Multipollutant Inhalation Exposure Modeling at EPA's Office of Air Quality Planning and Standards

The APEX and HAPEM Exposure Models

The Air Pollutant Exposure Model (APEX) and the Hazardous Air Pollutant Exposure Model (HAPEM) are both probabilistic multipollutant population exposure models designed to model the most significant sources of variability that affect people's exposures. These models simulate the movement of individuals through time and space and estimate their exposures to pollutants in indoor, outdoor, and in-vehicle microenvironments, and can be applied to the general population or a specific sub-population. APEX is used to model short and long-term exposures, from hourly to annual averaging times. HAPEM estimates long-term average exposure concentrations in order to address exposures to pollutants with carcinogenic and other long-term effects. HAPEM can be used to model spatial scales ranging from urban to national, whereas APEX is typically not applied for areas greater then large metropolitan areas.

Features common to both models:

- Designed to estimate the distribution of inhalation exposures of population groups. Neither model is designed to be able to assess the exposure of individuals.
- Stochastic treatment of variability of the several factors that influence people's exposures (activity patterns, ambient concentrations, microenvironmental parameters, etc.)
- Tract-level spatial resolution is the default. Other resolutions can also be modeled.
- Multipollutant.
- Choice of methods provided for longitudinal activity diary construction.[1]
- Commuting of adult workers is modeled.
- Modular code written in Fortran and can run either in a DOS or UNIX environment or through EPA's MIMS graphical user interface (Windows).
- Are available in the internet with extensive documentation, and have been under continuing development for more than 20 years (pNEM is APEX predecessor).

Differences between the models:

- APEX and HAPEM can both calculate concentrations in microenvironments using a "factor" approach. APEX has a mass balance approach that can also be used.
- APEX reads hourly air quality data while HAPEM uses annual average air quality data that are stratified by time of day and day of week. Annual average concentrations may be stratified into 24 one-hour time intervals, or 8 three-hour blocks. HAPEM will sample from multiple values (up to 500) for same tract to account for within tract variability.

[1] A key issue in modeling exposures is the approach for creating year-long activity sequences for individuals based on a cross-sectional activity data base of 24-hour records. The typical subject in the time/activity studies in CHAD provided one or two days of diary data. For this reason, the construction of a season-long activity sequence for each individual requires some combination of repeating the same data from one subject and using data from multiple subjects. An appropriate approach should adequately account for the day-to-day and week-to-week repetition of activities common to individuals while maintaining realistic variability between individuals.

- HAPEM generates a fixed number of replicates of annual exposures for each demographic group in a census tract, whereas APEX generates exposures for a set of randomly selected persons in randomly selected census tracts. Thus, the number of annual exposure estimates per demographic group and census tract is fixed for HAPEM but varies for APEX.
- HAPEM builds activity sequences from daily activity data using a cluster analysis Markov chain model. APEX uses an algorithm that targets two statistics, a population diversity statistic that reflects the relative importance of within-person and between-person variance in a user-specified variable, and a within-person autocorrelation statistic.
- HAPEM has an algorithm that allows for modeling near roadway exposures that uses a near-major-roadway residential/business database developed nationally for each census tract with three distance categories (0-75 m, 75-200 m, > 200 m from major roadways), which is provided with HAPEM.
- The activity patterns in HAPEM take into account the mode of commuting (public or private transit) as well as the commuting time for commuters.

Recent Applications of APEX and HAPEM

APEX
NAAQS review of ozone (12 urban areas). Now beginning work on NO_2, SO_2, PM.

HAPEM
1999 National Air Toxics Assessment (NATA) (> 30 pollutants).
Mobile Source Air Toxic Rule (benzene).
CAA Section 812 Study (benzene, Houston).

Future Plans for APEX and HAPEM

APEX
- Indoor chemistry module.
- Improved treatment of near-roadway exposures.
- Improved algorithm for constructing longitudinal activity sequences.
- Commuting of children to/from school.
- Model evaluation and uncertainty analysis.

HAPEM
- Census block and block group resolution.
- Seasonal and monthly air quality.
- The current version of HAPEM contains enhanced algorithms for estimating exposure concentrations from indoor emission sources. However, the databases required to implement these algorithms are currently under development.
- Commuting of children to/from school.
- Comparison of model with DEARS exposure data.

Research Questions

Research Question 1. How to prioritize research and data collection activities to improve exposure models?

For mature models, an analysis of uncertainties appears to be the best way to prioritize efforts, so they can be specifically designed to focus resources cost-effectively on reducing the overall uncertainties. A recent analysis of ozone exposure modeling uncertainties indicates that there are three primary drivers of uncertainty in the exposure results:[2]

The activity pattern data. The Consolidated Human Activity Database (CHAD) is comprised of people's activity diaries from a collection of older studies conducted for different purposes. Uncertainties result from diary errors, difficulties in matching CHAD categories with the coding schemes in the different studies in CHAD, and nonrepresentativeness of the data for the populations modeled. In addition to this, a person's repeated routine behavior from one day to the next is not adequately characterized, which results in a significant underestimation of the number of repeated exposures to high levels of ozone.

Ambient concentrations. For this modeling analysis, measured ozone concentrations were interpolated from the monitoring sites to locations where people live and work, in order to model people's exposures. The non-uniformity of ozone concentrations in a city, primarily due to the titration of ozone by automobile emissions, results in errors in the interpolated concentrations. Ambient concentrations will also be a significant source of uncertainty in exposure modeling studies which use air quality models, or air quality models in conjunction with measured concentrations, to produce the ambient concentrations that are input to the exposure model.

Air exchange rates. A key parameter in modeling concentrations in indoor microenvironments.

For pollutants with indoor sources, the indoor source emission rates will also be a driver of uncertainty. The important sources of uncertainty may be different for modeling long-term exposures using HAPEM.

Research Question 2. How good are our population exposure models and how can we evaluate them?

- Comparison of model results with personal exposure measurements.
- Evaluation of the component algorithms in the model.

Data requirement issues. Due to the high variability of exposures over short time periods, measurements with short averaging times are needed. Since the model results are population distributions, many subjects are required for a useful comparison. These data are not currently available.

[2] This exposure modeling uncertainty analysis used a Monte Carlo approach to quantify the extent to which the uncertainties of the APEX model inputs contribute to the overall uncertainty of the model results for modeling short-term exposures to ozone. For ozone, the uncertainty of model structure (for example, simplifying assumptions) turns out to be of lesser importance than the uncertainties of the model inputs.

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