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ABSTRACT

The significance of spatial variability of meteorological data was evaluated using calculated and observed annual average air concentrations. The joint frequency distributions of wind velocity and stability measured at eight locations were used as input to a simple diffusion model recommended by NRC to predict annual average air concentrations at 13 sites surrounding the Savannah River Plant, Aiken, SC.

The model caused an overprediction of about a factor of three with a variability of about 50% among the eight locations examined. A comparison of linear correlation coefficients between calculated and observed concentration ranges between .73 and .96 depending upon tower location. The linear correlation coefficients showed no relationship between either distance from the source

* The information contained in this article was developed during the course of work under Contract No. DE-AC09-76SR00001 with the U. S. Department of Energy.

release point or to the amount of meteorological data used to represent the annual frequency distribution of wind and stability.

INTRODUCTION

Meteorologists are frequently asked to perform annual average diffusion calculations for a proposed site for which no meteorological data exist. In practice, annual average meteorological data from the nearest source are assumed to be the same as would have been measured at the proposed site had such data been available. (Implicit in NRC guidelines is that the best data to assess the environmental effects of a site are measured at that site.*) Under ideal conditions, the meteorologist has sufficient information to select the most representative data source from those available. Often this information does not exist and the meteorologist does not know how well the meteorological data used represents the proposed site. This uncertainty reduces the reliability of the calculations.

DESCRIPTION OF SITE AND SAMPLING NETWORK

The Savannah River Plant is the major production facility of the U. S. Department of Energy (DOE). The SRP includes a nuclear fuel manufacturing facility, three production reactors, two chemical separations plants, a heavy water production plant, and various waste management activities. These facilities are located on a 770-km^2 site south of Aiken, South Carolina.

* United States Atomic Energy Commission, 1972: Safety Guides for Water Cooled Nuclear Power Plants. USAEC, Division of Reactor Standards, Washington, DC 20545. Safety Guide Number 23: Onsite Meteorological Programs, pp 23.1-23.13.

The terrain within 150 km of the SRP is gently rolling hills ranging in elevation from 150 m above sea level to the northwest to about 25 m toward the southeast. The SRP is covered with mixed hardwood and pine forests; the surrounding area consists of equal amounts of mixed forests and cleared farm land.

Krypton-85 is released during dissolving operations from the two chemical separations plants located near the center of the SRP. The ^{85}Kr is released as a non-buoyant plume through two 62-m stacks.

The ^{85}Kr samplers were located at 13 sites surrounding the SRP as shown in Figure 1. For a complete description of the ^{85}Kr sampling program, see Telegadas et al. (1980).

Meteorological data are monitored at eight towers in the SRP area. The WJBF television tower, indicated with a T on Figure 1, is instrumented at seven levels between 2 and 335 m above ground with temperature sensors and turbulence-quality wind sensors.

Adjacent to the main SRP operating areas, seven onsite towers with a wind sensor at 62 m are located in pine forests within a 10-km radius of the SRP source. Annual wind-rose statistics were computed for each tower using 15 min. averaged data. Wind direction was divided into 22.5-degree sectors, wind speed was divided into six wind speed classes, and atmospheric stability was divided into seven classes.* Figure 2 shows the

* Input meteorological data were similar for all calculations: wind speed and direction at 62-m level, and stability determined from measured values of standard deviation of wind azimuth following Safety Guide 23.

annual wind rose for all 8 towers for all stability conditions. The wind rose shows the percentage of time that the wind is blowing toward the indicated direction. These data show that ^{85}Kr from SRP would be carried toward three preferential directions; east, southwest, and northwest.

PROCEDURE

Data from eight meteorological towers operated by the Savannah River Plant are used to demonstrate the variability of meteorological data over distances of 4-30 km. The variability is evaluated through use of annual average air concentrations calculated from data at the 62-m level of the eight towers. These calculated air concentrations are compared with observed annual average concentrations of ^{85}Kr available downwind from a source near the center of the SRP. The ^{85}Kr is released nearly continuously from 62-m stacks. Figure 1 shows 13 ^{85}Kr observation sites numbered 2-14 and the eight towers T, A, C, D, F, H, K, and P. The source of ^{85}Kr is between towers labeled F and H.

The procedure was to 1) assume wind data at each tower applies to the ^{85}Kr source location, 2) calculate relative concentration using the computer model developed by Sagendorf and Goll (1977) for each of 13 ^{85}Kr sites, 3) compare calculated relative concentrations at 13 ^{85}Kr sites with observed relative concentrations, and 4) repeat using data from other towers.

The model is based upon the modified Gaussian plume equation

$$(\chi/Q')_D = 2.032 \sum_{ij} \frac{n_{ij}}{N x U_i \Sigma_{zj}} \; e^{[-h_e^2/2\sigma_{zj}^2]}$$

where

h_e is the effective release height given by $h_e = h_s - h_t$, and h_s is the height of the stack above plant grade.

h_t is the maximum terrain height above plant grade between the release point and the point for which the calculation is made ($h_t > 0$).

n_{ij} is the length of time weather conditions are observed to be at a given wind direction, D, windspeed class, i, and atmospheric stability class, j.

N is the total period of the valid data.

U_i is the midpoint of windspeed class, i, at a height representative of release.

σ_{zj} is the vertical plume spread without volumetric correction at distance x for stability class, j.

Σ_{zj} is the vertical plume spread with a volumetric correction for a release within the building wake cavity at distance x for stability class, j.

$$\Sigma_{zj} = [\sigma_{zj}^2 + 0.5 \; D_z^2/\pi]^{\frac{1}{2}} < \sqrt{3}\sigma_{zj}$$

where

D_z is the maximum adjacent building height.

$(\chi/Q')_D$ is the average effluent concentrations, χ, normalized by source strength, Q', at distance x in a given downwind direction, D, and

2.032 is $2/\sqrt{2\pi}$ divided by the width in radians of a 22.5° sector.

RESULTS

Table 1 lists the calculated relative concentration for 1976 at each of the 13 sites, using the eight different data sources. Note these relative concentrations are assumed to be the result of a release of ^{85}Kr from a stack located midway between towers F and H. The estimates for each site are generally within 20% of one another. For some sites, however, variations of as much as a factor of 2 occur. Readily apparent is the consistent over-prediction of all estimates when compared with the observed relative concentrations listed in the far right column. The overprediction may be caused by the assumption that horizontal spread is limited to the 22.5-degree sector. However, Weber (1980) has presented evidence that errors in the specification of horizontal spread of plumes, σ_y, at travel distances of 100 km lead to an overprediction of air concentration by a factor of 3.

Data from Table 1 were summarized to show how well the various estimates agree with the observed values. The results of this analysis are shown in Table 2. Listed are 1) the average ratio of calculated to observed relative concentrations, 2) the linear correlation coefficient between observed and calculated concentrations, 3) the percentage of possible meteorological data used to represent the annual wind frequency distribution, and 4) the distance from each tower to the ^{85}Kr release point.

The average ratio of calculated to observed relative concentration ranges from 2.3 for tower T to 3.6 for tower D. The magnitude of the linear correlation coefficient ranged from .73

at tower K to a value of .96 at tower A. Note the closer to a value of 1.0 the better the agreement between calculated and observed. The percentage of possible data used at each tower ranged from a low of 35% for tower A to a high of 76% for tower T. (Note, all tower data sets are far below the 90% recovery rate required by the NRC.)

Clearly obvious from the data in Table 2 is that no relationship exists between how well calculated and observed concentrations agree with one another and distance from the ^{85}Kr source, or even with the amount of meteorological data used.

CONCLUSIONS

The effect of spatial variability of meteorological data on annual average air concentrations has been examined for distance from the source ranging from 2-21 km. Annual average relative air concentrations varied by about 20% for the stations examined. This variation appeared to be random with respect to distance from the source release point. This study also showed that annual average concentrations obtained with a simple wind-rose model, although overpredicting by a factor of 3, are not particularly sensitive to the amount of meteorological data used to represent the frequency distribution of wind and stability. These results indicate that a much smaller data recovery rate than the 90% required by NRC might be appropriate.

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O Kr-85 Sampling Stations

• Meteorological Observation Towers

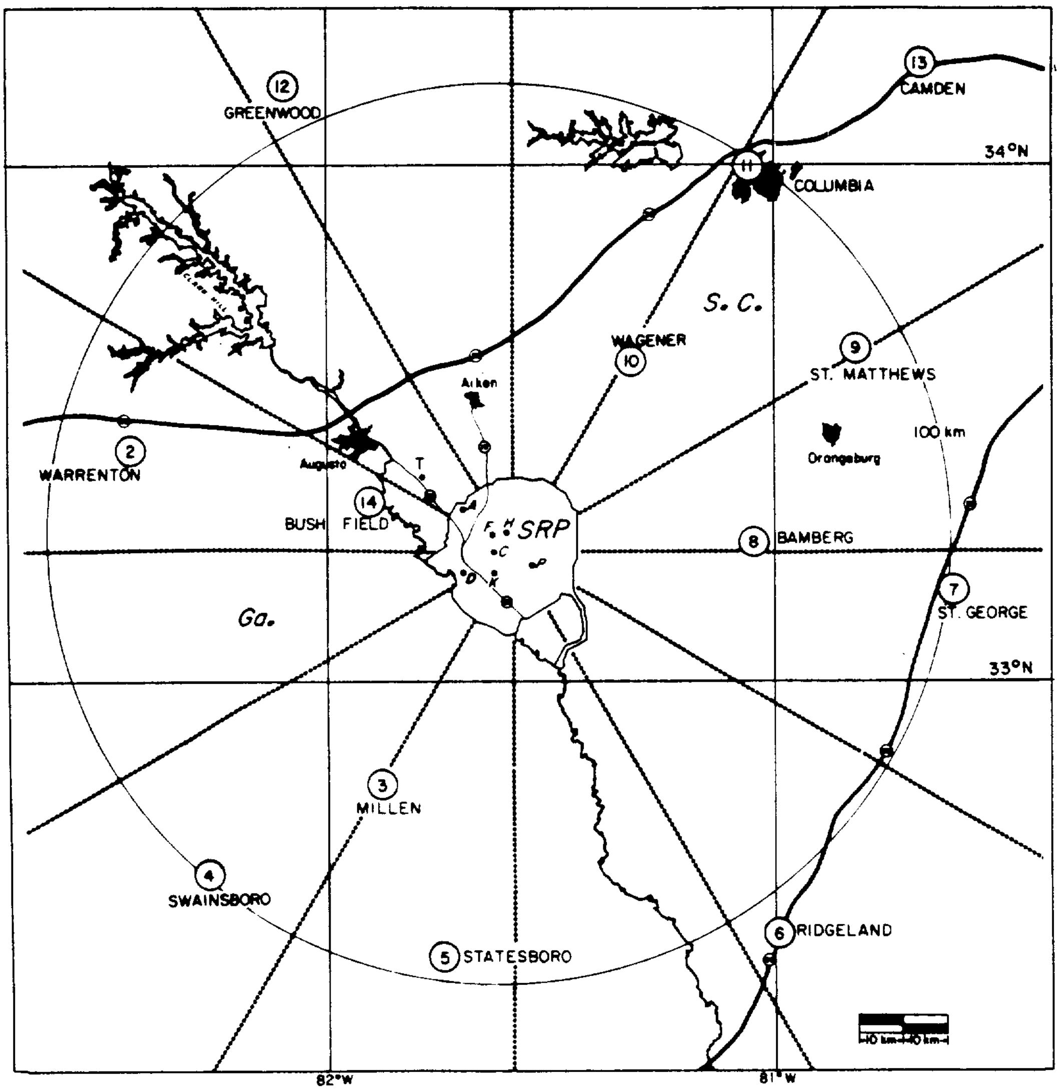

FIGURE 1. Map of the Savannah River Plant Area

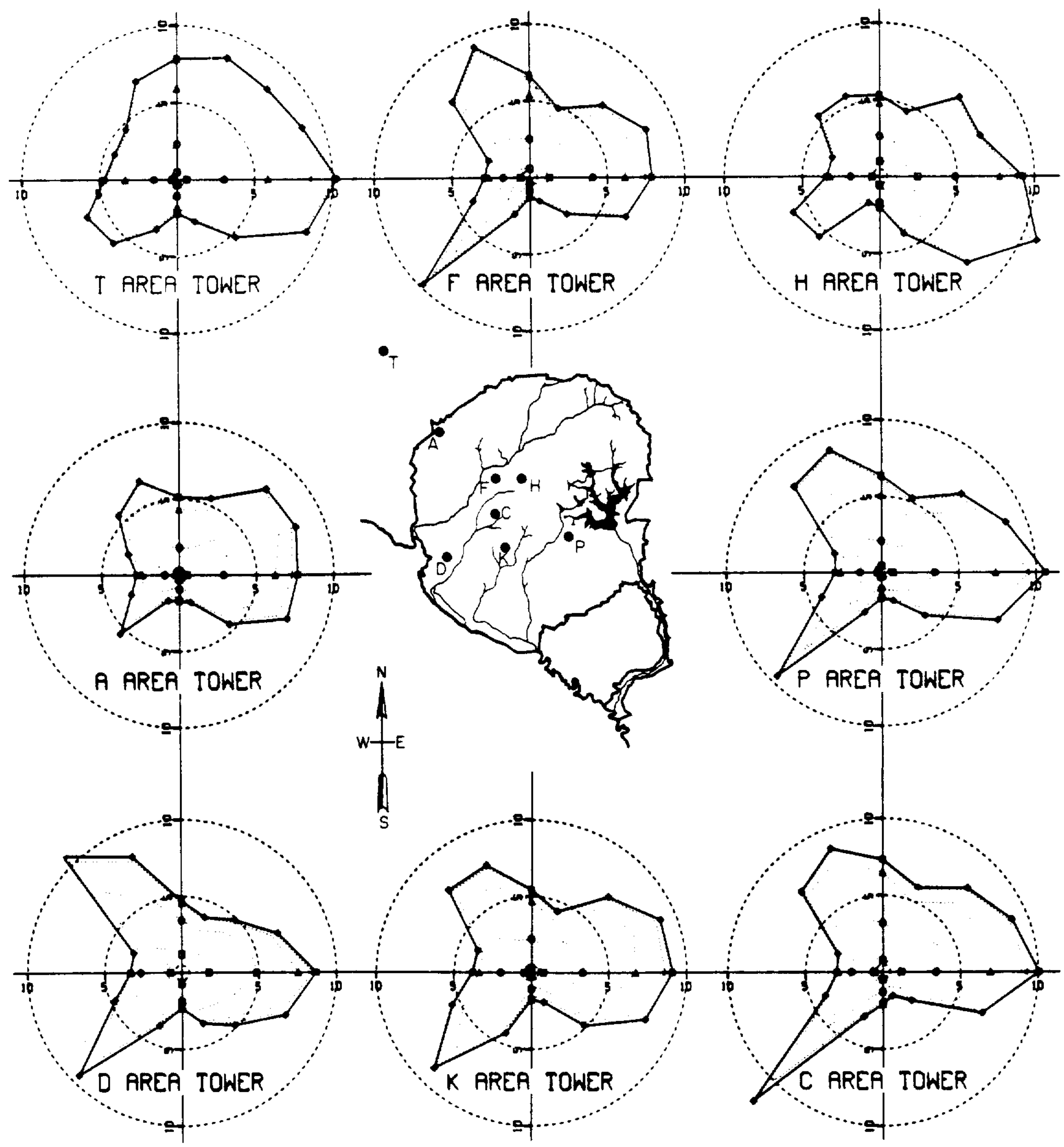

FIGURE 2. Annual Wind Roses for 1976 for the 62-m Level of Eight Towers Used in the Study.

The wind roses show the percentage of time that the wind is blowing toward the indicated sectors for all wind speeds and stability classes. Table 2 gives the percentage of possible wind data used to compute the wind-rose statistics.

TABLE 1. A Comparison of Calculated and Observed Relative Concentrations* at 13 ^{85}Kr Monitoring Sites Using Meteorology Collected at Eight Locations Near the SRP

^{85}Kr Site No.	$(X/Q)_{CALC}$ for Eight Towers								Average $(X/Q)_{CALC}$ for all towers	$(X/Q)_{OBS}$
	T	D	P	A	K	C	F	H		
2	10.	11.	9.1	6.6	10.	7.8	9.5	6.8	8.85	1.3
3	11.	22.	15.	8.4	41.	13.	17.	12.	17.43	4.6
4	9.9	33.	37.	13.	25.	27.	49.	20.	26.74	6.2
5	4.7	9.6	6.7	6.0	5.5	6.1	5.1	8.1	6.48	2.5
6	8.4	13.	6.3	9.5	7.5	8.9	9.6	16.	9.90	3.6
7	15.	25.	21.	19.	19.	22.	23.	33.	22.13	8.0
8	31.	50.	41.	36.	37.	45.	45.	68.	44.13	20.
9	15.	24.	23.	20.	23.	21.	25.	29.	22.5	12.
10	33.	38.	48.	45.	39.	36.	44.	57.	42.50	29.
11	14.	16.	21.	20.	18.	16.	19.	25.	18.63	9.6
12	11.	21.	21.	15.	16.	20.	22.	17.	17.88	4.7
13	8.7	9.9	13.	12.	11.	9.9	12.	16.	11.56	4.3
14	45.	49.	44.	42.	45.	37.	41.	37.	42.50	18.

*All X/Q values are in units of 1×10^{-10} sec/m^3

TABLE 2. Summary of the Effect of Spatial Variability of Meteorological Data on Annual Average Air Concentrations

Data Source	*T*	*D*	*P*	*A*	*K*	*C*	*F*	*H*
Average of ratio $\frac{(X/Q)_{CALC}}{(X/Q)_{OBS}}$	2.3	3.6	3.2	2.5	3.3	2.8	3.4	3.3
Linear correlation coefficient between $(X/Q)_{CALC}$ and $(X/Q)_{OBS}$	.86	.80	.87	.96	.73	.85	.75	.91
Percentage of possible wind data	76	51	70	35	62	67	57	65
Distance from ^{85}Kr release point, km	21	12	10	10	9	4	2	2