Developing a “Probabilistic Sampling Toolkit” to supplement judgmental sampling approaches used during initial assessment sampling following a terrorism incident

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Presentation Overview

- Background and scenarios
- Approach – Incorporating judgmental sampling into a probabilistic sample plan
- Using software to aid field investigator
- Status and Future Plans
- Secondary benefits?

Goal: Provide orientation about ongoing project
(Minimal discussion of statistics)
Background – 2001 Investigations

NIOSH investigators successfully used professional judgment to quickly identify the presence of *Bacillus anthracis* contamination during the 2001 bioterrorism incidents.
Background – NIOSH role in initial response

Inputs for targeted sampling strategy during initial response

- Incident details
- Epidemiological findings
- IH expertise
## Anthrax Environmental Sampling Results By Location at Postal Processing and Distribution Facilities*

<table>
<thead>
<tr>
<th>Sampling Location</th>
<th>Number of Samples</th>
<th>Number and Proportion Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mail sorting devices</td>
<td>435</td>
<td>151 (34.7%)</td>
</tr>
<tr>
<td>Other postal machines</td>
<td>288</td>
<td>59 (20.5%)</td>
</tr>
<tr>
<td>Office furniture</td>
<td>49</td>
<td>20 (40.8%)</td>
</tr>
<tr>
<td>Office equipment</td>
<td>32</td>
<td>8 (25.0%)</td>
</tr>
<tr>
<td>Ventilation system</td>
<td>26</td>
<td>10 (38.5%)</td>
</tr>
<tr>
<td>Windows</td>
<td>24</td>
<td>11 (45.8%)</td>
</tr>
<tr>
<td>Mailbag/pouch/box</td>
<td>16</td>
<td>13 (81.3%)</td>
</tr>
<tr>
<td>Wall/wall boxes</td>
<td>14</td>
<td>2 (14.3%)</td>
</tr>
<tr>
<td>Floor</td>
<td>5</td>
<td>2 (40.0%)</td>
</tr>
</tbody>
</table>

* Surface samples taken by NIOSH investigators

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*NIOSH*
Bioterrorism Scenarios – Three major types

1: Discovery of physical evidence (e.g. suspicious package)

2: Report of medical symptoms or illness with suspicion that it is not due to a natural outbreak

3: Detection of agent by an environmental sampling surveillance system (e.g. BioWatch or BDS)
Judgmental (or targeted) sampling for initial assessment

Pros

– Rapid response
– Efficient when limited lab capability for analysis of samples
– Allows general inferences (but non-statistical)

Cons

– Dependent on availability and quality of incident details
– Does not allow statistical inferences
Random sampling (e.g. using systematic grid) for initial assessment

Pros
– Allows statistical inferences

Cons
– Takes longer to implement
– Requires large number of samples
– Locations of interest not given any higher chance of inclusion in sample plan
The Problem

What if incident details are lacking or uncertain?

If your judgmental results are negative, what confidence can you then have that they truly correspond to an absence of detectable contamination?

Using probabilistic methods can supplement a judgmental approach and allow statistical inferences about the likelihood of contamination being present.
Other sampling challenges

Need limit of detection and collection efficiency data
- Validation studies still underway
- Need to use default values for statistical sampling

No lower limit or standard dictating public health response
- Limited health-based criteria
- Binary responses (positive or negative)
"...strategies that include probability sampling need to be developed in order to provide statistical confidence in negative results. Further, even if information on all the performance characteristics of methods is not yet available, a probability sampling strategy could be developed from assumptions about the efficiency of some of the methods...This would enable agencies and the public to have greater confidence in negative test results than was associated with the sampling strategy used in 2001.(p26)"
NIOSH developing Toolkit approach in response

Target Samples
- Rapid and responsive when reliable details;
- Does not quantify confidence

Probabilistic Samples
- Provides Quantifiable confidence;
- Requires more time and samples;

Combined approach for greater efficiency and confidence

Develop as suite of tools to assist investigator in the field
Use Bayesian statistics to combine Judgmental and Probabilistic approaches

“Unlike conventional statistical methods applied to exposure data, Bayesian statistical techniques can be adapted to explicitly take into account professional judgment or other sources of information” [Hewett et al, 2006]

Bayesian approaches allow the user to include some prior knowledge about the chances that the judgment samples will come back contaminated, and about the relative chances that judgment samples are contaminated relative to non-judgment samples.

In addition to the judgment samples, how many probabilistic samples (all negative) are needed to obtain a given level of confidence of no detectable contamination? (or a specified level of cleanliness)
Use software support for probabilistic sampling

Using Visual Sample Plan

developed by Pacific Northwest National Lab (PNNL) with
Sponsorship from DHS, DOE, EPA, DoD, UK, CDC

- Planning Software designed for the Non-Statistician
- Visual, Graphical, DQO (Data Quality Objective) based
- In public domain – Free VSP Download at http://dqo.pnl.gov/vsp
Visual Sample Plan features

- Performs Statistical and Graphical Tests of Distribution Assumptions. Designs/Displays Sampling Schemes

- Allows Quick Tradeoff or “What-if” evaluations to see the effect of changing requirements

- Visual Features with Sampling Locations Displayed on Maps
Visual Sample Plan features

- Both Normal and Non-Normal Distribution Methods
- Automatic Report Generator
- Technical support system via online help, user’s manual, technical basis documents, training
- Input building plans as AutoCAD or ArcView GIS files (also contains a drawing feature)

About > 5000 VSP users world-wide – being used to focus on Buildings/Rooms, Surfaces, Sediment/Soil Layers, Unexploded Ordinance contamination
Overview of approach

Assess Incident details
Develop Judgmental sampling plan
Perform sampling

If results negative – have probabilistic option
Inputs include judgmental results, other inputs
Generate probabilistic sample plan options

Proceed with probabilistic sampling
Judgmental/targeted sampling steps

1. Evaluate circumstances of event via interview and observation.
2. Identify **all** plausible contamination pathways (e.g. process, foot traffic, air movement, maintenance or other pathways).
3. Develop a sampling plan to target locations for **each** plausible pathway that are “most likely to be contaminated”.
4. Classify overall site into one of 4 zones.
5. Collect surface samples.
Classifying contamination zones using judgmental approach

Zone 1:  Definitely contaminated
(e.g. the immediate location where evidence was found to be positive)

Zone 2:  High Likelihood of contamination
(e.g. initial assessment suggests location is part of plausible pathway)

Zone 3:  Low likelihood of contamination
(e.g. borders a zone 2 location)

Zone 4:  Unlikely to be contaminated
(e.g. not contiguous or linked to areas bordering zone 2 location)
Estimating overall confidence in judgmental sampling plan

<table>
<thead>
<tr>
<th>Pre-sampling confidence and expectations</th>
<th>Incident detail information</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Contamination path and timeframe?</td>
</tr>
<tr>
<td></td>
<td>Contamination vehicle? (e.g. letter or device)</td>
</tr>
<tr>
<td><strong>HIGH</strong></td>
<td>Recovered</td>
</tr>
<tr>
<td><strong>MEDIUM</strong></td>
<td>Recovered</td>
</tr>
<tr>
<td><strong>LOW</strong></td>
<td>Not Recovered</td>
</tr>
</tbody>
</table>

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Judgmental outputs are used as inputs for combined “Toolkit” approach

EXAMPLE
- Discovery of physical evidence (Scenario 1) with positive on evidence.
- Question you want to answer: *Is contamination present in other locations? (Zone 2 or 3 locations)*

STEPS
- Judgmental samples are collected ---found to be “negative”
- Decision made to supplement with probabilistic sampling
- Location site plans are loaded into Visual Sample Plan (VSP) software on laptop
- Judgmental results and locations are entered into VSP plan
- VSP overlays surface sample sized grid (100 cm²) over floor plan
Toolkit approach cont.

Software walks investigator through a series of questions based on:

- Level of confidence in incident details and judgmental plan (for informative prior distribution)
- Specify how much more likely contamination is in the judgment area samples than in the non-judgment area samples
- User must specify the level of cleanliness required
- Desired statistical design objectives for probabilistic plan (e.g. 90 vs 95% confidence)
- Investigator can review options prior to deciding on design

VSP then randomly selects locations and number of samples needed and facilitates “gridding out” the location.
Before any sampling took place, I suspected there was a low probability that the selected areas contained detectable contamination.

I took (or will take) 15 targeted (judgmental) samples.

I believe that a targeted (judgmental) sample location is 5 times more likely to contain detectable contamination than a random location.

I want 95.00% confidence that at least 99.00% of the grid cells in the selected areas do not contain detectable contamination.

Number of random samples: 40

If all 15 targeted (judgmental) samples and 40 random samples do not contain detectable contamination, then I am 95.01% confident that at least 99% of the 1000 grid cells in the selected areas do not contain detectable contamination.

If any of the targeted (judgmental) or random samples contain detectable contamination, then the confidence statement above no longer applies and I must assume that at least some portion of the selected areas is contaminated. This would suggest that the selected areas should be decontaminated or that the extent of contamination be further delineated.
Prior to sampling, the chances that all judgment samples will be negative is 70%.

Judgment sample locations are 3 times more likely to be contaminated than random locations.

Information from Prior Assumptions & Negative Judgment samples is used to reduce the number of random samples required to obtain the desired confidence.

95% Confident that at least 99% of the surface area in the office does not contain detectable contamination.

Parameters controlled by the investigator are highlighted in yellow.
Scenario 1 example

Scenario 1:
- Contaminated letter delivered to mail station
- Letter carried to desk and opened there
- Suspicious dust falls out
- Dust noticed right away
- 2 co-workers and guard visit to help
Scenario 1: Zones of Contamination

- Zone 1 (Confirmed Contamination)
- Zone 2 (Possible Contamination)
- Zone 3 (Potential Contamination)

Contaminated Letter Opened
Scenario 1: Judgmental Samples for adjacent Zone 2 room

light switch

doorway

wall

floor

wall

wall

wall

ceiling

computer monitor

below vent

vent

suspicious spot on wall
Scenario 1: Probabilistic Samples

- 20 judgmental samples taken
- All judgmental samples negative
- Judgment samples are considered 5 times more likely to show contamination than probabilistic samples
- 95% confidence that 99% of unsampled area of room will give negative samples
- 56 probabilistic samples (all negative) needed
Future Work

• Software implementation
• Evaluation of approach using simulations and field exercise
• Develop enhancements to account for furniture and surfaces within a room
• Guidance document for field use

Thanks to NIOSH and PNNL colleagues for input and suggestions!
Secondary benefits?

• EPA and others can develop further for application to characterization and clearance sampling
• Use for related surface sampling scenarios – e.g. PCBs, lead?
• Increasing interest in use of Bayesian methods for other aspects of IH practice?
• Increasing use of software tools?
Questions?

Statistical questions?

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  • 513.841.4231  wks1@CDC.GOV
Brent Pulsipher – lead PNNL contact at
  • 509-375-3989  brent.pulsipher@pnl.gov
VSP info at http://dqe.pnl.gov/vsp/

The findings and conclusions in this presentation have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.
Anthrax Detection: Agencies Need to Validate Sampling Activities In Order to Increase Confidence in Negative Results. GAO-05-251, March 31.2005


