ENTERED

Allen, Pam, NMENV

From: Maestas, Ricardo, NMENV
Sent: Thursday, October 01, 2015 9:46 AM
To: Allen, Pam, NMENV
Subject: FW: WIPP Information - For Call Today
Attachments: CEMRC 2005 Study of Station A Probe Occlusion Experiment.pdf

-----Original Message-----
From: Russell Hardy [mailto:rhardy@cemrc.org]
Sent: Wednesday, March 11, 2015 10:31 AM
To: 'Russ Patterson'; 'Anthony Stone'; 'Bignell, Dale - CTAC'; Kliphuis, Trais, NMENV; 'peake.tom@epa.gov'; 'Edwards, Jonathan'; 'Walsh, Jonathan'; 'Perrin, Alan'; 'Stone.Nick@epa.gov'; Smith, Coleman, NMENV; 'brozowski.george@epa.gov'; 'Fraass, Ron'; 'Veal.Lee@epamail.epa.gov'; 'Economy.Kathleen@epa.gov'; 'Poppell.Sam@epa.gov'; Maestas, Ricardo, NMENV; 'Faller, Scott H.'; Holmes, Steve, NMENV; 'gene.turner@nnsa.doe.gov'; 'Karen.armijo@nnsa.doe.gov'; 'laura.day@nnsa.doe.gov'; 'david.nickless@nnsa.doe.gov'; 'Peter Maggiore - LANL NNSA'; 'Robinson, Bruce Alan (robinson@lanl.gov)'; 'Sisk-Scott, Charlotte - WSMS (charlotte.sisk-scott@wipp.ws)'; LucasKamat, Susan, NMENV; 'Schreiber, Arleen Thorn (arleen@lanl.gov)'
Cc: 'George Basabilvazo - WIPPNet'; 'Reynolds, Tammy - NWP'; 'Harris, Alton - DOE EM'; 'Kennedy, Scott - NWP'; 'Anderson Ward'; 'Jones, Stewart - RES'; 'Oates, Berta - CTAC'; 'schultheisz.daniel@epa.gov'; 'Philip Theisen - ORISE'; 'Kouba, Steve - WRES'; 'Roger Nelson - WIPPNet'; 'Susan McCauslin - WIPPNet'; 'Pace, Berry'; 'J.R. Stroble - WIPPNet'; 'Heidi Lowe'; 'Keffer, Sue'; 'christine.gibbs@nnsa.doe.gov'; 'Chavez, Rick - RES'; 'Kehrman, Bob - RES'; 'Dunagan, Sean - SNL'; 'Mark Pearcy - NWP'; 'Salness, Rick - RES (richard.salness@wipp.ws)'
Subject: RE: WIPP Information - For Call Today

Good morning all - in response to yesterday's discussion regarding the fact that probe pulls at Station A have not occurred since shortly before the 2/14/14 incident, I recalled that the CEMRC conducted a probe occlusion experiment at Station A in 2005. Attached is the experiment and the results obtained from that experiment.

As determined by this study, there were insignificant differences in the gross alpha/beta results between the sampler of record (SOR) and the experimentally occluded (XO) probe - regardless of the extent of occlusion of the shroud (1/3, 2/3, or fully occluded). However, it was determined that as the shroud became more occluded - the amount of salt buildup increased significantly (as can be seen by the photos at the end of the report). Obviously, as the salt buildup increases in the shroud to the point that the sampling nozzle becomes occluded, one would expect that sampling efficiency would eventually be negatively impacted.

Please understand, I'm not advocating that the probe pulls should not be performed - I'm simply informing you that a previous occlusion study was conducted and the results of that study showed little to no difference in the variability of gross alpha/beta activity between the various stages of occlusion of one probe and a separate un-occluded probe for the duration of this experiment.

Happy reading - let me know if you have any questions or need any additional information regarding this study.

Russell Hardy, Ph.D.
Director
Carlsbad Environmental Monitoring & Research Center
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150313

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-----Original Message-----
From: Russ Patterson [mailto:russ.patterson@cbfo.doe.gov]
Sent: Tuesday, March 10, 2015 10:56 AM
To: Anthony Stone; 'Bignell, Dale - CTAC'; 'Kliphuis, Trais'; 'peake.tom@epa.gov'; 'Edwards, Jonathan'; 'Walsh, Jonathan'; 'Perrin, Alan'; 'Stone.Nick@epa.gov'; 'coleman.smith@state.nm.us'; 'brozowski.george@epa.gov'; 'Fraass, Ron'; Russell Hardy; 'Veal.Lee@epamail.epa.gov'; 'Economy.Kathleen@epa.gov'; 'Poppell.Sam@epa.gov'; 'Ricardo.Maestas@state.nm.us'; 'Faller, Scott H.'; 'Holmes, Steve'; 'gene.turner@nnsa.doe.gov'; 'Karen.armijo@nnsa.doe.gov'; 'laura.day@nnsa.doe.gov'; 'david.nickless@nnsa.doe.gov'; Peter Maggiore - LANL NNSA; 'Robinson, Bruce Alan (robinson@lanl.gov)'; 'Sisk-Scott, Charlotte - WSMS (charlotte.sisk-scott@wipp.ws)'; 'susan.lucaskamat@state.nm.us'; 'Schreiber, Arleen Thorn (arleen@lanl.gov)'
Cc: George Basabilvazo - WIPPNet; 'Reynolds, Tammy - NWP'; 'Harris, Alton - DOE EM'; 'Kennedy, Scott - NWP'; Anderson Ward; 'Jones, Stewart - RES'; 'Oates, Berta - CTAC'; 'schultheisz.daniel@epa.gov'; Philip Theisen - ORISE; 'Kouba, Steve - WRES'; Roger Nelson - WIPPNet; Susan McCauslin - WIPPNet; 'Pace, Berry'; J.R. Stroble - WIPPNet; Heidi Lowe; 'Keffer, Sue'; 'christine.gibbs@nnsa.doe.gov'; 'Chavez, Rick - RES'; 'Kehrman, Bob - RES'; 'Dunagan, Sean - SNL'; Mark Pearcy - NWP; 'Salness, Rick - RES (richard.salness@wipp.ws)'
Subject: RE: WIPP Information - For Call Today

Happy March 10, 2015

The call in number is: 1-866-757-5307
Participant code: 5794706

Below is a summary of activities for today's call. (Please note that activities and dates are subject to change. Please verify the most current dates of any information provided.)

* The safe and successful moderate efficiency filter change-out occurred last week. This filter change-out evolution was completed in two days.

* Catch up bolting activities resumed on the Wednesday night shift following the filter change-out last week. Catch up bolting is approximately 68% complete, with more than 1,400 bolts installed in the underground.

* Bolting is underway to the entrance of Panel 6 this week, and other preparations area underway for initial panel closure, including downloading fans for additional ventilation.

* Bulkhead fabrication is underway in the underground maintenance shop in preparation for Panel 7, Room 7 closure.

* Fabrication of the supplemental ventilation fan is in progress, and work continues on the bulkhead design. The supplemental ventilation system project will reconfigure the mine's ventilation system so that there are two separate air exhausts for the clean and contaminated sides of the mine.

* Swapping of the 860B Fan to the 860A Fan occurred last Saturday (3/7) afternoon.

* The next Town Hall Meeting is scheduled for April 2nd.

If you have any questions for this week's call please contact me or George Basabilvazo,

Russell Patterson
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575-234-7457 or 575-706-0027

CHAPTER 11

In situ Aerosol Probe Occlusion Tests at Station A

BACKGROUND

This study was funded by the United States Department of Energy through Washington TRU Solutions. The United States Environmental Protection Agency (EPA) developed National Emission Standards for Hazardous Air Pollutants (NESHAPS) under Section 112(r) (Prevention of Accidental Releases) of the Clean Air Act. For radionuclides other than radon, the EPA established standards for Department of Energy Facilities under 40 CFR 61 Subpart H (Department of Energy Facilities). This regulation requires facility owners and operators to monitor and track emissions, calculate the highest effective dose equivalents, and report that information back to the EPA. Guidance relative to the sampling of airborne radionuclides was provided in ANSI N13.1-1969 (Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities). In 1999, a major revision to ANSI N13.1 –1969 (Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stack and Ducts of Nuclear Facilities) was issued, and it identified shrouded probes as the preferred samplers for most applications involving airborne radioactive substances in stacks and ducts of nuclear facilities.

At the Waste Isolation Pilot Plant (WIPP), Station A is used for exhaust-air compliance monitoring purposes, and the aerosol sampling systems deployed there were designed to collect $\geq 50\%$ of the 10 μm diameter aerosols under the expected range of exhaust air velocities (Rodgers, 1987). The samplers in use at Station A are three nearly identical shrouded-probes, and they are of the same basic type as that used to develop the ANSI standard. These probes operate at flow rates of ~170 L min^{-1} (~6 cfm), and each unit consists of a machined stainless steel shroud and inner nozzle. When sampling, the probes are deployed approximately 21 feet below the surface in the exhaust shaft. The air from three aerosol sampling probes flows through separate transfer lines into the Station A enclosure where the air in each line is distributed among three sampling legs. Each of these legs in turn feeds a Fixed Air Sampler (FAS) that operates at ~2 cfm. Normally, Skid A3 is the sampler of record (SOR), A2 is the main back-up sampler (BUS), and A1 is at times used as an alternative back-up sampler or for other purposes.

Laboratory tests have shown that shrouded probes are less sensitive to salt accumulations than several other types of samplers (Chavez et al. 1997), but salt buildup has been observed on the surfaces of the Station A sampling probes and in the transport lines. Further, the encrustation problem is thought to be exacerbated by groundwater seeping into the exhaust shaft. That is, when water vapor is entrained in the effluent air stream, it mixes with the salt, and the wet salt particles deposit on the probe and transport-line surfaces.

This salt fouling of the probes has become a concern because the representativeness of the backup samples collected when the probes are occluded has been called into question (EEG report #80). More specifically, the stated concern is that salt deposits occluding or partially occluding the shroud/nozzle

could alter the sampler's air-flow and increase the overall surface roughness of the sampler to the point where its performance would be degraded.

With respect to fouling of the probe, laboratory experiments conducted at Texas A&M demonstrated that when a 3-mm thick layer accumulated on the inside surface of the nozzle (approximately 10% of the inner nozzle occluded), the transmission ratio dropped about 22% relative to a clean probe. In the 1993 report, McFarland made the following statement:

> "...if a 20% reduction is the maximum level that can be accepted in sampling performance for 10 μm aerosol particles at a free stream velocity of 14 m s^{-1}, the system should be cleaned when the diameter of the inner probe (nozzle) is reduced by approx-imately 20% (6 mm)."

Blockage in the shroud alone (i.e., the inner nozzle not occluded) apparently has little impact on the shrouded probe's performance. In wind tunnel experiments, Chandra, et al. (1993) found no difference in the transmission ratio for a 10 μm aerodynamic diameter aerosol (at wind speed of 14 m s^{-1} for a clean probe compared to probe which had one-third of the flow passages between the inside of the shroud and the inner nozzle blocked. This "one-third blockage rule," as determined by a visual inspection, has been adopted as the criterion for determining when the Station A samplers' performance has been compromised.

PURPOSE AND SCOPE

Concerns over salt fouling the probes have persisted despite the results of the laboratory studies of aerosol transmission efficiencies cited above. It is worth emphasizing that to this point there is no empirical evidence indicating that a problem actually exists with the samplers. Indeed, a preliminary study based on data for ^{7}Be and ^{210}Pb (EEG-88, 2003) indicates that neither water in the exhaust shaft nor salt fouling of the probe had a significant effect on the collection of aerosol particles larger than 2 micrometers at Station A. That report also concluded with remarks to the effect that Station A samples were representative of the WIPP exhaust air stream.

Even so, in meetings of the Effluent Monitoring Improvement Group (EMIG), several possible solutions for mitigating the salt encrustation problems have been identified, discussed, and in some cases implemented. First and simplest, it was suggested that sampling and maintenance protocols could be changed to reduce the amount of salt build up and corrosion to the probe surface. Changes in these procedures have in fact been implemented. Second, a more quantitative approach was tested for evaluating and tracking the extent of the salt encrustation problems. The prototype system for this was based on a computerized light-measuring device, but preliminary tests indicated that technical problems involving the depth of field of the images limited its usefulness. Third, an assessment has been performed to evaluate metal coatings that could be applied to the probes to forestall the formation of salt crusts; results of that study were the subject of a report from CEMRC to Washington TRU Solutions (CEMRC, 2004).

The purpose of the tests reported here was to directly address the salt-fouling sampling concerns and secondarily to provide information on primary skid vs. back-up skid variability. It is important to emphasize that no judgments are made about the performance of the probes relative to compliance issues. Rather, this was simple, field-oriented approach for evaluating the effects of probe fouling: the strategy for the studies was to compare the performance of clean versus occluded probes *in situ*. Preliminary studies showed good comparability for trace element and aerosol mass data produced for matched sets of filters collected with the SOR and BUS (see below page 11-32 and 11-42). The comparisons presented here are between normal SOR (Skid A3) filters versus samples collected using an experimentally-occluded (XO) probe deployed at Skid A2.

We note that an alternative strategy for evaluating the salt encrustation problem would be to conduct transmission tests of occluded probes taken from Station A, using test methods similar to those employed by Chandra et al. (1993). While such studies would likely be revealing and may be desirable at some point in the future, they were not pursued at this point because they require access to test facilities, including a wind tunnel, not locally available.

EXPERIMENTAL PROCESS DESCRIPTION

As a major part of its WIPP Environmental Monitoring (WIPP-EM) Program, CEMRC routinely monitors aerosol mass and both gross alpha and beta activities in individual, daily, filter samples collected at Station A. In addition, trace element concentrations are determined for weekly composites of these filters. The methods employed in the Station A studies along with selected results have been presented in the CEMRC annual reports starting in 1999, and a data archive for the WIPP-EM, including the FAS data for Station A, has been established. These WIPP-EM analyses also have provided baseline data that were used in designing the probe-fouling studies.

The strategy for the *in situ* probe-fouling studies is to compare four matched quantities between samples collected with the SOR at Skid A3 vs. an intentionally occluded XO probe deployed at Skid A2; these quantities are: (1) aerosol mass concentrations (micrograms per cubic meter of air sampled)[3], (2 and 3) gross α and β activities reported in several different ways, and (4) trace element concentrations (micrograms per cubic meter). The analyses of the SOR filters were part of the continuing WIPP-EM project, and the additional analyses required for the probe-fouling study were those involving the filters collected with the occluded sampler and the BUS filters.

Quarterly, or more recently (beginning in October 2004) monthly, composites of the FAS samples also are analyzed for a selected set of actinides, but with one exception, the actinide activities have been below method detection limits, and therefore those methods and results generally cannot be used to address the probe-fouling issues of concern here. It is worth noting, however, that the $^{239,240}Pu$ activities in the SOR and BUS were found to be similar in composites of the second quarter samples from 2003 (see CEMRC Annual Report for 2003). As the fouling study is predicated on comparability

[3] A limited comparison of matched gravimetrics data for samples collected from Skids A3 and A2 is discussed beginning on page 11-42.

between matched samples collected at Skids A3 and A2 (see Appendices 1 and 2), the similarity in actinide data for the two sets of quarterly samples can be taken as further evidence for good comparability for the sampler of record and back-up unit.

The experimental design called for the space between the shroud and probe on the outlet side of the unit to be occluded in increments (Figure 11.1). Routine inspections of the probes prior to the study showed that fouling was most commonly seen in this portion of the sampler, not the inner nozzle. A probe with one-third of the shroud exhaust occluded was installed at Skid A2 on July 11, 2005. (The installation date was delayed from June 13, 2005 because of problems with birds nesting in the crane. See Table 11-1 for chronology of deployments) Duct Seal™ (Panduit, Tinley Park, IL), a commercially available mastic, was installed in a clean probe between the shroud and the probe near the outlet end of the unit, i.e., the side closer to the filter. For the first test of an occluded probe, one of the three segments was completely sealed with the Duct Seal™ (see Figures 11.2-11.11 for pictures of the probes).

Sample collection from the 1/3 occluded probe began on 27 July 2005. This meant that there were twelve pairs of matched daily samples for comparison for the first test.

The Station A, skid A-2, (1/3 occluded) probe was changed again on the morning of 8 August 2005. On that date, the probe with 1/3 blockage was removed and the 2/3 occluded probe was installed. The Station A, skid A-2, (2/3 occluded) probe was changed on the morning of 12 September 2005 when the probe with 2/3 blockage was removed and the fully occluded probe was installed. The 2/3 occluded probe was removed, and the fully occluded probe was installed on 12 September 2005. Sampling for the final test was concluded on 10 October 2005 when the fully occluded probe was retrieved.

The paired sets of daily SOR and XO FAS filters (that is from skids A3 and A2) were removed from the samplers at Station A and returned to CEMRC where they were desiccated and weighed. After allowing for the decay of short-lived radon daughters, the filters were counted for gross α and β activities with the use of a Canberra LB4100 gas proportional counter (see below page 11-32). Following those analyses, the filters were digested and analyzed for trace elements using the same methods and procedures that have been used for the FAS studies since the inception of the program (see below page 11-42). Weekly composites were prepared from the digestates of the individual filters, and these composite samples were then analyzed for a suite of trace elements by inductively-coupled plasma mass spectrometry (ICP-MS). These elemental methods can provide data for up to ~35 elements, but in practice the concentrations of some elements, including As, Be, Cd, Er, Eu, Sc, Se, Sm, Tl and V are often below detectable or quantifiable levels, and a second set of elements (notably Ag, Li and Sn) have variable concentrations in blank filters which makes their quantification difficult. These two sets of "problem" elements are normally excluded from the data analyses.

The aerosol mass loadings, gross α and β activities, and trace element concentrations (quantified both as mass per filter) were compared to evaluate the differences between the clean probe at A3 and the

incrementally occluded probes at A2. These comparisons were based on graphical analyses and in some cases, paired t-tests and correlations between the two sets of samples were calculated using standard statistical procedures and commercially available statistical software (JMP, SAS Institute, Cary North Carolina).

Results and Discussion

Mass Concentrations

At the standard flow rate of 2 cfm (~56 l min^{-1}), each FAS filter should sample ~80.6 m^3 of air during a 24 hr period. This can be seen as a large number of points in a horizontal band at this approximate volume in Figure 11.12, but samples with lower than expected volumes also are evident in that figure. In eight of the low-flow cases (SOR with start dates on 8/8 and 9/26; XO on 7/29, 8/5, 10/2, 10/3, 10/8; BU on 9/26), the flow rates fell to less than ~90% of the standard flow, and the filters were quickly replaced, generally in the afternoon or early evening. In four other cases, all involving the SOR, (with start dates of July 27 and 31 and August 15 and 17), the sample runs were terminated prematurely due to low flows, but the filters were not replaced until the next morning. For each of these cases, the flows for the BU sampler were normal, however, and therefore the continuity of effluent sampling was not compromised.

A time-series plot of aerosol mass concentrations for all samples (Figure 11.13) shows that the three (SOR, XO, and BU) samplers generally had similar aerosol loadings, but on several days, the filters from the XO samplers had obviously higher mass loadings. These elevated mass loadings always occurred towards the end of the test periods and only during the 1/3 and 3/3 occluded sampler deployments, i.e., this effect was not seen for the 2/3 occluded sampler. One BU filter, with a start date of 8/18, showed an anomalously high mass concentration, but a check of the flow records showed that the filter in question had several abnormalities; specifically, the chain of custody form stated the skid was down, but the flow file data indicated that the filter ran in low-flow from approximately 17:49 to the end of the run.

An important point that can be seen in Figure 11.13 is that XO samples with high mass concentrations were not isolated cases involving single filters. Rather, for each of the four, XO, low-flow/rapid replacement scenarios mentioned above, the mass loadings were elevated on the second filter of the pair as well as the first. This suggests that the cause for the increased aerosol loading was not a discrete pulse of air enriched with particulate matter, but rather the elevated masses were the result of a process or processes with timescales probably of the order of hours.

Another way to consider the effects of the occlusions on the performance of the samplers is by direct, point-by-point comparisons between samples collected with the SOR and XO. Such comparisons require that the two samplers collected particles from comparable volumes of air during the same period time. Therefore, the first step for this part of the data analysis was to match the samples by volume and time, and these direct comparisons were made only when the difference in the volumes for the SOR and XO samples was less than or equal to 10%. This is an arbitrary value that was chosen to retain almost all of the samples while also

keeping the difference in volumes sampled to a reasonable level.

In six cases involving low-flow SOR and XO filters with prompt replacements, the net masses and volumes for the initial and replacement filters were summed and the summed net masses were divided by the summed volumes to calculate the composite mass concentrations (micrograms per cubic meter). In a seventh case, involving the SOR sample which was started on August 9, the composite volume was less than 10% of that of the XO sampler, and as a result this pair of samples was excluded from the direct comparisons. In all but one other case in which the SOR and XO volumes differed by more than 10%, the samplers ran for near the normal 24 hour period, but the flows were ~50% to 95% of normal. In the final excluded case (SOR 8/23 to 8/24), the volume of air sampled was only about 4 m^3 because the sampler was shut off during an underground CAM alarm. The volumes for the matched samples are shown as a time-series plot in Figure 11.14.

A time-series plot of the matched gravimetric data (Figure 11.15) shows much the same features as the unscreened data, that is, the mass concentrations for some of the 1/3 and 3/3 occluded XO samples taken late in the deployments were higher than the matched SOR filters. An x-y plot of the matched SOR vs. XO gravimetric data (Figure 11.16) shows that most of the mass concentrations for the matched samples fall along a 1:1 line, which demonstrates that the aerosol loadings obtained with the occluded sampler most often were similar to those of the SOR. However, there is a second field of points that are clearly above the 1:1 line, indicating that the occluded sampler sometimes had higher loadings than the SOR. The largest difference is for the samples collected from October 3 to 4; the RPD for this pair of samples was 1.87, reflecting a difference of over 60-fold.

Summaries of the gravimetric data for each of the three deployments, calculated separately for all samples and for the matched sample pairs are presented in Tables 11-2 to 11-4. The most notable result from the studies, as mentioned above, is that the XO sampler had higher mass concentrations than the SOR in some cases but only in the 1/3 and 3/3 occluded tests. The RPDs between the SOR and XO sampler in the 2/3 occluded test were only -12.7% and -6.2% compared with PRDs of ~100 for the four other cases in the 1/3 and 3/3 occluded tests. As shown in these tables, the XO collected on average approximately three times as much mass as the SOR during the 1/3 and 3/3 deployments.

The reason for the differences in results among studies with different levels of occlusion is not clear. Possible influences that might be considered for follow-up analysis are changes in the relative humidity in the underground and differences in the level of mining activities during the three phases of the study.

Another important result that can be seen in the summary tables of the gravimetric data is that the relative standard errors (RSEs, that is, the standard errors divided by the means) are much larger for the XO sampler compared with the SOR, but again only in the 1/3 and 3/3 occluded tests. Indeed, the large RSEs for the XO sampler in the 1/3 and 3/3 occluded tests are a reflection of the fact that the high mass loadings occurred in a

relatively small number samples; this point also can be seen in Figures 11.13 and 11.15.

There are at least two possible explanations for the differences in the amounts of material collected by the SOR and XO samplers. The first is that the XO sampler collected more aerosol particles than the SOR, and the second is that the XO sampler collected some non-aerosol material that the SOR did not. The gross α and β data discussed in the next section provide some insight into which of these explanations is more likely.

4.2. Gross Alpha and Beta Activities

Time-series plots of the gross α and β data for the SOR and XO samplers are presented in three ways: (1) as activities per filter (Figure 11.17), (2) as activity concentrations (i.e., the activity per cubic meter of air, in Figure 11.18), and (3) as activity densities (i.e., the activity per gram of aerosol, in Figures 11.19 and 11.20, with the latter showing the data plotted on a logarithmic scale). These plots show that the SOR and XO filters generally had similar gross α and β activities when the data were calculated as activity per filter or as activity per cubic meter of air (Figures 11.17 and 11.18, see also Tables 11.5 to 11.7). There were several instances when one sampler or the other had a higher activity or activity concentration, but no clear or persistent trends were evident when the data were plotted in this way. For example, for several days in late September and early October, the gross α activities for the XO sampler were somewhat higher than those of the SOR, but within a day, the good agreement between samplers returned. Along these same lines, there were three or four isolated incidences of higher gross β activity concentrations for the SOR during the 2/2 XO occluded sampler deployment, but this was not consistently the case for that deployment or the others, and furthermore, corresponding differences between samplers were not seen in the gross α data for the same time period.

Graphs of the gross α and β activity densities, that is the activities divided by the accumulated aerosol masses (Figures 11.19 and 11.20), are especially revealing because the results plotted in this way show some important information with respect to the material responsible for the additional mass collected by the XO sampler. The first point that stands out in these graphs is the high activity densities for two samples from the SOR, one collected from 8/30 to 31 and the other on 9/19 to 20. Further inspection of the data shows that the high activity densities for these samples were the result of low masses (< 1 microgram per cubic meter) rather than differences in the activities of the α and β emitters. As shown above in Tables 11-2 to 11-4, the mean filter masses, which ranged from 56 to 308 $\mu g\ m^{-3}$, were many times higher than what was recorded for these filters; there is, however, no basis for discounting the gravimetrics results for the two anomalous filters.

The more important finding regarding the material collected by the XO sampler can be seen in Figure 11.20, in which the activity densities are plotted on a logarithmic scale. This figure shows that both the gross α and β activity densities for the XO sampler were low in those samples that had elevated mass loadings towards the end of the 1/3 and 3/3 occlusion deployments (see Figure 11.13). This means that the material responsible for the high mass loadings had lower levels of α and β activity per unit mass than is typical of

the aerosols normally collected by the samplers.

Salt that had sloughed off of the occluded sampler is the most obvious and likely candidate for the low α and β emitter collected by the XO probe. As shown in the pictures of the occluded probes (Figures 11.3, 11.6, 11.7, 11.10 and 11.11), these samplers had become encrusted with salt. If the additional mass is in fact the result of salt sloughing, one would predict from the plots presented in Figure 11.20 that the encrusting salt would have ~0.1 Bq of alpha activity and ~0.5 Bq of beta activity per gram compared with activity densities of roughly 10 Bq g^{-1} (α) and 50 Bq g^{-1} (β) for aerosols that have been collected with the FAS samplers. The trace element data discussed in the follow section provide some additional insights into the type of material responsible for the high mass loadings in some of the XO samples.

Trace Elements

The elemental data presented here are for composite samples prepared by combining the digestates of individual filters that were prepared with the use of strong acids and a microwave digestion unit. The first XO and SOR sample pair do not match precisely in time because the XO collections commenced between the days on which composite batches were normally started.

The first focus of the analysis of the trace element data was on a set of elements found to satisfy three criteria in the baseline comparison of the SOR with the BU sampler: (1) absolute values of the RPDs between sampler means that were less than or equal to 15%, (2) correlations greater than 80% and (3) data for all thirteen sample pairs (see Appendix 2). Even though these criteria are arbitrary, they do provide a way to select a group of elements that showed good agreement between samplers in the preliminary studies. For convenience, this group of elements, which is composed of Al, Ba, Ce, La, Na, Nd, Pb, Th and Zn, is collectively referred to as Group A. The working null hypothesis for this part of the study was that the test occlusions would have no effect on the XO sampler's collection efficiency, and therefore, the concentrations of the elements would be similar for the SOR and XO samples.

Timeseries plots of the Group A elements (Figure 11.21) shows that with several exceptions, the concentrations for the SOR and XO samplers did indeed agree well. The first exception was the set of Al samples collected in September and October. In those samples, the SOR Al concentrations were 3 to 15 times those of the XO sampler. The reasons for the difference in Al concentrations are unknown, but this element is commonly used as an indicator of mineral dust (e.g., Arimoto et al., 2005), and one cannot exclude the possibility that the samplers simply collected some different materials. On the other hand, what is curious is that other Group A elements, i.e., Ce, La, and Nd, that also are typically associated with mineral dust (Rahn, 1976) showed very good agreement between samplers, except for the first sample pair. In fact, the correlations between the SOR and XO sampler for the ten matched sample pairs were 0.96, 0.93, and 0.94 for Ce, La, and Nd, respectively.

While the first pair of samples was slightly mismatched, it is worth noting that the XO composite had consistently higher concentrations of the Group A elements

compared with the SOR (see Figure 11.21 and Section 4.1 above). This is consistent with the observation that the XO filters from the last part of the 1/3 occlusion study that had high mass loadings. Furthermore, the Na concentrations showed much higher concentrations in the XO composite pair and also in the composites for the samples collected towards the end of the 3/3 occlusion study.

The observed differences in the elemental mass concentrations between the SOR and XO sampler were small, and this is further evidence that the experimental occlusions did not compromise the performance of the XO probe. Summary tables for the Group A elements (Table 11-8), show that with the Al was the only element for which the absolute value of the RSD between the SOR and XO sampler exceeded 15%. There were too few samples for a meaningful comparison of Th results, but the RPDs for all other elements ranged from 0 to 14%, with those for Ba, Ce and Zn less than 5%.

Plots of other elements that did not satisfy the Group A criteria are presented in Figure 11.22. Even though the comparability in the preliminary studies was not as good as the elements considered above, this group (Group B) does provide some information on the composition of the material that we hypothesize was responsible for the high mass loadings. In particular, extremely high concentrations of Ca, Mg, and K were found in the XO composites prepared from the latter parts of 1/3 and 3/3 occlusion studies, and this was when the high mass loadings occurred. These elements are likely to be major components of the salt crusts that formed on the occluded probe, and these findings thus support the notion that the sloughing of encrusting salts lead to the high mass concentrations in some of the XO samples. In anticipation of possible follow up studies, some samples of the encrusting salts were collected during a routine probe pull, and these are available for subsequent analyses.

COMPARISON OF GRAVIMETRIC, GROSS ALPHA AND GROSS BETA DATA FOR AEROSOL SAMPLERS AT STATION A

Objective

The Probe-fouling Study at Station A was predicated on comparability between sampling skids, and this preliminary study was conducted to establish that samples collected with the use of a Back-Up Sampler (BUS, usually Skid A2) were similar to those collected with the Sampler of Record (SOR, most often Skid A3). The data used for this study were the aerosol mass concentrations (mass per unit volume of air sampled, i.e., micrograms per cubic meter) and the gross alpha and gross beta activity concentrations (activities per unit volume of air). These data were collected with paired fixed air samplers (FASs).

Approach

Gravimetric analyses of FAS filters from the Station A SOR have been conducted by CERMC since early December 1998, which was when the Center's WIPP-environmental monitoring (EM) program began. In preparation for the Probe-fouling Study, mass determinations for the BUS began in October 2004, and this continued up until July 2005, when the occluded probe was installed. The gravimetric analyses were performed using the same procedures for all

samples. Briefly the weighing procedure involved conditioning the filters for at least 24 hr in a dessicator prior to weighing both before and after sampling. The filters are weighed using a microbalance (Mettler UMT 2) to 0.01 mg. The aerosol mass is simply calculated as the filter plus accumulated aerosol mass after sampling minus the filter mass before sampling.

Gross alpha and beta concentrations in FAS filters were determined using the Canberra LB4100 Gas Proportional Counter (GPC). Quality Assurance activities conducted for this project include using an attenuation curve to calibrate detector efficiency, tracking and verification of analytical instrument performance daily, and use of NIST-traceable radionuclide solution control sources. In addition, a 60-minute instrument background history is established as part of the instrument quality assurance. Instrument backgrounds are monitored using an empty planchet holder and a count time of 60 minutes.

Filters were loaded onto the stainless steel planchets and counted for a preset time of 20 hours (1200 minutes). No special preparations were needed to count the filter samples. After the completion of the count, the gross alpha and gross beta raw data counts were used with the sample preparation data (gravimetric data), volumes, calibration data and background history to calculate the sample results using Microsoft Access™.

The comparisons between the SOR and BUS were based on two types of statistical analyses. All statistical analyses were performed using JMP IN Release 5.1.2 – Windows (Academic Product) Copyright 1989 - 2004 SAS Institute Inc. First, paired comparisons were performed to determine whether the SOR and BUS samples had the same aerosol mass concentrations and the same gross alpha and beta activities. These were two-sided, paired Student's t-tests. Twenty-four pairs of samples were excluded from the test comparing gravimetric data because of large (2-fold) differences in the volume of air sampled. Likewise, fourteen pairs of samples were excluded from the gross alpha and gross beta comparisons for the same reason. Such large differences in sampling volumes most often occurred during routine probe pulls.

The second statistical method used to compare the matched gravimetric and gross alpha and gross beta data for the SOR and BUS was an orthogonal regression. This, not the standard least-squares model, which is commonly used, is the preferred method for regressing two variables when both have measurement errors associated with them. The orthogonal regression model is sometimes referred to as a functional regression. The assumption of equal variances was made for the FAS regressions, and this is supported by the similar standard deviations shown in Tables 11-9, 11-10 and 11-11 (below).

Results and Discussion

Paired- t Tests

Summary statistics and the results of a paired t-test comparing the matched gravimetric data from the SOR and BUS are presented in Table 11-9. This comparison of mass concentrations is based on 260 sample pairs, and it shows that the relative percent difference (RPD) calculated from the means for the SOR (86.02 $\mu g\ m^{-3}$) and BUS (86.45

$\mu g\ m^{-3}$) is only 0.5%. The RPD is calculated as the difference between the arithmetic means for the SOR and BUS divided by the average of the two means This comparison thus demonstrates very good agreement in mass concentrations between matched samples from the two skids. Results of a paired t-test indicate that the probability (p) for obtaining a greater absolute t-value by chance alone when there was zero difference in means is $p > 80\%$. Traditionally, a null hypothesis of zero difference in means would be rejected if $p \leq 1\%$ or $p \leq 5\%$. For this test, then, the probability for chance occurrence is such that one would accept the null hypothesis that there was no difference in the mean mass concentrations as determined from the SOR and BUS.

Results of the paired t-tests comparing the gross alpha and gross beta data for the SOR and BUS are presented in Tables 11-10 and 11-11. These comparisons show that the RPDs between the means for the SOR and BUS were 2.5% and 5.4% for the gross alpha and gross beta activities, respectively. These results confirm the good agreement between the two skids as was indicated by the gravimetric data discussed above. The t-ratio calculated for the paired gross alpha activities indicates that the difference in means between the SOR and BUS was not significant, but the probability for the paired t-test of gross beta activities was $p = 0.0035$, which is clearly significant from a statistical standpoint. However, the difference in means was only 5.4%, and therefore, while there was a systematic difference in activities, the difference was small. It is also worth noting that the gross beta counts were generally closer to the minimum detectable activities than were the gross alpha counts.

Time-series Plots

Time-series (Fig. 11.23 and 11.24a-c) plots are presented to graphically illustrate the close agreement between the gravimetric data for the SOR and BUS. In addition to a plot of the entire dataset, three months were chosen to illustrate the close agreement in the gravimetric data for periods of low, high, and intermediate aerosol loadings, these are represented by the months of October 2004 (Figure 11.24a), December 2004 (Figure 11.24b), and May 2005 (Figure 11.24c), respectively. While not useful for assessing statistical significance of the differences between samplers, no evidence of systematic differences between the SOR and BUS is seen in any of these plots of the gravimetric data.

The corresponding time-series plots for the gross alpha and gross beta activities do show some trends in the data, however. As shown in Figure 11.25a, the gross alpha activities measured by the SOR were consistently lower during the first month of the comparison, i.e., in October 2004, but the trend was reversed beginning in December 2004. During the first part of the study the difference was larger, in some cases exceeding 50%, but during the latter part of the study the differences, although consistent, were small, 5% to 10%. The gross beta activities (Figure 11.25b) also showed systematic differences during October 2004, but these differences were generally small, < 10%. Interestingly, the reverse trend as seen in the gross alpha counts was not observed for the gross beta data for December 2004.

Orthogonal Regression Analyses

The orthogonal regression of the mass concentration data (A3 data as X and A2 as Y) produced an intercept of -3.25, a slope of 1.033, and a correlation of 0.912. The corresponding regressions for gross alpha and gross beta activities had intercepts of 0.00004 and -0.00002, slopes of 0.82 and 0.99, and correlations of 0.89 and 0.98, respectively. These results for the gravimetric and gross beta data show that the SOR and BU samplers produced data that agreed to within 1% to 3%, while the agreement for the gross alpha comparison was 11%.

COMPARABILITY OF TRACE ELEMENT DATA FROM AIR SAMPLING TWO SKIDS AT STATION A

Background

Concerns have been raised about the sampling of effluent air from the WIPP exhaust shaft (Webb et al., 2004). The specific concern expressed was that:

> "since the concentration of salt particles and water aerosol is different from one side of the shaft to the other (Fig. 4), the concentration of radioactive particles may be different from one side of the shaft to the other and it may be difficult to collect a representative sample from a single point at Station A."

Recently, a set of air samples collected during the second calendar quarter of 2003 using the "back-up" sampling skid at Station A was provided to CEMRC for a special study. In preparing the samples for that study, whose results have been reported elsewhere, individual filters from the back-up (fixed air) sampler (BUS) were digested, and weekly composites were prepared for trace element determinations using the same methods previously used for the filters from the sampler of record (SOR). The trace element data for the two sets of filters thus provide the opportunity to directly compare results obtained with the SOR and BUS, and in so doing address the representativeness issue raised by EEG. While the results presented here are mostly for non-radiological constituents, two radioactive elements U and Th are included in the analyte list. This appendix summarizes the results of the comparisons.

Samples and Methods

CEMRC routinely determines the concentrations of trace elements in weekly composite samples prepared from the Station A filters as part of its WIPP Environmental Monitoring (WIPP-EM) Program. The methods employed in those studies along with selected results have been presented in the Center's annual reports starting in 1999. A data archive for the WIPP-EM has been established, and this includes the trace element data for the weekly composites prepared from the SOR at Station A. As noted above, a second set of weekly composites was recently prepared from filters collected with the BUS during the second calendar quarter of 2003. The matched trace element data for the SOR and BUS weekly composites from that quarter are the basis for the comparisons presented here

Both sets of FAS samples were prepared and analyzed by the same methods, but they were prepared and analyzed more than six months apart in time, using different reagents,

standards, calibrations, etc. Briefly, the individual filters were digested using a mixture of strong acids in a microwave digestion unit, and weekly composites were prepared from the digestates of the individual filters. The weekly composites were then analyzed for a suite of trace elements by inductively-coupled plasma mass spectrometry (ICP-MS). The instrumental methods can provide data for up to ~35 elements, but in practice the concentrations of one set of elements, including As, Be, Cd, Er, Eu, Sc, Se, Sm, Tl and V, are often below detectable or quantifiable levels, and a second set of elements (notably Ag, Li and Sn) have variable concentrations in blank filters which makes their quantification difficult. These two sets of "problem" elements are excluded from the analyses that follow.

The SOR and BU sampler collected slightly different volumes of air during the second quarter of 2003; the SOR sampled a total of 6899 cubic meters of air while the BUS collected 7537 cubic meters. To enhance comparability between data sets, the data for each weekly composite from the BUS were normalized to the SOR by adjusting for the average percentage difference in flow volumes (i.e., 6899/7537). In addition, there also was one day (3/31/03) for which a BU sample was not available, but that minor difference in the data sets was not taken into account.

Results and Discussion

Differences in the trace element concentrations in the matched weekly SOR vs. BUS composites were tested for statistical significance through paired t-tests. For these tests, higher t-values indicate a greater likelihood for real differences between pairs—this is reflected in a lower probabilities for chance occurrence, which are denoted as Prob >|t|. As shown in Table 11-12, the results of these tests show that for most elements, the concentrations obtained with the SOR and BUS were not statistically different. The average probability for a obtaining a greater absolute paired t-value by chance alone, assuming no difference in sample means (that is the null hypothesis), was 0.22. Only two elements (Dy, whose concentration was close to its minimum detectable level of ~0.015, and Fe) had Prob > |t| less than 0.01, that is, low enough to be statistically significant; but several elements (Al, Mg, Mn, Mo, Na, Ni, Sb, Si and Sr) had Prob > |t| values between 0.01 and 0.05, and these would likely be construed as marginally significant.

An estimate of the relative percent difference (RPDs) for each element in the two sets of samples was calculated as the difference between the arithmetic mean concentrations for the SOR and BUS divided by the average of the two means. The ensemble average RPD for all elements was only -13% (Table 11-12), indicating that the BUS had, on average, slightly higher concentrations than the SOR. There are no established standards for comparability of paired aerosol samplers, but to place this difference in perspective, the allowable relative percent difference for duplicate analyses of given element in a single sample (simultaneous preparation) by ICP-MS is ± 20% (EPA Method 6020). Seventeen of the twenty-six elements had RPDs for the paired SOR vs. BUS composites that were less than or equal to 20%; this means that the observed differences between the SOR and BUS for the majority of elements in the study were

comparable to, if not less than, the method precision of the ICP-MS.

In addition to the comparisons of concentrations by the paired t-tests and the calculation of RPDs, correlations between the results for the SOR and the BUS were calculated. There were thirteen pairs of weekly composites available for this statistical analysis (for some elements, the number of pairs were less than thirteen owing to concentrations below detection limits), and for reference, at twelve degrees of freedom, the correlation coefficients at the 5% and 1% levels of significance are 0.532 and 0.661, respectively. Results of the analyses show that in almost all cases where the differences in the paired t-values were significant or marginally significant, the concentrations in the paired SOR and BUS composites were highly correlated. In fact, the average correlation for all elements was 0.79, and the correlations for only two elements (Mg and Sr) were not statistically significant, while three others (Cu, K, and Sb) were marginally significant. The results of the correlation analyses are important because they show that even for those elements whose mean concentrations differed between the two samplers, the data for matched samples were strongly correlated. Therefore, one can conclude that even if there were a slight systematic offset in concentrations between the SOR and BUS, either set of samples is arguably representative of the other.

While most of the elements in the study are non-radiogenic, the concentrations of two radioactive elements, Th and U, were determined by the ICP-MS (their concentrations were calculated based on natural isotopic abundances). The RPDs for Th and U were extremely small, -2% and –6%, respectively, and the Prob > |t| for the concentration differences measured by the paired t-tests were clearly not significant (Table 11-12). The correlation coefficients for both U and Th in the two sets of samples were highly significant (0.92 and 0.83). Thus, by all measures, the concentrations of these two radionuclides in the paired SOR and BUS samples were in close agreement.

In summary, the results of direct comparisons of trace element data presented here show that in the overwhelming majority of cases, the differences between the SOR and BUS were insignificant. The differences in concentrations between the SOR and BUS, as determined by paired t-tests, were significant at $p < 0.01$ for less than 10% (2 of 26) of the twenty-six elements considered. Furthermore, for more than 80% (21 of 26) of the elements investigated, the correlation between the paired samples was significant at $p < 0.01$ and for three more elements the correlations were significant at $0.01 < p < 0.05$. This study of trace elements in exhaust air from the WIPP thus demonstrates a high degree inter-comparability between the sampler of record and the back-up sampler.

Conclusions

In summary, the first part of the overall picture that has emerged from the probe occlusion study is that the XO probe and SOR collected comparable amounts of α and β emitting aerosol particles. That is, the differences between the XO probe and SOR in terms of gross α and β activities per filter and activity concentrations were reasonably small, of the order of 10 to 30% (see Tables 5 to 7). This was true for all three levels of occlusion. Furthermore, there was no consistent pattern in terms of which sampler had higher activity, and higher alpha

activities in a given set of XO or SOR filters did not necessarily correspond with higher beta activities in that same set of filters. For the most part, both the gross α and the gross β activities of filters from the two samplers also tracked each other well, showing that the occluded sampler captured the variability in the gross α and β emitters as well as the mean values.

The XO sampler did become encrusted with salt to a greater extent than the unblocked sampler, and analysis of the gravimetric data showed that filters collected with the occluded sampler did have systematically higher masses than the SOR in some cases. The elemental data suggest that Ca, Mg, K, and Na contributed to the high mass loadings, most likely due to the sloughing of encrusting salts. Despite greater propensity for salt fouling of the XO probe, these results indicate that the intentional occlusion of the test probe did not lead to significant over- or under-sampling of gross α or β emitters or trace elements in the WIPP exhaust airstream.

Recommendations

The analyses presented here suggest that as salt built up on the surface of the probe, some of the encrusting material sloughed off the probe and was collected on the filter. That salt is predicted to have lower concentrations of alpha and beta emitters compared with the aerosol particles normally collected at Station A. Therefore, determinations of α and β activity for samples of the encrusting salt are recommended as follow-up studies to test the predictions regarding sloughing of salt from encrusted probes. These analyses could be performed at CEMRC. Similarly, elemental analyses of the encrusting salt would be useful for assessing the composition of the excess material collected by the probe and further testing the hypothesis regarding the sloughing of the salt crusts. Follow-up analyses of flow data and information on the relative humidity in the underground also may provide additional insights into the performance of the aerosol samplers used for exhaust-air compliance monitoring.

Table 11-1: Comparisons for the Probe Occlusion Tests

Start	Stop	Test	Comparisons		
			Daily		Weekly
			Mass	Gross α & β	ICP-MS
4/1/2003	6/30/2003	Primary vs. Backup	---	---	Yes
10/1/2004	12/21/2004	Primary vs. Backup	---	Yes	---
10/1/2004	7/11/2005	Primary vs. Backup	Yes	---	---
7/27/2005*	8/8/2005	Primary vs. 1/3 Blocked	Yes	Yes	(Yes)
8/8/2005	9/12/2005	Primary vs. 2/3 Blocked	Yes	Yes	(Yes)
9/12/2005	10/10/2005	Primary vs. 3/3 Blocked	Yes	Yes	(Yes)

*One-third occluded probe was installed on 7/11. Sampling began on 7/27

Table 11-2: Comparison of Gravimetric Data: 1/3 Occluded XO Probe vs. Sampler of Record (SOR)

Group	Sampler	Count	Mean $\mu g\ m^{-3}$	Standard Error $\mu g\ m^{-3}$	RSE	RPD
All Samples	SOR	12	90.31	7.77	8.6%	109.5%
	XO	14	308.77	79.47	25.7%	
Matched Pairs	SOR	9	86.01	10.00	11.6%	94.7%
	XO	9	240.69	70.46	29.3%	

RPD stands for Relative Percent Difference, see text for explanation.

Table 11-3: Comparison of Gravimetric Data: 2/3 Occluded XO Probe vs. Sampler of Record (SOR)

Group	Sampler	Count	Mean $\mu g\ m^{-3}$	Standard Error $\mu g\ m^{-3}$	RSE	RPD
All Samples	SOR	36	65.67	9.77	14.9%	-12.7%
	XO	35	57.84	7.30	12.6%	
Matched Pairs	SOR	29	59.96	8.53	14.2%	-6.2%
	XO	29	56.33	8.16	14.5%	

RPD stands for Relative Percent Difference, see text for explanation.

Table 11-4: Comparison of Gravimetric Data: 3/3 Occluded XO Probe vs. Sampler of Record (SOR)

Group	Sampler	Count	Mean $\mu g\ m^{-3}$	Standard Error $\mu g\ m^{-3}$	RSE	RPD
All Samples	SOR	33	68.17	7.91	11.6%	117.9%
	XO	35	263.87	66.59	25.2%	
Matched Pairs	SOR	26	61.56	6.91	11.2%	100.8%
	XO	26	186.66	60.46	32.4%	

RPD stands for Relative Percent Difference, see text for explanation.

Table 11-5: Comparison of Gross Alpha and Beta Activities: 1/3 Occluded XO Probe vs. Sampler of Record (SOR)

Variable	Sampler	All Samples				Matched Pairs			
		Count	Mean	Std Error	RPD	Count	Mean	Std Error	RPD
Volume (Cubic meters)	SOR	12	77.67	4.76	-23.2%	9	82.90	0.25	-6.2%
	XO	14	69.09	6.13		9	80.42	0.95	
Alpha Activity (Bq/filter)	SOR	12	1.64E-02	1.68E-03	-4.8%	9	1.79E-02	1.90E-03	-7.6%
	XO	14	1.60E-02	1.92E-03		9	1.72E-02	2.07E-03	
Alpha Activity Concentration (Bq/m3)	SOR	12	2.21E-04	2.38E-05	5.3%	9	2.17E-04	2.33E-05	9.3%
	XO	14	2.27E-04	1.43E-05		9	2.28E-04	1.93E-05	
Alpha Activity Density (Bq/g)	SOR	12	2.990	0.677	-3.1%	9	3.231	0.876	23.3%
	XO	14	2.934	1.349		9	3.773	2.040	
Beta Activity (Bq/filter)	SOR	12	4.91E-02	4.75E-03	-23.2%	9	5.36E-02	4.96E-03	-24.4%
	XO	14	4.35E-02	4.93E-03		9	4.73E-02	5.11E-03	
Beta Activity Concentration (Bq/m3)	SOR	12	6.42E-04	5.14E-05	1.5%	9	6.48E-04	6.04E-05	-1.8%
	XO	14	6.47E-04	4.91E-05		9	6.41E-04	5.37E-05	
Beta Activity Density (Bq/g)	SOR	12	9.096	2.365	-22.8%	9	10.092	3.105	1.3%
	XO	14	7.923	3.663		9	10.176	5.528	

RPD stands for Relative Percent Difference, see text for explanation. SOR stands for Sampler of Record, XO represents the Experimental/Occluded Probe

Table 11-6: Comparison of Gross Alpha and Beta Activities: 2/3 Occluded XO Probe vs. Sampler of Record (SOR)

Variable	Sampler	All Samples				Matched Pairs			
		Count	Mean	Std Error	RPD	Count	Mean	Std Error	RPD
Volume (Cubic meters)	SOR	36	75.42	4.10	15.1%	30	82.44	2.88	-0.3%
	XO	35	81.93	2.47		30	82.33	2.86	
Alpha Activity (Bq/filter)	SOR	36	1.53E-02	1.40E-03	29.6%	30	1.61E-02	1.45E-03	21.2%
	XO	35	1.82E-02	1.51E-03		30	1.82E-02	1.71E-03	
Alpha Activity Concentration (Bq/m3)	SOR	36	1.96E-04	1.51E-05	20.3%	30	1.96E-04	1.59E-05	19.7%
	XO	35	2.20E-04	1.74E-05		30	2.19E-04	1.95E-05	
Alpha Activity Density (Bq/g)	SOR	36	14.452	8.980	-64.6%	30	16.441	10.759	-71.2%
	XO	35	8.731	1.908		30	9.296	2.194	
Beta Activity (Bq/filter)	SOR	36	5.70E-02	5.55E-03	-10.0%	30	6.13E-02	5.99E-03	-21.1%
	XO	35	5.40E-02	4.86E-03		30	5.49E-02	5.58E-03	
Beta Activity Concentration (Bq/m3)	SOR	36	7.60E-04	5.71E-05	-31.0%	30	7.44E-04	6.54E-05	-24.6%
	XO	35	6.51E-04	5.48E-05		30	6.55E-04	6.25E-05	
Beta Activity Density (Bq/g)	SOR	36	58.603	35.007	-104.7%	30	64.273	41.959	-102.7%
	XO	35	26.444	5.905		30	28.225	6.782	

RPD stands for Relative Percent Difference, see text for explanation. SOR stands for Sampler of Record, XO represents the Experimental/Occluded Probe

Table 11-7: Comparison of Gross Alpha and Beta Activities: 3/3 Occluded XO Probe vs. Sampler of Record (SOR)

Variable	Sampler	All Samples				Matched Pairs			
		Count	Mean	Std Error	RPD	Count	Mean	Std Error	RPD
Volume (Cubic meters)	SOR	29	77.45	3.01	-11.1%	26	78.91	2.53	8.7%
	XO	31	73.22	3.41		26	82.63	0.71	
Alpha Activity (Bq/filter)	SOR	29	1.82E-02	1.32E-03	23.9%	26	1.90E-02	1.35E-03	32.9%
	XO	31	2.08E-02	1.85E-03		26	2.30E-02	1.89E-03	
Alpha Activity Concentration (Bq/m3)	SOR	29	2.36E-04	1.43E-05	32.1%	26	2.43E-04	1.52E-05	31.2%
	XO	31	2.84E-04	2.00E-05		26	2.90E-04	2.00E-05	
Alpha Activity Density (Bq/g)	SOR	29	11.339	5.562	-151.5%	26	12.310	6.186	-137.4%
	XO	31	4.055	0.825		26	4.778	0.919	
Beta Activity (Bq/filter)	SOR	29	5.69E-02	3.85E-03	-22.4%	26	5.94E-02	3.88E-03	-11.2%
	XO	31	5.08E-02	4.06E-03		26	5.61E-02	4.01E-03	
Beta Activity Concentration (Bq/m3)	SOR	29	7.53E-04	4.66E-05	-15.8%	26	7.71E-04	4.97E-05	-16.1%
	XO	31	6.95E-04	3.98E-05		26	7.10E-04	4.16E-05	
Beta Activity Density (Bq/g)	SOR	29	35.514	17.307	-180.6%	26	38.508	19.251	-166.2%
	XO	31	10.451	2.480		26	12.296	2.820	

RPD stands for Relative Percent Difference, see text for explanation. SOR stands for Sampler of Record, XO represents the Experimental/Occluded Probe

Table 11-8: Comparison of Trace Element Data: Experimental/Occluded Probe (XO) vs. Sampler of Record (SOR)

Element	Aluminum		Barium		Cerium	
Sampler	SOR	XO	SOR	XO	SOR	XO
Number of Samples	10	10	10	10	10	10
Mean (ng m^{-3})	117	75	2.53	2.54	0.169	0.151
Standard Error (ng m^{-3})	20	42	0.39	0.44	0.031	0.032
Relative Percent Difference	-32%		-0%		3%	
Element	**Lanthanum**		**Lead**		**Neodymium**	
Sampler	SOR	XO	SOR	XO	SOR	XO
Number of Samples	10	10	10	10	10	10
Mean (ng m^{-3})	0.097	0.084	1.71	1.46	0.062	0.054
Standard Error (ng m^{-3})	0.017	0.019	0.18	0.11	0.015	0.016
Relative Percent Difference	-10%		-11%		-10%	
Element	**Sodium**		**Thorium**		**Zinc**	
Sampler	SOR	XO	SOR	XO	SOR	XO
Number of Samples	10	10	3	2	10	10
Mean (ng m^{-3})	14394	18051	0.027	0.045	73.60	71.13
Standard Error (ng m^{-3})	2363	3220	0.005	0.002	7.96	8.08
Relative Percent Difference	14%		---		-2%	

Table 11-9: Summary Statistics and t-test Results for a Comparison of Aerosol Mass Concentrations on the Sampler of Record vs. Back-Up Filters

Mean Mass Concentration (Standard Deviation) μg m^{-3}		Mean Difference	Std Error
Sampler of Record	**Back-Up Sampler**		
86.45 (68.36)	86.02 (70.40)	0.43	1.81
Number of pairs	t-Ratio	DF	Prob* > |t|
260	0.238	259	0.812

*Average probability for obtaining a greater absolute paired t-value by chance alone for a difference between sample means of zero

Table 11-10: Summary Statistics and t-test Results for a Comparison of Gross Alpha Activities on the Sampler of Record vs. Back-Up Filters

Mean Gross Alpha Activity (Standard Deviation), Bq m^{-3}		Mean Difference	Std Error
Sampler of Record	**Back-Up Sampler**		
1.92×10^{-4} (1.52×10^{-4})	2.02×10^{-4} (1.27×10^{-4})	-9.34×10^{-6}	8.24×10^{-6}
Number of pairs	t-Ratio	DF	Prob* > |t|
72	-1.13	71	0.26

*Average probability as defined in footnote to Table 11-9

Table 11-11: Summary Statistics and t-test Results for a Comparison of Gross Beta Activities on the Sampler of Record vs. Back-Up Filters

Mean Gross Beta Activity (Standard Deviation), Bq m^{-3}		Mean Difference	Std Error
Sampler of Record	**Back-Up Sampler**		
7.10×10^{-4} (4.33×10^{-4})	6.79×10^{-4} (4.28×10^{-4})	3.11×10^{-5}	1.03×10^{-5}
Number of pairs	t-Ratio	DF	Prob* > |t|
72	3.02	71	0.0035

*Average probability as defined in footnote to Table A2.1

Table 11-12: Trace Element Concentrations in Filter Samples (mg per filter) from Station A

Element	Mean Mass in Weekly Composite		Difference between Means	RPD[3]	N-Pairs	Correlation	t-Ratio	Prob > |t|[4]
	SOR[1]	BUS[2]						
Al	284	330	-46	-15%	13	0.815	-2.35	0.037
Ba	3.67	3.60	0.07	2%	13	0.919	-0.37	0.721
Ca	3769	4600	-831	-20%	13	0.768	-2.16	0.052
Ce	0.373	0.333	0.04	11%	13	0.911	1.43	0.177
Cr	40.7	53.8	-13.2	-28%	9	0.835	-2.02	0.078
Cu	13.5	17.5	-4	-26%	10	0.658	-1.78	0.111
Dy	0.024	0.029	-0.005	-19%	8	0.898	-3.60	0.009
Fe	313	519	-206	-50%	13	0.832	-3.86	0.002
Gd	0.033	0.029	0.004	20%	12	0.714	0.89	0.391
K	415	469	-54	-12%	13	0.538	-1.40	0.187
La	0.172	0.179	-0.007	-4%	13	0.915	-0.63	0.538
Mg	811	1330	-519	-48%	13	0.469	-2.89	0.014
Mn	9.26	12.3	-3.04	-28%	13	0.826	-2.93	0.012
Mo	3.50	5.37	-1.87	-42%	13	0.791	-2.64	0.022
Na	26955	30966	-4011	-14%	13	0.859	-2.19	0.049
Nd	0.144	0.136	0.007	6%	13	0.871	0.65	0.529
Ni	16.8	25.0	-8.2	-39%	13	0.847	-2.43	0.032
Pb	2.54	2.77	-0.23	-9%	13	0.811	-1.42	0.182
Pr	0.042	0.040	0.002	7%	13	0.930	-0.92	0.376
Sb	1.76	1.05	0.71	51%	13	0.639	3.07	0.010
Si	1024	1217	-193	-17%	8	0.837	-2.51	0.040
Sr	34.9	49.2	-14.3	-34%	13	0.389	-2.95	0.012
Th	0.051	0.052	-0.002	-2%	13	0.921	-0.47	0.646
Ti	17.1	16.7	0.33	2%	6	0.940	0.30	0.777
U	0.047	0.050	-0.003	-6%	5	0.827	-0.64	0.557
Zn	44.6	51.3	-6.7	-14%	13	0.893	-1.67	0.120
Average				**-13%**		**0.794**	**-1.36**	**0.219**

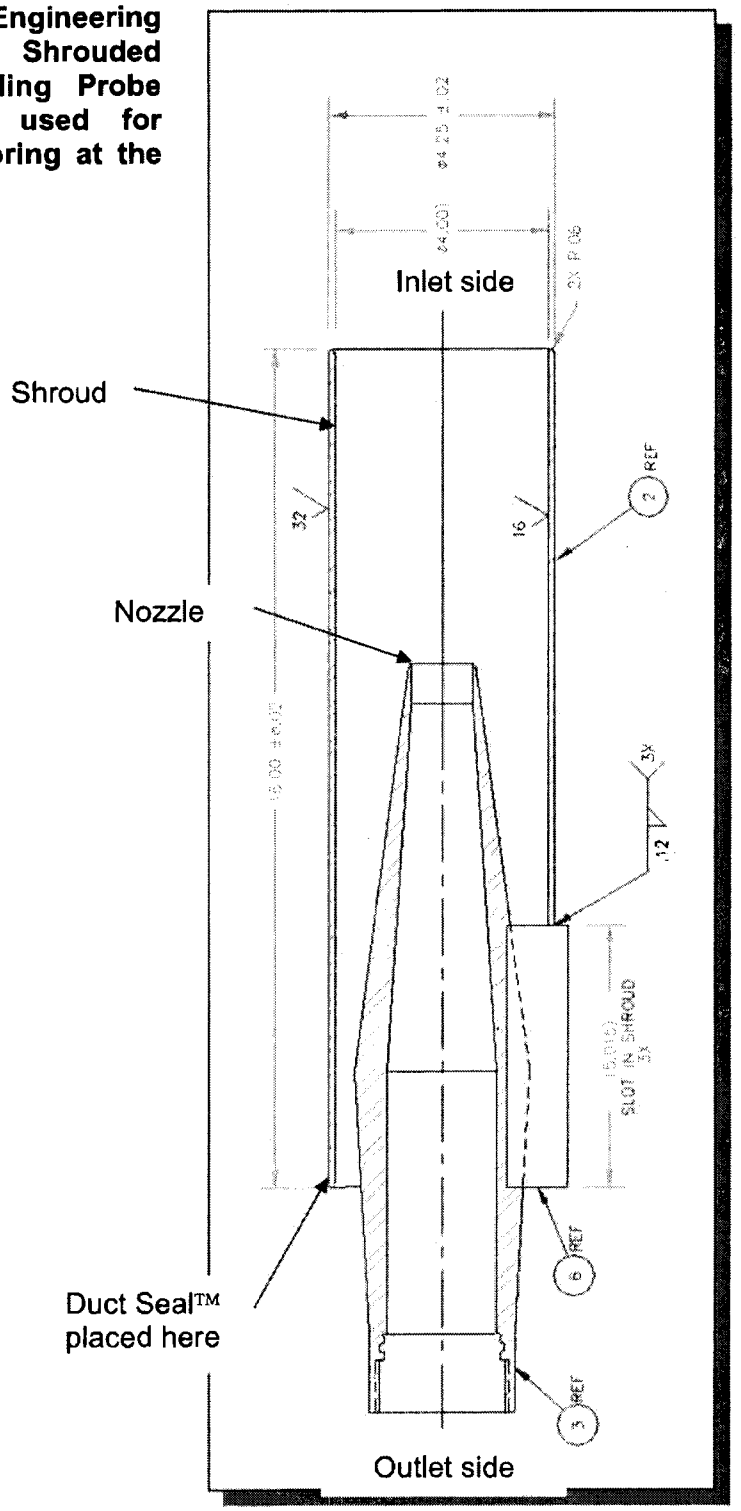
1SOR stands for Sample of Record

2BU stands for Back Up

3RPD stands for Relative Percent Difference

4Average probability for a obtaining a greater absolute paired t-value by chance alone for a hypothesized difference of zero between sample means

Figure 11.1: Engineering Drawing of a Shrouded Aerosol Sampling Probe of the Type used for Effluent Monitoring at the WIPP



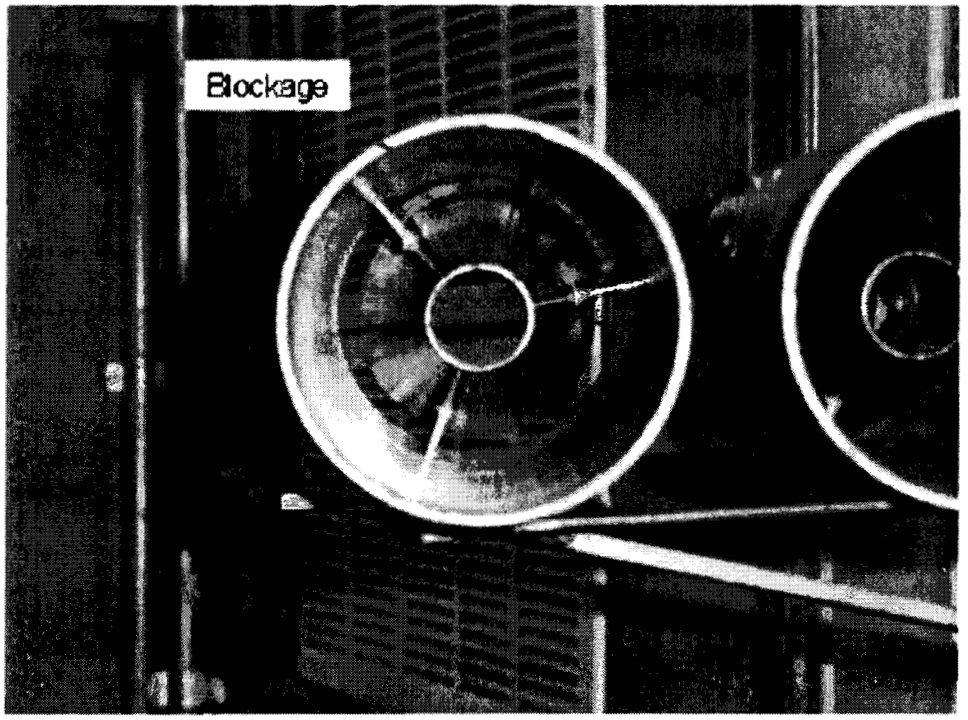


Figure 11.2: Probe One-third Blocked, Prior to Deployment

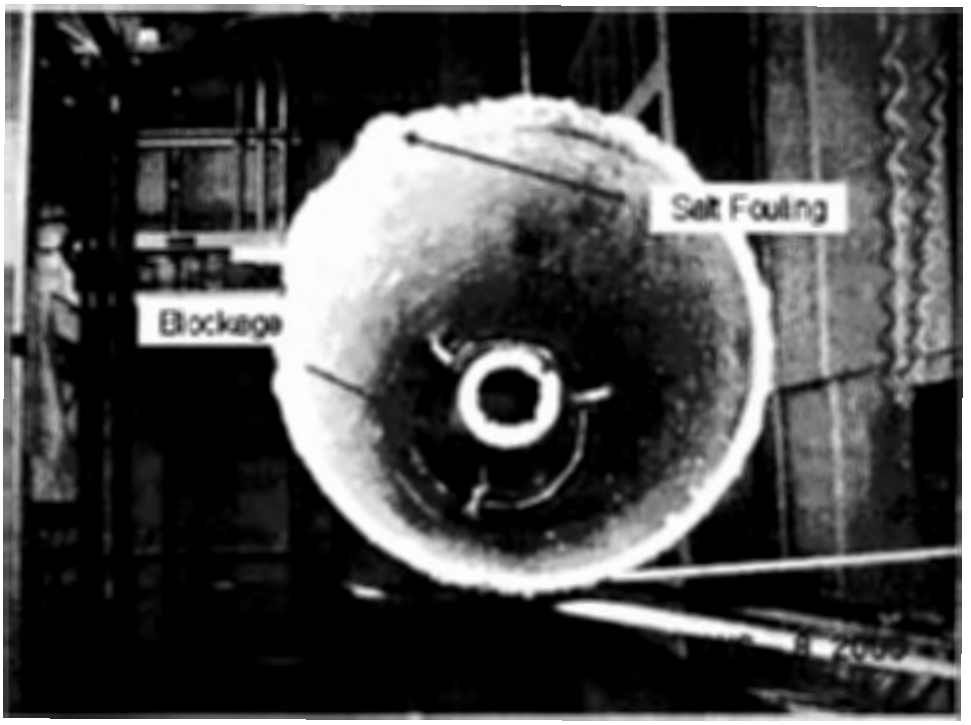


Figure 11.3: Probe One-third Blocked, After Deployment

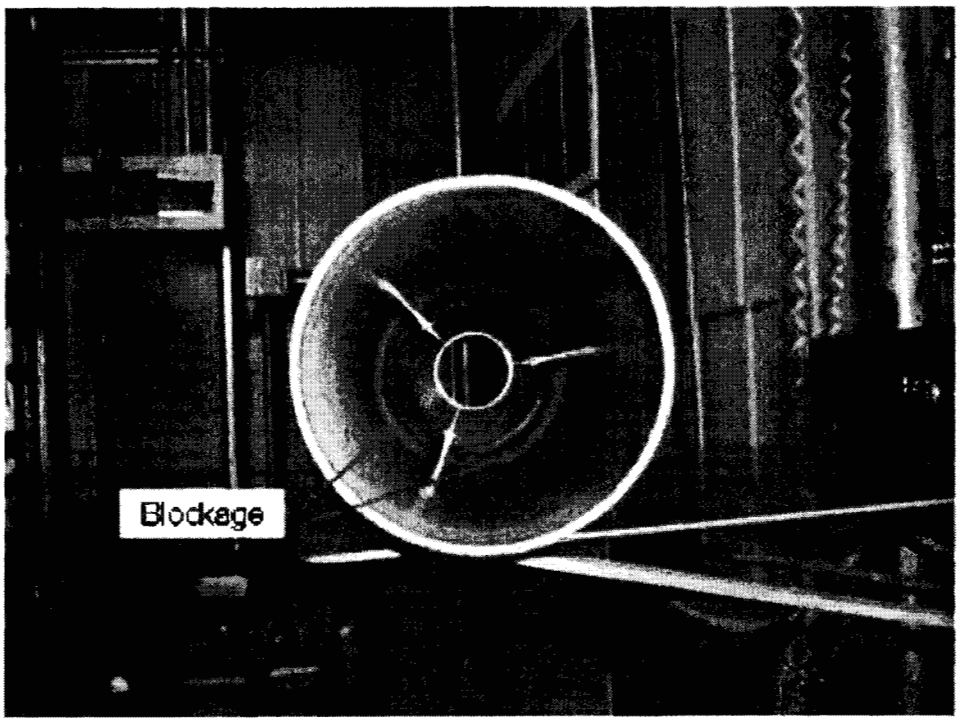


Figure 11.4: Probe Two-thirds Blocked, Prior to Deployment

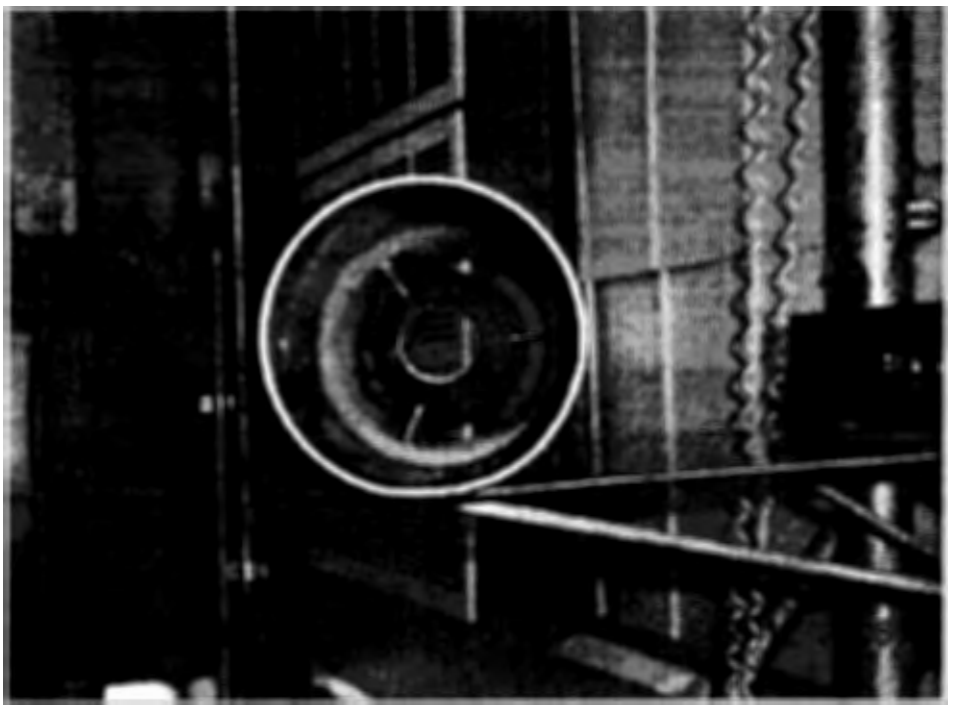


Figure 11.5: Unblocked (Control) Probe as Recovered September 12, 2005

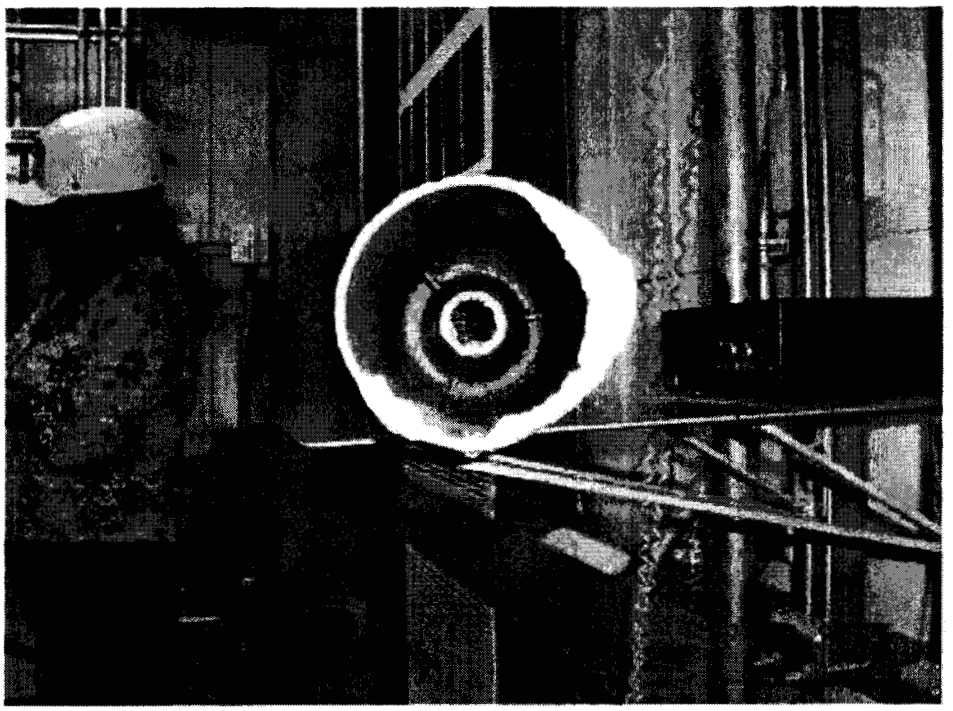


Figure 11.6: Probe Two-thirds Blocked, as Recovered

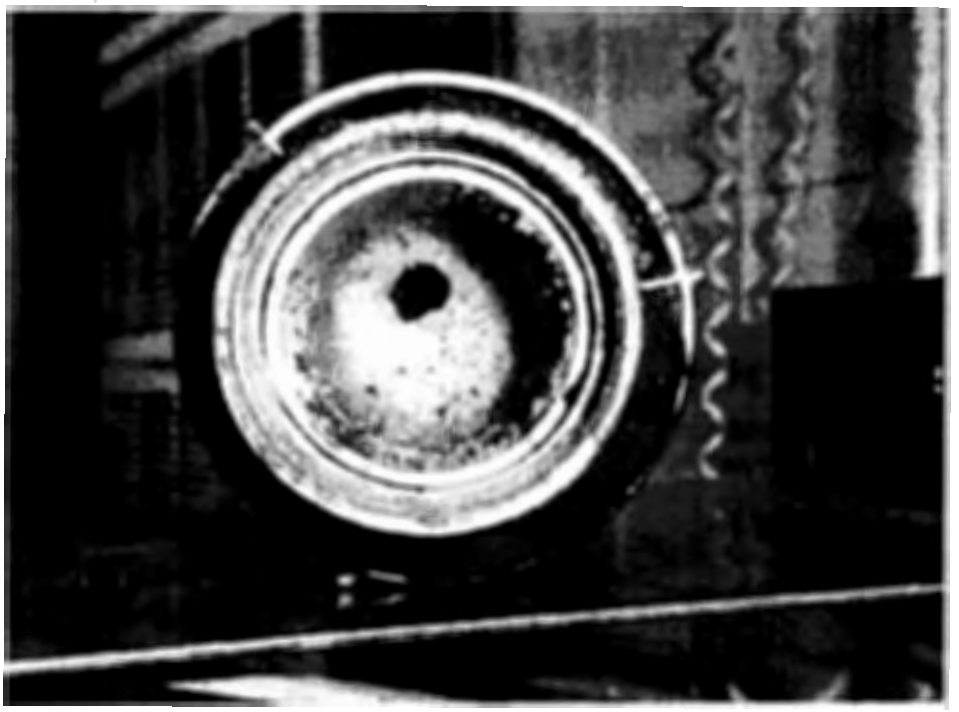


Figure 11.7: Probe Two-thirds Blocked, as Recovered (viewed from outlet side)

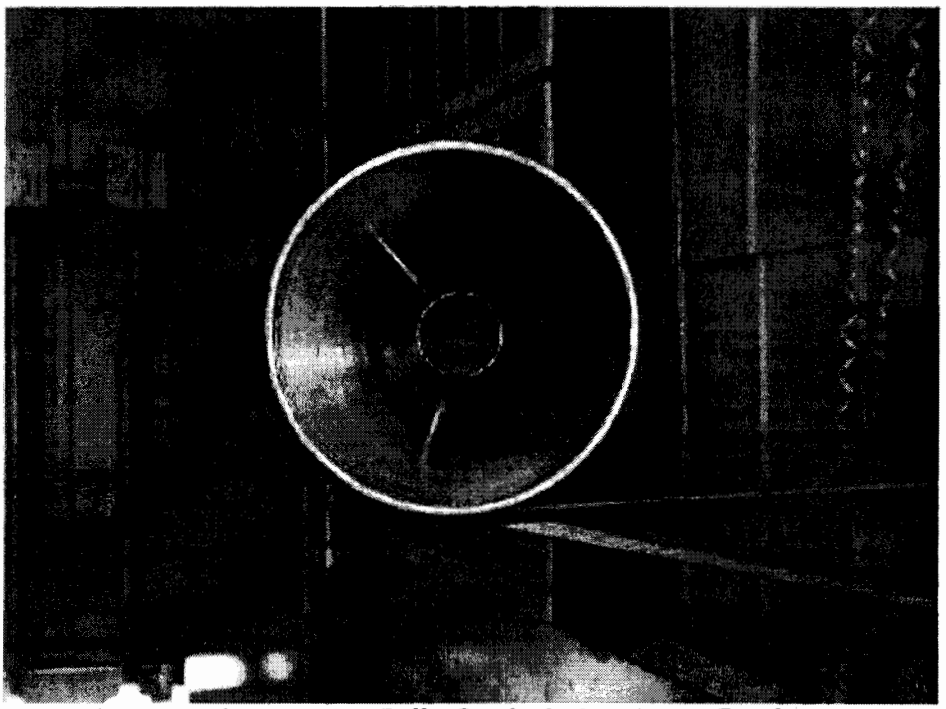


Figure 11.8: Probe Fully Occluded, Prior to Deployment

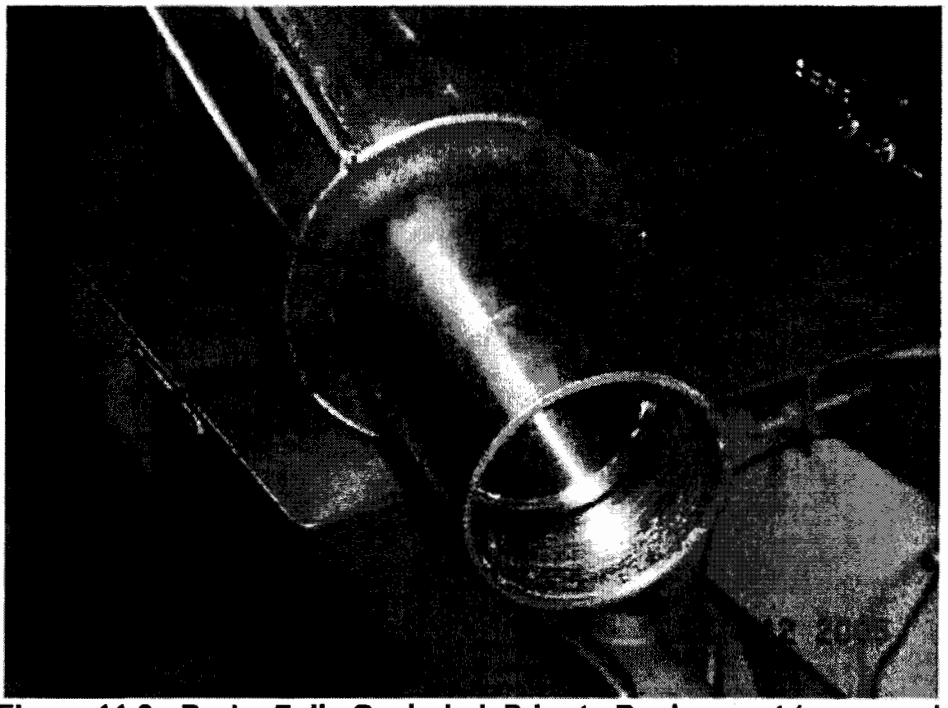


Figure 11.9: Probe Fully Occluded, Prior to Deployment (reverse view)

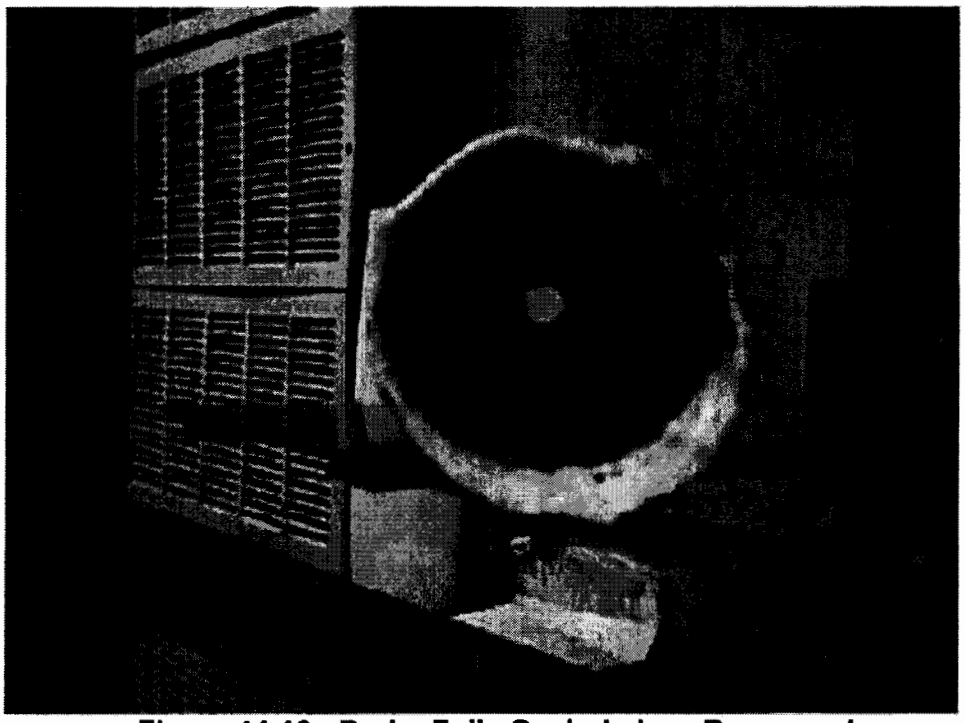


Figure 11.10: Probe Fully Occluded, as Recovered

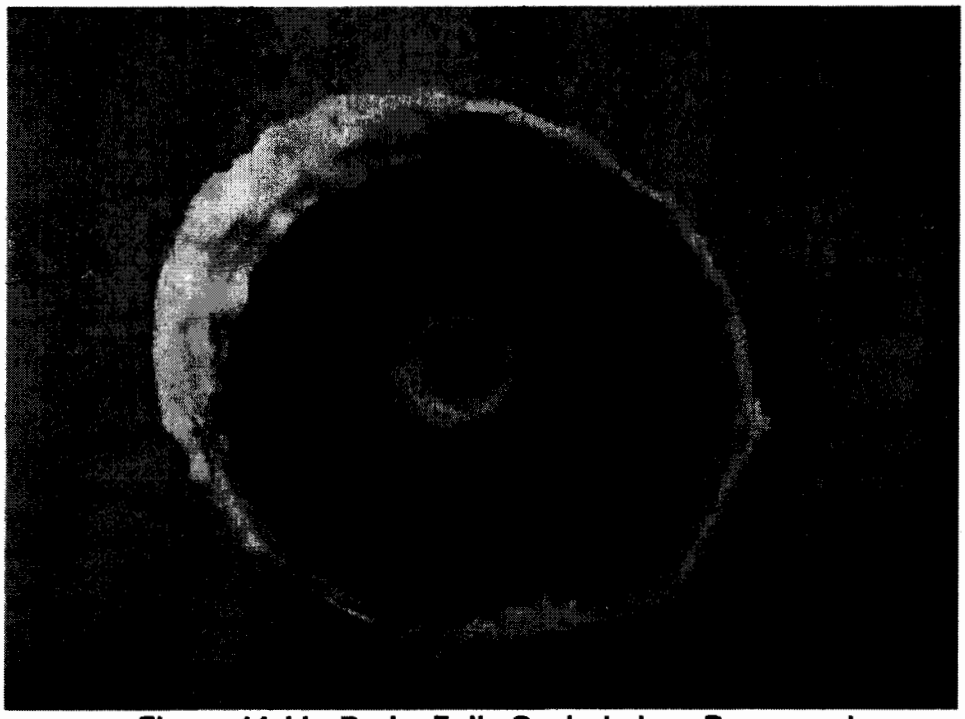


Figure 11.11: Probe Fully Occluded, as Recovered

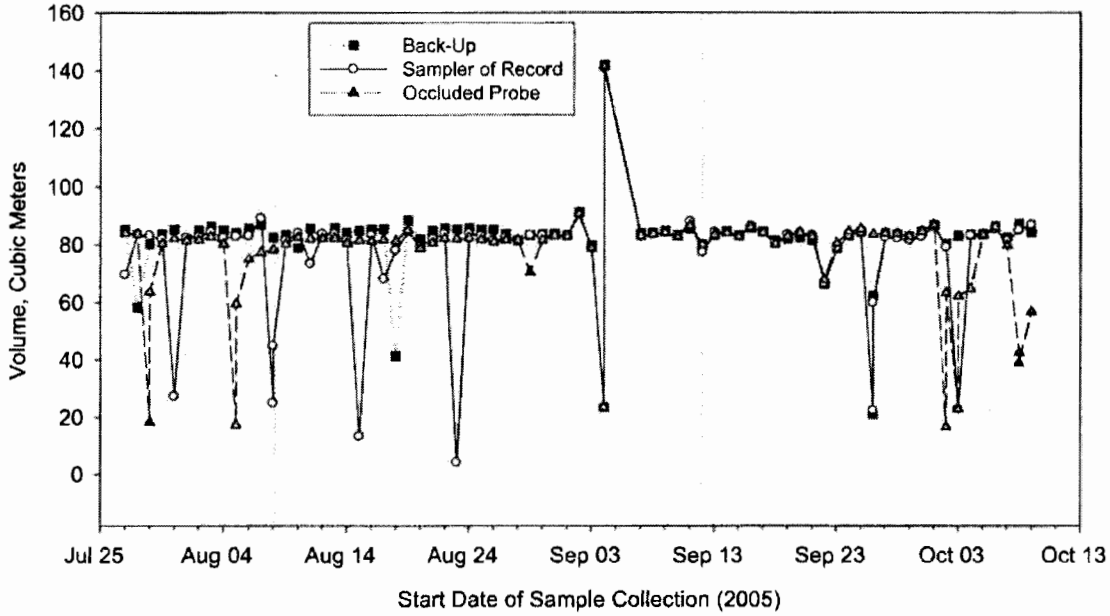


Figure 11.12: Sample volumes for all samples. Dotted vertical lines separate phases of the study: (1) 1/3 occluded 7/11-8/8, (2) 2/3 occluded 8/8-9/12, and (3) 3/3 occluded 9/12-10/10.

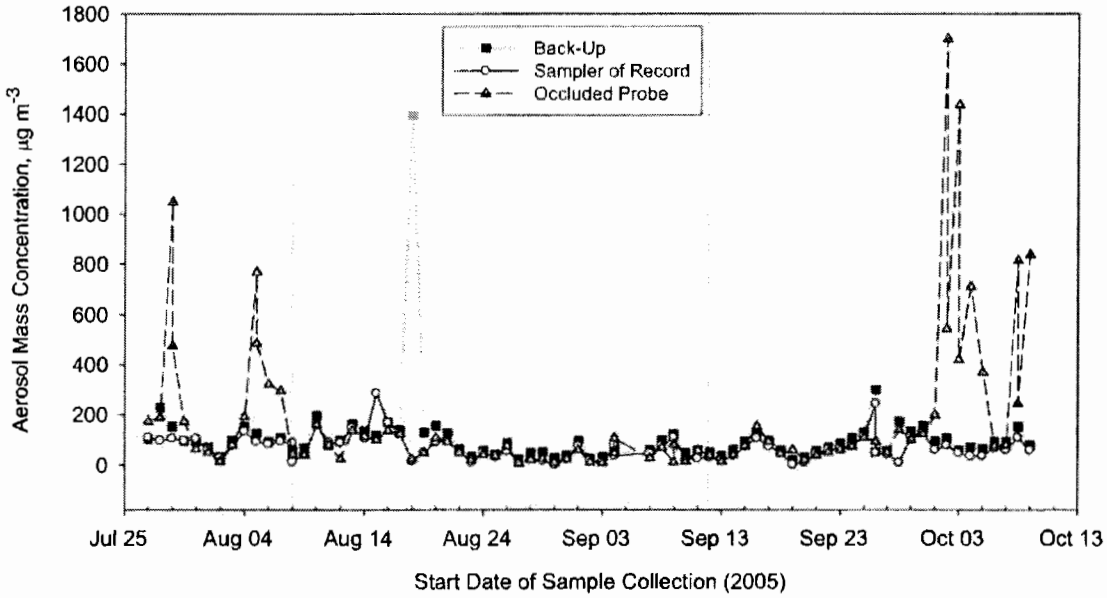


Figure 11.13: Mass concentrations for all samples. Dotted vertical lines separate phases of the study: (1) 1/3 occluded 7/11-8/8, (2) 2/3 occluded 8/8-9/12, and (3) 3/3 occluded 9/12-10/10.

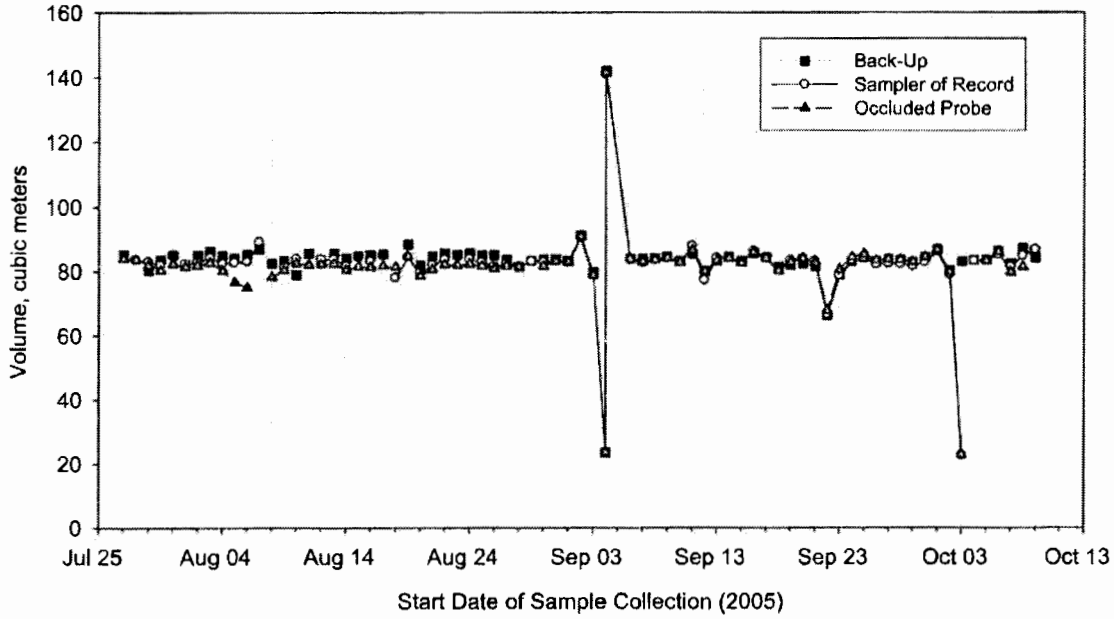


Figure 11.14: Sample volumes for matched samples. Dotted vertical lines separate phases of the study: (1) 1/3 occluded 7/11-8/8, (2) 2/3 occluded 8/8-9/12, and (3) 3/3 occluded 9/12-10/10.

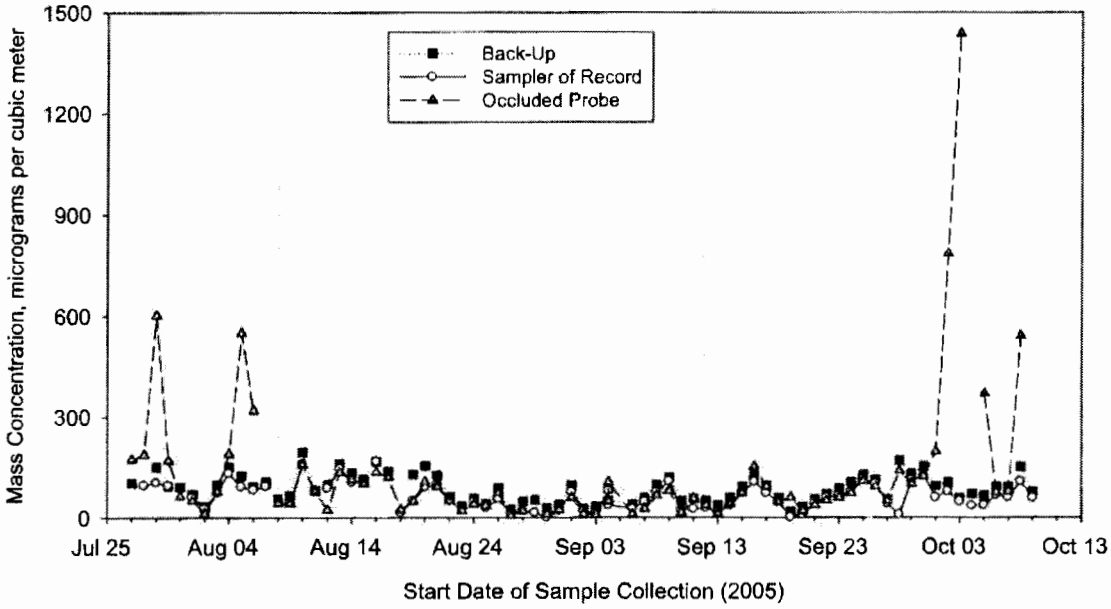


Figure 11.15: Mass concentrations for matched samples. Dotted vertical lines separate phases of the study: (1) 1/3 occluded 7/11-8/8, (2) 2/3 occluded 8/8-9/12, and (3) 3/3 occluded 9/12-10/10.

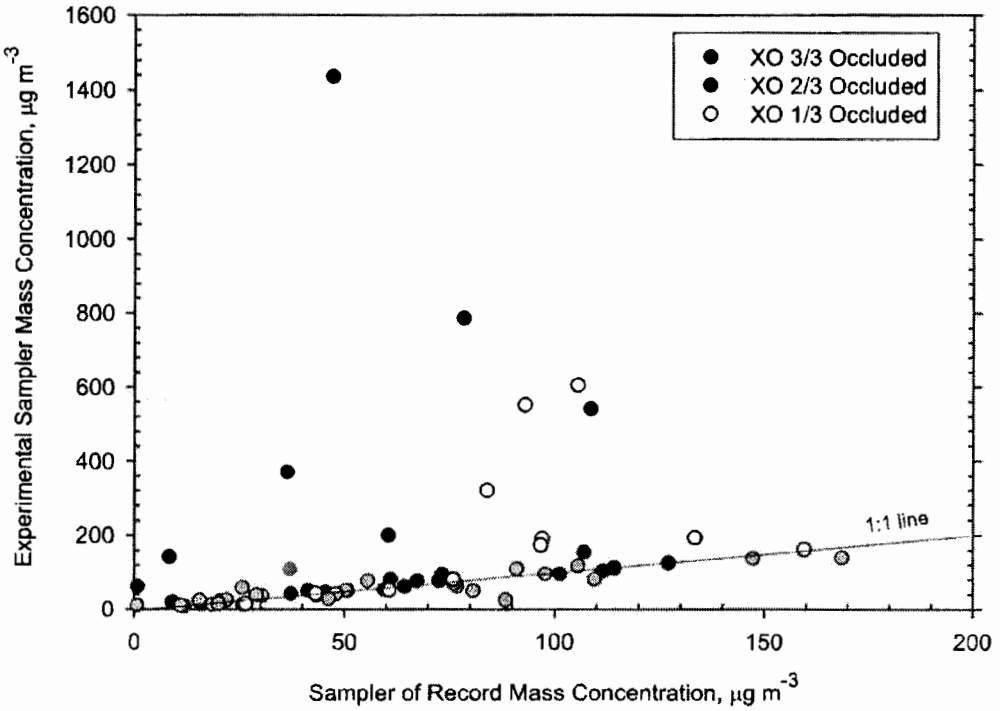


Figure 11.16: Mass concentrations for matched samples from the Experimental/Occluded Sampler vs. the Sampler of Record.

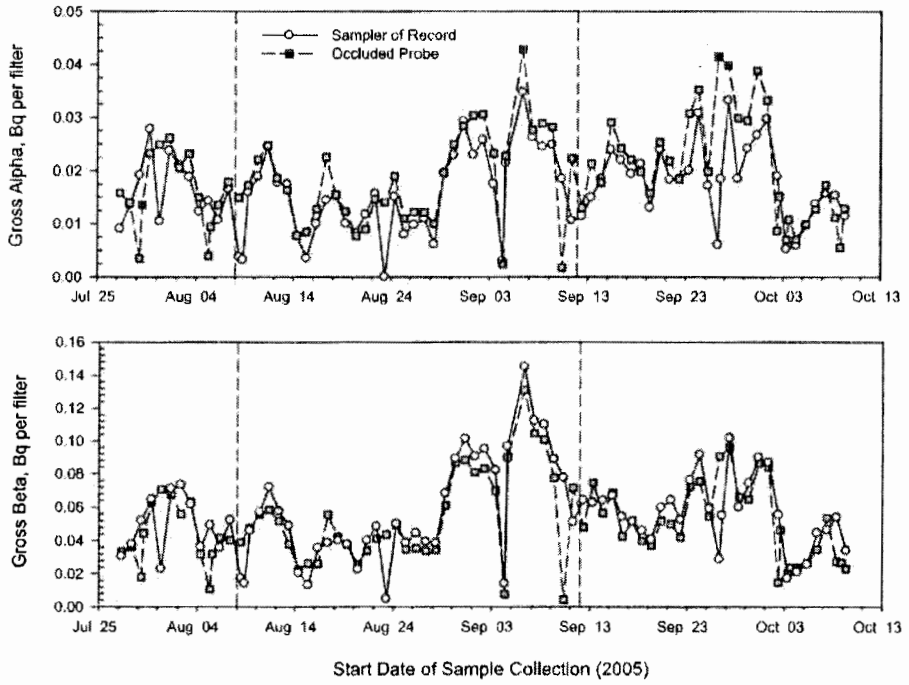


Figure 11.17: Gross alpha and beta activities for all sample filters. Dotted vertical lines separate phases of the study: (1) 1/3 occluded 7/11-8/8, (2) 2/3 occluded 8/8-9/12, and (3) 3/3 occluded 9/12-10/10.

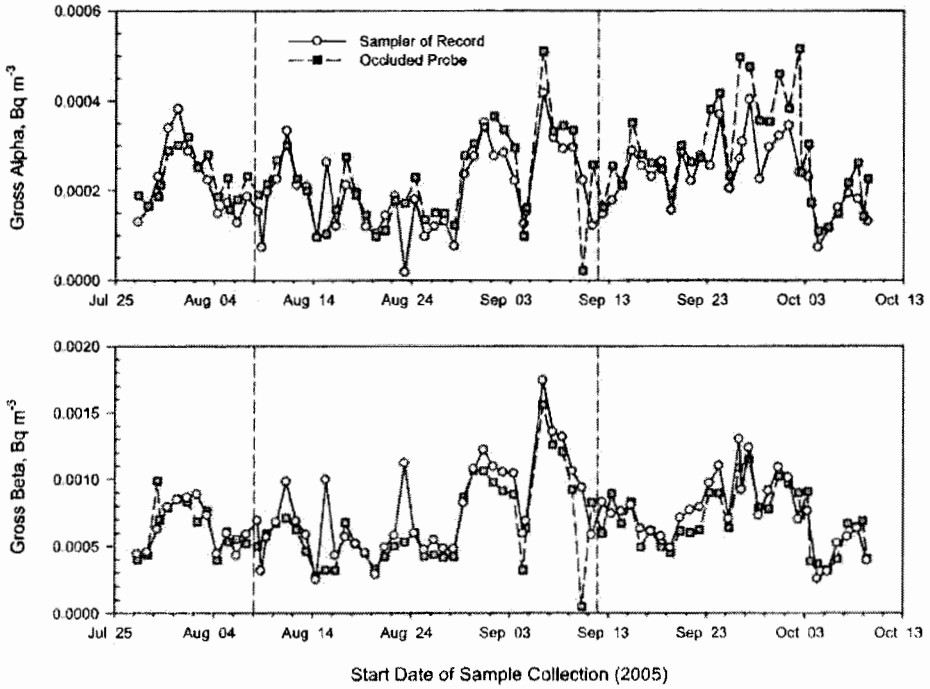


Figure 11.18: Gross alpha and beta activity concentrations for all sample filters. Dotted vertical lines separate phases of the study: (1) 1/3 occluded 7/11-8/8, (2) 2/3 occluded 8/8-9/12, and (3) 3/3 occluded 9/12-10/10.

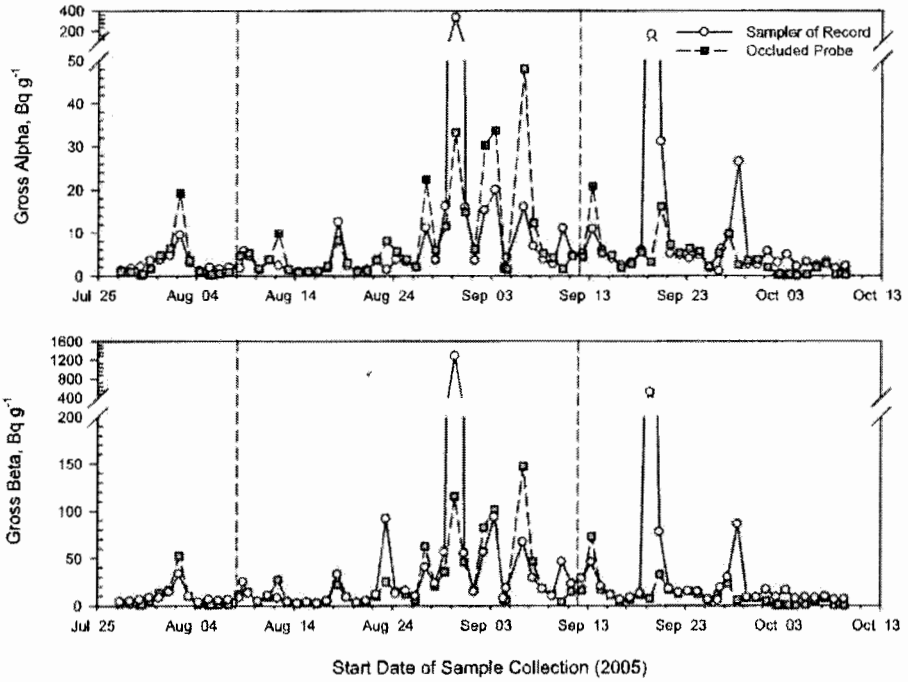


Figure 11.19: Gross alpha and beta activity densities for all sample filters. Dotted vertical lines separate phases of the study: (1) 1/3 occluded 7/11-8/8, (2) 2/3 occluded 8/8-9/12, and (3) 3/3 occluded 9/12-10/10.

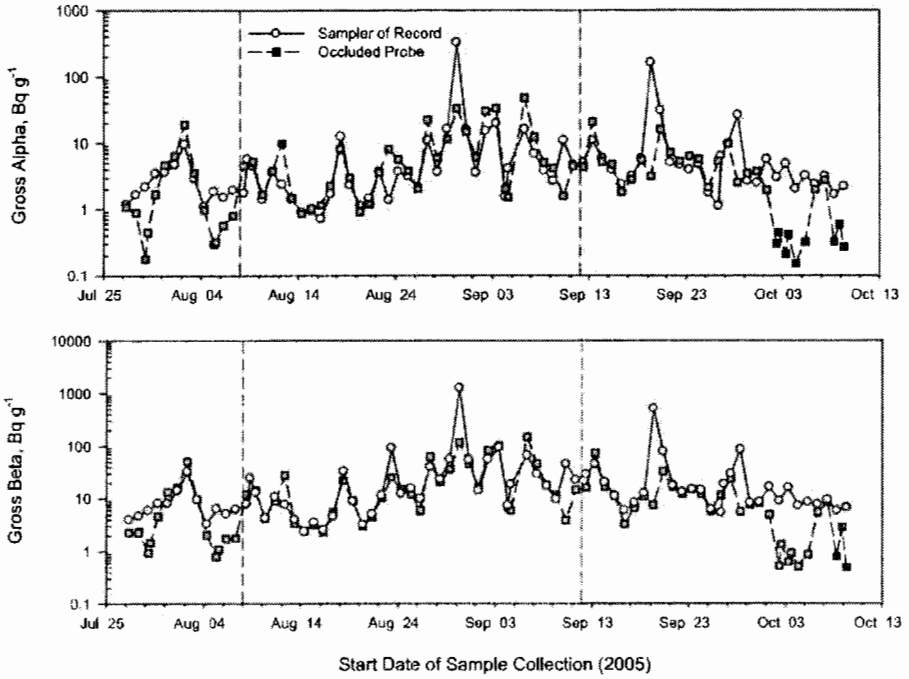


Figure 11.20: Gross alpha and beta activity densities plotted on a logarithmic scale for all sample filters. Dotted vertical lines separate phases of the study: (1) 1/3 occluded 7/11-8/8, (2) 2/3 occluded 8/8-9/12, and (3) 3/3 occluded 9/12-10/10.

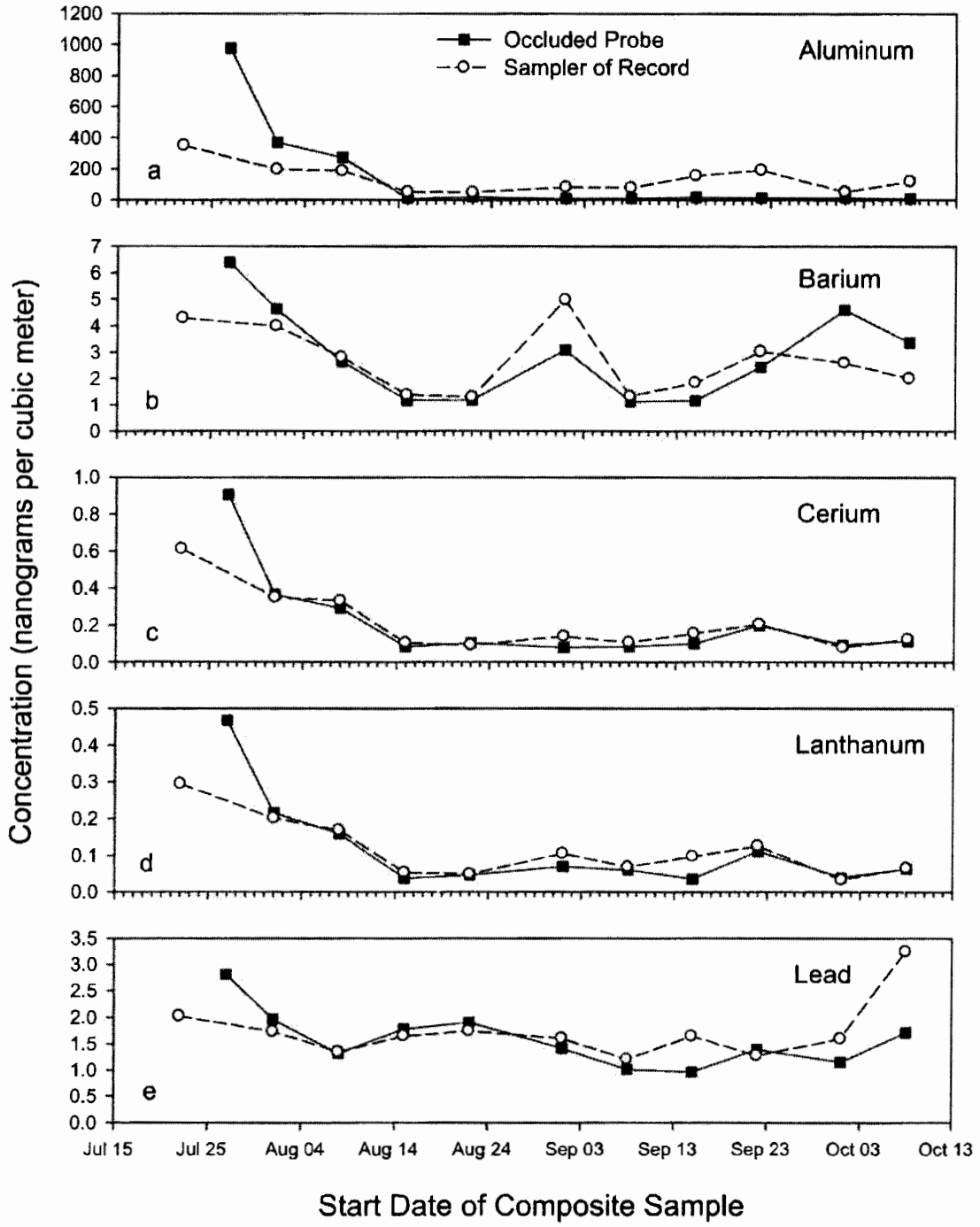


Figure 11.21 (a-e): Timeseries Plots of Group A Trace Elements (see text for explanation of groups)

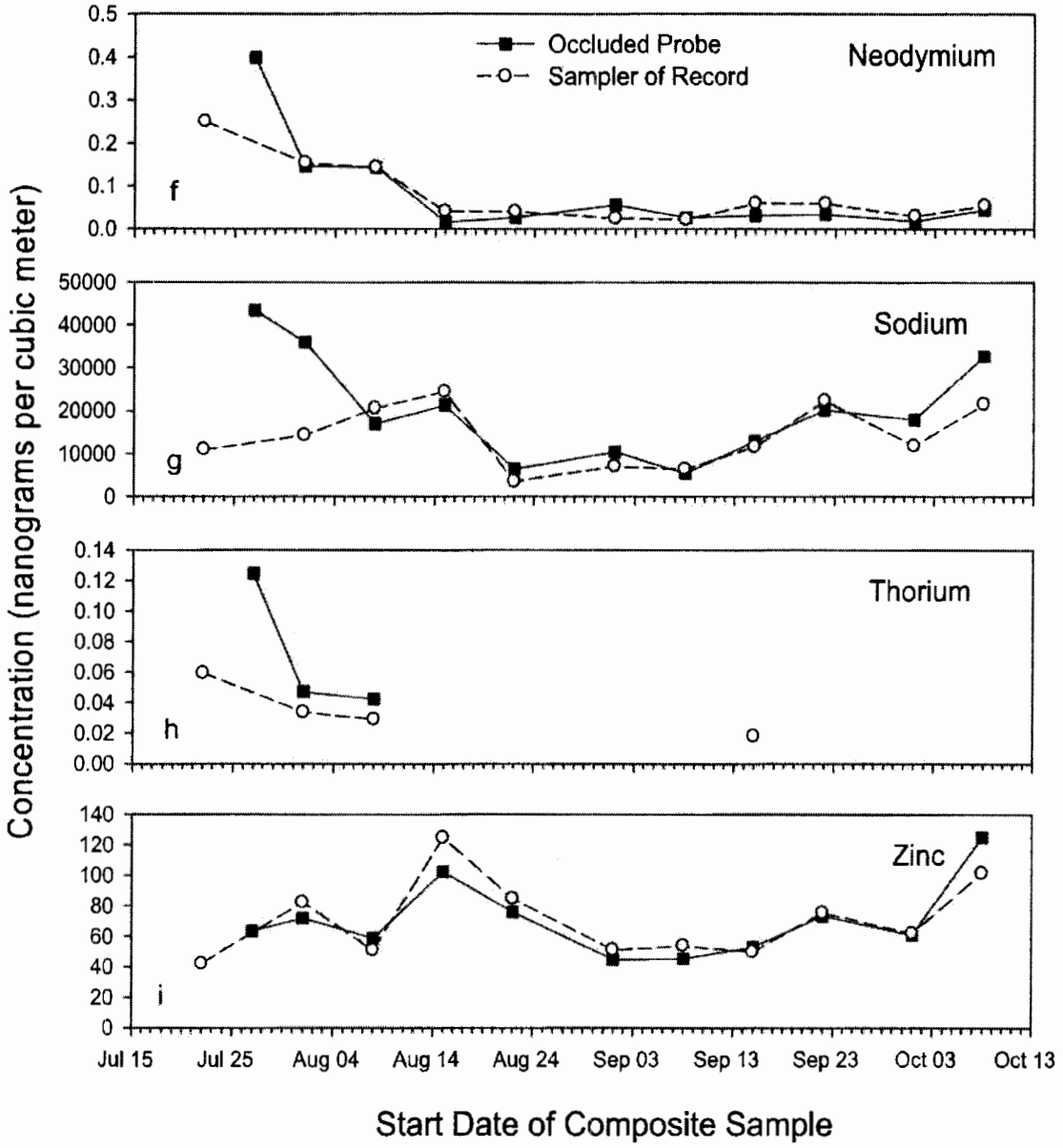


Figure 11.21 (f-i): Timeseries Plots of Group A Trace Elements (see text for explanation of groups)

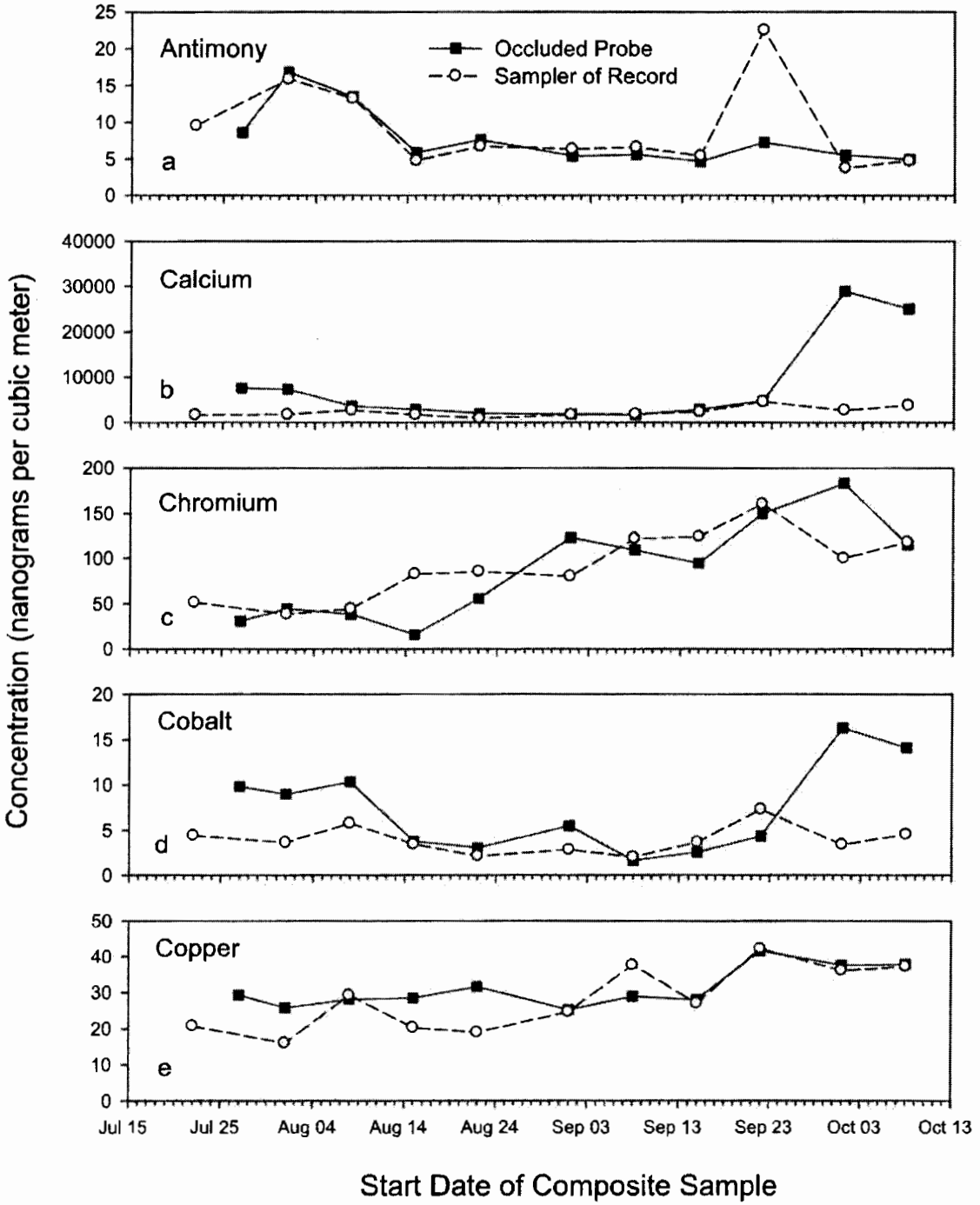


Figure 11.22 (a-e): Timeseries Plots of Group B Trace Elements (see text for explanation of groups)

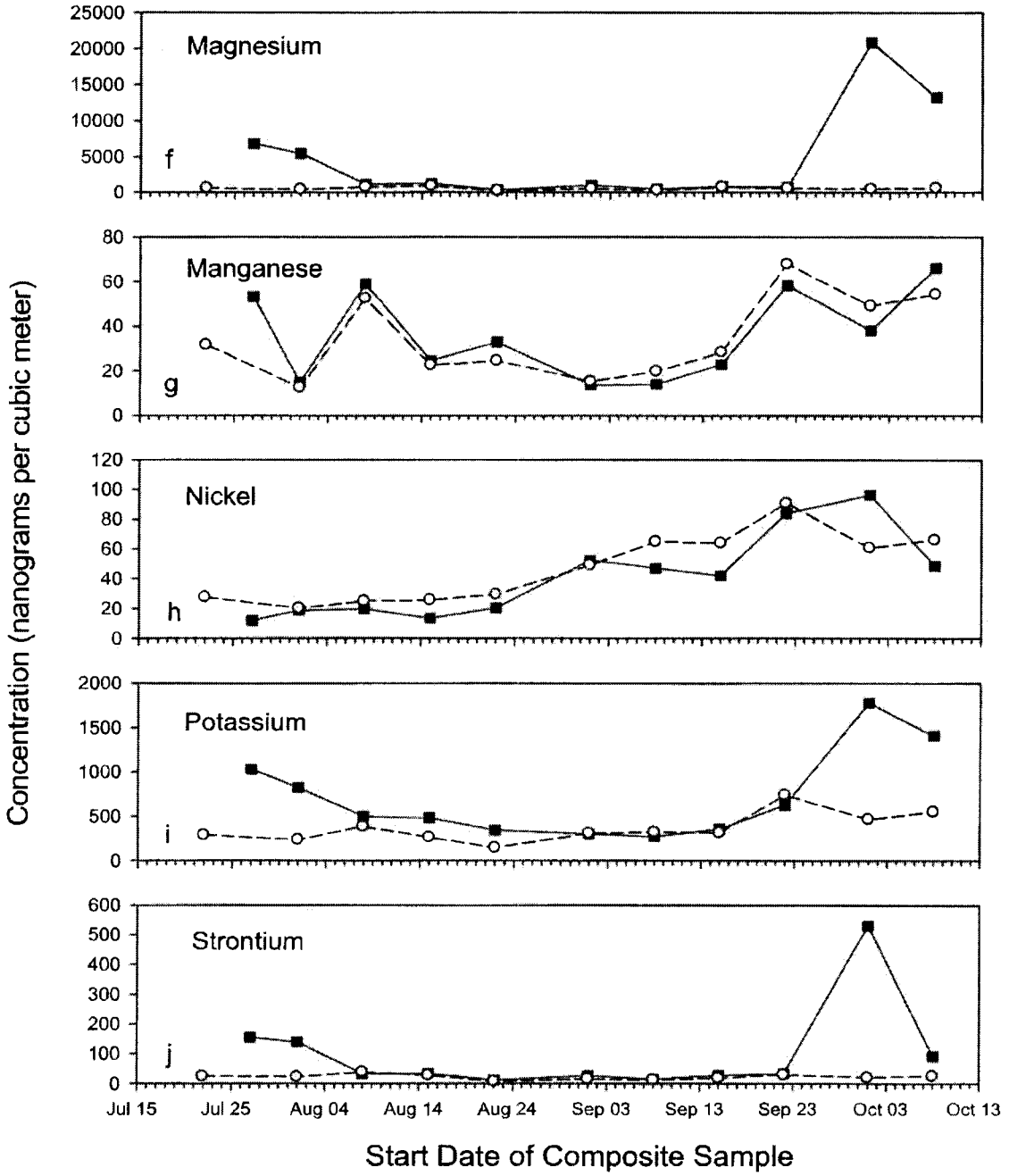


Figure 11.22 (f-j): Timeseries Plots of Group B Trace Elements (see text for explanation of groups)

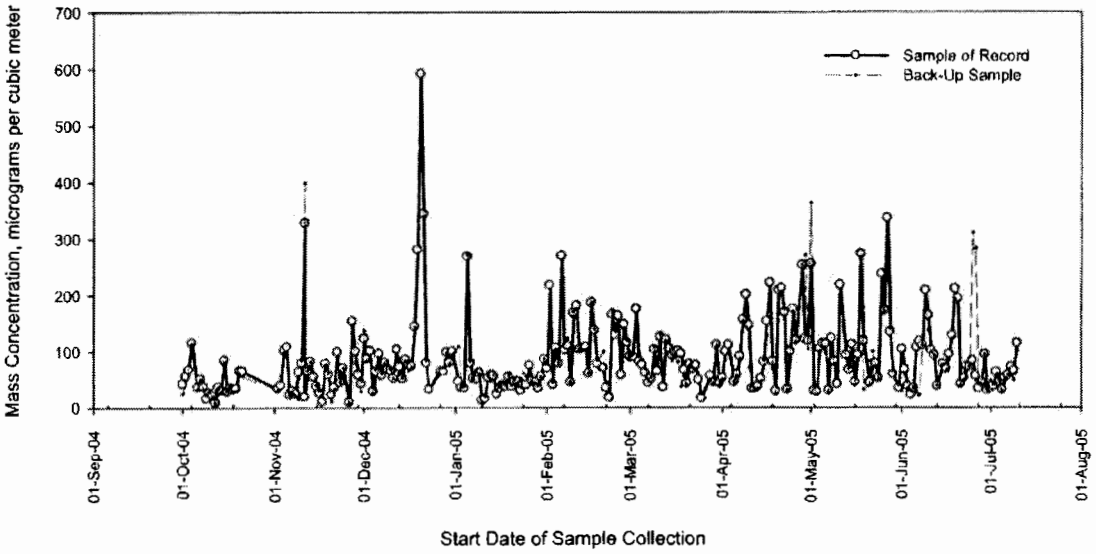


Figure 11.23: Timeseries Plot of Mass Concentrations vs. Time for the Sampler of Record and Back-up Sampler at Station A

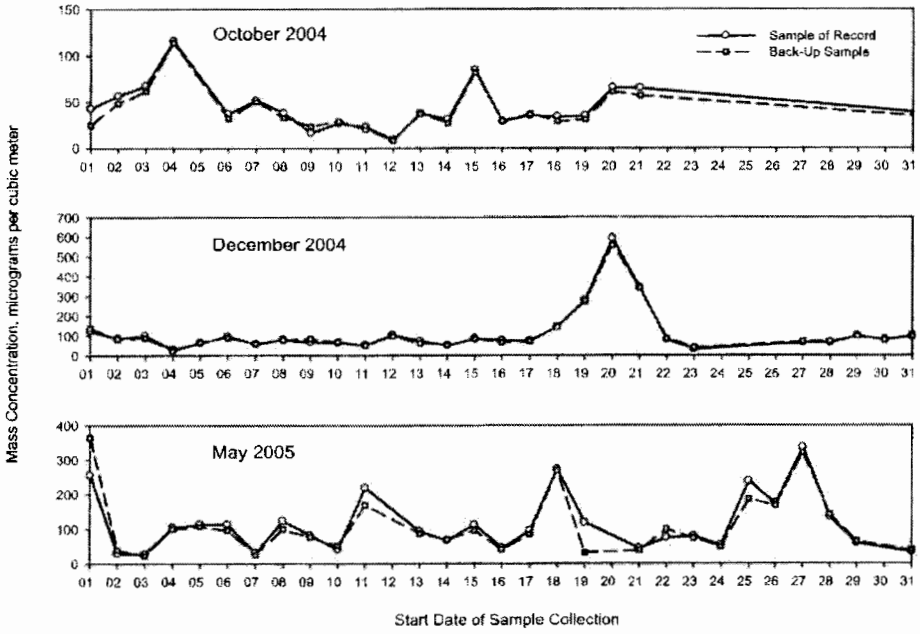


Figure 11.24 (a-c): Selected Monthly Plots of Mass Concentrations vs. Time for the Sampler of Record and Back-Up Sampler at Station A: (a) October 2004, (b) December 2004, and (c) May 2005.

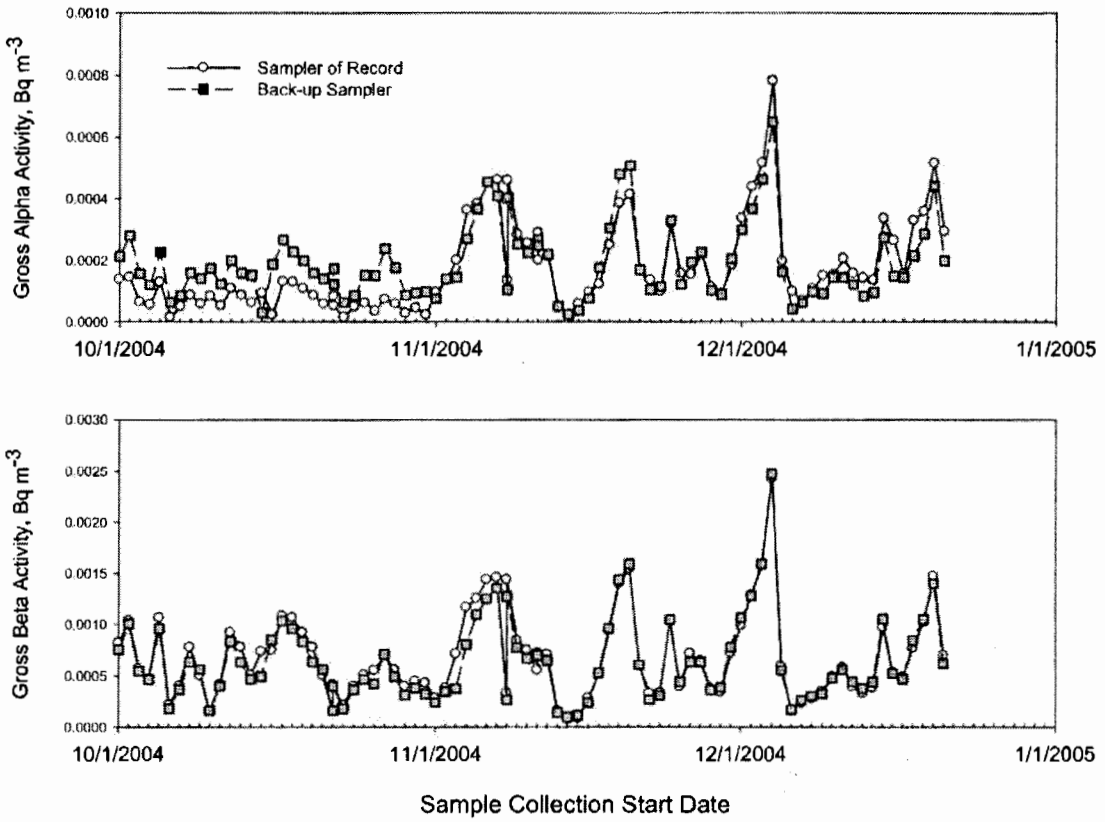
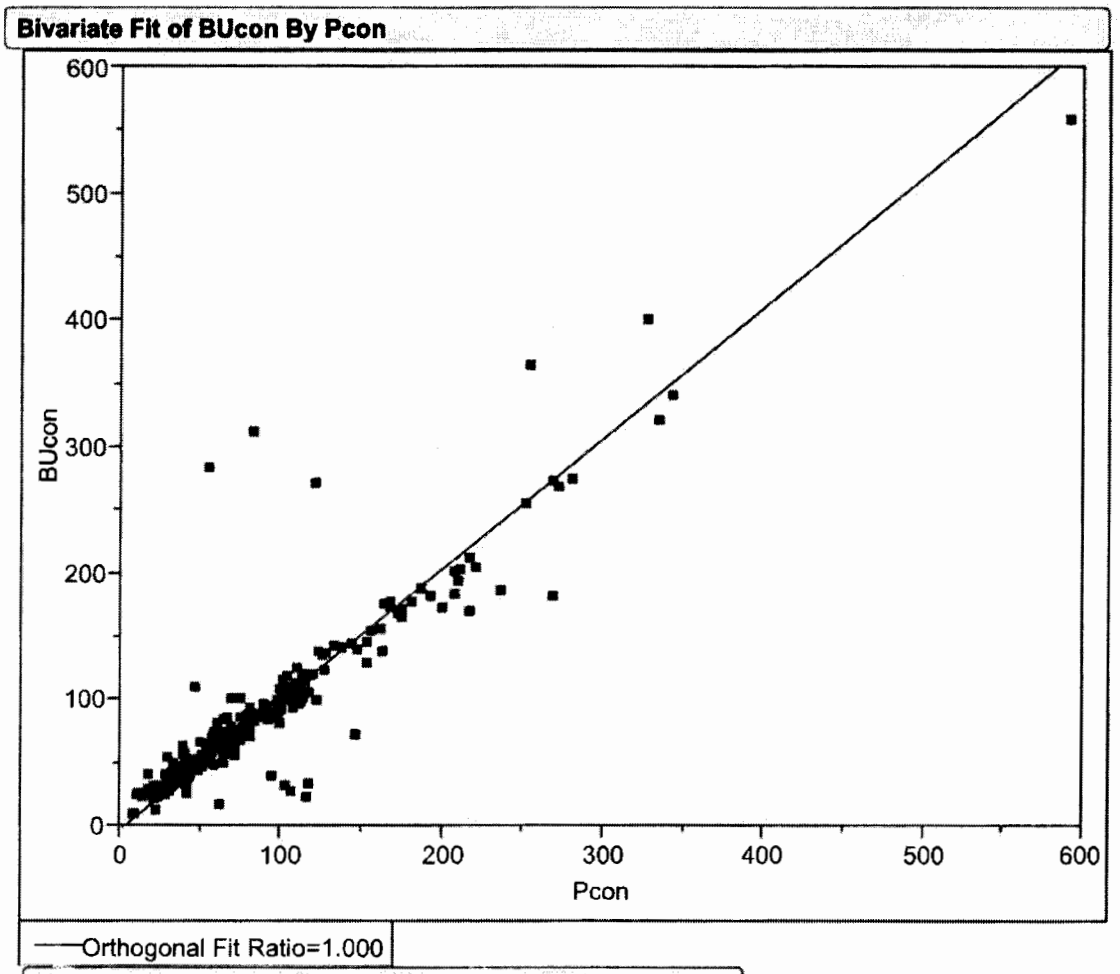


Figure 11.25 (a-b): Timeseries plots for the Sampler of Record and Back-Up Sampler at Station A: (a) gross alpha activity (b) gross beta activity.

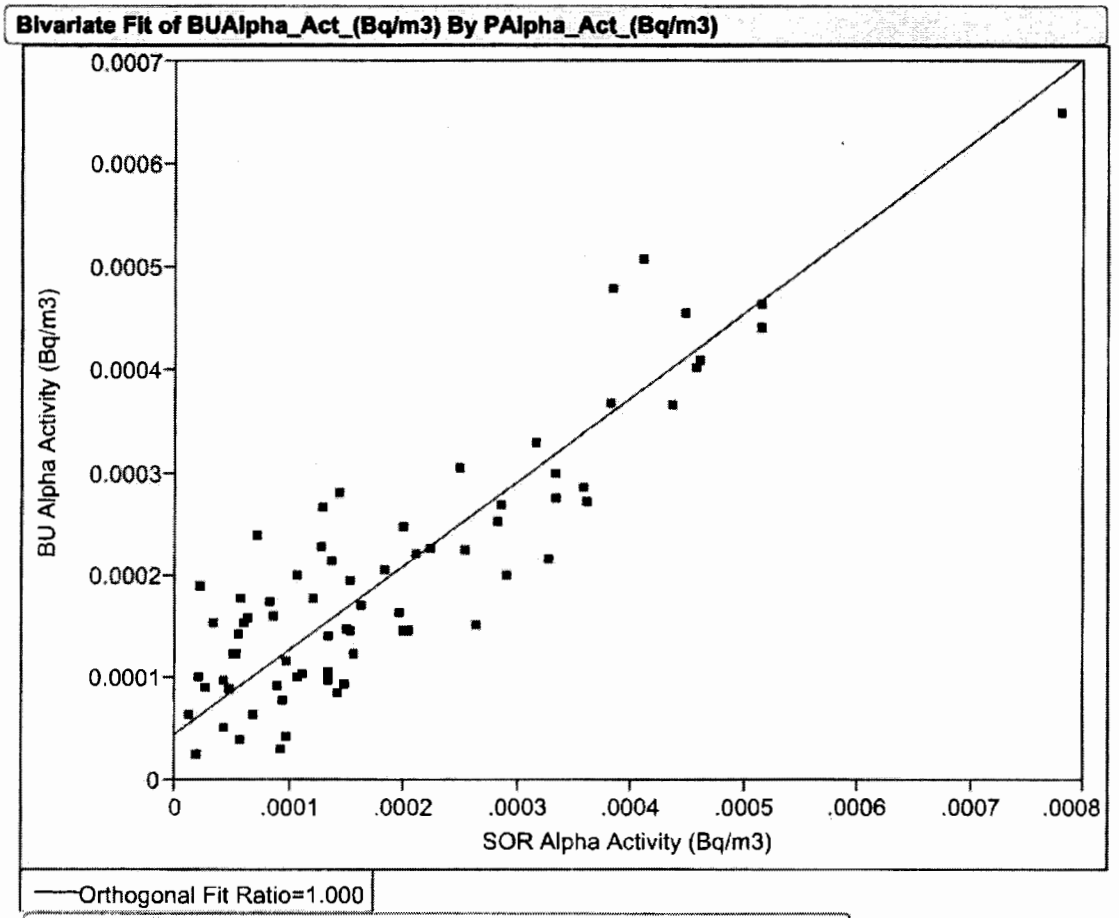


Orthogonal Regression

Variable	Mean	Std Dev	Variance Ratio	Correlation
Pcon	86.44857	68.36458	1	0.9120
BUcon	86.01862	70.39891		

Intercept	Slope	LowerCL	UpperCL	Alpha
-3.25445	1.032673	0.977276	1.091317	0.05000

Figure 11.26: Bivariate Fit of Back-Up Filter versus Primary Filter Mass Concentrations

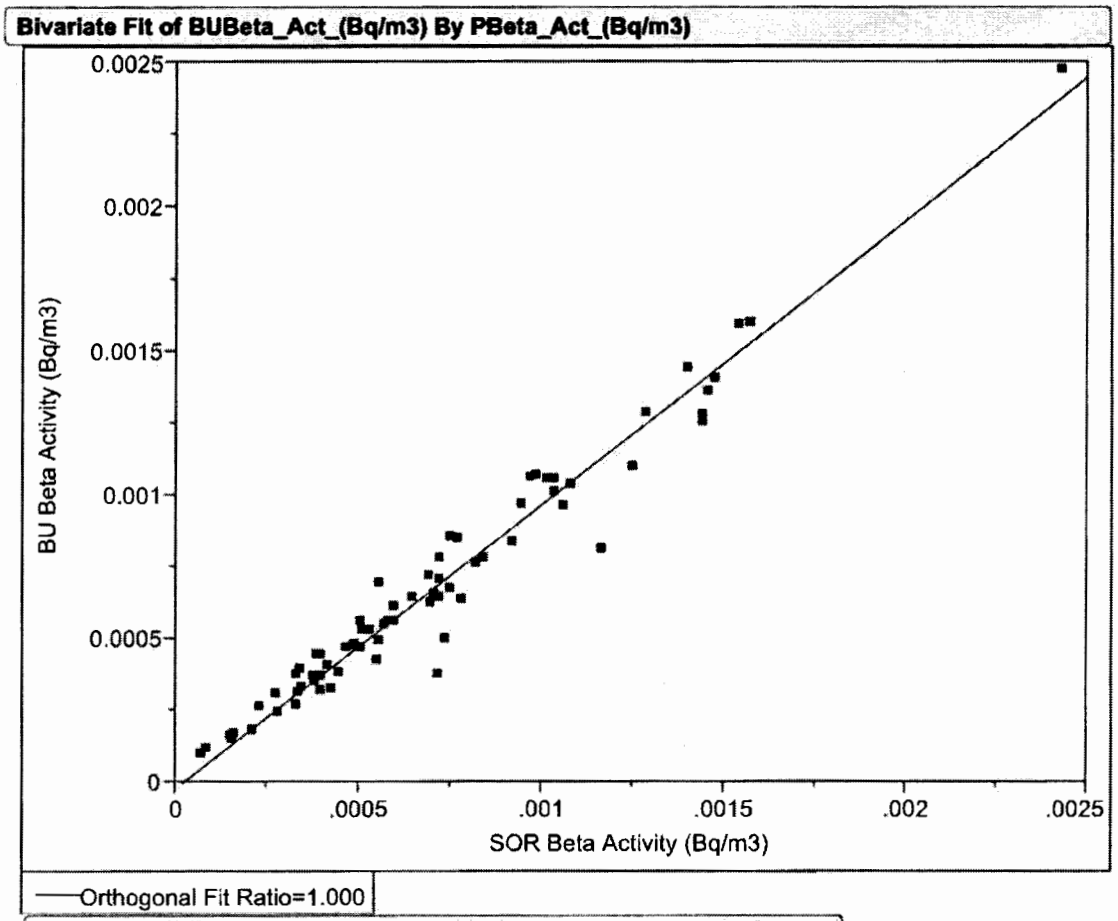


Orthogonal Regression

Variable	Mean	Std Dev	Variance Ratio	Correlation
PAlpha_Act_(Bq/m3)	0.000192	0.000152	1	0.8893
BUAlpha_Act_(Bq/m3)	0.000202	0.000127		

Intercept	Slope	LowerCL	UpperCL	Alpha
0.000044	0.820488	0.724326	0.926664	0.05000

Figure 11.27: Bivariate Fit of Back-Up Filter versus Primary Filter Gross Alpha Activities



Orthogonal Regression

Variable	Mean	Std Dev	Variance Ratio	Correlation
PBeta_Act_(Bq/m3)	0.00071	0.000433	1	0.9795
BUBeta_Act_(Bq/m3)	0.000679	0.000428		

Intercept	Slope	LowerCL	UpperCL	Alpha
-0.00002	0.986523	0.93925	1.036141	0.05000

Figure 11.28: Bivariate Fit of Back-Up Filter versus Primary Filter Gross Beta Activities