Inhalation Exposure and Intake Dose Model Improvements

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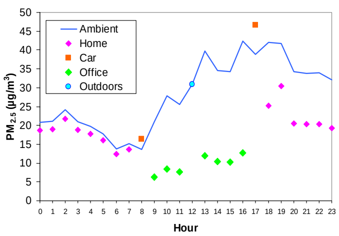
Abstract

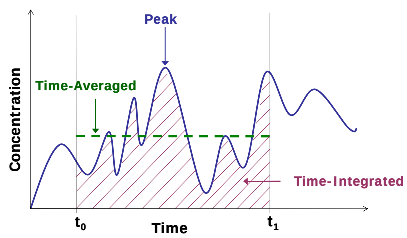
EMRB scientists have been improving its human exposure/intake dose model (i.e., Stochastic Human Exposure and Dose Simulation [SHEDS] model) by performing high-priority human exposure assessment research. One such area of research is in enhancing population-based inhalation exposure and dose modeling, and the EMRB staff have developed a coordinated modeling program to improve methodologies and algorithms utilized within various exposure models in the US EPA program offices. For example, the OAQPS uses a set of regulatory models, including the Air Pollutants Exposure (APEX) model (which is the current inhalation model for the Total Risk Integrated Methodology for Exposure (TRIM.Expo)), and the Hazardous Air Pollutants Exposure Model (HAPEM) to evaluate alternative national ambient air quality standards (NAAQS) and emission standards for toxic, hazardous air pollutants (HAPS). While the SHEDS model is most similar in structure and function to the APEX model, all three models (as well as others) use the EMRB's Consolidated Human Activity Database (CHAD) as their source of human activity data. Since CHAD data are fundamental to both the NERL's and OAQPS's exposure models, the EMRB staff have been evaluating the validity and effectiveness of the CHAD to address significant research questions posed by external scientific review groups. Results of the first three evaluation efforts have been published in peer-reviewed journals; subsequently, the OAQPS is modifying its exposure modeling approach to account for the EMRB research findings. The same is true for the new 2000 US Census commuting data that the EMRB has obtained and modified; it currently is being input into the OAQPS models to replace the 1990 version. In addition, EMRB scientists have developed new ventilation (breathing)-to-oxygen consumption relationships that are an integral part of the intake dose-estimating algorithms used in all of the models. This presentation highlights recent human exposure model improvements and products developed by the EMRB in coordination with scientists in the OAQPS and provides insight into how these products are used by the OAQPS in its regulatory exposure models.

Research Drivers

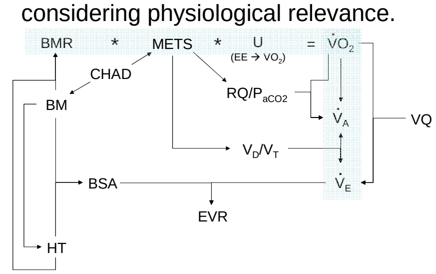
- Uptake dose is determined by where people are and what they are doing.



- Exposure/dose metrics should be consistent with health effect of concern.



- Inhalation rates are estimated considering physiological relevance.



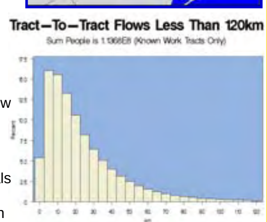
Research Project 1:

Commuter Database Development

ISSUE

People are not stationary over time. Commuting and other geographic relocations are important factors in better estimating inhalation exposure. APEX and SHEDS models use 1990 commuting data and 2000 Census tracts.

Houston Example



SOLUTION

Two databases consisting of the number of people living in one tract and commuting to other tracts were designed to replace the outdated APEX and SHEDS-AirToxics databases for those commuting ≤120 km.

FUTURE RESEARCH

A third database was developed for creation of new commuting databases that contain additional attributes such as:

1. Separation of individuals working at home from those commuting within their home tract.
2. Ability to identify home tracts related to a specific work tract.
3. Inclusion of individuals commuting over 120km, those working outside the US, and those who work at unknown locations.

Research Project 2:

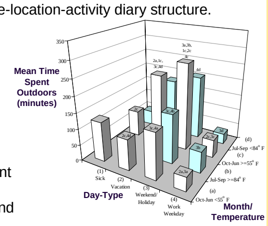
CHAD Data Evaluation

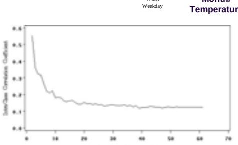
ISSUE

CHAD (McCurdy et al., 2000) is a valuable tool for use in human exposure modeling; however, due to the cross sectional data comprising CHAD, an in-depth evaluation of why people spend time in certain microenvironments was necessary to develop strategies for longitudinal time-location-activity diary structure.

SOLUTION

1. Develop typology of explanatory metrics of human activity for a specific cohort (McCurdy and Graham, 2003).
2. Test typology and determine significant factors affecting time spent in microenvironments for all individuals (Graham and McCurdy, 2004)
   - Age, gender, PAI, day-type, temperature within seasons
3. Estimate number of diaries needed to represent inter- and intra-individual variability (Xue et al., 2004)





Intraclass correlation coefficient (ICC) for the daily time spent outdoors and number of days from each person

FUTURE RESEARCH

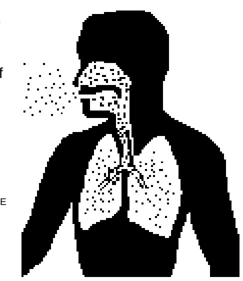
Evaluate exercise levels for children in CHAD to determine if the types and amount contained in it conform to exercise surveys recently undertaken by other organizations. If the results are positive, we will gain increased confidence in usefulness of CHAD regarding this important attribute.

Research Project 3:

Ventilation Algorithm

ISSUE

OAQPS requested that EMRB review the literature on estimating alveolar ventilation (V_A) since a previous review of the algorithms used in pNEM/CO indicated that a constant in the equation possibly varied non-linearly with exercise rate. As an outgrowth of this work EMRB decided to first investigate a V_E algorithm for use in both the APEX and SHEDS inhalation modules.



SOLUTION

Age (A) and gender (G) were used as independent variables along with body mass normalized (BM) VO_2 in a multiple linear regression (Graham and McCurdy, 2005).

$$Ln(V_E/BM)_i = b_0+(b_1*Ln(VO_2/BM_i))+(b_2*Ln(A_i))+(b_3 * G_i)+ e_b+ e_{wi}$$

Parameter estimates (b_i), coefficient standard errors (se), and residual distributions standard deviation estimates (e_i) assuming above equation.

Age (n)	b_0 (se)	b_1 (se)	b_2 (se)	b_3 (se)	e_b	e_w	R^2
<20 (1085)	4.43 (0.06)	1.09 (0.01)	-0.28 (0.01)	0.05 (0.004)	0.10	0.11	0.92
20-<34 (3646)	3.57 (0.08)	1.17 (0.01)	0.11 (0.02)	0.04 (0.003)	0.12	0.13	0.89
34-<61 (1083)	3.19 (0.13)	1.12 (0.01)	0.18 (0.03)	0.04 (0.01)	0.13	0.12	0.89
61+ (457)	2.45 (0.36)	1.04 (0.02)	0.27 (0.08)	-0.03 (0.01)	0.11	0.07	0.89

All coefficients statistically significant at $p < 0.01$

FUTURE RESEARCH

The goal of the research, recognizing that air pollutants will vary in absorption location depending on the substances' physical and chemical characteristics, is to have a unified approach for the various ventilation metrics with VO_2 at the core of the algorithm. A method for estimating V_A to remain consistent with the V_E estimation is under investigation. Previously, the pathway from VO_2 to V_A was considered as a linear proportionality (i.e., 19.63) and also estimated independently from V_E. Research indicates the approximation is reasonable for low to moderate exercise levels, but there is variability in V_A at all exercise levels that are not accounted for by the point estimate used to modify VO_2.

Literature Referenced

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