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# Effect of Updating Meteorological Data on Assessment Modeling Using VENTSAR XL©

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## 1. Introduction

The Savannah River Site (SRS), one of the facilities in the United States Department of Energy (DOE) complex, is located in south central South Carolina and has an area of about 800 km$^2$. The SRS mission was the production of special nuclear materials (such as $^{239}$Pu and $^3$H) for national defense from the 1950s to the early 1990s. This mission was accomplished through the operation of five nuclear reactors, chemical processing and separation plants, and various support facilities. Even though the production at most SRS facilities has been terminated, substantial quantities of high-level nuclear and mixed hazardous waste remain stored at SRS. SRS's current mission includes the stewardship of the nation's nuclear weapons stockpile, nuclear materials, and the environment. SRS will continue addressing environmental quality and managing any radioactive waste from current and future operations. Managing waste involves working with DOE, the State of South Carolina, the Environmental Protection Agency (EPA), and the Nuclear Regulatory Commission (NRC) (Mamatey, 2009).

Savannah River National Laboratory (SRNL) periodically generates an updated meteorological database in order to facilitate dosimetric calculations of accident and routine release scenarios for onsite and offsite populations. This meteorological database includes wind speed, direction, temperature, dew point, and horizontal and vertical turbulence intensities from a height of 61-m above ground-level. This information becomes the input of various environmental dosimetry codes run by the Environmental Dosimetry Group (EDG) at SRNL. The three most recent databases prior to the current one were completed for the time periods 1987-1991, 1992-1996, and 1997-2001. The current database covers the period 2002-2006 (Kabela & Weber, 2007). The advantage of updating the database at regular intervals is that meteorological observations are steadily growing more complete and reliable with the implementation of better electronic data archiving software and hardware, and improved data quality assurance procedures. Additionally, changes in the region's climate may be noticeable (Kabela & Weber, 2007).

The updated meteorological data is applied in various dosimetry models approved for risk and dose assessment at SRS. One of these models is VENTSAR XL©, which is an upgraded and improved spreadsheet version of the FORTRAN-based program named VENTSAR, which originated from the code VENTX (Smith & Weber, 1983) on the SRS IBM Mainframe**. It is a dose assessment model used to calculate dose following short-term atmospheric releases and concentrations of chemical or radiological pollutants. The user may include building effects and plume rise near a release point. The dose to individuals in or near the building can also be calculated if the pollutant is radiological. VENTSAR XL© "calculates the concentrations for a given meteorological exceedance probability or for a given stability and wind speed combination" (Simpkins, 1997). The switch to a spreadsheet-based code from Mainframe-based FORTRAN program makes it more user-friendly, allowing the user to have a better access to the code and run it without any knowledge of Mainframe commands.

VENTSAR XL© is a Gaussian Plume model that includes building effects and plume rise. The building being modeled can be a simple structure with or without a penthouse on its top. The model considers recirculation cavities, high turbulence zones, wakes beyond the building, and plume rise caused by buoyancy and momentum, and downwash (Simpkins, 1997). Doses are calculated at up to 200 user-specified increments and effective dose equivalents are estimated for plume shine and inhalation exposure pathways (Simpkins, 1997). VENTSAR XL© has been developed through the use of Macros, which are a group of coded instructions under Microsoft® Visual Basic® applications (e.g., Microsoft® Excel®) that are used to automate routine tasks and the resolution of complex mathematical calculations. VENTSAR XL© can be run on any computer that supports Microsoft® Excel® 4.0 or later (Simpkins, 1997). The code is exceptionally user-friendly and the user-input template is easy to comprehend. In addition, the code contains a number of checks to prevent the user from entering the wrong input; for example, a parameter value that is beyond the parameter range indicated on the VENTSAR XL© template. The typical input involves the location of the release, building dimensions, distance to the building, release height, vent diameter, vent gas temperature, gas molecular weight, ambient air temperature, breathing rate, meteorological conditions, radionuclides and their amount released. The output is easily converted into tables and graphs for further analysis and shows the concentrations and pathway doses for each of the incremental downwind distances (Simpkins, 1995, 1997). VENTSAR XL© has been used at SRS to investigate building effects such as reactor cooling towers in support of safety analyses. VENTSAR XL© has also been applied to Good Engineering Practice (GEP) stack height evaluations for various projects at SRS.

VENTSAR XL© test cases are executed each time for a new set of meteorological data by the EDG. Subsequently, the results from the code are compared to the test cases of the previous time period to ensure that there are no abnormalities in the new meteorological data. Lines of code in the program must be changed for VENTSAR XL© to access the new meteorological data. Executing the test cases also provides the means to verify that these changes have been properly made. This study presents test cases for four periods (1987-1991, 1992-1996, 1997-2001, and 2002-2006) and wind frequency comparisons among these four periods for various locations at SRS.

## 2. VENTSAR XL© methodology

The VENTSAR XL© methodology and data are described in detail in the following sections, which represent a summary of Simpkins' report (1997).

### 2.1 Gaussian plume model

The pollutant dispersion calculations in the VENTSAR XL© code are based on the Gaussian plume model (Hanna et al., 1982). Along the plume centerline, the dispersion factor or relative air concentration, defined as the ratio of the pollutant concentration $\chi$ (kg $m^{-3}$ or Ci $m^{-3}$) to the source strength $Q$ (kg $s^{-1}$ or Ci $s^{-1}$), is given by the equation:

$$\frac{\chi}{Q} = \frac{1}{2\pi\sigma_y\sigma_z U_S}\left[e^{-\left(\frac{(z-h_e)^2}{2\sigma_z^2}\right)} + e^{-\left(\frac{(z+h_e)^2}{2\sigma_z^2}\right)}\right] \tag{1}$$

where,

$\chi/Q$ = the dispersion factor (s $m^{-3}$)
z = height above the ground surface (m)
$h_e$ = effective release height (m)
$U_s$ = wind speed at the release height (m $s^{-1}$)
$\sigma_y$ = the standard deviation of the concentration distribution in the horizontal cross-plume direction (m)
$\sigma_z$ = the standard deviation of the concentration distribution in the vertical direction (m)

The annual average values of $\chi/Q$ are calculated as:

$$annual(\overline{\chi / Q}) = \sum_{i,j}^{6,7} P_{ij}\left(\frac{\chi}{Q}\right)_{ij} \tag{2}$$

where,

$i$ = wind speed category
$j$ = stability class
$(\chi/Q)_i$ = relative air concentration for meteorological condition (i,j)
$P_i$ = the probability of a particular meteorological condition (i,j) occurring within a five-year time period

### 2.1.1 Meteorological data

VENTSAR XL© accesses a meteorological joint frequency distribution containing six wind speed classes (Table 1) and 7 stability categories (Pasquill, 1976). VENTSAR XL© contains meteorological data files already available for used at SRS, but the user may add data files of his or her selection from any location.

| Speed Category | Range (m $s^{-1}$) |
|---|---|
| 1 | $0<U\leq 2$ |
| 2 | $2<U\leq 4$ |
| 3 | $4<U\leq 6$ |
| 4 | $6<U\leq 8$ |
| 5 | $8<U\leq 12$ |
| 6 | $U\geq 12$ |

Table 1. Wind speed category ranges for SRS Files

Atmospheric stability is classified by standard deviations of the lateral or azimuthal wind direction. SRS meteorological towers contain instrumentation at 61 m (200 ft) that measures horizontal (azimuth) and vertical (elevation) wind directions. In addition, direct measurements of turbulence, expressed as standard deviations of fluctuations about mean azimuth (noted either as $\sigma_a$ or $\sigma_\theta$) and elevation ($\sigma_e$) angles, are made at 61 m.

For calculational purposes within the spreadsheet, an assumed average value of $\sigma_\theta$ is selected for the atmospheric stability class of interest. Ranges for $\sigma_\theta$ and the values that are used within VENTSAR XL© are shown in Table 2.

| Pasquill Category | Range for $\sigma_\theta$ (degrees) | $\sigma_\theta$ Used in VENTSAR XL© (degrees) |
|---|---|---|
| A | $23 \le \sigma_\theta$ | 27.5 |
| B | $18 \le \sigma_\theta < 23$ | 22.5 |
| C | $13 \le \sigma_\theta < 18$ | 17.5 |
| D | $8 \le \sigma_\theta < 13$ | 12.5 |
| E | $4 \le \sigma_\theta < 8$ | 7.5 |
| F | $2 \le \sigma_\theta < 4$ | 3.75 |
| G | $\sigma_\theta < 2$ | 2.00 |

Table 2. Classification of atmospheric stability

### 2.1.2 Pasquill-Briggs diffusion coefficients

The lateral and vertical diffusion coefficients within VENTSAR XL© are those derived by Pasquill (1976) and Briggs (1973), respectively. The equation representing Pasquill's lateral diffusion coefficients is

$$\sigma_y = \sigma_\theta X f(X) \tag{3}$$

where,

$\sigma_\theta$ = standard deviation of lateral wind direction in radians (Table 2)

$X$ = downwind distance (km)

$f(X)$ = function of distance, $X$ (km), as discussed below

Pasquill developed formulations for $f(X)$ with a table of values for distances less than 10 km and the following equation for distances greater than 10 km:

$$f(X) = 0.33\left[\frac{10}{X}\right]^{0.5} \tag{4}$$

For distances less than 10 km, the following equation was derived from the table of values with $X$ in km:

$$f(X) = \frac{1}{1 + 0.031(1000X)^{0.46}} \tag{5}$$

Pasquill (1976) gives a detailed description on how the coefficients were developed using data from experiments at various sites. The vertical diffusion coefficients defined by Briggs (1973) and then refined by Briggs and published in Hanna et al. (1982) for open-country conditions are represented in Table 3 as a function of Pasquill's atmospheric stability classes.

| Pasquill Stability Category | $\sigma_z$ (X in m) |
|---|---|
| A | $0.20X$ |
| B | $0.12X$ |
| C | $0.08X(1 + 0.0002X)^{-0.5}$ |
| D | $0.06X(1 + 0.0015X)^{-0.5}$ |
| E | $0.03X(1 + 0.0003X)^{-1}$ |
| F | $0.02X(1 + 0.0003X)^{-1}$ |
| G | $0.01X(1 + 0.0003X)^{-1}$ |

Table 3. Brigg's vertical diffusion coefficient formulas.

## 2.2 Plume rise

Plume rise models are based on fundamental laws of fluid mechanics, conservation of mass, potential density, and momentum. VENTSAR XL© considers plume rise due to both buoyancy and momentum effects. Several different mechanisms can increase or decrease the height of the plume at downwind distances. Plume rise due to momentum and buoyancy effects can increase the height of the plume while downwash can decrease the height of the plume. The effective plume height at a given distance, X, downwind is

$$h(X) = h_s - \Delta h_D + \Delta h_B(X) + \Delta h_M(X) \tag{6}$$

where,
$h_s$ = initial height of the source
$\Delta h_D$ = source height change due to downwash
$\Delta h_B$ = source height change due to buoyancy effects
$\Delta h_M$ = source height change due to momentum effects
Downwash, buoyancy, momentum, and building wake effects considered in VENTSAR XL© are described in detail by Simpkins (1997).

## 2.3 Dose estimation

VENTSAR XL© can calculate inhalation and plume shine dose using dose factors provided in the United States Department of Energy (DOE) documents (1988a and 1988b). Inhalation dose is estimated by the product of the radionuclide concentration in the air that is breathed, the rate at which the air is breathed, and a factor to convert intake quantities to dose. The inhalation dose to a given individual, assuming exposure during the entire plume passage, is calculated using the following general equation:

$$D_{inh} = 3.17E-08(Q_n)(\frac{\chi}{Q})(DFI_n)(B)e^{-\lambda_n t} \tag{7}$$

where,
$3.17\text{x}10^{-8}$ =conversion factor (years per second)
$Q_n$ = total release (Ci)
$\chi/Q$ = relative concentration at receptor (s m$^{-3}$)
$DFI_n$ = effective dose equivalent factor for inhalation (rem Ci$^{-1}$)
$B$ = adult maximum breathing rate (m3 yr$^{-1}$)

$\lambda_n$ = decay constant ($s^{-1}$)
$t$ = travel time from release to receptor (s)

The uniform plume model assumes that the exposed individual is located in a time integrated uniform concentration of a given nuclide throughout the infinite hemisphere above ground level. The gamma-shine external dose is therefore directly proportional to the integral air concentration and is determined by multiplying the integral concentration by an infinite-plume shine dose factor. The external dose for a given nuclide, n, is expressed as:

$$D_{PS} = (\frac{\chi}{Q})(Q_n)(DFS_n)e^{-\lambda_n t} \tag{8}$$

where,
$\chi/Q$ = relative air concentration at the receptor (s $m^{-3}$)
$Q_n$ = total release of nuclide n (Ci)
$DFSn$ = shine dose factor for nuclide n (mrem $s^{-1}$ per Ci $m^{-3}$)
$\lambda_n$ = decay constant for nuclide n ($s^{-1}$)
$t$ = transit time between release and exposure (s)

A library of dose factors for about 500 radionuclides is contained under the file name "Dose Factor." Doses are calculated only for the radionuclides that are entered. No ingrowth is considered, but the user can enter the associated progeny as appropriate.

### 2.4 Relative concentration

In accordance with the Clean Air Act Amendments of 1977, GEP must be used in determining the height of any stack that will be used to disperse routine emissions (United States Environmental Protection Agency [EPA], 1981a, 1981b). With respect to stack heights, the GEP height is “the height necessary to ensure that emissions from the stack do not result in excessive concentrations of any air pollutant in the immediate vicinity of the source as a result of atmospheric downwash, eddies and wakes which may be created by the source itself, nearby structures or nearby terrain obstacles” (EPA, 1981a). The EPA has set specific criteria to determine if a stack is of the acceptable height. These criteria have been used to determine a GEP stack height for several emission assessments at SRS.

The EPA documents (1981a, 1981b) contain detailed information on how the height of a stack is determined. The general rule for stack height determination is to make the stack at least 2½ times the height of nearby buildings. This estimated height can be increased or decreased based on other factors such as plume rise, downwash, and building wake effects. According to U.S. Nuclear Regulatory Commission Guide 1.145 (NRC, 1982) ground level releases should be considered for “all release points or areas that are effectively lower than two and one-half times the height of adjacent solid structures.” This regulation is applied when performing calculations for Emergency Preparedness Hazard Assessments.

Sometimes it is necessary to construct a stack with a lower height than the one required by federal or state regulations. Employing VENTSAR XL©, detailed analyses of air concentrations within the vicinity of the building can be performed to justify using a lower stack by ensuring that the maximum downwind concentration in the presence of the building is not more than 40% greater than the maximum downwind concentration without the building (EPA 1981a, 1981b). Therefore, an acceptable stack height can be demonstrated using the following equation:

$$\frac{\left(\frac{\chi}{Q_{\max}}\right)_{building}}{\left(\frac{\chi}{Q_{\max}}\right)_{\text{no building}}} \leq 1.4, \tag{9}$$

where,

$\left(\frac{\chi}{Q_{\max}}\right)_{building}$ = maximum ground level concentration with building present;

$\left(\frac{\chi}{Q_{\max}}\right)_{\text{no building}}$ = maximum ground level concentration with no building present;

$\chi$ = air concentration (Bq $m^{-3}$); and

Q = amount released (Bq $s^{-1}$).

To pinpoint the maximum ground level concentrations with a building present and without the building for Eq. (9), the annual average air concentrations (s $m^{-3}$) versus downwind distances are plotted from the VENTSAR XL© output.

## 3. Meteorological data update

Every five years meteorological data are updated for use in environmental dosimetry codes at SRNL. Data for the period 2002-2006 are available and are tested in this study using test cases and approved environmental dosimetry procedures for VENTSAR XL©. Test cases consider seven areas of SRS where radionuclide releases are possible (A, C, D, F, H, K, and P) and an alternate release location. The various SRS areas where the possibility of radionuclide releases exist are shown in Fig. 1. The meteorological data, used for dosimetry purposes at SRS, consists of hourly averages of wind speed and direction at the various SRS meteorological towers for a 5-year period. The SRS meteorological data for the periods 1987-1991, 1992-1996, 1997-2001, and 2002-2006 were reported by Kabela and Weber (2007), Weber (2002), Weber (1998), and Parker et al. (1992), respectively. The frequency at which the wind blows from the various sectors for these periods and SRS areas including L-Area is illustrated in Fig. 2.

Test cases were executed using identical parameters with the exception of the new meteorological data. The parameter input values for the test cases are presented in Table 4. The Eastern and Northern grid coordinates in VENTSAR XL© are SRS site-specific and must be included when a meteorological file name is not entered by the user. Cases 1, 2, 4 and 7 consider plume rise, Cases 1, 2, 6, and 7 involve meteorological averaging, Cases 3, 5, 6, and 8 include radioactive releases. The parameters for building and penthouse in Case 2 are set to zero; to model the absence of a building. When the VENTSAR XL© plume rise option is selected, the vent diameter, vent gas temperature, ambient air temperature, and molecular weight of the gas released must be entered. The averaging option is used when a meteorological exceedance probability is specified. For meteorological conditions that do not exceed 99.5% of the time, a value of 0.005 (0.5%) would be used (Simpkins, 1997). If the averaging option is not selected, the wind speed and stability class must be entered as VENTSAR XL© input. If the release is considered to be radioactive, the user must select the breathing rate of the individual for VENTSAR XL© to calculate dose (Simpkins, 1997).

Depending on the release (radioactive or chemical), the output and its headings vary. When a specific wind speed and stability class is selected, the annual average dilution factor ($\chi/Q$, s $m^{-3}$) is not estimated. However, instead of calculating effluent concentrations ($\chi$, Bq $m^{-3}$) at specific distances from the release point, dilution factors are generally estimated (by selecting the VENTSAR XL© averaging option) since the dilution factors are independent from the source strength (Q, Bq $s^{-1}$) (Faw & Shultis, 1999).

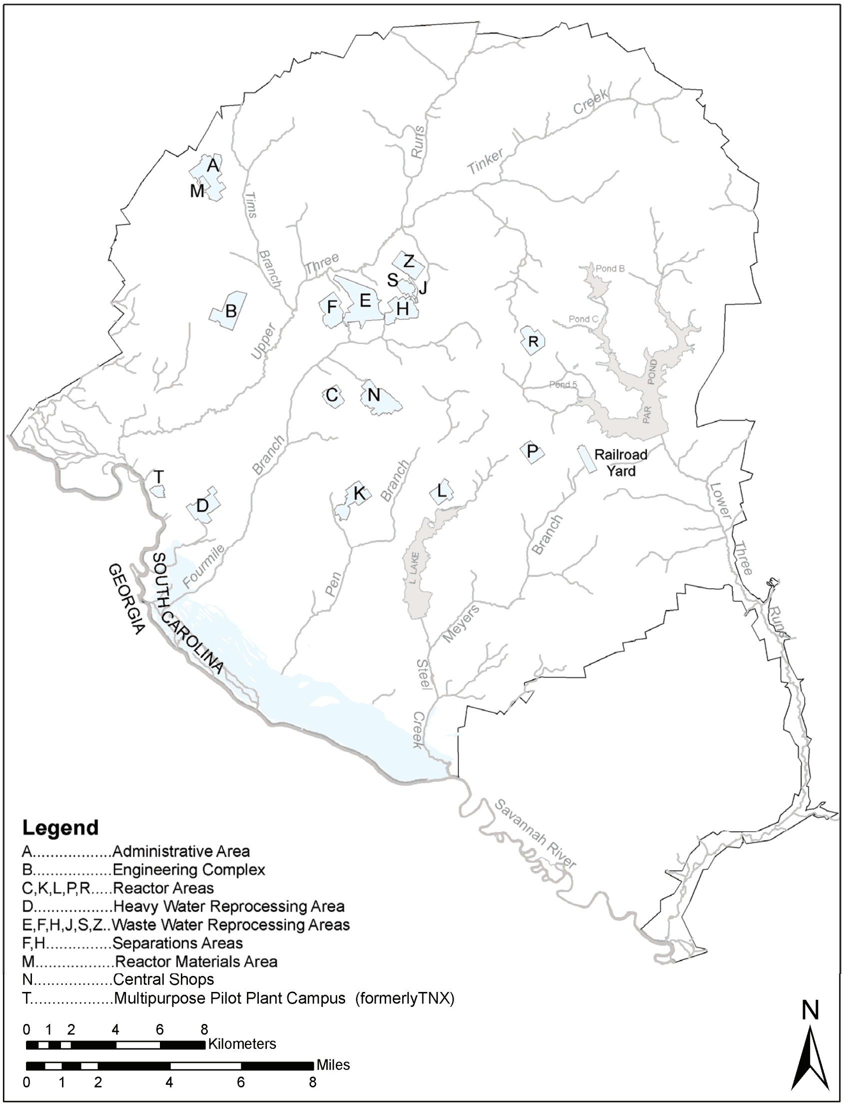



Fig. 1. Location of major Savannah River Site areas with potential to release radioactive materials.

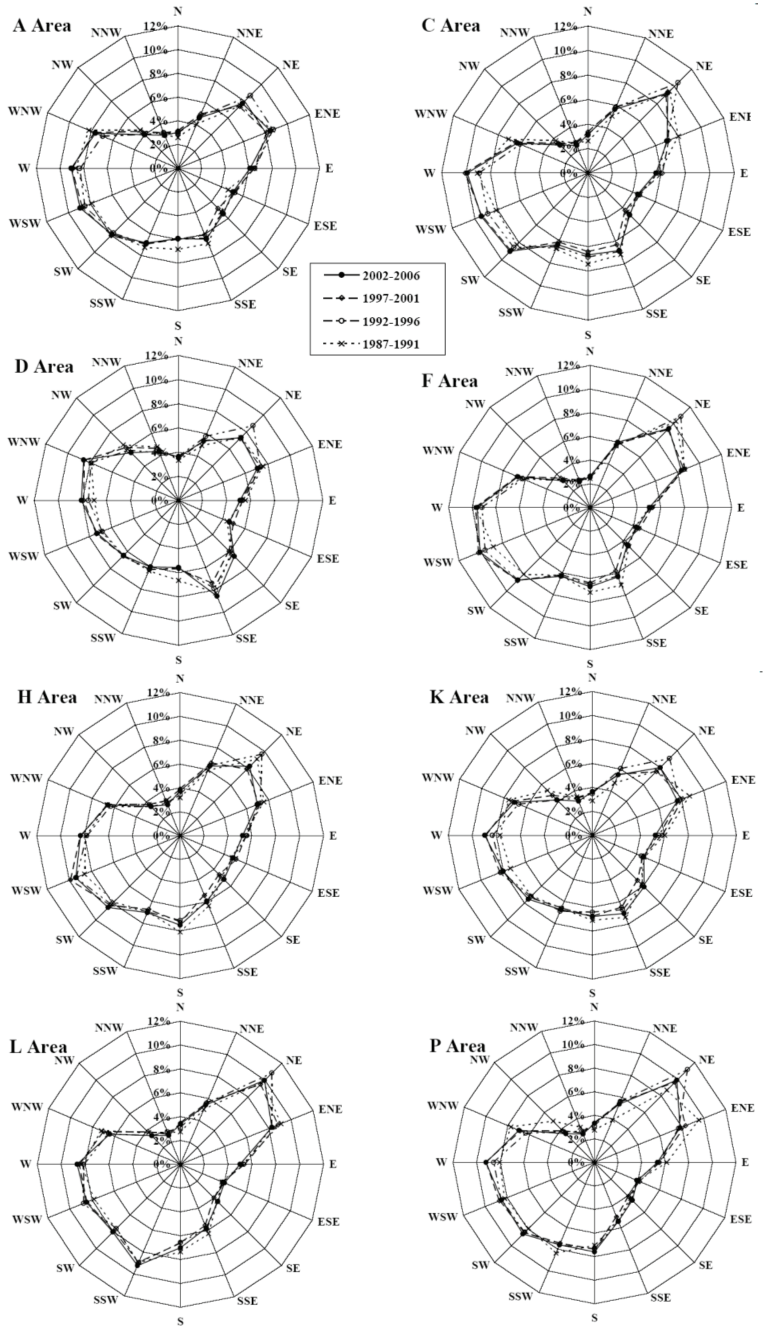



Fig. 2. Wind frequencies for 2002-2006, 1997-2001, 1992-1996, and 1987-1991 SRS meteorological data.

| Parameter | Case | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Consider Plume Rise | YES | YES | NO | YES | NO | NO | YES | NO |
| Area of Release | P | D | H | C | A | K | F | OTHER[a] |
| Building Height[b] | 10 | 0 | 5 | 20 | 15 | 8 | 10 | 12 |
| Building Width[b] | 20 | 0 | 30 | 100 | 200 | 200 | 10 | 30 |
| Building Length[b] | 30 | 0 | 100 | 30 | 200 | 10 | 10 | 15 |
| Penthouse Height[b] | 1 | 0 | 3 | 6 | 7 | 3 | 5 | 6 |
| Penthouse Width[b] | 2 | 0 | 5 | 10 | 200 | 150 | 5 | 20 |
| Penthouse Length[b] | 3 | 0 | 5 | 10 | 100 | 8 | 5 | 10 |
| Bldg. to Penthouse[b] | 5 | 0 | 20 | 0 | 100 | 2 | 0 | 1 |
| Min. Vent to Receptor[b] | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Max. Vent to Receptor[b] | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Compass Sector | NNW | S | N | NE | WNW | SSE | ENE | E |
| Vent to Roof Edge[b] | -500 | 0 | -100 | 10 | -10 | 500 | 100 | -30 |
| Vent Height[b] | 50 | 25 | 5 | 0 | 100 | 50 | 5 | 0 |
| Radioactive Release? | NO | NO | YES | NO | YES | YES | NO | YES |
| Release Rate (GBq $min^{-1}$) | - | - | 37 | - | 37 | 37 | - | 37 |
| Pollutant Mole Fraction | $1 \times 10^{-6}$ | $1 \times 10^{-6}$ | - | $1 \times 10^{-6}$ | - | - | $1 \times 10^{-6}$ | - |
| Vent-Gas Flow Rate ($m^3 s^{-1}$) | 500 | 750 | 1000 | 100 | 500 | 750 | 1000 | 100 |
| Meteorological Averaging? | YES | YES | NO | NO | NO | YES | YES | NO |
| Probability Level | 0.005 | 0.005 | - | - | - | 0.005 | 0.005 | - |
| Wind Speed ($m s^{-1}$) | - | - | 2 | 1 | 4 | - | - | 3 |
| Stability Class | - | - | D | F | B | - | - | A |
| Vent Diameter[b] | 3 | 2 | 3 | 1 | 3 | 2 | 2 | 1 |
| Vent-Gas Molecular Weight | 210 | 200 | 200 | 190 | 200 | 180 | 230 | 220 |
| Vent-Gas Temp(°C) | 20 | 17 | 17 | 18 | 17 | 17 | 19 | 14 |
| Ambient Air Temp(°C) | 15 | 17 | 17 | 12 | 17 | 17 | 16 | 13 |
| Calculate Dose | N | N | Y | N | N | Y | N | N |
| Breathing Rate ($m^3 y^{-1}$) | - | - | 12,000 | - | - | 12,000 | - | - |
| Radionuclide, Source Term | $^{3}H$, 0.11 TBq $^{137}Cs$, 74 GBq $^{137m}Ba$, 74 GBq | $^{3}H$, 0.11 TBq $^{137}Cs$, 74 GBq $^{137m}Ba$, 74 GBq | $^{3}H$, 0.11 TBq $^{137}Cs$, 74 GBq $^{137m}Ba$, 74 GBq | $^{3}H$, 0.11 TBq $^{137}Cs$, 74 GBq $^{137m}Ba$, 74 GBq | $^{3}H$, 0.11 TBq $^{95}Zr$, 0.19 TBq $^{95m}Nb$, 0.19 TBq | $^{3}H$, 0.11 TBq $^{95}Zr$, 0.19 TBq $^{95m}Nb$, 0.19 TBq | $^{3}H$, 0.11 TBq $^{95}Zr$, 0.19 TBq $^{95m}Nb$, 0.19 TBq | $^{3}H$, 0.11 TBq $^{95}Zr$, 0.19 TBq $^{95m}Nb$, 0.19 TBq |

[a] Release at SRS's Center of Site. [b] Units in meters (m).

Table 4. Input for VENTSAR XL tests cases.

## 4. Results

For most SRNL environmental studies, the airborne concentrations under a given meteorological condition are not the main focus. The center of attention is the concentrations averaged over a year and over all meteorological conditions that occur during the typical averaging period of one year, during which the weather conditions fluctuate to a great extent. Consequently, averaging the concentrations becomes necessary by measuring the wind and atmospheric stability on a daily basis for various averaging periods. From these measurements, the distribution of wind velocities are calculated and usually presented as a *wind rose*. The wind rose for the H-Area meteorological tower at SRS for the 2002-2006 period is presented in Fig. 3. H-Area is located near to the SRS center of site, which is used for risk and dose assessments. The wind class frequency graph for H-Area shown in Fig. 4 illustrates the frequency of each wind speed class.

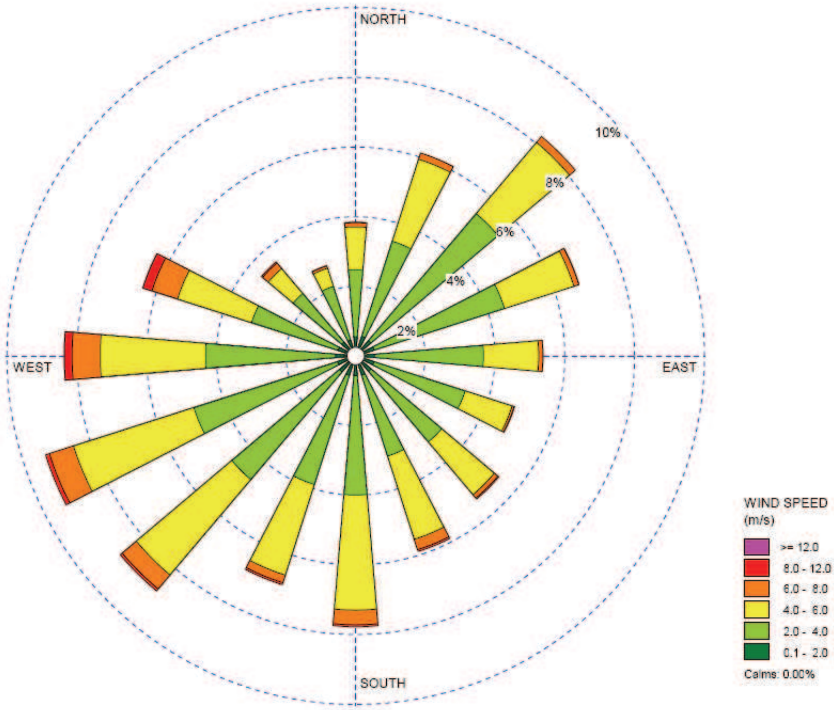



Fig. 3. Wind Rose for the SRS's H-Area meteorological tower for the 2002-2006 period.

The SRS wind direction percent differences between the meteorological periods 2002-2006 and 1997-2001 are shown in Table 5. The maximum increase (15.1%) in wind frequency is for the southeast cardinal direction for the K-Area. The maximum decrease (-12.1%) is for the northwest direction for the L-Area. The average percent difference is -0.3% for the periods 2002-2006 and 1997-2001 (Table 5). However, the average percent difference is 0.04% for the four periods and all the areas considered in this study. The minimum and maximum SRS wind direction percent differences are -30.7% (NW) and 38.1% (NNE), respectively. These considerable differences occur for P-Area when comparing the wind direction percents for the periods of 1987-1991 and 2002-2006 (Fig. 2).

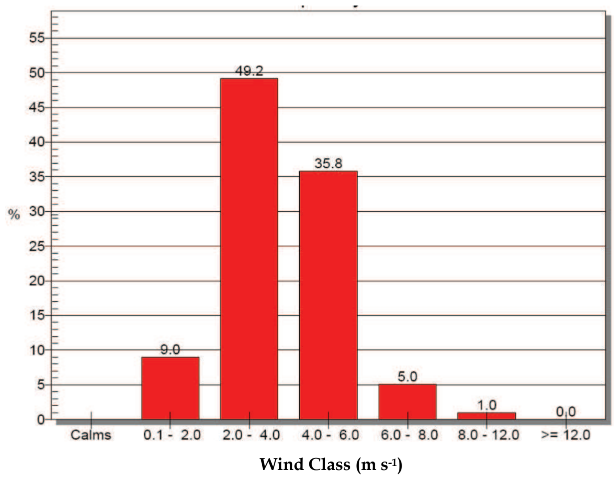



Fig. 4. Wind class frequency distribution for the SRS's H-Area meteorological tower for the 2002-2006 period.

| Wind Direction | SRS Areas A | C | D | F | H | K | L | P |
|---|---|---|---|---|---|---|---|---|
| N | -4.8 | -3.0 | 4.4 | -3.1 | -3.8 | 0 | -1.6 | 0 |
| NNE | -7.4 | -3.4 | -1.5 | 2.8 | -4.5 | 0 | -4.3 | -1.8 |
| NE | 4.0 | 2.2 | 1.0 | 0.8 | 4.4 | 6.7 | 4.4 | 3.1 |
| ENE | 3.8 | -1.4 | -3.7 | -3.1 | -1.9 | -6.2 | -5.9 | -6.0 |
| E | -6.1 | -8.2 | -4.3 | -5.4 | -5.5 | -10.3 | -6.5 | -3.6 |
| ESE | -0.1 | -2.2 | -6.7 | -2.7 | -5.1 | 2.2 | 3.8 | -4.8 |
| SE | 12.7 | 11.6 | 11.3 | 6.8 | 12.1 | 15.1 | 11.3 | 12.2 |
| SSE | 5.8 | 7.9 | 14.9 | 9.2 | 9.5 | 9.4 | 5.2 | 8.0 |
| S | -1.2 | 4.7 | -1.2 | 5.2 | 3.6 | 0 | 6.1 | 4.1 |
| SSW | -2.1 | 3.3 | -3.3 | 2.4 | 4.6 | 1.5 | 3.0 | 1.3 |
| SW | -1.3 | 1.1 | 0.0 | -0.1 | 3.0 | 2.7 | 1.1 | 2.4 |
| WSW | 1.9 | 0.0 | -1.0 | -1.1 | -4.7 | -3.6 | 0.5 | -2.3 |
| W | -0.1 | -2.0 | 2.6 | -1.0 | -0.1 | 1.1 | 2.4 | 0.0 |
| WNW | -0.9 | -1.6 | 1.0 | -1.9 | -0.3 | -2.8 | -8.2 | 2.9 |
| NW | -9.1 | -8.6 | -9.7 | -8.8 | -6.3 | -10.6 | -12.1 | -10.5 |
| NNW | -6.4 | -11.1 | -5.2 | -4.4 | -11.7 | -8.8 | -3.7 | -3.7 |

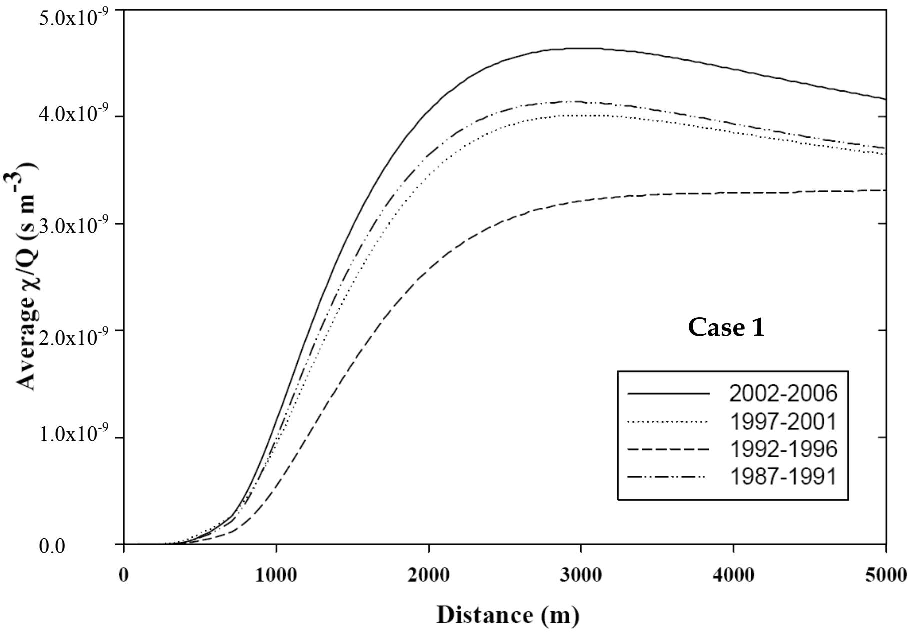
Table 5. SRS wind direction percent differences between the periods 2002 2006 and 1997-2001.

Table 6 shows the VENTSAR XL© input and output for Case 6, which involves a radioactive release, 2002-2006 meteorological data for K-Area, meteorological averaging with a probability level of 0.5%, and dose calculations at various distances from the release point. The first three columns present a list of all the input parameters and their values with units. The next two columns display the valid range of the parameters. The last five columns show the output, which includes the distance (m), 99.50% dilution factor χ/Q (s $m^{-3}$), annual average dilution factor χ/Q (s $m^{-3}$), inhalation dose (mrem), plume shine dose (mrem), and total dose (mrem).

| CALCULATE | VENTSAR XL © | | | | Distance (m) | 99.50% x/Q s/m^3 | Annual Average s/m^3 | Inhalation Dose (mrem) | Plume Shine Dose (mrem) | Total Dose (mrem) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Test Case 6 2002-2006 met data | | | | 10.0 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| | TQ Foley (5-5184) & EB Farfan (5-2257) | | | | 15.0 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| | SRNL Environmental Dosimetry Group | | | | 19.9 | 3.58E-37 | 2.53E-39 | 1.45E-32 | 2.34E-34 | 1.47E-32 |
| | | Units | VALID RANGE | | 24.9 | 4.61E-25 | 3.26E-27 | 1.86E-20 | 3.01E-22 | 1.89E-20 |
| Meteorological File Name | Kmet0206 | | | | 29.8 | 1.61E-18 | 1.14E-20 | 6.52E-14 | 1.05E-15 | 6.62E-14 |
| OR enter "SRS" and coordinates | | | | | 34.8 | 1.33E-14 | 9.40E-17 | 5.37E-10 | 8.67E-12 | 5.45E-10 |
| SRS Grid Coordinates Easting | 0 | ft | 0 | 120000 | 39.7 | 4.36E-12 | 3.09E-14 | 1.76E-07 | 2.85E-09 | 1.79E-07 |
| Northing | 0 | ft | 0 | 120000 | 44.7 | 2.22E-10 | 1.57E-12 | 8.96E-06 | 1.45E-07 | 9.10E-06 |
| **Building Dimensions** | | | | | 49.6 | 3.54E-09 | 2.50E-11 | 1.43E-04 | 2.31E-06 | 1.45E-04 |
| Building Height | 8 | m | 0 | 1000 | 54.6 | 2.66E-08 | 1.88E-10 | 1.08E-03 | 1.74E-05 | 1.09E-03 |
| Building Width | 200 | m | 0 | 1000 | 59.5 | 1.20E-07 | 8.51E-10 | 4.86E-03 | 7.86E-05 | 4.94E-03 |
| Building Length | 10 | m | 0 | 1000 | 64.5 | 3.80E-07 | 2.69E-09 | 1.54E-02 | 2.48E-04 | 1.56E-02 |
| Penthouse Height | 3 | m | 0 | 1000 | 69.4 | 9.29E-07 | 6.58E-09 | 3.76E-02 | 6.07E-04 | 3.82E-02 |
| Penthouse Width | 150 | m | 0 | 1000 | 74.4 | 1.88E-06 | 1.33E-08 | 7.59E-02 | 1.23E-03 | 7.71E-02 |
| Penthouse Length | 8 | m | 0 | 1000 | 79.3 | 3.29E-06 | 2.33E-08 | 1.33E-01 | 2.15E-03 | 1.35E-01 |
| Distance to Penthouse on Rooftop | 2 | m | 0 | 1000 | 84.3 | 5.16E-06 | 3.66E-08 | 2.09E-01 | 3.37E-03 | 2.12E-01 |
| | | | | | 89.2 | 7.45E-06 | 5.27E-08 | 3.01E-01 | 4.86E-03 | 3.06E-01 |
| Minimum Distance of Interest | 10 | m | 10 | 99999 | 94.2 | 1.00E-05 | 7.12E-08 | 4.06E-01 | 6.56E-03 | 4.13E-01 |
| Maximum Distance of Interest | 1000 | m | 10 | 100000 | 99.1 | 1.28E-05 | 9.10E-08 | 5.19E-01 | 8.39E-03 | 5.28E-01 |
| Number of Increments | 200 | | 1 | 200 | 104.1 | 1.57E-05 | 1.12E-07 | 6.36E-01 | 1.03E-02 | 6.46E-01 |
| Compass Sector of Building | 8 | | 1 | 16 | 109.0 | 1.86E-05 | 1.32E-07 | 7.52E-01 | 1.22E-02 | 7.64E-01 |
| (1-N, 2-NNE, 3-NE ...) | | | | | 114.0 | 2.14E-05 | 1.52E-07 | 8.65E-01 | 1.40E-02 | 8.79E-01 |
| Distance of Vent from Roof Edge | 500 | | -1000 | 1000 | 118.9 | 2.40E-05 | 1.71E-07 | 9.70E-01 | 1.57E-02 | 9.86E-01 |
| (negative is upwind) | | | | | 123.9 | 2.64E-05 | 1.89E-07 | 1.07E+00 | 1.73E-02 | 1.09E+00 |
| Vent Height | 50 | m | 0 | 500 | 128.8 | 2.86E-05 | 2.06E-07 | 1.16E+00 | 1.87E-02 | 1.17E+00 |
| Radioactive Calculations(Y or N) | y | | | | 133.8 | 3.05E-05 | 2.21E-07 | 1.23E+00 | 1.99E-02 | 1.25E+00 |
| | | | | | 138.7 | 3.22E-05 | 2.34E-07 | 1.30E+00 | 2.10E-02 | 1.32E+00 |
| If No Mole Fraction of Vent Gas | 0.00E+00 | | | | 143.7 | 3.37E-05 | 2.46E-07 | 1.36E+00 | 2.20E-02 | 1.38E+00 |
| Vent Gas Flow Rate | 750 | m3/s | 0 | 1000 | 148.6 | 3.49E-05 | 2.56E-07 | 1.41E+00 | 2.28E-02 | 1.43E+00 |
| Averaging Option (Y or N) | y | | | | 153.6 | 3.58E-05 | 2.65E-07 | 1.45E+00 | 2.34E-02 | 1.47E+00 |
| If YES Specify Probability Level | 0.005 | | 0.001 | 0.5 | 158.5 | 3.66E-05 | 2.73E-07 | 1.48E+00 | 2.39E-02 | 1.50E+00 |
| If NO Windspeed at Vent Height | 0 | m/s | 0.1 | 15 | 163.5 | 3.72E-05 | 2.79E-07 | 1.50E+00 | 2.43E-02 | 1.53E+00 |
| Stability Class(1-7 to A-G) | 0 | | 1 | 7 | 168.4 | 3.76E-05 | 2.84E-07 | 1.52E+00 | 2.46E-02 | 1.55E+00 |
| Plume Rise(Y or N) | n | | | | 173.4 | 3.79E-05 | 2.89E-07 | 1.53E+00 | 2.48E-02 | 1.56E+00 |
| Vent Diameter | 2 | m | 0.001 | 100 | 178.3 | 3.81E-05 | 2.92E-07 | 1.54E+00 | 2.49E-02 | 1.56E+00 |
| Gas Molecular Weight | 180 | | 0 | 400 | 183.3 | 3.81E-05 | 2.95E-07 | 1.54E+00 | 2.49E-02 | 1.57E+00 |
| Vent Gas Temperature | 17 | C | | | 188.2 | 3.80E-05 | 2.97E-07 | 1.54E+00 | 2.48E-02 | 1.56E+00 |
| Ambient Air Temperature | 17 | C | | | 193.2 | 3.79E-05 | 2.99E-07 | 1.53E+00 | 2.47E-02 | 1.56E+00 |
| Calculate Dose?(Y or N) | y | | | | 198.1 | 3.76E-05 | 3.00E-07 | 1.52E+00 | 2.46E-02 | 1.55E+00 |
| Inhalation Rate | 12000 | m^3/yr | 8000 | 20000 | 203.1 | 2.01E-05 | 3.01E-07 | 8.14E-01 | 1.32E-02 | 8.27E-01 |
| **Radionuclide** | Curies | | | | 208.0 | 2.09E-05 | 3.01E-07 | 8.44E-01 | 1.36E-02 | 8.58E-01 |
| H-3 | 3.00E+00 | | | | 213.0 | 2.16E-05 | 3.01E-07 | 8.72E-01 | 1.41E-02 | 8.86E-01 |
| Zr-95 | 5.00E+00 | | | | 217.9 | 2.22E-05 | 3.00E-07 | 8.98E-01 | 1.45E-02 | 9.12E-01 |
| Nb-95m | 5.00E+00 | | | | 222.9 | 2.28E-05 | 3.00E-07 | 9.21E-01 | 1.49E-02 | 9.36E-01 |

Table 6. VENTSAR XL© input and output for Case 6 based on Simpkins' template (1997).

The results of the test cases were compared graphically (Fig. 5). Cases 3, 4, 5, and 8 do not use the averaged meteorological data; therefore, a wind speed, stability class, and vent diameter for each of these cases were entered as shown in Table 4 (Foley, 2008). Since these cases are independent from the meteorological data, the dilution factors for the four periods



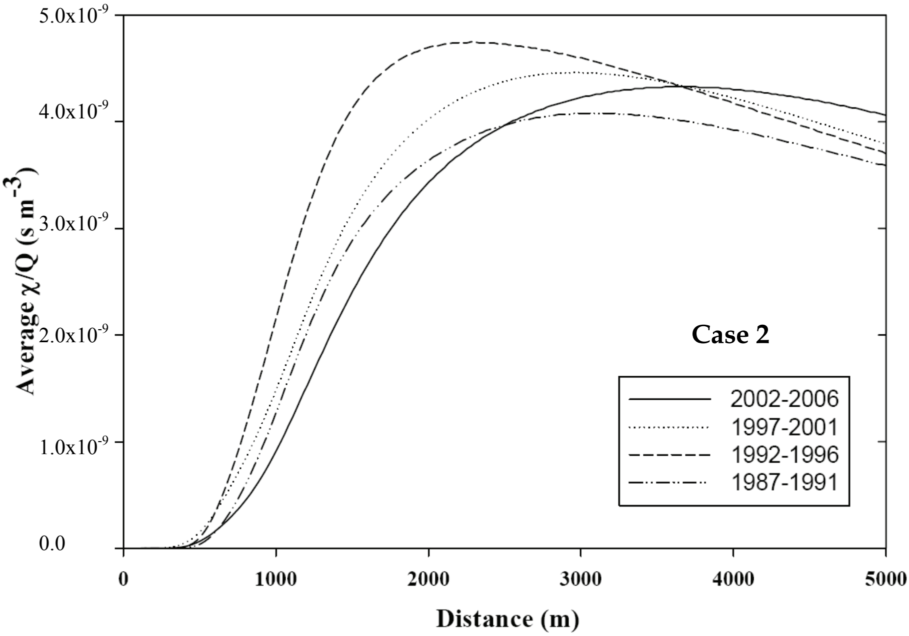
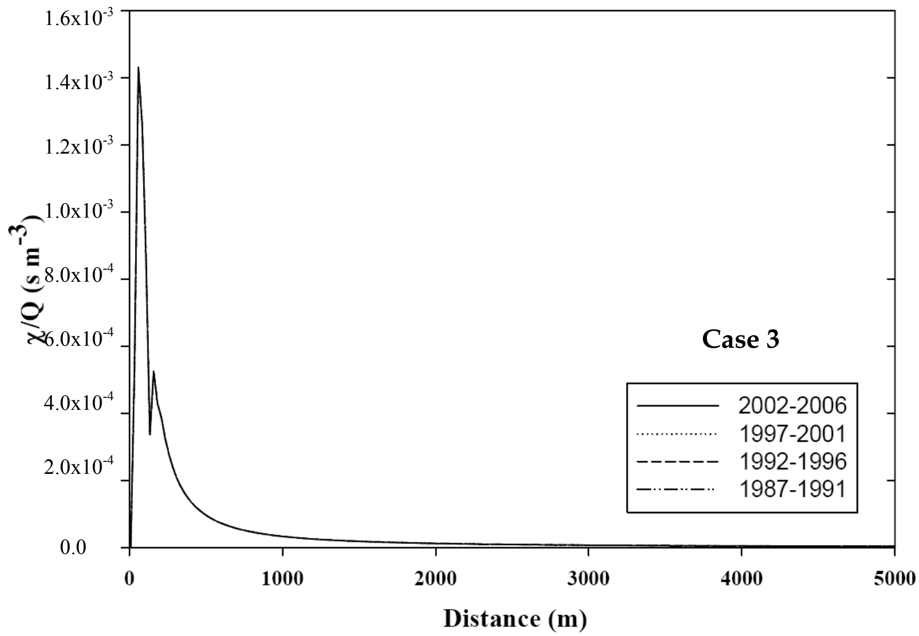




Fig. 5. Test Case comparison for periods 2002-2006, 1997-2001, 1992-1996, and 1987-1991. Cases 1, 2, 6, and 7 represent cases with average meteorological data.



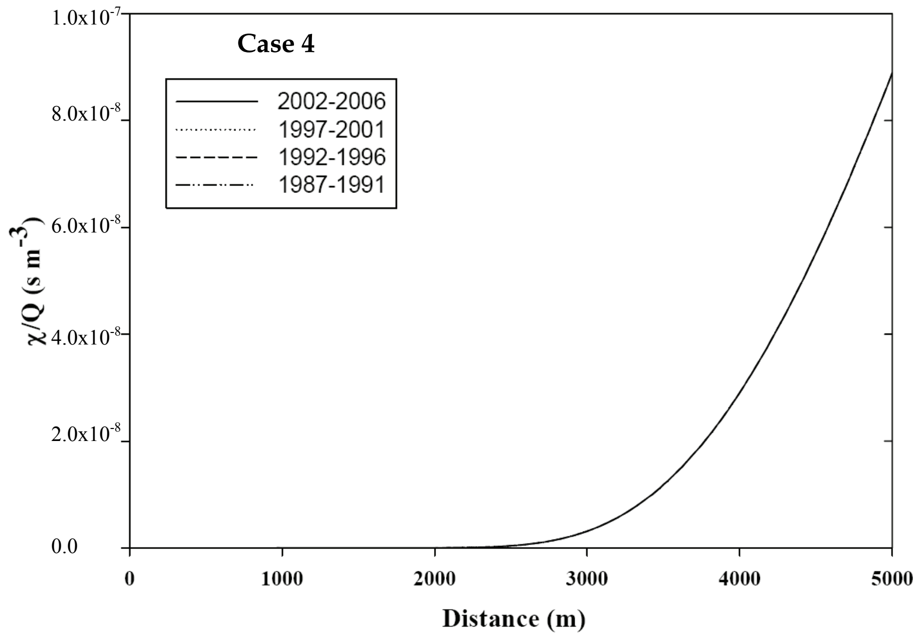
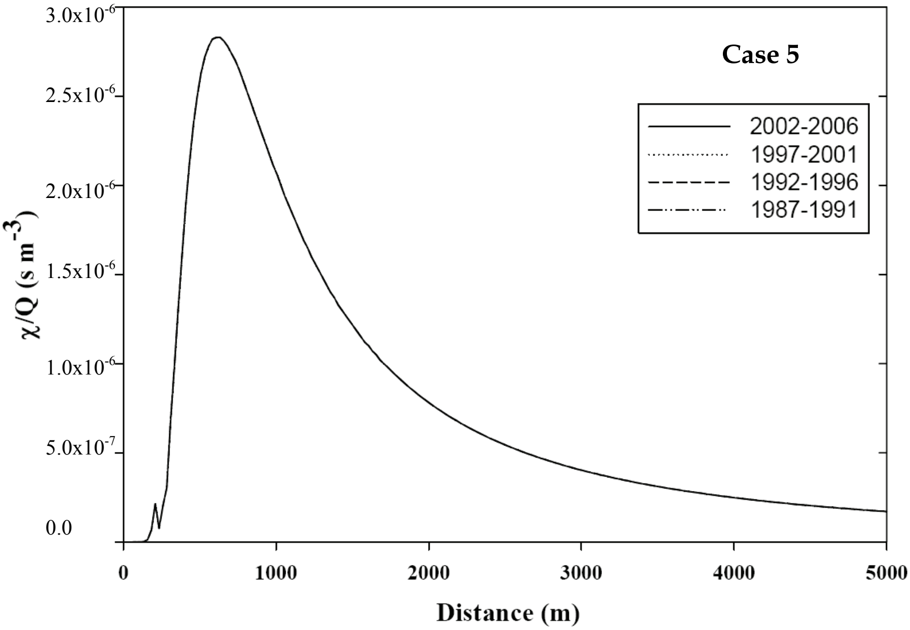




Fig. 5. Cont. Test Case comparison for periods 2002-2006, 1997-2001, 1992-1996, and 1987-1991. Cases 1, 2, 6, and 7 represent cases with average meteorological data.



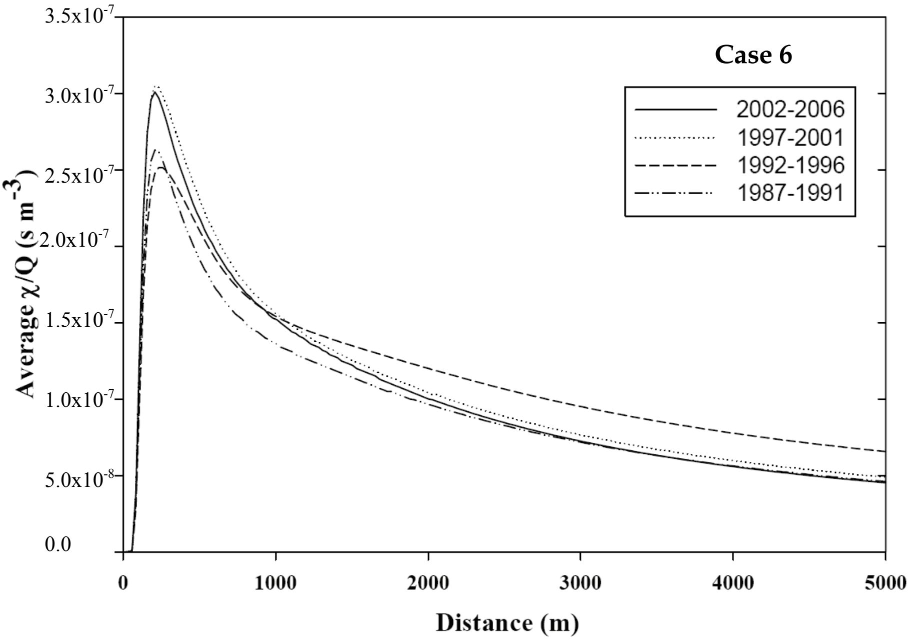
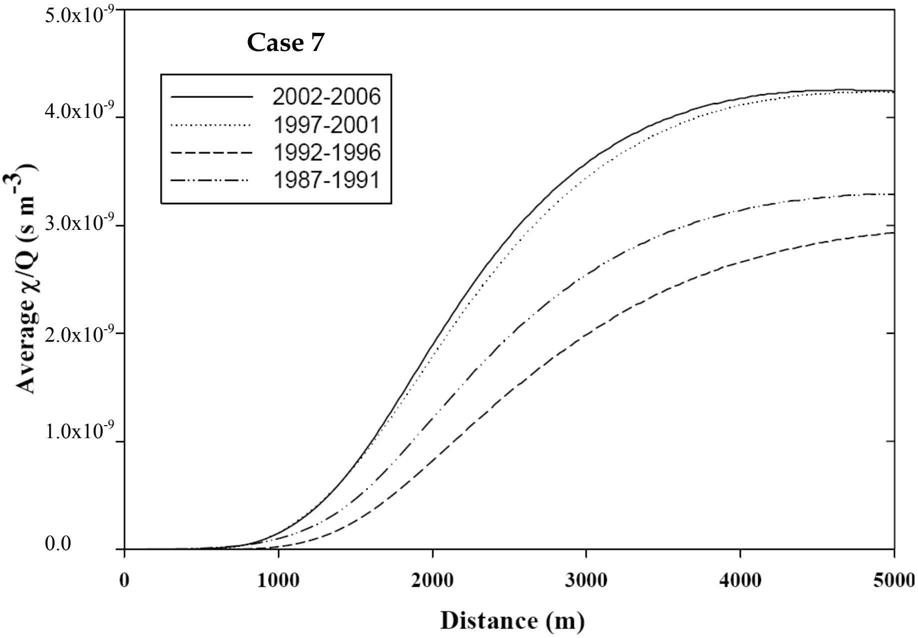




Fig. 5. Cont. Test Case comparison for periods 2002-2006, 1997-2001, 1992-1996, and 1987-1991. Cases 1, 2, 6, and 7 represent cases with average meteorological data.



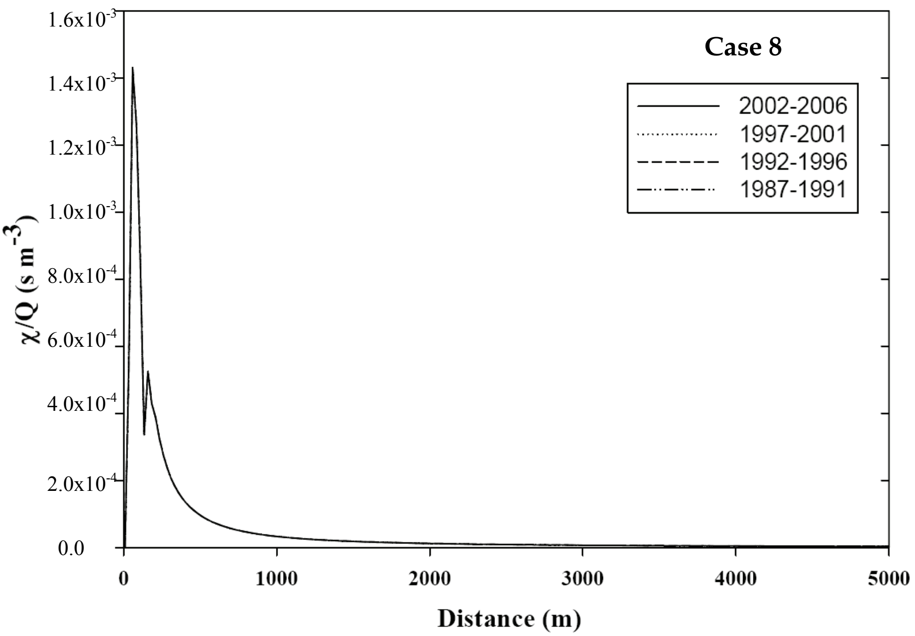




Fig. 5. Cont. Test Case comparison for periods 2002-2006, 1997-2001, 1992-1996, and 1987-1991. Cases 1, 2, 6, and 7 represent cases with average meteorological data.

of time are the same for these cases (Fig. 5). On the other hand, the average meteorological data is applied for Cases 1, 2, 6, and 7 with a probability level of 0.5%. The differences observed for these cases in Fig. 5 are caused only by the change in the meteorological data for all the periods. Two plots can be obtained for cases considering average meteorological data: annual average concentrations ($\chi/Q$, s $m^{-3}$) and concentrations for meteorological conditions not exceeded 99.5% of the time (99.5% $\chi/Q$, s $m^{-3}$). The curves for these cases follow a similar trend with various peaks and dips. However, the main sections of interest on these plots are the maximum values. To visually identify the maximum ground level concentrations with a building present and without the building for Eq. (9), the annual average air concentrations (s $m^{-3}$) versus downwind distances are plotted from the VENTSAR XL© output. The maximum concentrations are easily determined from these plots as shown in Fig. 5.

## 5. Conclusion

The past and current SRS missions involve dealing with significant quantities of nuclear and mixed hazardous wastes. The EDG at SRNL assesses the potential risk and doses to individuals and surrounding populations from atmospheric releases of radionuclides, using various approved computer models with SRS site-specific data. Every five years, SRNL generates a meteorological database to perform dosimetric calculations of accident or routine release scenarios for onsite and offsite populations. This information becomes the input of various environmental dosimetry codes used by the EDG. This study presents comparisons of wind frequencies among four five-year periods for various locations where the possibility of radionuclide releases exist at SRS and the comparison among test cases for these periods involving the computer model VENTSAR XL©, which is a dose assessment model used to estimate dose following short-term atmospheric releases involving GEP stack height evaluation and building effects caused by reactor cooling towers.

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## 7. Disclaimer

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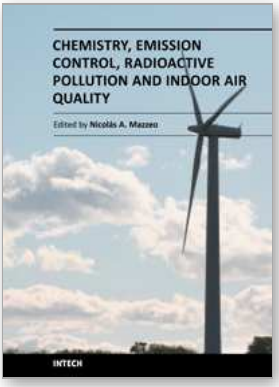


**Chemistry, Emission Control, Radioactive Pollution and Indoor Air Quality**

Edited by Dr. Nicolas Mazzeo

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The atmosphere may be our most precious resource. Accordingly, the balance between its use and protection is a high priority for our civilization. While many of us would consider air pollution to be an issue that the modern world has resolved to a greater extent, it still appears to have considerable influence on the global environment. In many countries with ambitious economic growth targets the acceptable levels of air pollution have been transgressed. Serious respiratory disease related problems have been identified with both indoor and outdoor pollution throughout the world. The 25 chapters of this book deal with several air pollution issues grouped into the following sections: a) air pollution chemistry; b) air pollutant emission control; c) radioactive pollution and d) indoor air quality.

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