Cars and Cancer

Toxic Pollution from Cars and Trucks in Maryland

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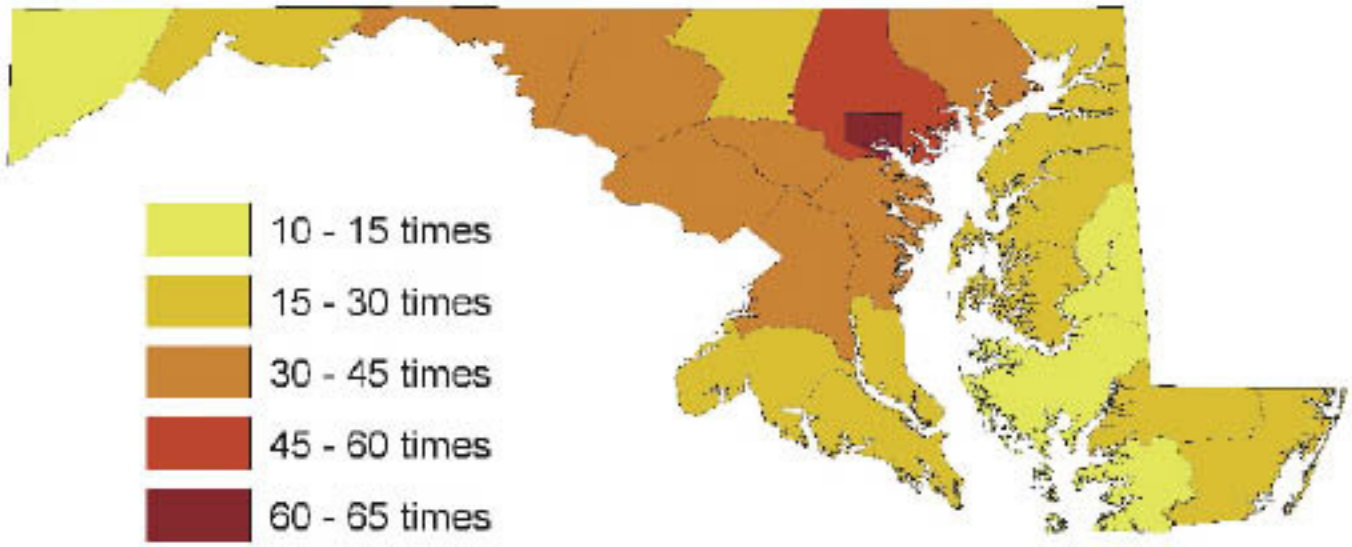
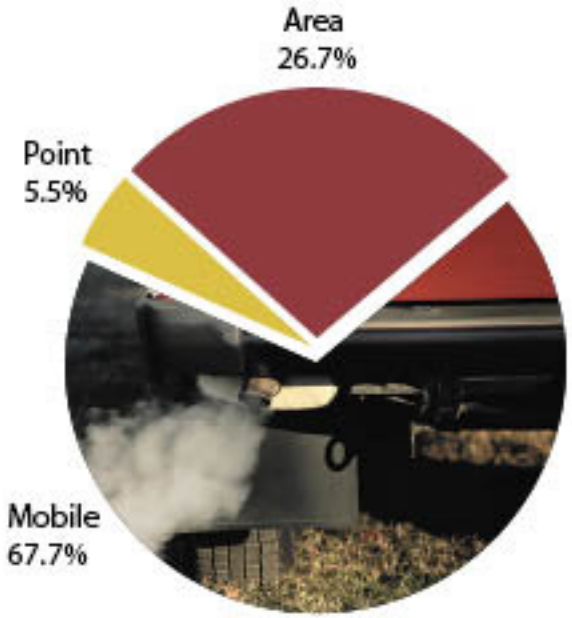
Amount by Which Each County Exceeds Cancer Risk Guideline



The cancer risk in all Maryland counties is at least 10 times higher than the federal cancer risk standard.

Sources of Cancer Risk from Air Toxics in Maryland



More than two thirds of the cancer risk from air toxics comes from mobile sources such as cars and trucks.

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Executive Summary

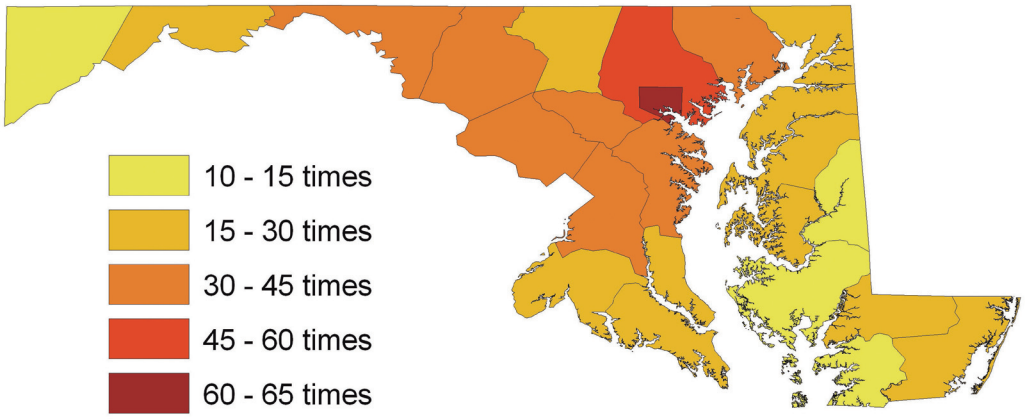
The concentrations of toxic chemicals in Maryland's air pose a serious health threat. These hazardous substances, known as air toxics, come mostly from cars, trucks, and other motor vehicles.

Marylanders exposed to air toxics can suffer from a variety of illnesses, including cancer, birth defects, neurological damage, and respiratory problems such as asthma. While scores of harmful air toxics exist, a few of the chemicals, including acetaldehyde, 1,3-butadiene, and benzene, are responsible for most of the health risk.

According to data from the federal Environmental Protection Agency (EPA), residents of every Maryland county faced an excessive risk of cancer—greater than one case for every million residents—from exposure to air toxics in 1999 (the most recent year for which data is available). Cars and trucks were leading contributors to those excessive risks.

- Marylanders were exposed to levels of **benzene** an average of 11.3 times higher than EPA's standard for the health risk from cancer. Residents of every county in Maryland were exposed to benzene levels above EPA's cancer risk threshold, with residents of Baltimore City exposed to benzene levels more than 20 times the cancer risk threshold.
- Average exposure to levels of **1,3-butadiene** was 4.1 times as large as EPA's guideline in Maryland. Exposure exceeded the cancer risk threshold in more than half of Maryland's counties.
- Marylanders' exposure to **acetaldehyde** averaged 3.4 times the cancer risk threshold. Airborne acetaldehyde exceeded the guideline in every Maryland county.
- **All air toxics** combined were present at levels averaging 40 times the health-protective threshold across Maryland. The factor by which exposure exceeded the cancer risk threshold ranged between 11.3 and 62.1 throughout the state's counties. (See Figure ES-1.)

Figure 1. Amount by Which Each County Exceeds Cancer Risk Guideline



The cancer risk in all Maryland counties is at least 10 times higher than the federal cancer risk standard.

This data does not include the serious non-cancer health effects associated with the pollutants and understates their full health impacts as a result.

Cars, trucks, and other mobile sources were responsible for:

- 84 percent of Maryland's benzene emissions.
- 99 percent of Maryland's 1,3-butadiene emissions.
- 87 percent of Maryland's acetaldehyde emissions.

Maryland can reduce citizens' exposure to air toxics and the accompanying health risks from mobile sources by adopting air pollution standards that are more protective of public health.

As a strong first step, the Maryland Department of the Environment should immediately adopt the Clean Cars Program to reduce toxic emissions from cars and trucks. A 2005 Maryland PIRG Foundation study found that the Clean Cars Program would reduce emissions of air toxics from light-duty vehicles by approximately 12 to 15 percent within 20 years compared with *projected* emission levels, under weaker federal air pollution standards. On a pollutant by pollutant level, the Clean Cars Program reduces air toxics emissions by 57 to 79 percent versus *today's* pollution levels. Those emission reductions would be the equivalent of taking approximately 190,000 of today's cars off the state's roads.

Table 1. The Seven Counties with the Greatest Cancer Risk from Air Toxics in Maryland

County	Factor by which cancer risk exceeds federal standard
Baltimore City	62.1
Baltimore County	45.3
Montgomery	45.0
Prince George's	41.0
Frederick	39.2
Anne Arundel	38.8
Howard	35.6

Introduction

Ask a Marylander about air pollution in the state, and you're likely to hear about hazy horizons, smoggy days, or even the black dust that settles on windowsills in Baltimore. You're less likely to hear about cancer-causing air toxics, despite the elevated health threat they represent.

Air toxics get little public attention for several reasons. They are invisible to the eye—unlike smoggy haze or the exhaust of a tractor-trailer—and do their damage to health subtly, over the course of years and decades. The types of disease caused by air toxics—from cancer to neurological damage—can also be caused by a variety of other environmental exposures or by natural processes. Additionally, government agencies tend to invest fewer resources in monitoring and tracking levels of toxic chemicals in the air, unlike the daily "smog alerts" in newspapers and on television during the summer months.

Nonetheless, evidence from a variety of medical studies suggests air toxics deserve a lot more attention. By combining knowledge of the health impacts of air toxics from medical studies with the U.S. Environmental Protection Agency's estimates of the levels of toxic chemicals present in Maryland's air, we can begin to understand how dangerous air toxics are to our health. Moreover, we can identify the sources of the toxic chemicals in our air. In Maryland, the most important sources are cars, trucks, and other so-called "mobile sources" of pollution.

The technology to reduce emissions of air toxics from cars and trucks exists today. Maryland can significantly reduce air toxics emissions in the years to come by following the lead of 11 other states in adopting the Clean Cars Program and by taking other prudent steps to reduce the health risks posed by toxic chemicals in Maryland's air.

Motor Vehicles Are a Major Source of Air Toxics in Maryland

Sources of Toxic Air Pollutants

Cars and trucks, as well as construction equipment and other non-road engines—collectively referred to as "mobile sources"—are the largest source of hazardous air pollutants in Maryland and nationwide. Stationary sources, such as power plants, refineries, and dry cleaners, as well as natural sources, such as forest fires, produce the remainder of the toxics in the outdoor air.

Mobile Sources

Mobile sources include on-road vehicles (cars, trucks, and buses) and non-road vehicles and equipment (airplanes, ships, construction equipment, and farm equipment). The vast majority of mobile sources are powered by gasoline or diesel engines and produce toxics through incomplete combustion, evaporation, engine wear and secondary formation of pollutants in the atmosphere.

Mobile sources are responsible for 68 percent of the cancer risk from air toxics in Maryland.[1]

Major (Point) Sources

The Clean Air Act defines "major sources," or point sources, as large, stationary facilities that release more than 10 tons per year of a single hazardous air pollutant or 25 tons or more of a combination of chemicals. Typical examples of major sources include power plants, oil refineries, and waste incinerators. These sources may release toxic chemicals from equipment leaks, during transport of materials, or through direct emissions from smokestacks and pipes.

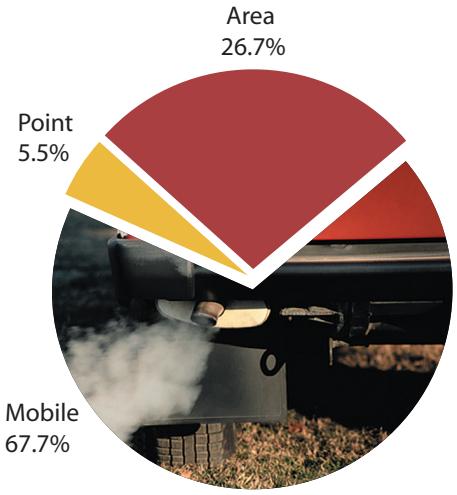
Point sources are responsible for 5 percent of the cancer risk from air toxics in Maryland.

Area Sources

The Clean Air Act defines "area sources" as smaller, stationary sources that emit less than 10 tons per year of a single toxic air pollutant and less than 25 tons per year of a combination of chemicals. Typical examples of area sources include dry cleaners, gas stations and landfills. While emissions from individual area sources usually are relatively small, large numbers of area sources can be located in heavily populated areas.

Area sources are responsible for 27 percent of the cancer risk from air toxics in Maryland.

Figure 2. Sources of Cancer Risk from Air Toxics in Maryland



Estimating Potential Cancer Risks from Toxic Air Pollutants

The Clean Air Act requires EPA to ensure that its regulations for major sources of hazardous air pollutants "provide an ample margin of safety to protect public health." For carcinogens, Congress defined this margin of safety as an added lifetime cancer risk "to the individual most exposed" of less than one-in-one million.[2] This means that exposure to air toxics at the cancer threshold will cause one out of every million people to contract cancer at some point during 70 years of exposure (about the average lifetime of an individual). EPA has used

Other Sources of Air Toxics

Emissions from a few minor sources of air toxics are not recorded or tracked. Most notable among these are natural sources, which include forest fires and volcanoes, and anything that has not been identified as a significant source or is otherwise not monitored. These, together with any emissions from sources more than 50 kilometers away from the county in question, are counted as "background sources."

The EPA analysis that informs this report (see "Background on EPA's National-Scale Assessment," p. 9) uses background sources to help explain discrepancies between toxics levels measured in the air and the levels predicted from its model of emission sources. Since the contribution from background sources is highly variable and not well understood, they are excluded from EPA's modeling and from the estimates of cancer risk in this report.

this one-in-one-million cancer benchmark to evaluate the health risks posed by air toxics.[3]

EPA has conducted three national assessments of the health risks posed by toxic air pollutants. The Cumulative Exposure Project, released in 1998, used 1990 emissions data and computer modeling to estimate outdoor air concentrations of 148 air toxics nationwide. EPA found that ambient air concentrations of seven cancer-causing chemicals, including benzene, exceeded health-protective thresholds in every census tract in the continental United States. Mobile sources were responsible for the majority of the emissions that threatened human health.[4]

The National-Scale Air Toxics Assessment (NATA), released first in 2002 and then again in 2006, is the most comprehensive national study to date on the health risks posed by air toxics. For the second NATA release, EPA used 1999 emissions data and computer modeling to estimate cancer and non-cancer health risks from hazardous air pollutants nationwide. The NATA focuses on the 177 air toxics of greatest public health concern in urban areas.[5]

EPA found that benzene was the most dangerous cancer-causing agent in 1999, accounting for 25 percent of the average individual cancer risk studied in the report. The agency also found that 68 percent of benzene emissions were from mobile sources.[6]

Background on EPA's National-Scale Assessment

Since EPA's updated National-Scale Air Toxics Assessment (NATA) is the only comprehensive source of airborne cancer risks in Maryland, it is important to understand the report's structure and findings.

The 1999 NATA report was designed to be a comprehensive risk assessment of air toxics in the United States. Risk assessment combines what is currently known about chemical toxicity and human exposure to characterize potential public health risks. While risk assessment is an uncertain science, EPA used state-of-the-art risk assessment tools and updated data for the 1999 NATA.

The 1999 National-Scale Air Toxics Assessment

The NATA project involved the following four steps:

1. **Emission Sources –** The types of emissions sources in the inventory include large sources, such as waste incinerators and factories, and smaller sources, such as dry cleaners, small manufacturers, and wildfires. Also included in the inventory are emissions from highway and non-road mobile sources, such as cars, trucks, and boats.
2. **Toxics Concentrations –** The concentration estimates were developed using a computer model that analyzes a number of factors, including total emissions, the number of emissions sources in a particular area, weather patterns, and pollution source characteristics.
3. **Population Exposures –** Estimates of population exposures were based on estimated outdoor concentrations and on a model that looked at the amount of a toxic air pollutant a person is likely to inhale in a year's time. The average concentration of a pollutant that people breathe is known as an exposure concentration. Estimating exposure,

assuming 1999 levels over the course of a lifetime, is a key step in determining potential health risk.

4. **Public Health Risk –** Characterization of potential public health risks from cancer and other adverse health effects uses available information on air toxics health effects, current EPA risk assessment and risk characterization guidelines, and estimated population exposures to outdoor sources of air toxics.[7]

The 1999 National-Scale Air Toxics Assessment and potential limitations are further discussed in the methodology section.

Air Toxics Increase Cancer Risk in Maryland

Exposure to airborne toxics creates a cancer risk for Marylanders that is greater than the federal benchmark of one additional case of cancer per one million residents. Three specific pollutants—acetaldehyde, benzene, and 1,3-butadiene—contribute to much of the problem, but the cancer risk is even greater when all air toxics are factored in. Mobile sources are responsible for most of this pollution.

Acetaldehyde

Potential Health Risks from Acetaldehyde

EPA has classified acetaldehyde as a probable human carcinogen.[8] Animal studies have found that exposure to acetaldehyde causes nasal tumors in rats and laryngeal tumors in hamsters. In animal studies, chronic exposure to acetaldehyde damages the respiratory tracts of rats. Data from animal studies also suggests that acetaldehyde may cause developmental disorders. No direct data is available on the developmental effects of acetaldehyde in humans, but acetaldehyde has been shown to cross the placenta to the fetus in studies of rodents. Acute exposure to acetaldehyde causes eye, skin, and respiratory tract irritation.[9]

Cancer Risk from Acetaldehyde in Maryland

Based on the toxicity data used by EPA in the NATA project, lifetime exposure to acetaldehyde at concentrations above 0.5 micrograms per cubic meter is associated with a potential cancer risk greater than the standard established in the Clean Air Act.[10] EPA's estimates of average human exposure to acetaldehyde exceeded this cancer benchmark concentration in every Maryland county in 1999. Marylanders were exposed to levels of acetaldehyde on average 3.4 times as high as the cancer benchmark, with mobile sources contributing 67 percent of the cancer risk.[11]

Sources of Acetaldehyde Emissions

In 1999, cars, trucks, and non-road engines released more than 680 tons of acetaldehyde into Maryland's environment—87 percent of Maryland's acetaldehyde emissions.[12] Vehicles create the substance as a by-product of the incomplete combustion of gasoline and diesel fuel. It can also be formed in the atmosphere from chemical reactions involving other pollutants.[13]

Benzene

Potential Health Risks from Benzene

EPA, as well as several other national and international agencies, has classified benzene as a known human carcinogen. It is well established that exposure to benzene causes leukemia and other cancers.[14]

In addition to cancer, long-term exposure to benzene is associated with anemia and damage to the immune system.[15] Several occupational studies suggest that benzene may impair fertility in women. While the available human data on the developmental effects of benzene is inconclusive, adverse effects on the fetus, including low birth weight, delayed bone formation, and bone marrow damage have been observed in animal studies. Acute exposure to benzene can cause dizziness, drowsiness, headaches, and unconsciousness, as well as eye, skin, and respiratory tract irritation.[16]

Cancer Risk from Benzene in Maryland

EPA's estimates of average human exposure to benzene exceeded the cancer benchmark concentration by more than 150 percent in every county in Maryland in 1999. The average Marylander was exposed to benzene levels 11.3 times as high as the threshold for cancer. Two thirds of the cancer risk from benzene came from mobile sources.[17]

Sources of Benzene Emissions

In 1999, cars, trucks, and non-road engines released 3,690 tons of benzene into Maryland's environment—84 percent of total benzene emissions.[18]

Despite the dominance of mobile sources among emissions of airborne benzene, it is a widely used chemical in the United States, ranking among the top 20 chemicals for production volume.[19] It is used as a gasoline constituent, an industrial solvent, and in the manufacture of dyes, detergents, pharmaceuticals, and other products.

Cars and other mobile sources emit the benzene in gasoline when fuel evaporates or passes through the engine unburned. Benzene also is formed from the incomplete combustion of compounds in gasoline that are chemically similar to benzene, such as toluene and xylene. As with benzene, these compounds occur naturally in petroleum and become more concentrated through the refining process.[20]

1,3-Butadiene

Potential Health Risks from 1,3-Butadiene

EPA has classified 1,3-butadiene as a probable human carcinogen.[21] Epidemiological studies of workers in the rubber industry suggest that exposure to 1,3-butadiene is associated with an increased incidence of leukemia and

possibly other cancers as well.[22] Animal studies have found that rats and mice exposed to 1,3-butadiene develop a variety of cancers. In addition to cancer, long-term exposure to 1,3-butadiene may result in increases in cardiovascular and blood diseases. While no direct data is available regarding the reproductive or development effects in humans of 1,3-butadiene exposure, adverse effects, including miscarriages, birth defects, low birth weights, skeletal abnormalities, and damage to the reproductive organs have been observed in animal studies. Acute exposure to 1,3-butadiene causes irritation of the nasal passages, throat, and lungs, as well as such neurological effects as blurred vision, fatigue, headaches, and vertigo at very high exposures.[23]

Cancer Risk from 1,3-Butadiene in Maryland

EPA's estimates of average human exposure to 1,3-butadiene exceeded the cancer benchmark concentration in 13 of Maryland's 24 counties in 1999.[24] The statewide average was four times as high as the benchmark, and 72 percent of the risk was attributable to mobile sources.[25]

Sources of 1,3-Butadiene Emissions

In 1999, cars, trucks, and non-road engines released more than 570 tons of 1,3-butadiene into Maryland's environment, or more than 99 percent of total 1,3-butadiene emissions.[26]

As with the other toxics discussed, 1,3-butadiene is a by-product of the incomplete combustion of fuel.[27]

Cumulative Cancer Risks

Based on its analyses of the 177 air toxics included in the NATA study, EPA estimates that the average Marylander faces a cancer risk from all outdoor air toxics that is 40 times the standard established in the Clean Air Act.[28] As shown in Table 3, average cancer risks in each county ranged from a low of 11 times higher than the cancer benchmark in Somerset County, to a high of 62 times more than the cancer benchmark in Baltimore City.

More than two thirds of Maryland's cancer-causing emissions were from mobile sources such as cars and trucks, with the remaining 32 percent of cancer risk coming from point and area sources.[29]

Table 2. Cancer Risk from Major Air Toxics and Portion of Maryland Emissions from Mobile Sources

	Factor by which exposure exceeds cancer benchmark	Portion of MD emissions from mobile sources
Acetaldehyde	3.4	87%
Benzene	11.3	84%
1,3-Butadiene	4.1	99%

Table 3. Average Cumulative Cancer Risks from Air Toxics in Maryland by County

County	Rank by cancer risk (1 = highest, 24 = lowest)	Factor by which air toxics exceed cancer benchmark	Portion of emissions from mobile sources
Allegany	12	24	66%
Anne Arundel	6	39	70%
Baltimore City	1	62	73%
Baltimore County	2	45	71%
Calvert	15	18	64%
Caroline	23	12	66%
Carroll	10	25	59%
Cecil	14	22	64%
Charles	11	25	67%
Dorchester	21	15	66%
Frederick	5	39	31%
Garrett	22	14	47%
Harford	8	31	69%
Howard	7	36	70%
Kent	20	16	64%
Montgomery	3	45	65%
Prince George's	4	41	72%
Queen Anne's	18	17	63%
St. Mary's	19	17	66%
Somerset	24	11	68%
Talbot	16	18	66%
Washington	9	31	47%
Wicomico	13	23	53%
Worcester	17	17	66%
Maryland average		40	68%

Maryland average is weighted by population and represents the average exposure of Marylanders.

Recommendations

Maryland has taken steps to improve certain aspects of air quality, including reductions in the toxins released by paints, coatings, and industrial processes. Most recently, the Healthy Air Act will significantly reduce smog forming pollutants from power plants. While these changes are steps in the right direction for improving the quality of air that Marylanders breathe, the problem of air toxics has been left unaddressed for too long. It is time for Maryland to address the health threat presented by toxic air pollution from motor vehicles and other sources.

Adopt the Clean Cars Program

Maryland should join Pennsylvania, New Jersey, New York and eight other states in adopting the Clean Cars Program.

The Clean Cars Program offers reductions in both tailpipe and evaporative emissions. A 2005 Maryland PIRG Foundation study found that the Clean Cars Program would reduce emissions of air toxics from light-duty vehicles by 12 to 15 percent in 2025 relative to business as usual. (See Table 4.) Once enacted,

Table 4. Light-Duty Vehicle Emissions of Selected Air Toxics in 2025 Under Status Quo and Clean Cars Program for Selected Maryland Metropolitan Counties (tons)[30]

	Status Quo	Clean Cars Program	Difference	Reduction (%)
1,3- Butadiene	65.5	56.7	8.8	13%
Acetaldehyde	49.7	43.7	5.9	12%
Benzene	495.8	432.8	63.0	13%

the program would become increasingly effective for more than a decade as old vehicles with higher emissions are gradually retired and replaced with low-emission vehicles.

The benefits of the Clean Cars Program are even more clear when compared to current vehicle emissions, rather than what they will be in 2025 without the Clean Cars Program; the policy would create air toxics emissions reductions of 57 to 79 percent for the major toxic air pollutants relative to today's pollution levels.[31]

The Maryland Department of the Environment should adopt the Clean Cars Program to reduce emissions of smog-forming pollutants, to protect citizens from the health dangers posed by air toxics, and to strengthen the state's long-term economic and environmental security.

The Clean Cars Program makes sure that technologies already on the market that allow cars to emit less pollution are used in more cars sold in Maryland. With 11 states already implementing the program, automakers are gearing up production of cleaner cars such as hybrids, alternative fuel vehicles, and conventional cars with advanced emission reduction technology. Maryland should join the program to bring the cleaner cars here.

Consider Additional Ways to Reduce Vehicle Emissions

Maryland should consider additional ways to reduce air pollution from vehicles. Even under the Clean Cars Program, it would be several years before significant numbers of clean vehicles are on the road. There are several ways the state can encourage the speedy introduction of clean vehicles:

- Require that government or public agencies purchase zero-emission and alternative fuel vehicles for appropriate uses.
- Strengthen efforts to reduce the growth in vehicle miles traveled, such as telecommuting and carpooling incentives, rail transit, and walkable development.
- Provide incentives to purchase and use cleaner vehicles through licensing fees, taxes, and tax breaks.
- Expand Maryland's Vehicle Emission Inspection Program statewide to prevent excessive toxic pollution from older cars and trucks.

Advocate for Federal Action

Action should be taken on the federal level as well. To reduce all Americans' exposure to toxic chemicals, including acetaldehyde, benzene, and 1,3-butadiene from cars, trucks, and non-road engines, the U.S. EPA should strengthen the Mobile Source Air Toxics rule. The current proposed rule is an improvement, but fails to address many public health threats, even where solutions already exist.

To improve the Mobile Source Air Toxics rule, EPA should:

- further reduce the average benzene content in gasoline, which would impose only minor costs on refineries that are enjoying enormous profits,
- maintain the cap on benzene content in gasoline from individual refineries to avoid dramatically higher concentrations in certain regions, and
- implement caps on the other air toxics that pose public health threats, including acetaldehyde and 1,3-butadiene.

Methodology

All of the air toxics data in this report comes from the National-Scale Air Toxics Assessments.

To characterize potential cancer risks, we adopted the methodology EPA used in its peer-reviewed Cumulative Exposure Project and compared exposure concentrations of air toxics to benchmark concentrations for cancer.[32] As established in the Clean Air Act, concentrations posing a one-in-one-million cancer risk were used as benchmark concentrations for cancer effects. Benchmark concentrations were derived from the toxicity data EPA used in the NATA project for acetaldehyde, benzene, and 1,3-butadiene.

Estimates of Average Exposures

We used the annual average human exposure concentrations derived from EPA's inhalation exposure model. These estimates typically are 20 to 30 percent lower than EPA's estimates of ambient air concentrations of the pollutants. As a result, the cancer risk estimates we present are more conservative than risk estimates based on ambient air concentrations.

Estimates of Cancer Risks

To calculate the cancer benchmarks, we multiplied the unit risk estimate, an estimate of the risk associated with exposure to one microgram per cubic meter of the chemical over a 70-year period, by one million. The resulting benchmark represents the lifetime human exposure concentration of the pollutant that is associated with a potential cancer risk at least as great as the one-in-one-million standard established in the Clean Air Act. To estimate potential cancer risks, we compared the annual average human

exposure concentrations to the cancer benchmark concentrations.

It is important to note that the one-in-one-million benchmark values used in the report serve as yardsticks to assess potential cancer risks posed by air toxics. The benchmarks are not "safe" or "no risk" levels but rather represent levels that EPA has set as a target.

To estimate the percent of added cancer risks from mobile sources, we divided EPA's estimate of the mobile source contribution to the average human exposure concentration by the average human exposure concentration.

Again, there are uncertainties in modeling air toxic emissions, ambient air concentrations, exposures, and risks. Cancer risk estimates should not be interpreted as an accurate prediction of health outcomes. Rather, the risk estimates provide a way to screen for those pollutants that are of public health significance in order to prioritize research and regulatory efforts.

Comparisons to Available Monitoring Data

The 1999 NATA predicted air toxics levels using known quantities of emissions in different locations and knowledge of wind and dispersal patterns across the United States. In order to check the strength of the predictions, actual concentrations were measured in several locations across the country. EPA has found that its modeled ambient air concentrations are typically lower than measured ambient annual average concentrations, which indicate that estimated health risks based on the modeled data likely underestimate actual risks.[33]

EPA's model-to-monitor comparisons indicate that the model performs best for benzene, with good agreement between model predictions and monitor measurements. For acetaldehyde, the model's estimates tend to be lower than the monitored averages, such that the model may systematically underestimate concentrations of these pollutants in at least some areas.

Limitations of the 1999 NATA Data

The results apply to geographic areas, not specific locations. Concentrations of air toxics and associated cancer risks can vary a great deal from location to location. EPA's estimates, however, are calculated only at the county level and cannot, therefore, be used to identify "hot spots" within a census tract or county.

The results are restricted to 1999. The risk assessment assumes these 1999 levels remain constant throughout one's lifetime.

The results do not reflect exposures and risk from all compounds. It is particularly significant that the assessment did not quantify cancer risk from diesel particulate matter. This is because EPA does not believe the available data is sufficient to establish a unit risk estimate at this time, although the agency plans to include such an estimate in future reports. When the cancer risk from diesel is included, it will likely become a large contribution to total air toxics cancer risk.

The results do not reflect all pathways of exposure. The assessment included only risks from direct inhalation of the emitted air toxics compounds. It did not consider air toxics compounds that might then deposit onto soil, water, food, etc, and therefore enter the body through ingestion or skin contact.

Consideration of these other routes of exposure is expected to raise the exposure and risk estimates.

The assessment results reflect only compounds released into the outdoor air. The assessment did not include exposure to air toxics compounds produced indoors, such as from stoves, off-gassing from building materials, or evaporative benzene emissions from cars in attached garages. For some compounds, these indoor sources can contribute significantly to the total exposure for an individual, even if only inhalation exposures are considered.

The assessment does not fully reflect variation in background ambient air concentrations. Much more research is needed before an accurate estimate of background concentrations at the level of census tracts, or even at the higher geographic scales (counties, states, etc), can be made.

The assessment might systematically underestimate ambient air concentration for some compounds. The ASPEN model used to estimate ambient air concentration has been shown in this assessment to underestimate the measured concentration in many cases. This would tend to result in an underestimation of the exposure and risk.

The assessment may not accurately capture sources that have episodic emissions. Examples include wildfires and prescribed burning or facilities with short-term deviations such as startups, shutdowns, malfunctions, and upsets.

Estimates of risk are uncertain. First, some air toxics are known to be carcinogens in animals but lack data in humans. These have been assumed to be human carcinogens. Second, all the air toxics in this assessment were assumed to have linear relationships between exposure and the probability of cancer (i.e. effects at low exposures were extrapolated from higher, measurable, exposures by a straight line). Third, some estimates of cancer risk are considered to be best estimates of cancer risk (those based on human data); others are "upper bound" estimates (usually based on animal data but sometimes based on human data).

Appendix: Cancer Risk by County

	All Air Toxics		Acetaldehyde		Benzene		1,3-Butadiene	
	Cancer Risk Factor*	Risk From Mobile Sources^	Cancer Risk Factor*	Risk From Mobile Sources^	Cancer Risk Factor*	Risk From Mobile Sources^	Cancer Risk Factor*	Risk From Mobile Sources^
Allegany	23.8	66%	1.7	45%	6.9	54%	1.9	76%
Anne Arundel	38.8	70%	3.8	73%	11.5	70%	4	69%
Baltimore	45.3	71%	4.3	73%	13.3	73%	4.8	68%
Calvert	17.8	64%	1.6	46%	4.7	48%	0.6	94%
Caroline	11.6	66%	1.2	31%	3	40%	0.3	95%
Carroll	25.1	59%	2.2	58%	6.8	55%	1.3	82%
Cecil	21.5	64%	2.1	58%	6.1	55%	0.9	95%
Charles	25.1	67%	2.4	62%	6.7	58%	1.4	70%
Dorchester	14.9	66%	1.2	27%	3.5	38%	0.3	95%
Frederick	39.2	31%	2.1	55%	7.2	56%	2.2	69%
Garrett	13.5	47%	1.3	34%	3.3	44%	0.4	98%
Harford	30.7	69%	2.9	67%	8.6	64%	2.3	69%
Howard	35.6	70%	3.5	72%	10.3	69%	3	72%
Kent	15.7	64%	2.1	55%	4.6	55%	0.4	97%
Montgomery	45	65%	3.5	72%	12.3	70%	4.9	67%
Prince George's	41	72%	3.4	71%	11.3	69%	4.5	64%
Queen Anne's	16.7	63%	1.7	48%	4.4	50%	0.5	95%
St. Mary's	16.6	66%	1.1	24%	2.7	35%	0.2	95%
Somerset	11.3	68%	1.4	39%	4.3	46%	0.5	97%
Talbot	17.8	66%	1.3	33%	4.7	49%	0.8	98%
Washington	30.5	47%	1.9	53%	7.1	57%	2.1	66%
Wicomico	22.7	53%	1.6	42%	5.7	47%	1.3	69%
Worcester	16.8	66%	1.4	37%	4.5	46%	0.6	99%
Baltimore city	62.1	73%	5.4	79%	20.7	81%	8.7	77%
Maryland Average°	**40**	**68%**	**3.4**	**67%**	**11.3**	**67%**	**4.1**	**72%**

* Cancer risk factor is the factor by which 1999 air toxic levels exceeded the Clean Air Act carcinogenic benchmark of one cancer case per million people exposed for 70 years.

^ Risk from mobile sources is the portion of the region's airborne pollutant concentration attributed to mobile sources such as cars, trucks, and non-road vehicles.

° Maryland average is weighted by population and represents the average exposure of Marylanders.

Notes

1. U.S. Environmental Protection Agency (EPA), 1999 National-Scale Air Toxics Assessment (NATA), *County Level Risk Summaries*, downloaded from www.epa.gov/ttn/atw/nata1999/tables.html, 20 October 2006.
2. In 1996, Congress reaffirmed this basic goal when it passed the Food Quality Protection Act, which established new standards for cancer-causing pesticides in food. The law requires that standards for acceptable pesticide levels in food provide a "reasonable certainty that no harm will result," which in the case of cancer-causing pesticides was understood to be a "one-in-one million lifetime risk." Clean Air Act, Section 112(f)(2).
3. T. Woodruff et al, "Public Health Implications of 1990 Air Toxics Concentrations Across the United States," *Environmental Health Perspectives*, May 1998, 245-251.
4. Ibid.
5. U.S. EPA, 1999 NATA, available at www.epa.gov/ttn/atw/nata1999/index.html.
6. U.S. EPA, 1999 NATA, *Estimated Emissions, Concentrations, and Risks*, downloaded from www.epa.gov/ttn/atw/nata1999/natafinalfact.html, 19 October 2006.
7. U.S. EPA, 1999 NATA, *Technical Factsheet, NATA 1999 Estimated Emissions, Concentrations and Risks*, downloaded from www.epa.gov/ttn/atw/nata1999/natafinalfact.html, 19 October 2006. A complete description of the NATA methodology can be found at www.epa.gov/ttn/atw/nata1999/4steps99.html.
8. U.S. EPA, *Acetaldehyde: Hazard Summary*, 9 March 2006.
9. U.S. EPA, Integrated Risk Information System, *Acetaldehyde*, 8 March 2006.
10. See note 8.
11. U.S. EPA, 1999 NATA, *County-Level Risk Summaries*, downloaded from www.epa.gov/ttn/atw/nata1999/tables.html, 20 October 2006.
12. Note that while mobile sources were responsible for 87 percent of Maryland's acetaldehyde emissions, they account for only 67 percent of cancer risk in Maryland, due to a significant contribution to the cancer risk from out of state stationary sources. Emissions data from U.S. EPA, 1999 NATA, *County Level Emissions Summaries*, downloaded from www.epa.gov/ttn/atw/nata1999/tables.html, 20 October 2006.
13. U.S. EPA, *Technical Support Document: Control of Emissions of Hazardous Air Pollutants from Motor Vehicles and Motor Vehicle Fuels*, (EPA 440-R-00-023), December 2000.
14. U.S. EPA, *Benzene: Hazard Summary*, downloaded from www.epa.gov/ttn/atw/hlthef/benzene.html, 20 October 2006.

U.S. EPA, *Carcinogenic Effects of Benzene: An Update*, (EPA/600/P-97/001F), April 1998.

15. U.S. EPA, *Health Effects Notebook for Hazardous Air Pollutants, Benzene Fact Sheet*, downloaded from www.epa.gov/ttn/atw/hlthef/benzene.html, 5 July 2002.
16. Ibid.
17. See note 11.
18. Note that while mobile sources were responsible for 84 percent of Maryland's benzene emissions, they account for only two thirds of benzene's cancer risk in Maryland, due to a significant contribution to the cancer risk from out of state stationary sources. Emissions data from: U.S. EPA, 1999 NATA, *County-Level Emissions Summaries*, downloaded from www.epa.gov/ttn/atw/nata1999/tables.html, 20 October 2006.
19. U.S. Agency for Toxic Substances and Disease Registry, *Public Health Statement for Benzene*, September 1997, downloaded from www.atsdr.cdc.gov/ToxProfiles/phs8803.html, 5 July 2002.
20. See note 14.
21. Based on epidemiological data, EPA is reevaluating the cancer classification for 1,3-butadiene. U.S. EPA, Integrated Risk Information System (IRIS), *1,3-Butadiene*, downloaded from www.epa.gov/iris/subst/0139.htm, 5 July 2002.
22. U.S. Agency for Toxic Substances and Disease Registry, *Public Health Statement for 1,3-Budadiene*, July 1992, downloaded from www.atsdr.cdc.gov/toxprofiles/phs28.html, 5 July 2002; and U.S. EPA, *Health Effects Notebook for Hazardous Air Pollutants, 1,3-Butadiene Fact Sheet*, downloaded from www.epa.gov/ttn/atw/hlthef/butadien.html, 5 July 2002.
23. U.S. EPA, Integrated Risk Information System, *1,3-Butadiene*, downloaded from www.epa.gov/iris/subst/0139.htm, 10 October 2006
24. The counties with 1,3-butadiene concentrations above the benchmark are Allegany, Anne Arundel, Baltimore, Carroll, Charles, Frederick, Harford, Howard, Montgomery, Prince George's, Washington, Wicomico, and Baltimore City.
25. See note 11.
26. Note that while mobile sources were responsible for 99 percent of Maryland's 1,3-butadiene emissions, they account for only 72 percent of cancer risk in Maryland, due to a significant contribution to the cancer risk from out of state stationary sources. Emissions data from U.S. EPA, 1999 NATA, *County-Level Emissions Summaries*, downloaded from www.epa.gov/ttn/atw/nata1999/tables.html, 20 October 2006.
27. See note 13.
28. U.S. EPA, 1999 NATA, *1999 Risk Estimates (All Carcinogens)*,downloaded from www.epa.gov/ttn/atw/nata1999/tables.html, 20 October 2006.
29. Ibid.
30. Elizabeth Ridlington, Tony Dutzik, and Brad Heavner, MaryPIRG Foundation, *Cleaner Cars, Cleaner Air: How Low-Emission Vehicle Standards Can Cut Air Pollution in Maryland*, February 2005. Note: Emission reductions listed in this table assume that Maryland implemented the Clean Cars Program in calendar year 2008. Under federal law, Maryland could not now implement the program until at least calendar year 2009. Thus, the emission reductions shown for the program in 2025 likely slightly overstate the benefits of the Clean Cars Program.
31. Estimate of "average car" VOC emissions based on multiplying grams per mile emissions factors for passenger cars in Anne Arundel, Baltimore, Baltimore City, Carroll, Harford, and Howard counties by 12,000 miles per year.
32. See note 3.
33. U.S. EPA, 1999 National Air Toxics Assessment, *Comparison of 1999 Model-Predicted Concentrations to Monitored Concentrations*, downloaded from www.epa.gov/ttn/atw/nata1999/99compare.html, 19 October 2006.