



*A Statistical Survey for the Presence of Beryllium
in an LLNL Engineering Facility*

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Topics



- **Drivers**
- **Statistical Design**
- **Findings**
- **Future Actions**

NNSA Assessment of Its Contractor Programs



- **The NNSA investigation of the CBD case at the North Las Vegas facility prompted Ambassador Linton Brooks to direct the NNSA Field Offices to do an assessment of Baseline Beryllium Inventories at its contractor sites to assess:**
 - **Adequacy and completeness of the baseline inventory.**
 - **Adequacy of evaluation of historical activities.**
 - **Practices and procedures minimize the inadvertent spread of contamination.**
 - **Periodic monitoring of uncontrolled areas adjacent to beryllium-controlled areas.**

LLNL Baseline Inventory



- **DOE Livermore Site Office found that the LLNL baseline inventory did not meet the Ambassador's expectations.**
- **Guidance for surveying for contamination in LLNL buildings was provided in general terms and left to the discretion of the cognizant industrial hygienist.**
 - **Fundamental questions of how large or small of an area to sample, where to sample, what to sample, how to sample were generally not answered.**
 - **Each industrial hygienist had a different opinion as to how the survey should be conducted.**
 - **Establishing a statistical goal was no assurance that it would be met.**
- **The conclusion was that our survey did not have statistical rigor.**

Original Baseline Survey



- **A moderate number of samples were taken.**
- **Sampling locations were identified as “legacy” areas in buildings.**
 - A small number of samples were taken in each room.
 - Samples were taken only in “occupied” space, that is, where someone would normally work. No overhead samples; samples behind or under equipment. Floors were typical sample locations.
 - No building was systematically evaluated.
- **Surface swipes were taken dry following our conventional protocol.**
- **Process record reviews found areas that weren’t sampled.**
- **Results were compared to the 10 CFR 850 release criteria of $0.2 \mu\text{g}/100 \text{ cm}^2$.**
- **Typical results were $<0.02 \mu\text{g}/100 \text{ cm}^2$; few were detectable, and very few were at levels of concern.**
- **The survey did not indicate a contamination issue.**

The Design Starts ...



- **Can we take the approach of trying to validate our original survey?**
 - In principle, yes; but any finding of contamination invalidates the original survey, and then we're back at the beginning.
 - We decided not to take this approach.
- **The question ultimately becomes “How much risk do we accept?”**
 - Our original survey is not suggestive of widespread contamination.
 - We want a somewhat high level of confidence in finding contamination.
 - We don't want to expend an unreasonable amount of resources.

... and Matures



- **We assume a finite population size, that is, the population is the number of 100 cm² areas that could be swiped.**
- **We define how confident we want to be in finding the contamination.**
- **The statistical problem becomes one of sampling a population of two distinct types.**
 - **Detected vs. not detected or contaminated vs. not contaminated depending on what we find.**
 - **For a finite population this is described by the hypergeometric distribution.**
- **We can make some assumptions, and do some modeling.**

... and Starts to Congeal



- If we assume an “expected rate for contamination” and choose sample sizes, our confidence, or detection probability, is defined.

Expected Rate:	0.1	0.05	0.01
Sample Size	Detection Probability		
20	0.880	0.644	0.183
29	0.954	0.778	0.255
50	0.995	0.927	0.401

We need to scope the problem.



- **Is a building homogeneous?**
 - Probably not; define “survey units.”
 - A survey unit is a group of rooms (labs, shops) that did a similar function or part of the same activity, contiguous to one another; logically fit together.
- **Are survey units homogenous?**
 - Probably not; define “strata.”
 - Strata are surfaces in the survey unit that are assumed to be similar.
 - This is a judgment call. We chose four strata: floors, furniture, equipment, and elevated surfaces over eight feet.
- **Guideline: when in doubt, split a survey unit into parts.**
 - Once the data is in, we can test the hypothesis as to whether or not the survey units consist of one or more populations.

And define the population to be surveyed



- **Our target building population is 208 buildings.**
 - Buildings vary considerably in function or complexity, age, size, and beryllium history.
 - We do not have the resources to survey the entire 208 buildings.
- **We proposed a pilot survey of a complex building with a long Be history to test the method and the assumptions.**
- **We chose a major building in the Engineering Directorate:**
 - Be Work Areas
 - Be Legacy Areas
 - Non-Be Areas
- **Built in 1954**
- **180,184 square feet**
- **Supported fundamental LLNL projects**
- **Usage changed over time**
- **Moderate amount of historical documentation is available**
- **Two high bays**
- **Manufacturing facilities**
- **Research facilities**
- **Labs and shops, active and inactive**
- **Storage areas**
- **Offices**

Decisions



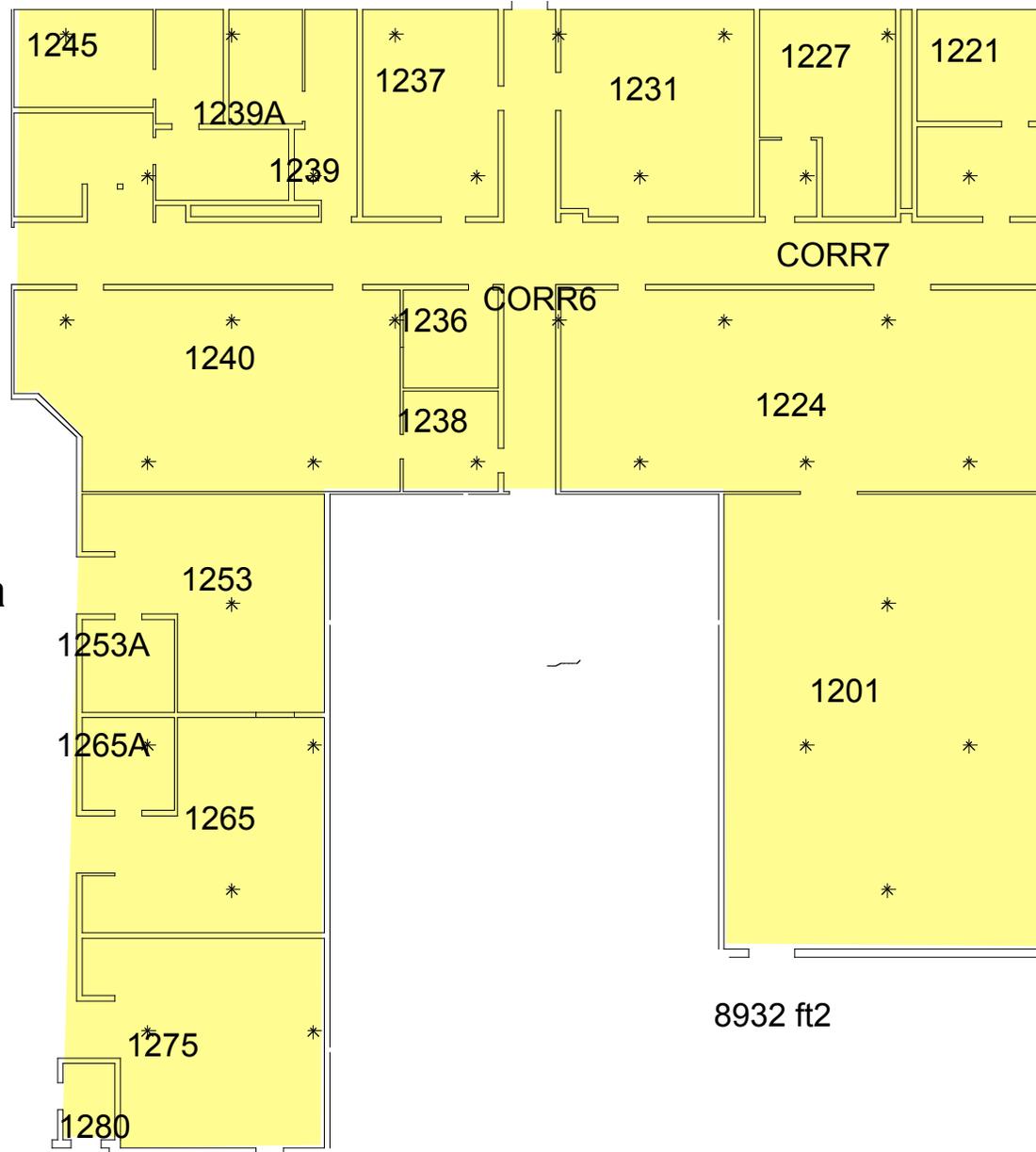
- **We considered**
 - The probability of finding contamination assuming a percentage of the population to be sampled could be contaminated.
 - The number of buildings to be sampled.
 - The number of survey units and strata to be sampled.
- **We concluded that our sampling would have a 95% probability of sampling in the top 10% of contaminated spots.**
 - We need to take 29 samples per strata.
- **“Contamination” is removable beryllium above the release criteria of $0.2 \mu\text{g}/100 \text{ cm}^2$.**
- **The pilot building was then divided into 23 survey units, with 4 strata per survey unit, for more than 2600 statistically random samples.**

Process



- **Sampling plans are written for each survey unit.**
- **We chose Pacific Northwest National Laboratory's Visual Sample Plan (VSP) to establish sampling points based on the LLNL CAD drawings.**
- **We defined rules for choosing sampling points if VSP picked a location that could not be sampled (not accessible or not existent).**
- **We gave the sampler the option of "judgmental" samples based on conditions found, in addition to the statistical samples.**
- **We have a defined sampling protocol and trained the samplers.**
 - **Sampling protocol is changed from "dry" to "wet."**
- **Guidance for bulk sampling on "dirty" surfaces comes from the project manager.**
- **All samples were analyzed for "total beryllium" (a method that will determine high fired BeO) at an AIHA accredited laboratory. Detection limit is 0.02 $\mu\text{g}/100 \text{ cm}^2$.**

**VSP sample:
floor
locations in a
survey unit**



Results ~ Qualitative



- **The pilot is approximately 50% complete.**
- **We have sampled shops, labs, offices, storage areas that include active Be work areas, legacy areas, and non-Be work areas.**
 - **Sampled surfaces varied from relatively clean (no visible dust) to quite dusty.**
 - **Most of the data is unremarkable. A “typical” strata is mostly below limit of detection, with an occasional low, detectable result. Bulk samples of dust did not differ in Be content from the general LLNL environment.**
- **One strata, elevated surfaces, in two adjacent survey units appeared to be different.**
 - **Approximately 40% of the samples had detectable beryllium.**
 - **A few samples were above the release criteria.**

Results ~ Quantitative



- **First approach: evaluate survey strategy.**
 - Do our survey units represent the same or different populations?
 - Can we combine survey units to increase efficiency?
 - Can we combine strata?
- **Second approach: evaluate survey results.**
 - Do we exceed criteria?

Evaluation strategy



- Look at the data in a survey unit/strata from the perspective of detected vs non-detected.
 - This is a classic χ^2 test or a 2 x n contingency table.

	No. detected	No. non-detect
Survey unit #1	x_1	y_1
Survey unit #2	x_2	y_2
Survey unit #3	x_3	y_3

$$\chi^2 = \sum \frac{(o - e)^2}{e}$$

Interpretation



- χ^2 evaluates the hypothesis that the data comes from one population.
- Examination of the data can suggest which elements may differ.

Overview of data: elevated strata



	A	B	C	D	E	F	G	H	I	J	K
No. of samples	30	37	32	32	32	32	32	32	32	32	32
Non-detects	25	36	29	30	31	27	28	30	17	26	15
detects	5	1	3	2	1	5	4	2	15	6	17
% > 0.2	0%	0%	0%	0%	0%	0%	0%	0%	3%	0%	9%

Floor Data (Qualitative Review)



- **12 survey units done**
- **Generally not enough "detected" data to do statistics on.**
 - 10 of 12 sets have 0 or 1 "detects" per set
 - 2 of 12 sets have 2 detects
 - Largest detected value is 24.5% of release criteria
- **Conclusion: Combine all floors data into one survey unit with 371 samples.**
- **Don't bother to calculate estimates of summary statistics.**

Furniture and Equipment



- These both tend to occupy the same “space.”
- We took the conservative view that they might be different and sampled separately.
- Most of the detected results were low, with an occasional “spike” in both.

	Detects	Non-detects
Furniture	11	341
Equipment	15	339

- $\chi^2 = 0.615 < 3.84$; not significant at 95%.
- Survey units in the pilot can probably be combined.

The Elevated Surfaces



- **Qualitatively the data “looked different” from the rest of the building.**
 - Relative number of detected results was much higher.
 - Elevated data appeared to be localized to one part of the building.
- **Evaluation of the elevated surfaces strata gives $\chi^2 = 66.12 > 18.31$; therefore, result is significant at 95%.**
 - The data represents more than one population.
 - Run χ^2 on the apparent two populations.
 - Each population now appears uniform.

Estimates of Summary Statistics



- **We are trying to use the R routines developed by ORNL.**
 - When there are very few (0 or 1) detectable results calculation is not possible.
 - At 2 detectable results estimates of upper confidence limits seem to be over estimated.
- **For one survey unit (32 samples; elevated strata; data ranges from <LOD to 0.72 $\mu\text{g}/100 \text{ cm}^2$) estimate of selected statistics:**
 - Arithmetic mean (MLE): 0.051
 - Upper confidence limit (95%): 0.104
 - Exceedance fraction (MLE for limit of 0.2): 4.83%
- **These suggest that beryllium is detected, but that the area is not contaminated.**
- **Within normal IH criteria, 95% confidence, we don't have a problem.**

Comparison of strata



- **It is probably not necessary to split the floor into many survey units.**
- **Furniture and equipment may be combined into one strata.**
- **Elevated surfaces, which are almost never cleaned, may be a likely place or the presence of contamination.**
 - **Review of the building history can provide clues as to when this may be an issue.**

Public Relations



- **Beryllium generates a lot of interest.**
- **When the sampling team descends on a building, concern among building occupants is raised.**
- **We met with building management prior to the survey.**
- **We prepared a flyer for building occupants explaining what we were doing and why.**
- **We spoke with some building occupants who had more questions.**
- **We will provide a report to the building management and all interested parties at the conclusion.**
- **This is fine until you find something ... and we did.**

Addressing questions and concerns



- **Results were provided to the building management.**
- **The immediate questions: Are these results real and what is the risk to building occupants?**
- **Our actions:**
 - **Resample and either validate or refute the survey results (we validated).**
 - **Determine presence or absence of airborne beryllium (none found).**
 - **Brief all levels of management that need to know what is going on.**
 - **Brief building occupants; allow ample time for all questions to be answered.**
 - **We chose a periodic building staff meeting.**
 - **Participants included the beryllium subject matter expert (and survey manager), the Safety Team supporting the area (Team Leader and industrial hygienist), and a representative from the medical department.**
 - **Brief the DOE site office and answer their questions.**

Immediate and future actions



- **Evaluate activities that can disturb dust**
 - Put appropriate controls in place to prevent exposure.
 - Communicate results to all relevant parties.
- **Develop a plan to clean up the area at a convenient time.**

What's it all mean, Alfie?



- **When a data set is mostly “non-detect”, and the largest value is a fraction of the release criteria, what statistical evaluation, if any, is needed?**
- **How much “detected” data is necessary for valid statistical analysis?**
- **What is the appropriate metric?**
- **What is the health significance of a few sample locations with beryllium present above $0.2 \mu\text{g}/100 \text{ cm}^2$?**
- **Should there be a measurement process analogous to time weighted average air sampling for surface sampling?**

Summary



- **We have a sampling plan that works, based on our partially completed pilot.**
- **Evaluation of the data suggests that we may be able to limit or consolidate future surveys.**
- **Statistical analysis can be done at two levels.**
- **Building occupants need to be part of the process and kept fully informed.**
- **Future building surveys can probably be streamlined to reduce the number of survey units and number of strata, and thereby increase efficiency.**
- **We have identified the need for further guidance.**

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