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Title: MARSAME Radiological Release Report for Archaeological Artifacts Excavated from Area L

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MARSAME Radiological Release Report for Archaeological Artifacts Excavated from Area L

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Summary

In 1991 Los Alamos National Laboratory's (LANL's) cultural resources team excavated archaeological site LA 4618 located at Technical Area 54, within Material Disposal Area L (MDA L). MDA L received non-radioactive chemical waste from the early 1960s until 1985. Further development of the MDA required excavation of several cultural sites under National Historic Preservation Act requirements; artifacts from these sites have been subsequently stored at LANL. The LANL cultural resources group would now like to release these artifacts to the Museum of Indian Arts and Culture in Santa Fe for curation.

The history of disposal at Area L suggests that the artifact pool is unlikely to be chemically contaminated and LANL staff washed each artifact at least once following excavation. Thus, it is unlikely that the artifacts present a chemical hazard.

LANL's Environmental Stewardship group (EPC-ES) has evaluated the radiological survey results for the Area L artifact pool and found that the items described in this report meet the criteria for unrestricted radiological release under Department of Energy (DOE) Order 458.1 *Radiation Protection of the Public and the Environment* and are candidates for release without restriction from LANL control. This conclusion is based on the known history of MDA L and on radiation survey data.

Description of Artifacts

Approximately 49 boxes of archaeological artifacts were radiologically characterized. Each box contains one or more artifact; smaller artifacts have been grouped by type and are bagged within the boxes. Artifact types include:

1. Wood - likely structural used for ceilings and support beams for buildings (latillas and vigas);
2. Turquoise - likely a trade item. Used for jewelry;
3. Stone/metate/ground stone - exhibit ground or abraded surfaces. *Manos* are cobbles or slabs used to grind against a *metate*. Primarily used for foodstuffs. May also include polishing stones, mortars and pestles, abraders, stone axes and tools, shaped slabs used to cover door openings/ventilator shafts;
4. Sherds/Ceramics - broken ceramic vessel fragments including utility wares and painted wares;
5. Jewelry – ornamentation, typically made of stone;
6. Macro botanicals/Seeds/Corn Cob/ Flotation - plant remains that can be seen with the naked eye;
7. Lithics/Chipped Stone - pertains to stone tools and the manufacture of stone tools;
8. Faunal/Faunal Bead/ Bones - non-human ecofacts derived from animals including bones, teeth and antlers;
9. Charcoal - a porous form of black carbon derived from wood burning; AND
10. Adobe/Clay - sun-dried mud bricks and chinking used for building construction.

Due to the large number of artifacts, it was not feasible to individually survey each item within the artifact pool, and so a survey was planned and conducted using guidance from the *Multi-Agency Radiation Survey and Assessment of Materials and Equipment* (MARSAME) manual.

History and Characterization of MDA L

MDA L has not had radiological operations and had never been posted for radiological purposes. It received non-radioactive liquid chemical waste for disposal from the early 1960s until 1985. Based on historical process knowledge, there is sufficient justification to classify the artifacts as radiologically non-impacted under DOE Order 458.1. Confirmatory surveys were performed as a defense-in-depth measure, and this release documentation is not subject to DOE Independent Verification. However, for the purposes of this report, the artifact pool was treated as a MARSAME Class 3 survey (e.g., small potential for contamination, but at levels near background) due to the proximity to TA-54 Area G and the potential for atmospheric and/or terrestrial transport toward the excavation site.

Historic radioactivity concentrations for soils in the area surrounding MDA L were evaluated (Table 1, Figures 1 and 2). Only samples collected in years after excavation occurred contained measurable radioactive materials, mostly tritium. Measured concentrations near the dig site and MDA L are at the low end of the range of background tritium concentrations found in the Northern Hemisphere, and there is not any historical or process knowledge linking measured tritium concentrations to LANL operations.

Table 1 Summary of highest results for soils sampled near MDA L (within 500m).

Year	Analyte	Result (pCi/g)	Apprx. Max. Background (pCi/g)
1994	Gross beta	64.66	80
2002	Gross beta	43	80
2002	Gross beta	43	80
2002	Tritium	425	1600
2002	Tritium	567	1600
2003	Gross beta	36.5	80
2004	Gross beta	46	80
2004	Gross beta	49.2	80
2007	Potassium-40	33.4	40
2007	Gross beta	40.6	80
2007	Gross beta	40.6	80
2007	Gross beta	43	80

Notes: 1) Excavation was conducted in 1991 and 2) “High” results for tritium in 2002 are still well-within normal Tritium background for North America (due to environmental tritium derived from atmospheric weapons testing). The background value listed for tritium is the regional statistical reference level, which is updated annually and reported in the LANL Annual Site Environmental Report.

Figure 1 Map of MDA L, showing nearby soil sampling locations (green triangles), approximate location of artifact excavation site (orange shaded circle) and the boundaries of the material disposal area (yellow dashed line) displayed on top of 2014 aerial flyover imagery.

Figure 2 Map of MDA L, showing those areas where gross-β and/or tritium measurements exceeded 30 pCi/g (orange squares), approximate location of artifact excavation site (orange shaded circle) and the boundaries of the material disposal area (yellow dashed line) displayed on top of 2014 aerial flyover imagery. The highest tritium measurements (c.a., 425 and 567 pCi/g) occurred at the circled point.

Note that artifact excavation, as well as some sampling efforts, predate industrial development at MDA L.

Sampling and Measurement Quality Objectives

The artifacts included in this report have been classified as radiologically non-impacted consistent with the MARSAME methodology (LANL TPP). Despite the non-impacted classification, out of an abundance of caution, EPC-ES performed a Class 3 MARSAME-type survey for surface radioactivity prior to the release of these artifacts. Based on process knowledge, sampling and data analysis for volumetric radioactivity is not required. The MARSAME data analysis approach was used to evaluate the artifact survey results.

The sampling and analysis protocol for the artifact pool was consistent with LANL policy (LANL P412). The measurement objective was to confirm, within the stated statistical confidence limits, that total and removable surface radioactivity are below preapproved authorized limits (Table 2 below, taken from Table 10.2 in LANL P412).

Table 2 DOE Preapproved Authorized Limits for surface radioactivity

U-natural, U-235, U-238 and associated decay products (Removable)	1,000	dpm/100cm^2
U-natural, U-235, U-238 and associated decay products (Total)	5,000	dpm/100cm^2
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129 (Removable)	20	dpm/100cm^2
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129 (Total)	100	dpm/100cm^2
Th-natural, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133 (Removable)	200	dpm/100cm^2
Th-natural, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133 (Total)	1,000	dpm/100cm^2
β/γ emitters (Removable)	1,000	dpm/100cm^2
β/γ emitters (Total)	5,000	dpm/100cm^2
Tritium and Special Tritium Compounds	10,000	dpm/100cm^2

For this release, items were compared to the surface release limits for total β/γ (5000 dpm/100cm^2) and total α (100 dpm/100cm^2). The transuranic alpha limit was used for comparison in this case because it was the most restrictive limit available. However, a comparison to the 5000 dpm/100cm^2 alpha limit would also be appropriate because natural Uranium is likely to be the only radioactive constituent of interest in this near-background area.

All data met the Measurement Quality Objectives (MQOs). Specifically:

1) Appropriate instrumentation and techniques were used for the measurements and the expected radionuclides (LANL TPP); AND
2) Instruments were calibrated, response checked and background measurements were within expected ranges

Results and Analyses of Measurements

None of the types of artifacts surveyed have been well-characterized for background levels of radioactivity, so surrogate materials were used as a reference for background radioactivity comparisons (*note*: surrogate comparisons are informational only; surface radioactivity limits are the formal release criteria). For the purpose of comparison, artifacts were grouped as either stone-based, biological, or ceramics and an appropriate, well-characterized surrogate was assigned. The characteristics of surrogate materials are given in Table 3.

Table 3 Surrogate materials for archaeological artifacts.

Sample Category	Surrogate Material	Alpha background * (dpm/100cm^2)	Alpha σ (dpm/100cm^2)	Beta background * (dpm/100cm^2)	Beta σ (dpm/100cm^2)
Stones	Bare concrete	43	25	1500	1131
Biological	Wood	20	23	341	250
Ceramics	Ceramic Tile	54	21	1735	118

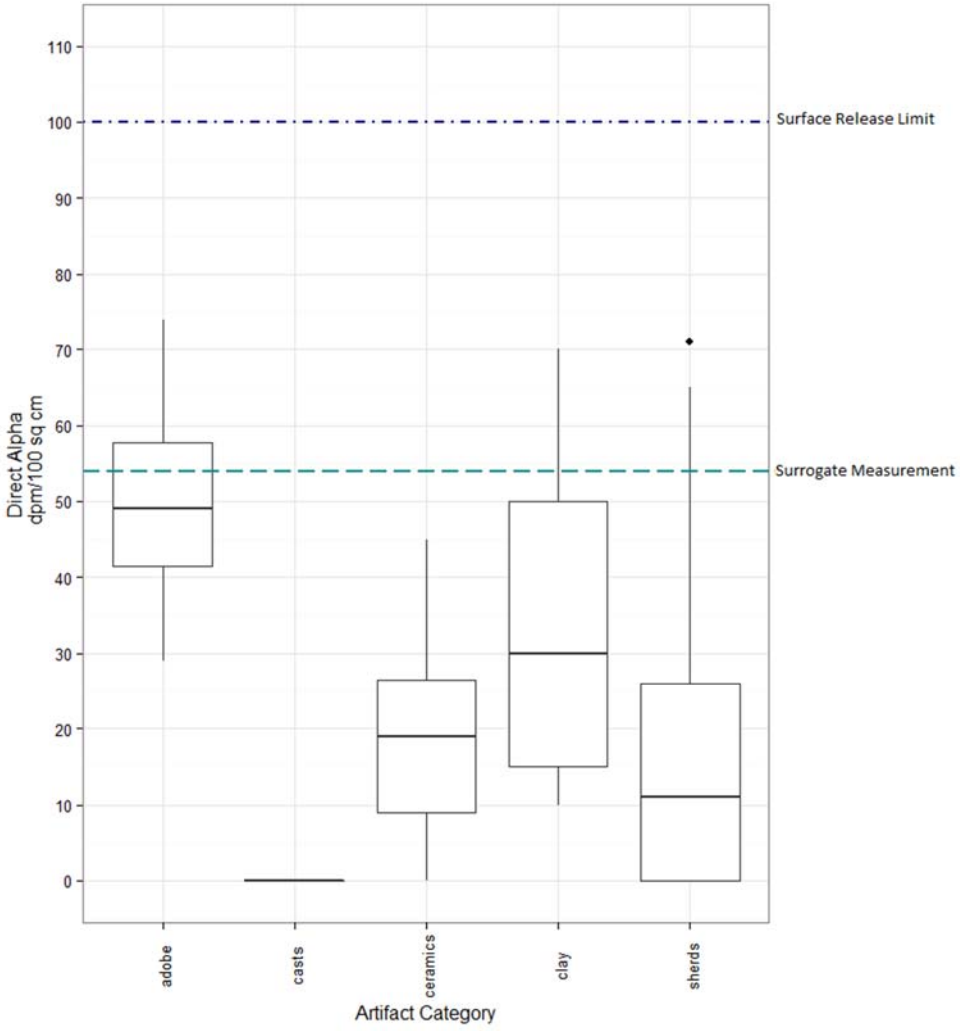
* "Background" means 95% upper confidence limit (UCL) of the mean value.

None of the surveyed artifacts exceeded direct or total surface radioactivity release limits. All measurements for removable radioactivity were below detection limits. Most of the artifacts were below the known background of the surrogate material chosen (Figures 3-8). A notable exception was "flotation" samples, which significantly exceeded the background characteristics of wood (but were still well below DOE's surface radioactivity release limits). Flotation samples are acquired by using water to separate light and heavy fractions from a sample pool, which usually consists of mixed materials (e.g., charcoal, soil, small rocky material, etc). Typically, the organic fraction is expected to float (density < 1 g/cm^3), while denser, inorganic material sinks. Because the organic portion is collected in a flotation sample, wood was chosen as the most appropriate surrogate material. However, the results of this analysis suggest that the radiological characteristics of the flotation samples differ from other organic materials within the artifact pool. One possible explanation for this discrepancy is that pumice, which is commonly found on the Pajarito Plateau, may have been collected with the organic flotation fraction. Being rocky, pumice would have different radiological characteristics from that expected from a purely organic sample, which could explain the elevated "flotation" results.

Conclusion

Confirmatory surveys support the conclusion that the artifacts from MDA L are radiologically non-impacted and are candidates for clearance under DOE Order 458.1. All sampled artifacts within the pool were well-below DOE's surface radioactivity release limits, and most were within the background range for the selected surrogate material (except for flotation, which differed slightly from the selected, organic surrogate material). Artifacts within the pool were all washed at least once, mitigating any chemical hazard. Given both the results of this survey and the site history of MDA L, the artifact pool is a candidate for unrestricted radiological release from LANL control.

Figure 3 Direct alpha survey results for ceramics and materials most comparable to a tile surrogate. In the plot, the thick line in the center of each box represents the median value for each artifact type, while the box spans the range of values from the 25th to the 75th percentile (e.g., the range of 50% of the data). Vertical lines display the first (0-25%) and last (75-100%) quartiles, and outliers are indicated as dots.



Note: Adobe is likely elevated relative to the surrogate tile sample due to the presence of naturally-occurring uranium; trace quantities of uranium are commonly found in inorganic materials (e.g., clay and rock) throughout Northern New Mexico.

Figure 4 Direct beta survey results for ceramics and materials most comparable to a tile surrogate. In the plot, the thick line in the center of each box represents the median value for each artifact type, while the box spans the range of values from the 25th to the 75th percentile (e.g., the range of 50% of the data). Vertical lines display the first (0-25%) and last (75-100%) quartiles, and outliers are indicated as dots.

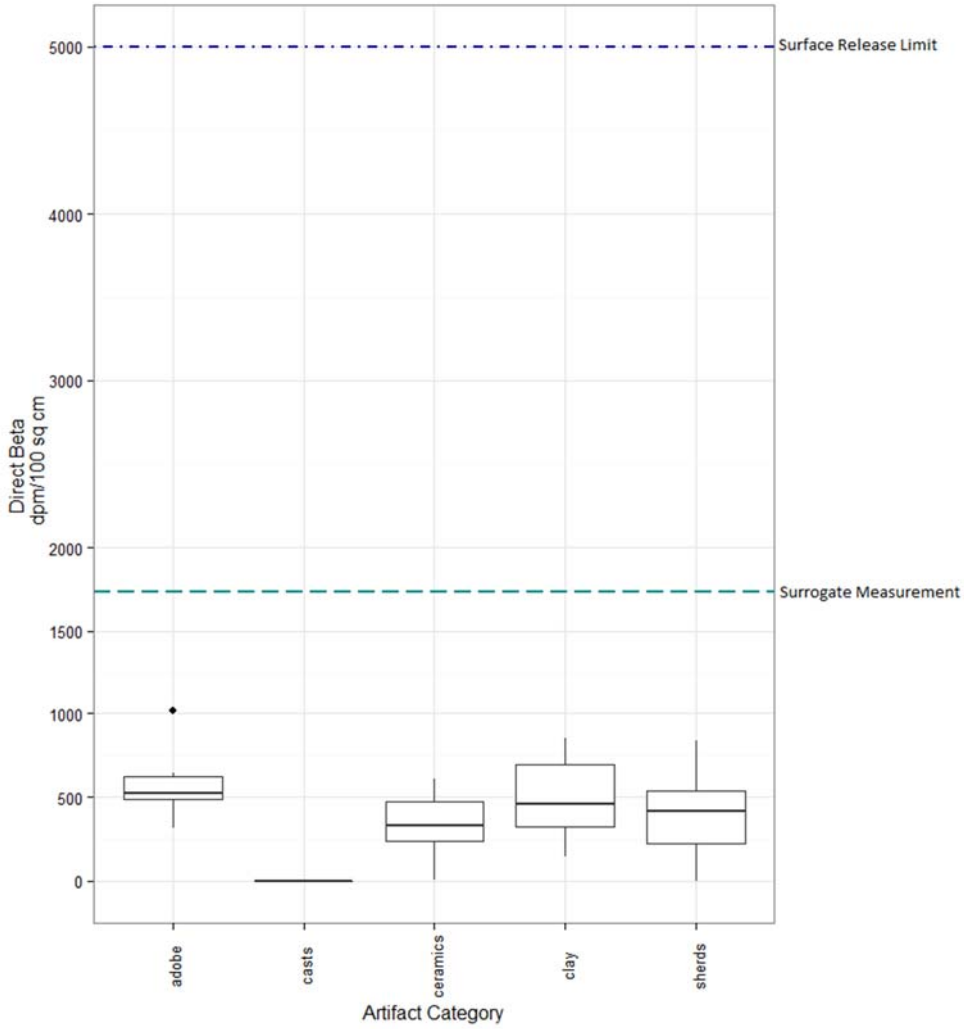


Figure 5 Direct alpha survey results for stones and materials most comparable to a concrete surrogate. In the plot, the thick line in the center of each box represents the median value for each artifact type, while the box spans the range of values from the 25th to the 75th percentile (e.g., the range of 50% of the data). Vertical lines display the first (0-25%) and last (75-100%) quartiles, and outliers are indicated as dots.

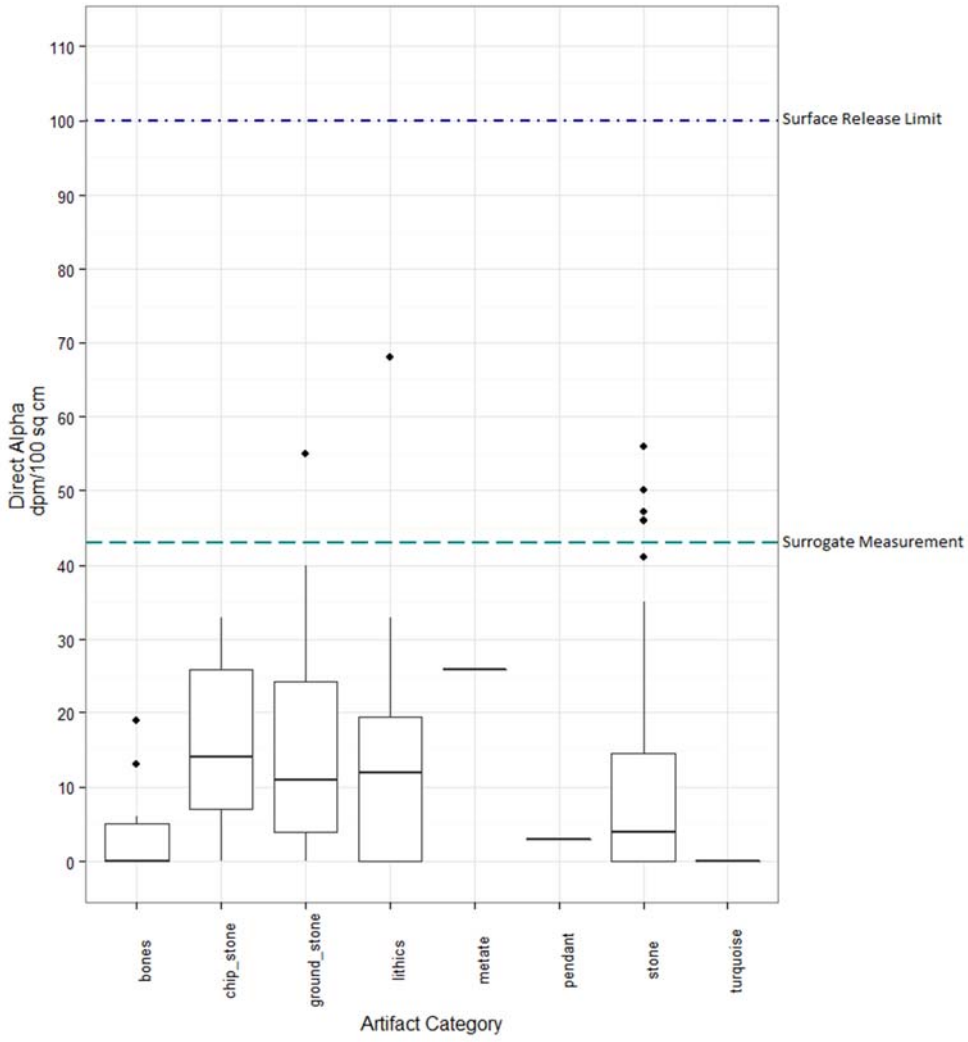


Figure 6 Direct beta survey results for stones and materials most comparable to a concrete surrogate. In the plot, the thick line in the center of each box represents the median value for each artifact type, while the box spans the range of values from the 25th to the 75th percentile (e.g., the range of 50% of the data). Vertical lines display the first (0-25%) and last (75-100%) quartiles, and outliers are indicated as dots.

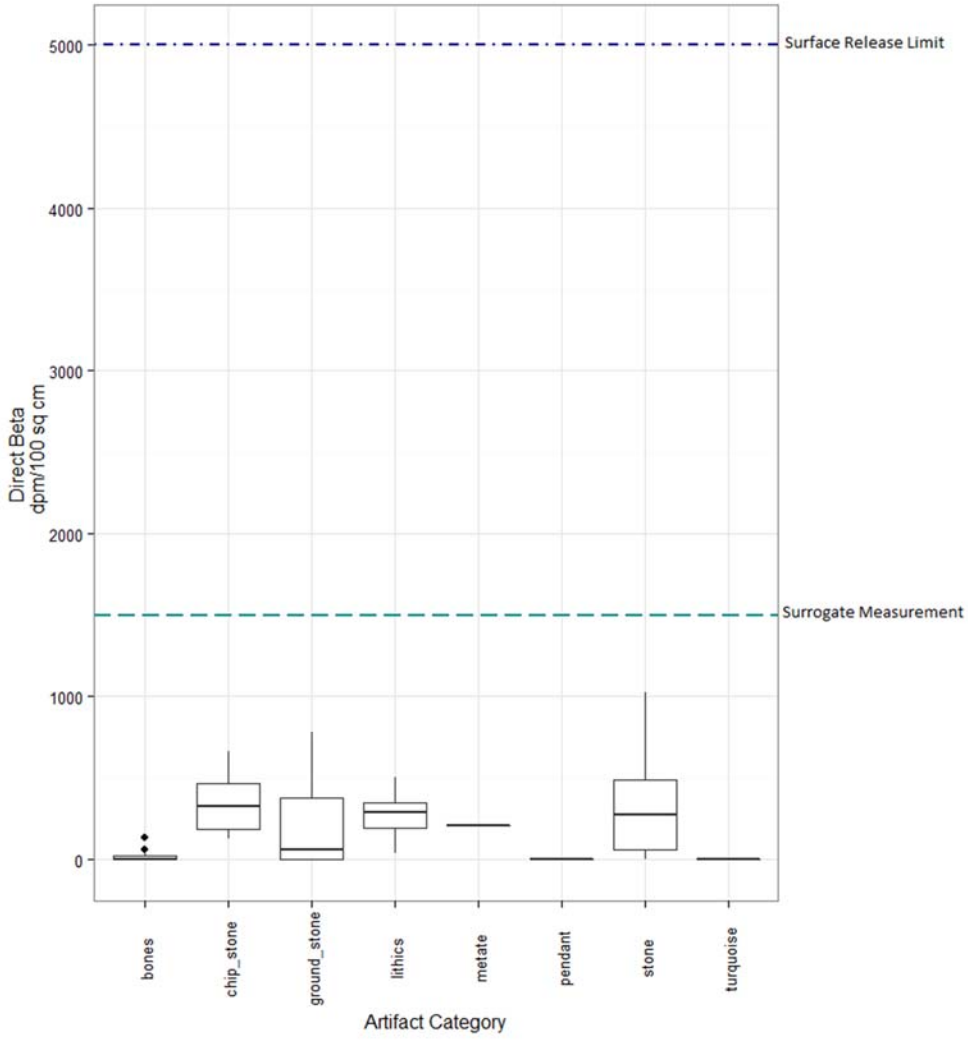
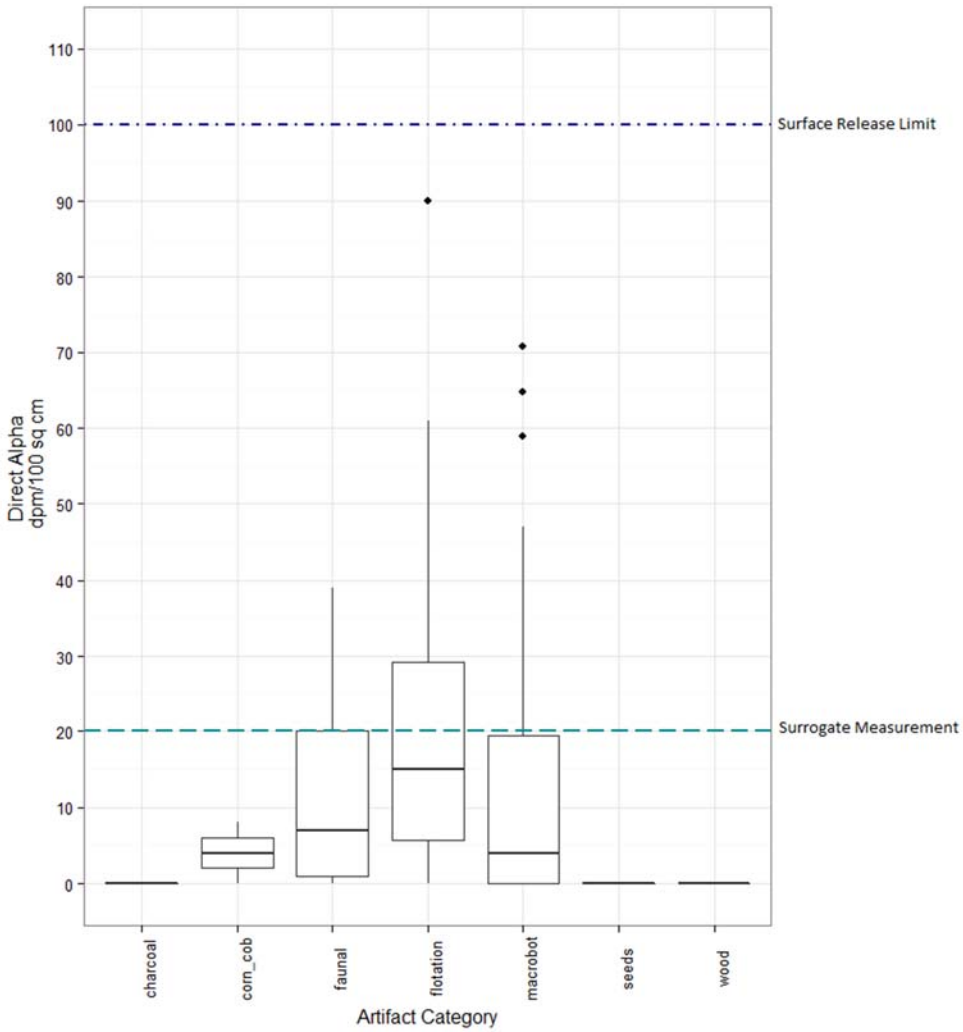
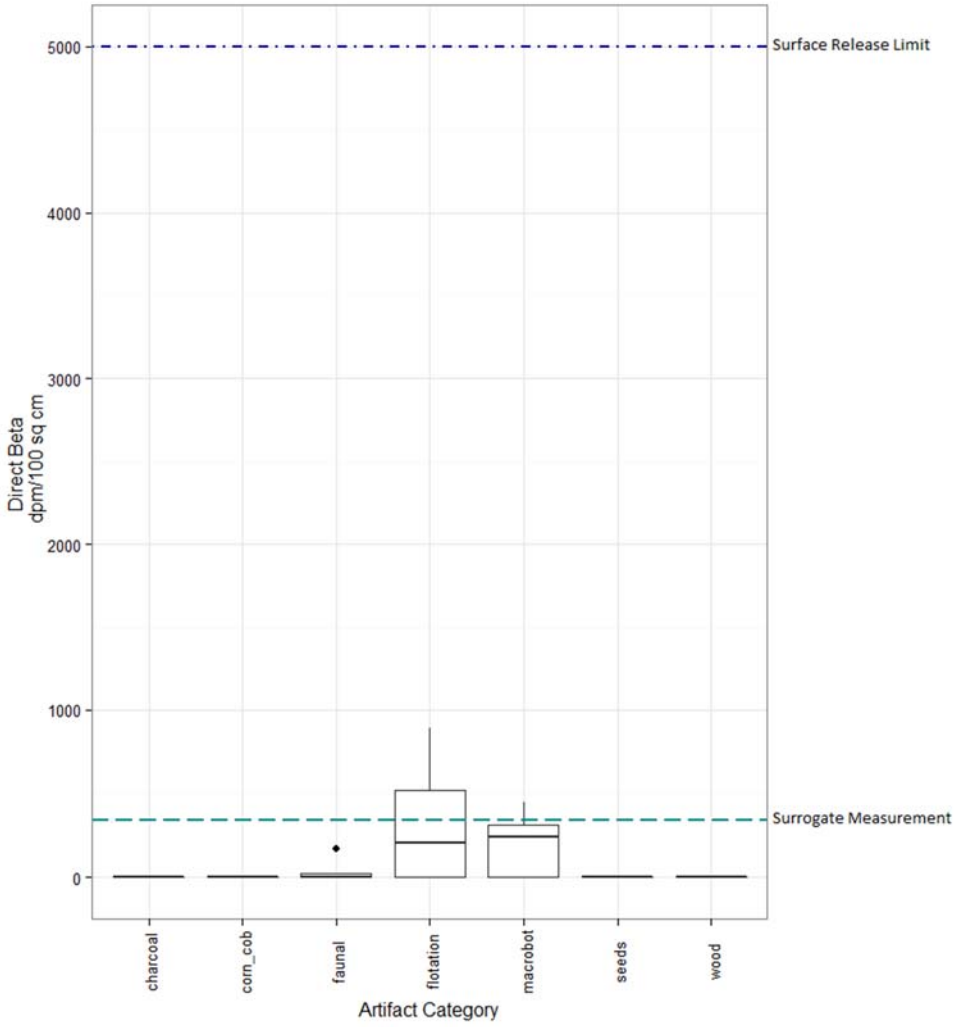


Figure 7 Direct alpha survey results for biologics and materials most comparable to a wood surrogate. In the plot, the thick line in the center of each box represents the median value for each artifact type, while the box spans the range of values from the 25th to the 75th percentile (e.g., the range of 50% of the data). Vertical lines display the first (0-25%) and last (75-100%) quartiles, and outliers are indicated as dots.



Note: High results for flotation relative to the surrogate material (wood) suggestion that flotation samples may contain some rocky material (e.g., pumice). For a more complete explanation of this phenomena, see text.

Figure 8 Direct beta survey results for biologics and materials most comparable to a wood surrogate. In the plot, the thick line in the center of each box represents the median value for each artifact type, while the box spans the range of values from the 25th to the 75th percentile (e.g., the range of 50% of the data). Vertical lines display the first (0-25%) and last (75-100%) quartiles, and outliers are indicated as dots.



Note: High results for flotation relative to the surrogate material (wood) suggestion that flotation samples may contain some rocky material (e.g., pumice). For a more complete explanation of this phenomena, see text.

References

(LANL P412) Los Alamos National Laboratory (2014). *Environmental Radiation Protection*. LANL Policy P412, R1.

(LANL TPP) Los Alamos National Laboratory (2015). *Data Quality Objectives for Measurement of Radioactivity in or on Items for Transfer into the Public Domain.* LANL Technical Project Plan ENV-ES-TPP-001, R1.

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