Date: August 10, 2009

To:
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From:
State and Federal Drywall Technical Evaluation Team (CPSC, EPA, CDC/ATSDR, FLDOH, LADHH, and VADOH) (see Appendix 3 for the names and affiliations of Team members)

Subject:
Technical evaluation of "EPA's analysis of Florida drywall samples[1] and review of analytical results from the Florida Department of Health," from the EPA's National Air and Radiation Environmental Health Laboratory (NAREL). 7/31/09

Executive Summary

Testing by federal and state agency radiation laboratories indicates that samples of imported and domestic drywall contain only background concentrations of naturally-occurring radionuclides that are typically found in soil-derived materials and used in common building materials. As a result of recent speculation by consultants, homeowners, and the media about imported drywall containing phosphogypsum[2], the Florida Department of Health (FLDOH) Radiation Laboratory and the EPA National Air and Radiation Environmental Laboratory (NAREL) analyzed the same set of 21 drywall samples for radiological evidence of phosphogypsum contamination.

Based on the data from the two laboratories, the Technical Team concludes that there is no phosphogypsum contamination in the drywall samples tested. In particular, the levels of ^{226}Ra found in these samples were generally more than a factor of 10 lower than those found in phosphogypsum (10 to 35 pCi/g), but comparable to levels found in other commonly used building materials including bricks and concrete. Seventeen of the 21 drywall samples analyzed were collected by the U.S. Consumer Product Safety Commission (CPSC) and four were collected by the FLDOH. Both agencies' samples included imported and domestic drywall (Table 1).

[1] The Technical Team notes that the drywall samples were from CPSC and FLDOH (CPSC samples were collected from multiple states).
[2] Phosphogypsum is gypsum generated as a by-product of phosphate production and contains elevated levels of naturally occurring potassium, and thorium and uranium radionuclides and decay products.

Table 1: Sample Collection Breakdown

Drywall Origin	Number of Samples	Collected by
Imported	5[§]	CPSC
Domestic	12[§]	CPSC
Imported	2	FLDOH[†]
Domestic	1[+]	FLDOH[†]
Unknown	1	FLDOH[†]

§All CPSC samples were unpainted drywall manufactured approximately between 2006-2007. They included the same brands that residents said were in their homes.
[+]Sample collected from a home with domestic and imported drywall present.
[†]Samples collected by the FLDOH were from homes that met the Florida case definition of copper corrosion associated with imported drywall.

Based on the analytical results from this limited sampling event, the Technical Team believes that neither the imported nor domestic drywall tested pose a radiological concern.

Background

As a result of recent speculation by consultants, homeowners, and the media about imported drywall containing phosphogypsum, the FLDOH and CPSC initiated a blind study of 21 samples of both imported and domestic drywall. CPSC initially submitted the samples to the FLDOH radiation laboratory, who after analysis forwarded the samples to NAREL for comparative testing. CPSC tasked this Technical Evaluation Team (Technical Team) to review the resultant EPA NAREL report: "EPA's analysis of Florida drywall samples and review of analytical results from the Florida Department of Health" (Appendix 1).

After receiving the EPA report, this Technical Team was provided CPSC sample identification information, and the analytical methods and the tabulated results from the FLDOH and NAREL laboratories. The sample identification information indicated which samples were imported (n=7) and which were domestic (n=13)[3]. This sample set included selections of imported drywall that homeowners reported to be installed in their homes. Seventeen of the 21 samples analyzed were drywall samples obtained by CPSC from domestic and imported manufacturers, and four were obtained by the FLDOH[4] from homes with severe copper corrosion.

[3] In addition, one sample was unmarked.
[4] Because of the small number of samples, the Technical Team cannot conclude that these samples represent all imported and domestic drywall nor that the results demonstrate statistical significance. However, the Technical Team notes that the approach used by FLDOH was to collect drywall from homes exhibiting the most severe signs of copper corrosion, odors and occupant complaints, and that homes with the most severe corrosion problems were assumed to have the strongest sources of corrosive gasses. Therefore, the Technical Team believes that this approach allows the results to be cautiously applied to homes with less severe signs of corrosion, odors, and occupant complaints.

This memo compares the methods and results from FLDOH and NAREL, and reviews the approach, results, and conclusions of the EPA NAREL report.

Results/Discussion

Both FLDOH and NAREL used high-purity germanium detector gamma spectroscopy to analyze an identical set of 21 drywall samples for ^{226}Ra, ^{40}K, ^{232}Th, and ^{238}U (greater-than-background concentrations of these naturally-occurring radionuclides may indicate potential phosphogypsum contamination). In addition to performing confirmatory measurements and a quality control/quality assurance audit, NAREL performed two types of statistical tests on the paired results from FLDOH and NAREL to test for a systematic difference between the two laboratories. NAREL also identified and discussed variations in the Florida procedures that differed from the procedures used by NAREL.

The Technical Team performed a data review of the results. In general there were no major differences between the averages of the radioisotopes detected by FLDOH or by NAREL as determined by the ANOVA statistical test comparing the domestic samples between the two laboratories. Similarly, there was no significant difference between the imported drywall samples. The ANOVA test determines if the procedures used by the two labs are statistically different.

The Technical Team also compared the imported drywall samples to the domestic drywall samples. The analyses were run for ^{226}Ra content, ^{238}U content, and ^{232}Th content using an F-test which helps determine if two sets of data are similar. In this series of tests, Technical Team evaluations suggested that there were no significant differences in the two types of samples, the domestic drywall as compared to the imported drywall samples.

The analytical results from the FLDOH and NAREL laboratories were consistent. The few exceptions were explainable and do not change this conclusion. Notable differences are as follows:

The 1 standard deviation (1σ) was calculated differently by the two laboratories. FLDOH included only the counting error while NAREL calculated the total error. The reported errors compared favorably except for samples #40, 53, 56, and 58 (for ^{226}Ra); #55 (for ^{40}K), #56 and #58 (for ^{40}K); #44, #56, and #57 (for ^{232}Th/^{228}Ra); and #42 (^{238}U/^{234}Th). These observations do not impact the validity of the results and the inter-comparison of concentration values.

There are some distinct differences in concentration results reported by the two laboratories that were considered to be the result of using non-standard factors for gamma-ray intensity and differences in sample homogeneity and calibration source geometry.

The Technical Team concluded that FLDOH ^{226}Ra results were slightly lower than the NAREL results due to the use of too low an intensity (3.28% vs. 3.59%) for the 186.2 keV photopeak, and that the NAREL ^{234}Th results were slightly higher due to the use of too high an intensity (5.6% vs. 4.25%) for the 63.3 keV photopeak. Although these differences proportionally change the reported results, both approaches support the Technical Team conclusions.

1. As discussed in the EPA report, the Technical Team noted that for 8 samples there was interlaboratory variability. Those were for ^{226}Ra (#44), ^{40}K (#42 and 55), ^{232}Th/^{228}Ra (38, 41, 48, and 52), and ^{238}U/^{234}Th (#45). After considering the standard errors and differences in intensity values used, the Technical Team conclusion was that the differences were likely due to non-homogeneous samples (either as non-uniform distribution of sample material in the container or non-uniform distribution of radioactivity within the sample) and secondarily to differences between sample geometries. Homogenizing the samples and spacing the samples farther from the detector, or at equal distances, may reduce interlaboratory variability.

2. The Technical Team conducted a comparison of the 7 imported, 13 domestic, and 1 of unknown origin samples. The Technical Team noted that four samples contained levels of radioactive material that were at the upper end of the range of the other samples. One was of imported origin (#53 for ^{226}Ra). Three were of domestic origin (#42 for ^{226}Ra and ^{238}U/^{234}Th, #46 for ^{40}K and ^{228}Ra, and #48 for ^{40}K).

Conclusions

1. The Technical Team concurs with the conclusions of the EPA NAREL, July 31, 2009 report: Specifically,

   a. Within the limited sample of drywall assayed, there were no elevated levels of radioactivity measured.

   b. The ^{226}Ra content measured in these samples were generally more than a factor of 10 lower than those found in phosphogypsum (10 to 35 pCi/g)(see Appendix 2, Table 3), and comparable to levels found in other commonly used building materials including brick and concrete (see Appendix 2, Tables 1 and 2).

   c. The EPA assessment confirms FLDOH measurements which demonstrate that these drywall samples contain only background concentrations of naturally-occurring radionuclides (see Appendix 2, Table 1).

2. Based on the above, the Technical Team concludes that: the reported concentrations were typical of background soil but not of phosphogypsum as reported by Rajkovic

and Toskovic (2002) and as measured by the former US Navy Charleston Naval Shipyard Environmental Monitoring Laboratory (Sam Keith, personal correspondence, FN342). The conclusions that can be reached are that there is no indication that these drywall samples contain phosphogypsum, there is no indication that imported drywall contains any more radioactive material than domestic sources, and drywall associated with these samples would not represent a significant source of radiation exposure.

3. Both laboratory analytical approaches are appropriate and valid.

4. There were no differences in measured radionuclides between imported and domestic drywall.

5. Results of these 21 drywall samples may not be representative of all domestic or all imported drywall.

References:

1. Rajkovic, M.B. (2002). Investigation of the possibilities of phosphogypsum application for building partitioning walls – elements of a prefabricated house, APTEFF 33, 1-174.
2. UNSCEAR 2000 Vol. I, Annex B, Table 5 (http://www.unscear.org/docs/reports/annexb.pdf)
3. Kovler, K. (2009). Radiological constraints of using building materials and industrial by-products in construction, Construction and Building Materials 23, 246–253.
4. Roessler, C.E. (updated 19 May 2009) (http://hps.org/publicinformation/ate/q25.html)

APPENDIX 1

EPA's Analysis of Florida Drywall Samples and Review of Analytical Results from the Florida Department of Health

Conclusions

The U.S. Environmental Protection Agency's assessment supports the test results reported by the Florida Department of Health on the Florida drywall samples. The EPA measurements confirm that these drywall samples contain only background concentrations of naturally-occurring radionuclides. Phosphogypsum contamination is not indicated.

In particular, the levels of radium-226 found in these samples were generally more than a factor of 10 lower than those found in phosphogypsum (10 to 35 pCi/g), but comparable to levels found in other commonly used building materials, such as brick or concrete. Thus, *within the limited sample of drywall assayed*, there does not appear to be any radiological concern.

Laboratory Assessment

Sample Receipt and Login

The EPA National Air and Radiation Environmental Laboratory (NAREL) received 21 drywall samples from the Florida Department of Health (FDOH), Bureau of Radiation Control on July 23, 2009, at 8:50 AM. The samples were received in good condition with no visible damage to the shipping box. After completing all safety and contamination checks, the samples were removed from the shipping box. Two portions for each sample were received: (1) prepared sample in a plastic container for gamma analysis (approximately 200-400 g); (2) remaining sample as an unprepared 6" x 12" block of drywall.

The sample IDs on the containers were compared to the sample IDs on the letter and spreadsheet report received with the samples, and there were no discrepancies. The NAREL Sample Prep Lab staff verified the weights of the sample portions prepared for gamma analysis, and then transferred the samples to the Counting Room. The remaining portion of each sample was retained in the Sample Prep Lab.

The following table contains a reference between the NAREL sample number and the sample identifications provided by the client.

NAREL Sample No.	Lab ID#	FDOH ID#/ CPSC ID#
A9.06050X-1 & 2	38Z09	33928-13579
A9.06051Y-1 & 2	39Z09	34202-15314
A9.06052Z-1 & 2	40Z09	34239-193
A9.06053A-1 & 2	41Z09	34987-10400-105
A9.06054B-1 & 2	42Z09	09-810-7639-09
A9.06055C-1 & 2	43Z09	09-810-7069-04
A9.06056D-1 & 2	44Z09	09-302-1379-01

A9.06057E-1 & 2	45Z09	09-810-7932-04
A9.06058F-1 & 2	46Z09	09-840-9175-01
A9.06059G-1 & 2	47Z09	09-810-8213-05
A9.06060Z-1 & 2	48Z09	09-810-8037-04
A9.06061A-1 & 2	49Z09	09-840-9961-02
A9.06062B-1 & 2	50Z09	09-840-9139-07
A9.06063C-1 & 2	51Z09	09-840-9858-07
A9.06064D-1 & 2	52Z09	09-840-9962-09
A9.06065E-1 & 2	53Z09	09-840-9707-02
A9.06066F-1 & 2	54Z09	09-810-8036-04
A9.06067G-1 & 2	55Z09	09-810-8235-04
A9.06068H-1 & 2	56Z09	09-810-8236-01
A9.06069YJ-1 & 2	57Z09	09-810-7339-01
A9.06070YB1 & 2	58Z09	09-810-8357-09

Analysis at NAREL

The 21 samples were counted without re-packaging, however, NAREL re-weighed each sample. Twelve high-purity germanium (HPGe) gamma-ray detectors of various types and sizes were used. NAREL uses peak background correction based on 3000-minute background measurements. The most recent back-ground measurement, started on July 2, 2009, was used. Count time was preset to 170,000 seconds (47.2 hours) for all samples. The samples were divided into two quality control batches, the first with 11 samples, the second with 10. Instrument quality control checks consisting of peak center channel, peak resolution at Full Width at Half Maximum, and efficiency, at three different energies, were performed before and after each measurement and all were within their limits. For each batch of samples, one replicate count, one laboratory control sample (LCS), and one method blank were counted. These quality control samples met acceptance criteria for the first batch. As of 4:30 pm CDT on July 27th, counting of the quality control samples for the second sample batch is not complete.

NAREL analyzes gamma spectra using Quantum Technology's GDR Version 6.1. This software performs a Mariscotti peak search (versus a library-directed peak search).

Selection of the appropriate efficiency calibration to use is a matter of professional judgment when a sample does not closely match an existing calibration. Because all of the sample containers as received at NAREL were nearly full (maximum capacity is about 450 mL), NAREL used a 400 mL liquid density efficiency calibration for all 21 samples. Some samples had densities significantly below 1.0 g/mL, which would be expected to overestimate activity, particularly at lower energies. During review of the FDOH spectra files, NAREL noticed that some appear to have been analyzed using efficiency calibrations and background corrections for a 300 mL geometry. Using a smaller volume geometry that more closely matches the actual density is just as valid a professional judgment call as using a geometry (as NAREL did) that matches the volume but not the density. However, using the smaller volume geometry would be expected to underestimate activity, particularly at higher gamma-ray energies.

Comparison of Lab Results from FDOH and NAREL

Two types of statistical tests were performed on the paired results from FDOH and NAREL to test for a systematic difference between the two labs. Each test was performed once for each of the four radionuclides originally measured by FDOH: ^{226}Ra, ^{40}K, ^{232}Th, and ^{238}U. NAREL did not produce results for ^{232}Th and ^{238}U but it produced results for ^{228}Ra and ^{234}Th, which are based on

the same lines in the gamma-ray spectrum. The results for ^{232}Th and ^{228}Ra should be comparable because both are actually based on measuring gamma-rays from the decay product ^{228}Ac. The results for ^{238}U and ^{234}Th should be comparable because both are actually based on the gamma-rays from ^{234}Th.

For both of these statistical tests, each sample for which one or both labs failed to detect and measure the radionuclide of interest was omitted from the data set.

Test 1: For the first test, each difference was normalized by dividing it by its standard uncertainty (i.e., an estimated standard deviation).[5] A two-sided *t*-test was then performed on the normalized differences to test whether the mean normalized difference was different from zero at the 5 % level of significance. For ^{226}Ra, ^{40}K, and ^{238}U/234Th no significant differences were detected. However, a statistically significant difference was found for ^{232}Th/^{228}Ra. NAREL's results for ^{228}Ra were significantly higher than FDOH's results for ^{232}Th (both of which were based on the activity of the gamma-emitting decay product ^{228}Ac).

Test 2: For the second test, the differences were not normalized. A two-sided *t*-test was performed on the unnormalized differences to test whether the mean difference was different from zero at the 5 % level of significance. Test 2 produced the same conclusions as Test 1 for all four radionuclides. A statistically significant difference (at the 5 % level) was found only for ^{232}Th/^{228}Ra.

The "relative percent differences" (RPD) between NAREL's results and FDOH's results were also calculated and averaged by nuclide. The RPD is defined as follows

$$\text{RPD} = \frac{N - F}{(N + F)/2} \times 100\ \%$$

where N = NAREL's result for a particular sample and F = FDOH's result for the same sample. Although the sample-by-sample RPD values vary from less than −100 % to more than +100 %, the average RPD is large (37 %) only for ^{232}Th/^{228}Ra.

Nuclide	**RPD**
^{226}Ra	+4.2 %
^{40}K	−0.5 %
^{232}Th/^{228}Ra	+37.0 %
^{238}U/^{234}Th	+6.8 %

Note: Some of the normalized differences for particular samples and nuclides are unusually large. If there were no systematic differences between the labs and if the measurement uncertainties were realistic, one would expect nearly all the normalized differences to fall between −3 and +3. In fact several of the normalized differences exceed ±3 and one of them exceeds +5. The large difference between the two ^{40}K results for sample 90675-04963 is particularly hard to explain, since ^{40}K is generally considered to be easy to measure. NAREL double-checked its result for this sample, which is similar to the ^{40}K results for other samples. FDOH's result for this sample is smaller than the ^{40}K result for any other sample in the group.

[5] The uncertainties reported with the FDOH results represent counting uncertainty only. The uncertainties reported by NAREL include counting uncertainty and other uncertainty components.

Review of FDOH Lab Data

A review of the instrument quality control charts for all four instruments reported to have been used for the measurements revealed no out-of-control conditions. NAREL also reviewed reports of FDOH's participation in the Department of Energy's Mixed Analyte Performance Evaluation Program (MAPEP) for both their fixed and mobile laboratories. All results were within the acceptable ranges.

Further review of the RADIUM.NLB gamma library provided by FDOH revealed some significant differences in gamma-ray intensities compared to the NAREL library:

Nuclide	Energy keV	FL Intensity %	NAREL Intensity %	Relative Difference (%)
^{234}Th(^{238}U surrogate)	63.3 92.6	3.8 5.66	4.8 5.6	-20.8 +1.1
^{226}Ra	186.2	3.28	3.59	-8.6
^{228}Ac(^{228}Ra surrogate)	338.3 911.6 969	12.4 29.0 17.4	11.27 25.8 15.8	+10.0 +12.4 +10.1

These library differences should tend to cause values obtained by NAREL to be lower than those obtained by FDOH for ^{234}Th and ^{226}Ra, and higher for ^{228}Ac. When more than one gamma-ray is found for a radionuclide, both the FDOH and NAREL gamma-analysis software systems calculate a weighted average of the individual results obtained for those gamma-rays. Since NAREL uses consistently lower gamma-ray intensities for all three ^{228}Ac gamma-rays, the average difference between the FDOH and NAREL results can be expected to be most pronounced for ^{228}Ac.

NAREL selected at least one gamma spectrum file provided by FDOH for each of the four detectors reported to have been used for FDOH's analysis, and reanalyzed the spectra using Genie2K for PCs, version 3.1A. The energy, FWHM, and efficiency calibrations stored in each spectrum file, together with background spectra and the radium nuclide library provided by FDOH. NAREL used the Library (Gamma-M) peak search engine that FDOH stated that they had used and obtained comparable, but not identical, results.

NAREL does not routinely use Genie2K for gamma spectrometry and therefore has not attempted to optimize the many user-definable variables that can affect the results of peak searches and quantitative analysis. At NAREL, all of these parameters remain set to the factory defaults, thus results obtained are not expected to correspond exactly with those obtained elsewhere.

Summary

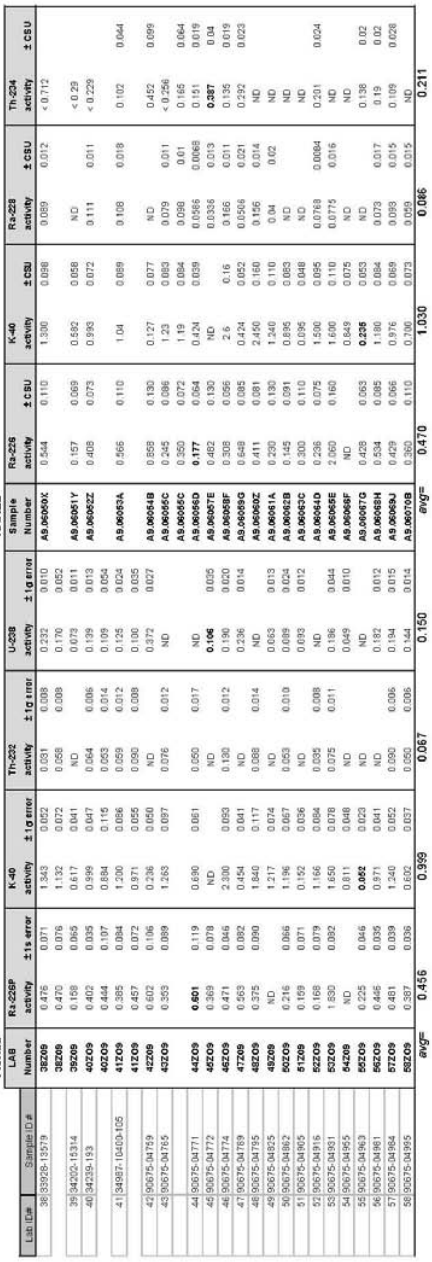
NAREL's data quality review of FDOH's data, instrument control charts and spectral files revealed no observable problems or data quality issues. Statistical tests performed on the paired results from FDOH and NAREL showed no significant differences for ^{226}Ra, ^{40}K and ^{238}U/^{234}Th. A statistically significant difference was found for ^{232}Th/^{228}Ra with NAREL's results being higher than FDOH's results. While the difference is statistically significant from a measurement perspective, it may have little practical significance given the levels of the radionuclides and the issue being investigated.

Attachments:

(1) Sample Analysis Results

(2) NAREL Statistical Tests and Comparisons

Appendix 1, Attachment 1
EPA NAREL Sample Analysis Results



Florida — **NAREL**

Lab ID#	Sample ID #	LAB Number	Ra-226P activity	± 1s error	K-40 activity	± 1σ error	Th-232 activity	± 1σ error	U-238 activity	± 1σ error	Sample Number	Ra-226 activity	± CSU	K-40 activity	± CSU	Ra-228 activity	± CSU	Th-234 activity	± CSU
38	83928-13579	**38Z09**	0.476	0.071	1.343	0.052	0.031	0.008	0.232	0.010	**A9.06060X**	0.544	0.110	1.390	0.098	0.089	0.012	< 0.712	
		38Z09	0.470	0.076	1.132	0.072	0.056	0.008	0.170	0.052									
39	34202-15314	**39Z09**	0.158	0.065	0.617	0.041	ND		0.073	0.011	**A9.06061Y**	0.157	0.069	0.592	0.058	ND		< 0.29	
40	34239-193	**40Z09**	0.402	0.035	0.999	0.047	0.064	0.006	0.139	0.013	**A9.06062Z**	0.408	0.073	0.993	0.072	0.111	0.011	< 0.229	
		40Z09	0.444	0.107	0.684	0.115	0.053	0.014	0.109	0.054									
41	34987-10400-105	**41Z09**	0.385	0.084	1.200	0.096	0.059	0.012	0.125	0.024	**A9.06063A**	0.566	0.110	1.04	0.089	0.108	0.018	0.102	0.044
		41Z09	0.457	0.072	0.971	0.055	0.090	0.008	0.100	0.035									
42	90675-34759	**42Z09**	0.602	0.106	0.236	0.050	ND		0.372	0.027	**A9.06064B**	0.668	0.130	0.127	0.077	ND		0.452	0.099
43	90675-34765	**42Z09**	0.353	0.069	1.263	0.097	0.076	0.012	ND		**A9.06065C**	0.245	0.086	1.23	0.093	0.079	0.011	< 0.256	
											A9.06065C	0.350	0.072	1.19	0.084	0.098	0.01	0.165	0.064
44	90675-34771	**44Z09**	**0.601**	0.119	0.690	0.061	0.050	0.017	ND		**A9.06066D**	**0.177**	0.064	0.424	0.039	0.0566	0.0068	0.151	0.019
45	90675-34772	**45Z09**	0.369	0.078	ND		ND		**0.106**	0.035	**A9.06067E**	0.462	0.130	ND		0.0336	0.013	**0.387**	0.04
46	90675-34774	**45Z09**	0.471	0.046	2.930	0.059	0.130	0.012	0.190	0.020	**A9.06068F**	0.308	0.056	2.6	0.16	0.166	0.011	0.135	0.019
47	90675-34789	**47Z09**	0.563	0.092	0.454	0.041	ND		0.236	0.014	**A9.06069G**	0.648	0.085	0.424	0.052	0.0566	0.021	0.292	0.023
48	90675-34795	**48Z09**	0.375	0.090	1.840	0.117	0.088	0.014	ND		**A9.06070Z**	0.411	0.081	2.450	0.160	0.156	0.014	ND	
49	90675-34825	**49Z09**	ND		1.217	0.074	ND		0.063	0.013	**A9.06061A**	0.230	0.130	1.240	0.110	0.04	0.62	ND	
50	90675-34862	**50Z09**	0.216	0.066	1.196	0.067	0.053	0.010	0.089	0.024	**A9.06062B**	0.145	0.091	0.696	0.083	ND		ND	
51	90675-34965	**51Z09**	0.159	0.071	0.152	0.036	ND		0.093	0.012	**A9.06063C**	0.300	0.110	0.096	0.048	ND		ND	
52	90675-34916	**52Z09**	0.168	0.079	1.166	0.084	0.035	0.008	ND		**A9.06064D**	0.236	0.075	1.500	0.095	0.0768	0.0084	0.201	0.024
53	90675-34931	**53Z09**	1.930	0.092	1.650	0.078	0.075	0.011	0.196	0.044	**A9.06065E**	2.060	0.160	1.600	0.110	0.0775	0.016	ND	
54	90675-34955	**54Z09**	ND		0.811	0.048	ND		0.049	0.010	**A9.06066F**	ND		0.849	0.075	ND		ND	
55	90675-34963	**55Z09**	0.225	0.046	**0.662**	0.023	ND		ND		**A9.06067G**	0.428	0.063	**0.238**	0.053	ND		0.138	0.02
56	90675-34981	**56Z09**	0.446	0.035	0.971	0.041	ND		0.182	0.012	**A9.06068H**	0.534	0.085	1.180	0.084	0.073	0.017	0.19	0.02
57	90675-34984	**57Z09**	0.481	0.039	1.340	0.052	0.090	0.006	0.194	0.015	**A9.06069J**	0.429	0.066	0.976	0.069	0.093	0.015	0.109	0.028
58	90675-34995	**58Z09**	0.387	0.036	0.602	0.037	0.050	0.006	0.144	0.014	**A9.06070B**	0.362	0.110	0.706	0.073	0.059	0.015	ND	
		avg=	0.456		0.999		0.067		0.150		*avg=*	0.470		1.030		0.066		0.211	

Activity units - picocuries per gram (pCi/g)

ND=Not detected
CSU=combined standard uncertainty

Appendix 1, Attachment 2
EPA NAREL Statistical Tests and Comparisons

Normalized Differences (Z Scores)

	Ra-226	K-40	Th-232 Ra-228	U-238 Th-234
	0.52	-0.39	**3.96**	
	-0.01	-0.49		
	0.07	-0.07	**3.73**	
	1.31	**-1.30**	2.27	-0.47
	1.53	**-1.19**		0.78
	-0.87	-0.26	0.17	
	-3.14	**-3.69**	0.45	
	0.75			**5.26**
	-2.24	**1.62**	2.20	-2.01
	0.72	-0.46		2.07
	0.30	**3.08**	**3.51**	
		0.17		
	-0.63	-2.82		
	1.08	-0.95		
	0.63	2.64	**3.56**	
	1.28	-0.37	0.10	
		0.43		
	2.61	**3.16**		
	0.96	2.23		0.32
	-0.68	**-3.06**	0.22	-2.67
	-0.23	1.19	0.58	
avg=	0.207	-0.026	1.886	0.467
s=	1.337	1.938	1.613	2.661
n=	19	20	11	7
t=	0.6751	-0.0591	3.8768	0.4648
critical=	2.1009	2.0930	2.2281	2.4469
Different?			**Different**	

Differences

	Ra-226	K-40	Th-232 Ra-228	U-238 Th-234
	0.0676	-0.0429	0.0574	
	-0.0010	-0.0346		
	0.0060	-0.0058	0.0473	
	0.1812	-0.1605	0.0495	-0.0234
	0.2558	-0.1091		0.0799
	-0.1075	-0.0330	0.0027	
	-0.4240	-0.2660	0.0083	
	0.1130			0.2808
	-0.1630	0.3000	0.0356	-0.0549
	0.0852	-0.0303		0.0555
	0.0363	0.6098	0.0683	
		0.0228		
	-0.0706	-0.3010		
	0.1407	-0.0573		
	0.0685	0.3340	0.0422	
	1.8740	-0.0500	0.0020	
		0.0384		
	0.2029	0.1827		
	0.0880	0.2089		0.0075
	-0.0520	-0.2640	0.0035	-0.0850
	-0.0270	0.0977	0.0094	
avg=	0.1197	0.0220	0.0297	0.0372
s=	0.4511	0.2215	0.0249	0.1221
n=	19	20	11	7
t=	1.1563	0.4440	3.9497	0.8065
critical=	2.1009	2.0930	2.2281	2.4469
			Different	

Relative Percent Differences

	Ra-226	K-40	Th-232 Ra-228	U-238 Th-234
	13.3%	-3.2%	95.5%	
	-0.6%	-5.8%		
	1.5%	-0.6%	54.2%	
	36.1%	-14.3%	59.4%	-20.6%
	35.0%	**-60.1%**		19.4%
	-36.0%	-2.6%	3.5%	
	-109.0%	-47.8%	15.2%	
	26.5%			**113.9%**
	-41.8%	12.2%	24.1%	-33.8%
	14.1%	-6.9%		21.0%
	9.2%	28.4%	56.1%	
		1.9%		
	-39.2%	-28.8%		
	61.2%	-46.4%		
	33.9%	25.1%	75.8%	
	11.8%	-3.1%	2.6%	
		4.6%		
	62.2%	**127.1%**		
	16.0%	19.4%		4.0%
	-11.4%	-23.8%	3.8%	-56.1%
	-7.2%	15.0%	17.3%	
avg=	4.2%	-0.5%	37.0%	6.8%

APPENDIX 2

Table 1. Natural radionuclide content in soil*								
	Concentration in soil (pCi/g)							
	Ra-266		U-238		Th-232		K-40	
Country	Mean	Range	Mean	Range	Mean	Range	Mean	Range
United States	1.1	0.2 - 4	0.9	0.1 - 4	0.9	0.1 - 4	10	3 - 19
China	0.9	0.1 - 12	0.9	0.1 - 19	1	0.03 - 10	12	0.2 - 49
Medium	0.9	0.5 - 2	0.9	0.4 - 3	0.8	0.3 - 2	11	4 - 23
Population-weighted average	0.9		0.9		1		11	
*Source: UNSCEAR 2000 Vol. I, Annex B, Table 5 (http://www.unscear.org/docs/reports/annexb.pdf)								

Table 2. Typical and maximum activity concentrations in common building materials and industrial by-products used for building materials in Europe**						
	Typical activity concentration (pCi/g)			Maximum activity concentration (pCi/g)		
	Ra-266	Th-232	K-40	Ra-266	Th-232	K-40
Most common building materials (may include by-products)						
Concrete	1.1	0.8	11	6	5	43
Aerated and light-weight concrete	1.6	1.1	12	70	5	43
Clay (red) bricks	1.4	1.4	18	5	5	54
Sand-lime bricks	0.3	0.3	9	0.7	0.8	19
Natural building stones	1.6	1.6	17	14	8	108
Natural gypsum	0.3	0.3	2	2	3	5
Most common industrial by-products used in building materials						
Phosphogypsum	11	0.5	2	30	4	8
Blast furnace slag	7	2	6	57	9	27
Coal fly ash	5	3	18	30	8	41
**Kovler, K. (2009). Radiological constraints of using building materials and industrial by-products in construction, Construction and Building Materials 23, 246–253.						

Table 3. Ra-226 concentrations in phosphogypsum derived from the major sources of phosphate rock in the United States***

Location	Ra-226 content (pCi/g)
Central Florida	20 - 35
North Florida	13 - 15
Idaho	23

***Roessler, C.E. (updated 19 May 2009) (http://hps.org/publicinformation/ate/q25.html)

APPENDIX 3

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