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Document title/subject: "Development of Microenvironmental Factors for the HAPEM4 in Support of the National Air Toxic Assessment (NATA) - External Review Draft Report."

Originating Organization/Office: Office of Air and Radiation (OAR)

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Background:
The Office of Air Quality, Planning and Standards (OAQPS) has the primary responsibility within EPA to evaluate and regulate health risks associated with toxic substances emitted to the ambient air. The National Air Toxics Assessment (NATA) activities program is dedicated to providing technical information to support the appropriate development of control strategies to address these health risks. The initial NATA 1996 National-Scale Assessment (NSA) represents the most current nationwide quantitative assessment of health risks associated with the inhalation of the 33 priority compounds identified as contributing significantly to human exposures and risks in urban areas. While this NSA builds from work performed as part of EPA's Cumulative Exposure Project, it extends the inhalation portion of that assessment by starting from an inventory of air emissions which has been compiled primarily from State and local agency data, and by incorporating an exposure modeling step which accounts for human mobility and the partitioning of pollutant concentrations between macro- and microenvironments.

The agency has selected the Hazardous Air Pollutant Exposure Model, Version 4 (HAPEM4) as the tool to predict the inhalation exposure as part of the initial NSA. HAPEM4 examines the activity patterns of cohorts in various physical locations, termed "microenvironments" (MEs). An ME is a small space in which human contact with a pollutant takes place, and which can be treated as a well-characterized, relatively homogenous location with respect to pollutant concentrations for a specified time period. In the initial NSA, HAPEM4 will consider cohort activities in thirty-seven ME locations. Currently, the MEs being considered include: (1) indoor locations (e.g., residence, office, store, school, restaurant, church, manufacturing facility, auditorium, health care facility, service station, other public building, garage); (2) outdoor locations (e.g., parking lot/garage, near road, motorcycle, service station, construction site, residential grounds, school, sports arena, park/golf course); and (3) in-vehicle locations (e.g., car, bus, truck, other, train/subway, airplane).

The HAP concentrations available for human inhalation within these various MEs are predicted by applying predetermined, HAP-specific concentration relationships (ME factors) to the nearest ambient air quality estimate. In the initial NSA, ambient air quality levels will be supplied from ASPEN dispersion model predictions at the census tract level. ME factors for HAPEM4 have been compiled for the 33 urban air toxics. These ME factors incorporate (1) the HAP's ability to physically penetrate into the specific ME, (2) the proximity of the air quality data to the ME, and (3) non-ambient sources of the HAP. A complete listing of these factors and the supporting data in their development is contained in the above referenced report being proposed for peer review. Reviewers have also been given a copy of materials describing the planning and scoping of the initial national-scale air toxics screening assessment and the HAPEM4 Model Users Guide. These materials have undergone separate peer review, and are being supplied as additional background information.

Overview of Charge:
Review the technical report: "Development of Microenvironmental Factors for the HAPEM4 in Support of the National Air Toxic Assessment (NATA) - External Review Draft Report." In addition to examining the state-of-the-science and completeness of the ME factor development for the 33 HAPs, the review should consider the HAPEM4 models approach to determining ME concentration and its usage in the initial NSA. The Agency is seeking a peer review of the HAPEM4 modeling approach for the following three main reasons: 1) to determine areas of deficiency in the development and application of ME factors with HAPEM4 and recommend new analyses to improve them, 2) to develop the necessary technical data on key limitations and uncertainties associated with this methodology, and 3) to formulate the best approaches to convey this information to its users. A more detailed ~~draft~~ charge follows below.

Past Peer Reviews:
The USEPA's Office of Transportation and Air Quality (OTAQ) (formerly the Office of Mobile Sources) in conjunction with the Office of Research and Development's (ORD) developed the Hazardous Air Pollutant Exposure Model (HAPEM). The initial versions of HAPEM were primarily developed and employed to predict carbon monoxide exposure for National Ambient Air Quality Standard (NAAQS) reviews and mobile source emission control assessments. Recently, the Office of Air Quality Planning and Standards (OAQPS) modified HAPEM for use as a modeling tool to predict inhalation exposure concentrations to HAPs. The most recent version, HAPEM4, has been modified to predict nationwide census-tract-level annual average human exposure levels.

Background information, including information on past peer reviews of earlier versions of HAPEM, are available from the Office of Transportation and Air Quality (formerly: Office of Mobile Sources) toxics web site at: http://www.epa.gov/oms/toxics.htm

Charge For External Independent Peer Review Of The HAPEM4 ME Factor Report For The Initial NSA:
The NATA 1996 initial NSA is an application of a modeling approach that has been developed over the last several years. This application is being performed by the Office of Air and Radiation as part of its technical support for the Agency's regulatory decision-making for hazardous air pollutants. While a number of the components of this assessment have been subjected to previous scientific peer review, the Agency is seeking a peer review of this technical document in order to determine what improvements we may make to our exposure assessment, and to establish the scientific credibility of using such an approach in the development of priorities within the context of the Agency's Air Toxics Program.

1. Is HAPEM4's application proposed for the initial NSA consistent with the recommended uses of this model? Given the national goals of the initial NSA, is this model the appropriate model to use?

   RESPONSE: Yes. Yes. The Agency is to be commended for developing and applying HAPEM4 to the NSA instead of relying solely on estimates of ambient air quality to establish population risks. Given the scope of the assessment and the screening nature of the survey, the approximate nature of the exposure model is consistent with and appropriate to the goal of this effort. A strength of this approach is that HAPEM4 provides a relatively transparent structured array of the exposure assumptions and approximations required to implement the national screen. It also provides a mechanism to test the impact of small changes in model parameters on the results of the modeling exercise. The relative magnitudes of the resulting perturbations in model output will allow the Agency to identify the key variables. EPA should then focus its available resources towards improving the parameter estimates with the greatest impact on the modeling results. A weakness of EPA's current NSA application of HAPEM4 is that the Agency hasn't used these strengths to optimize the model and further reduce the uncertainties inherent in the approximate nature of the screening effort. See Responses #5 & 6.

2. Is the proper scientific approach to developing a ME concentration employed by the HAPEM4 model? If not, what other approach would you recommend.

RESPONSE: The present empirical approach to developing microenvironmental factors is preferable given the disparate nature 33 air toxic species considered in the NSA and their wide range of physical properties and atmospheric lifetimes. Alternative mass balance or semi-empirical modeling approaches require a larger number of parameter estimates. For example, calculated indoor/outdoor ratios may require knowledge of open/closed window/door frequencies/durations, vertical/horizontal opening types, presence/absence of flow-through ventilation, indoor/outdoor temperature differences, A/C activity, indoor surface/volume ratios, indoor surface composition, mixed/stratified status of indoor volume, and compound specific deposition rates. At the screening level of the initial NSA, use of available measured indoor/outdoor ratios provides an appropriately rough operational averaging across the many parameters that influence the penetration of ambient pollutants indoors.

However, some refinement in the methods used to develop of the microenvironmental factors can be recommended. Given the incremental exposure goal of the NSA, it would be preferable to consider both the ranges and the mean/median values of the data, using only empirical data where there is no evidence of indoor sources of the pollutant of interest. The current guidelines discussed at page 15 of the Report should add a Case 0 to identify such data sets where both the range and mean/median I/O values are less than or equal to unity. Cases 1-3 include data sets where there is evidence of indoor sources and merely choosing the lower part of the range does not necessarily preclude their influence, only that they are operating intermittently or at reduced intensity. A consequence of these guidelines is that the microenvironmental factors developed are likely to underestimate substantially the protection afforded by indoor spaces against exposure to outdoor pollutants.

A couple examples may suffice. Johnson et al., (1998) report little change in hourly indoor CO levels in response to diurnal changes in CO over a 24-hour period. Minimal (< 0.1) penetration of CO was recorded that day for a long-lived species often used as a surrogate for mobile source emissions such a benzene. Spicer et al., (1989) report linear fits to hourly indoor and outdoor values for 10 of the 33 air toxics during closed and open window situations. Slopes for the closed/open window situations ranged 0.3-0.4/0.4-0.8 for the six of these 10 species without evidence of substantial indoor sources. These slopes are in comparison to HAPEM4 PEM values estimated in the Report that range from 0.7-1.0. These two comparisons suggest that estimated NSA exposures may be high-biased several fold as a result of the guidelines used to derive the microenvironmental factors.

Johnson, T., M. Weaver, J. Mozier, T. Kleindienst, D. Smith, C. Nero, W. Ollison, (1998) Variation of residential air exchange rates under scripted ventilation conditions, in Measurement of Toxic and Related Air Pollutants, VIP-85, Proceedings of a Specialty Conference, September 1-3, Cary, NC, pp 633-651, Air and Waste Management Association, Sewickly, PA.

Spicer, C.W., B.E. Buxton, M.W. Holdren, T.J. Kelly, S.W. Rust, M.Ramamurthi, D.L. Smith, A.D. Pate, G.M. Sverdrup, J.C. Chuang, J. Shah, (1989) Variability and source attribution of hazardous urban air pollutants – Columbus field study, Contract 68-D-80082, USEPA-AREAL, RTP, NC (unpublished report). A portion of the outdoor data is published as reference MZ 66.

3. Has a complete and appropriate scientific literature review been performed in the development of the HAPEM4's ME factors?

RESPONSE: As discussed at page 8-9 of the Report, the literature review was based on a machine search of codified library documents from1994-1999. From approximately 5500 identified titles, 250 abstracts were obtained and 100 complete documents reviewed as potential sources of I/O data. In view of the paucity of useful information retrieved, extant reviews of pre-1994 data were investigated and 40 additional documents obtained. A difficulty with mechanized searches is that they often miss substantial portions of the available data. Such data includes recently published information that hasn't yet made it into the search engine database, proceedings of scientific conferences, progress reports of ongoing studies, preprints of accepted articles, and orphaned projects that remain unpublished for various reasons.

A recommended alternative/supplemental approach that often avoids the substantial chaff turned up by search engines is to personally contact the active researchers in the exposure monitoring/modeling field and ask them to identify specific sources of information that might help to develop microenvironmental factors for the 33 HAPs. In the experience of some such 'networking' leads efficiently to both more recent and more relevant data as well as identifying available unpublished information not likely to be encountered in any other way.

Given the acknowledged scarcity of relevant data, a second search for additional information by this alternative approach should be implemented before the factors tabulated in Appendix C of the Report are accepted as representing the best available evidence. It is recommended that the scheduled August 2000 release of the microenvironmental factor Report be postponed until this is done.

4. Are there significant scientific improvements in the exposure assessment field that should be incorporated in this model for future national-scale assessments?

RESPONSE: Yes. (1) The CHAD activity database incorporates breathing rate information (along with time-activity data and population demographics. Although inhalation rate modeling is mentioned (page 17) in the Planning & Scoping document, HAPEM4 currently makes no use of this information (page 1-5, Appendix 2). As a policy matter, EPA often assumes linear low-dose extrapolations and zero thresholds for HAP dose-response models but emerging pharmacokinetic research is increasingly likely to document the importance of dose-rate in projecting population risks. Future HAPEM versions should make use of the available breathing rate data to model distributions of population dose-rate. (2) Given the recent Agency emphasis on children's health (page 28, Planning & Scoping document), it is strange that HAPEM4 continues to ignore commuting and at school exposures (page 1, Report) for this group, restricting them to the home exposure tract. School commuting models (API, 1999) have been developed for children and should be incorporated into future versions of HAPEM.

API, (1999), A home-to-school commuting model for use in population exposure assessments, API HESD Pub. No. FR 5, American Petroleum Institute, Washington, DC, April.

5. Can the uncertainties associated with the use of the HAPEM4 model be defined? If so, how can a quantitative assessment of this uncertainty be defined and implemented?

RESPONSE: Yes. The simplest method would be to compare modeled exposures to those reported from microenvironmental or personal exposure measurements. This approach is used as a 'reality check' quantifying 'reasonable accuracy' for ASPEN (pages, 13 & 28, Planning & Scoping document) although, strangely enough, not for HAPEM4. For example, projected indoor levels could be compared to those provided in Spicer et al., (1989). Hourly and daily average personal exposures to PM2.5 (Chang et al., 2000; Johnson et al., 2000; Sarnat et al., 2000) and BTEX/MTBE species measured in the recent EPRI-API Baltimore study could be compared to daily HAPEM4 estimates (page 5-12, Appendix 2, Planning & Scoping document) tailored to the appropriate local conditions. Contemporaneous ambient 1-, 3-, and 24-hour HAP values are available from the 1998 PAMS Baltimore database. See the following EPA website (http://www.epa.gov/oar/oaqps/pams/freqfile.html). Such comparisons to reality would provide both a measure of bias and uncertainty and some confidence of the degree of predictive skill afforded by HAPEM4 functioning as proposed in the NSA. It is recommended that findings from the initial NSA not be released until the HAPEM4 modeling component undergoes such a 'reality check'.

Chang, L. P. Koutrakis, P. Catalano, H. Suh, (2000) Hourly personal exposures to fine particles and gaseous pollutants: results from Baltimore, MD. JAWMA (in press).

Johnson, T., T. Long, W. Ollison, (2000) Prediction of hourly microenvironmental exposures from a scripted activity study. JEAEE (in press).

Sarnat, J.A., P. Koutrakis, H. Suh, (2000) Assessing the relationship between personal particulate and gaseous exposures of senior citizens living in Baltimore, MD. JAWMA (in press).

6. Does the HAPEM4 modeling system deal with uncertainty in an adequate and transparent way? Does HAPEM4 adequately integrate the uncertainty, qualitative or quantitative, into the presentation of the analyses such that the eventual consumer of the NATA will understand the nature and magnitude of uncertainties associated with the exposure estimates? If not, how can we improve the treatment of uncertainty in this modeling system?

RESPONSE: No. No. Sensitivity tests of model output response to reasonable changes in individual parameter values should identify the principal model drivers and routes of potential model improvement. Available resources for refinement should be expended on those parameters to optimally achieve output stability. Development of synchronized random number generators, recently applied to sensitivity analyses of the pNEM/O3 model (Johnson et al., 1997), has provided a means to efficiently test probabilistic model sensitivity to parameter changes.

However, the stability of the output maps generated by the initial NSA are untested with regards to stochastic noise resulting from the random choice of specific activity patterns. HAPEM4 should be configured to record the initial random number chosen to initiate the individual model runs. The variability of model output with different choices of the initial random number should be investigated to ensure that NSA output maps do not substantially change as a result of this choice. It is recommended that draft NSA output maps not be released until such stability testing is accomplished.

Johnson, T. et al., (1997), "Sensitivity Testing of pNEM/O3 Exposure Estimates to Improvements in Model Algorithms", VIP-74, proceedings *AWMA Measurement of Toxic and Related Air Pollutants Conference*, Research Triangle Park, NC, pp. 226-245; API, (1997), "Sensitivity Testing of pNEM/O3 Exposure Estimates to Changes in the Model Algorithms", by T. Johnson, TRJ Environmental, Inc. API HESD Pub. No. FR 2. Washington, DC.

7. Can a more quantitative estimate of uncertainty be attempted? If so, can you make specific suggestions about quantifying individual as well as composite uncertainties associated with the HAPEM4 model.

RESPONSE: Yes, see response #6. Methods to quantify model variability attributable to individual model parameters are identified above. Similarly, composited parameter uncertainties might be estimated from the model output variation encountered over multiple runs where individual parameters are stochastically sampled from reasonable ranges of parameter values.

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