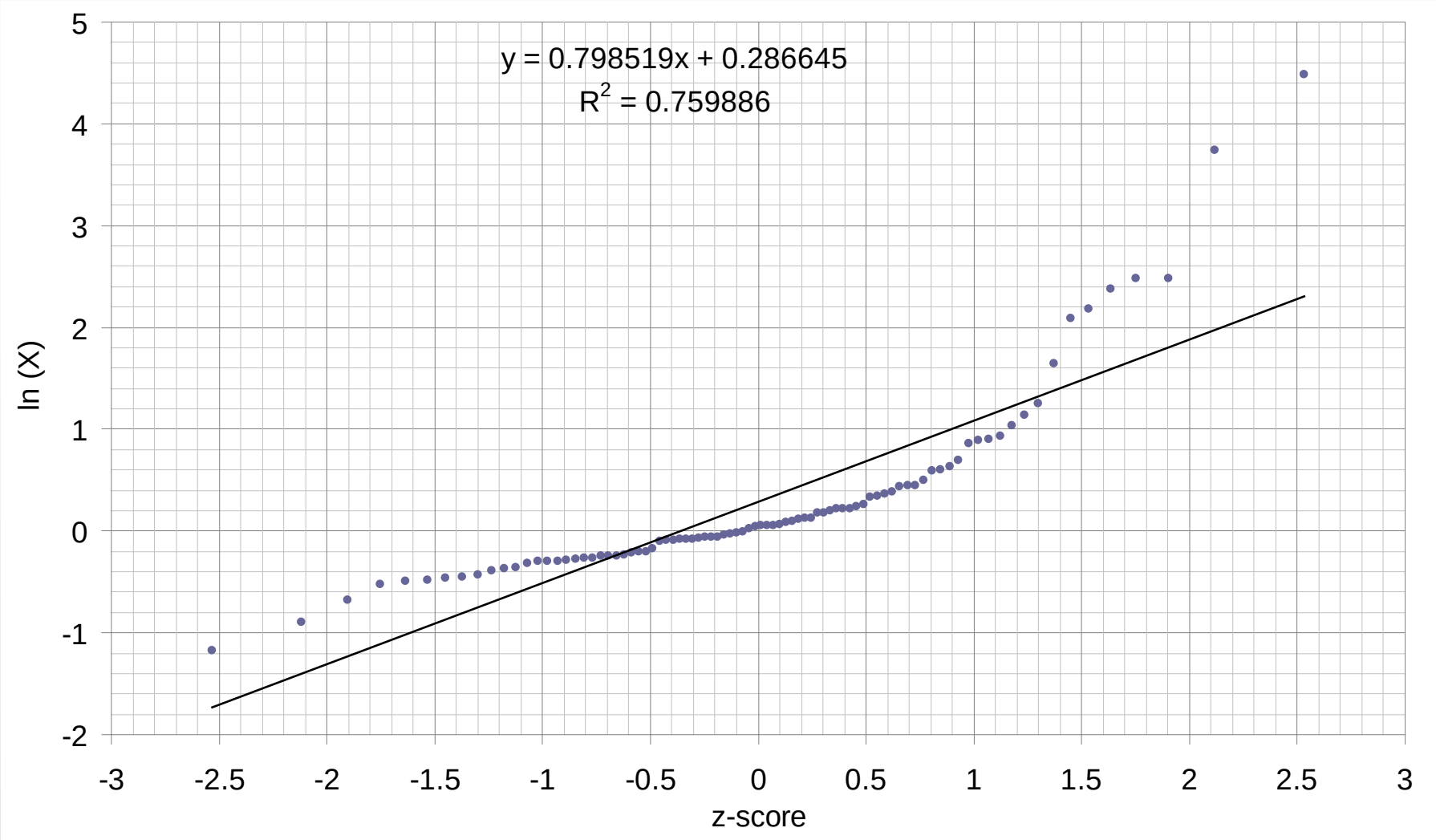
Calculation of ^{232}Th concentrations in pipes

- Solving for $[^{232}Th_p]$, we obtain

$$[^{232}Th_p] = \frac{[^{232}Th_s][^{238}U_p]}{[^{238}U_s]}$$

- Soil concentrations represented by lognormal distributions fitted to Sowell data
  - Used methods recommended by ORAUT-OTIB-0019
  - ^{238}U concentrations in pipes represented by lognormal distributions fitted to Weston data, weighted by volume of residue in each pipe
- ^{232}Th concentrations in pipes evaluated by Monte Carlo sampling of three distributions on the right-hand side of equation 1,000,000 times
- 95th percentile of derived values recommended as ^{232}Th concentration for intake and dose assessments
- Alternate analysis derived lognormal distribution of $[^{238}U_s]$ based on ORAUT-RPRT-0053

Lognormal distribution of ^{232}Th in soil



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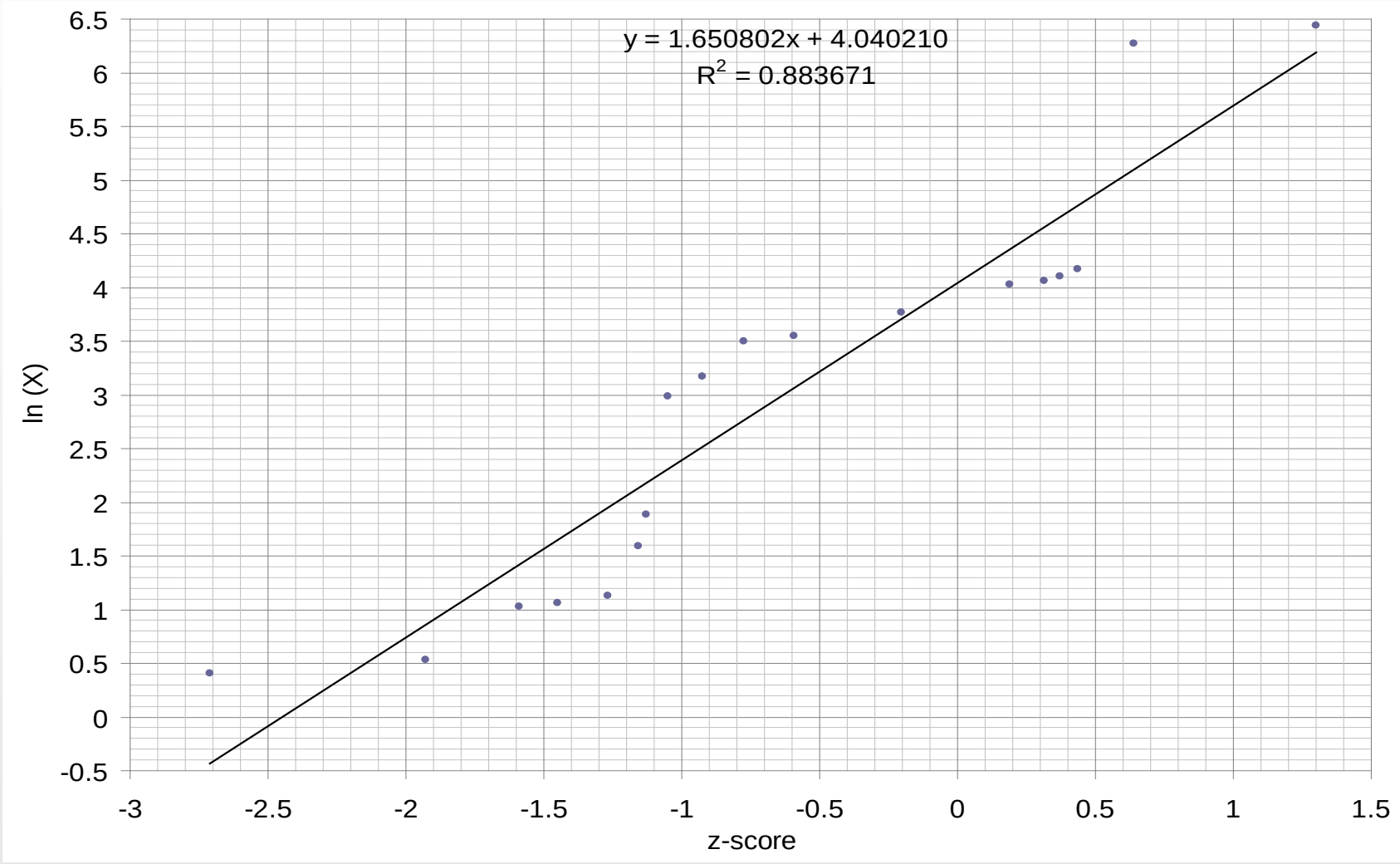
^{238}U activity distribution in pipe sediments under Building 10

U-238 (pCi/g)	Volume (mL)	CVD [a] (mL)	Midpoint [b] (mL)
1.5	6,178	6,178	3,089
1.7	37,067	43,244	24,711
2.8	16,062	59,307	51,276
2.9	16,371	75,678	67,492
3.1	37,067	112,744	94,211
4.9	1,977	114,721	113,733
6.6	8,031	122,752	118,737
19.8	24,248	147,000	134,876
23.8	32,124	179,125	163,062
33.1	43,553	222,678	200,901
34.9	62,087	284,765	253,721
43.4	200,160	484,925	384,845
56.1	86,180	571,105	528,015
58.1	2,471	573,576	572,340
60.5	37,067	610,642	592,109
64.8	6,178	616,820	613,731
529.2	123,556	740,376	678,598
624.7	177,920	918,296	829,336

[a] Cumulative volume distribution (CVD)

[b] CVD – ½ Volume

Lognormal distribution of ^{238}U in sediments under Building 10



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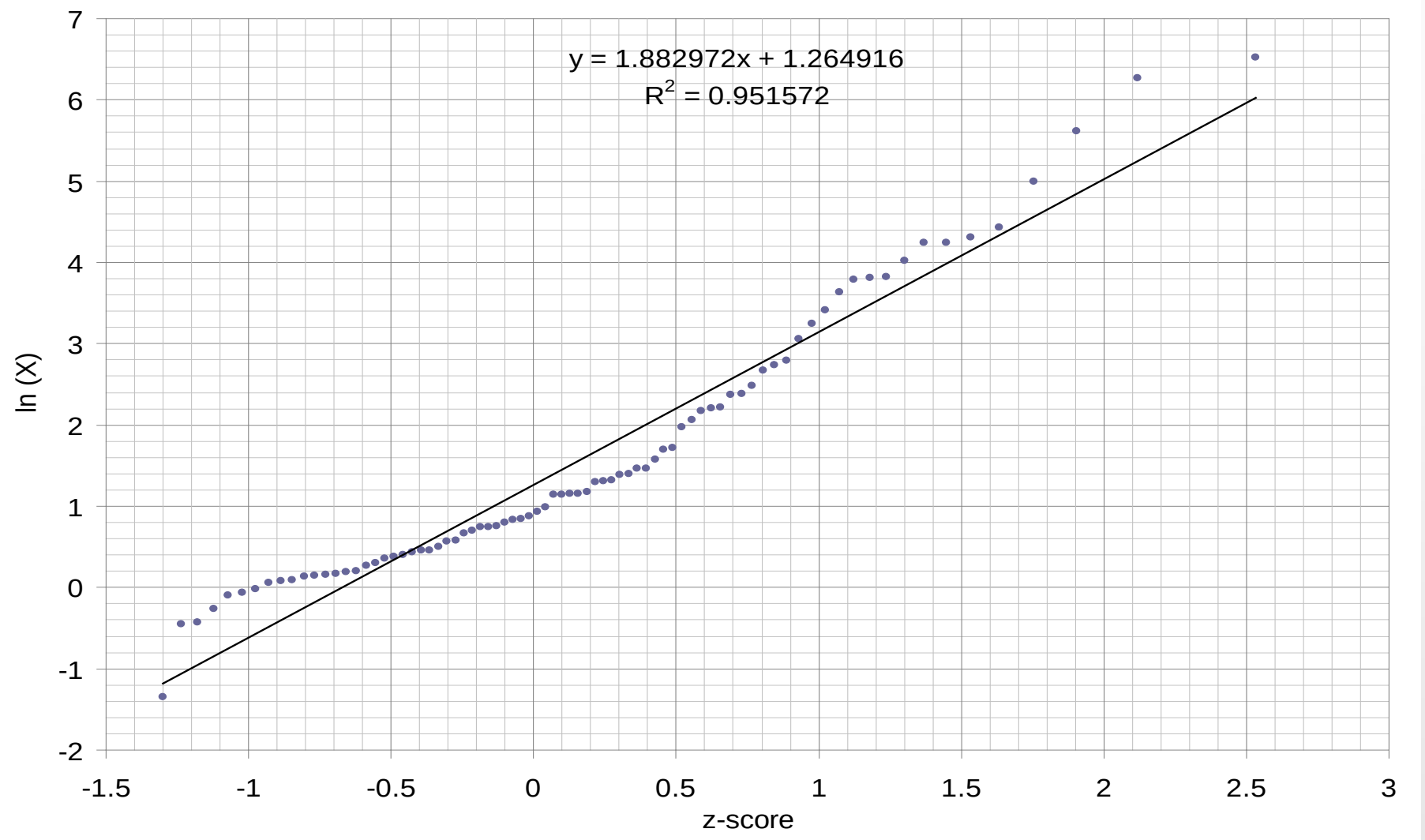
Lognormal distribution of ^{238}U in soil



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Lognormal distribution parameters

Parameter	[$^{232}Th_s$]	[$^{238}U_s$]	[$^{238}U_p$]	[$^{238}U_s$] [a]
R^2	0.760	0.952	0.884	0.936
GM (pCi/g)	1.332	3.543	56.838	7.887
GSD	2.222	6.573	5.211	4.924

[a] Recalculated using multiple LOD values

Results of thorium inhalation assessment

Model	Airborne ^{232}Th activity (µCi/mL)	Effective dose (mrem/y)
NIOSH	2.42 E-13	10.42
SC&A	3.56 E-13	14.00
SC&A (alternate) [a]	1.16 E-13	4.54

[a] Recalculated using multiple LOD values

Welding scenario

- Internal exposures from welding
  - Aggressive cleaning of metal surfaces prior to welding
  - Surficial activity concentrations based on plant-wide wipe tests
  - Airborne concentrations based on resuspension factor (RF)
  - Inhalation exposure duration – 4 h/mo – based on documented worker testimony
- NIOSH white paper
  - Used 1×10^{-3} m^{-1} RF
- SC&A
  - ORAUT-OTIB-0070 lists RFs of 1.02×10^{-2} to 4.2×10^{-2} m^{-1} from “vigorous sweeping by two workmen”
  - Assume aggressive cleaning of metal surfaces at least as disruptive as sweeping floor
  - Use rounded value of RF = 1×10^{-2} m^{-1} for 4 h/mo
  - Restricted to welding scenario only – other exposure scenarios at M&C not affected

References

- Roy F. Weston, Inc. (Weston). (1996). *Texas Instruments Incorporated, Attleboro Facility: Building interiors remediation drainage system characterization*. SRDB Ref. ID 165965
- Sowell, L. L. (1985). *Radiological survey of the Texas Instruments site, Attleboro, Massachusetts.* SRDB Ref. ID 94371

Questions?