Desert Research Institute

DOE/NV/0000939-29

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Submitted to

Nevada Field Office
National Nuclear Security Administration
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March 2016

## Publication No. 45265

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The work upon which this report is based was supported by the U.S. Department of Energy under Contract #DE-NA0000939. Approved for public release; further dissemination unlimited.

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## ABSTRACT

Airborne particulates are collected at U.S. Department of Energy sites that exhibit radiological contamination on the soil surface to help assess the potential for wind to transport radionuclides from the contamination sites. Collecting these samples was originally accomplished by drawing air through a cellulose-fiber filter. These filters were replaced with glass-fiber filters in March 2011. Airborne particulates were collected side by side on the two filter material between May 2013 and May 2014.

Comparisons of the sample mass and the radioactivity determinations for the side-by-side samples were undertaken to determine if the change in the filter medium produced significant results. The differences in the results obtained using the two filter types were assessed visually by evaluating the time series and correlation plots and statistically by conducting a nonparametric matched-pair sign test. Generally, the glass-fiber filters collect larger samples of particulates and produce higher radioactivity values for the gross alpha, gross beta, and gamma spectroscopy analyses. However, the correlation between the radioanalytical results for the glass-fiber filters and the cellulose-fiber filters was not strong enough to generate a linear regression function to estimate the glass-fiber filter sample results from the cellulose-fiber filter sample results.

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UNLV-RSL Radioanalytical Service Laboratory of the University of Nevada, Las Vegas

## INTRODUCTION

Since June 2008, airborne particulate samples have been collected for radionuclide analysis at the Sandia National Laboratory Range Operations Center (ROC) and the Clean Slate I and III test locations at the Tonopah Test Range. These samples have been used to assess the transport of radionuclides from the Clean Slate I and III contamination areas. Measurements of meteorological and dust conditions are recorded in conjunction with the sample collection at each location. Radioanalytical results, meteorological observations, and comparisons of the dust and meteorological conditions are discussed in a series of annual reports (e.g., Nikolich *et al.*, 2015) and a multiyear assessment for the period April 2008 through December 2012 (Mizell *et al.*, 2014).

Samples are collected by drawing ambient air through a filter. The deployed filters are collected and new filters are installed at approximately 14-day intervals. The collected filters are submitted to the Radioanalytical Service Laboratory of the University of Nevada, Las Vegas (UNLV-RSL), which performs gross alpha and gross beta radiation determinations and gamma spectroscopy analysis. Particulate sampling is accomplished using a Hi-Q™ continuous-flow, low-volume sample pump that runs at approximately 2.0 cubic feet/minute (cfm). The pump self-adjusts to maintain a near-constant flow of air as particulates accumulate on the filter. During a two-week filter deployment, there is no more than a 0.1 cfm change in flow rate. Filters are 10 cm (4 in) in diameter.

In March 2011, cellulose-fiber filters were replaced with glass-fiber filters. The switch was made as interest increased in the radionuclide characteristics of the inhalable fraction of airborne particulates. Particulate matter with an aerodynamic radius of less than 10 micrometers (µm) ($PM_{10}$) can pass through the nose and throat and enter the lungs. These particulates have the potential to affect human health. Cellulose-fiber filters have a pore size of 20 to 25 µm, which allows $PM_{10}$ materials to pass through. Glass-fiber filters have a pore size of 0.3 µm. Therefore, the glass-fiber filters are expected to retain the smaller particulates that pass through the cellulose-fiber filter as well as a greater total mass of particulates. To determine the significance of the change in filter medium, side-by-side sample collection was performed at the ROC using both cellulose- and glass-fiber filters between May 29, 2013, and May 28, 2014. The results of the radiological analyses from the two filters were then compared.

**SAMPLE MASS RECORD**

During the year of side-by-side sample collection, 26 samples were collected on both the glass- and cellulose-fiber filters. The mass of airborne particulates collected in each sample is presented in Appendix Table A-1. The sample mass was determined by the difference between the deployed and recovered filter mass. The samples collected on the glass-fiber filter had an average mass of 0.0217 g, whereas the samples collected on the cellulose-fiber filter had an average mass of 0.0144 g. As expected, the smaller pore size permits the glass-fiber filters to collect approximately 46 percent more particulate mass in the sample than the cellulose-fiber filters. Additionally, the greatest mass measured (0.0629 g) on an individual filter was found on the glass-fiber filter retrieved on July 12, 2013, and the least mass measured (0.002 g) was found on the cellulose-fiber filter retrieved on September 18, 2013.

Figure 1 shows the observed sample mass collected on the glass- and cellulose-fiber filters through the period of comparison. The time series plot suggests that the sample mass on the two filters reflect the same general trends but not necessarily the same sample-to-sample trend. The plot of the sample mass of the glass-fiber filter versus the cellulose-fiber filter shows that all but four of the paired data points plot above the 1:1 line, which indicates that the glass-fiber filters typically retain more material than the cellulose-fiber filters. The coefficient of determination (0.5248) shows that only approximately 52 percent of the variation in mass on the glass-fiber filter is explained by the variation in mass on the cellulose-fiber filters.

To determine if the mass on the glass- and cellulose-fiber filters represent different statistical populations, a nonparametric matched-pair sign test (Helsel and Hirsch, 1995) was performed. The null hypothesis for this test states that the two data sets represent the same sample-mass population. The test is performed by determining the difference between the data pairs and assigning plus signs when the glass-fiber filter has the greater mass and minus signs when the cellulose-fiber filter has the greater mass. The test resulted in 22 plus signs and 4 minus signs. At $\alpha = 0.01$, there is 0.00 probability that the two data sets represent the same sample-mass population. Therefore, the null hypothesis is rejected and the glass- and cellulose-fiber filters are statistically determined to represent different sample-mass populations because of the difference in the filter pore size. The glass-fiber filter represents a population of larger sample mass.

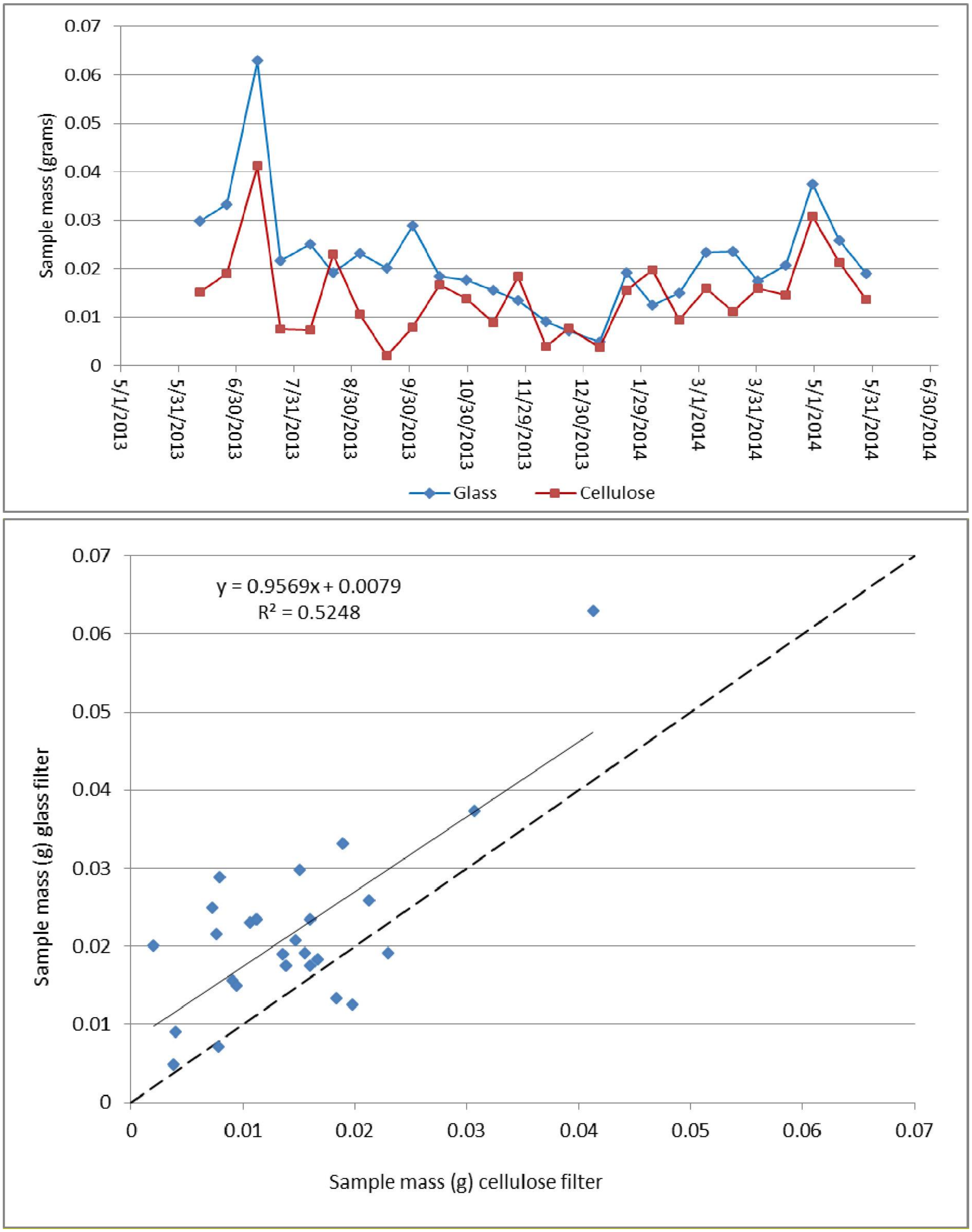



Figure 1. Sample mass for airborne particulate samples collected on side-by-side glass- and cellulose-fiber filters.

## RADIOLOGICAL RESULTS

Summary statistics for the gross alpha and gross beta results are shown in Table 1. Statistics for the gamma spectroscopy results are presented in Table 2. For each constituent, the average and maximum value was determined for the glass-fiber filters. The minimum gross alpha and gross beta results were obtained from cellulose-fiber filters and the minimum gamma spectroscopy values, nondetections, were determined on both glass-fiber and cellulose-fiber filters. These summary results suggest that glass-fiber filters produce higher radioactivity determinations. It is likely that the additional radioactivity is associated with the smaller particles that pass through the cellulose-fiber filters but are retained by the glass-fiber filters.

Table 1. Descriptive statistics for gross alpha and gross beta determinations for airborne particulate samples collected on side-by-side glass- and cellulose-fiber filters.

| Statistic | Gross Alpha ($x10^{-15}$ µCi/mL) | | Gross Beta ($x10^{-14}$ µCi/mL) | |
|---|---|---|---|---|
| | Glass | Cellulose | Glass | Cellulose |
| Count | 26 | 26 | 26 | 26 |
| Maximum | 3.50 | 2.63 | 2.62 | 1.57 |
| Minimum | 0.66 | 0.18 | 1.08 | 0.51 |
| Average | 1.95 | 1.36 | 1.90 | 0.97 |
| Standard Deviation | 0.79 | 0.59 | 0.43 | 0.31 |

Table 2. Descriptive statistics for the three radionuclides identified during gamma spectroscopy analyses of airborne particulate samples collected on side-by-side glass- and cellulose-fiber filters. (ND = nondetectable)

| Statistic | Beryllium-7 (Be-7) ($x10^{-13}$ µCi/mL) | | Potassium-40 (K-40) ($x10^{-14}$ µCi/mL | | Lead-210 (Pb-210) ($x10^{-14}$ µCi/mL | |
|---|---|---|---|---|---|---|
| | Glass | Cellulose | Glass | Cellulose | Glass | Cellulose |
| Detection count | 24 | 18 | 5 | 0 | 19 | 12 |
| Maximum | 2.20 | 1.52 | 3.88 | ND | 4.01 | 2.81 |
| Minimum | ND | ND | ND | ND | ND | ND |
| Average | 1.43 | 0.58 | 0.40 | ND | 1.84 | 0.95 |
| Standard Deviation | 0.53 | 0.50 | 0.93 | ND | 1.58 | 1.10 |

Assessments of the radiological analysis results for the individual samples were conducted to further evaluate the differences between the glass-fiber filter results and the cellulose-fiber filter results. Appendix A shows the individual sample results for gross alpha (Tables A-3 and A-4), gross beta (Tables A-5 and A-6), and gamma spectroscopy (Table A-7). Laboratory results are reported in picocuries (pCi) for the samples, with an uncertainty value that is "based on the 2σ counting error and corresponds to a 95 percent confidence interval" (UNLV-RSL, 2014a,b). These results are converted to microcuries/milliliter of air (μCi/mL) based on the volume of air that passed through the collector to obtain the sample. The time-series plots of the glass- and cellulose-fiber filter sample results display the laboratory uncertainty associated with each analysis. These plots permit a visual assessment of differences between the paired samples as well as differences in the trend patterns exhibited by sequential samples. A plot of glass-fiber filter sample results against the paired cellulose-fiber filter values allows comparison against the 1:1 line that would indicate perfect correlation between the paired data. Fitting a linear regression to the paired sample values quantifies the potential for estimating radiological results for one filter type from data collected using the other filter type. Finally, the likelihood that the glass- and cellulose-fiber filter samples represent the same population is evaluated using the nonparametric matched-pair sign test (Helsel and Hirsch, 1995). The test requires paired data values; equal paired values are deleted. The difference between the data pairs is determined and assigned a plus sign if the glass-fiber filter result is greater or a minus sign if the cellulose-fiber filter result is greater.

**Gross Alpha**

A time series plot of the gross alpha results for the glass- and cellulose-fiber filter data (Figure 2) suggests that the gross alpha concentration on the glass-fiber filter is generally greater than on the cellulose-fiber filter. The gross alpha concentration reported for the glass-fiber filter samples was higher than the value reported for the cellulose-fiber filter samples in 18 of the 26 samples (Figure 2, Tables A-3 and A-4). In eight of the samples, the cellulose-fiber filter produced the higher concentration. In 13 of 26 filter pairs, the gross alpha value reported for the glass-fiber filter sample is greater than the gross alpha plus the analytical uncertainty for the cellulose-fiber filter. Only three sample pairs were determined to have cellulose-fiber filter values of gross alpha that exceeded the value plus the uncertainty reported for the corresponding glass-fiber filter sample. Sixty-five percent of the gross alpha values for the cellulose-fiber filters lie within the range of the average gross alpha value plus/minus one standard deviation (1.95 +/- 0.79) for glass-fiber filter results, which suggests that many of the gross alpha results for both filter types are in the same range. These observations suggest that gross alpha determinations for the glass-fiber filter samples are typically greater than the result from the cellulose-fiber filter sample but this difference may not be consistent. Generally, changes in gross alpha values for sequential samples trend the same direction for both filter types. Changes between the gross alpha values for subsequent samples go in different directions for nine of the 25 two-sample sequences (Figure 2).

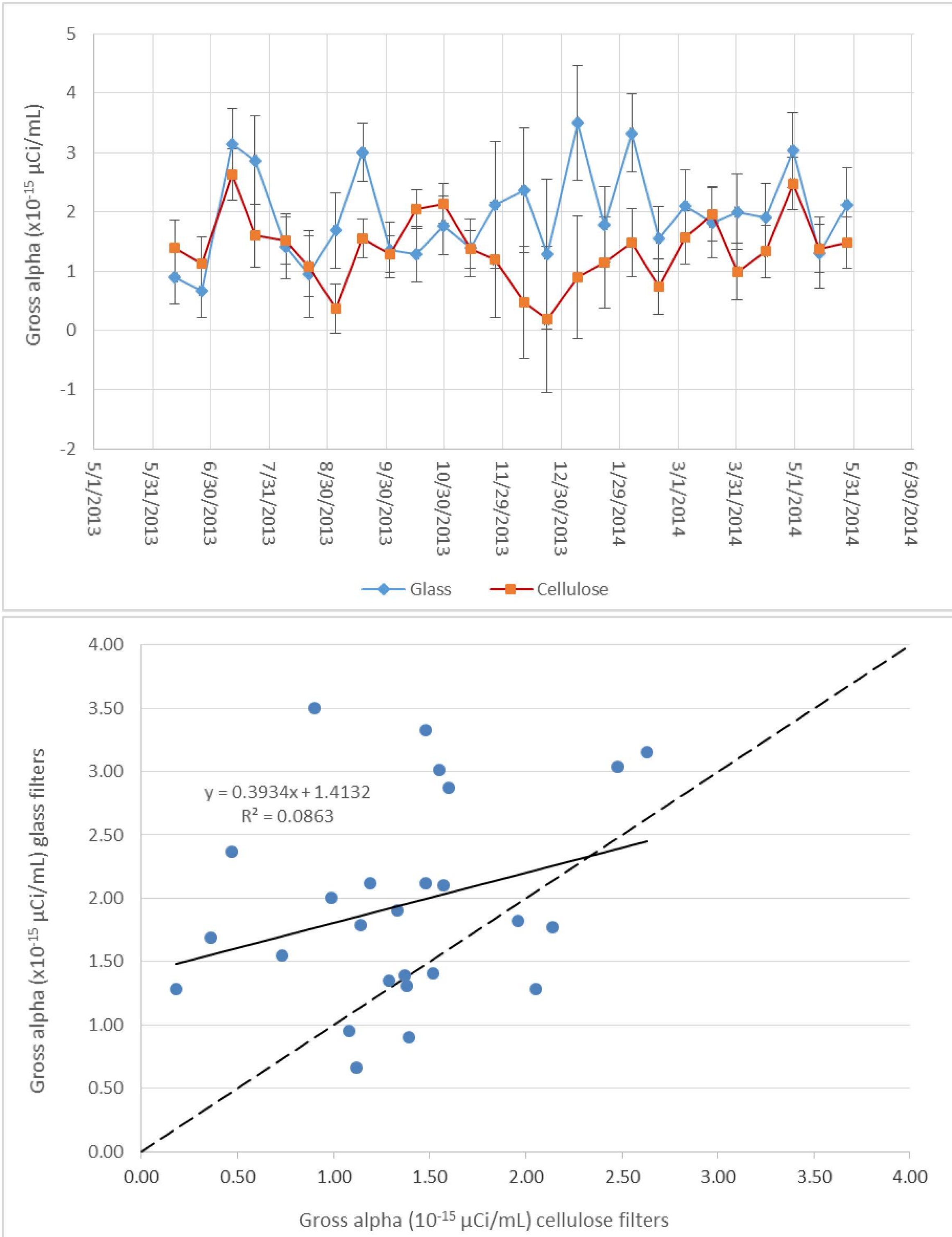
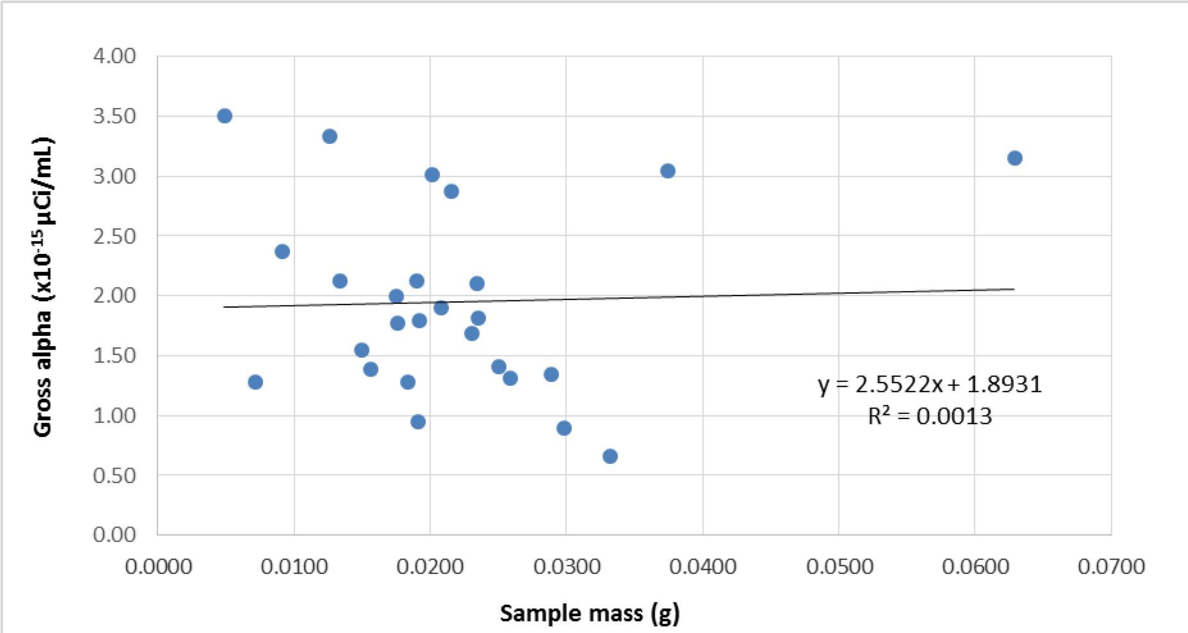



Figure 2. Gross alpha concentrations for airborne particulate samples collected on side-by-side glass- and cellulose-fiber filters. Error bars in time series graph indicate laboratory analysis uncertainty.

The plot of gross alpha results for the glass-fiber filter samples against the paired cellulose-fiber filter sample results (Figure 2) shows that 18 of 26 points fall above the 1:1 line, which further shows that the glass-fiber filter results are greater than the cellulose-fiber filter results. A linear regression of these paired gross alpha results produces a coefficient of determination of 0.0863, which indicates that little of the variations in the glass-fiber filter values can be explained by variations in the cellulose-fiber filter results.

Applying the nonparametric matched-pair sign test (Helsel and Hirsch, 1995) to the gross alpha data resulted in 17 of the 26 data pairs having a plus sign, which indicated that the glass-fiber filter result was greater. Therefore, at the significance level of $\alpha = 0.01$, the probability that the two data sets represent the same gross alpha activity population is approximately 0.1 (estimated from Table B5 in Helsel and Hirsch [1995]). This probability is so small that the null hypothesis is rejected and the alternative hypothesis that the glass- and cellulose-fiber filter data represent different gross alpha activity populations is accepted.

Although the increased mass associated with the glass-fiber filters would suggest a corresponding increase in gross alpha, this does not appear to be the case. Both a linear regression of gross alpha against sample mass (Figure 3, top graph) and a linear regression of gross alpha against sampled air volume (Figure 3, bottom graph) exhibit insignificant correlation and poor coefficients of determination. The gross alpha data fails to produce a strong linear correlation with sample mass or sampled air volume because high gross alpha activities occur across the full range of sample mass and sampled air volume. Visual examination of the graphs in Figure 3 suggests that a linear regression would be a reasonable approximation of activity to sample size if the six highest activity values were removed from the data set. The existence of the high gross alpha results over the range of observed sample sizes suggests a “hot particle” issue, which means that a few particles with significant naturally occurring radioactivity can substantially influence the gross alpha activity regardless of the sample size or total number of particles present.



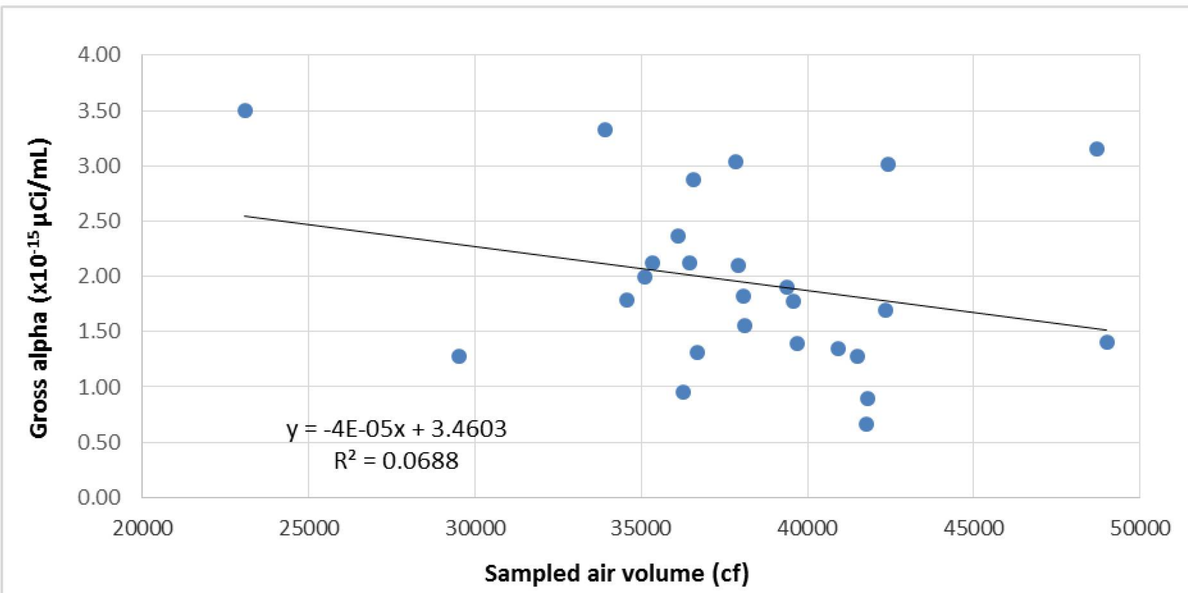




Figure 3. A linear regression of gross alpha results (activity per milliliter of air) for the glass-fiber filters against the sample mass (top) and sampled air volume (bottom) indicate poor correlation.

**Gross Beta**

The tight 95 percent confidence intervals surrounding the gross beta results for both the glass- and cellulose-fiber filter samples shows a clear difference between the gross beta results for the two filter media (Figure 4). There are no occasions where the confidence intervals of the paired gross beta results overlap. The gross beta concentrations on the glass-fiber filters are always greater than on the cellulose-fiber filters. Generally changes in gross beta values for sequential samples change the same direction for both filter types. Changes between the gross beta values for subsequent samples go in different directions on only four occasions.

The plot of gross beta results for the glass-fiber filter samples against the paired cellulose-fiber filter samples shows that all 26 points fall above the 1:1 line, which further substantiates that the glass-fiber filter results are greater than the cellulose-fiber filter results. The linear regression model for the gross beta results (Figure 4) produced a correlation coefficient of 0.5025, which indicates that approximately 50 percent of the variability in the glass-fiber filter gross beta results may be explained by the cellulose-fiber filter gross beta observations. Therefore, the linear regression model would give a first approximation of the gross beta values.

When the matched-pair test was applied to the gross beta data, all 26 data pairs received a plus sign. Therefore, at $\alpha = 0.01$, there is 0.00 probability that the two data sets represent the same gross beta activity population. Again, the null hypothesis is rejected and the alternative hypothesis, that the glass- and cellulose-fiber filter data represent different gross beta activity populations, is accepted.

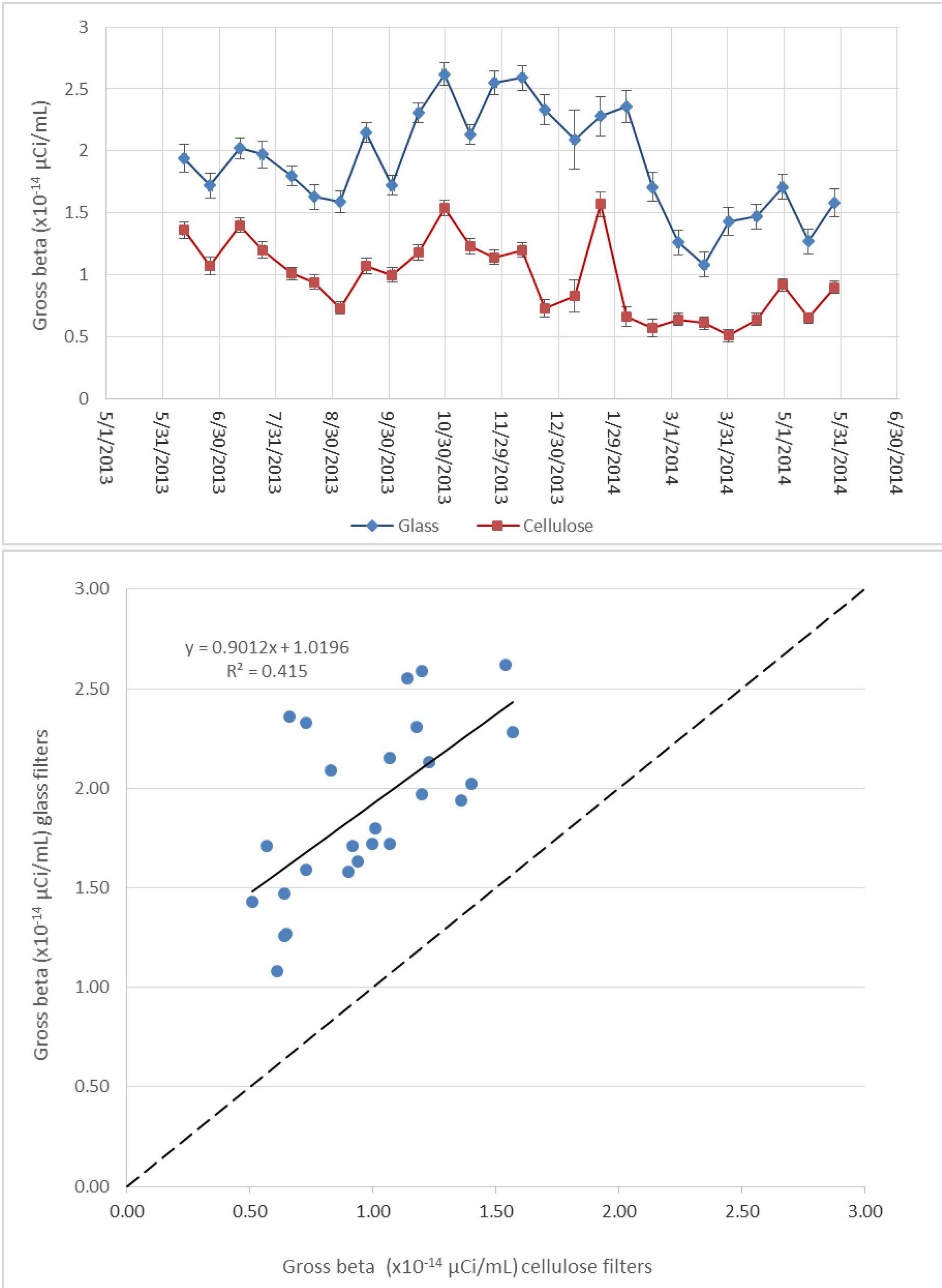



Figure 4. Gross beta concentrations for airborne particulate samples collected on side-by-side glass- and cellulose-fiber filters.

**Gamma Spectroscopy**

Gamma spectroscopy identified detectable levels of three radionuclides on the glass-fiber filters and two radionuclides on the cellulose-fiber filters all of which are naturally occurring radionuclides. Beryllium-7 (Be-7) was reported for both the glass-fiber and cellulose-fiber filter samples 18 times (Table A-7). Beryllium-7 was reported for six of the glass-fiber filter samples for which the paired cellulose-fiber filter sample was reported as nondetectable and two paired samples were reported as nondetectable for both the glass-fiber and cellulose-fiber filter samples. Lead-210 (Pb-210) was detected in seven paired samples (Table A-7). Lead-210 was reported for nine glass-fiber filter samples for which the paired cellulose-fiber filter sample was reported as nondetectable and for five cellulose-fiber filter samples for which the paired glass-fiber filter sample was reported as nondetectable. Both the glass-fiber and cellulose-fiber filter samples were reported as nondetectable for Pb-210 for five additional samples. Potassium-40 (K-40) was identified in five glass-fiber filter samples but was not detected in any of the cellulose-fiber filter samples. Potassium-40 is not considered in the comparison of the glass-fiber and cellulose-fiber filter results because there are no paired samples of detectable K-40.

Time-based plots of the Be-7 (Figure 5) and Pb-210 (Figure 6) results suggest that the Be-7 and Pb-210 values determined for the glass-fiber filter samples are greater than the values determined for the cellulose-fiber filter samples. These plots do not show the nondetectable results. The uncertainty range for the Be-7 results for the glass-fiber and cellulose-fiber filters overlapped for only one of the 18 paired samples (Figure 5). The uncertainty range overlapped for four of the seven paired Pb-210 samples and of these, the reported Pb-210 value for the glass-fiber filter exceeded the value plus the uncertainty for the cellulose-fiber filter. The change in gamma concentration for sequential samples trended the same direction for both the glass- and cellulose-fiber filters nine times and were in opposite directions five times for Be-7. Because of the large number of nondetectable results for Pb-210, there were only three occasions in which sequential paired samples occurred. The change in all three of the Pb-210 sample sequences were in opposite directions.

All of the 18 paired Be-7 samples plotted above the 1:1 line (Figure 5), which further indicate that the glass-fiber filter samples produced consistently greater values. All seven of the paired Pb-210 samples also plotted above the 1:1 line (Figure 6). Linear regression analysis produced a coefficient of determination of 49.35 percent for the Be-7 data and 32.62 percent for the Pb-210 data. These results show that the linear regression model could be used to make a first approximation of these gamma emitting radionuclides.

The Be-7 results for the glass-fiber filter samples were assigned a plus sign for 17 of the 18 paired samples. At a significance level of $\alpha = 0.01$, the probability that the two data sets represent the same Be-7 activity is approximately 0.0001. The glass-fiber filter samples were assigned all of the plus signs for the seven paired Pb-210 results. These results show that the probability that the two data sets represent the same Pb-210 activity is approximately 0.008. In both instances, the probability that samples from the glass-fiber filters and the cellulose-fiber filters represent the same radionuclide population is very small. The glass-fiber filter samples represent a population that has greater Be-7 and Pb-210 concentrations.

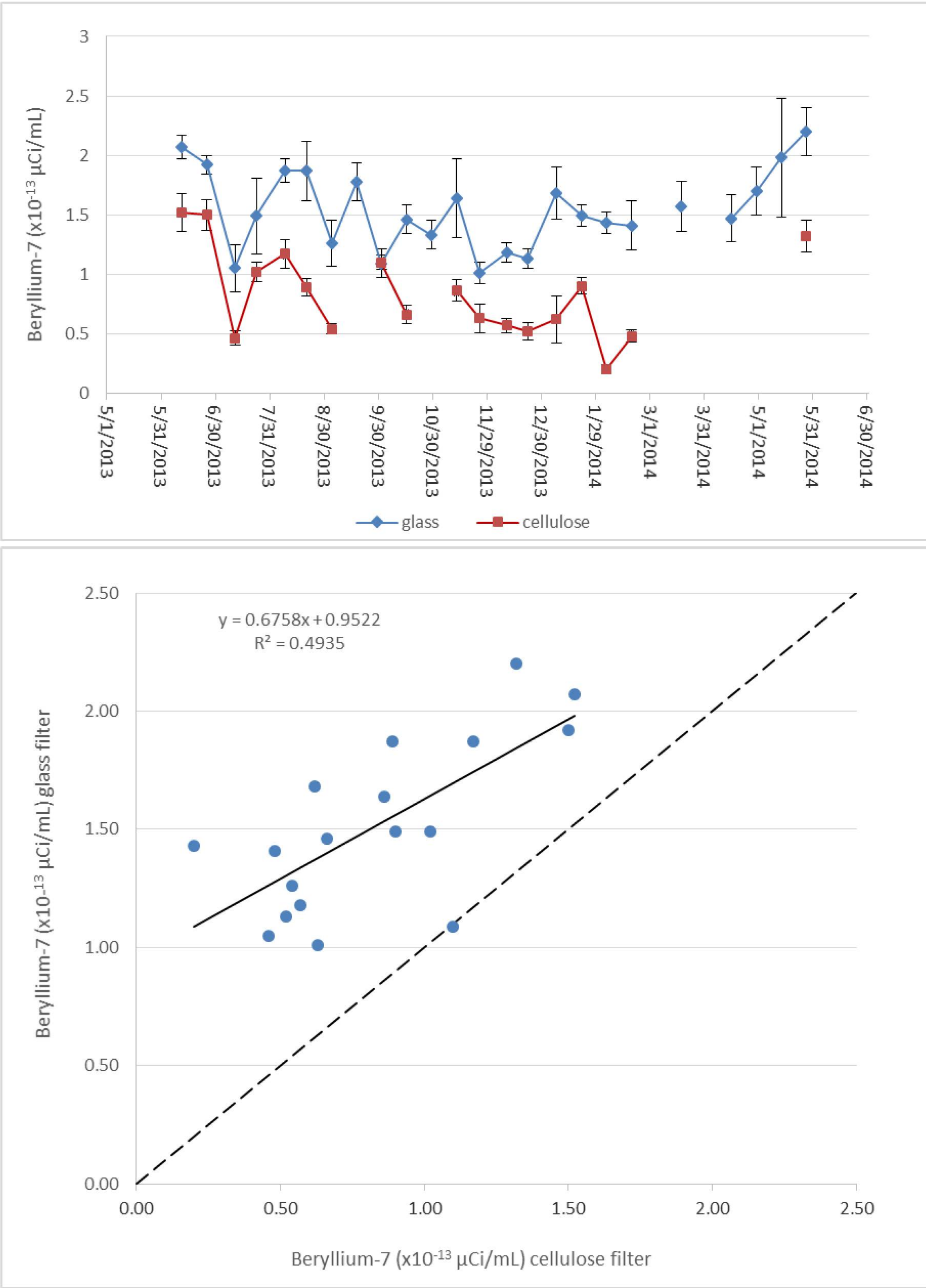



Figure 5. Comparison of beryllium-7 observations for glass-fiber and cellulose-fiber filters. (Samples reported as nondetectable are not shown in these plots.)

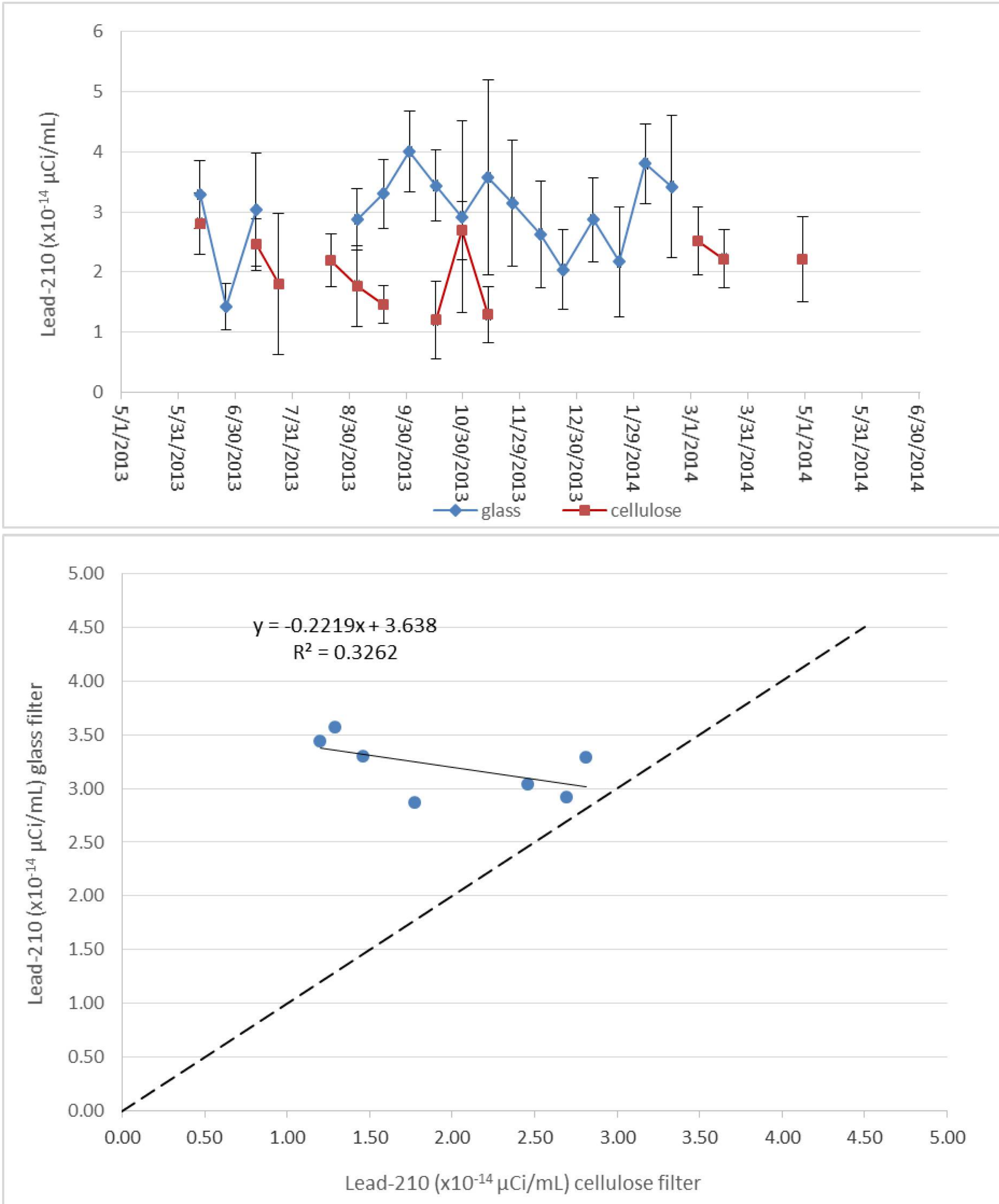



Figure 6. Comparison of lead-210 observations for glass-fiber and cellulose-fiber filters. (Samples reported as nondetectable are not shown in these plots.)

The considerable overlap of the 95 percent confidence intervals for the pairs of glass- and cellulose-fiber filter samples suggests minimal statistical difference between gross alpha results for the two filter media. However, further analysis of the gross alpha results from the two filter types and analysis of the gross beta and gamma spectroscopy results all suggest that the samples collected on the glass-fiber filters represent a population with greater radiological concentrations than the samples collected on the cellulose-fiber filters.

## CONCLUSIONS

1) The statistical analysis substantiates the visual assessments, which suggests that the sample mass collected on glass-fiber filters is different from and greater than the sample mass collected on cellulose-fiber filters. However, the smaller pore size of the glass-fiber filters does not always result in greater particulate mass for the paired samples.
2) Although gross alpha results for the glass-fiber and cellulose-fiber filter samples exhibit an overlap in the range of values, the statistical analyses of the gross alpha and other radionuclide determinations indicate that the radiological results for the glass-fiber filter samples are different from and greater than the radiological results for the cellulose-fiber filter samples.
3) The difference in the gross alpha activity for the glass-fiber filter samples and the cellulose-fiber filter samples is not necessarily proportional to the additional mass resulting from the smaller pore size of the glass-fiber filter. This may be the result of a "hot particle" problem in which particles of notably higher concentration may be collected as part of a smaller sample size.
4) Linear regression provides an approach for estimating an equivalent glass-fiber result for the gross beta parameter as a function of the observed cellulose-fiber result with a moderate level of confidence. However, the linear regression model does not permit estimating the glass-fiber filter equivalent gross alpha data with the same level of confidence.
5) The lack of a strong correlation between the gross alpha results and the increased mass on the glass-fiber filters suggests that the gross alpha activity of a sample is determined by factors other than the quantity of the small-sized particulates collected. These factors have not yet been identified.

## REFERENCES


Helsel, D.R., and R.M. Hirsch, 1995. Statistical Methods in Water Resources. Studies in Environmental Science, 49. Elsevier, New York, p. 529.

Mizell, S.A., V. Etyemezian, G. McCurdy, G. Nikolich, C. Shadel, and J.J. Miller, 2014. Radiological and Environmental Monitoring at the Clean Slate I and III Sites, Tonopah Test Range, Nevada with Emphasis on the Implications for Off-site Transport. Desert Research Institute Publication Number 45257, Department of Energy report DOE/NV/00000939-19, 144pp.

Nikolich, G., C. Shadel, J. Chapman, S. Mizell, G. McCurdy, V. Etyemezian, and J.J. Miller, 2015. Tonopah Test Range Air Monitoring: CY2014 Meteorological, Radiological, and Airborne Particulate Observations. Desert Research Institute Publication Number 45XXX, Department of Energy report DOE/NV/00000939-XX, 82pp.

UNLV-RSL, 2014a. Analysis Report DRI-TTR Air Filter Samples Sampling Period: 1. Quarter 2014.

UNLV-RSL, 2014b. Analysis Report DRI-TTR Air Filter Samples Sampling Period: 2. Quarter 2014.

# APPENDIX A: OBSERVATIONS FROM SIDE-BY-SIDE AIRBORNE PARTICULATE COLLECTION USING GLASS- AND CELLULOSE-FIBER FILTERS

Table A-1. Measured sample mass (g) for airborne particulate samples collected on side-by-side glass- and cellulose-fiber filters.

| Retrieval date | Sample mass | |
|---|---|---|
| | **Glass (g)** | **Cellulose (g)** |
| 6/12/2013 | 0.0298 | 0.0151 |
| 6/26/2013 | 0.0332 | 0.0189 |
| 7/12/2013 | 0.0629 | 0.0413 |
| 7/24/2013 | 0.0216 | 0.0076 |
| 8/9/2013 | 0.0250 | 0.0073 |
| 8/21/2013 | 0.0191 | 0.0230 |
| 9/4/2013 | 0.0231 | 0.0106 |
| 9/18/2013 | 0.0201 | 0.0020 |
| 10/2/2013 | 0.0289 | 0.0079 |
| 10/16/2013 | 0.0184 | 0.0167 |
| 10/30/2013 | 0.0176 | 0.0138 |
| 11/13/2013 | 0.0156 | 0.0090 |
| 11/26/2013 | 0.0134 | 0.0184 |
| 12/11/2013 | 0.0091 | 0.0040 |
| 12/23/2013 | 0.0072 | 0.0078 |
| 1/8/2014 | 0.0049 | 0.0038 |
| 1/22/2014 | 0.0192 | 0.0155 |
| 2/5/2014 | 0.0126 | 0.0198 |
| 2/19/2014 | 0.0150 | 0.0094 |
| 3/5/2014 | 0.0234 | 0.0160 |
| 3/19/2014 | 0.0235 | 0.0112 |
| 4/1/2014 | 0.0175 | 0.0160 |
| 4/16/2014 | 0.0208 | 0.0147 |
| 4/30/2014 | 0.0374 | 0.0307 |
| 5/14/2014 | 0.0259 | 0.0213 |
| 5/28/2014 | 0.0190 | 0.0136 |
| **Maximum** | 0.0629 | 0.0413 |
| **Minimum** | 0.0049 | 0.0020 |
| **Average** | 0.0217 | 0.0144 |
| **Standard Deviation** | 0.0113 | 0.0085 |

Table A-3. Gross alpha results and uncertainty levels for samples collected on glass-fiber filters (replicate lab results shown where run).

| DRI Sample No. | Station | Date | Total air volume (cf) | Activity (x10$^{-15}$ µCi/mL) | Uncertainty (x10$^{-15}$ µCi/mL) | MDA (x10$^{-15}$ µCi/mL) | Activity (x10$^{-15}$ µCi/mL) | Uncertainty (x10$^{-15}$ µCi/mL) | MDA (x10$^{-15}$ µCi/mL) |
|---|---|---|---|---|---|---|---|---|---|
| TTR-1-061213 | 400 | 6/12/2013 | 41820 | 0.90 | 0.45 | 0.81 | | | |
| TTR-1-062613 | 400 | 6/26/2013 | 41763 | 0.66 | 0.44 | 0.80 | | | |
| TTR-1-071213 | 400 | 7/12/2013 | 48692 | 3.15 | 0.59 | 0.70 | 2.89 | 0.58 | 0.70 |
| TTR-1-072413 | 400 | 7/24/2013 | 36578 | 2.88 | 0.75 | 0.93 | | | |
| TTR-1-080913 | 400 | 8/9/2013 | 49004 | 1.41 | 0.55 | 0.70 | | | |
| TTR-1-082113 | 400 | 8/21/2013 | 36251 | 0.94 | 0.73 | 0.93 | | | |
| TTR-1-090413 | 400 | 9/4/2013 | 42343 | 1.69 | 0.64 | 0.80 | | | |
| TTR-1-091813 | 400 | 9/18/2013 | 42428 | 3.01 | 0.49 | 0.79 | 2.92 | 0.49 | 0.79 |
| TTR-1-100213 | 400 | 10/2/2013 | 40932 | 1.35 | 0.47 | 0.81 | | | |
| TTR-1-101613 | 400 | 10/16/2013 | 41497 | 1.28 | 0.47 | 0.82 | | | |
| TTR-1-103013 | 400 | 10/30/2013 | 39582 | 1.77 | 0.50 | 0.86 | | | |
| TTR-1-111313 | 400 | 11/13/2013 | 39687 | 1.39 | 0.49 | 0.85 | | | |
| TTR-1-112613 | 400 | 11/26/2013 | 35355 | 2.11 | 1.07 | 1.08 | 3.57 | 1.09 | 1.08 |
| TTR-1-121113 | 400 | 12/11/2013 | 36108 | 2.37 | 1.05 | 1.06 | | | |
| TTR-1-122313 | 400 | 12/23/2013 | 29525 | 1.28 | 1.27 | 1.27 | | | |
| TTR-1-010814 | 400 | 1/8/2014 | 23091 | 3.50 | 0.96 | 1.41 | 2.00 | 0.93 | 1.41 |
| TTR-1-012214 | 400 | 1/22/2014 | 34576 | 1.79 | 0.63 | 0.97 | | | |
| TTR-1-020514 | 400 | 2/5/2014 | 33925 | 3.32 | 0.65 | 1.01 | 2.52 | 0.64 | 1.01 |
| TTR-1-021914 | 400 | 2/19/2014 | 38111 | 1.55 | 0.55 | 0.89 | | | |
| TTR-1-030514 | 400 | 3/5/2014 | 37937 | 2.10 | 0.61 | 0.86 | 1.62 | 0.60 | 0.86 |
| TTR-1-031914 | 400 | 3/19/2014 | 38083 | 1.82 | 0.59 | 0.84 | | | |
| TTR-1-040114 | 400 | 4/1/2014 | 35110 | 2.00 | 0.64 | 0.93 | | | |
| TTR-1-041614 | 400 | 4/16/2014 | 39381 | 1.90 | 0.58 | 0.83 | | | |
| TTR-1-043014 | 400 | 4/30/2014 | 37827 | 3.04 | 0.63 | 0.87 | | | |
| TTR-1-051414 | 400 | 5/14/2014 | 36695 | 1.31 | 0.61 | 0.90 | | | |
| TTR-1-052814 | 400 | 5/28/2014 | 36461 | 2.12 | 0.63 | 0.89 | | | |

Table A-4. Gross alpha results and uncertainty levels for samples collected on cellulose-fiber filters (replicate lab results shown where run).

| DRI Sample No. | Station | Date | Total air volume (cf) | Activity ($x10^{-15}$ µCi/mL) | Uncertainty ($x10^{-15}$ µCi/mL) | MDA ($x10^{-15}$ µCi/mL) | Activity ($x10^{-15}$ µCi/mL) | Uncertainty ($x10^{-15}$ µCi/mL) | MDA ($x10^{-15}$ µCi/mL) |
|---|---|---|---|---|---|---|---|---|---|
| TTR-1-061213 D | 400 | 6/12/2013 | 40555 | 1.39 | 0.47 | 0.68 | 2.10 | 0.48 | 0.68 |
| TTR-1-062613 D | 400 | 6/26/2013 | 40893 | 1.12 | 0.46 | 0.66 | | | |
| TTR-1-071213 D | 400 | 7/12/2013 | 50809 | 2.63 | 0.44 | 0.58 | 3.61 | 0.46 | 0.58 |
| TTR-1-072413 D | 400 | 7/24/2013 | 39012 | 1.60 | 0.53 | 0.73 | | | |
| TTR-1-080913 D | 400 | 8/9/2013 | 53161 | 1.52 | 0.40 | 0.54 | | | |
| TTR-1-082113 D | 400 | 8/21/2013 | 39723 | 1.08 | 0.52 | 0.71 | | | |
| TTR-1-090413 D | 400 | 9/4/2013 | 47621 | 0.36 | 0.42 | 0.59 | | | |
| TTR-1-091813 D | 400 | 9/18/2013 | 47602 | 1.55 | 0.32 | 0.56 | 1.49 | 0.31 | 0.56 |
| TTR-1-100213 D | 400 | 10/2/2013 | 46077 | 1.29 | 0.31 | 0.57 | | | |
| TTR-1-101613 D | 400 | 10/16/2013 | 48518 | 2.05 | 0.33 | 0.55 | | | |
| TTR-1-103013 D | 400 | 10/30/2013 | 46783 | 2.14 | 0.34 | 0.58 | | | |
| TTR-1-111313 D | 400 | 11/13/2013 | 46617 | 1.37 | 0.32 | 0.58 | | | |
| TTR-1-112613 D | 400 | 11/26/2013 | 43484 | 1.19 | 0.98 | 0.81 | 1.31 | 0.98 | 0.81 |
| TTR-1-121113 D | 400 | 12/11/2013 | 44826 | 0.47 | 0.95 | 0.79 | | | |
| TTR-1-122313 D | 400 | 12/23/2013 | 34099 | 0.18 | 1.23 | 1.00 | | | |
| TTR-1-010814 D | 400 | 1/8/2014 | 26230 | 0.90 | 1.04 | 1.23 | 0.89 | 1.04 | 1.23 |
| TTR-1-012214 D | 400 | 1/22/2014 | 36240 | 1.14 | 0.77 | 0.93 | | | |
| TTR-1-020514 D | 400 | 2/5/2014 | 36153 | 1.48 | 0.57 | 0.87 | 0.87 | 0.56 | 0.87 |
| TTR-1-021914 D | 400 | 2/19/2014 | 41808 | 0.73 | 0.47 | 0.75 | | | |
| TTR-1-030514 D | 400 | 3/5/2014 | 41949 | 1.57 | 0.45 | 0.67 | 1.64 | 0.45 | 0.67 |
| TTR-1-031914 D | 400 | 3/19/2014 | 40314 | 1.96 | 0.46 | 0.69 | | | |
| TTR-1-040114 D | 400 | 4/1/2014 | 37428 | 0.99 | 0.48 | 0.74 | | | |
| TTR-1-041614 D | 400 | 4/16/2014 | 42212 | 1.33 | 0.44 | 0.66 | | | |
| TTR-1-043014 D | 400 | 4/30/2014 | 43884 | 2.48 | 0.44 | 0.64 | | | |
| TTR-1-051414 D | 400 | 5/14/2014 | 44710 | 1.38 | 0.41 | 0.62 | | | |
| TTR-1-052814 D | 400 | 5/28/2014 | 43271 | 1.48 | 0.43 | 0.65 | | | |

Table A-5. Gross beta results and uncertainty levels for samples collected on glass-fiber filters (replicate lab results shown where run).

| DRI Sample No. | Station | Date | Total air volume (cf) | Activity (x10$^{-14}$ µCi/mL) | Uncertainty (x10$^{-14}$ µCi/mL) | MDA (x10$^{-14}$ µCi/mL) | Activity (x10$^{-14}$ µCi/mL) | Uncertainty (x10$^{-14}$ µCi/mL) | MDA (x10$^{-14}$ µCi/mL) |
|---|---|---|---|---|---|---|---|---|---|
| TTR-1-061213 | 400 | 6/12/2013 | 41820 | 1.94 | 0.11 | 0.12 | | | |
| TTR-1-062613 | 400 | 6/26/2013 | 41763 | 1.71 | 0.10 | 0.12 | | | |
| TTR-1-071213 | 400 | 7/12/2013 | 48692 | 2.02 | 0.08 | 0.11 | 2.06 | 0.08 | 0.11 |
| TTR-1-072413 | 400 | 7/24/2013 | 36578 | 1.97 | 0.11 | 0.14 | | | |
| TTR-1-080913 | 400 | 8/9/2013 | 49004 | 1.80 | 0.08 | 0.11 | | | |
| TTR-1-082113 | 400 | 8/21/2013 | 36251 | 1.63 | 0.10 | 0.14 | | | |
| TTR-1-090413 | 400 | 9/4/2013 | 42343 | 1.59 | 0.09 | 0.12 | | | |
| TTR-1-091813 | 400 | 9/18/2013 | 42428 | 2.15 | 0.08 | 0.13 | 2.20 | 0.08 | 0.13 |
| TTR-1-100213 | 400 | 10/2/2013 | 40932 | 1.72 | 0.08 | 0.13 | | | |
| TTR-1-101613 | 400 | 10/16/2013 | 41497 | 2.31 | 0.08 | 0.13 | | | |
| TTR-1-103013 | 400 | 10/30/2013 | 39582 | 2.62 | 0.09 | 0.13 | | | |
| TTR-1-111313 | 400 | 11/13/2013 | 39687 | 2.13 | 0.08 | 0.13 | | | |
| TTR-1-112613 | 400 | 11/26/2013 | 35355 | 2.55 | 0.10 | 0.14 | 2.57 | 0.10 | 0.14 |
| TTR-1-121113 | 400 | 12/11/2013 | 36108 | 2.59 | 0.10 | 0.14 | | | |
| TTR-1-122313 | 400 | 12/23/2013 | 29525 | 2.33 | 0.12 | 0.17 | | | |
| TTR-1-010814 | 400 | 1/8/2014 | 23091 | 2.09 | 0.24 | 0.23 | 2.23 | 0.24 | 0.23 |
| TTR-1-012214 | 400 | 1/22/2014 | 34576 | 2.28 | 0.16 | 0.15 | | | |
| TTR-1-020514 | 400 | 2/5/2014 | 33925 | 2.36 | 0.13 | 0.15 | 2.22 | 0.13 | 0.15 |
| TTR-1-021914 | 400 | 2/19/2014 | 38111 | 1.71 | 0.12 | 0.14 | | | |
| TTR-1-030514 | 400 | 3/5/2014 | 37937 | 1.26 | 0.10 | 0.13 | 1.36 | 0.10 | 0.13 |
| TTR-1-031914 | 400 | 3/19/2014 | 38083 | 1.08 | 0.10 | 0.13 | | | |
| TTR-1-040114 | 400 | 4/1/2014 | 35110 | 1.43 | 0.11 | 0.15 | | | |
| TTR-1-041614 | 400 | 4/16/2014 | 39381 | 1.47 | 0.10 | 0.13 | | | |
| TTR-1-043014 | 400 | 4/30/2014 | 37827 | 1.71 | 0.10 | 0.14 | | | |
| TTR-1-051414 | 400 | 5/14/2014 | 36695 | 1.27 | 0.10 | 0.14 | | | |
| TTR-1-052814 | 400 | 5/28/2014 | 36461 | 1.58 | 0.11 | 0.14 | | | |

Table A-6. Gross beta results and uncertainty levels for samples collected on cellulose-fiber filters (replicate lab results shown where run).

| DRI Sample No. | Station | Date | Total air volume (cf) | Activity ($x10^{-14}$ µCi/mL) | Uncertainty ($x10^{-14}$ µCi/mL) | MDA ($x10^{-14}$ µCi/mL) | Activity ($x10^{-14}$ µCi/mL) | Uncertainty ($x10^{-14}$ µCi/mL) | MDA ($x10^{-14}$ µCi/mL) |
|---|---|---|---|---|---|---|---|---|---|
| TTR-1-061213 D | 400 | 6/12/2013 | 40555 | 1.36 | 0.07 | 0.08 | 1.30 | 0.07 | 0.08 |
| TTR-1-062613 D | 400 | 6/26/2013 | 40893 | 1.07 | 0.07 | 0.08 | | | |
| TTR-1-071213 D | 400 | 7/12/2013 | 50809 | 1.40 | 0.06 | 0.07 | 1.38 | 0.06 | 0.07 |
| TTR-1-072413 D | 400 | 7/24/2013 | 39012 | 1.19 | 0.07 | 0.08 | | | |
| TTR-1-080913 D | 400 | 8/9/2013 | 53161 | 1.01 | 0.05 | 0.06 | | | |
| TTR-1-082113 D | 400 | 8/21/2013 | 39723 | 0.94 | 0.06 | 0.08 | | | |
| TTR-1-090413 D | 400 | 9/4/2013 | 47621 | 0.73 | 0.05 | 0.07 | | | |
| TTR-1-091813 D | 400 | 9/18/2013 | 47602 | 1.07 | 0.06 | 0.07 | 1.02 | 0.06 | 0.07 |
| TTR-1-100213 D | 400 | 10/2/2013 | 46077 | 1.00 | 0.06 | 0.07 | | | |
| TTR-1-101613 D | 400 | 10/16/2013 | 48518 | 1.18 | 0.06 | 0.07 | | | |
| TTR-1-103013 D | 400 | 10/30/2013 | 46783 | 1.54 | 0.06 | 0.07 | | | |
| TTR-1-111313 D | 400 | 11/13/2013 | 46617 | 1.23 | 0.06 | 0.07 | | | |
| TTR-1-112613 D | 400 | 11/26/2013 | 43484 | 1.14 | 0.06 | 0.07 | 1.17 | 0.06 | 0.07 |
| TTR-1-121113 D | 400 | 12/11/2013 | 44826 | 1.20 | 0.06 | 0.07 | | | |
| TTR-1-122313 D | 400 | 12/23/2013 | 34099 | 0.73 | 0.07 | 0.09 | | | |
| TTR-1-010814 D | 400 | 1/8/2014 | 26230 | 0.84 | 0.13 | 0.12 | 0.89 | 0.13 | 0.12 |
| TTR-1-012214 D | 400 | 1/22/2014 | 36240 | 1.57 | 0.10 | 0.09 | | | |
| TTR-1-020514 D | 400 | 2/5/2014 | 36153 | 0.66 | 0.08 | 0.09 | 0.68 | 0.08 | 0.09 |
| TTR-1-021914 D | 400 | 2/19/2014 | 41808 | 0.57 | 0.07 | 0.08 | | | |
| TTR-1-030514 D | 400 | 3/5/2014 | 41949 | 0.64 | 0.05 | 0.07 | 0.53 | 0.04 | 0.07 |
| TTR-1-031914 D | 400 | 3/19/2014 | 40314 | 0.61 | 0.05 | 0.08 | | | |
| TTR-1-040114 D | 400 | 4/1/2014 | 37428 | 0.51 | 0.05 | 0.08 | | | |
| TTR-1-041614 D | 400 | 4/16/2014 | 42212 | 0.64 | 0.05 | 0.07 | | | |
| TTR-1-043014 D | 400 | 4/30/2014 | 43884 | 0.93 | 0.05 | 0.07 | | | |
| TTR-1-051414 D | 400 | 5/14/2014 | 44710 | 0.65 | 0.04 | 0.07 | | | |
| TTR-1-052814 D | 400 | 5/28/2014 | 43271 | 0.90 | 0.05 | 0.07 | | | |

Table A-7. Gamma spectroscopy results for 26 airborne particulate samples collected on side-by-side glass-fiber and cellulose-fiber filters (replicate lab analyses are not shown).

| Sample Retrieval Date | Beryllium-7 (Be-7) µCi/ml E-13 | | | | Potassium-40 (K-40) µCi/ml E-14 | | Lead-210 (Pb-210) µCi/ml E-14 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Glass | | Cellulose | | Glass | Cellulose | Glass | | Cellulose | |
| | Activity | Uncertainty | Activity | Uncertainty | | | Activity | Uncertainty | Activity | Uncertainty |
| 6/12/2013 | 2.07 | 0.1 | 1.52 | 0.16 | ND | ND | 3.29 | 0.57 | 2.81 | 0.51 |
| 6/26/2013 | 1.92 | 0.08 | 1.50 | 0.13 | 1.53 | ND | 1.42 | 0.39 | ND | |
| 7/12/2013 | 1.05 | 0.2 | 0.46 | 0.06 | ND | ND | 3.04 | 0.94 | 2.46 | 0.43 |
| 7/24/2013 | 1.49 | 0.32 | 1.02 | 0.08 | ND | ND | ND | | 1.80 | 1.17 |
| 8/9/2013 | 1.87 | 0.1 | 1.17 | 0.12 | ND | ND | ND | | ND | |
| 8/21/2013 | 1.87 | 0.25 | 0.89 | 0.07 | ND | ND | ND | | 2.19 | 0.44 |
| 9/4/2013 | 1.26 | 0.19 | 0.54 | 0.04 | 1.51 | ND | 2.87 | 0.51 | 1.77 | 0.67 |
| 9/18/2013 | 1.78 | 0.16 | ND | | ND | ND | 3.30 | 0.57 | 1.46 | 0.31 |
| 10/2/2013 | 1.09 | 0.12 | 1.10 | 0.06 | ND | ND | 4.01 | 0.67 | ND | |
| 10/16/2013 | 1.46 | 0.12 | 0.66 | 0.08 | 1.97 | ND | 3.44 | 0.59 | 1.20 | 0.64 |
| 10/30/2013 | 1.33 | 0.12 | ND | | 3.88 | ND | 2.92 | 1.6 | 2.69 | 0.48 |
| 11/13/2013 | 1.64 | 0.33 | 0.86 | 0.09 | 1.48 | ND | 3.57 | 1.62 | 1.29 | 0.47 |
| 11/26/2301 | 1.01 | 0.09 | 0.63 | 0.12 | ND | ND | 3.15 | 1.05 | ND | |
| 12/11/2013 | 1.18 | 0.08 | 0.57 | 0.06 | ND | ND | 2.63 | 0.89 | ND | |
| 12/23/2013 | 1.13 | 0.08 | 0.52 | 0.07 | ND | ND | 2.04 | 0.67 | ND | |
| 1/8/2014 | 1.68 | 0.22 | 0.62 | 0.2 | ND | ND | 2.87 | 0.7 | ND | |
| 1/22/2014 | 1.49 | 0.09 | 0.90 | 0.07 | ND | ND | 2.17 | 0.91 | ND | |
| 2/5/2014 | 1.43 | 0.09 | 0.20 | 0.04 | ND | ND | 3.80 | 0.67 | ND | |
| 2/19/2014 | 1.41 | 0.21 | 0.48 | 0.05 | ND | ND | 3.42 | 1.19 | ND | |
| 3/5/2014 | ND | | ND | | ND | ND | ND | | 2.52 | 0.57 |
| 3/19/2014 | 1.57 | 0.21 | ND | | ND | ND | ND | | 2.22 | 0.49 |
| 4/1/2014 | ND | | ND | | ND | ND | ND | | ND | |
| 4/16/2014 | 1.47 | 0.2 | ND | | ND | ND | ND | | ND | |
| 4/30/2014 | 1.70 | 0.2 | ND | | ND | ND | ND | | 2.21 | 0.71 |
| 5/14/2014 | 1.98 | 0.5 | ND | | ND | ND | ND | | ND | |
| 5/28/2014 | 2.20 | 0.2 | 1.32 | 0.13 | ND | ND | ND | | ND | |

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