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Air Toxics Emissions From Motor Vehicles

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INTRODUCTION

Considerable effort is underway within the Environmental Protection Agency (EPA) to determine the magnitude of the air toxics problem in the United States. This paper focuses on air toxics emissions from motor vehicles, specifically, all air carcinogens for which EPA has unit risk estimates and are emitted from motor vehicles. Specific pollutants and pollutant categories which are discussed include diesel particulate, formaldehyde, benzene, gasoline vapors, gas phase organics, organics associated with gasoline particulate, dioxins, asbestos, vehicle interior emissions, and metals. This paper summarizes information contained in an EPA technical report.[1]

For each pollutant, information is provided regarding emissions, ambient concentrations, and health effects. Where adequate information was available, quantitative estimates of cancer incidence were made for calendar years 1986 and 1995. The risk estimates are 95 percent upper confidence limits.

Following this is a summary of the aggregate risk from mobile source air toxics emissions, together with the limitations inherent in the estimate.

DIESEL PARTICULATE

Composition and Emissions

Diesel particulate is composed of an elemental carbon core with hundreds of condensed and/or adsorbed fuel and lubricant components and other varied combustion products. Over 90 percent of diesel particulate is less than 1 micron in size and is therefore small enough to be inhaled and deposited deep within the lungs.

The light-duty vehicle and truck diesel particulate emissions standard, prior to 1987, was 0.6 gram/mile. Effective in 1987, the standards are 0.20 gram/mile for light-duty vehicles and 0.26 gram/mile for light-duty trucks. For heavy-duty diesel engines, a standard of 0.6 gram/brake horsepower-hour (g/bhp-hr) begins in 1988, with increasingly more stringent standards effective in 1991 (0.25 g/bhp-hr) and 1994 (0.10 g/bhp-hr). For urban bus engines, the standard is 0.10 g/bhp-hr beginning in 1991. These increasingly stringent standards are accounted for in the 1995 projections.

The diesel particulate standards are not based on potential carcinogenic risk, but rather on adverse health effects associated with particulate matter in general, as described in the Federal Register notice describing EPA's revisions to the National Ambient Air Quality Standards for particulate matter.[2]

Emission factors (in grams/mile) for each vehicle type and a composite emission factor for the fleet were estimated for calendar years 1986 and 1995. Model year data for the previous 20 years are used, i.e., for 1986, model year data back to 1967 are used; for 1995, model year data back to 1976 are used. Each model year's emission factor is multiplied by that model year's fraction of calendar year vehicle miles travelled (VMT) and the diesel sales fraction for that model year, and then summed across all 20 model years to obtain calendar year emission factors. The heavy-duty classes 7-8 emit far more particulate on a g/mile basis than any of the other vehicle classes. Please refer to reference 1 for a detailed discussion of these model year inputs.

The resulting fleet emission factors for calendar years 1986 and 1995 are 0.1669 g/mile and 0.0650-0.0797 g/mile, respectively. The range in 1995 is due to a range of diesel sales assumed in future years. Nationwide diesel particulate emissions (metric tons/year) for 1986 and 1995 were then calculated by combining the calendar year emission factors with estimated VMT for 1986 and 1995. Estimated VMT for 1986 and 1995 is 1626.84×10^9 miles and 1934.33×10^9 miles, respectively.[3] VMT is projected to increase 19 percent from 1986 to 1995.

Nationwide diesel particulate emissions in 1986 were estimated to be 273,572-273,643 metric tons, or roughly 3.9 percent of the 1984 total suspended particulate (TSP) emissions. Diesel particulate emissions are projected to drop to 125,352-153,944 metric tons/year in 1995. This decrease is due to the more stringent diesel particulate standards.

Urban diesel particulate emissions are projected to be roughly 35,700 metric tons in 1995. Urban emissions do not comprise the bulk of nationwide emissions because the VMT fraction of the highest emitting heavy-duty trucks is small in urban areas. In comparison, the Motor Vehicle Manufacturers Association (MVMA) predicts that 30,500 metric tons of diesel particulate will be emitted in U.S. urban areas in 1995.[4]

Ambient Concentrations of Diesel Particulate

Urban and rural concentrations of diesel particulate are estimated for 1986 and 1995, using a modified version of the EPA NAAQS Exposure Model (NEM) for CO.[5] This modified NEM model was also used to calculate urban and rural concentrations for many of the mobile source pollutants discussed in this paper.

The modified NEM model provides an estimate of nationwide annual person-hours of exposure to any non-reactive mobile source pollutant of interest. Using this information, mean exposure levels may be calculated. The CO NEM was used since outdoor CO is almost exclusively mobile source related. Since the CO monitor data, on which the CO NEM was based, can be assumed to be related to mobile source emission rates, exposure to other non-reactive mobile source pollutants can be modeled using this relationship.

The modified NEM includes more recent 1981 CO monitoring data, including an expanded number of monitors, relative to the original NEM. Emission factors in grams/minute for the pollutant of interest are input to the modified NEM. Exposures in three mobile source microenvironments (street canyons, tunnels and parking garages), where elevated concentrations of mobile source pollutants could be experienced, were included in the modified NEM. Finally, a national extrapolation procedure designed expressly for mobile sources was devised.

The exposure levels predicted by the model are those resulting from direct exhaust emissions, and do not account for either the destruction or photochemical formation of the pollutant in the atmosphere. The model also assumes that the pollutant of interest has emission formation and dispersion characteristics similar to that of CO. For diesel particulate, CO appears to be a particularly good surrogate.

The mean urban, rural, and nationwide diesel particulate exposure levels predicted by the model for 1986 are 2.63, 2.38, and 2.56 ug/m^3, respectively. For 1995, the mean urban, rural, and nationwide exposure levels are projected to drop to 1.27-1.69, 1.06-1.27, and 1.22-1.58 ug/m^3, respectively.

Health Effects of Diesel Particulate

Diesel particulate was found to be mutagenic in the late 1970's. Subsequent studies revealed that nitropolynuclear aromatic hydrocarbons (nitro-PAH), specifically, nitropyrenes, dinitropyrenes and nitrohydroxypyrenes together account for much of the mutagenicity observed. The organics extracted from

diesel particulate and other known carcinogens such as coke oven emissions were tested in a battery of bioassays. These included bacteria and mammalian cell bioassays, and one skin painting study with SENCAR mice. Animal inhalation studies were conducted at that time but gave negative or inconclusive results. The unit risk for diesel particulate was determined by comparing the potency of diesel particulate with the potencies of the other carcinogens determined in these tests. The range of upper confidence limit unit risks used in this paper, $0.2\text{-}1.0 \times 10^{-4}$, is based on various analyses of the comparative potency data.[6,7,8] It should be noted that the comparative potency method is a novel approach to risk assessment, and represents a departure from conventional risk assessment methodologies used by EPA. The method involves a series of assumptions which have been acknowledged by EPA and criticized by others as introducing uncertainties much larger than those commonly associated with the conduct of risk assessment.[6]

Several animal inhalation experiments have been recently completed which, in contrast to the earlier studies, demonstrate that diesel exhaust, when inhaled chronically at high concentrations, is a pulmonary carcinogen in the rat. These studies are currently being evaluated.

The unit risks used in this paper are defined as the individual life time excess cancer risk from continuous exposure to 1 ug carcinogen per m^3 inhaled air. Assuming a life time is 70 years, the excess lung cancer risk in 1 year is derived by simply dividing the unit risk by 70. Using this approach, latency is ignored. The unit risks used in this paper are 95 percent upper confidence limits rather than best estimates. This is consistent with current EPA practice. The risk estimates presented should therefore be considered upper bound estimates.

Current and Projected Cancer Risk

The unit risks are combined with the exposure estimates and population estimates to obtain estimates of cancer incidence for 1986 and 1995. Urban and rural populations for 1986 and 1995 were estimated based on U.S. Department of Commerce data.[10] The annual cancer risk from diesel particulate exposure for the U.S. population is 178-860 in 1986 and drops to 92-443 in 1995. The range is due to the range of unit risk estimates which were used and, to a lesser extent, a range of assumptions regarding future diesel sales. The roughly 40 percent decrease in risk from 1986 to 1995 can be attributed to the more stringent future diesel particulate standards.

FORMALDEHYDE

Composition and Emissions

Formaldehyde is the most prevalent aldehyde in vehicle exhaust and is formed as a result of incomplete combustion of the fuel. Formaldehyde is emitted in the exhaust of both gasoline- and diesel-fueled vehicles. It has the chemical formula CH_2O. Formaldehyde is of interest due to its photochemical reactivity in ozone formation and suspected carcinogenicity.

Formaldehyde exhaust emissions from motor vehicles correlate well with exhaust hydrocarbon (HC) emissions. For this analysis, formaldehyde emissions were expressed as a weight percentage of exhaust HC. These percentages were then applied to the exhaust HC output from the MOBILE3 emissions model for 1986 and 1995 to obtain the FTP formaldehyde emission factors. In this way, deterioration and other effects are included. The percentages generally vary from 1 to 4 percent, depending on the vehicle class. Resulting composite FTP formaldehyde emission factors are 0.0418-0.0453 g/mile in 1986 and 0.0201-0.0224 g/mile in 1995. The range accounts for both the presence and absence of an Inspection/Maintenance (I/M) program. Characteristics of the I/M program selected represent the minimum EPA requires of I/M programs.

Mobile source formaldehyde emissions in 1986 were estimated to be 68,003-73,697 metric tons, or roughly 28 percent of the total formaldehyde emissions in the U.S. Mobile source formaldehyde emissions are expected to drop to 38,880-43,329 metric tons in 1995. This is due to the increasing use of 3-way and 3-way plus oxidation catalyst-equipped gasoline-fueled vehicles together with the phase out of non-catalyst-equipped vehicles. The result is a marked decrease in projected HC and, by association, formaldehyde emissions.

Ambient Concentrations of Formaldehyde

The mean urban, rural, and nationwide formaldehyde exposure levels predicted by the modified NEM model for 1986 are 1.21-1.30, 0.56-0.60, and 1.04-1.13 ug/m^3, respectively. For 1995, the mean urban, rural, and nationwide exposure levels are projected to drop to 0.68-0.76, 0.31-0.35, and 0.59-0.65 ug/m^3, respectively. The exposure levels predicted by the model are those resulting from direct exhaust emissions only and do not account for either the destruction or photochemical formation of formaldehyde in the atmosphere. Since the

majority of formaldehyde in the atmosphere is thought to be formed from photochemical reactions of volatile organic compounds (VOC), the exposure levels predicted by the model are likely underestimates.

Another approach intended to include photochemistry was also developed. With this approach, a mobile source fraction was applied to an annual average formaldehyde concentration developed using available ambient monitoring data. Mobile sources account for 28 percent of the total VOC emissions and roughly 30 percent of the formaldehyde emitted directly. Assuming that the VOC from all sources have the equivalent potential to form formaldehyde, a mobile source fraction of 0.30 was selected. This fraction was applied to an urban population weighted average of 12.71 ug/m^3 (based on data obtained in 4 cities) and a rural concentration of 1.50 ug/m^3.[11] Since the summer concentrations used to calculate the urban concentration probably represent maximum rather than average values, the risk estimates can be used to represent a plausible upper limit. Resulting urban and rural formaldehyde concentrations due to mobile sources currently are 3.81 and 0.45 ug/m^3, respectively.

Health Effects of Formaldehyde

Formaldehyde can cause a number of acute adverse health effects such as eye, nose, throat and skin irritation, headaches and nausea, as well as death. EPA has classified formaldehyde as a probable carcinogen in humans. An upper confidence limit unit risk of 1.3×10^{-5} was used.[12] It is based on a single study in which rats exposed to formaldehyde developed malignant and benign tumors in the nasal cavities; the unit risk is based on malignant tumor formation only.[13] The consideration of benign tumors would increase the formaldehyde risk by a factor of 15.

Current and Projected Cancer Risk

Using the nationwide exposure levels estimated from the modified NEM model (which do not account for photochemistry), the resulting risk is 46-50 in 1986 and 29-31 in 1995. Accounting for photochemistry, using the approach outlined above, the annual cancer risk from mobile source formaldehyde is 131 in 1986 and 77 in 1995. Combining both approaches, the cancer incidences due to mobile sources range from 46-131 in 1986 and 29-77 in 1995.

BENZENE

Composition and Emissions

Benzene is an aromatic hydrocarbon with the formula C_6H_6. It is present in both exhaust and evaporative emissions. Very little exhaust benzene is unburned fuel benzene. Some work indicates that non-benzene aromatics in the fuels cause about 70-80% of the exhaust benzene formed. Benzene also forms from engine combustion of non-aromatic fuel hydrocarbons.

For this analysis, benzene emissions were expressed as a weight percentage of exhaust and evaporative HC. These percentages were then applied to the HC output from the MOBILE3 emissions model for 1986 and 1995 to obtain the FTP benzene emission factors. A standard, minimum I/M program was assumed. The fraction of benzene in the exhaust varies depending on control technology and fuel composition but is generally about 3-5%. The fraction of benzene in the evaporative emissions also depends on control technology (e.g., whether the vehicle has fuel injection or a carburetor) and fuel composition (e.g., benzene level and RVP) and is generally about 1%.

Resulting composite FTP benzene emission factors for 1986 and 1995 are 0.128-0.135 g/mile and 0.055-0.057 g/mile, respectively. The range is due to consideration of both a low and high range evaporative emissions estimate for light-duty gasoline-fueled vehicles. Diesel vehicles account for only about 3% of the total mobile source benzene emitted. Based on an analysis conducted by EPA's Office of Mobile Sources, RVP control, which would be accompanied by a small increase in both benzene content and total aromatic content of gasoline, would have little or no effect on overall fleet emissions or on the number of cancer cases.[14]

Mobile sources dominate the nationwide benzene emission inventory. In 1982, mobile source benzene emissions were roughly 250,000 metric tons, or 85 percent of the total benzene emissions. Of the mobile source contribution, 70 percent comes from exhaust, 14 percent from evaporative emissions and 1 percent from motor vehicle refueling.[14]

Ambient Concentrations of Benzene

Nationwide exposure levels from both exhaust and evaporative emissions, estimated using the modified NEM model, are roughly 3.1-3.2 ug/m^3 and 1.7-1.8 ug/m^3 for 1986 and 1995, respectively. The reason for the marked decrease is the decrease in projected HC in 1995 and, thus, benzene emissions.

An alternative approach, similar to that used for formaldehyde, was also developed. With this approach, a mobile source fraction was applied to estimated urban and rural concentrations developed using available ambient monitoring data. Mobile sources account for 85 percent of the total benzene emissions. Therefore, a fraction of 0.85 was applied to an urban population weighted average of 10.24 ug/m^3 and a rural concentration of 7.52 ug/m^3.[11,15] Resulting estimated urban and rural benzene concentrations due to mobile sources currently are 8.70 and 6.39 ug/m^3, respectively.

The concentrations predicted using the ambient apportionment approach are somewhat higher than those calculated with the NEM modeling approach. Both approaches contain uncertainties. The six day half-life of benzene in air likely results in a build-up of benzene in the atmosphere that is not accounted for with the NEM modeling approach. With the ambient apportionment approach, the ambient data may be from fixed site monitors recording peak levels that could overrepresent average 24-hour exposures of the population. It is also not certain whether the cities chosen are representative of the entire urban population.

Health Effects of Benzene

Several epidemiology studies on workers exposed to benzene have identified benzene as a carcinogen causing leukemia in humans. The unit risk estimate determined from these studies and used by EPA is 8.2×10^{-6}.[14,16] EPA is presently evaluating more recent data.

Current and Projected Health Risk

Using the nationwide exposure levels estimated from the modified NEM model, annual cancer incidences from exhaust and evaporative emissions are estimated to be 84-89 in 1986 and 50-52 in 1995. Refueling emissions were also considered. Exposure to benzene during refueling includes self-service refueling, occupational exposure (service station attendants) and community exposure in an urban area. Annual cancer incidences from benzene refueling are estimated to be 8 in 1986 and 7 in 1995.[16] Total cancer incidences from benzene exhaust, evaporative and refueling emissions are 92-97 in 1986 and 57-59 in 1995.

Using the alternate approach outlined above, the annual cancer risk from mobile source benzene is 223 in 1986. Emissions of benzene from mobile sources are projected to decrease roughly 40 percent from 1986 to 1995. Accounting for this decrease and the projected population increase, the annual lung cancer risk is 145 in 1995. Combining both approaches, the lung cancer incidences due to mobile sources range from 92-223 in 1985 and 57-145 in 1995.

GASOLINE VAPORS

Totally vaporized gasoline has been found to cause a statistically significant increase in kidney tumors in male rats and liver tumors in female mice.[17] EPA has classified gasoline vapors as a B2 probable human carcinogen. An upper confidence limit based on the rat data is 1.18×10^{-6}.[16,18] The significance of the rat kidney tumors has been questioned since the male rat may be unique in its response to gasoline vapors; however, EPA is retaining the B2 classification.[19] As more data become available, the classification may be reconsidered.

Exposure to gasoline vapors during refueling was estimated based on an American Petroleum Institute (API) study that involved measuring gasoline and vapor levels in the region of the face of a person refueling a vehicle tank.[16] The exposure in a typical urban area for these refueling emissions was also estimated using the Industrial Source Complex dispersion model to calculate annual concentrations. Based on these exposures, the risk from gasoline vapors (excluding benzene) was estimated as 65 lung cancer incidences per year.

GAS PHASE ORGANICS

Gas phase organics, or volatile organic compounds (VOC), are present in both exhaust and evaporative emissions. Over 300 VOC have been identified. The majority of VOC consist of unsaturated and saturated hydrocarbons along with benzene, alkyl benzenes, aliphatic aldehydes and a variety of polycyclic aromatic hydrocarbons.

Of all the VOC emitted from motor vehicles, only benzene, formaldehyde, benzo(a)pyrene (B(a)P), ethylene, and 1,3-butadiene have unit risks. Gas phase B(a)P was considered with particle-associated B(a)P since the majority of B(a)P is in the particulate phase. Therefore, this section will focus on ethylene and 1,3-butadiene.

Ethylene

Composition and Emissions. Ethylene emissions are present in vehicle exhaust. Ethylene in evaporative emissions is negligible and was not considered. Ethylene emissions were expressed as a weight percentage of exhaust HC. These percentages were then applied to the exhaust HC output from the MOBILE3 emissions model for 1986 and 1995 to obtain the FTP ethylene emission factors. The percentages generally vary from 6 to 13 percent, depending on the vehicle class. Resulting composite FTP ethylene emission factors, with and without I/M, are 0.2367-0.2607 g/mile in 1986 and 0.0946-0.1092 g/mile in 1995.

Ambient Concentrations of Ethylene. The mean urban, rural, and nationwide formaldehyde exposure levels predicted by the modified NEM model for 1986 are 6.77-7.49, 3.46, and 5.94-6.48 ug/m^3, respectively. For 1995, the mean urban, rural, and nationwide exposure levels are projected to drop to 3.32-3.59, 1.60, and 2.89-3.09 ug/m^3, respectively. These exposure estimates are rather uncertain, since ethylene is photochemically reactive.

Health Effects of Ethylene. The upper confidence limit unit risk of 2.7×10^{-6} for ethylene was provided in an EPA study although it was not developed by EPA.[20] The unit risk is extremely tentative, since there is no available direct evidence that ethylene is carcinogenic. The unit risk was estimated based on assumptions regarding its potency relative to ethylene oxide, a metabolite of ethylene and an animal carcinogen.

Current and Projected Cancer Risk. The annual cancer risk from ethylene exposure for the U.S. population is 55-60 in 1986 and 29-31 in 1995. Since the unit risk is so tentative, a lower bound risk of zero is also used. The resulting ranges of cancer risk are 0-60 in 1986 and 0-31 in 1995.

1,3-Butadiene

Composition and Emissions. 1,3-Butadiene is a photochemically reactive compound present in vehicle exhaust. The report upon which this paper is based assumed 1,3-butadiene was roughly 0.94 percent of the total FID exhaust HC. This was estimated based on very limited data in which 1,3-butadiene and n-butane were reported together. Assumptions had to be made about the percentage attributable to 1,3-butadiene. Recently, 1,3-butadiene data for light-duty three-way catalyst-equipped vehicles has become available. Based on a preliminary review of the available data, 1,3-butadiene constitutes roughly 0.35 percent of the total FID exhaust HC.[21] Due to lack of data

for the other vehicle classes, this percentage was simply applied to the MOBILE3 composite exhaust HC emission factor. Resulting composite 1,3-butadiene emission factors with and without I/M for 1986 and 1995 are 0.0089-0.0098 g/mile and 0.0045-0.0053 g/mile, respectively.

Ambient Concentrations of 1,3-Butadiene. The modified NEM model was used to estimate exposure. Urban and rural exposure from mobile sources in 1986 is estimated to be 0.26-0.28 ug/m^3 and 0.12-0.13 ug/m^3, respectively. In 1995, urban and rural exposure from mobile sources is estimated to be 0.16-0.18 ug/m^3 and 0.07-0.09 ug/m^3, respectively.

Since the NEM-predicted exposure estimates are rather uncertain, due to the photochemical reactivity of 1,3-butadiene, available monitoring data for 1986 were reviewed and compared to the exposure estimates. Average 6-9 a.m. summer values for 18 cities range from 0.24-1.98 ug/m^3.[22] The 1986 NEM estimate of urban exposure from motor vehicles lies within this range.

Health Effects of 1,3-Butadiene. Exposure to 1,3-butadiene results in a wide spectrum of cancers in mice and rats. EPA has classified 1,3-butadiene as a probable B2 human carcinogen. The 95 percent upper confidence limit unit risk for 1,3-butadiene is 2.8 x 10^{-4}, based on a mouse inhalation study.[23] The use of this study for risk estimation has been questioned because of the high dose levels used and the possibility that the animals were infected with a virus known to cause one of the most prevalent tumor types observed in the exposed groups.[24]

Current and Projected Health Risk. The risk in 1986 is 221-244 cancer incidences and drops to 146-171 cancer incidences in 1995.

ORGANICS ASSOCIATED WITH GASOLINE PARTICULATE

Gasoline-fueled vehicles emit far less particulate than their diesel counterparts. Data indicate that the classical polycyclic aromatic hydrocarbons (PAHs) may be responsible for the mutagenicity of these organics rather than the nitro-PAH's.

Three approaches were used to estimate the risk. The first approach assumes the risk from B(a)P emissions adequately represents the risk of all gasoline particle-associated organics. B(a)P emission data and the B(a)P unit risk were used. Using this approach, the resulting annual cancer risk is 1.3 in 1986, and is projected to drop to 0.78 in 1995.

The second approach uses estimated emission rates of gasoline particle-associated organics (as an unspeciated mixture) together with an upper confidence limit unit risk for these organics. Exposures were estimated using the modified NEM model. Estimated composite emission factors, with and without I/M, are 0.0075-0.0082 g/mile in 1986 and 0.0048-0.0058 g/mile in 1995.

An upper confidence limit unit risk based on one catalyst-equipped vehicle (1978 Ford Mustang) is 2.5 x 10^{-4}.[6] The bioassays used to estimate the unit risk were the same as those used to estimate the unit risk for diesel particulate, and the same approach was used. The vehicle had exceptionally high exhaust emissions, comparable to those from a non-catalyst-equipped vehicle. The mutagenic activity of the particle-associated organics from this vehicle, however, as indicated by the Ames Salmonella bioassay (strain TA-98), is on the low end of the range when compared with other catalyst-equipped vehicles. As a result, the vehicle and the unit risk should be considered of uncertain representativeness. Using this approach, the risk in 1986 is 163-176 cancer incidences and drops to 115-136 cancer incidences in 1995.

The third approach uses B(a)P emission factors for gasoline-fueled vehicles together with the products of incomplete combustion (PIC) unit risk (which is expressed per unit of exposure of B(a)P) to calculate cancer incidence.[20] The resulting cancer risk is 122 in 1986 and drops to 72 cancer incidences in 1995.

For this analysis, a range of risk estimates was chosen, which encompasses the results of all three approaches. The resulting range of cancer incidences is 1.3-176 in 1986 and 0.78-136 in 1995.

ASBESTOS

Asbestos is used in brake linings, clutch facings, and automatic transmissions. Asbestos emissions from vehicles with front disc brakes and rear drum brakes ranged from 4-28 ug/mile. Based on these emission rates, maximum annual average asbestos levels in urban areas due to motor vehicles are estimated to range from 0.25-1.75 nanograms per cubic meter (ng/m^3). The individual upper bound cancer risk from urban levels of asbestos is estimated to range from 9×10^{-9} to 3.6×10^{-7} per ng/m^3 exposure.[25] Assuming an urban population of 180 million, the resulting cancer risk is estimated to range from 0.405-113.4 cancer incidences per year.

OTHER AIR TOXICS EMISSIONS

Other mobile source air toxics emissions examined include dioxins, vehicle interior emissions, ethylene dibromide (EDB), and cadmium. These pollutants appear to be present in only trace quantities and no significant risk is apparent.

SUMMARY

The risks presented in this study are summarized in Table I. The aggregate risk in 1986 for the total U.S. population is estimated to range from 629 to 1874 cancer incidences and drops roughly 40 percent by 1995. Reasons for the projected decrease in risk in 1995 include: 1) more stringent diesel particulate standards for both light- and heavy-duty vehicles, and 2) the increasing use of 3-way catalyst-equipped vehicles coupled with the phase out of non-catalyst-equipped vehicles.

As seen in Table I, there is a wide range of risk estimates associated with each pollutant. For diesel particulate, the range is due to the range of potency (or unit risk) estimates which were used and, for 1995, a range of assumptions regarding future diesel sales. For formaldehyde, the low end of the range attempts to account only for formaldehyde directly emitted from the exhaust of motor vehicles. The high end of the range attempts to account for both formaldehyde directly emitted and formaldehyde formed in the atmosphere from other mobile source volatile organic compound (VOC) emissions.

For benzene, the lower limit is based on ambient concentrations predicted by a model, whereas the upper limit is based on actual monitoring data, with a mobile source fraction assigned based on the mobile source emissions contribution. For ethylene, the uncertainty is based on the unit risk estimate. The range for gasoline particle-associated organics and asbestos is due to a number of different assumptions regarding both emission factors and unit risk estimates.

Mobile source emissions are extremely complex. Hundreds of compounds, both in the gas phase and associated with particles are present. The lack of emissions data and/or health data and/or exposure data prevented quantitative risk estimates for any additional pollutants. Of particular concern are pollutants which are formed photochemically from mobile source emissions. This category of pollutants could have considerable impact but not enough is known to make a quantitative estimate.

Table I. Summary of risk estimates.[a]

Motor Vehicle Pollutant	U.S. Cancer Incidences/Year[b] 1986	1995[c]
Diesel Particulate	178- 860	92-576
Formaldehyde	46- 131	29- 77
Benzene	92- 223	57-145
Gasoline Vapors	65	ND[d]
Other Gas Phase Organics		
1,3-Butadiene	244	171
Ethylene	0- 60	0-31
Gasoline Particulate	1.3 - 176	0.78-136
Dioxins	ND	ND
Asbestos	0.41- 113.4	ND
Vehicle Interior Emissions	ND	ND
Cadmium	0.18	0
Ethylene Dibromide	1.8	0.54
Total:	629-1874	350-1137

[a] The risk estimates are 95% upper confidence limits.

[b] The risk estimates for gasoline vapors, asbestos, cadmium and ethylene dibromide are for urban exposure only. Risks for the other pollutants include both urban and rural exposure.

[c] The total risk in 1995 is slightly underestimated. Due to inadequate information and the sensitivity of 1995 risk to control decisions which have not yet been made, projected risk estimates were not made for some of the pollutants.

[d] ND=Not Determined.

NOTE: The risk estimates are upper bound estimates; therefore, they are not intended to represent actual numbers of cancer cases but rather can be used to rank the mobile source pollutants and to guide further study.

The risk estimates are upper bound estimates; therefore, they are not intended to represent actual numbers of cancers but rather can be used to rank the mobile source pollutants and to guide further study. Currently, 1,3-butadiene emissions data are being collected and additional research on gasoline particle-associated organics is anticipated. EPA is also investigating factors leading to formaldehyde formation in the atmosphere. EPA's *Integrated Air Cancer Project* is a long-term research project currently underway, the goal being to identify the principal airborne carcinogens and their sources.

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