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Dispersion modeling of PM10 released during decontamination activities

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Abstract

The decontamination and decommissioning of radioactively contaminated structures and facilities, volume reduction of massive metal structures, and demolition of large concrete structures, result in release of large quantities of contaminants that become airborne and thus could be inhaled by workers and population living in the neighborhood. In order to provide adequate protection to the workers, adequate monitoring of the airborne particulates and proper models that predict the dispersion of the airborne contaminants are needed. The dispersion model will enable development of decision tools on the extent of decontamination that needs to be performed prior to dismantlement and the optimization of personal protective equipment requirements during D&D operations. The Gaussian plume dispersion model is used in this study to predict the dispersion of airborne particulate PM10 ($d_p < 10\,\mu m$) released from: (1) a 35 m height contaminant plant where the plume is affected by the presence of 36 buildings around the emission source, (2) a building during decontamination and removal of process equipment and (3) demolition of contaminant building. The potential impact of PM10 on 180 receptors located at five downwind distances between 0.1 and 20 km around the emission source was performed. A short-term (1–48 h) prediction of average concentration of PM10 from point and area sources on receptors located at ground level was obtained. The concentrations of PM10 over 24 h time period were compared to the U.S. air quality standards. The results obtained in the course of this study are used to predict the inhalation exposures of workers and population living in neighborhood.

Keywords: PM10; Dispersion modeling; Point/area sources; Short-term prediction; Decontamination and decommissioning activities

1. Introduction

Many facilities constructed in the past to support nuclear and weapons production and other activities are contaminated with radioactive materials, hazardous chemicals, asbestos, and lead; have exceeded their design life; and no longer serve their mission. Because of the deterioration of these facilities, proper maintenance and adequate monitoring of potential release of radioactive and hazardous materials to environment and local communities are needed. Decontamination and decommissioning of these facilities are needed to reduce these risks and associated costs. Deactivation activities include planning; removal of surplus materials, chemicals, supplies, classified equipment and documents; and stabilization of radioactive contamination. It also includes recycling, minimization, treatment, storage, and disposal of all secondary wastes generated during deactivation. Decommissioning activities include developing regulatory and project management documents, characterization and engineering work plans to establish cleanup criteria, and characterization reports; decontamination and dismantlement; disposing of contaminated waste; verifying project completion; and issuing completion reports.

During decontamination and decommissioning of contaminated structures and facilities, contaminants are released and become airborne and thus, could be inhaled by the workers. The mechanisms contributing to such releases are mechanical disturbances and meteorological conditions. Site parameters such as vegetations or topography also affect air movement. There are four factors that determine the hazards associated with a specific airborne particulate, namely: the type of particulate involved and its biological effects; the concentration of airborne particulates in the breathing zone of the worker; the size of particles present in the breathing zone; and the duration of the exposure. In order to provide adequate protection to the workers, adequate monitoring of the airborne particulates that workers may inhale is required. Air monitoring instruments are used to assess the concentration of airborne. The location of the air monitoring instruments and knowledge of airflow patterns are

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Nomenclature

C	concentration ($\mu g/m^3$)
d_p	particle diameter for particulate emissions (μm)
D	exponential decay term for Gaussian plume equation
D_S	stack inside diameter (m)
h_s	release height (m)
H_B	building height (m)
H_S	physical stack height (m)
K	scaling coefficient
p	wind speed power law profile exponent
PM10	particulate matter with $d_p < 10\ \mu m$
QA	area source emission rate ($g/s\ m^2$)
s	pollutant emission rate (g/s)
T_S	stack gas exit temperature (K)
u_{ref}	wind speed measured at reference anemometer height (m/s)
u_s	wind speed adjusted to release height (m/s)
V	vertical term of the Gaussian plume equation
V_S	stack exit velocity (m/s)
x	downwind distance from source to receptor (m)
X	X-coordinate in a Cartesian grid receptor network (m)
y	crosswind distance from source to receptor (m)
Y	Y-coordinate in a Cartesian grid receptor network (m)
z_{ref}	reference measurement height (m)
z_i	mixing height (m)

Greek letters

θ	direction in a polar receptor network (°)
ψ	decay coefficient = $0.693/T_{1/2}$ (s^{-1})
σ_y	horizontal (lateral) dispersion parameter (m)
σ_z	vertical dispersion parameter (m)

important for assessing the concentrations of airborne contaminants and worker exposure. For outdoor decontamination and decommissioning operations, large structures are dismantled in large open areas. These operations require the use of a large number of air monitoring instruments to provide reliable estimate of worker exposure. These instruments suffer from high dust loading that reduces airflow rates through dust-collection filters. Dust loading also degrades the energy of the emitted radiation, making the resolution poor. While efforts are underway to develop continuous air monitors suitable for decontamination and decommissioning operations, there is a need for models that can predict the concentration of airborne contaminants.

Dispersion models (Turner [1], Scire et al. [2], Petersen et al. [3], Touma et al. [4]) are the most widely used techniques for estimating the impact of non-reactive pollutant. Air dispersing models accomplish two principal objectives: (1) simulation of downwind dispersion process and (2) simulation of an emission plume's movement and other characteristics. A Gaussian model disperses emissions in the horizontal and vertical planes using Gaussian pollutant concentration distributions (U.S. EPA [5]). A plume's shape over time depends largely upon the wind speed and the atmosphere's tendency to become well mixed or unstable. When the atmosphere is unstable, a plume spreads out and disperses more quickly than when the atmosphere is stable. For different stability conditions, the typical Gaussian model uses standard dispersion parameters that describe concentration deviations about a plume's centerline. The plume direction remains constant in any given direction for at least 1 h, the minimum averaging time. In addition to dispersion parameters, the ground level concentrations depend upon the effective plume centerline height. Effective plume height is the source height plus plume rise due to gas momentum from mechanical air forcing, or from heated gas buoyancy. Plume movement and behavior are influenced by local meteorology, building downwash and terrain (Huber and Snyder [6] and Huber [7]). Meteorological parameters used in dispersion models include wind direction, wind speed, ambient temperature, atmospheric mixing height, and various stability parameters. Stack emission sources on buildings can be affected by building downwash. Air flowing up and over structures tends to direct these emissions closer to the ground than if the structures did not exist. As a result, ground level concentrations downwind can increase.

Dispersion models address building downwash by adjusting initial plume spreading and rise for downwash effects. Plume behavior can also be affected by interaction with mountains or complex terrain (terrain located above final emission plume height during a given hour). Dispersion models require specific information to run, including emission rates, source release parameters, building parameters, receptor location information, terrain height data, meteorological data, and other model specific options. Source release parameter selection depends upon the source configuration selected. Point sources (high level and from plant above ground level), volume sources (several point sources), area sources (low level or ground level releases with no significant plume rise i.e. contaminated sites, mining operations) and open pits are typical source configurations.

Several experimental and numerical studies can be found in literature on the dispersion of airborne particluates from different emisssion sources. For example, Schuhmacher et al. [8] predicted the polluant emitted to the atmosphere in the course of cement production. The dispersion model was used to estimate the dispersion of contaminants such as NO_2, SO_2, PM10, metals emitted by the cement plant. The aim of this study was to investigate the health risks due to combustor emissions in the manufacturing of cement for the population living in the neighborhood of the emission source. Based on contaminant concentrations, the human exposures were caluculated. Individual cancer risks for the emissions of the cement kiln were assesed. De Haan et al. [9] used a novel approach to atmospheric dispersion modeling based on Puff-particle model for dispersion modeling of PM10 for Switzerland. Zemba et al. [10] and Schuhmacher et al. [11] performed quantitave risk assessment emissions from municipal waste combustors using different dispersion modeling techniques. For the experimenal studies, Hoover et al. [12], Newton et al. [13] and Dua et al. [14] investigated aerosols generated from metal cuting techniques

typically used in decommissioning nuclear facilities. Valuable data needed for assessment of inhalation exposures of workers were obtained. Baughman et al. [15], and Drescher et al. [16] investigated mixing of point source pollutant by natural convection flow within a room. The level of an individual inhalation exposure in an enclosed worplace is directly related to the aerosol concentration in the breathing zone, which in turn is influenced by the air flow patterns.

Previous studies have pronded detailed information on the dispersion of airborne particulates from different types of emission sources. Unfortunately there is still a lack of well-established knowledge concerning the dispersion of airborne particulate released from decontamination and decommissioning activities. It is important to advance the current understanding of PM10 dispersion from contaminated structures and facilities that could be inhaled by workers and population living in proximal areas. Dispersion modeling of airborne particulates at construction sites could help us to selection of equipment during D&D operations. It can also be an input to on the level of decontamination that needs be performed prior to dismantling of facilities.

This study focuses on modeling of the dispersion of PM10 during D&D operations. Site specific data (site plan, estimate emission rate and source emission parameters) and site meteorological conditions during decontamination and decommissioning operations were collected and analyzed. Based on the characteristics of air particulates generated, the Gaussian dispersion model was selected as the basic models and used to predict aerosol concentrations. The basis of this model is the straight-line, steady-state Gaussian plume equation, which is used to model simple source emissions from stacks, emissions from stacks that experience the effects of aerodynamic downwash due to nearby buildings, and area emission sources. The model can also be used to calculate average concentrations over time periods ranging from 1 h to 1 year.

2. Dispersion model equations

For a point source, the short-term model uses a steady-state Gaussian plume equation to model emissions such as stacks and isolated vents (Petersen et al. [3], Touma et al. [4] and U.S. EPA [5]). The equations for Gaussian point source model, including the basic Gaussian equation, the plume rise formulas, and the formulas used for determining dispersion parameters are summarized in this paper. For a steady-state Gaussian plume, the hourly concentration at a downwind distance (x) and crosswind distance (y) is given by

$$C = (Q_S KVD/2\pi u_s \sigma_y \sigma_z) \exp(-0.5(y/\sigma_y))^2 \quad (1)$$

where Q_S is the pollutant emission rate (g/s); K is the scaling coefficient to convert calculated concentrations to desired units ($K = 10^6$ for Q in g/s and concentration in $\mu g/m^3$); V is the vertical term (dimensionless number: accounts for the vertical distribution of the Gaussian plume); D is the decay term (dimensionless number: pollutant removal by physical or chemical process); σ_y and σ_z standard deviation of lateral and vertical concentration distribution (m) and u_s is the mean wind speed (m/s) at release height.

The vertical term (V), which is included in Eq. (1), accounts for the vertical distribution of the Gaussian plume. It includes the effects of source elevation, receptor elevation, plume rise, mixing height, and the gravitational settling and dry deposition of particulates. The simplified (no receptor elevation and the gravitational settling and dry deposition of particulates are neglected) equation for the vertical term V requires the vertical dispersion parameter (σ_z) and mixing height (z_i)

$$V = \sqrt{2\pi}\sigma_z / z_i \quad (2)$$

The short-term model uses an interpolation scheme to assign hourly rural and urban mixing heights on the basis of the early morning and afternoon mixing heights calculated using the Holzworth [17] procedures.

The decay term in Eq. (1) is a simple method of accounting for pollutant removal by physical or chemical processes. It is of the form

$$D = \exp(-\psi x/u_s) \quad \text{for } \psi > 0 \text{ and } D = 1 \text{ for } \psi = 0 \quad (3)$$

where ψ is the decay coefficient (s^{-1}), a value of zero means decay is not considered.

For the wind speed u_s, the wind power law is used to adjust the observed wind speed, u_{ref}, from a reference measurement height, z_{ref}, to the stack or release height, h_s. The power law equation is as follows:

$$u_s = u_{ref}(h_s/z_{ref})^p \quad (4)$$

where p is the wind profile exponent ($p = 0.07 - 0.55$). It is a function of stability category (when the atmosphere is unstable, a plume spreads out and disperses more quickly than when the atmosphere is stable) and wind speed class (rural or urban).

For point source, equations that approximately fit the Pasquill–Gifford curves (Turner [1] and Gifford [18]) are used to calculate σ_y and σ_z for the rural mode. The equation used to calculate the standard deviation of lateral concentration distributions σ_y is written as

$$\sigma_y = 465.11628(x)\tan(T_H) \quad (5)$$

where

$$T_H = 0.017453293[c - d\ln(x)] \quad (6)$$

The two coefficients c and d (U.S. EPA [5]) depend on Pasquill stability category (A to F). The equation used to calculate the standard deviation of vertical concentration distributions is of the form

$$\sigma_z = ax^b \quad (7)$$

where the downwind distance x is in kilometers and σ_z is in meters. The coefficients (a) and (b) depend on the downwind distance x and the stability category (U.S. EPA [5]).

The effects of the aerodynamic wakes and eddies produced by buildings on plume dispersion (Huber and Snyder [6] and Huber [7]) are principally based on the results of wind-tunnel

experiments using a model building with a crosswind dimension double that of the building height. The atmospheric turbulence simulated in the wind-tunnel experiments was intermediate between the turbulence intensity associated with the slightly unstable Pasquill C category and the turbulence intensity associated with the neutral D category. Thus, the data reported by Huber and Snyder reflect a specific stability, building shape and building orientation with respect to the mean wind direction. It follows that the wake effects evaluation procedures may not be strictly applicable to all situations. The model also provides for the revised treatment of building wake effects for certain sources, which uses modified plume rise algorithms, following the suggestions of Schulman and Hanna [19]. This treatment is largely based on the work of Scire and Schulman [2]. When the stack height is less than the building height plus half the lesser of the building height or width, the methods of Schulman and Scire are followed. Otherwise, the methods of Huber and Snyder are followed. In the model, direction specific building dimensions may be used with either the Huber–Snyder or Schulman–Scire downwash algorithms.

The model for the short-term area source is based on numerical integration over the area in the upwind and crosswind directions of the Gaussian point source plume formula given in Eq. (1). The ground-level concentration at a receptor located downwind of the source area (U.S. EPA [20] and U.S. EPA [21]) is given by

$$C = (Q_A K/2\pi u_s) \int_x (VD/\sigma_y\sigma_z) \times \left(\int_y \exp\left[-0.5(y/\sigma_y)^2\right] dy \right) dx \quad (8)$$

where Q_A is the area source emission rate (g/m^2 s).

In Eq. (8), the integral in the lateral (crosswind or y) direction is solved analytically as follows:

$$\int_{y1}^{y2} \exp\left(-0.5(y/\sigma_y)^2\right) dy = \mathrm{erfc}(y/\sigma_y) \quad (9)$$

where erfc is the complementary error function.

In Eq. (8), the integral in the longitudinal (upwind or x) direction is approximated using numerical methods based on Press et al. [22]

$$I = \int_{x1}^{x2} (VD/\sigma_y\sigma_z)\mathrm{erfc}(y/\sigma_y)\, dx = I_{2N} + (I_{2N} - I_N)/3) \quad (10)$$

where the integral term refers to the integral of the plume function in the upwind direction, and I_N and I_{2N} refer to successive estimates of the integral using a trapezoidal approximation with N intervals and $2N$ intervals. The model performs Romberg integration by treating the sequence I_k as a polynomial in k. The technique is described in detail in Press et al. [22].

Two basic types of inputs are needed to run the program for both point and area source emissions: (1) the input run-stream file, and (2) the meteorological data file. The run-stream setup file contains the selected modeling options, as well as source location and parameter data, receptor locations, meteorological data file specifications, and output options. The modeling options include the dispersion, source and receptor options. The dispersion option includes: stack-tip downwash, buoyancy-induced dispersion, final plume rise. The short-term model also incorporates screening model dispersion algorithms for receptors in complex terrain, i.e., where the receptor elevation is above the release height of the source. Rural or urban dispersion parameters can be selected depending on the characteristics of the source location. For the source options, the model is capable of handling point and area sources. The model contains algorithms for modeling the effects of aerodynamic downwash due to nearby buildings on point source emissions, and algorithms for modeling the effects of settling and removal (through dry deposition) of large particulates. Source emission rates can be treated as constant throughout the modeling period, or may be varied by month, season, hour-of-day, or other optional periods of variation. For the receptor options, Cartesian or polar grid receptor network can be used in this study. Elevated receptor heights can be selected in order to model the effects of terrain above (or below) stack base, and may also specify receptor elevations above ground level. For simple terrain calculations, any terrain heights input above the release height for a particular source are "chopped-off" at the release height and the model will calculate impacts for terrain above the release height. The source information includes the source type (type of particulate matter) and location, source parameters such as emission rates; stack high, stack exit temperature, exit velocity and stack diameter. The receptor information includes the number of receptors and their locations. The meteorological information includes the wind direction and speed and mixing heights. The output data includes: (1) summaries of high values (highest, second highest, etc.) by receptor for each averaging period, (2) summaries of overall maximum values (e.g., the maximum 50) for each averaging period, and (3) tables of concurrent values summarized by receptor for each averaging period.

3. Results and discussion

The dispersion model has been used in this study to predict the dispersion of the airborne particulate PM10 released from: (1) a 35 m height contaminant plant, (2) contaminant building during removal of process equipment and (3) demolition of contaminant building. An assessment of the potential PM10 impacts on 180 receptors located at five downwind distances around the emission source was performed. A short-term (1–48 h) prediction of average concentration of PM10 from point source or area source on receptors located at ground level was obtained. Following is a description of source, receptor, meteorological inputs conditions and the results obtained with each field data during decontamination decommissioning operations.

3.1. Release of airborne particulate from 35 m height contaminant plant

The airborne particulates are released from a contaminant plant or facility such as the facilities used in decontamination

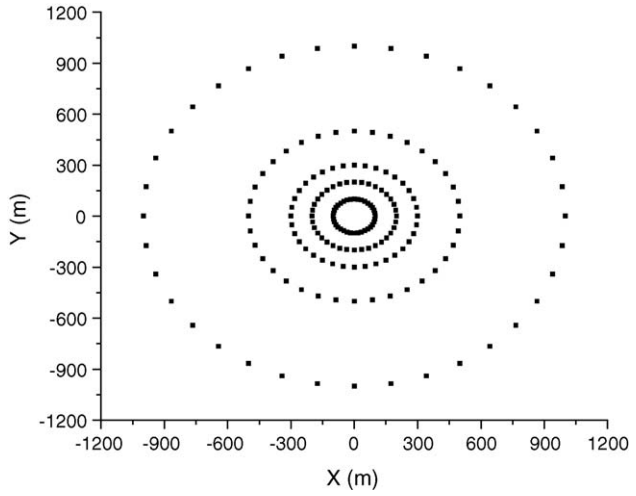

Fig. 1. Position of receptors around the point source.

and decommissioning operations at Oak Ridge Reservation. The plant or the airborne emission source is considered a point source. The source emission conditions are: emission rate $Q_S = 1.00$ g/s, the stack height $H_S = 35$ m, the stack exit temperature $T_S = 432$ K, the stack exit velocity $V_S = 11.7$ m/s and the stack diameter $D_S = 2.1$ m. The plume behavior is affected by the presence of 36 buildings with different height and width around the point source. Average concentration of PM10 over 3-h, 24-h time period and the full time period (2 days) were selected. For the receptors inputs, we have selected a polar network with receptors located at five downwind distances 100, 200, 300, 500 and 1000 m for every 10° flow vector around the emission source. The emission source is located at the center ($x = 0$ and $y = 0$). There are a total of 180 receptors around the stack source as shown in Fig. 1. The meteorological input data file includes the day and hour where the data were taken, the flow vector, the wind speed (m/s), the temperature (K) and the rural mixing height (m). The meteorological parameters for the full time period are shown in Table 1. The first and second highest concentration of PM10 over 3 and 24 h and the average concentration over the full period of time (48 h) were selected for the output file.

Figs. 2 and 3 show the first highest concentration of particulate matter PM10 at 180 receptor locations over, respectively 3 and 24 h period time. It is noted that the highest concentration is obtained at a distance close to the emission source (100 m). The presence of 36 building around the emission source will help to disperse the airborne particulate for receptors close to the source due to downwash effect or eddies created by air movement around building obstacles. With the meteorological conditions registered during these 2 days and the location and dimensions of the buildings around the emissions sources, two peaks of PM10 concentrations are obtained at $\theta = 50°$ and 240°. The maximum concentration of PM10 is about 44 and 19 μg/m^3, respectively for the 3 and 24 h period time. The concentration of PM10 decreases with increasing the average period time and the receptor distance as shown in Fig. 4. It is noted the maximum concentration of PM10 over 24 h period time with an emission rate of 1.0 g/s is less than the U.S. air quality standard of 150 μg/m^3. No significant impact of PM10 is expected to occur at receptor located at distance of 100 m and higher.

Table 1
Meteorological input data file for PM10 released from 35 m height contaminant plant

Month	Day	Hour	Flow vec.	Wind speed (m/s)	T (K)	Mixing height (m)
1	1	1	251.0000	3.0866	268.1	517.2
1	1	2	268.0000	5.1444	268.7	505.9
1	1	3	274.0000	5.1444	269.3	494.6
1	1	4	273.0000	5.1444	269.8	483.2
1	1	5	263.0000	6.1733	270.4	471.9
1	1	6	272.0000	6.1733	270.4	460.6
1	1	7	255.0000	6.1733	270.9	449.3
1	1	8	243.0000	7.2022	270.9	437.9
1	1	9	237.0000	3.6011	271.5	426.6
1	1	10	231.0000	6.6877	272.6	415.3
1	1	11	254.0000	7.2022	272.6	404.0
1	1	12	226.0000	2.5722	272.0	392.6
1	1	13	173.0000	2.5722	272.0	381.3
1	1	14	209.0000	4.1155	272.0	370.0
1	1	15	242.0000	3.0866	272.0	370.0
1	1	16	314.0000	2.5722	272.0	370.0
1	1	17	41.0000	2.0578	272.0	370.3
1	1	18	77.0000	2.5722	272.0	387.4
1	1	19	84.0000	4.1155	272.0	404.6
1	1	20	87.0000	7.2022	273.7	421.7
1	1	21	90.0000	10.2888	273.7	438.8
1	1	22	92.0000	6.1733	272.0	456.0
1	1	23	80.0000	8.2310	272.0	473.1
1	1	24	80.0000	7.2022	272.0	490.2
1	2	1	66.0000	7.2022	270.4	507.2
1	2	2	62.0000	6.6877	269.8	524.3
1	2	3	52.0000	6.1733	270.4	541.5
1	2	4	50.0000	7.2022	270.4	558.6
1	2	5	46.0000	7.2022	270.9	575.8
1	2	6	57.0000	6.6877	270.9	592.9
1	2	7	69.0000	7.7166	270.9	610.0
1	2	8	56.0000	7.7166	270.9	627.2
1	2	9	50.0000	7.7166	270.9	644.3
1	2	10	51.0000	7.7166	270.9	661.5
1	2	11	65.0000	9.2599	270.9	678.6
1	2	12	51.0000	9.7744	271.5	695.7
1	2	13	49.0000	8.2310	272.0	712.9
1	2	14	47.0000	8.2310	272.6	730.0
1	2	15	50.0000	7.7166	273.7	730.0
1	2	16	54.0000	6.6877	273.7	730.0
1	2	17	48.0000	6.1733	274.3	730.0
1	2	18	51.0000	6.1733	274.3	727.9
1	2	19	42.0000	5.6588	274.3	725.9
1	2	20	25.0000	4.6300	274.8	723.8
1	2	21	44.0000	6.1733	275.9	721.8
1	2	22	35.0000	6.6877	277.0	719.8
1	2	23	27.0000	6.6877	277.6	717.7
1	2	24	38.0000	8.2310	278.7	715.7

3.2. Airborne released from building during decontamination and removal of process equipment

The process equipment decontamination and decommissioning is remedial actions that address the decontamination and removal of process equipment and the decontamination of DOE

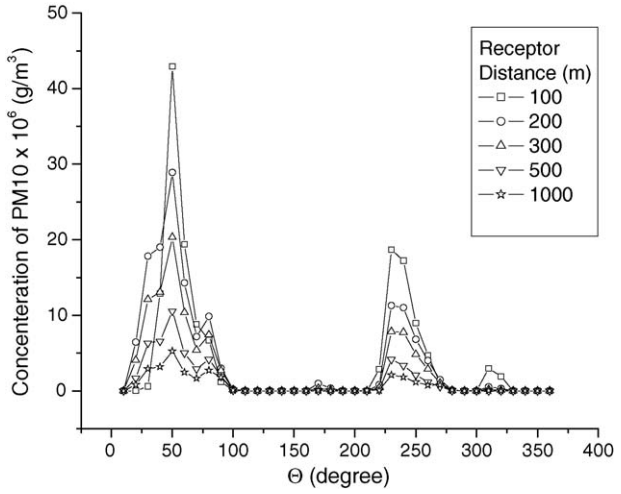

Fig. 2. First highest concentration of particulate matter PM10 over 3 h time period.

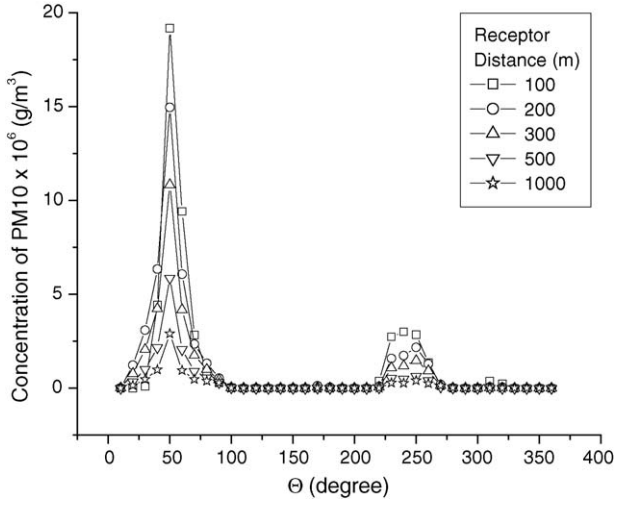

Fig. 3. First highest average concentration of particulate matter PM10 over 24 h.

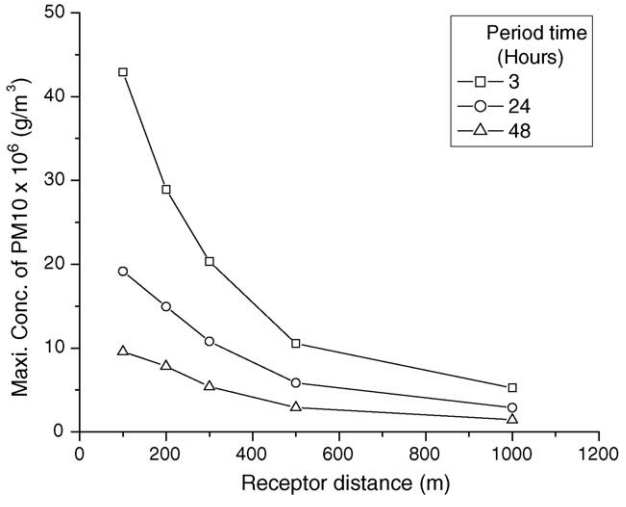

Fig. 4. Maximum concentration of PM10 over different time period.

contaminant buildings K-29, K-31, and K-33 (East Tennessee Technology Park). These building were originally designed and built to house the low enrichment operations of the gaseous diffusion plant. The process building were constructed in the early 1950s, placed in stand by in 1985, and placed in permanent shutdown status in 1987. The condition of buildings presents a threat of potential release of contaminants to the environment. The equipment in these three buildings totals 126,000 t of material. The scope of the activities includes the preparation of endpoint specifications for the decontamination tasks followed by the decontamination and recycling of process equipment. For the second example we simulate the dispersion of PM10 released with different emission rates from one of the DOE contaminant building during the removal process equipment.

The emission source of airborne particulate is building K-33 (point source), the emission rate $Q_S = 2.00$–12 g/s, stack height $H_S = 22.85$ m, stack exit temperature $T_S = 293$ K, stack exit velocity $V_S = 17.56$ m/s and stack diameter $D_S = 1.37$ m. The downwash effect is not considered in this example (no buildings around the point source). The average concentration of PM10 over 1 and 4-h time period and the full time period (24 h) were selected. For the receptors inputs, we have selected a polar network with receptors located at five downwind distances 200, 500, 1000, 2000 and 5000 m for every 10° flow vector around the emission source. For the meteorological input data file, the mean annual temperature for the Oak Ridge area is 14.7 °C (287.7 K) and the winds speeds are less than 11.9 km/h (3.30 m/s) 75% of the time. Among these data, we have selected a constant wind speed of 3.0 m/s for the 24 h period. The flow vector and the mixing height are the same as for the first example. Figs. 5 and 6 show the average concentration of particulate matter PM10 over 24 h for different source emission rate Q_S (g/s) at 180 receptor locations. With the meteorological conditions selected in example 2, two peaks of PM10 concentrations are obtained at receptor orientation angle of $\theta = 80°$ and 270°. It is also noted that because of the absence of downwash effect, the maximum concentration of PM10 is obtained at receptor located at a distance of 1 km and not for receptors located close to the emission source (200 m). The presence of building close of the emission source increases the ground level concentration downwind.

The average concentration of PM10 over 24 h and at each receptor increases with increasing the emission source rate Q_S (g/s) as shown in Fig. 6 and Fig. 7Figs. 6 and 7. It is also noted that the maximum concentrations of PM10 over 24 h period time with an emission rate of 2–12 g/s is less than the U.S. air quality standard of 150 $\mu g/m^3$. No significant impact of PM10 is expected to occur at receptors located at distance between 200 and 5000 m with these emission rate, meteorological conditions and field data inputs.

3.3. Airborne released during demolition of contaminant building

The K-25 and K-27 DOE facilities at East Tennessee Technology Park (ETTP) have been proposed for demolition based on their poor physical condition and the expense and risk of surveillance and maintenance activities. The K-25 facility includes five

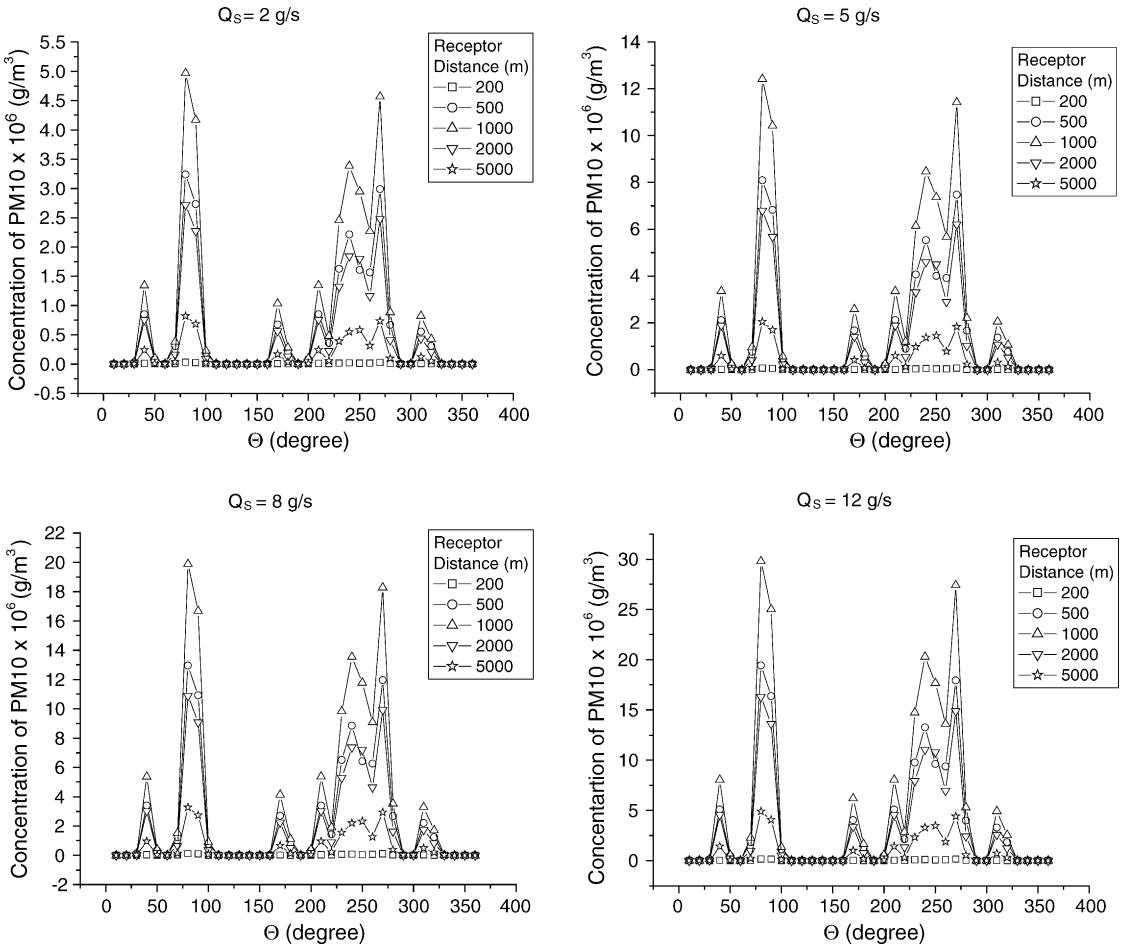

Fig. 5. Average concentration of PM10 over 24 h for different source emission rate Q_S (g/s) and at 180 receptor locations.

buildings: K-724, K-725, K-1031, K-1131, and K-1410. The K-724 (798.96 m^2) and K-725 (2006.71 m^2) are contaminated with beryllium and radioactivity in excess of release limits, and both buildings have structurally deteriorated. Building K-1031 (269.42 m^2) was a maintenance and storage facility in support of the decontamination operations in near by K-1410. Building K-1131 (5174.70 m^2) was used to support the gaseous diffusion process and building K-1410 (836.13 m^2) was originally used for decontamination equipment with uranium contamination and later for nickel-plating the metal parts of uranium enrichment

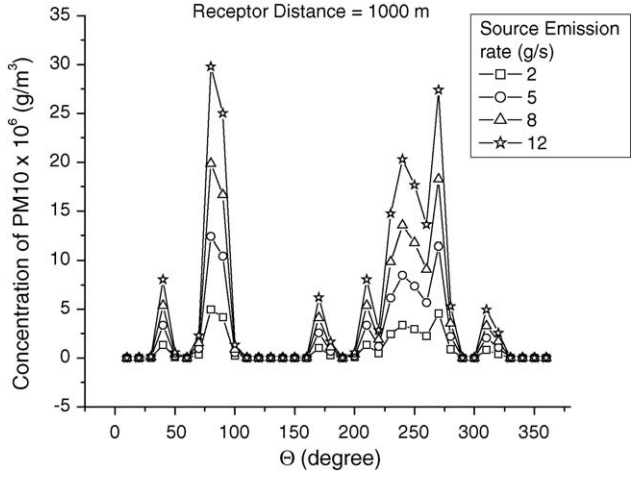

Fig. 6. Effect of source emission rate Q_S (g/s) on concentration of PM10 over 24 h at receptors located at 1 km from the source emission.

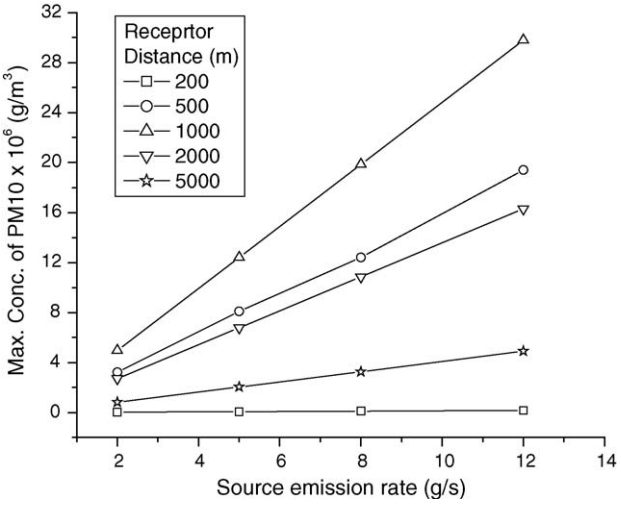

Fig. 7. Effect of source emission rate Q_S (g/s) on maximum concentration of PM10 over 24 h.

equipment. These facilities all contain high levels of radioactive contaminants that exceed the release limits and have deteriorated.

For the third example, the airborne particles are released during the demolition of building K-1131. The emission source is considered as an area source because the particles are released from contaminated sites near ground level. Two area source emissions will be considered in this study: $Q_A = 0.0015$ and 0.0050 g/s m^2. The height of release above the ground source $H_S = 3.0$ m, the length of X and Y sides of the area are, respectively $X_S = 136.5$ m and $Y_S = 700.0$ m and the orientation angle of the rectangular area in degrees from North Angle is 0. The downwash effect is not considered in this example i.e. no buildings are around the area emission source. The average concentration of PM10 will be predicted over 1 and 4-h time period and the full time period (24 h). For the receptor inputs, a polar network with receptors located at five downwind distances 1, 2, 5, 10 and 20 km for every 10° flow vector around the emission source was selected. The total number of receptors around the area source is 180. The meteorological parameters for the 24 h period used to predict the ground average concentration of PM10 released during demolition of building K-724 are shown in Table 2. The wind speed is between 2.0 and 3.2 m/s, and the ambient temperature is about 14 °C (287 K). The average concentrations of PM10 over 24 h for the 180 receptors and for the two area emission rates (0.00015 and 0.0005 g/s m^2) are shown in Fig. 8. The average concentrations of PM10 over 24 h increase with increase in area emission rate. The high concentrations are obtained at receptors located close to the area source (1 km). The concentration of PM10 is higher for a receptor located close to the area emission source even without the presence of building obstacles around the area source (building around the emission source generally help to disperse the airborne particulate for receptors close to the source due to eddies created by air movement around building obstacles). The high impact near the area source can be explained by the short release height above ground ($H_S = 3.0$ m) during demolition of buildings. In general, for airborne pollutants released from the plant or facilities, lowering the stack heights means greater impacts, raising the stack is usually the simplest way of reducing impacts. To assess the results of our air dispersion modeling with regulatory compliance programs of U.S. Environmental Protection Agency (EPA), the maximum concentration of PM10 was compared with the U.S. air quality standard. The maximum average concentrations of PM10 over 24 h period time with an area emission rate of 0.00015 g/s m^2 is about 68 μg/m^3 which is less than the U.S. air quality standard of 150 μg/m^3. On the other hand, the maximum concentration of PM10 during 24 h period time with an area emission rate of 0.0005 g/s m^2 is 226 μg/m^3, which is far above the standard 150 μg/m^3. Proper and adequate protection to the workers and population in the vicinity of the area source are needed during

Table 2
Meteorological input data for PM10 released during demolition of contaminant building

Month	Day	Hour	Flow vec.	Wind speed (m/s)	T (K)	Mixing height (m)
1	1	1	251.0000	3.0000	287	517.2
1	1	2	268.0000	3.0000	287	505.9
1	1	3	274.0000	3.0000	287	494.6
1	1	4	273.0000	3.0000	287	483.2
1	1	5	263.0000	3.0000	287	471.9
1	1	6	272.0000	3.0000	287	460.6
1	1	7	255.0000	2.5000	287	449.3
1	1	8	243.0000	2.5000	287	437.9
1	1	9	237.0000	2.5000	287	426.6
1	1	10	231.0000	2.5000	287	415.3
1	1	11	254.0000	2.5000	287	404.0
1	1	12	226.0000	2.5000	287	392.6
1	1	13	173.0000	2.0000	287	381.3
1	1	14	209.0000	2.0000	287	370.0
1	1	15	242.0000	2.0000	287	370.0
1	1	16	314.0000	2.0000	287	370.0
1	1	17	41.0000	2.0000	287	370.3
1	1	18	77.0000	2.0000	287	387.4
1	1	19	84.0000	3.2000	287	404.6
1	1	20	87.0000	3.2000	287	421.7
1	1	21	90.0000	3.2000	287	438.8
1	1	22	92.0000	3.2000	287	456.0
1	1	23	80.0000	3.2000	287	473.1
1	1	24	80.0000	3.2000	287	490.2

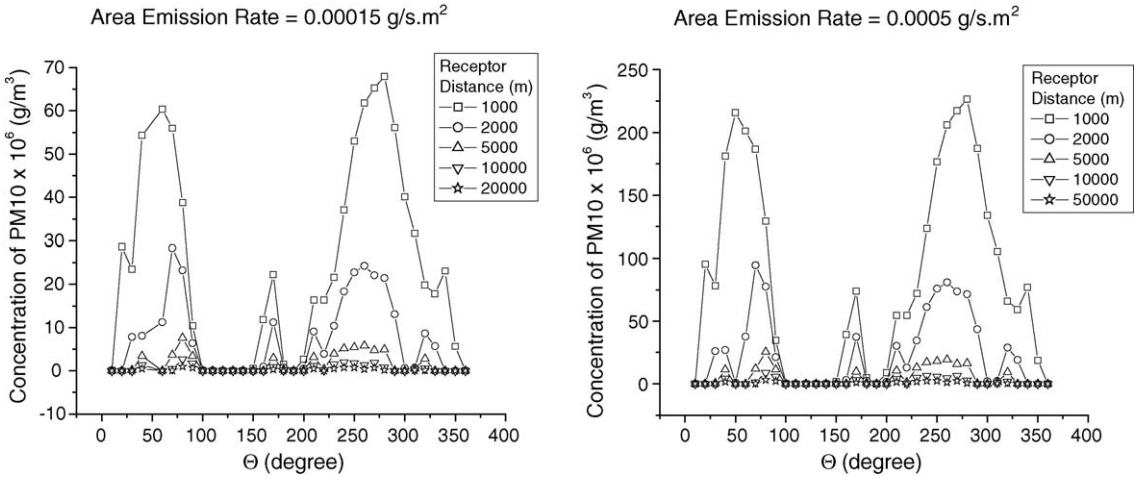

Fig. 8. Average concentration of particulate matter PM10 over 24 h.

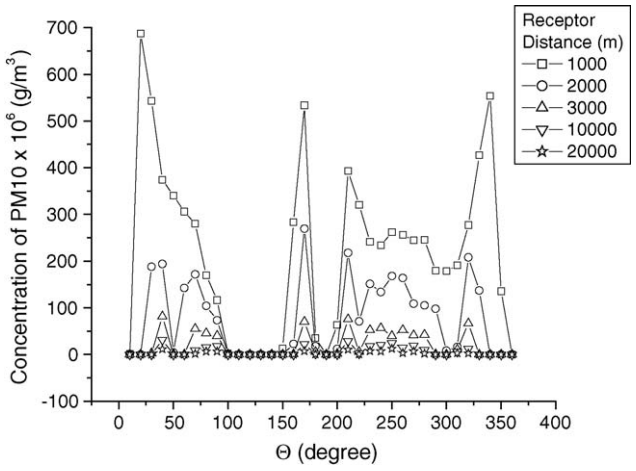

Fig. 9. First highest concentration of particulate matter PM10 over 1-h with an area emission rate of AER = 0.00015 g/s m^2.

the first day. These results will enable development of decision tools on the extent of decontamination that needs be performed prior to dismantlement and the optimization of personal protective equipment requirements during D&D operations. It is also noted that the maximum concentration of PM10 during the first hour of the demolition process is very high as shown in Fig. 9. The peak concentration of PM10 over 1-h at receptor located at 1000 m with an orientation angle of 25° can reach 700 μg/m^3 with an area emission rate of 0.00015 g/s m^2. Tables 3 and 4 summarize the first six highest concentration of PM10 over 24 h and the position of the receptor (*X* and *Y* coordinates). No significant impact is expected to occur at all the receptors located at a distance of 1 km and up during area emission rate of 0.00015 g/s m^2 during demolition of contaminant building but there is an impact on receptors located at a distance around 1 km with an area emission rate of 0.0005 g/s m^2.

Table 3
First six highest concentration of PM10 over 24 h with an area source emission rate of 0.00015 g/s m^2

	Concentration (μg/m^3)	Receptor *X* (m)	Receptor *Y* (m)
1st highest value	67.93371	−984.81	173.65
2nd highest value	65.20976	−1000.00	0.00
3rd highest value	64.71952	766.04	642.79
4th highest value	61.81841	−984.81	−173.65
5th highest value	60.33957	866.03	500.00
6th highest value	56.13650	−939.69	342.02

Table 4
First six highest concentration of PM10 over 24 h with an area source emission rate of 0.0005 g/s m^2

	Concentration (μg/m^3)	Receptor *X* (m)	Receptor *Y* (m)
1st highest value	226.44566	−984.81	173.65
2nd highest value	217.36591	−1000.00	0.00
3rd highest value	215.73175	766.04	642.79
4th highest value	206.06139	−984.81	−173.65
5th highest value	201.13190	866.03	500.00
6th highest value	187.12170	−939.69	342.02

4. Conclusions

This study focuses on dispersion modeling of PM10 generated during decontamination and decommissioning (D&D) of radioactively contaminated structures and facilities. Information on D&D operations sites, airborne release parameters and meteorological input data for specific sites have been collected. Based on the characteristics of air particulates generated during D&D operations the dispersion model ISC3 was selected as the basic model to predict the aerosol concentration. The model was used to predict the dispersion of PM10 released from: (1) a 35 m height contaminant plant, (2) building during decontamination and removal of process equipment and (3) demolition of contaminant building. The potential impact of PM10 on 180 receptors located at five downwind distances around the emission source was performed.

For the PM10 released from 35 m height contaminant plant, the highest concentration at ground level is obtained at a distance close to the emission source due to the presence of downwash effect that create air movement around buildings obstacles. The concentration of PM10 over 24 h period time with a source emission rate of 1.0 g/s is less than the U.S. air quality standard of 150 μg/m^3. For the PM10 released from a 22.85 m height contaminant building without downwash effect (no building around the emission source), no impacts of PM10 on receptors located close to the emission source. The maximum impact of PM10 was obtained at receptors located at about 1 km from the source. The average concentration of PM10 over 24 h with an emission rate of 2–12 g/s is between 5 and 30 μg/m^3 that is less than the U.S. air quality standard of 150 μg/m^3. For the last and third example where the PM10 particles were released from the demolition of contaminant building (area source), the higher concentration of PM10 is obtained for receptors located close to the area emission source even without the presence of building obstacles around the area source. This is due to the short release height above ground (H_S = 3.0 m) during demolition of building. The maximum concentrations of PM10 over 24 h period time with an area emission rate of 0.00015 g/s m^2 is about 68 μg/m^3 which is less than the U.S. air quality standard of 150 μg/m^3 but it is about 226 μg/m^3 with an area emission rate of 0.0005 g/s m^2 which is above the standard 150 μg/m^3. It is very important to monitor and to measure exactly the area emission rate during the demolition of building because it affects directly the workers and population living in the neighborhood. The results obtained in the course of this study are important for the development of decision tools that needs be performed prior the D&D operations and optimization of personal protective equipment requirements.

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