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Project Summary

A Sensitivity Analysis of the Enhanced Simulation of Human Air Pollution Exposure (SHAPE) Model

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A sensitivity analysis was undertaken of the Simulation of Human Air Pollution Exposure (SHAPE) model, which incorporates an enhanced version of the Coburn-Forster-Kane (CFK) physiological model for predicting a person's blood carboxyhemoglobin (COHb) as a function of time in response to carbon monoxide (CO) exposure. The SHAPE model simulates the physical activities of a sample of people in an urban area, exposing them to pollutant concentrations from appropriate microenvironments as they move through time and space in a 24-hour period. The CFK model dynamically calculates their blood COHb from their CO exposures, and their ventilation rate which is altered in response to their level of activity. To conduct this sensitivity analysis, the SHAPE program was run many times using different combinations of values for its parameters, thus allowing the contribution to COHb of each of many variables to be examined. The following phenomena were found to have significant effect, over and above the influence of the ambient CO on the predicted frequency distribution of the maximum COHb levels of the population: (1) CO exposure contributed by the highway microenvironment; (2) altitude of the city; (3) the CFK physiological parameters (e.g., Haldane constant and endogenous CO production). In contrast, if it is assumed that a person using an indoor parking garage spends less than 10 minutes there, then use of a parking garage has very little effect on the COHb frequency distribution of the population. For low-level CO exposure, use of either the linear or nonlinear form of the CFK model yields essentially the same results.

This Project Summary was developed by EPA's Environmental Monitoring Systems 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 Simulation of Human Air Pollution Exposure (SHAPE) model estimates human exposure to carbon monoxide (CO). It develops an "activity pattern profile" for an individual by allocating each minute of the day into any of 14 microenvironments (home, car, office, parking garage, etc.). By knowing where the person is and approximately what he or she is doing, another part of the program "exposes" the person to CO concentrations appropriate for that microenvironment. Random number generators provide minute-by-minute concentration levels roughly equivalent to those found in the actual microenvironment, based on empirical field studies. For each person, these sequential microenvironmental exposures are brought together to form an "exposure profile" providing CO concentration and estimates of the carboxyhemoglobin (COHb) of the blood as functions of time over the 24-hour period.

The previous version of the SHAPE program used a simplified Coburn CO-COHb model, a first-order linear differential equation with three constant coefficients. This formulation did not permit physiological and other subcomponent parameters (for example, blood volume, ventilation rate, altitude) to be varied by themselves, because the latter parameters were lumped together into the three constants.

The research summarized in the full report covers enhancements to the SHAPE model and a sensitivity analysis of the enhanced model.

The goal of this analysis is to determine how changes in a variety of fundamental parameters (highway CO concentrations, CO concentrations inside a parking garage, time patterns of ambient CO concentrations, and various Coburn physiological parameters) affect the following three dependent variables for the population:

- Maximum 1-hour average exposure (M1AE)
- Maximum moving 8-hour average exposure (MM8AE)
- Maximum 1-hour blood carboxyhemoglobin (M1COHb)

In each case, we are interested in the population's frequency distributions of these variables and the impact of a change in each parameter on these frequency distributions. In general, we examined changes in frequency distributions that result while one parameter is allowed to vary and all the others are held constant. In some cases, two parameters were varied at the same time.

Our simulation sample consisted of 400 non-smoking people employed in a large urban area. Their simulated commute habits are based on data from the U.S. Census Bureau's "Nationwide Personal Transportation Study", (1973).

Modifications to SHAPE

The following enhancements have been made to the SHAPE computer program:

- All individual Coburn parameters appear explicitly.
- Both linear and the more accurate nonlinear versions of the Coburn model can be used to compute blood COHb.
- Once the age and sex of the person have been established, height is determined by random sampling from distributions based on data from the National Health and Nutrition Examination Survey (HANES) conducted by the National Center for Health Statistics.
- Weight is determined from empirical height-weight equations, also based on sex and age.
- Blood volume is determined from height and weight, and hemoglobin content is randomly sampled from the HANES data, based on sex.
- Some of the person's lung functions (alveolar ventilation and diffusion rates, for example) are allowed to vary throughout the day and are determined from the activities he or she performs, based on metabolic rate assumptions for each physical activity level.
- For each person, the program runs through an extra 24-hour exposure sequence on the previous day in order to set the initial conditions for the day of interest.

Once these enhancements were made, the program was run many times with different combinations of values. Ambient data for three different dates were used, each with relatively high CO levels selected from an earlier sensitivity analysis.

In this study, only subsamples of an urban population were simulated for their exposure experience to CO. The subsample consisted of nonsmoking employed commuters during a week day. As such, the distributions generated of maximum 1 hour CO exposure, maximum 8 hour exposure and maximum 1 hour COHb are seen to have small standard deviations and less than 10% coefficients of variation.

Conclusions

The findings of the study are among the following:

- Changes in CO levels inside automobiles exert a statistically significant effect on computed blood COHb of the population.
- Altitude exerts a statistically significant effect on computed blood COHb.
- Changes in the levels of CO in indoor parking garages have little effect on total CO exposure and blood COHb of the population due to the brief time (10 minutes) assumed spent there.
- For low-level CO exposure, the linear approximation of the solution to the Coburn equation does not differ significantly from the nonlinear solution.

This sensitivity analysis has identified the relative significance of a variety of parameters in generating estimates of blood COHb and has provided insight into the manner in which the parameters affect person-to-person variability of blood COHb. It also has identified the likely contribution of various human activities — driving a car, parking in a garage — to population exposure distributions and human dose distributions.

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The complete report, entitled "A Sensitivity Analysis of the Enhanced Simulation of Human Air Pollution Exposure (SHAPE) Model ," (Order No. PB 85-201 101/AS; Cost: $18.95, subject to change) will be available only from:
National Technical Information Service
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