

Title ***Contaminant Concentrations
in Conifer Tree Bark and
Wood Following the Cerro
Grande Fire***

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Contaminant Concentrations in Conifer Tree Bark and Wood Following the Cerro Grande Fire

G.J. Gonzales, P.R. Fresquez, and C.M. Bare

Abstract

After the Cerro Grande Fire of 2000, conifer trees in Mortandad Canyon within the Los Alamos National Laboratory (LANL) were felled as a hazard reduction effort. Several potential disposal options and uses of those trees and of trees that continue to be thinned throughout LANL have been identified. There was interest in knowing whether onsite samples of conifer trees contained elevated levels of radionuclides or other contaminants. After the fire, we measured radioactivity in three samples each of bark and wood from ponderosa pine trees in Mortandad Canyon. We also made preliminary estimates of radiation dose to the public that could result from burning trees and wood waste material in air curtain destructors. In bark, ^{238}Pu , ^{239}Pu , and ^{235}U were two to three orders of magnitude higher in Mortandad Canyon samples than in an offsite sample and ^{234}U , ^{238}U , ^{137}Cs , and ^{90}Sr were one order higher. In wood, ^{90}Sr , ^3H , ^{137}Cs , and ^{239}Pu concentrations in Mortandad Canyon were between one and two orders of magnitude higher than in the reference site sample. The actinides were generally two to three orders of magnitude higher in bark than in wood, and the ^{90}Sr concentration was about one order of magnitude higher in wood than in bark. The 50-year committed effective dose equivalent (CEDE) to the maximally-exposed individual (MEI) resulting from one year of burning was $9.7\text{E}-03$ mrem, which is about a 0.002% increase in the annual average radiation dose to individuals from other, non-Laboratory, sources of radiation. The 50-year CEDE to the MEI resulting from 10 years of burning was 0.097 mrem and the risk to the surrounding population would be negligible (<0.01 latent cancer fatalities). No health effects from the inhalation of radionuclides are expected because doses are well below the $>10,000$ mrem dose at which health effects from radiation exposure have been observed in humans. We believe that the proposed burning operations will be safe to the public with regard to radiation dose. Additional broader, statistically robust sampling of wood, bark, and slash is ongoing.

Introduction

The Cerro Grande Fire in May 2000 burned approximately 50,000 acres of conifer forest in New Mexico including about 7,500 acres of forest at the Los Alamos National Laboratory (LANL). Following the fire, the general public had concerns over the possibility of contaminant transport from LANL. Burned conifer trees of various species remained as hazards and

were cut to reduce their availability for uprooting by heavy flooding. Some of the wood and wood waste material will be burned at LANL in burn control units called air curtain destructors (ACDs). The burn units have high combustion efficiencies (Kluko et al. 2000). Health risks from potential emissions from ACD operation are believed to be negligible, but actual measurement and documentation of contaminant levels have not been done. As

such, this report documents the results of preliminary range-finding sampling for the measurement of radionuclides in wood and bark of trees burned in Mortandad Canyon by the Cerro Grande Fire. Also, a large-scale tree-thinning plan (LANL 2001) is underway at LANL, which will generate additional wood waste to be burned.

On the basis that assimilation of actinides from soil and pore water by tree roots is low, risk assessors have believed for some time that the impact to human health that could result from various uses of this wood is negligible. However, this belief can only be accurately quantified with knowledge of measured levels of contaminants in wood. Also, some radionuclides, such as the non-actinides ^{90}Sr and ^{137}Cs , have nutrient analogs and this could result in their uptake by conifer roots to levels that can be detected and quantified. Additionally, concentrations of radionuclides in canyon sediment at LANL can be higher at intermediate depths (0.5–0.75 m) (Gonzales and Newell 1996), where conifer tree roots prevail (Tierney and Foxx 1987), than at shallow depths. Therefore, several factors have led to the need to verify suspected low levels of radionuclides in conifer trees at LANL. We conducted range-finding sampling (sampling that is biased toward establishing upper levels of radionuclides in the range of values that exist across LANL) of wood and bark from trees in Mortandad Canyon.

Purpose and Objectives

Following the Cerro Grande Fire, partially burned trees (with burned bark and needles but not wood) in Mortandad Canyon were felled and stockpiled as a hazard reduction effort. Given several alternatives for the disposition of these trees (LANL 2000) and trees in other canyons with radionuclide contamination, an objective for the Mortandad Canyon tree wood sampling

was to estimate upper range human radiation doses that could result from the scenario of burning stockpiled trees. We believe that radiocontaminant levels in trees at LANL are well within health standards for any conceivable pathway; however, any levels above regional background radioactivity levels have the potential to cause public concern. Therefore, the primary objective of the study was to obtain a preliminary indication of whether onsite samples of conifer tree bark and wood contain levels of contaminants that are elevated above offsite levels such that the need for more robust sampling could be determined. Although not directly comparable, levels of contaminants in wood and bark were also compared to levels previously measured in shoot tips.

Materials and Methods

Sampling and Analysis

Roughly 3.7 km² or 55% of Mortandad Canyon burned at low and moderate intensities in the Cerro Grande Fire. Low-intensity burn areas include patches of unburned vegetation. Mortandad Canyon traverses LANL and has long had sources of permitted, treated discharge from the Laboratory's Radioactive Liquid Waste Treatment Facility (RLWTF) at Technical Area (TA) 50. On June 26, 2000, we segmented the extent of the burned area in Mortandad Canyon into three sections of roughly equal length along the long axis of the canyon. We selected one tree from each section for sampling. Within each segment, we selected mature ponderosa pine trees that were growing in the stream channel. We selected mature trees in order to maximize the time over which trees could have been exposed to radioactivity, i.e., they were present since the origination of the Laboratory. A reference site, or background, sample was collected for comparison. The

location of the reference sample was northwest of LANL off of NM State Road 4.

In the field, bark of each sampled tree was stripped at approximately breast height. The tree was then felled with props in place to avoid contact of the tree sample material with soil or surface ash. Two cross sections were then cut and bark and wood samples transported to our sample prep lab for recording general dimensions and age, processing, weighing, and ashing. Table 1 has tree ages and other information.

At our lab, we distilled water from the wood samples for ^3H analysis. The water was analyzed for ^3H using liquid scintillation. One cross section of wood and a bark sample from each tree were ashed in ovens to a consistent weight and the ash was submitted for analysis. The ash was analyzed for ^{90}Sr using liquid scintillation. Total uranium was analyzed by kinetic phosphorescence analysis. The radionuclides ^{238}Pu , ^{239}Pu , ^{234}U , ^{235}U , ^{238}U , and ^{241}Am were analyzed by alpha spectrometry.

Dose Estimation

Many tons of wood and other tree waste material from conifer trees at LANL will be burned in ACDs at 2,000 to 2,800°F. At this temperature, fire generates heat that will destroy the structural integrity of woody material, resulting in particles onto which radioactive materials may be deposited. The buoyancy of the air above and surrounding the fire can lead to the airborne release of the radioactive materials, which is then entrained in general convective currents that provide transport for particulate materials (Mishima and Pinkston 1994). As such, we estimated the internal dose (from inhalation) to a maximally-exposed individual (MEI) located 6,000 m from the source. In the direction of the predominant wind, this distance (6,000 m) is the approximate

distance from the location of burn units at TA-16 to the first significant public boundary, the Los Alamos town site at Trinity Drive. While there is a closer permanent public location, the Bandelier National Monument residential area, it is upwind from LANL and opposite the predominant wind direction. Also, the dose at that distance (~750 m) would be less using the particular meteorology that we used because some of the plume passes over objects that are relatively close to the source. The dose estimate is a 50-year committed effective dose equivalent (CEDE) that could result from the use of one ACD unit for an eight-hour period. We also extended the dose resulting from an eight-hour operation to the dose resulting from one year and 10 years of operation. The one-year operation was based on eight hours per day for 245 days. This is conservative (lending the analysis toward overestimating dose) because it assumes that a person is outdoors eight hours per day of 245 days per year. Buildings and vehicles exclude airborne radionuclides such that the indoor dose is one-half to one-twentieth the outdoor dose (Englemann 1990).

Although conservative dose parameters and assumptions were chosen so as to err to the side of overestimating dose to the public, the estimates are based on measured, not postulated or modeled, radioactivity in wood and bark and measured particulate production rates for ACD units. The three major components of the dose estimate were the source term—the amount of radioactive material released to the air—the dispersion modeling, and the dose calculation.

Source Term. Modified from Mishima and Pinkston (1994), the source term was estimated as

$$\text{Source Term} = [\text{PPR} \times F_W \times \text{RAct}_W \times \text{RF}]_i + [\text{PPR} \times F_B \times \text{RAct}_B \times \text{RF}]_i, \quad (1)$$

where

Source Term = The amount of radioactive material released to the air for the *i*th radionuclide,
 PPR = particulate production rate for the ACD unit (g/hr),
 F_W = fraction of PPR as wood,
 F_B = fraction of PPR as bark,
 RAct = radioactivity (pCi/g), and
 RF = respirable fraction.

Replicated emissions testing was conducted on a model S-127 ACD unit following Environmental Protection Agency (EPA) methods (Kluko et al. 2000). This testing included the collection of particulate samples using a modified EPA “Method 5D.” In our calculations we used the highest PPR (1,397 g/hr) of four values from emissions test trials, where they used maximum ACD load rates that averaged 14,780 kg. The F_W and F_B values used were 0.8045 and 0.1955, respectively, as based on the wood-to-bark ratio of Sample Mort 3 (Table 1). Mort 3 had the highest percentage bark. The highest measured radioactivities (RAct) of the paired wood/bark values of eight radionuclides (^{241}Am , ^{238}Pu , ^{239}Pu , ^{234}U , ^{235}U , ^{238}U , ^{137}Cs , and ^{90}Sr) were used. ^3H was not included in the dose calculation. It contributes little to total dose because of a low “quality factor,” i.e., it has a low dose conversion factor (DCF). Also, much of the ^3H in bark will have evaporated when it was

burned in the fire, and some of the ^3H in wood will evaporate during the time (weeks and months) when wood is stacked before being burned.

Particle size distribution of the samples collected in emissions tests was not determined. The RF most frequently used is the fraction of the airborne material that is less than 10 μm in diameter, but since the particle size distribution of the particulate samples collected in the above-referenced emissions tests was not determined, we reviewed a Department of Energy (DOE) report by Mishima and Pinkston (1994) where they published conservative source-term-related factors for a long list of materials as based on experimentation. RFs less than 1.0 are cited, such as 0.04 for Pu metal under thermal oxidizing conditions, or 1E-03 for powders under thermal stress, but a bounding of 1.0 is recommended for the majority of cellulosic materials. Although there are substantial density differences between the loosely compacted cellulosic materials tested by Mishima and Pinkston (1994) and our materials and this difference would result in an $\text{RF} < 1.0$, we assumed a conservative RF of 1.0.

Dispersion Modeling. The maximum (plume centerline) contaminant concentration in air at a downwind distance x from an elevated release point was estimated by the following Gaussian equation (Turner 1970):

$$\chi(x, 0, 0, H, s) = \frac{Q}{\pi \sigma_y(x, s) \sigma_z(x, s) u} \exp \left[-0.5 \left(\frac{H}{\sigma_z(x, s)} \right)^2 \right], \quad (2)$$

where

$\chi(x, 0, 0, H, s)$ = contaminant concentration at ground level at downwind distance x resulting from a continuous release at height H above grade under conditions characterized by stability category s (Ci/m^3),

Q = release rate (Ci/s),

$\sigma_y(x, s)$ = horizontal dispersion coefficient for downwind distance x and stability category s (m),

$\sigma_z(x, s)$ = vertical dispersion coefficient for downwind distance x and stability category s (m),

u = wind speed (m/s), and

H = plume height (release height plus plume rise) (m).

For elevated releases, stable conditions (Pasquill Stability Categories E and F) generally result in the highest concentrations at distant locations because the plume is diluted very slowly under these conditions. Bowen (1990) has published dispersion coefficients derived from measurements of atmospheric turbulence at LANL. Worst-case meteorology (Pasquill Stability Category F, 1.0 m/sec wind speed) was assumed for an eight-hour exposure (assuming eight hours of continuous ACD unit operation), and a more realistic wind speed of 3 m/sec was assumed for 10 years of non-continuous operation. The values of σ_y and σ_z reported by Bowen were estimated using the 3 m/s wind speed and then these coefficients were corrected for the 1 m/s wind speed.

The plume height H is the sum of the ACD unit height above grade and any plume rise resulting from the exit velocity or the buoyancy of the discharge. We ignored plume rise. The height of release was 3.1242 m (10 ft 3 in.), which is the height of the model S-127 ACD unit. With fires, the plume rise associated with buoyancy would likely be significant. Increasing the plume

elevation tends to decrease the maximum ground-level concentrations encountered downwind. Therefore, it is conservative to ignore plume rise and assume that the initial plume height equals the ACD unit height (3.1242 m).

Dose Calculation. The 50-year CEDE was estimated for the inhalation pathway as

$$\text{CEDE} = \sum(I_i \times \text{DCF}_i), \quad (3)$$

where

CEDE = the 50-year committed effective dose equivalent,

I = intake for the i th radionuclide, where Intake = source term (Eq. 1) \times dispersion factor (Eq. 2) \times breathing rate ($3.3\text{E}-04 \text{ m}^3/\text{s}$),

and DCF = dose conversion factor.

The maximum source term was used, meaning the highest value resulting from applying Equation 1 to the paired wood/bark data for Mort 1 through Mort 3 for each radionuclide. For example, application of Equation 1 to the Mort 1 wood and bark data for ^{241}Am resulted in a source term of $2.17\text{E}+03 \text{ pCi}/\text{hr}$, which was higher than the source term for Mort 2 ($8.13\text{E}+02 \text{ pCi}/\text{hr}$) and Mort 3 ($6.09 \text{ pCi}/\text{hr}$). DCFs for the most conservative inhalation class were taken from DOE (1988); i.e., the highest DCF for each radionuclide was used.

Results

Radioactivity Levels

Appendix 1, "Sample Results Summary," has the raw data resulting from the radioactivity analyses. Table 2 is a summary of the results of the tree wood and bark analyses for radioactivity at Mortadad Canyon and the reference site. Concentrations are per unit of ash. In bark

the onsite actinide (^{238}Pu , ^{239}Pu , and ^{241}Am) radioactivity was generally orders of magnitude higher than for the reference site sample. In wood the nonactinide (^{90}Sr and ^{137}Cs) radioactivities were generally orders of magnitude higher onsite than offsite. More specifically, in bark ^{238}Pu , ^{239}Pu , and ^{235}U were two to three orders of magnitude higher in Mortandad Canyon samples than in the offsite sample and ^{234}U , ^{238}U , and ^{90}Sr were one order higher. In wood ^{90}Sr , ^3H , and ^{239}Pu concentrations were between one and two orders of magnitude higher than in the reference site sample. The actinides were generally two to three orders of magnitude higher in bark than in wood, and bark consistently had detectable values (i.e., greater than three times the total propagated uncertainty).

Committed Effective Dose Equivalent (CEDE)

Internal dose to a MEI located 6,000 m from the source was estimated from the Mortandad Canyon radioactivity data. This estimate was for a dose that could result from the use of one ACD unit for a one-hour period. We also extended the one-hour dose to eight-hour and 10-year periods.

Appendix 2 shows the dispersion parameters, DCFs, and the results of the dose modeling. At a breathing rate of $3.3 \times 10^{-4} \text{ m}^3/\text{s}$, the estimated maximum 50-year CEDE to the MEI at 6,000 m resulting from an eight-hour exposure (eight hours of continuous ACD operation) was $2.46\text{E-}04$ mrem. The CEDE to the MEI at 6,000 m from one year of ACD operation (not shown in Table 1) was $9.7\text{E-}03$ mrem, which is about a 0.002% increase in the annual average radiation dose (414 mrem) to individuals from other, non-LANL, sources (Kraig and Soholt 2001). The CEDE to the MEI from 10 years of ACD operation was 0.097 mrem. Using a latent cancer fatality (LCF) DCF of 5×10^{-4} LCFs per person-rem

and the 50-year dose from 10 years of operating one ACD, the surrounding population would experience no measurable health effects (<0.01 LCF).

Discussion

The actinides were generally two to three orders of magnitude higher in bark than in wood. The deposition of wind-borne soil more so than plant uptake may be largely responsible for the elevated concentrations of the actinides in bark. Plant uptake factors for the actinides are low (Whicker and Schultz 1982) minimizing their uptake by plants. The ^{90}Sr concentration was one order of magnitude higher in wood than in bark. Ca is a nutrient analog of Sr (Whicker and Schultz 1982) and relatively large amounts of Ca are deposited in tree wood. The onsite ^{90}Sr concentrations in wood were between one and two orders of magnitude higher than in the reference site sample. ^{238}U is a weak nutrient analog of S in plants (Whicker and Schultz 1982) and the concentration in wood was one to two orders of magnitude higher than in bark. ^{137}Cs is a nutrient analog of K but no distinct pattern of ^{137}Cs concentration occurred with regard to wood vs bark. In a study of radioactive contamination of wood from the Chernobyl accident, Hus et al. (2001) concluded that ^{137}Cs in bark cannot be ascribed only to surface contamination implying that some of the ^{137}Cs taken up by roots is deposited in bark and wood.

As Hus et al. point out, a number of factors can influence the radioactivity of wood, such as the radioactivity of soil (or in this case sediment), tree species and age, and, especially, physiological processes of the tree. The ages of all four trees (three in Mortandad and one from the reference site) were ≥ 50 years. The Laboratory was established in 1942, but did not begin discharging treated radioactive liquid waste from the RLWTF into Mortandad Canyon

until 1963 (Bond and Gonzales 1995), therefore, all of the trees were present for all of the time period over which they could have been exposed to radioactive contaminants from discharges from the RLWTF. As such, the possibility of age affecting tree contaminant levels in a heterogeneous manner was for the most part eliminated. But the influence of age on tree contaminant levels was maximized for all four trees because the existence of the trees and the contamination coincided. Physiological processes can affect radionuclide levels in trees, but the effect would be similar in trees of the same species. Thus, the primary reason for differences in the trees that we sampled would be the radionuclide levels in the sediment.

Sampling locations were chosen with the intent of representing the upper range of radionuclide concentrations that can be expected to occur in trees in canyons with elevated levels of radionuclides. There may be higher concentrations in trees at potential release sites, solid waste management units, or at select particular locations, however, guidance on the identification, removal, and disposition of potentially contaminated trees and other vegetation from LANL TAs is intended to adequately dispose of those trees. Conservative source term, dispersion, and dose estimation parameters were chosen to result in conservative doses estimates. For many reasons our estimated doses are not directly comparable to doses calculated from air monitoring done during the Cerro Grande Fire (Kraig et al. 2001), however, it is interesting to note that our dose of 0.097 mrem to the MEI is remarkably close to their dose to a maximally exposed person within the Los Alamos area of 0.2 mrem.

A related issue is the contribution of sediment to the source term. While we intentionally avoided contaminating our samples with sediment, such as while felling

trees, slash that is burned in the ACDs will contain sediment that was mixed into the slash in the process of loading, transporting, and stockpiling slash. However, much of the sediment is likely larger than 10 μm in diameter, thus not respirable.

This study, by definition as a range-finding study, was not planned to fill all of the gaps of knowledge that exist regarding contaminant levels related to conifer trees. The small sample size, especially of reference site samples, was not expected to be statistically robust. Our dose estimates are intended to serve as preliminary information using one method. From broader Laboratory-wide sampling mentioned below, additional dose estimates will be made, possibly using a different model such as CAP-88, and additional potential pathways may be addressed. To date, upwards of 40 additional samples Laboratory-wide have been collected (Gonzales, personal communication, 2001). The collective information on contaminants and dose estimates will contribute information to the decision-making process for tree disposition that is more representative of the Laboratory's 43 mi^2 .

Conclusions

We believe that the radioactivities measured in wood and bark in Mortandad Canyon generally represent some of the highest levels that occur at LANL, an exception possibly being the U isotopes. Because conservative parameters were used for source-term modeling, dispersion modeling, and dose conversion and since the cancer risk resulting from 10 years of operation were very low, we believe that the proposed burning operations will be safe to the public with regard to radiation dose. No health effects from the inhalation of radionuclides are expected because doses, which are in the fractions of a mrem, are

well below the >10,000 mrem dose at which health effects from radiation exposure have been observed in humans (HPS 1996).

The primary objective of the study was to obtain a preliminary indication of whether onsite samples of conifer tree bark and wood contain levels of contaminants that are elevated above offsite levels so that the need for more robust sampling could be assessed. Since some levels of radioactivity were well above offsite levels, we are currently conducting Laboratory-wide sampling of conifer wood, bark, and slash.

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Literature Cited

- Bond, A. and G. Gonzales. 1995. Safety analysis report for the Radioactive Liquid Waste Treatment Facility. *Los Alamos National Laboratory report LW-CST13-MS*, Los Alamos National Laboratory, Los Alamos, NM.
- Bowen, B. M. 1990. Los Alamos climatology. *Los Alamos National Laboratory report LA-11735-MS*, Los Alamos National Laboratory, Los Alamos, NM.
- DOE (U.S. Department of Energy). 1988. Internal dose conversion factors for calculation of dose to the public. *U.S. Department of Energy report DE88-014297*, U.S. Department of Energy, Washington, D.C.
- Englemann, R. 1990. Effectiveness of sheltering in buildings and vehicles for plutonium. *U.S. Department of Energy report DOE/EH-0159T*, U.S. Department of Energy, Washington, D.C.
- Gonzales, G., P. Fresquez, M. Mullen, and L. Naranjo, Jr. 2000. Radionuclide concentrations in vegetation at the Los Alamos National Laboratory in 1998. *Los Alamos National Laboratory report LA-13704-PR*, Los Alamos National Laboratory, Los Alamos, NM.
- Gonzales, G. and P. Newell. 1996. Ecotoxicological screen of potential release site 50-006(d) of Operable Unit 1147 of Mortandad Canyon and relationship to the Radioactive Liquid Waste Treatment Facilities Project. *Los Alamos National Laboratory report LA-13148-MS*, Los Alamos National Laboratory, Los Alamos, NM.
- HPS (Health Physics Society). 1996. Radiation risk in perspective. Health Physics Society position statement, *HPS Newsletter*, March 1996.
- Hus, M., K. Kosutic, and S. Lulic. 2001. Radioactive contamination of wood and its products. *J. Environ. Radio. 55:179-186*.
- Kluko, M., D. DeRuiter, and B. Bawkon. 2000. Final report describing particulate and carbon monoxide emissions from the Whitton S-127 air curtain destructor. *Fountainhead Engineering Limited unpublished report*, Fountainhead Engineering Ltd, Chicago, IL.
- Kraig, D. and L. Soholt. 2001. Environmental radiological dose assessment. Chapter 3 in *Environmental Surveillance at Los Alamos during 2000*. *Los Alamos National Laboratory report LA-13861-ENV*, Los Alamos National Laboratory, Los Alamos, NM.

- Kraig, D., T. Buhl, C. Eberhart, and E. Gladney. 2001. Updated calculation of the inhalation dose from the Cerro Grande Fire based on final data. *Los Alamos National Laboratory report LA-UR-01-1132*.
- LANL (Los Alamos National Laboratory). 2001. Wildfire hazard reduction project plan. *Los Alamos National Laboratory report LA-UR-01-2017*, Ecology Group, Los Alamos National Laboratory, Los Alamos, NM.
- LANL (Los Alamos National Laboratory). 2000. Identification, removal, and disposition of potentially contaminated trees and other vegetation from Los Alamos National Laboratory technical areas. *Unpublished Los Alamos National Laboratory report*.
- Mishima, J. and D. Pinkston. 1994. DOE handbook: Airborne release fractions/rates and respirable fractions for nonreactor nuclear facilities. *U. S. Department of Energy handbook DOE-HDBK-3010-94*, U.S. Department of Energy, Washington, D.C.
- Tierney, G. and T. Foxx. 1987. Root lengths of plants on Los Alamos National Laboratory lands. *Los Alamos National Laboratory report LA-10865-PR*, Los Alamos National Laboratory, Los Alamos, NM.
- Turner, D. B. 1970. Workbook of atmospheric dispersion estimates. *U.S. Environmental Protection Agency report NTIS No. PB191482*, U.S. Environmental Protection Agency, Research Triangle Park, NC.
- Whicker, W. F. and V. Schultz. 1982. *Radioecology: Nuclear Energy and the Environment*, CRC Press, Inc., Boca Raton, FL.

Table 1. Age, bark/wood composition, and weight ratios for various hydration states of wood sampled for radionuclide analysis.

| Sample | Age | Composition (%) | | Wood | | Bark | |
|------------------|-----|-----------------|------|---------|---------|-----------|-------------|
| | | Bark | Wood | Dry/Wet | Ash/Dry | Ash/Wet | Ash/Wet |
| Mort 1 | 60 | * | * | 0.423 | 0.0042 | 0.0017669 | 0.0094639** |
| Mort 2 | 50 | 12 | 88 | 0.415 | 0.0036 | 0.0015108 | 0.0115936 |
| Mort 3 | 100 | 20 | 80 | 0.428 | 0.0046 | 0.0019514 | 0.0073341 |
| Reference | 72 | 13 | 87 | 0.411 | 0.0061 | 0.0025254 | 0.0177530 |

*Not measured.

**Value is mean of Mort 1 and Mort 2.

Table 2. Radioactivity ± 2 s total propagated uncertainty in wood and bark of ponderosa pine trees in Mortandad Canyon and at a reference site, both within the Cerro Grande Fire area.

| Sample ID | ²⁴¹ Am (pCi/g ash) | | ³ H (pCi/mL) | | ²³⁸ Pu (pCi/g ash) | | ²³⁹ Pu (pCi/g ash) | | | |
|---------------------------------|-----------------------------------|-------------|------------------------------|--------------|------------------------------------|---------------|-----------------------------------|-------------|------|------|
| | Wood | Bark | Wood | Bark* | Wood | Bark | Wood | Bark | Wood | Bark |
| Mort 1 | 0.099±0.041 | 7.52±0.95 | 1.21±0.25 | Not measured | -0.004±0.027 | 2.14±0.31 | 0.027±0.028 | 5.50±0.74 | | |
| Mort 2 | 0.055±0.028 | 2.75±0.37 | 4.04±0.56 | Not measured | -0.016±0.021 | 0.63±0.12 | 0.047±0.037 | 1.86±0.28 | | |
| Mort 3 | 0.058±0.023 | 1.99±0.27 | 0.53±0.20 | Not measured | 0.015±0.015 | 0.438±0.091 | 0.015±0.015 | 1.41±0.22 | | |
| Mean (std dev) | 0.071 (0.025) | 4.09 (3.00) | 1.93 (1.86) | Not measured | -0.002 (0.016) | 1.069 (0.932) | 0.030 (0.016) | 2.92 (2.24) | | |
| Reference | 0.017±0.011 | 0.016±0.011 | 0.08±0.17 | Not measured | 0.000±0.012 | 0.007±0.020 | 0.0023±0.009 | 0.007±0.020 | | |
| 1998 Onsite Shoot Tips** | Mean = 0.014±0.014 Max = 0.038 | | Mean = 463±723 Max = 1530 | | Mean = 0.0004±0.002 Max = 0.003 | | Mean = 0.008±0.004 Max = 0.026 | | | |

| Sample | ²³⁴ U (pCi/g ash) | | ²³⁵ U (pCi/g ash) | | ²³⁸ U (pCi/g ash) | | ⁹⁰ Sr (pCi/g ash) | | ¹³⁷ Cs (pCi/g ash) | |
|---------------------------------|--------------------------------|-------------|--------------------------------|---------------|---------------------------------|-------------|---------------------------------|-------------|--------------------------------|--------------|
| | Wood | Bark | Wood | Bark | Wood | Bark | Wood | Bark | Wood | Bark |
| Mort 1 | 0.066±0.036 | 1.33±0.20 | 0.031±0.026 | 0.125±0.036 | 0.031±0.026 | 1.64±0.23 | 171.0±31.0 | 35.3±6.7 | Not Measured | Not Measured |
| Mort 2 | 0.170±0.054 | 1.15±0.17 | 0.043±0.027 | 0.134±0.037 | 0.152±0.049 | 2.12±0.29 | 88.0±16.0 | 12.7±2.6 | 4.6±2.6 | 4.8±1.5 |
| Mort 3 | 0.049±0.023 | 0.93±0.14 | 0.019±0.014 | 0.111±0.031 | 0.026±0.017 | 1.36±0.19 | 58.0±11.0 | 8.7±2.0 | 0.00±0.47 | 1.50±0.84 |
| Mean (Std. Dev.) | 0.095 (0.066) | 1.14 (0.20) | 0.031 (0.012) | 0.123 (0.012) | 0.070 (0.071) | 1.71 (0.38) | 105.7 (58.5) | 18.9 (14.3) | 2.3 (3.3) | 3.2 (2.3) |
| Reference | 0.057±0.023 | 0.369±0.07 | 0.013±0.012 | 0.0023±0.015 | 0.040±0.019 | 0.381±0.07 | 3.3±1.1 | 1.96±0.41 | 0.59±0.57 | 0.38±0.46 |
| 1998 Onsite Shoot Tips** | Mean = 0.125*** Max = 0.267 | | Mean = 0.006*** Max = 0.012 | | Mean = 0.129*** Max = 0.0275 | | Mean = 1.97±0.045 Max = 4.50 | | Mean = 1.51±2.26 Max = 8.32 | |

*³H exists as water. It was not measured in burnt bark because the burning process evaporated most of the water.

**Source: Gonzales et al. (2000). Total propagated uncertainty is 1 s.

*** The 2 s total propagated uncertainty for the total uranium mean concentration was 0.078 or 20.2%.

APPENDIX 1

Sample Results Summary

Sample Results Summary

Client Name: Los Alamos National Laboratory SMO
 Client Project Name:
 Client Project Number: 7249R

Laboratory Name: Paragon Analytics, Inc.
 PAI Work Order: 0008045

Page: 1 of 1
 Reported on: Thursday, September 14, 2000
 07:35:10

| Lab Sample ID | Client Sample ID | Test | Nuclide | Result +/- 2 s TPU | MDC | Units | Matrix | Prep Batch | Date Analyzed | Flags |
|---------------|------------------|--------|---------|--------------------|--------|-------|--------|------------|---------------|-------|
| 0008045-1 | BGW | AM-241 | Am-241 | 0.017 +/- 0.011 | 0.0047 | pCi/g | Soil | AS03650 | 9/1/2000 | LT |
| 0008045-2 | MORT1B | AM-241 | Am-241 | 7.52 +/- 0.95 | 0.012 | pCi/g | Soil | AS03650 | 9/1/2000 | |
| 0008045-3 | MORT1W | AM-241 | Am-241 | 0.099 +/- 0.041 | 0.038 | pCi/g | Soil | AS03650 | 9/1/2000 | LT |
| 0008045-4 | MORT2B | AM-241 | Am-241 | 2.75 +/- 0.37 | 0.0049 | pCi/g | Soil | AS03650 | 9/1/2000 | |
| 0008045-5 | MORT2W | AM-241 | Am-241 | 0.055 +/- 0.028 | 0.0093 | pCi/g | Soil | AS03650 | 9/10/2000 | LT |
| 0008045-6 | MORT3B | AM-241 | Am-241 | 1.99 +/- 0.27 | 0.0047 | pCi/g | Soil | AS03650 | 9/10/2000 | |
| 0008045-7 | MORT3W | AM-241 | Am-241 | 0.058 +/- 0.023 | 0.015 | pCi/g | Soil | AS03650 | 9/10/2000 | LT |

Comments:

Data Package ID: AMS0008045-1

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

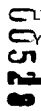
LT - Result is less than Requested MDC, greater than sample specific MDC.

Y2 - Chemical Yield outside default limits.

Abbreviations:

TPU - Total Propagated Uncertainty (see PAI SOP 743)

MDC - Minimum Detectable Concentration (see PAI SOP 709)



Paragon Analytics Inc.

Sample Results Summary

Client Name: Los Alamos National Laboratory SMO
 Client Project Name:
 Client Project Number: 7249R

Laboratory Name: Paragon Analytics, Inc.
 PAI Work Order: 0008045

Page: 1 of 1
 Reported on: Monday, August 28, 2000
 16:57:10

| Lab Sample ID | Client Sample ID | Test | Nuclide | Result +/- 2 s TPU | MDC | Units | Matrix | Prep Batch | Date Analyzed | Flags |
|---------------|------------------|---------|---------|--------------------|-----|-------|--------|------------|---------------|-------|
| 0008045-8 | BGW | TRITIUM | H-3 | 80 +/- 170 | 270 | pCi/l | Water | LS00425 | 8/18/2000 | U |
| 0008045-9 | MORT1W | TRITIUM | H-3 | 1210 +/- 250 | 310 | pCi/l | Water | LS00435 | 8/19/2000 | |
| 0008045-10 | MORT2W | TRITIUM | H-3 | 4040 +/- 560 | 310 | pCi/l | Water | LS00435 | 8/19/2000 | |
| 0008045-11 | MORT3W | TRITIUM | H-3 | 530 +/- 200 | 310 | pCi/l | Water | LS00435 | 8/20/2000 | |

Comments:

Data Package ID: H3W0008045-1

Qualifiers/Flags:

- U - Result is less than the sample specific MDC.
- T - Result is less than Requested MDC, greater than sample specific MDC.
- Y2 - Chemical Yield outside default limits.

Abbreviations:

- TPU - Total Propagated Uncertainty (see PAI SOP 743)
- MDC - Minimum Detectable Concentration (see PAI SOP 709)

Paragon Analytics Inc.

Sample Results Summary

Client Name: Los Alamos National Laboratory SMO
 Client Project Name:
 Client Project Number: 7249R

Laboratory Name: Paragon Analytics, Inc.
 PAI Work Order: 0008045

Page: 1 of 2
 Reported on: Thursday, September 14, 2000
 07:35:10

| Lab Sample ID | Client Sample ID | Test | Nuclide | Result +/- 2 s TPU | MDC | Units | Matrix | Prep Batch | Date Analyzed | Flags |
|---------------|------------------|--------|---------|--------------------|--------|-------|--------|------------|---------------|-------|
| 0008045-1 | BGW | PU-ISO | Pu-238 | 0.000 +/- 0.012 | 0.031 | pCi/g | Soil | AS03650 | 8/31/2000 | U |
| 0008045-1 | BGW | PU-ISO | Pu-239 | 0.0023 +/- 0.0092 | 0.022 | pCi/g | Soil | AS03650 | 8/31/2000 | U |
| 0008045-2 | MORT1B | PU-ISO | Pu-238 | 2.14 +/- 0.31 | 0.025 | pCi/g | Soil | AS03650 | 8/31/2000 | |
| 0008045-2 | MORT1B | PU-ISO | Pu-239 | 5.50 +/- 0.74 | 0.018 | pCi/g | Soil | AS03650 | 8/31/2000 | |
| 0008045-3 | MORT1W | PU-ISO | Pu-238 | -0.004 +/- 0.027 | 0.070 | pCi/g | Soil | AS03650 | 8/31/2000 | U |
| 0008045-3 | MORT1W | PU-ISO | Pu-239 | 0.027 +/- 0.028 | 0.038 | pCi/g | Soil | AS03650 | 8/31/2000 | U |
| 0008045-4 | MORT2B | PU-ISO | Pu-238 | 0.63 +/- 0.12 | 0.036 | pCi/g | Soil | AS03650 | 8/31/2000 | |
| 0008045-4 | MORT2B | PU-ISO | Pu-239 | 1.86 +/- 0.28 | 0.023 | pCi/g | Soil | AS03650 | 8/31/2000 | |
| 0008045-5 | MORT2W | PU-ISO | Pu-238 | -0.016 +/- 0.021 | 0.069 | pCi/g | Soil | AS03650 | 8/31/2000 | U |
| 0008045-5 | MORT2W | PU-ISO | Pu-239 | 0.047 +/- 0.037 | 0.047 | pCi/g | Soil | AS03650 | 8/31/2000 | U |
| 0008045-6 | MORT3B | PU-ISO | Pu-238 | 0.438 +/- 0.091 | 0.0084 | pCi/g | Soil | AS03650 | 8/31/2000 | |
| 0008045-6 | MORT3B | PU-ISO | Pu-239 | 1.41 +/- 0.22 | 0.0084 | pCi/g | Soil | AS03650 | 8/31/2000 | |

Comments:

Data Package ID: PUS0008045-1

Qualifiers/Flags:

- U - Result is less than the sample specific MDC.
- LT - Result is less than Requested MDC, greater than sample specific MDC.
- Y2 - Chemical Yield outside default limits.

Abbreviations:

- TPU - Total Propagated Uncertainty (see PAI SOP 743)
- MDC - Minimum Detectable Concentration (see PAI SOP 709)

Paragon Analytics Inc.

Sample Results Summary

Client Name: Los Alamos National Laboratory SMO
 Client Project Name:
 Client Project Number: 7249R

Laboratory Name: Paragon Analytics, Inc.
 PAI Work Order: 0008045

Page: 2 of 2
 Reported on: Thursday, September 14, 2000
 07:35:11

| Lab Sample ID | Client Sample ID | Test | Nuclide | Result +/- 2 s TPU | MDC | Units | Matrix | Prep Batch | Date Analyzed | Flags |
|---------------|------------------|--------|---------|--------------------|-------|-------|--------|------------|---------------|-------|
| 0008045-7 | MORT3W | PU-ISO | Pu-238 | 0.015 +/- 0.015 | 0.010 | pCi/g | Soil | AS03650 | 8/31/2000 | LT |
| 0008045-7 | MORT3W | PU-ISO | Pu-239 | 0.015 +/- 0.015 | 0.010 | pCi/g | Soil | AS03650 | 8/31/2000 | LT |

Comments:

Data Package ID: PUS0008045-1

Qualifiers/Flags:

- U - Result is less than the sample specific MDC.
- LT - Result is less than Requested MDC, greater than sample specific MDC.
- Y2 - Chemical Yield outside default limits.

Abbreviations:

- TPU - Total Propagated Uncertainty (see PAI SOP 743)
- MDC - Minimum Detectable Concentration (see PAI SOP 709)

Paragon Analytics Inc.

Sample Results Summary

Client Name: ESH20_LANL
 Client Project Name: Mortandad Bark
 Client Project Number:

Laboratory Name: Paragon Analytics, Inc.
 PAI Work Order: 0012163

Page: 1 of 1
 Reported on: Wednesday, February 14, 2001
 14:23:57

| Lab Sample ID | Client Sample ID | Test | Nuclide | Result +/- 2 s TPU | MDC | Units | Matrix | Prep Batch | Date Analyzed | Flags |
|---------------|------------------|--------|---------|--------------------|-------|-------|--------|------------|---------------|-------|
| 0012163-1 | BGB | PU-ISO | Pu-238 | 0.007 +/- 0.020 | 0.020 | pCi/g | Ash | AS04096 | 1/24/2001 | U |
| 0012163-1 | BGB | PU-ISO | Pu-239 | 0.007 +/- 0.020 | 0.020 | pCi/g | Ash | AS04096 | 1/24/2001 | U |

Comments:

Data Package ID: PUA0012163-1

Qualifiers/Flags:

- U - Result is less than the sample specific MDC.
- LT - Result is less than Requested MDC, greater than sample specific MDC.
- Y2 - Chemical Yield outside default limits.

Abbreviations:

- TPU - Total Propagated Uncertainty (see PAI SOP 743)
- MDC - Minimum Detectable Concentration (see PAI SOP 709)

Paragon Analytics Inc.

Sample Results Summary

Client Name: Los Alamos National Laboratory SMO
 Client Project Name:
 Client Project Number: 7249R

Laboratory Name: Paragon Analytics, Inc.
 PAI Work Order: 0008045

Page: 1 of 2
 Reported on: Thursday, September 14, 2000
 07:35:10

00349

| Lab Sample ID | Client Sample ID | Test | Nuclide | Result +/- 2 s TPU | MDC | Units | Matrix | Prep Batch | Date Analyzed | Flags |
|---------------|------------------|-------|---------|--------------------|--------|-------|--------|------------|---------------|-------|
| 0008045-1 | BGW | U-ISO | U-234 | 0.057 +/- 0.023 | 0.016 | pCi/g | Soil | AS03650 | 9/8/2000 | LT |
| 0008045-1 | BGW | U-ISO | U-235 | 0.013 +/- 0.012 | 0.016 | pCi/g | Soil | AS03650 | 9/8/2000 | U |
| 0008045-1 | BGW | U-ISO | U-238 | 0.040 +/- 0.019 | 0.0057 | pCi/g | Soil | AS03650 | 9/8/2000 | LT |
| 0008045-2 | MORT1B | U-ISO | U-234 | 1.33 +/- 0.20 | 0.016 | pCi/g | Soil | AS03650 | 9/8/2000 | |
| 0008045-2 | MORT1B | U-ISO | U-235 | 0.125 +/- 0.036 | 0.0058 | pCi/g | Soil | AS03650 | 9/8/2000 | |
| 0008045-2 | MORT1B | U-ISO | U-238 | 1.64 +/- 0.23 | 0.016 | pCi/g | Soil | AS03650 | 9/8/2000 | |
| 0008045-3 | MORT1W | U-ISO | U-234 | 0.066 +/- 0.036 | 0.036 | pCi/g | Soil | AS03650 | 9/8/2000 | LT |
| 0008045-3 | MORT1W | U-ISO | U-235 | 0.031 +/- 0.026 | 0.036 | pCi/g | Soil | AS03650 | 9/8/2000 | U |
| 0008045-3 | MORT1W | U-ISO | U-238 | 0.031 +/- 0.026 | 0.036 | pCi/g | Soil | AS03650 | 9/8/2000 | U |
| 0008045-4 | MORT2B | U-ISO | U-234 | 1.15 +/- 0.17 | 0.030 | pCi/g | Soil | AS03650 | 9/8/2000 | |
| 0008045-4 | MORT2B | U-ISO | U-235 | 0.134 +/- 0.037 | 0.021 | pCi/g | Soil | AS03650 | 9/8/2000 | |
| 0008045-4 | MORT2B | U-ISO | U-238 | 2.12 +/- 0.29 | 0.015 | pCi/g | Soil | AS03650 | 9/8/2000 | |

Comments:

Data Package ID: US0008045-1

Qualifiers/Flags:

U - Result is less than the sample specific MDC.
 LT - Result is less than Requested MDC, greater than sample specific MDC.
 Y2 - Chemical Yield outside default limits.

Abbreviations:

TPU - Total Propagated Uncertainty (see PAI SOP 743)
 MDC - Minimum Detectable Concentration (see PAI SOP 709)

Sample Results Summary

Client Name: Los Alamos National Laboratory SMO
 Client Project Name:
 Client Project Number: 7249R

Laboratory Name: Paragon Analytics, Inc.
 PAI Work Order: 0008045

Page: 2 of 2
 Reported on: Thursday, September 14, 2000
 07:35:10

00350

| Lab Sample ID | Client Sample ID | Test | Nuclide | Result +/- 2 s TPU | MDC | Units | Matrix | Prep Batch | Date Analyzed | Flags |
|---------------|------------------|-------|---------|--------------------|--------|-------|--------|------------|---------------|-------|
| 0008045-5 | MORT2W | U-ISO | U-234 | 0.170 +/- 0.054 | 0.027 | pCi/g | Soil | AS03650 | 9/8/2000 | |
| 0008045-5 | MORT2W | U-ISO | U-235 | 0.043 +/- 0.027 | 0.027 | pCi/g | Soil | AS03650 | 9/8/2000 | LT |
| 0008045-5 | MORT2W | U-ISO | U-238 | 0.152 +/- 0.049 | 0.0098 | pCi/g | Soil | AS03650 | 9/8/2000 | |
| 0008045-6 | MORT3B | U-ISO | U-234 | 0.93 +/- 0.14 | 0.021 | pCi/g | Soil | AS03650 | 9/8/2000 | |
| 0008045-6 | MORT3B | U-ISO | U-235 | 0.111 +/- 0.031 | 0.0048 | pCi/g | Soil | AS03650 | 9/8/2000 | |
| 0008045-6 | MORT3B | U-ISO | U-238 | 1.36 +/- 0.19 | 0.017 | pCi/g | Soil | AS03650 | 9/8/2000 | |
| 0008045-7 | MORT3W | U-ISO | U-234 | 0.049 +/- 0.023 | 0.023 | pCi/g | Soil | AS03650 | 9/8/2000 | LT |
| 0008045-7 | MORT3W | U-ISO | U-235 | 0.019 +/- 0.014 | 0.016 | pCi/g | Soil | AS03650 | 9/8/2000 | LT |
| 0008045-7 | MORT3W | U-ISO | U-238 | 0.026 +/- 0.017 | 0.020 | pCi/g | Soil | AS03650 | 9/8/2000 | LT |

Comments:

Data Package ID: *US0008045-1*

Qualifiers/Flags:

U - Result is less than the sample specific MDC.
 LT - Result is less than Requested MDC, greater than sample specific MDC.
 Y2 - Chemical Yield outside default limits.

Abbreviations:

TPU - Total Propagated Uncertainty (see PAI SOP 743)
 MDC - Minimum Detectable Concentration (see PAI SOP 709)

Sr-90 ANALYSIS RESULTS SUMMARY

Method ASTM D5811-95

Lab Name: Paragon Analytics, Inc. Date Collected: 07/06/2000

Client Name: Los Alamos National Lab Date Analyzed : 08/31/2000

Client Project ID: 7249R Sample Matrix : Ash

Lab Sample ID Series: 00-08-045 Count Duration: 60 Min.

Analyzed by: JE

| Client Sample ID | Lab Sample ID | Sr-90 (pCi/g) |
|------------------|---------------|------------------|
| BGW | 00-08-045-01 | 3.3 ± 1.1 |
| MORT1B | 00-08-045-02 | 35.3 ± 6.7 |
| MORT1W | 00-08-045-03 | 171 ± 31 |
| MORT2B | 00-08-045-04 | 12.7 ± 2.6 |
| MORT2W | 00-08-045-05 | 88 ± 16 |
| MORT3B | 00-08-045-06 | 8.7 ± 2.0 |
| MORT3W | 00-08-045-07 | 58 ± 11 |

Reported Uncertainties are the Estimated Total Propagated Uncertainties (2σ). See PAI SOP743 for details of TPU determinations.

Reported activities are the calculated net activities, not truncated or censored by an *a priori* detection limit estimate. Sample results should be compared to the decision level calculated from the appropriate blank.

These samples were prepared using PAI SOP707 and analyzed using PAI SOP724.

00613

Sr-90 ANALYSIS RESULTS SUMMARY

Method ASTM D5811-95

Lab Name: Paragon Analytics, Inc.

Date Collected: 07/06/2000

Client Name: ESH20_LANL

Date Analyzed : 02/12/2001

Client Project ID: Mortandad Bark

Sample Matrix : Solid

Lab Sample ID Series: 00-12-163

Count Duration: 60 Min.

Analyzed by: JE

| Client Sample ID | Lab Sample ID | Sr-90 (pCi/g) |
|------------------|---------------|------------------|
| BGB | 00-12-163-01 | 1.96 ± 0.41 |

Reported Uncertainties are the Estimated Total Propagated Uncertainties (2σ). See PAI SOP743R3 for details of TPU determinations.

Reported activities are the calculated net activities, not truncated or censored by an *a priori* detection limit estimate. Sample results should be compared to the decision level calculated from the appropriate blank.

These samples were prepared using PAI SOP721R6 and PAI SOP707R4 and analyzed using PAI SOP724R5.

00124

Gamma Spectroscopy Results

Method PAI 713R5

Sample Results

Page: 1 of 2

Reported on: Wednesday, January 31, 2001
16:04:15

Client Name: ESH20_LANL

Client Project Name: Mortandad Bark

Client Project Number:

Laboratory Name: Paragon Analytics, Inc.

PAI Work Order: 0012163

Field ID: BGB
Lab ID: 0012163-1

Sample Matrix: Ash
Date Prepared: 05-Jan-01
Prep SOP: PAI 739R4
Prep Batch: GS00704

Date Collected: 06-Jul-00
Date Analyzed: 15-Jan-01
Analytical SOP: PAI 713R5

Final Aliquot: 6.700
Aliquot Units: g
Report Basis: Dry Weight
Count Time (min.): 800

| Target Nuclide | Result +/- 2 s TPU | MDC | Reporting Units | Lab Qualifier |
|----------------|--------------------|------|-----------------|---------------|
| Ac-228 | -2 +/- 57 | 1.5 | pCi/g | U |
| Am-241 | 2.4 +/- 2.7 | 2.2 | pCi/g | U |
| Ann-rad | 0 +/- 0 | 0.42 | pCi/g | SQ |
| Ba-140 | 0 +/- 0 | 0 | pCi/g | SQ |
| Bi-212 | 0 +/- 0 | 21 | pCi/g | SQ |
| Bi-214 | 0.1 +/- 1.2 | 0.85 | pCi/g | U |
| Cd-109 | 0 +/- 16 | 10 | pCi/g | U |
| Ce-139 | 0.6 +/- 2.3 | 0.72 | pCi/g | U |
| Ce-144 | -0.4 +/- 6.5 | 3.4 | pCi/g | U |
| Co-57 | -0.17 +/- 0.89 | 0.45 | pCi/g | U |
| Co-60 | 0.08 +/- 0.58 | 0.45 | pCi/g | U |
| Cs-134 | 0.21 +/- 0.56 | 0.39 | pCi/g | U |
| Cs-137 | 0.38 +/- 0.46 | 0.37 | pCi/g | U |
| Eu-152 | -0.3 +/- 1.2 | 0.98 | pCi/g | U |
| Hg-203 | 0 +/- 110 | 5.3 | pCi/g | U |
| K-40 | 108 +/- 22 | 7.5 | pCi/g | |
| La-140 | 0 +/- 0 | 0 | pCi/g | SQ |
| Mn-54 | -0.1 +/- 1.1 | 0.62 | pCi/g | U |
| Na-22 | -0.08 +/- 0.67 | 0.48 | pCi/g | U |
| Np-237 | 0.0 +/- 2.7 | 2.3 | pCi/g | U |
| Pa-231 | -1 +/- 13 | 11 | pCi/g | U |
| Pa-233 | -2 +/- 13 | 6.3 | pCi/g | U |
| Pa-234m | 0 +/- 110000 | 69 | pCi/g | U |
| Pb-211 | -1 +/- 39 | 9.2 | pCi/g | U |
| Pb-212 | -1.7 +/- 1.3 | 0.56 | pCi/g | U |
| Pb-214 | 2.0 +/- 1.2 | 0.75 | pCi/g | |
| Ra-223 | -2 +/- 15 | 4.0 | pCi/g | U |
| Ra-226 | 8 +/- 17 | 9.6 | pCi/g | U |
| Rn-219 | 0.4 +/- 4.8 | 4.1 | pCi/g | U |
| Ru-106 | 1.5 +/- 8.1 | 4.7 | pCi/g | U |
| Se-75 | -0.2 +/- 4.4 | 1.2 | pCi/g | U |

Data Package ID: GSS0012163-1

Paragon Analytics Inc.

00371

Gamma Spectroscopy Results

Method PAI 713R5

Sample Results

Page: 1 of 10

Reported on: Monday, March 26, 2001
10:43:11

Client Name: ESH20_LANL

Client Project Name: Mortandad

Client Project Number:

Laboratory Name: Paragon Analytics, Inc.

PAI Work Order: 0102135

Field ID:BGW
Lab ID:0102135-1

Sample Matrix: Ash
Date Prepared: 01-Mar-01
Prep SOP: PAI 739R4
Prep Batch: GS00803

Date Collected: 06-Jul-00
Date Analyzed: 13-Mar-01
Analytical SOP: PAI 713R5

Final Aliquot: 4.160
Aliquot Units: g
Report Basis: As Received
Count Time (min.): 800

| Target Nuclide | Result +/- 2 s TPU | MDC | Reporting Units | Lab Qualifier |
|----------------|--------------------|------|-----------------|---------------|
| Ac-228 | -0.8 +/- 1.5 | 1.1 | pCi/g | U |
| Am-241 | -14.0 +/- 3.2 | 2.1 | pCi/g | U |
| Ann-rad | 0 +/- 0 | 0.30 | pCi/g | SQ |
| Ba-140 | 0 +/- 0 | 0 | pCi/g | SQ |
| Bi-212 | 0 +/- 0 | 11 | pCi/g | SQ |
| Bi-214 | -1.3 +/- 2.1 | 0.79 | pCi/g | U |
| Cd-109 | 1 +/- 20 | 12 | pCi/g | U |
| Ce-139 | 1.4 +/- 3.3 | 0.62 | pCi/g | U |
| Ce-144 | 1.0 +/- 8.7 | 4.0 | pCi/g | U |
| Co-57 | 0.0 +/- 1.2 | 0.53 | pCi/g | U |
| Co-60 | 0.06 +/- 0.42 | 0.32 | pCi/g | U |
| Cs-134 | 0.26 +/- 0.63 | 0.42 | pCi/g | U |
| Cs-137 | 0.59 +/- 0.57 | 0.32 | pCi/g | TI |
| Eu-152 | -0.3 +/- 1.1 | 0.87 | pCi/g | U |
| Hg-203 | 10 +/- 610 | 12 | pCi/g | U |
| K-40 | 163 +/- 23 | 6.2 | pCi/g | |
| La-140 | 0 +/- 0 | 0 | pCi/g | SQ |
| Mn-54 | 0.1 +/- 1.1 | 0.52 | pCi/g | U |
| Na-22 | -0.01 +/- 0.54 | 0.37 | pCi/g | U |
| Np-237 | 0.7 +/- 2.9 | 2.4 | pCi/g | U |
| Pa-231 | -3 +/- 12 | 10 | pCi/g | U |
| Pa-233 | -0.3 +/- 8.0 | 5.9 | pCi/g | U |
| Pa-234m | 250 +/- 130 | 56 | pCi/g | TI |
| Pb-211 | 2.5 +/- 9.2 | 7.7 | pCi/g | U |
| Pb-212 | 0.64 +/- 0.58 | 0.51 | pCi/g | |
| Pb-214 | 1.5 +/- 1.4 | 0.83 | pCi/g | |
| Ra-223 | 0.0 +/- 4.6 | 3.9 | pCi/g | U |
| Ra-226 | 2 +/- 17 | 9.8 | pCi/g | U |
| Rn-219 | -2 +/- 37 | 3.5 | pCi/g | U |
| Ru-106 | -0.8 +/- 9.3 | 4.9 | pCi/g | U |
| Se-75 | 0.6 +/- 8.0 | 1.6 | pCi/g | U |

Data Package ID: GSS0102135-1

Paragon Analytics Inc.

00012

Gamma Spectroscopy Results

Method PAI 713R5

Sample Results

Page: 2 of 10

Reported on: Monday, March 26, 2001
10:43:10

Client Name: ESH20_LANL

Client Project Name: Mortandad

Laboratory Name: Paragon Analytics, Inc.

Client Project Number:

PAI Work Order: 0102135

Field ID: BGW
Lab ID: 0102135-1

Sample Matrix: Ash
Date Prepared: 01-Mar-01
Prep SOP: PAI 739R4
Prep Batch: GS00803

Date Collected: 06-Jul-00
Date Analyzed: 13-Mar-01
Analytical SOP: PAI 713R5

Final Aliquot: 4.160
Aliquot Units: g
Report Basis: As Received
Count Time (min.): 800

| Target Nuclide | Result +/- 2 s TPU | MDC | Reporting Units | Lab Qualifier |
|----------------|--------------------|------|-----------------|---------------|
| Sn-113 | -0.9 +/- 9.5 | 1.7 | pCi/g | U |
| Sr-85 | 16 +/- 88 | 4.9 | pCi/g | U |
| Th-227 | -0.4 +/- 8.7 | 2.0 | pCi/g | U |
| Th-234 | 6.1 +/- 2.9 | 5.8 | pCi/g | TI |
| Tl-208 | 0.58 +/- 0.85 | 0.42 | pCi/g | U |
| U-235 | -10 +/- 46 | 2.4 | pCi/g | U |
| Y-88 | 1.7 +/- 10.0 | 1.6 | pCi/g | U |
| Zn-65 | -0.7 +/- 3.1 | 1.2 | pCi/g | U |

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC or less than the associated TPU.

Y2 - Chemical Yield outside default limits.

* - Duplicate DER not within control limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

SQ - Spectral interference prevents accurate quantitation.

SI - Identification is tentative due to spectral interference.

TI - Nuclide identification is tentative.

Abbreviations:

TPU - Total Propagated Uncertainty (see PAI SOP 743)

MDC - Minimum Detectable Concentration (see PAI SOP 709)

Data Package ID: GSS0102135-1

Paragon Analytics Inc.

00013

Gamma Spectroscopy Results

Method PAI 713R5

Sample Duplicate Results

Page: 1 of 2

Reported on: Monday, March 26, 2001
10:43:12

Client Name: ESH20_LANL

Client Project Name: Mortandad

Client Project Number:

Laboratory Name: Paragon Analytics, Inc.

PAI Work Order: 0102135

Field ID: BGW
Lab ID: 0102135-1-D1

Sample Matrix: Ash
Date Prepared: 01-Mar-01
Prep SOP: PAI 739R4
Prep Batch: GS00803

Date Collected: 06-Jul-00
Date Analyzed: 14-Mar-01
Analytical SOP: PAI 713R5

Final Aliquot: 4.160
Aliquot Units: g
Report Basis: As Received
Count Time (min.): 800

| Target Nuclide | Result +/- 2 s TPU | MDC | Reporting Units | Lab Qualifier |
|----------------|--------------------|------|-----------------|---------------|
| Ac-228 | 2.0 +/- 1.8 | 1.2 | pCi/g | |
| Am-241 | -0.1 +/- 1.6 | 1.3 | pCi/g | U |
| Ann-rad | 0 +/- 0 | 0.34 | pCi/g | SQ |
| Ba-140 | 0 +/- 0 | 0 | pCi/g | SQ |
| Bi-212 | 0 +/- 0 | 14 | pCi/g | SQ |
| Bi-214 | 1.2 +/- 2.6 | 1.2 | pCi/g | U |
| Cd-109 | 24 +/- 17 | 9.7 | pCi/g | SI |
| Ce-139 | 0.3 +/- 4.3 | 1.0 | pCi/g | U |
| Ce-144 | 0.2 +/- 8.7 | 4.0 | pCi/g | U |
| Co-57 | -0.2 +/- 1.2 | 0.52 | pCi/g | U |
| Co-60 | 0.09 +/- 0.48 | 0.37 | pCi/g | U |
| Cs-134 | 0.12 +/- 0.66 | 0.44 | pCi/g | U |
| Cs-137 | 0.01 +/- 0.41 | 0.34 | pCi/g | U |
| Eu-152 | -0.1 +/- 1.1 | 0.92 | pCi/g | U |
| Hg-203 | 10 +/- 610 | 12 | pCi/g | U |
| K-40 | 168 +/- 32 | 6.8 | pCi/g | |
| La-140 | 0 +/- 0 | 0 | pCi/g | SQ |
| Mn-54 | 0.1 +/- 1.1 | 0.52 | pCi/g | U |
| Na-22 | 0.12 +/- 0.62 | 0.43 | pCi/g | U |
| Np-237 | -1.5 +/- 2.7 | 2.2 | pCi/g | U |
| Pa-231 | -3 +/- 13 | 11 | pCi/g | U |
| Pa-233 | 5.1 +/- 7.5 | 6.2 | pCi/g | U |
| Pa-234m | -250 +/- 510 | 63 | pCi/g | U |
| Pb-211 | 0 +/- 160 | 8.7 | pCi/g | U |
| Pb-212 | -0.44 +/- 0.94 | 0.57 | pCi/g | U |
| Pb-214 | 1.4 +/- 2.8 | 1.2 | pCi/g | U |
| Ra-223 | 2.1 +/- 4.9 | 4.1 | pCi/g | U |
| Ra-226 | 33 +/- 19 | 8.3 | pCi/g | SI |
| Rn-219 | 1.1 +/- 4.5 | 3.8 | pCi/g | U |
| Ru-106 | 1.0 +/- 9.8 | 5.1 | pCi/g | U |
| Se-75 | 0.1 +/- 8.2 | 1.6 | pCi/g | U |

Data Package ID: GSS0102135-1

Paragon Analytics Inc.

00014

Gamma Spectroscopy Results

Method PAI 713R5

Sample Duplicate Results

Page: 2 of 2

Reported on: Monday, March 26, 2001
10:43:12

Client Name: ESH20_LANL

Client Project Name: Mortandad

Client Project Number:

Laboratory Name: Paragon Analytics, Inc.

PAI Work Order: 0102135

Field ID: BGW
Lab ID: 0102135-1-D1

Sample Matrix: Ash
Date Prepared: 01-Mar-01
Prep SOP: PAI 739R4
Prep Batch: GS00803

Date Collected: 06-Jul-00
Date Analyzed: 14-Mar-01
Analytical SOP: PAI 713R5

Final Aliquot: 4.160
Aliquot Units: g
Report Basis: As Received
Count Time (min.): 800

| Target Nuclide | Result +/- 2 s TPU | MDC | Reporting Units | Lab Qualifier |
|----------------|--------------------|------|-----------------|---------------|
| Sn-113 | 0 +/- 10 | 1.8 | pCi/g | U |
| Sr-85 | 40 +/- 110 | 6.0 | pCi/g | U |
| Th-227 | 0.5 +/- 2.2 | 1.9 | pCi/g | U |
| Th-234 | 51 +/- 17 | 5.6 | pCi/g | TI |
| Tl-208 | 0.07 +/- 0.67 | 0.41 | pCi/g | U |
| U-235 | -1.9 +/- 9.1 | 2.2 | pCi/g | U |
| Y-88 | -1 +/- 12 | 1.9 | pCi/g | U |
| Zn-65 | 1.2 +/- 3.4 | 1.4 | pCi/g | U |

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC or less than the associated TPU.
Y2 - Chemical Yield outside default limits.
* - Duplicate DER not within control limits.
LT - Result is less than Requested MDC, greater than sample specific MDC.
SQ - Spectral interference prevents accurate quantitation.
SI - Identification is tentative due to spectral interference.
TI - Nuclide identification is tentative.

Abbreviations:

TPU - Total Propagated Uncertainty (see PAI SOP 743)
MDC - Minimum Detectable Concentration (see PAI SOP 709)

Data Package ID: GSS0102135-1

Paragon Analytics Inc.

00015

Gamma Spectroscopy Results

Method PAI 713R5

Sample Results

Page: 3 of 10

Reported on: Monday, March 26, 2001
10:43:13

Client Name: ESH20_LANL

Client Project Name: Mortandad

Client Project Number:

Laboratory Name: Paragon Analytics, Inc.

PAI Work Order: 0102135

Field ID: MORT2B
Lab ID: 0102135-2

Sample Matrix: Ash
Date Prepared: 01-Mar-01
Prep SOP: PAI 739R4
Prep Batch: GS00803

Date Collected: 26-Jun-00
Date Analyzed: 14-Mar-01
Analytical SOP: PAI 713R5

Final Aliquot: 3.120
Aliquot Units: g
Report Basis: As Received
Count Time (min.): 800

| Target Nuclide | Result +/- 2 s TPU | MDC | Reporting Units | Lab Qualifier |
|----------------|--------------------|------|-----------------|---------------|
| Ac-228 | -0.6 +/- 3.4 | 1.7 | pCi/g | U |
| Am-241 | 12.5 +/- 3.1 | 2.1 | pCi/g | TI |
| Ann-rad | 0 +/- 0 | 0.38 | pCi/g | SQ |
| Ba-140 | 0 +/- 0 | 0 | pCi/g | SQ |
| Bi-212 | 0 +/- 0 | 17 | pCi/g | SQ |
| Bi-214 | 3.5 +/- 3.2 | 1.1 | pCi/g | |
| Cd-109 | -5 +/- 29 | 16 | pCi/g | U |
| Ce-139 | 0.0 +/- 6.0 | 1.3 | pCi/g | U |
| Ce-144 | 2 +/- 12 | 5.4 | pCi/g | U |
| Co-57 | -0.1 +/- 1.7 | 0.72 | pCi/g | U |
| Co-60 | -0.10 +/- 0.60 | 0.45 | pCi/g | U |
| Cs-134 | -0.02 +/- 0.79 | 0.52 | pCi/g | U |
| Cs-137 | 4.8 +/- 1.5 | 0.56 | pCi/g | |
| Eu-152 | 0.0 +/- 1.4 | 1.1 | pCi/g | U |
| Hg-203 | 20 +/- 840 | 14 | pCi/g | U |
| K-40 | 53 +/- 20 | 8.9 | pCi/g | |
| La-140 | 0 +/- 0 | 0 | pCi/g | SQ |
| Mn-54 | 0.2 +/- 1.5 | 0.70 | pCi/g | U |
| Na-22 | 0.03 +/- 0.66 | 0.46 | pCi/g | U |
| Np-237 | -1.1 +/- 4.0 | 3.3 | pCi/g | U |
| Pa-231 | -1 +/- 15 | 13 | pCi/g | U |
| Pa-233 | -0.6 +/- 9.9 | 7.6 | pCi/g | U |
| Pa-234m | 94 +/- 76 | 61 | pCi/g | TI |
| Pb-211 | 0 +/- 12 | 10 | pCi/g | U |
| Pb-212 | 0.70 +/- 0.75 | 0.67 | pCi/g | U |
| Pb-214 | 1.0 +/- 1.8 | 1.0 | pCi/g | U |
| Ra-223 | 1.8 +/- 6.4 | 5.3 | pCi/g | U |
| Ra-226 | -2 +/- 27 | 13 | pCi/g | U |
| Rn-219 | 1.0 +/- 5.4 | 4.6 | pCi/g | U |
| Ru-106 | 0 +/- 12 | 6.2 | pCi/g | U |
| Se-75 | 1 +/- 12 | 2.2 | pCi/g | U |

Data Package ID: GSS0102135-1

Paragon Analytics Inc.

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Gamma Spectroscopy Results

Method PAI 713R5

Sample Results

Page: 4 of 10

Reported on: Monday, March 26, 2001
10:43:13

Client Name: ESH20_LANL

Client Project Name: Mortandad

Client Project Number:

Laboratory Name: Paragon Analytics, Inc.

PAI Work Order: 0102135

Field ID: MORT2B
Lab ID: 0102135-2

Sample Matrix: Ash
Date Prepared: 01-Mar-01
Prep SOP: PAI 739R4
Prep Batch: GS00803

Date Collected: 26-Jun-00
Date Analyzed: 14-Mar-01
Analytical SOP: PAI 713R5

Final Aliquot: 3.120
Aliquot Units: g
Report Basis: As Received
Count Time (min.): 800

| Target Nuclide | Result +/- 2 s TPU | MDC | Reporting Units | Lab Qualifier |
|----------------|--------------------|------|-----------------|---------------|
| Sn-113 | 0 +/- 14 | 2.3 | pCi/g | U |
| Sr-85 | 20 +/- 150 | 7.2 | pCi/g | U |
| Th-227 | 0.3 +/- 3.1 | 2.6 | pCi/g | U |
| Th-234 | 2.4 +/- 1.5 | 8.5 | pCi/g | U |
| Tl-208 | 1.1 +/- 1.2 | 0.54 | pCi/g | U |
| U-235 | -10 +/- 470 | 3.1 | pCi/g | U |
| Y-88 | 3 +/- 14 | 2.2 | pCi/g | U |
| Zn-65 | 0.4 +/- 4.1 | 1.6 | pCi/g | U |

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC or less than the associated TPU.

Y2 - Chemical Yield outside default limits.

* - Duplicate DER not within control limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

SQ - Spectral interference prevents accurate quantitation.

SI - Identification is tentative due to spectral interference.

TI - Nuclide identification is tentative.

Abbreviations:

TPU - Total Propagated Uncertainty (see PAI SOP 743)

MDC - Minimum Detectable Concentration (see PAI SOP 709)

Data Package ID: GSS0102135-1

Paragon Analytics Inc.

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Gamma Spectroscopy Results

Method PAI 713R5

Sample Results

Page: 5 of 10

Reported on: Monday, March 26, 2001
10:43:13

Client Name: ESH20_LANL

Client Project Name: Mortandad

Client Project Number:

Laboratory Name: Paragon Analytics, Inc.

PAI Work Order: 0102135

Field ID: MORT2W
Lab ID: 0102135-3

Sample Matrix: Ash
Date Prepared: 01-Mar-01
Prep SOP: PAI 739R4
Prep Batch: GS00803

Date Collected: 26-Jun-00
Date Analyzed: 13-Mar-01
Analytical SOP: PAI 713R5

Final Aliquot: 2.760
Aliquot Units: g
Report Basis: As Received
Count Time (min.): 800

| Target Nuclide | Result +/- 2 s TPU | MDC | Reporting Units | Lab Qualifier |
|----------------|--------------------|-----|-----------------|---------------|
| Ac-228 | -5 +/- 90 | 4.0 | pCi/g | U |
| Am-241 | 0.3 +/- 2.0 | 1.7 | pCi/g | U |
| Am-rad | 0 +/- 0 | 1.1 | pCi/g | SQ |
| Ba-140 | 0 +/- 0 | 0 | pCi/g | SQ |
| Bi-212 | 0 +/- 0 | 44 | pCi/g | SQ |
| Bi-214 | 8.0 +/- 4.5 | 2.2 | pCi/g | |
| Cd-109 | -1 +/- 37 | 21 | pCi/g | U |
| Ce-139 | 0 +/- 12 | 2.7 | pCi/g | U |
| Ce-144 | 2 +/- 20 | 9.1 | pCi/g | U |
| Co-57 | 0.6 +/- 2.8 | 1.2 | pCi/g | U |
| Co-60 | 0.3 +/- 1.6 | 1.2 | pCi/g | U |
| Cs-134 | -0.3 +/- 2.1 | 1.4 | pCi/g | U |
| Cs-137 | 4.6 +/- 2.6 | 1.3 | pCi/g | |
| Eu-152 | 3.4 +/- 3.3 | 1.9 | pCi/g | TI |
| Hg-203 | 0 +/- 2600 | 45 | pCi/g | U |
| K-40 | 127 +/- 30 | 17 | pCi/g | |
| La-140 | 0 +/- 0 | 0 | pCi/g | SQ |
| Mn-54 | -0.9 +/- 4.0 | 1.8 | pCi/g | U |
| Na-22 | 1.3 +/- 1.9 | 1.2 | pCi/g | U |
| Np-237 | 0.2 +/- 5.0 | 4.2 | pCi/g | U |
| Pa-231 | 17 +/- 38 | 32 | pCi/g | U |
| Pa-233 | -11 +/- 24 | 20 | pCi/g | U |
| Pa-234m | 60 +/- 230 | 190 | pCi/g | U |
| Pb-211 | 0 +/- 670 | 27 | pCi/g | U |
| Pb-212 | 6.1 +/- 6.8 | 2.0 | pCi/g | U |
| Pb-214 | 6.5 +/- 5.2 | 2.6 | pCi/g | |
| Ra-223 | -1 +/- 12 | 10 | pCi/g | U |
| Ra-226 | 19 +/- 59 | 26 | pCi/g | U |
| Rn-219 | -5 +/- 15 | 12 | pCi/g | U |
| Ru-106 | -7 +/- 29 | 15 | pCi/g | U |
| Se-75 | 0 +/- 29 | 5.4 | pCi/g | U |

Data Package ID: GSS0102135-1

Paragon Analytics Inc.

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Gamma Spectroscopy Results

Method PAI 713R5

Sample Results

Page: 6 of 10

Reported on: Monday, March 26, 2001
10:43:13

Client Name: ESH20_LANL

Client Project Name: Mortandad

Client Project Number:

Laboratory Name: Paragon Analytics, Inc.

PAI Work Order: 0102135

Field ID: MORT2W

Lab ID: 0102135-3

Sample Matrix: Ash

Date Prepared: 01-Mar-01

Prep SOP: PAI 739R4

Prep Batch: GS00803

Date Collected: 26-Jun-00

Date Analyzed: 13-Mar-01

Analytical SOP: PAI 713R5

Final Aliquot: 2.760

Aliquot Units: g

Report Basis: As Received

Count Time (min.): 800

| Target Nuclide | Result +/- 2 s TPU | MDC | Reporting Units | Lab Qualifier |
|----------------|--------------------|------|-----------------|---------------|
| Sn-113 | -1 +/- 37 | 6.1 | pCi/g | U |
| Sr-85 | 0 +/- 250 | 13 | pCi/g | U |
| Th-227 | -0.1 +/- 7.2 | 6.0 | pCi/g | U |
| Th-234 | 30 +/- 22 | 8.6 | pCi/g | TI |
| Tl-208 | 0 +/- 51 | 0.98 | pCi/g | U |
| U-235 | -1.1 +/- 5.6 | 4.7 | pCi/g | U |
| Y-88 | 4 +/- 38 | 5.7 | pCi/g | U |
| Zn-65 | 4 +/- 12 | 4.6 | pCi/g | U |

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC or less than the associated TPU.

Y2 - Chemical Yield outside default limits.

* - Duplicate DER not within control limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

SQ - Spectral interference prevents accurate quantitation.

SI - Identification is tentative due to spectral interference.

TI - Nuclide identification is tentative.

Abbreviations:

TPU - Total Propagated Uncertainty (see PAI SOP 743)

MDC - Minimum Detectable Concentration (see PAI SOP 709)

Data Package ID: GSS0102135-1

Paragon Analytics Inc.

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Gamma Spectroscopy Results

Method PAI 713R5

Sample Results

Page: 7 of 10

Reported on: Monday, March 26, 2001
10:43:14

Client Name: ESH20_LANL

Client Project Name: Mortandad

Client Project Number:

Laboratory Name: Paragon Analytics, Inc.

PAI Work Order: 0102135

Field ID: MORT3B
Lab ID: 0102135-4

Sample Matrix: Ash
Date Prepared: 01-Mar-01
Prep SOP: PAI 739R4
Prep Batch: GS00803

Date Collected: 26-Jun-00
Date Analyzed: 13-Mar-01
Analytical SOP: PAI 713R5

Final Aliquot: 4.130
Aliquot Units: g
Report Basis: As Received
Count Time (min.): 800

| Target Nuclide | Result +/- 2 s TPU | MDC | Reporting Units | Lab Qualifier |
|----------------|--------------------|------|-----------------|---------------|
| Ac-228 | -3.4 +/- 7.0 | 2.2 | pCi/g | U |
| Am-241 | 0.2 +/- 1.1 | 0.95 | pCi/g | U |
| Ann-rad | 0 +/- 0 | 0.54 | pCi/g | SQ |
| Ba-140 | 0 +/- 0 | 0 | pCi/g | SQ |
| Bi-212 | 2 +/- 28 | 24 | pCi/g | U |
| Bi-214 | -1.1 +/- 3.1 | 1.5 | pCi/g | U |
| Cd-109 | 4 +/- 22 | 13 | pCi/g | U |
| Ce-139 | -0.3 +/- 7.1 | 1.6 | pCi/g | U |
| Ce-144 | 0 +/- 13 | 5.8 | pCi/g | U |
| Co-57 | -0.3 +/- 1.7 | 0.74 | pCi/g | U |
| Co-60 | 0.11 +/- 0.83 | 0.63 | pCi/g | U |
| Cs-134 | 0.2 +/- 1.1 | 0.75 | pCi/g | U |
| Cs-137 | 1.50 +/- 0.84 | 0.54 | pCi/g | U |
| Eu-152 | 1.0 +/- 2.0 | 1.6 | pCi/g | U |
| Hg-203 | 0 +/- 1500 | 26 | pCi/g | U |
| K-40 | 45 +/- 27 | 12 | pCi/g | U |
| La-140 | 0 +/- 0 | 0 | pCi/g | SQ |
| Mn-54 | -0.5 +/- 2.2 | 1.0 | pCi/g | U |
| Na-22 | 0.4 +/- 1.1 | 0.75 | pCi/g | U |
| Np-237 | 0.0 +/- 3.1 | 2.6 | pCi/g | U |
| Pa-231 | -8 +/- 22 | 18 | pCi/g | U |
| Pa-233 | -10 +/- 18 | 12 | pCi/g | U |
| Pa-234m | 20 +/- 110 | 95 | pCi/g | U |
| Pb-211 | -10 +/- 110 | 16 | pCi/g | U |
| Pb-212 | -3 +/- 12 | 1.4 | pCi/g | U |
| Pb-214 | 5.4 +/- 2.8 | 1.4 | pCi/g | U |
| Ra-223 | 0 +/- 12 | 6.1 | pCi/g | U |
| Ra-226 | 25 +/- 31 | 15 | pCi/g | U |
| Rn-219 | -1.1 +/- 8.5 | 7.1 | pCi/g | U |
| Ru-106 | 2 +/- 18 | 9.1 | pCi/g | U |
| Se-75 | -3 +/- 17 | 3.2 | pCi/g | U |

Data Package ID: GSS0102135-1

Paragon Analytics Inc.

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Gamma Spectroscopy Results

Method PAI 713R5

Sample Results

Page: 8 of 10

Reported on: Monday, March 26, 2001
10:43:14

Client Name: ESH20_LANL

Client Project Name: Mortandad

Client Project Number:

Laboratory Name: Paragon Analytics, Inc.

PAI Work Order: 0102135

Field ID: MORT3B

Lab ID: 0102135-4

Sample Matrix: Ash

Date Prepared: 01-Mar-01

Prep SOP: PAI 739R4

Prep Batch: GS00803

Date Collected: 26-Jun-00

Date Analyzed: 13-Mar-01

Analytical SOP: PAI 713R5

Final Aliquot: 4.130

Aliquot Units: g

Report Basis: As Received

Count Time (min.): 800

| Target Nuclide | Result +/- 2 s TPU | MDC | Reporting Units | Lab Qualifier |
|----------------|--------------------|------|-----------------|---------------|
| Sn-113 | -1 +/- 21 | 3.5 | pCi/g | U |
| Sr-85 | 20 +/- 220 | 11 | pCi/g | U |
| Th-227 | 0.5 +/- 4.2 | 3.6 | pCi/g | U |
| Th-234 | 33 +/- 11 | 5.6 | pCi/g | TI |
| Tl-208 | 3.3 +/- 2.1 | 0.69 | pCi/g | |
| U-235 | -0.2 +/- 8.1 | 3.2 | pCi/g | U |
| Y-88 | 3 +/- 20 | 3.0 | pCi/g | U |
| Zn-65 | -0.3 +/- 6.7 | 2.7 | pCi/g | U |

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC or less than the associated TPU.

Y2 - Chemical Yield outside default limits.

* - Duplicate DER not within control limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

SQ - Spectral interference prevents accurate quantitation.

SI - Identification is tentative due to spectral interference.

TI - Nuclide identification is tentative.

Abbreviations:

TPU - Total Propagated Uncertainty (see PAI SOP 743)

MDC - Minimum Detectable Concentration (see PAI SOP 709)

Data Package ID: GSS0102135-1

Paragon Analytics Inc.

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Gamma Spectroscopy Results

Method PAI 713R5

Sample Results

Page: 9 of 10

Reported on: Monday, March 26, 2001
10:43:14

Client Name: ESH20_LANL

Client Project Name: Mortandad

Client Project Number:

Laboratory Name: Paragon Analytics, Inc.

PAI Work Order: 0102135

Field ID: MORT3W

Lab ID: 0102135-5

Sample Matrix: Ash

Date Prepared: 01-Mar-01

Prep SOP: PAI 739R4

Prep Batch: GS00803

Date Collected: 26-Jun-00

Date Analyzed: 13-Mar-01

Analytical SOP: PAI 713R5

Final Aliquot: 3.540

Aliquot Units: g

Report Basis: As Received

Count Time (min.): 800

| Target Nuclide | Result +/- 2 s TPU | MDC | Reporting Units | Lab Qualifier |
|----------------|--------------------|------|-----------------|---------------|
| Ac-228 | -5.8 +/- 7.4 | 1.7 | pCi/g | U |
| Am-241 | 0.2 +/- 1.9 | 1.6 | pCi/g | U |
| Ann-rad | 0 +/- 0 | 0.37 | pCi/g | SQ |
| Ba-140 | 0 +/- 0 | 0 | pCi/g | SQ |
| Bi-212 | -3 +/- 17 | 15 | pCi/g | U |
| Bi-214 | 2.2 +/- 3.9 | 1.5 | pCi/g | U |
| Cd-109 | 25 +/- 21 | 12 | pCi/g | SI |
| Ce-139 | -0.3 +/- 5.6 | 1.3 | pCi/g | U |
| Ce-144 | 1 +/- 11 | 4.8 | pCi/g | U |
| Co-57 | 0.1 +/- 1.5 | 0.64 | pCi/g | U |
| Co-60 | -0.02 +/- 0.56 | 0.43 | pCi/g | U |
| Cs-134 | 0.18 +/- 0.81 | 0.53 | pCi/g | U |
| Cs-137 | 0.00 +/- 0.47 | 0.39 | pCi/g | U |
| Eu-152 | 0.1 +/- 1.3 | 1.1 | pCi/g | U |
| Hg-203 | 20 +/- 970 | 17 | pCi/g | U |
| K-40 | 155 +/- 26 | 7.7 | pCi/g | |
| La-140 | 0 +/- 0 | 0 | pCi/g | SQ |
| Mn-54 | -0.1 +/- 1.4 | 0.67 | pCi/g | U |
| Na-22 | -0.09 +/- 0.73 | 0.50 | pCi/g | U |
| Np-237 | -0.6 +/- 3.1 | 2.6 | pCi/g | U |
| Pa-231 | -3 +/- 15 | 12 | pCi/g | U |
| Pa-233 | -0.6 +/- 8.8 | 7.4 | pCi/g | U |
| Pa-234m | -290 +/- 630 | 75 | pCi/g | U |
| Pb-211 | -9 +/- 34 | 10 | pCi/g | U |
| Pb-212 | 1.27 +/- 0.69 | 0.58 | pCi/g | |
| Pb-214 | -1.1 +/- 3.4 | 1.4 | pCi/g | U |
| Ra-223 | -1.5 +/- 5.8 | 4.9 | pCi/g | U |
| Ra-226 | 27 +/- 14 | 9.2 | pCi/g | SI |
| Rn-219 | 2.5 +/- 5.3 | 4.4 | pCi/g | U |
| Ru-106 | -2 +/- 12 | 6.1 | pCi/g | U |
| Se-75 | 1 +/- 11 | 2.0 | pCi/g | U |

Data Package ID: GSS0102135-1

Paragon Analytics Inc.

00022

Gamma Spectroscopy Results

Method PAI 713R5

Sample Results

Page: 10 of 10

Reported on: Monday, March 26, 2001
10:43:14

Client Name: ESH20_LANL

Client Project Name: Mortandad

Client Project Number:

Laboratory Name: Paragon Analytics, Inc.

PAI Work Order: 0102135

Field ID: MORT3W

Lab ID: 0102135-5

Sample Matrix: Ash

Date Prepared: 01-Mar-01

Prep SOP: PAI 739R4

Prep Batch: GS00803

Date Collected: 26-Jun-00

Date Analyzed: 13-Mar-01

Analytical SOP: PAI 713R5

Final Aliquot: 3.540

Aliquot Units: g

Report Basis: As Received

Count Time (min.): 800

| Target Nuclide | Result +/- 2 s TPU | MDC | Reporting Units | Lab Qualifier |
|----------------|--------------------|------|-----------------|---------------|
| Sn-113 | 0 +/- 14 | 2.3 | pCi/g | U |
| Sr-85 | 20 +/- 160 | 8.2 | pCi/g | U |
| Th-227 | -1 +/- 16 | 2.4 | pCi/g | U |
| Th-234 | 58 +/- 19 | 6.9 | pCi/g | TI |
| Tl-208 | 0.00 +/- 0.88 | 0.48 | pCi/g | U |
| U-235 | 3.1 +/- 2.8 | 2.3 | pCi/g | TI |
| Y-88 | 3 +/- 15 | 2.2 | pCi/g | U |
| Zn-65 | 1.6 +/- 4.0 | 1.6 | pCi/g | U |

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC or less than the associated TPU.

Y2 - Chemical Yield outside default limits.

* - Duplicate DER not within control limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

SQ - Spectral interference prevents accurate quantitation.

SI - Identification is tentative due to spectral interference.

TI - Nuclide identification is tentative.

Abbreviations:

TPU - Total Propagated Uncertainty (see PAI SOP 743)

MDC - Minimum Detectable Concentration (see PAI SOP 709)

Data Package ID: GSS0102135-1

Paragon Analytics Inc.

00023

APPENDIX 2

Dispersion parameters, dose conversion factors (DCFs), and the results of dose modeling using the Gaussian plume centerline method.

| Radio-nuclide* | Scenario | Height ("H") (m) | Distance to MEI ("X") (m) | Stability Category ("S") | Wind Speed ("u") (m/sec) | σ_z | σ_y | σ_z adjusted | σ_y adjusted | Continuous release at height H | Dispersion Coeff (sec/m ³) | Maximum Source Term** (pCi/hr) | Breathing rate (m ³ /sec) | Intake (pCi/hr) | DCF (mrem/pCi) | Dose Rate (mrem/hr) | 50-Year CEDE @ 10-Yr Operation (mrem) |
|-------------------|----------|------------------|---------------------------|--------------------------|--------------------------|------------|------------|---------------------|---------------------|--------------------------------|--|--------------------------------|--------------------------------------|-----------------|----------------|----------------------------|---|
| ²⁴¹ Am | 10 year | 3.1242 | 6,000 | F | 3 | 40 | 430 | | | 9.97E-01 | 6.15E-06 | 2.17E+03 | 3.30E-04 | 4.4E-06 | 5.20E-01 | 2.3E-06 | 4.5E-02 |
| ²³⁸ Pu | 10 year | 3.1242 | 6,000 | F | 3 | 40 | 430 | | | 9.97E-01 | 6.15E-06 | 5.80E+02 | 3.30E-04 | 1.2E-06 | 4.60E-01 | 5.4E-07 | 1.1E-02 |
| ²³⁹ Pu | 10 year | 3.1242 | 6,000 | F | 3 | 40 | 430 | | | 9.97E-01 | 6.15E-06 | 1.53E+03 | 3.30E-04 | 3.1E-06 | 5.10E-01 | 1.6E-06 | 3.1E-02 |
| ²³⁴ U | 10 year | 3.1242 | 6,000 | F | 3 | 40 | 430 | | | 9.97E-01 | 6.15E-06 | 5.05E+02 | 3.30E-04 | 1.0E-06 | 7.10E-03 | 7.3E-09 | 1.4E-04 |
| ²³⁵ U | 10 year | 3.1242 | 6,000 | F | 3 | 40 | 430 | | | 9.97E-01 | 6.15E-06 | 8.49E+01 | 3.30E-04 | 1.7E-07 | 6.70E-03 | 1.2E-09 | 2.3E-05 |
| ²³⁸ U | 10 year | 3.1242 | 6,000 | F | 3 | 40 | 430 | | | 9.97E-01 | 6.15E-06 | 7.50E+02 | 3.30E-04 | 1.5E-06 | 6.20E-03 | 9.4E-09 | 1.9E-04 |
| ⁹⁰ Sr | 10 year | 3.1242 | 6,000 | F | 3 | 40 | 430 | | | 9.97E-01 | 6.15E-06 | 2.02E+05 | 3.30E-04 | 4.1E-04 | 1.30E-03 | 5.3E-07 | 1.0E-02 |
| ¹³⁷ Cs | 10 year | 3.1242 | 6,000 | F | 3 | 40 | 430 | | | 9.97E-01 | 6.15E-06 | 6.48E+03 | 3.30E-04 | 1.3E-05 | 3.20E-05 | 4.2E-10 | 8.3E-06 |
| Sum | | | | | | | | | | | | | | | | 5.0E-06 | 9.73E-02 |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | Dose Rate (mrem/hr) | 50-Year CEDE @ 1-Yr Operation (mrem) |
| ²⁴¹ Am | 8-hour | 3.1242 | 6,000 | F | 1 | | | 27 | 305 | 9.93E-01 | 3.81E-05 | 2.17E+03 | 3.30E-04 | 2.7E-05 | 5.20E-01 | 1.4E-05 | 1.1E-04 |
| ²³⁸ Pu | 8-hour | 3.1242 | 6,000 | F | 1 | | | 27 | 305 | 9.93E-01 | 3.81E-05 | 5.80E+02 | 3.30E-04 | 7.3E-06 | 4.60E-01 | 3.4E-06 | 2.7E-05 |
| ²³⁹ Pu | 8-hour | 3.1242 | 6,000 | F | 1 | | | 27 | 305 | 9.93E-01 | 3.81E-05 | 1.53E+03 | 3.30E-04 | 1.9E-05 | 5.10E-01 | 9.8E-06 | 7.9E-05 |
| ²³⁴ U | 8-hour | 3.1242 | 6,000 | F | 1 | | | 27 | 305 | 9.93E-01 | 3.81E-05 | 5.05E+02 | 3.30E-04 | 6.4E-06 | 7.10E-03 | 4.5E-08 | 3.6E-07 |
| ²³⁵ U | 8-hour | 3.1242 | 6,000 | F | 1 | | | 27 | 305 | 9.93E-01 | 3.81E-05 | 8.49E+01 | 3.30E-04 | 1.1E-06 | 6.70E-03 | 7.2E-09 | 5.7E-08 |
| ²³⁸ U | 8-hour | 3.1242 | 6,000 | F | 1 | | | 27 | 305 | 9.93E-01 | 3.81E-05 | 7.50E+02 | 3.30E-04 | 9.4E-06 | 6.20E-03 | 5.9E-08 | 4.7E-07 |
| ⁹⁰ Sr | 8-hour | 3.1242 | 6,000 | F | 1 | | | 27 | 305 | 9.93E-01 | 3.81E-05 | 2.02E+05 | 3.30E-04 | 2.5E-03 | 1.30E-03 | 3.3E-06 | 2.6E-05 |
| ¹³⁷ Cs | 8-hour | 3.1242 | 6,000 | F | 1 | | | 27 | 305 | 9.93E-01 | 3.81E-05 | 6.48E+03 | 3.30E-04 | 8.2E-05 | 3.20E-05 | 2.6E-09 | 2.1E-08 |
| Sum | | | | | | | | | | | | | | | | 3.08E-05 | 2.46E-04 |

*³H was not included in the dose calculation. It contributes little to total dose because of a low "quality factor", i.e., it has a low DCF. Also, most of the ³H in bark will have vaporized when it was burned in the fire and some of the ³H in wood will evaporate during the days and weeks when wood is stacked before being burned.

**Maximum means the highest value resulting from applying Equation 1 to the paired wood/bark data for "Mort 1" – "Mort 3" for each radionuclide. For example, application of Equation 1 to the Mort 1 wood and bark data for ²⁴¹Am resulted in a source term of 2.17E+03 pCi/hr, which was higher than the source term for Mort 2 (8.13E+02 pCi/hr) and Mort 3 (6.09 pCi/hr).

