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Project Summary

User's Guide for PAL 2.0, A Gaussian-Plume Algorithm for Point, Area, and Line Sources

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PAL is an acronym for the Point, Area, and Line source algorithm. PAL is a method of estimating short-term dispersion using Gaussian-plume steady state assumptions. The algorithm can be used for estimating concentrations of non-reactive pollutants at 99 receptors for averaging time of from 1 to 24 hours, and for a limited number of point, area, and line sources (99 of each type).

Calculations are performed for each hour. The hourly meteorological data required are wind direction, wind speed, stability class, and mixing height. Single values of each of these four parameters are assumed representative for the area modeled. The Pasquill-Gifford or McElroy-Pooler dispersion curves are used to characterize dispersion.

The PAL model can treat deposition of both gaseous and suspended particulate pollutants in the plume since gravitational settling and dry deposition of the particles are explicitly accounted for. In the limit when pollutant settling and deposition velocities are zero, they reduce to the usual Gaussian-plume diffusion algorithm.

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

PAL 2.0 incorporates two major enhancements from previous versions of PAL. The analytical solutions of a gradient-transfer model for dry deposition of gaseous and particulate pollutants which was included in a version of PAL called PAL-DS are included in PAL 2.0. The other major enhancement is the inclusion of urban diffusion coefficients. This document supersedes EPA-600/4-78-013 and EPA-600/8-82-023.

PAL is a multisource Gaussian-Plume atmospheric dispersion algorithm for estimating concentrations of non-reactive pollutants. Concentration estimates are based on hourly meteorology, and averages can be computed for averaging time from 1 to 24 hours. Six source types are included in PAL: point, area, two types of line sources, and two types of curved path sources. As many as 99 sources may be included under each source type. PAL is not intended as an urban-wide model but may be applied to estimate the contribution of part of an urban area to the concentration. Portions of urban areas assessed by PAL for impact on air quality are:

- Industrial complexes
- Sports stadiums
- Parking lots
- Shopping areas
- Airports

At the heart of PAL is the Gaussian-Plume point source equation. The equation is used directly in the computations for point, line, and curved path sources, and in a modified form for area sources. A unique feature of PAL is the computational technique for estimating the concentration from area sources. This technique incorporates edge effects and is theoretically more accurate than the methods used in the Climatological Dispersion Model (CDM) and the Air Quality Display Model (AQDM). The horizontal line source algorithm is similar to the Highway Air Pollution Model (HIWAY). Input source types also include two types of curved paths, one of which considers variation of emissions along the path. PAL will also estimate concentrations from a line source which has a variation in emission along the source. This line source may be slanted or elevated relative to the ground. PAL offers considerable flexibility to the user. Any or all of the six source subroutines may be utilized. The user also has the options of employing an hourly variation to emission rates and of allowing the wind speed to change with height. Concentration estimates can be made at up to 99 user specified receptor locations.

The PAL model can treat deposition of both gaseous and suspended particulate pollutants in the plume since gravitational settling and dry deposition of the particles are explicitly accounted for. The analytical diffusion-deposition expressions listed in this report are easy to apply and, in the limit when pollutant settling and deposition velocities are zero, they reduce to the usual Gaussian plume diffusion algorithms.

Basis for PAL 2.0

The following assumptions are made: 1) Dispersion from points, and area and line elements result in Gaussian distributions in both the horizontal and vertical directions through the dispersing plume from that point or element, and therefore steady-state Gaussian plume equations can be used for point sources and the integration of these equations for line and area sources. 2) Concentration estimates may be made for each hourly period using the mean meteorological conditions appropriate for each hour. 3) The total concentration at a receptor is the sum of the concentrations estimated from all point and area sources, that is, concentrations are additive.

Point Sources

The basis for the point source calculations is the point source form of the Gaussian diffusion equation. A computation is made for each source-receptor pair. The upwind distance of a source from an individual receptor is first calculated. If this distance is negative, indicating that the source is downwind of the receptor, no calculation for this source-receptor pair is needed. For positive upwind distances, the crosswind distance of the source from the receptor is also determined. Plume rise for each source is calculated once for each hourly simulation period. The plume rise is added to the physical stack height to give effective height of emission. The dispersion equation is then evaluated. The standard deviations of plume spreading are determined as functions of the Pasquill stability class and of the source-receptor distance. As each concentration from a point source at a receptor is calculated, it is added to the accumulated concentrations from point sources for that particular hour.

Area Sources

The calculation of concentrations from area sources is simulated by a number of finite crosswind line sources. If all four corners of the area source have positive upwind distances from the receptor, an integration will be performed starting from the corner of minimum distance to the corner of maximum distance. If some but not all of the corners have a negative upwind distance, then the integration will be performed from an upwind distance of zero to the greatest distance. If all four corners have negative distances from the receptor, this indicates the entire area source is downwind of the receptor position. A number of crosswind (that is, perpendicular to the upwind direction) line sources at various distances from the minimum to the maximum distance are considered. Concentrations for each of these distances are calculated using the infinite line source form of the Gaussian equation. This concentration from an infinite line source is corrected for the finite extent of each individual line by considering the distance in units of σ_y of each end of the line from the upwind azimuth line through the receptor. The fraction of the area under a Gaussian curve between these limits determines the correction. An integration is performed using the concentration contribution from a number of lines and considering the distance between lines. This integration is the first estimate of the concentration from the area source. A second estimate is made by using the first estimate with additional calculations made for lines lying half-way between all the previously calculated lines. This second estimate is compared with the first and if the second falls within a set criteria the second estimate is taken as the final concentration. If the second estimate is not within the criteria, additional calculations are made, each time choosing additional lines lying half-way between lines of the previous total set.

Line Sources

The calculation of concentrations from line sources is done by an integration of the point source equation. Distances to the end points of the lines are determined in terms of upwind and crosswind distances. The line source is limited to those parts of the line which contribute concentrations to the receptor. Calculations are made for a number of points on the line, and, assuming linear change in concentration between these points, an estimate of the concentration from the line is determined. This first estimate is then compared to a second estimate, made by taking additional points between the existing ones and then assuming linear changes of concentrations between each of the adjacent points. The second estimate is compared to the first, and if it falls within a set criteria, the second estimate is taken as the concentration. If the second estimate is not within the criteria, third and subsequent estimates may be required by taking additional points. Estimates for curved sources are determined similarly by evaluating for locations on the curve and integrating. For the specialized line and curved sources, provisions are included to determine the height and emission rate for each location evaluated.

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The complete report, entitled "User's Guide for PAL 2.0—A Gaussian-Plume Algorithm for Point, Area, and Line Sources," (Order No. PB 87-168 787/AS; Cost: $13.95, subject to change) will be available only from:

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