United States
Environmental Protection
Agency

Research and Development

Hazardous Waste Engineering
Research Laboratory
Cincinnati OH 45268

EPA/600/S2-87/071 Nov. 1987

EPA

Project Summary

Sensitivity Analysis for Application of the Inhalation Exposure Methodology (IEM) to Studies of Hazardous Waste Management Facilities

F. R. O'Donnell and C. C. Gilmore

This study investigated the uncertainties associated with using the Inhalation Exposure Methodology (IEM) to determine human exposures to hazardous waste management facility air emissions. The Inhalation Exposure Methodology is an integrated system of computer programs that simulates the atmospheric transport of and the resulting human exposures to pollutants released from one or more sources at an industrial complex. The full report illustrates the sensitivity of IEM predictions to (1) variations of important user-supplied source, meteorological, and pollutant parameter values and (2) use of three IEM source modeling options to represent emission sources found at hazardous waste management facilities.

This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The Inhalation Exposure Methodology (IEM) is an integrated system of computer programs that simulates the atmospheric transport of and the resulting human exposures to pollutants released from one or more sources at an industrial complex. This study was undertaken to determine the sensitivity of IEM predictions of pollutant concentrations and population exposures to (1) variations of selected, user-supplied source, meteorological, climatological, and pollutant parameter values and (2) use of the three available source modeling options to represent emission sources found at hazardous waste management facilities (HWMFs). These sources include incinerators and associated structures, storage and treatment tanks, drum stacks, process buildings, surface impoundments, landfills, waste piles, and land treatment areas. Several sources may be found at one HWMF.

The study only determined the sensitivity of IEM predictions to the above factors. It did not validate the model by comparing IEM predictions with actual field data.

Modeling the sources found at an HWMF could present problems because they may be located close together or near buildings and structures that could influence pollutant dispersion, and they may have ill-defined pollutant release rates. In some cases, source-specific pollutant release rates may be unavailable, thus forcing the modeler to represent several sources at a single source.

The IEM uses a Garissian-plume atmospheric dispersion model, the Inhalation Source Complex Long Term Model (ISCLTM), to calculate annual-average, sector-averaged, centerline, ground-level, air concentrations of released pollutants at user-selected receptor points. It uses these concentrations to calculate average concentrations over each sector segment of a user-specified polar grid. Finally, it multiplies the sector-segment-averaged concentrations and their corresponding sector-segment populations to give estimates of human exposures to the released pollutants. Although applicable to a variety of problems, the IEM was developed as a tool for estimating pollutant concentrations and associated human exposures in the vicinity of hazardous waste management facilities (HWMFs).

Approach

Emission sources found at HWMFs have relatively low pollutant release heights, may be located near structures that influence pollutant dispersion, and, except for incinerator stacks, may have essentially no associated plume rise. Previous studies have examined the sensitivity of ISCLTM predictions to typical hazardous waste incinerator stack parameters (e.g. stack height, gas temperatures). Based on these studies and the fact that all stack parameters except the physical stack height affect only plume rise, these parameters were not studied in detail. The remaining, important, user-supplied input parameters include meteorological parameters (wind speed, wind direction, and stability class), source parameters (release height, source area, and adjacent building cross sections), pollutant parameters (decay coefficient, settling velocity, and reflection coefficient), and the array of receptor grid points chosen.

The study report documents the effects of varying these parameters on ambient pollution concentrations and population exposures. In addition, the effects of using three different source representation options (point, area or volume representations) on pollution concentrations are investigated.

Several typical HWMF sources were selected for detailed study; a stack with essentially no plume rise, a 14.1-m square (200 m^2) area, an 80.6-m square (6500 m^2) area, a 316.2-m square (100,000 m^2) area, and a 2236.1-m square (5,000,000 m^2) area. Since the ISCLTM algorithm will not accept zero values for a stack diameter or gas exit velocity, our stack source was assumed to have a diameter of 1.0 m and a gas exit velocity of 1 x 10^{-5} m/s, the ISCLTM default value. Source (release) heights of 0, 5, 10, 15, and 20 m were considered for these sources. Limited evaluations were made of the effects of representing a 200-m^2 process building with a release height of either 5 or 10 m by one stack source, by two area sources, and by two volume sources. Similar evaluations were made for a 200-m^2 tank farm containing four tanks with release heights of either 3 or 6 m that were represented by four point sources, with and without building wake effects; by one area source; by four area sources; by one volume source; and by four volume sources.

In order to investigate the sensitivity of different IEM input parameters and programming options, the following computer outputs were generated:

1. Plots of the exceptor grid-point concentrations directly downwind of the source. (These are defined as primary grid-point concentrations).
2. Value and location of the maximum primary grid-point concentration.
3. The exposure to all individuals living directly downwind of the source. (The area directly downwind of the source is defined as the "primary sector," which lies within ± 11.25° of the wind direction.)
4. Plots of the sum of the pollution concentrations for all grid points at a given distance from the source, which indicates total exposure as a function of distance from the source.
5. The magnitude and distance from the source of the maximum concentration for each profile generated in Item 4.
6. The total potential exposure to the population based on summing the exposure potentials over all directions and distances from the source out to 50Km.

The analyses specified in Items 4-6 were included because the dimensions of some of the area sources were large enough to cause substantial air concentrations to occur at grid points that lie outside the primary sector. Ignoring these concentrations would give a false impression of the importance of area size. These measures also give a better picture of IEM predictions under real meteorological conditions.

Differences in concentration and exposure potential predictions due to the choice of source representation option were also investigated. Two typical HWMF sources were chosen, a process building and a small tank farm.

The process building was assumed to be 10-m high, to cover 2 m^2, and to release pollutants either from a rooftop or a midheight vent. The building was modeled as one stack source, as one 14.1-m square area source, as two 10-m square area sources, and as two volume sources having standard deviations of 2.33 for their crosswind source distributions and 4.65 for their vertical source distributions.

The tank farm was assumed to contain four 6.1-m high tanks, to cover 200 m^2, and to release pollutants from vents located on top of the tanks. The tanks were modeled as four stack sources, as four stack sources with adjacent 6.0-m^2 high structures, as one 14.1-m square area source, as four 7.07-m square area sources, as one volume source having standard deviations of 3.29 for its crosswind source distribution and 2.84 for its vertical source distribution, and as four volume sources having standard deviations of 1.64 for their crosswind source distributions and 2.84 for their vertical source distributions. Midheight (3.05-m) releases were considered only for the single area and volume source representations.

Results and Conclusions

Based on the analysis of variations in user-supplied input parameters and of the use of several modeling options for representing emissions sources, the study made the following findings:

1. Predicted ground-level air concentrations are probably accurate to within a factor of 2, if the IEM is applied under well-behaved meteorological conditions over flat terrain.
2. The IEM method for estimating the total exposed population is as accurate as any other general method. However, the accuracy of the method used to link exposed persons to specific pollutant concentrations (i.e., to calculate exposures) is unknown, but likely is comparable to the accuracy of other existing methods.
3. For the sources considered in this study, wind speed acted as a linear scaling factor, except when pollutant decay and decomposition were considered. This relationship also would not hold for stacks that have an associated plume rise.
4. The effects on predicted pollutant concentrations due to variations in atmospheric stability, pollutant release height, and source area are interdependent. All three parameters are strongly influenced by predicted concentrations, and every effort should be made to use accurate values for them.

5. Increasing atmospheric stability increased exposure estimates, but it may either increase or decrease maximum concentration predictions, depending largely on the release height.
6. Increasing release height decreased both exposure and concentration estimates.
7. Increasing source area had little effect on exposure estimates for the same receptor array. Maximum concentration predictions varied by as much as 60% for the source areas considered in this study.
8. Use of the building wake effects option increased concentration predictions within 200 m of the source center, but had little effect on more distant concentration predictions and on exposure estimates.
9. For pollutants that have half-lives of a few days or less, pollutant decay could significantly reduce airborne concentrations at receptors beyond 1 km. For longer-lived pollutants, decay is unimportant.
10. Pollutant disposition significantly affected both concentration and exposure predictions, especially at sites characterized by stable atmospheric conditions and low wind speeds. The pollutant deposition option in IEM should be used if the emitted pollutants are particles or can form particles that can be characterized.
11. The choice of a receptor array can bias predictions significantly. An array with receptors concentrated between the minimum allowed-radial receptor distance and 2 km should produce the most accurate estimates of maximum concentrations and exposures.
12. The various available emissions source modeling options produced essentially the same exposure estimates and airborne concentrations at receptors beyond approximately one kilometer. At the closer receptors, the stack and the area source representations produced very similar results. Volume source representations predicted close-in concentrations higher than those predicted using stack and area source representations for the more stable atmospheric conditions. For the less stable conditions, volume sources tended to predict the close-in concentrations which were lower than for the other two options.

References

1. O'Donnell, F. R., P. M. Mason, J. E. Pierce, G. A. Holton, and E. Dixon, *User's Guide for the Automated Inhalation Exposure Methodology (IEM)*, EPA-600/2-83-029 (1983).

F. R. O'Donnell and C. C. Gilmore are with Oak Ridge National Laboratory, Oak Ridge, TN 37830.
***Benjamin L. Blaney** is the EPA Project Officer (see below).*

The complete report, entitled "Sensitivity Analysis for Application of the Inhalation Exposure Methodology (IEM) to Studies of Hazardous Waste Management Facilities," (Order No. PB 87-232 641/AS; Cost: $18.95, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:
Hazardous Waste Engineering Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

EPA/600/S2-87/071