Journal of Environmental Radioactivity 184–185 (2018) 32–45

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

journal homepage: www.elsevier.com/locate/jenvrad

Comparisons between a new point kernel-based scheme and the infinite plane source assumption method for radiation calculation of deposited airborne radionuclides from nuclear power plants

Xiaole Zhang[a,b,*], George Efthimiou[c], Yan Wang[a], Meng Huang[d]

[a] Institute of Public Safety Research, Department of Engineering Physics, Tsinghua University, Beijing 100084, PR China
[b] Institute for Nuclear and Energy Technologies, Karlsruhe Institute of Technology, Karlsruhe, D-76021, Germany
[c] Environmental Research Laboratory, INRASTES, NCSR "Demokritos", Patriarchou Grigoriou & Neapoleos Str., 15310, Aghia Paraskevi, Greece
[d] State Key Laboratory for Information Engineering in Surveying, Mapping and Remote Sensing, Wuhan University, 129 Luoyu Road, Wuhan 430079, PR China

ARTICLE INFO

Keywords:
Radionuclide deposition
Ground shine
Point kernel method
Atmospheric dispersion prediction
Nuclear power plant accident

ABSTRACT

Radiation from the deposited radionuclides is indispensable information for environmental impact assessment of nuclear power plants and emergency management during nuclear accidents. Ground shine estimation is related to multiple physical processes, including atmospheric dispersion, deposition, soil and air radiation shielding. It still remains unclear that whether the normally adopted "infinite plane" source assumption for the ground shine calculation is accurate enough, especially for the area with highly heterogeneous deposition distribution near the release point. In this study, a new ground shine calculation scheme, which accounts for both the spatial deposition distribution and the properties of air and soil layers, is developed based on point kernel method. Two sets of "detector-centered" grids are proposed and optimized for both the deposition and radiation calculations to better simulate the results measured by the detectors, which will be beneficial for the applications such as source term estimation. The evaluation against the available data of Monte Carlo methods in the literature indicates that the errors of the new scheme are within 5% for the key radionuclides in nuclear accidents. The comparisons between the new scheme and "infinite plane" assumption indicate that the assumption is tenable (relative errors within 20%) for the area located 1 km away from the release source. Within 1 km range, the assumption mainly causes errors for wet deposition and the errors are independent of rain intensities. The results suggest that the new scheme should be adopted if the detectors are within 1 km from the source under the stable atmosphere (classes E and F), or the detectors are within 500 m under slightly unstable (class C) or neutral (class D) atmosphere. Otherwise, the infinite plane assumption is reasonable since the relative errors induced by this assumption are within 20%. The results here are only based on theoretical investigations. They should be further thoroughly evaluated with real measurements in the future.

1. Introduction

External gamma irradiation from accidentally released radionuclides contributes significantly to the radiation exposure, which is indispensable information for effectively planning countermeasures such as sheltering, evacuation and iodine-prophylaxis (NEA, 2002; NEA/OECD, 1994.). The exposure assessment depends on both atmospheric dispersion model and gamma radiation model (Andronopoulos and Bartzis, 2010; Benamrane et al., 2013; Simsek et al., 2014), leading to the development of coupled dispersion-radiation model systems. Andronopoulos and Bartzis (2010) developed radiation dose calculation method for Lagrangian puff atmospheric dispersion models, e.g. DIPCOT (Andronopoulos et al., 2009) and RIMPUFF (Thykier-Nielsen et al., 1999; Connan et al., 2013), which have been integrated in the Real-time On-line DecisiOn Support (RODOS) system (Raskob, 2003; Raskob and Ehrhardt, 2000; Raskob et al., 2006, 2011) for off-site emergency management in Europe. In the Japanese System for Prediction of Environmental Emergency Dose Information (SPEEDI) (Terada and Chino, 2005, 2008) and Worldwide Version of SPEEDI (Katata et al., 2012a, 2012b), cell integrated dose evaluation method is applied for radioactive plume gamma dose computation. Recently, Rakesh et al. (2015) has implemented point kernel method into FLEXPART model for gamma dose calculation, which has been applied to the assessment of atmospheric dispersion and radiological impact during the Fukushima accident (Srinivas et al., 2012, 2014).

Previous studies have already developed fast and sophisticated

---

[*] Corresponding author. Institute of Public Safety Research, Department of Engineering Physics, Tsinghua University, Beijing 100084, PR China.
E-mail address: zhangxiaole10@outlook.com (X. Zhang).

https://doi.org/10.1016/j.jenvrad.2018.01.002
Received 13 August 2017; Received in revised form 4 December 2017; Accepted 4 January 2018
0265-931X/ © 2018 Elsevier Ltd. All rights reserved.

models for external radiation from radioactive cloud, but simplified methods are still applied for the radiation from deposited radionuclides. Currently, ground shine is normally calculated based on deposited activities and conversion coefficients of infinite plane source. The "infinite plane" assumption is justified by the large surface of the grid size in comparison to the heights of detectors. Conversion coefficients from deposition concentration to air kerma rates at 1 m above ground are available for infinite plane source (Jacob et al., 1990) and exponentially distributed sources in ground (International Commission on Radiation Units Measurements, 1994) based on the Monte Carlo codes, e.g. YURI (Saito and Moriuchi, 1985). Recently, the conversion coefficients of ambient dose equivalent (Lemercier et al., 2008; Saito and Petoussi-Henss, 2014) and effective dose (Saito et al., 2012) for exponentially distributed sources in ground have also been determined. These coefficients assume that the contaminated field is large and horizontally uniform enough relative to the small size of a detector (Pecha and Pechova, 2014). These methods neglect the spatially heterogeneous distribution of the deposited radionuclides, which may cause significant errors in the area with large concentration gradient, e.g. the area near the release source. Moreover, source term estimations (Saunier et al., 2013; Tsiouri et al., 2011, 2012a, 2012b; Zhang et al., 2013; Zhang et al., 2017a) also have to utilize dispersion-radiation models in conjunction with environmental observations to reconstruct the releases, as was the case for the Fukushima accident. The decay of ground shine contains the composition information of the deposited radionuclides, which is needed for source term estimation (Zhang et al., 2017b). Model-measurement comparisons are usually conducted to estimate the source term (Zhang et al., 2015a, 2015b, 2014). However, the errors in the radiation calculation will be transferred into the release estimations, so the inverse estimation requires high quality simulation results, which raises the need to evaluate the accuracy of the simplified "infinite plane" assumption, especially for the detectors close to nuclear power plant.

The goal of this study is threefold. Firstly, instead of "infinite plane" assumption, a new air kerma rate calculation scheme based on point kernel method is developed for the ground shine calculation. The new scheme accounts for both the spatial deposition distribution and the properties of air and soil layers, and it is evaluated against the available results from Monte Carlo methods in literature. Then we propose and optimize the "detector-centered" grid systems (grid coverage and resolution) for both the deposition and radiation calculations to minimize the computational effort. The radiation calculation may also improve the quality of the radiation estimations at the detectors, which in turn will be hopeful for source term reconstructions. The new scheme is compared with "infinite plane" assumption to investigate the errors caused by the assumption in different situations. Finally, the criteria are defined to distinguish the situations where the "infinite plane" assumption is tenable and where the spatial distribution of deposition should be considered.

2. Methods and materials

2.1. Detector-centered grid systems

Air kerma rate measurements are primarily influenced by the deposition near the detectors, so a detailed deposition and radiation calculation scheme for this area will improve the calculation quality. In this study, we utilize two different sets of grids respectively for the deposition and radiation calculations. The detectors are all located at the centers of the computational domain, as shown in Fig. 1. The grids are referred to as "detector-centered" grids hereafter.

The deposition calculation depends on the upper grid (as shown in Fig. 2). The grid is relatively coarse to reduce the computational cost, considering the fact that the characteristic plume size is usually tens or hundreds of meters due to atmospheric turbulence. A nested grid is applied to get a balance between accuracy and efficiency. The specific configurations of the nested grid are provided in Table 1. The reasons for the adopted coverage and resolution of the grid will be further discussed in Section 3.2 and 3.4. Depositions are calculated at the center of each grid cell, and it is assumed that the concentration is uniform within the cell. The lower grid system, with a constant and much finer resolution (1 m), is utilized to calculate concentration-air kerma rate conversion factors, which convert the deposition concentration in each cell to the radiation received by the detector. The final air kerma rate is obtained by the combination of the deposition field and the conversion factors.

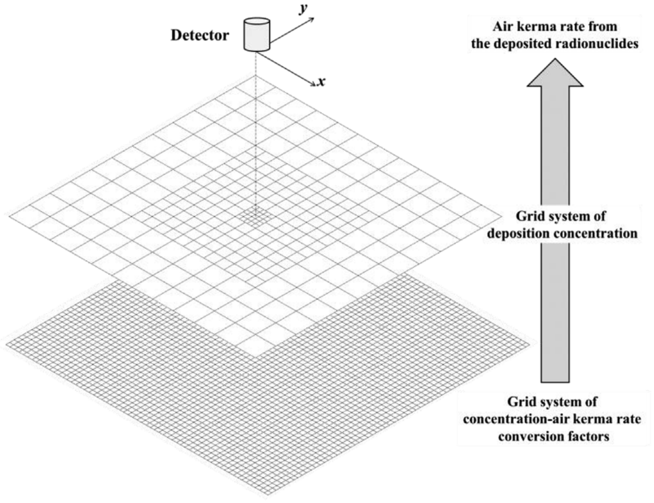

Fig. 1. Grid systems for the computation of deposition concentration and concentration-air kerma rate conversion factors.

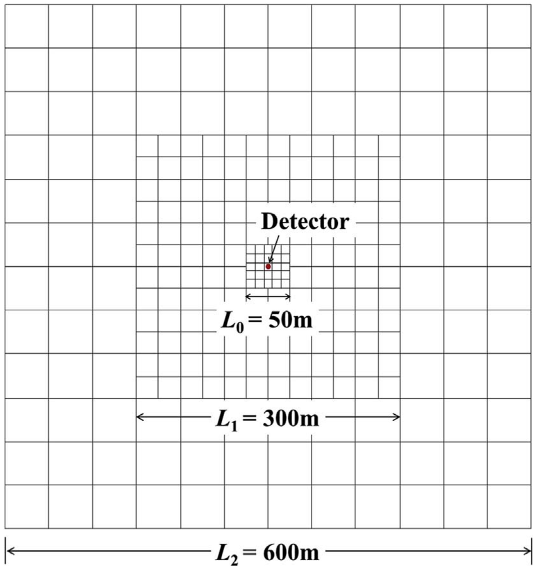

Fig. 2. Three-layered nested grids for the deposition calculation.

Table 1
Configurations of the nested grids for deposition calculation. The coordinates are relative to the location of the detector.

Layer	Bottom-left corner (m)	Top-right corner (m)	Grid size (m)	Grid number
L_0	(−25, −25)	(25, 25)	10	25
L_1	(−150, −150)	(150, 150)	25	140
L_2	(−300, −300)	(300, 300)	50	108

Download English Version:

https://daneshyari.com/en/article/8080681

Download Persian Version:

https://daneshyari.com/article/8080681

Daneshyari.com