AN ANALYTICAL TECHNIQUE FOR DISTRIBUTING AIR SAMPLING LOCATIONS AROUND NUCLEAR FACILITIES

by

D. A. Waite

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I. INTRODUCTION

The objective of environmental monitoring may be expressed as (1) to test compliance with the relevant national or local requirements; (2) to establish, with reasonable confidence, that individual members of the population are not, as a result of the operation of nuclear facilities, exposed to radiation or radioactive materials at levels in excess of approximate standards; (3) to protect man and animals from unnecessary radiation exposure; and (4) to control radiation doses received by members of the general public as a result of the normal operation of a nuclear establishment. As has recently been re-emphasized by Johnston, a multitude of factors are involved in making a surveillance system meet these objectives. Both Pelletier and Johnston have illustrated the relatively low probabilities of short duration release detection presently obtainable within reasonable economic constraints.

General realization of this situation among those directly involved in the design and conduct of environmental surveillance systems around all types of nuclear facilities has resulted in the common use of undisciplined programs for environmental surveillance of routine releases. In an attempt to provide a consistent, uncomplicated, economical mechanism for the examination of surveillance systems, a search was begun for factors which influence a system's ability to assess population exposures and which could be incorporated into a workable sampling location distribution procedure. An examination of parameters involved in release mechanisms, transport models and exposure pathways for airborne releases from nuclear fuel cycle facilities, revealed that population exposure magnitudes were most directly related to population and contaminant transport characteristics of the site involved.

II. WEIGHTING TECHNIQUE

A. Bases

Distances of environmental media sampling locations are generally selected to correspond to plant boundaries, maximum potential
II. WEIGHTING TECHNIQUE (Continued)

A. Bases (Continued)

points, population centers and relatively unaffected areas. Examination of existing surveillance programs indicated that the needed guidance was in the radial partitioning of sampling locations. The relationship, \( (8) \) seen on Slide #1,

\[
\text{Weighting Factor} = \frac{\text{Fraction of the population}}{\text{Distance}} + \frac{\text{Fraction of time}}{\text{downwind of source}}
\]

associating variables involving demographic and meteorologic data, was found to yield useful recommendations when applied to a site on an octant basis. Furthermore, the distribution of locations derived in this manner were found to correspond well with existing placements on sites which have been occupied by long-established programs with their inherent evolution and refinements.

Results of sampling location distribution comparisons for 11 mature sites having up to 40 sampling locations, including power reactors, uranium enrichment facilities, fuel fabrication plants and research establishments, are presented on Slide #2. The deviation noted on the abscissa is the difference between calculated and actual number of sampling locations present per octant.

It should be noted that nearly 3/4 of all nonzero deviations are of magnitude 1. A large proportion of the greater deviations can be attributed, upon closer examination of the raw data, to the relatively arbitrary placement of octant boundaries and to necessary criteria for rounding the calculated values.
Slide #2 - Deviations in Location Distributions
II. WEIGHTING TECHNIQUE (Continued)

B. Mechanism

The sum of 8 calculated weighting factors is scaled to equal the desired number of sampling locations. The total number of locations can be decided on purely economic grounds or can be derived by normalizing the weighting factors to a specific minimum number per octant, a minimum number per unit population or by any other elected criteria. The scaling factor, when multiplied by each individual octant weighting factor, yields the number of sampling locations within that particular octant when rounded to the nearest integer.

The method is exemplified on Slide #3
1. Cities

<table>
<thead>
<tr>
<th>Direction From Source</th>
<th>Population</th>
<th>Distance From Source</th>
<th>Fraction Total Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>A NW</td>
<td>50,000</td>
<td>2 miles</td>
<td>.5</td>
</tr>
<tr>
<td>B SW</td>
<td>30,000</td>
<td>6 miles</td>
<td>.3</td>
</tr>
<tr>
<td>C E</td>
<td>20,000</td>
<td>10 miles</td>
<td>.2</td>
</tr>
</tbody>
</table>

2. Annual average wind direction

<table>
<thead>
<tr>
<th>Direction From Source</th>
<th>Fraction of Time Downwind of Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>.20</td>
</tr>
<tr>
<td>NW</td>
<td>.15</td>
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<tr>
<td>W</td>
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<tr>
<td>E</td>
<td>.20</td>
</tr>
<tr>
<td>NE</td>
<td>.10</td>
</tr>
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</table>

3. Total of 15 air sampling locations

<table>
<thead>
<tr>
<th>Direction From Source</th>
<th>Fraction of Population Distance</th>
<th>Fraction of Time Downwind</th>
<th>Scaled W</th>
<th>Number of Samplers</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>0</td>
<td>.20</td>
<td>.20</td>
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<tr>
<td>NW</td>
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<td>.15</td>
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<td>0</td>
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<tr>
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<td>.15</td>
<td>.20</td>
<td>2</td>
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<tr>
<td>S</td>
<td>0</td>
<td>.10</td>
<td>.10</td>
<td>1</td>
</tr>
<tr>
<td>SE</td>
<td>0</td>
<td>.10</td>
<td>.10</td>
<td>1</td>
</tr>
<tr>
<td>E</td>
<td>.02</td>
<td>.20</td>
<td>.22</td>
<td>3</td>
</tr>
<tr>
<td>NE</td>
<td>0</td>
<td>.10</td>
<td>.10</td>
<td>1</td>
</tr>
</tbody>
</table>

Scaling factor = \( \frac{15}{1.32} = 11.4 \)
Data:

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<th>Fraction of Time Downwind</th>
<th>Scaled W</th>
<th>Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
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<td>.20</td>
<td>.20</td>
<td>2</td>
</tr>
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</table>

Scaling factor = \( \frac{15}{1.32} = 11.4 \)
II. WEIGHTING TECHNIQUE (Continued)

B. Mechanism (Continued)

The application of this method to sites in coastal or agricultural areas requires only minor modification of the procedure illustrated in the example. In coastal zones it is usually appropriate to adjust the number of radial divisions to the number required to cover the surrounding inhabited land mass.

For agricultural areas, an equivalent population index is necessarily applied. This index is derived by multiplying the number of people who are direct recipients of produce, dairy products, etc., from the area by the biological discrimination factor for the critical nuclide in the exposure pathway involved.

C. Testing

To assess the utility of the procedure, a site in Germany with a well-established surveillance system was chosen as a model for testing. Two individuals unfamiliar with the site but knowledgeable in environmental program design were asked to distribute 8 air sampling locations around the facility first on an experience basis and then using the weighting factor procedure. Any site data requested was supplied. The local geography of the facility is illustrated on Slide #4. Winds are predominantly toward the west-southwest (54%) and east-northeast (29%). The locations of the approximately 300,000 local inhabitants is indicated by the relative size of the population centers noted on the Slide.
Umgebung des Kernkraftwerks Obrigheim
Probenahme- und Meßorte

1. Obrigheim NW, Hof Horn
2. Obrigheim O, Neckarbrücke
3. Obrigheim, Trinkwassernetz
4. Diedesheim, am Wasserwerk
5. Schreckhof
6. Binau-Siedlung
7. Binau NO, Hof Krämer
8. Mortelstein NO, am Wasserwerk
9. Mortelstein, Trinkwassernetz
10. B292, Hochspannungsleitung
11. Gewann Hinterfeld
12. Gewann Frankenäcker
13. KWO, Verwaltungsgebäude
14. Neckar, oberhalb KWO
15. Neckar, unterhalb KWO
16. Neckar bei Guttenbach
17. Bad Wimpfen, an der B 27
18. Haßmersheim
II. WEIGHTING TECHNIQUE (Continued)

C. Testing (Continued)

A comparison of the design results with the existing program at the site is indicated on Slide #5. In addition to the noticeable improvement in accuracy with the weighting factor technique, a substantial savings of time also resulted from using the calculational method. It should also be emphasized that successful employment of this technique requires no extensive background in environmental surveillance system design. Regardless of the individuals involved in the calculational process, a program consistent with the input data will result. This fact, plus the simplicity of the data input, makes it economically possible for any undisciplined surveillance program to be updated to include sampling location distributions which correlate well with placements on sites which have been occupied by long-established programs with their inherent evolution and refinements.
Slide #5 - Deviations in Distribution Methods

- Experience Based Design
- Weighting Factor Design

Frequency (y) vs. Observed Deviation (x)
REFERENCES


