ADDENDUM

Determination of Microenvironmental Factors for Diesel PM

INTRODUCTION

ICF Consulting (ICF) and TRJ Environmental, Inc. (TRJ) prepared a report titled ADevelopment of Microenvironmental Factors for the HAPEM4 in Support of the National Air Toxics Assessment (NATA)@ for the Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency (USEPA). That report describes the procedures ICF and TRJ used to estimate pollutant-specific microenvironmental (ME) factors for 35 hazardous air pollutants (HAPs) in 37 microenvironments. USEPA will use these ME factors to run Version 4 of the Hazardous Air Pollution Exposure Model (HAPEM4) and estimate inhalation exposures as part of the NATA assessment activities.

To broaden the scope of these exposure assessments, USEPA requested that ICF and TRJ develop ME factors for one additional pollutant: particulate matter associated with diesel engine emissions (diesel PM). Diesel PM ME factors developed as part of this effort are presented in Table 1 of this addendum. This addendum also provides a list of references in Tables 2 and 3, as well as a brief description of the procedures ICF and TRJ used to develop ME factors for diesel PM. Additional details on the definition and development of HAPEM4 ME factors are contained in the main report.

METHODOLOGY

Defining the HAPEM4 ME Factors

The initial NATA assessment is concerned with estimating the influence of outdoor sources on inhalation exposure. HAPEM4 is a computer-based exposure model that estimates the contribution of outdoor HAP concentrations to air concentrations in indoor, outdoor, and vehicle microenvironments using three ME factors: *PEN*, the penetration factor; *PROX*, the proximity factor; and *MULT*, the multiplicative factor.

For indoor and in-vehicle microenvironments, *PEN* is defined as the ratio of the microenvironmental concentration to the outdoor concentration in the immediate vicinity of the microenvironment. This ratio is often reported in the literature as the I/O (indoor/outdoor) ratio in the absence of indoor sources. Since *PEN* factors are not applicable to outdoor microenvironments, all outdoor *PEN* factors have been set to 1.0 for this project.

The *PROX* factor relates the HAP concentration at a specific location (e.g., at a fixed-site monitor or at the centroid of a census tract) to the outdoor concentration in the immediate vicinity of the microenvironment, or to the concentration in the microenvironment itself for outdoor microenvironments. *PROX* is defined as the ratio of the outdoor concentration in the

immediate vicinity of the microenvironment (or outdoor microenvironmental concentration) to the measured or modeled ambient concentration.

The *MULT* factor is the product of the *PEN* and *PROX* factors, or the overall ratio of the microenvironmental concentration to the measured or modeled ambient concentration. A fourth ME factor, the additive (*ADD*) factor, is used by HAPEM4 to account for the contribution of sources within the microenvironment, such as indoor sources. For this initial NATA assessment emphasizing outdoor sources, all *ADD* factors have ben set to zero.

Calculating HAPEM4 ME Concentrations and Estimation of Proximity Factors

The HAPEM4 uses these ME factors to estimate concentrations within microenvironments with the equation

$$ME(m,c,t) = ADD(m) + [PROX(m)][PEN(m)][AMB(c,t)] \quad (1)$$

where:

ME(m,c,t):	concentration in microenvironment *m* located in census tract *c* at time *t*,
ADD(m):	additive factor for microenvironment *m*,
PEN(m):	penetration factor for microenvironment *m*,
PROX(m):	proximity factor for microenvironment *m*, and
AMB(c,t):	ambient concentration for census tract *c* at time *t*.

In the NATA application of HAPEM4, the ambient concentration values used in Equation (1) are obtained from a dispersion model which computes the ambient concentration at the centroid, or population center, of each census tract based on information on emission sources in the surrounding area. This method provides an average concentration estimate applicable to the entire census tract. However, this estimate would tend to be biased low for microenvironments usually located near predominant sources of a pollutant. For diesel PM, which is emitted by onroad motor vehicles, this low bias would be observed in microenvironments near roadways. These near-road microenvironments include outdoor locations near roads (HAPEM4 microenvironment No. 7), in-vehicle microenvironments (Nos. 1, 2, 3, 4, 8, and 36), service stations (No. 10), and parking facilities (No. 6).

The effect of the low bias in the computed ambient concentration is to yield *PROX* factors greater than 1.0 for diesel PM in these microenvironments. In other words, the outdoor concentration in the immediate vicinity of the microenvironment is expected to be higher than the ambient concentration measured at a remote fixed-site monitor or computed by the dispersion model. *PROX* factors for all other microenvironments have been assigned a default value of 1.0.

Literature Search

ICF and TRJ conducted a broad literature search similar to that described in the main report to identify references useful for developing diesel PM ME factors. Researchers performed an online search using key words relating to diesel PM. The initial large list of titles and key

word descriptors was reviewed and ranked according to the potential for containing valuable data for ME factor estimation. Abstracts were retrieved for citations with a high probability of containing both indoor and outdoor measurements for the various microenvironments. Researchers reviewed these abstracts and obtained the complete paper or report for the 12 citations identified as most likely to provide relevant information.

In addition to the online search, researchers used several other sources to identify relevant articles. Several extended abstracts from the American Waste Management Association=s PM2000 Conference in January, 2000 contained useful information on I/O ratios for particles of various sizes, particle size distribution of diesel PM, and other data which could be combined to estimate diesel PM ME factors. Researchers also contacted air quality experts for suggestions on relevant literature, yielding several articles. Some documents relating to diesel PM were retrieved from existing ICF and TRJ files. Finally, researchers retrieved relevant citations from the reference lists of articles found by other methods.

Despite this broad literature review, relatively few articles were found to contain actual measurement data on diesel PM I/O ratios in the absence of microenvironmental sources; that is, data which would be directly applicable to estimation of *PEN* factors. Therefore, researchers combined general particulate matter data in certain microenvironments with information on characteristics of diesel PM to arrive at diesel PM ME factors. Researchers found sufficient information to estimate ME factors for key microenvironments, allowing development of factors for the remaining microenvironments using the grouping scheme described below.

Grouping Microenvironments

Since published diesel PM I/O measurement data were not available for most of the 37 HAPEM4 microenvironments, analysts decided to use the microenvironmental grouping scheme described in the main report to estimate ME factors for those microenvironments. In this grouping scheme, the microenvironments were organized into five groups. Each group consists of microenvironments expected to have similar *PEN* factors, thus enabling ME factors developed for one microenvironment to be applied to other microenvironments in the same group. Table 4 in the main report shows the ME grouping assignments. The five ME groups were established based on the general ME type (indoor, outdoor, or in-vehicle), expected location relative to roadways (near road, away from road), and building type (residence, other). For specific microenvironments without useful data in the literature, researchers calculated the average of ME factors developed for other microenvironments in the same group and used the result as the ME factor estimate. This is indicated in the ME factor table, Table 1, by a Data Code of 2.

RESULTS

Table 1 presents the diesel PM ME factors developed in this effort. An estimated value is provided for each ME factor in each microenvironment, except for *ADD* factors, which represent indoor sources and were therefore not included in this project. Because onroad mobile sources are significant for diesel PM, analysts developed separate estimates of the *PROX* and *MULT* factors to be used for the onroad source category and the nonroad, major, and area source

categories. A Data Code in brackets follows each factor estimate, indicating how the ME factor value was derived. These Data Codes are defined below:

Data Code [1]: indicates that measurement data for that microenvironment were available and used.
Data Code [2]: indicates that useful measurement data were not available, and that the ME factor was obtained through the grouping scheme described above in the Methodology section.
Data Code [3]: indicates that a default value of 1.0 was used.

The most commonly studied microenvironment was residence - indoors (ME #13). For this microenvironment, multiple references containing high-quality data were available. Analysts used the average of factors determined from these references as the *PEN* factor estimate for ME #13.

The last column in Table 1 lists the references used to develop factors for each microenvironment. If no reference code is provided, then researchers did not find any useful documents for that particular microenvironment. Table 2 provides specific information on the reference documents reviewed for this addendum, including both those with and without sufficient data to estimate ME factors. Table 2 lists the title, author, citation, pollutants addressed, and a brief description of the pertinent results for each document. It also includes a Sources column with codes matched to the Reference Sources codes in Table 1. An alphabetized version of the reference list is provided in Table 3.

SUMMARY

This addendum extends the scope of the main report by developing *PEN*, *PROX*, and *MULT* ME factors for one additional pollutant, diesel PM. Researchers identified relatively few studies with measurement data directly applicable to estimating diesel PM ME factors, and these studies tended to focus on the residential microenvironment. Analysts combined information from various studies on the characteristics of diesel PM, apportionment of PM to diesel sources, and general PM measurement data to develop ME factors in those microenvironments with sufficient data. These ME factors were then propagated to other related microenvironments using a grouping scheme, enabling analysts to develop factors for all applicable microenvironments. The use of default values was restricted to those microenvironments for which ME factors are not applicable. Default values for the *PEN* factor were used only for outdoor microenvironments, where the *PEN* factor is not relevant. Since diesel PM *PROX* factors greater than 1.0 are only expected in near-road microenvironments for the onroad mobile source category, researchers assigned default values for the *PROX* factor to all other microenvironments. As additional measurement information becomes available, these ME factor values can be refined and updated to provide improved estimates of the influence of outdoor sources on indoor diesel PM concentrations.

Table 1. Diesel PM Microenvironmental Factors by Microenvironment

HAPEM Microenvironment	ADD (Fg/m^3)	PROX [Data Code] [a]		PEN [Data Code] [a]	MULT = PROX H PEN		Reference Sources
		Onroad [b]	Major, area, and nonroad [c]		Onroad [d]	Major, area, and nonroad [d]	
1. Car - In vehicle		1.76 [1]	1.0 [3]	0.63 [1]	1.1088	0.63	TL33
2. Bus - In vehicle		1.76 [2]	1.0 [3]	0.63 [2]	1.1088	0.63	
3. Truck - In vehicle		1.76 [2]	1.0 [3]	0.63 [2]	1.1088	0.63	
4. Other - In vehicle		1.76 [2]	1.0 [3]	0.63 [2]	1.1088	0.63	
5. Public garage - Indoors		1.0 [3]	1.0 [3]	0.75 [2]	0.75	0.75	
6. Parking lot/garage - Outdoors		1.45 [2]	1.0 [3]	1.0 [3]	1.45	1	
7. Near road - Outdoors		1.45 [1]	1.0 [3]	1.0 [3]	1.45	1	TL33
8. Motorcycle - Outdoors		1.45 [2]	1.0 [3]	1.0 [3]	1.45	1	
9. Service station - Indoors		1.0 [3]	1.0 [3]	0.75 [2]	0.75	0.75	
10. Service station - Outdoors		1.45 [2]	1.0 [3]	1.0 [3]	1.45	1	
11. Residential garage - Indoors		1.0 [3]	1.0 [3]	0.65 [2]	0.65	0.65	
12. Other repair shop - Indoors		1.0 [3]	1.0 [3]	0.75 [2]	0.75	0.75	
13. Residence (no CO source) - Indoors		1.0 [3]	1.0 [3]	0.74 [1]	0.74	0.74	TL23, TL27, TL29, TL30, TL32, TL34, TL35, TL39
14. Residence (gas stove) - Indoors		1.0 [3]	1.0 [3]	0.56 [1]	0.56	0.56	TL39
15. Residence (attached garage) - Indoors		1.0 [3]	1.0 [3]	0.65 [2]	0.65	0.65	
16. Residence (stove and garage) - Indoors		1.0 [3]	1.0 [3]	0.65 [2]	0.65	0.65	
17. Office - Indoors		1.0 [3]	1.0 [3]	0.54 [1]	0.54	0.54	TL27
18. Store - Indoors		1.0 [3]	1.0 [3]	0.76 [1]	0.76	0.76	TL27
19. Restaurant - Indoors		1.0 [3]	1.0 [3]	0.75 [2]	0.75	0.75	
20. Manufacturing facility - Indoors		1.0 [3]	1.0 [3]	0.75 [2]	0.75	0.75	
21. School - Indoors		1.0 [3]	1.0 [3]	0.69 [1]	0.69	0.69	TL27
22. Church - Indoors		1.0 [3]	1.0 [3]	0.76 [1]	0.76	0.76	TL27
23. Shopping mall - Indoors		1.0 [3]	1.0 [3]	0.76 [1]	0.76	0.76	TL27
24. Auditorium - Indoors		1.0 [3]	1.0 [3]	0.75 [2]	0.75	0.75	
25. Health care facility - Indoors		1.0 [3]	1.0 [3]	0.76 [1]	0.76	0.76	TL27
26. Other public building - Indoors		1.0 [3]	1.0 [3]	0.75 [2]	0.75	0.75	
27. Other location - Indoors		1.0 [3]	1.0 [3]	0.75 [2]	0.75	0.75	
28. Not specified - Indoors		1.0 [3]	1.0 [3]	0.95 [1]	0.95	0.95	TL22
29. Construction site - Outdoors		1.0 [3]	1.0 [3]	1.0 [3]	1	1	
30. Residential grounds - Outdoors		1.0 [3]	1.0 [3]	1.0 [3]	1	1	

HAPEM Microenvironment	ADD (Fg/m^3)	PROX [Data Code] [a]		PEN [Data Code] [a]	MULT = PROX H PEN		Reference Sources
		Onroad [b]	Major, area, and nonroad [c]		Onroad [d]	Major, area, and nonroad [d]	
31. School grounds - Outdoors		1.0 [3]	1.0 [3]	1.0 [3]	1	1	
32. Sports arena - Outdoors		1.0 [3]	1.0 [3]	1.0 [3]	1	1	
33. Park/golf course - Outdoors		1.0 [3]	1.0 [3]	1.0 [3]	1	1	
34. Other location - Outdoors		1.0 [3]	1.0 [3]	1.0 [3]	1	1	
35. Not specified - Outdoors		1.0 [3]	1.0 [3]	1.0 [3]	1	1	
36. Train/subway - In vehicle		1.76 [2]	1.0 [3]	0.63 [2]	1.1088	0.63	
37. Airplane - In vehicle		0.0 [3]	0.0 [3]	0.90 [2]	0	0	

[a] Data Code: 1 = value obtained from literature; 2 = value obtained using grouping scheme; 3 = default value.
[b] Onroad vehicle source category (see text).
[c] Major, area, and nonroad-mobile source categories (see main report text).
[d] The MULT factor is the product of the PROX factor and the PEN factor for the onroad vehicle source category and for the major, area, and nonroad-mobile source categories for this pollutant.
Formula: Microenvironmental concentration, $\mu g/m^3$ = ADD + (PROX)(PEN)(monitor concentration, $\mu g/m^3$).
Abbreviations: ADD = additive factor; PROX = proximity factor; PEN = penetration factor; MULT = PROX H PEN.