Effects of Surface Paint Coatings on ^{232}Th Surface Contamination Detection

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Overview

- Review the physics related to electron interaction with matter
- Review past study by ORISE for NRC on Effect of paint density thickness on source efficiency (NUREG-1507).
- Develop a correlation between energy and source efficiency as a function of electron energy.
- Compare modeling with study performed using various paint samples and a thorium lantern mantle.

Physics of Electron Attenuation

- Electron Interaction with Matter
  - Function of number of absorbing electrons in path, or areal density (electrons cm^{-2})
  - Electron mass stopping power doesn't differ significantly for materials with similar elemental composition.
  - Mass collision stopping power for electrons is smaller for high Z materials than for low Z materials.
  - Reasonably conservative to apply data for water with a suitable mass density to paint.

Paint Composition

- Comprised mostly of low Z materials, such as water, latex (hydrocarbons), potassium sulfates, and pigments, with trace quantities of copper, iron, sodium, lead.
- Paint analysis for project showed lead content was less than 1%.
- Effective density for a 1% lead/epoxy based paint is 1.4 g/ml.

  [0.01*11.35 g/ml (lead) + 0.99*1.26 g/ml (remainder)]

Beta Particle Ranges*

ICRU Report 37 (1984) Data

Energy (keV)	CSDA** Range ($mg\ cm^{-2}$)	CSDA Range (millimeters)
50	4.32	0.03
100	14.3	0.10
300	84.2	0.60
500	177	1.3
1000	437	3.1

* For an effective density of 1.4 g cm^{-3}.

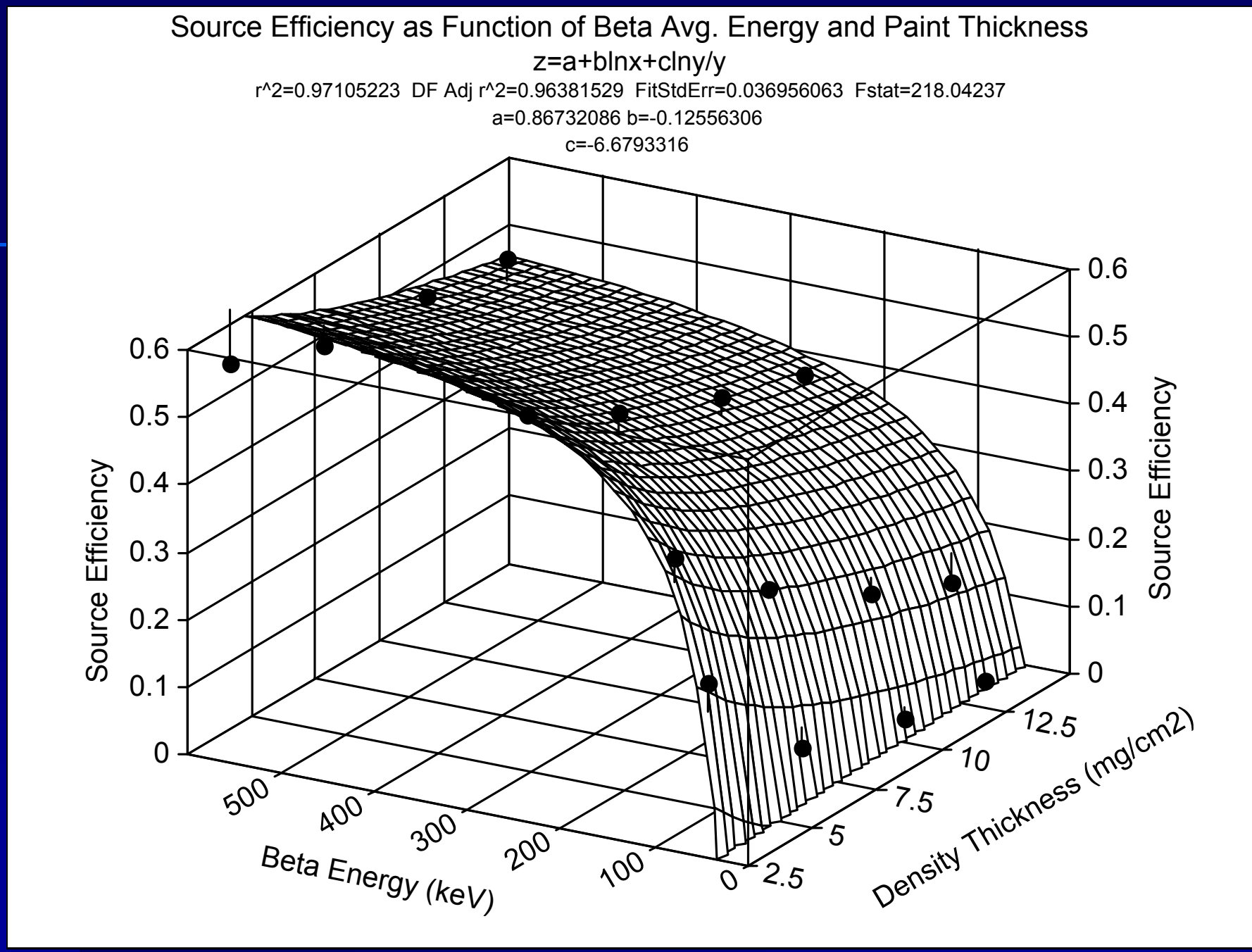
** Continuous slowing-down approximation

Paint Density Thickness and Source Efficiency – ORISE Study (NUREG-1507)

Density Thickness (mg/cm^2)	Source Efficiency			
	^{14}C (49 keV)	^{99}Tc (85 keV)	^{204}Tl (244 keV)	$^{90}Sr/Y$ (195+934 keV)
2.77 (0.02 mm)	0.252	0.427	0.596	0.584
6.38 (0.045 mm)	0.074	0.30	0.515	0.530
10.32 (0.073 mm)	0.0026	0.201	0.449	0.513
13.47 (0.096 mm)	0.0012	0.147	0.410	0.498

Curve-fit of Data

- $Z = 0.967 - [0.125 * \ln(X)] - [(6.679 * \ln(Y))/Y]$
  - Where
    - Z = source efficiency (beta surface emission considering paint attenuation)
    - X = density thickness of paint (mg/cm^2)
    - Y = beta energy (keV)


Source Efficiency as Function of Beta Avg. Energy and Paint Thickness
z=a+blnx+clny/y
r^2=0.97105223 DF Adj r^2=0.96381529 FitStdErr=0.036956063 Fstat=218.04237
a=0.86732086 b=-0.12556306
c=-6.6793316
Source Efficiency
0
0.1
0.2
0.3
0.4
0.5
0.6
Beta Energy (keV)
500
400
300
200
100
0
Density Thickness (mg/cm2)
2.5
5
7.5
10
12.5

Paint Thickness of Test Samples

Sample ID	Thickness (mm ± 10%)	Density Thickness (mg/cm^2)
Window Frame	0.25	36
Brick (Green)	0.38	53
Concrete Floor	0.51	71
Plaster, Stairs	0.51	71
Glass (Painted)	0.61	85
Concrete Column	0.74	103
Brick (Maroon)	0.74	103
Brick Stairs	1.24	174

Beta Emissions

- ^{232}Th (plus progeny) decay accompanied by 4.1 detectable electrons
- Using modeling equation, a 2 π surface emission rate of 2.6 detectable betas is calculated (nominal 1 mg/cm^2 paint cover)
- Modeling indicates a 27% backscatter.
- Consistent with NUREG-1507 -- measured backscatter of 20% for wood, 30% for concrete and 43% for steel.

Correlation of Thorium-232 Beta Emissions and Source Efficiency

Nuclide	Branch Ratio	Prominent Beta & Electron Energies (keV)	Source Efficiency (as a Function of Density Thickness)			
			1 mg/cm2	53 mg/cm2	103 mg/cm2	174 mg/cm2
Th-232	1	54 (6%)	2.32E-02			
Ra-228	1	None				
Ac-228	1	386 (25%), 611 (10%)	8.61E-01	2.34E-01	1.49E-01	9.09E-02
Th-228	1	65 (19%)	1.19E-01	2.15E-04		
Ra-224	1	None				
Rn-220	1	None				
Po-216	1	None				
Pb-212	1	94 (85%), 148 (33%)	8.05E-01	1.20E-01	3.85E-02	6.73E-03
Bi-212	1	531 (8%), 832 (48%)	5.06E-01	1.89E-01	1.36E-01	9.42E-02
Po-212	0.6407	None				
Tl-208	0.3593	439 (23%), 532 (23%), 646 (49%)	2.95E-01	1.08E-01	7.67E-02	5.21E-02
		Total	2.61E+00	6.51E-01	4.00E-01	2.44E-01
		Normalized Total	6.4E-01	1.6E-01	9.8E-02	6.0E-02

Measurements of Paint Attenuation and Source Efficiency for ^{232}Th

Gas Flow Proportional Detector	Source Efficiency		
	53 mg/cm^2	103 mg/cm^2	174 mg/cm^2
Ludlum 43-37	0.14	0.10	0.037
Ludlum 43-37	0.18	0.12	0.058
Ludlum 43-20	0.14	0.087	0.036
Ludlum 43-20	0.19	0.12	0.058
Average	0.16	0.11	0.047

Conclusion

- Paint thickness > 0.05 mm significant for very low energy electrons (C-14).
- For radionuclides with energetic electrons (> 300 keV), paint of 0.5 mm reduces source efficiency by ~ 0.5.
- Modeling can be used to evaluate effect on detection level caused by overlying paint and resulting lower source efficiency.