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Alpha Attenuation Due to Dust Loading

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Abstract

Previous studies had been done in order to show the attenuation of alpha particles in filter media. These studies provided an accurate correction for this attenuation, but there had not yet been a study with sufficient results to properly correct for attenuation due to dust loading on the filters. At the Savannah River Site, filter samples are corrected for attenuation due to dust loading at 20%. Depending on the facility the filter comes from and the duration of the sampling period, the proper correction factor may vary. The objective of this study was to determine self-absorption curves for each of three counting instruments. Prior work indicated significant decreases in alpha count rate (as much as 38%) due to dust loading, especially on filters from facilities where sampling takes place over long intervals. The alpha count rate decreased because of a decrease in the energy of the alpha. The study performed resulted in a set of alpha absorption curves for each of three detectors. This study also took into account the affects of the geometry differences in the different counting equipment used.

Introduction

Due to factors such as dust loading and filter media self-absorption, estimating airborne alpha activity through the use of air monitoring systems can be tricky. Because the alpha particle is a heavy charged particle, it is very easily attenuated and stopped. Even a few centimeters of air can completely attenuate an alpha particle. Because of the vulnerability of the alpha, many correction factors must be used in order to determine alpha lung dose based on alpha activity on filter papers. In the past, many extensive studies have been performed in order to determine the self-absorption that takes place in certain filter media and very accurate correction factors have been formed for said filters. However, there have not been many studies to account for the buildup of a dust layer on the filters during the sampling period. The studies that have been done showed that dust could cause significant decreases in alpha count rate, as much as 38% [Broome 2005]. The amount of the decrease is closely related to both sampling times in the field as well as the amount of dust present in the sampling area. At the Department of Energy Savannah River Site, air filters are corrected for attenuation due to dust loading at 20% [Hadlock 2005]. It has been discussed and considered that 20% may be an underestimate of attenuation due to dust loading. In order to determine the accuracy of this correction factor, a study was completed to result in a set of alpha attenuation curves for each of three detectors for varying density thicknesses of simulated dust layer. The study also took into account the affects of the geometry differences in the different counting equipment used.

Materials and Methods

The key utensil used in this study was an attenuator set composed of 9 attenuators, of varying density thicknesses of Mylar (DuPont Teijin Films U.S. Limited Partnership, 1 Discovery Drive, Hopewell, VA 23860) ranging from 0.41mg cm^{-2} to 3.51mg cm^{-2}, intended to act as a simulated dust layer. This attenuator set was built using cards with the dimensions equal to the cards that surround the glass fiber filters being investigated. A 5.72 cm hole was punched in the card, approximately equal (slightly larger) to the diameter of the glass fiber filters. These cards were then adhered to layers of Mylar of varying density thicknesses, simulating different levels of attenuation due to the dust covering. The dimensions and appearance of these attenuators are shown in Figs. 1a and 1b.

Other tools needed for this study included the three detectors used at SRS for analysis of air samples. These were a Canberra Series 5 low background gas proportional counter (Canberra, 800 Research Parkway, Meriden, CT 06450), a dual phosphor Eberline HandECount portable scaler and a Canberra PIPS detector with Ortec vacuum chamber. The source used was a 47mm 1184Bq NIST traceable ^{241}Am source.

The Canberra Series 5 low background gas proportional counter has a beta background as low as 0.5 counts per minute (cpm) and no alpha background. The detector is shielded by 10.16 cm of lead and is 5.72 cm in diameter. The density thickness of the detector window is 80 μg cm^{-2}. This detector has an alpha efficiency of approximately 27% and a beta efficiency of 27%. This detector has built-in diagnostics to continuously monitor parameters including gas pressure and flow, system voltage, power distribution, sample and guard counts. In the Canberra Series 5 setup, the counted sample sits 8.92 mm from the detector, as shown in Fig. 2a.

The dual phosphor Eberline HandECount (Corporate Headquarters, 7021 Pan American Fwy NE, Albuquerque, NM 87109-4238) portable scaler is a 5.08 cm dual phosphor scintillation counter. The pulse-height discriminator thresholds are 45% for alpha and 4.8% for beta. The HandECount has an alpha efficiency of 90% and a beta efficiency of 25 to 35%. The background in the counting chamber is less than 3 cpm alpha and less than 60 cpm beta. In the HandECount setup, the counted sample sits 4.2mm below the scintillator, as shown in Fig. 2b.

The Ortec 808 Alpha Spectroscopy chamber (ORTEC main office, 801 South Illinois Avenue, Oak Ridge, TN 37830) contains a Canberra Passivated Implanted Planar Silicon (PIPS) detector. The alpha efficiency for the PIPS detector is 37%. The window thickness for this detector is <500Å. In the Canberra PIPS setup, the counted sample sits 12.17mm from the detector, as shown in Fig. 2c.

A background count was obtained and recorded for each detector used every day to ensure stability of detection systems. The ^{241}Am source was counted for either 30 minutes or duration sufficient to acquire 10,000 counts, whichever was obtained first. This count was done ten times per density thickness attenuator in order to eliminate any bias in the data. The count data was statistically analyzed in order to ensure accuracy of counts. A percent relative standard deviation of no more than 6% in the data was the standard. These multiple counts were taken, first with the source uncovered to establish a baseline, and successively for each density thickness attenuator. The data collected was analyzed, using Microsoft Excel, and alpha absorption curves were produced for each detector. These curves were produced by plotting the count rate (counts per minute) vs. the density thickness of the attenuator (mg cm^{-2}).

Results and Discussion

The theoretical density thickness needed to completely attenuate an alpha particle having energy of 5.5MeV is 5.447mg cm^{-2}. The assumption made in making this calculation was that all alpha particles would be emitted perpendicular to the attenuating media and strike the media with full energy. It also assumes that any alpha particle (no matter how small its energy) will be counted when it strikes the detector. However, such is not the case. The alphas are emitted at varying angles and lose some energy due to air attenuation and scatter taking place between the source and the attenuator. The 5.447mg cm^{-2} is a nice estimate of the attenuation of the most difficult alphas to attenuate. Empirically, it was shown in this study that very nearly all of the 5.5MeV alphas can be attenuated with 3.51mg cm^{-2} of attenuator.

As shown in Figure 3, the counts without attenuation are varied due to the distance from the source to the detector. These distances are 4.2mm, 8.92mm and 12.17mm for the HandECount, Canberra Series 5 and Canberra Pips Alpha Spectrometer, respectively. The number of counts is inversely proportional to the distance between the source and the detector. This relationship is attributable to the range of an alpha in air, given by $R_a = 1.24 \cdot E - 2.62$ (for $4MeV<E<8MeV$), where R_a is the range of the alpha in centimeters and E is the energy of the alpha particle in MeV. Alpha absorption curves were created for each detector. Dust loading can have an extreme effect on alpha particle energy. Of the three detectors, the Canberra PIPS Alpha Spectrometer was most accurate in that it didn't show 20% attenuation until reaching a density thickness greater than 1.78mg cm^{-2}. Both the Canberra Series 5 and HandECounts showed 20% attenuation at slightly greater than 0.82mg cm^{-2} density thickness.

When using the Canberra Series 5 and HandECount detectors, the count was decreased because the energies at which the alphas reached the detectors were not sufficient to reach the threshold value. When this threshold was not met on the HandECount apparatus, the counts were often counted as beta rather than alpha radiation and not counted at all on the Canberra Series 5. This attenuation resulted in an erroneous count of alpha and/or beta activity on the filter. In the Canberra PIPS alpha spectrometer, the counts did not decrease, but the energy of the alphas did. The problem posed with the spectrometer was that the elemental source of the radiation may be improperly identified. The energy shift caused by the attenuation may cause one to mistakenly identify the radionuclide as a radionuclide other than ^{241}Am.

Conclusion

This study showed that dust loading can have a significant attenuating effect on alpha particles. While the density thicknesses of the simulated dust coverings were larger than is generally seen in the field, this study did find a density thickness at which the 20% attenuation is not an appropriate correction factor. Knowing this threshold density thickness will result in standardizing the sampling times in certain facilities. Before these sampling times can be standardized, a further study will need to be done in order to determine the sampling times at which certain facilities reach the dust loading threshold.

Alpha Attenuation Due to Dust Loading on Glass Fiber Filters

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FOOTNOTES

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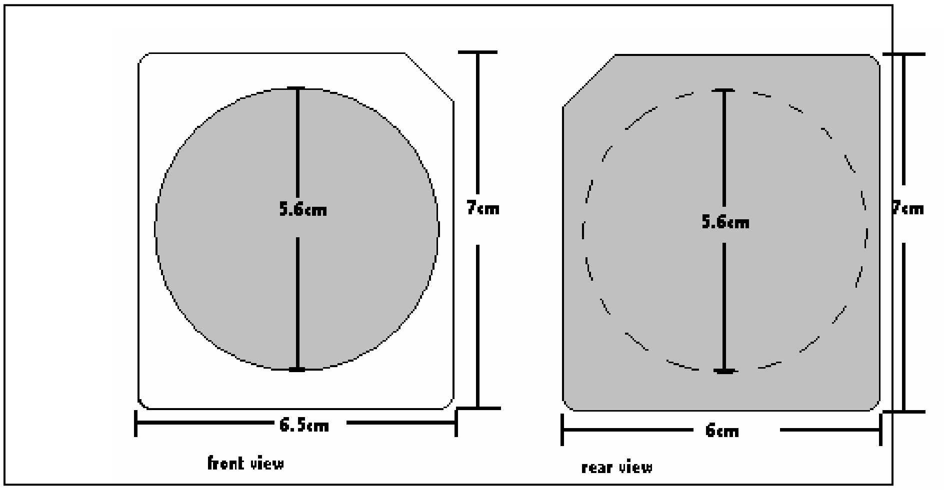
(a)



(b)

Fig. 1 (a) Illustration of dimensions and appearance of front and back of attenuator cards, (b) Photograph of appearance and dimension of attenuator card vs. filter card.

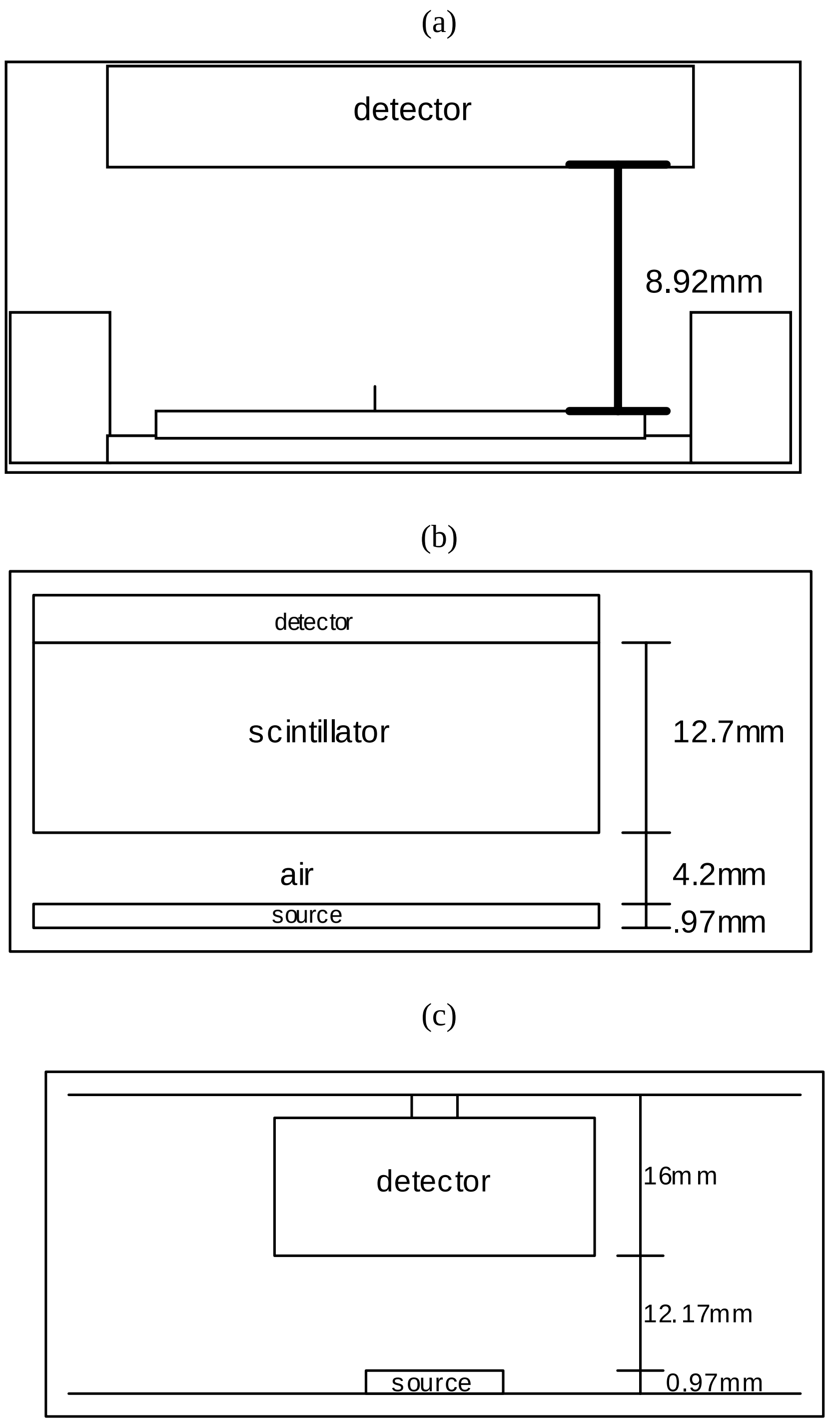


Fig. 2 (a) Showing distance between source and detector in Canberra Series 5 detection system, (b) Showing distance between source and detector in Eberline HandECount detection System, (c) Showing distance between source and detector in the ORTEC vacuum chamber and Canberra PIPS detector alpha spectrometry system.

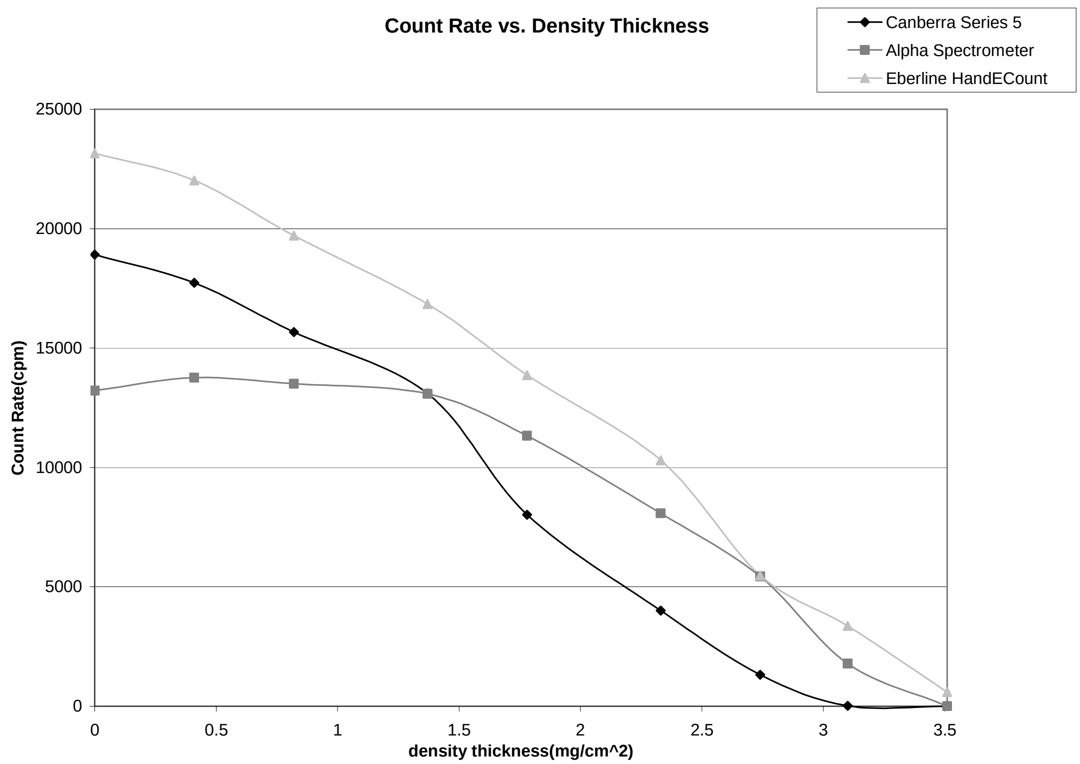


Fig. 3 Shows correction curves for alpha attenuation due to dust loading in Canberra Series 5 detector, ORTEC vacuum chamber with Canberra PIPS detector and Eberline HandECount.

Last Page