Abstract: Measurement of Field Swipes Using Field and Laboratory Instrumentation: DU Self/Media Absorption & Attenuation Issues

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This study was undertaken to examine the potential differential effect on alpha and beta measurement results due to self/media absorption and attenuation. Where absorption/attenuation is a significant variable, the selection of an instrument (method) of analysis may significantly effect quantification of alpha activity and, to a lesser degree, beta. Several different instruments were used to count a set of DU swipes and differing results were obtained based on conventionally calibrated instruments employing different analytical methods.

The results of these analyses are presented and discussed. Also considered is an alternative means of quantifying uranium alpha activity in surface contamination to demonstrate compliance with 10CFR835 Appendix D requirements.

Purpose

- Over-arching Purpose:

  Evaluate the significance of self/media absorption & attenuation on the quantification of alpha activity for heavy metal particulate contamination.

- Focused Purpose:

  1. Consider the relative affect of self-absorption & attenuation, overall, within the context of quantifying particulate contamination using different field and laboratory instrumentation.

  2. Consider the possibility of using beta activity to provide a better quantification for DU contamination.

Relevant General Facts

- Depleted uranium refers to uranium with lower than natural isotopic ratios of ^{235}U
- DU, as a metal/oxide, is very dense (19/11 g/cm^3 respectively)
- Greater the depletion, the greater the alpha activity is due to ^{238}U
- Beta/alpha ratios for DU *typically* run between 1.2 and 1.7
- The primary beta emitters are ^{234}Th (low E) and ^{234}Pa (high E)

Recognition of Alpha Self/Media Absorption & Attenuation Issues

Industry recognizes and often applies correction factors for absorption, e.g.:

- Waste water, sewer & environmental liquid samples
- Environmental, stack and occupational air sampling

DOE Radiological Control Technological Position Paper (RCTP 2010-01)

- Recognizes that alpha absorption may be a significant problem for 10CFR835 Appendix D compliance regarding uranium surface contamination

SNL RMWMF contamination control/air monitoring

- LSC results on known DU contaminated surfaces/subsequent investigation

Earlier Reported DU Related Studies

- Results of comparative analysis of DU samples using field instrumentation with measurements collected at “contact”, 0.3, 0.7 and 1.0 cm detector-source distance

DOE Radiological Control Technical Position (RCTP 2010-01)

- Recognizes the problem of adequately quantifying alpha contamination to assure compliance with 10CFR835 Appendix D surface contamination limits, due to self absorption issues
- Identifies acceptability of monitoring for beta-gamma emitters (from U-daughters) to demonstrate compliance with Appendix D limits for uranium
- Caveats include knowing the true beta/alpha ratio.
- One assumption has been made throughout the document, self-absorption is not significant for beta
- Attenuation is not recognized in this technical position

Study Materials

- 10 Swipes of DU oxide were used for this study (~ 5K-120 dpm)
- 1 dual channel scaler alpha-beta sample counter w/field type, open probe, ZnS(Ag) for alpha detection, plastic scintillator for beta counting
- 1 dual channel scaler alpha-beta sample counter w/enclosed counting chamber (ZnS(Ag) for alpha detection, plastic scintillator for beta counting)
- 1 low background gas flow proportional alpha/beta laboratory instrument
- 1 laboratory LSC counter (alpha/beta/LEB)
- 1 laboratory gamma spectrometer (HPG)

Comparative Measurements DU Alpha

	ZnS/Scint "F" dpm	ZnS/Scint "E" dpm	GPC dpm	**LSC** (alpha) dpm	^{tot}U (γ-spec) dpm
A	**573**	**697**	**839**	**722**	**5021**
B	**500**	**638**	**802**	**586**	**5301**
C	**2733**	**3159**	**4598**	**1740**	**83577**
D	**2213**	**2513**	**3739**	**1960**	**38196**
E	**4393**	**5266**	**7870**	**1860**	**120405**
F	**2407**	**3313**	**4993**	**1880**	**33562**
G	**1647**	**2122**	**3158**	**1240**	**21871**
H	**1873**	**2353**	**3310**	**1510**	**13994**
I	**1907**	**2238**	**2966**	**1530**	**12224**
J	**947**	**947**	**1338**	**675**	**6468**
Mean	**1919**	**2325**	**3361**	**1370**	**34062**

Notes: "F" = field, "E" = enclosure.   ZnS (Ag) used for alpha counting, plastic scintillation used for beta analysis

Comparative Measurements
Gross Alpha/ɣ Spectroscopy Ratios

	ZnS/Scint "F" dpm	ZnS/Scint "E" dpm	GPC dpm	LSC (alpha) dpm
A	**0.11**	**0.14**	**0.17**	**0.14**
B	**0.09**	**0.12**	**0.15**	**0.11**
C	**0.13**	**0.14**	**0.06**	**0.02**
D	**0.06**	**0.07**	**0.10**	**0.05**
E	**0.04**	**0.04**	**0.07**	**0.02**
F	**0.07**	**0.10**	**0.15**	**0.06**
G	**0.08**	**0.10**	**0.14**	**0.06**
H	**0.13**	**0.17**	**0.24**	**0.11**
I	**0.16**	**0.18**	**0.24**	**0.13**
J	**0.15**	**0.15**	**0.21**	**0.10**
Mean	**0.09**	**0.11**	**0.15**	**0.08**

Notes: “F” = field, “E” = enclosure. ZnS (Ag) used for alpha counting, plastic scintillation used for beta analysis

Comparative Measurements DU Beta

	ZnS/Scint "F" dpm	ZnS/Scint "E" dpm	GPC dpm	LSC (beta) dpm	LSC(LEB+beta) dpm	^{tot}U (γ-spec) dpm
A	4647	4804	2632	2560	5110	5021
B	4353	4442	2295	2380	5150	5301
C	42624	44388	26569	16000	43800	83577
D	29329	30838	18404	13200	35700	38196
E	67682	71050	43090	27500	91400	120405
F	21094	22663	14245	11700	32100	33562
G	13682	15233	9129	8040	20040	21871
H	12094	12388	7864	6700	15080	13994
I	10741	11383	7246	6030	13210	12224
J	5088	4958	3122	2860	5460	6468
Mean	8453	8886	5384	3879	10682	34062

Notes: Regarding LSC analysis, Beta activity will be identified in both the traditional "beta" channel and the **L**ow **E**nergy **B**eta (LEB) channel.
"F" = field, "E" = enclosure. ZnS (Ag) used for alpha counting, plastic scintillation used for beta analysis (beta Eff. Based on ^{36}Cl)

Comparative Measurements
Beta/Alpha Ratios

	ZnS/Scint "F"	ZnS/Scint "C"	GPC	LSC beta	LSC beta + LEB
Samples Mean	9.6	8.3	3.5	10.5	16.8
Samples Min.	5.4	5.1	2.3	3.5	7.1
Samples Max.	15.6	14.1	5.8	34.4	49.1

Comparative Measurements DU Beta

	ZnS/Scint "F" dpm	ZnS/Scint "E" dpm	GPC dpm	LSC(LEB+beta) dpm	^{tot}U (ɣ-spec) dpm	Stoic. beta dpm
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B	4353	4442	2295	5150	5301	7800
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G	13682	15233	9129	20040	21871	32200
H	12094	12388	7864	15080	13994	20600
I	10741	11383	7246	13210	12224	17980
J	5088	4958	3122	5460	6468	9520
Mean	8453	8886	5384	10682	34062	50128

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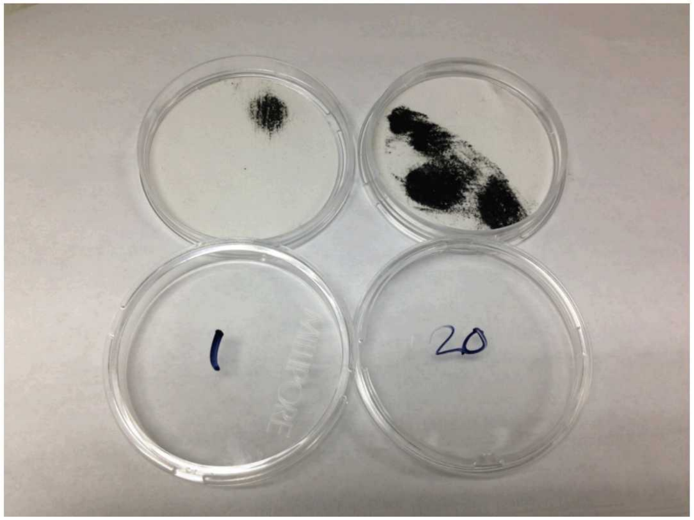
“F” = field, “E” = enclosure. ZnS (Ag) used for alpha counting, plastic scintillation used for beta analysis

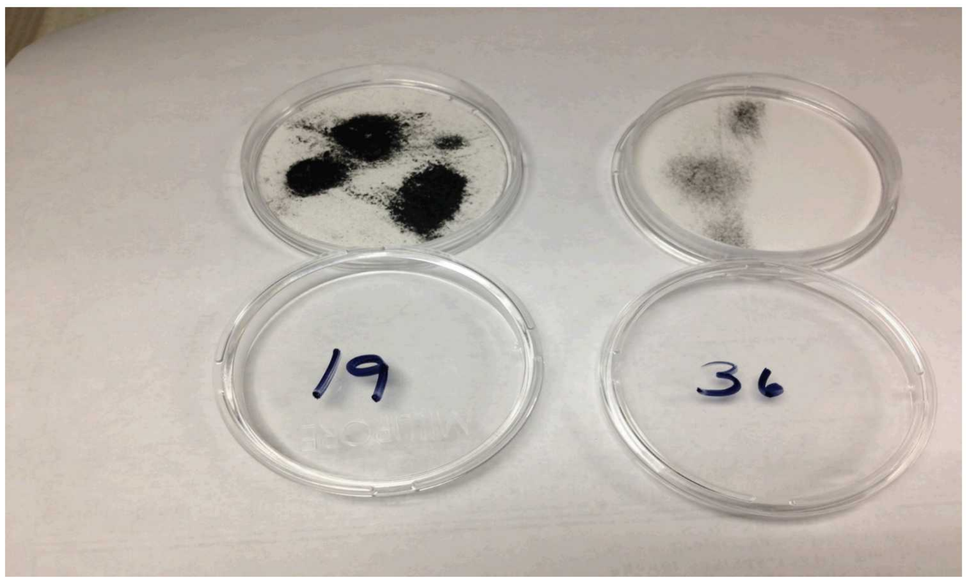
Variability in Swipe Collection Area



Build-up Variability

- For #19: $\alpha_\gamma/\alpha_g = 14.6$ β/α ratio = 16.1
- For #36: $\alpha_\gamma/\alpha_g = 4.2$ β/α ratio = 3.8

Note: Values based on “contact” readings w/hand-held field instrument



Potential Geometry Issue

- Due to settling, the LSC samples don't perfectly mimic the vial geometry
- Actually a hybrid vial/filter geometry should be considered
- Among methods evaluated, the worst alpha quantifications were from LSC analysis
- Among methods evaluated, the best beta ("beta" + LEB) quantifications were from LSC analysis

Results Summary

- Comparative Measurements (Alpha)
  - Based on standard/given alpha efficiencies, different instruments generally yielded significantly differing alpha quantifications
  - The closest quantifications were for the two instruments using the same detection methodology
  - All gross counting methods significantly under-quantify alpha activity
  - The best alpha quantification was by GPC, underestimating alpha between a factor of 4-20
  - The hand-held field instrument (**contact readings**) under-estimated alpha activity by a factor of >6 - >20

Point: Alpha absorption/attenuation is a significant factor for gross alpha measurement quantification that can lead to significant errors in activity measurements, particularly where dense metal particulate is the form of uranium. All gross counting methods yielded result much lower than gamma.

Results Summary (Cont.)

- Comparative Measurements (Beta)
  - Based on standard/given beta efficiencies, different instruments generally yielded significantly differing beta quantifications
  - The exception was for the two instruments using the same detection methodology
  - All gross counting methods report beta values < the corresponding "true" alpha values, except for a few of the LSC results. The degree is variable based on method and sample. In all cases reported beta was less than theoretical beta activity.
  - The lowest (worst) beta quantification was by GPC, underestimating alpha between a factor of 4-20
  - The highest (best) beta quantification was by LSC (LEB + "beta" channels)
  - For LSC, 50% to 70% of the total beta was identified in the LEB channel

Point: Beta absorption/attenuation, while far lower than for alpha, is potentially significant, particularly attenuation. To use beta activity measurements to quantify alpha activity for 10CFR835 Appendix D compliance appears possibly viable, however, careful consideration of the effects of absorption of low energy beta and attenuation of higher energy beta, relative to the chosen instrumentation, is essential, particularly where dense metal particulate is the form of uranium.

Results Summary (Cont.)

- Comparative Measurements (Beta/Alpha)
  - Beta/alpha ratios were all > 1.2-1.7 the ratios expected, indicating a potential issue
  - With LSC analysis, far lower beta energies are detectable than for any of the other methods considered. That the beta/alpha ratios are much higher for LSC analysis is in part, and likely primarily due to attenuation of the lower energy ^{234}Th betas. The degree is variable based on method and sample
  - The lowest beta/alpha ratios were from GPC
  - There was considerable variability in beta/alpha ratios , both for a given analysis method and between methods

Point: For a given facility or operation, the theoretical beta/alpha ratio is often well known. However, in the field, even considering a single analysis methodology, beta/alpha ratios may be quite variable as absorption/attenuation may vary from one measurement to the next. While elevated beta/alpha ratios are a good indicator of absorption/attenuation issues, the method of analysis must be carefully considered as, although beta/alpha ratios for GPC appear only modestly elevated, they are still problematic.

Further Comments

- Instrumentation (methodology) chosen can differentially affect gross alpha/beta quantification where self/media absorption and attenuation is significant
- Counting efficiencies based on laboratory calibration do not account for field conditions such as variable source to detector distance, surface characteristics, self/media absorption and attenuation, among other variables. Failure to account for these can lead to quality problems that are serious
- The effect of these parameters is relevant in considering quantification of all heavy metal alpha emitting contamination (e.g.:   TRU, LEU, HEU...)
- These observations apply to other material forms of alpha emitting contaminants although the extent depends on the material density, overall density thickness and other variables (filter burial, surface condition, particle size, etc.)
- While this study utilized swipes, the issues raised have been seen from earlier work to effect air sample results, biasing the activity low. Likewise, these parameters apply to in situ quantification of surface contamination
- The DOE Technical Position paper may be a reasonable first approximation for consideration. However, it is largely idealized and reality in the field is somewhat more complex, requiring careful application