EPA/AA/CTAB/PA/81-2

An Approach for Determining Levels of Concern for Unregulated Toxic Compounds from Mobile Sources

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Emission Control Technology Division
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Technical Reports do not necessarily represent final EPA decisions or positions. They are intended to present technical analysis of issues using data which are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments which may form the basis for a final EPA decision, position or regulatory action.

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Introduction

This report presents an approach for determining ranges of concern for vehicle emissions of toxic unregulated pollutants. The information used in deriving this approach was generated either in-house at EPA or under EPA contract to Midwest Research Institute in Kansas City, Missouri; and/or Southwest Research Institute in San Antonio, Texas.

This work represents an EPA technical effort designed as one input that may bear on EPA policy with respect to implementation of section 202(a)(4) of the Clean Air Act amendments of 1977. As such, this report does not represent EPA policy at this time. This report will also be of interest to parties outside EPA, such as the automobile manufacturers, who are involved with deciding whether unregulated pollutants from motor vehicles constitute a public health hazard. This approach, outlined in the subsequent sections of this report, has four separate parts, the last of which is a summary of the previous three. An example of how the approach works is presented for a sample mobile source pollutant; sulfuric acid (H_2SO_4).

The range of compounds which are expected to be assessed by this approach are those compounds which have non-zero "thresholds" (e.g. not genotoxic) associated with them. This approach is not intended for the evaluation of mutagenic, teratogenic, and/or carcinogenic effects of substances emitted from mobile sources, but may be used to evaluate the non-genotoxic health aspects of a substance which may have other harmful effects also.

It is important to point out that this approach is not intended to be a rigorous examination of all the issues and variables surrounding any hazardous pollutant question. Such an effort would require an extensive program similar to the procedures used to determine and support the NAAQS process. The intent of this approach is to identify and prioritize hazardous pollutants that are emitted from mobile sources so that research by EPA and the automobile manufacturers can focus on those emission products of significant concern. If one pollutant, for example, is shown to fall within a potential problem range, then additional work can be initiated to determine in more detail the hazards of that pollutant.

The first step in determining the range of concern for a pollutant involves compiling a list of emission factors of the various motor vehicle categories. These categories are assigned to as many discrete subsets of the mobile source population as are necessary to characterize the current and future mobile source fleet.

The second step is to review the relevent health effects literature on the pollutant of interest. The basic review would involve selecting valid health effects studies on a particular unregulated pollutant which fall within a range of exposure concentrations suspected to be of concern to human health. The lowest value of this range would represent the lowest concentration at which negative physiological effects* can be detected. The highest value would represent that level above which the hazards are so well defined as to encourage regulation. A simplified means of approaching the upper level would be to use a Threshold Limit Value (TLV) as the basis from which to estimate the range of concern. The TLV can be adjusted for exposure time and safety margin and subsequently can be used to estimate the range of concern.

The third step is to use an appropriate set of pollutant dispersion scenarios to convert emission factors to concentrations that people may be exposed to. Both worst case and average cases for a number of situations are evaluated.

The fourth step will combine the results of the previous three steps and determine ranges of concern for unregulated pollutants from mobile sources.

Background

The Clean Air Act (CAA) was amended in August 1977 to include section 202 (a)(4) and 206 (a)(3) dealing with the emissions of hazardous pollutants from vehicles produced after 1978. The specific language of the statute is:

202 (a)(4)

> "(4)(A) Effective with respect to vehicles and engines manufactured after model year 1978, no emission control device, system, or element of design shall be used in a new motor vehicle or new motor vehicle engine for purposes of complying with standards prescribed under this subsection if such device, system, or element of design will cause or contribute to an unreasonable risk to public health, welfare, or safety in its operation or function.
>
> (B) In determining whether an unreasonable risk exists under subparagraph (A), the Administrator shall consider, among other factors, (i) whether and to what extent the use of any device, system, or element of design causes, increases, reduces, or eliminates emissions of any unregulated pollutants; (ii) available methods for reducing or eliminating any risk to public health, welfare, or safety whch may be associated with the use of such devices, systems, or elements of design which may be used to conform to standards prescribed under this subsection without causing or contributing to such unreasonable risk. The Administrator shall include in the consideration required by this paragraph all relevant information developed pursuant to section 214."

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*It is recognized that controversy exists as to what a negative physiological effect is in relation to regulatory action pursuant to protecting the public health. Since this approach attempts to separate clear health problem emissions from non health problem emissions, it is prudent to be conservative in selecting the lowest level of the range.

206 (a) (3)

"(3) (A) A certificate of conformity may be issued under this section only if the Administrator determines that the manufacturer (or in the case of a vehicle or engine for import, any person) has established to the satisfaction of the Adminstrator that any emission control device, system, or element of design installed on, or incorporated in, such vehicle or engine conforms to applicable requirements of section 202(a)(4).

(B) The Administrator may conduct such tests and may require the manufacturer (or any such person) to conduct such tests and provide such information as is necessary to carry out subparagraph (A) of this paragraph. Such requirements shall include a requirement for prompt reporting of the emission of any unregulated pollutant from a system, device or element of design if such pollutant was not emitted, or was emitted in significantly lesser amounts, from the vehicle or engine without the use of the system, device, or element of design."

In response to these 1977 CAA requirements EPA began a program to modify the existing procedures dealing with hazardous compounds or conditions. The existing sections pertaining to the hazardous pollutant areas were contained in 40CFR 86.078 subsection 5(b) as follows:

"Any system installed on or incorporated in a new motor vehicle (or new motor vehicle engine) to enable such vehicle (or engine) to conform to standards imposed by this subpart:

(i) Shall not in its operation or function cause the emission into the ambient air of any noxious or toxic substance that would not be emitted in the operation of such vehicle (or engine) without such system, except as specifically permitted by regulation; and

(ii) Shall not in its operation, function, or malfunction result in any unsafe condition endangering the motor vehicle, its occupants, or persons, or property in close proximity to the vehicle.

(2) Every manufacturer of new motor vehicles (or new motor vehicle engines) subject to any of the standards imposed by this subpart shall, prior to taking any of the action specified in section 203 (a)(1) of the Act, test or cause to be tested motor vehicles (or motor vehicle engines) in accordance with good engineering practice to ascertain that such test vehicles (or test engines) will meet the requirements of this section for the useful life of the vehicle (or engine)."

Furthermore 40 CFR 86.078-23(d), which deals with data required as a precondition for certification, states the following:

> d) "A statement that the vehicles (engines) for which certification is requested conform to the requirements in 86.078-5(b) and that the descriptions of tests performed to ascertain compliance with the general standards in 86.078-5(b) and the data derived from such tests are available to the Adminstrator upon request."

In past years, the manufacturers simply submitted the required statement but not the data on which it was based.

As a first attempt at bringing attention to and developing procedures for the implementation of section 202(a)(4), a working draft Advisory Circular was sent to the manufacturers for constructive comment on October 18, 1978. As a result of the input received from the manufacturers and other interested parties, EPA has proceeded to refine the approach to implementation of section 202(a)(4) of the Clean Air Act. EPA had issued Advisory Circular (AC) 76 (on June 28, 1978) requiring the manufacturers to continue to provide statements to the effect that the new model vehicles certified to be in compliance with the vehicle emission standards would not contribute to an unreasonable risk to public health. On November 30, 1978, EPA issued AC 76-1 which continued the procedures set forth in AC 76 for the 1980 and later model years.

In addition to the aforementioned activities, EPA has been developing and documenting measurement methodologies for the automobile industry to use in investigating unregulated pollutants from mobile sources. Two reports on unregulated pollutant measurement methods have been produced and widely distributed among auto manufacturers (1,2)*. Also, EPA has produced an initial data base on unregulated pollutants under a variety of conditions from vehicles utilizing different emission control systems (3,4,5).

Methodology

The following sections will discuss the methodology developed for determining a range of concern for toxic unregulated pollutants from mobile sources. It should be reemphasized that this is an approach to this problem but not the only approach. It is felt that this methodology provides a valid procedure that is neither too complex nor too simple for the problem. It is also felt that this methodology could be used for a wide range of unregulated compounds and yield acceptable results.** Figure 1 is provided to illustrate the way this approach is structured.

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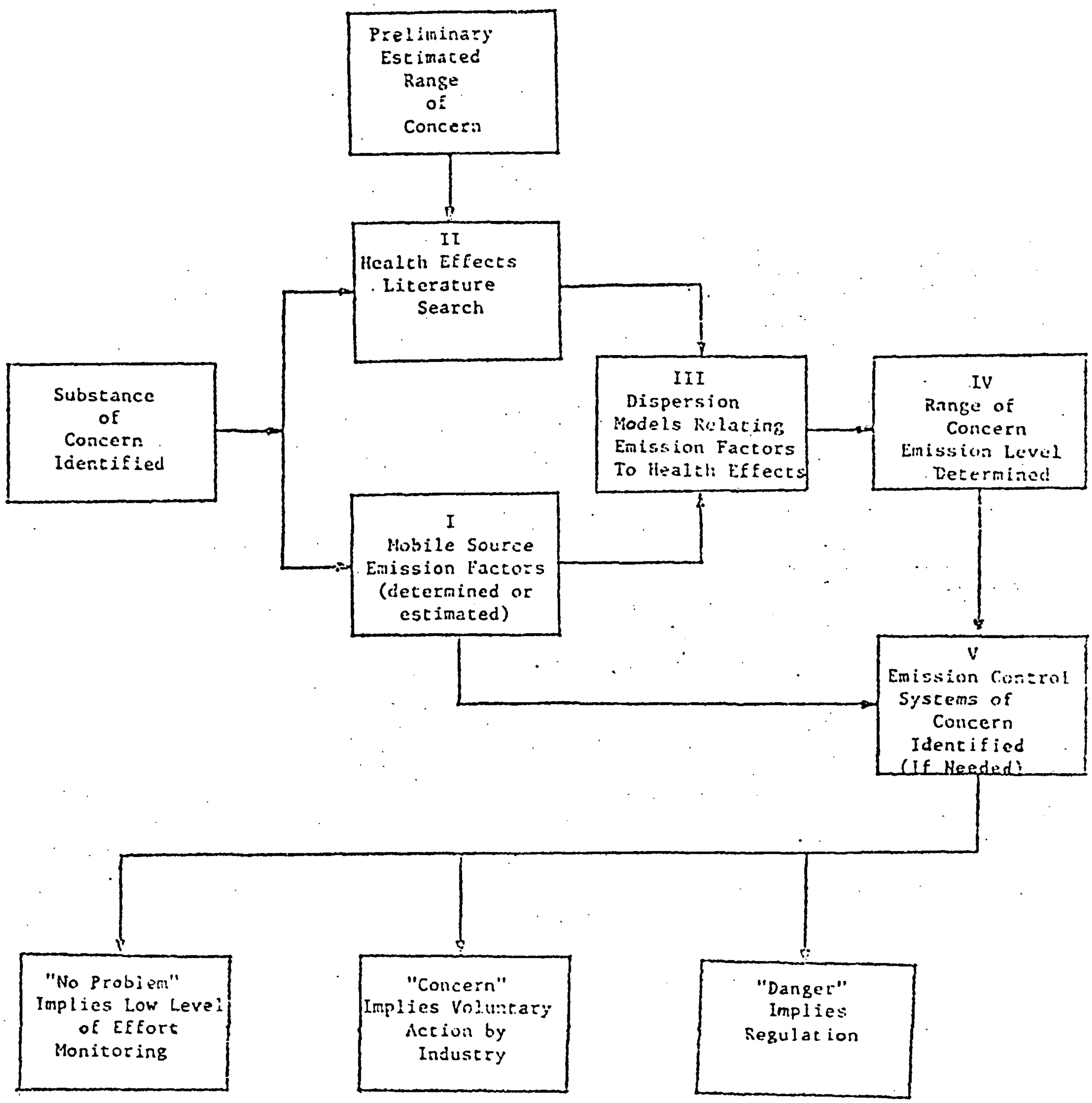
* Numbers in parentheses refer to references which are listed at the end of this report.

** We invite comments from interested parties on this approach to implementing one part of section 202(a)(4) of the Clean Air Act.

Figure 1

Flow Diagram - Toxic Pollutant Range of Concern



I Emission Factors

An essential part of the information for this methodology is accurate vehicle emission factors. An emission factor may be determined from the available literature and is the mass per unit distance or unit time of a pollutant which is emitted from a particular vehicle type over a certain driving cycle or mode. A complete listing of vehicle emission factors for the pollutant of interest is needed for the full range of vehicle types and driving schedules that contribute to the fleet emissions of the pollutant. Since most of the exposure situations (to be discussed later) involve highway situations or city street canyons, emission factors are needed on the vehicle types which may be present in these locations. Therefore, emission factor information will be needed for the categories listed in Table I. This list is not intended to be all-inclusive and the groupings may change from specific pollutant case to specific pollutant case depending on the information available and the information needed.

Table I
Emission Factor Categories

I. Heavy Duty Vehicles (HDV)

- A. Gasoline-Fueled Heavy Duty Trucks (HDT-G)
- B. Diesel-Fueled Heavy Duty Trucks (HDT-D)

II. Light Duty Vehicles (LDV)

- A. Gasoline-Fueled Light Duty Vehicles (LDV-G)
- B. Diesel -Fueled Light Duty Vehicles (LDV-D)

III. Light Duty Trucks (LDT)

- A. Gasoline-Fueled Light Duty Trucks (LDT-G)
- B. Diesel-Fueled Light Duty Trucks (LDT-D)

IV. Motorcycles

V. Others

In general, under each classification, an entry for the emission factor of the unregulated pollutant under study is needed, if it is appropriate. Sometimes certain emission factors are not needed. For example, if the unregulated pollutant had to do with tetraethyl lead or motor mix and/or its combustion products, an emission factor for those vehicles that use Diesel fuel would not be necessary,since Diesel fuel does not contain lead.

On the other hand, subclassifications more detailed than those shown in Table I, may be needed, if the emissions of the unregulated pollutant are not adequately described by that level of detail. For example, for sulfuric acid emissions the presence or absence of an oxidation catalyst and the details of the air injection system are known to influence the emission factor significantly, so some more detailed subclassification is necessary.

The "Other" category is for gas turbine-powered vehicles or electric or hybrid vehicles, etc, a catch-all category of unusual and/or potentially problematical power-plants or vehicles which might emit the unregulated pollutant of interest.

Unregulated pollutant emission factors are frequently a function of the vehicle and engine type, emission control system design, vehicle driving schedule, vehicle condition (e.g. malfunction), vehicle mileage and other variables. The combination of these factors provide a fleet average emission factor. However, simplifying assumptions can be made for a given pollutant so that the combination of these factors can be reduced to a workable calculation.

The fleet average emission factor for the unregulated pollutant of interest should be calculated for a variety of vehicle fleet situations. Two primary sources of information used to determine fleet average emission factors are the Pedco report (6) and the EPA publication "Mobile Source Emission Factors: For Low Altitude Areas Only" (7). This information can be used to determine fleet emission factors for use in the ambient concentration models. Examples of these procedures can be found in the sulfuric acid example in later sections of this report.

The information contained in the Pedco report allows the determination of weighting factors for the different major categories of vehicles in Table 1. The information contained in the EPA mobile source emission factors report allows for a further demarkation of the weighting factors to include different emission control system designs. Both of these references aid in calculating a fleet average emission factor.

When one vehicle category is of particular interest, such as the 3-way plus oxidation catalyst light duty vehicle in the sulfuric acid example, the fleet emission factors should be calculated for various percentages of this vehicle category. Using values of 25%, 50%, 75% and 100% of the vehicle category comprising the entire vehicle fleet will allow the effects of the specific vehicle/control system type to be estimated.

In most cases it will be desirable to compare the emissions and corresponding air quality of a specific vehicle category to the ranges of concern for an unregulated pollutant. Thus, the above method of determining fleet emission factors will probably be most desirable. However, other suitable methods of making this determination are also possible using different references and averaging schemes. This method has been picked because of the author's familiarity with the cited references and the simplicity of application.

II Health Effects

A health effects literature review is necessary to determine a range of concern for a particular pollutant. Health effects information at low levels of exposure are quite important for this assessment, especially since the health effects at these levels are not always as easily detected, or readily apparent. Also, chronic exposure at low levels, such as exposure to a low concentration of pollutant for 1-2 hours per day, 5 days a week for a significant portion of the subject's life, are very important due to the fact that this is the type of exposure which most people will be encountering in their day to day activities. Of particular interest, of course, is that health effects information involving human subjects. Complete and appropriate information on these lower levels is a very desirable element in the determination of a range of concern for mobile source emissions. The lowest level of the range of concern can be defined as the lowest concentration of the pollutant at which adverse physiological effects are detectable. This definition provides a useful and workable concept for later calculations involving vehicle emissions, but does not adequately address the actual causative factors relating to hazardous pollutants. Other concepts which are of critical importance in the ultimate determination of a pollutant hazard are exposure and dose or effective dose. Exposure can be defined as that parameter resulting from the calculation of concentration multiplied by time. Dose is defined as some fraction of the exposure which is presented to the critical organ or subpart of the organism of interest. However, in order to provide a reasonable workable methodology, only concentration and occasionally exposure information will be used. It is recognized that if a potential concern is determined by this methodology then a more detailed assessment involving dose determination may need to be done. In general, this type of terminology is used in conjunction with experiments involving various doses of the chemical of interest. Below the lowest level of the range there should be no evidence, from the available literature, which would lead to the belief that there is a hazard to human health. The highest value of the range, on the other hand, can be defined as the concentration above which studies show hazards so well defined as to encourage regulation. Both the highest and lowest levels of the range are not static quantities and may vary depending on the interpretation of the health effects data and results from new tests. Each, however, provide important information on the estimation of the levels which may be hazardous to humans.

The literature search, that will result in a set of relevant citations on the pollutant of interest, comprises the first step in the health effects review. A thorough computer assisted search using the computer data bases TOXLINE and TOXBACK as well as a manual journal search is usually appropriate to uncover most of the health effects data on a given pollutant. An example of this type of search is contained in Appendix II.

Prior to the evaluation of the literature search information, a preliminary range of pollutant level concern with respect to public exposure should be established that will bracket the range of concern. The selection of a preliminary range of concern allows a closer focus on the literature review, eliminating from primary consideration those studies which provide health effects data due to very high concentration exposures. To simplify this calculation, the upper value of the range will be the Threshold Limit Value (TLV) as listed by the ACGIH, if available and appropriate. The lower value of the range should represent the lowest concentration suspected to cause health effects. This lower value can be determined from the available literature. In the event that such a level cannot readily be determined, the lower level will be estimated according to the guidelines provided for hazardous pollutants from multimedia sources (MEGs)(8).

The studies obtained during the literature search and document acquisition should be reviewed and rated as to their scientific merit and suitability for further use. The studies which are rated as being of high quality and which are suitable for use in range of concern determinations should be used to develop a concise set of tables listing the results of all related studies.* These tables are ultimately used to sort out the data prior to a decision on a range of concern.

The whole process of the health effect literature review can be considered as an effort to narrow, or validate, the preliminary range of exposure concentration suspected to be of concern which was determined at the start of the process. The detailed information may allow the higher and lower values of this range to be changed such that the differences between the high and low become smaller.

Once the appropriate information has been tabulated, a large table will be prepared compiling, separately, all the information for the animal and human studies. These studies will be arranged in numerical order from highest to lowest concentration, noting especially the exposure time, and will later be used in conjunction with the ambient air scenarios to graphically represent the conversion from an ambient air concentration range of concern to an emission factor range of concern.

In the event that health effects information is not readily available for a particular pollutant at low concentrations, but a TLV has been established for that same pollutant, an equation using the TLV can be used to compute ambient air concentrations for various exposure times (8). This equation is represented below.

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* Rating of the scientific studies should be performed by a competent, professional in the particular field of study (i.e. epidemiologist, toxicologist, pharmacologist). The rating process may vary but should include the evaluation of several aspects of each study such as the number of animal subjects in each test group, the suitability of the control groups used, comparison with historical controls and experimental results, suitability of analytical/pathological methods, etc. Peer reviews and judgements of independent experts are expected to be helpful when available.

$$TLV_{int} = \frac{TLV}{100} \times \frac{40}{e_x}$$

where TLV_{int} = Threshold Limit Value based intercept

TLV = Threshold Limit Value

100 = a safety factor (this value may vary but for the purpose of this paper is chosen to be 100)

40 = hours worked per week (assuming 8 hours per day, 5 days per week)

e_x = exposure time per week (in hours) corresponding to scenario X

It is desirable to have a full and complete literature search, but this is not always possible. The TLV-based approach is one that is not far from being a last resort. The TLV-based approach is also somewhat conservative as the following table indicates, as far as carbon monoxide (CO) goes.

Table II

Example of the TLV - Based Method

CO TLV	50 ppm (10)
CO value based on daily 8 hr exposure (50/100) x (40/40)	0.5 ppm
8 hr NAAQS for CO	9.0 ppm
CO value based on daily 1 hr exposure (50/100) x (40/5)	4.0 ppm
1 hr NAAQS for CO	35 ppm

It can be seen that the TLV-based method predicts lower values than those of the NAAQS, at least for CO.

III Concentrations To Which People Might Be Exposed

In order to relate the health effects information gathered in the health effects literature review to vehicle emission rates, a set of models must be chosen to represent situations of appreciable mobile source pollutant concentrations with significant public exposure. This involves the application of pollutant dispersion modeling techniques to estimate the concentrations of mobile source pollutants. Since toxic (non carcinogenic) pollutants are of primary interest in this report, special emphasis has been given to those models and situations which may reflect short-term scenarios to which the public is exposed.

In relating the public exposure of a mobile source pollutant to known health effects information, the most important parameter is the dose which the public receives. However, a pollutant dose determination for the general public is a very difficult parameter to measure, and there is expected to be considerable variation in the parameter throughout the population. Therefore, for the purposes of this approach, the exposure time of the general populace to the pollutant of interest in most cases will be assumed to be of approximately 1-2 hours per day, probably on each day of a 5 day work week. This overall exposure time may be spread among one or more of the scenarios listed below. This assumption is made to keep this approach simple with the intent that if the resulting analysis shows that a significant potential problem may exist, then a more detailed analysis of both the health effects and the exposure or dose may be desired.

Public exposure to mobile source pollutants occur in a variety of situations from potential short-term, high concentration events involving personal garages, parking garages or other enclosed spaces, to long-term low concentration events in an area wide scenario. For non genotoxic pollutants, the most relevant situations to be concerned about with respect to public health would appear to be high concentration short-term situations (acute exposures). This is not to imply that chronic effects of these pollutants are not of concern, but rather that these chronic situations require data from long term health studies, of which very few have been done. This report will be concerned with short-term high concentration exposures. These acute exposures are probably repeated often, perhaps five or more times in each week so that a chronic exposure to a repeated acute dose may be the most relevant exposure regimen. However, it is expected that little, if any, health effects data will be available for these conditions and that the most closely related health data will be used as a comparison to the mobile source case. The scenarios which should be used in this assessment are listed in Table III.

Table III - Exposure Scenarios

I. Enclosed Space

A. Single Family Garage

B. Parking Garage

C. Roadway Tunnel

II. Street Canyons

III. Expressway

A. On Expressway

B. Beside Expressway

IV. Localized Area Sources

A. Parking Lots, Airports

These scenarios may vary in the maximum concentrations of mobile source pollutants but each scenario has the potential for elevated concentrations under certain conditions which may lead to a public health hazard. For each of the scenarios listed above, it is possible to select an infinite number of input variables to determine the results. Among the variables which may have strong effects on the results are meteorological variables such as windspeed and atmospheric stability, model parameters such as the mixing factor, as well as physical parameters such as number of lanes per highway, number of vehicles, fleet composition, emission factors, and building height. Within this myriad of choices we selected two collections of variables for each scenario to represent an "average" and a "severe" situation with respect to the particular scenario. Each average and severe situation was chosen to represent a "real world" situation. A more detailed discussion of the situations listed above, along with the the models and conditions chosen, can be found in Appendix I.

Enclosed Space Models

The enclosed space scenarios which we have chosen to model include private residential garages, parking garages, and roadway tunnels. Each situation will be estimated using some form of Turk's equation (see Appendix I).

Residential Garage

The example conducted for the residential garage involves two situations, one with an operator entering the garage, opening the garage door, starting the car, warming the car up for 30 seconds, and driving out of the garage. This situation results, for example, in a garage concentration of 58 ppm CO in the case of an emission rate of 7 grams/min. CO. The second situation involves the previous condition followed by a 5 minute period of idle, with the garage door open, before the car is driven out. In this case, the CO has increased from 58 ppm to 280 ppm. The equations and charts in Appendix I can be used to perform similar calculations for other pollutants.

Parking Garage

The parking garage scenario is being estimated by the use of two separate parking structures. An underground parking structure (Los Angeles Music Center) is being used to simulate a severe case while an above ground parking structure (San Antonio, Texas) is being used to simulate an average or typical case for this scenario.

The ambient air concentrations for the parking garage scenarios were calculated using the following equations;

1. For contribution of initial concentration in garage

$$C_1 = C_o \exp(-R_i F_{V2} t/V)$$

2. For contribution of pollutant concentration in incoming ventilation air

$$C_2 = C_i [1 - \exp(-R_i F_{V2} t/V)]$$

3. For contribution of vehicles within the garage

$$C_3 = \frac{ng}{R_i F_{v3}} [1 - \exp(-R_i F_{V3} t/V)]$$

4. The total ambient concentration is:

$$C = C_1 + C_2 + C_3$$

where:

C = nominal pollutant concentration, ug/m^3

C_o = initial pollutant concentration at time, t = o, ug/m^3

C_1 = contribution of initial pollutant concentration, ug/m^3

C_2 = contribution of ventilation air, ug/m^3

C_3 = contribution of pollutant source, ug/m^3

C_i = concentration of pollutant in ventilation air, ug/m^3

F_v = effective ventilation factor, dimensionless

n = number of vehicles or emission sources, dimensionless

q = pollutant source rate of emission, g/min

R_i = ventilation rate, ft^3/min

t = time, minutes

V = volume, ft^3

In the severe case, the exposed population is assumed to be located at level 5 of the parking structure and is leaving the structure after a major event, 20 minutes after the garage started to empty. Then, for an emission factor (EF) of 1 g/min of pollutant, and an initial concentration assumed to be 1 mg/m^3 the following factors pertain to this severe case.

<u>Severe case parking garage (1 g/min EF)</u>

Level 5	9,600 ug/m^3 for 1g/min EF (ramp intake)
	46,100 ug/m^3 for 1g/min EF
Ramp 5 to 4	14,900 ug/m^3 for 1g/min EF
Ramp 4 to 3	12,300 ug/m^3 for 1g/min EF
Ramp 3 to street	10,100 ug/m^3 for 1g/min EF

As in all these situations, the emission factor (EF) is a direct multiplier so that pollutant concentrations can be directly factored up from the base level. To illustrate this severe case, CO can be used. If an emission rate of 7 g/min is used for both ramp and level areas then the following numbers are generated.

Level 5	9,600 x 7 g/min = 67,200 ug/m^3 (Ramp air)
	46,100 x 7 g/min = 322,700 ug/m^3
	Total Level 5 = 389,900 ug/m^3
	or 339 ppm
Ramp 5 to 4	14900 x 7 = 90 ppm
Ramp 4 to 3	12300 x 7 = 75 ppm
Ramp 3 to street	10100 x 7 = 61 ppm

This example illustrates the substantial build up of mobile source pollutants which may occur in an underground, mechanically-ventilated garage during a <u>high</u> vehicle use period.

The typical case provides factors for an above ground, naturally ventilated parking structure in San Antonio, Texas. For a 1 g/min emission rate these factors are:

Typical Parking Garage Scenario

Parking level	3,900 ug/m^3 for 1 g/min EF
Ramp Room	13,750 ug/m^3 for 1 g/min EF

To illustrate this example for CO, assuming a 0 ppm inlet air concentration, the concentrations corresponding to a 7 g/min emission rate are:

Parking level	7 x 3900 = 24 ppm
Ramp Room	7 x 13750 = 84 ppm

Roadway Tunnel

The average and severe roadway tunnel situations have been simulated by use of two separate roadway tunnels. The severe case has been selected as the Baltimore Harbor tunnel, which is a long, heavily used tunnel with a somewhat aged ventilation design. The typical case is a Minnesota highway tunnel. Details on these two tunnels and on the modelling methods used for the tunnel scenario can be found in Appendix I. The multiplicative factors for these situations are:

Tunnel Scenarios (1 g/mile emission rate)

Typical - 1123 ug/m^3 for 1 g/mile EF
Severe - 2856 ug/m^3 for 1 g/mile EF

Street Canyon

The street canyon situation will be simulated by a form of an equation developed by researchers at SRI, Int'l. and is represented by the general equation below.

$$C_v = \frac{7 \times 10^6 Q_L}{(U + 0.5)(S + 2)}$$

where:

C_V = ambient concentration resulting from the vehicles in the street canyon, ug/m^3

Q_L = vehicle emission rate, g/sec m

U = rooftop wind speed m/sec

S = slant distance from exhaust to receptor, m

7 = empirical correlation factor

10^6 = units conversion, grams to ug

0.5 = empirical wind correction, m/sec

2 = empirical slant distance correction, m

The general form of this equation has been indirectly verified by wind tunnel tests. Several situations have been worked out for the street canyon scenario. The example situations model a street canyon in San Antonio and Houston, Texas with specific physical characteristics. This example, using a unity emission factor of 1 g/mile results in the pollutant concentrations listed in Table IV.

Table IV

Street Canyon Ambient Air Concentration

		Concentration from Vehicle ug/m^3
Average Case	Sidewalk	31.3
	In Vehicle	114.1
Severe Case	Sidewalk	97.5
	In Vehicle	334.8

Since the emission factor in this equation is a direct multiplier, the concentration of any pollutant can be scaled up by multiplying the emission factor by a specific entry in Table IV.

Expressways

Expressway related exposure to mobile source pollutants can occur in essentially two ways: either by being in close proximity to the expressway (living and working close) or by being on the expressway as a commuter. These two situations call for different approaches to modeling. The close proximity case can be estimated by using one of the available line source dispersion models. This report will make use of the G.M. model developed by Chock. The close proximity expressway example uses an existing Houston, Texas freeway and obtains an ambient concentration vs distance from the roadway for a unity emission factor. Details on this can be found in Appendix I. The commuter case will be handled by use of the EPA Point, Area and Line model ("PAL") which can input both point and line source. The approach used can best be described as a relative motion procedure viewing each vehicle as a point source upwind of the commuter.

The close proximity expressway situation can be considered to be a severe case simulation. A typical case is not provided here because the ambient air concentrations resulting from this situation are very low compared to the other scenarios and thus only the severe case assumptions provide data that is useful in making up the various pollutant concentration profiles. The short term factors are calculated for a rush hour time period (one hour average) with an average traffic density of 3780 vehicles/hour. The factors that result from this expressway model treatment are listed below.

Table V
Close Proximity Expressway Situation (1 g/mile EF)

Distance downwind from road edge, meters	Ambient Concentration Short Term ug/m^3	Long Term*
1	397.0	61.0
5	368.0	55.0
10	334.0	48.0
25	248.0	35.0
50	171.0	27.0
100	105.0	14.0
500	26.3	4.0
1000	13.6	1.6

* The long term case has been developed using a long term average of observed values for CO along the Houston freeway. The values were corrected for emission factor in deriving the table above.

The on-expressway (commuter) scenario is simulated using a typical and severe case. This scenario used a specifically designed computer program, called ONEX, to calculate ambient concentrations of pollutants in the vicinity of the vehicles on the expressway. The typical exposure case used a San Antonio expressway running north and south during the peak rush hour. A 4 lane segment of this freeway with an average daily traffic of 30,000 vehicles per day was used in the simulation.

Table VI presents the multiplicative factors for the typical expressway situation using a range of wind directions and speeds. The range of these values (61 to 124 mg/m^3) is fairly close considering the large range of wind speeds used (1.0 to 6.0 mph).

TABLE VI AMBIENT CONCENTRATION FOR RECEPTOR ON EXPRESSWAY
TYPICAL EXPRESSWAY EXPOSURE SITUATION
1 g/mile EF

Wind Direction Degrees Relative	Wind Speed m/sec (mph)	Outside downwind lane Ambient Concentration ug/m^3
357.5	1.0 (2.2)	120
355.0	1.0 (2.2)	120
340.0	1.0 (2.2)	122
315.0	1.0 (2.2)	124
270.0	1.0 (2.2)	122
357.5	2.0 (4.5)	114
355.0	2.0 (4.5)	113
340.0	2.0 (4.5)	109
315.0	2.0 (4.5)	103
270.0	2.0 (4.5)	95
357.5	3.0 (6.7)	109
355.0	3.0 (6.7)	107
340.0	3.0 (6.7)	99
315.0	3.0 (6.7)	85
270.0	3.0 (6.7)	77
357.5	6.0 (13.4)	96
355.5	6.0 (13.4)	92
340.0	6.0 (13.4)	75
315.0	6.0 (13.4)	61
270.0	6.0 (13.4)	72

The severe exposure case used the Santa Monica freeway in Los Angeles. A 10 lane portion of this highway with a 200,000 vehicle/day traffic load was used in the simulation. Table VII presents the multiplicative factors for the severe situation.

TABLE VII. AMBIENT CONCENTRATION FOR RECEPTOR ON EXPRESSWAY
SEVERE EXPRESSWAY EXPOSURE SITUATION
1 g/mile EF

Wind Direction Degrees Relative	Wind Speed m/sec (mph)	Outside downwind lane Ambient Concentration ug/m^3
357.5	1.0 (2.2)	454
355.0	1.0 (2.2)	467
340.0	1.0 (2.2)	494
315.0	1.0 (2.2)	506
270.0	1.0 (2.2)	495
357.5	2.0 (4.5)	453
355.0	2.0 (4.5)	458
340.0	2.0 (4.5)	428
315.0	2.0 (4.5)	400
270.0	2.0 (4.5)	369
357.5	3.0 (6.7)	444
355.0	3.0 (6.7)	435
340.0	3.0 (6.7)	375
315.0	3.0 (6.7)	327
270.0	3.0 (6.7)	285
357.5	6.0 (13.4)	399
355.0	6.0 (13.4)	366
340.0	6.0 (13.4)	275
315.0	6.0 (13.4)	200
270.0	6.0 (13.4)	148

Area Wide Sources

Parking lots are an exposure scenario which may also involve large populations of people in close proximity to mobile sources. However, EPA studies (see Appendix I) have not shown appreciable levels in parking lots, although several measurements have shown levels up to 50 ppm CO where the parking lot enters the street. Normally, the levels were 20 ppm or less for CO even during peak use of a sports stadium parking lot where the intermittent use is important. Thus, it appears that parking lots do not produce as high a level of automotive pollutants as do the other scenarios. Because of the difficulty which was encountered in locating suitable models and applying them, no case was developed for this scenario.

IV Range of Concern Determination

Using the compiled information from the previous sections of this report, it is possible to convert the health effects data to corresponding mobile source emission factors for the various ambient air scenarios.

Figure 2 represents graphically the output of the mathematical models used to simulate the different scenarios used in this report. An inspection of this plot (Fig. 2) reveals that, for any specific ambient air concentration of pollutant, a large number of vehicle emission factors, one for each scenario, can be selected. However, if an ambient air concentration is intended to represent a lower or upper level of health effects concern, then an additional variable is important, and that variable is exposure time. The health effects data used to project or estimate a range of concern in the ambient air always has a specific exposure time associated with it, which relates back to the actual dose the organism receives when the adverse health parameters are measured. When comparing these health data to mobile source emission scenarios it is important to remain consistent regarding the exposure time. However, in practice it has been determined that very few if any health effects data have exposure times and exposure schedules similar to the actual human exposure to mobile source pollutants. Another confounding factor related to this exposure time issue is that the exposure time and exposure schedule of a specific individual in the population would be spread out among a number of the mobile source scenarios in any given day. As an example from Appendix I, consider the hypothetical exposure pattern of a typical suburban commuter.

Suburban Commuter Exposure (Weekday)

1)	Starts car in garage	5 minutes	-personal garage scenario
2)	Expressway to work	20 minutes	-Expressway scenario
3)	Tunnel on trip	5 minutes	-Tunnel scenario
4)	Central Business district on trip	10 minutes	-Street canyon scenario
5)	Evening reversal of above		

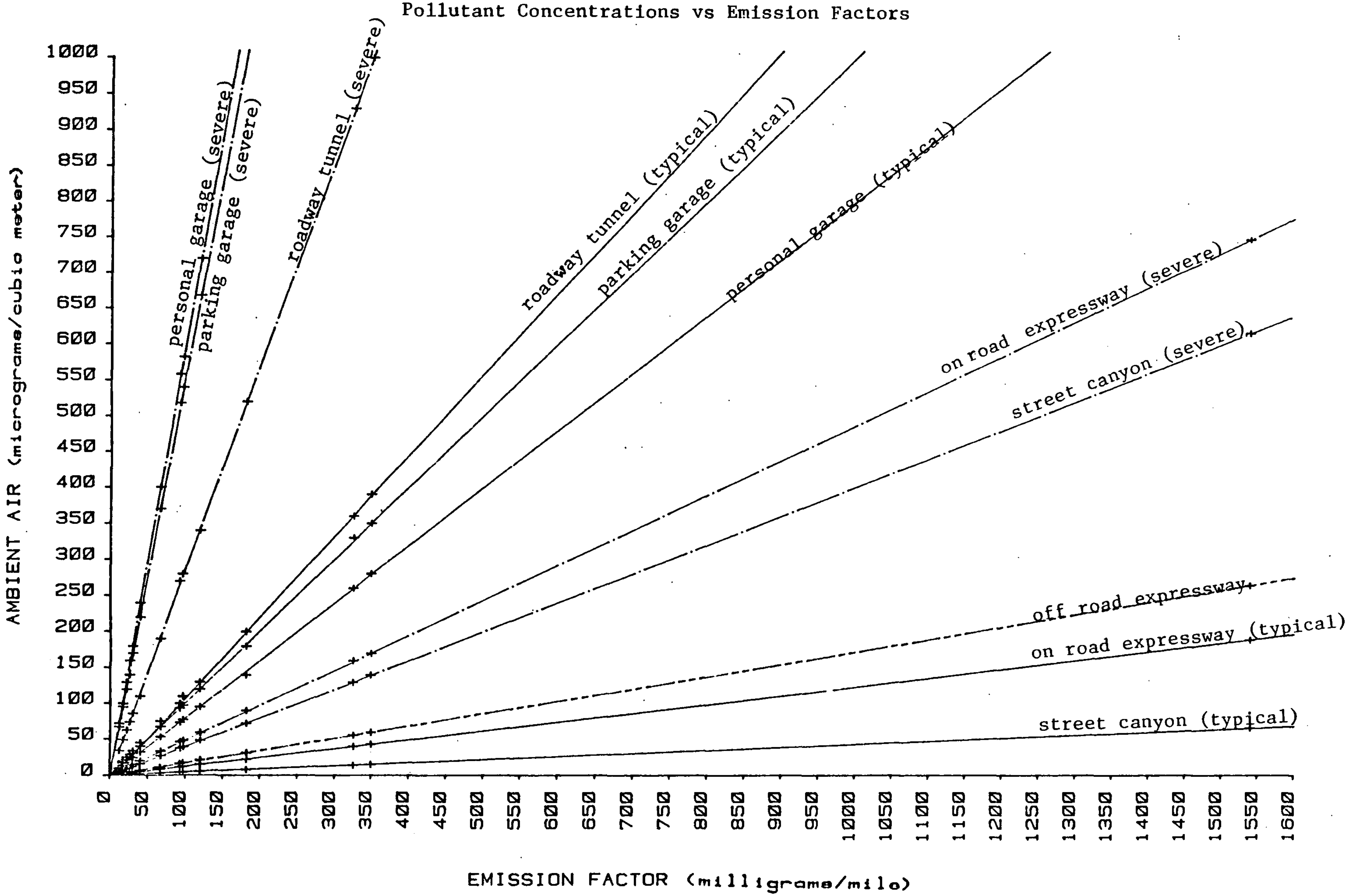
It can be seen from this example that this one individual experiences several types of automotive pollutant exposure in his/her work day.

In order to provide, in this methodology, a workable approach to estimate the levels of unregulated pollutants that may constitute a human hazard it has proven necessary to assume a standard exposure time and schedule and then try to fit the available health data into this regimen. Thus, for the purposes of this methodology the exposure time of the general population is assumed to be 1-2 hours/day, 5-7 day/week throughout the year. It is felt that this type of exposure is similar to what most populations are affected by in their normal activities. In most cases, health effects data resulting from exposures of this type will not be available, necessitating the use of judgement in arriving at the ranges of concern for mobile source pollutants. It should be emphasized at this point that this methodology is intended to provide an initial conservative assessment of the potential hazardous levels of unregulated pollutants from mobile sources. If a significant hazard appears possible, then it may be prudent to perform additional health and exposure studies to more concretely identify the potential hazard to exposed humans.

In addition to exposure time, other issues may be important to the overall evaluation of a mobile source pollutant. One such issue is atmospheric reactivity of a pollutant after it is emitted, which may decrease or increase the exposure of the population to mobile source pollutants. When information

Figure 2

Pollutant Concentrations vs Emission Factors



D> C. DEMEYER/emk

on the reactivity of a pollutant is available, it can be used to modify the emission factors by an appropriate amount. However, in most cases this information is not expected to be readily available and should not be considered necessary for the use of this methodology.

After the ambient air range of concern is identified using the appropriate health effects data and utilizing the assumptions on exposure time stated previously, then this range of concern can be converted to vehicle emission factors for the various mobile source exposure scenarios. The result of this exercise should be a table (illustrated fully in the example provided later in the report as Table XII) compiling, in effect, a range of concern for each scenario and situation. In certain cases, the use of both the high and low levels of the range of health effects may be inappropriate, such as when a severe situation (e.g. Severe Expressway) is compared to the low level of the range of concern, if the low level were derived using long term exposure data, and the severe situation were derived using parameters (e.g. meteorology) that would only occur infrequently.

An examination of this table of ambient concentrations will reveal that one scenario will be dominant in that it will have the lowest emission factor range of concern. However, if this scenario is an inappropriate measure of the potential levels of human health hazard for the specific pollutant of interest, or if other scenarios are of specific interest, then other portions of the exposure table will also be important.

Initially, the derivation of the emission range of concern for a specific scenario will apply to the average emissions of that pollutant for the entire vehicle fleet, except for the residential garage situation. However, in most cases, it will be desirable to compare specific vehicle/ emission control technology combinations to this range. Obviously, if a high emitting technology, with respect to a particular pollutant (compared to the other technologies) has a maximum emission rate below the lowest level of the range, then that technology poses no concern relative to that pollutant. However, if a specific emission control technology has an emission factor which falls within the range of concern for a specific scenario, then some question will exist with respect to that technology and it will, therefore, be subject to closer scrutiny. The overall evaluation will take into consideration additional factors which include the fleet average emissions of the pollutant and the maximum percentage of that technology which can be expected in the future. Any technology which has an emission factor above the highest level of the range will be considered as potentially hazardous with respect to that pollutant.

Summary and Conclusions

This methodology has been designed to be a valid and workable approach toward estimating whether emissions of an unregulated pollutant are a potential hazard to public health. The effort of trying to maintain a simple approach has resulted in the necessity of using several simplifying assumptions to avoid complexities inappropriate to the nature of this methodology. If a potential problem is uncovered by this methodology for an unregulated pollutant, then a more detailed investigation of that specific pollutant can be undertaken to provide a more complete evaluation of the hazard. The more important simplifying assumptions are that pollutants are non-reactive within the time frames considered, short term exposures are most relevant and health effects data can be used to estimate the effects of mobile sources on public health.

To illustrate the way that this methodology works, the last section of this report provides an example of one pollutant, sulfuric acid.

Sulfuric Acid Example

This section is presented as an illustration of the way in which major portions of this approach are intended to work. Sulfuric acid has been chosen as the example pollutant for the approach because there is a large amount of existing data on it, both in the health effects and emission factors area. In spite of this apparent depth of information and data, no range of concern for mobile source emissions has ever been estimated or established for this compound.

Sulfuric Acid Emission Factors

Emission factors for sulfuric acid were collected from a number of available sources and are listed in Table VIII. These emission factors have been compiled at this time only for the Congested Freeway Driving Schedule. This particular driving schedule is most applicable to the expressway exposure situation, but may still have utility for the street canyon situation. The emission factors for the enclosed space conditions, which would best be derived from an idle or slow speed schedule, will be the subject of further work to identify concrete emission factors for these situations.

While this example is concerned with sulfuric acid only, the emission factors reported here generally are measurements of aqueous soluble sulfates. In most cases, the predominant soluble sulfate species in mobile source exhaust is sulfuric acid (10). However, other sulfates such as ammonium sulfate could be present. For the purposes of this example, it is assumed that the mobile source emission factors represent 100 percent sulfuric acid.

These emission factors can be combined to calculate fleet average emission factors for the vehicle fleet by using available information on vehicle miles traveled (VMT) for the different vehicle classes. For simplicity in this example the VMT fractions will be derived from information in the Pedco report (6) for calendar year 1980 and Mobile Source Emission Factors: For Low Altitude Areas Only (7). In future assessments, other references may be used to perform these calculations. Table IX provides a breakdown of the vehicle class VMT's and the fleet average emission factor for sulfuric acid.

Obviously this particular set of calculations does not represent any specific fleet emission factor. Depending on the make up of the vehicle fleet at any point in place or time that is of interest, the fleet emission factor will differ. The most severe case could be considered to be the scenario where high sulfuric acid emitting technology is the predominant member of the vehicle fleet. To address this possibility, and the possible presence

TABLE VIII
Sulfuric Acid Emission Factors*

Vehicle Category	Sulfuric Acid (mg/mile)** Avg
Light Duty Diesel Vehicles	9
w catalyst	100
w trap Oxidizers	100
Light Duty Diesel Trucks	16
Heavy Duty Diesel Trucks	100
Light Duty Gasoline Vehicles	
Non Catalyst; no air pump	0.2
Non Catalyst; air pump	1.0
Oxidation Catalyst; no air pump	10
Oxidation Catalyst; air-pump	20
3-way Catalyst	4
3-way Plus Oxidation Catalyst; air pump	30
Light Duty Truck	
Non Catalyst	1.0
Catalyst, no air pump	20
Heavy Duty Gasoline Vehicles	4

* Based on congested Freeway Driving Schedule and 0.030 wt % Sulfur for gasoline and 0.2 wt % for Diesel fuel. These emission factors may change with other fuel sulfur levels or test cycles.

** Reference 9-14.

TABLE IX

Fleet Average Emission Factors - Sulfuric Acid*

Vehicle Class	Fraction VMT	Emission Factor (mg/mile)	EFxVMT Fraction
Light Duty Diesel Automobiles	0.015	9.0	0.135
Light Duty Diesel Trucks	0.002	16.0	0.032
Heavy Duty Diesel Trucks	0.027	100.0	2.700
Light Duty Gasoline Vehicles			
Non Cat.; no air pump	0.147	0.2	0.029
Non Cat.; air pump	0.098	1.0	0.098
Ox. Cat.; no air pump	0.289	10.0	2.890
Ox. Cat.; air pump	0.261	20.0	5.220
3-way Cat.; no air pump	0.012	4.0	0.048
3-way Plus Ox. Cat.; air pump	0.008	30.0	0.240
Light Duty Gasoline Trucks			
Non Catalyst	0.096	1.0	0.096
Catalyst	0.010	20.0	0.200
Heavy Duty Gasoline Trucks	0.035	4.0	0.140

Total Fleet Average Sulfuric Acid 11.8 mg/mile

*These calculations were based on available information from the reference listed above (7,8) and in Table 1. Buses, which may be a significant source of sulfuric acid emissions under certain conditions, are not included in these fleet averages.

of future technology, the fleet average emission factor can be modified to reflect different proportions of these higher emitting technologies. As a worst case, a vehicle fleet consisting of 100 percent of the highest emitting technology could be calculated.

Table VIII also presents emission factors for vehicle/emission control categories which are expected to be the highest emitters of sulfuric acid under a variety of conditions. Obviously, it is these technologies, on an individual basis, that might be expected to constitute the most likely source of an unreasonable risk to public health. Since most of these technologies are not yet in common use except on an experimental basis, the potential risk can be considered to be a future concern. To establish bounds on the potential risk from sulfuric acid that these technologies present, they will be considered in a number of hypothetical calculations to comprise 25, 50, 75 and 100 percent of the total vehicle miles traveled.

By using the fleet average emission factors in Table IX and the hypothetical calculations listed above, a list of emission factors can be calculated to use in subsequent steps. This list is presented in Table X.

Sulfuric Acid Health Effects

A literature review on the health effects of sulfuric acid was performed as an input to the determination of a range of concern for mobile source emissions of this compound. At the present time only a preliminary draft of this literature is available and further information may modify the conclusions. The preliminary draft of the literature search is included as Appendix II to this report.

As indicated in the methodology, in order to focus the health effects literature review, a preliminary range of ambient levels has been selected to bracket the region of uncertainty with respect to sulfuric acid health effects. This range has been determined to be 10 ug/m^3 - 1000 ug/m^3 for sulfuric acid. The lower end of this range has been selected to approximate the lowest level at which adverse physiological effects can be detected. The preponderance of the evidence has shown little or no health effects at levels of sulfuric acid below this, although there are some indications that sensitive subgroups of asthmatics may show some reaction to these levels of sulfuric acid. To as great an extent as possible, this lower level also takes into account the interactions of various pollutants such as SO_2 and H_2SO_4.

The upper level of the range is chosen to be the TLV recommended by NIOSH and the ACGIH as 1000 mg/m^3 (9). Above this level several studies have shown an adverse reaction in healthy subjects which may be harmful under repeated exposures.

Table X
Sulfuric Acid Emission Factors - Compiled

Fleet Category	mg/mile@
Fleet Average (FA)	12
FA + 25% 3W +OC*	17
FA + 50% 3W+OC	22
FA + 75% 3W+OC	26
100% 3W+OC	30
FA + 25% D+C**	34
FA + 50% D+C	56
FA + 75% D+C	75
100% Diesel Cat.	100
FA + 25% D+To***	34
FA + 50% D+To	56
FA + 75% D+To	75
100% D+To	100

@ Normalized to the Congested Freeway Driving Schedule
* Light Duty Gasoline Vehicle - Three way + Oxidation Catalyst with air pump
** Light Duty Diesel Vehicle - Catalyst equipped
*** Light Duty Diesel Vehicle - Trap-oxidizer equipped

Sulfuric Acid Ambient Air Concentrations

By using modeling techniques in conjunction with sulfuric acid emission factors, ambient concentrations can be determined that should bracket the range of possible sulfuric acid emission concentrations from mobile sources. This matrix of ambient concentrations (Table XI) is composed of five scenarios, out of thousands possible, and was chosen at this time as one example of the exposure ranges. More work is currently being done to more concretely specify the most appropriate scenarios to use and thus the scenarios may change in future efforts of this kind. The information in Table XI is depicted graphically in Figure 2.

As indicated above, the range of exposures to the general public can be estimated by considering a limited number of specific scenarios. The scenarios selected are all expected to be dominantly influenced by mobile source emissions. Personal garages, parking garages, roadway tunnels, street canyons, and urban expressways have been selected to bracket the range of sulfuric acid concentrations from mobile sources that influence short term health effects in the exposed population. Each scenario is developed as both severe and average exposure situations calculated by the use of existing ambient air modeling techniques. No attempt has been made to determine the cumulative effects of these situations on general public health. Appendix I contains a detailed explanation of the rationale for choosing the specific situations and parameters which lead to the numerical results presented here.

Table XI presents the ambient air concentration of sulfuric acid for eleven ambient situations as a function of vehicle emission rates. Two personal garage situations are presented, one (average or typical) using a 30 second vehicle warmup time and the other (severe) using a five minute vehicle warmup time. These two situations are intended to simulate summer and winter conditions, respectively.

The two parking garage situations simulate average and severe conditions, with an above ground, naturally ventilated garage for the former and an underground garage for the latter. The average parking garage case is calculated assuming an exit time in which the vehicle spends equal time on the parking level and the ramp level. The severe parking garage is calculated assuming that the exposure takes place 20 minutes after a major sporting event finishes, wherein the exposed population is at parking level 5. The initial concentration of sulfuric acid in this garage is assumed to be low (1 mg/m^3).

The roadway tunnel situations used two different specific tunnels to estimate an average and severe condition. A new design, two lane roadway tunnel with moderate traffic flow is used for average conditions, while an old design, heavily used roadway tunnel is used for severe conditions.

The two street canyon situations are simulated by examining the parameters of two street canyons. The most sensitive parameter in this model appears to be the number of traffic lanes in the canyon. The severe condition is calculated for a six lane street canyon with a 2400 vehicle/hr traffic load and with the exposed population located inside of the vehicle. The typical condition is calculated for a two lane canyon with 800 vehicles/hr of traffic and a sidewalk location of the exposed population.

The expressway situations require three specific estimations to cover the range of possible concentrations. One highway condition tends to estimate an exposure involving a close proximity to the highway such as would be gotten by living or working close to a heavily travelled freeway. This case is calculated on a short term basis for a distance of 50 meters downwind of the roadway. The other two expressway situations simulate a commuter (located in the vehicle) exposure, with the average case using a four lane, medium use 1400 vehicle/hour) and a westerly wind at 1.0 meters/sec and the severe case using a ten lane, heavily travelled (3600 vehicles/hr) freeway with a 1.0 meter/sec westerly wind.

Determination of the Range of Concern

The range of concern for sulfuric acid emissions from automobiles is determined using the outputs from the previous three areas, emission factors, health effects and exposure estimation (the emission factors and exposure estimates have already been combined in Table XI). Using the preliminary range (10 ug/m^3 - 1000 ug/m^3) as a stepping stone for this effort, along with the guidelines explained earlier in the methodology section of this report, an upper and lower value can be determined for the final range of concern.

The literature search reveals a human study which shows that an acute exposure concentration as low as 66.0 ug/m^3 caused significant differences in lung function parameters in 3 out of 18 subjects tested (Gardner et. al. 1976). The evidence provided in the literature also shows that no physiological effects were detected for exposure concentrations below 66.0 ug/m^3. Since, at this time, there is no available information definitely concluding that there are adverse physiological effects at concentrations of sulfuric acid below 66.0 ug/m^3, this value will be chosen as the lower value in the range of concern.

The upper value of the range will remain at 1000 ug/m^3 as was set for the preliminary range of concern. This TLV for sulfuric acid is the time-weighted average concentration for a normal 8-hour workday or 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effects. The evidence of adverse health effects above this level would be sufficient to support regulatory action.

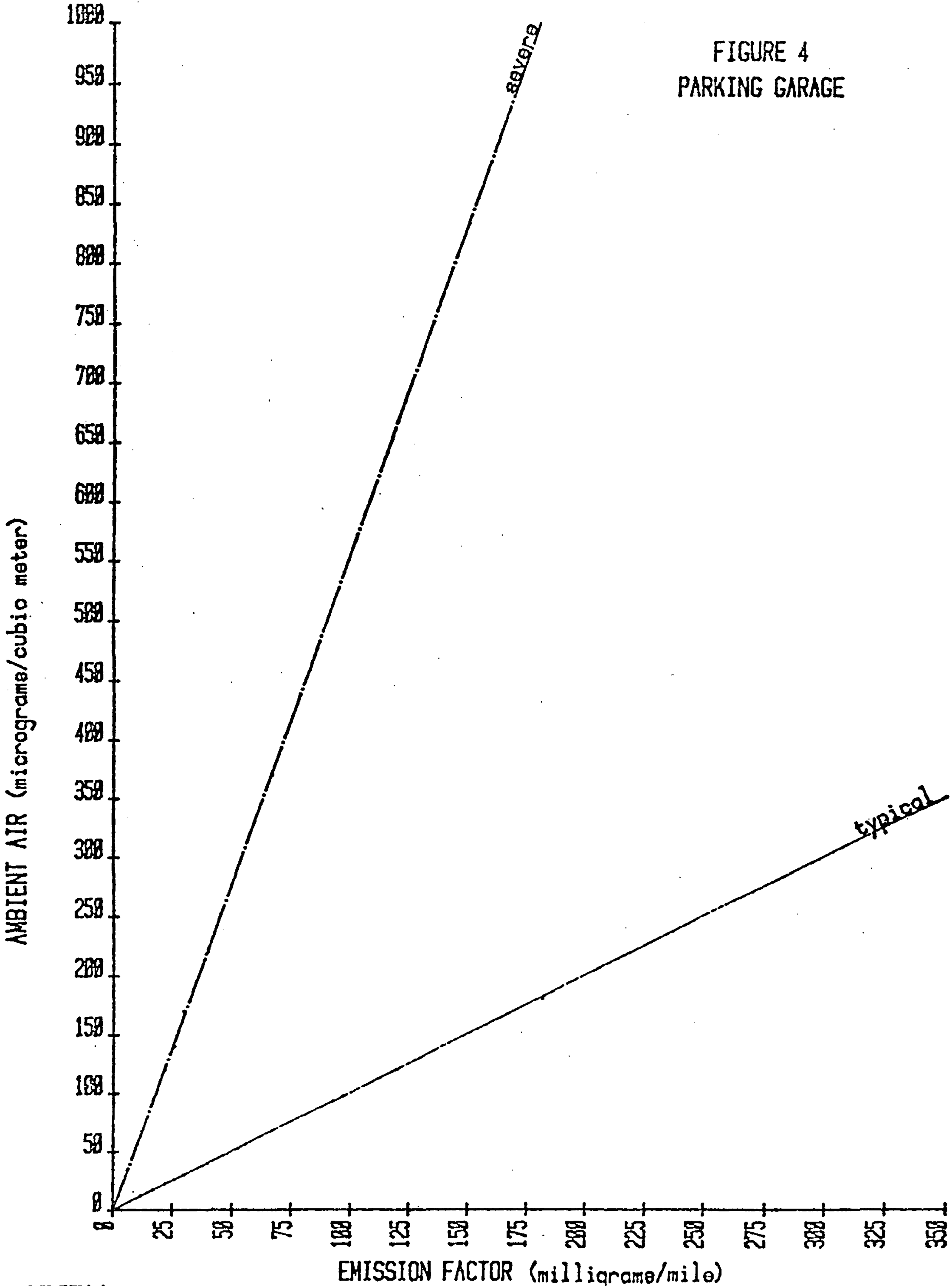
Between the chosen limits of this range, there are scattered data points providing evidence of adverse physiological effects caused by exposure to various concentrations of sulfuric acid. Therefore, this region has been termed the "range of concern" for sulfuric acid concentrations in the ambient air. This range can now be used in conjunction with the emission factor data to graphically present the conversion of sulfuric acid emissions to ambient air concentrations.

Once the literature search was completed and the appropriate information was tabulated for sulfuric acid, a large table was prepared compiling all the information for the animal and human studies (see Appendix III). These tables list the studies according to the exposure concentration of sulfuric acid (highest to lowest concentration). Using this health effects information along with the emission factor data presented in Table XI, graphs were composed representing the relationship between ambient air concentrations, emissions factors, and the various types of public exposure situations (see Figure 2-7).

According to the methodology described earlier in the report, the lower and upper levels which comprise the health effects range of concern are compared to the mobile source situations to calculate the emission factor range of concern. The chief element of comparability between the health effects range and the ambient situations is exposure time. Most of the mobile source situations simulate short term exposures (durations of an hour or less per day) perhaps repeated several times per week over an extended period. The average exposure situations appear more likely to be repeated often, while the severe exposure conditions would likely only occur on infrequent occasions.

With the above information, the mobile source range of concern for sulfuric acid can be estimated for the different mobile source situations. Table XI lists the vehicle emission factors which correspond to the high (1000 ug/m^3) and low (66 ug/m^3) portions of the range of concern for sulfuric acid. Inspection of this table shows that the scenarios result in a variety of ambient concentrations corresponding to the health effects range of concern of 66 ug/m^3 to 1000 ug/m^3.

FIGURE 4
PARKING GARAGE



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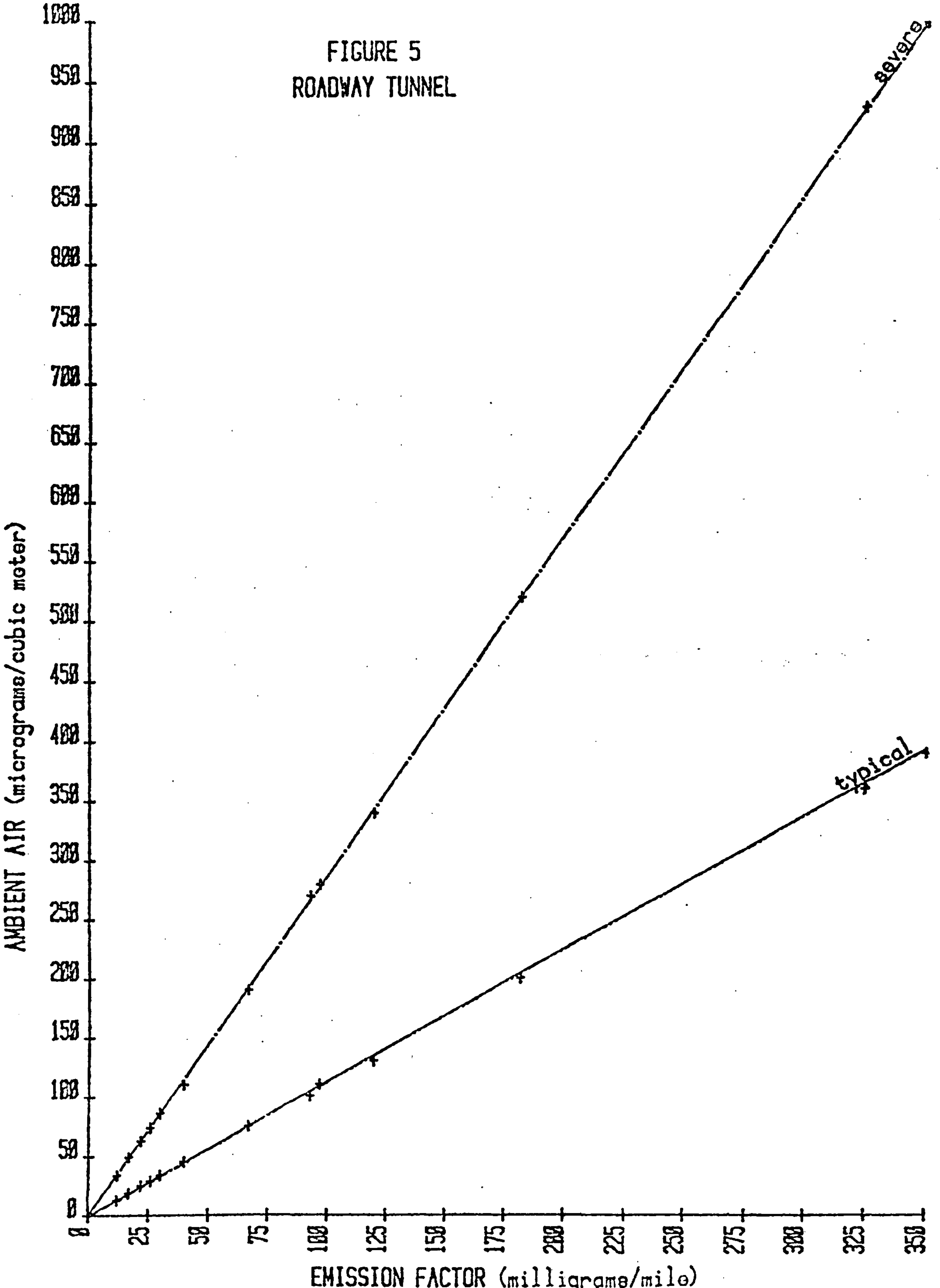

C.DEMEYER/amk

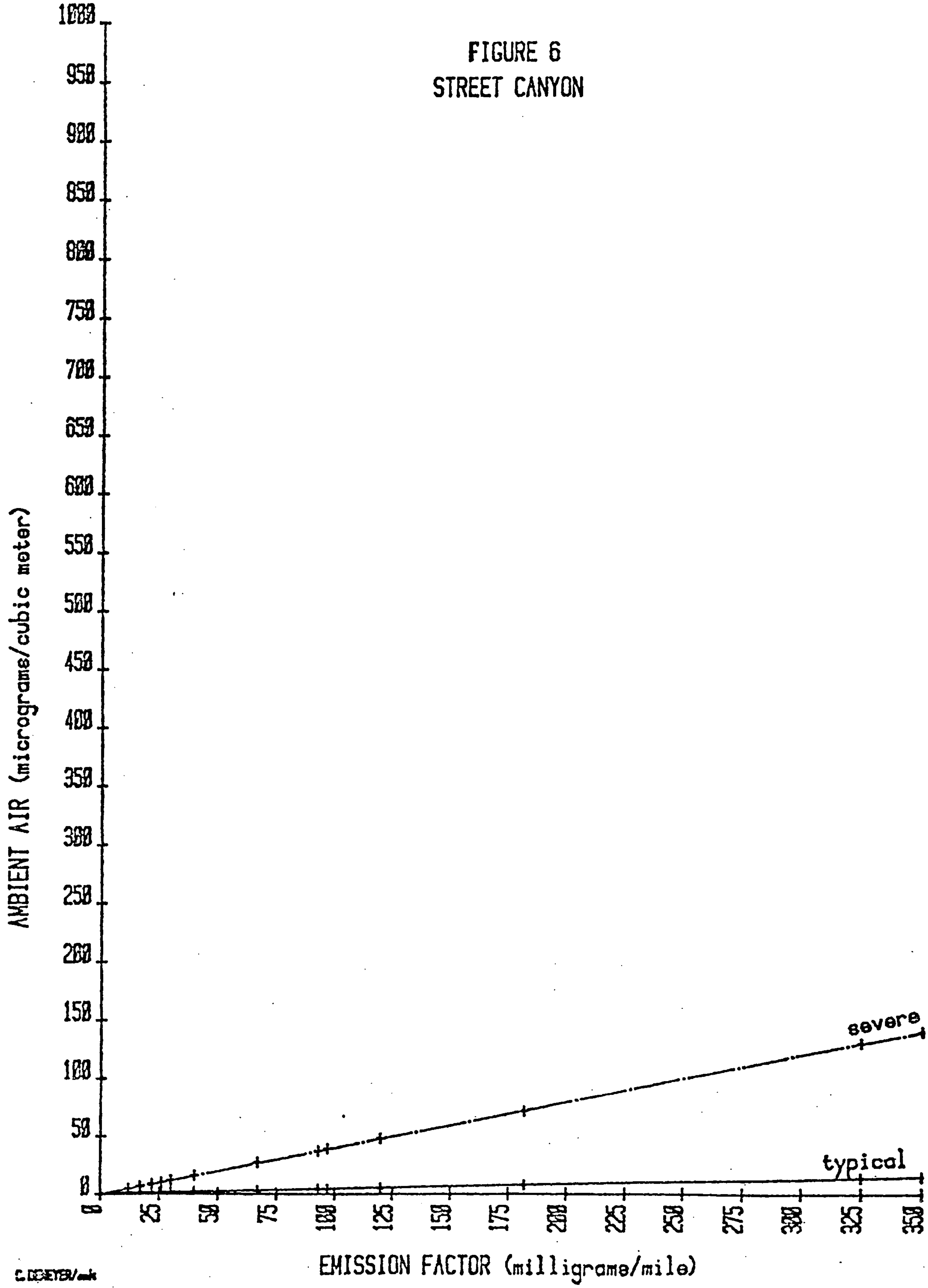
FIGURE 6
STREET CANYON
AMBIENT AIR (micrograms/cubic meter)
1000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
severe
typical
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
EMISSION FACTOR (milligrams/mile)

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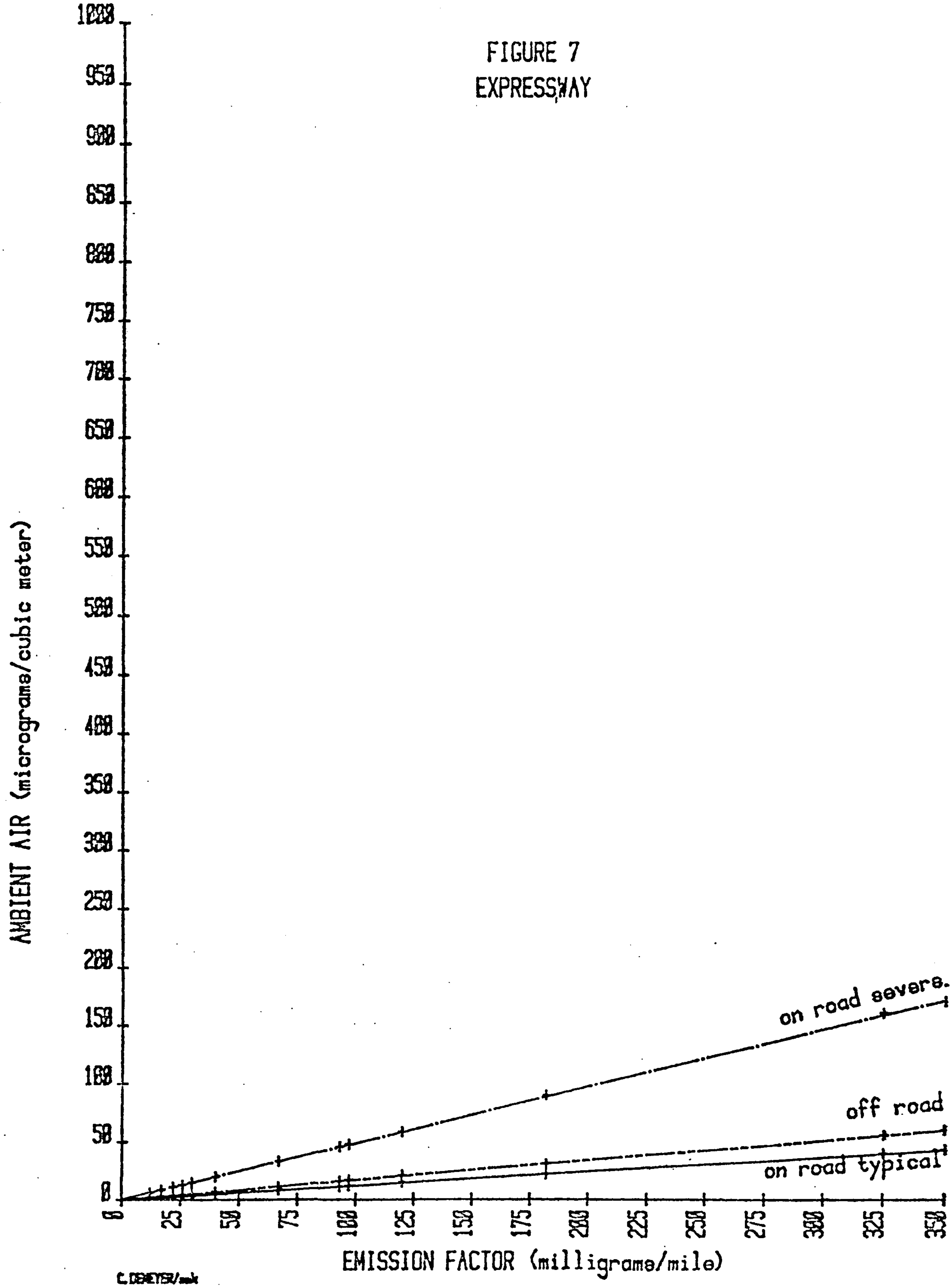
FIGURE 7
EXPRESSWAY
AMBIENT AIR (micrograms/cubic meter)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
EMISSION FACTOR (milligrams/mile)
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
on road severe
off road
on road typical
C.DEHEYSR/mak

TABLE XI
Emission Factors Required to Result in Two Different Ambient Sulfuric Acid Levels***

Ambient Situation*	Emission Factor mg/mile for 66 ug/m^3 exposure	Emission Factor mg/mile for 1000 ug/m^3 exposure
Street Canyon - Typical	1540	23077
Expressway - Typical	619	9375
Expressway - Close Proximity	388	5882
Street Canyon - Severe	165	2500
Expressway - Severe	132	2000
Personal Garage - Typical**	-	-
Parking Garage - Typical**	-	-
Roadway Tunnel - Typical	59	822
Roadway Tunnel - Severe	22	350
Parking Garage - Severe**	-	-
Personal Garage - Severe**	-	-

* In order of increasing ug/m^3 concentration for 1 g/mile (or 1 g/min) emission rate.

** These situations were not evaluated for sulfuric acid because of an inadequate data base for emission factors under idle and low speed conditions.

*** If the severe roadway tunnel situation is of primary interest then a fleet emission factor of 22 mg/mile over an appropriate driving schedule will be enough to put the ambient concentration within the range of concern. However, if expressway operation is of primary interest, then emission factors of up to 132 mg/mile would yield ambient concentrations below the range of concern even for severe conditions.

Summary and Conclusions - Sulfuric Acid

1) The range of concern for sulfuric acid emissions from motor vehicles varies from 22-350 mg/mile to 1540-23077 mg/mile depending on the scenario and situation of interest.

2) The lowest level of this range (22 mg/mile) is based on an ambient air concentration of 66 ug/m^3 for a severe roadway tunnel situation.

3) No vehicle emission factors from the garage scenarios were considered in calculating the range of concern. More data is probably needed on emissions of sulfuric acid from light duty vehicles under idle and slow speed conditions to evaluate the effects of the garage situations on the sulfuric acid range of concern.

4) The roadway tunnel scenario appears to be a controlling factor in this methodology for the sulfuric acid case. There is some doubt whether this scenario identifies a potential mobile source problem or a potential roadway tunnel ventilation problem. If a potential problem were identified resulting from roadway tunnel exposures to mobile source pollutants, then it is possible that the most appropriate solution would be to increase tunnel ventilation rather than to reduce the vehicle emissions.

5) This preliminary example of sulfuric acid has not considered a specific margin of safety. It is possible that the inclusion of the roadway tunnel scenario as the controlling factor in the range of concern consitutes a margin of safety in view of conclusion 4 above, but no specific factor has been calculated.

6) The current vehicle fleet emission factor for sulfuric acid is 12 mg/mile, which is well below the lowest of the ranges of concern for sulfuric acid.

7) With respect to specific vehicle emission control designs, and referring to Table IV, it appears that the emission control design/ vehicle categories that have emission factors most often appearing within the ranges of concern are Heavy Duty Trucks and Light Duty Diesel vehicles with trap-oxidizers (100 mg/mile).

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(2) Analytical Procedures for Characterizing Unregulated Emissions from Vehicles Using Middle Distillate Fuels, EPA Report No. 600/2-80-068.

(3) Regulated and Unregulated Exhaust Emissions from Malfunctioning Non Catalyst and Oxidation Catalyst Gasoline Automobiles, EPA Report No. 460/3-80-003.

(4) Regulated and Unregulated Exhaust Emissions from Malfunctioning Three-way Catalyst Gasoline Automobiles, EPA Report No. 460/3-80-004.

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(10) Regulated and Unregulated Emissions from Malfunctioning Automobiles, SAE Paper 790606.

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(13) Light Duty Diesel Catalysts, EPA Report No. 460/3-80-002.

(14) Automobile Sulfate Emissions - A Baseline Study, SAE Paper 770166.