

A simulation study of short-range atmospheric dispersion for hypothetical air-borne effluent releases using different turbulent diffusion methods

C. V. Srinivas · R. Venkatesan · K. M. Somayaji · R. Indira

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Abstract Radiological impact due to hypothetical air-borne effluent releases for an upcoming fast reactor (PFBR), at a tropical coastal site in Kalpakkam is studied using the HYSPLIT dispersion model. Short range air dispersion simulations are conducted with HYSPLIT for a weakly forced synoptic condition on 3rd March, 2008 with three turbulent diffusion methods, i.e., standard velocity deformation (A), short range isotropic similarity (B) and turbulent kinetic energy (TKE) (C) schemes to assess their performance in predicting the dose distribution at a local scale. The time varying 3-d meteorological parameters for the case study are predicted using a nested grid meso-scale dynamical atmospheric model MM5. Results indicate that the velocity deformation method gives spatially more complex dose pattern while the short-range similarity and TKE methods provide smoother horizontal dose profiles. The downwind dose in different pathways due to elevated releases is found to be the highest for the method A followed by B and C. For the ground releases, the TKE method produced higher doses than the other two. The difference in the dose values from the three methods is due to the variation in the horizontal and vertical mixing calculation and the assumptions involved in the respective methods. The total dose at the site boundary from different pathways is highest from the TKE method. Values from all the methods are about one to two orders less than the values given by a Gaussian Plume model for similar atmospheric conditions. The total dose estimated from the TKE method is 20.62 mSv at the release location and 1.25 mSv at the site boundary.

Keywords Atmospheric dispersion · HYSPLIT · Turbulent diffusion · Dose

Introduction

Estimation of atmospheric dispersion from nuclear facilities is required for an assessment of the radiological impact from normal and off-normal release scenarios for safe design purposes. Coupled atmospheric and dispersion models are currently used in place of Gaussian models to realistically simulate the 3-d atmospheric circulation and dispersion of air pollutants at coastal and hilly terrain to fully account the complexity of the flow and meteorological conditions. Kalpakkam is a tropical coastal site and has several nuclear facilities including two units of a pressurized heavy water reactor. A prototype fast breeder reactor (PFBR) of 500 MWe is coming up at this site. The study of potential hazards during an unlikely event of a core disruptive accident (CDA) conditions of PFBR requires an estimate of the environmental radiological impact right at the design stage for emergency planning and preparedness. The earlier studies on dispersion for CDA used a Gaussian Plume Model (GPM) (Rajagopal and Venkatesan 2002) following regulatory procedures (IAEA 1980; Clarke and Macdonald 1978) and a FLEXPART dispersion model (Srinivas and Venkatesan 2005) for a more realistic assessment. The coupled modeling system MM5+FLEXPART has given interesting results due to the prognosis of the local topographic flow (land-sea breeze), mixing depth variation and the corresponding diurnally and spatially varying dose pattern.

Estimates from dispersion models typically depend on the treatment of horizontal and vertical turbulent diffusion and the meteorological data used in the calculation. The meteorological issues in dispersion are the vertical/horizontal

C. V. Srinivas (✉) · R. Venkatesan · K. M. Somayaji · R. Indira
Radiological Safety Division, Safety Group,
Indira Gandhi Centre for Atomic Research,
Kalpakkam PIN 603102, India
e-mail: cvsri@igcar.gov.in

resolution of the input data for capturing the extremities in mixing, availability of crucial parameters such as vertical temperature/wind profiles, turbulent kinetic energy (TKE), turbulent fluxes, etc for treatment of turbulent diffusion of pollutants. Several approaches of turbulent diffusion calculation have been developed based on available data and the complex schemes involve more details of input parameters. The dose estimates may vary according to the diffusion schemes which need evaluation for their application at any given region or location.

In the present study, an advanced atmospheric dispersion model HYSPLIT is used to study the dispersion of air-borne effluent releases from hypothetical CDA scenario for PFBR at Kalpakkam coastal site. The objective of the present work is to examine the various turbulent diffusion methods available in HYSPLIT model for dispersion estimates in a range of a few tens of kilometers at the coastal site Kalpakkam and to analyze the relative estimates of dose distribution. The simulation is conducted for a weak synoptic condition on 3rd March, 2008 and the necessary meteorological data is simulated by the PSU/NCAR 3-D non-hydrostatic meso-scale atmospheric model MM5 (Grell 1994). Simulation with the coupled modeling system enables to find the differences of different diffusion methods for short-range dispersion calculations. A brief description of the modeling system, the meteorological prediction from MM5 model, and the dispersion estimates using the three turbulent diffusion methods for the hypothetical CDA for PFBR is presented.

Brief description of the modeling aspects

Dispersion model

In the present study a Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model (Draxler and Hess 1998) developed by Air Resources Laboratory, NOAA is used to simulate the dispersion and deposition of radio nuclides of the air-borne effluents released from CDA. It computes simple trajectories to complex dispersion and deposition using puff or particle approaches. The dispersion is treated to comprise the particle transport by the mean wind and turbulent diffusion in the medium. The mean particle trajectory is the integration of the particle position vector in space and time. The turbulent component of the motion is computed by adding a random component to the mean advection velocity in each of the three-dimensional wind component directions. The horizontal turbulent velocity at any given time is computed from the turbulent velocity at the previous time, an auto-correlation coefficient that depends upon the time step, the Lagrangian time scale, and a computer-generated random component. The model has three different schemes for turbulent diffusion treat-

ment. The standard method (method A) computes the horizontal mixing from deformation field (Smagorinsky 1963; Deardorff 1973) and the vertical mixing from similarity (Troen and Mahrt 1986; Holtslag and Boville 1993; Beljaars and Betts 1993), where the inverse Obukov length ($1/L$) is estimated from surface fluxes when available or the wind/temperature profiles otherwise. The vertical diffusivity is averaged over the entire boundary layer, and the method is generally followed in long-range calculations. In the short range isotropic method (method B), both horizontal and vertical velocity variances are computed from the stability parameters calculated from the heat and momentum fluxes. The horizontal and vertical mixing coefficients are set equal. In method C, the velocity variances are computed from meteorological model TKE field (Kantha and Clayson 2000), and the variances vary vertically with height. Pollutant concentrations are estimated as integrated mass of individual particles as they pass over the concentration grid which is a matrix of cells, each with a volume defined by its dimensions. The details of the model equations and the dispersion methods are detailed in the technical paper (Draxler and Hess 2004).

Atmospheric model

A non-hydrostatic, primitive equation meso-scale atmospheric model (MM5) developed by PSU/NCAR (Grell 1994) is used to predict the fields of u , v , w (horizontal, vertical wind components), T (temperature), Z (height) or P (pressure), surface pressure (P_o), and the optional fields moisture and vertical motion for the dispersion model. MM5 uses Arakawa-B horizontal grid staggering, terrain following sigma vertical coordinate, a second-order leapfrog time integration scheme, nesting of multiple domains, and has a number of parameterization schemes for atmospheric physical processes. For the present study, MM5 model is configured with three nested domains of 18, 6, and 2 km horizontal resolution and 28 vertical levels, the fine mesh covers the Kalpakkam region around the PFBR site. Each nest has 100×100 grids. The initial conditions for the model domains have been interpolated from NCEP Global Forecasting System (GFS) data available at 0.5×0.5 degree resolution corresponding to 18 UTC of 2nd March 2008. The physics options used are the Eta Mellor-Yamada second-order turbulence closure scheme for Planetary Boundary Layer (Mellor and Yamada 1982), five layer soil diffusion scheme for surface temperature prediction, Monin-Obukhov similarity theory for surface layer, Kain-Fritsch (Kain and Fritsch 1993) scheme for convective parameterization, simple Ice scheme for cloud microphysics (Dudhia 1989), rapid radiative transfer model (RRTM) scheme (Mlawer et al. 1997) for radiation transfer in the atmosphere. The model is integrated for 48 h between 18 UTC 2nd March 2008 to 18 UTC of 3rd March 2008.

Dispersion and dose calculation

The meteorological data needed in dispersion simulation is taken from MM5 model inner domain at every 1 h over a $200 \times 200 \text{ km}^2$ grid centered at Kalpakkam. The domain of calculations comprises a mesh area of $50 \times 50 \text{ km}^2$ with 1.0 km grid size and covers a range of 25 km around PFBR between $79.91\text{--}80.36^\circ \text{ E}$ and $12.31\text{--}12.76^\circ \text{ N}$ at Kalpakkam. Vertically, a total 20 levels are considered between the surface and 5,000 m height; the height of the first level is 25 m. The release location of PFBR is fixed at 80.16° E , 12.56° N coordinate. Two cases of continuous point sources are considered at the release location (1) 100 m stack release for the first 1 min after CDA, and (2) ground release of activity for 24 h. The source term is taken from the PFBR report (Rajagopal and Venkatesan 2002) and consists of fission product noble gases and particulates (Srinivas and Venkatesan 2005). The source emission mass for various species is provided from this inventory. The concentration is averaged every 15 min, and the model output is taken at 1-h intervals. Three separate simulations are conducted each time varying the method of turbulence diffusion computation as (a) Standard Velocity Deformation, (b) Short Range Isotropic Similarity, (c) Meteorological model TKE.

The dose estimates are made following AERB (1992) guidelines for a case of a maximally exposed individual at different distances from the source location. The pathways of exposure considered for the calculation are, cloud gamma dose due to fission product noble gases (FPNG), inhalation dose due to particulates and vapors and external exposure to ground deposited activity. The accident is considered to occur at 00 hours IST on 3rd March 2008. The inhalation dose is calculated from the ground level air concentration, the average breathing rate of adults ($1.2 \text{ m}^3/\text{h}$), the period of exposure and effective dose conversion factor (e_{50}). The cloud gamma dose is calculated using a Cell-Integrated Dose Evaluation (CIDE) procedure (Kai 1984) for an arbitrarily distributed radioactive cloud based on the dose conversion factors for each cell with unit concentration in the cloud. Exposure rates to ground contamination are calculated by multiplying the ground-deposited activity with dose conversion factor (Till and Meyer 1983).

Results

Meteorological model parameters

A few meteorological parameters that are significant in the dispersion calculation are analyzed from the atmospheric model from the innermost domain at 2 km resolution. The flow pattern in the study region is influenced by the synoptic as well as local scale flow. The large-scale flow field is

predominantly easterly for the case study period in March 2008. The wind at the lower atmospheric levels ($\sigma=0.995$ ~100 m above ground level) in the nocturnal hours was easterly. Due to the establishment of a reverse temperature gradient (cooling land) westerly land-breeze circulation was initiated at 0300 hours IST which continued until 11 h IST. The wind was calm (~2 m/s) up to 50 km inland from coast until 6 h when a complete land-breeze flow is seen. The flow pattern at 12 h clearly shows onset of sea breeze at the coast from the inner domain (Fig. 1). At the upper atmospheric levels ($\sigma=0.770$ ~1,000 m above ground level) the wind is relatively free from topography/surface effects. Simulated mixing depth of the atmosphere varied from 200 m in the night to 600 m at 12 h IST during the day time at Kalpakkam grid. During daytime, it varied to 1,000 m inland. Stability of the simulated lower atmosphere varied as (1) stable (00 to 0600 hours), (2) neutral regime (0700 to 0900 hours), (3) slightly unstable (0900–1200 hours), (4) highly unstable (1200 to 1700 hours), and neutral condition (1900 to 00 hours). Simulated winds are about $2\text{--}3 \text{ ms}^{-1}$ from 0 to 6 h IST, 5 ms^{-1} at 9 h IST, 4 to 4.5 ms^{-1} between 15 to 18 h IST, and 3 to 2 ms^{-1} between 21 to 24 h IST.

Simulated winds, temperature, and humidity are compared with meteorological tower observations at Kalpakkam and Radiosonde profiles from Chennai (not shown). The model profiles indicate stable atmosphere up to 800 m AGL at 0600 hours IST, a deep mixing layer of about 1,000 m depth in the noon and a stable atmosphere in the lower regions at 1800 hours IST. The diurnal wind speed and surface air temperature are slightly under-predicted. Both the model and tower data indicate the change in the wind direction due to the sea–land breeze circulation.

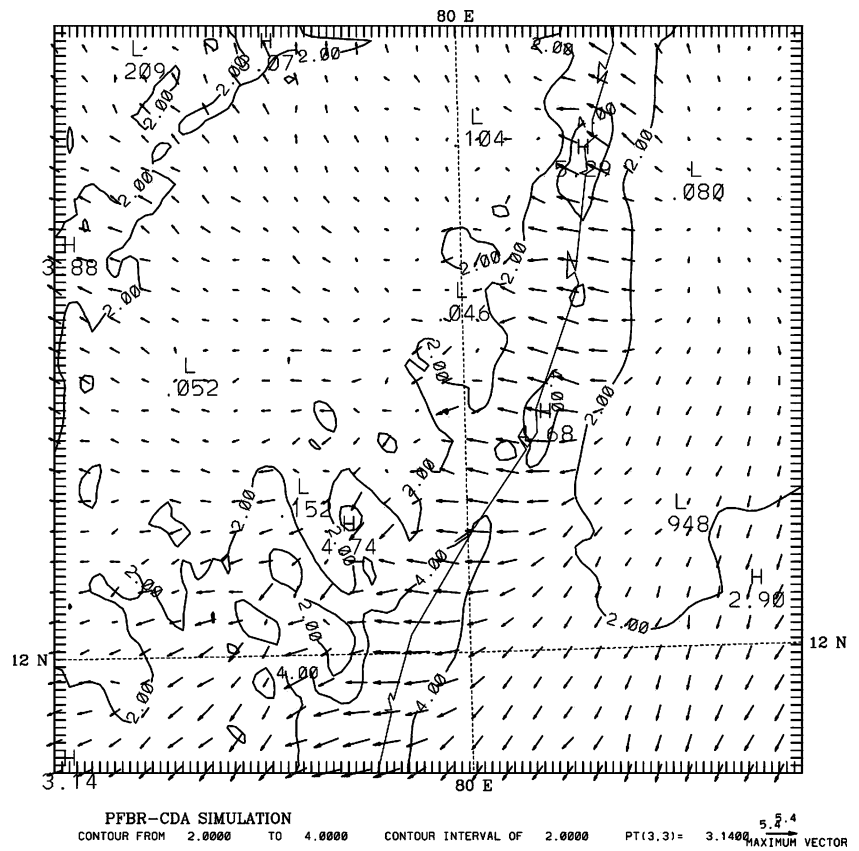
Dispersion model results

The dispersion from the ground and stack releases is calculated separately, and the corresponding dose values from the three methods are compared. The dispersion from ground release is calculated for 24 h. The release from stack occurs for 60 s duration after accident. To analyze the dose distribution pattern from stack releases for different possible atmospheric conditions, the elevated release dispersion is computed for 60 s for different times separately. The dose at the site boundary distance (1.5 km) and downwind dose up to 15 km distance is analyzed from the three different methods.

Particle distribution in different cases of diffusion

The pattern of vertical distribution of the pollutant particles for the case of stack releases centered at the source location (12.56° N and longitude 80.12° E) in the west–east and south–north directions is shown in Fig. 2. It is seen that particles are more densely distributed during morning stable conditions

Fig. 1 Surface level wind flow pattern simulated by MM5 along the Kalpakkam coast at 1500 LST



(06 LST) than during the daytime unstable conditions (12 LST). Particles are widely distributed in method “C” with TKE than in the other two cases. Particles reached up to 1,500 m AGL in method C while they reached up to 1,000 m AGL in the other two cases in the unstable conditions. Particles are more densely distributed in cases A, B unlike C which produced wide distribution both in the stable and unstable atmospheric conditions. Thus, for the elevated releases

method C based on TKE has given well-distributed particles, i.e., more turbulent diffusion than the other two methods.

Dispersion results from ground releases

The inhalation dose is calculated from the ground level air concentration of the radio-isotopes for both particles and fission product noble gases for the 24-h release time. From

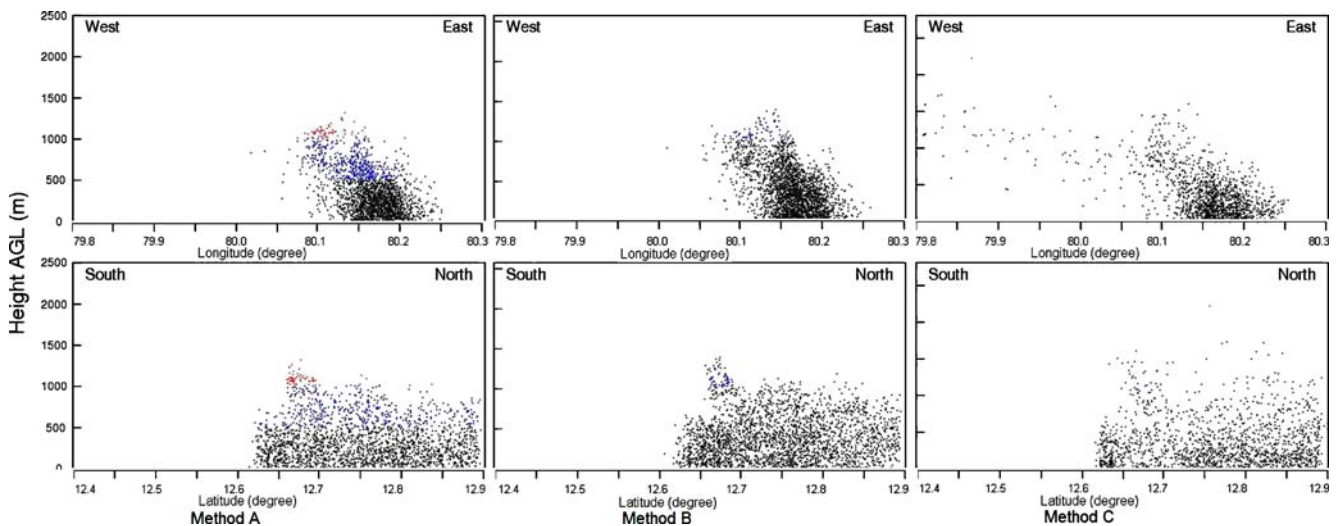


Fig. 2 Particle positions calculated using **a** velocity deformation, **b** short-range similarity, and **c** TKE for highly unstable condition at 12 h IST

the dose pattern, it is seen that the contours are smoother in cases B, C. The contours $4.91\text{e-}4$, $2.03\text{e-}4$, $8.37\text{e-}5$, $3.45\text{e-}5$ are spread to a wider area in case A followed by B and C (Fig. 3). The dose fell rapidly in a distance of 1 km and reduced gradually thereafter in all the three cases, the method C based on TKE gave the highest value (0.0005 mSv) followed by the methods B (0.00049 mSv) and method A (0.00044 mSv), respectively, at the site boundary distance. The same trend is found in the doses up to 15 km distance. The spatially complex dose pattern in the case A can be attributed to the horizontal diffusivity determined from wind field deformation. The variation in the wind field from the coast line determines this diffusivity in the first method and hence is different from other two methods.

The cloud gamma dose pattern for the ground releases as in the case of inhalation dose is smoother in the cases of diffusion methods B, C, while it is spatially complex for A. Method C gives the highest dose at the site boundary (1.0346 mSv), while methods A, B give similar values (0.859, 0.841 mSv), respectively. The exposure dose is calculated from ground deposition of ^{137}Cs and ^{131}I and is found to be distributed smoother in cases C, B and is spatially more complex in method A. The exposure dose at the site boundary is estimated as $1.74\text{e-}7$, $2.4\text{e-}7$, $5.32\text{e-}8$ mSv, respectively, from methods A, B, C, respectively, and is very less in magnitude in comparison to the inhalation and cloud shine doses. Method B gives highest value due to higher ground deposition in case B. This is perhaps due to the variation in the deposition values from the three methods. The exposure dose at the site boundary is very less in magnitude in comparison to the inhalation and cloud shine doses.

Dispersion from stack releases

In the present study, the plume effluent temperature and effluent velocity are not considered, as the current version of the HYSPLIT does not fully incorporate these parameters. The dose from stack releases is calculated for 60 s for various atmospheric conditions to identify the meteorological condition that yields the highest dose at the site boundary distance. The plume from the stack releases is seen to follow the stream line at different times on the given day. The plume is oriented in the southeast direction during the stable atmospheric conditions of the late night (until 0300 hours IST) and moved slowly in the south, southwest, and west direction in the subsequent hours until 1200 hours IST. Subsequently, the plume moved in the northwest under the influence of the sea-breeze onset at the coast. The plume stayed overland under this flow condition until late night hours. The plume levels varied at different times according to the diurnal variation in atmospheric stability and wind flow. The inhalation dose values from stack releases at different hours vary, and the maximum values are noticed in the daytime at 15–17 h IST (Table 1).

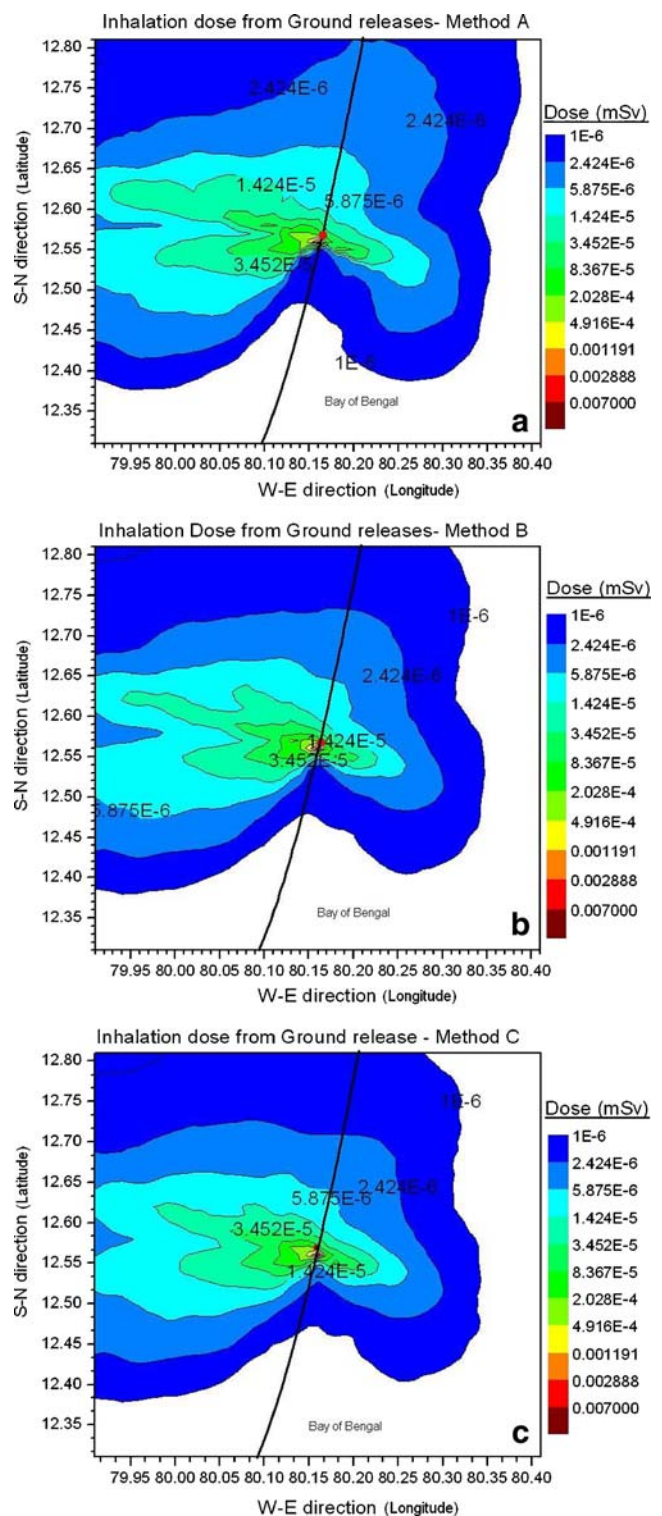


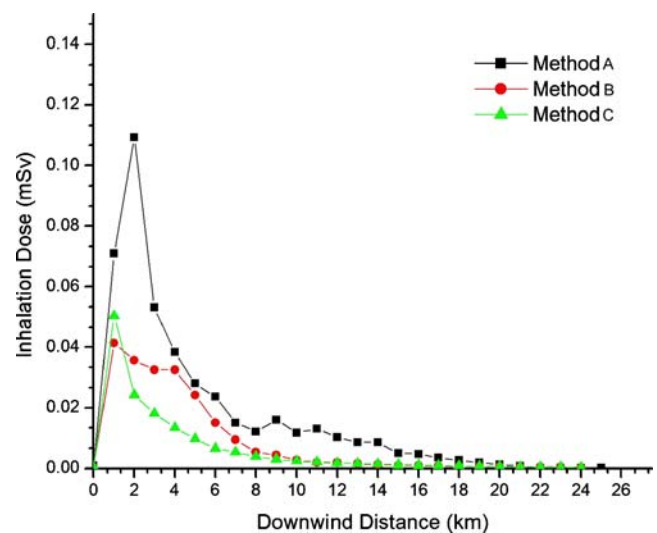
Fig. 3 Inhalation dose pattern due to ground releases (24 h) simulated with **a**) Velocity deformation, **b**) Short-range isotropic similarity, **c**) Velocity variance (TKE). The solid black line is the coast line

The plume pattern and its extent are distinctly different in each of the cases for any particular stability condition/hour considered. For example, for stable night condition at 3 h IST, the plume in the lower dose levels $2.08\text{e-}4$, $4.258\text{e-}4$,

Table 1 Inhalation dose due to stack releases—60 s during different stability conditions

Time/stability	Diffusion method	Dose at 1.5km (mSv)	Maximum dose (mSv)	Distance of D_{max} (km)	Dose at 5km (mSv)	Dose at 10km (mSv)	Dose at 15km (mSv)
6 h IST (F)	A	0.0133	0.0295	3	0.0198	0.00532	0.00295
	B	0.008425	0.0296	4	0.0198	0.0068	0.00325
	C	0.011155	0.0222	3	0.0089	0.00228	0.00136
8 h IST (E)	A	0.034595	0.05027	1	0.00827	0.00473	0.00159
	B	0.018475	0.02128	1	0.00591	0.00212	0.0018
	C	0.01613	0.02368	1	0.00231	4.44E-04	4.44E-04
12 h IST (A)	A	0.049065	0.0798	1	0.0218	0.00169	4.14E-06
	B	0.03415	0.0414	1	0.00739	0.00171	8.57E-04
	C	3.73E-02	0.0503	1	0.00681	0.0023	5.62E-04
14 h IST (A)	A	0.055135	0.0946	1	1.48E-06	3.84E-05	7.39E-05
	B	0.0238	0.0325	1	0.00414	5.03E-04	1.01E-04
	C	2.93E-02	0.03552	1	0.0059	0.00115	3.26E-04
15 h IST (A)	A	0.05515	0.0296	3	0.0207	5.61E-04	3.84E-05
	B	0.010164	0.0195	2	0.0074	0.00271	5.62E-04
	C	1.49E-02	0.02	2	0.0098	0.0022	8.88E-04
17 h IST (A/B)	A	0.09018	0.1094	1	0.0281	0.0118	5.00E-03
	B	0.03356	0.0414	1	0.0243	0.00269	1.00E-03
	C	3.73E-02	0.0503	1	0.0098	0.0024	1.20E-03
19 h IST (D)	A	0.000099	2.80E-02	5	0.028	0.011	9.00E-03
	B	0.061	0.089	1	0.013	0.003	2.00E-03
	C	3.05E-02	0.035	1	0.007	0.004	2.00E-03
22 h IST (D)	A	0.0095	0.0325	4	0.022	0.011	0.004
	B	0.0252	0.038	1	0.0065	0.0032	0.0023
	C	2.46E-02	0.02812	1	9.80E-03	0.00385	0.002
24 h IST (E)	A	0.0517	0.104	2	0.0195	0.0065	0.0044
	B	0.0259	0.0355	1	0.0047	0.0022	0.0017
	C	2.45E-02	0.036	1	0.005	0.001	9.77E-04

8.787e-4, 0.001813 mSv is spread to a wider area in the case C, followed by case B, while the plume under the dose levels 0.00374, 0.00772, 0.01593, 0.03288 has spread to wider area in case A. The contours are smoother in cases B, C, while they are more complex in A due to difference in turbulence diffusivity. Similar differences are noticed in the dose distribution pattern at other hours. For inhalation dose, unlike in the case of ground releases, method 'A' based on velocity deformation gives highest dose values followed by methods B and C (Fig. 4). This is due to the relatively less turbulent diffusion of the elevated release from method A as seen from the particle distribution. The maximum dose from stack releases is seen to occur away from the source, roughly at 2 km from the stack. Among the cases tested, method A provides the highest doses followed by methods B, C which almost computed similar values. The maximum inhalation dose at the site boundary distance is found to occur between 15 and 17 h; the values are 0.0902, 0.0336, 0.0373 mSv from methods A, B, C, respectively.

**Fig. 4** Downwind inhalation dose simulated with different turbulence diffusion methods at different hours at 15 h IST on 3rd March 2008

Simulated cloud gamma dose from stack releases by various diffusion methods indicates the plume is narrow near the source and expands in cross-wind direction beyond 3–5 km in the cases of methods A and B, whereas method C shows a widely distributed plume around the source (not shown). The dose maximum due to stack releases is seen to occur at roughly 1.5–2 km away from the source, and thereafter, it falls rapidly in all the three cases. The cloud shine dose at the site boundary distance is found to occur at 15–17 h IST—the values being 0.2918, 0.174, 0.176 mSv from the three cases A, B, and C, respectively. The highest cloud shine dose at the site boundary is given by method A, while methods B and C give similar values. The same trend is found in the downwind cloud shine dose pattern. From the estimated exposure dose due to stack releases at different times, the maximum dose at the site boundary from methods A, B, and C is 0.0000217, 0.0000167, 0.000013 mSv, respectively, and occurs at 15 h IST under the unstable condition A associated with sea breeze. Here again, the method A provides the highest doses.

Total dose under CDA due to ground and stack releases

The total dose under different pathways from the assumed CDA event due to all ground discharges from different diffusion methods is estimated to be 10.258, 11.509, 20.339 mSv at the release location which falls to 0.859, 0.841, 1.038 mSv, respectively, at site boundary. Method C based on variances calculated from meteorological model TKE gives the highest doses for ground releases. The total dose for stack discharges considering the unstable (A/B) condition during sea breeze time at 15 h as the worst situation is 0.382, 0.207, 0.2128 mSv at the site boundary, respectively, from the three diffusion methods.

Considering the unstable condition “A” during sea breeze as the worst situation, the total dose due to all ground and stack releases from CDA event is estimated as 10.45, 11.71, 20.62 mSv at the release location and 1.241, 1.0484, 1.2514 mSv at the site boundary, respectively, from the three diffusion methods used in HYSPLIT code. Method A has given the highest stack dose about twice that given by method C, while method C has given the highest ground dose. The dose from ground release is about four times higher than the dose from stack release. The total dose from ground and stack discharges from CDA event would amount to 20.62 mSv at the release location and 1.25 mSv at the site boundary considering the TKE diffusion method.

Comparison with estimates from Gaussian Plume Model

Evaluation of the three different turbulence diffusion methods requires comparison with experimental/observation data of concentration/dose which are not available for the

present hypothetical CDA case. However, an attempt is made to compare the dose values obtained using the three diffusion schemes in HYSPLIT with the estimates from a Gaussian Plume Model. Although GPM is not standard as it involves several assumptions and not realistic for a complex coastal site, the values from a GPM are considered conservative estimates in a regulatory framework. The GPM was run separately for ground and stack releases for different atmospheric conditions identified from the meteorological model simulation (stability, mixing height, wind strength). From the GPM values, the maximum doses are noticed to be associated with poor diffusive conditions of night time (at 21/24 h IST, 0600 hours IST), while minimum doses are found in the highly diffusive conditions of daytime at 12 h/15 IST (not shown). Values given by the three methods A, B, C from HYSPLIT are an order lower in magnitude than the GPM estimate. The nearest comparison is provided by method C. Thus, the velocity deformation, short-range isotropic similarity with surface fluxes, and turbulence kinetic energy methods have given very low dose values though the downwind concentration/dose trends follow the Gaussian.

The difference in the dose pattern from the three methods in HYSPLIT could be due to difference in the treatment of horizontal and vertical diffusion in the respective methods. In the short-range method B, the horizontal and vertical mixing coefficients are calculated from stability derived from surface fluxes and are assumed equal (isotropic condition). In the long-range method A, the vertical diffusivity coefficient is calculated as in the short-range method, but the horizontal diffusivity is estimated from velocity deformation. In both methods A, B, vertical diffusivity is averaged over the whole boundary layer which probably contributed to weak vertical diffusion as seen from dense particle distribution and higher dose values for elevated release. Also, the dose from stack release is slightly less from method B than from method A which may be because the horizontal diffusivity in method A is estimated from wind field deformation, i.e., the horizontal dispersion rate depends on the spatial variability in the wind field. It is seen that the flow field changes dramatically between the grid points along the coast line thus leading to a complex horizontal dispersion in the case A near the coast. In the TKE method, the velocity variance calculated from TKE equation provides the turbulent velocity. Also, the vertical diffusivity in this case varies vertically within the boundary layer which may have caused strong vertical diffusion as seen from well-distributed particle cloud for the case C and lower dose from elevated release.

Conclusions

The calculations with MM5-HYSPLIT modeling system for the air-borne effluent releases from an assumed hypothetical

CDA event clearly reveal that the site boundary dose and the trends of spatial concentration/dose distribution pattern are different in each case of turbulence diffusion. Although the total dose due to the ground and stack releases from all the pathways is under the prescribed limits, the method based on TKE has given the highest dose values for ground release, while the velocity deformation method has given the highest dose for stack release. For the elevated releases, the long-range method has produced values up to two factors higher than the other two methods at the site boundary distance and beyond. The difference in the dose values from the three methods is due to the turbulent diffusion of pollutants calculated using deformation and diffusivity approach in method A, isotropic similarity using surface fluxes from method B, and the velocity variance dependence on TKE from method C, respectively. To determine the validity of any of the diffusion assumptions used in the calculation, it is necessary to compare the dispersion results with experimental observations. As there is no possibility of observations for this hypothetical case, values from the three methods are compared against values from the Gaussian plume model to verify if they are in the order of GPM values. Values from all the three methods are found to fall much lower (at least by one to two orders) than the GPM values, although the downwind dose distribution follows the GPM trend. In order to verify the validity of the three turbulent diffusion methods for short-range dispersion assessment at the site, a short-range tracer release experiment is planned. This would generate observation data sets of air concentration for various meteorological conditions prevailing at the coastal site. Observations from this experiment would provide helpful information for a comprehensive evaluation of the three diffusion schemes in HYSPLIT for further understanding of the short-range dispersion and model validation.

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