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Project Summary

User's Guide for PEM-2: Pollution Episodic Model (Version 2)

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The Pollution Episodic Model Version 2 (PEM-2) is an urban-scale model designed to predict short term average ground-level concentrations and deposition fluxes of one or two gaseous or particulate pollutants at multiple receptors. The two pollutants may be non-reactive, or chemically-coupled through a first-order chemical transformation. Up to 300 isolated point sources and 50 distributed area sources may be considered in the calculations. Concentration and deposition flux estimates are made using hourly mean meteorological data. Up to a maximum of 24 hourly scenarios of meteorology may be included in an averaging period.

The concentration algorithms and computational techniques used in the PEM-2 program are described and input/output parameters, optional features, capabilities, and limitations of the model are discussed.

This Project Summary was developed by EPA's Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 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 Pollution Episodic Model Version 2 (PEM-2) is an urban-scale air quality model designed to predict short term ground-level concentrations and deposition fluxes of one or two, gaseous or particulate, reactive or non-reactive pollutants in an urban area with multiple point and area sources. PEM-2 uses the concentration algorithms which explicitly account for the effects of dry deposition, gravitational settling, and a first-order chemical transformation. These algorithms, derived analytically from a gradient-transfer model, are based on Gaussian plume modeling assumptions. For chemically-coupled pollutants, the surface concentrations and deposition fluxes of both the primary (reactant) and the secondary (reaction product) pollutant are calculated.

The complete report contains information directed to the model user and the programmer. It presents an overview of the PEM-2's capabilities, assumptions, and limitations. Detailed technical discussions on the theoretical basis of the model are presented. Details of the program's input and a guide to output are included. Input and output for test examples using the various features of the model, flow diagrams, and a complete listing of the computer program are also included.

Theoretical Basis

The concentration algorithms used in PEM-2 are derived from analytical solutions of a steady state gradient-transfer (K-theory) model, which describes the atmospheric transport, diffusion, deposition, and first-order chemical transformation of gaseous or particulate pollutants from an elevated continuous point source. The eddy diffusivity coefficients in these analytical solutions are expressed in terms of the empirical Gaussian plume dispersion parameters, so that the latter can be conveniently specified as functions of the downwind distance and the atmospheric stability class within the framework of the standard turbulence-typing schemes. The point-source concentration algorithms for the primary (reactant) and the secondary (product) pollutants are presented for various stability and mixing conditions of the atmosphere. In the limit when deposition and settling velocities and the chemical transformation rate are zero, these algorithms reduce to the well-known Gaussian plume dispersion algorithms.

In PEM-2, the ground-level concentrations of the primary and secondary pollutants resulting from urban area source emissions are computed by numerical integration of the corresponding point-source concentration algorithms. For point sources, PEM-2 provides options for using the standard or new plume rise formulations by Briggs and new schemes for plume penetration of an elevated stable layer. For both point and area sources, PEM-2 uses the Briggs expressions for urban dispersion parameters.

The capabilities of PEM-2 are as follows:

1. PEM-2 is an urban-scale air quality model applicable to downwind distances of up to 50 km. Up to a maximum of 300 point sources and 50 area sources can be included in the model inputs to estimate concentrations at a maximum of 2500 receptors located on a 50 x 50 square receptor grid.
2. PEM-2 calculates short-term (1 to 24 hr) average ground-level concentrations and deposition fluxes of one or two gaseous or particulate pollutants.
3. The two pollutants may be non-reactive, or chemically-coupled through a first-order chemical transformation. If only one pollutant is calculated, the effects of a first-order chemical decay can be considered. The chemical transformation (or decay) rate may vary from 0.1 to 100 percent per hour.
4. The deposition (and settling) velocities of the two species may be equal or different. Direct emission of the secondary (reaction product) pollutant can be considered for both point and area sources.

PEM-2 is based on steady state Gaussian plume modeling assumptions. Some of the important assumptions of PEM-2 are as follows:

1. Concentration estimates may be made for each hour using the mean meteorological conditions for that hour. Average concentrations for a period longer than an hour are determined in the program by averaging the hourly concentrations of that period.
2. The sources are stationary and the emission rates are constant over the concentration-averaging period. The latter assumption is reasonable since PEM-2 is designed to predict only short-term average concentrations; this assumption is intended solely to limit the amount of input data required by the model.
3. If the hourly emission rates are highly variable over the concentration-averaging period, then the average concentrations may be obtained by averaging externally, with minimal programming, the concentrations calculated hourly and stored on tape by the model. This can be done, for example, to calculate the daily mean concentrations with diurnally varying emission rates.
4. Total concentration at a receptor is the sum of the concentrations calculated at the receptor from each source; i.e., concentrations are additive.
5. Pollutants released from a stack are transported downwind at a rate equal to the mean wind speed at the physical stack height. The wind direction is constant for each hour. The horizontal wind field is homogeneous and the effects of directional wind shear are neglected.
6. Diffusion of continuous plumes gives time-averaged Gaussian distributions for concentrations in the crosswind and vertical directions. The diffusion in the downwind direction is negligible compared to advection.
7. The reactant and the product species are coupled through a first-order chemical transformation. The deposition and settling velocities of the species, and the chemical transformation rate are constant over the concentration-averaging period. The diurnal variation of these parameters can be considered, if necessary, by averaging the hourly concentrations as discussed above.
8. Particulate pollutants consist of particles of a known size (or size distribution) with a representative settling velocity.
9. Pollutant concentration at a receptor due to the distributed area sources depends only on sources located in a narrow upwind sector. Therefore, horizontal diffusion can be ignored for area sources.
10. The crosswind variations of urban area source-strength patterns can be ignored. The contributions of more remote upwind area sources to the concentration at a receptor are quite small. For this reason, it is generally adequate to consider only eight area source grid squares immediately upwind of each receptor grid square.

PEM-2 is subject to the same basic limitations of any Gaussian plume-type model. General limitations of the model can be summarized as follows:

1. Receptors farther than 50 km downwind of a source are ignored.
2. The number of point sources is limited to 300, and the number of area sources is limited to 50. The computer program can be easily modified by the user to increase the maximum number of point and/or area sources, if necessary. All sources are stationary.
3. The maximum number of scenarios (sets of hourly meteorological data) in an averaging period is limited to 24. PEM-2 is designed to calculate only short-term (1 to 24 hr) average surface concentrations and deposition fluxes of one or two pollutants.
4. PEM-2 does not make any adjustment for differences in terrain elevation between sources and/or receptors. The model assumes level terrain. No adjustments are made for building wake-induced downwash, wake entrainment, or other building-related effects on the various effluent plumes.
5. Only a first-order chemical transformation/decay is considered. The transformation rate, and the deposition and settling velocities of the species, must be specified by the user, if these options are selected.
6. The model cannot perform calculations for calm conditions; if such conditions occur, the wind speed is arbitrarily set to 1 m/s.
7. PEM-2 does not attempt to deal with wet removal processes; hence, the model does not apply during periods of precipitation.

Model input is divided into four main categories. Control parameters and various options must be selected, while deposition and settling velocities, and chemical transformation rate constant, if applicable, must be provided by the user. Hourly mean meteorological data required for input include: atmospheric stability, wind speed and direction, ambient temperature, mixing height, and temperature gradient in the elevated stable layer. Emission rates for point and/or area sources must be given as well as their location coordinates on the model grid, nd stack parameter information, and ea source height. Various output options are available including printer output or tape storage for the fields of predicted concentrations and deposition fluxes.

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The complete report, entitled "User's Guide for PEM-2: Pollution Episodic Model (Version 2)," (Order No. PB 87-132 098/AS; Cost: $24.95, subject to change) will be available only from:
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