INTERNATIONAL CENTER FOR TECHNOLOGY ASSESSMENT

In-Car Air Pollution

The Hidden Threat to Automobile Drivers

REPORT NO. 4
AN ASSESSMENT OF THE AIR QUALITY
INSIDE AUTOMOBILE PASSENGER COMPARTMENTS

Foreword

This report by the International Center for Technology Assessment (CTA) represents the fourth in a series of studies designed to assess the environmental and social impacts of transportation technology. These reports are meant to aid policymakers and the public in their ongoing deliberations concerning the future course of transportation in the United States.

This particular report contains an in-depth analysis of the concentrations of auto pollution that collect inside automobiles and affect the health of drivers and passengers. This report found that pollution levels inside cars are often much higher than those detected in the ambient air, at the roadside, and in other commonly used vehicles.

CTA gratefully acknowledges the contributions of many individuals, organizations, and government entities which assisted in the production of this report. In particular, CTA would like to thank John A. Harris, Henry Griggs (Communications Consortium), Bob Rose (Breakthrough Technologies Institute), Angie Farleigh (U.S. PIRG), Jayne Mardock (Clean Air Network), Ann Mesnikoff (Sierra Club), and Kristy Paulsen (Your Next Car Campaign). CTA offers special thanks to The Changing Horizons Charitable Trust for funding this project.

CTA was formed in 1994 to assist the general public and policymakers in better understanding how technology affects society. CTA is devoted to fully exploring the economic, ethical, social, environmental, and political impacts of technology or technological systems. Using this holistic form of analysis, CTA provides the public with independent, timely, and comprehensive information about the potential impacts of technology. CTA is also committed to initiating appropriate legal, grassroots, public education, and legislative responses relevant to its assessment findings.

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Executive Summary

Americans spend more time than ever before inside of cars. We drive to work, we drive to the supermarket, we drive to the family vacation spot. If we are going somewhere, chances are good that we are driving. People in this country traveled more than 2.8 trillion miles by automobile in 1995, up half a trillion miles from five years earlier and nearly double the number of miles driven in 1965. Not only are people driving more miles, traffic and other roadway delays mean that it often takes more time to go a shorter distance. The average amount of time spent commuting to and from work has increased steadily since the 1980s, with a growing number of people now facing a daily drive time of thirty minutes or more each way.

Most people realize that there are risks associated with traveling by automobile—drunk drivers, road rage, and speeding tickets come to mind. The greatest concern of drivers stuck in traffic is most likely that they won't get to their destinations on time. Few people, however, are concerned about the health effects of the air quality inside of their cars. If their thoughts turn to the subject at all, they are more likely to consider air pollution an "outdoor" problem.

This unprecedented survey of international studies shows that air pollution may be even more severe inside of cars than out. The results of 23 separate scientific studies conducted during the 1980s and 1990s reveal that in-car air pollution levels frequently reach concentrations that may threaten human health. The reports show that the air inside of cars typically contains more carbon monoxide, benzene, toluene, fine particulate matter, and nitrogen oxides than ambient air at nearby monitoring stations used to calculate government air-quality statistics. In-car pollution is often even worse than pollution in the air at the side of the road.

The air pollution accumulating in the interior of automobiles consists almost exclusively of gasoline and diesel exhaust. This toxic soup of gases, aerosols, and microscopic particles includes benzene (a known carcinogen), carbon monoxide (which interferes with the blood's ability to transport oxygen), particulate matter (which studies have associated with increased death rates), and a host of other hazardous chemicals.

Public health officials frequently issue warnings reported in local weather broadcasts when concentrations of auto pollutants exceed healthful levels in the ambient air. The air quality inside of cars is typically much worse. In-car benzene concentrations sometimes exceed concentrations in the roadside air by up to four fold. Carbon monoxide concentrations may be more than 10 times higher inside of cars than at the side of the road.

Elevated in-car pollution concentrations particularly endanger children, the elderly, and people with asthma and other respiratory conditions. While it receives little attention, in-car air pollution may pose one of the greatest modern threats to human health.

Recommendations

While individuals can take some actions to reduce in-car pollution levels—driving less, ensuring that their vehicles are properly maintained, and using public transportation whenever possible—the main burden falls on the shoulders of policymakers.

Initiatives to address this problem should include the following:

1). Federal, state and local governments must provide greater funding for public transportation projects, especially in cities plagued by high levels of traffic congestion. Tax incentives for individuals and employers should promote the use of public transportation, while tax breaks that encourage people to drive, including parking incentives, should be phased out.

2). The EPA must fix a major failing of its recent Tier 2 rule by requiring automakers to develop and sell zero-emissions alternatives to gasoline- and diesel-powered vehicles.

3). The California Air Resources Board must preserve its zero-emissions-vehicle mandate, which comes up for review later this year. This provides the greatest incentive for automakers to actively develop and sell nonpolluting cars that do not contribute to in-car pollution problems.

4). Until EPA addresses the issue of alternative vehicles, states should opt to implement California LEV 2 emissions rules, including the ZEV mandate, rather than the federal Tier 2.

5). The EPA's final heavy duty vehicles/diesel rule, due out later this year, must include steep reductions of PM and NOX emissions outlined in the agency's proposed rule. The final rule must require 100% of diesel fuel to contain low sulfur levels (less than 10 ppm) by 2007. The agency must not give in to industry demands for a lengthened timeline or a phase-in of the low-sulfur fuel.

6). EPA must end its history of repeated delays and issue a tough mobile source toxics rule that will significantly reduce new cars' emissions of benzene, toluene, 1,3 butadiene, xylenes, ethylbenzene, and other VOCs. This rule should include federal incentives for the development of zero-emission vehicles.

SECTION ONE

INTRODUCTION

Automakers have come a long way in recent years in terms of improving the interior comfort and safety of the cars they sell. Nearly all new models come equipped with stereo systems, dual airbags, tilt steering wheels, and power locks and windows. For a few dollars more a customer can get heated leather seats, dual-zone climate control, a hands-free cellular phone, a CD changer, and power seats with memory to store several position settings. Some minivan models even come with built-in televisions and VCRs to entertain passengers on lengthy trips.

All of this innovation has given drivers and passengers a heightened sense of comfort and well being inside their automobiles, even if the conditions outside happen to be oppressively hazy, hot, and humid. Driving on a code-red smog day with their windows sealed tight and their air conditioners set to high, some drivers may feel a tinge of remorse or guilt for their contribution to the air quality problems outside of their cars, but it is likely that few are seriously concerned about their own health or the health of their families as long as they are inside.

However, numerous studies conducted over the past two decades indicate that any sense of disconnection from the air pollution conditions outside is completely unwarranted. The truth is, the quality of air inside cars is often much worse than that of nearby ambient air samples or even the air at the side of the road. Hazardous pollutants, including carbon monoxide, volatile organic compounds, nitrogen oxides, and particulate matter, accumulate inside cars driving in moderate to heavy traffic. Aerodynamic effects of the moving vehicles, combined with the tendency of auto exhaust pollutants to dissipate quickly after emission, concentrates these chemicals and particles in the midst of the traffic flow in the roadway. In effect, cars on busy roadways drive through an invisible tunnel of concentrated pollutants. The exterior shells and ventilation systems of cars do little to divert these pollutants or filter them from the air entering the car's interior, and thus afford little protection to the people driving through this toxic tunnel.

These higher concentrations of pollutants commonly detected inside automobiles boost the overall exposure of drivers and passengers to a number of very dangerous chemicals, including benzene, carbon monoxide, particulate matter, and toluene. Medical researchers have linked many of these substances to serious health problems, including respiratory irritation, cancer, and premature death. Many of these dangerous chemicals' effects on human health depend on a person's cumulative exposure, so each time a driver or passenger is subjected a high concentration of the pollutant is meaningful.

This report analyzes the results of 23 separate studies published between 1982 and 1998 that measured the concentrations of particulate matter, volatile organic compounds, carbon monoxide, nitrogen oxides, and/or ozone inside of automobiles. Many of the studies also looked at pollutant concentrations in ambient air samples, in the traffic stream immediately outside of test vehicles, at the roadside, in transit buses, on light rail cars, and in

subways. Several also specifically investigated the exposure of bicyclists and/or pedestrians to auto pollutants. Of the 23 studies, 14 included carbon monoxide measures, 11 considered various volatile organic compounds (benzene, toluene, xylenes, formaldehyde, etc.), five included particulate matter, four included nitrogen oxides, and two included ozone.

The results are consistent. All of the pollutants common to auto exhaust also appear in the air within automobiles. For all except carbon monoxide and the largest particulate matter, concentrations are typically higher inside cars in heavy traffic than other places—the roadside, nearby fixed measurement sites, and inside transit buses, trains, and subways—where we might also expect the presence of auto pollutants.

The purpose of this report is to educate the public and policymakers. There are actions that individuals can take to protect themselves from elevated in-car pollution levels. First and foremost, avoid driving whenever possible. When you are able, take public transportation, walk, or ride a bicycle. Second, avoid driving during heavy traffic periods. The studies considered by this report show that in-car pollution levels are highest when vehicles are traveling on congested roads or passing through busy intersections. Third, if you must drive, whenever possible avoid following high-polluting vehicles, such as diesel trucks and buses, older model cars and sport utility vehicles, and out-of-tune vehicles with visible exhaust. The studies indicate that much of the pollution inside vehicle cabins likely consists of the exhaust from other vehicles in the immediate vicinity.

Scientific studies beginning in the 1970s have shown that the pollutants in automobile and diesel exhaust readily make their way into cars' passenger compartments. Often, the pollutant levels inside cars far exceed those in the ambient air or at the roadside.

Real progress towards solving the in-car pollution problem, however, can only come through changes in existing public policies that encourage people to drive internal-combustion automobiles, exacerbate traffic congestion problems, and allow numerous high-polluting vehicles to remain on the roads. Public officials need to realize that the American addiction to polluting cars and trucks poses a national health crisis that must be aggressively confronted and requires decisive and innovative leadership. The conclusion of this report outlines several policy initiatives that would begin to address the problem.

SECTION TWO

PARTICULATE MATTER

Particulate matter (PM) pollution consists of solids and liquid droplets of up to 10 micrometers in diameter suspended in the air. Large, dark PM may include smoke and soot from incomplete combustion, though PM may also include dust. These "coarse" particles along with smaller ones are known as PM10. So-called "fine" PM measures less than 2.5 micrometers in diameter and can include particles so small that they may only be seen using an electron microscope. These are known as PM2.5. Even the largest PM particles are very small—the width of a human hair averages about 70 micrometers. Diesel vehicles are a major source of both coarse and fine PM pollution.

Health Effects of PM Exposure

People have realized for centuries that smoke and soot have adverse effects on human health. In 1307, King Edward I of England prohibited the burning of sea coal in London and several other towns because, according to his royal proclamation, "the air there [was] polluted over a wide area, to the considerable annoyance of the … prelates, magnates, citizens and others dwelling there, and to the detriment of their bodily health." The original law imposed heavy fines on those who fouled the air with excessive amounts of PM; during the reign of Edward II, which began later that same year, violators of this early clean air standard became subject to physical torture or even execution.[1]

Particulate matter is arguably the most dangerous component of automobile exhaust. Particles are small enough to infiltrate nasal, sinus, and bronchial passages where they can accumulate and calcify. Fine PM can penetrate the deepest portions of the lungs and the very smallest particles can be absorbed into the bloodstream. In the nose, throat, and lungs, particulates act as extreme irritants. Exposure to even low levels of PM can cause nasal congestion, sinusitis, throat irritation, coughing, wheezing, shortness of breath, and chest discomfort. Medical studies have associated exposure to elevated PM10 levels with the aggravation of existing respiratory conditions, including asthma, and more serious medical problems.

Several studies have linked exposure to elevated PM2.5 levels to increased hospital admissions. One of the largest looked at people insured by Kaiser Permanente in Southern California. For every 10 micrograms/meter^3 (μ/m^3) increase in PM exposure, hospital admissions rose by 7% for patients with respiratory disease, 3.5% for patients with acute respiratory illnesses, and 3% for patients with cardiovascular disease. A similar study by the California Environmental Protection Agency associated every 10 μ/m^3 increase in PM exposure levels to a 2.5% increase in emergency room visits and a 1% increase in mortality for people with pneumonia.[2]

The so-called "Six Cities Study" by the Harvard

Heavy-duty diesel trucks are a prime culprit when it comes to elevated in-car PM levels. Several studies found that cars registered the highest in-car PM-levels when following these vehicles.

School of Public Health found that test subjects exposed to higher PM concentrations were 26% more likely to die prematurely than subjects exposed to lower concentrations.[3] A study published in 1995 by C. Arden Pope, et al., of Brigham Young University found that test subjects exposed to higher levels of PM were 17% more likely to die prematurely than those exposed to lower levels. Both of these studies accounted for the subjects' other individual risk factors and evaluated the effects of PM exposure independently.[4] All told, tens of thousands of Americans die prematurely due to PM exposure each year.[5]

Other research into the effects of long-term PM exposure is relatively sparse. Preliminary results indicate a possible link between fine PM and cancer. Several studies have demonstrated that known carcinogens, including several commonly found in automobile exhaust (see the section on VOCs, below), may latch onto fine particles that are breathed into and accumulate in the deepest recesses of the human respiratory system.

PM Exposure Studies

Europe, which proportionally has a higher concentration of diesel vehicles on the road than the United States, has provided the staging ground for most of the studies on the exposure of drivers, bicyclists, and pedestrians to PM pollution.

In 1995, researchers Joop H. van Wijnen, et al., in the Netherlands found levels of PM10 inside vehicles on busy streets in Amsterdam ranging from 90 to 194 μ/m^3 in tests conducted during May. In tests conducted on congested highways with stop-and-go traffic, in-car PM10 levels ranged from 120 to 139 μ/m^3. Concentrations during tests on a rural route ranged from 71 to 166 μ/m^3. In-car levels of PM10 were much lower in tests con-

PM2.5 Levels Measured in the 1998 CARB Study

Type of Road	Mean In-Car Car 1	Mean In-Car Car 2	Maximum In-Car Car 1	Maximum In-Car Car 2	Ambient Air	Roadside Mean	Roadside Max.
Los Angeles							
Arterial, Non-rush hour	67.7	56.4	86.0	71.7	63.5	nd	nd
Arterial, Rush hour	41.0	32.9	53.1	45.1	48.0	52.9	102.8
Freeway, Non-rush hour	54.7	44.9	59.0	47.0	33.3	nd	nd
Freeway, Rush hour	45.4	32.1	56.0	38.9	32.1	44.7	76.0
Freeway, Carpool lane	46.9	43.3	54.6	47.5	58.1	69.7	78.1
Sacramento							
Arterial, Rush hour	9.6	9.7	10.3	16.4	10.8	5.8	18.7
Freeway, Non-rush hour	14.4	12.4	16.6	14.2	10.3	9.6	19.9
Freeway, Rush hour	14.7	6.6	21.8	16.2	5.7	5.9	18.2
Rural	6.1	2.0	6.1	2.0	nd	3.1	4.2

Note: nd = no data available.
Source: California Air Resources Board.

ducted during January, ranging from 17 to 62 μ/m^3 in the city, 14 to 48 μ/m^3 on a busy highway, and 16 to 38 μ/m^3 on a rural route. The researchers said that higher winds and rainy weather caused the lower in-car PM10 levels measured in January.[6]

A year later, researchers from Middlesex University reported the exposure of London bicyclists to vehicle-generated PM and compared this to the exposure of commuters who ride the London Underground. For this study, the scientists measured exposure to PM of less than 5 micrometers in diameter, a proven danger to human health and a prime ingredient of diesel exhaust. Again, the results showed that weather conditions had a great bearing on test subjects' PM exposure. Cyclists studied during dry weather on days without wind showed exposure to PM5 of 88.54 μ/m^3. However, data sets collected while the cyclists were riding the same routes in rainy or windy conditions showed exposure levels ranging from 14 to 16.49 μ/m^3. Riders of the Underground, however, were exposed to staggeringly high PM5 levels of 708.6 μ/m^3. Further analysis showed that the types of PM exposure were different in the Underground and at street level. The vast majority of the particles that comprised the PM in the subway measured greater than 1 micrometer in diameter, while the concentrations encountered by the cyclists were mostly in the 0.2 to 0.4 micrometer range. Therefore, the subway riders were exposed to a greater volume of PM, but the cyclists riding in good weather were exposed to a greater number of total particles and to the types of particles most likely to cause serious negative health effects. Over 90% of the particles breathed by cyclists were likely components of diesel exhaust. The PM measured on the Underground more likely consisted of dust.[7]

—"The [automobile] passenger compartment air quality can be described as 'unhealthful'"

Researchers T.J. Ptak and S.L. Fallon

A 1994 study that looked at the exposure of U.S. automobile drivers to PM similarly found that more than 90% of the particles found inside vehicle passenger compartments measured less than 1 micrometer in diameter. Overall, T.J. Ptak and Stephen L. Fallon measured average in-car PM concentrations of 105 μ/m^3 during highway driving conditions, and concluded that "the passenger compartment air quality can be described as 'unhealthful.'" The highest exposure to PM, predict-

Studies indicate that overall exposure to PM may be lower inside cars than outside, but concentrations of the most dangerous fine particles in the in-car air often exceed those at the roadside.

ably, occurred in test cars traveling on gravel roads with their windows down. The second highest exposure occurred during city driving, where the in-car PM level was measured to be 133 μ/m^3. Filtering devices did little to help. Cars' air conditioning systems can remove between 40% and 75% of the largest PM, but remove only 2% to 15% of the dangerous particles less than 1 micrometer in diameter. A commercial interior air filter can reduce the concentration of large particles by up to 90%, but again has little effect on the concentration of the smallest particles—reducing them by as little as 5%.[8]

In a 1998 California Air Resources Boards study, PM was the only pollutant that appeared at significantly lower concentrations inside of cars than outside. However, PM measuring greater than 2.5 micrometers in diameter accounted for the vast majority of this reduction. In air samples from fixed monitoring sites along the test routes, fine particulates account for from 37.4% to 64% of the PM. In roadside air samples, fine particulates made up from 56.9% to 64.4% of PM. Inside the test vehicles, however, fine particles were between 76.8% and 97.2% of all PM. This indicates, as in the earlier studies, that the cars' ventilation and air conditioning systems filter out some of the largest particles, but do little to protect passengers from the much more dangerous fine particles.

The CARB study found high levels of PM pollution inside of cars under a variety of driving conditions. On Sacramento routes, in-car PM10 concentrations ranged from 16.5 to 30.3 μ/m^3, while PM2.5 (which is a subset of the PM10 figure) ranged from 6.1 to 17.0 μ/m^3. In Los Angeles, in-car levels were even higher, ranging from 45.6 to 89.1 μ/m^3 for PM10 and from 41.0 to 83.0 μ/m^3 for PM2.5.[9] (See chart, p. 11.)

SECTION THREE

VOLATILE ORGANIC COMPOUNDS

Volatile organic compounds (VOCs), also known as aromatic hydrocarbons, comprise a class of pollutants released during the combustion or evaporation of solvents, paints, glues, and fossil fuels. The exhaust of gasoline and diesel automobiles contains significant concentrations of about two dozen VOCs, the most important of which are benzene, 1,3-butadiene, m&p-xylenes (typically measured together), o-xylene, ethylbenzene, toluene, and formaldehyde.

These chemicals have the potential to do serious harm to the environment and human health. VOCs serve as ingredients in the chemical reactions that form ground-level ozone, better known as smog. The EPA has designated many VOCs, including those typically found in auto pollution, as air toxics or hazardous air pollutants (HAPs), which are known or suspected to cause serious health hazards. Both benzene and 1,3-butadiene are known carcinogens, and other VOCs, including formaldehyde, are suspected carcinogens.

Cancer Agents

It is difficult to directly link exposure to in-car VOCs to any individual cancer case. However, the carcinogenic effects of VOCs are associated with individuals' cumulative exposures. With people spending increasing amounts of time driving or riding in automobiles, elevated in-car levels of carcinogenic VOCs contribute a growing portion of many individuals' cumulative exposure.

The U.S. EPA classifies benzene as a "'known' human carcinogen by all routes of exposure," and multiple studies have linked inhaled benzene to the development of leukemia. Additional studies suggest that benzene exposure may induce changes in chromosomes, blood cells, and bone marrow cells, though these results are not regarded as conclusive. Most of the studies on benzene carcinogenicity have looked at the occupational exposure of adults. The leukemia risk of children exposed to benzene is likely much higher than that of adults, even at lower levels of exposure.[1] Because of its status as a known carcinogen, the World Health Organization has set the acceptable human exposure level for benzene at zero.

EPA classifies both 1,3-butadiene and formaldehyde as "probable human carcinogens." Animal and human studies, while not conclusive, have shown that exposure to 1,3-butadiene, including exposure by inhalation, may be responsible for respiratory, bladder, stomach, lymphatic, and blood-related cancers. According to the EPA, "limited human studies have reported an association between formaldehyde exposure and lung and nasopharyngeal cancer. Animal inhalation studies have reported an increased incidence of nasal squamous cell cancer."[2] One animal study suggests that ethybenzene exposure may be associated with the formation of tumors. However, this study was extremely limited and the few studies involving humans have shown no elevated cancer risks. EPA says that with currently available information, ethylbenzene is "not classifiable as to human car-

cinogenicity."[3] Other VOCs may also promote the growth of cancerous cells in humans, but conclusive medical research is lacking.

Non-Cancer Health Effects

Low-level exposure to the majority of VOC air pollutants, including benzene, 1,3-butadiene, ethylbenzene, formaldehyde, and xylenes, can irritate the eyes, nose, throat, and lungs. Short-term exposure to benzene may result in drowsiness, dizziness, or headaches. Toluene acts on the central nervous system and can cause short-term fatigue, sleepiness, headaches, and nausea.

Both animal and human studies have associated the long-term exposure to benzene via inhalation with blood disorders, including aplastic anemia, excessive bleeding, and the loss of antibodies and white blood cells. This final disorder can disrupt the immune system and make the individuals chronically exposed to benzene more susceptible to infections including influenza and the common cold. Women exposed to elevated benzene concentrations for long periods of time have exhibited menstrual disorders and atrophied ovaries. Limited studies suggest that benzene exposure can reduce fertility in women. Pregnant animals exposed to elevated benzene levels have produced offspring with low birth weights and damaged bone marrow. Fetuses of animals exposed to benzene have exhibited delayed bone formation.[4]

Long-term exposure to 1,3-butadiene air pollution may cause certain types of heart disease, according to at least one epidemiological study. Animal studies have also shown that inhaled 1,3-butadiene may hinder functioning of the respiratory and cardiovascular systems as well as the liver. Additional animal studies reveal that mothers exposed to elevated 1,3-butadiene levels are more likely to produce offspring with low body weights and skeletal deformities. Animals that have inhaled the pollutant in long-term studies have exhibited atrophied ovaries and testicles.[5]

Long-term exposure to inhaled toluene can irritate the upper respiratory tract and result in chronic sore throats, nausea, skin conditions, dizziness, headaches, and sleep disorders. The children of mothers exposed to high levels of toluene during pregnancy may exhibit attention deficit and central nervous system disorders. A link between lower-level exposure and these problems is less certain. Some studies have shown that pregnant women exposed to toluene have an increased vulnerability for spontaneous abortions, but these studies are not conclusive.[6]

Animal and human studies have also shown that long-term effects of the inhalation of ethylbenzene, formaldehyde, and xylenes may include problems with reproduction and fetal development. Additionally, ethylbenzene exposure may adversely affect the blood, liver, and kidneys, while chronic exposure to xylenes may result in chest pain, reduced heart and lung function, and increased heart palpitation.[7]

—The Wolrd Health Organization set the acceptable human exposure level for benzene at zero

VOC Exposure Studies

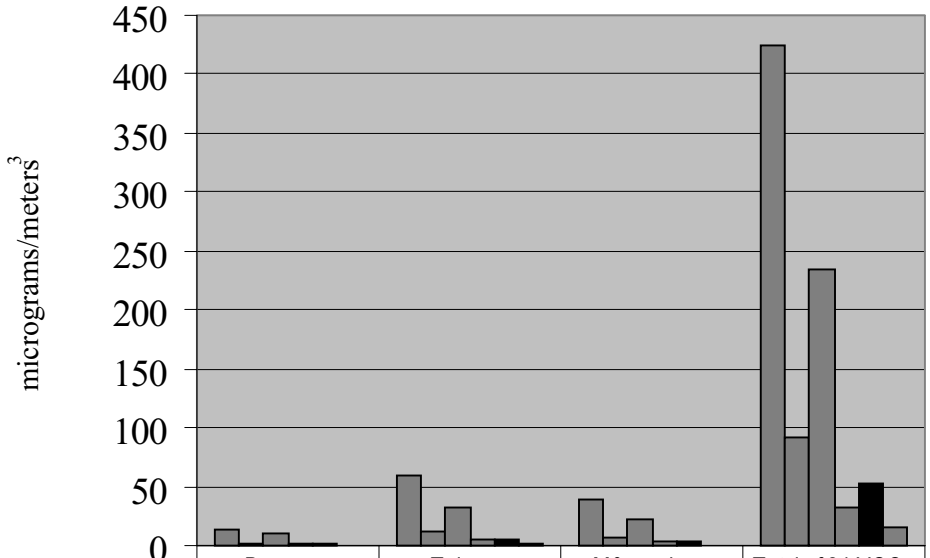
The first studies to measure the levels of VOCs within automobile passenger compartments took place in the late 1980s and early 1990s. These evaluations of cars on predominantly urban roads in Los Angeles, Raleigh, Boston, and New York/ New Jersey found average concentrations of benzene ranging from 13.6 to 50.4 $\mu g/m^3$. Toluene concentrations ranged from 33.3 to 158.0 $\mu g/m^3$, ethylbenzene from 5.8 to 11.6 $\mu g/m^3$, m&p-xylene from 20.9 to 154.0 $\mu g/m^3$, o-xylene from 7.3 to 16.0 $\mu g/m^3$, and formaldehyde from 0.2 to 13.7$\mu g/m^3$. The high concentrations in these ranges come out of one of the two Los Angeles studies for all of the pollutants, except ethylbenzene and o-xylene, which the Los Angeles studies did not consider. The low concentrations in the ranges given come from the Raleigh and Boston studies for all of the

pollutants except formaldehyde, which was measured at the lowest average concentration in the New York/New Jersey study. The research completed in Raleigh also reported average concentrations inside cars during highway driving: 9.9 μg/m^3 for benzene, 34.5 μg/m^3 for toluene, 6.7 μg/m^3 for ethylbenzene, 23.1 μg/m^3 for m&p-xylene, and 8.6 μg/m^3 for o-xylene. During suburban driving, the New York/New Jersey study found average concentrations of 13.4 μg/m^3 for benzene, 51.2 μg/m^3 for toluene, 10.1 μg/m^3 for ethylbenzene, 29.2 μg/m^3 for m&p-xylene, 12.5 μg/m^3 for o-xylene, and 0.4 μg/m^3 for formaldehyde. In both of these studies, in every case except that of formaldehyde, the in-car concentrations were significantly higher during urban driving than during suburban or highway driving.[8]

The New York/New Jersey study also showed that improperly maintained vehicles may have significantly higher in-car VOC concentrations than well-maintained vehicles. A car in the test with a malfunctioning carburetor, under some driving conditions, registered more than 12 times the benzene, 5 times the toluene, 44 times the ethylbenzene, 23 times the m&p-xylene, and 40 times the o-xylene found in a properly maintained car on the same suburban test route.[9]

A Harvard School of Public Health study published in 1991 compared in-car VOC concentrations to those measured just outside the automobile passenger compartment, at the roadside, and at nearby fixed-site monitoring stations away from

In-Car and Fixed-Site VOC Concentrations in Raleigh



	Benzene	Toluene	M&p-xylene	Total of 24 VOCs
City In-car	13.8	59.1	39.5	424.1
City Fixed site	2.4	12.1	7	91.3
Interstate In-car	9.5	32.4	22.3	233.5
Interstate Fixed site	1.6	4.5	3	31.5
Rural In-car	1.5	5.2	3.7	53.2
Rural Fixed site	0.7	1.8	0.8	14.8

Source: Chang-Chuan Chan, et al., Environmental Science and Technology, *1991.*

the roadway. The project also looked at in-car VOC concentrations at different times of day and on different types of roadways. (See graphic, p. 15.)

For benzene, 1,3-butadiene, toluene, m&p-xylene, o-xylene, and most of the 19 other VOCs measured, concentrations in the automobile passenger compartment were roughly the same as concentrations in the traffic stream immediately outside of the car. This was the case whether the vehicles were driven with the windows up or down and with the ventilation systems on or off. In-car concentrations were slightly lower when cars were driven with their air conditioners on.

The average in-car benzene concentration (11.6 $\mu g/m^3$) was 6.1 times higher than the average in the ambient air at fix-site measuring stations and 1.7 times higher than at the side of the road. The maximum in-car concentration of benzene, 42.8 $\mu g/m^3$, was nearly five times higher than the maximum at roadside. The in-car 1,3-butadiene average concentration (3.3 $\mu g/m^3$) was 2.8 times higher than both the fixed-site measurement and the roadside average. Again the in-car maximum concentration (17.2 $\mu g/m^3$) was significantly higher (14.3 times higher) than the roadside maximum.[10]

In 1990, Lars Lofgren, et al., of the Chalmers University of Technology in Goteborg, Sweden, conducted one of the first European studies to measure the levels of VOCs inside automobile passenger compartments. The researchers found total VOC concentrations inside cars during commuter trips in heavy traffic ranging from 200 to 400 $\mu g/m^3$. The researchers did not consider levels of VOCs at the roadside or in the ambient air, but did determine that in-car total VOC levels were 6 to 11 times higher than levels measured inside commuter trains making the same trips.

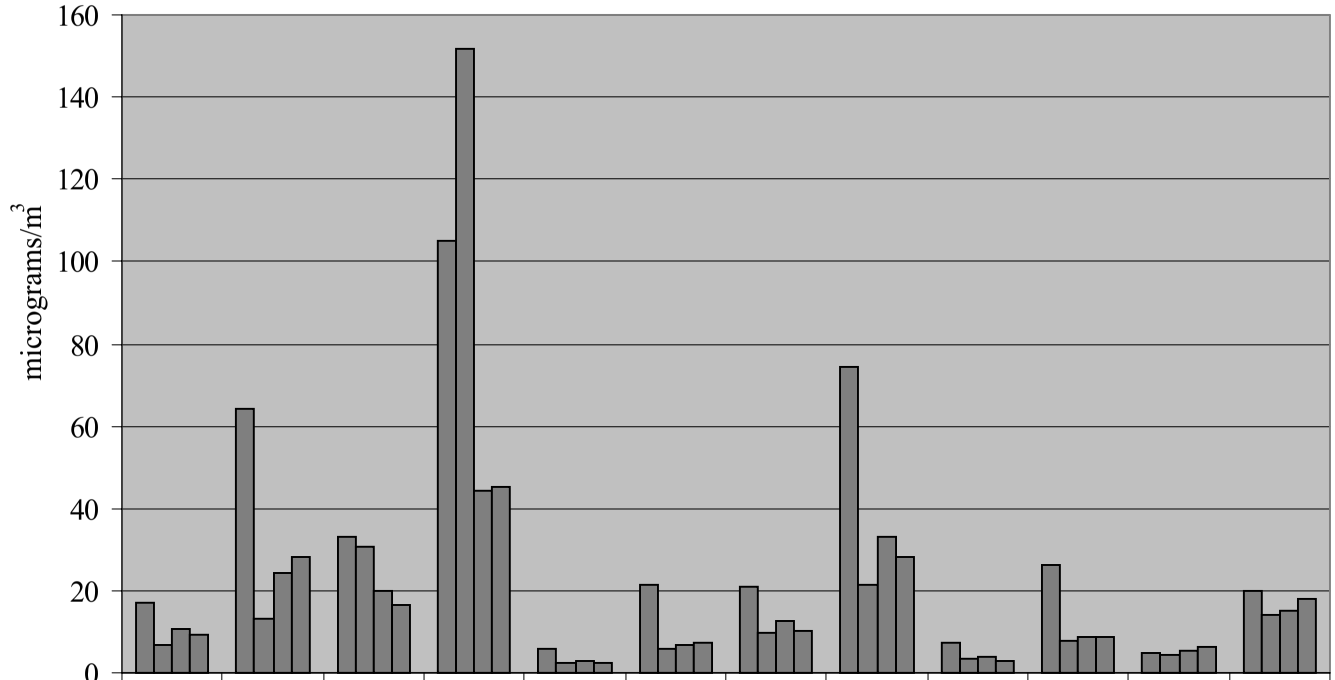
Benzene levels inside automobiles averaged 57.1 $\mu g/m^3$, nearly nine times higher than the average concentration of 6.6 $\mu g/m^3$ measured inside the commuter trains. The study found similar ratios for toluene (99.9 $\mu g/m^3$ in-car, 8.1 times higher than in-train), ethylbenzene (17.9 $\mu g/m^3$ in-car, 8 times higher than in-train), m&p-xylene (58.9 $\mu g/m^3$ in-car, 7.9 times higher than in-train), and o-xylene (23.0 $\mu g/m^3$ in-car, 7.9 times higher than in-train).[11] Lofgren and his colleagues reported that in-car concentrations for all of the VOCs reached their peak during commuter trips marked by heavy traffic or frequent stops at traffic lights behind other vehicles.

A second study published in 1991 by researchers from the Harvard School of Public Health compared the exposure to six different VOCs of automobile, subway, bicycle, and pedestrian commuters. (See graphic, p. 17.) The average concentrations of benzene, toluene, ethylbenzene, m&p-xylene, and o-xylene were higher inside automobiles than inside subway cars or in the air breathed by pedestrian or bicycle commuters. Formaldehyde concentrations were slightly higher for pedestrians and bicycle riders than for drivers and subway riders. For benzene, the average concentrations were: 17.0 $\mu g/m^3$ inside the cars (with a maximum concentration of 64 $\mu g/m^3$), 6.9 $\mu g/m^3$ in subway trains (13.5 $\mu g/m^3$ maximum), 10.6 $\mu g/m^3$ for pedestrians (24.2 $\mu g/m^3$ maximum), and 9.2 $\mu g/m^3$ for bicyclists (28.0 $\mu g/m^3$ maximum). For toluene, ethylbenzene, m&p-xylene, and o-xylene, concentrations inside cars ranged from 1.1 to 2.3 times higher than in subway cars, from 1.6 to 1.9 times higher than in the air breathed by pedestrians, and from 2.0 to 2.4 times higher than in the air breathed by bicyclists.

This study looked beyond the concentrations of the pollutants in different commuting environments by considering both the levels of VOC exposure and the average length of time that commuters were exposed. Thus, automobile drivers, with an average commute of 76 minutes, would have to be exposed to significantly higher concentrations of VOCs than subway commuters, who

—Harvard researchers found that the daily commute accounted for 21% of car drivers' total benzene exposure

Boston Commuters' Exposure to VOCs



	Benzene		Toluene		Ethybenzene		M&p-xylene		O-xylene		Formaldehyde	
	mean	max.	mean	max.	mean	max.	mean	max.	mean	max.	mean	max.
Car	17	64	33.1	105.1	5.8	21.6	20.9	74.6	7.3	26.1	5.1	19.7
Subway	6.9	13.2	30.8	151.7	2.5	5.8	9.8	21.6	3.6	7.8	4.5	14.1
Pedestrian	10.6	24.2	19.8	44.3	3	6.8	12.6	32.9	4.1	8.9	5.5	15.1
Bicyclist	9.2	28	16.3	45.1	2.4	7.1	10	28.3	3	8.9	6.3	18

Source: Chang-Chuan Chan, et al., Journal of Air & Waste Management, *1991*.

Concentrations of benzene, a known carcinogen, reach levels inside automobiles nearly two-and-a-half times higher than in the air breathed by bicyclists, according to a Raleigh, NC, study.

took an average of 87 minutes getting to and from work, to have a higher total exposure. For benzene, ethylbenzene, m&p-xylene, and o-xylene, this was indeed the case—the total exposure of automobile commuters exceeded that of subway commuters despite the car drivers' shorter commutes. For toluene and formaldehyde, however, the longer commuting time pushed the exposure of subway riders slightly above that for auto commuters. In all cases, the total VOC exposures for bicyclists, with an average commute of 54 minutes, and pedestrians, with an average commute of 47 minutes, fell well below those of automobile and subway commuters.

The Harvard study also measured typical VOC levels in the commuters' homes and offices. Using these data, the researchers determined that the daily commute accounted for approximately 21% of automobile drivers' benzene exposure each day, with the commute contributing from 13% to 20% of the drivers exposure to the other four VOCs measured in the study. Thus, the drivers were breathing in more than one-fifth of the total amount of benzene they inhaled over the course of an entire day during the one hour and fifteen minutes they spent in their cars. For train commuters, the trip to and from work accounted for 10% of their daily benzene exposure and 11% to 13% of other VOC exposure.[12]

Three European studies published during 1995 and 1996 also compared the exposure to VOCs of people using different types of transportation. In the first, Joop H. van Wijnen, et al., measured the exposure of automobile drivers and bicyclists in and around Amsterdam to VOCs and other pollutants on different types of roadways and at different times of the year. The study also incorporated the exposure of pedestrians walking along an inner-city route during the summer. In-car exposures to benzene, toluene, and xylenes (these research-

ers did not differentiate between the different xylenes) were consistently higher than the exposures of bicyclists and pedestrians. Drivers along inner-city routes were exposed to average benzene concentrations ranging from 43 to 74 µg/m^3, which were 1.9 to 4.1 times higher than the concentrations in the air breathed by the bicyclists. Drivers' exposure to toluene was 2.2 to 3.9 times greater than that of bicyclists, while their exposure to xylenes was 2.0 to 3.8 times greater.

Analysis of exposure along rural routes was complicated by the fact that the average concentration of benzene and xylenes in the air breathed by bicyclists fell below the study's minimum detection level of 8 µg/m^3. In-car average concentrations of benzene and xylenes during tests conducted in May were 25 µg/m^3 and 50 µg/m^3, respectively. For toluene, in-car concentrations were 2.7 times higher than those in the air breathed by bicyclists during tests conducted in January and 6.5 times higher during the May tests.

Van Wijen, et al., note that while the in-car concentrations of benzene, toluene, and xylenes is much higher than in the air breathed by bicyclists, the actual exposure of bicyclists to these pollutants may approach that of automobile drivers during trips of like duration. The reason for this is that a bicyclist inhales more than 2 times the volume of air inhaled by a car driver over the same period of time.[13]

In the second European study of VOC exposure, researchers considered personal-automobile, bus, subway, and pedestrian commuters in Paris. The average concentrations of VOCs inside cars on routes in central Paris were 46 µg/m^3 for benzene and 260 µg/m^3 for toluene. These were significantly higher than concentrations breathed by other commuters. These concentrations ranged from 12 to 25 µg/m^3 for benzene and 80 to 110 µg/m^3 for toluene.

Researchers also compared in-car pollutant levels of a gasoline-powered car and an electric vehicle, which emitted no VOCs. The two vehicles driving the same commuter route in and around Paris registered relatively similar average in-car concentrations of benzene, toluene, and four other VOCs, leading the researchers to conclude that the vast majority of in-car VOCs come from the exhaust of nearby cars on the road. Using data from this and other studies, the researchers also determined that the commute of non-smoking drivers with no inordinate occupational exposure to VOCs accounts for 20-30% of the individuals' total daily exposure to benzene.[14]

The final European study looked at the exposure of Swedish subway and bus riders to VOCs. The cumulative concentration of all VOCs averaged 217.3 µg/m^3 on local buses, 151.7 µg/m^3 on commuter buses, and 93 µg/m^3 on commuter trains. On comparable commuter routes, in-bus pollutant concentrations averaged between 11.7 and 27.0 µg/m^3 for benzene, while in-train concentrations were from 1.8 to 3.1 times lower. For all VOCs combined, in-train concentrations were 2.0 to 3.5 times lower than in-bus concentrations.[15]

Research by the Kyungpook National University, Taegu, South Korea, compared personal exposure to five VOCs (benzene, toluene, ethylbenzene, m&p-xylene, and o-xylene) during personal-automobile and bus commutes along three different suburban-urban routes in that Asian city. Average in-car concentrations of each of the pollutants were higher than average in-bus concentrations on every route. The total average concentration of the five VOCs measured during urban commutes was 191.4 µg/m^3 inside the automobiles and 142.8 µg/m^3 inside the buses. The concentration of benzene inside the cars was more than 50% greater than the concentration inside the buses. Concentrations of the other measured VOCs were from 25% to 37% higher inside the cars than inside the buses. Comparatively, results from tests on suburban commutes were similar, though, as we might expect, in-car and in-bus concentrations of all the VOCs were slightly lower.[16]

The 1998 California Air Resources Board study measured 13 different VOCs inside a pair of cars on a variety of roads in Los Angeles and Sacramento, immediately outside of the cars in the traffic stream, and at the roadside. (See charts, p. 20-21.) In almost every instance, concentrations of benzene, 1,3-butadiene, m&p-xylenes, o-xylene,

Benzene Levels Measured in the 1998 CARB Study

Type of Road	Mean In-Car Car 1	Mean In-Car Car 2	Maximum In-Car Car 1	Maximum In-Car Car 2	Ambient Air	Roadside Mean	Roadside Max.
Los Angeles							
Arterial, Non-rush hour	16.7	13.9	19.0	14.7	6.6	nd	nd
Arterial, Rush hour	14.5	12.5	20.7	14.9	2.8	5.2	8.5
Freeway, Non-rush hour	14.4	12.5	15.1	12.8	3.9	nd	nd
Freeway, Rush hour	14.4	15.5	21.9	20.2	4.0	11.8	19.5
Freeway, Carpool lane	12.7	17.4	14.8	18.6	3.0	11.2	12.5
Sacramento							
Arterial, Rush hour	12.1	11.2	15.2	13.9	2.9	5.0	5.9
Freeway, Non-rush hour	6.5	7.2	7.4	7.6	0.9	1.0	1.4
Freeway, Rush hour	10.3	13.9	13.9	15.9	1.4	2.6	5.3
Rural	3.1	2.0	3.1	2.0	nd	1.0	1.1

Note: nd = no data available.
Source: California Air Resources Board.

ethylbenzene, toluene, and formaldehyde inside the test cars exceeded those measured immediately at the roadside and in the ambient air measured at remote fixed sites.[17] The in-car concentrations of all the VOCs generally were very similar to those measured in the traffic stream immediately outside of the vehicles.

In the Sacramento tests, the highest average in-car concentrations of all the VOCs occurred during rush hour on arterial and freeway routes. Average in-car benzene concentrations on these runs ranged from 10.3 to 13.9 µg/m^3, while roadside measurements during these tests revealed average concentrations of 2.6 to 5.0 µg/m^3. While the in-car and roadside benzene concentrations were lower on rural roads and freeways during non-rush hour, in-car concentrations still measured 2 to 7 times greater than the roadside concentrations. For toluene, average in-car concentrations ranged from 3.2 µg/m^3 in one of the test cars on a rural route to 35.4 µg/m^3 on an arterial road during rush hour. Roadside measures were 2.2µg/m^3 on the rural route and 12.3 µg/m^3 along side the artery. Average m&p-xylene concentrations ranged from 1.8 µg/m^3 inside one of the test cars on a rural road to 31.0 µg/m^3 inside a test vehicle on an artery during rush hour. The average roadside measures were 1.2 µg/m^3 and 8.9 µg/m^3, respectively.

Toluene Levels Measured in the 1998 CARB Study

Type of Road	Mean In-Car Car 1	Mean In-Car Car 2	Maximum In-Car Car 1	Maximum In-Car Car 2	Ambient Air	Roadside Mean	Roadside Max.
Los Angeles							
Arterial, Non-rush hour	44.4	32.8	53.9	38.2	23.2	nd	nd
Arterial, Rush hour	37.0	30.1	49.6	34.0	9.6	16.4	27.4
Freeway, Non-rush hour	38.8	33.0	42.3	37.5	39.9	nd	nd
Freeway, Rush hour	34.0	31.2	52.4	39.7	19.0	43.9	70.5
Freeway, Carpool lane	31.5	50.8	36.1	57.6	10.3	26.4	28.8
Sacramento							
Arterial, Rush hour	35.4	24.4	45.9	27.7	8.2	12.3	14.8
Freeway, Non-rush hour	13.1	15.3	17.0	15.7	5.8	6.2	9.3
Freeway, Rush hour	32.0	24.1	38.4	35.8	4.6	7.3	10.6
Rural	7.4	3.2	7.4	3.2	nd	2.2	2.2

Note: nd = no data available.
Source: California Air Resources Board.

M&P-Xylene Levels Measured in the 1998 CARB Study

Type of Road	Mean In-Car		Maximum In-Car		Ambient	Roadside	
	Car 1	Car 2	Car 1	Car 2	Air	Mean	Max.
Los Angeles							
Arterial, Non-rush hour	35.5	23.7	43.6	27.3	9.4	nd	nd
Arterial, Rush hour	28.8	22.4	40.6	24.9	5.3	9.9	14.8
Freeway, Non-rush hour	26.9	27.7	21.5	23.4	5.7	nd	nd
Freeway, Rush hour	28.2	23.4	45.5	28.9	7.4	20.2	36.9
Freeway, Carpool lane	23.6	31.0	28.9	31.0	5.2	18.3	20.6
Sacramento							
Arterial, Rush hour	31.0	19.8	38.2	22.1	5.0	8.9	10.9
Freeway, Non-rush hour	12.6	11.0	12.7	11.0	1.8	2.6	3.5
Freeway, Rush hour	24.7	21.2	30.1	26.7	2.7	4.9	8.0
Rural	5.3	1.8	5.3	1.8	nd	1.2	1.3

Note: nd = no data available.
Source: California Air Resources Board.

Average in-car and roadside concentrations of all VOCs tended to be higher in Los Angeles than in Sacramento. For benzene, average in-car levels ranged from 12.5 $\mu g/m^3$ for a vehicle on an arterial road during rush hour and for another on a freeway during non-rush hour (the Los Angeles tests did not include a rural route) to 17.4 $\mu g/m^3$ for a vehicle in the carpool lane of a freeway during rush hour. Roadside concentrations averaged from 5.2 to 11.8 $\mu g/m^3$. Despite the fact that one of the test vehicles on Los Angeles arterial roads during rush hour posted the lowest average benzene concentration in the Los Angeles tests, this vehicle's in-car concentration was still nearly two-and-a-half times higher than the average roadside concentration. The other vehicle on the same arterial non-rush hour route recorded an average in-car concentration nearly three times higher than the roadside average.

For toluene, average in-car concentrations ranged from 30.1 to 50.8 $\mu g/m^3$, with a peak measurement of 57.6 $\mu g/m^3$. Average ethylbenzene concentrations ranged from 5.7 to 9.7 $\mu g/m^3$, and were up to 2.8 times higher than those measured at the roadside. M&p-xylene in-car concentrations averaged between 21.5 and 35.5 $\mu g/m^3$ (up to 2.9 times roadside concentrations), while average o-xylene in-car concentrations were between 7.8 and 12.9 $\mu g/m^3$ (1.1 to 2.7 times higher than at roadside). Average in-car formaldehyde concentrations ranged from 7.2 to 19.7 $\mu g/m^3$.

SECTION FOUR

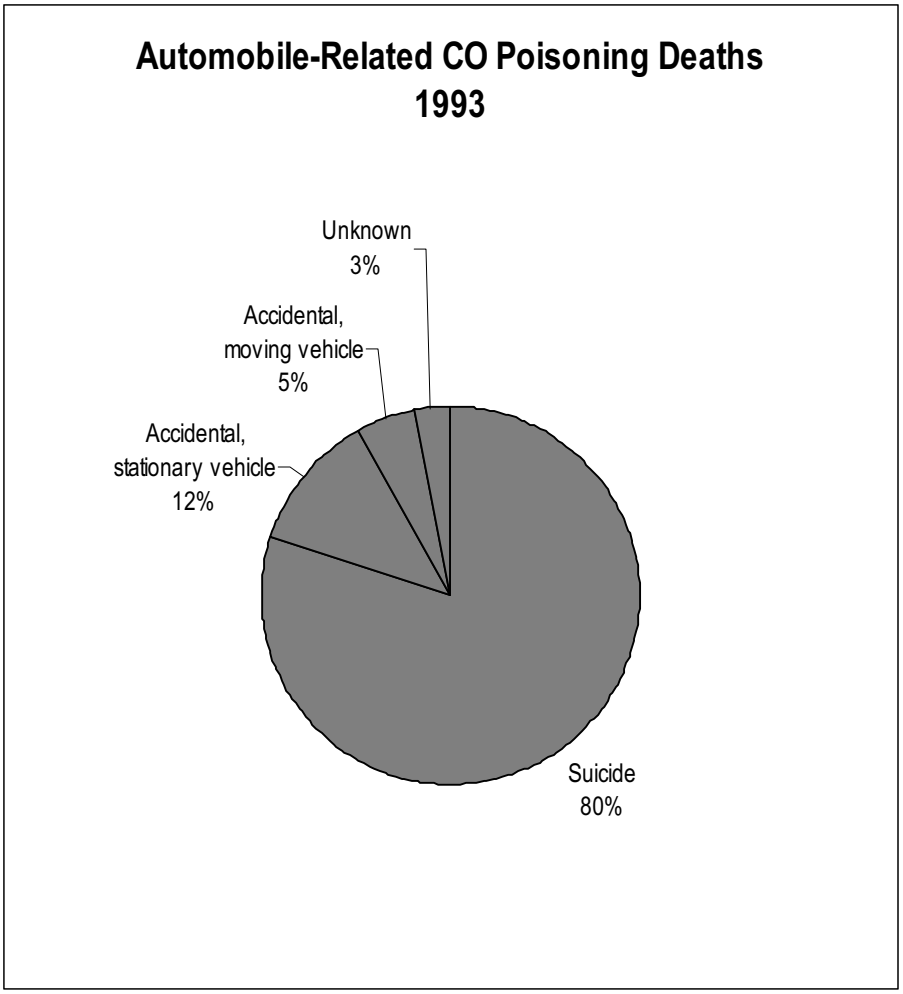
CARBON MONOXIDE

Carbon monoxide (CO), a very simple molecule consisting of a single carbon atom and a single oxygen atom, primarily enters the air we breathe as a gaseous byproduct of the incomplete combustion of hydrocarbon fuels, such as gasoline and diesel. A newer model, properly maintained car emits about 420 pounds of CO each year, while a newer model, properly maintained SUV emits about 547 pounds over the same period. Older vehicles and those with malfunctioning emissions-control systems can create much more CO.[1] A cold engine, whether or not it is properly maintained, emits significantly more CO than a warm one. Therefore, CO emissions and concentrations in urban and roadside air are often much higher during the winter months than in the summer. Nationwide, the exhaust from cars and trucks accounts for about 60% of the CO released into the air. In major urban areas, motor vehicles are responsible for up to 95% of CO emissions. CO disperses quickly in the air, so moderate and high levels of the gas are usually detected only in areas with significant motor vehicle traffic or within enclosed spaces where it may accumulate.[2]

CO is highly toxic and potentially deadly to humans and other animals. Each year, more than 10,000 people in the United States seek medical attention or are incapacitated for at least one day due to CO poisoning. Incidents in which people commit suicide by intentionally exposing themselves to CO in car exhaust have received significant coverage in the media and popular culture and number about 1,500 cases each year; it is less well known that an additional 1,500 people die from unintentional automobile-related CO poisoning annually. (See graphic, p. 24.) A study by the National Highway Traffic Safety Administration found that in 1993 nearly one-third of the accidental CO poisonings that resulted in fatalities and were caused by automobile exhaust involved drivers or passengers in moving vehicles.[3] Between 1977 and 1988, more than 1,100 people in the United States died due to accidental exposure to CO while they were driving or riding in moving vehicles.[4]

Health Effects of CO Exposure

Acute CO poisoning occurs when inhaled CO combines with hemoglobin in the bloodstream, thereby preventing the hemoglobin from supplying oxygen to the brain, heart, and other bodily organs and tissues. Low levels of CO, relative to levels of oxygen, in inhaled air can prove highly toxic because CO binds with hemoglobin some 200 to 230 times more readily than oxygen and, on top of that, CO can alter hemoglobin so that it is no longer able to deliver oxygen to organs and tissues. CO has no color, no smell, and no taste. Moderate exposure may produce flu-like symptoms–headaches, dizziness, and weakness–in healthy people. Therefore, many people who suffer non-fatal CO poisoning probably remain unaware that they have been exposed to the gas. It is likely that the majority of cases of acute poisoning



Source: Morbidity and Mortality Weekly Report, *1996.*

go untreated and unreported, and the actual number of poisonings certainly exceeds the 10,000 cited above.[5]

Concentrations of CO inside properly maintained cars rarely exceed federal or international standards. However, acute poisoning of vehicle drivers and passengers may constitute less of a concern than the potential effects of chronic exposure. The health ramifications of long-term exposure to elevated CO levels are not fully understood. Preliminary studies indicate that regular exposure to even moderately elevated CO levels may carry some health consequences, especially among the elderly, people with cardiovascular diseases or lung dysfunction, and infants and unborn children. Meanwhile, numerous scientific studies have demonstrated that the driver and passengers in a motor vehicle potentially breathe in much higher levels of CO than people breathing normal, ambient air or even than people breathing air at the side of the road while the car is passing by.

In-Car CO Exposure Levels

At least 15 studies conducted during the 1980s and 1990s measured and examined the concentrations of CO inside vehicle passenger compartments, and a number of these studies compared in-car CO levels to those measured at the roadside, at remote fixed-site monitoring stations, or inside public buses, subway cars, or trains. The research shows that CO concentrations inside cars consistently measure higher than those at the roadside or inside other types of vehicles typically used for commuter transportation.

Researchers first discovered in 1978 that one of the strongest causal factors of elevated CO levels in passenger cars is other vehicles on the road; this conclusion grew out of research demonstrat-

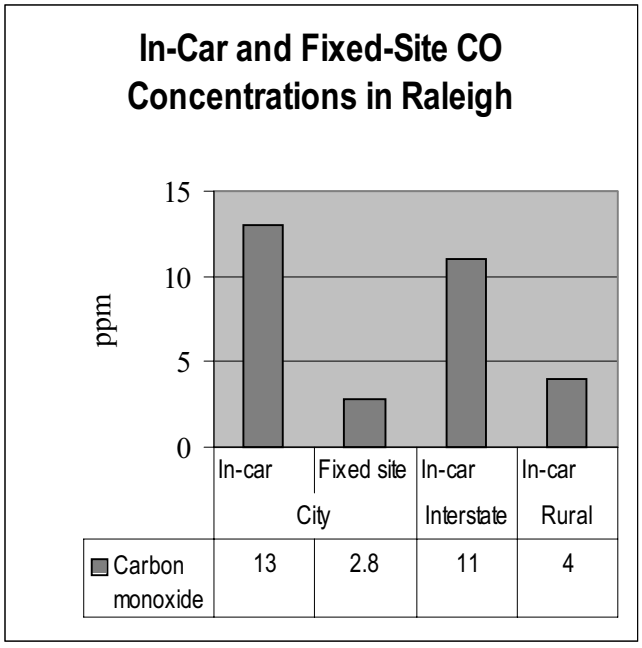
ing that cars on cross-country trips following directly behind high-polluting vehicles, such as older cars lacking emissions-control systems, registered significantly elevated CO levels in their passenger compartments.[6] Since then, researchers have measured the interior CO concentrations of automobiles driving in numerous cities around the world and have considered such variables as road type, traffic conditions, vehicle speed, time of day, and searchers measured average in-car CO concentrations ranging from 9.1 to 22.3 ppm. These compare to an average ambient air CO level, calculated from measurements at fixed stations near the commuter routes, of between 2.2 and 2.3 ppm. Typically the in-car levels were about seven times higher than those at the remote sites. CO levels for cars on one of the designated commuter routes in this study tended to be much higher inside cars

—Typical in-car CO levels were seven times higher than those at a nearby outdoor site in Washington, DC

"comfort state" (i.e., windows up or down, vents open or closed, etc.).

In 1982, William B. Petersen of the U.S. Environmental Protection Agency and Rodney Allen of Comp-Aid, Inc., measured CO concentrations inside cars on commuter routes in Los Angeles and compared them with levels just outside the vehicles and at remote monitoring stations nearby the commuter routes. They found that CO levels inside the test vehicles were nearly identical to those immediately outside the vehicles and were an average of nearly four times higher than levels recorded at remote monitoring stations. CO concentrations within vehicles traveling along these Los Angeles commuter routes where highest when the vehicles experienced heavy, stop-and-go traffic conditions. Under these conditions, peak CO levels frequently exceeded 40 ppm and sometimes exceeded 60 ppm. However, the in-car concentrations for these commuter routes never exceeded an hourly average of 35 ppm. Petersen and Rodney found that average CO concentrations in cars with their windows up were about the same as those with their windows down. Similarly, opening or closing the cars' vents had no significant effect on in-car CO concentrations.[7]

Peter G. Flachsbart, et al., reported even greater elevation of in-car CO levels compared to levels at remote measuring centers for Washington, D.C.-area commuters in 1987. During 213 automobile trips along routes through the metro Maryland, Virginia, and District of Columbia area, the researchers measured average in-car CO concentrations ranging from 9.1 to 22.3 ppm. These compare to an average ambient air CO level, calculated from measurements at fixed stations near the commuter routes, of between 2.2 and 2.3 ppm. Typically the in-car levels were about seven times higher than those at the remote sites. CO levels for cars on one of the designated commuter routes in this study tended to be much higher inside cars during evening commutes, even though ambient CO levels were slightly lower in the evening. This is because this route ended the morning commute and began the afternoon commute in an indoor parking facility. CO concentrations inside the garage averaged 20.9 ppm in the morning and 94.0 ppm in the evening. As previously mentioned, a cold engine produces more CO than a warm one. Multiple vehicle cold starts in the garage each evening when many commuters began their trips home at about the same time caused this extreme CO buildup in the parking structure. Interestingly,



Source: Chang-Chuan Chan, Environmental Science and Technology, *1991.*

CO Levels Measured in the 1998 CARB Study

Type of Road	Mean In-Car Car 1	Mean In-Car Car 2	Maximum In-Car Car 1	Maximum In-Car Car 2	Ambient Air	Roadside Mean	Roadside Max.
Los Angeles							
Arterial, Non-rush hour	4.2	4.6	31.0	13.0	0.8	nd	nd
Arterial, Rush hour	4.2	4.4	48.0	11.0	0.0	0.6	7.0
Freeway, Non-rush hour	4.4	4.5	39.0	20.0	1.3	nd	nd
Freeway, Rush hour	5.1	5.4	67.0	22.0	0.5	3.1	11.0
Freeway, Carpool lane	3.5	4.9	12.0	22.0	0.0	3.6	10.0
Sacramento							
Arterial, Rush hour	2.3	3.0	16.0	14.0	0.0	0.4	8.0
Freeway, Non-rush hour	1.4	3.5	19.0	15.0	0.0	0.0	1.0
Freeway, Rush hour	2.1	3.1	17.0	52.0	0.0	0.3	4.0
Rural	0.7	0.4	22.0	6.0	nd	0.0	1.0

Note: nd = no data available.
Source: California Air Resources Board.

the vehicles on this particular test run showed extremely elevated in-car CO levels during the entire first leg of their homeward commute, indicating that residual CO from the high parking garage levels remained in the cars for a significant part of their commute home. Flachsbart, et al., also found a correlation between the speed of a test car on the commuter route and its average level of in-car CO. Increasing the vehicle speed from 10 to 60 mph decreased the average CO exposure by 35%.[8]

In 1991, researchers from the Department of Environmental Health, Harvard School of Public Health, compared in-car, out-of-car, and remote fixed-site CO measurements for a variety of urban, interstate, and rural routes in and around Raleigh, North Carolina. (See graphic, p. 25.) Overall, in-car CO concentrations ranged from 1 to 32 ppm, with an average of 11.3 ppm. This compares to levels of between 6 and 22 ppm with and average of 11.7 ppm on the immediate exterior of the car. Measurements at a nearby fixed site ranged from 1.7 to 5.5 ppm, with an average of 2.9 ppm. Thus, the average in-car CO level equaled nearly 97% of the car exterior average and was 3.9 times the average for the ambient air. This study found that in-car CO levels on urban streets and interstate highways were not significantly different, with median concentrations of 13 and 11 ppm, respectively. The median concentration of CO inside vehicles on rural roads, however, was substantially lower at 4 ppm. The researchers concluded that this fact is due to differing traffic densities, CO dispersion patterns, and air turbulence patterns.[9]

The California Air Resources Board, working with scientists from the Research Triangle Institute in North Carolina, conducted the most recent and most thorough project assessing CO concentrations inside automobiles. (See chart, this page.) This study measured the concentration of pollutants inside cars on various types of roads in and near Sacramento and Los Angeles. The CARB study included vehicles traveling under several different driving conditions and compared in-car pollutant levels to levels just outside the test cars and to levels at the side of the road. This differs from the previously cited studies, which reported CO concentrations from fixed-site monitoring stations that were near test routes, but not necessarily at the roadside.

Sacramento tests measured in-car CO concentrations on arterial roads during rush hour, on freeways during rush hour and non-rush hour, and on rural roads. Average levels in the main test car ranged from 0.7 ppm on the rural runs to 2.1 ppm on the arterial rush hour runs. The roadside CO concentration averaged 0 ppm for the non-rush hour freeway runs and the rural runs, 0.3 ppm for the freeway rush hour runs, and 0.4 ppm for the arterial road rush hour runs.

In Los Angeles, CARB ran tests on arterial

roads at rush hour and non-rush hour; freeways at rush hour and non-rush hour; and in car pool lanes of freeways at rush hour. Average in-car CO levels ranged from 3.5 ppm in the freeway carpool lanes to 5.1 ppm in regular freeway lanes during rush hour. The average peak CO concentration in the lead test car during the freeway rush hour runs was 34.0 ppm, compared to 26.5 ppm for freeway non-rush hour runs, and 9.0 ppm for freeway carpool lane runs. Researchers analyzed videotapes of driving conditions during the various runs to determine the causes of peak CO levels. Nearly all of the peak concentrations occurred when the test vehicle followed directly behind a heavily polluting vehicle in dense traffic. The highest peak CO concentrations occurred when the test vehicle was following an out-of-tune delivery truck and an older-model sedan.[10]

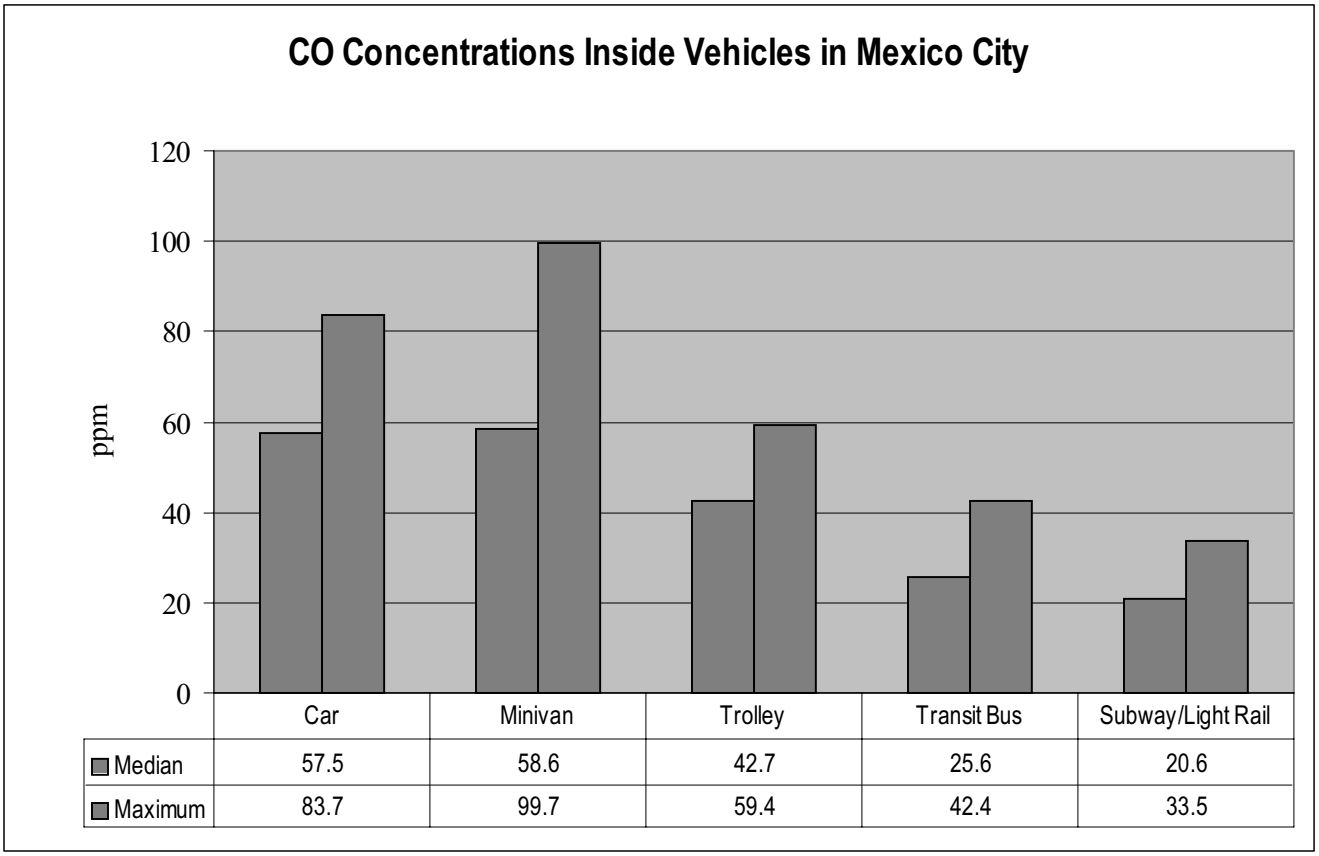
—The highest in-car CO concentrations in the CARB study occurred when the test vehicle followed an out-of-tune delivery truck and an older-model sedan

Several international studies have also measured and evaluated the exposure of automobile drivers and passengers to CO. A 1995 study of pollutant levels inside cars driving typical commuter routes in and around Paris reported average in-car CO levels of 12 ppm in central Paris, 10 ppm along a route from Paris to a western suburb, and 9 ppm along a route from Paris to an eastern suburb. This study also compared in-car CO concentrations on similar routes taken during the summer and the winter. In central Paris, CO concentrations averaged 15.3 ppm in the winter and 9.7 ppm in the summer. The seasonal difference in CO concentrations was less pronounced in cars traveling suburban routes. The Paris study found that CO concentrations at pedestrian sidewalks in central Paris were approximately three times lower than in the cars on the streets there.[11]

A 1997 study by researchers at the University of Nottingham found that drivers in that city in England were exposed to average CO levels of between 3 and 22 ppm. High concentrations typically resulted when the test car followed behind a particularly dirty lead vehicle and when the test car passed through extremely busy intersections. The study found only a very small correlation between meteorological effects, such as wind speed and direction, and in-car CO concentrations. Interestingly, the researchers reported that the speed of the test vehicle had no association with interior CO levels, independent of other traffic conditions. This suggests that other studies reporting a link between vehicle speed and in-car CO concentrations merely reflected the fact that cars tend to move more slowly in congested traffic where interior CO concentrations are likely to be high.[12]

Mexico City presents an interesting site for testing of in-car CO concentrations, because the city is notorious for its automobile-generated air pollution in general and its high ambient CO measures in particular. Readings at five fixed-site monitors around Mexico City in 1991 yielded average CO concentrations of between 7.2 and 11.3 ppm. Researchers Adrian A. Fernandez-Bremauntz and Michael R. Ashmore reported in 1995 that drivers and passengers in cars driving typical Mexico City commuter routes endured an average CO exposure of 56.1 ppm, more than five times ambient levels. The elevation of in-car CO levels was particularly pronounced during evening commutes, with in-car CO levels averaging six times those of ambient levels. During morning commutes, CO levels within cars were about 3.5 times the ambient levels.

Researchers explained that the high in-car CO measures in Mexico City are based on several factors. First, the city is located in a valley that acts as a sink to trap high levels of ambient CO. Second, Mexico has been slower than the United States to enact automobile emissions regulations. Finally, now that tighter emissions regulations for new cars are in place, these do not apply to many older cars



Source: Adrian A. Fernandez-Bremauntz, et al., Atmospheric Environment, *1995.*

on the road in Mexico. Studies indicate that the average age of a car on the road in Mexico City is 11 years, and a high percentage of these older vehicles are not properly maintained.[13]

A 1992 study measured the interior and exterior CO concentrations for cars on commuter routes in Riyadh, Saudi Arabia, and considered traffic volume, vehicle speed, the period of the day, and wind velocity. Interestingly, this study also made measurements inside of cars whose occupants were smoking cigarettes. The average CO exposure of nonsmoking commuters ranged from 30 to 40 ppm during rush hour periods, which amounted to 84% of levels measured immediately outside of the vehicles. Traffic volume had the greatest influence on test cars' interior CO levels. Test cars on a road serving 5,000 vehicles per hour exhibited CO concentrations 71% higher than those on the same road serving 1,000 vehicles per hour. Average interior CO concentrations during non-peak traffic times ranged from 10 to 25 ppm. Vehicle speed also had an effect. A vehicle traveling 55 kilometers per hour had an interior CO concentration 36% lower than one traveling just 14 kilometers per hour. Again, however, this may be due to the fact that the slower vehicle was operating in heavier traffic. Predictably, smoking by automobile passengers had a noticeable effect on in-car CO concentrations. These levels often exceeded 100 ppm.[14]

Other Commuters' Exposure to CO

Several of the studies cited above compared the average CO exposure of automobile drivers and passengers to those of other commuters, including pedestrians, cyclists, and bus, train, and subway riders. The 1987 Washington, D.C., study found that average CO levels experienced by public bus riders were about half of those of automobile commuters, ranging from 4 to 8 ppm. Average CO levels inside subway cars were even lower—ranging from 2 to 5 ppm. Researchers found that the average CO exposure for bus riders was 2 to 6 ppm

higher than levels of CO in the ambient air. Some subway commuters actually breathed air with CO levels lower than in the ambient air.[15] The Mexico City studies revealed similar trends. (See graphic, p. 28.) The median CO concentration inside public buses was 30.2 ppm, compared to 25.6 ppm inside public trolleys, and 20.6 ppm on subway and light rail cars. These figures compare to a median concentration of 57.5 ppm in Mexico City cars. Average in-bus concentrations ranged from 2.5 to 4 times the ambient CO concentrations, while trolley concentrations were 2.5 to 3.5 times ambient concentrations and subway concentrations ranged from 1.7 to 2.5 times those of the ambient air.[16]

A 1995 research project conducted in and around Amsterdam used personal air sampling equipment to measure the exposure of pedestrians, bicyclists, and drivers on various types of roads to CO and other pollutants. Along an inner city route, the personal exposure to CO of automobile drivers averaged 4.23 ppm as measured by the personal air sampling devices (in-vehicle CO monitoring equipment reported somewhat higher concentrations). Bicyclists' personal exposure levels were much lower, averaging 1.65 ppm. Exposure levels of pedestrians in a much smaller study sample averaged 2.15 ppm. Along a rural route, CO exposure was very low for both drivers and cyclists.[17]

SECTION FIVE

NITROGEN OXIDES

Nitrogen dioxide (NO_2) is the best known of the nitrogen oxides (NO_X) and has been listed by the U.S. EPA as a criteria air pollutant under the Clean Air Act. NO_X contributes to the formation of ground-level ozone and acid rain. Chemical reactions involving NO_X in auto exhaust can lead to the creation of acidic particulate matter (see the section on PM above).

Health Effects of NO_x Exposure

Direct exposure to NO_X can irritate the eyes, nose, throat, and lungs, and can exacerbate respiratory diseases, including asthma and influenza. NO_X exposure can also reduce the capacity of the lungs to resist infectious viruses and bacteria, which could lead to increased incidence of colds, influenza, and pneumonia. Studies have associated exposure to concentrations of less than 30 parts per billion (ppb) with hyperactivity of airway muscles, and exposures as low as 15 ppb can cause nasal irritation and a cough. Research has correlated exposure to higher concentrations, around 80 ppb, with increased incidence of respiratory infections and sore throats. Children regularly exposed to NO_X levels of around 80 ppb may be more likely come down with colds and miss days of school.[1]

NO_x Exposure Studies

Chang-Chuan Chan, et al., of the Harvard School of Public Health measured in-car nitrogen dioxide (NO_2) on urban roads and interstate highways of between 8.0 and 196.0 ppb, with an average concentration of 87.3 ppb. Unfortunately, this study did not compare the in-car NO_2 levels with roadside or ambient air levels. The researchers concluded that in-car NO_2 levels were similar for vehicles on urban roads and on interstate highways.[2]

A more useful study for comparative purposes is one by Joop H. van Wijnen, et al., which examined the exposure of bicyclists, car drivers, and pedestrians in Amsterdam to NO_2 and other pollutants. Researchers found in-car NO_2 concentrations, measured via personal air sampling devices, ranging from less than 31 ppb on a rural route up to 144.5 ppb on a route that included a tunnel. On the rural route, the concentration of NO_2 in the air breathed by bicyclists averaged 47 ppb. On inner-city testing routes, average in-car NO_2 concentrations ranged from less than 31 ppb up to 90.8 ppb. Bicyclists on inner-city routes were exposed to

—The average NO_x exposure of a person driving a car was 370 ppb, compared to 130 ppb for a person bicycling on a city street

average NO_2 concentrations ranging from 49.6 ppb to 81.4 ppb. Pedestrians were exposed to an average NO_2 concentration of 55.3 ppb. The researchers found that the exposure of drivers to NO_2 was only slightly higher than that of bicyclers.[3]

An earlier study of pedestrians and bus commuters in Hong Kong found that on-bus NO_2 concentrations averaged about 76 ppb, compared to average roadside concentrations of 50 ppb. Average in-bus concentrations of NO, which makes up about 90% of automobile NO_X emissions, were more than 3 times higher than average roadside concentrations. The researchers determined that the air quality on city buses violated Hong Kong's Air Quality Objective for NO_2 during at least 10% of the measurements, while roadside NO_2 levels exceeded the Objective in less than 2% of the measurements.[4]

Finally, a 1989 report by the Transport and Road Research Laboratory in Berkshire, England, is interesting because it considers exposure to not just NO_2 but all forms of NO_X. This study reported that the average exposure of a person driving a car amounted to 370 ppb, compared to 130 ppb for a person bicycling on a city street.[5]

A study conducted in Hong Kong found that NO_2 concentrations inside transit buses exceeded those in the air breathed by pedestrians by 50%.

SECTION SIX

OZONE

Ozone is a molecule consisting of three bound oxygen atoms. Existing in the stratosphere, ozone protects us and other life forms on Earth from the destructive ultraviolet rays of the sun. Ground-level ozone, a byproduct of the internal combustion engine, constitutes the prime ingredient of urban smog and is highly harmful to human health. Cars and trucks do not directly emit ozone. Rather, VOCs and NO_X in auto exhaust react with sunlight to create the pollutant. Because sunlight and heat play a crucial role in the formation of ozone, smog levels are typically highest during the summer months.

Health Effects of Ozone Exposure

Ozone is highly caustic and prolonged exposure to elevated levels can damage lung tissues, exacerbate existing respiratory diseases, and decrease lung function. Short-term exposure can result in choking, coughing, burning eyes, and nasal and respiratory irritation. Repeated ozone exposures can diminish the body's ability to fight off respiratory infections and may be linked to scarring of lung tissues. Several studies have linked elevated ozone exposure to increases in visits to hospital emergency rooms by people with respiratory complaints. In fact, meta-analysis of a variety of studies indicates that hospitalizations for asthma, pneumonia, and chronic obstructive pulmonary disease increase by 6% to10% for every 50 ppb increase in peak ozone exposure.

Different people may have very different reactions to the same level of ozone exposure. For example, 10% to 20% of individuals may experience a 12% decline in lung function following one to two hours of exposure to 120 parts per billion (ppb) ozone. A few individuals may experience a 38% decline in lung function following six and a half hours of exposure to 80 ppb ozone. Children, the elderly, and people with existing respiratory diseases, such as asthma, tend to be most adversely effected by ozone.[1] Studies have also found a possible link between increased death rates and exposure to elevated ozone levels, especially among individuals over the age of 65.[2]

In-Car Ozone Exposure Studies

Despite the profound health implications of ozone, the concentration of ozone inside vehicles has not been well studied. From limited research, it appears that ozone is one of the few automobile exhaust-related pollutants for which concentrations tend to be lower inside vehicles than in the ambient air. There are several reasons for this. First, as noted above, automobiles do not directly emit ozone, but the pollutant is formed during a chemical reaction involving sunlight and other components of auto exhaust. Because the majority of in-car air pollutants consist of the exhaust of nearby vehicles, it is likely that the exhaust enters the automobile passenger cabin before significant amounts of ozone are formed. Second, ozone tends to quickly react with NO, the primary component of NO_X, which is likely to be present in high con-

centrations in air surrounding a busy roadway. Third, ozone tends to decay within the auto passenger compartment. Nonetheless, in-car ozone concentrations may still reach significant levels and further tests would seem to be in order.

In 1991, Chang-Chuan Chan et al. of the Harvard School of Public Health reported that the average ozone concentration inside test vehicles driving commuter routes near Raleigh, North Carolina, was 15.4 ppb, with a maximum concentration of 86.0 ppb. The highest in-car ozone concentrations occurred during afternoon driving. Ambient air measurements taken at a fixed site near the commuter route averaged 52.8 ppb with a maximum of 123.0 ppb. Unfortunately, the researchers did not measure ozone concentrations in the roadway or at the roadside.[3]

In 1995, Ted R. Johnson of International Technology Corp. conducted a study which determined the ratio of ozone detected inside test vehicles on roads in and around Cincinnati, Ohio, to that detected outside. Unfortunately, Johnson does not report the actual ozone concentrations but only that concentrations inside the test vehicles were approximately one-third of those outside.[4]

SECTION SEVEN

CONCLUSION

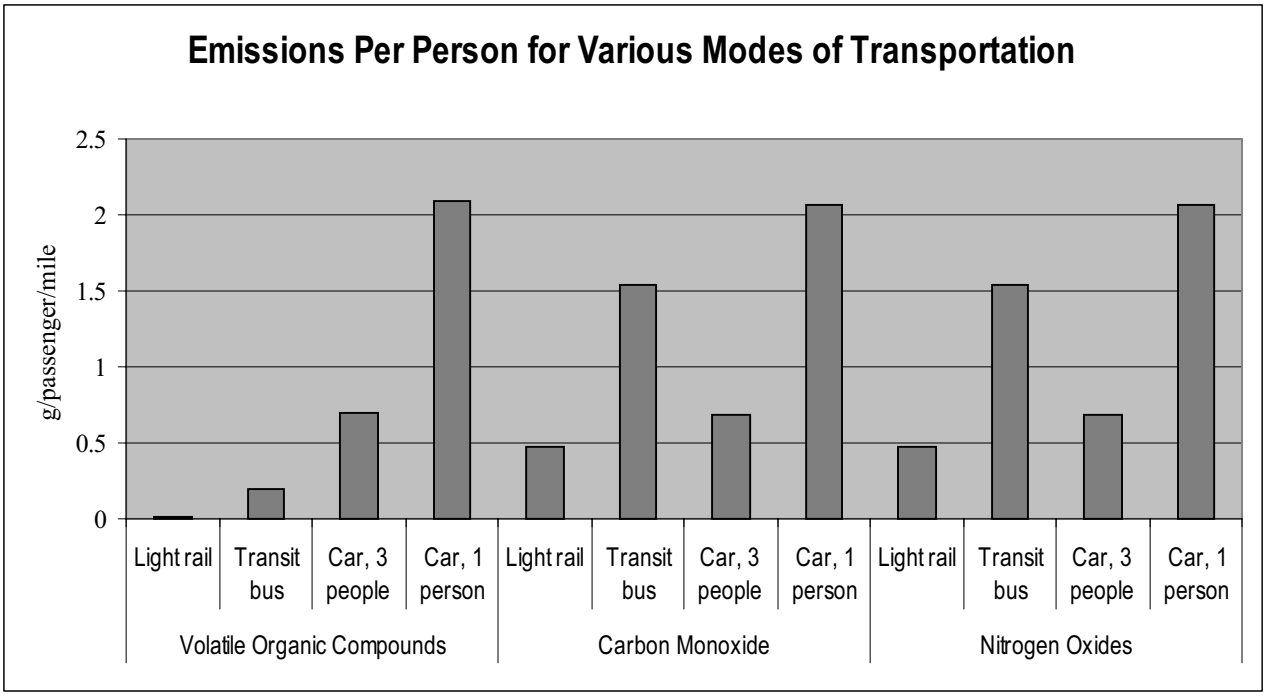
Studies conducted over the past two decades conclusively demonstrate that the shell of an automobile does little to protect the passengers inside from the dangerous air pollutants, including respiratory irritants, neurological agents, and carcinogens, commonly found in the exhaust of gasoline and diesel vehicles. In fact, the levels of exposure to most auto pollutants, including potentially deadly particulate matter, volatile organic compounds, and carbon monoxide, are generally much higher for automobile drivers and passengers than at nearby ambient air monitoring stations or even at the side of the road.

Similarly, drivers' exposures to these pollutants significantly exceed the significant exposures endured by bicyclists, pedestrians, and public transit riders. The amount of time Americans spend in their cars is increasing—not only are they driving more miles, but they are taking longer to get where they want to go. Several of the in-car pollution studies also considered pollution exposure in other environments and found that a person who commutes to and from work in a car each day may amass nearly a quarter of his or her total daily exposure to VOCs, PM, and other pollutants during those few hours he or she spends in the car.

Increased exposure to the pollutants in auto exhaust can produce serious health problems. Benzene is a known carcinogen, while several other VOCs and some forms of very fine PM are likely cancer agents. Nearly all of the pollutants covered by this report can irritate the eyes, nose, and respiratory systems of people exposed to them. They also may hinder the development of fetuses and infants. Studies indicate that CO, VOCs, NO_x, and PM can suppress the immune system, making people more vulnerable to colds, influenza, and other respiratory infections. Breathing elevated concentrations of PM in the air has been conclusively linked to increased hospital admissions and mortality. Studies also indicate that children, who breathe a proportionally greater volume of air based on body weight than adults, and people with preexisting respiratory conditions, including asthma, face even greater risks than the general public from exposure to elevated levels of auto exhaust.

Policy Recommendations

There is no easy way to reduce the levels of in-car auto pollution exposure. Federal regulations require a significant minimal airflow from the outside of the car to the interior, even when the vents are closed. In the California Air Resources Board in-car pollution study, the lowest air exchange rate for a vehicle sitting still with the vents set to low was 1.8 air changes per hour (ach). An air change amounts to the complete exchange of the air inside the vehicle with air from the outside. The air exchange rate increases with vehicle speed; that is, the faster a vehicle is moving, the faster the air from the outside is vented inside, even if the vents are closed. At 55 miles per hour with the vents set



Source: APTA, Mass Transit—The Clean Air Alternative, *1991.*

on low, the air exchange rates in the CARB study ranged from 13.5 to 39.0 ach. Thus, a complete air change occurred once every 1 ½ to 4 ½ minutes. Predictably, the rates were even higher with the vents open.

Standard filters do not significantly clean the air entering a car's passenger cabin. A number of the in-car pollution studies measured the concentrations of pollutants in the traffic stream just outside of the test cars and found that the in-car levels were nearly identical. VOCs, CO, and NO_X are microscopic gases and aerosols, able to easily pass through any filter that permits the exchange of air. One exception is coarse particulate matter, some of which automobile ventilation systems are able to filter out. However, filters can do little to stop the smallest of the fine particles, the ones most injurious to human health.

The studies show for all of the significant auto exhaust pollutants that elevated in-car levels are most closely associated with: 1). Congested traffic conditions, and 2). The proximity of high polluting vehicles, such as older-model cars, light trucks, diesel trucks and buses, and out-of-tune vehicles.

Get People Out of Their Cars

One step towards mitigating the problem of in-car air pollutants would be reducing the amount of congestion on highways and urban and arterial roads. Road construction is not the answer. Several studies indicate that building new roads or widening existing roads does little to alleviate congestion—more roads or bigger roads just bring more cars.[1] Americans now drive more miles each year than ever in the past. Since 1960, the total number of miles driven per year has tripled, while the number of miles traveled on local transit systems has only slightly increased. People use automobiles for more than 86% of local trips and nearly 80% of long-distance trips.[2] It is crucial to break this addiction to the automobile, and one solution is public transportation. On a per-passenger basis, a single-person automobile emits 209 times more VOCs than a transit train and 10.5 times more than a transit bus. Similar figures apply for other air pollutants. (See graphic, this page.) Aside from the reduced emissions associated with public transportation, an increase in ridership of trains and buses would reduce traffic congestion and alleviate one of the factors responsible for high in-car pollution levels. There is also an added bonus.

According to the in-car pollution studies, passengers on transit buses and trains are typically exposed to much lower levels of O_3, NO_X, VOCs, and fine PM than automobile drivers and passengers.

Federal, state, and local governments must do more to promote the use of public transit. Government spending on road construction and maintenance currently dwarfs spending on public transportation. Additionally, federal tax incentives permit employers to write off up to $155 per month per employee for parking reimbursement. Until 1998, businesses could not deduct compensation for employees' public transportation expenses. Now, a transit deduction does exist, but it amounts to less than half of the parking allowance—$60 per employee per month.[3] Similar disparities exist in state and local tax statutes. This is no small matter—government parking subsidies may total between $108.7 and $199.3 billion dollars per year.[4] This inequity provides an incentive for commuters to choose their automobiles over public transportation options.

Federal, state, and local governments need to increase appropriations for public transit projects, especially in areas such as Los Angeles, Washington, DC, San Francisco-Oakland, Miami, Chicago, and Detroit, where road congestion and traffic delays are epidemic. They also should remove tax incentives that encourage people to drive to work and replace them with greater incentives for employers who promote public transportation and employees who choose to leave their cars at home.

Put Cleaner Cars on the Road

The second policy response to the in-car pollution problem should involve government support for vehicle technologies that do not choke the other cars on the road with toxic fumes. Researchers realized during the first studies of in-car pollutants that the very highest interior pollution concentrations often occurred when a test vehicle followed a high-polluting vehicle, such as an improperly maintained car or a diesel truck. The second arm of a policy response to the problem of in-car pollution should encourage the replacement of these high-polluting vehicles with more benign alternatives.

EPA has made great strides toward cleaning up new cars with its Tier 2 rule published late last year. The Tier 2 regulations will eventually result in new cars that are up to 75% cleaner than those being produced today. New sport utility vehicles and other light trucks will be up to 95% cleaner, once the final phase of the rule takes effect. The Tier 2 regulations are also important because they will ensure that the cleaner cars will have low-sulfur gasoline, which they need to function properly. One failing of the Tier 2 rule, however, is that it does nothing to promote the development and marketing of zero-emission cars and trucks, such as electric vehicles now in production and fuel-cell vehicles now in development.

Fortunately, the federal regulations allow the states to choose between Tier 2 and the California emissions standards, which include a zero-emissions-vehicle mandate. The California ZEV mandate requires automakers doing business in the state to ensure that 10% of their sales are ZEVs by 2003. The ZEV mandate comes up for review every two years with the next review scheduled for September 2000. It is crucial that the California Air Resources Board stave off pressure from the automakers and maintain a strong ZEV mandate. Not only would this help relieve the problem of elevated in-car pollution levels, but it would also help alleviate ambient air smog problems and reduce automobiles' production of carbon dioxide and other greenhouse gases that contribute to global warming.

Currently, several states in the Northeast, including Massachusetts and New York, have decided to adopt the California standards, including the ZEV mandate, using the federal Tier 2 standard as a backstop. Other states, such as New Jersey and Pennsylvania should do the same. Implementing the California ZEV mandate in these large new-car markets would create a significant incentive for automakers to develop and sell zero-emissions vehicles. This would allow all the drivers on the road to breathe a little easier. While the in-car pollution studies found that drivers of electric

vehicle experienced nearly the same in-car pollution levels as drivers of traditional cars, this is because the EVs were operating in traffic filled with polluting vehicles. If a higher percentage of the cars in the traffic stream produced zero emissions, in-car air quality for all vehicles would surely improve.

Diesel vehicles emit a large portion of the dangerous roadway exhaust that often poisons the passenger compartments of other vehicles on the road. The in-car pollution studies indicate that levels of PM can be up to eight times higher within a car following a diesel truck or bus than the air at roadside. Separate studies have linked exposure to elevated levels of PM to increased hospitalization and premature death, and possibly to cancer. EPA is now in the process of finalizing a rule that will clean up PM emissions from new diesel vehicles by 90% in 2007. However, the agency is under strong pressure from engine manufacturers and fuel companies to weaken the final rule. One of the most contentious issues involves the sulfur content of diesel fuel. For cleaner diesel technologies to work, clean fuel must be available. It is critical that EPA maintain a strong diesel rule that requires 100% of diesel fuel to be low-sulfur (less than 10 ppm) prior to 2007. Also, EPA should alter the final rule to encourage the development of even lower polluting alternatives, include zero-emission technologies.

Finally, according to a timetable set by the 1990 revision of the Clean Air Act, the EPA is due to propose regulations concerning cars' emissions of mobile source air toxics, which include many of the VOCs mentioned in this report. The EPA published a study on the toxics' health effects and emissions trends in 1993, but has not yet taken regulatory action. EPA delays led to a lawsuit which set a September 1999 deadline for the promulgation of a proposed rule. However, the Agency obtained an extension from the court and still has not acted. The EPA must end the delays and issue a strong mobile source toxics rule to limit the highly hazardous automobile and diesel truck emissions of benzene, toluene, 1,3 butadiene, xylenes, and other mobile source toxics.

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