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# ANALYSIS OF AN ANALYTICAL TECHNIQUE FOR DISTRIBUTING AIR SAMPLING LOCATIONS AROUND NUCLEAR FACILITIES

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## Abstract

A new analytical mechanism for distributing air sampling locations around nuclear facilities, including reactors, fuel fabrication, fuel reprocessing and research centers, has been devised. This method was developed to facilitate the efficient incorporation of past experiences into environmental surveillance programs for new or developing installations. The technique provides an initial distribution of air samplers around a site which correlates well with placements on sites which have been occupied by long established programs with their inherent evolution and refinements. The applicability of this approach has been examined by comparing sampling locations in well-established air monitoring programs scattered worldwide with location distributions recommended by this mechanism. Results of these comparisons will be detailed.

## Introduction

In recent years public pressure has compelled an increase in attention to environmental surveillance around industrial complexes of all types. Information involving probabilities of detecting short duration releases in the environment have been widely circulated. It is seldom noted, however, that in contrast to emergency monitoring, the worth of systems for routine environmental surveillance is judged on the basis of long-term productivity. Even though this fundamental difference exists between monitoring accident and routine conditions, the publicity in some cases has had an adverse influence on industrial confidence in data obtainable from routine surveillance. This lack of confidence is reflected in some environmental surveillance programs.

An examination of existing systems indicates a need for surveillance network design techniques which can be applied by environmental surveillance

personnel. Even though there are recognized analytical techniques for designing surveillance systems around nuclear installations,[1,2] there is little evidence to show that these are being widely applied by those responsible for operating the programs.

In an attempt to provide a consistent, uncomplicated, economical mechanism for the examination of surveillance systems, an evaluation of variables which influence a program's ability to assess population exposures was begun. Acceptability of the mechanism would be based, it was decided, upon its ability to provide: a) an initial sampling location distribution around a facility which correlates well with air sampler locations on sites having long-established programs, and b) respectable agreement between distributions derived by well-recognized analytical techniques and this method.

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 distribution and contaminant transport characteristics of the local environment involved.

## Procedure

Examination of existing surveillance programs indicated that distances of environmental media sampling locations from the source of contamination are generally selected to correspond to plant boundaries, maximum potential concentration points, population centers and relatively unaffected areas. It was determined that the most needed guidance was in the radial partitioning of sampling locations. The relationship,

$$\text{Weighting Factor (W)} = \frac{\text{fraction of total population}}{\text{distance}} + \text{fraction of time sector is downwind of sources,}$$

associating demographic and meteorological variables was found to yield useful recommendations when applied to a site on an octant basis. The maximum applicable population distance has been limited to ten miles except for very large nuclear facility sites. At distances greater than this the equation loses the desirable characteristic of giving approximately equal importance to the population and wind-related terms.

The application of this method to sites in coastal or agricultural areas requires only minor modification of the basic procedure.[3] 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. In this way critical population exposure pathways other than inhalation, originating from atmospheric releases can be properly considered.

The sum of eight 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 octant weighting factor, yields the number of sampling locations within that octant when rounded to the nearest integer. For example, an octant which is downwind of the source twenty percent of the time and has fifty percent of the regional population at three miles from the site, the calculation of its portion of a seventeen sampling location program would go as follows:

$$W = \frac{.50}{3} + .2 = .37$$

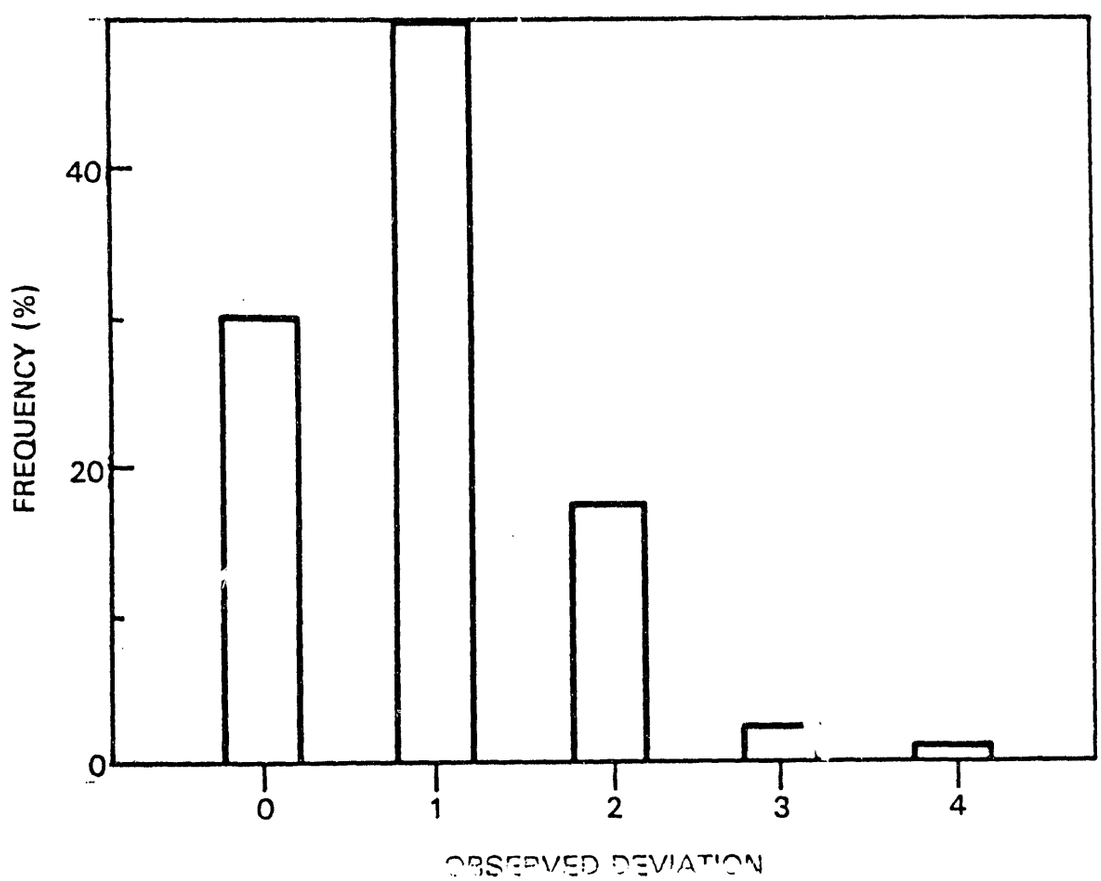
Assuming the sum of eight weighting factors is 1.7, the scaling factor (SF) is 17/1.7 = 10, which simply indicates that the unit weighting factor infers ten sampling locations. The number of locations per octant = W x SF = 3.7 which would be rounded to 4 to indicate the number of locations to be allotted to that sector.

## Analysis

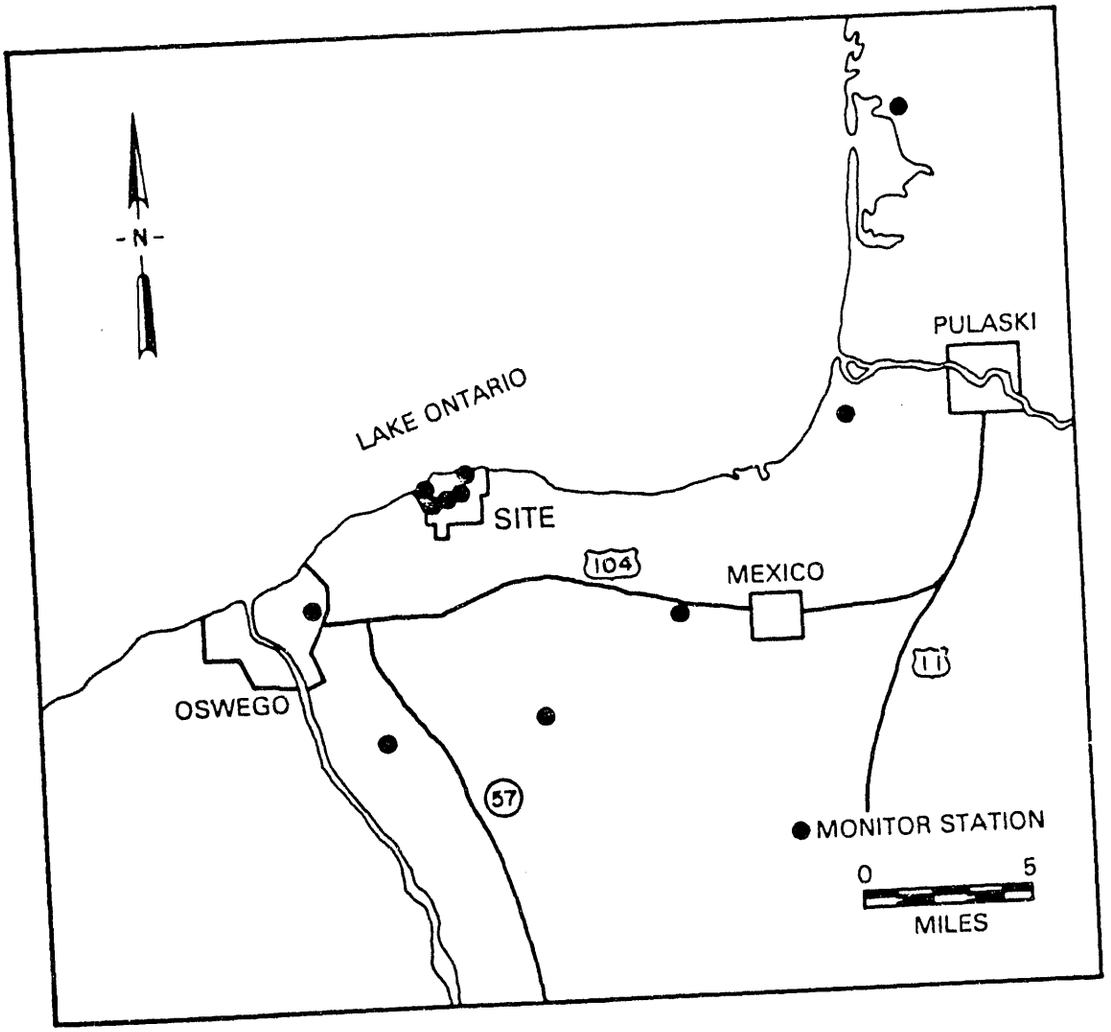
To test acceptability of the method on the basis of its ability to provide distributions which correlate well with air sampler locations on sites with well-established programs, eleven mature sites were selected as models for testing. The sites were located in the United States, India, Japan, and Germany. The

facilities included power reactors, uranium enrichment facilities, fuel fabrication plants and nuclear research establishments. Sampling locations per site varied from eight to forty. Results of sampling location distribution comparisons are shown in Figure I below. The deviation noted on the abscissa is the difference between the calculated and actual number of sampling locations present per octant.

It should be noted that over thirty percent of the octants had zero deviations. Most of the greater deviations can be attributed to the relatively arbitrary divisions formed by the octant boundaries and to criteria applied in the rounding off of calculated values. The process of normalizing the weighting factor to actual numbers of sampling locations also contributes to the observed deviations noted. This normalization necessitates the sum of all overestimates in numbers of sampling locations equal the sum of all underestimates. Since both situations are treated equally in the determination of observed deviation, the cumulative number of deviations indicated are approximately a factor of two greater than actually reflected by the raw data.



The model site chosen to test agreement of this calculational method with distributions derived by recognized analytical techniques was the Nine Mile Point Power Reactor.[4] The land environmental monitoring system includes five inner and six outer stations. The determination of the necessary number of on-site stations was based on meteorological data collected over a two-year period. The inner stations are located onsite at points in each land sector calculated to give the maximum average annual ground concentration. The outer stations are designed to measure background for comparison with on-site measurements. The layout of the land program is indicated in Figure II below.



Applying the weighting factor procedure to demographic and meteorologic data for this site to distribute eleven sampling locations yielded the following comparison of programs:

Comparison With an Actual Program

| Octant No. | Actual Sampling Locations | Calculated Sampling Locations | Observed Deviation |
|---|---|---|---|
| 1 | 0 | 0 | 0 |
| 2 | 1 | 1 | 0 |
| 3 | 2 | 3 | 1 |
| 4 | 2 | 2 | 0 |
| 5 | 4 | 3 | 1 |
| 6 | 2 | 2 | 0 |
| 7 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 |

On the basis of this favorable comparison and the eleven mature sites comparison, the acceptability criteria were met. 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 surveillance program to be designed or updated to include sampling location distributions which correlate well with air sampler locations on sites which have been occupied by long-established programs with their inherent evolution and refinements.

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