On the use of the HOTSPOT code for evaluating accidents involving radioactive materials

D. Sattinger, R. Sarussi, Y. Tzarfati, S. Levinson and A. Tshuva

NRC Negev, BeerSheva, Israel

Abstract

The HOTSPOT Health Physics code was created by LLNL in order to provide Health Physics personnel with a fast, field – portable calculation tool for evaluating accidents involving radioactive materials. The HOTSPOT code is a first – order approximation of the radiation effects associated with the atmospheric release of radioactive materials. HOTSPOT programs are reasonably accurate for a timely initial assessment. More importantly, HOTSPOT code produce a consistent output for the same input assumptions, and minimize the probability of errors associated with reading a graph incorrectly. Four general programs, Plume, Explosion, Fire, and Resuspension, calculate a downwind assessment following the release of radioactive material resulting from a continuous or puff release, explosive release, fuel or fire, or an area contamination event. Additional programs estimate the dose commitment from inhalation of any one of the radionuclides listed in the database of radionuclides, calibrate a radiation survey instrument for ground survey measurements, and screening of alpha emitters in the Lung. We believe that the HOTSPOT code is extremely valuable in providing reasonable and reliable guidance for a diversity of application. For example, we demonstrate the release of ^{241}Am(20Ci) to the atmosphere.

Introduction of the Model Capabilities

HOTSPOT uses the well – established Gaussian Plume Model, widely used for an initial emergency assessment or safety analysis planning of a radionuclide release. Virtual source terms are used to model the initial 3D distribution of material associated with an explosive release, fire release, resuspension, or user – input geometry. The HOTSPOT documentation describes the HOTSPOT algorithms in detail. The dosimetric methods of ICRP Publication 30/60/70 were used throughout the HOTSPOT programs. Individual doses are produced, along with the 50 – year committed effective dose equivalent (CEDE). Hotspot supports both CLASSIC units such as rem, rad, curie, and SI units. The HOTSPOT dose values are due solely to the inhalation of released material during the passage of the plume. In the specific case of noble gases, e.g., Kr-85, the submersion dose is output. The specific dose conversion factors for all of the radionuclides in the HOTSPOT library can be viewed in the "HOTSPOT Library" program. The ground shine dose is not included because the effective dose equivalent (per hour of stay time in the contaminated area), due to ground is typically several orders of magnitude less than the CEDE due to plume passage. For alpha – emitting radionuclides e.g., Am -241, the hourly ground shine component is at least 7 orders of magnitude less than the inhalation component. Emergency preparedness requires a fast and adequate means of generating an initial assessment of an actual or scheduled atmospheric release. Just as important, is the need for consistency in the assessment methodology, e.g., well documented, consistent output for a particular set of input assumptions, etc. Actual source terms, the substances involved, meteorological conditions, etc., are seldom accurately known. Overly sophisticated and data intensive models seldom provide useful and timely information in emergencies involving the release or potential release of radioactive material into the atmosphere. In the specific case of emergency planning and response, we are usually interested in worst – case scenarios, i.e., if the plume of radioactive material does reach a target community, what are the projected committed effective dose equivalent values. Unless specific accident scenarios are accurately detailed and proven to be reliable, large modeling errors are possible. Such errors render the use of large, complex, and time consuming models no more accurate than using a simple Gaussian model. The Gaussian model should be recognized as a starting place for analyses and in many cases the only necessary tool due to the large uncertainly associated with the release scenario.

Example – General Plume

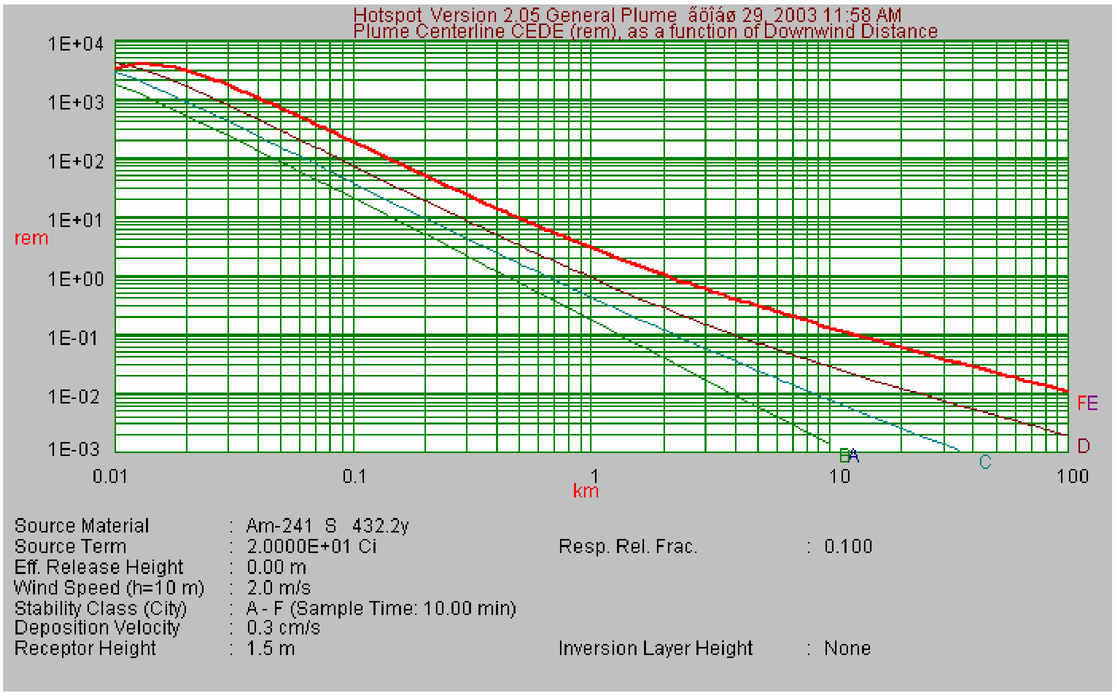
We can estimate the dose commitments from a release of 20 curies of Am – 241 from the ground level. Below we can see a typical output summary due to the release scenario (Table & Graphics).

Hotspot Version 2.05 General Plume

Source Material : Am-241 S 432.2y
Source Term : 2.0000E+01 Ci
Airborne Fraction : 1.000
Respirable Fraction : 0.100
Respirable Release Fraction: 0.100
Effective Release Height : 0.00 m
Wind Speed (h=10 m) : 2.0 m/s
Distance Coordinates : All distances are on the Plume Centerline
Stability Class (City) : F
Respirable Dep. Vel. : 0.30 cm/s
Non-respirable Dep. Vel. : 8.00 cm/s
FGR-13 Dose Conversion Data

Receptor Height : 1.5 m
Inversion Layer Height : None
Sample Time : 10.000 min
Breathing Rate : 3.33E-04 m3/sec
Maximum Dose Distance : 0.013 km
MAXIMUM CEDE : 3.89E+03 rem

DISTANCE (km)	**CEDE** (rem)	**TIME-INTEGRATED AIR CONCENTRATION** (Ci-sec)/m^3	**GROUND SURFACE DEPOSITION** (uCi/m^2)	**GROUNS SHINE DOSE RATE** (rem/hr)	**TIME** (hour:min)
0.030	1.7E+03	8.5E-02	3.0E+04	9.3E-03	<00:01
0.100	1.8E+02	9.3E-03	7.5E+02	2.3E-04	00:02
0.200	4.9E+01	2.5E-03	9.6E+01	3.0E-05	00:04
0.300	2.3E+01	1.2E-03	3.0E+01	9.3E-06	00:06
0.400	1.4E+01	7.0E-04	1.4E+01	4.3E-06	00:08
0.500	9.3E+00	4.7E-04	7.8E+00	2.4E-06	00:10
0.600	6.8E+00	3.4E-04	4.9E+00	1.5E-06	00:13
0.700	5.2E+00	2.7E-04	3.4E+00	1.0E-06	00:15
0.800	4.2E+00	2.1E-04	2.4E+00	7.5E-07	00:17
0.900	3.5E+00	1.8E-04	1.8E+00	5.7E-07	00:19
1.000	2.9E+00	1.5E-04	1.4E+00	4.5E-07	00:21
2.000	1.0E+00	5.2E-05	3.4E-01	1.1E-07	00:43
4.000	4.0E-01	2.0E-05	1.0E-01	3.1E-08	01:27
6.000	2.4E-01	1.2E-05	5.4E-02	1.7E-08	02:11
8.000	1.7E-01	8.5E-06	3.5E-02	1.1E-08	02:55
10.000	1.3E-01	6.6E-06	2.6E-02	8.1E-09	03:38
20.000	5.9E-02	3.0E-06	1.0E-02	3.2E-09	07:17
40.000	2.8E-02	1.4E-06	4.6E-03	1.4E-09	14:35
60.000	1.8E-02	9.2E-07	3.0E-03	9.2E-10	21:53
80.000	1.3E-02	6.8E-07	2.2E-03	6.8E-10	>24:00



Source Material : Am-241 S 432.2y
Source Term : 2.0000E+01 Ci
Resp. Rel. Frac. : 0.100
Eff. Release Height : 0.00 m
Wind Speed (h=10 m) : 2.0 m/s
Stability Class (City) : A - F (Sample Time: 10.00 min)
Deposition Velocity : 0.3 cm/s
Receptor Height : 1.5 m
Inversion Layer Height : None

Hotspot Version 2.05 : Plume Centerline CEDE (rem), as a function of Download Distance for the (The scenario information is on the figure).

Summary

The HOTSPOT code has a well – deserved reputation for ease-of-use in emergency situations. It is used extensively by government agencies in the United States and in Western and Eastern European countries. The code uses a Gaussian model formulation so the atmospheric physics are only first – order approximations, nevertheless, HOTSPOT has proven to be extremely valuable in providing reasonable and reliable guidance for a diversity of applications. The salient features of this code are contained in its source term modules which are extensive and well formulated.

References

1. Hotmann, S.G., 1994, "HOTSPOT Health Physics Codes for the PC", Hazards Control Department and the Emergency Preparedness and Response Program, Nonproliferation, Arms Control, and International Security Directorate, UCRL – MA – 106315, Lawrence Livermore National Laboratory, University of California, Livermore, California, 94551.
2. http://www.llnl.gov/nai/technologies/hotspot/