EPA-450/2-89-012a
July 1989

ANALYSIS OF AIR TOXICS EMISSIONS, EXPOSURES, CANCER RISKS AND CONTROLLABILITY IN FIVE URBAN AREAS

VOLUME I

Base Year Analysis And Results

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EPA 450/2-89-012a

EXECUTIVE SUMMARY

BACKGROUND

The U.S. Environmental Protection Agency (EPA), under its National Air Toxics Strategy (U.S. EPA, 1985a), has initiated a program to assess the nature and magnitude of the air toxics problem in urban areas. This urban air toxics problem, sometimes called "urban soup," is characterized by complex multi-source interactions and multi-pollutant exposures. Numerous studies, including this study, suggest that areawide lifetime excess cancer risks from urban soup may range from about 1 in 10,000 to 1 in 1,000, and that cancer incidence may range from 1 to 23 excess cases per year per million population (Lahre, 1988a).

EPA has been encouraging state and local air pollution control agencies to assess their urban air toxics problems. Numerous assessment activities have been undertaken in the last several years in the areas of ambient air monitoring, emission inventorying, exposure and risk characterization, and mitigation analyses. At the same time, EPA is promoting the coordination of air toxics control programs with ozone (O_3) and particulate matter (PM_{10}) control programs to assure that, whenever possible, State Implementation Plans (SIPs) incorporate measures that reflect co-control of air toxics (52 FR 45072).

PURPOSE OF STUDY

The purpose of this study was as follows:

- define the multi-source, multi-pollutant nature of the urban air toxics problem, and
- discern what control measures (or combinations of measures) can best be employed to mitigate the urban air toxics problem.

This study was conducted in two phases, each phase relating directly to the above-stated goals. The first phase was the base year analysis, and involved dispersion modeling of emissions data for five urban areas in the country. In this first phase, the latest available emissions and source data were compiled and used as input to EPA's Human Exposure Model (HEM) to estimate ambient air concentrations and population exposures to 25 known or suspected air carcinogens. From this modeling exercise, estimates were made of the sources and pollutants contributing to additive (i.e., multi-pollutant) cancer risk throughout each urban area. Emphasis was placed on estimating areawide population risk, i.e., aggregate incidence, from multi-pollutant, multi-source exposures. The year 1980 was nominally defined as the base year in this analysis, although some later year data were incorporated into the data base.

The second phase was the projection analysis, and included an evaluation of the mitigation potential of various control measures when superimposed on the base year emission inventory. One set of measures represented "baseline" controls, i.e., those

controls already in place as a result of current "on-the-books" measures. These "baseline" measures include the Federal Motor Vehicle Control Program (FMVCP), New Source Performance Standards (NSPS), and National Emission Standards for Hazardous Air Pollutants (NESHAP). In addition, various alternative control measures were evaluated over and above the baseline measures. These alternative measures included new measures reasonably anticipated to be in effect in the near future as well as a maximum controls or Best Available Control Technology (BACT) strategy. The year 1995 was defined as the "projection year" in this analysis. Changes unrelated to emissions (e.g., meteorology) were not considered in this analysis.

VOLUME I REPORT ORGANIZATION

This study is documented in two major parts. Volume I reports on the methods and results associated with the base year analysis. Volume II will be published under separate cover as a companion document and reports on the methods and results associated with the projection, or controllability, analyses.

Volume I is organized according to each major activity as follows:

- methodology overview
- emission inventory enhancement
- dispersion modeling and exposure/risk characterization
- base year results
- assumptions/limitations
- conclusions

DISPERSION MODELING ANALYSIS

Two major approaches are currently used for conducting urban air toxics assessments: (1) ambient air monitoring and (2) dispersion modeling of emissions. In the former, measured ambient levels of air toxics in an urban area are multiplied by cancer unit risk factors and applied to population data to calculate individual risks and aggregate incidence. In the dispersion modeling approach, an emission inventory is compiled for the air toxics of concern and is modeled (using various long-term dispersion models) to predict ambient air concentrations over the urban area. These modeled ambient air concentrations are then used to estimate individual risks and aggregate incidence as if they were measured data.

Important advantages of the dispersion modeling approach are that it allows one to predict risk reductions as a function of anticipated emission changes and it allows ambient air levels to be projected at many more receptors than may be possible in air sampling networks. It also allows one to handle pollutants (e.g., Cr^{+6}) for which ambient sampling

methods are not available or cost effective and to assign risk to different emitters of the same pollutant.

This study employs the dispersion modeling approach for all pollutants with the exception of secondary formaldehyde. No validated photochemical models were available to predict secondary formaldehyde production via modeling; hence, ambient formaldehyde measurements were used to estimate cancer incidence and risks associated with secondary formaldehyde exposures.

EMPHASIS ON CANCER

This study estimated cancer risks from long-term (i.e., annual average) exposures to multiple pollutants. This type of analysis has predominated urban soup assessments. To date, limited work has been done to quantify noncancer risks associated with short-term (i.e., acute and subchronic) exposures to air toxics.

The most commonly used measure of cancer risk in urban soup assessments is "aggregate cancer incidence," which is a measure of the number of excess lifetime cancer cases over an entire urban area associated with multi-source, multi-pollutant exposures to air toxics. (This is also called "population risk.") Incidence is typically expressed as the number of excess cancer cases expected in a single year, but is estimated based on an assumed 70 year "lifetime" exposure. In this study, incidence is considered additive (incidence is estimated for individual compounds and then summed) and is population-normalized by adjusting per million persons. As such, the measure of cancer risk most commonly expressed herein is "excess aggregate additive incidence per year per million population." Normalization by population allows incidence to be compared from one urban area to another.

SCREENING STUDY

This study, like most urban assessments to date, should be considered a screening (or scoping) analysis, performed to yield an order-of-magnitude estimate of the relative nature of the urban cancer problem rather than to provide an absolute prediction of cancer incidence and individual risks. It is especially critical in this type of study to ensure that the scope and use of the conclusions be kept compatible with one's confidence in the underlying data base and analyses. Most studies to date of this type are acknowledged to be screening or scoping studies whose results should be used only in a relative sense for providing broad program direction to suggest where more detailed and focused follow-up work is needed.

Not all of the data and procedures used in this analysis have been reviewed and approved by the States or local air agencies whose jurisdictions encompass the study cities. In many cases, especially with small point and area sources, EPA and its support contractor made their own emission estimates based on national data and "top down" procedures. For

these reasons, no results are associated with any particular city in this report. Instead, all city-specific results are associated with "Study Area A," "Study Area B," etc.

Because of the many assumptions and limitations inherent in this type of assessment, and because of different characteristics of each of the five cities, the composite results for all five cities may provide a better overall representation of the urban air toxics problem in the United States than the results for any single city.

RELATIONSHIP TO PREVIOUS CONTROLLABILITY STUDY

EPA conducted a controllability study for these same five cities in 1985. The results were not formally published, but were used to help formulate EPA's National Air Toxics Strategy. Since 1985, many of the procedures and data used for conducting urban assessments have changed significantly (especially the emission factors and cancer potency factors for a number of important pollutants). Hence, this study builds on the previous data base by (1) updating the source and emissions data with more recent national and local information, (2) incorporating more recent cancer unit risk factors, and (3) reflecting a new comparative potency approach (U.S. EPA, 1987b) for quantifying risks from polycyclic organic matter (POM), previously defined as products of incomplete combustion (Haemisegger, 1985). Nevertheless, for many point sources, the same data exist in the data base as were present in the 1985 study.

Because the results from the 1985 controllability study are now considered outdated, little emphasis is placed on them in this report. The major changes are highlighted briefly in Chapter III.

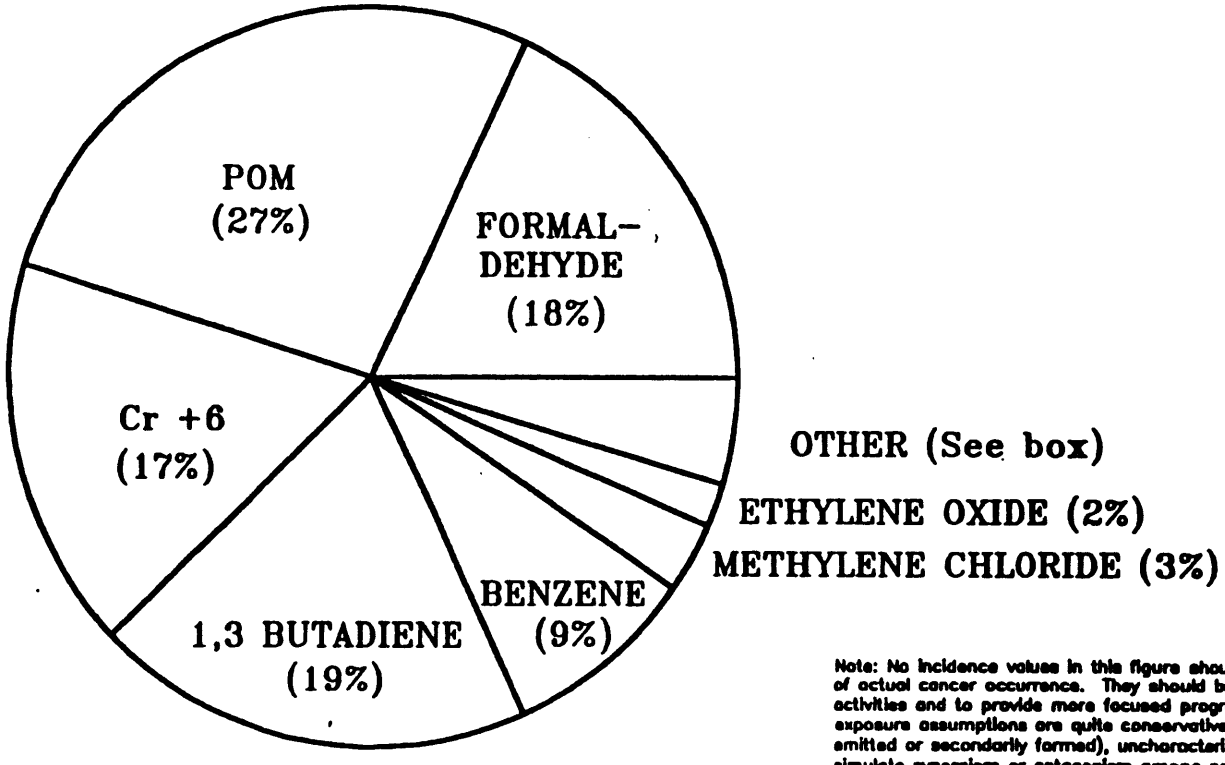
SUMMARY OF RESULTS

Aggregate cancer incidence across the five cities in this study averaged about 6 excess annual cases per million persons, ranging from about 2 to 10 in individual cities. Area wide individual lifetime cancer risks averaged about 4×10^{-4}, ranging from about 1.5×10^{-4} to 7×10^{-4}. Note that these risks are not maximum individual risks, which can be as high as 10^{-3} or even 10^{-2} at specific receptor sites around some large point sources (Haemisegger, 1985). Instead, these are individual risks averaged over entire urban populations. This phase of this study did not estimate maximum individual risks.

Figures 1 and 2 show the major sources and pollutants contributing to urban cancer incidence from air toxics, based on average results from the five cities. The major contributors to total aggregate incidence tend to be small point and area sources and road vehicles, the last source category figuring importantly in most urban studies. Not surprisingly, the pollutants of primary importance tend to be those associated with these same source contributors. Total cancer incidence associated with POM in Figure 2 is largely due to diesel particulate (45 percent), gasoline particulate (32 percent) and wood smoke (17 percent), all area sources. Total cancer incidence associated with chromium is

FIGURE 1

POLLUTANTS CONTRIBUTING TO FIVE CITY AVERAGE AGGREGATE CANCER INCIDENCE



OTHER (5%)

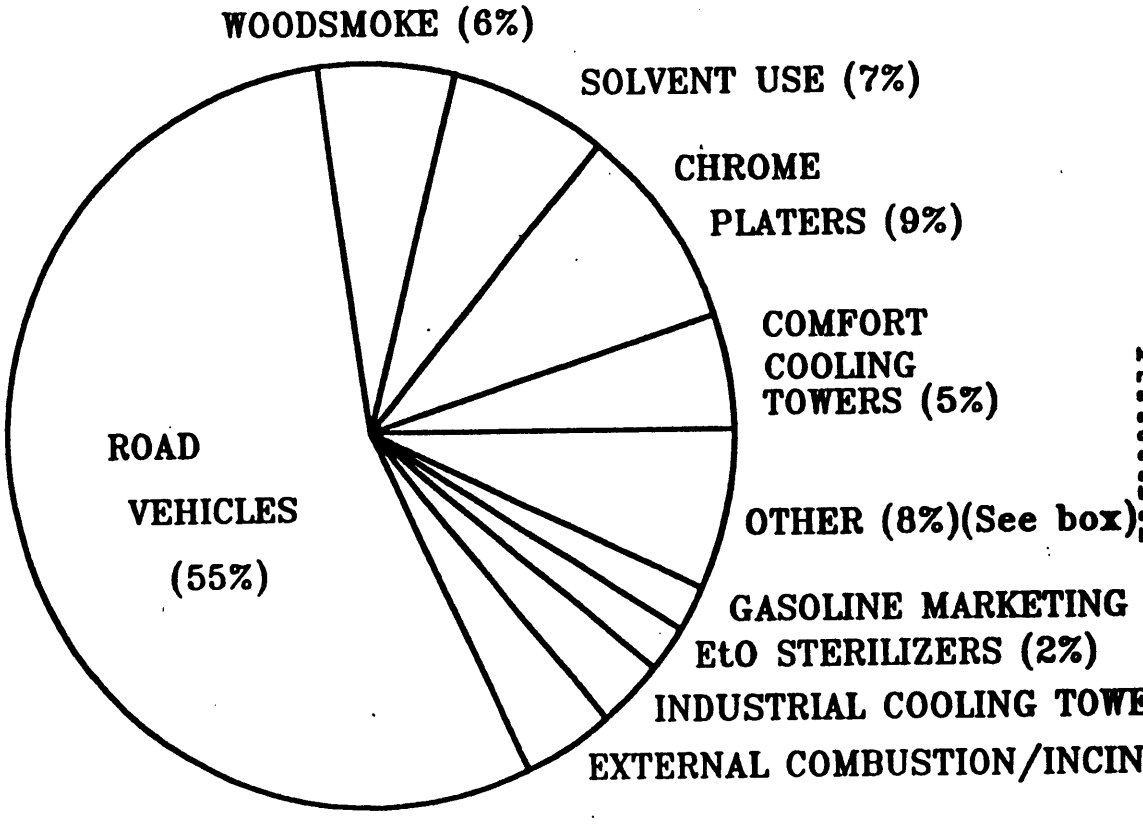
ARSENIC (1.2%)
EDC (0.9%)
GASOLINE VAPORS (0.8%)
CARBON TET (0.5%)
PERC (0.4%)
CHLOROFORM (0.2%)
TRICHLOROETHYLENE (0.2%)
CADMIUM (0.2%)
ASBESTOS (0.2%)
BERYLLIUM (0.1%)
VINYL CHLORIDE (<0.1%)

Note: No incidence values in this figure should be considered to represent absolute predictions of actual cancer occurrence. They should be used in a relative sense only for broad screening activities and to provide more focused program direction. The dose-response relationships and exposure assumptions are quite conservative. Errors due to missing pollutants (either directly emitted or secondarily formed), uncharacterized sources, and the lack of any mechanism to simulate synergism or antagonism among pollutants may potentially offset this conservative bias, but to an unknown extent.

AVERAGE FIVE CITY INCIDENCE = 5.8 CASES/YR/MILLION POPULATION

FIGURE 2

SOURCES CONTRIBUTING TO FIVE CITY AVERAGE AGGREGATE CANCER INCIDENCE



OTHER (8%)

- CHEMICAL MFG (1.3%)
- REFINING (1%)
- IRON & STEEL (0.7%)
- GLASS MFG (0.7%)
- REFRACTORY MFG (0.5%)
- POTWs (0.5%)
- NON FERROUS METAL (0.2%)
- OTHER (3.1%)

Note: No incidence values in this figure should be considered to represent absolute predictions of actual cancer occurrence. They should be used in a relative sense only for broad screening activities and to provide more focused program direction. The dose-response relationships and exposure assumptions are quite conservative. Errors due to missing pollutants (either directly emitted or secondarily formed), uncharacterized sources, and the lack of any mechanism to simulate synergism or antagonism among pollutants may potentially offset this conservative bias, but to an unknown extent.

AVERAGE FIVE CITY INCIDENCE = 5.8 CASES/YR/MILLION POPULATION

predominantly due to hexavalent chromium (Cr^{+6}) emitted from industrial cooling towers (19 percent), comfort cooling towers (28 percent), and chrome platers (51 percent). Cancer incidence from benzene and 1,3-butadiene exposures is primarily due to road vehicles.

Risks from formaldehyde exposures are attributable both to secondary (or photochemically produced) formaldehyde and to primary (or directly emitted) formaldehyde. This study suggests that direct formaldehyde emissions account for about 40 percent of the total formaldehyde-related cancer risk whereas secondary formaldehyde accounts for about 60 percent. The primary VOC sources contributing to secondary formaldehyde production are road vehicles (35 percent), solvent use (29 percent), gasoline marketing (8 percent), and refining (6 percent).

Detailed results are presented in Chapter IV.

ONGOING ASSESSMENT PROCESS

The methods, data, and assumptions reflected in any study such as this tend to change, sometimes rapidly, as one's understanding of the urban air toxics problem evolves and matures. For example, new sources and pollutants may be identified, new emission factors may be developed, and new assumptions may be adopted concerning how exposure and risk characterizations should be conducted. Indeed, numerous such changes have been required in this study since the original controllability study concluded just 5 years ago. The biggest change reflected updated emission factors for the major area sources.

Because continued changes are expected, EPA intends to continue this analysis to reflect new trends in urban assessments. Hence, just as the original 1985 controllability study's results are no longer considered current, it is expected that the results presented herein will also become outdated. For this reason, all major data, procedures, and assumptions are documented herein to help the reader judge the validity of the conclusions at some future date.

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CHAPTER I

METHODOLOGY OVERVIEW

An overview of the methodology used in this study is shown in Figure I.1. This chapter briefly discusses the overall data flow from development of the base year emissions inventory to estimation of cancer incidence. Details are given in subsequent chapters on each of the major steps in this process.

A. BASE YEAR INVENTORY

A base year inventory was compiled for each of the five cities from a number of different sources of information. Since considerable resources had gone into inventory development in the prior controllability study done in 1985, the decision was made to use this previous inventory as a starting point and use the limited resources available in this effort mainly to upgrade those areas of most importance reflecting newer source and emissions data. The base year nominally represents the year 1980 but, in fact, the data were not this well resolved temporally. Thus, the base year should really be considered to represent conditions generally existing between 1980 and 1985. Motor vehicle emissions were estimated using 1980 emission factors, but emission estimates for other categories were updated to current conditions when better information was available than existed in the 1980 emission inventory. These revisions included deleting plants from the data base which were known to have shut down after 1980. The first reliable ambient formaldehyde data, used to estimate total formaldehyde-related risk, were not available until 1987.

The pollutants covered in this study were those for which cancer unit risk factors exist and which are known or reasonably suspected of contributing to aggregate cancer incidence in urban areas. These pollutants are listed below:

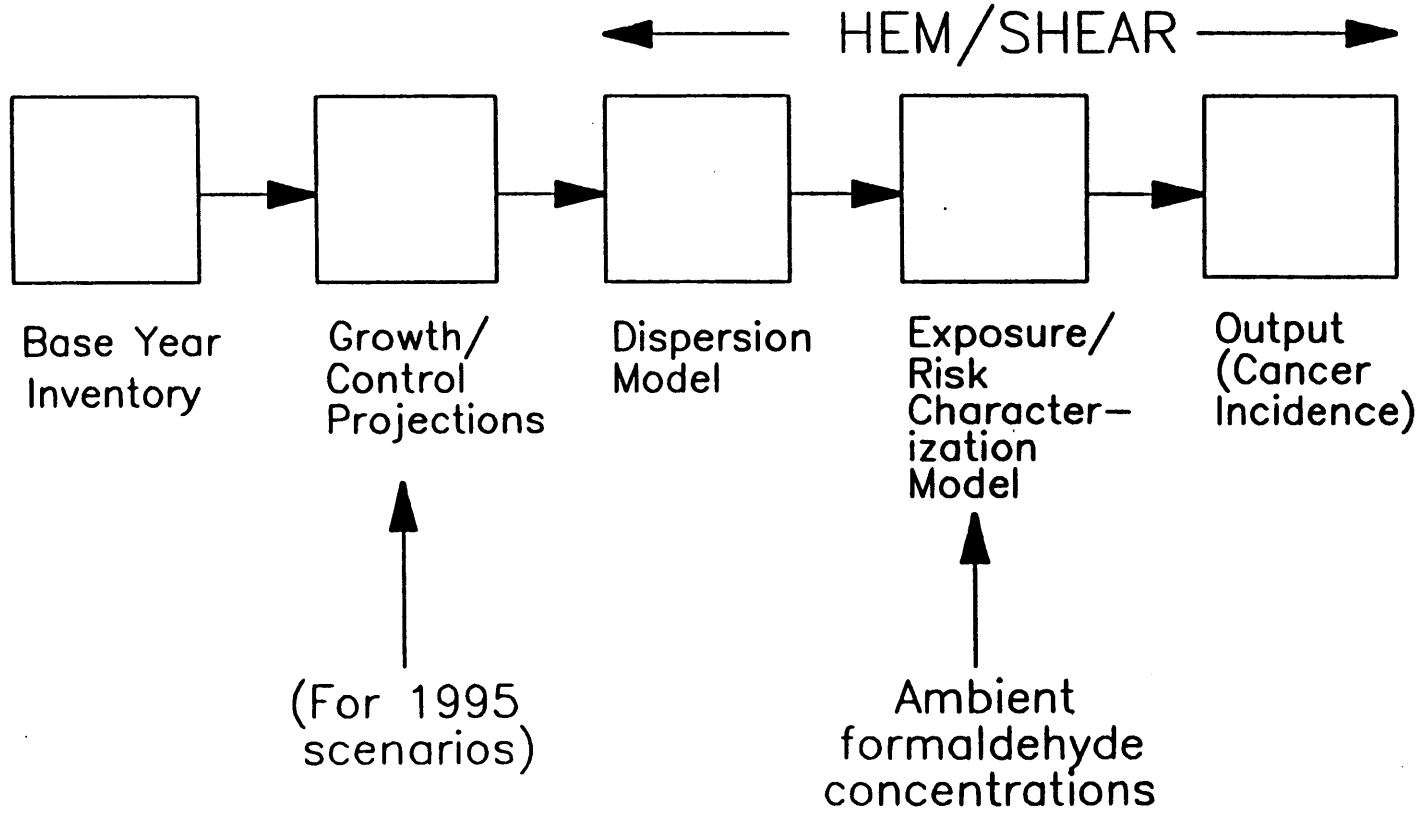
arsenic
asbestos
benzene
benzo(a)pyrene, or B(a)P*
beryllium
1,3-butadiene
cadmium
carbon tetrachloride
chloroform
chromium (VI and total)
diesel particulate
ethylene dichloride
ethylene oxide
formaldehyde
gasoline particulate
gasoline vapors
manganese
mercury
methylene chloride
nickel
perchloroethylene
trichloroethylene
vinyl chloride

*B(a)P was used as a surrogate for all polycyclic organic matter for certain sources.

FIGURE 1.1

FIVE CITY CONTROLLABILITY STUDY

DATA FLOW



The base year inventory was compiled from a number of sources. The starting point was the 1980 National Acid Precipitation Assessment Program (NAPAP) emission inventory. This inventory was improved by incorporation of the following:

- information from local surveys;
- comments from State and local-air agencies;
- information and methodologies from EPA's Integrated Environmental Management Projects (IEMP) "geographic" studies;
- updated emission factors and emission estimates from EPA's National Emission Standards for Hazardous Air Pollutants (NESHAP) program;
- updated emission factors and emission estimates from EPA's Office of Mobile Sources (OMS);
- updated emission factors from EPA's emission factor documents; and
- special contractor studies of area source activity levels and emissions (hospital sterilizers, waste oil combustion, dry cleaning, residential wood combustion, and wastewater treatment).

B. DISPERSION MODELING AND EXPOSURE/RISK CHARACTERIZATION

Figure I.1 characterizes dispersion modeling, exposure assessment, and risk characterization as three separate and sequential operations. Conceptually, they are separate operations and are accomplished sequentially in some other studies. EPA's HEM, used in this study, performs all of these steps during the course of a single model run. In HEM, there are two modeling options: Systems Applications Human Exposure and Dosage Model (SHED) and Systems Applications Human Exposure and Risk Model (SHEAR). (See Chapter III for further discussion.) HEM/SHEAR was used in this study.

In HEM, air toxics emissions data are first modeled to estimate annual average ambient concentrations of each pollutant throughout each study area. (Point and area sources are modeled in fundamentally different ways in HEM.) The resulting model-predicted concentrations are then applied to block group/enumeration district (BG/ED) populations to estimate the number of people exposed to different pollutant concentrations. These exposures are then converted to estimates of cancer incidence by applying cancer unit risk factors, which relate individual exposures to certain probabilities of contracting cancer. The number of excess cancer cases in each BG/ED is then summed for all pollutants and across the entire urban area to estimate aggregate cancer incidence from multi-source, multi-pollutant exposures.

In this study, secondary formaldehyde exposures and risks could not be assessed using the emissions inventory/dispersion modeling approach. Instead, measured ambient air levels of formaldehyde were used to calculate total formaldehyde-related risk for each urban area after which secondary formaldehyde risks were estimated by subtracting primary formaldehyde-related risk from total formaldehyde-related risk. Secondary formaldehyde-related risks were apportioned to source categories according to their VOC emission totals.

To evaluate exposures and cancer incidence in 1995, a module was used that superimposes various growth factors and emission reductions onto the base year inventory prior to emissions modeling. This module is discussed only in the companion Volume II, which addresses the controllability aspects of this study. Volume I reports only on the exposures and cancer incidence associated with the base year inventory. The growth and control projection module was not needed for the base year analysis.

CHAPTER II

EMISSION INVENTORY ENHANCEMENT

The emissions data base used in this study has benefitted from recent national studies of toxic emissions from specific source types and from local inventory efforts in some of the cities. The purpose of this chapter is to describe specific changes made to the emissions data base since the original air toxics controllability study in 1985. This chapter is divided into three sections. The first section presents revised toxic emission estimates for source categories where new information has become available nationally. This is followed by a description of how local survey information was incorporated into the inventory. A description of how the original emission inventory was developed for the 1985 study is presented in the third section for completeness.

A. IMPORTANT SOURCE CATEGORIES

1. Road Vehicles

Mobile source emission factors were completely revised from the 1985 study. This affected mobile source emissions estimates for the following compounds: formaldehyde, benzene, 1,3-butadiene, gaseous particle associated organics, and diesel particulates. The source of new motor vehicle emissions information (Carey, 1987c) did not include emission factors for the base year (1980) and contained only composite emission factors. Separate factors for each of the four motor vehicle categories in the National Emissions Data System (NEDS) were needed. Hence, some additional calculations were required. This section of the report describes how motor vehicle emission calculations were performed and how these numbers were applied in the analysis. A summary of resulting emission factors by vehicle type is shown in Table II.1. The emission factor calculation process is described separately for each pollutant below.

MOBILE3 was used to calculate 1980 total hydrocarbon emission factors by vehicle type. This information was then the basis for estimating emission factors for all organic toxic compounds. MOBILE3 was used to estimate emission factors for three different vehicle speeds -- 20, 45, and 55 miles per hour -- which are used to represent urban, rural, and expressway driving, respectively. All other conditions are kept constant in the model: low altitude, Federal test procedure conditions are simulated. Emission factors for the three speeds are weighted according to the percentage of travel on each roadway type (urban -- 16 percent, rural -- 30 percent, expressway -- 54 percent) to develop a composite number for each of the four vehicle types. These composites are then used to estimate formaldehyde, benzene, and 1,3-butadiene emission factors.

Table II.1

Mobile Source Air Toxic Emission Factors for 1980

Pollutant	Vehicle Type	Emission Factors (grams/mile)
Formaldehyde	LDGV	0.0497
	LDGT	0.0762
	HDGV	0.2908
	HDDV	0.1475
Benzene	LDGV	0.1686
	LDGT	0.2292
	HDGV	0.4124
	HDDV	0.0513
1,3-butadiene	LDGV	0.0127
	LDGT	0.0205
	HDGV	0.0328
	HDDV	0.0159
Particulates	LDGV	0.0149
	LDGT	0.0182
	HDGV	0.0313
	HDDV	1.9730

LDGV = Light-duty gasoline powered vehicle
LDGT = Light-duty gasoline powered truck
HDGV = Heavy-duty gasoline powered vehicle
HDDV = Heavy-duty diesel powered vehicle

a. Formaldehyde

To perform the 1980 formaldehyde emission factor calculation for light-duty gasoline powered vehicles, it was necessary to know (by technology type) the percentage of exhaust VOC that was formaldehyde. For this, EPA's Office of Mobile Sources provided the following numbers (Carey, 1987a):

Control Technology	Formaldehyde Emissions
noncatalyst	1.66 percent of exhaust VOC
oxidation catalyst	1.11 percent of exhaust VOC
3-way catalyst	0.83 percent of exhaust VOC

Formaldehyde is emitted in the exhaust, not the evaporative, portion of the organic emissions, so the percentages identified above are applied to the exhaust hydrocarbon (HC) values only. Table II.2 illustrates the calculations made to estimate 1980 motor vehicle emissions by vehicle type. As Table II.2 shows, formaldehyde fractions are identified separately for four different diesel vehicle types as well as for the three different technology types for light-duty gas vehicles (LDGVs). Fractions of diesel travel by vehicle type were estimated from MOBILE3 Fuel Consumption Model values. Exhaust HC emission factors listed in Table II.2 are from MOBILE3. The result of the weighting of vehicle class/control technology fractions, formaldehyde fractions, and exhaust HC emission factors is the formaldehyde emission factor shown in the right-most column of the table. Use of these values to estimate 1980 motor vehicle formaldehyde emissions is described later in this road vehicles section.

b. Benzene

Benzene is emitted in both exhaust and evaporative HC, and the percentage of HC that is benzene varies by vehicle type. These differences were accounted for in estimating 1980 benzene emissions. Benzene emissions expressed as percentages of HC are taken from Table 4-1 of an Office of Mobile Sources report (Carey, 1987c). Table II.3 shows how these percentages and MOBILE3-generated HC emission factors were used to estimate benzene emission factors by vehicle type. For diesels, the calculation is simplest because there are no evaporative emissions. The fractions listed under technology type are vehicle miles traveled (VMT) fractions from MOBILE3 for diesels. Diesel-emitted benzene then is estimated by multiplying exhaust HC emission factors by the benzene-in-exhaust fraction. The VMT fractions are used to estimate the emission factors by vehicle type shown in the right-most column of Table II.3.

For light-duty gasoline powered vehicles, evaporative emissions vary according to whether vehicles have fuel injectors or carburetors. It was estimated that 90 percent of LDGVs were carbureted in 1980 and that the remainder were fuel injected.

Table II.2
Formaldehyde Motor Vehicle Emission Factor Calculations - 1980

Vehicle Type	(A) Vehicle Class/Control Technology Type, Fraction	(B) Exhaust HC g/mile	(C) Formaldehyde Fraction	(A*B*C) Emission Fac by Class/ Technology Type (g/mile)	Emis Fac by Vehicle Type (g/mile)
LDGV-non-cat	0.473	3.63	0.0166	0.0285	0.0497
-ox cat	0.523	3.63	0.0111	0.0211	
-3 way	0.004	3.63	0.0083	0.0001	
LDGT		5.86	0.0130	0.0762	0.0762
HDGV		9.38	0.0310	0.2908	0.2908
Diesel-LDDV	0.0838	0.48	0.0410	0.0016	0.1475
-LDDT	0.0684	1	0.0410	0.0028	
-HDDV	0.8194	5.22	0.0300	0.1283	
-Buses	0.0283	5.22	0.1000	0.0148	

Table II.3

Benzene Motor Vehicle Emission Factor Calculations - 1980

Vehicle Type	(A) Vehicle Class/Control Technology Type, Fraction	(B) Exhaust HC g/mile	(C) Evap. HC g/mile	(D) Benzene Exhaust Fraction	(E) Benzene Evap. Fraction	A*(B*D+C*E) Emission Fac. by Class/ Technology Type (g/mile)	Emis. Fac. by Vehicle Type (g/mile)
LDGV-carbureted	0.9000	3.63	2.05	0.0395	0.0132	0.1677	0.1686
-fuel injected	0.1000	3.63	2.05	0.0395	0.0041	0.1442	
LDGT		5.86	3.58	0.0324	0.0110	0.2292	0.2292
HDGV		9.38	7.82	0.0348	0.0110	0.4124	0.4124
Diesels-LDDV	0.0838	0.48	0	0.0240		0.0010	
-LDDT	0.0684	1.00	0	0.0240		0.0016	0.0513
-HDDV	0.8477	5.22	0	0.0110		0.0487	

Benzene emission factors for LDGVs and other gasoline-powered vehicles were then estimated by multiplying exhaust HC by the benzene exhaust fraction, multiplying evaporative HC by the benzene evaporative fraction, and summing the products. Where Carey (1987c) provided a range of evaporative HC percentages, the midpoint was used in the calculations.

c. 1,3-butadiene

Motor vehicle emissions of 1,3-butadiene are roughly 0.35 percent of the total exhaust HC (Carey, 1988). The 1,3-butadiene emission factors provided by the Office of Mobile Sources were shown earlier in Table II.1.

d. Particulate Matter

Particulate emission estimates have also been significantly changed from previous work so that risk assessments could be made using the comparative potency approach. (See Section B of Chapter III for more discussion of the comparative potency approach.) Motor vehicle emission factors for gaseous particle associated organics were estimated as the soluble organic fraction. Diesel particulate emission estimates were made using total particulate. Emission estimation methods for gasoline and diesel particulates are described separately below.

i. Diesel Particulate

Diesel particulate emission factors by model year were taken from Table 2-2 of an Office of Mobile Sources (Carey, 1987c) report. Carey does not estimate emissions for 1980, so diesel particulate emission factors and VMT fractions by model year estimated from MOBILE3 were used to estimate composite emission factors by vehicle type. These calculations are shown in Table II.4. The calculation of 1980 diesel travel fractions used to estimate the amount of travel by light-duty diesel vehicles (LDDV), light-duty diesel trucks (LDDT), and heavy-duty diesel vehicles (HDDV) is illustrated in Table II.5.

ii. Gasoline Particle-associated Organics

Gasoline particle-associated organic emission rates were estimated using methods consistent with the unit risk factor that is applied for gasoline particle-associated organics (see Section B of Chapter III on the comparative potency approach). The original estimate of gasoline particle-associated organic emission factors for 1980 was made with the Office of Mobile Sources particulate model, using the organic fraction of the particulate. The organic fraction in the particulate model includes elemental carbon, however, and because only the soluble organic fraction should be counted, the earlier values were revised. The correct values were listed in Table II.1 under particulates. These revised values were provided by Penny Carey (1987b).

e. Application to Study Areas

Table II.1 emission factors were used along with the NEDS county fuel consumption values to estimate toxic compound emissions for each of the four vehicle types. Because fuel consumption estimates were available for only three vehicle types, the gasoline

Table II.4

Diesel Particulate Emission Factor Calculation

Calculation of 1980 Light-duty Diesel Vehicle Particulate Emission Factor

Model Year	(A) PM Emission Factor (grams/mile)	(B) VMT Fraction	(A*B) Composite Emission Factor
1980	0.5	0.038	0.0190
1979	0.8	0.142	0.1136
1978 and earlier	0.7	0.820	0.5740
			0.7066

Calculation of 1980 Light-duty Diesel Truck Particulate Emission Factor

Model Year	(A) PM Emission Factor (grams/mile)	(B) VMT Fraction	(A*B) Composite Emission Factor
1980	0.5	0.035	0.0175
1979 and earlier	0.9	0.965	0.8685
			0.8860

Calculation of 1980 Diesel Composite Emission Factor

Model Year	(A) 1980 Emission Factor (grams/mile)	(B) VMT Fraction	(A*B) Composite Emission Factor
LDDV	0.7066	.0838	0.0592
LDDT	0.8860	.0684	0.0606
HDDV	2.1859	.8477	1.8530
			1.9731

Table II.5

Calculation of 1980 Diesel Travel Fractions

Diesel Vehicle Categories	(A) 1980 Estimated Fuel Use (billion gals)	(B) Road Miles per Gallon	(A*B) 1980 Estimated VMT (billions)	VMT Fractions
LDDV	0.462	15.78	7.290	0.0838
LDDT	0.541	11.00	5.951	0.0684
HDDV	13.989	5.27	73.722	0.8477
			86.963	

light-duty vehicle estimates were dissaggregated by percentage fuel consumption into LDGV and LDGT emissions. Weighting factors were 77.9 percent for LDGVs and 22.1 percent for LDGTs.

2. Chrome Platers

The estimated chromium emissions from chrome plating operations were revised from the previous study. Previously only total chromium emissions were estimated for this source category. For the current effort, information was available to estimate hexavalent and total chromium emissions. Emission estimates for each pollutant are described separately below.

a. Hexavalent Chromium

The EPA Engineering Standards Division, as part of its NESHAPS program, provided hexavalent chromium emissions data by process type (hard and decorative plating), state, and county for the five study areas (U.S. EPA, 1987d). The emissions were summed by county for Study Areas B, C, D, and E. Study Area A was reported to have no hexavalent chromium emissions.

The local air quality management agency provided total chromium emissions for Study Area B based on extensive local surveys and source testing. These local agency-supplied emissions agreed to within 10 percent of the EPA/NESHAPS data and were used in this study. Only 92 percent of the local agency totals were assumed to be $Cr,^{+6}$ based on EPA/NESHAPS test results identifying the hexavalent-to-total chromium ratios.

The EPA/NESHAPS data suggested there are no hexavalent chromium emissions in Study Area A. The local air toxic survey noted, however, that there are at least six operating chrome platers in the area, but the survey did not provide emission estimates for each chrome plater. Hence, as an approximation, the national hexavalent chromium emissions were apportioned to the county level by population (Radian, 1987a). The resulting estimates of hexavalent chromium emissions by study area are listed in Table II.6.

b. Total Chromium

According to EPA tests, on average about 92 percent of the chromium emitted from platers is hexavalent (U.S. EPA, 1987a). Using this percentage and the hexavalent chromium emissions listed in Table II.6, total chromium emissions were calculated for each study area by county, except for Study Area B. The local agency provided total, not hexavalent, chromium emissions for this study area. Hexavalent chromium emissions were then estimated using the 92 percent assumption mentioned above.

3. Cooling Towers

Cooling tower chromium emissions were revised to include hexavalent chromium emissions as well as total chromium emissions. To further enhance the emission inventory,

Table II.6

Hexavalent and Total Chromium
Emissions from Chrome Plating Operations

Study Area	Emissions (Tons/year) Hexavalent Chromium	Total Chromium
A	0.024	0.026
B	13.8	15.0
C	0.025	0.027
D	0.6	0.64
E	0.806	0.876

Source: U.S. EPA, 1987d

cooling towers were divided into two categories: comfort and industrial cooling towers. Comfort cooling towers are inventoried as area sources while industrial cooling towers are inventoried as point sources.

It was assumed that total chromium emissions for cooling towers are equivalent to hexavalent chromium, although EPA is still conducting source tests to ascertain if this assumption is true. The following discussion describes the emission estimation method used for each type of cooling tower.

a. Comfort Cooling Towers

EPA's Office of Air Quality Planning and Standards (OAQPS) provided current documentation (U.S. EPA, 1987b) to estimate hexavalent chromium emissions from comfort cooling towers. These emissions were estimated using a per capita emission factor specific to each state. These emission factors and the calculated hexavalent chromium emissions for the five study areas are presented in Table II.7.

b. Industrial Cooling Towers

EPA-OAQPS provided national hexavalent chromium emissions (U.S. EPA, 1988) from industrial cooling towers in eight industrial categories. These were reduced to four categories by aggregating five that individually account for low or negligible emissions into an "other" category, as shown in Table II.8. The five categories aggregated into "other" are tobacco, utilities, tire and rubber, textiles, and glass manufacturing. The emissions for each source category were apportioned to the county level by employment in the related Standard Industrial Classification (SIC) category, as reported to the Department of Commerce. The calculated hexavalent chromium emissions by industry and study area are presented in Table II.8.

In prior work, industrial cooling towers were included in the emission inventory as an area source. This possibly overpredicted cancer incidence, as area sources are allocated within the modeling region by population. Cooling towers are at industrial sites, which may be removed from residential areas. To obtain a more realistic estimate of cancer incidence from cooling towers, the county level emissions were inventoried as point sources. Petroleum refining, chemical manufacturing, and primary metals account for more than 98 percent of the industrial cooling tower chromium emissions in each study area. Each study area was examined to determine the location of the greatest concentration (or grouping) of facilities in each of these three industries. Once a grouping of facilities was chosen to represent each industry, the cooling tower emissions were assigned as a new point at one of the facilities within the group.

The emissions from the industrial category labeled "other" were assigned to a single cooling tower. The utility industry was chosen to represent this category because the majority of the remaining emissions are from utilities and there are utility plants in each study area. The emissions were assigned to the largest utility in the study area. The NESHAP Background Information Document (BID) (U.S. EPA, 1988) for chromium

Table II.7

Hexavalent Chromium Emissions From Comfort Cooling Towers

Study Area	Hexavalent Chromium Emission Factor (lb/person-yr)*	Hexavalent Chromium Emissions (Ton/yr)
A	1.21 (10^{-3})	0.92
B	1.19 (10^{-3})	6.5
C	1.44 (10^{-3})	0.27
D	1.01 (10^{-3})	0.7
E	8.81 (10^{-4})	0.74

Source: U.S. EPA, 1987b.

* Average emission factor used from cited reference rather than upper bound of range.

Table II.8

Industrial Process Cooling Towers
Hexavalent Chromium Emissions
by Study Area (tons/year)

Industry	U.S. Total*	Study Area					5 City Total
		A	B	C	D	E	
Chemical Mfg.	47.5	0.033	0.996	0.686	0.345	0.313	2.37
Petroleum Refining	35.1	0.033	2.47	0.923	0.117	0.840	4.38
Primary Metals	9.3	0.016	0.178	0.005	0.292	0.006	0.50
Other	1.5	0.003	0.058	0.006	0.001	0.001	0.066
All Industries	93.5	0.08	3.70	1.62	0.76	1.16	7.32

* Source: U.S. EPA, 1988.

emissions from industrial cooling towers provided model stack parameters for each industrial category. The stack parameters assigned to each cooling tower are presented in Table II.9.

4. Wood Stoves

EPA-OAQPS provided current emission factor documentation describing particulate matter (PM_{10}) emissions from wood stoves. Based on the information provided, the PM emission factor for a conventional noncatalytic wood stove of 23.5 g/kg (47 lbs/ton) of wood burned was used (U.S. EPA, 1987c). Particulate matter was computed rather than B(a)P or some other POM because the comparative potency factor used to estimate total POM cancer risk is applied to particulate matter. (See Chapter III, Section B for details.)

Based on the information in the revised VOC species data manual, benzene emissions from wood stoves were estimated to be 6.3 percent of the total VOC emissions (Radian, 1987b). Therefore, it was assumed that 6.3 percent of the VOC emission factor would represent the benzene emission factor. Using this assumption, the benzene emission factor was estimated to be 126 pounds of benzene per ton of VOC emitted.

5. Coal/Oil Combustion

Coal and oil combustion emission factors for arsenic, chromium, formaldehyde, and nickel were revised from those of the original study using more recent test data (Radian, 1986). Radian (1986) also provided emission factors for beryllium, cadmium, manganese, and mercury, which were compounds not included in the 1985 study. Hexavalent chromium combustion emission factors were developed using the information provided in two EPA chromium screening test report documents on coal fired boilers (U.S. EPA, 1985b and 1985e). According to these documents, approximately 0.41 percent of the uncontrolled chromium emitted is hexavalent and 0.15 percent of the controlled chromium emitted is hexavalent. Lacking data on chromium emissions from oil combustion, these factors were also applied to oil fired boilers.

6. Other Hexavalent Chromium Emissions

Hexavalent chromium emission factors for refractories, electric arc furnaces, and argon-oxygen decarburization (AOD) furnaces were obtained from EPA chromium screening study test reports for these source categories (U.S. EPA, 1985c and 1985d).

7. Methylene Chloride Emissions

The EPA source assessment document for methylene chloride provided nationwide emission estimates by source category (U.S. EPA, 1985f). Degreaser emission estimates were provided at the state level and were apportioned to the study areas by population. According to the source assessment document, 67 percent of the degreasing emissions are from cold cleaners and the remaining emissions are split equally between open top and

Table II.9

Model Stack Parameters for Industrial Cooling Towers

Industry	Stack Height (feet)	Stack Diameter (feet)	Exit Gas Temperature (F)	Flow (cu ft/min)
Petroleum Refining	46	22	100	666,797
Chemical Manufacturing	34	18	100	440,888
Primary Metals	38	19	100	448,997
Utilities	80	32	100	1,344,333

conveyorized vapor degreasers. Using this information, methylene chloride emissions from degreasing operations were assigned to the source categories: cold cleaners, open top vapor degreasers, and conveyorized vapor degreasers. All other emissions were apportioned to the study areas by population and assigned to the miscellaneous solvent use source category. No large point source emitters of methylene chloride were identified in the five study areas of concern.

B. STATE AND LOCAL DATA INPUTS

Plant specific emissions were verified and updated using local air toxic surveys and plant specific information from EPA. Local air toxic surveys were available for Study Areas A and B for the year 1985. These surveys also provided area source emissions which were compared with the emissions in the existing inventory. Changes in the area source categories resulting from this comparison, which were discussed briefly above, are discussed in more detail here. Baseline air toxic emissions for Study Area D were compared with the emissions in the Program Integration Project -- Queries Using Interactive Commands (PIPQUIC) computer data base. PIPQUIC is a data handling system developed by EPA as part of the IEMP to calculate exposures and risks from air toxics emissions data. PIPQUIC is being used in various urban air toxics studies. The PIPQUIC data base for Study Area E had been available in the previous air toxics controllability study and was incorporated in the five city data file at that time. The EPA provided plant specific information for two point sources of 1,3-butadiene in Study Area C. These were incorporated into the emissions data base.

State and local air pollution control agencies were also given an opportunity to review the plant specific emission estimates by compound during the course of the 1985 study. Their comments resulted in some significant changes to the emission inventory data base, particularly for Study Areas B and C. These changes have now been incorporated.

In general, if a study area had a small number of air toxic emitting sources and local air toxic emission estimates were available, changes were made to individual records in the point source emission inventory to reflect these data. Project resources did not allow this detailed point-by-point matching between local air toxic survey data and the five city data base for all cities and all compounds. For compounds where there were local survey estimates for hundreds of facilities (many of which were too small to be included in the 1980 NEDS/NAPAP Emissions Inventory), only the largest emitters were inventoried as point sources. The remainder were included in the emissions data base as area sources so that five city data base emission totals matched those determined from local surveys. This inventorying procedure has implications for the conclusions that may be drawn about the relative importance of point vs. area sources because it does not completely reflect all point source emissions as such. The extent of this bias will vary by compound, with perchloroethylene being a good example of a compound whose point source emissions are underrepresented in this analysis.

C. ORIGINAL EMISSION INVENTORY DEVELOPMENT

1. Introduction

While the toxic emission inventory used in the 1985 study was updated for many source categories as described in the previous sections, there were many parts of the original emission inventory that were not changed. For completeness, this section provides a summary of the methods that were used to develop the original inventory, particularly for those categories for which special techniques were used.

The starting point in developing the baseline inventory was the National Acid Precipitation Assessment Program (NAPAP) emissions inventory for 1980. The NAPAP inventory was chosen because it was considered to represent the best available detailed inventory of emissions on a national scale at that time. The NAPAP inventory is similar to EPA's National Emissions Data System (NEDS) but it has been improved substantially by incorporation of the latest available emission factors, substituting data from the Northeast Corridor Regional Modeling Project (NECRMP) and recent state submittals, and incorporating electric utility data compiled by Pechan.

To further improve the NAPAP inventory, for the purposes of the toxics study, specific air toxic emissions information was obtained from EPA Emission Factor Documents, Source Assessment Documents, and local air toxic surveys. If more than one data source was available for a pollutant and source category, the following criteria, listed in order of priority, were applied to estimate air toxic emissions:

(1) Plant specific emission information from local air toxic surveys or source assessment documents.

(2) Emission factors.

(3) National or statewide emission estimates apportioned to counties.

The inventories developed using these procedures were reviewed by the appropriate local agency for each study area. Corrections were then made to the air toxic inventories based on comments received from these local agencies. The plant specific information needed was facility name, control equipment, control effectiveness, location (coordinates), pollutant, emissions, process (by Source Classification Code -- SCC), and stack parameters (height, diameter, temperature, and flow).

All of these data items were necessary in order to meet the multiple needs of emission inventory users. Locations, emissions, and stack data were needed for dispersion modeling. Controlled and uncontrolled emissions and current control equipment data were needed to

estimate the effect of future regulations and to estimate future control costs for the controllability portion of this study.

2. Special Methods for Selected Source Categories

A few source categories were identified for independent analyses of their toxic emissions because it was felt that using NEDS data and emission factors (or species profiles) would be inadequate. The following subsections describe the methods used to make emission estimates for these selected source categories.

a. Data and Sources

Radian Corporation provided Pechan with baseline emission estimates for dry cleaners (VOC), refractory manufacturing (TSP), residential wood combustion (TSP and VOC), and sterilizers (ethylene oxide) (Hall, 1985). These emission estimates are listed in Table II.10. The dry cleaning VOC estimates were obtained directly from state agencies. The data for refractory manufacturing were extracted from source assessment documents and represent two model plants located in Study Area D. Sterilizer estimates include only ethylene oxide emissions from hospital usage. Actual values were obtained for one study area and a coefficient was developed; other areas are based on this value with adjustments made for the number of hospitals and admissions.

b. Residential Wood Combustion

Residential wood combustion emissions were prepared by OMNI Corporation for Radian Corporation. OMNI's estimates of residential wood combustion emissions (Simons, 1984) for each of the five study areas were divided into three categories: (1) fireplaces used primarily for ornamental or aesthetic wood burning, (2) primary heating, done primarily with wood stoves, and (3) secondary heating, done primarily with modified fireplaces (inserts) and wood stoves.

i. Fireplace Emission Estimate Methodology

Using the 1980 census data (U.S. DOC, 1982a) in conjunction with U.S. Bureau of Census data (U.S. DOC, 1975, 1980, and 1982b), OMNI estimated at the county level the number of single family households having one or more fireplaces. OMNI used a conservative approach, however, in that single family houses estimated to have two or more fireplaces were assumed to have only one operating fireplace. No attempt was made to estimate the amount of wood burned in fireplaces in multi-family dwelling units or mobile homes because residential wood fuel use studies indicate that more than 96 percent of all wood used for residential wood combustion purposes occurs in single family dwelling units (Skog and Watterson, 1983).

OMNI applied a utilization factor to each of the calculated number of installed fireplaces to estimate the number of operating fireplaces. OMNI estimated only those fireplaces installed as part of the original construction of single family homes even though

Table II.10

Emission Estimates for Selected Toxic Emitting Source Categories

VOC Emissions (TPY)

Category	Study Areas A	B	C	D	E
PCE Dry Cleaning	911	0	*	443	338.4
Sterilizers (Ethylene Oxide)	7.8	44	2.8	9.7	11.4
Residential Wood Combustion:					
Fireplaces	923	6,968	461	820	243
Woodstoves	6,177	32,832	1,639	5,180	2,457

TSP Emissions (TPY)

Category	Study Areas A	B	C	D uncont	D cont	E
Refractory Manufacturing	*	*	*	5,192.1	236.06	*
Residential Wood Combustion:						
Fireplaces	1,008	7,295	475	-	866	260
Wood Stoves	2,592	13,771	685	-	2,234	1,040

* not available
** original OMNI Corporation emission estimates listed for fireplaces and wood stoves for Study Area B were later adjusted downward from the estimates listed above per comments from the local agency.
cont=controlled
uncont=uncontrolled

Source: Hall, 1985

national fireplace sales data (HID, 1984) indicate that 36 percent to 43 percent of recent fireplace installations are associated with residential repair and remodeling projects.

OMNI estimated the number of operating fireplaces used for ornamental or aesthetic purposes by applying a conversion factor that assumes a certain percentage of existing operating fireplaces were modified (i.e., inserts installed) to be used for secondary heating rather than for aesthetic wood burning purposes. Fireplace conversion factors were estimated from residential fuel wood use studies (Skog and Watterson, 1983; EIA, 1982b and 1982c) and a review of regional marketing data of residential wood burning devices.

The average amount of wood burned per dwelling unit having operating fireplaces was based on a number of studies, discussions with state and regional foresters, state energy officials, and commercial/retail wood dealers. OMNI calculated the total amount of wood (in cords) burned in fireplaces used primarily for ornamental or aesthetic purposes in a county. AP-42 fireplace emission factors (U.S. EPA, 1985g) were applied to the estimated amount of wood burned to estimate TSP and VOC emissions.

ii. Primary Heating Emission Estimate Methodology

To estimate primary wood heating emissions, OMNI used 1980 census data to determine the number of households using wood as a primary heating fuel. The households answering "wood" are summarized at the county level in the 1980 Census Survey. Other studies (Skog and Watterson, 1983; EIA, 1982b, 1982c) have indicated that the 1980 Census Survey may have underestimated the number of households using wood as a primary heating fuel by as much as a factor of 2.5 on a nationwide basis. These studies do not provide data at a county level, however, and it was OMNI's opinion that in lieu of more detailed site-specific data the 1980 Census Survey Data should be used and would represent a conservative estimate of households using wood as a primary heating fuel.

OMNI estimated the average amount of wood consumed per primary wood burning household using a variety of residential fuel wood use studies (Skog and Watterson, 1983; EIA, 1982a, 1982b, 1982c; Marshall, 1981) as well as information derived from discussions with other experts in the wood energy field. Since there is very little data regarding the average amount of wood consumed per primary wood burning household for the areas evaluated, OMNI estimates are to be considered conservative since the values selected were generally on the low end of data ranges available from these studies.

For each study area, total amount of wood consumed (in cords) was estimated for all households using wood as a primary heating source. It was assumed that all households using wood as a primary heating fuel used space heating devices that had the emission performance characteristics of an "average" wood stove. Therefore, AP-42 wood stove emission factors were applied to this residential wood combustion class.

iii. Secondary Heating Emission Estimate Methodology

As noted above, it was assumed that most of the secondary or supplemental heating was done primarily with modified fireplaces or wood stoves. It was recognized that ordinary

fireplaces are occasionally used to provide supplemental heat (primarily for emergencies), but it was OMNI's view that the emission contribution of this source was insignificant.

The average amount of wood burned per modified fireplace was based on national and regional residential firewood use studies' (Skog and Watterson, 1983; EIA, 1982b; 1982c; DER, 1982; NRBP, 1984; USDA, 1980) evaluations of heating demand characteristics of single family homes by geographic area and discussions with regional foresters and commercial firewood dealers.

OMNI assumed, based on its emission testing experience, that fireplace inserts essentially have the same emissions characteristics as the average population of both airtight and nonairtight wood stoves. Therefore, AP-42 wood stove emission factors were applied to the amount of wood burned in modified fireplaces for secondary heating purposes to estimate TSP and VOC emissions.

The number of wood stoves used for secondary heating purposes was estimated from data in the 1980 Annual Housing Survey (U.S. DOC, 1983) and data regarding sales of wood stoves in the United States (EIA, 1982b). Sales data indicate that the secondary wood heating device market did not evolve until after the 1973 Arab oil embargo. Therefore, OMNI estimates reflect wood stove installations occurring between 1975 and 1980.

The average amount of wood used per secondary heating wood stove was determined using the same data sources and methodology as used for modified fireplaces. AP-42 wood stove emission factors were used to estimate TSP and VOC emissions.

Note that there is considerable uncertainty in the residential wood combustion emission estimates. Comments received from one local air quality agency indicated that the OMNI emission estimates were much higher than its own estimates. Therefore, OMNI's estimates of the amount of wood burned per wood burning device were adjusted downward to try to better account for the local conditions in that study area.

c. Toxic Emissions from POTWs

The 35 County study methodology (Versar, 1984) was adopted for calculating emissions from POTWs. This method involves a multistep process. First, EPA's Industrial Facilities Discharge (IFD) file was used to identify POTWs known to handle industrial discharges. The following plant specific data were extracted from the IFD file for each POTW: county, state, total flow, level of treatment (primary, secondary, or tertiary), percentage industrial contribution, and type of industry discharging into the POTW (by SIC code). The POTWs were next sorted into 13 categories based on industrial dischargers and level of treatment. The 35 County study then derived seven prototype plants and two equations to be used to calculate annual POTW air toxic emissions. Industrial discharges and level of treatment were used to determine the appropriate equation and prototype plant to be applied.

d. Toxic Emissions from Waste Oil Burning

The method used to calculate toxic emissions from waste oil burning was adopted from the 35 County study (Versar, 1984). Each state's total residual oil consumption was obtained from NEDS. If this value was not zero, equations were used to calculate waste oil burned based on residential, commercial/institutional, and industrial residual oil consumption.

3. Source Assessment Documents

Source assessment documents have been developed by EPA to provide information on significant emitters of an air pollutant to help determine whether regulation is needed and how effective controls might be. In these documents each source category is assessed separately and emission information is provided either in the form of plant specific emissions or nationwide emission rates. Plant specific information usually includes plant name, location (longitude-latitude or UTM coordinates), stack parameters, pollutants, and emissions. Plant specific data obtained from these documents were used in preference to those in the NAPAP file.

Nationwide emission rates were used for source categories for which plant specific or area specific emissions could not be found. These source categories were usually area sources (grain fumigation, unidentified, or miscellaneous sources). The nationwide average emission estimates were apportioned to counties by population. If regional or state emission estimates were provided, these data were used instead of apportioning the nationwide average estimate.

4. Emission Factors

Emission factors for air toxic compounds were developed from a number of different sources including EPA emission factor documents, VOC species profiles, and air pollution periodicals. EPA emission factor documents are for individual pollutants and contain uncontrolled emission factor estimates for numerous sources. Unfortunately, emission factor documents were not available for all of the compounds included in this study.

CHAPTER III

DISPERSION MODELING AND EXPOSURE/RISK ASSESSMENT

A. MODELING METHODS

Assessing the cancer risks posed by a suspected airborne carcinogen requires three basic pieces of information: (1) an estimate of the carcinogenic potency of the pollutant in question, (2) an estimate of the ambient concentration to which an individual or a population is exposed, and (3) an estimate of the exposed population. Described below are the methods for developing and combining the above three pieces of information in order to estimate cancer incidence in the five study areas.

The carcinogenic potency of a compound represents the probability of contracting cancer from a lifetime (70 years) exposure to a 1 microgram per cubic meter concentration of that pollutant. The carcinogenic potency estimates used in this study were developed by EPA's Carcinogen Assessment Group. They are listed in Table III.1.

EPA's Human Exposure Model was used in this analysis. HEM is a general model designed to estimate the population exposed to air pollutants emitted from point and area sources and the carcinogenic risk associated with this exposure (U.S. EPA, 1986). The HEM comprises (1) an atmospheric dispersion model, with included meteorological data, (2) a population data base of Bureau of Census data, and (3) a procedure for estimating risks resulting from the predicted exposure. Using emission source data as input, HEM estimates the magnitude and distribution of ambient air concentrations of the pollutant in the vicinity of the source. These concentration estimates are coupled with population to estimate public exposure to the pollutant. The HEM then estimates population risks if a unit risk number determined from health data is input for the pollutant.

As discussed in Chapter I, within HEM there are two models, SHED and SHEAR. The SHED model was developed to assess sources on a nationwide source category basis, e.g., all primary copper smelters. The SHEAR model was developed from SHED to model hot spots, or smaller regions with more than one source. In addition to modeling major point sources, SHEAR can also be used to model prototype sources (model plants and area sources). Thus, SHEAR was appropriate for the urban scale modeling being performed in this study.

In SHEAR, two basic dispersion algorithms are used: a plume algorithm for computing concentration patterns resulting from a single source (point sources) and a box algorithm for computing concentration patterns resulting from an urban-wide distribution of a single source type (area sources). The dispersion zone for each modeled point source is limited to

Table III.1

Compounds and Associated Unit Risk Values

Pollutant	Unit Risk*
1. Formaldehyde	1.3×10^{-5}
2. Ethylene Oxide	1.0×10^{-4}
3. Chloroform	2.3×10^{-5}
4. Carbon Tetrachloride	1.5×10^{-5}
5. Ethylene Dichloride	2.6×10^{-5}
6. Perchloroethylene	5.8×10^{-7}
7. Trichloroethylene	1.3×10^{-6}
8. Vinyl Chloride	4.1×10^{-6}
9. Benzene	8.0×10^{-6}
10. Gas Vapors	6.6×10^{-7}
11. Arsenic	4.3×10^{-3}
12. Chromium (Total)	see Hexavalent Chromium
13. Nickel	3.3×10^{-4}
14. PIC (BaP)	4.2×10^{-1}
15. Lead	not available
16. 1,3-Butadiene	2.8×10^{-4}
17. Diesel Particulates	3.0×10^{-5}
18. Gasoline Particle Associated Organics	
A. Catalyst	1.2×10^{-4}
B. Non catalyst	7.9×10^{-4}
19. Asbestos	7.6×10^{-3}
20. Chromium (Hexavalent)	1.2×10^{-2}
21. Beryllium	2.4×10^{-3}

Table III.1 (continued)

Pollutant	Unit Risk*
22. Cadmium	1.8×10^{-3}
23. Mercury	not available
24. Manganese	not available
25. Methylene Chloride	4.1×10^{-6}

*The unit risk value is the estimated probability of contracting cancer as the result of a constant exposure over 70 years to an ambient concentration of 1 microgram per cubic meter. Values for some compounds have changed since the modeling portion of this study was performed. If the revised unit risk factors were used in this study, incidence estimates would differ by about 2 percent.

a circle of a 20 kilometer radius about the source location. This limitation should have minimal effect on study results because concentrations from most sources will be small beyond 20 kilometers.

Exposure to air toxics in SHEAR is computed for residential population patterns for annual-average concentrations. No account is taken of varying source strengths or varying population patterns within a year. In this study, atmospheric transformation of toxic compounds has been ignored. (The assumptions and limitations of this study are delineated in Chapter V.)

In the point source model in SHEAR, the concentrations from each source are computed on a separate polar grid centered on that source. Population is defined on an irregular grid of block group/enumeration district centroids. To define all concentrations at a common set of points with a minimum of interpolation, SHEAR adds interpolated values of concentration from each polar grid to the grid of centroids.

SHEAR was applied in the five study areas to estimate expected increases in cancer incidence resulting from air toxics exposure as it exists in the base year (1980). All point sources for which Pechan had coordinates and stack parameters (from NEDS) and which exceeded a specified emission cutoff (see discussion on following page) were modeled individually in SHEAR as point sources. Area sources, point sources for which Pechan had no stack or locational information, and point sources below the emission cutoff levels, were all modeled collectively as area sources. All area source emissions were subcounty apportioned by the population density in each block group/enumeration district by HEM. (This is a limitation of HEM and is handled in other ways in other studies, through the use of other surrogate parameters.)

A sensitivity analysis of the difference between apportioning area source emissions by the population density in each block group/enumeration district versus modeling area source emissions as if they were constant throughout the study area, showed a fairly dramatic increase in area source related incidence in each study area in the population weighted approach. Depending on the characteristics of the urban area being modeled, results varied by a factor of 2 to 4 between the two cases.

Because the SHEAR was not designed to be run for large urban areas with many point sources, a large number of pollutants, and many scenarios, some changes were made to the model to make it more efficient for the purposes of the present analysis. Rather than running the SHEAR separately for each scenario and pollutant, it was run once assuming 100 tons per year of pollutant emissions from each major point source. For each point, the output of SHEAR was saved in an intermediate file for later use. This intermediate file contained the cumulative population exposure (micrograms/m^3-persons/year) for each modeled point. These values were then used to estimate population exposure to individual pollutants by multiplying them by the ratio of actual emissions to modeled emissions (100 TPY). This normalized modeling approach saved considerable computer resources.

Because the cost and execution time of SHEAR is linearly related to the number of point sources modeled, it was necessary to establish a point source emissions cutoff level for each pollutant in each study area. These cutoff levels were set to minimize the number of sources to be modeled individually as point sources while maximizing the percentage of emissions so treated. For some pollutants, there were so few emitters that all sources within a study area could be modeled (e.g., carbon tetrachloride). Other pollutants had so many sources that a cutoff level was needed to avoid having hundreds of sources included in the modeling of that pollutant (e.g., formaldehyde).

Table III.2 shows the point source cutoff levels defined for each pollutant by study area. Point sources with emissions below these levels were modeled as area sources.

Because accuracy in the stack data used in the dispersion modeling is as critical as the emission rates in estimating ground-level concentrations, considerable effort was taken in performing quality control checks on the point source stack parameters. Steps taken to ensure reasonable values for stack parameters were as follows:

(1) UTM coordinates that were widely different for the same plant were corrected.

(2) The stack heights and diameters were reviewed for compatibility.

(3) Sources with stacks taller than 100 feet should be fuel combustion sources and have a stack gas temperature of more than 200 degrees F.

(4) If temperature, height, and diameter are zero or missing, values were assigned.

(5) Default values for exhaust gas flow rate and stack temperature for utility and industrial boilers are based on the type of fuel burned.

(6) In cases where plume height was estimated but needed stack data were missing, plume height was used to estimate stack height. Other stack parameters were then estimated using plume rise formulas.

B. COMPARATIVE POTENCY APPROACH FOR ESTIMATING POM RISKS

The approach used for estimating cancer incidence from exposure to POM in this study differs markedly from previous approaches that used B(a)P as a surrogate for POM. Where possible, this study adopted the comparative potency approach which allows published cancer unit-risk estimates to be applied to particle emission estimates directly (Lewtas, 1987), thus directly accounting for all POM emitted by each source category. (For sources where comparative potency factors were not available, the "old" approach of using B(a)P as a surrogate of POM was still used.)

In this comparative potency method, the risk of a suspect human carcinogen for which there are no epidemiologic cancer data (e.g., diesel particulate) is estimated by comparison

Table III.2

Emission Cutoff Levels Used for Identifying Major Point Sources for Modeling Purposes* (TPY)

Pollutant	Study Areas A	B	C	D	E
Arsenic	0.0	0.2	0.0	0.05	0.1
Benzene	0.0	1.0	0.0	0.0	0.0
Carbon Tetrachloride	0.0	0.0	0.0	0.0	0.0
Chloroform	0.0	0.4	0.0	0.0	0.0
Chromium	0.0	0.1	0.0	0.05	0.05
Ethylene Dichloride	0.0	0.04	0.0	0.0	0.0
Ethylene Oxide	0.0	0.0	0.0	0.0	0.2
Formaldehyde	1.0	70.0	100.0	20.0	1.0
Gasoline Vapors	0.0	40.0	0.0	100.0	0.0
Lead	0.0	10.0	0.0	1.0	1.0
Nickel	0.0	0.1	0.01	0.1	0.1
Perchloroethylene	0.0	50.0	0.0	0.0	1.0
PIC	0.0	0.0	0.0	0.0	0.0
Trichloroethylene	0.0	1.0	0.0	0.	1.0
Vinyl Chloride	0.0	0.0	0.0	0.0	0.0
1,3-Butadiene	0.0	0.0	0.0	0.0	0.0
Diesel PM	0.0	0.0	0.0	0.0	0.0
Gasoline PM	0.0	0.0	0.0	0.0	0.0
Asbestos	0.0	0.0	0.0	0.0	0.0

* As defined in the text, sources having emissions above these levels were modeled individually as point sources, whereas sources with lower emissions were modeled collectively as area sources.

Table III.2 (continued)

Pollutant	Study Areas A	B	C	D	E
Chromium (Hex)	$1x10^{-5}$	$1x10^{-5}$	$1x10^{-5}$	$1x10^{-5}$	$1x10^{-5}$
Beryllium	$1x10^{-3}$	$1x10^{-3}$	0.0	$1x10^{-3}$	$1x10^{-3}$
Cadmium	0.0	$2x10^{-3}$	0.0	$2x10^{-3}$	$2x10^{-3}$
Mercury	0.0	$1x10^{-3}$	0.0	$1x10^{-3}$	$1x10^{-3}$
Manganese	0.0	$5x10^{-3}$	0.0	$5x10^{-3}$	$5x10^{-3}$
Methylene Chloride	0.0	0.0	0.0	0.0	0.0

* As defined in the text, sources having emissions above these levels were modeled individually as point sources, whereas sources with lower emissions were modeled collectively as area sources.

with a known human carcinogen (e.g., coke oven emissions) according to the following equation:

$$\text{estimated human risk (diesel)} = \text{human risk (coke oven)} * \frac{\text{bioassay potency (diesel)}}{\text{bioassay potency (coke oven)}}$$

The relative bioassay potency is obtained by the ratio of the slopes of the dose responses from the same in vitro or in vivo bioassays.

The comparative potency method described here estimates the risk of human lung cancer from diesel particulate (or other) emissions based upon lung cancer data obtained from humans exposed to other organic combustion and pyrolysis products. Epidemiologic studies have shown an increased incidence of lung cancer in humans exposed to coke oven emissions, roofing tar emissions, and cigarette smoke. The estimation of cancer risk from diesel particles was, therefore, determined by comparing the carcinogenic and mutagenic potencies of diesel exhaust particulate extracts with those of coke oven emissions, roofing tar emissions, and cigarette smoke tars in a battery of in vitro mutagenicity and mouse skin tumor initiation and carcinogenicity bioassays. Particle unit risk estimates recommended for estimating comparative POM risks in an Integrated Environmental Management Project (IEMP) are shown in Table III.3. These Table III.3 unit risk factors were applied to the particulate emissions by source category to estimate POM related cancer incidence. Essentially, this is the same as treating each source category as if it emits a unique pollutant. The incidence for all categories is then summed to estimate particulate based incidence.

Table III.4 presents some of the combustion source test results that were considered in selecting the Table III.3 unit risk values. EPA's Office of Mobile Sources recommended using the Mustang II unit-risk data across the board for gasoline particulates. Because a significant portion of the light-duty vehicle fleet in 1980 was noncatalyst (and most trucks would be noncatalyst), a separate factor was applied to the noncatalyst portion of the gasoline-powered fleet. The data for the Chevrolet 366 were used for this case (see Table III.4).

For diesels, the only heavy-duty vehicle tested was the Caterpillar. This Caterpillar was tested to represent the lower end of the potency range and, therefore, was not considered representative of the diesel fleet. (Caterpillar tests were performed under low speed and load conditions and the sample was stored for one year.) Thus, as was done by Carey (1987c), the light-duty vehicle test data were used to represent diesel particulate unit-risk.

C. FORMALDEHYDE MODELING APPROACH

This study used (1) the emissions data bases and (2) modeling and exposure capabilities built into HEM/SHEAR to estimate excess cancer incidence associated with all pollutants except secondary formaldehyde. Because the majority of ambient formaldehyde is believed

Table III.3

Particle Unit Risk Estimates Used for Estimating Comparative POM Risks

Emission Source	Particle Unit-Risk Estimates* (Lifetime risk/ug/cubic meter)
VEHICLES	
Gasoline-Catalyst	1.2×10^{-4}
Gasoline-Noncatalyst	7.9×10^{-4}
Diesel	3.0×10^{-5}
RESIDENTIAL HEATING	
Oil	0.9×10^{-5}
Coal	1.0×10^{-5}
Wood	1.0×10^{-5}
INDUSTRIAL AND UTILITY POWER PLANTS	
Oil	0.030×10^{-5}
Coal	0.008×10^{-5}
MUNICIPAL INCINERATION	0.008×10^{-5}
COKE OVEN EMISSIONS	6.5×10^{-5}

Source: Lewtas, 1987.

* These factors have been adjusted such that they are applied to the total particle concentration to estimate risk from the POM fraction of the particulate matter.

Table III.4

Application of the Comparative Potency Method to Estimation of Lung Cancer Unit Risks for Combustion Emissions

Emission Sources	Unit-Risk Estimates (Lifetime risk per million persons per microgram per cubic meter)			
	Organics		Particles	
	Relative Potency in Skin Tumor Initiation	Relative Potency in Short-Term Bioassays	Relative Potency in Skin Tumor Initiation	Relative Potency in Short-Term Bioassays
DIESELS				
Nissan	440	---	35	---
Volkswagen Rabbit	170	130	30	23
Oldsmobile	240	120	39	20
Caterpillar	---	6.6	---	2
GASOLINE CATALYST				
Mustang II	120	140	51	60
GASOLINE NONCATLYST				
Chevrolet 366	---	790	---	16
Ford Van	---	1600	---	300
RESIDENTIAL HEATERS				
Oil	95	240	9.1	23
Wood	---	4-800	---	4-800
UTILITY POWER PLANTS				
Coal	---	10-4000	---	0.002-0.8

Source: Lewtas, 1987

to be formed secondarily, it was felt that the previously used technique of estimating ambient formaldehyde concentrations exclusively from primary emissions was inappropriate. Therefore, in this study, total formaldehyde exposure in the base year was estimated from observed ambient concentrations. (No validated photochemical models were available to estimate secondary formaldehyde production from VOC and other precursors.)

The method used to estimate incidence from formaldehyde exposure was quite simple. A single representative annual average formaldehyde concentration was selected for each city; this value was multiplied by the number of people exposed; and this product was then multiplied by the formaldehyde unit risk factor of 1.3×10^{-5} Table III.5 shows the data used to make base year formaldehyde incidence estimates for each study area. The considerable uncertainty in these incidence estimates should be recognized.

Once total formaldehyde-related cancer incidence was estimated, secondary formaldehyde-related cancer incidence was estimated by subtracting, from total incidence, that incidence associated only with directly emitted formaldehyde (also termed "primary formaldehyde risk"). Primary formaldehyde incidence was determined from dispersion modeling of emissions just as all other incidence figures were in this study.

Table III.5

Base Year Total Formaldehyde Incidence Estimates

URE = 1.3x10^-5

Study Area	Formaldehyde Unit Risk (per million)	Annual Average Ambient Concentration* (ug/m^3)		Population (millions)	Estimated 70 Year Incidence
A	13	3	3.9x10^-5	1.509	59
B	13	6.7	8.71x10^-5	10.867	947
C	13	3.1	4.03x10^-5	0.383	15
D	13	3.7	4.81	1.438	69
E	13	3.7	4.81	1.688	81
Total					1,171

* These concentrations were based on ambient measurements (Lahre, 1988b) and are assumed in this analysis, to account for total (direct and secondarily formed) formaldehyde exposures and incidence.

CHAPTER IV

BASE YEAR RESULTS

A. AGGREGATE RESULTS

Aggregate cancer incidence (or population risk) across the 5 cities in this study averaged about 6 excess annual cases per million persons, ranging from about 2 to 10 in individual cities. Areawide individual lifetime cancer risks averaged about 4×10^{-4} and ranged from about 1.5×10^{-4} to $7 \times 10.^{-4}$ (Note that these risks are not maximum individual risks, which can be as high as 10^{-2} near some large point sources. Instead, these are individual risks averaged for entire urban populations. This study did not estimate maximum individual risks.)

Figure IV.1 shows the pollutants and their contribution to aggregate incidence for the five cities combined. Of the 18 compounds listed in Figure IV.1, only 4 contribute to more than 10 percent of the aggregate incidence. These four, in order of importance, are POM, 1,3-butadiene, formaldehyde, and hexavalent chromium. Compounds contributing more than 1 percent of the five city incidence but less than 10 percent are benzene (9 percent), methylene chloride (3 percent), and ethylene oxide (2 percent). All of the other studied compounds combined account for only 5 percent of the aggregate incidence. (These other pollutants may be responsible for high risk point source-related problems, though.)

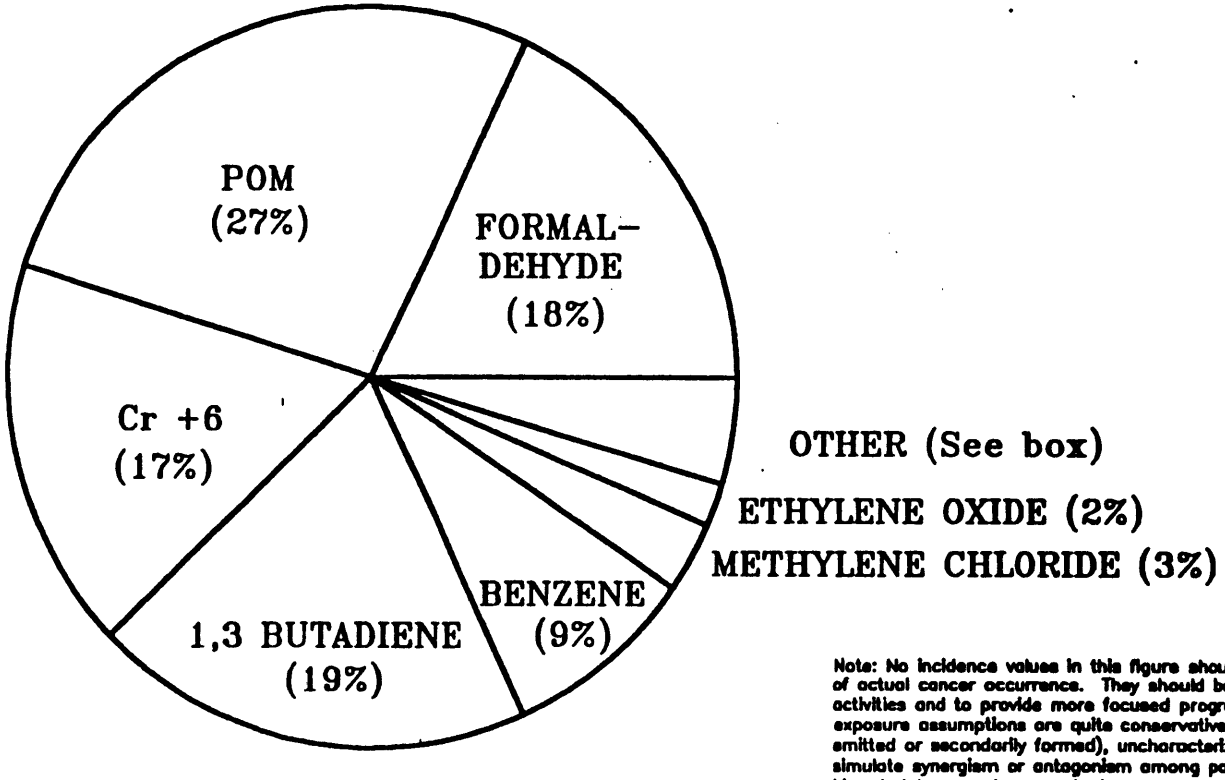
Figure IV.2 provides further information about the sources responsible for the incidence estimates shown in Figure IV.1. The most important source category contributors to aggregate incidence are road vehicles, comfort and industrial cooling towers, chrome platers, solvent use, and fuel combustion, with road vehicles contributing more than all other source types combined.

A detailed breakdown of the sources of POM risk is shown in Figure IV.3. About 77 percent of the POM risk is associated with road vehicle emissions, be they diesel particulate or gaseous particle associated organics. POM emitted by residential wood combustors -- primarily wood stoves -- is the source of 17 percent of the POM risk. The only other sources with 1 percent or more of the POM risk are external fuel combustors and iron and steel facilities. Thus, area sources dominate estimated incidence from POM exposure.

Contributors to secondary formaldehyde risk are detailed in Figure IV.4. Because contributions to secondary formaldehyde risk are assumed to be in proportion to VOC emissions, Figure IV.4 also depicts the distribution of VOC emissions by source type in the base year. Road vehicles and solvent use are the primary VOC emitting categories. There are other significant VOC emitting source types, but none with more than 10 percent of total emissions.

FIGURE IV.1

POLLUTANTS CONTRIBUTING TO FIVE CITY AVERAGE AGGREGATE CANCER INCIDENCE



OTHER (5%)

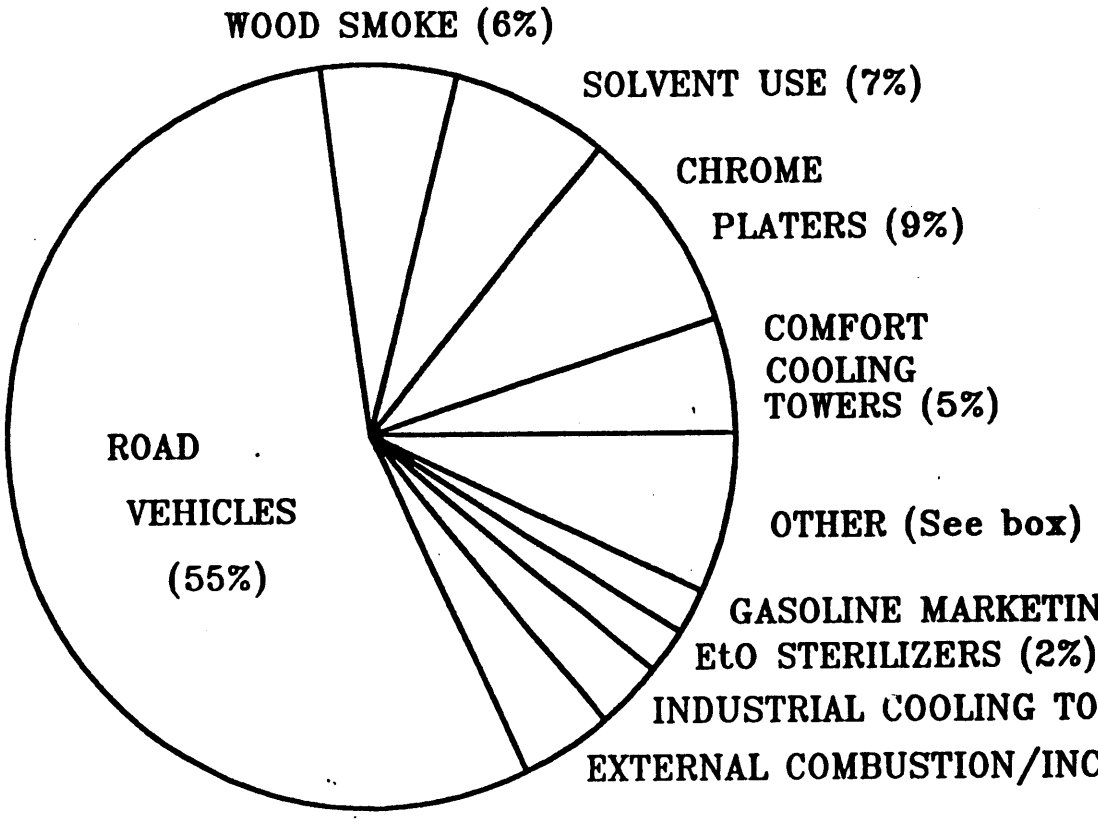
ARSENIC (1.2%)
EDC (0.9%)
GASOLINE VAPORS (0.8%)
CARBON TET (0.5%)
PERC (0.4%)
CHLOROFORM (0.2%)
TRICHLOROETHYLENE (0.2%)
CADMIUM (0.2%)
ASBESTOS (0.2%)
BERYLLIUM (0.1%)
VINYL CHLORIDE (<0.1%)

Note: No incidence values in this figure should be considered to represent absolute predictions of actual cancer occurrence. They should be used in a relative sense only for broad screening activities and to provide more focused program direction. The dose-response relationships and exposure assumptions are quite conservative. Errors due to missing pollutants (either directly emitted or secondarily formed), uncharacterized sources, and the lack of any mechanism to simulate synergism or antagonism among pollutants may potentially offset this conservative bias, but to an unknown extent.

AVERAGE FIVE CITY INCIDENCE = 5.8 CASES/YR/MILLION POPULATION

FIGURE IV.2

SOURCES CONTRIBUTING TO FIVE CITY AVERAGE AGGREGATE CANCER INCIDENCE



OTHER (8%)

- CHEMICAL MFG (1.3%)
- REFINING (1%)
- IRON & STEEL (0.7%)
- GLASS MFG (0.7%)
- REFRACTORY MFG (0.5%)
- POTWs (0.5%)
- NON FERROUS METAL (0.2%)
- OTHER (3.1%)

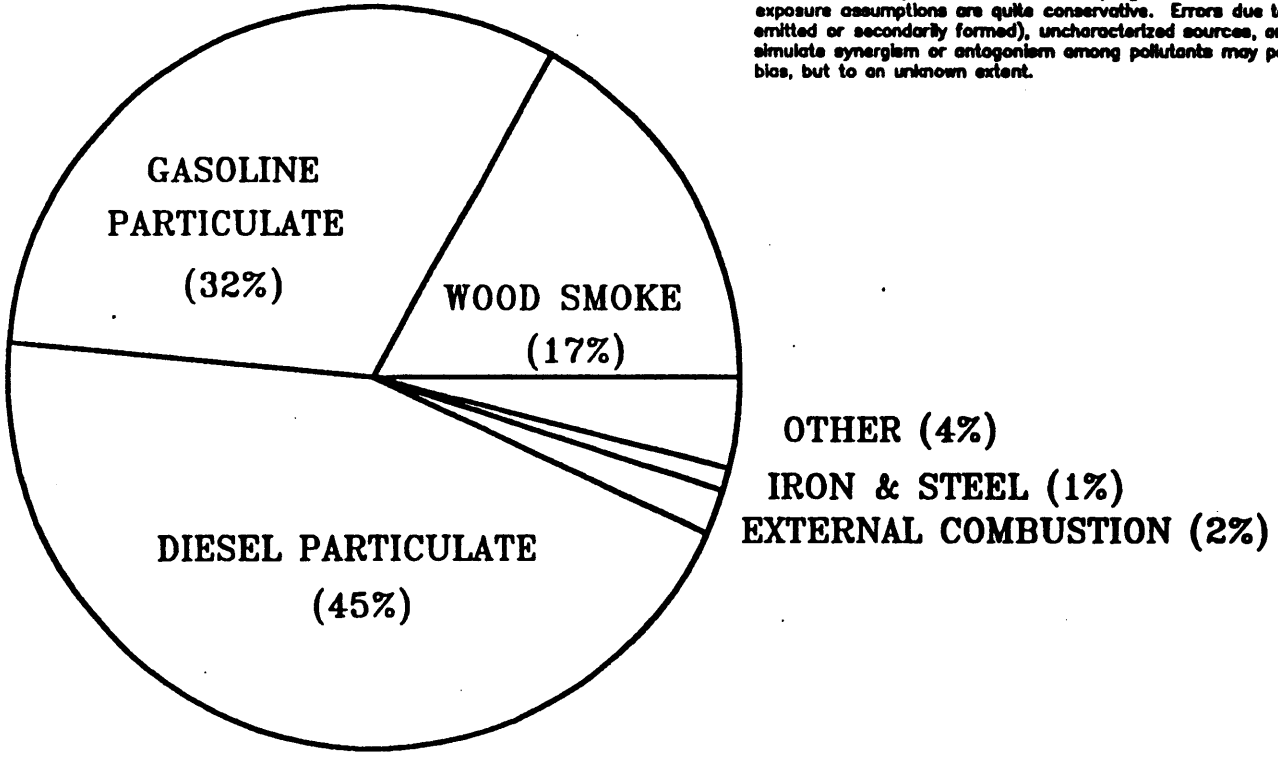
Note: No incidence values in this figure should be considered to represent absolute predictions of actual cancer occurrence. They should be used in a relative sense only for broad screening activities and to provide more focused program direction. The dose-response relationships and exposure assumptions are quite conservative. Errors due to missing pollutants (either directly emitted or secondarily formed), uncharacterized sources, and the lack of any mechanism to simulate synergism or antagonism among pollutants may potentially offset this conservative bias, but to an unknown extent.

AVERAGE FIVE CITY INCIDENCE = 5.8 CASES/YR/MILLION POPULATION

FIGURE IV.3

SOURCES OF POM-RELATED INCIDENCE

Note: No incidence values in this figure should be considered to represent absolute predictions of actual cancer occurrence. They should be used in a relative sense only for broad screening activities and to provide more focused program direction. The dose-response relationships and exposure assumptions are quite conservative. Errors due to missing pollutants (either directly emitted or secondarily formed), uncharacterized sources, and the lack of any mechanism to simulate synergism or antagonism among pollutants may potentially offset this conservative bias, but to an unknown extent.

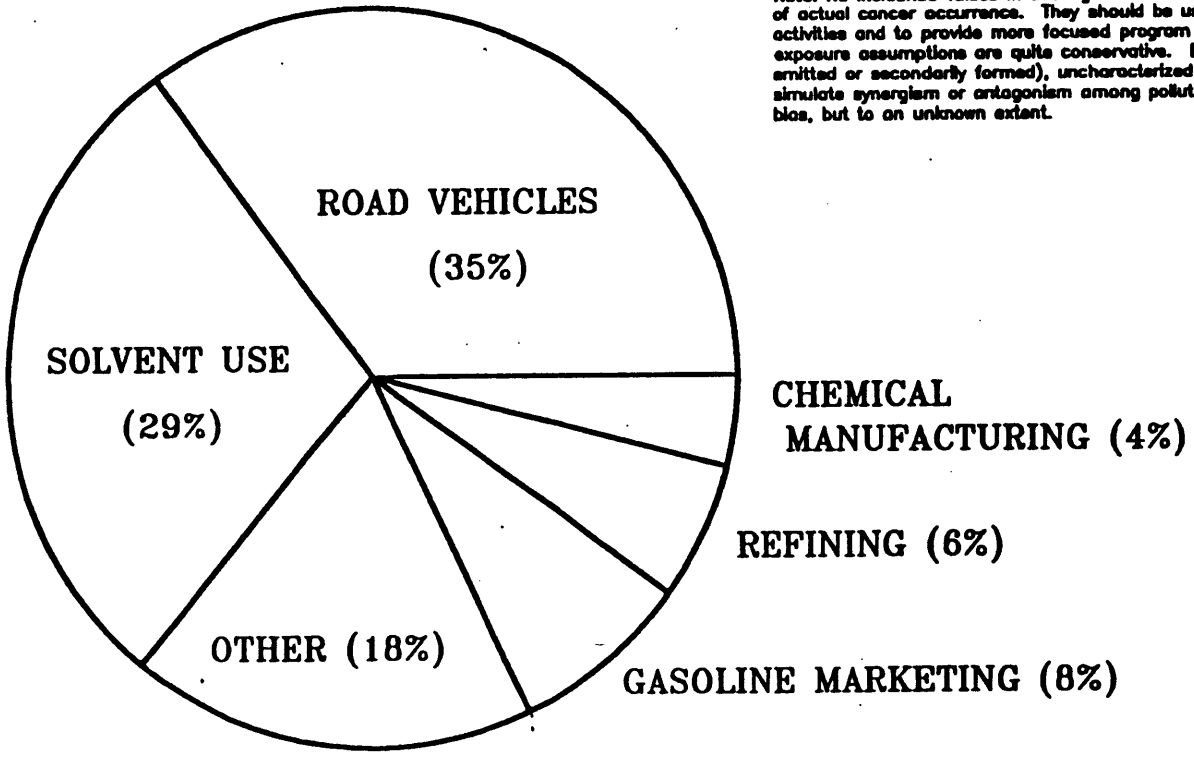


AVERAGE FIVE CITY POM-RELATED INCIDENCE
= 1.6 CASES/YR/MILLION POPULATION

FIGURE IV.4

SOURCES CONTRIBUTING TO SECONDARY FORMALDEHYDE-RELATED INCIDENCE

Note: No incidence values in this figure should be considered to represent absolute predictions of actual cancer occurrence. They should be used in a relative sense only for broad screening activities and to provide more focused program direction. The dose-response relationships and exposure assumptions are quite conservative. Errors due to missing pollutants (either directly emitted or secondarily formed), uncharacterized sources, and the lack of any mechanism to simulate synergism or antagonism among pollutants may potentially offset this conservative bias, but to an unknown extent.



AVERAGE FIVE CITY FORMALDEHYDE-RELATED INCIDENCE
= 0.6 CASES/YR/MILLION POPULATION

Sources contributing to incidence from directly emitted formaldehyde are shown in Figure IV.5. Direct emitted formaldehyde is estimated (via HEM) to contribute 40 percent of total formaldehyde related incidence. Road vehicles are the predominant contributor to direct formaldehyde related incidence, with 63 percent of the total. Incineration, off-highway vehicles, and external combustors are the next most prominent contributors to direct formaldehyde related incidence, in order of importance.

Sources of benzene related incidence are illustrated in Figure IV.6. This pollutant's incidence is dominated by motor vehicles, which account for 76 percent of the total. Residential wood combustion is the only other category with more than 10 percent of the benzene contributed incidence. As Figure IV.7 shows, road vehicles contribute 98 percent of the 1,3-butadiene related incidence in the five study areas. Chemical manufacturing facilities that emit 1,3-butadiene are found in one of the study areas and contribute 2 percent of the incidence estimated for this compound for the five areas. Primary sources of hexavalent chromium-related incidence are chrome platers and industrial and comfort cooling towers as shown in Figure IV.8.

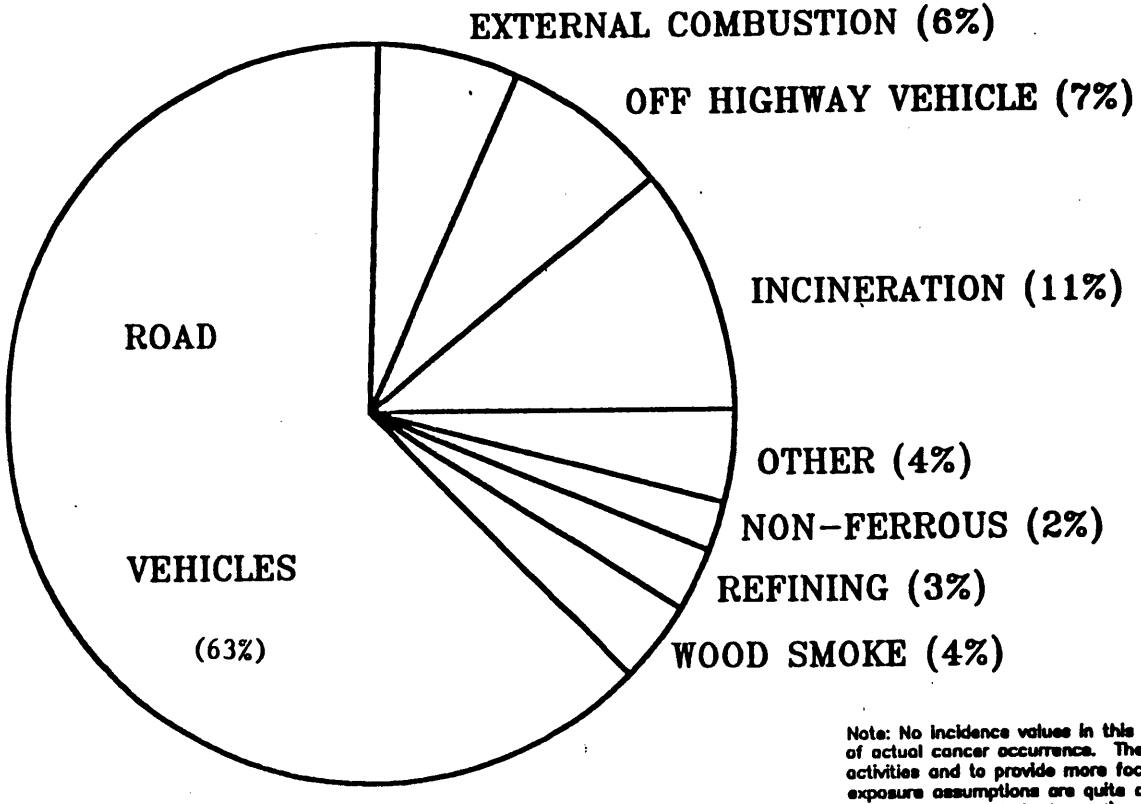
Tables IV.1 and IV.2 provide source category specific information broken down by VOC or PM related compounds. Table IV.1 results combine the secondary formaldehyde related incidence with the HEM model results for the other organic compounds. The two tables are important when evaluating future control options for reducing incidence because VOC control options would be expected to lower organic toxic compound emissions and PM controls would be expected to reduce particulate toxic emissions. Expected differences between 1980 emissions and incidence and the same values in 1995 under different control scenarios for the Table IV.1 and IV.2 source categories will be presented in Volume II of this study report.

B. CITY-SPECIFIC RESULTS

To accompany the five city aggregate results presented thus far, it was also of interest to see if the same source categories and pollutants were important in the individual city results. Figure IV.9 shows that expected incidence per million people varies from a low of 2.1 cases in Study Area A to 10 cases in Study Area D. In general, the city-specific results mirror the five city aggregate results, with the primary source categories of road vehicles, cooling towers, chrome platers, residential wood combustion, and solvent use being important contributors to incidence in all the study areas. The "other" category in Figure IV.9 has varying degrees of importance in the five cities, with Study Area C having the greatest percentage of its total incidence contributed by source categories other than the primary five. Study Area C was selected for inclusion in this study because of its chemical manufacturing facilities and petroleum refineries, so it is not surprising that point sources contribute more to the incidence in that area than they do in the other cities. (Although not identified in Figure IV.9, point sources contribute a majority of what is shown as "other" incidence for Study Area C in that figure. Point sources contribute less to the "other" incidence in Study Areas A, B, D, and E than they do in Study Area C.)

FIGURE IV.5

SOURCES CONTRIBUTING TO INCIDENCE FROM DIRECTLY EMITTED FORMALDEHYDE



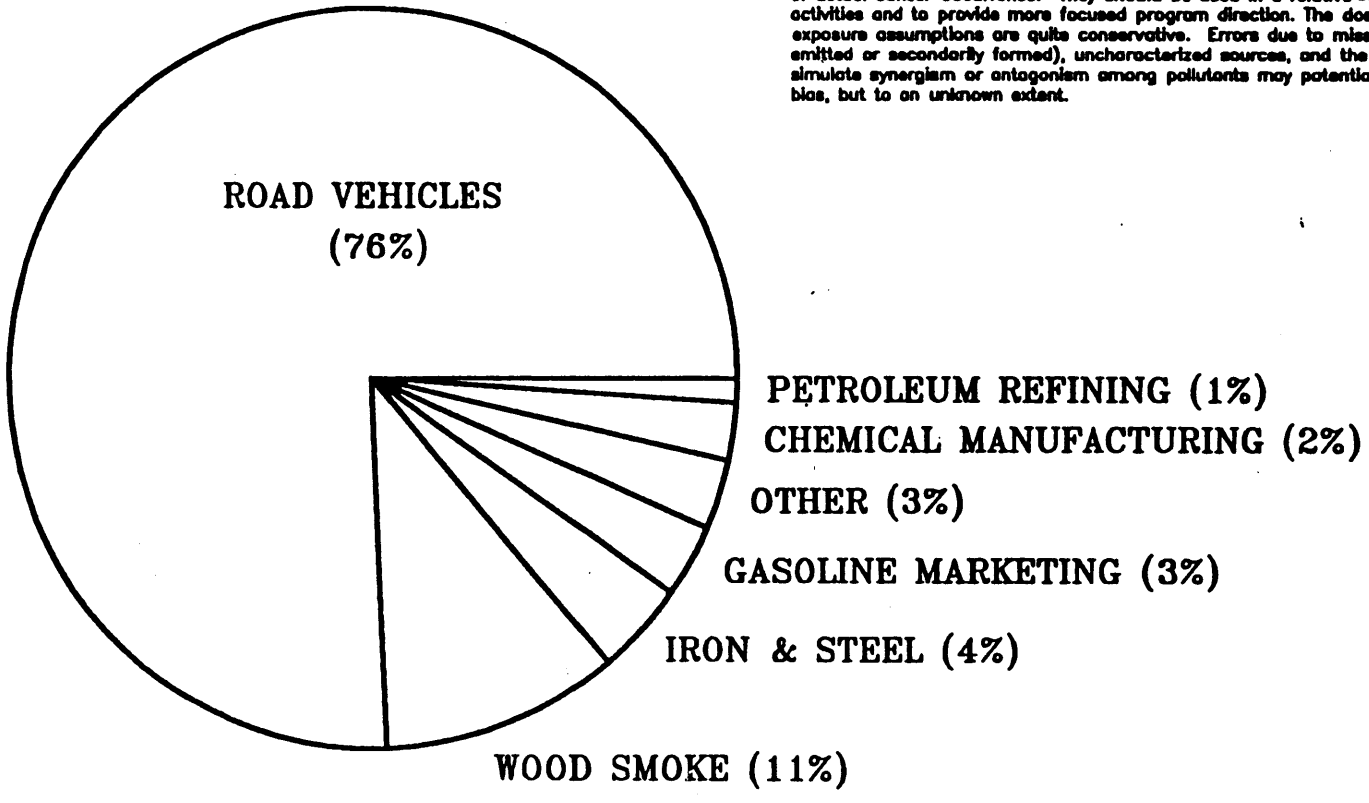
Note: No incidence values in this figure should be considered to represent absolute predictions of actual cancer occurrence. They should be used in a relative sense only for broad screening activities and to provide more focused program direction. The dose-response relationships and exposure assumptions are quite conservative. Errors due to missing pollutants (either directly emitted or secondarily formed), uncharacterized sources, and the lack of any mechanism to simulate synergism or antagonism among pollutants may potentially offset this conservative bias, but to an unknown extent.

AVERAGE FIVE CITY DIRECT FORMALDEHYDE-RELATED INCIDENCE
= 0.4 CASES/YR/MILLION POPULATION

FIGURE IV.6

SOURCES OF BENZENE–RELATED INCIDENCE

Note: No incidence values in this figure should be considered to represent absolute predictions of actual cancer occurrence. They should be used in a relative sense only for broad screening activities and to provide more focused program direction. The dose–response relationships and exposure assumptions are quite conservative. Errors due to missing pollutants (either directly emitted or secondarily formed), uncharacterized sources, and the lack of any mechanism to simulate synergism or antagonism among pollutants may potentially offset this conservative bias, but to an unknown extent.

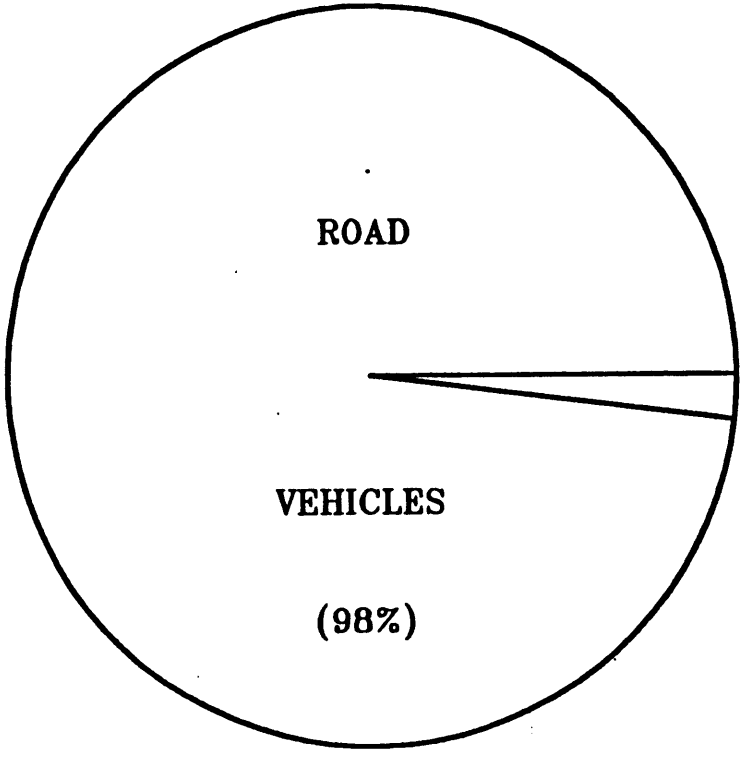


AVERAGE FIVE CITY BENZENE–RELATED INCIDENCE
= 0.5 CASES/YR/MILLION POPULATION

FIGURE IV.7

SOURCES OF 1,3 BUTADIENE–RELATED INCIDENCE

Note: No incidence values in this figure should be considered to represent absolute predictions of actual cancer occurrence. They should be used in a relative sense only for broad screening activities and to provide more focused program direction. The dose–response relationships and exposure assumptions are quite conservative. Errors due to missing pollutants (either directly emitted or secondarily formed), uncharacterized sources, and the lack of any mechanism to simulate synergism or antagonism among pollutants may potentially offset this conservative bias, but to an unknown extent.

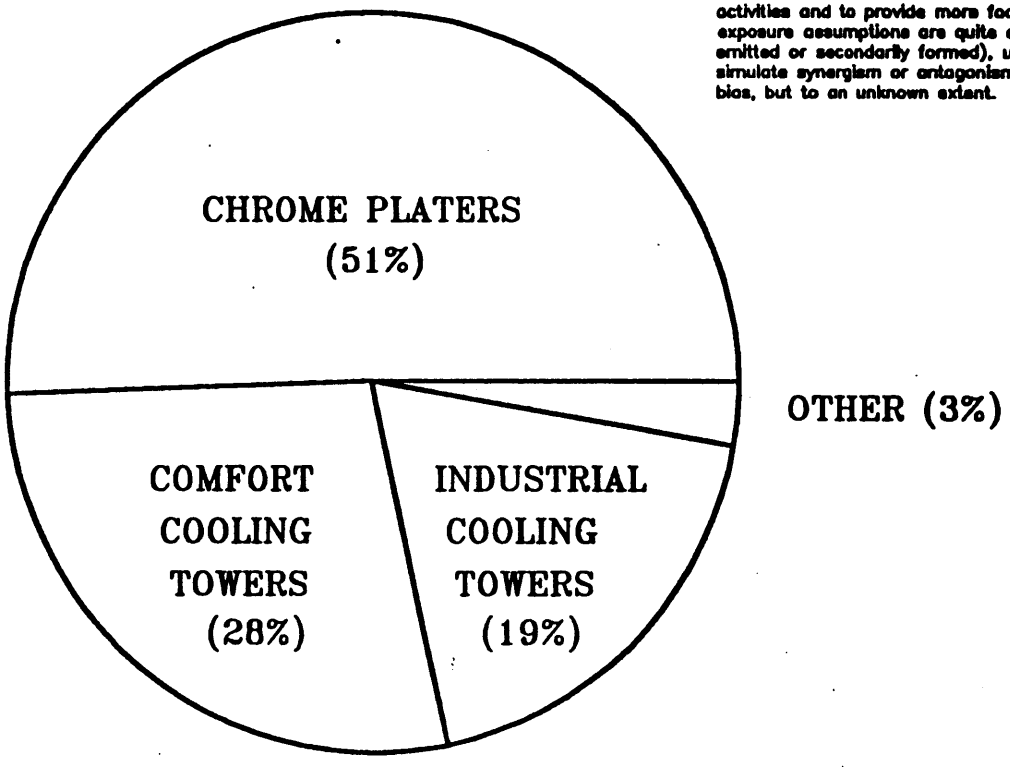


AVERAGE FIVE CITY 1,3 BUTADIENE–RELATED INCIDENCE
= 1.1 CASES/YR/MILLION POPULATION

FIGURE IV.8

SOURCES OF HEXAVALENT CHROMIUM-RELATED INCIDENCE

Note: No incidence values in this figure should be considered to represent absolute predictions of actual cancer occurrence. They should be used in a relative sense only for broad screening activities and to provide more focused program direction. The dose-response relationships and exposure assumptions are quite conservative. Errors due to missing pollutants (either directly emitted or secondarily formed), uncharacterized sources, and the lack of any mechanism to simulate synergism or antagonism among pollutants may potentially offset this conservative bias, but to an unknown extent.



AVERAGE FIVE CITY HEXAVALENT CHROMIUM-RELATED INCIDENCE
= 1 CASE/YR/MILLION POPULATION

Table IV.1

VOC Related Annual Incidence by Source Category*
Five Cities Combined

Source Category	1980 Incidence	Incidence per Million People
Light-duty Gas Vehicles	20.0	1.26
Light-duty Gas Trucks	6.4	0.40
Miscellaneous Solvent Use	2.8	0.18
Heavy-duty Gas Trucks	1.9	0.12
Surface Coating	1.6	0.10
Hospital Sterilizers	1.5	0.09
Heavy-duty Diesel Vehicles	1.3	0.08
Woodstoves	0.9	0.06
Residential Incineration	0.7	0.04
Cold Cleaners	0.5	0.03
POTWs	0.5	0.03
Dry Cleaning	0.5	0.03
Miscellaneous EDC	0.4	0.03
Total - All Categories	50.2	3.16

* VOC related compounds include formaldehyde, ethylene oxide, chloroform, carbon tetrachloride, ethylene dichloride, perchloroethylene, trichloroethylene, vinyl chloride, benzene, gasoline vapors, 1,3-butadiene, and methylene chloride.

Note: No incidence values in this table should be considered to represent absolute predictions of cancer occurrence. They should be used in a relative sense only for broad screening activiies and to provide more focused program direction. The dose-response relationships and exposure assumptions inherent in this type of cancer assessment are generally quite conservative. Errors resulting from missing pollutants (either directly emitted or secondarily formed), uncharacterized sources, and the lack of any mechanism to simulate synergism among pollutants may potentially offset this conservative bias, but to an unknown extent.

Table IV.2

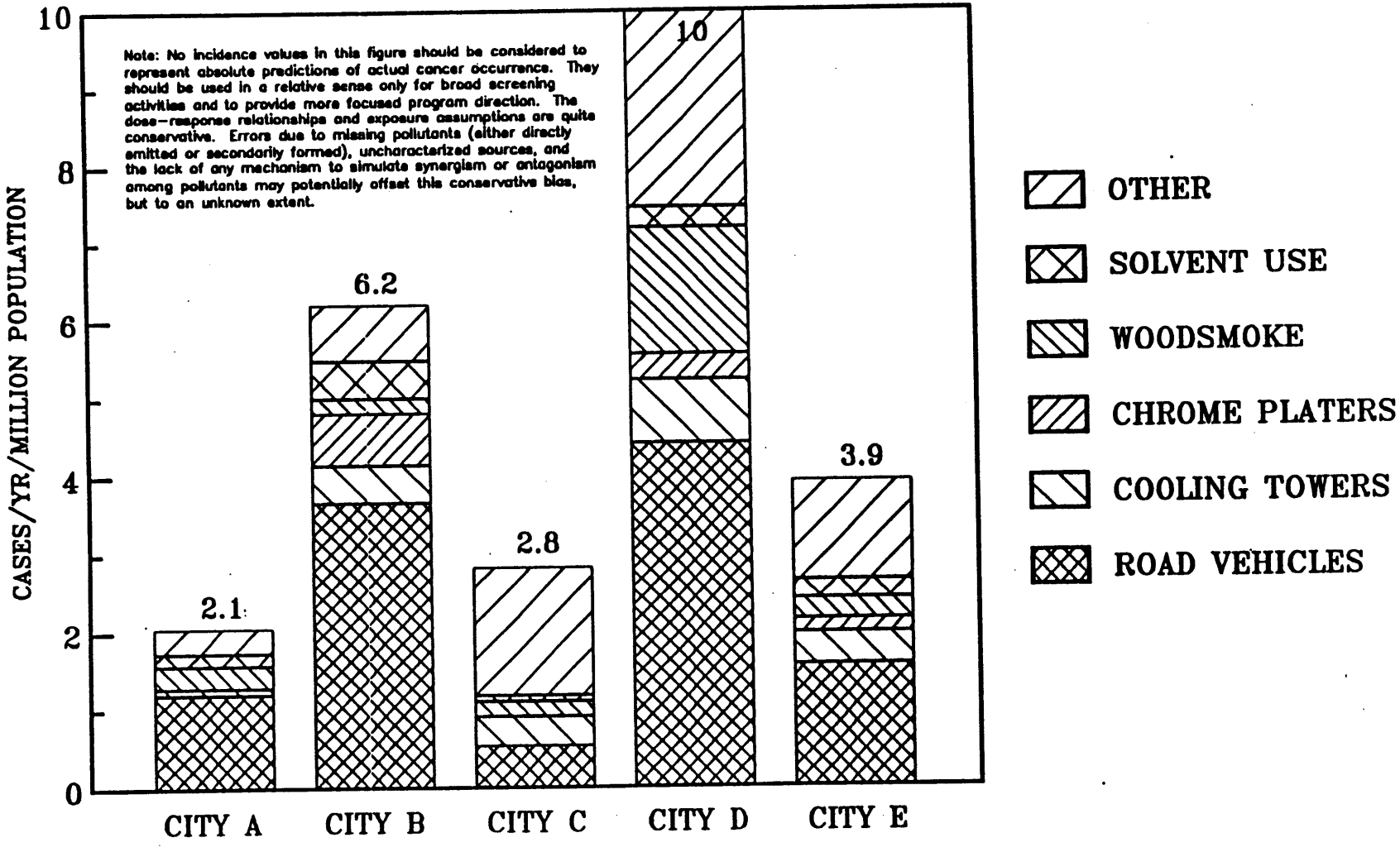
PM Related Annual Incidence by Source Category*
Five Cities Combined

Source Category	1980 Incidence	Incidence Per Million People
Heavy-duty Diesel Vehicles	11.2	0.71
Chrome Plating	8.0	0.50
Light-duty Gas Vehicles	6.2	0.39
Comfort Cooling Towers	4.4	0.28
Industrial Cooling Towers	3.0	0.19
Woodstoves	2.9	0.18
Light-duty Gas Trucks	1.4	0.09
Fireplaces	1.4	0.09
Glass Mfg. - Melting Furnace	0.7	0.04
Total - All Categories	42.5	2.68

* PM related compounds include arsenic, chromium (hexavalent), nickel, POM, diesel particulates, gasoline particle associated organics, asbestos, beryllium, and cadmium.

Note: No incidence values in this table should be considered to represent absolute predictions of cancer occurrence. They should be used in a relative sense only for broad screening activiies and to provide more focused program direction. The dose-response relationships and exposure assumptions inherent in this type of cancer assessment are generally quite conservative. Errors resulting from missing pollutants (either directly emitted or secondarily formed), uncharacterized sources, and the lack of any mechanism to simulate synergism among pollutants may potentially offset this conservative bias, but to an unknown extent.

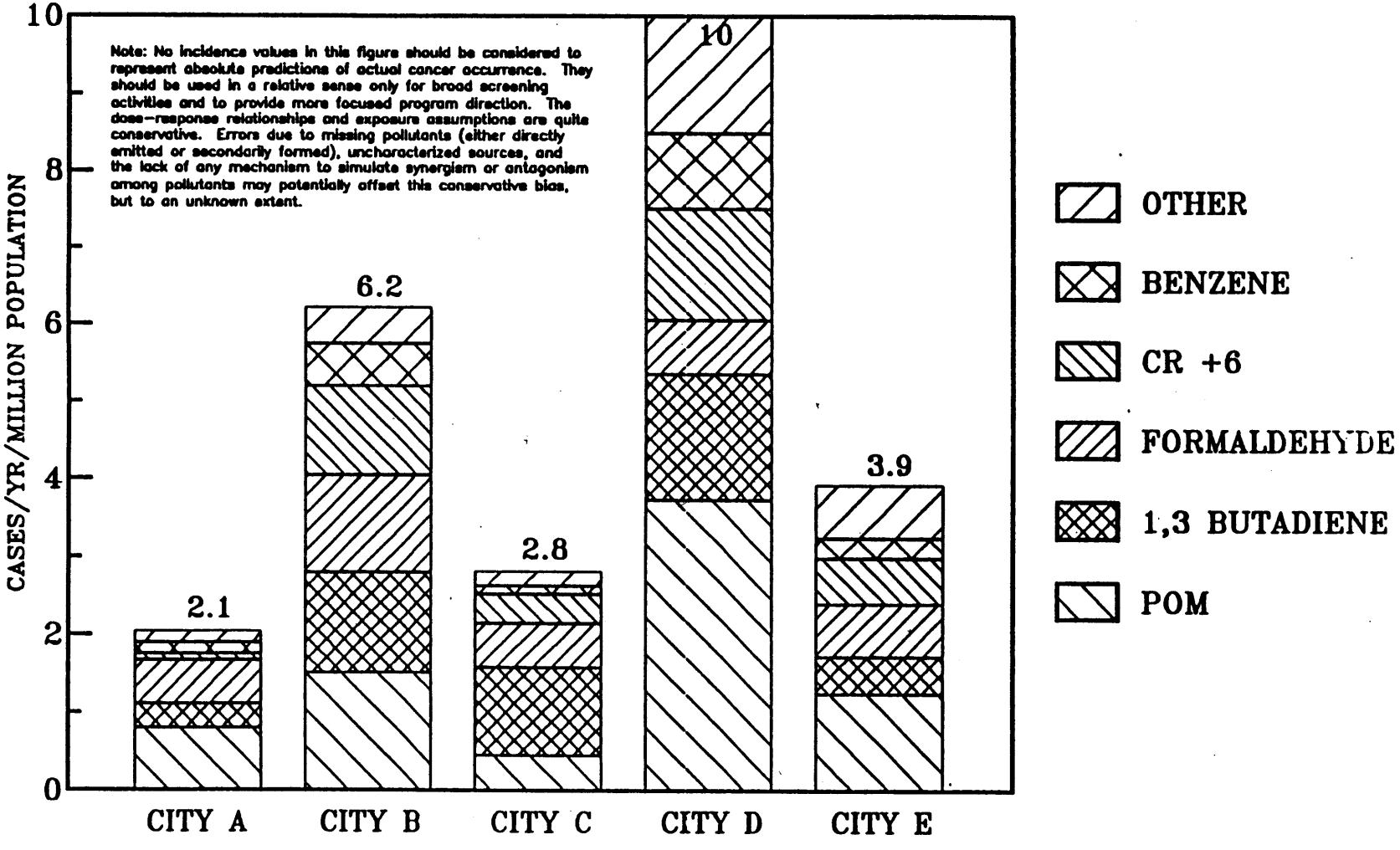
FIGURE IV.9
CITY–SPECIFIC AGGREGATE CANCER INCIDENCE
BY SOURCE CATEGORY



FIVE CITY AVERAGE INCIDENCE = 5.8 CASES/YR/MILLION POPULATION

City-specific results are presented by pollutant in Figure IV.10. Benzene, hexavalent chromium, formaldehyde, 1,3-butadiene, and POM contribute to more than 80 percent of the incidence estimated for each city. These top five pollutants constitute as much as 93 percent of the incidence in some study areas. POM related incidence seems to vary quite a bit by city, and this variation is probably related to the percentage of emissions in each study area that are from mobile sources. Incidence attributable to 1,3-butadiene exposure is a larger portion of the total in Study Area C than it is elsewhere. This occurs because there were some point source emitters of 1,3-butadiene identified for Study Area C, but not in the other areas.

FIGURE IV.10
CITY–SPECIFIC AGGREGATE CANCER INCIDENCE
BY POLLUTANT



FIVE CITY AVERAGE INCIDENCE = 5.8 CASES/YR/MILLION POPULATION

CHAPTER V

ASSUMPTIONS/LIMITATIONS

Some of the more important assumptions and caveats associated with this study are as follows:

(1) Personal exposure to air toxics was estimated using annual-average concentration estimates and it was assumed that exposures occur where people reside. In addition, only outdoor exposures were modeled. Thus, this methodology ignores people's movements throughout the urban area, travel outside the urban area, indoor exposures and seasonal or diurnal variations in emissions. Because exposures were simulated over a 70-year period, it is unclear how much this restricted modeling methodology affects the study results.

(2) The study relied solely on quantitative estimates of cancer risk associated with inhalation of ambient air over long periods. Acute and subchronic effects were not included, and cancer cases associated with exposure routes other than inhalation of ambient air were not quantified.

(3) Only 25 compounds were explicitly included in this study, although monitoring studies have shown that urban atmospheres typically contain additional carcinogenic pollutants. The compounds selected for study were chosen because they were estimated to be the most important contributors to excess cancer incidence.

(4) This study focused on routine, continuous emissions. Accidental releases were not modeled.

(5) Unit risk factors employed in this study represent the chance of contracting cancer from a lifetime (70 years) exposure to a given concentration of that pollutant. It was assumed that the resulting lifetime incidence levels could be divided by 70 to represent annual incidence levels. The carcinogenic potency estimates used in this study were developed by EPA's Carcinogen Assessment Group, and generally represent conservative (upper bound) dose/response relationships.

(6) Cancer incidence estimates are presented for "existing" conditions (1980). These incidence estimates are based on the assumption that emission levels for each scenario remain constant for a 70-year period. In reality, emissions will vary from year to year.

(7) In assessing cancer risk within an urban area, each of the compounds under study has been analyzed individually and the effects considered additive. No synergistic or antagonistic health effects of these compounds have been assumed.

(8) Sources included in the exposure modeling data set for each study area were limited to those in the counties under study. Therefore, while contributions from these sources to areas outside the county boundaries were considered, contributions of sources outside the county boundaries to air toxic concentrations within the study areas were not.

(9) Modeling results presented in this report for exposure to gasoline vapors from marketing operations do not include self-service exposures at service stations.

(10) Except for secondary formaldehyde formation, atmospheric transformation of toxic compounds and precursors has been ignored. Both secondary formation and scavenging may occur for the compounds included in this study. Thus, it is difficult to quantify how neglecting transformation might affect the final results.

(11) Incidence from formaldehyde exposure was estimated using ambient monitoring data and assuming that everyone within an urban area is exposed to the same concentration. This is a relatively crude technique, but because so much of formaldehyde is formed secondarily, this procedure was judged to be preferable to modeling direct formaldehyde concentrations and ignoring secondary formation.

(12) It has been suggested that global background concentrations of some toxic compounds, notably carbon tetrachloride, may be contributing significantly to observed ambient readings. No attempt has been made in the dispersion modeling performed for this study to account for background concentrations.

(13) While the comparative potency approach used to estimate POM risks for several important sources is judged to be an improvement, conceptually, over previous techniques which used B(a)P as a surrogate for POM, available comparative potency factors are, in fact, based on few measurements, especially for the important motor vehicle categories, and the uncertainty in these values should be recognized.

(14) The handling of some point sources as area sources for modeling purposes may introduce some upward bias in the resulting exposure/risk estimates since HEM distributes area source emissions by population and since area sources are emitted closer to ground level.

(15) Caution is urged when applying the study results to other cities since the sources and pollutants may not be representative of some other areas. For example, no study areas include the heavy concentration of wood stoves that characterize some northern cities; hence, the relative importance of wood smoke may be understated in this report.

(16) Any study such as this represents a "snapshot in time" of one's collective understanding of the urban air toxics problem. In fact, the emission estimates and dose-response relationships used in this study are subject to frequent revision as newer data become available. Hence, care should be taken when interpreting any results from this study or comparing these results to those from other studies where different data have been used.

CHAPTER VI

CONCLUSIONS

There are three primary conclusions that can be drawn from the exposure analyses conducted to date. The first is that small point and area sources dominate point sources in contributing to area wide cancer incidence in the five urban areas studied. The second finding is that a few pollutants dominate cancer incidence (POM, formaldehyde, 1,3-butadiene, hexavalent chromium, and benzene). In fact, the same sources and pollutants are important in all the cities analyzed in this study. The third finding is that there is a high level of uncertainty in the results because of the rapidly changing data bases and because of the many assumptions made, which continually evolve. Cancer incidence estimates can change by a large magnitude and the ranking in importance of various sources and pollutants can change depending on the emission factors, unit risk factors, and assumptions made in the analysis, and these assumptions will continue to change as new information becomes available.

An unpublished modeling study conducted for the same five cities in 1985 produced incidence estimates that were 800 percent higher than the current results. This dramatic decrease in incidence occurred despite adding a number of compounds to the study that were not analyzed previously and changing the approach for estimating formaldehyde-related incidence to capture secondary formation. One major reason for this decrease was the change in emission estimates for all important source categories reflecting newer emission factors and activity levels. A second reason is that many of the unit risk values listed in Table III.1 have been changed in the past 5 years as new information has become available. Another major change affecting analysis results has been the method for estimating POM-related incidence. The comparative potency approach used here produces much lower POM incidence estimates for some important source categories than the previous approach of using B(a)P as a surrogate for POM.

Of the compounds modeled in this study but not included in the previous study, 1,3-butadiene had the greatest effect on results. In fact, incidence associated with 1,3-butadiene exposure was estimated to be higher than that of any other compound except POM. The uncertainty in these 1,3-butadiene related incidence results is pointed out by revisions made within the last year by the Office of Mobile Sources to its motor vehicle emission factors for 1,3-butadiene that lowered the previous estimates by 63 percent. Thus, readers of this report should use caution in making judgments from results which may change significantly in the future as more information becomes available on air toxic emissions, atmospheric reactions, and risks associated with exposure.

One significant conclusion of the previous study which has not changed here is the dominance of mobile, small point, and area sources in contributing to incidence. Large

point sources are not in the list of top five source category-pollutant contributors to incidence in any of the study areas. This suggests that either large point sources are removed from where most people live or they are already well controlled, or both. An important measure of the impact of point sources is maximum individual risk (MIR), a distinctly different measure from the aggregate incidence measure that was the focus of this phase of this study. Maximum individual risk and the potential for reducing this risk through alternative control strategies is addressed in Volume II of this report.

GLOSSARY OF TERMS

Acute exposure - One or a series of short-term exposures generally less than 24 hours.

Additive risk/incidence - Risk/incidence due to the interaction of two or more chemicals in which the combined health effect is equal to the sum of the effect of each chemical alone.

Aggregate incidence - In an urban air toxics context, this term generally refers to areawide, additive incidence. This term sometimes refers to just areawide incidence or additive incidence, so one should pay attention to the contextual use for the proper meaning.

Ambient (air) monitoring - The collection of ambient air samples and the analysis thereof for air pollutant concentrations.

Annual incidence - Lifetime incidence adjusted to a yearly basis, typically by dividing lifetime incidence by 70.

Area source - Any source too small and/or numerous to consider individually as a point source in an emissions inventory.

Areawide average individual risk - Average individual risk to everyone in an area (but not necessarily the actual risk to anyone). May be computed by dividing lifetime aggregate incidence by the population within the area.

Areawide incidence - Incidence over a broad area, such as a city or county, rather than at a particular location, such as an individual grid cell.

B(a)P - Benzo(a)pyrene. One of a group of compounds called polycyclic organic matter (POM). B(a)P is sometimes used as a surrogate for all POM in computing emissions, exposures and risks.

Background - A term used in dispersion modeling representing the contribution to ambient concentrations from sources not specifically modeled in the analysis, including natural and manmade sources.

BACT - Best Available Control Technology.

BG/ED - Block group/enumeration district. Designated by the Bureau of Census. A block group is an area representing a combination of contiguous blocks having an average

population of about 1100. An enumeration district is an area containing an average of about 800 people and is designated when block groups are not defined.

Bioassay - A test in living organisms, e.g., a test for carcinogenicity in laboratory animals, generally rats and mice, which includes a near-lifelong exposure to the agent under test.

Box model - A simplified modeling technique that assumes uniform emissions within an urban area and uniformly mixed concentrations within a specified mixing depth.

CAG - Cancer assessment group. EPA group that prepares qualitative and quantitative carcinogenic risk assessments.

Cancer - A cellular tumor, the natural course of which is fatal. Cancer cells, unlike benign cells, exhibit properties of invasion and metastasis (malignancy). Cancers are divided into two broad categories: carcinoma and sarcoma.

Carcinogenicity - The extent to which a substance is able to induce a cancer response.

Catalyst - A substance which promotes a chemical reaction. In the context of this report, a device installed on the tailpipe of a motor vehicle to control exhaust emissions.

CDM - Climatological Dispersion Model. A Gaussian dispersion model whose particular strength is its detailed area source treatment. Can also handle point sources, but not in as detailed a manner as the Industrial Source Complex (ISC) model.

Centroid (population, source) - A single point whose coordinates represent the location of a BG/ED, in the case of a population centroid, or the location of an emission point, in the case of a complex source.

Chronic exposure - Long-term exposure usually lasting 6 months to a lifetime.

Co-control - In the context of air toxics, co-control represents the simultaneous control or mitigation of air toxics and criteria pollutants via the same control measure. For example, a motor vehicle catalyst would reduce VOC and CO emissions and also reduce benzene and other gaseous toxics.

Comparative potency factor - A cancer unit risk factor for a complex substance or mixture that is extrapolated from human risk data for a reference substance and the ratio of short term bioassay responses of the complex substance to the reference substance. EPA is developing comparative potency factors for various classes of POM.

Coverage (pollutant, source, spatial) - The extent of inclusion of pollutants or sources in an emission inventory or risk analysis or the amount of space or area represented in a monitoring program or inventory or risk analysis.

Cr^{+6} - Hexavalent chromium, i.e., chromium in the +6 valence state.

Criteria pollutants - Pollutants defined pursuant to Section 108 of the Clean Air Act and for which national ambient air quality standards are prescribed. Current criteria pollutants include particulate matter, SOx, NOx, ozone, CO and lead.

Culpability - The extent to which something (generally a pollutant or source) is responsible for some effect (such as exposure or risk).

Decay - A term that represents pollutant removal by physical or chemical processes.

Deposition - The removal of particulate matter and gases, at a land or water body surface, by precipitation or dry removal mechanisms, including surface reactions and filtering.

Dispersion coefficients - Parameters used in Gaussian dispersion modeling to estimate plume growth through dispersion along the horizontal and vertical axes. These are computed as a function of downwind distance and atmospheric stability.

Dispersion modeling - A means of estimating ambient concentrations at locations (receptors) downwind of a source, or an array of sources, based on emission rates, release specifications and meteorological factors such as wind speed, wind direction, atmospheric stability, mixing height and ambient temperature.

DNPH - Dinitrophenylhydrazine. Material used in special cartridges for monitoring of formaldehyde and other aldehydes.

Effective stack height - The height above ground level of the centerline of a plume. It is the sum of the physical stack height, plume and stack-tip downwash (as applicable).

EPA - U.S. Environmental Protection Agency.

Excess cancer risk - An increased risk of cancer above the normal background.

Exposure - An event in which an organism comes into contact with a chemical or physical agent.

Exposure assessment - Measurement or estimation of the magnitude, frequency, duration and route of exposure to substances in the environment. The exposure assessment also describes the nature of exposure and the size and nature of the exposed populations.

FMVCP - Federal Motor Vehicle Control Program. EPA's program to control motor vehicle emissions.

Fugitive emission/release - Emissions unconfined to a stack or duct, such as equipment leaks from valves, flanges, etc., or open spills.

Gaussian model - A Gaussian dispersion model represents the distribution of concentrations within a plume by assuming a normal distribution along the horizontal and vertical axes. In the basic form, predicted concentrations are estimated as a function of emission rate, horizontal and vertical dispersion coefficients, and vertical and horizontal distance from the plume centerline.

Global buildup - The widespread accumulation of pollutants in the atmosphere over the years. Global buildup is generally associated with more inert compounds such as halogens (e.g., carbon tetrachloride).

Grid - A network of rectilinear or polar grid cells superimposed over an area, generally for modeling analyses. A rectilinear grid is defined by a series of perpendicular lines defining rectangular or square grid cells whereas a polar grid is defined by a series of concentric circles and straight lines radiating from the center of the circles.

Grid cell - The smallest area resolved within a modeling grid.

Grid spacing - The dimensions of the grid cells within a grid.

Grid square - A grid cell whose sides are equal.

HC - Hydrocarbon.

HDDV - Heavy duty diesel vehicles.

HEM - Human Exposure Model. EPA model used for exposure and risk analysis, which defines polar receptor grids around each point source. Can also model area sources by apportioning county level emissions to each BG/ED and running a simple box model. HEM contains two component modules: SHED and SHEAR.

Highway vehicle source - Car, truck or motorcycle. Also called road vehicles or motor vehicles.

Hotspot - A particular receptor, grid cell or localized area wherein exposure or risk is high.

IACP - Integrated Air Cancer Program. EPA long-term research and development program to develop methods and conduct field and lab tests to learn what causes cancer in complex urban air mixtures and what sources are contributing to this cancer burden.

IEMP - Integrated Environmental Management Project. A series of studies conducted in Philadelphia, Baltimore, Santa Clara, Kanawha Valley and Denver to evaluate multi-media contributions to various health risks, with emphasis on cancer.

Incidence - The frequency of occurrence of a certain event or conditions, such as the number of new cases of a specific disease or tumor occurring during a certain period. The incidence rate is the number of new cases during a certain period divided by the population size (e.g., 10 cases per 100,000 exposed persons).

Individual risk - The increased risk for a person exposed to a specific concentration of a toxicant. May be expressed as a lifetime individual risk or as an annual individual risk, the latter usually computed as 1/70 of the lifetime risk.

LDDT - Light-duty diesel truck.

LDDV - Light-duty diesel vehicle.

LDGV - Light-duty gasoline vehicle.

Lifetime - Considered to be 70 years in EPA health risk assessments.

MEI - Maximum exposed individual.

Microenvironment - Localized environment in which one may be exposed to pollutant concentrations considerably different than in ambient (outdoor) air, e.g., indoor household air, occupational exposures, air within automobiles. EPA's Total Exposure Assessment Methodology (TEAM) studies evaluate personal exposures as individuals are exposed to air in different microenvironments during each day.

Micron - One millionth of a meter. A dimensional unit used to measure the diameters of particles.

MIR - Maximum individual risk, i.e., risk to the most exposed individual.

Mitigation - The reduction or control of emissions, exposures or risks due to air toxics.

Mobile source - Any motorized vehicle, such as cars, trucks, airplanes, trains. Sometimes refers specifically to highway vehicle sources.

Model(ing) - See dispersion modeling or receptor modeling. This term can also be used in the context of emissions modeling, referring to the prediction of emissions from a source or source category.

Monitoring - The collection and analysis of ambient air samples. Sometimes refers specifically to just sampling and not to analysis. Can also refer to source (stack) sampling.

Motor vehicle - On-road or off-road cars, trucks or motorcycles.

Mutagenicity - The extent to which a chemical or physical agent interacts with DNA to cause a permanent, transmissible change in the genetic material of a cell.

NAAQS - National Ambient Air Quality Standard. Set by EPA for criteria pollutants under the Clean Air Act.

NAPAP - National Acid Precipitation Assessment Program.

NEDS - National Emissions Data System. EPA's centralized emission inventory of criteria pollutant emissions.

NESHAP - National Emission Standards for Hazardous Air Pollutant. Standards set by EPA for hazardous air pollutants under Section 112 of the Clean Air Act.

Noncancer risk - Risk of a health effect other than cancer.

Nontraditional sources - Sources not usually included in an emission inventory, such as wastewater treatment plants, groundwater aeration facilities, hazardous waste combustors, landfills, which are air emitters due to intermedia transfer from water or solid waste.

Normalized modeling - Modeling of unit weights (e.g., 1 Mg/yr) of emissions from each source, rather than modeling of actual emissions, and displaying incremental receptor concentrations or receptor coefficients. Thereafter, the resulting normalized receptor

coefficients are adjusted by actual emission rates to simulate different emission scenarios rather than re-running the model over and over with different emissions totals. This process assumes linearity between emissions and modeled ambient air concentrations, which does not always hold if stack and exhaust parameters change.

NSPS - New Source Performance Standards.

NSR - New Source Review. Permit process for evaluating emissions and need for controls before construction and operation of a proposed facility. EPA as well as many States and local agencies have NSR requirements for air toxics sources.

OAQPS - EPA's Office of Air Quality Planning and Standards.

OMS - EPA's Office of Mobile Sources.

OPPE - EPA's Office of Policy, Planning and Evaluation. Initiator of the Integrated Environmental Management Project, a series of geographic, multi-media studies in various cities (see IEMP).

PAN - Peroxyacetyl Nitrate. A photochemical oxidant formed in urban atmospheres along with ozone.

Photochemically formed pollutant - A secondarily formed pollutant due to atmospheric photochemistry. Some exampels are formaldehyde and PAN.

PIC - Products of incomplete combustion. A term used somewhat loosely in various studies referring generally to polycyclic organic matter.

PIPQUIC - Program Integration Project -- Queries Using Interactive Commands. A data handling system developed by EPA as part of the IEMP to calculate exposures and risks from air toxics emissions data. PIPQUIC is being used in various urban air toxics studies.

PM - Particulate matter.

PM_{10} - PM less than 10 microns in diameter.

Point source - A source large enough to keep an individual record on in an emission inventory, often emitting above a certain cutoff level or threshold.

Polar grid - See grid.

POM - Polycyclic organic matter. A broad class of compounds which generally includes all organic structures having two or more fused aromatic rings (i.e., rings sharing a common border). POM includes polynuclear aromatic hydrocarbons (PAH or PNA).

Primary pollutant - One emitted directly from an emission source, prior to any secondary physical or chemical reaction.

Receptor - A particular point in space where a monitor is located or where an exposure or risk is modeled.

Receptor grid - An array of receptors. Generally synonymous with network.

Receptor modeling - A technique for inferring source culpability at a receptor(s) by analysis of the ambient sample composition. There are various receptor models employing microscopic and chemical methods for analysis.

Release specifications - Release specifications are used as model inputs to characterize the location, release height, and buoyant and momentum fluxes of each source. Required terms include stack height, exit velocity, inner stack diameter, exhaust temperature and the dimensions of nearby structures.

Risk - The probability of injury, disease, or death under specific circumstances. In quantitative terms, risk is expressed in values ranging from zero (representing the certainty that harm will not occur) to one (representing the certainty that harm will occur).

Risk assessment - The use of the factual base to define the health effects of exposure of individuals or populations to hazardous materials and situations. May contain some or all of the following four steps:

Hazard identification - The determination of whether a particular chemical is or is not causally linked to particular health effects.

Dose-response assessment - The determination of the relation between the magnitude of exposure and the probability of occurrence of the health effects in question.

Exposure assessment - The determination of the extent of human exposure.

Risk characterization - The description of the nature and often the magnitude of human risk, including attendant uncertainty.

Risk management - The decision-making process that uses the results of risk assessment to produce a decision about environmental action. Risk management includes consideration of technical, social, economic and political information.

Road vehicle source - See highway vehicle source.

Sampling - See monitoring or ambient air monitoring.

Scoping study - Also known as screening study. An assessment or analysis using tentative or preliminary data whose results are not accepted as absolute indicators of risk or exposures, but rather, are taken as an indication of the relative importance of various sources, pollutants and control measures. Most urban air toxics assessments conducted to date have been considered to be scoping studies, useful for pointing out where more detailed work is needed prior to regulation.

Screening study - See scoping study.

Secondary pollutant - Also, "secondarily formed pollutant." A pollutant formed in the atmosphere as a result of chemical reaction and/or condensation, such as PAN. Some pollutants (e.g., formaldehyde) are both primary and secondary pollutants.

SHEAR - Systems Application Human Exposure and Risk. A module within EPA's Human Exposure Model designed to focus on multiple pollutant, multiple source exposures, including area source analyses. SHEAR uses a Gaussian dispersion model for point sources and a box model for area sources.

SHED - Systems Applications Human Exposure and Dosage Model.

SIC - Standard Industrial Classification. A series of codes or classifications to categorize industry, published regularly by the Office of Management and Budget.

SIP - State Implementation Plan. Required by States under the Clean Air Act to indicate plan of action to meet National Ambient Air Quality Standards for criterial pollutants.

Source apportionment - See receptor modeling.

Source grid - A grid defined to encompass all emission sources that one wants to model. The source grid is sometimes defined bigger than a corresponding receptor grid so that all local sources impacting on the receptor grid will be considered. More typically, the source grid and receptor grid coincide in most studies.

Spatial coverage - The area included or covered by a sampling network or a source/receptor grid.

Spatial resolution - The extent to which emissions, monitoring or any other data are subdivided or resolved in space, generally across a geographical area. For example, emissions data may be spatially resolved to 1 km by 1 km squares within an urban area.

Species profile - A set of apportioning factors that allow one to subdivide VOC or PM emission totals into individual chemicals or chemical classes. Generally, species profiles are multiplicative in nature.

Stability - A parameter to describe the degree of turbulence in the atmosphere ranging from unstable (vigorous mixing) to stable (suppressed mixing).

Subchronic exposure - Exposure to a substance spanning approximately 10 percent of the lifetime of an organism.

Surrogate indicator - A variable whose spatial or temporal distribution is assumed to behave in the same manner as some variable of interest. Surrogate indicators are used for spatial and temporal apportionment of emissions data, especially for area sources.

Temporal resolution - The extent to which some variable, typically emissions and monitoring data, is subdivided or resolved in time. Data, for example, may be resolved hourly or seasonally.

Transformation - The conversion, through chemical or physical processes, of one compound or several compounds into other compounds as a result of aging and irradiation in the atmosphere.

Transport - The movement of pollutants by wind flow. Transport is characterized for modeling purposes by wind speed and wind direction.

Unit cancer risk factors - The incremental upper bound lifetime risk estimated to result from a lifetime exposure to an agent if it is in the air at a concentration of 1 microgram per cubic meter.

Urban soup - An expression referring to the multi-source, multi-pollutant urban air toxics problem resulting from the complex interaction of many pollutants, sources and atmospheric transformation.

VMT - Vehicle miles traveled. Mobile source emission factors are typically expressed in terms of grams per VMT.

VOC - Volatile organic compounds.

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TECHNICAL REPORT DATA
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1. REPORT NO. EPA-450/2-89-012a	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Analysis of Air Toxics Emissions, Exposures, Cancer Risks and Controllability in Five Urban Areas Volume I - Base Year Analysis and Results		5. REPORT DATE July, 1989
		6. PERFORMING ORGANIZATION CODE OAQPS
7. AUTHOR(S) Jim Wilson, Deborah Istvan, and Erica Laich of E. H. Pechan; Tom Lahre, EPA, OAQPS		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS E. H. Pechan and Associates, Inc. 5537 Hempstead Way Springfield, VA 22151		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Noncriteria Pollutant Programs Branch Air Quality Management Division Office of Air Quality Planning and Standards Research Triangle Park, N.C. 27711		13. TYPE OF REPORT AND PERIOD COVERED
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This report (Volume I) is the first phase of a study to (1) define the multiple source, multiple pollutant nature of the urban air toxics problem (also known as "urban soup"), and (2) to discern what control measures (or combinations of measures) can best be employed to mitigate the urban air toxics problem. This report documents the base year analysis, involving dispersion modeling of emissions data for 25 carcinogenic air toxics in five U. S. urban areas and a subsequent exposure/risk assessment to estimate aggregate cancer incidence.

Aggregate (multi-source, multi-pollutant) cancer incidence (or population risk) across the 5 cities in this study averaged about 6 excess cases per million persons, ranging from about 2 to 10 in individual cities. The most important pollutants contributing to aggregate incidence are polycyclic organic matter (POM), 1,3-butadiene, formaldehyde and hexavalent chromium. The most important sources are road vehicles, comfort and industrial cooling towers, chrome platers, solvent use and fuel combustion, including woodstoves.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air toxics Cancer incidence, air toxics Controllability, air toxics Hazardous air pollutants Mitigation, air toxics Risk assessment, air toxics Urban air toxics (urban soup)		

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES 90
	20. SECURITY CLASS *(This page)*	22. PRICE

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